3 Subbasin Assessment

3.1 Subbasin Overview

3.1.1 General Description

The Willamette Subbasin occupies more than 11,000 square miles in northwest Oregon and is home to 70 percent of Oregon's population. Its main geographic features include Oregon's largest river, the Willamette; the Coast Range, which borders the subbasin on the west; and the Cascade Range on the east. The 4,000-square-mile Willamette Valley has some of the richest farmland in the nation and produces about half of Oregon's yearly farm sales.

3.1.1.1 Location

The Willamette Subbasin runs north to south between the Cascade Mountains on the east and the Coast Range on the west. It is bounded to the south by the Calapooia Range of the Cascade Mountains. The basin's northern boundary is the mouth of the Willamette, at approximately Mile 86 of the Columbia River. The basin lies within the Lower Columbia ecological province defined by the Northwest Power and Conservation Council. All or parts of 13 Oregon counties fall within the Willamette Basin (see Table 3-1).

Table 3-1: Oregon Counties with Acreage in the Willamette Basin

County	Total Area of the County (acres)	Acres within the Willamette Basin	Percentage of Total County Area in the Willamette Basin	Percentage of the Willamette Basin in the County
Benton	434,201	328,097	75.6%	4.5%
Clackamas	1,201,728	943,429	78.5%	12.8%
Columbia	423,101	83,774	19.8%	1.1%
Douglas	3,236,500	65,112	2%	0.9%
Lane	2,950,997	2,255,820	76.4%	30.7%
Lincoln	627,843	9,331	1.5%	0.1%
Linn	1,476,732	1,468,204	99.4%	20%
Marion	764,295	760,714	99.5%	10.4%
Multnomah	281,735	140,633	49.9%	1.9%
Polk	475,890	422,518	88.8%	5.8%
Tillamook	704,962	6146	.9%	0.1%
Washington	469,001	413,944	88.3%	5.6%
Yamhill	459,391	422,481	92.0%	5.8%

Source: Adapted from Pacific Northwest Ecosystem Research Consortium, 2002.

3.1.1.2 Size

The Willamette River Subbasin is approximately 180 miles long and 100 miles wide. With an area of 11,478 square miles (7.3 million acres), the Willamette Basin occupies nearly 12 percent of the state of Oregon (see Figure 3-1) (U.S. Army Corps of Engineers, 2000; Pacific Northwest Ecosystem Research Consortium, 2002). The Willamette River has a mainstem channel length of 185 miles. A tributary to the Columbia River, the Willamette is Oregon's largest river wholly contained within state boundaries (see Figure 3-2). In addition, it is the nation's 13th largest river by volume, with more runoff per square mile of drainage than any other large river in the coterminous United States (Kammerer, 1990).

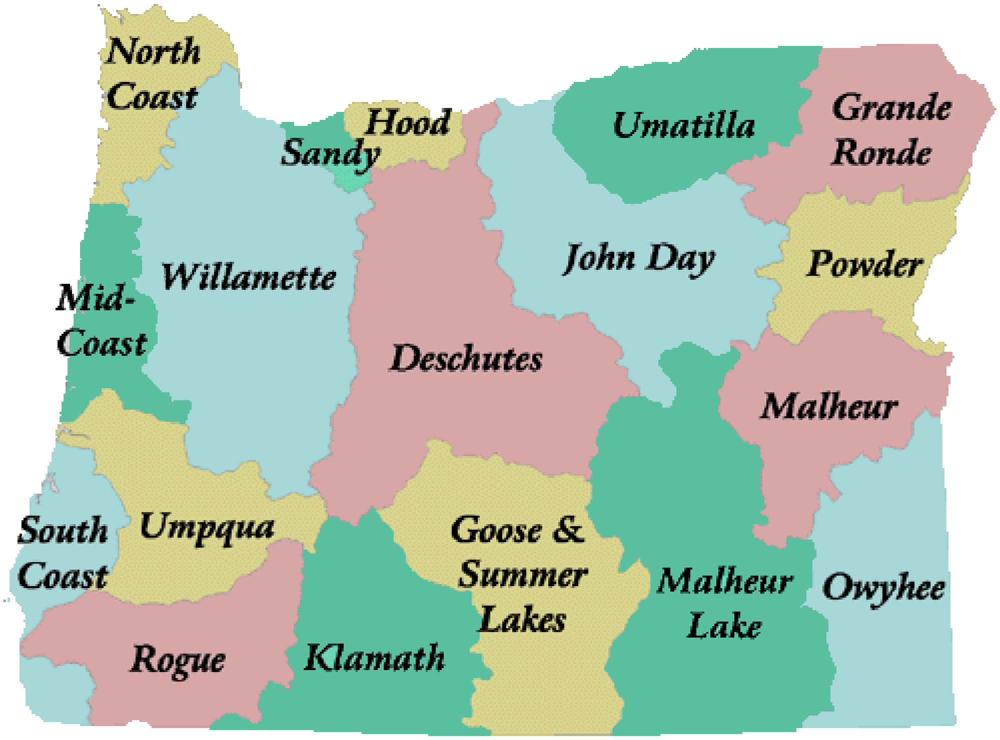

Figure 3-1: The Willamette and Other Basins Within the State of Oregon

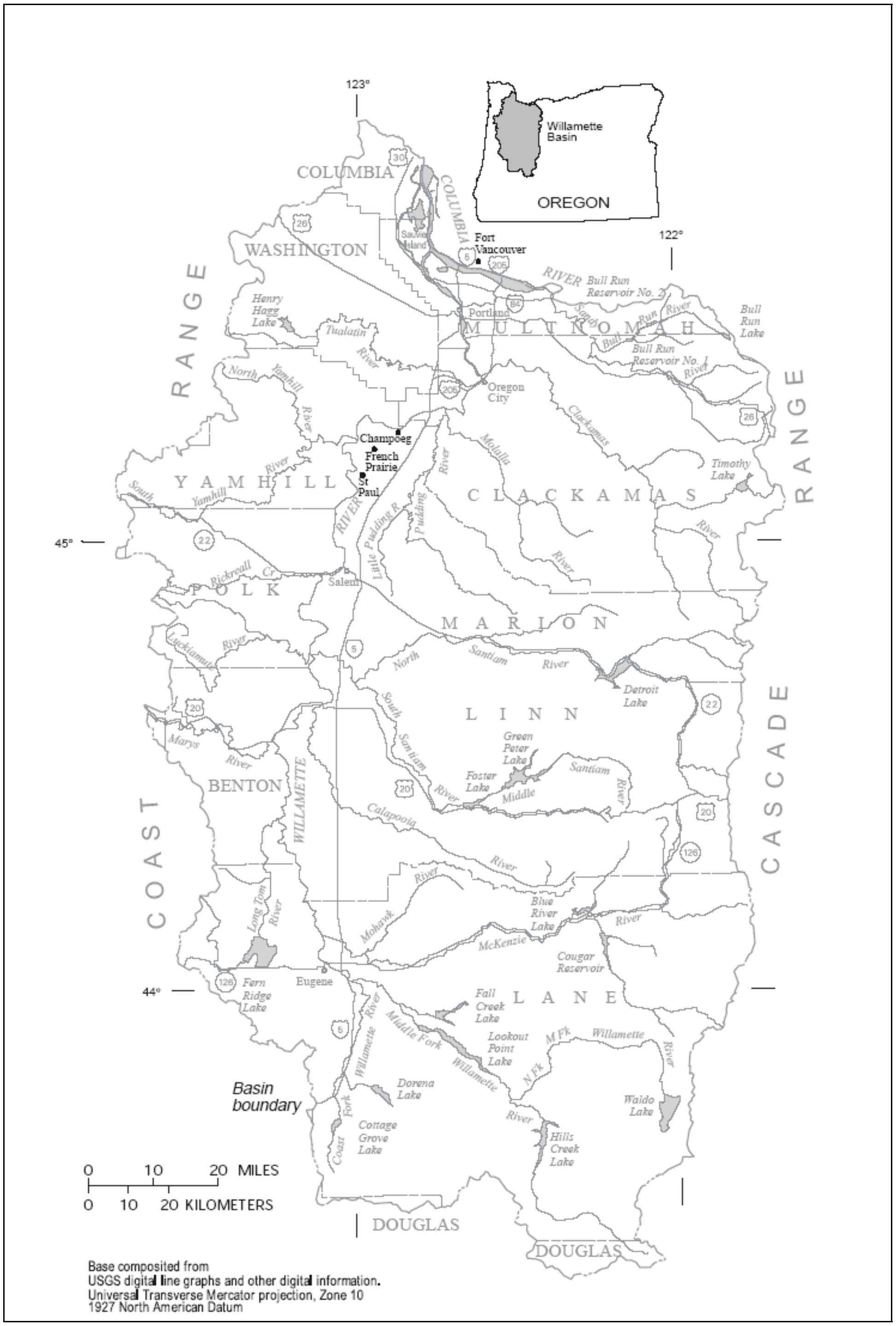

Figure 3-2: The Willamette Basin

Source: Uhrich and Wentz, 1999:

3.1.1.3 Geology

The Willamette Basin lies within the Cascadia geologic province, which extends from British Columbia to Northern California. The western boundary of the province is about 70 miles off the Pacific Coast where the Juan de Fuca tectonic plate slides beneath the North America plate. Over millions of years, as the Juan de Fuca oceanic plate has collided with the western edge of the North American continent, the Coast Range has been lifted, forming the western boundary of the basin. As the Juan de Fuca plate continued its slow northeastern migration, the once-shallow ocean floor on the western edge of the Cascade Range also lifted, from south to north, draining what has become the Willamette Valley. The eastern boundary of the Willamette Basin is defined by the volcanic crest of the Cascade Range (Pacific Northwest Ecosystem Research Consortium, 2002; Atlas of Oregon, 2001; Thieman, 2000)

A variety of rock types are present in the Willamette Basin. The Coast Range consists predominantly of marine sedimentary rock such as sandstone, siltstone, and mudstone. The slopes and foothills of the Coast Range make up about 20 percent of the basin area. The Cascade Range consists of numerous lava flows and volcanic sediments. The slopes and foothills of the Cascade Range account for more than 50 percent of the basin area (Oregon Department of Environmental Quality, 2004; Lee and Risley, 2002)

During the early stages of the basin’s development, basalt flows accumulated in the northern two-thirds of the basin. Tectonic forces folded and faulted these flows, creating uplands that separate the valley into four smaller subbasins. Alluvial sediments such as clay, silt, sand, and gravel have accumulated in the subbasins. Recent alluvium (less than 10,000 years old) occurs along the Willamette River and tributaries to depths of less than 60 feet. Older alluvial deposits can be up to 1,500 feet deep. A silt and clay layer, called the Willamette Silt, is on top of the older alluvium in the basin’s northern part and can be 120 feet thick, but it thins to zero in the southern end of the Willamette Valley near Eugene (Oregon Department of Environmental Quality, 2004).

The Willamette Valley, generally considered the part of the basin below 500 feet, represents about 30 percent of the basin area. Much of the valley up to an elevation of about 400 feet is covered by sandy to silty terrace deposits that border existing rivers and form alluvial fans near river mouths. These deposits came from the surrounding mountains and consist of intermingling layers of clay, silt, sand, and gravel. At the surface, the valley floor is covered mostly by fine-grained deposits (silt to fine sand), except in the Portland area, Canby, and the floodplain of some of the major streams where coarse-grained deposits predominate. Coarse-grained material underlies the fine-grained deposits. In some areas, such as in buried alluvial fans along the east side of the valley, these deposits are hundreds of feet thick. With the exception of the Willamette, Santiam, and McKenzie rivers, most rivers flow over the fine-grained material. (Lee and Risley, 2002)

Volcanic activity has played a major role in shaping the Willamette Valley. The Cascade Range is part of what is known as “the ring of fire,” a series of volcanoes that encircles the Pacific Ocean. More than 1,000 volcanoes exist between Mount Rainier to the north and Lassen Peak to the south in Northern California (Pacific Northwest Ecosystem Research Consortium, 2002). The Cascade Range consists of belts of older and newer rock. The Western Cascades, which began erupting about 40 million years ago, are lower and more eroded. The High Cascades to the east, which erupted around 10 million years ago, include higher and less eroded areas topped by volcanic peaks (Bishop, 2003).

The High Cascades represent a huge hydrologic sponge that stores many decades worth of water. This water rises from springs along the Cascade crest, fed by very large regional aquifers flowing through the young volcanic rock. Even during drought years, creeks and rivers fed by this groundwater flow at nearly constant levels. Prior to construction of dams on the Willamette tributaries, 60 percent of the late summer streamflow of the Willamette in Portland came from the McKenzie drainage, a High Cascade watershed (Grant, 2002). Much of the basin's biological signature, including its salmon runs, was historically tied to this clear, cold discharge.

The Willamette Valley also has been greatly influenced by volcanic activity originating outside of the basin boundaries. The northern two-thirds of the valley is underlain by Columbia River Basalt that flooded over southern Washington and northern Oregon around 15 million years ago (Pacific Northwest Ecosystem Research Consortium, 1998). The flows originated 200 miles to the east and arrived as fluid lavas, pouring through the ancestral Columbia River valley (Bishop, 2003). One of these flows solidified at the northern edge of the valley, creating the 40-foot-tall Willamette Falls—a significant geographic feature that has influenced fish distribution and floodplain characteristics in the upper basin (Thieman, 2000). The flows also formed Portland's West Hills and are the bedrock of the Salem and Eola hills (Bishop, 2003).

One of the most important aspects of Willamette geology is its history of repeated ice age flooding. There may have been upwards of 100 massive floods caused by the repeated formation and bursting of ice dams near Missoula, Montana. Starting approximately 19,000 years ago and ending about 6,000 years later, glaciers periodically dammed the Clark Fork River canyon, forming a 3,000-square-mile lake. When the ice dams gave way, 500 cubic miles of water blew out at about 17 million gallons per second. The resulting floods swept across Idaho, through southeast Washington, and down the Columbia and rushed into the Willamette Valley, creating a Willamette lake 100 miles long, 60 miles wide, and 300 feet deep. More than 300 feet of sediment now coats the Willamette Valley floor (Bishop, 2003).

The generalized geography of the basin and a geologic cross section of the Willamette Valley are shown in Figures 3-3 and 3-4, respectively.

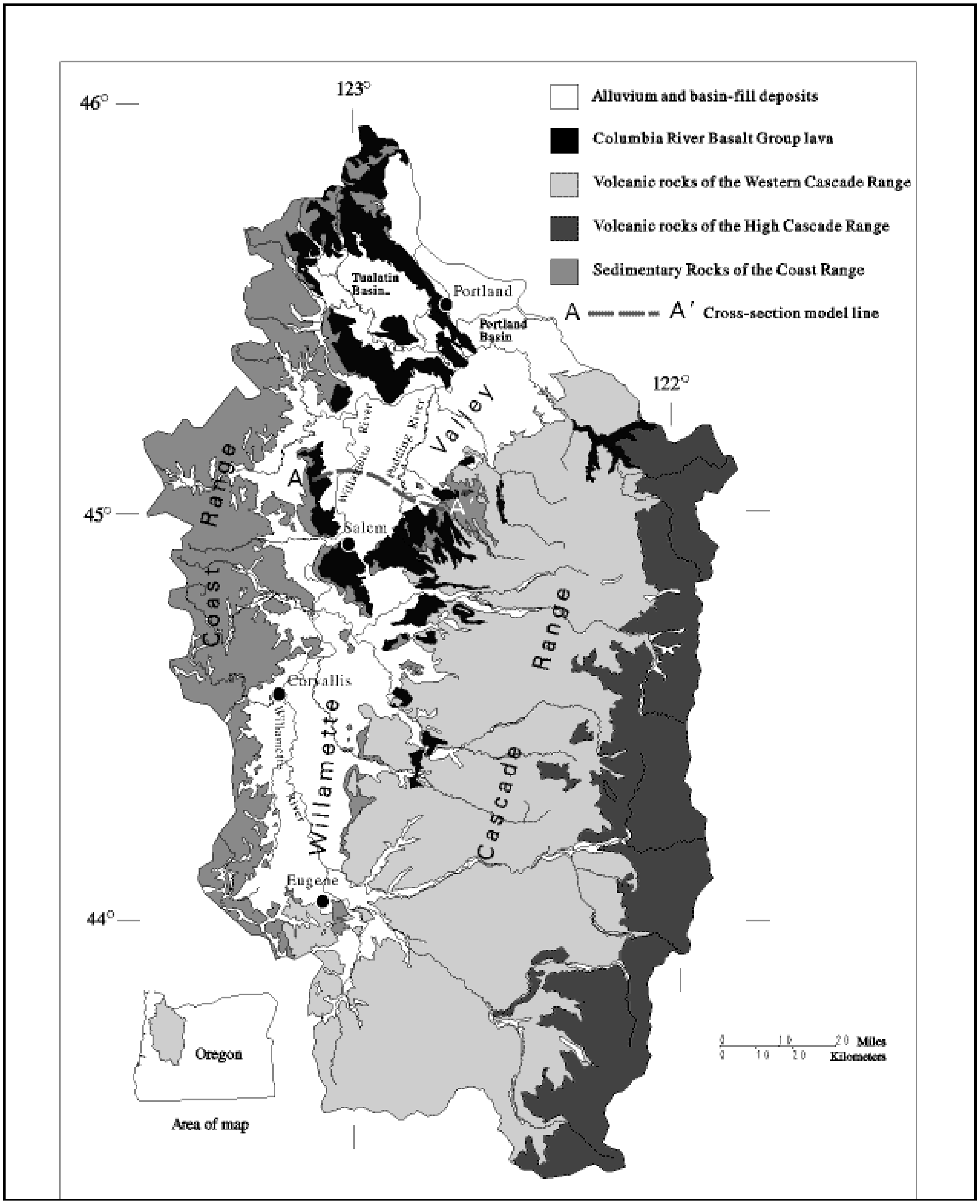

Figure 3-3: Generalized Geology and Geographic Features in the Willamette Basin

Source: U.S. Geological Survey.

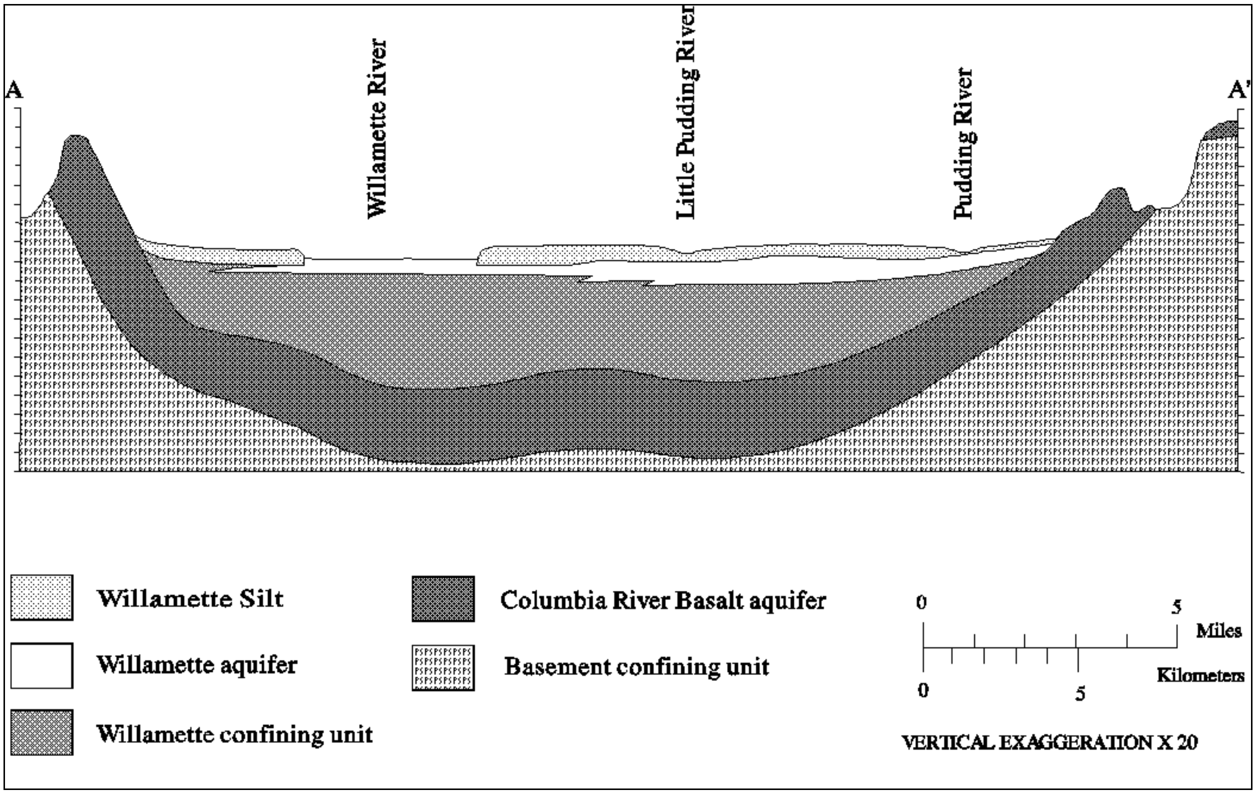

Figure 3-4: Generalized Geologic Section East-West Across the Central Willamette Valley

Source: U.S. Geological Survey.

3.1.1.4 Climate and Weather

The climate of the Willamette Basin is heavily influenced by the barrier effects of the Cascade Range and the rain shadow of the Coast Range. During the late fall and winter months, warm, wet maritime air masses from the southwest are forced up by the Coast and Cascade ranges, causing the moisture in the air masses to cools and condense as frequent and heavy rain in the lower elevations an snow in the upper elevations. Seventy-five percent of the annual precipitation in the Willamette Basin occurs from October through March. Precipitation at the crests of the Cascades and Coast Range can be as high 200 inches per year but declines sharply with elevation. The Willamette Valley floor receives only between 40 to 45 inches of precipitation annually (see Figure 3-5).

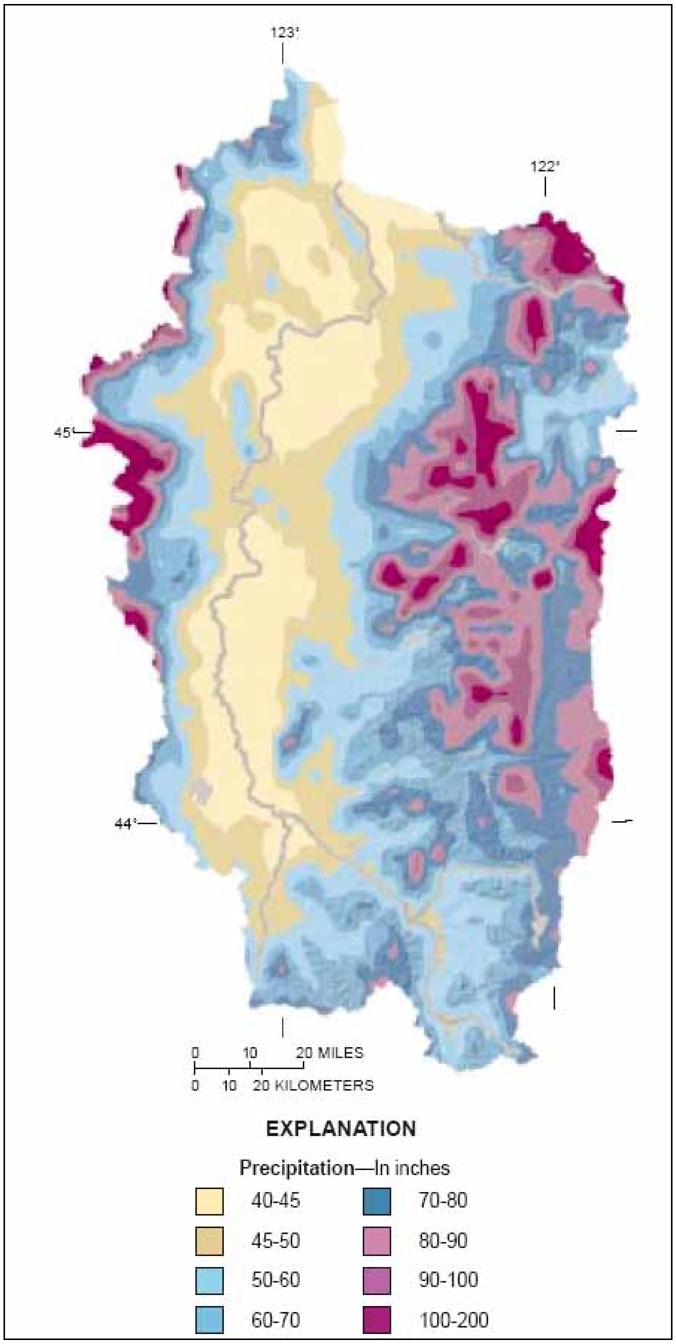

Figure 3-5: Precipitation in the Willamette Basin

Source: Uhrich and Wentz, 1999.

During the summer months, the Coast Range blocks maritime air from the Willamette basin, creating warmer, drier conditions. Only five percent of the total annual precipitation in the Willamette Basin occurs in the summer months from July through September (Uhrich and Wentz, 1999; Pacific Northwest Ecosystem Research Consortium, 2002) (Wentz, 1998; Uhrich and Wentz, 1999). Most precipitation falls as snow above 5,000 feet in the Cascades (Uhrich and Wentz, 1998). Mean monthly temperatures in the valley range from about 40 degrees Fahrenheit during January to just above 60 degrees F during August.

3.1.1.5 Land Cover and Habitat

Due in large part to the influence of the Coast Range and Cascades, 60 percent of the subbasin is forested. Agricultural land makes up 27 percent of the basin and is located mainly in the Willamette Valley. About a third of the agricultural land is irrigated (Wentz et al., 1998). Urban areas account for 5 percent of the basin (Oregon Watershed Enhancement Board, 2003; see Figure 3-6).

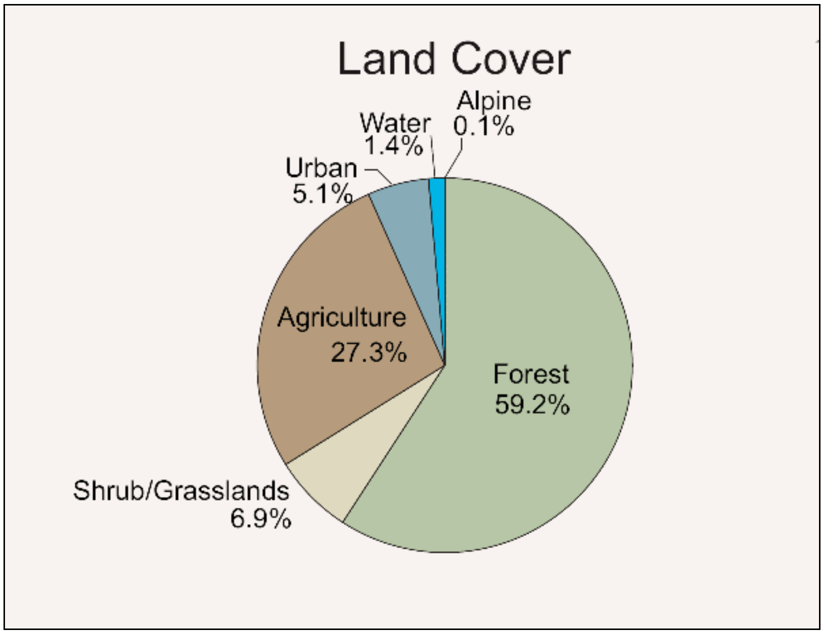

Figure 3-6: Land Cover in the Willamette Basin

Source: Oregon Watershed Enhancement Board, 2003.

A variety of systems are used to describe the Willamette Basin's habitats. The first in common use is that of ecoregions. In turn, each ecoregion hosts different kinds of fish and wildlife habitat. These are described generally, below. More detailed habitat information is included in Section 3.1.4.7.

Ecoregions. Ecoregions are ecologically distinct areas that result from the interplay of different environmental factors, ecosystems, physical and landscape features, and human interactions (Pacific Northwest Ecosystem Research Consortium, 2002). Ecoregions have unique "fingerprints" of landform, geology, soil, climate, potential vegetation, and land use cover. They cross over watershed boundaries and are made up of different habitat types.

The Willamette Basin has five ecoregions: Coastal Mountains, Willamette Valley Plains, Willamette Valley Foothills, Western Cascades, and High Cascades (Clarke and others, 1991). These are described in Table 3-2 and shown in Figure 3-7.

Table 3-2: Descriptions of Ecoregions in the Willamette Basin

Ecoregion	Percent of Basin	Description
Coastal Mountains	8	Generally 1,500 to 2,000 feet in elevation. Extensively dissected by streams, with a typical density of 2 to 3 miles of perennial streams per square mile (Omernick and Gallant, 1986). Very wet and dominated by productive and intensively logged Douglas fir plantations (Pacific Northwest Ecosystem Research Consortium, 2002).
Willamette Valley Plains	22	Nearly level to low sloping floodplains, ranging from 100 to 300 feet in elevation. Once hosted prairies and savannas of Oregon white oak, Oregon ash, and Douglas fir. Agriculture mixed with urban and rural development now occupies this region.
Willamette Valley Foothills	20	The foothills border the plains and have steeper slopes; elevations average 1,000 feet in the north to more than 2,000 feet in the central and southern basin. The foothills are characterized by Oregon white oak and madrone on dry sites and Douglas fir and western red cedar on wet. Current land use supports forestlands, orchards, vineyards, and Christmas tree farms, as well as rural residential development.
Western Cascades	44	Generally 5,000 to 6,000 feet in elevation and stream densities of 1.5 to 2 miles of perennial streams per square mile (Omernick and Gallant, 1986). Dominant vegetation types include conifer forests of Douglas fir, western hemlock, and western red cedar, interspersed with alder and vine maples.
High Cascades	6	High plateaus and glaciated, volcanic peaks that rise above subalpine meadows. Elevations range from 5,600 to 10,000 feet. Glaciation occurs on the highest volcanoes. In lower elevations, the ecoregion is extensively forested with mountain hemlock and Pacific silver fir. At higher elevations, cold winters and short growing seasons favor herbaceous and shrubby subalpine meadow vegetation and scattered patches of mountain hemlock, subalpine fir, and whitebark pine.

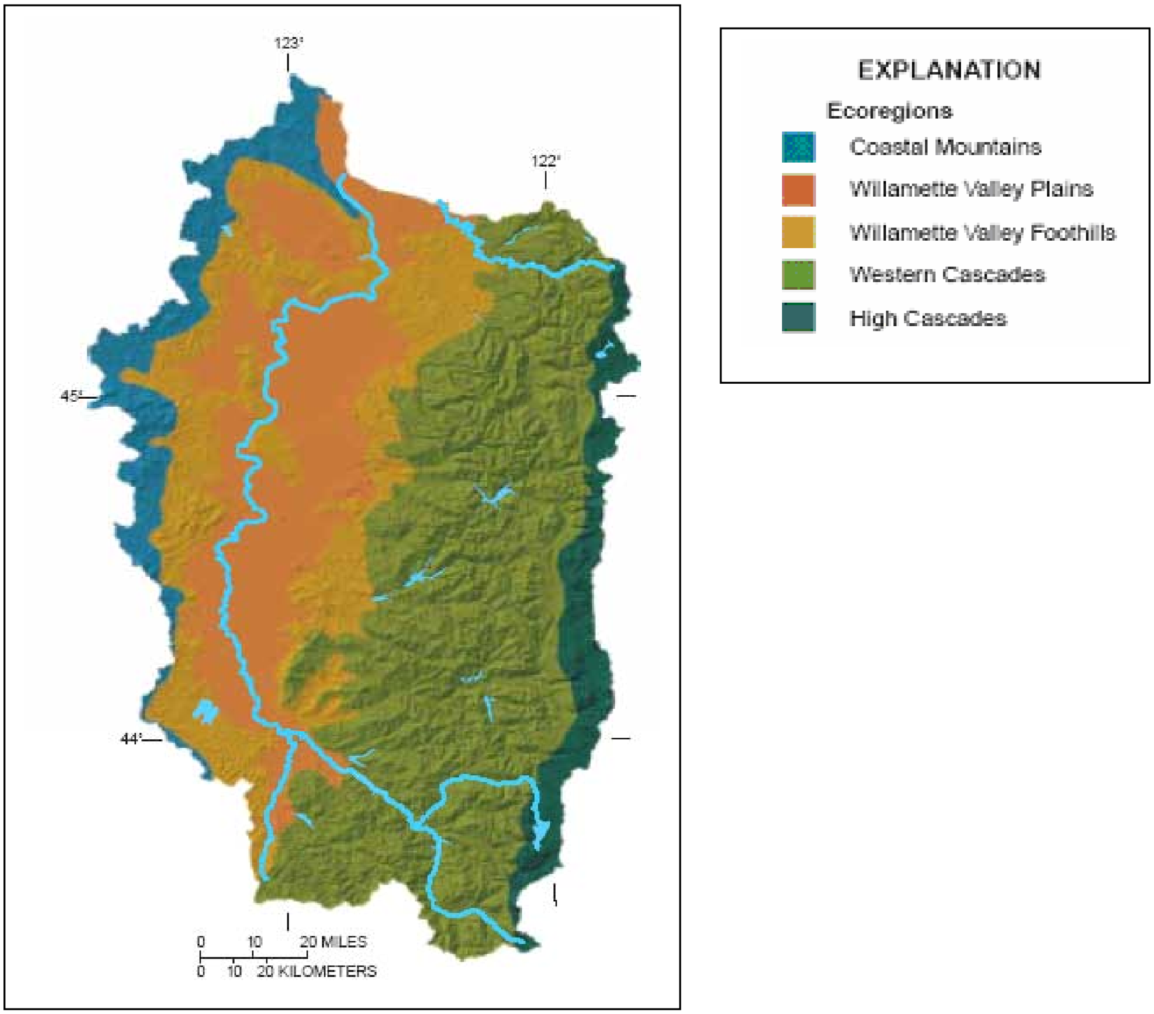

Figure 3-7: Locations of Ecoregions in the Willamette Basin

Source: Uhrich and Wentz, 1997.

Fish and Wildlife Habitat. Biologists estimate that there are 18 species of native amphibians, 15 reptiles, 154 birds, 69 mammals, and 31 native fish currently breeding in the basin (Pacific Northwest Ecosystem Research Consortium, 2002). These species make their homes in widely diverse areas across the Willamette landscape. There are many ways scientists and land managers catalog these habitats.

For example, the *Willamette Restoration Strategy* (Willamette Restoration Initiative, 2001) used six types based on historical habitats in the Willamette. The Interactive Biodiversity Information System[1] (IBIS, 2004) describes 10 historical habitat types and 14 current habitat types associated with the Willamette Basin. Adamus and others have defined 31 distinct habitat types (Adamus et. al., 2001). The Oregon Natural Heritage Center and The Nature Conservancy identified 96 subcategories of habitat types within nine structural classes (July 2000). The *Willamette*

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[1] "The IBIS is an informational resource developed by the Northwest Habitat Institute (NHI) to promote the conservation of Northwest fish, wildlife, and their habitats through education and the distribution of timely, peer-reviewed scientific data … IBIS contains extensive information about Pacific Northwest fish, wildlife, and their habitats, but more noteworthy, IBIS attempts to reveal and analyze the relationships among these species and their habitats. … IBIS [is] not only a fish, wildlife, and habitat information distribution system but also as a peer-review system for species data" (Interactive Biodiversity Information System, 2004).

Subbasin Summary (Willamette Restoration Initiative, 2001) also describes nine general habitat types but categorizes them differently (NPCC, 2001).

Habitats might be thought of as natural neighborhoods. It might not be possible to assign strict boundaries, but each habitat has a character that can be described in terms of who lives there and the type of "housing" available. Table 3-3 represents one characterization of the Willamette Basin's natural neighborhoods.

Habitat types are described in more detail in Section 3.1.4.7.

Table 3-3: Habitat Types in the Willamette Basin

Habitat Type	Focal Species
Oak Woodlands	**Wildlife:** Acorn woodpecker, chipping sparrow, western wood-pewee, white-breasted nuthatch, southern alligator lizard, sharptail snake, western gray squirrel
Upland Prairie, Savannah, and Rock Outcrops	**Wildlife:** American kestrel, horned lark, vesper sparrow, western meadowlark, western rattlesnake, black-tailed jackrabbit, Taylor's checkerspot, Fender's blue butterfly **Plants:** Kincaid's lupine, golden paintbrush, white rock larkspur, white-topped aster
Wetland Prairie and Seasonal Marsh	**Wildlife:** Dunlin, common yellowthroat, northern harrier, sora, red-legged frog **Plants:** Water howellia, Bradshaw's lomatium, Nelson's checkermallow, Willamette Valley daisy, peacock larkspur
Perennial Ponds, Sloughs, and Their Riparian Areas	**Wildlife:** Western pond turtle, Oregon spotted frog, Cascades frog, purple martin, green heron, wood duck, yellow warbler
Riparian Areas of Rivers and Streams	**Wildlife:** American dipper, bald eagle, harlequin duck, red-eyed vireo, willow flycatcher, coastal tailed frog, American beaver, river otter
Old-Growth Conifer Forest	**Wildlife:** Pileated woodpecker, olive-sided flycatcher, Vaux's swift, marbled murrelet, spotted owl, great gray owl, Oregon slender salamander, American marten, red tree vole, Townsend's big-eared bat

3.1.1.6 Population and Land Use

Population. Human beings have been present in the basin for around 10,000 years. Before settlement, an estimated 30,000 Native Americans lived in the Willamette Basin. There were a variety of tribal and lingual groups (see Figure 3-8), including lower river peoples such as the Clackamas, who relied more on fishing and trading, and upper river peoples such as the Kalapuya, who managed a prairie landscape for game and roots. Early in the settlement period, the vast majority of these people were killed by severe epidemics of introduced diseases that swept the region between 1830 and 1832. In the 1850s, the United States negotiated treaties with Indian tribes and bands of the Willamette, Umpqua and Rogue River valleys. The treaties required that separate bands would confederate and move to reservations. In the late 1850s and early 1860s, the United States removed more than 20 Indian bands from their traditional homes and relocated them on the Grand Ronde Indian Reservation, located on the headwaters of the Yamhill River in the Coast Range. In 1954, federal legislation severed the trust relationship between the federal government and the tribes of western Oregon, terminating the Grand Ronde Reservation. However, in 1983, Congress restored the trust relationship between the federal government and the Confederated Tribes of the Grand Ronde Community (Confederated Tribes of the Grande Ronde, 2004a).

Figure 3-8: Native American Languages and Tribes, 1840-1850

Source: Confederated Tribes of the Grande Ronde, 2004b.

The first large wave of settlers arrived in the 1840s. By 1848 Oregon was a territory of the United States, and it became a state in 1859. The first census, which was taken in 1850, showed a population of just more than 13,000, nearly all in the Willamette Valley. By 1880, about 105,000 people lived in the Willamette Valley (Pacific Northwest Ecosystem Research Consortium, 2002).

Today, about 2.5 million people, or 70 percent of Oregon's population, live in the Willamette Basin. The Portland metropolitan area has 1.2 million people and is the state's largest urban area.

The three largest population centers of Portland, Salem, and Eugene-Springfield are situated along the banks of the Willamette River and the Interstate 5 corridor. Population growth in the basin is expected to double to nearly 4.0 million by 2050 (Willamette Restoration Initiative, 2001). In the Portland metropolitan region, a 37 percent increase is expected between 2000 and 2020 (Metro, 2003).

From 1990 to 2000, the basin grew by approximately 418,000 people, with about 68 percent of the increase due to in-migration; in the Portland metro region, about two-thirds of population growth came from in-migration. Growth during this period is attributed to a strong economy and attractive quality of life (Metro, 2003). Less than half of the current population was born in the Willamette Valley, and roughly one out of seven has moved to the valley in the last 5 years (Willamette Valley Livability Forum, 1999). Currently, about 80 percent of the basin's population lives in areas with 1,000 or more people per square mile (Pacific Northwest Ecosystem Research Consortium, 2002).

In 1997, nearly 90 percent of Willamette Valley residents were non-Hispanic whites, 6 percent were Hispanic, and 4 percent were Asian/Pacific Islander (see Table 3-4). Between 1991 and 1997, the median home sales price increased nearly 90 percent in the Portland area, 84 percent in the Eugene area, and 79 percent in the Salem area, compared to a 27 percent increase nationwide. (Willamette Valley Livability Forum, 1999).

Table 3-4: Ethnic Diversity in the Willamette Valley

Category	Percent of Total Population
White, non-Hispanic	87
Hispanic	6
Asian/Pacific Islander	4
Black	2
Native American	1

Source: Willamette Valley Livability Forum, 1999.

During the 1990s, for the first time there were more Oregonians over the age of 70 than there were teenagers. The senior population in the state of Oregon is expected to double by 2030 (Preister, 2002).

In the Willamette Basin south of Portland, from 1990 to 2000 the population of urban centers grew by 14 to18 percent, while rural areas either lost population or held steady. Very rapid growth happened in the small towns near the urban centers, such as Aumsville (28 percent growth), Dallas (21 percent), Gervais (47 percent), Independence (26 percent), Monmouth (19 percent), Silverton (21 percent), Stayton (25 percent), Sublimity (29 percent), Woodburn (30 percent), Philomath (26 percent), and Tangent (22 percent) (Preister, 2002).

According to a recent study, urban residents tend to hold strong values for outdoor aesthetics and environmental stewardship, and they find ways to express those values close to home through parks and trails programs, outdoor education, and social programs. Urban centers are the largest source of recreational impacts on public lands and reveal a diverse orientation to public lands. South of Portland, the Willamette River forms an important boundary, with people living west of the river relating more to the coast and people living east of the river oriented more to the Cascades and central Oregon. Primary users of public lands are individuals who are not particularly organized (Preister, 2002).

Land Use. Land use is diverse but is dominated by forest and agriculture (see Table 3-5).

Table 3-5: Land Use in the Willamette Basin

Zoning Designation (1990)	Percent of Basin Area
Exclusive forest use	64
Farm use	25
Urban (area within urban growth boundaries)	6
Rural residential	3.5

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Of the basin area devoted to agricultural land use, about 39 percent is used for pasture and hay production, 27 percent is for grass seed, 13 percent is for vegetable crops, 10 percent is for grains, and 5 percent is for fruit. The remainder is used for tree production, nursery crops, and other farm uses (Pacific Northwest Ecosystem Research Consortium, 2002).

3.1.1.7 Economy

The Willamette Basin accounts for 51 percent of Oregon’s total gross farm sales and 58 percent of Oregon’s crop sales (Oregon Agricultural Statistics Service, 1993) through the production of grass seed, wheat, hay, oats, corn, and many specialty crops. The lower basin from Salem to Portland serves as the economic hub of Oregon, with a concentration of manufacturing, retail trade, and professional and business related services. Portland serves as a major seaport for trade between the western United States and Pacific Rim countries.

Employment in the Portland metropolitan region is characterized by both its diversity and an emphasis on private-sector rather than public-sector employment. Computer component manufacturing, health care and insurance, retail merchandizing, and financial management are the leading employment categories. Over the last 20 years, the Portland metropolitan region broadened its manufacturing base to focus on metals, high-tech machinery, and semiconductors. The region’s proportion of employment in the manufacturing, construction, and mining sectors is higher than the national average. The metro region also is the leading warehousing and distribution center for the Pacific Northwest, serving as a market area for roughly 7 million people through a network of marine, air, rail, and road systems. The metro area is a port of call for 16 regularly scheduled steamship lines serving world trade routes. In terms of total tonnage, the Port of Portland is ranked third largest on the West Coast, after Long Beach and Los Angeles. The value of marine shipments through the Port in 1999 was nearly $10 billion. Portland International Airport handled more than 12 million passengers and 256,000 tons of cargo in 2002, with a forecast of nearly 27 million passengers by 2020. In the late 1990s, the region also underwent a transformation in its agricultural sector, with nursery and seed growers becoming the top-grossing sales category for the entire state (Metro, 2003).

The major employers in the Willamette Basin south of the Portland metro area are medical care facilities, forest products manufacturing, high technology manufacturing, recreational vehicle manufacturing, higher and secondary education, government, and trades and services (Preister, 2002) .

A change that has recently accelerated is the rise of the “commuting economy.” Particularly with the decrease in timber-related activity in rural economies, commuting patterns have changed from going up to the mountains for work to going down to the larger communities. While this has increased a number of employment and educational opportunities, it also has resulted in “leakage” of workers, local jobs, community structure, and leaders from smaller communities (Preister, 2002). Nearly 250,000 people, or 25 percent of Willamette Basin workers, travel outside the county they reside in to go to work (Pacific Northwest Ecosystem Research Consortium, 2002).

3.1.1.8 Land Ownership

Approximately 36 percent of the basin is in federal ownership (see Figures 3-9 and 3-10). Most of the federal land is located in the higher elevations of the Cascade and Coast ranges and is managed by the U.S. Forest Service (USFS) and U.S. Bureau of Land Management (BLM). More than 60 percent of the basin area outside urban growth boundaries—and more than 90 percent of the valley floor—is privately owned (Pacific Northwest Ecosystem Research Consortium, 2002).

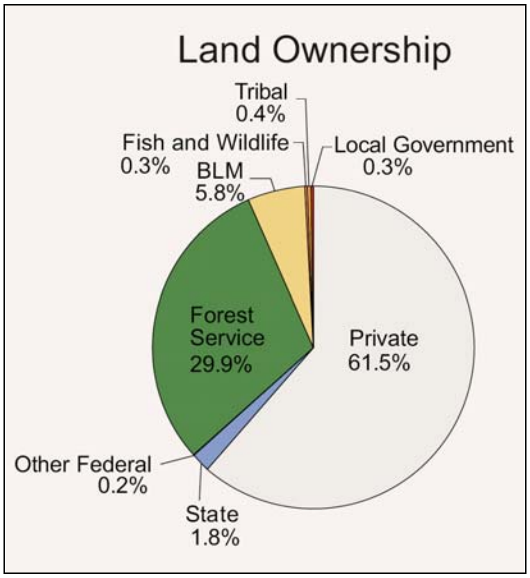


Figure 3-9: Proportion of Land Ownership in the Willamette Basin

Source: Oregon Watershed Enhancement Board, 2003.

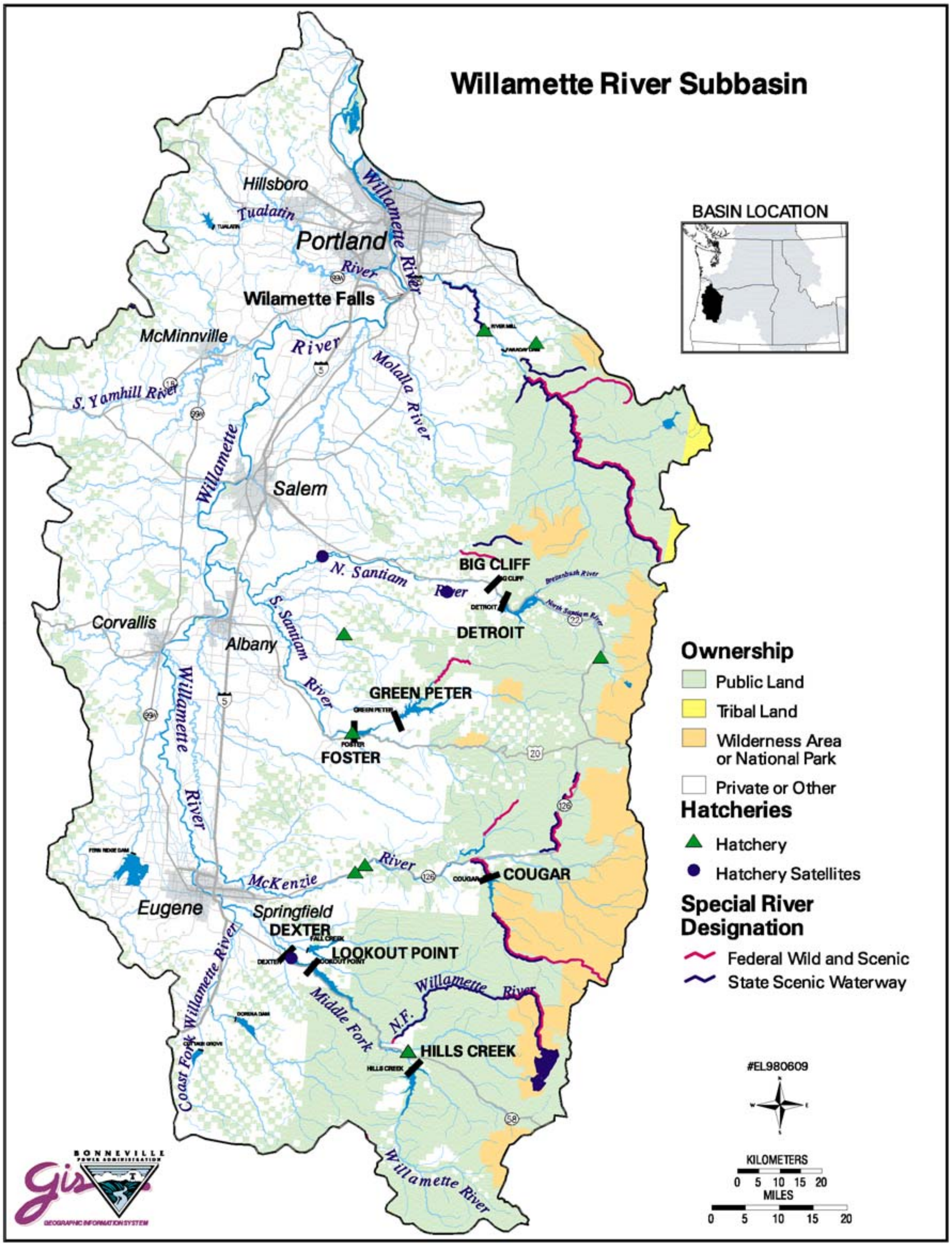


Figure 3-10: Land Ownership in the Willamette Subbasin

Source: Northwest Power and Conservation Council, 1999.

3.1.1.9 Human Disturbances to the Aquatic and Terrestrial Environments

Human disturbance has played a role in the Willamette Valley for the entire history of its habitation—more than 10,000 years. Native Americans burned the valley to produce food and fiber. Tree ring studies suggest that frequent fires took place at least from 1647 to 1848. Burning grasslands in late summer suppressed invading shrubs and trees and kept ecological conditions favorable for camas and tarweed, which were dietary staples (Pacific Northwest Ecosystem Research Consortium, 2002).

The extent and pace of human disturbance increased with Euro-American settlement in the mid-1800s. Intensive trapping essentially eradicated beaver populations by the early 1830s, dramatically changing the basin's hydrology, vegetation, fish, and wildlife. As settlers displaced a native population decimated by disease, grassland burning stopped and farming began. (Pacific Northwest Ecosystem Research Consortium 2002)

Habitat Conversion. The Pacific Northwest Ecosystem Research Consortium concluded in its 2002 *Willamette River Basin Planning Atlas* that land and water uses over the past 150 years have dramatically changed the patterns and composition of natural vegetation. More than 60 percent of the basin's older conifer forests have been converted to other land cover types or land uses. In the lowlands, natural grasslands have almost entirely been eradicated, shrubland has been cut in half, and hardwood forests have diminished by three-quarters (see Table 3-6). About 75 percent of what formerly was wet and dry prairie, and about 60 percent of what was wetland, is now in agricultural production. Today, less than 3 percent of the original area of bottomland prairie grasslands remain, with the rest having been converted to agricultural and urban uses. The area of riparian (also called bottomland) forests along the valley's streams and rivers has diminished by 80 percent as a result of conversion to agriculture, logging, and human-caused changes to stream systems (Pacific Northwest Ecosystem Research Consortium, 2002).

Table 3-6: Changes in Land Cover in the Willamette Basin

Vegetation Types	Percentage of Valley, Presettlement	Percentage of Valley, circa 1990
Natural grasslands	22.9	0.7
Natural shrubland	14.6	9.8
Hardwood forest	22.5	6.5
Mixed forest	4.8	10.5
Conifer forest	23.3	13.8
Wetlands	9.8	0.6

Roads. One of the greatest manifestations of human disturbance has been the construction of the basin's extensive road network. As of 1990, less than 1.5 percent of the basin was more than a mile from roads mapped by the Oregon Department of Transportation. On average, there are nearly 4 miles of road for every square mile of land in the basin. This road network is estimated to have a combined length of more than 44,000 miles, a figure that rivals or exceeds some estimates of the stream network. Roads affect ecosystem functions by increasing the volume and rate of runoff, which in turn can increase sediment and pollutant loads and temperature. Roads also can fragment wildlife habitat, disrupt or cut off fish migration, and expand the dispersal of invasive plant species (Pacific Northwest Ecosystem Research Consortium, 2002).

Channel Structure and Hydrology. Human manipulation of stream flows and channel structure also has had enormous impacts on aquatic and terrestrial environments. Upon Euro-American settlement, the Willamette River became a principal arterial for transporting farm and forest goods. From 1880 to around 1950, the U.S. Army Corps of Engineers removed more than 69,000 snags and overhanging trees from the river to protect river boats. In 1908, the Corps began dredging the Willamette above Oregon City. For the next 20 years, it removed an average of 102,000 cubic yards of material per year. Dredging continued on the Upper Willamette until the early 1970s. In addition, the Corps blocked side channels, scraped gravel bars, and built wing dikes to change the depth and course of the river (Benner, 1997).

Beginning in the 1960s, the U.S. Army Corps of Engineers built the Willamette River Basin Project, a complex of 13 flood-control dams on tributaries, mostly in the Cascades. These dams have dramatically altered the flow regime of the Willamette by controlling downstream flooding in the winter, nearly doubling the flow in the summer (which dilutes pollution), and altering channel dynamics. The project also included a bank protection component that protects agricultural, suburban, and urban land from erosion along the mainstem Willamette River from New Era upstream to each of the Willamette River Basin Project dams on the tributaries. As of September 1996, the program had protected a total of 489,795 linear feet (or nearly 93 miles) of banks at 230 locations. Project components include riverbank revetments, pile and timber bulkheads, drift barriers, minor channel improvements, and maintenance of existing works for the control of floods and prevention of bank erosion.

These streamflow and channel structure activities are largely responsible for large-scale decreases in channel complexity in the Willamette River, with the loss of many different habitats (for example, side channels, wetlands, and wet prairies) important for salmonids and numerous wildlife species.

Human disturbance is discussed further in Sections 3.1.3, 3.1.4, and 3.2.

3.1.2 Existing Subbasin Water Resources

3.1.2.1 Watershed Hydrography

Hydrographic Overview. The average annual runoff of the Willamette, which is about 24 million acre feet, contributes approximately 15 percent of the total annual discharge of the Columbia River (U.S. Army Corps of Engineers, 2000). Major tributaries include the Santiam, McKenzie, Clackamas, Middle Fork, Coast Fork, Long Tom, Luckiamute, Mary’s, Molalla, Calapooia, Tualatin, and Yamhill rivers. The tributaries have their headwaters along the eastern slopes of the Coast Range, the northern slopes of the Calapooya Mountains, and the western slopes of the Cascade Range.

The mainstem of the Willamette River is formed by the confluence of the Coast and Middle forks near Eugene and flows 187 miles to the Columbia. The mainstem has four distinct reaches whose physical nature governs the hydraulics of flow. The upper reach extends from Eugene to Albany, roughly from River Mile (RM) 187 to RM 119. This reach has a braided, meandering channel with many islands and sloughs. The river is shallow and its bed consists almost entirely of cobbles and gravel that, during the summer, are covered with biological growth. The middle reach—roughly from Albany to the mouth of the Yamhill River (RM 119 to RM 55)—is characterized by a meandering channel that is deeply cut into the valley. The Newberg Pool reach extends from RM 55 to Willamette Falls at RM 26.5. In essence, this deep, slow-moving pool acts as a reservoir. The pool is a depositional area for small gravel- to silt-sized material. It terminates at Willamette Falls, a 42-foot-high natural falls, with flashboards used to control pool elevation during the summer. Lastly, the tidal reach extends downstream from Willamette Falls and is controlled by backwater from the Columbia River (Lee and Risley, 2002).

The Willamette's hydrography has three major distinguishing elements:

- **Upper and lower basin.** The Willamette system is strongly influenced by Willamette Falls at Oregon City, which divides the Willamette basin into two distinct areas. Below the falls, the very low-gradient river is subject to tidal influences and backwater effects of the Columbia (Pacific Northwest Ecosystem Research Consortium, 2002). With a drop of 42 feet and a width of 1,300 feet, these falls are some of the biggest in the Pacific Northwest. They have been altered by human additions such as timber cribs and concrete revetments to manage flow, navigation locks (the oldest west of the Mississippi), and fish ladders. Historically, the falls acted as a biological control. They were passable to fish only in high water; thus, only winter steelhead could get above them. Coho tended to use only downstream tributaries, and cutthroat trout's "sea-run" life form existed below the falls, not above.
- **Coast Range (west side) and Cascade (east side) tributaries.** The Willamette system is characterized by very unequal contributions from east and west (see Figure 3-11). The Cascade streams are larger, colder, and historically supported more salmon runs. Flows on the east side are maintained by snow-melt and springs during the summer. About 73 percent of the Willamette's total annual flow is from the east side of the basin. Coast Range streams, on the other hand, are shorter, with less volume, and hosted a different suite of native fish species. These streams are warmer and have very little flow in the summer. About 20 percent of the Willamette's total annual flow is from the west side (Bastasch, 1998).
- **Major dams.** Because the source of most of the Willamette's water (and flooding) is the east side, the basin's major dams all have been built on streams originating in the Cascades (see Table 3-7 and Figure 3-10). Combined, the eastside reservoirs control approximately 27 percent of the runoff from the watershed and provide approximately 1.6 million acre-feet of flood control storage in the basin. This means that the fish and wildlife impacts of hydrologic change, habitat inundation, and downstream in-channel habitat disruption have occurred predominantly on the east side of the basin.

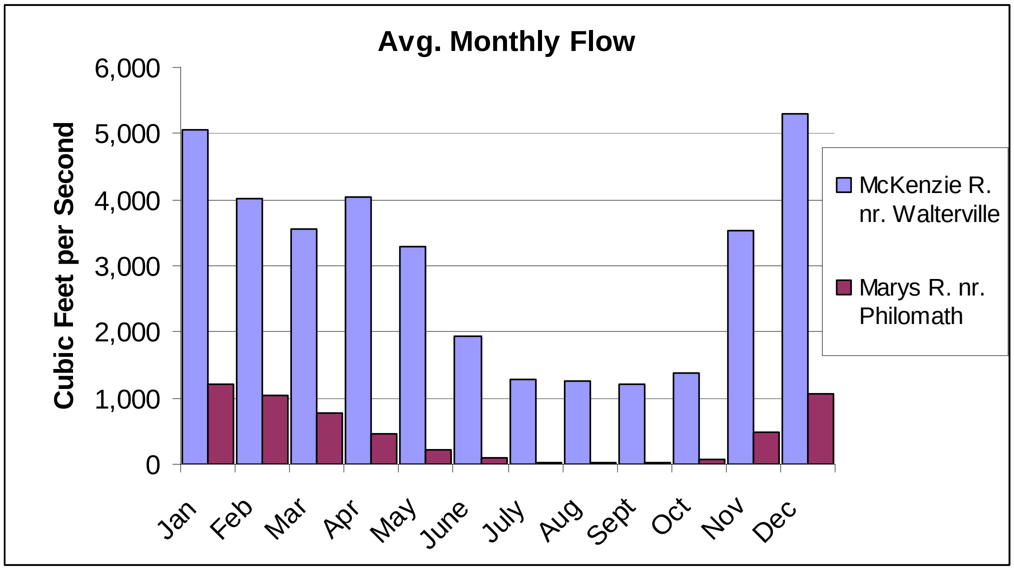


Figure 3-11: Comparison of Average Monthly Flows of an Eastside (McKenzie River) and Westside (Marys River) Tributary

Table 3-7: Willamette Basin Project Dams

Dam	Stream location	Volume (acre-feet)	Average Power Generated (megawatts, 1983-95)
Big Cliff*	North Santiam	7,000	133.6
Blue River	Blue River	85,000	-
Cottage Grove	Coast Fork Willamette	33,500	-
Cougar	South Fork Mckenzie	219,300	205.4
Detroit	North Fork Santiam	455,000	526.5
Dexter*	Middle Fork Willamette	27,500	102.7
Dorena	Row River	77,600	-
Fall Creek	Fall Creek tributary to Middle Fork Willamette	125,000	-
Fern Ridge	Long Tom	101,200	-
Foster	South Santiam	61,000	135.6
Green Peter	Middle Santiam	430,000	333.0
Hills Creek	Middle Fork Willamette	356,000	222.3
Lookout Point	Middle Fork Willamette	453,000	445.8
			Total: 2,104.9

* Re-regulating dams with little or no storage.

Source: U.S. Army Corps of Engineers; from Bastasch, 1998.

In addition to the major flood-control dams operated by the U.S. Army Corps of Engineers, there are more than 350 other large dams in the basin that control water for agricultural, municipal, and power production purposes.

Hydrographic Classifications. There are two major and slightly different classification schemes for characterizing the Willamette's hydrography.

The first is the Hydrologic Unit Coding of the U.S. Geological Survey (USGS). In this system, USGS has divided the United States into 21 major regions that usually contain the drainage area of a major river. These regions are further divided into subregions (there are 222 in the United States), based on smaller river systems; these subregions, in turn, are further divided on the basis of smaller tributaries (U.S. Geological Survey, 2004).

The Willamette Basin is within the Pacific Northwest Region (17), the Willamette subregion (09), basin (00). Within the basin, major tributary areas—a fourth division—are given an additional two-digit code. These are called "4th-field" hydrologic unit codes. They correspond to the major tributary drainages of the Willamette. Further subdivisions include smaller "5th-field" (or HUC-5) and "6th-field" (HUC-6) watersheds. For example, the Willamette Basin has a code of 17090000. The Mohawk River, a McKenzie tributary, has a hydrologic unit code of 1709000402, as illustrated in Figure 3-12.

			"4th-field HUC"	"5th-field HUC"
17	09	00	04	02
Pacific NW region	Willamette Subregion	Willamette basin	McKenzie drainage	Mohawk sub-drainage

Figure 3-12: USGS Hydrologic Unit Coding of the Mohawk River

The Willamette Basin contains 12 4th-field hydrologic units, 72 5th-field hydrologic units, and 170 6th-field hydrologic units (Pacific Northwest Ecosystem Research Consortium, 2002). The basin's 5th-field hydrologic units are shown in Figure 3-13. Hydrologic units tend to be used by hydrologists and other technical experts, especially at the federal level, when describing streamflows, water quality, and other measurements.

However, another classification system is used more frequently for management purposes: watersheds. Although similar to hydrologic unit codes, watersheds are defined by how the landscape catches and conveys water down channels, and the system is not as detailed as USGS hydrologic coding. Watersheds have names, not numbers, and any smaller drainage areas are similarly identified by name, not a code. Watersheds are used especially by citizens, watershed councils, and state agencies to describe the natural subunits of the Willamette Basin. Unlike hydrologic units, the trace of a watershed begins right at its confluence with the stream it flows into, so each watershed tends to be shaped like a leaf with the tip of the stem being the mouth of the river or stream. Hydrologic units tack on other areas near the mouth so that all areas of the basin are covered by a hydrologic unit. The map of Willamette Basin watersheds (Figure 3-14) shows gaps that are actually collections of very small, unnamed watersheds.

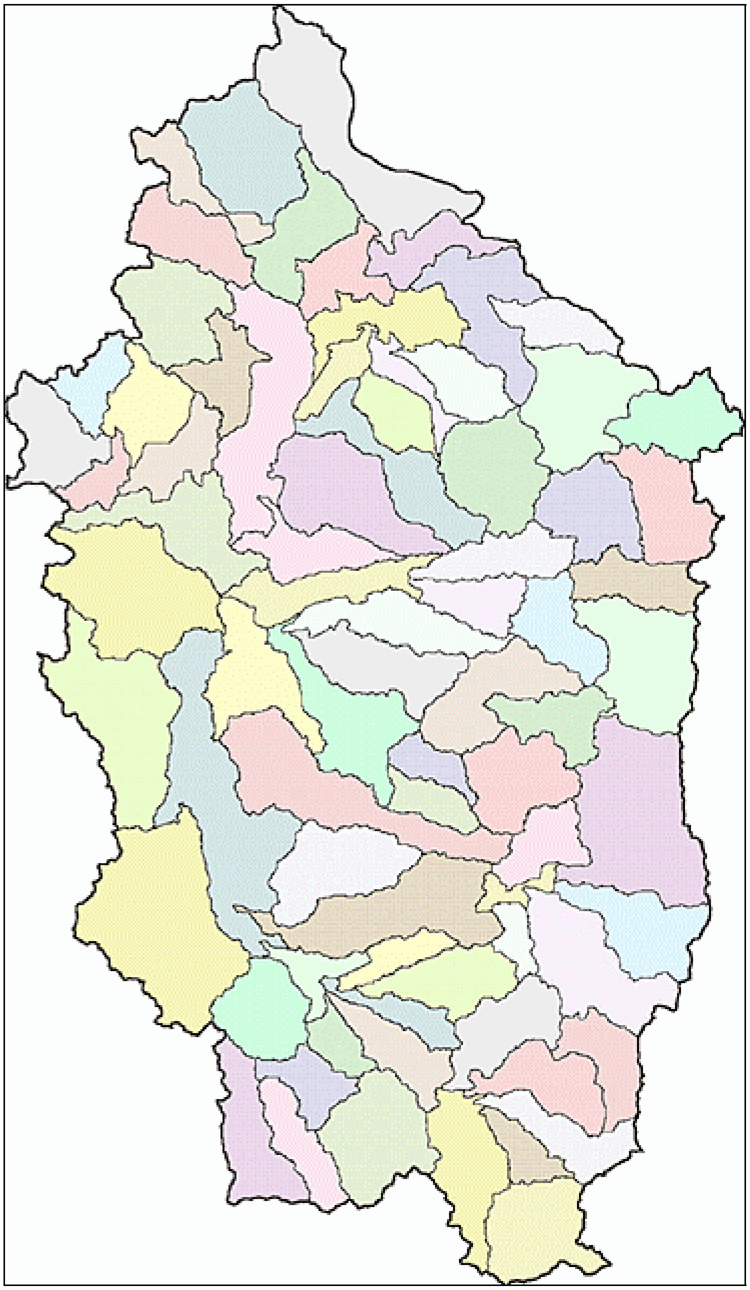


Figure 3-13: 5th-Field Hydrologic Units in the Willamette Basin

Source: Pacific Northwest Ecosystem Research Consortium, 2004.

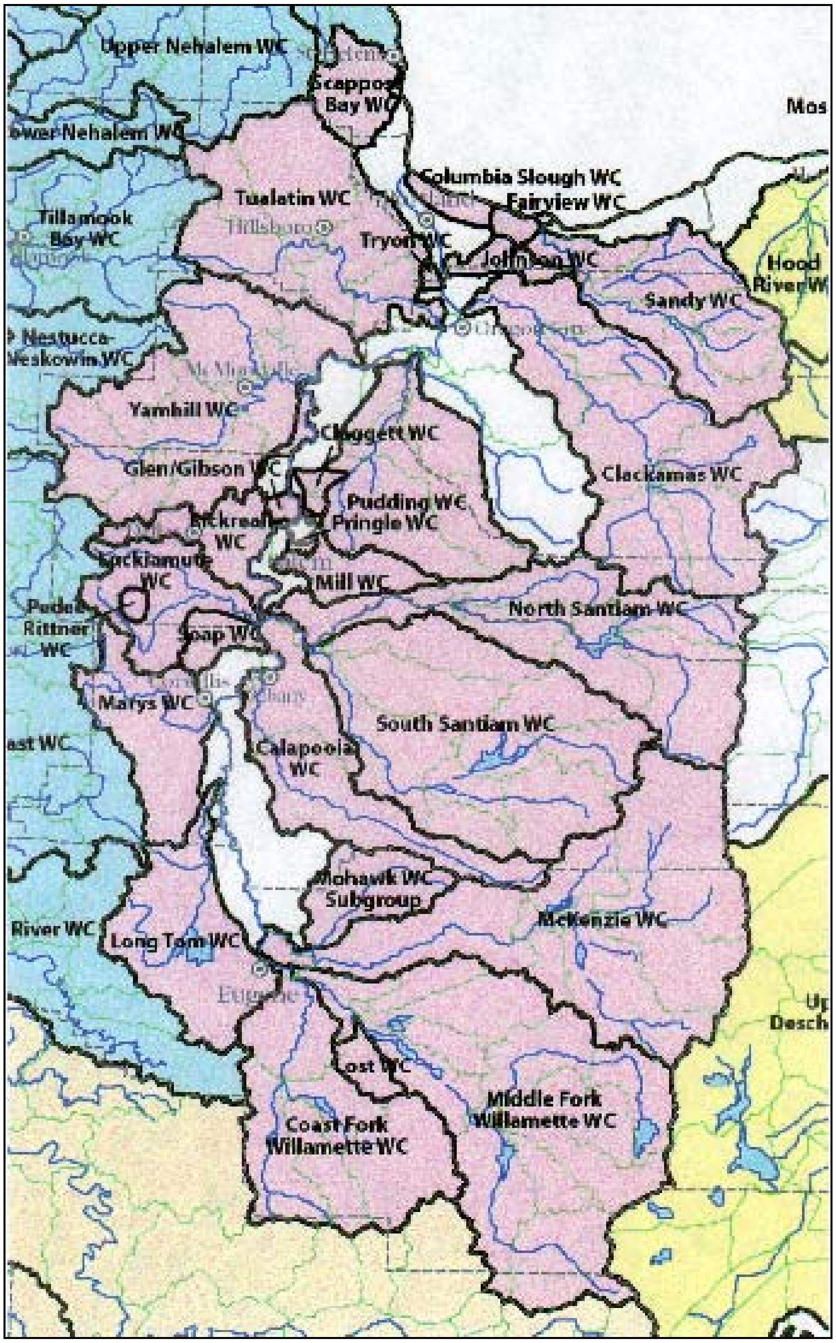


Figure 3-14: Watershed Council Boundaries

Source: Oregon Watershed Enhancement Board, undated.

Watersheds are primary management units that will be used in this plan to ground the subbasin assessment and strategies in ways that make sense for local managers and project planners and initiators.

3.1.2.2 Hydrologic Regime

Streamflow in the Willamette Basin reflects the seasonal distribution of precipitation, with 60 to 85 percent of the streamflow occurring from October through March, but with less than 10 percent during July and August. Releases from 13 major tributary reservoirs operated by the U.S. Army Corps of Engineers are managed to control flood flows in winter and for water quality enhancement in the summer by maintaining a flow of 6,000 cubic feet per second (cfs) in the Willamette River at Salem (U.S. Army Corps of Engineers, 1989). Combined, these reservoirs control approximately 27 percent of the runoff from the watershed and provide approximately 1.6 million acre-feet of flood control storage in the Willamette Basin.

Annual discharge of the Willamette River near its mouth at Portland averages 32,400 cubic feet per second (cfs), or nearly 24 million acre-feet. Typical monthly flows at Portland range from about 8,000 cfs in August to about 70,000 cfs in December. Recorded extreme flows were 4,200 cfs in July 1978 and 283,000 cfs in January 1974, although the river reached an estimated peak flow of 460,000 cfs during the flood of February 1996.

There are significant variations in streamflow regimes throughout the basin. Summertime flows in westside streams originating in the Coast Range are extremely low. These streams include the Marys, Yamhill, and Tualatin rivers. Eastside streams in low-lying watersheds, such as the Calapooia, Pudding, and Mohawk rivers, have similar flow patterns. Other streams with higher elevation headwaters generally have more abundant summer flow conditions. These include the Santiam and McKenzie rivers. In addition, the federal flood control projects on these streams are used to augment flows below the dams, including in the mainstem Willamette River. Figure 3-11 illustrates the differences between eastside and westside flows.

3.1.2.3 Groundwater

The main groundwater aquifers in the Willamette Basin occur in the alluvial sediment and basalt geologic units (Oregon Department of Environmental Quality, 2004). There are four regional hydrogeologic units for the Willamette Basin: the low-yield bedrock unit, the Columbia River Basalt unit, the basin-fill sediment unit, and the Willamette Silt unit (Oregon Water Resources Department, 2002; see Figure 3-15).

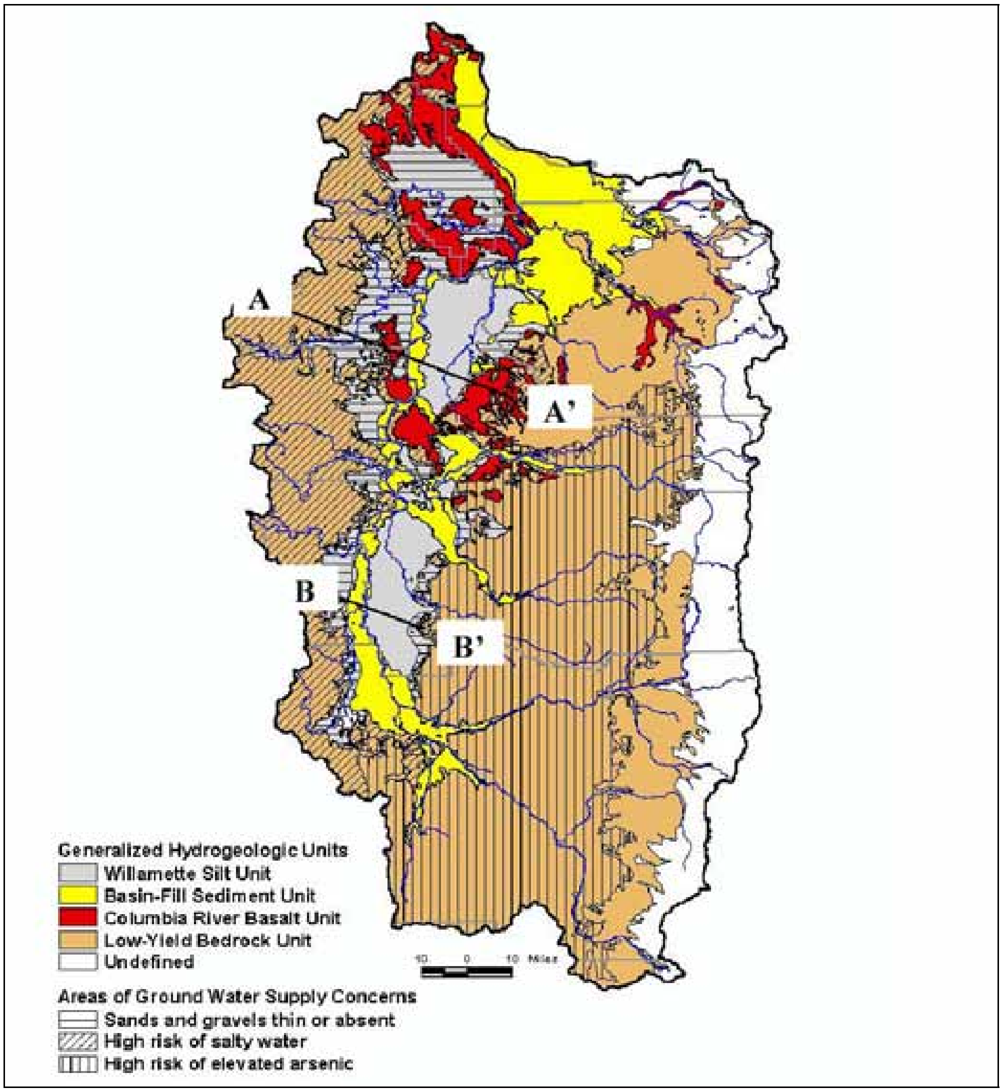
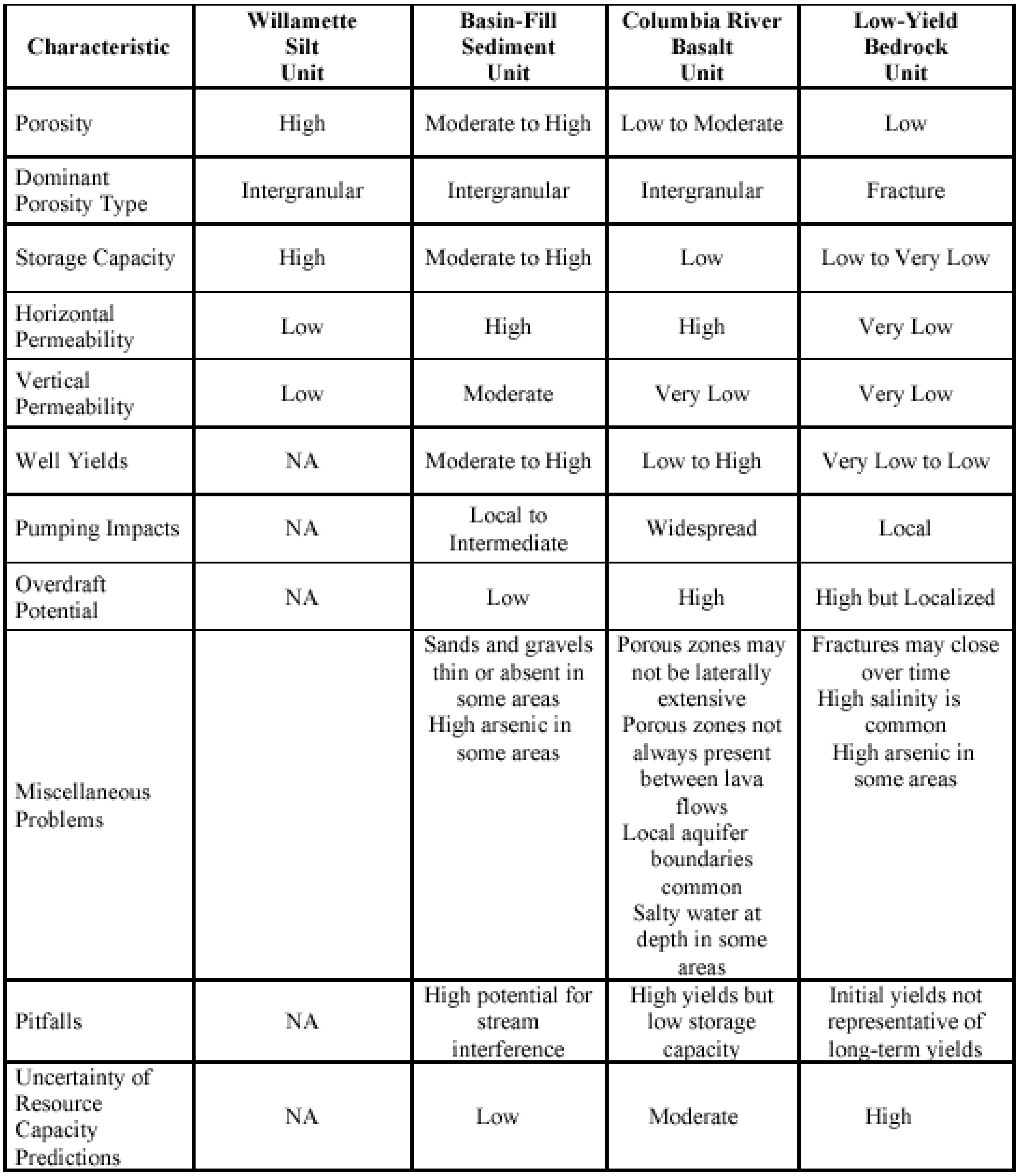


Figure 3-15: Generalized Hydrogeology of the Willamette Basin and Areas of Groundwater Supply Concern

Source: OWRD, 2002.

Groundwater Use and Supply. There can be several types of water supply problems within these units. For example, production from individual wells may deteriorate with time. Neighboring wells may interfere with each other such that neither gets enough water. Water levels in entire aquifers may decline if pumping is excessive. And overuse may gradually create an inflow of saline water, making the water supply unusable. These types of problems along with the distribution and general characteristics of each unit are described Table 3-8.

Table 3-8: General Characteristics of Hydrogeologic Units in the Willamette Basin



Characteristic	Willamette Silt Unit	Basin-Fill Sediment Unit	Columbia River Basalt Unit	Low-Yield Bedrock Unit
Porosity	High	Moderate to High	Low to Moderate	Low
Dominant Porosity Type	Intergranular	Intergranular	Intergranular	Fracture
Storage Capacity	High	Moderate to High	Low	Low to Very Low
Horizontal Permeability	Low	High	High	Very Low
Vertical Permeability	Low	Moderate	Very Low	Very Low
Well Yields	NA	Moderate to High	Low to High	Very Low to Low
Pumping Impacts	NA	Local to Intermediate	Widespread	Local
Overdraft Potential	NA	Low	High	High but Localized
Miscellaneous Problems		Sands and gravels thin or absent in some areas High arsenic in some areas	Porous zones may not be laterally extensive Porous zones not always present between lava flows Local aquifer boundaries common Salty water at depth in some areas	Fractures may close over time High salinity is common High arsenic in some areas
Pitfalls	NA	High potential for stream interference	High yields but low storage capacity	Initial yields not representative of long-term yields
Uncertainty of Resource Capacity Predictions	NA	Low	Moderate	High

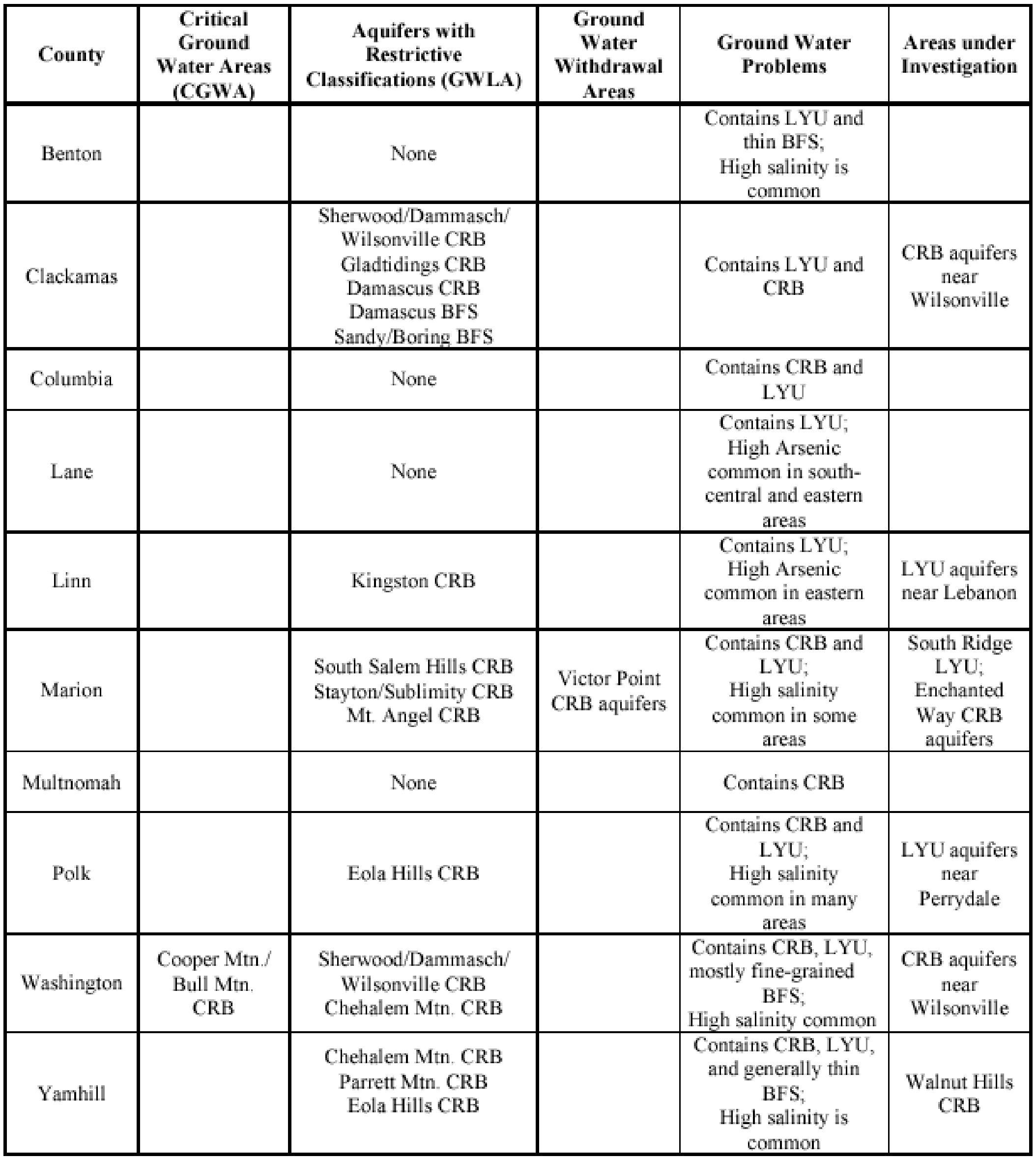
Source: Oregon Water Resources Department, 2002.

In terms of groundwater use, the Willamette Basin has 11,108 recorded groundwater rights for uses requiring permits or water rights. The recorded uses include campground, fish culture, fish and wildlife, irrigation, manufacturing, municipal, stock, and wildlife. The Willamette Basin has more than 1,765 groundwater-based public water supply systems. These systems either use groundwater exclusively or use a combination of groundwater and surface water to supply various public uses, including municipal drinking water (Oregon Department of Environmental Quality, 2004).

Groundwater rights or permits are not required for small domestic wells. The Oregon Water Resources Department has record of more than 100,400 domestic water wells on file for the Willamette Basin. The number of water wells in the basin is probably higher because, prior to 1955, state law did not require water well owners to file well logs for wells drilled and completed on their property (Oregon Department of Environmental Quality, 2004).

In response to the different types of groundwater supply problems described above, the Oregon Water Resources Department has restricted groundwater use in 13 groundwater administrative areas in the Willamette Basin, as shown in Table 3-9.

Table 3-9: Designated Groundwater Areas and Areas of Supply Concern in Willamette Valley Counties



County	Critical Ground Water Areas (CGWA)	Aquifers with Restrictive Classifications (GWLA)	Ground Water Withdrawal Areas	Ground Water Problems	Areas under Investigation
Benton		None		Contains LYU and thin BFS; High salinity is common	
Clackamas		Sherwood/Dammasch/ Wilsonville CRB Gladtidings CRB Damascus CRB Damascus BFS Sandy/Boring BFS		Contains LYU and CRB	CRB aquifers near Wilsonville
Columbia		None		Contains CRB and LYU	
Lane		None		Contains LYU; High Arsenic common in south-central and eastern areas	
Linn		Kingston CRB		Contains LYU; High Arsenic common in eastern areas	LYU aquifers near Lebanon
Marion		South Salem Hills CRB Stayton/Sublimity CRB Mt. Angel CRB	Victor Point CRB aquifers	Contains CRB and LYU; High salinity common in some areas	South Ridge LYU; Enchanted Way CRB aquifers
Multnomah		None		Contains CRB	
Polk		Eola Hills CRB		Contains CRB and LYU; High salinity common in many areas	LYU aquifers near Perrydale
Washington	Cooper Mtn./ Bull Mtn. CRB	Sherwood/Dammasch/ Wilsonville CRB Chehalem Mtn. CRB		Contains CRB, LYU, mostly fine-grained BFS; High salinity common	CRB aquifers near Wilsonville
Yamhill		Chehalem Mtn. CRB Parrett Mtn. CRB Eola Hills CRB		Contains CRB, LYU, and generally thin BFS; High salinity is common	Walnut Hills CRB

LYU = Low-yield bedrock unit.

CRB = Columbia River Basalt unit.

BFS = Basin fill sediment unit.

Source: Oregon Water Resources Department, 2002.

Groundwater Quality. DEQ, USGS, and other organizations have conducted at least 17 extensive studies of Willamette Basin groundwater quality since 1984, four of which have been basinwide in extent. A March 2004 report summarized the results of these studies (Oregon Department of Environmental Quality, 2004). Unless otherwise noted, the information in this section is taken entirely from that report.

While much of the basin is forestland, these recent studies have focused on groundwater quality in the following:

- Willamette Valley agricultural lands
- Areas of significant Willamette Valley population density
- Urban areas, including the three largest cities in Oregon (Portland, Salem, and Eugene)

Groundwater in the Willamette Basin is an important natural resource. The basin has more than 11,000 water rights for groundwater use. More than 1,700 public drinking water systems in the basin use groundwater either exclusively or in combination with surface water. Another 100,000 domestic water wells in the basin provide drinking water to rural residences and areas with no public water supply systems.

Shallow Willamette Valley alluvial sediments contain productive aquifers that are vulnerable to pollution from human activities. In fact, groundwater quality studies in the Willamette Basin have shown impacts from several pollutants, including nitrate, pesticides, and volatile organic compounds (VOCs), as described below.

Nitrates. Willamette Basin nitrate contamination is widespread, particularly in the southern Willamette Valley near Coburg and Junction City (see Figure 3-16). The Mission Bottom area north of Salem also has significant nitrate levels, and DEQ has proposed a Groundwater Management Area (GWMA) for parts of Lane, Linn, and Benton counties. The GWMA would include a management plan specifying actions, such as best management practices (BMPs), to address high nitrate levels.

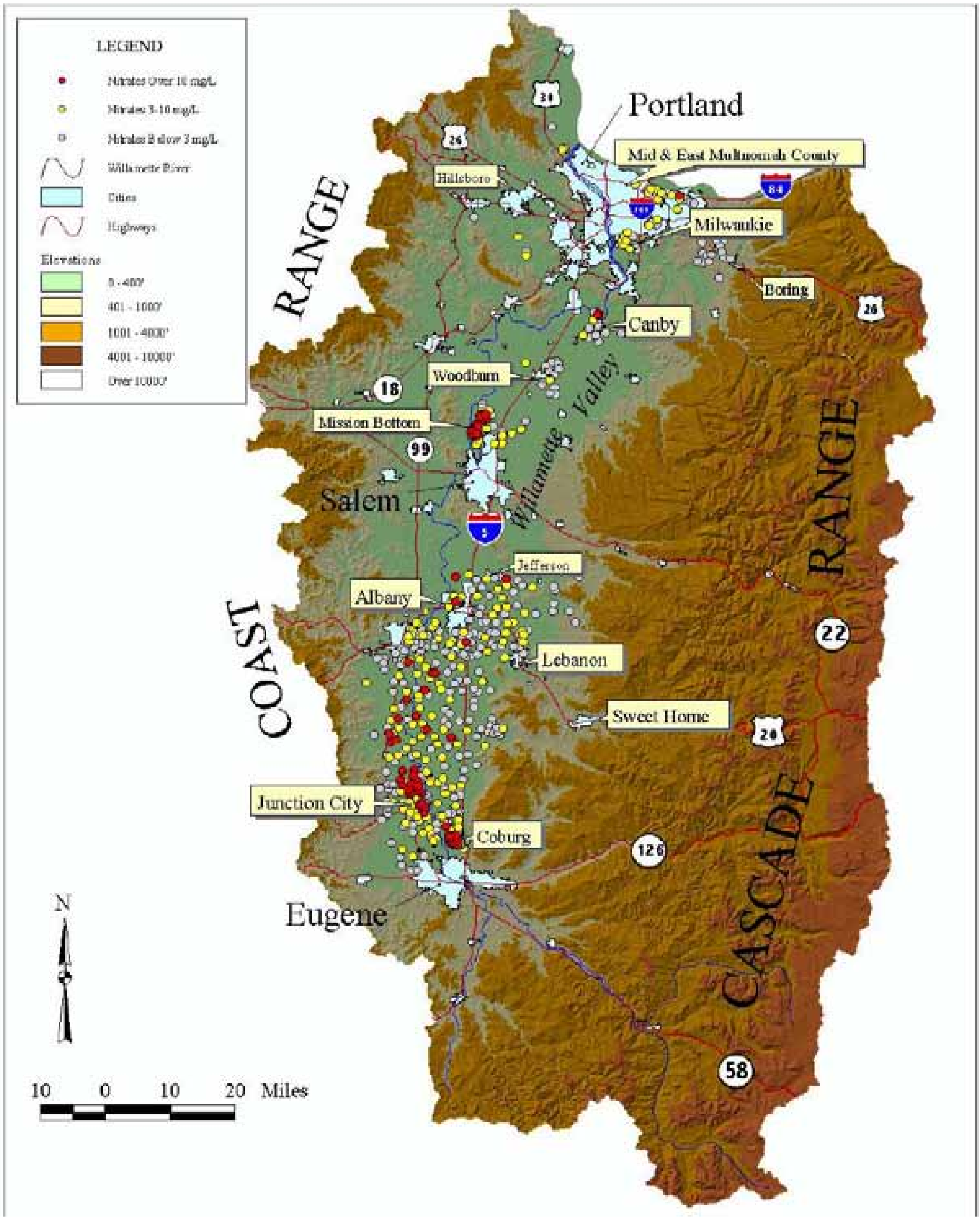


Figure 3-16: Nitrate Levels in Wells

Note: gray = less than 3 milligrams per liter [mg/L], yellow = 3-10 mg/L, red = more than 10 mg/L.

Source: Oregon Department of Environmental Quality, 2004.

Bacteria. Bacterial contamination is present in scattered locations throughout the basin, and in local areas around Scio and North Albany.

Pesticides. Pesticide-contaminated groundwater has been found throughout the basin at levels generally in the part-per-trillion range. These levels are below risk-based standards. A USGS basinwide assessment found pesticide contaminated groundwater in one third of sampled wells. Atrazine is the most commonly detected pesticide. In some of the studies, pesticides have not been detected using analytical methods with detection limits in the part per billion range.

VOCs. Groundwater contaminated with VOCs has been found in several urban areas in the basin, and in areas of dense population. In one study, the USGS found VOCs in eight of ten monitoring wells. VOCs have contaminated public drinking water supplies in four basin study areas.

Point and Nonpoint Sources. Many potential point sources of nitrate and VOC pollution exist within the Willamette Basin, including the following:

- Permitted waste discharge facilities
- Underground injection control systems
- Confined animal feeding operations
- Hazardous substance release sites
- Leaking underground storage tanks
- Onsite sewage disposal systems
- Solid waste facilities

Nonpoint sources of nitrate and pesticide pollution include agricultural land use areas and areas with high population densities using onsite sewage disposal systems. The occurrence of VOCs in some areas may also be a nonpoint source problem from areawide industrial or other activities typically using chlorinated solvents.

3.1.2.4 Water Quality

Surface Water. Studies showing serious pollution problems in the Willamette River started as early as 1927. At least eight other major studies followed through 1963 and documented that the Willamette had high loads of organic wastes, dense beds of algae, and floating and river-bottom sludge, which resulted in critically low dissolved oxygen concentrations that limited salmon migration. In some instances, the pollutant levels were lethal to local trout and salmon populations (Altman, Henson, and Waite, 1997).

The main pollutants being directly discharged into the river were untreated sewage from municipalities and residences and industrial wastes from canneries and paper mills. The discharge of sulphite pulp liquor from these mills was the most serious pollutant affecting fishery resources because of its toxicity. In addition to the Willamette, the lower portions of several tributaries—including Rickreall Creek and the Calapooia, Pudding, Tualatin, Yamhill, North and South Santiam, and Long Tom rivers—also were highly polluted (Altman, Henson, and Waite, 1997).

Historically, the pollution load from domestic and industrial wastes discharged into the Willamette River was the most important factor contributing to the great decline of former great runs of anadromous fish (Altman, Henson, and Waite, 1997). However, most current pollution problems in the Willamette Basin are from nonpoint sources, such as urban development, forest practices, and agriculture. Recent Oregon Department of Environmental Quality (DEQ) studies suggest that agricultural land is the largest source of nonpoint-source pollution. Most of the nonpoint-source pollution to the Willamette River is from the Pudding, Tualatin, Yamhill, and Long Tom subbasins (Altman, Henson, and Waite, 1997).

Point and nonpoint pollution problems are addressed through a process called total maximum daily load (TMDL). A maximum daily load is a pollution limit set for any stream segment that violates current water quality standards. There are about 150 TMDLs being developed in the Willamette Basin. The biggest water quality problems are temperature and bacterial contamination; they make up about two-thirds of the listings. Some sections of the mainstem Willamette are listed for biological issues relating to water quality, based on observed skeletal deformities in fish. Mercury is the cause of a number of listings and appears to be related to past mining activities in the Upper Basin. There also are some scattered listings for various toxic materials, including dieldrin, DDT, arsenic, and polychlorinated biphenyls (PCBs). The remaining listings are for violations relating to excessive nutrients, dissolved oxygen, and pH. The pollutants of concern for the mainstem are bacteria, temperature, mercury, and—for the Middle and Lower Willamette River—biological criteria (fish skeletal deformities). (There are also seven listings for habitat and flow modification; however, these do not require TMDLs based upon direction from the U.S. Environmental Protection Agency) (Oregon Department of Environmental Quality, 2000).

Table 3-10: Willamette TMDLs by Subbasin

	Number of Stream Segments Listed for Each Condition/Pollutant								
Subbasin	**Temp**	**Dissolved Oxygen**	**Bacteria**	**pH**	**Toxics**	**Nutrient Related**	**Biological Criteria**	**Flow Modifi-cation**	**Other**	**Total Segments**
Tualatin	19	22	49	2	1 each for arsenic, manganese, and iron	6	10			111
Upper Willamette	7	2	9		4 for mercury, 2 for PAHs,1 for arsenic		1	1	1	28
McKenzie	9									9
Coast Fork	6		2		3 for mercury					11
Middle Fork	15									15
North Santiam	6									6
South Santiam	6		1							7
Middle Willamette	4		6		2 for mercury, 1 for dieldrin		2	1		16
Clackamas	1								1-hab.	2

Table 3-10: Willamette TMDLs by Subbasin

	Number of Stream Segments Listed for Each Condition/Pollutant									
Subbasin	**Temp**	**Dissolved Oxygen**	**Bacteria**	**pH**	**Toxics**	**Nutrient Related**	**Biological Criteria**	**Flow Modifi-cation**	**Other**	**Total Segments**
Lower Willamette	4	1	9	5	1 each dioxin, DDE, PCBs, DDT lead, dieldrin	7	3	2	2 for habitat	41
Yamhill (2007)	9	1	12		1, for chloropyrifos	1		2	26	
Molalla/Pudding (2007)	8	1	6		1 each for arsenic, iron, manganese, and DDT			1		20
TOTAL	94	27	94	7	29	14	16	7	4	292

Source: Oregon Department of Environmental Quality, 2000.

DEQ regulates several types of waste discharges through permits. Permitted facilities and activities include the following:

- Sewage
- Pulp and paper waste
- Food processing waste
- Smelting/refining waste
- Cooling water
- Industrial stormwater
- Mining
- Municipal wastewater

Figure 3-17 shows the locations of the following permitted facilities in the Willamette Basin:

- 27 major permits for industries with large pollutant loads, toxic discharges, or large domestic waste treatment facilities
- 1,208 minor permits for other types of discharges (Oregon Department of Environmental Quality, 2000)

Approximately one-third of the minor permittees and two-thirds of the major permittees discharge into the mainstem Willamette River. Thus, most concern regarding the effects of point-source pollution on aquatic biota is within the valley floor, including the Willamette River and the lower reaches of its tributaries (Altman, Henson, and Waite, 1997).

Table 3-11 shows the types and numbers of water quality pollution sources that are known and regulated by DEQ.

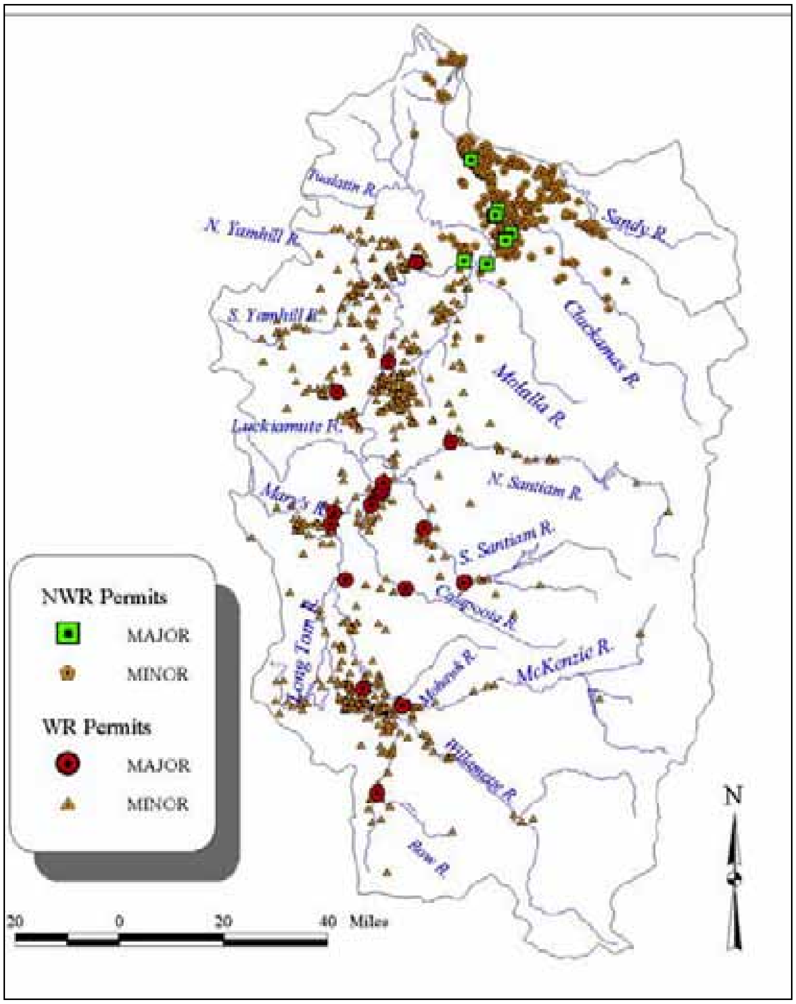


Figure 3-17: Permitted Discharges in the Willamette Basin

Note: NWR=DEQ Northwest Region; WR=DEQ Willamette Region.

Source: Oregon Department of Environmental Quality, 2004.

Table 3-11: Known and Regulated Water Quality Pollution Sources

Source	Number in the Willamette Basin
Underground Injection Control (UIC) Systems: A UIC system includes structures or activities that place or discharge fluids into the subsurface. Examples of UICs include dry wells, sumps, septic system drainfields above a certain service or design size, and other wells used for injection purposes.	20,146
Confined Animal Feeding Operations: These include animal confinement areas; manure storage areas, such as lagoons, runoff ponds, storage sheds, stockpiles, and liquid impoundments; and waste containment areas, such as settling basins.	259
Hazardous Substance Release Sites.	334
Leaking Underground Storage Tanks (LUSTs): Cleanups of releases from tanks, including home heating oil tanks.	21,681
Solid and Hazardous Waste Facilities: Landfills in the Willamette Basin for which DEQ has groundwater, surface water, or leachate monitoring data.	22

Source: Oregon Department of Environmental Quality, 2004.

Hyporheic Zone. Water in alluvial rivers often flows through a hyporheic zone—an area below and alongside the streambed where water percolates through spaces between gravel, rocks, and cobbles. The most visible channel features associated with this zone are point bars, islands, gravel bars, and alcoves. Under natural conditions these features are not permanent; rather, they are continuously being created, destroyed, and modified by changing river flows.

During summer, water emerging from the hyporheic zone is often cooler than water in the main channel of the river. Based on dye studies, Fernald has calculated that as much as 70 percent of the summer flow of the Willamette River spends some time in the hyporheic zone in the 67-kilometer-long reach between Eugene and Corvallis (Fernald et al., 2000).

Over the last 150 years, human actions have reduced the surface extent of the Willamette's hyporheic zone by about 80 percent by regulating flow and armoring river banks (such as with riprap) (Hulse, Gregory et al., 2002). However, even with this reduction, during the summer river water has been found to be cooled significantly (that is, from 2 ^{o}C to 7 ^{o}C) by traveling through point bar hyporheic zones. (Fernald et al., 2000) It is estimated that the current amount of hyporheic-caused cooling in the 67-kilometer Eugene-to-Corvallis reach of the Willamette River may range from 0.2 ^{o}C to about 2.5 ^{o}C. There is significant uncertainty (that is, one order of magnitude) in this estimate because of the rudimentary understanding of hyporheic processes and extent in the Willamette system (Fernald, personal communication).

3.1.2.5 Riparian Resources

Riparian areas are the areas immediately adjacent to streams and rivers. Although they occupy a fairly small percentage of any watershed, riparian areas have large impacts on fish and wildlife:

- Their vegetation controls stream temperature and contributes organic matter and wood used by aquatic organisms for food and shelter. The contribution of wood also controls channel form and complexity.

- They can act as vegetative filters, screening out sediment and other pollutants from nearby runoff.
- They have a high level of biodiversity, providing the interface between aquatic and terrestrial species.
- They link land and water habitats by capturing the interdependencies of physical processes, such as channel formation and flooding, and the strongly coupled processes such as energy and nutrient exchanges.

Riparian resources of the Willamette Basin fall into three categories: those along the Willamette mainstem, those in major tributaries, and those in small streams.

Mainstem Riparian Areas. Historically, along the mainstem, riparian areas were often wide forests of black cottonwood, Oregon ash, alder, big-leaf maple, willow, Douglas fir, western red cedar, and Ponderosa pine. In 1850, hardwood riparian forests made up nearly 70 percent of the Willamette’s length, with mixed forests constituting about 14 percent and the rest in conifer forests. As a result of human activity, by 1895 more than half of the hardwood riparian areas had been converted to other uses and nearly all the conifer riparian forests were gone. By 1990, hardwood riparian forests occupied about 17 percent of the Willamette’s length, mixed forests 18 percent, farmland 30 percent, and development 16 percent. In other words, today about half of the riparian areas along the mainstem are in either agricultural or urban land uses (Pacific Northwest Ecosystem Research Consortium, 2002).

Riparian Areas in Major Tributaries. Historically, the riparian areas of major tributaries, such as the Santiam and McKenzie rivers, were similar in makeup to mainstem riparian areas but smaller in extent, and they took on more open, upland characteristics. In 1850, hardwood forests made up about 50 percent of tributary riparian areas, with about another one-third in mixed or coniferous forests and 20 percent in grass- and shrubland. Hardwood and mixed forests now make up about a quarter of the riparian zone, with conifer forests occupying but 2 percent. Today, agricultural and urban lands occupy about 55 percent of the riparian area (Pacific Northwest Ecosystem Research Consortium, 2002).

Riparian Areas of Small Streams. About 96 percent of all the riparian area in the Willamette Basin lies along small streams. Small streams have very different characters, depending on whether they are in the lowlands or uplands of the basin. Lowland streams are marked by flat gradients and less steep banks, while upland streams tend to have steep banks and high gradients. In 1850, coniferous and hardwood forests together occupied about 55 percent of lowland stream riparian areas. Wetlands, grasslands, and shrublands made up the remainder, each about equally. By 1990, more than half the riparian area of lowland streams had been converted to farming or city uses. Forests now make up about a third of the riparian area. Riparian areas of upland streams in 1850 were 98 percent coniferous forest. By 1990, half of the riparian area was coniferous and half was mixed and hardwood forests, largely as a result of commercial forestry practices. About two percent was farm and city land (Pacific Northwest Ecosystem Research Consortium, 2002).

3.1.2.6 Wetland Resources

Wetlands provide unique and significant ecological functions, including flood detention, the cooling and filtering of overland flow, nutrient cycling, and aquatic and terrestrial habitat.

Before settlement, there were approximately 320,000 acres of wetlands in the lowlands of the Willamette Basin (Pacific Northwest Ecosystem Research Consortium, 2002). In 1982, wetlands constituted an estimated 8.5 percent of the Willamette Valley ecoregion, or about 273,000 acres. The major wetland types were palustrine forested, palustrine emergent, and palustrine farmed. By 1994, more than 6,500 wetland acres had been lost, with many of them having been converted to agricultural uses. In addition, some wetland types changed; about 17,000 acres were converted from one wetland type to another (Daggett et al., 1998).

3.1.3 Hydrologic and Ecologic Trends in the Subbasin

3.1.3.1 Influence of Human Use on Hydrology in the Subbasin

Human influence on the Willamette Basin's hydrology has been great. As previously summarized, the strongest influences began with Euro-American settlement and the eradication of beavers. Human influence grew to include major channel modifications to support navigation in the mainstem Willamette and tributaries—modifications that included dredging, miles of bank armoring, removal of large wood, and the closing of side channels. Other modifications have included the construction of major dams on the Willamette's main tributaries, the diking and damming of smaller channels, the draining of wetlands, surface and groundwater uses to support agriculture and cities, the development of a very dense road network, surface drainage ditches, subsurface tiling, and creation of large areas of impervious surfaces from urban development. The affects of federal dams are addressed specifically below.

In general these human modifications have tended to do the following:

- Simplify channels
- Create "flashier" runoff patterns in undammed drainages
- Cause lower summer flows in streams
- Create lower winter flows and higher summer flows in dammed drainages
- Increase the duration of bank-full flows in dammed tributaries

Physical Channel Changes. Perhaps one of the biggest changes in the Willamette system has been the result of the construction of navigation and bank-protection structures. Beginning in 1870 the U.S. Army Corps of Engineers initiated efforts to increase navigational flows by closing unwanted side channels, thus confining water from many braided channels into fewer channels. Dredging spoils were deposited into side channels and gravel bars were scraped away. In addition, downed trees and drift piles of large wood were systematically cleared; between 1870 and 1950, the Corps removed more than 69,000 snags and overhanging trees (Benner and Sedell, 1997).

The River and Harbor Act/Flood Control Act of 1938 authorized the Corps to construct and maintain a navigation channel on the Willamette River from Willamette Falls to Eugene. The maintained channel ranged from 4.5 to 2.5 feet deep and up to 100 feet wide, with additional depth provided by streamflow augmentation from the reservoirs. Owing to dwindling commercial navigation on the river, continued maintenance of the navigation channel above Willamette Falls was determined to be economically infeasible. The last maintenance dredging completed by the Corps of Engineers was in 1973 (U.S. Army Corps of Engineers, 1999).

The Corps of Engineers' Willamette River Bank Protection Program is managed as part of its Willamette River Basin Project. The program, which protects agricultural, suburban, and urban land from erosion along the mainstem Willamette River from New Era upstream to each of the Willamette Project dams, represents one of the earliest flood protection efforts in the basin. It predates the construction of flood control dams by many decades and has had at least as profound an impact on habitat as the dams have had. As of September 1996, the program had protected a total of 489,795 linear feet (or nearly 93 miles) of banks at 230 locations. Project components include riverbank revetments, pile and timber bulkheads, drift barriers, minor channel improvements, and maintenance of existing works for control of floods and prevention of bank erosion.

The impacts of these Corps of Engineer management activities on habitat have been profound. With fewer meanders in the river, the length of the Willamette's channel has been cut nearly in half. The result has been an 84 percent loss of tributary and slough habitat (Benner and Sedell, 1997; Institute for the Northwest, 1999).

An estimated 75 percent of the original shoreline has been lost to channelization, which was largely completed in the Willamette River by 1946. The river was channelized to aid river navigation, reduce land erosion, and increase land available for farming. Several kinds of stabilization techniques have been used since the first revetment on the Willamette River in 1888, with use of stone (riprap) being the most extensive. More than 100 miles of stone revetments have been constructed in the Willamette Basin, which means that 11 percent of the Willamette River shoreline is riprapped. Most revetments have been built by the U.S. Army Corps of Engineers since the 1930s as part of its Willamette River Bank Protection Program (Altman, Henson, and Waite, 1997).

Stone revetments change the physical environment of shoreline substrate, shoreline gradient, and water velocity. The principal change in the shoreline is a reduction in riparian vegetation and large wood. Revetments also reduce side channels, backwater areas, and oxbows, which are important habitat for juvenile salmonids and the Oregon chub. Fish assemblages at stone revetments on the Willamette below Salem are characterized by lower species richness and diversity than at natural banks but higher densities of small fish. Fish species associated positively with revetments are likely attracted by the high densities of invertebrate prey (Altman, Henson, and Waite, 1997).

Federal Columbia River Power System Dams. Dams have been a part of the basin since the mid-1800s. However, extensive flood-control efforts began in the 1930s. Most of these flood-control dams were built by the U.S. Army Corps of Engineers between 1941 and 1968. Currently, there are 25 major dams in the Willamette Basin: 11 single-purpose hydroelectric projects operated by public and private utilities, one multipurpose project on the Tualatin River, and 13 multipurpose reservoirs operated by the Corps of Engineers (Altman, Henson, and Waite, 1997).

These 13 reservoirs are operated for flood control, power generation, recreation, irrigation, public water supply, navigation, pollution abatement, and anadromous fish propagation. Summer flows in the Willamette are due primarily to releases from these dams and are higher and cooler than those before the dams were constructed. When combined with passage improvements at Willamette Falls and hatchery inputs, this improved water quality has helped establish upriver runs of summer steelhead, coho, and fall Chinook, which historically did not occur (Altman, Henson, and Waite, 1997).

Dams affect aquatic species upstream and downstream of the dam in both beneficial and harmful ways. Benefits include control of floods, which has reduced siltation, and augmentation of historical low flows in the summer with cooler water. The principal negative impact of dams is the inundation of spawning areas and physical blockage of migration to upstream spawning areas. Roughly 400 miles of previously important spawning and rearing habitat for salmon is no longer accessible. Other negative impacts include increased water temperature variations and extremes, a reduction in the amount of production and rearing habitat for some species of fish, alteration of the natural hydrologic functions of seasonal flooding and recruitment of spawning gravel, and mortality in turbines at the dams. In addition, reservoirs may contribute to disease problems and favor warm-water introduced fish species that often prosper at the expense of native fish (Altman, Henson, and Waite, 1997).

Dams and reservoirs in the Willamette Basin also adversely affect fish behavior and reproductive capacity. Dams can delay the migration of adult salmonids, particularly during spring high flows, when Chinook have difficulty using fishways. Natural migration timing can also change as a result of water temperature modifications caused by dams. And flow disruption from drawdowns may expose redds or strand adults (Altman, Henson, and Waite, 1997).

The Willamette Basin Project. The Willamette Basin Project (the U.S. Army Corps of Engineer's system of 11 flood control and two re-regulating dams) has reduced the frequency of extremely high and low flows and disrupted the once-dynamic rhythm of floods and dry spells. Flow and temperature regimes in the Willamette have been drastically altered as a result of extensive development of flood control structures in the upper basin (Hughes and Gammon, 1987). Flood control modifications have largely disconnected the Willamette River from its braided channels, oxbows, and sloughs—wetland types that characterized much of its historical floodplain (Oregon Progress Board, 2000). The loss of sloughs, islands, and side channels has not only destroyed habitat for fish and wildlife, but has also reduced the river system's ability to absorb floodwaters (Oregon Progress Board, 2000). The speed and severity of modern flooding has been exacerbated by the loss of the "sponge effect" of the natural floodplains. The Willamette Bank Protection Program, a major component of the Corps' Willamette Basin Project, is a primary cause of this disconnection.

Prior to the construction of the 11 water storage dams in the Willamette basin, beginning in the early 1940s, frequent and substantial flooding was a dominant ecological process along the mainstem Willamette. Mainstem floodplains used to be refreshed by floods every 10 years, which maintained vital ecological processes such as nutrient exchange, sediment trapping and recycling, and the movement of large wood within the land and the river channel (Oregon Progress Board, 2000). This flooding now happens only once every 100 years, on average (Benner and Sedell, 1997).

In addition, recent studies indicate that erosion has increased downstream from the Corps dams to compensate for sediment trapped by reservoirs. With dams capturing upstream sediment and reducing flood peaks, sediment characteristics in downstream reaches are affected proportionately more by channel velocities from bank protection, channel incision, bank erosion, land-use conversions, and downstream sources of coarse sediments. In other words, about the same amount of sediment is being transported as before dam construction, which means that the amount trapped by the reservoirs is being made up for by channel- or other land-erosion downstream (Wentz et al., 1998).

The impacts on habitat from these Corps of Engineers activities have been profound. The upper mainstem Willamette River's channel length has been nearly halved as a result of these management activities, with a resulting 84 percent loss of tributary and slough habitat (Benner and Sedell, 1997; Institute for the Northwest, 1999).

3.1.3.2 Nonfederal Hydropower Facilities

For most nonfederal hydroelectric power projects, the Federal Energy Regulatory Commission (FERC) must issue a license authorizing construction or, in the case of an existing project, continued project operation. Licenses are issued for a term of between 30 to 50 years, and exemptions are granted in perpetuity. Most hydroelectric projects serve other purposes such as navigation, flood control, recreation, irrigation, and flow augmentation.

Projects authorized by Congress and operated by the U.S. Army Corps of Engineers or the U.S. Bureau of Reclamation do not require FERC licenses. All nonfederal hydroelectric projects operating in Oregon, whether FERC-licensed or not, require either a state license or a power claim issued by the Oregon Water Resources Department. Relicensing takes a minimum of 5 years and involves a series of public reviews as well as new studies to address current needs, including for environmental protection. At the end of this period, FERC either approves or denies a relicensing request. There are 18 active FERC projects in the Willamette Basin (see Table 3-12).

Once FERC receives an application to renew the license of an existing operation, it consults with the U.S. Fish and Wildlife Service (USFWS) and/or NOAA Fisheries under Section 7 of the federal Endangered Species Act (ESA). This is done within the framework of ensuring compliance with National Environmental Policy Act (NEPA). Often an applicant is required to develop a biological assessment. Based on this assessment, FERC works with the USFWS and/or NOAA Fisheries on a biological opinion that will result in a determination of a species' jeopardy and, where needed, a reasonable and prudent alternative to the proposal that will avoid any jeopardy.

Table 3-12: Active FERC Hydroelectric Power Projects (identified by the Oregon Department of Fish and Wildlife)

Project Name and FERC Number	Stream	Relicensing Issues
Oak Grove (135)	Oak Grove Fork of the Clackamas	Work groups studying mitigation needs
North Fork/Faraday/River Mill Projects (2195)	Clackamas	Screening, passage; work groups studying mitigation needs
Sullivan Plant (2233)	Willamette Falls—Willamette River	Fish passage, turbine mortality; work groups studying mitigation needs
Carmen-Smith (2242)	McKenzie	
Leaburg/Walterville (2496)	McKenzie	Fish passage, flow; ESA Section 7 consultation under way
Blue River (3109)	Blue River tributary to McKenzie	Mitigation for fish passage problems, cost share for temperature study

Table 3-12: Active FERC Hydroelectric Power Projects (identified by the Oregon Department of Fish and Wildlife)

Project Name and FERC Number	Stream	Relicensing Issues
Stone Creek (5264)	Stone Creek tributary to Oak Grove Fork of the Clackamas	Flows, velocities, mitigation for endangered plant
Canyon Creek (6414)	Canyon Creek tributary to Clackamas	No fish and wildlife concerns currently identified
Brunswick Creek (6564)	Brunswick Creek tributary to Tualatin	Blocks 2 miles of cutthroat habitat; reservoir stocked with exotic rainbow
LaComb (6648)	Crabtree Creek tributary to South Santiam	Fish passage, flow problems, water quality
Falls Creek (6661	Falls Creek tributary to South Santiam	Screening improvements
Water Street (6943)	North Santiam	Screening
Wolf Creek (7058)	(City of Portland water system)	No fish and wildlife concerns identified
Thompson’s Mills (9169)	Calapooia	Flows
Woodcock Creek (1423)	Woodcock Creek tributary to Molalla	
Stayton (11429)		Flows, passage, water quality, screening
Albany Hydroelectric Project (11509)	South Santiam	Screening, passage, flows, habitat protection
Bigelow (11512)	McKenzie	Screens, passage, bull trout mitigation required by ESA consultation

3.1.3.3 Influence of Human Use on Ecology in the Subbasin

Fish Impacts. Beginning 40 years ago, all Willamette Project dams (except Foster) completely blocked fish migration, either because no passage facilities were provided or because those provided did not work. Upper Willamette spring Chinook and winter steelhead are no longer found above these dams (see Figure 3-10).

In addition to blocking migration, much historical spawning and rearing habitat has been inundated by reservoir (see Table 3-13). Dams built in the 1950s and 1960s on the Santiam, Middle Fork Willamette, and McKenzie rivers blocked more than 400 stream miles that were originally the most important spawning areas for native Chinook salmon (Bennett, 1994).

Table 3-13: Summary of Federal Columbia River Power System Impacts on Anadromous Fish

Species	Stream	Impacts
Spring Chinook	Santiam	71 percent of production occurred above Detroit Dam (Mattson, 1948). All access to upstream spawning habitat was lost because the dam was built without fish

Table 3-13: Summary of Federal Columbia River Power System Impacts on Anadromous Fish

Species	Stream	Impacts
		passage facilities.
	Middle Fork Willamette	Dexter and Fall Creek dams blocked access to about 80 percent of the subbasin’s Chinook habitat (Oregon Department of Fish and Wildlife,, 1990f).
	McKenzie	The McKenzie produced roughly 40 percent of the spring Chinook run above Willamette Falls (Mattson, 1948). Cougar Dam has blocked off 25 miles of some of the most productive spawning habitat historically available (Oregon Department of Fish and Wildlife,, 1990e).
	Coast Fork Willamette	Dorena and Cottage Grove dams block upstream access to spawning areas. Also, it is likely that low flows and warm-water discharge from the dams limit downstream Chinook salmon production (Oregon Department of Fish and Wildlife,, 1990d).
Steelhead	Santiam	Major habitat blockages from Big Cliff Dam on the North Santiam River and Green Peter Dam on the South Santiam River.
	Other watersheds	Dexter, Dorena, and Cougar dams were identified by NOAA Fisheries as the cutoff of current steelhead distribution for the critical habitat designation for steelhead (64 Federal Register [FR] 5750).

Table 3-14 lists estimated spawning habitat for salmon and steelhead in the upper Willamette River basin prior to the construction of the dams. The estimates are for mainstem habitat only. Considerably more spawning and rearing habitat was blocked in the tributaries (Fulton, 1968 and 1970). Cottage Grove and Dorena dams blocked the better quality spawning and rearing habitat in the Coast Fork Willamette subbasin (Thompson et al., 1966).

Table 3-15 lists the approximate amounts of habitat lost to inundation by Willamette Project reservoirs, as represented by reservoir length. The actual amounts were slightly greater because of the sinuosity of the river channel. Foster and Green Peter dams inundated approximately 19 percent of good-quality anadromous fish habitat present above the Foster dam site (Thompson et al., 1966).

Table 3-14: Estimated Spawning Habitat Quantities Above and Below Willamette Project Dams (for mainstems of streams shown, not tributaries)

Stream	Lineal Miles Surveyed				Spawning Area Available (square yards)			
	Below Dam	Above Dam	Total	Percent Above Dam	Below Dam	Above Dam	Total	Percent Above Dam
North Santiam	66.2	61.1	127.3	48.0	1,875,001	800,778	2,684,779	30.1

Table 3-14: Estimated Spawning Habitat Quantities Above and Below Willamette Project Dams (for mainstems of streams shown, not tributaries)

Stream	Lineal Miles Surveyed				Spawning Area Available (square yards)			
	Below Dam	Above Dam	Total	Percent Above Dam	Below Dam	Above Dam	Total	Percent Above Dam
South Santiam	87.7	63.5	151.2	42.0	2,352,539	874,278	3,226,817	27.1
McKenzie	76.7	103.3	180.0	57.4	3,224,923	1,841,112	5,066,035	36.3
Middle Fork Willamette	83.6	74.5	158.1	47.1	2,501,145	1,226,140	3,727,285	32.9
Total	314.2	302.4	616.6		9,953,608	4,751,308	14,704,916	

Source: Craig and Townsend, 1946.

Table 3-15: Approximate Miles* of River Habitat Inundated by Willamette Project Reservoirs

Dam	Stream	Length of Reservoir (miles)
Big Cliff	North Santiam River	2.8
Detroit	North Santiam River	9.0
Green Peter	Middle Fork Santiam River	10.0
Foster	South Fork Santiam River	3.5
Blue River	Blue River	6.4
Cougar	South Fork McKenzie	6.5
Fall Creek	Fall Creek	10.3
Hills Creek	Middle Fork Willamette River	7.6
Lookout Point	Middle Fork Willamette River	14.2
Dexter	Middle Fork Willamette River	2.8
Dorena	Row River	5.0
Cottage Grove	Coast Fork River	3.0
Fern Ridge	Long Tom River	4.5

* Does not necessarily account for former sinuosity.

Source: USACE project data.

Willamette Project dams may delay migration as adult salmon and winter steelhead are turned around and forced to search for spawning habitat elsewhere. Winter steelhead returning below Foster Dam also are delayed before they are collected and transported upstream. Any delays may result in reduced spawning fitness of the adults or survival and their progeny.

While the construction of the federal dams has severely curtailed any possible upstream migration of anadromous fish, it is also worth noting that, even should upstream passage of adults be restored, the extent to which downstream juvenile migrants are able to negotiate the difficulties presented by slack-water reservoirs is also problematic.

Fragmentation and isolation of bull trout populations have created a patchwork of remnant populations in the Columbia River basin (63 FR 31674). For example, barriers caused by the Willamette Project dams prevent bull trout from freely migrating between winter refuge areas and summer foraging areas, and they prevent gene flow among isolated populations. In addition, fragmentation and isolation of fish populations resulting from dam operation have been observed for resident cutthroat trout in the Long Tom River.

Oregon chub also have been affected by dams. Today, Oregon chub exist primarily as a series of 32 isolated populations distributed in the Middle Fork Willamette, Coast Fork Willamette, Santiam River, and Mainstem Willamette. Opportunities for migration may be limited to extreme flooding events; however, no data exist on either the population structure or potential dispersal among populations. Historically, floods were the primary mechanism for dispersal and genetic exchange among populations. This basic life history strategy has been substantially reduced as a result of flood control dams and channel simplification throughout the Willamette Basin. In terms of dam influences, the Dexter/Lookout Point, Fall Creek, and Hills Creek projects appear to have the highest potential to affect Oregon chub populations. The Foster/Green Peter and Big Cliff/Detroit reservoirs have a moderate influence (U.S. Fish and Wildlife Service, 1998a).

Wildlife. Wildlife abundance and distribution have been heavily affected by human influences in the Willamette Basin. Chief among these influences are habitat loss and degradation as a result of conversion to other uses, as described in previous sections of this document. Native terrestrial wildlife habitats in the Willamette Basin overall have been reduced by 44 percent since European settlement, and the abundance of terrestrial wildlife that depended on that habitat has decreased by more than 75 percent (Pacific Northwest Ecosystem Research Consortium, 2002). As an example of just one type of habitat change, NPPC—in consultation with the Bonneville Power Administration and the U.S. Army Corps of Engineers—identified wildlife losses attributable to hydropower facilities of the Willamette Basin Project (see Table 3-16).

Habitat degradation and loss associated with conversion to other uses are significant and compounding. Habitat conversion reduces the accessibility or suitability of essential food, water, cover/substrate, and habitat space, which in turn tends to increase crowding, competition for increasingly scarce resources, predation, pathogen and parasite transmission, and mortality.

The effects of human influences on wildlife in the Willamette Basin will be described in more detail in Section 3.2.4.

Table 3-16: Estimated Wildlife Losses Attributable to Willamette Basin Project Hydropower Construction*

Species	Total Habitat Units
Black-tailed Deer	-17,254
Roosevelt Elk	-15,295
Black Bear	-4,814

Table 3-16: Estimated Wildlife Losses Attributable to Willamette Basin Project Hydropower Construction*

Species	Total Habitat Units
Cougar	-3,853
Beaver	-4,477
River Otter	-2,408
Mink	-2,418
Red Fox	-2,590
Ruffed Grouse	-11,145
California Quail	-2,986
Ring-necked Pheasant	-1,986
Band-tailed Pigeon	-3,487
Western Gray Squirrel	-1,354
Harlequin Duck	-551
Wood Duck	-1,947
Spotted Owl	-5,711
Pileated Woodpecker	-8,690
American Dipper	-954
Yellow Warbler	-2,355
Common Merganser	+1,042
Greater Scaup	+820
Waterfowl	+423
Bald Eagle	+5,693
Osprey	+6,159

Source: National Power and Conservation Council, 2000.

*Reflects pre- versus post-dam conditions, with the first federal hydropower dam (Fern Ridge) being built in 1941 and the last (Blue River) built in 1969.

“-” indicates losses.

“+” indicates gains.

A habitat unit is a measure of habitat based on the acreage of a given habitat at a particular site multiplied by a suitability index factor under the Habitat Evaluation Procedure developed by USFWS. The suitability factor characterizes the amount of optimal habitat present. For example, if a 20-acre site had a suitability index of 0.5 for black-tailed deer, the site would be “worth” 10 habitat units.

3.1.4 Regional Context

3.1.4.1 Relation to the Columbia Basin

The Willamette Subbasin is located at the westernmost extent of the Columbia Basin (see Figure 3-18). The Willamette Subbasin constitutes roughly 5 percent of the total area of the Columbia Basin. The Willamette River contributes about 17 percent of the Columbia's flow at Portland. The subbasin's population of roughly 2.5 million people represents about 36 percent of the Columbia Basin's population of nearly 7 million people (Columbia Basin Water Transactions Program, 2004).

Figure 3-18: Northwest Power and Conservation Council Ecoprovinces

The Willamette is the largest subbasin in the Columbia River basin, as delineated by the Northwest Power and Conservation Council. Other large basins include the Owyhee (11,049 square miles) and the Deschutes (10,500 square miles). The Willamette's dense stream network also gives it the distinction of having one of the greatest, if not the greatest, number of 6th-field hydrologic unit codes out of the subbasins in the Columbia River system: 170 6th-field hydrologic units.

3.1.4.2 NOAA Fisheries Evolutionary Significant Units

There are five evolutionarily significant units (ESUs) in the Willamette Basin: Lower Columbia River fall Chinook Salmon, Upper Willamette spring Chinook salmon, Columbia River chum salmon, Lower Columbia River steelhead, and Upper Willamette River steelhead (see Section 3.2.1.1).

3.1.4.3 USFWS-Designated Bull Trout Planning Units

The Willamette Basin is a designated bull trout planning unit. Recovery criteria in the draft recovery plan call for populations in the Clackamas, McKenzie, and Middle Fork Willamette subbasins (U.S. Fish and Wildlife Service, 2003).

3.1.4.4 USFWS-Designated Oregon Chub Planning Units

The 1998 Oregon Chub Recovery Plan calls for at least four populations in each of three subbasins: the Willamette River mainstem, the Middle Fork Willamette, and the Santiam (U.S. Fish and Wildlife Service, 1998).

3.1.4.5 Priority Species and Habitats

As of this writing, the following numbers of Willamette Basin species are listed as threatened and endangered (includes both state and federal designations of threatened, endangered, and species of concern):

- 10 plant species
- 7 fish species
- 110 wildlife species (includes bird species listed in Partners in Flight continental watchlist, draft 2002 super region rankings, Oregon priority and focal species, Breeding Bird Survey Willamette, and NPAC)

Habitats of concern include streams and six terrestrial habitats: oak woodlands; upland prairies and savanna; wetland prairie and seasonal marsh; perennial ponds, sloughs, and their riparian areas; stream riparian; and old-growth conifer forest.

See Section 3.2.3.2 for a more detailed discussion of priority species and habitats.

3.1.4.6 Summary of External Environmental Impacts on Fish and Wildlife

The most significant out-of-subbasin influence for fish in the Willamette Basin is ocean conditions. Ocean conditions are associated with fluctuations in abundance of anadromous fish. At present, ocean conditions are favorable and Willamette Basin salmon runs are abundant—more than 100,000 Chinook salmon are expected to pass Willamette Falls by the end of the spring run. See Section 3.3 for more discussion about the impact of climatic cycles and ocean conditions on the focal species of this plan.

Migratory bird species have vast ranges and may be affected by a variety of factors outside the Willamette Basin. Information about the factors and influence of out-of-subbasin effects on migratory bird species is generally lacking.

3.2 Focal Species Characterization and Status

3.2.1 Native/Nonnative Wildlife, Plant, and Resident/Anadromous Fish of Ecological Importance

The Willamette Basin has a very rich assemblage of plants, fish, and wildlife. It is difficult to assign a scientifically based import to any individual species, for all play a role in maintaining ecosystem integrity and function. However, a number of species are recognized as ecologically important by virtue of their role as indicator species or because they are culturally and positively associated with healthy ecosystems. Salmon and steelhead enjoy both classifications. Resident fish such as bull trout and cutthroat trout are becoming more appreciated by today's culture as inhabitants of cold, clean systems. The lamprey is valued by Native Americans, but not so much by others in society. In terms of wildlife, bald eagles and Columbia white-tailed deer are appreciated by most Willamette basin residents, but listed Willamette pond turtles and the Oregon chub, while ecologically significant, may be perceived as curiosities at best. Native fish and wildlife have a higher intrinsic ecosystem value than nonnative species, which can either be benign, such as introduced wild turkeys, or environmentally threatening, such as the bullfrog.

3.2.1.1 Special-Status Aquatic Species in the Willamette

Several species that are federally or state-listed as endangered, threatened, or sensitive are found in the Willamette Basin. They are the Oregon chub, bull trout, and five ESUs of salmonids, including chum salmon, spring and fall Chinook, and two winter steelhead ESUs. Table 3-17 lists these special-status species, the various subbasins in which they occur currently or have occurred historically, and their individual state and federal status. As described further in Section 3.2.3.1, these are included as focal species in the *Willamette Subbasin Plan's* assessment.

Salmonids. The Willamette/Lower Columbia Technical Recovery Team (TRT) designated distinct population segments for threatened anadromous salmonids within the Willamette/Lower Columbia ESUs (Myers et. al., 2002). The team also defined core and genetic legacy populations for listed anadromous salmonids (McElhany et. al., 2003); these core and genetic legacy populations are shown in Table 3-18. A core population is one with historical abundance important to ESU recovery, while genetic legacy populations retain the most intact representatives of the genetic character of the ESU. Describing core and genetic legacy populations provides a framework for species recovery planning both within and between subbasins. While populations of each of the anadromous salmon considered to be focal species in this plan occur in other subbasins (the Molalla and Calapooia, for example), recovery of core and genetic legacy populations is essential for retaining genetic fitness and recovering population abundance (McElhany et al., 2003).

Out of the four Lower Columbia ESU species that occur in the Clackamas Basin, this plan will address only the status and trends of the Clackamas populations of Lower Columbia ESUs and their use of the lower Willamette mainstem and tributaries below Willamette Falls. Lower Columbia River coho salmon are not currently listed as threatened, but in several discussions with local fisheries experts, Clackamas River coho salmon clearly emerged as a species of concern. Coho are a relatively large ESU, with 25 distinct populations; however, the Clackamas coho run is one of very few populations in the ESU thought to still contain wild late-run spawners (personal communication, Technical Advisory Group, Dave Roberts). Upper Willamette spring Chinook core populations occur in the Clackamas, North and South Santiam, and Middle Fork Willamette subbasins. The McKenzie subbasin retains a genetic legacy population of spring Chinook salmon. The North and South Santiam subbasins have core and genetic legacy populations of winter steelhead. Recovery plans for Willamette/Lower Columbia River anadromous salmon ESUs do not yet exist, but viability criteria have been established and guide the framework of the species characterizations presented in Section 3.2.4 (see Appendix A).

Bull Trout. The Willamette Basin is a designated bull trout recovery unit. A draft recovery plan exists for bull trout populations and will provide the framework for discussion of status, trends, limiting factors, and recovery strategies. Recovery criteria in the draft plan call for populations in the Clackamas, McKenzie, and Middle Fork Willamette subbasins (U.S. Fish and Wildlife Service, 2003). Recovery criteria for bull trout are presented in Appendix B.

Oregon Chub. USFWS adopted a recovery plan for Oregon Chub in 1998. The recovery plan criteria for delisting require the existence of 20 populations, with at least 500 adults in each population and at least four populations located in each of the three subbasins: the Willamette River mainstem, Middle Fork Willamette, and Santiam (U.S. Fish and Wildlife Service, 1998). Recovery criteria for Oregon chub are presented in Appendix C.

Table 3-17: Threatened and Endangered Fish Species of the Willamette Basin*

Fish	Common Name	Subbasin Occurrence (Historical or Current Populations)	Federal Status	State Status
Oncorhynchus tshawytscha	Chinook salmon			
Lower Columbia ESU	Fall Chinook	Clackamas	Threatened	Sensitive-critical
Upper Willamette River ESU	Spring Chinook	Clackamas, Molalla, North Santiam, South Santiam, Calapooia, McKenzie, Middle Fork	Threatened	
Oncorhynchus keta Columbia River ESU	Chum salmon	Clackamas	Threatened	Sensitive-critical
Oncorhynchus mykiss	Steelhead			
Lower Columbia River ESU	Winter steelhead	Clackamas	Threatened	Sensitive-critical
Upper Willamette River ESU	Winter steelhead	Molalla, North Santiam, South Santiam, Calapooia	Threatened	Sensitive-critical
Salvelinus confluentus	Bull trout	McKenzie, Middle Fork, Clackamas, North Santiam, South Santiam	Threatened	Sensitive-critical
Oregonichthys cramer)	Oregon chub	Clackamas, North Santiam, South Santiam, McKenzie, Middle Fork, Coast Fork, Long Tom, Marys, Luckiamute, Mainstem	Endangered	Sensitive-critical

*Includes both state and federal designations of threatened, endangered, and sensitive species.

Table 3-18: Willamette/Lower Columbia Domain Core and Genetic Legacy Chinook and Steelhead Populations and Required Recovery Populations for Bull Trout and Oregon Chub

	Clackamas River	McKenzie River	North Santiam	South Santiam River	Middle Fork Willamette River	Mainstem Willamette
Lower Columbia River Fall Chinook Salmon	Core					
Upper Willamette River Spring Chinook Salmon	Core	Core/ Genetic Legacy	Core	Core	Core	
Lower Columbia River Winter Steelhead	Core					
Upper Willamette River Winter Steelhead			Core/ Genetic Legacy	Core/ Genetic Legacy		
Lower Columbia River Coho	Only Willamette Population					
Lower Columbia River Chum Salmon	Core					
Bull Trout	Core Habitat Area	Core Area			Core Area	
Oregon Chub			Recovery Area		Recovery Area	Recovery Area

Source: McElhany et al., 2003; U.S. Fish and Wildlife Service, 1998; U.S. Fish and Wildlife Service, 2003).

3.2.1.2 Special-Status Terrestrial Species in the Willamette Basin

Currently in the Willamette Basin, four wildlife species, one butterfly, and six plants are federally listed as threatened or endangered, and an additional 28 wildlife species and three plants are state listed. Table 3-19 lists threatened and endangered plant species in the Willamette Basin, and Table 3-20 lists special-status wildlife species. Many of these species are described in more detail in Section. 3.2.5.

Table 3-19: Threatened and Endangered Plant Species* of the Willamette Basin

Scientific Name	Common Name	County of Occurrence	Federal Status	State Status
Aster curtus Cronq.	White-topped aster	Clackamas, Lane, Linn, Marion, Multnomah	Species of Concern	Threatened
Aster vialis (Brads.) Blake	Wayside aster	Lane, Linn	Species of Concern	Threatened

Table 3-19: Threatened and Endangered Plant Species* of the Willamette Basin

Scientific Name	Common Name	County of Occurrence	Federal Status	State Status
Castilleja levisecta(Greenm.)	Golden paintbrush	Linn, Marion, Multnomah	Threatened	Endangered
Delphinium leucophaeum Greene	White rock larkspur	Clackamas, Marion, Multnomah, Washington, Yamhill	Species of Concern	Endangered
Delphinium pavonaceum Ewan	Peacock larkspur	Benton, Lane, Linn, Marion, Polk, Washington, Yamhill	Species of Concern	Endangered
Erigeron decumbens Nutt. Var. decumbens	Willamette Valley daisy	Benton, Clackamas, Lane, Linn, Marion, Polk, Washington, Yamhill	Endangered	Endangered
Howellia aquatilis A. Gray	Howellia	Clackamas, Marion, Multnomah	Threatened	-
Lomatium bradshawii	Bradshaw's lomatium	Benton, Lane, Linn, Marion	Endangered	Endangered
Lupinus sulphureus Douglas ssp. Kinkaidii	Kinkaid's lupine	Benton, Lane, Linn, Marion, Polk, Washington, Yamhill	Threatened	Threatened
Sidalcea nelsoniana Piper	Nelson's sidalcea	Benton, Linn, Marion, Polk, Washington, Yamhill	Threatened	Threatened

* Includes both state and federal designations of threatened, endangered, and species of concern.

Source: Willamette Restoration Initiative, 2001.

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Acorn Woodpecker					PIF		
American Dipper					PIF		
American Goldfinch						D	D
American Kestrel					PIF		
American Marten		SS-V					
Bald Eagle	FT	ST					

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Band-Tailed Pigeon			PIF	MA (Pacific)	PIF		D
Barrow's Goldeneye		SS-US					
Black Swift		SS-PN	PIF	IM (Pacific, Intermountain West)	PIF		
Black-Backed Woodpecker		SS-C		PR (Northern Forests)	PIF		
Black-Headed Grosbeak					PIF		
Black-Throated Gray Warbler				MO (Pacific)	PIF		
Blue Grouse				MA (Pacific, Intermountain West)			
Brown Creeper					PIF		
Bufflehead		SS-US					
Bullock's Oriole					PIF		
Bushtit					PIF	D	
Cascade Torrent Salamander		SS-V					
Cascades Frog		SS-V					
Cassin's Verio							D
Chestnut-Backed Chickadee				PR (Pacific)			
Chipping Sparrow					PIF		
Clark's Nutcracker				PR (Intermountain West)	PIF		
Clouded Salamander		SS-US					

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Common Nighthawk		SS-C					
Common Snipe							D
Common Yellowthroat						D	
Downy Woodpecker					PIF	D	
Dusky Flycatcher				MA (Intermountain West)	PIF		
Fisher		SS-C					
Foothill Yellow-legged Frog		SS-V					
Fox Sparrow					PIF		
Fringed Myotis		SS-V					
Grasshopper Sparrow		SS-V/PN		MA (Prairies)	PIF		
Gray Jay				PR (Northern Forests)			D
Great Blue Heron							D
Great Gray Owl		SS-V			PIF		
Hammond’s Flycatcher					PIF		
Harlequin Duck		SS-US					
Hermit Thrush					PIF		
Hermit Warbler			PIF	MO (Pacific)	PIF		
Horned Lark	FC	SS-C			PIF		
House Wren					PIF	D	
Hutton’s Vireo					PIF		
Killdeer							D
Lark Sparrow					PIF		

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Lesser Goldfinch					PIF		
Lewis's Woodpecker		SS-C	PIF	MO (Intermountain West, Prairies)	PIF		
Lincoln's Sparrow				PR (Northern Forests)	PIF		
Long-eared Myotis		SS-US					
Long-legged Myotis		SS-US					
Lynx	FT						
Macgillivray's Warbler					PIF	D	
Marbled Murrelet	FT	ST					
Mountain Quail		SS-US		MO (Pacific)			
Nashville Warbler				PR (Northern Forests)	PIF		
Northern Flicker						D	
Northern Goshawk		SS-C					
Northern Harrier					PIF		
Northern Pygmy-Owl		SS-C		PR (Pacific)			
Olive-Sided Flycatcher		SS-V		MA (Pacific, Northern Forests, Intermountain West)	PIF		D
Orange-Crowned Warbler					PIF		D

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Oregon Slender Salamander		SS-US					
Pacific-Slope Flycatcher				PR (Pacific)	PIF		
Painted Turtle		SS-C					
Pallid Bat		SS-V					
Peregrine Falcon		SE		PR (Arctic)			
Pileated Woodpecker		SS-V			PIF		
Purple Finch					PIF		D
Purple Martin		SS-C			PIF		
Red Crossbill					PIF		D
Red-Breasted Sapsucker				MO (Pacific)	PIF		
Red-Eyed Vireo					PIF		
Red-legged Frog		SS-V/US					
Red-Shouldered Hawk				PR (East)			
Rufous Hummingbird			PIF	MA (Pacific, Intermountain West)	PIF		D
Savannah Sparrow							D
Sharptail Snake		SS-V					
Short-Eared Owl			PIF	MA (Arctic, Northern Forests, Intermountain West, Prairies)	PIF		

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Silver-haired Bat		SS-US					
Southern Torrent Salamander		SS-V					
Spotted Owl	FT	ST		IM (Pacific, Intermountain West, Southwest)			
Swainson’s Thrush					PIF		
Tailed Frog		SS-V					
Townsend’s Big-eared Bat		SS-C					
Townsend’s Solitaire					PIF		
Townsend’s Warbler					PIF		
Varied Thrush					PIF		
Vaux’s Swift					PIF		
Vesper Sparrow		SS-C			PIF		
Warbling Vireo					PIF		
Western Bluebird		SS-V			PIF		
Western Gray Squirrel		SS-US					
Western Meadowlark		SS-C			PIF	D	
Western Pond Turtle		SS-C					
Western Rattlesnake		SS-V					
Western Tanager					PIF		
Western Toad		SS-V					

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC
Western Wood-Pewee					PIF		
White-Breasted Nuthatch					PIF	D	
White-footed Vole		SS-US					
Willow Flycatcher		SS-V/US		MA (Prairies, East)	PIF		D
Wilson's Warbler					PIF		
Winter Wren					PIF		
Wolverine		ST					
Wrentit				MA (Pacific)	PIF		
Yellow Warbler					PIF		D
Yellow-billed Cuckoo	FC*	SS-C			PIF		
Yellow-Breasted Chat		SS-C			PIF		
Yellow-Rumped Warbler					PIF	D	

Note: Abbreviations are derived from the Northwest Habitat Institute.

FT = Federally Threatened.

FC = Species for which enough information is collected on biological vulnerability and threats to support proposals to list as endangered or threatened.

FC* = U.S. Fish and Wildlife Service anticipates developing and publishing proposed rules for candidate species in the future.

SS-C = Species for which listing as threatened or endangered is pending, or those for which listing as threatened or endangered may be appropriate if immediate conservation actions are not taken. Also considered critical are some peripheral species which are at risk throughout their range and some disjunct populations.

SS-V = Species for which listing as threatened or endangered is not believed to be imminent and can be avoided through continued or expanded use of adequate protective measures and monitoring. In some cases, populations are sustainable and protective measures are being implemented; in others, populations may be declining and improved protective measures are needed to maintain sustainable populations over time.

Table 3-20: Threatened and Endangered Wildlife Species and Species of Concern in the Willamette Basin

Common Name	Federal Status Oregon	State Status Oregon	Partners in Flight 1998-1999 Continental Watchlist	Partners in Flight Ranking by Super-Region, draft 2002	Oregon Partners in Flight Priority & Focal Species	Breeding Bird Survey Willamette	Breeding Bird Survey NPAC

SS-PN = Peripheral species refer to those whose Oregon populations are on the edge of their range. Naturally rare species are those which had low population numbers historically in Oregon because of naturally limiting factors. Maintaining the status quo is a minimum necessity. Disjunct populations of several species which occur in Oregon should not be confused with peripheral species.

SS-V/PN = Species has a combined status for definitions, please see above.

SS-US = Species for which status is unclear. Species may be susceptible to population decline of sufficient magnitude to qualify for endangered, threatened, critical or vulnerable status, but scientific study would be needed before a judgment can be made.

SS-V/US = Species has a combined status: for definitions, please see above.

SE = State Endangered.

ST = State Threatened.

SS = State Sensitive.

SC = Special Concern.

PIF = Partners in Flight.

D = Declining.

3.2.1.3 Other Species of Importance

Many native species were central to tribal life. Table 3-21 lists species that have been historically documented as important resources throughout the ceded lands. This is followed by a description of lamprey, a tribally significant aquatic species found in the Willamette Basin.

Table 3-21: Willamette Basin Species Significant to Tribes

Type of Use	Species
Plant Species Used for Food	Camas (*Camassia quamash*) Cattail (*Typha latifolia*) Wapato (*Sagittaria latifolia*) Cow parsnip (*Heracleum lanatum*) Skunk cabbage (*Lysichiton americanum*) Salmonberry (*Rubus spectabilis*) Wild celery (*Oenanthe sarmentosa*) Huckleberry (*Vaccinium spp*.) Oak acorns (*Quercus spp*.) Salal (*Gaultheria shalion*) Cascara (*Rhamnus purshiana*) Blackcap (*Rubus leucodermis*) Thimbleberry (*Rubus praviflorus*)
Species Used for Traditional Arts	Ash (*Fraxinus latifolia*) Cattail (*Typha latifolia*) Western red cedar (*Thuja plicata*) Bear-grass (*Xerophyllum tenax*) Spruce (*Picea sitchensis*) Pacific yew (*Taxus brevifolia*) Beaked hazelnut (*Corylus cornuta*) Willow (*Salix spp*.)
Fish and Other Aquatic Species	Steelhead (*Oncorhynchus mykiss*) Lamprey (*Lampetra tridentata*) Coho (*Oncorhynchus kisutch*) Cutthroat trout (*Oncorhynchus clarki*) Chinook (*Oncorhynchus tshawytscha*) Sturgeon (*Acipenser spp*.) Chum (*Oncorhynchus keta*) Red-legged frog (*Rana aurora*) Western pond turtle (*Clemmys marmorata*)

Source: The Confederated Tribes of Grand Ronde Unified Watershed Assessment, 2001.

Lamprey. There are two known lamprey species in the Willamette Basin. The Pacific lamprey is a large, anadromous, and parasitic species and has received the most research and management attention. The smaller, nonanadromous and nonparasitic western brook lamprey has received little attention. There is scant information on historical and current population abundance, particularly for western brook lamprey. Historically, the Willamette Basin probably produced the largest proportion of Pacific lamprey of any basin in the Columbia system. Limited data from the Willamette Basin indicate that the abundance of Pacific lamprey has declined, yet the Willamette remains the most important production area in the Columbia Basin. Even with large yearly fluctuations, it appears that more lamprey pass over Willamette Fall annually than are counted at Bonneville Dam (Kostow, 2002). Harvest of Pacific lamprey at Willamette Falls provides the best estimate of trends in Pacific lamprey abundance. Hundreds of thousands of adult lamprey were harvested at Willamette Falls during the 1940s and early 1950s, and it is unlikely that this number currently passes the Falls (Kostow, 2002).

There have been no systematic inventories of lamprey distribution within the Willamette Basin (Kostow, 2002). Most observations of lamprey have been incidental observations noted during stream habitat inventories or winter steelhead spawning surveys. Most observations are of juvenile lamprey (ammocoetes). Because ammocoetes from western brook and Pacific lamprey are difficult to distinguish, distribution observations tend to generalize across the species. These limited observations suggest that lampreys are still well distributed through the Willamette Coast Range subbasins, in the Molalla/Pudding system, and in the lower Santiam and Calapooia rivers (Kostow, 2002). However, lamprey distribution has been substantially restricted as a result of barriers at U.S. Army Corps of Engineers dams, other dams, and fish passage barriers at culverts and other structures (Kostow, 2002). There is evidence that lamprey cannot pass above many fish ladders. For example, lampreys are restricted below the North Fork Dam on the Clackamas River, even though the dam is equipped with a functional fish ladder (Kostow, 2002). Water diversions and dams also can contribute to lamprey mortality during downstream migration (Kostow, 2002). Lampreys continue to be harvested (by permit) at Willamette Falls. In 2001 about 15,500 lampreys were harvested (Kostow, 2002).

3.2.1.4 Introduced Species

The annual cost imposed by nonnative (exotic) species in the United States is estimated to be $123 billion (Oregon Progress Board, 2000) Exotic species can compete with native species, change food sources for native and commercial species, impede forest regeneration, increase unnatural wildland fire risks, and change the character of streambanks and streams.

Nearly 1,000 exotic species have been introduced to Oregon since about 1850. Some have been intentionally introduced for sport, such as bass and wild turkey (by the state of Oregon) or bullfrogs and baitfish (by private individuals). Many exotic species are kept as pets or raised commercially, and these animals occasionally escape and establish breeding populations (examples include nutria, snapping turtles, and carp). Some species introduce themselves—for example, English sparrows and European starlings flew into Oregon on their own, while walleye swam into the Willamette from introductions in the Columbia. (Oregon Progress Board, 2000; Altman et al., 1997)

Introduced Aquatic Species. The Willamette River Basin has 31 native fish species and 30 introduced fish species (see Figure 3-19 and Table 3-22). Generally, the greatest number of species are found in the lower Willamette mainstem, and fewer species are found in headwater streams. More than half of the fish species present in the Portland Harbor have been introduced to the Willamette River system. It is likely that an increase in slow-moving, deep-water habitat created by dam construction and bank revetments has helped support many of the introduced species in the basin (Pacific Northwest Ecosystem Research Consortium, 2002; Altman et al., 1997).

Introduced fish tend to dominate in highly disturbed habitats, with the greatest diversity of introduced species being found in lowland rivers, lakes, and ponds that have warm water ecosystems similar to the native habitats of the introduced species. Also, introduced species are often more pollution-tolerant than native fish species. For example, of the Willamette Basin's native fish species, only 13 percent are considered pollution tolerant, while nearly 70 percent of introduced species (carp, bullhead, bass, etc.) are classified as pollution-tolerant (Pacific Northwest Ecosystem Research Consortium, 2002; Altman et al., 1997)

Declines of native fish following introduction of nonnative fish are widely reported. In the Willamette Basin, for example, largemouth bass and bluegill have been identified as a cause for the decline of the Oregon chub. Large black crappie and white crappie prey on small juvenile salmonids. The common carp—widely viewed as a difficult-to-control nuisance species—was introduced into the Pacific Northwest in the late 1800s as a food fish. Carp stir up turbidity in shallow ponds, lakes, and marshes, thus limiting the production of native plants important to water-fowl. Carp now occur throughout lowland aquatic habitats in the Willamette Basin. Another example is the mosquito fish *(Gambusia affinis*), which has been introduced in lowland aquatic habitats, particularly urban and residential areas, to control mosquitoes. Also, the Asiatic clam, introduced early in the 20th century, is found in the mainstem Willamette and the lower sections of most tributaries (Altman et al., 1997)

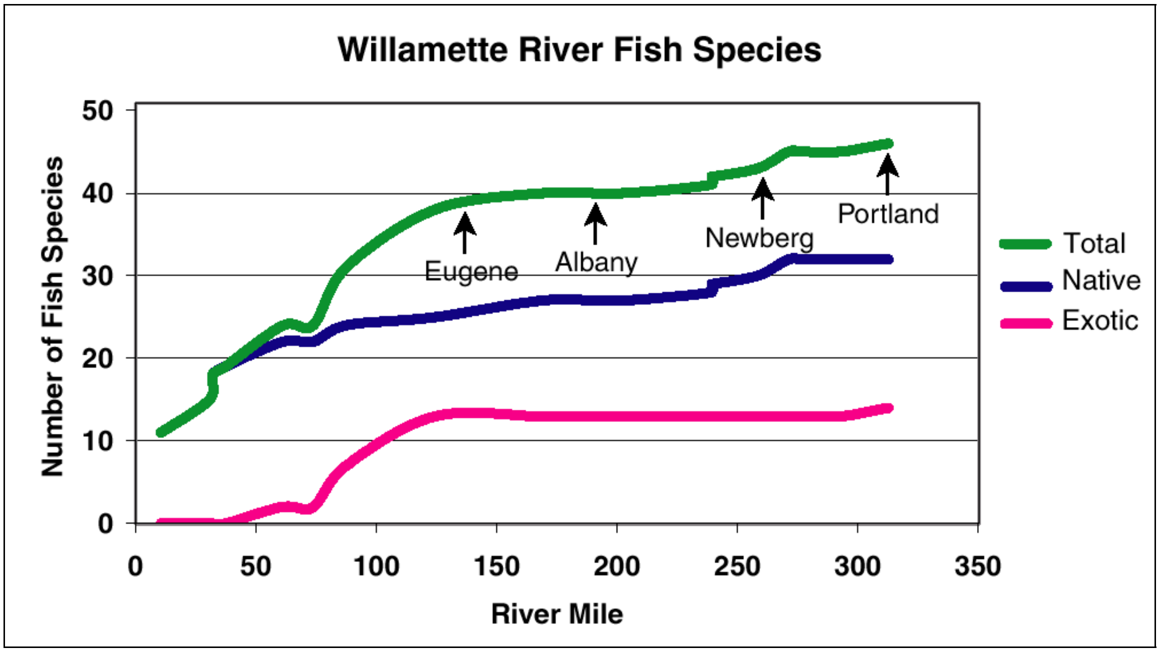


Figure 3-19: Willamette River Fish Species

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Table 3-22: Introduced Fishes

Family	Common Name	Mainstem Abundance	Mainstem Location	Scientific Name	Adult Trophic Group
Centrarchidae	Black crappie	Common	All	*Pomoxis nigromaculatus*	Insectivore
Centrarchidae	Bluegill	Common	All	*Lepomis macrochirus*	Insectivore
Centrarchidae	Green sunfish	Absent	Lakes	*Lepomis cyanellus*	Insectivore
Centrarchidae	Largemouth bass	Common	All	*Micropterus salmoides*	Piscivore
Centrarchidae	Pumpkinseed	Common	All	*Lepomis gibbosus*	Piscivore
Centrarchidae	Redear sunfish	Absent	Lakes	*Lepomis microlophus*	Insectivore
Centrarchidae	Smallmouth bass	Common	All	*Micropterus dolomieui*	Carnivore
Centrarchidae	Warmouth	Medium	All	*Lepomis gulosus*	Insectivore
Centrarchidae	White crappie	Common	All	*Pomoxis annularis*	Insectivore
Clupeidae	American shad	Medium	Low	*Alosa sapidissima*	Omnivore
Cobitidae	Oriental weatherfish	Absent	Tributaries	*Misgurnus anguillicaudatus*	Omnivore
Cyprinidae	Common carp	Common	All	*Cyprinus carpio*	Omnivore
Cyprinidae	Fathead minnow	Absent	Lakes	*Pimephales promelas*	Omnivore
Cyprindae	Golden shiner	Rare	Low	*Notemigonus chrysoleucas*	Insectivore
Cyprinidae	Goldfish	Rare	Low	*Carassius auratus*	Omnivore
Cyprinidae	Tench	Rare	Low	*Tinca tinca*	Insectivore
Cyprinidae	Grass carp	Rare	Low	*Ctenopharyngodon idella*	Omnivore/ Herbivore
Cyprinodontidae	Banded killifish	Absent	Low	*Fundulus diaphanus*	Insectivore
Ictaluridae	Black bullhead	Rare	Low	*Ameiurus melas*	Omnivore
Ictaluridae	Brown bullhead	Common	All	*Ameiurus nebulosus*	Omnivore
Ictaluridae	Channel catfish	Rare	All	*Ictalurus punctatus*	Omnivore
Ictaluridae	White catfish	Rare	Low	*Ameiurus catus*	Omnivore
Ictaluridae	Yellow bullhead	Common	All	*Ameiurus natalis*	Omnivore
Percidae	Walleye	Rare	All	*Stizostedion vitreum*	Piscivore
Percidae	Yellow perch	Common	All	*Perca flavescens*	Insectivore
Poeciliidae	Western mosquitofish	Common	All	*Gambusia affinis*	Insectivore
Salmonidae	Brook trout	Absent	Tributaries	*Salvelinus fontinalis*	Insectivore

Table 3-22: Introduced Fishes

Family	Common Name	Mainstem Abundance	Mainstem Location	Scientific Name	Adult Trophic Group
Salmonidae	Brown trout	Absent	Tributaries	*Salmo trutta*	Insectivore
Salmonidae	Kokanee	Absent	Lakes	*Oncorhynchus nerka*	Insectivore
Salmonidae	Lake trout	Absent	Lakes	*Salvelinus namaycush*	Insectivore

Source: Pacific Northwest Ecosystem Research Consortium, Table 22, p. 45.

Introduced Terrestrial Species. There are about 17 introduced vertebrate species in the Willamette Basin—one amphibian, six birds, and nine mammals. The Willamette Valley has some of the highest occurrences of introduced vertebrate species in the Pacific Northwest.. Some of the exotics, such as turkey and ring-necked pheasant, were intentionally introduced as game species Most, however, simply occurred with European settlement; examples include starling, house sparrow, eastern gray squirrel, Norway rat, and the house mouse (Pacific Northwest Ecosystem Research Consortium, 2002).

Nutria were originally farmed for fur but were introduced to natural environments when they escaped or were released. This South American rodent has spread rapidly throughout the basin. Nutria prefer the instream and shoreline habitat of lowland lakes, ponds, and slow-moving rivers. They are considered pests because they compete with native beaver and muskrat, and they increase erosion because through their bank-burrowing (Altman et al., 1997).

Many amphibians experience high rates of predation because they did not evolve in the presence of the voracious introduced predators, such as pumpkinseed, largemouth bass, bluegill, and bullfrogs. The bullfrog *(Rana catesbeian*a) was introduced into the western United States to be farmed and marketed for food. It swiftly spread in lowland aquatic habitats, often becoming the dominant species. Bullfrogs have caused the decline or elimination of a number of native amphibians and reptiles, particularly other *Rana* frogs, including the extirpation of the spotted frog from the Willamette Valley. Bullfrogs are believed to use the burrows of nutria, an introduced rodent, to survive valley winters. Diseases spread by introduced red-eared slider turtles have probably contributed to declines of the western pond turtle (Altman et al., 1997; Oregon Progress Board, 2000).

Introduced Plant Species. Many problems are caused by introduced plant species in Oregon, including increased fire hazard (gorse), livestock poisoning (tansy ragwort), interference with re-establishing conifers on harvested lands (Scotch broom), decreased amounts of pasture and rangeland for grazing livestock (various thistles), elimination of native vegetation in wetlands (purple loosestrife), and clogging of waterways (hydrilla). In addition, Eurasian water milfoil, an aggressive water plan, was discovered in the upper Willamette Basin in the 1980s (it was introduced in British Columbia in the 1960s). In the Willamette Valley, grand fir has largely been eliminated at lower elevations by an exotic insect, and cheatgrass, diffuse knapweed, spotted knapweed, Canada thistle, and tansy ragwort are especially troublesome (Oregon Progress Board, 2000; Altman et al., 1997).

3.2.2 Scientific Foundation for Assessment of Willamette River Aquatic Habitats

Development of the assessment elements of this *Willamette Subbasin Plan* was guided by a conceptual, scientific foundation that grew, in part, out of the work of the Northwest Power and Conservation Council and its Independent Scientific Group (Northwest Power Planning Council, 2000).

In 1996, the Northwest Power and Conservation Council charged its Independent Scientific Group (ISG, now called the Independent Scientific Advisory Board) to review the scientific basis for the NPCC's Fish and Wildlife Program. The ISG review, entitled *Return to the River*, noted that NPCC's program was a collection of ideas and solutions without a coherent scientific basis (Independent Scientific Group, 2000). In other words, there were no grounds for evaluating the scientific rationale for potential restoration actions or their efficacy in achieving identified recovery goals.

In response, NPCC developed a scientific foundation for restoration actions—a foundation that was intended to provide an explicit scientific link between identified goals and actions within a framework of adaptive management. Elements of the scientific foundation were incorporated into NPCC's 2000 *Columbia River Basin Fish and Wildlife Program* (Northwest Power Planning Council, 2000). Among other things, the scientific foundation described a new conceptual foundation for salmon management in the Columbia River. This conceptual foundation was based on the premise that goals for specific species, such as salmon, can only be achieved by managing those species' ecosystems to provide needed environmental conditions. This was the basis for NPCC's assertion that its program was "habitat-based" and that it intended to rebuild fish runs and wildlife populations by "protecting, mitigating and restoring habitats and biological systems."

NPCC's conceptual foundation has two key elements that guided the construction of this plan for the Willamette Basin. First, NPCC defined the concept of biological objectives as the basis for shaping and evaluating measures incorporated into its *Columbia River Basin Fish and Wildlife Program* (Northwest Power Planning Council, 2000). Second, NPCC defined a set of principles that describe the scientific basis for how species performance is controlled by their environment. During the development of this *Willamette Subbasin Plan*, NPCC's definition of biological objectives guided the overall approach to habitat assessment and management, while the scientific principles shaped the working hypothesis of the Willamette River system.

3.2.2.1 Application of NPCC's Scientific Principles to the Willamette River Subbasin Plan

A key element of NPCC's scientific foundation was a set of eight scientific principles that lay out the scientific basis for NPCC's habitat-based approach (Northwest Power Planning Council, 2000). NPCC's program states that "actions taken at the basin, province, and basin levels to fulfill [NPCC's vision] should be consistent with, and based upon, these principles." The scientific principles recognize the fundamental relationship between species performance and their environments and argued against the "command and control" paradigm that guided fisheries management throughout much of the 20th century. The following is a description of how the working hypothesis of this *Willamette Subbasin Plan* is structured around NPCC's principles.[2]

1. **The abundance, productivity, and diversity of organisms are integrally linked to the characteristics of their ecosystems.**

   An ecosystem is an organized complex of physical and biological components (Tansley, 1935). Physical and biological elements such as minerals, soil, vegetation and animals self-organize into a system that captures and processes energy to produce the observed diversity, abundance and productivity of plant and animal species, including humans (Kauffman, 1993; Odum, 1993). The characteristics and abundance of individual species reflect their coevolution with other species and their response to their environment. Because of the pervasive impact of human actions on ecological systems (Vitousek et al., 1997), achieving goals for individual species of commercial, cultural or other human interest will require managing human activities to support ecological processes (Christensen et al., 1996).

   Although scientists may have an intuitive feel for what constitutes an ecosystem, management goals and actions frequently focus on individual species rather than on the species' ecosystems—the physical and biological systems that species are a part of, contribute to and depend on. In the past, species of commercial and cultural concern have been given priority, with sporadic success. There is increasing recognition of the need for multiple species management and the integration of land management with fish and wildlife management (Puchy and Marshall, 1993; Christensen et al., 1996; Dale et al., 2000). This means recognizing both the processes that form the habitats necessary for species (processes such as channel dynamics and habitat connectivity) and the functions that species provide to the ecosystem (such as input of organic matter, primary and secondary production and energy flow). For example, many of the flood control dams constructed in the upper Willamette River basin did not provide fish passage, thereby eliminating crucial nutrient cycling. The combination of suitable habitats and needed ecological functions combine to form the ecosystems needed to provide the desired abundance and productivity of specific species.

   Local climate, hydrology and geomorphologic factors as well as species interactions strongly affect ecological processes and the abundance and distribution of species at any one place (Dale et al., 2000). The life histories, physical features and diversity of individual species are shaped by climate, the physical structure of their habitat and biological interactions. Change in physical or biological features of the ecosystem, either natural or human-induced, affects the capacity, productivity and diversity of fish and wildlife species.

   Implications. Management of species or ecological problems in isolation at best provides an incomplete picture and at worst misleads by not accounting for the context and mechanisms that control species abundance, capacity and diversity, or the ecological processes that support these. This principle notes the integral relationship between species and their environment and the role that species themselves play in maintaining that environment. It couples ecological conditions with the productivity and abundance of species, including those of management interest.

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[2] Much of the language used to explain these principles is taken from the public review draft of the City of Portland's *Framework for Integrated Management of Watershed Health* (March 2004).

Natural resource management, especially fisheries management, often isolates species from their environment to insulate them from habitat loss or other impacts of human actions (Bottom, 1997). Insulating species in this manner neglects the role of biological and physical factors of the ecosystem—such as dynamic conditions of flow, habitat and water quality—in shaping individuals, populations and species through natural selection. In addition, this approach does not replace habitats themselves or the ecological functions that species provide, such as supplying nutrients and food to other species. For salmon, hatcheries historically have not been successful. This is not to say that hatcheries do not have a role to play in salmonid recovery, particularly during the stages in which habitat and ecological functions are being restored. Rather, hatchery operations should be conducted with an understanding of the contribution salmonids make to healthy functioning of the ecosystem and the reliance of salmonids on biological and physical characteristics of their environment.

Application to Assessment. The Willamette system consists of a diverse set of biological and environmental elements. For portions of the Willamette system, the authors of this *Willamette Subbasin Plan* have brought these elements together within an EDT framework that explicitly links environmental characteristics and biological performance. For EDT-treated watersheds, these relationships are embodied in the species-habitat rules in EDT. For other watersheds, these linkages are made qualitatively through professional judgment based on experience and literature review. It is expected that eventually the entire basin will be captured in a common analytical framework.

Our assessment of aquatic habitat in the Willamette River has focused on spring Chinook, winter steelhead, cutthroat trout, bull trout, Oregon Chub, and Pacific lamprey; however, anadromous salmonids are the only species included in the EDT analytical framework. Anadromous salmonids are indicators of a particular type of the environment that characterizes the normative condition for the Willamette system. The habitat requirements of salmon have been extensively documented and are captured in the habitat rating rules of EDT. This allows us to construct explicit linkages between habitat and species performance.

2. Ecosystems are dynamic, resilient, and develop over time.

Although ecosystems have definable structures and characteristics, their behavior is highly dynamic, changing in response to internal and external factors (Dale et al., 2000). The system present today is the product of its geological, biological and human legacy. Natural cycles of change structure biological communities and affect species abundance and distribution (Beamish et al., 1999). Disturbance and change are normal ecological processes and are essential to the structure and maintenance of habitats (Bisson et al., 1997).

Disturbance can be the result of natural processes such as fire, flood or insect outbreaks, or they can result from human activities, such as the creation of impervious surfaces, development of riparian zones, timber harvest or agriculture. Natural disturbance patterns create a mosaic of habitats across the landscape and through time (Reeves et al., 1995). At the same time, ecosystems maintain characteristic features and support definable communities of organisms. Habitat-forming processes—which result from the underlying geology, climate and hydrology and species' ecological functions—impart a degree of resilience to the system, allowing it to accommodate change and maintain essential characteristics (Holling, 1973). Once a disturbance dissipates, the ecosystem may come to resemble its previous condition, depending on the type and degree of disturbance and the ecosystem's resilience.

However, an ecosystem's ability to absorb change and retain its original characteristics is limited (Holling, 1973; Reice et al., 1990). Human actions and natural events can dramatically alter ecological systems such that the system is not destroyed but instead shifts into a new configuration in which different species are favored and new biological and physical interactions develop. This is particularly true in urban ecosystems, where disturbance is essentially a continuous rather than episodic event and the resilience of the ecosystem is compromised to the extent that it will not return to predisturbance characteristics even when the disturbance is reduced or eliminated.

A natural ecosystem will show describable, if not generally predictable, patterns of change over time (Odum, 1969). For example, a forest, like other ecosystems, may appear stable when observed at one point in time, but it changes over longer time frames. Similarly, a lake or stream matures to have a dramatically different ecological character at various points in time (Cummins et al., 1984). Natural disturbances can interrupt succession locally, leading to a mosaic of habitats across the landscape (Reeves et al., 1995). More widespread and pervasive disturbance, including many human activities, can stop or reset ecological succession patterns and prevent the formation of habitats and processes that may be essential to the continuation and abundance of some species.

Many natural resource management actions are designed to control the environment, reduce variability, and achieve a stable and predictable yield from a highly dynamic system (Holling and Meffe, 1996). For example, dams and other structures are designed to dampen seasonal variation in water flow. In many developed areas, river and streambanks are stabilized and diked to minimize out-of-channel flooding during high flow events. Fish hatcheries were conceived, in part, to smooth out natural variation in fish populations and to sustain harvest over time (Bottom, 1997). Hatchery production and fish passage measures are timed and engineered to provide a predictable fish migration with minimal conflict with human uses of the river. Fires are suppressed, altering forest succession, species composition and the frequency and severity of insect outbreaks (Quigley et al., 1996).

Implications. Natural resource management programs should anticipate and accommodate both natural and human-induced change. This would be a departure from traditional management, which has attempted to freeze the system in a certain constant state and manage it for constant yields by not allowing natural change to occur. Expectations of constant abundance or yield from natural resources are unrealistic and ignore fundamental features of ecological systems. Similarly, efforts to protect only areas that currently possess desirable conditions, without considering the long-term, dynamic nature of ecosystems, will not result in successful, comprehensive natural resource management. Natural patterns of disturbance should be recognized as events that develop and maintain a diversity of habitats. Efforts to stabilize the environment and reduce disturbance will fundamentally alter habitats to the detriment of the abundance, productivity, spatial structure and diversity of species of management interest.

Given the limited resilience of ecosystems in urban areas, it is not realistic to expect a return to predisturbance conditions. Nonetheless, ecological functions can be restored to some degree. The challenge for urban areas in particular is to allow habitat-forming processes to occur in a built-out environment with high human population densities. The *Johnson Creek Restoration Plan* (City of Portland Bureau of Environmental Services 2001) is one example of an approach that has attempted to do this. The plan calls for buying properties along Johnson Creek to provide flood storage in the floodplain, as well as create off-channel habitat for salmonids. This approach came about as a result of a combination of factors, including strong public support, a history of failed flood control attempts, and increased regulatory scrutiny by federal and state agencies as a result of the Endangered Species Act.

Application to Assessment. Our assessment is based on human development of the Willamette Basin from about 1850 to the present. This provides a basis for hypotheses regarding the effect of future conditions. Much work remains to analytically characterize stochastic and dynamic elements responsible for creation and maintenance of habitat characteristics.

3. **Biological systems operate on various spatial and time scales that can be organized hierarchically.**

Ecosystems, landscapes, communities and populations are usefully described as hierarchies of nested components (Allen and Hoekstra, 1992), with levels in the hierarchies distinguished by different spatial and time scales. A higher level addresses larger areas that fluctuate over relatively long time intervals, whereas lower levels encompass smaller areas and vary at greater frequencies. For example, factors such as climate and geology might be addressed at a regional scale, hydrology and water quality might be addressed at the watershed scale and localized habitat components might be addressed on a local, site-specific scale. Expansive ecological patterns and processes constrain, and in turn reflect, localized patterns and processes (Wiens, 1989).

The appropriate hierarchy and scale to use for watershed management depend on the question asked (Levin, 1992). There is no single, intrinsically correct scale, only one that usefully addresses the issue in question. Conditions at any given level reflect both the cumulative effect of actions at lower levels and the constraints imposed by higher level factors (Allen and Hoekstra, 1992). Therefore, to understand conditions at any particular level, it is necessary to consider the higher level constraints (the context) and the lower level mechanisms, both of which influence conditions (Wiens, 1989). This suggests neither a top-down nor a bottom-up management approach but rather an integration of both.

Viewing ecosystems as hierarchies is useful in depicting the underlying structure of ecological components. Regional climates, for example, vary through time on scales ranging from millennial to interannual (Greenland, 1998). Disturbance regimes within ecosystems can be described at a variety of spatial and temporal scales (Delcourt et al., 1983) that can affect life history patterns and genetic structure (Wissmar and Simenstad, 1998). Frissell et al., (1986) describe a hierarchical classification system for aquatic habitats based on underlying geomorphic hierarchies.

This principle also provides an ecologically based way to structure recovery efforts (Quigley et al., 1996). As a necessary first step, the ecosystem is defined at the point in the ecological continuum appropriate to the problem to be solved. The ecosystem at that point reflects both the characteristics of the features nested within it and higher level constraints on performance.

Implications. If ecosystems are viewed as nested hierarchies, it is necessary to define appropriate scales for their management and study (Holling and Meffe, 1996). To address problems in the entire Willamette Basin, for example, it may be necessary to filter out local, site-specific data. On the other hand, questions concerning localized components (such as the Willamette's reach within Portland or tributaries to the Willamette, such as Johnson and Tryon creeks) cannot be effectively addressed by looking solely at the entire basin. Understanding basin-level problems requires knowledge of actions and processes that take place in individual reaches and tributaries, while the success of reach- or tributary-level actions may depend on factors operating at basin and regional levels.

Effective restoration of physical, chemical, and biological components of the Willamette River and its tributaries requires coordination with upstream and downstream jurisdictions as well as with agencies that control water flows, water quality and fish and wildlife communities. This involves working at multiple scales involving both the site-specific and the basinwide context.

Application to Assessment. Our assessment is constructed hierarchically. The environment is described in the analytical framework for portions of the basin at the scale of the geomorphic reach and then aggregated to form geographic areas within watersheds. For non-EDT-treated areas of the basin, the environment is described at the 4th–field HUC scale. This hierarchical physical description is reflected in biological performance that is scaled from life stages occurring in reaches and over geographic areas to populations that reflect conditions across geographic areas and watersheds. We have scaled species performance at the watershed scale to the total life-cycle scale by using appropriate out-of basin-factors within our EDT depiction. We also have begun to form an overall picture of the Willamette basin that is composed of populations within each of the major watersheds.

4. Habitats develop, and are maintained, by physical and biological processes.

Habitat refers to the resources and conditions present in an area that allow a species or a group of species to exist and thrive (Hall et al., 1997). From a species perspective, the habitat is the string of conditions encountered over the species' life cycle that contribute to the species' survival and reproduction (Independent Scientific Group, 2000). Factors such as geology, climate, geomorphology, soils, hydrology, vegetation and topography regulate habitat-forming processes, which for salmonids include stream flow, contributions of large wood, sediment supply, temperature and channel dynamics (Frissell et al., 1986; Imhof et al., 1996; Beechie and Bolton, 1999). All of these elements act over a range of spatial and time scales to create, alter and maintain habitats (Allen and Hoekstra, 1992).

Regional-scale climatic conditions determine temperatures and precipitation that are important in the development of habitats. At both the regional and local scales, habitats are created and maintained by hydrologic, geologic and biotic processes that affect other aquatic and terrestrial conditions throughout the watershed. Locally observed conditions often reflect more than local processes and influences; in fact, they often reflect non-local—even regional—processes, including human actions. The presence of essential habitat features created by these processes determines the abundance, productivity, spatial structure and diversity of species and communities (Morrison et al., 1998).

The active agent of many aquatic habitat-forming processes is water acting with the underlying geology and topography. Because habitat processes are hydrologically linked, the impacts of actions can manifest themselves downstream. As an example, downstream habitat conditions (such as high water temperature or increased sediment) can be the result of upstream actions and conditions (such as the removal of trees along streambanks or streamside construction). The impacts of these terrestrial actions and conditions accumulate (that is, the water temperature increases continually) as water moves downhill, affecting aquatic habitat conditions downstream.

Terrestrial habitats are often described in terms of food, water and cover. Formation of these features is related to vegetative and biotic patterns that result from the environmental needs of individual plant species, succession and patterns of human-caused and natural disturbance (Whittaker, 1975). In turn, the vegetation pattern is related to local geology, topography and climate in the context of the regional climate and other factors. In an urban context, terrestrial habitats are often described in terms of their land uses, levels of impervious surface and vegetative cover.

Implications. Understanding the processes that create and maintain aquatic and terrestrial habitats is key to managing the human impacts on those habitats (Imhof et al., 1996; Beechie and Bolton, 1999). Even though the perceived problem may be local, it is necessary to consider the habitat-forming processes acting at the watershed or basin level. Often efforts are focused on correcting the symptoms of habitat degradation and loss, rather than on their causes, and problems are addressed with local, technological solutions. Often these efforts prove futile because the process and conditions creating the problem are still in place (Kauffman et al., 1997).

This principle stresses the need to understand and address habitat-forming processes in order to restore and maintain aquatic and terrestrial habitats (Beechie and Bolton, 1999). Habitat restoration actions undertaken without appreciation of the underlying habitat-forming processes will not be effective in the long term (Reeves et al., 1995). Land use affects habitats through processes similar to those structuring natural habitats. Understanding the relationship between land use practices and their impacts on watershed processes is key to ensuring that habitats are available to support biological communities and species of interest.

In urban areas, efforts have been made to control or eliminate the impacts of flooding, with the result that important habitat-forming processes that native aquatic species have adapted to have been altered. Controlling water flows through reservoirs and dams has given many people the sense that rivers can effectively be separated from their floodplains. Activities such as filling floodplains and building flood control bank structures has given human populations the perception that they can safely build next to streams and rivers.

As the population continues to increase in the Willamette Basin, the size and impact of cities located along the river corridor will increase. This will present the challenge of how to allow habitat-forming processes to occur via careful management of high flows, in conjunction with restored bank and floodplain habitat. It also will be necessary to change the management of reservoirs and dams and redesign fish-friendly bank and near-shore treatments to handle the increased flows while also providing ecological benefits. Given the potential for conflict with regard to historical uses and properties, there will need to be an educational component in addition to coordination to facilitate decisions at site- and basinwide scales.

Application to Assessment. Habitat-forming processes in the Willamette River basin have been heavily altered by human activities. Natural processes such as flow dynamics have been altered by regulation, while new processes, such as the effects of urbanization, road building, and agricultural field tiling, have been introduced. Many of these changes are captured within our analytical framework, but much work is needed to fully understand the cumulative systemic interactions and impacts of these alterations.

Ideally, physical process models of sediment and temperature dynamics, channel structure, and so on could be linked to our environmental characterization to provide an analytical basis for linking aquatic and terrestrial processes and to describe the effect of human actions. In the absence of these analytical linkages, we have explicitly made qualitative linkages between management actions and habitat change.

5. Species play key roles in developing and maintaining ecological health.

Organisms do not act as passive occupants of their habitats. Instead, each species has an ecological function that may be key to the development and maintenance of ecological conditions such as habitat and food supply (Walker, 1995). Although not every species' ecological role is well understood, it is clear that each group of species has a distinct job or "occupation" that is essential to the diversity, sustainability and productivity of the ecosystem over time (Morrison et al., 1998). For example, plant, animal and bacterial species structure habitats, cycle energy and control species abundance and diversity. Beavers create ponds, plants make the sun's energy available to herbivores (and ultimately carnivores) and bats help keep mosquitoes in check. The existence, productivity and abundance of species depend on functions such as these.

To varying degrees, similar ecological functions may be performed by different species, and having a diversity of species with similar "occupations" enhances the resilience of the entire ecosystem in the face of disturbance or environmental variation (Walker, 1995). However, some ecological functions are performed by a limited number of species. The decline or disappearance of these species can have significant impacts on their associated ecological function, the ecosystem as a whole and other species.

In Pacific Northwest ecosystems, for example, salmon often play a unique role in cycling nutrients and energy from the ocean to freshwater and terrestrial habitats (Cederholm et al., 1999). Salmon carcasses naturally fertilize freshwater systems, providing a unique array of nutrients, lipids and biochemicals to freshwater and riparian food webs. Algae, bacteria, invertebrates and young salmon fry in particular depend on these nutrients—many of them marine-derived—to survive and remain viable throughout the year. In fact, "the watershed fertility once provided by healthy runs of salmon may be essential to recovery of declining salmon stocks" (Pacific Northwest Research Station, 2001). The disappearance or decline of salmon stocks in a particular watershed can have far-reaching impacts on coexisting aquatic and terrestrial plants and wildlife; these impacts include changing the nutrient cycle and other ecological functions (Willson and Halupka, 1995; Cederholm et al., 1999).

Salmon hatcheries may provide harvest benefits to some human users when habitats have been altered or destroyed, but generally hatcheries do not replace the ecological role that salmon play in the ecosystem, such as nutrient cycling. Recent experiments show that placing hatchery-origin salmon carcasses into streams (one carcass per square meter) jump-starts trophic level production and results in accelerated growth rates in fish. Through its Salmon Trout Enhancement Project, ODFW enlists volunteers to place carcasses in streams. Although the ecological impact of these particular carcass placements has not been measured, the strategy of carcass placement remains a potential short-term method for incorporating marine-derived fatty acids and biochemicals into aquatic food webs. (It should be noted, however, that just as some streams have never supported certain fish populations, individual watersheds will respond differently to added nutrient loads, depending on biological, chemical and physical attributes unique to that system.)

Implications. This principle affirms the need to consider resource management actions in the context of species' ecological functions. In the case of salmon, it is generally understood that spawned-out carcasses provide important nutrients to ecosystems as the carcasses decompose and release minerals. Although scientists do not know the degree to which declines in local salmon runs—and the concomitant changes in nutrient cycling—have affected Portland's watershed ecosystems, the declines have doubtless had an effect. The result can be significant ecological change affecting the presence and abundance of other aquatic and terrestrial species (Cederholm et al., 2000).

Ill-placed or poorly designed culverts or other fish passage barriers affect the number of salmonids that can return to spawn, the temporal and spatial distribution of salmonids throughout a subbasin and—ultimately—the nutrient balance of that freshwater system. Managing waterways so that salmonids can return unimpeded to spawn is critical to reestablishing the nutrient bank in those freshwater systems.

Hatcheries may continue to play a role in natural resource management, but their operation must be changed so that they not only bolster salmon survival but so they restore or replace the functions that salmon provide in the ecosystem and boost the overall carrying capacity and productivity of the environment.

Application to Assessment. Because scientific knowledge of the effects of species on ecological conditions is limited (although rapidly increasing), we have probably not fully captured all aspects of how species shape habitats.

6. Biological diversity allows ecosystems to persist in the face of environmental variation.

Biological diversity occurs at a variety of scales: in the variety of life forms across the landscape, in the ecological roles they play and in the genetic diversity within their populations (Odum, 1993). Biological diversity develops as a result of various physical and biological processes in response to variability in the physical and biological conditions of the environment (Southwood, 1977). Variation in biological characteristics among species, populations and individuals is what drives adaptation in response to environmental variation.

Biological diversity contributes to ecological stability and resilience (Walker et al., 1999) at two levels:

- **Within ecosystems.** Resilience is enhanced by the presence of multiple, functionally similar species within a single ecosystem. As the populations of individual species increase or decrease over time, they can alternate in providing essential ecological functions (Morrison et al., 1998; Peterson et al., 1998; Walker et al., 1999). Species that are abundant contribute to ecological function and performance at a particular time, whereas rarer species contribute to ecological resilience over time (Walker et al., 1999). Loss of species, particularly those for which there are few ecological equivalents, jeopardizes overall ecological structure and stability (Walker 1995).
- **Within a species.** Genetic diversity contributes to the stability of a species over time by providing a wider range of possible evolutionary responses to the challenges posed by variation in the environment. As the environment changes over time, survival rates vary from one population to the next. As some populations suffer under an environmental extreme such as an El Niño condition, others might fare better. However, the species as a whole survives, bolstered by its ability to respond to the shifting environment (Bisbal and McConnaha, 1998).

Human actions often reduce biological variation at both levels (Urban et al., 1987; Policansky and Magnuson, 1998). As the environment is simplified and its natural variability is decreased, biological variation at the various scales is reduced as well. This leads to the potential loss of organisms as they become less capable of responding adaptively to environmental change. The subsequent loss of ecological functions (functions that the organisms formerly provided) can decrease the stability and resilience of ecosystems.

Implications. Activities should be managed to encourage natural expression of biological diversity. While diversity can be quantified, it probably is not possible to determine the “proper” level of biological diversity, partly because it varies over time in response to various physical and biological processes. Furthermore, because future environments or situations cannot be predicted, the level of biological diversity needed to maintain future ecological systems cannot be known. It is not simply that more diversity is always good; in fact, increasing diversity by introducing nonnative species can actually disrupt ecological functions. Rather, it is important that the ecosystem be able to express its own species composition and diversity, so that it remains productive and resilient in the face of environmental variation. The challenge is to manage human activities to encourage the development of compatible native biological communities while at the same time minimizing our impacts on selection so that diversity can develop accordingly.

Application to Assessment. Biological diversity is one of four biological performance attributes that we use to characterize the quality and quantity of habitat. EDT uses life history trajectories to sample habitat along a stream length and across months within a year. The number of these trajectories that can be sustained (productivity > 1.0) compared to a reference condition is a measure of the spatial and temporal heterogeneity of habitat and the diversity of life histories within a species.

In addition, we have characterized habitat for multiple species, for multiple populations within species and, finally, for multiple life stages within populations.

7. Ecological management is adaptive and experimental

Our depiction of the Willamette system is a working hypothesis. We expect that hypothesis to continually evolve as scientific knowledge advances and social conditions change. For those areas characterized within EDT, this working hypothesis is composed of a number of individual hypotheses about species/life stage-habitat relationships. These hypotheses are based on an environmental depiction composed of specific attributes.

We propose a three-step adaptive management system for the Willamette subbasin:

1. A working hypothesis based on an assessment of the Willamette watersheds is created within the subbasin plan.
2. Monitoring and evaluation to address the following questions:
   - Did we take the actions proposed in our management plan?
   - Did these actions produce the kind of environmental change contained in our analysis?
   - Did biological performance change in response to the environmental change as predicted in the model?
3. Change the working hypothesis in response to monitoring and evaluation.

8. Ecosystem function, habitat structure, and biological performance are affected by human actions.

Humans are integral parts of ecosystems, and human actions have a pervasive impact on the structure and function of ecosystems; at the same time, human health and well-being are tied to the condition of the ecosystem (Vitousek et al., 1997). Like many other organisms, people structure and control ecosystems for their own needs. In some ecosystems, particularly urban ones, human impacts are major factors controlling the environment. However, unlike other organisms, humans can consciously control their actions to allow needed ecological conditions to develop. While human actions may be unique in the scale of their impact on ecological systems, the method of interaction is not; ecological principles apply to human interactions with ecosystems as much as they do to the interactions of fish and wildlife species with the ecosystem.

It is a reasonable assumption that for most species, the ecological conditions that are most conducive to their long-term survival and productivity are those under which they evolved. But urbanization and associated human actions have shifted ecosystems away from their predevelopment conditions, with negative impacts for many native species, especially fish. Some changes are irreversible: the urbanized landscape has been permanently changed; increased stormwater runoff has altered flow, water quality and habitat conditions in stream channels; and nonnative plant and animal species have been introduced that compete with and in some cases displace native species. Even with complete cessation of urban development, the ecosystem would not return to its previous condition. However, the impacts of urbanization and associated human actions on ecosystems can be managed to move the system to a state that is more compatible with the needs of other species.

Implications. Some people view humans as separate and distinct from the natural world—as observers and users rather than as active participants. This principle stresses the integral role of humans in the ecosystem and their unique ability to shape society's ecological future. For millennia, humans have altered the natural landscape in the Willamette Basin and the abundance and distribution of its plants and animals. In intensely developed areas, human activities will continue to dominate the ecosystem. However, it is possible to manage those actions in a manner that is more consistent with the needs of other species and ecological processes.

As scientists learn more about urban ecosystems, there will be more opportunities to incorporate considerations related to ecological functions and processes into traditional urban development and redevelopment objectives. Ecosystem objectives do not have to be incompatible with urban objectives. For example, fish-friendly objectives can be incorporated into bank and near-shore redevelopments along with more traditional objectives, such as flood control. Zoning can establish and protect effective riparian corridors along streams and rivers to buffer the impacts of humans on the aquatic system. And stormwater best management practices can be implemented to detain and infiltrate stormwater onsite at existing facilities and redevelopment sites, thus reducing high stormwater runoff flows.

Application to Assessment. Our assessment of the Willamette contrasts the current condition of the basin to historical conditions to depict a normative condition for the Willamette and a fully degraded condition. EDT is used to define these states in terms of species performance. We define the health of the system relative to these reference states. Proposed future states for the system affected by human actions will be depicted as alternative states within the continuum defined by the reference conditions.

3.2.2.2 Development of a Scientific Foundation for Portland Urban Streams

A particular application of NPCC's scientific principles is the development of a framework for watershed health for aquatic resources within the city of Portland (City of Portland, 2004). The Portland *Framework for Integrated Management of Watershed Health* represents a unique commitment to ecological health within a major urban area. While the City's *Framework* is focused on aquatic habitat, it acknowledges the need to integrate aquatic and terrestrial environments. The City presents an outline for ecological health that stresses that, although urban watersheds offer distinct challenges, the biological requirements of fish and wildlife in urban areas are the same as for fish and wildlife in more natural settings. The City's *Framework* expands NPCC's scientific foundation by providing additional guidelines and principles that stress the relationship between environmental conditions and biological performance. The City also has included monitoring procedures and incorporated a set of analytical tools to assist in the incorporation of the concepts into City policies and actions.

The City's *Framework* is reflected in our assessment of the lower Willamette, including Johnson Creek and Tryon Creek—two urban streams within the city. Because of the City's development of its *Framework* and the associated analytical framework, this portion of the system has received a particularly detailed EDT assessment (McConnaha, 2003). In the lower Willamette (the portion of the river below Willamette Falls), the City's analysis has been augmented by assessments of Kellogg Creek and the Clackamas River.

3.2.2.3 The Use of EDT for Assessment of Aquatic Habitats

The Northwest Power Act of 1981 directed NPCC to adopt cost-effective means of achieving "sound biological objectives." In its 2000 *Columbia River Basin Fish and Wildlife Program,* NPCC defined biological objectives as consisting of two parts (Northwest Power Planning Council, 2000):

- **Biological performance of specific species**. This included NPCC's definition of a healthy salmon and steelhead population: "Healthy populations are defined as having an 80 percent probability of maintaining themselves for 200 years at a level that can support harvest rates of at least 30 percent."
- **Environmental characteristics**. These describe features of the environment needed to achieve the biological performance objectives, including NPCC's definition of a healthy fish population.

For portions of the Willamette Basin, the authors of this *Willamette Subbasin Plan* captured this simple relationship within an analytical framework based on Ecosystem Diagnosis and Treatment (EDT), a habitat model that links a reach-level description of the environment to the life stage and population level performance of salmonid fishes (Mobrand Biometrics, 2004). EDT depictions were developed of the environment for the McKenzie River (spring Chinook), the Clackamas River (spring Chinook, fall Chinook, coho, and steelhead), and lower Willamette urban streams: Johnson Creek (coho and steelhead), Tryon Creek (coho and steelhead) and Kellogg Creek (coho and steelhead). Time and resources did not allow construction of EDT depictions of the other major subbasins in the Willamette Basin. However, there is broad agreement that EDT assessment is needed to create a common, basinwide framework for decision making. In fact, work has already begun with the U.S. Army Corps of Engineers to facilitate EDT development in the Santiam, Middle Fork, and Coast Fork. For those streams for which EDT assessments have not yet been completed, this document used qualitative depictions based on the terminology and logic employed by EDT.

EDT uses a set of explicit rules that link habitat characteristics to life stage survival. For each basin treated with EDT, local technical experts were convened to assemble an environmental template using a software application called the Stream Reach Editor (SRE). Local planners and biologists defined reaches within each subbasin and documented habitat conditions in each reach using the 45 environmental attributes in EDT. The boxes in Figure 3-20 show how the species-habitat rules in EDT relate the environmental depiction developed in the SRE to biological performance of fish species. Details of how these rules work and the species-habitat relationships are provided in Mobrand Biometrics (2003).

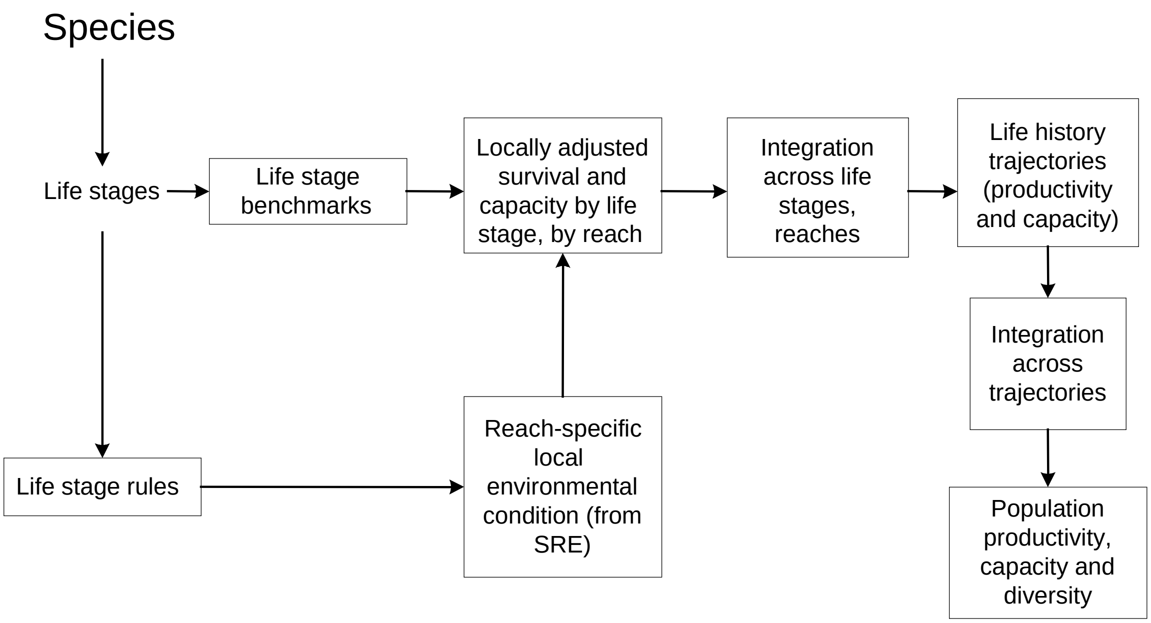

Figure 3-20: Expansion of the Biological Objectives Model within EDT

EDT provides four measures of biological performance as a function of the environmental template:

- **Biological capacity:** The maximum number of individual fish that can be supported by the quantity of suitable habitat.
- **Biological productivity:** The maximum survival rate of individuals in a population as a function of the quality of habitat.
- **Equilibrium abundance:** The abundance of fish at which the population would tend to equilibrate given constant environmental conditions. Equilibrium abundance is a function of both the capacity and the productivity and is a convenient aggregate measure.
- **Life History Diversity:** A measure of the breadth of habitat based on the number of weeks within a year and the area within a stream where suitable conditions exist for the focal species. EDT constructs life history trajectories starting from points along the stream and at times within a year. The percentage of viable trajectories (those having a productivity greater than 1.0) relative to the number of trajectories in a reference condition is a measure of life history diversity and breadth of habitat.

Habitat was assessed by contrasting the current condition—defined by local technical experts with experience in the basin—to a set of reference conditions (see Figure 3-21) (McConnaha, 2003). This was done explicitly for the EDT subbasins, but the same logic was used for the non-EDT subbasins in the Willamette as well. The “restored” reference condition (often referred to in EDT as the template) was represented by the normative condition for the stream, which in most cases was analogous to its historical condition. The “degraded” reference was a condition in which the environment was highly degraded. Biological performance under the “current” and “restored” conditions were defined in EDT for the focal species based on environmental descriptions developed for each subbasin in the Stream Reach Editor. The reference conditions allowed us to define the relative terms “good” and “bad” with regard to habitat conditions for the species. The position of the current condition relative to these reference states also allowed us to define the restoration and protection priorities for a subbasin. For example, if the current condition was located very close to the restored reference condition (far to the right in Figure 3-21), it would have a high protection value but relatively small restoration potential. Similarly, if the current condition was near the degraded reference condition (far to the left in Figure 3-21), it would have little protection value but a high restoration value. Because the depiction of the environment captured in the Stream Reach Editor was developed for each reach, it was possible to disaggregate the EDT rating of the environment and define restoration and protection values for each reach and for the subbasin as a whole.

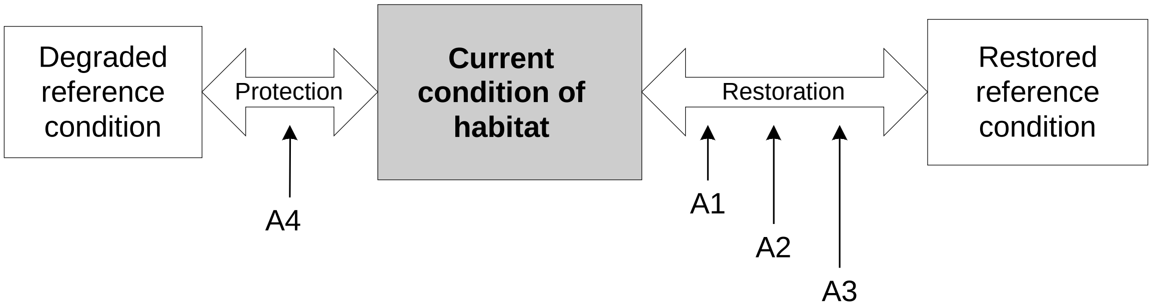

Figure 3-21: Analytical Framework for Subbasin Assessment in the Willamette

The assessment framework in Figure 3-21 makes it possible to examine management alternatives for the EDT subbasins in the Willamette. Actions that would change the current condition (including alternatives that make conditions worse) are represented as points A1 through A4 in Figure 3-21. One of these—Point A3, for example—might represent the environmental condition for a stream needed to achieve a “healthy” fish population as defined in NPCC’s biological objectives (see above and Section C.2. of Northwest Power Planning Council, 2000).

The examination of management alternatives in the Willamette has not been completed. Work to date has progressed to the point of establishing the assessment framework shown in Figure 3-21, including establishment of the current and reference points within EDT. However, management alternatives have not yet been analytically developed. The authors of this *Willamette Subbasin Plan* recommend that an analysis of management alternatives be completed in the near future as a means of evaluating a complete suite of alternatives and analytically linking management strategies to the assessment presented in this document. In the meantime, management strategies (see Chapter 5) have been qualitatively matched to the habitat limitations revealed in the assessment presented in this chapter of the *Willamette Subbasin Plan*.

3.2.2.4 Limitations of EDT Within the Willamette System

No model can incorporate all aspects of a complex natural system. Models are designed for specific use and capture only a small portion of the natural world that we understand. EDT has limitations that should be understood in interpreting its results. The first limitation is the overall purpose of the model. EDT is system to rate aquatic habitat with respect to a salmonid fish species. It is not a population model. Questions of extinction risk, viable population parameters, and genetic interactions are best addressed using other tools. However, EDT can add considerably to the discussion of these issues because it relates habitat characteristics to the capacity and productivity of a potential fish population. This allows EDT to be used to explore the habitat implications of population goals such as NPCC's definition of a healthy fish population.

Although EDT contains a considerable library of species-habitat rules, it is not all encompassing. The library continues to evolve as new information is presented and new issues arise. In the Willamette Basin, two rule limitations were identified that should be highlighted because they affect potentially important aspects of the Willamette system in particular: the use of off-channel habitat by Chinook salmon and indirect temperature effects on survival. These are discussed below.

Use of Off-Channel Habitat by Chinook Salmon. Conventional wisdom has held that, during winter, juvenile Chinook salmon make little use of off-channel habitats but instead occupy stream margins and the main channel areas. However, off-channel areas, which include channel elements distinct from the primary and secondary channels but connected to the main channel, provide key over-wintering habitat for juvenile coho salmon. This hypothesis has been incorporated into the habitat rules for Chinook and coho in EDT (Mobrand Biometrics, 2003).

In addition, there is increasing evidence (much of it for the Willamette River) of winter use of off-channel habitat by Chinook. Several studies point to the use of off-channel sloughs, tributary mouths, and even gravel pits by Chinook in the lower McKenzie and Willamette rivers. This knowledge has not yet been incorporated into the EDT rules, although new rules are likely to be formulated over the next year. To the extent that off-channel areas are important over-wintering habitat for juvenile Chinook, EDT will underestimate the effects of these areas on Chinook potential.

Indirect Temperature Effects on Survival. Temperature plays an important role in determining species potential in EDT. For example, EDT has rules that relate acute temperature effects on life stage survival[3]. However, indirect effects of temperature that might be the result of effects on alevin growth or emergence time are not incorporated into EDT rules at the present time. Recognition of this limitation is particularly important in the Willamette, where high-head dams on the McKenzie and Santiam rivers result in a markedly altered temperature regime in stream reaches below the dams. The altered temperature regimes have been shown to have a pronounced effect on fish development and emergence timing. While EDT does account for direct mortality to eggs and other life stages as a result of temperature, the indirect effects of temperature are not incorporated and the effect of these dams on fish potential is underestimated.

3.2.3 Focal Species Selection

Both aquatic and terrestrial focal species were selected for this subbasin plan, as described below.

3.2.3.1 Aquatic Focal Species Selection

Aquatic focal species were identified and agreed to by the Subbasin Planning Technical Advisory Group in meeting discussions and through draft list reviews. Criteria used to determine whether a species should be considered a focal species were based on NPCCl technical guidance and included the following:

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[3] Temperature also affects species performance in EDT through other attributes such as predator activity and water quality.

- Does the species have special state or federal status?
- Is the species important culturally or ecologically?
- Is the species a good indicator of aquatic habitat conditions?
- Is enough known about the species that a management plan can be developed?

The group agreed that it was important to consider all special-status species, but there also was an interest in considering more widely distributed species that are good indicators of habitat conditions. Currently, all management direction for special-status species in the Willamette Basin is directed toward eastside tributaries. For the *Willamette Subbasin Plan*, resident cutthroat trout was chosen as a focal species because of its broad distribution (including westside tributaries) and its value as an indicator of habitat conditions. In addition, there is great interest in resident and anadromous lamprey species in the Willamette Basin, but the lack of sufficient information to develop an adequate management plan minimized the potential impact that this subbasin plan could make for the species. The final list of focal aquatic species, management units, and analysis tools that will be used in this plan is presented in Table 3-23.

Table 3-23: Focal Fish Species Selection and Assessment Tool by Planning Unit

Watershed Management Units	Resident Focal Fish Species	Anadromous Focal Fish Species	Evaluation Technique
Mainstem and Tributaries from Mouth to Falls	**Cutthroat**	**Coho salmon** (The Clackamas may have one of the last remaining wild populations.) **Lower Columbia fall Chinook** (TRT-identified core population) **Upper Willamette spring Chinook** (TRT-identified core population) **Lower Columbia winter steelhead** (TRT-identified core population) **Lower Columbia chum salmon** (Historically present and recovery opportunity exists—no current population exists) **Note:** EDT analysis will treat the entire drainage below Willamette Falls as one planning unit.	EDT, HSI, watershed assessments, professional opinion
Clackamas River Watershed	**Bull trout** (thought to be extirpated after 1960, but included in USFWS recovery plan as core habitat with potential to contribute to delisting) **Cutthroat**		EDT, HSI, USFWS draft bull trout recovery plan, watershed assessments, professional opinion
Molalla Watershed	**Cutthroat**	**Upper Willamette spring Chinook** **Upper Willamette winter steelhead**	HSI, watershed assessments, professional opinion
Pudding Watershed	**Cutthroat**	Not considered by NOAA Fisheries for recovery for either steelhead or Chinook	HSI, watershed assessments, professional opinion

Table 3-23: Focal Fish Species Selection and Assessment Tool by Planning Unit

Watershed Management Units	Resident Focal Fish Species	Anadromous Focal Fish Species	Evaluation Technique
North and South Santiam Watersheds	**Bull trout** (thought to be extirpated in the North Santiam after 1945 and in the South Santiam after 1953 but included in USFWS draft recovery plan as core habitat with potential to contribute to delisting) **Oregon chub** (Five recovery sites with existing populations in the Santiam subbasin are identified in USFWS recovery plan.) **Cutthroat**	**Upper Willamette spring Chinook** (TRT-identified core population) **Upper Willamette winter steelhead** (TRT-identified core/genetic legacy population)	HSI, USFWS draft bull trout recovery plan, USFWS Oregon chub recovery plan, watershed assessments, professional opinion
Calapooia Watershed	**Cutthroat**	**Upper Willamette spring Chinook**	HSI, watershed assessments, professional opinion
McKenzie River Watershed	**Bull trout** (identified as part of the Upper Willamette core area in USFWS draft recovery plan) **Cutthroat**	**Upper Willamette spring Chinook** (TRT-identified core population)	EDT, HSI, USFWS draft bull trout recovery plan, watershed assessments, professional opinion
Middle Fork Willamette	**Bull trout** (identified as part of the Upper Willamette core area in USFWS draft recovery plan) **Oregon chub** (USFWS recovery plan identifies 13 recovery sites with existing populations in the Middle Fork Willamette) **Cutthroat**	**Upper Willamette spring Chinook**	HSI, USFWS draft bull trout recovery plan, USFWS Oregon chub recovery plan, watershed assessments, professional opinion

Table 3-23: Focal Fish Species Selection and Assessment Tool by Planning Unit

Watershed Management Units	Resident Focal Fish Species	Anadromous Focal Fish Species	Evaluation Technique
Upper Willamette Mainstem	**Cutthroat** **Oregon chub (**USFWS recovery plan identifies recovery sites with existing populations in the Upper Willamette)	**Upper Willamette spring Chinook** **Upper Willamette winter steelhead**	HSI, watershed assessments, Oregon chub recovery plan professional opinion
Coast Fork Willamette	**Cutthroat** **Oregon chub** (One recovery site with an existing population is identified in the Coast Fork.)	Not considered by NOAA Fisheries for anadromous fish	HSI, USFWS draft bull trout recovery plan, USFWS Oregon chub recovery plan, watershed assessments, professional opinion
Long Tom Watershed	**Cutthroat**	**Upper Willamette spring Chinook** (juvenile rearing only)	HSI, watershed assessments, professional opinion
Marys River Watershed	**Cutthroat**	**Upper Willamette spring Chinook** (juvenile rearing only) **Upper Willamette winter steelhead** (juvenile rearing only)	HSI, watershed assessments, professional opinion
Luckiamute River w Watershed	**Cutthroat**	**Upper Willamette spring Chinook** (juvenile rearing only) **Upper Willamette winter steelhead** (juvenile rearing only)	HSI, watershed assessments, professional opinion
Rickreall Creek Watershed	**Cutthroat**	**Upper Willamette spring Chinook** (juvenile rearing only) **Upper Willamette winter steelhead** (juvenile rearing only)	HSI, watershed assessments, professional opinion

Table 3-23: Focal Fish Species Selection and Assessment Tool by Planning Unit

Watershed Management Units	Resident Focal Fish Species	Anadromous Focal Fish Species	Evaluation Technique
Tualatin River Watershed	**Cutthroat**	**Upper Willamette spring Chinook** (juvenile rearing only) **Upper Willamette winter steelhead** (juvenile rearing only)	HSI, watershed assessments, professional opinion
Yamhill River Watershed	**Cutthroat**	**Upper Willamette spring Chinook** (juvenile rearing only) **Upper Willamette winter steelhead** (juvenile rearing only)	HSI, watershed assessments, professional opinion

EDT = Ecosystem Diagnosis and Treatment.

HSI = Habitat Suitability Index.

3.2.3.2 Terrestrial Focal Species Selection

This plan uses focal habitats as an organizing concept to discuss the terrestrial focal species in the Willamette Basin. Focal habitats are land cover or vegetation classes that are considered to be the most important in the Willamette Basin because of their scarcity, rate of decline from their historical extent, exceptional wildlife or plant diversity, and/or consistent use by a relatively large number of plant and wildlife species that are threatened, endangered, sensitive, or declining in the basin (see Appendix D for the analytical approach). Table 3-24 lists the focal habitats used in this plan and shows how they compare to habitats identified in previous plans and assessments of wildlife in the Willamette Basin.

Terrestrial focal species are plant or wildlife species or subspecies that serve to focus management and/or monitoring activities. Some authors have used this phrase to denote species that encompass the structural and functional needs of broader ecological communities. Some of the terrestrial focal species in this plan were chosen not only to address this concept, but also (or instead) because they are keystone species (that is, species that significantly alter the physical environment), endemic to Oregon, highly specialized, declining, or especially vulnerable to extirpation. Table 3-25 lists the terrestrial focal species selected for this plan, and Table 3-26 groups those terrestrial focal species by habitat type and shows how the groupings compare with those of previous plans and assessments of wildlife in the Willamette Basin.

Several agencies and groups involved with the Willamette Basin (for example, USDA Forest Service, BLM, Corps of Engineers, ODFW) had previously used diverse criteria to designate particular species as “focal.” The composition of these lists is largely a function of legal and geographic responsibilities of the particular agency. The authors of this plan drew heavily from such lists, using the following criteria to select species for our purposes:

- The species is listed or a current candidates for listing as threatened or endangered by federal agencies.
- The species is listed by ODFW as sensitive, i.e., endangered, threatened, critical, or vulnerable.
- The species is declining in the basin or region as indicated by Breeding Bird Survey (BBS) data.
- The species is endemic to the Willamette Basin.
- The species performs ecological functions quite different from those performed by other species that regularly occur in the same habitat type.

All species that met the first of these five criteria were included, except for Canada lynx (federally listed as threatened), which probably has been extirpated as a resident of the Willamette Basin. Including species that met any of the other criteria would have resulted in an impractically long list of more than 120 species.[4] The geographic range of several of the

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[4] State-listed wildlife species of the Willamette Basin that were not designated as focal species are: *endangered*: peregrine falcon; *threatened*: wolverine; *critical*: fisher, black-backed woodpecker, northern goshawk, common nighthawk, northern pygmy-owl, yellow-breasted chat, painted turtle; *vulnerable*: western toad, Cascade torrent salamander, southern torrent salamander, foothill yellow-legged frog, pallid bat, fringed myotis. These species were excluded because of low fidelity to any of the focal habitats, likely extirpation, narrow geographic range within the Willamette Basin, or because other sensitive species

focal species does not encompass the entire Willamette Basin, and this should be considered when using these species to monitor focal habitats. In addition, the focal species in this plan should not be considered to be the only ones deserving heightened concern and attention.

A few of this plan's focal species did not meet any of these criteria but were included because of their consistent association with a particular focal habitat type and/or apparently minimal redundancy between their habitat associations and those of species already selected as focal species. To determine redundancy, Spearman rank correlations were computed among habitat scores of all species pairings (83,282 total). A flexible number of non-focal species that had a large negative correlation with the species already selected as focal -- indicating their habitat needs might be unmet by managing only for the focal species -- were added to the list of focal species. This was done iteratively. Additions were made based partly on our experience with the species, rather than by establishing a finite, rigid threshold based on statistical significance, e.g., as one might do in an attempt to optimize mechanically the suite of final suite of focal species. We compared the ability of the final 55 focal species to represent the six focal habitat types by comparing, within each focal habitat type, the scores of our focal species for that habitat type with scores of species used by the Habitat Evaluation Procedures (HEP; USFWS 1981) to represent that habitat type or the closest similar type. In all instances we found the habitat suitability means for our chosen focal species were higher than those of the HEP species. This suggests our focal species may be more tightly associated than the HEP species with the six focal habitat types.

Species were added in this manner mostly where a focal habitat hosts relatively few legally listed species. No attempt was made to mathematically optimize the suite of focal species selected to represent a particular focal habitat type.

Appendix D presents a list of some of the more important indicators of ecological condition for each focal habitat type. These are suggested partly because the focal species alone are not intended to represent the full spectrum of important successional stages, geomorphic conditions, and structural elements contained within each focal habitat type.

Although the focal species have been grouped according to the focal habitats in which they are most likely to occur, focal species are not necessarily the same as "indicator species" or "umbrella species." Among the species identified as focal in this plan, there is considerable variation in the strength of their association with the focal habitat under which they are listed and with their association with non-focal species. Most of these focal species use multiple habitat types, and the other habitats they use may or may be considered to be focal. Thus, any use of species surveys to monitor status and trends in the condition of focal habitats should not be limited just to species categorized as focal by this plan. The focal species concept is used mainly to ensure that evaluation and management of focal habitat types includes consideration of the needs of some of the rarest and most dependent species that use that type. Of course, by addressing only a limited list of focal species, one potentially overlooks the needs of many other species. Although this is unavoidable, an analytical approach used in this effort provided an estimate of the degree to which protecting only the selected focal species might "sweep" the habitat needs of the non-focal species (see Appendix D).

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associated with the focal habitat are mostly sufficient to address needs of the excluded species. ODFW is currently updating its listing of sensitive species. The presence of state-listed wildlife species in a particular area is a legal concern mainly if the area is a state-owned forest or other forest subject to the Oregon Forest Practices Act.

Table 3-24: Comparison of Focal Habitats in This Plan with Habitats Identified by Selected Previous Plans and Assessments That Address Wildlife in the Willamette Basin

Proposed by:	**The Nature Conservancy**	**ODFW**	**Oregon-Washington Partners In Flight**	**Defenders of Wildlife**	**ODFW & USFWS**
Source:	*Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment* (Floberg et al. 2004)	*Willamette River Basin Operational Plan* (draft chapter in the Oregon Plan and ODFW's Vision 2006 Strategic Plan)	*Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000)	*Restoring Rare Native Habitats in the Willamette Valley* (Campbell 2004)	Application of Habitat Evaluation Procedures (HEP) to Willamette Basin projects
Oak Woodlands	Oak woodlands	Oak woodland	Oak woodlands	Oak Woodlands	Oak savanna
Upland Prairie and Savanna	Upland prairies & savanna	Grassland; Rocky habitats	Grassland- savanna	Prairies and grasslands	Grass-forb; Oak savanna
Wetland Prairie and Seasonal Marsh	Wetland prairies; Vernal pools; Freshwater marshes	Wetland; Grassland	N/A	Prairies and grasslands; Wetlands	Herbaceous wetland; Grass-forb
Perennial Ponds, Sloughs, and Their Riparian Areas	Freshwater marshes; Freshwater aquatic beds	Wetland; Aquatic	N/A	Wetlands	Reservoir
Stream Riparian	Riparian forests & shrublands; Autumnal freshwater mudflats; Depressional wetland shrublands & broadleaf forests	Riparian	Riparian	Riparian forests	River Riparian hardwood; Red alder
Old-Growth Conifer Forest	Douglas fir—western hemlock—western redcedar forests	Conifer	N/A	N/A	Conifer forest

Table 3-25: Terrestrial Focal Species Selected for This Plan

- Acorn Woodpecker
- American (Pine) Marten
- American Beaver
- American Dipper
- American Kestrel
- Bald Eagle
- Black-tailed Jackrabbit
- Bradshaw's Lomatium (*Lomatium bradshawii*)
- Cascades Frog
- Chipping Sparrow
- Coastal Tailed Frog
- Common Yellowthroat
- Dunlin
- Fender's Blue Butterfly
- Golden Paintbrush (*Castilleja levisecta*)
- Great Gray Owl
- Green Heron
- Harlequin Duck
- Horned Lark (*strigata* subspecies)
- Kincaid's Lupine (*Lupinus sulphureus* var. *kincaidii*
- Marbled Murrelet
- Nelson's Checkermallow (*Sidalcea nelsoniana*)
- Northern Harrier
- Olive-sided Flycatcher
- Oregon Slender Salamander
- Peacock Larkspur (*Delphinium pavonaceum*)
- Pileated Woodpecker
- Purple Martin
- Red Tree Vole
- Red-eyed Vireo
- Red-legged Frog
- River Otter
- Sharptail Snake
- Sora
- Southern Alligator Lizard
- Spotted Owl
- Taylor's Checkerspot Butterfly
- Townsend's (Pacific Western) Big-eared Bat
- Vaux's Swift
- Vesper Sparrow (*affinis* subspecies)
- Water Howellia (*Howellia aquatilis*)
- Western Bluebird
- Western Gray Squirrel
- Western Meadowlark
- Western Pond Turtle
- Western Rattlesnake
- Western Wood-Pewee
- White Rock Larkspur (*Delphinium nuttallii* ssp. *ochroleucum*)
- White-breasted Nuthatch
- White-topped (Curtus's) Aster (*Aster curtus* = *Sericocarpus rigidus*)
- Willamette Valley Daisy (*Erigeron decumbens* var. *decumbens*)
- Willow Flycatcher
- Wood Duck
- Yellow Warbler

Table 3-26: Comparison of Focal Species with Species Identified as "Indicators" or "Focal Species" by Previous Wildlife Plans and Assessments in the Willamette Basin, Grouped by the Most Similar Focal Habitat Type

Sponsor:	**WRI/ NPCC**	**OWEB—ONHP**	**PIF**	**ODFW**	**ODFW & USFWS**
Source:	This plan	"Key species for land acquisition priorities" (Wiley, 2004)	*Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington*	*Willamette River Basin Operational Plan* (draft chapter in the *Oregon Plan* and ODFW's Vision 2006 Strategic Plan)	Application of Habitat Evaluation Procedures (HEP) to Willamette Basin projects
Oak Woodlands	Acorn woodpecker Chipping sparrow W. Wood-pewee White-breasted nuthatch Southern alligator lizard Sharptail snake W. gray squirrel	Acorn woodpecker Chipping sparrow W. Wood-pewee White-breasted nuthatch Sharptail snake W. gray squirrel Bullock's oriole	Acorn woodpecker Bewick's wren Bushtit Chipping sparrow W. Wood-pewee White-breasted nuthatch	Acorn woodpecker Band-tailed pigeon White-breasted nuthatch	Elk Black-tailed deer Black bear Cougar Ruffed grouse Yellow warbler Pileated woodpecker Red fox Western gray squirrel Ring-necked pheasant California quail Wood duck
Upland Prairie-Savanna and Rock Outcrops	American kestrel Horned lark Vesper sparrow Western meadowlark Western rattlesnake Black-tailed jackrabbit Taylor's checkerspot Fender's blue butterfly Kincaid's lupine Golden paintbrush White rock larkspur White-topped aster	American kestrel Bullock's oriole Grasshopper sparrow Horned lark Northern harrier Vesper sparrow Western meadowlark Taylor's checkerspot Fender's blue butterfly	American kestrel Grasshopper sparrow Horned lark Northern harrier Vesper sparrow Western meadowlark	Horned lark Vesper sparrow Western bluebird Western meadowlark Western rattlesnake	Elk Black-tailed deer Red fox Western gray squirrel Ring-necked pheasant California quail Wood duck

Table 3-26: Comparison of Focal Species with Species Identified as "Indicators" or "Focal Species" by Previous Wildlife Plans and Assessments in the Willamette Basin, Grouped by the Most Similar Focal Habitat Type

Sponsor:	WRI/ NPCC	OWEB—ONHP	PIF	ODFW	ODFW & USFWS
Wetland Prairie and Seasonal Marsh	Dunlin Common yellowthroat Northern harrier Sora Red-legged frog Water howellia Bradshaw's lomatium Nelson's checkermallow Willamette Valley daisy Peacock larkspur	Dunlin Short-eared owl	N/A	Dunlin Painted turtle Pond turtle Red-legged frog Wood duck	Roosevelt elk Black-tailed deer Black bear Cougar Ruffed grouse Red fox Ring-necked pheasant California quail Common merganser
Perennial Ponds, Sloughs, and Their Riparian Areas	Western pond turtle Oregon spotted frog Cascades frog Purple martin Green heron Wood duck Yellow warbler	Western pond turtle Painted turtle Red-legged frog Purple martin American bittern Hooded merganser Wood duck	Purple martin Yellow warbler	Western pond turtle Painted turtle Red-legged frog Yellow warbler	River otter American beaver Common merganser Mink Wood duck
Stream Riparian	American dipper Bald eagle Harlequin duck Red-eyed vireo Willow flycatcher Coastal tailed frog American beaver River otter	Foothill yellow-legged frog Yellow warbler	Downy woodpecker Red-eyed vireo Swainson's thrush Willow flycatcher	Bald eagle Great blue heron American beaver	American Beaver American Dipper Black Bear Black-tailed Deer California Quail Common Merganser Cougar Elk Harlequin Duck Mink Pileated Woodpecker Red Fox Ring-necked Pheasant River Otter Ruffed Grouse Western Gray Squirrel Wood Duck Yellow Warbler

Table 3-26: Comparison of Focal Species with Species Identified as "Indicators" or "Focal Species" by Previous Wildlife Plans and Assessments in the Willamette Basin, Grouped by the Most Similar Focal Habitat Type

Sponsor:	**WRI/ NPCC**	**OWEB—ONHP**	**PIF**	**ODFW**	**ODFW & USFWS**
Source:	This plan	"Key species for land acquisition priorities" (J. Kagan, pers. comm..)	*Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington*	*Willamette River Basin Operational Plan* (draft chapter in the *Oregon Plan* and ODFW's Vision 2006 Strategic Plan)	Application of Habitat Evaluation Procedures (HEP) to Willamette Basin projects
Old-growth conifer forest	Pileated woodpecker Olive-sided flycatcher Vaux's swift Marbled murrelet Spotted owl Great gray owl Oregon slender salamander American marten Red tree vole Townsend's big-eared bat	Townsend's big-eared bat	Brown creeper Red crossbill Vaux's swift	Elk Black-tailed Deer	Elk Black-tailed Deer Black Bear Cougar Ruffed Grouse Yellow Warbler Pileated Woodpecker Spotted Owl

N/A = Not applicable to the intended scope of that plan.

3.2.4 Aquatic Focal Species Population Delineation and Characterization

This section begins by characterizing the population status, trends, and key life history characteristics for five focal fish species in the Willamette Basin: Chinook salmon, winter steelhead, cutthroat trout, bull trout, and Oregon chub. Pacific lamprey also is discussed, briefly, because it is an important species culturally and one that is believed to have significantly declining trends. However, the absence of life history and distribution data on Pacific lamprey limits an adequate species characterization within the Willamette Basin.

The section concludes with a discussion of artificial production.

3.2.4.1 Chinook Life History, Population Status, and Trends

The Willamette River Basin historically provided important spawning and rearing grounds for large numbers of spring Chinook salmon of the Columbia River basin. Mattson (1948) estimated that the spring Chinook salmon run in the 1920s may have been five times the 55,000 fish counted in 1947. From 1946 to 1951, annual spring Chinook runs—including the mainstem Willamette River sport catch, escapement above Willamette Falls, and escapement to the Clackamas River—ranged from 25,100 to 96,800 fish (Mattson, 1963). Mean annual run size for this same period averaged 55,600, which was more than half the run size that passed Bonneville Dam in 1948: 97,543 fish (Fish Commission, 1948). In 2003 and 2004, more than 100,000 adult spring Chinook have crossed Willamette Falls each year. The average run size in the last 50 years has been around 40,000, with peaks as low as 11,000. A large fraction of fish passing the falls are of hatchery origin. The largest run on record was 156,033 adults in 1953 (Oregon Department of Fish and Wildlife 2000b).

Historically there were seven demographically independent populations of spring Chinook salmon in the Upper Willamette River spring Chinook salmon ESU: Clackamas, Molalla/Pudding, Calapooia, North Santiam, South Santiam, McKenzie, and Middle Fork Willamette—all eastside tributaries (Meyers et al., 2003). Today, four core populations survive in the Clackamas, North Santiam, McKenzie and Middle Fork Willamette subbasins, which historically sustained large populations and may have the intrinsic capacity to sustain large populations into the future (McElhany et al., 2003). In addition to these core populations, the McKenzie subbasin population represents an important element of the genetic legacy of the Upper Willamette ESU. The McKenzie spring Chinook salmon population has been the least influenced by intra- or interbasin transfers of hatchery stocks and probably has retained a relatively high degree of adaptation to local watershed conditions. It is thought that the Molalla and Calapooia spring Chinook salmon populations have been extirpated, or nearly so (U.S. Army Corps of Engineers, 2002).

Life History Patterns and Diversity

Adult Migration and Spawning. Before the Willamette Falls fish ladder was constructed, passage by returning adult spring Chinook salmon was possible only during the winter and spring high flow periods. As early as 1903, state fish biologists noted that Willamette River salmon are an early-run fish that entered the Columbia River system early in the season to navigate above Willamette Falls and get up into remote areas of the upper basin (Oregon Department of Fisheries, 1905). The early run timing of the Upper Willamette population relative to other Lower Columbia River populations is viewed as an adaptation to flow conditions and optimal passage at Willamette Falls (Myers et al., 2003). This adaptation to run timing during optimal flow conditions at the falls has led to significant local genetic adaptation relative to other Columbia River spring Chinook salmon (Myers et al., 2003).

Spring Chinook salmon begin to appear at in the Lower Willamette and at the base of the falls (RM 26) falls in February. The majority of the run ascends the falls in April and May and completes its migration back to natal spawning grounds through July. Passage over Willamette Falls was believed to be related to flow and temperature; passage increased when the river levels dropped and water temperatures exceeded 53.0 degrees F (Oregon Department of Fish and Wildlife, 1990). Although a large portion of the spring run passed and occupied the area above Willamette Falls, historical records show that an early run entered the Clackamas River in March, prior to the Upper Willamette fish run.

Adult spring Chinook sampled from 1946 through 1951 were mostly 4- and 5-year-old adults; 4 percent were 3-year-old fish, 24 percent were 4-year-old fish, 61 percent were 5-year-old fish, and 10 percent were 6-year-old fish (Mattson, 1963). Scales taken from adults showed that older adults experienced longer juvenile freshwater rearing (either in their natal stream or in the lower Willamette River) than younger adult returns. The number of yearling migrants increased proportionally with the age of adult return, and fry and fingerling emigrants made up a higher proportion of 3-year-old adults (Mattson, 1963).

Rich and Holmes (1929) observed that “5-year-old adults predominated, 6-year-old salmon returned in larger numbers than 4’s, and only a few 3-year-olds were recovered.” Rich and Holmes’ observations a quarter century earlier were consistent with Mattson’s observations that 5-year-old adults predominated; however, a key distinction was that 6-year-old fish returned in greater numbers than did 4-year-old fish. One hypothesis is that summer-run Chinook may have populated tributaries of the lower Willamette River. Fisherman of the lower Willamette claimed that (prior to 1927) a run of large salmon passed through the lower river each June. However, this summer run may have also been the later part of the spring run; these fish averaged 25 to 30 pounds and were believed to be mostly 6-year-old fish.

Regardless, the last sizeable run of June migrants passed Willamette Falls in 1934, which notably coincided with the loss of the Clackamas River fall run (Mattson, 1963). The disappearance of the June spring Chinook salmon run in the 1920s and 1930s was associated with the dramatic decline of water quality in the Willamette River during this period (Myers et al., 2003). A number of destructive activities in the 1880s and 1890s, along with poor water quality conditions in the lower Willamette River (for example, low dissolved oxygen), particularly during adult migrations, are believed to have significantly affected these native Chinook populations.

As a result of the fish ladder at Willamette Falls, the current run of spring Chinook salmon over the falls extends into July and August, which overlaps with the introduced fall run of Chinook salmon.

The earliest recorded observation of spring Chinook salmon spawning occurred at the North Fork Santiam hatchery rack (RM 65 at a site that is currently under Detroit Reservoir) on August 22, 1947 (Mattson, 1948). Spring Chinook salmon spawned near the rack in mid-August and continued spawning as late as the third week in October.

The timing of the run in the McKenzie River is monitored at Leaburg Dam, where passage usually peaks in June (Howell et al., 1988). A smaller pulse moves above the dam during the September spawning period. The period of peak passage appears to depend on temperature, occurring as early as the second half of May in warmer water years and as late as the first part of July in cooler years. Homolka and Downey (1995) calculated that spring Chinook salmon upstream of Leaburg Dam spawned from very late August until mid-October in 1992, with the peak centered on September 23. In comparison, from 1902 through 1907, hatchery operations on the McKenzie began egg takes in early- to mid-August, and peak egg collections generally occurred during the second week of September (Howell et al., 1988). The McKenzie River spawn timing observed in 1992 was a considerable shift from the historical pattern (Homolka and Downey 1995). In comparison to historical patterns, the current duration of the spawning period appears to have decreased by two-thirds or more from 1919 through 1985 (Lichatowich, 2000).

Above Willamette Falls, native spring Chinook declined in abundance and distribution after the construction of the Willamette Valley dams. In the 1940s, state biologists surveyed the middle and upper basin and estimated that nearly 48 percent of the spring Chinook spawning habitat would be lost with construction of the dams in the McKenzie, Santiam, and Middle Fork Willamette rivers (Fish Commission of Oregon, 1948). Notably, only 400 miles of spawning and rearing habitat remain today (Oregon Department of Fish and Wildlife, 2000a).

Changes in water temperature regimes from the dams have affected Upper Willamette spring Chinook spawn timing. Ingram and Korn (1969) reported that the timing of adult Chinook salmon reaching the Cougar Dam trap and haul facility changed after the project was completed (1964). About 60 percent of the run passed upstream in June during the 4 years before impoundment, but almost all passed upstream after June in 1964, 1965, and 1966. Mattson (1962) noted that, as a result of the thermal effects of Lookout Point and Dexter dams, spawning below Dexter was delayed until early October and lasted through November. Surveys above and below Fall Creek Dam in 1969 showed that spawning started in early- to mid-September and was completed by mid-October (Oregon Department of Fish and Wildlife, 1990). However, because naturally produced fish now make up a minute portion of the Middle Fork Willamette Subbasin population, little is known about the time of entry or spawning of the wild stock.

Adult Productivity and Abundance. The productivity and abundance of adult spring Chinook in subbasins throughout the Willamette Basin are described below. This is followed by information on distribution—again, organized by subbasin.

Calapooia Subbasin. A small run of spring Chinook salmon historically existed in the Calapooia River. Parkhurst et al. (1950) reported that the run size in 1941 was approximately 200 adults, while Mattson (1948) estimated the run at 30 adults in 1947.

A 2002 survey of 11.1 miles of stream in the Calapooia above Brownsville found 16 redds (Schroeder et al., 2002). The carcasses recovered in the Calapooia in 2002 were too decomposed to determine the presence or absence of fin clips. However, it was assumed that all the fish were surplus hatchery fish outplanted from the South Santiam hatchery (Schroeder et al., 2002). The Calapooia natural spring Chinook population is believed to be extirpated (Nicholas, 1995).

Hatchery releases to the Calapooia River from 1981 to 2002 are shown in Table 3-27.

Table 3-27: Hatchery Releases to the Calapooia, 1981-2002

Calapooia River Spring-Run DIP—Spring-Run Releases				Total Releases	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Calapooia	1981-1985	2	Santiam R.	46,188	
	1982-1985	4	Willamette R.	500,522	
	1991-1996	6	Dexter Ponds	3,698,362	
	1993-1997	4	McKenzie	2,596,851	
	1996	1	Bonneville (So. Santiam)	960,660	
			Total	7,802,583	**0**

Source: Northwest Fisheries Science Center, 2003.

Clackamas River Subbasin. The Clackamas River historically contained a spring run of Chinook salmon, but relatively little information about that native run exists. Barin (1886) observed a run of Chinook salmon that "commences in March or April, sometimes even in February." The construction of the Cazadero Dam in 1904 (River Kilometer [RKm] 43) and River Mill Dam in 1911 (RKm 37) limited migratory access to the majority of the historical spawning habitat for the spring run. In 1917, the fish ladder at Cazadero Dam was destroyed by floodwaters, eliminating fish passage to the upper basin (Oregon Department of Fish and Wildlife, 1992). Hatchery production of spring-run Chinook salmon in the basin continued using broodstock captured at the Cazadero and River Mill dams (Willis et al., 1995).

Transfers of upper Willamette River hatchery stocks (primarily from the McKenzie River Hatchery) began in 1913, and between 1913 and 1959 more than 21.3 million eggs were transferred to the Clackamas River Basin (Wallis, 1961, 1962, and 1963). Furthermore, a large proportion of the transfers occurred during the late 1920s and early 1930s to supplement the failure of the runs in the Clackamas River Basin at that time (Leach, 1932). In 1942, spring-run Chinook salmon propagation programs in the Clackamas River Basin were discontinued.

The recolonization of the upper Clackamas River progressed very slowly, with the average annual dam count (River Mill or North Fork Dam) from 1952 to 1959 being 461 (Murtagh et al., 1992). More importantly, 30 percent of the adult passage counts occurred in September and October. Artificial propagation activities were restarted in 1956 using eggs from a number of upper Willamette River hatchery stocks. The program released approximately 600,000 smolts annually through 1985. In 1976, the ODFW Clackamas Hatchery (located below River Mill Dam) began releasing spring-run Chinook salmon; Willamette River hatchery broodstocks were used because it was believed that the returns from the local population were too small to meet the needs of the hatchery (Murtagh et al., 1992)). Increases in adult returns over the North Fork Dam and increases in redd counts above the North Fork Reservoir corresponded to the initial return of adults to the hatchery in 1980 (Oregon Department of Fish and Wildlife, 1992; Willis et al., 1995). Adult counts over North Fork Dam rose from 592 in 1979 to 2,122 in 1980 (Murtagh et al., 1992). Recent changes in management policy by ODFW include releasing hatchery fish farther downstream and mass marking all hatchery releases to allow the removal of hatchery fish ascending the North Fork Dam.

Genetic analysis by NOAA Fisheries of naturally produced fish from the upper Clackamas River indicated that this stock was similar to hatchery stocks from the upper Willamette Basin (Myers et al., 1998). This finding agrees with an earlier comparison of naturally produced fish from the Collawash River (a tributary to the upper Clackamas River) and upper Willamette River hatchery stocks (Schreck et al., 1986). Fish introduced from the upper Willamette River have significantly introgressed into, if not overwhelmed, spring-run fish native to the Clackamas River Basin and obscured any genetic differences that existed prior to hatchery transfers.

The time series of abundance for Upper Willamette spring Chinook in the Clackamas River is shown in Figure 3-22. The total count is all fish passing above the dam. There is only one estimate (in 2002) of the number of fish passing above the dam that are of natural origin.

Hatchery releases of spring Chinook to the Clackamas from 1975 to 2002 are shown in Table 3-28.

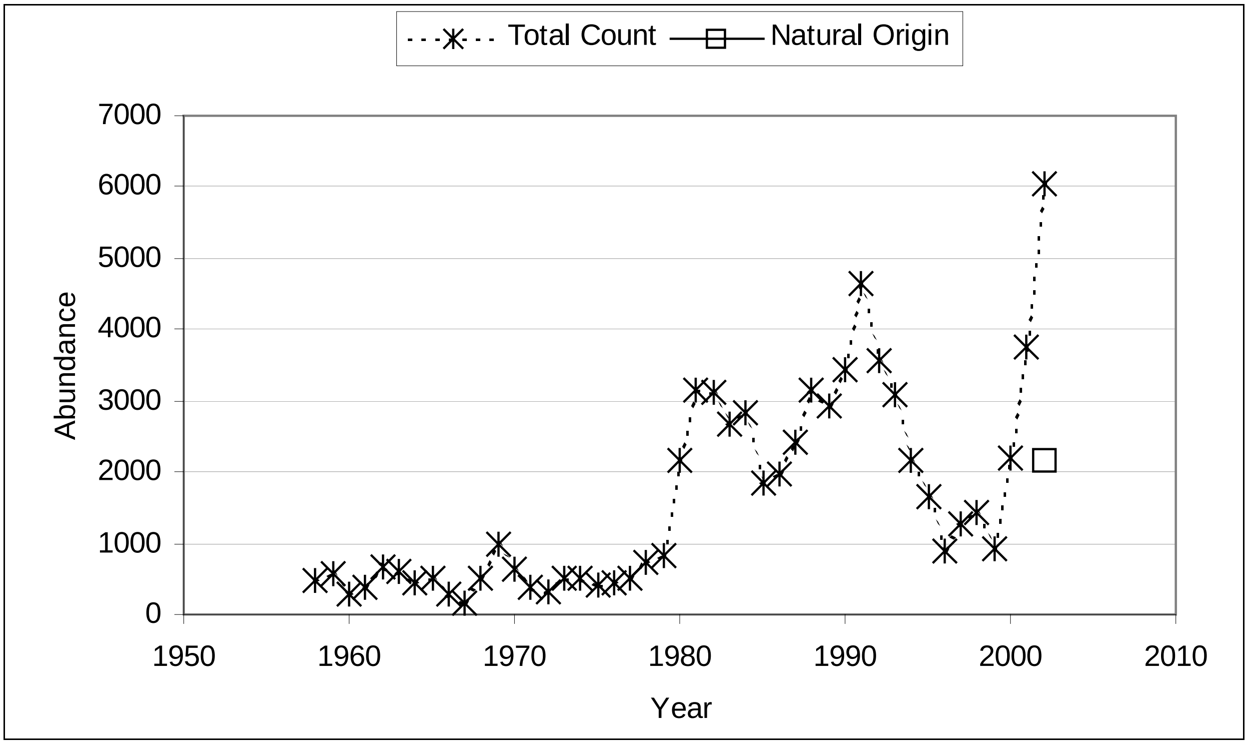

Figure 3-22: Time Series of Abundance for Upper Willamette Spring Chinook in the Clackamas River

Source: Northwest Fisheries Science Center, 2003.

Table 3-28: Hatchery Releases in the Clackamas River, 1975-2002

Clackamas River Spring-Run DIP				Total Releases	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Clackamas River	1975	1	Carson NFH	289,710	
	1977,78	**2**	**Cascade H.**		**195,203**
	1985,92	2	Clackamas R.	232,947	
	1978-2002	14	Clackamas R. (early)	24,123,672	
	1979	1	Clackamas R. (late)	98,461	
	1975-87	5	Eagle Cr. NFH	1,294,822	
	1978	1	Marion Forks H.	188,261	
	1979-88	4	Santiam R.	1,653,231	
	1996-2001	6	McKenzie H.	959,127	
	1939-89	30	Unknown	25,649,266	
	1982-89	6	Willamette H.	4,319,098	
	1992-2002	11	STEP (Clackamas H.)	1,063,775	
			Total	59,872,370	**195,203**

Source: Northwest Fisheries Science Center, 2003.

McKenzie Subbasin. Spring-run Chinook salmon are native to the McKenzie River Basin. Historical natural spawning areas included the mainstem McKenzie River, Smith River, Lost Creek, Horse Creek, South Fork, Blue River, and Gate Creek (Mattson, 1948; Parkhurst et al., 1950).

Currently, the McKenzie Subbasin supports the largest existing population of Upper Willamette River spring Chinook salmon. Downstream of Leaburg Dam, most spring Chinook spawners are hatchery-produced (U.S. Army Corps of Engineers, 2000). Spring Chinook salmon escapement to Leaburg Dam has varied over the last 30 or more years, with the 1988 through 1991 runs the strongest recorded (see Table 3-30). However, until 2001, it was difficult to distinguish naturally produced spawners from hatchery-origin fish, so these data may not represent the status of the wild population over time. Lindsay (2003) reported that in 2002, 55 percent of the spring Chinook salmon carcasses in the South Fork McKenzie below Cougar Dam and in the mainstem McKenzie between Leaburg Dam and the Carmen-Smith spawning channel were wild fish.

The time series abundance of spring Chinook at Leaburg Dam in the Mackenzie River is shown in Figure 3-23. Hatchery releases are shown in Table 3-29.

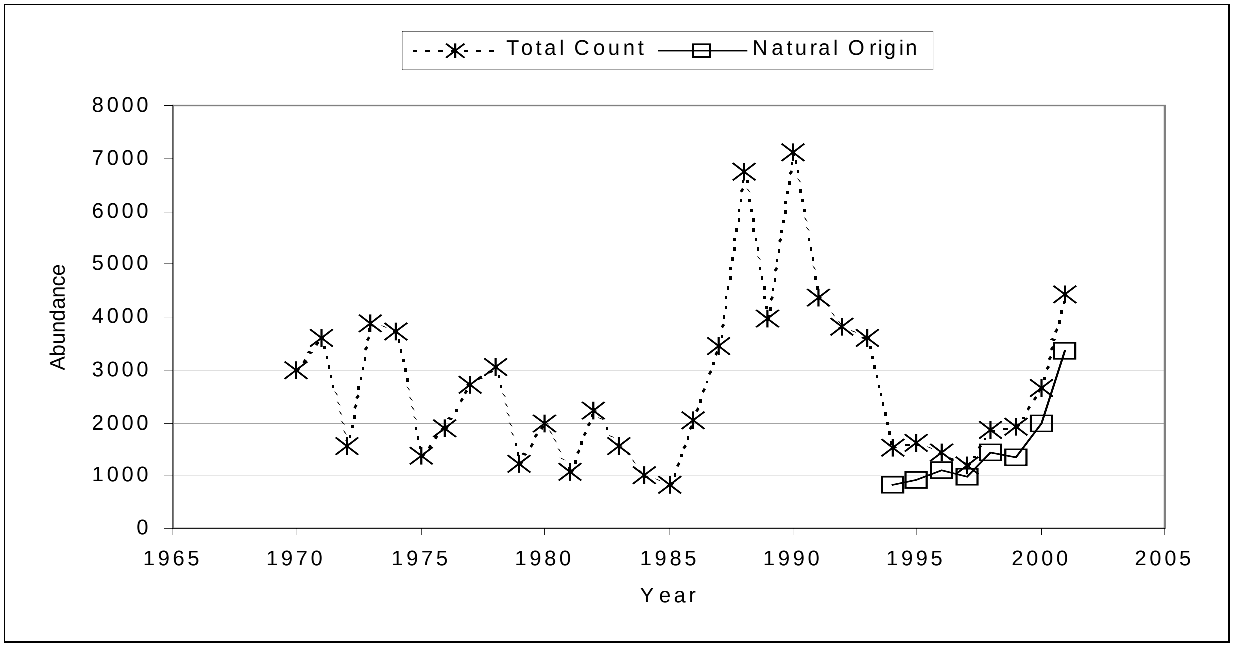

Figure 3-23: Time Series of Abundance of Spring Chinook at Leaburg Dam in the Mackenzie River

Source: Northwest Fisheries Science Center, 2003.

Table 3-29: Hatchery Releases in the McKenzie, 1902-2002

McKenzie River Spring-Run DIP—Spring-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
McKenzie Basin	1952, 1966	2	Marion Forks (N. Santiam)	1,176,345	
	1902-1969	62	McKenzie H.	192,671,426	
	1978-2002	25	McKenzie H.	24,250,965	
	1951-1965	4	McKenzie/Willamette H.	1,309,620	
	1932-1994	4	Santiam H.	288,820	
	1918-1977	17	Unknown	4,144,703	
	1966-1984	4	Willamette H.	1,318,574	
	1969-1975	**7**	**Hagerman NFH**		**1,424,563**
Blue River	1991-1994	4	McKenzie H.	672,707	
Mohawk River	1997-2002	6	McKenzie H.	164,169	
	1998	1	Willamette H.	14,625	
			Total	226,011,954	**1,424,563**
North Santiam River Spring-Run DIP—Fall-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Santiam Basin	**1966**	**1**	**Big Creek**		**1,000,848**
	1921-1951	**2**	**Bonneville/Oxbow H.**		**1,669,444**
	1966	**1**	**Cascade H.**		**350,000**
	1956-1957	**2**	**Klickitat H.**		**175,974**
	1958-1966	**2**	**Oxbow H.**		**599,911**
	1964-1976	**11**	**Unknown**		**54,032,611**
			Total		**57,828,788**

Source: Northwest Fisheries Science Center, 2003.

Table 3-30 shows the estimated return of spring Chinook salmon to the McKenzie River and Leaburg Dam.

Table 3-30: Estimated Return of Spring Chinook Salmon to the McKenzie River and Leaburg Dam

Run Year	Total Escapement to McKenzie River	Escapement to Leaburg Dam	Percentage (No.) of Naturally Produced Fish in Leaburg Dam Escapement
1970	4,787	2,991	N/A
1971	6,323	3,602	
1972	3,770	1,547	
1973	7,938	3,870	
1974	7,840	3,717	
1975	3,392	1,374	
1976	4,275	1,899	
1977	9,127	2,714	
1978	8,142	3,058	
1979	3,018	1,219	
1980	4,154	1,980	N/A
1981	3,624	1,078	
1982	5,413	2,241	
1983	3,377	1,561	
1984	4,739	1,000	
1985	4,930	825	
1986	5,567	2,061	
1987	7,370	3,455	
1988	12,637	6,753	
1989	10,020	3,976	
1990	12,743	7,115	
1991	11,553	4,359	
1992	8,976	3,816	
1993	8,148	3,617	
1994	2,992	1,526	54% (825)
1995	3,162	1,622	57% (933)
1996	3,640	1,445	76% (1,105)
1997	3,110	1,176	84% (991)
1998	3,997	1,874	77% (1,415)
1999	4,557	1,909	72% (1,383)
2000	6,804	2,657	75% (1,985)
2001	9,548[1]	4,428	76% (3,380)
2002	4,470[2]		

[1] Includes an estimated 750 fish harvested below Leaburg Dam.

[2] Based on counts at Leaburg Dam, counts of naturally spawned carcasses, and the number of unmarked fish taken for broodstock at Leaburg hatchery.

Source: Oregon Department of Fish and Wildlife, 2001.

Middle Fork Willamette Subbasin. Historically, the Middle Fork Willamette River spring Chinook salmon run may have been the largest in the Upper Willamette Basin (Hutchison, 1966; Thompson et al. 1966). Based on egg collections at the Willamette River Hatchery (Dexter Ponds, 1909 to the present), the largest egg collection, which was 11.3 million in 1918 (Wallis, 1962), would correspond to 3,559 females (3,200 eggs per female). This leads to an estimated minimum run size of approximately 7,100 adult spring Chinook for the area that is now above Lookout Point Dam (U.S. Army Corps of Engineers, 2002). This estimate does not include fish that spawned downstream of the hatchery rack (such as in the mainstem Middle Fork Willamette River below Dexter and in the Fall Creek watershed). Mattson (1948) estimated a run size of 2,550 naturally produced spring Chinook to the Middle Fork Willamette River in 1947. USFWS (1962) reported that approximately 450 spring Chinook salmon spawned above the site of Fall Creek Dams in the years immediately before construction (the project was completed in 1966).

Currently, the naturally spawning population of spring Chinook salmon in the Middle Fork Willamette Subbasin is very small and probably is made up mostly of the progeny of hatchery fish that were released to spawn in the wild. There is no estimate of the population growth rate or productivity for naturally spawning spring Chinook salmon in the Middle Fork Willamette subbasin. Lindsay (2003) reported that 4 percent of the spring Chinook salmon carcasses collected between Jasper and Dexter and in Fall Creek below the dam were wild fish.

From 1953 through 1966 (after the construction of Dexter and Lookout Point dams blocked access to the historical spawning grounds), an average of 3,502 Chinook salmon were caught in the trap at the base of Dexter Dam (U.S. Army Corps of Engineers, 2000). These total counts probably included some hatchery-origin fish. Thompson et al. (1966) estimated a total population of 6,100 naturally and artificially produced adults in the Middle Fork Willamette Subbasin in the mid-1960s.

For the 1,150 spring Chinook salmon released above Fall Creek Reservoir during 2002, biologists observed only 121 redds below the natural falls (Ziller, 2002). The high ratio of fish to redds indicates a high level of prespawning mortality, probably as a result of handling in the trap and haul system. In the North Fork Middle Fork River, Ziller (2002) estimated 162 redds over 35 miles of habitat. The ratio of 3,700 spawners to 162 redds also indicates a high level of prespawning mortality as a result of handling in the trap and haul system. Firman et al. (2002) estimated a natural-origin run of spring Chinook salmon to the Middle Fork Willamette subbasin of 987 fish in 2002, based on counts of naturally spawned carcasses and the number of unmarked fish taken for hatchery broodstock at Dexter Dam.

It appears that the Middle Fork Willamette Subbasin does not currently support a self-sustaining population of naturally produced spring Chinook salmon. A small amount of natural production probably does occur from spawning both above and below the dams but is based on ODFW's releases of hatchery-origin adults into the upper Middle Fork above Hills Creek Reservoir since 1992 and into the North Fork of the Middle Fork above Lookout Point Reservoir since 1999. Natural spawning occurs in the mainstem Middle Fork Willamette below Dexter Dam, although ODFW investigations indicated that warm water temperatures cause eggs to succumb to fungus infections, and those eggs that do survive produce juveniles that emerge early (Ziller et al., 2002).

Hatchery releases in the Middle Fork Willamette are shown in Table 3-31.

Table 3-31: Hatchery Releases in the Middle Fork Willamette, 1902-2002

Middle Fork Willamette River Spring-Run DIP—Spring-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
M Fk Willamette R.	1983,1990	2	Marion Forks (N. Santiam)	290,174	
	1979-2001	12	McKenzie H.	2,677,904	
	1928,1952	2	McKenzie H./Willamette H.	1,038,153	
	1978-1995	8	Santiam R.	3,551,626	
	1952-1966	6	Santiam H./Willamette H.	6,984,701	
	1950-1977	9	Unknown	17,681,493	
	1921-1999	64	Willamette H.	25,606,747	
	1995-2002	7	Dexter Pond	10,913,014	
	1992-2000	5	STEP	690,551	
	1993	1	Eagle Creek NFH	63,521	
	1974	**1**	**Hagerman NFH**		**41,379**
	1958	**1**	**Nehalem R./Willamette H.**		**19,962**
	1958	**1**	**Wenatchee/Willamette H.**		**67,827**
Row River	1997-2001	2	McKenzie Hatchery	59,070	
Fall Creek	1995-2001	5	McKenzie Hatchery	1,337,560	
	1991-1997	6	Willamette Hatchery	6,089,539	
			Total	76,984,053	**129,168**
Middle Fork Willamette River Spring-Run DIP—Fall-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
M. FK Willamette	**1953-1956**	**4**	**Bonneville H.**		**2,922,337**
	1977-1993	**16**	**Bonneville H.**		**88,960,581**
	1949	**1**	**Trask H./Bonneville H.**		**8,776**
	1970	**1**	**Hagerman NFH**		**14,560**
	1965-1985	**13**	**Willamette H.**		**34,294,598**
			Total		**57,828,788**

Source: Northwest Fisheries Science Center, 2003.

Molalla/Pudding Subbasin. Surveys in 1940 and 1941 recorded 882 and 993 spring-run Chinook salmon present, respectively (Parkhurst et al. 1950). In 1947, Mattson (1948) estimated the run size to be 500.

A 2002 survey of 16.3 miles of stream in the Molalla found 52 redds. However, 93 percent of the carcasses recovered in the Molalla in 2002 were fin-clipped and of hatchery origin

(Schroeder et al., 2002). Fin-clip recovery fractions for spring Chinook in the Willamette tend to underestimate the proportion of hatchery-origin spawners, so the true fraction is likely in excess of 93 percent (that is, it is likely to be near 100 percent). The Molalla natural spring Chinook population is believed to be extirpated, or nearly so (U.S. Army Corps of Engineers, 2002).

Hatchery releases to the Molalla River from 1964 to 1997 are shown in Table 3-32.

Table 3-32: Hatchery Releases in the Molalla River, 1964-1999

Mollala River Spring-Run DIP—Spring-Run				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Mollala River	1991	1	Clackamas H.	469,890	
	1964-1997	8	McKenzie H.	2,892,050	
	1981-1992	3	N.F. Santiam H.	2,032,335	
	1964-1965	2	Unknown	375,209	
	1982-1999	12	Willamette H.	10,717,425	
	1991	1	Oxbow H. (Clackamas)	71,380	
Pudding River	1964	1	McKenzie H.	62,550	
	1983-1985	3	Willamette H.	453,479	
			Total	17,074,318	**0**
Mollala River Spring-Run DIP—Fall-Run				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Mollala River	**1965-1967**	**2**	**Big Creek H**		**1,397,158**
	1958	**1**	**Bonneville H./Trask H.**		**100,000**
	1978	**1**	**Cascade H.**		**2,111,600**
	1959-1960	**2**	**LCR(OR)**		**401,858**
	1967	**1**	**Oxbow H.**		**500,132**
	1964-1976	**11**	**Unknown**		**9,310,823**
	1991-1995	**5**	**Bonneville H.**		**1,533,337**
			Total		**15,354,908**

Source: Northwest Fisheries Science Center, 2003.

North Santiam Subbasin. Estimates of the historical abundance of spring Chinook salmon in the North Santiam Subbasin range from 8,250 adults in 1934—excluding fish that spawned downstream of the current site of Detroit Reservoir (in the lower mainstem North Santiam and the Little North Santiam rivers)—to 2,830 in 1947 for the subbasin as a whole (Wallis, 1963; Mattson, 1948). Based on the proportion of marked hatchery adults at return versus release, ODFW (1995) concluded that fewer than 300 naturally produced spring Chinook salmon adults returned to the subbasin in 1994.

Systematic aerial inventories of fall and spring Chinook salmon spawning within the Santiam River watershed began in 1970. During these inventories, it was difficult to distinguish between spring Chinook salmon and the introduced fall Chinook salmon redds because so much introgression of fall Chinook spawning into areas once used by spring Chinook salmon had occurred (U.S. Army Corps of Engineers, 2002). It is likely that only redds observed in the uppermost reaches (upstream of Stayton on the North Santiam River) were attributed to spring Chinook salmon. From 1991 to 1994, redd counts in the North Santiam River upstream of the confluence with the Little Santiam ranged from 80 to 112 (Willis et al., 1995).

Because hatchery fish were not consistently marked prior to 1996, NOAA Fisheries cannot estimate a population growth rate for the natural-spawning population (U.S. Army Corps of Engineers, 2002). ODFW has begun to address this problem by collecting otoliths from adults caught in the sport fishery, on the spawning grounds, and at the Minto trap facility (Oregon Department of Fish and Wildlife, 1998). Lindsay (2003) reported that, based on the otolith data, 4 percent of the spring Chinook salmon carcasses collected between the Upper and Lower Bennett dams and Minto (including the Little North Santiam River) in 2000 were wild fish, that 2 percent collected in 2001 were wild fish, and that 8 percent collected in 2002 were wild fish. Firman et al. (2002) estimated a natural-origin run of spring Chinook salmon to the North Santiam subbasin of 1,233 fish in 2002, based on passage at Upper and Lower Bennett dams, counts of naturally spawned carcasses, and the number of unmarked fish taken for hatchery broodstock at the Minto trap.

ODFW released a total of 933 hatchery-origin adults into the Breitenbush and North Santiam rivers in 2000 and 1,068 adults in 2001 to assess the potential for establishing a naturally reproducing run above the reservoir. Limited surveys shortly after release indicate that these fish spawned successfully, and snorkel surveys during the summer of 2001 confirmed the presence of naturally produced juveniles (Mamoyac and Ziller, 2001). Hatchery releases to the North Santiam from 1918-1994 and 1991-2002 are shown in Tables 3-33 and 3-34, respectively.

Spring Chinook salmon also spawn in the Little North Santiam River up to Henline Creek (Olsen et al., 1992). There appears to be declining numbers of fish in the system, with 801 counted in 1946, 273 in 1954, 236 in 1971, and 242 in 1991 (Willis et al., 1995, BLMS, 1998; U.S. Army Corps of Engineers, 2000); counts dropped below 16 per year during 1992 through 1995 (Willis et al., 1995). In the period 1998 through 2001, redd counts in the Little North Santiam varied from 11 to 39 (Lindsay et al., 1998).

The time series of abundance for Upper Willamette Spring Chinook North Santiam redds per mile is shown in Figure 3-24. The number of stream miles surveyed varies from 26.8 to 43.5, and the total redds counted in a year varies from 116 to 310. It is estimated that more than 95 percent of the spawners are of hatchery origin.

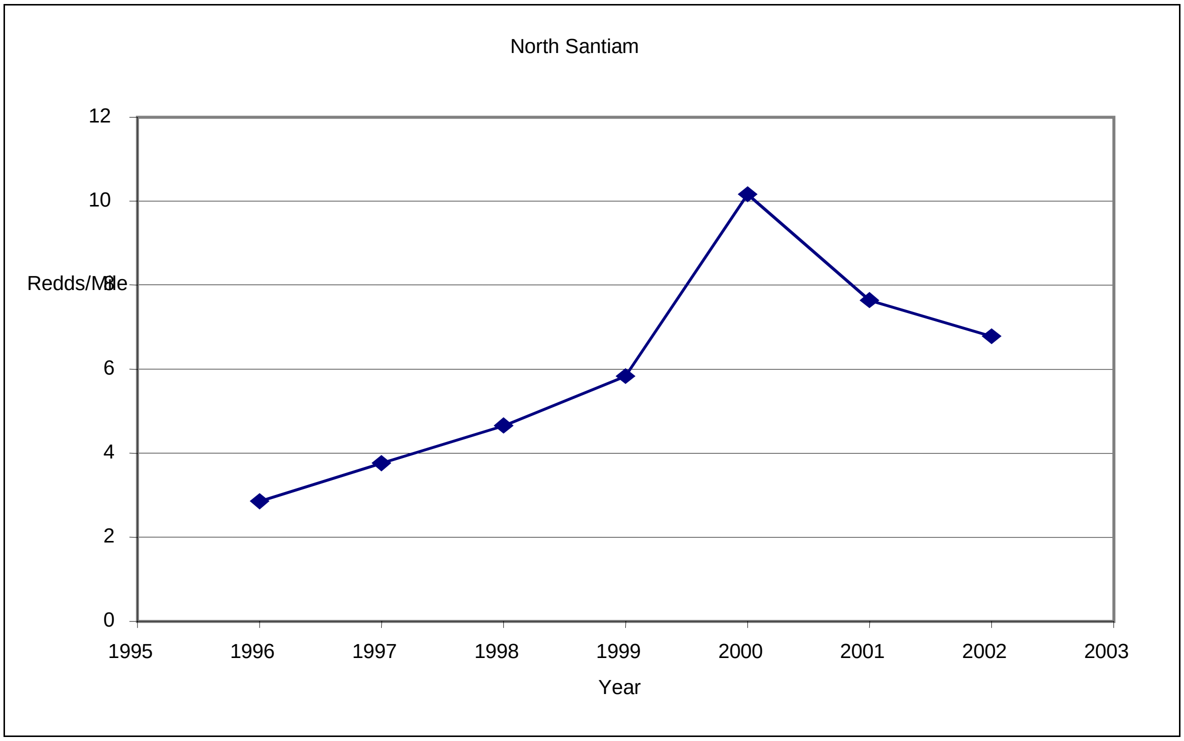

Figure 3-24: Time Series of Abundance for Upper Willamette Spring Chinook North Santiam Redds per Mile

Source: Northwest Fisheries Science Center, 2003.

Table 3-33 Hatchery Releases in the North Santiam, 1991-2002

North Santiam River Spring-Run DIP Spring-Run Releases				Total Releases	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
North Santiam River	1991-2002	12	Marion Forks	8,215,400	
	1995	1	Marion Forks (Clackamas H..)	61,976	
	1991	1	Dexter Ponds	12,423	
			Total	8,289,799	**0**

Source: Northwest Fisheries Science Center, 2003.

Table 3-34: Hatchery Releases in the North Santiam, 1918-1994

North Santiam River Spring-Run DIP—Spring-Run Releases				Total Releases	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Santiam Basin	1980-1981	2	Clackamas (early)	752,939	
	1923-1994	53	Marion Forks (N. Santiam)	87,932,370	
	1936-1937	2	Marion Forks/McKenzie	8,441,800	
	1961-1978	7	McKenzie H.	1,009,442	
	1941-1948	2	McKenzie/Santiam H.	1,63,717	
	1932-1994	46	Santiam H.	61,605,990	
	1963-1964	2	Santiam R./Willamette H	1,989,604	
	1918-1981	26	Unknown	16,976,462	
	1881-1986	6	Willamette H.	10,566,693	
	1965-1982	7	Carson NFH	0	**1,416,271**
	1967-1975	4	Hagerman NFH	0	**645,175**
	1962	1	Spring Creek NFH	0	**191,298**
			Total	189,339,018	**2,252,744**
North Santiam River Spring-Run DIP—Fall-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
Santiam Basin	**1966**	**1**	**Big Creek**		**1,000,848**
	1921-1951	**2**	**Bonneville/Oxbow H.**		**1,669,444**
	1966	**1**	**Cascade H.**		**350,000**
	1956-1957	**2**	**Klickitat H.**		**175,974**
	1958-1966	**2**	**Oxbow H.**		**599,911**
	1964-1976	**11**	**Unknown**		**54,032,611**
	1991-1995	**5**	**Bonneville H.**		**22,490,131**
			Total		**80,318,919**

Source: Northwest Fisheries Science Center, 2003.

South Santiam Subbasin. Mattson (1948) estimated an escapement of 1,300 spring Chinook salmon to the South Santiam River in 1947. USFWS (1963) reported an annual spawning run of about 1,400 above the current site of Foster Dam. About 70 percent of these were destined for the Middle Santiam River (above the current site of Green Peter Dam), 7 percent spawned in the reach that is now under Foster Reservoir, and 23 percent spawned in the South Santiam River above Foster. Thompson et al. (1966) estimated a total annual run size (natural- and hatchery-origin) of 3,700 adults during the 1960s. Estimates based on the sport catch and returns to Foster Dam indicate that the minimum total (natural-origin plus hatchery-origin) run size to the subbasin during the 1970s and 1980s varied from less than 500 to nearly 10,000 per year.

Spawning ground survey data reported in Lindsay et al. (1999) indicated a total of 163 spring Chinook salmon redds in the South Santiam below Foster Dam during September 1998. Redd counts in the South Santiam River upstream of Lebanon Dam ranged from 10 to 144 during the period 1970 to 1993 (Willis et al., 1995). Firman et al. (2002) estimated a natural-origin run of spring Chinook salmon to the South Santiam subbasin of 965 fish in 2002, based on counts of naturally spawned carcasses and the number of unmarked fish taken for hatchery broodstock at Foster Dam. Based on otoliths, Lindsay (2003) found that 14 percent of the spring Chinook carcasses collected between Waterloo and Foster in 2002 were naturally spawned fish. Snorkel surveys during 1998 through 2001 indicated significant natural production of spring Chinook salmon in the South Santiam above Foster Reservoir (Oregon Department of Fish and Wildlife, 2001).

Hatchery releases to the South Santiam from 1991 to 2002 are shown in Table 3-35.

Table 3-35: Hatchery Releases 1991-2002

South Santiam River Spring-Run DIP—Spring-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
South Santiam River	1991-2002	12	South Santiam	8,818,120	
	1998	1	McKenzie H.	242,000	
	1991-1996	6	Dexter Ponds	3,698,362	
Crabtree Creek	1994-1995	2	Dexter Ponds	50,157	
	1996-1998	3	Willamette Hatchery	81,168	
Thomas Creek	1994-1995	2	Dexter Ponds	40.436	
	1996-1998	3	Willamette Hatchery	60,009	
			Total	12,949,856 s	**0**
South Santiam River Spring-Run DIP—Fall-Run Releases				**Total Releases**	
Watershed	**Duration**	**Years**	**Source**	**(Within ESU)**	**(Outside ESU)**
North Santiam River	**1991-1995**	**5**	**Bonneville H.**		**29,620,627**
			Total		**29,620,627**

Source: Northwest Fisheries Science Center, 2003.

Emergence and Juvenile Out-Migration or Movement. Upper Willamette spring Chinook salmon exhibit highly variable life history patterns. Fry emerge from February through March, and sometimes as late as June (Mattson, 1962). There appear to be three distinct phases of juvenile emigration out of the tributaries into the Willamette River:

- Late winter to early spring as fry
- Fall to early winter as fingerlings
- Late winter through spring as yearling fish (Myers et al., 2003)

Historically, many of the juvenile fish resided for a period of time in the Willamette River. In the 1940s it was reported that large numbers of fry were present in the Willamette River from February through early April (Dimick and Merryfield, 1945).

Juvenile spring Chinook salmon begin their downstream migration from the North Santiam River at a variety of ages and sizes. Craig and Townsend (1946) showed that juveniles began moving downstream during March, soon after emergence. Changes in the water temperature regimes below the dams also have affected juvenile out migration patterns. Cramer et al. (1996) report that Chinook salmon fry in the North Santiam River move downstream in late November. This shift in emergence and migration timing is presumed to result from warm incubation temperatures below the dam. Emigration of juvenile fish was continuous throughout summer and fall. Since the construction of Lookout Point and Dexter dams, the release of warm water in the fall has accelerated the development of Chinook embryos downstream, leading to early emergence (U.S. Army Corps of Engineers, 2000).

Homolka and Downey (1995) calculated emergence dates for spring Chinook in the South Fork McKenzie based on USGS temperature data for 1992. Temperatures were below the median lethal high temperature for Chinook eggs (61°F), indicating that eggs would incubate quickly but not necessarily die. Homolka and Downey predicted that fry spawned during the median spawning week, which was centered on September 15, 1992, would emerge 57 days earlier than fry from eggs incubated in Lost Creek and 99 days earlier than fry incubated in Horse Creek, two unregulated tributaries to the upper McKenzie River. Warm water out of Cougar and Blue River reservoirs also affected emergence timing in the mainstem McKenzie River some distance below the South Fork and Blue River; the calculated emergence date for redds in the South Fork below Cougar Dam was 36 days earlier than for redds 6 miles below the mouth of the South Fork near Finn Rock. Field sampling generally supported this pattern. Holmolka and Downey (1995) began catching fry in the lower South Fork in early December and in the mainstem just below the South Fork during late January but did not catch the first emergent fry upstream of the South Fork until late January through mid-March. The South Fork of the McKenzie below Cougar Dam is an important spawning area. In 2002, 51 percent of the 922 spring Chinook salmon redds counted in the McKenzie Subbasin were below the dam (Schroeder et al., 2002), and presumably these redds were influenced by the warmer water temperatures.

Habitat: Rearing, Refuge, and Forage. Juvenile McKenzie River spring Chinook salmon demonstrate a variety of out-migration and rearing patterns, varying in nature between years. Zakel and Reed (1984) defined three life history types of wild Chinook at Leaburg Dam:

- Age-0 fry that migrate in late winter through early spring
- Age-0 fingerlings that migrate in the fall
- Yearling smolts that migrate in early spring

During the spring after emergence, an unknown proportion of fry from the upper subbasin pass Leaburg Dam and move downstream to rear in reaches of the lower McKenzie and in the Willamette Rivers (primarily between Harrisburg and Eugene). Juvenile spring Chinook salmon have been observed passing Willamette Falls as fry, but most appear to rear in the lower McKenzie and mainstem Willamette system. Studies in the 1960s confirm the pattern of rearing in the mainstem of rivers. Scale analyses of returning adults indicated that only 10 percent had entered the ocean as subyearlings, suggesting that a large proportion of the juveniles observed migrating downstream had overwintered in the mainstem Willamette or Columbia rivers (Mattson ,1963). Some subyearlings have been observed in off-channel areas of the Willamette and the lower reaches of valley floor tributaries, and their movements may be timed to co-occur with (or may be triggered by) fall and early winter freshets, which flood habitat that would be unsuitable during summer because of high temperatures and low flow (Kenaston, 2003). ODFW has found spring Chinook fingerlings up some valley floor tributaries as far as 20 miles from the mainstem. Juvenile spring Chinook have been observed during the winter in seasonal streams in the lower Calapooia Subbasin (Colvin, Oregon State University, personal communication, 2004).

There are considerable differences in out-migration timing of native and hatchery-produced spring Chinook salmon (Kenaston, 2003). Most of the subyearlings PIT-tagged at Leaburg Dam during the fall passed Willamette Falls the next spring (March though May). The passage of migrating yearlings tagged at Leaburg Dam during the spring peaked at Willamette Falls that May. The median transit time for tagged yearlings from Leaburg Dam to Willamette Falls was 46 days in 2001 and 53 days in 2002 (Schroeder et al., 2001 and 2002). In comparison, the median travel time to Willamette Falls for juvenile spring Chinook released from the Leaburg Hatchery was 6 days.

Population Distribution: Historical and Current Capacity. Maps showing the distribution of spring Chinook in the Willamette Basin are presented in Appendix E.

Calapooia Subbasin. Historically, spring Chinook salmon used the river between Holley (RM 45) and just upstream from the confluence with United States Creek (RM 80) for spawning and rearing (Wevers et al., 1992). Today, most of the spring Chinook salmon spawn upriver in the forested portion of the subbasin (RM 45). Parkhurst et al. (1950) estimated suitable habitat for 9,000 fish. In contrast, in the 1960s the estimated run size was only 100 to 500 fish (Willis et al., 1960). Nicholas (1995) considered the Calapooia River run extinct, with limited future production potential.

Clackamas River Subbasin. According to ODFW (2001), historical spawning by indigenous spring Chinook occurred in the upper Clackamas Basin in the mainstem and in tributaries including Eagle Creek, Fish Creek, Roaring River, and the Collawash River. Access to spawning areas was severely impeded or prevented by the Faraday and River Mill dams from 1906 to 1939. During this period, natural production of spring Chinook was restricted to the lower 23 miles of the Clackamas River and Eagle Creek. Passage into upriver spawning areas was restored in 1940 and counts of spring Chinook past River Mill Dam in the early 1950s indicate recolonization of the upper basin. The source of the spring Chinook that recolonized the upper Clackamas Basin is not known. Most likely, in included some Clackamas fish that persisted below Faraday Dam, plus strays that were deterred from their destination in upper Willamette River tributaries by passage problems at Willamette Falls (located just above the mouth of the Clackamas) and pollution in the lower Willamette.

Currently natural production habitat is thought to be relatively productive in at least the Clackamas mainstem and tributaries above North Fork Dam. Spawning ground surveys for spring Chinook salmon were conducted in the Clackamas River basin from 1996 through 1998 to document timing, distribution, and abundance of natural spawning. The mainstem of the upper Clackamas River above North Fork Dam is the most important spawning area for spring Chinook salmon accounting for an average of 85 percent of the reds in 3 years of intensive surveys (1996 to 1998). Only 15 percent are accounted for in tributaries. Mean annual red counts in the upper mainstem in 1996 to 1999 were 236. Reds in the upper mainstem from Sisi Creek to the head of North Fork reservoir are fairly uniformly distributed with the section from the mouth of the Collowash River to cripple Creek usually containing the highest red densities. Of the tributaries, the Collowash River is the most used by spring Chinook in the basin. Spring Chinook salmon also spawned in the lower Clackamas River below River Mill Dam, but not as heavily as above North Fork Dam. The lower Clackamas River accounted for 11 percent of the total rent in the Clackamas Basin in 1998 when both of her lower sections were surveyed. Although fall Chinook salmon also use the lower Clackamas River, spring Chinook predominate in the area just below River Mill dam.

McKenzie Subbasin. Historical spawning areas included the mainstem McKenzie River, Smith River, Lost Creek, Horse Creek, South Fork, Blue River, and Gate Creek (Mattson, 1948; Parkhurst et al., 1950). It has been estimated that historically there was suitable habitat for 80,000 fish in the McKenzie River Subbasin (Parkhurst et al., 1950). Construction of Cougar Dam at RM 4.5 on the South Fork McKenzie River in 1963 blocked access to at least 25 miles of high-quality spawning habitat. The South Fork was considered the best spring Chinook salmon production area in the McKenzie Basin (U.S. Fish and Wildlife Service, 1948). In 1956, 805 redds were observed in the South Fork (Willis et al., 1960). Although Cougar Dam was built with fish passage facilities, these did not function as intended and were not used for this function after 1966. Construction of Blue River Dam (at RM 1.8 in 1968) blocked a smaller amount of habitat; the Blue River watershed probably supported a historical population of about 200 adult Chinook salmon (WNF BRRD, 1996). The Eugene Water and Electric Board (EWEB) completed construction of its Carmen-Smith project on the upper mainstem McKenzie River in 1963. Of the three dams that make up the Carmen-Smith project, Trail Bridge Dam cut off access to about 4 miles of historical spring Chinook salmon spawning habitat and Smith Dam cut off about 3 miles. Carmen Dam is above a natural barrier to migration (Tamolich pool and falls).

Most of the current natural production of spring Chinook salmon is above Leaburg Dam (RM 39). Based on aerial redd surveys, approximately 10 to 20 percent of the Chinook salmon that spawn above Leaburg Dam use the lower few miles of the South Fork McKenzie River (that is, below Cougar Dam), 30 to 40 percent spawn in the mainstem McKenzie below the confluence with the South Fork, and 45 to 60 percent spawn in headwater areas above the mouth of the South Fork up to Trail Bridge Dam (U.S. Fish and Wildlife Service, 1994; Oregon Department of Fish and Wildlife 1999a).

Middle Fork Willamette Subbasin. Historically, spring Chinook salmon in the Middle Fork Willamette Subbasin spawned in Fall Creek, Salmon Creek, the North Fork of the Middle Willamette River, Salt Creek, and the mainstem Middle Fork Willamette River (Parkhurst et al., 1950). Mattson (1948) estimated that 98 percent of the 1947 run in the Middle Fork Willamette system spawned upstream of the Lookout Point dam site and that the remaining 2 percent spawned upstream of the Fall Creek dam site. Construction of these dams restricted the population to only 20 percent of its historical spawning area, below Dexter/Lookout Point and above Fall Creek Reservoir (Oregon Department of Fish and Wildlife, 1990). In 1998, 10 redds were observed in the reach between the town of Jasper and Dexter Dam, which was not used for spawning before the dams were built (Lindsay et al., 1999). ODFW (1998) states that there may be a small but unquantified amount of natural production in Little Fall Creek.

The Fall Creek Basin remains accessible to anadromous salmonids. Although Parkhurst et al. (1950) estimated that the Fall Creek Basin could support several thousand salmon, by 1938 the run had already been severally depleted. In 1947, the run had dwindled to an estimated 60 fish (Mattson, 1948). Construction of the Fall Creek Dam (1965) included fish passage facilities, but passage is only possible during high flow years (Connolly et al., 1992). ODFW (1995) concluded that the native spring-run population was extinct, although some natural production, presumably by hatchery-origin adults, still occurs. Of the 260 carcasses examined from the Middle Fork Willamette River (including Fall Creek), 11 (4 percent) were estimated to have been naturally produced (Schroder et al., 2003).

Molalla/Pudding River Subbasin. There is very little information on the historical run size or distribution of the Molalla spring Chinook population. By 1903, the abundance of spring Chinook salmon in the subbasin had already decreased dramatically (Myers et al., 2004). Surveys in 1940 and 1941 recorded 882 and 993 spawning spring Chinook salmon, respectively (Parkhurst et al., 1950). Surveys in the 1940s observed 250 spring Chinook salmon in Abiqua Creek, a tributary to the Pudding River (Parkhust et al., 1950). It was estimated in the 1950s that there was sufficient habitat in the Molalla River Subbasin to accommodate at least 5,000 fish (Parkhurst et al., 1950).

The historical run of spring Chinook in the Molalla and Pudding watersheds was believed to have declined to the point where it could no longer sustain a viable population during the 1960s (Cramer et al., 1996). Hatchery releases of spring Chinook have been made in the Molalla watershed since 1981 in an attempt to restore the population, although there is no evidence that this population has become self-sustaining (U.S. Army Corps of Engineers, 2000). There have been no recent observations of spring Chinook in the Pudding River watershed (Oregon Department of Fish and Wildlife, 1999a).

North Santiam Subbasin. Historically, the mainstem North Santiam River was free of natural barriers up to its headwaters, approximately 35 mainstem miles above the current site of Detroit Dam (WNF DRD, 1995). Before Detroit Dam was built, adult Chinook salmon spawned in the upper reaches of the North Santiam River and in headwater tributaries such as the Breitenbush River, Blowout Creek, and Marion Creek (WNF DRD, 1994, 1996, and 1997). Mattson (1948) estimated that 71 percent of the spring Chinook production in the North Santiam subbasin occurred above the dam site. Since dam construction, spring Chinook salmon have been restricted to the area below Big Cliff Dam. Spring Chinook salmon spawn and rear primarily in the first 10 miles of the North Santiam River below the Minto barrier weir and trap (Schroder et al., 2001), but also as far downstream as Stayton. The historical spring Chinook spawning areas within the North Santiam River Subbasin were located just above the town of Stayton up through the upper mainstem (Mattson, 1948). Key spawning tributaries included the Little North Fork and Breitenbush rivers. The mainstem Santiam River below the confluence with the North and South Santiam rivers also is believed to have supported spawning spring Chinook salmon (Wevers et al., 1992). Most of the historical spring Chinook salmon spawning habitat in the North Santiam Subbasin is now inaccessible because of dams. Detroit and Big Cliff Dam (RM 58) block access to the upper mainstem and Breitenbush River. Parkhurst et al. (1950) estimated that the historical habitat could accommodate at least 30,000 adults.

Currently the Little North Santiam River watershed has the largest spring Chinook salmon production potential of all accessible streams in the Santiam River Subbasin (U.S. Army Corps of Engineers, 2002). Midsummer snorkel surveys of the Little North Santiam River during the period 1991 to 1995 observed adult spring Chinook counts that ranged from 0 in 1994 and 1995 to 242 in 1994. There are no dams on this tributary and it is not subjected to the negative water temperature impacts from the storage reservoirs.

South Santiam Subbasin. Historically, spring Chinook salmon spawned in the mainstem South Santiam and Middle Santiam rivers and in all of their major tributaries, including Thomas, Crabtree, and Quartzville creeks (Thompson et. al, 1966; Fulton, 1968; WNF SHRD, 1995 and 1996). Construction of Foster and Green Peter dams blocked or impaired access into much of the area where Mattson (1948) observed Chinook spawning during 1947.

Beginning in 1996, ODFW transported and released spring Chinook that returned to the Foster trap into areas above Foster Reservoir in an effort to reestablish a naturally producing run. The number released increased from 120 fish (in 1996) to 980 (in 2001) (Hunt, 2003). Snorkel surveys (1998 through 2001) indicated significant natural production in this area (Hunt, 2003). Of 762 adult spring Chinook released above Foster in 2002, most (92 percent) were unclipped (Hunt, 2003). ODFW also has released spring Chinook trapped at Foster into Crabtree and Thomas creeks, tributaries to the South Santiam below Foster, as well as into other Willamette basin tributaries (Abiqua Creek and the Calapooia River).

Historical Hatchery Production and Distribution of Spring Chinook

North Santiam. Genetic analysis of naturally produced juveniles from the North Santiam River indicated that the naturally produced fish were most closely related to, although still significantly different from, other naturally and hatchery-produced spring-run Chinook from the upper Willamette and Clackamas rivers (NMFS, 1998a). Fish marked in the North Santiam River return primarily to the North Santiam (95 percent); there are few recoveries outside the upper Willamette River basin (W/LC TRT, 2002).

The native population of spring Chinook in the North Santiam has been affected by hatchery production since the first egg-take by the Oregon Fish Commission (OFC) in 1906 (Wallis, 1963). Although over the past century most of the fish released into the North Santiam have come from locally collected broodstock, stocks outside the ESU also have been released. The current program at Marion Forks Hatchery began in 1951, to mitigate for the loss of spring Chinook production upstream of Detroit and Big Cliff dams (completed in 1953). Hatchery fish have probably spawned in the wild every year since this hatchery program began. Genetic analyses of naturally produced juveniles from the North Santiam River indicated that the fish were most closely related to other naturally and hatchery-produced spring Chinook from the Upper Willamette River ESU (although they were still significantly different, $P>0.05$; Myers et al., 1998). Wild fish probably have been incorporated into the hatchery broodstock since the collections began at the Minto weir. However, until the 2001 return year, hatchery fish could not be distinguished from wild fish, and the numbers of hatchery fish that have spawned in the wild and the numbers of wild fish that have been incorporated into the hatchery program have been unknown. Now that all hatchery fish are externally marked, the current management strategy, as outlined in NMFS (2000), is to incorporate some wild fish into the broodstock (so that the hatchery broodstock reflects local adaptation) and to control the percentage of hatchery fish spawning in the wild. NOAA Fisheries' current Biological Opinion on the U.S. Army Corps of Engineers' hatchery program for Upper Willamette River Chinook salmon expired in September 2003. The Biological Opinion is expected to be updated in 2004.

McKenzie River. A number of hatcheries have operated on the McKenzie River since the early 1900s. The McKenzie River Salmon Hatchery, located on Highway 126 between Leaburg and Vida, collects returning hatchery adults and some spring Chinook of natural origin. The broodstock for this program originated from fish collected upstream at the Leaburg Trout Hatchery (near Leaburg Dam) and from mainstem reaches and tributaries of the McKenzie River. Relatively few intrabasin transfers have been received compared to other Upper Willamette River Chinook salmon hatchery stocks. ODFW's (1998) *Willamette Basin Fish Management Plan* called for incorporating 10 to 25 percent natural-origin fish into the broodstock each year. However, until 2001, when all of the hatchery fish (through age 5) returning to the McKenzie were fin-clipped, the unmarked fish collected for broodstock may have included some of hatchery origin. Since 1996, the percentage of the broodstock of known natural origin has ranged from 9 percent to 25 percent (Kruzic, 2003); according to ODFW (2003), an average of at least 15 percent wild fish has been incorporated into the McKenzie Hatchery broodstock each year since 1997. NOAA Fisheries' Biological Opinion on the U.S. Army Corps of Engineers hatchery program for Upper Willamette River Chinook salmon expired in September 2003. The Biological Opinion is expected to be updated in 2004.

Conversely, the rate of spawning by hatchery Chinook salmon in the wild has been high; hatchery fish constituted 63, 59, and 47 percent of the natural spawners below Leaburg Dam in 1990, 1994, and 1995, respectively (Willis et al., 1995). ODFW (1998) found that coded-wire tags collected from carcasses in the McKenzie River below Leaburg Dam included strays from Clackamas and South Santiam hatchery stocks that had been transferred to McKenzie Hatchery for rearing but then released in the Clackamas and South Santiam subbasins. Similar recoveries of non-McKenzie hatchery stock were made in 1997 (ODFW, 1997). To limit introgression of hatchery fish into the naturally spawning population, NMFS (2000) directed the federal action agencies for the Willamette Basin hatchery program (the U.S. Army Corps of Engineers and BPA) to limit the number of hatchery-origin fish allowed to pass above Leaburg Dam. However, the Leaburg trap has been inadequate for removing all the hatchery fish during the peak of the run without some level of injury to natural-origin fish.[5]

South Santiam. Hatchery-produced spring Chinook have been present in the South Santiam River since egg collection activities began in 1923, when a weir was placed across the river near the town of Foster (Mattson, 1948; Wallis, 1961). Sporadic and inefficient operation of the weir probably allowed a large portion of the run to escape upstream (Wallis, 1961). In other years, the hatchery may have taken all the naturally produced adults each year for

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[5] The U.S. Army Corps of Engineers, ODFW, and EWEB are currently developing plans to improve the Leaburg ladder trapping facility.

broodstock. The South Santiam Hatchery began operations in 1966 to mitigate for Foster Dam, which blocked spring Chinook salmon from nearly all their historical spawning areas.

Hatchery fish have probably spawned naturally below Foster Dam. Schroeder et al. (2002) reported that 84 percent of the carcasses on the South Santiam spawning grounds[6] in 2002 were fin-clipped, compared to 73 percent in the North Santiam and 77 percent in the Middle Fork Willamette subbasin. Most freshwater coded-wire tag recoveries from South Santiam hatchery spring Chinook salmon were made within 6 miles of the hatchery of origin (W/LC TRT, 2002).

Middle Fork Willamette. Hatchery Chinook were first released in the Middle Fork Willamette Subbasin in 1919 (ODFW, 1990). Before 1950, two temporary collecting racks were set up in the Middle Fork each year, one about 2 miles above the town of Oakridge and the other 1 mile above the mouth of Salmon Creek (Mattson, 1948; ODFW, 1990). Little is known about the contribution of hatchery releases to subbasin production during this period, but few adults are believed to have returned from releases made before the 1960s because of poor hatchery practices (Howell et al., 1985; ODFW, 1990).

The Willamette Hatchery, built as mitigation for lost production above U.S. Army Corps of Engineers dams, is located on the Middle Fork Willamette River near the town of Oakridge. Stock for the Willamette Hatchery comes from collection facilities at Dexter Dam and at Foster Dam on the South Santiam River (U.S. Army Corps of Engineers, 1997). Smolts have been released below Dexter each year since dam construction; fry and fingerlings have been released in Fall Creek Reservoir each year since Fall Creek Dam was completed (1965), except that no releases were made during 1970.

It is likely that hatchery-origin spring Chinook salmon have spawned naturally below Dexter Dam since the hatchery began operations and upstream passage was blocked by the dams. Hatchery fish were not marked until recently, so the fraction of natural spawners that were of hatchery origin was unknown. Surveys by ODFW have shown low numbers of Chinook spawning below Dexter Dam, which suggests that natural production in this reach, whether of hatchery- or natural-origin fish, is low. Of the 8,330 spring Chinook captured at the hatchery trap in 2002, 9.5 percent were unmarked (that is, naturally produced) (Firman, 2003). This suggests that some level of natural production is still occurring in the Middle Fork, either from spawning below Dexter Dam or from adults outplanted above Dexter and Lookout Point dams to spawn in historical habitat. NOAA Fisheries' current biological opinion on the U.S. Army Corps of Engineers hatchery program for Upper Willamette River Chinook salmon will expire in September 2003.

3.2.4.2 Winter Steelhead Life History, Population Status, and Trends

Of the three runs of steelhead currently found in the Upper Willamette River ESU, only the late-run winter steelhead is considered to be native (Myers et al., 2003). Summer and fall-run steelhead populations have been introduced to the Willamette River system. The same flow conditions at the Willamette Falls that distinguish Upper Willamette spring Chinook also distinguish winter steelhead. Flow conditions at the falls blocked access for steelhead during

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[6] Spawning ground surveys covered the mainstem South Santiam below Foster Dam and Thomas, Crabtree, and Wiley creeks (Schroeder et al., 2002).

fall and summer months prior to construction of the locks. The native late-run winter steelhead are distinguished from nonnative fall-run steelhead by the date of passage at Willamette Falls—February 15. Those fish ascending the falls prior to February 15 are considered introduced, nonnative early-run steelhead and those ascending after February 15 are considered native late-run steelhead (McElhany, 2003b).

Winter steelhead are only considered native to the eastside tributaries draining the Cascade Range. No native historical populations of winter steelhead existed above the Calapooia River Subbasin (McElhany, 2003b). Naturally spawning steelhead are present in westside tributaries draining the Coast Range, although there is considerable debate as to whether the existing fish are native or derived from introduced stocks (Myers et al., 2003). Winter steelhead have been observed spawning in the Tualatin (Gales Creek), the Luckiamute, Rickreall Creek, and the Yamhill River. With the exception of Gales Creek in the Tualatin Subbasin, Parkhurst et al. (1950) did not report the presence of any salmon or steelhead in westside tributaries. Based on hatchery records, large numbers of early-run winter steelhead were stocked in the Yamhill and Luckiamute rivers (Myers et al., 2003). ODFW observations suggest that late-run winter steelhead may have recently colonized the Yamhill River (National Marine Fisheries Service, 1999a). With the exception of the Tualatin River, there is little evidence to suggest that self-sustaining spawning aggregations of winter steelhead existed historically in the westside tributaries (Myers et al., 2003).

Most of the populations of winter steelhead have a large introduced component. While counts at Willamette falls have increased in the last 3 years, the overall trend of winter steelhead is declining in the last 30 years (McElhany, 2003b). In 1982 it was estimated that 15 percent of the late-run winter steelhead ascending Willamette Falls were of hatchery origin (Oregon Department of Fish and Wildlife, 1998). Through 1997, counts of native late-run winter steelhead past Willamette Falls had a 5-year geometric mean abundance of just more than 3,000 fish (Oregon Department of Fish and Wildlife, 1998). The North and South Santiam subbasins have the only core and genetic legacy populations of winter steelhead in the Upper Willamette Basin (McElhany et al., 2003).

Life History Patterns and Diversity: Adult Migration and Spawning. Winter steelhead spend 1 to 4 years in the ocean before spawning. Stone (1878) reported that steelhead began arriving at the base of Willamette Falls around Christmas but were most abundant in April. Spawning peaked in May and was completed by June. Dimick and Merryfield (1945) thought that the bulk of the run occurred somewhat earlier, in January and February. Prior to dam construction, some steelhead arrived in the upper reaches of the Santiam system between late March and the first of May, with spawning usually taking place between April and the first of June (Dimick and Merryfield, 1945). Winter steelhead spawn high in the Cascade tributary streams and do not spawn in the mainstem of the Willamette River. There appears to be little change from historical spawn timing. Currently, winter steelhead return to the Minto trap on the North Santiam from April through May (Wevers et al., 1992). Adult winter steelhead arrive at Foster Dam from February through June, with the peak of the run usually in mid-April, and there is no evidence that there has been a shift from the historical run timing (Oregon Department of Fish and Wildlife, 1990). Redd counts for winter steelhead in the Upper Willamette Basin are conducted in May.

Life History Patterns and Diversity: Abundance and Population Trends. While there is little historical information on the population status of upper Willamette River winter steelhead, the geographic range and historical abundance are believed to be relatively small in comparison to the range and abundance of other steelhead ESUs. The current production of winter steelhead probably represents a larger proportion of historical production than is the case in other Columbia Basin ESUs (Busby et al., 1996).

The limited data on winter steelhead adult escapement appear to indicate a declining population. Of the three winter steelhead subpopulations that have adequate adult escapement information to compute trends, the populations range from a 4.9 percent annual decline to a 2.4 percent annual increase. However, none of these winter steelhead population trends is significantly different from zero, indicating the precarious status of the stock. ODFW (1997) has determined that the South Santiam winter steelhead subpopulation is close to being unable to sustain itself.

Calapooia Subbasin. A time series of redds-per-mile data from the Calapooia shows a declining trend from 1980 to 2001 (WCS BRT, 2003). Based on indices of wild steelhead spawner abundance for the five Upper Willamette winter steelhead subpopulations, Chilcote (1998) determined that the Calapooia Subbasin meets the criteria for endangered classification (more than a 20 percent chance of extinction in 20 years).

The time series of abundance for winter steelhead in the Calapooia is shown in Figure 3-25.

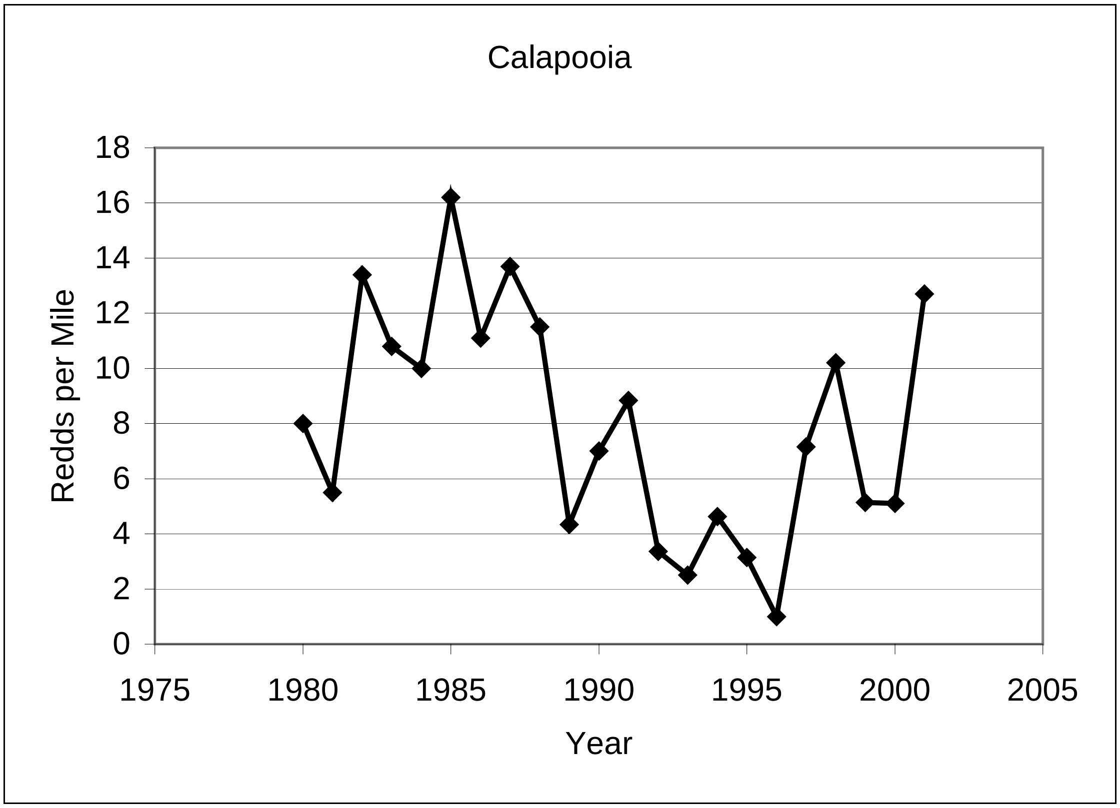

Figure 3-25: Time Series of Abundance for Upper Willamette Winter Steelhead in the Calapooia

Source: Northwest Fisheries Science Center, 2003.

Molalla/Pudding Subbasin. The Molalla River currently contains three distinct runs of steelhead: native late-run winter steelhead, introduced early-run steelhead (from the Lower Columbia River and Puget Sound populations), and introduced Skamania Hatchery summer-run steelhead (Chilcote, 1997). Releases of the early-run steelhead into the Molalla River were discontinued in 1997 (Chilcote, 1997), although some natural production of early-run winter steelhead may still occur. Most of the life history information available for Molalla River steelhead is specific to introduced Big Creek Hatchery early-run winter steelhead rather than native late-run fish.

A time series of redds-per-mile data from the Molalla shows a declining trend from 1980 to 2000 (WCS BRT 2003). Based on indices of wild steelhead spawner abundance for the five Upper Willamette winter steelhead subpopulations, Chilcote (1998) determined that Molalla/Pudding Subbasin meets the criteria for endangered classification (more than a 20 percent chance of extinction in 20 years).

Redd surveys for winter steelhead in the Molalla are shown in Figure 3-26. Hatchery releases are shown in Table 3-36.

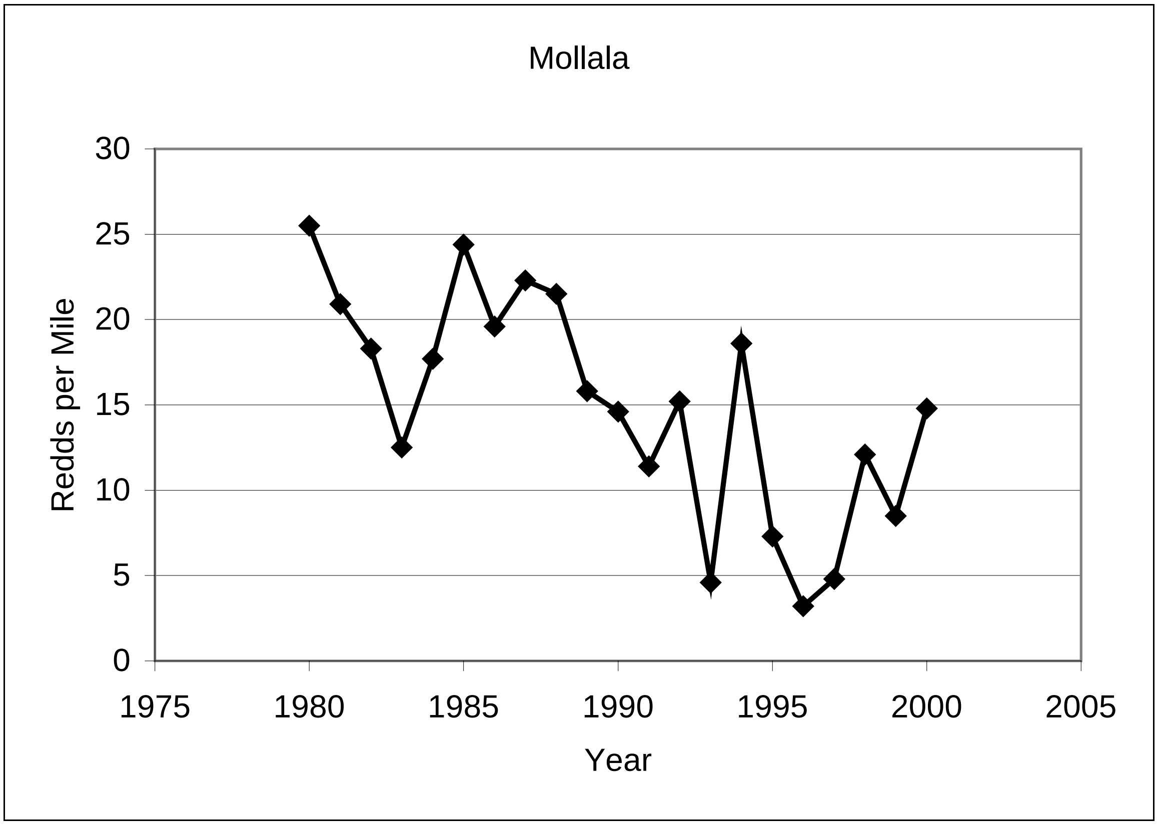

Figure 3-26: Redd Surveys of Winter Steelhead in the Molalla River

Source: Northwest Fisheries Science Center, 2003.

Table 3-36: Winter Steelhead Hatchery Releases in the Mollala, 1957–1997

Watershed	Duration	Years	Source	(Within ESU)	(Outside ESU)	Run
Molalla River	**1970-1996**	**10**	**Gnat Creek**		**497,922**	**W**
	1984-1997	**7**	**Skamania**		**909,134**	**S**
	1976-1993	**17**	**Big Creek Stock**		**908,516**	**W**
	1970-1974	**4**	**Alsea R. (Fall Cr. H.)**		**156,683**	**W**
	1957-1977	6	Marion Forks/S. Santiam	270,912		W
	1982	1	Marion Forks	23,492		W
			Total	294,404	**2,472,255**	

Source: Northwest Fisheries Science Center, 2003.

North Santiam Subbasin. Surveys performed in 1940 estimated at least 2,000 steelhead spawning in the mainstem North Santiam, with additional runs to the Breitenbush, Marion Fork, and Little North Santiam rivers (Parkhurst et al., 1950). Thompson et al. (1966) estimated that the subbasin supported a population of 3,500 winter steelhead in the 1950s and 1960s, including adults trapped at Minto. Escapement to the Minto trap averaged 446 fish during the period 1971 through 1997. ODFW’s (2001) redd count data show declining numbers of naturally spawned steelhead in the North Santiam over the period 1983 through 2000. The 6-year moving average of approximately 21 natural preharvest spawners appears to have been stable for several years (U.S. Army Corps of Engineers, 2002).

Redd surveys of winter steelhead in the North Santiam are shown in Figure 3-27. Figure 3-28 shows the time series of abundance for winter steelhead in the North Santiam at Minto. The fact that Minto is a hatchery-acclimation pond and release site suggests that the majority of fish are of hatchery origin.

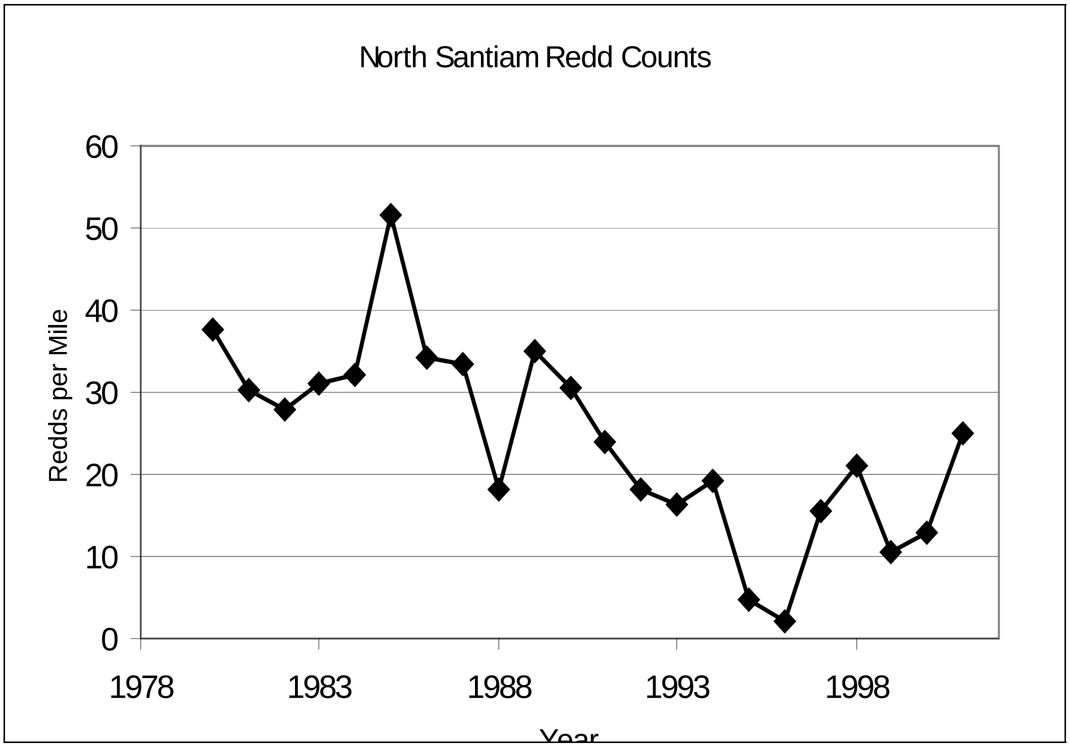

Figure 3-27: Redd Surveys of Winter Steelhead in the North Santiam

Source: Northwest Fisheries Science Center, 2003.

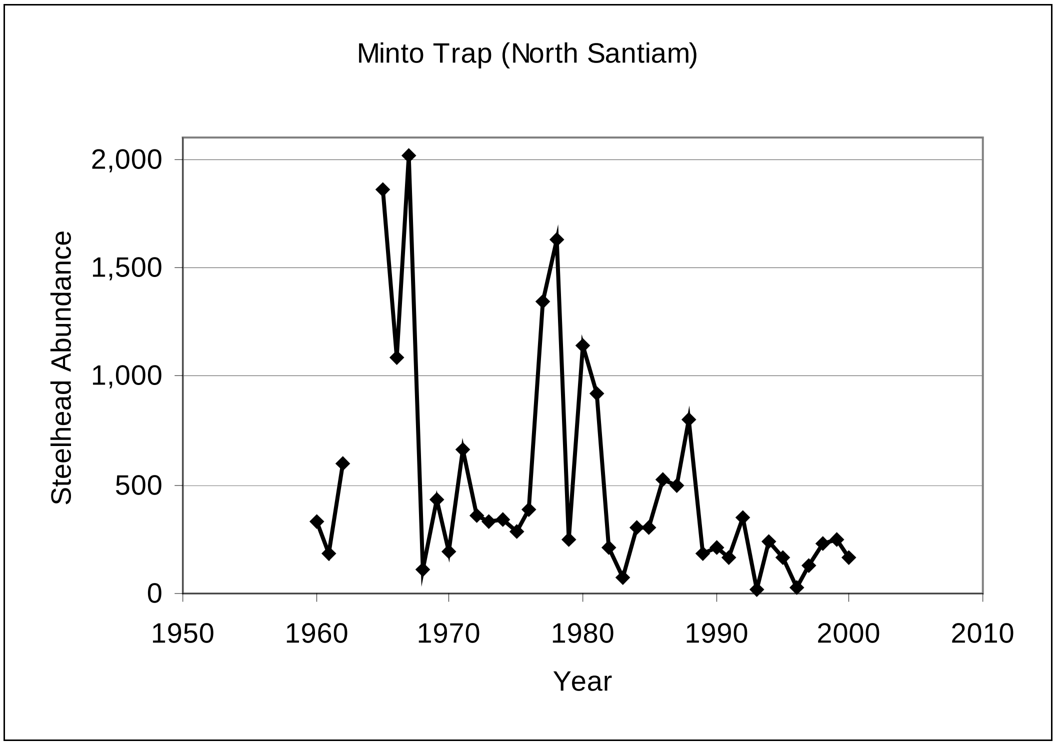

Figure 3-28: Time Series of Abundance for Upper Willamette Winter Steelhead in the North Santiam, Minto Trap

Source: Northwest Fisheries Science Center, 2003.

Table 3-37 shows hatchery releases of winter steelhead to the North Santiam.

Table 3-37: Winter Steelhead Hatchery Releases in the North Santiam, 1931–2002

Watershed	Duration	Years	Source	(Within ESU)	(Outside ESU)	Run
North Santiam River	1931-1985	18	Marion Forks	11,528,482		NA
	1968-1975	4	Unknown	394,191		NA
	1983-1997	**9**	**S. Santiam H. (Skamania**		**296,308**	**S**
	1991-1994	**4**	**McKenzie H. (Skamania)**		**159,715**	**S**
	1991-1997	**7**	**Roaring River (Skamania)**		**799,121**	**S**
	1998-2001	**2**	**Marion Forks (Skamania)**		**324346**	**S**
	2001-2002	**2**	**Minto Ponds**		**292,080**	**S**
	1976-1998	16	Marion Forks	2,267.428		W
	1984	1	S. Santiam H	21,064		W
	1969-1977	5	Unknown	354,692		W
			Total	14,172,779	**1,871,570**	

Source: Northwest Fisheries Science Center, 2003.

South Santiam Subbasin. Native late-run winter steelhead and introduced Skamania Hatchery summer-run steelhead are both present in the south Santiam River. Hatchery releases have not occurred in this basin since 1989, and the proportion of hatchery-reared fish that currently spawn naturally in the South Santiam river is believed to be less than 5 percent (Chilcote, 1997). Hatchery releases in the South Santiam are shown in Table 3-38.

Spawning ground surveys in the South Santiam Subbasin by personnel of the Fish Commission of Oregon, Oregon State Game Commission, and Bureau of Commercial Fisheries indicated a minimum annual spawning population of about 2,600 steelhead above the site of Foster Dam each year prior to the dam's construction (U.S. Fish and Wildlife Service, 1963). ODFW (2001) redd count data show declining numbers of wild spawners in the South Santiam from 1983 through 1996. The 6-year moving average of approximately 300 wild preharvest spawners appears to have been stable for several years (U.S. Army Corp of Engineers, 2002). Based on indices of wild steelhead spawner abundance for the five Upper Willamette winter steelhead subpopulations, Chilcote (1998) determined that the South Santiam Subbasin meets the criteria for endangered classification (more than a 20 percent chance of extinction in 20 years).

Redd surveys of winter steelhead in the South Santiam are shown in Figure 3-29, while Figure 3-30 shows the time series of abundance of steelhead in the South Santiam.

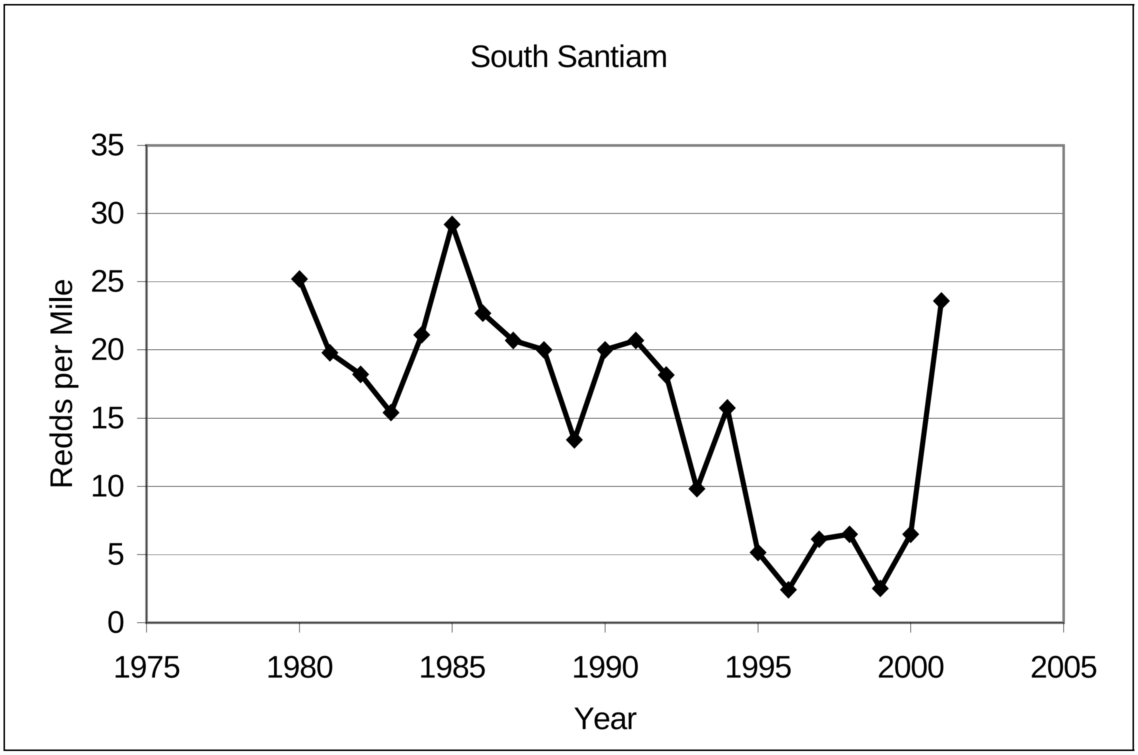

Figure 3-29: Redd Surveys of Winter Steelhead in the South Santiam Below Foster Dam

Source: Northwest Fisheries Science Center, 2003.

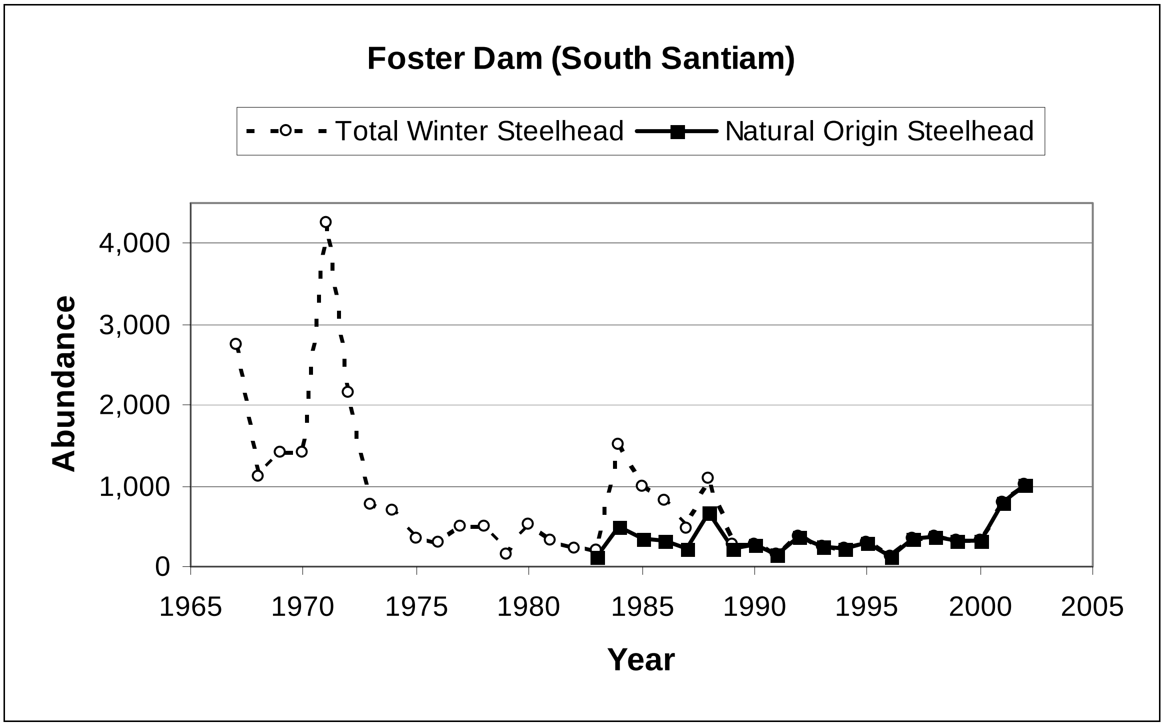

Figure 3-30: Time Series of Abundance for Upper Willamette Winter Steelhead South Santiam, Foster Dam

Source: Northwest Fisheries Science Center, 2003.

Table 3-38: Winter Steelhead Hatchery Releases in the South Santiam

Watershed	Duration	Years	Source	(Within ESU)	(Outside ESU)	Run
South Santiam River	1971	1	Foster Reservoir	84		NA
	1975	**1**	**Hagerman**		**8,022**	**NA**
	1960	1	Roaring R	9,620		NA
	1965	1	Wickiup Res	16,592		NA
	1928-1944	13	S. Santiam H	13,697,599		NA
	1969-1975	3	Unknown	350,192		NA
	1973-1976	**4**	**Foster Res**		**388,568**	**S**
	1978-1992	**15**	**S. Santiam H**		**1,867,166**	**S**
	1977	**1**	**Unknown**		**2,750**	**S**
	1959	**1**	**Wickiup Res**		**16,133**	**S**
	1968, 1969	**2**	**Wickiup Res**		**54**	**S**
	1972, 1976	**2**	**Alsea R and Tributaries**		**114,976**	**W**
	1976-1992	**12**	**Big Cr.**		**1,630,062**	**W**
	1985-1988	**3**	**Klaskanine R**		**222,317**	**W**
	1929	**1**	**Rogue R**		**411,056**	**NA**
	1976-2002	**26**	**S. Santiam H**		**4,348,730**	**S**
	1972-1977	**4**	**Unknown**		**641,043**	**S**
	1981	1	Marion Forks	26,489		W
	1972, 1977	2	Unknown	149,024		W
			Total	14,249,600	**9,650,877**	

Source: Northwest Fisheries Science Center. 2003.

Emergence and Juvenile Out-Migration or Movement. Winter steelhead egg incubation rates vary with water temperature, with eggs hatching anywhere between 18 and 101 days (U.S. Army Corps of Engineers, 2002). Fry emergence of native upper Willamette winter steelhead is thought to occur predominately in June (Oregon Department of Fish and Wildlife, 1990a).

Buchanan et al. (1995) stated that steelhead smolts migrated past Green Peter Dam from mid-April to late May and past Foster Dam during mid-April through mid-May. Smolt migration of winter steelhead over Willamette Falls begins in early April and extends through early June, with peak migration occurring in mid-May (U.S. Army Corps of Engineers, 2002). Mean lengths of naturally produced smolts sampled at Willamette Falls in 1976 to 1978 ranged from 170 millimeters to 220 millimeters. Larger smolts migrated significantly earlier than smaller smolts (Buchanan et al., 1979).

Habitat: Rearing, Refuge, and Forage. Most upper Willamette winter steelhead spend 2 years in the ocean before spawning (U.S. Army Corps of Engineers, 2002). Although there is some variability, most winter steelhead reside for 2 years in the spawning watershed or downstream reaches before out- migrating (Wevers et al., 1992). Winter rearing occurs more uniformly at lower densities across a wide range of fast and slow habitat types. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small wood. Some older juveniles move downstream to rear in larger tributaries and mainstem rivers (Nickelson et al., 1992).

Limited data on winter steelhead rearing distributions indicate that juvenile fish reside in both the spawning tributaries and the mainstem Willamette River. ODFW seining studies have found that juvenile winter steelhead in the mainstem are distributed primarily between Corvallis and the mouth of the McKenzie River (U.S. Army Corps of Engineers, 2002). Snorkel surveys in the Santiam River watershed found juvenile steelhead below Salmon Falls on the Little North Fork Santiam River, in the river below the confluence with the Little North Fork, in Crabtree and Thomas creeks, and in the South Santiam River above Foster Lake (U.S. Army Corps of Engineers, 2002). Rearing juvenile winter steelhead also have been observed in the Calapooia, Molalla, and Pudding River watersheds. Rearing winter steelhead (probably from eastside tributaries) have been observed in the lower ends of westside tributaries, including the Long Tom and the Marys River (Gregory, Oregon State University, personal communication, 2003). Juvenile winter steelhead have been observed during winter and early spring residing in seasonal tributaries in the Calapooia River (Colvin, Oregon State University, personal communication, 2004). In tracking studies in the lower Willamette River near Portland, winter steelhead smolts were observed in water that was generally farther from shore and shallower than water in areas used by yearling spring Chinook salmon smolts (U.S. Army Corps of Engineers, 2002).

Winter Steelhead Population Distribution: Historical and Current Capacity. Historically, there were probably five historical demographically independent populations of winter steelhead in the Upper Willamette River winter steelhead ESU, all of which are associated with eastside tributaries (McElhany et al., 2003). Two core populations survive in the North and South Santiam subbasins, which sustained large populations historically and may have the intrinsic capacity to sustain large populations into the future. Both of the Santiam subbasin populations represent an important element of the genetic legacy of the ESU (McElhany et al., 2003). See Appendix E for distribution maps for winter steelhead.

Calapooia Subbasin. The historical run size of winter steelhead native to the Calapooia River has not been estimated. Annual sport catch in the Calapooia River watershed ranged from 0 to 122 fish during 1977 to 1988 (Weavers et al., 1992b). Current winter steelhead spawning areas in the Calapooia River watershed include the Calapooia River mainstem above Holley, the North Fork, and Potts Creek (Wevers et al., 1992).

Molalla/Pudding Subbasin. There are no estimates of the historical winter steelhead production in the Molalla/Pudding Subbasin, although spawning areas are dispersed over approximately 110 miles of stream in the Molalla River and 57 miles in the Pudding River (Wevers et al., 1992a). Current key spawning areas in the Molalla/Pudding Subbasin include the North Fork, Table Rock Fork, Milk Creek, and Copper Creek in the Molalla River watershed and Butte and Abiqua creeks in the Pudding River watershed.

North Santiam Subbasin. Historically, winter steelhead spawning occurred throughout the upper mainstem North Santiam River, in all the major tributaries (such as the Breitenbush and Little North Santiam Rivers), and in many smaller tributaries (BLMS, 1998; Olsen et al., 1992; WNF DRD, 1994, 1995, 1996, 1997). Steelhead also used most of the mainstem North Santiam for spawning.

Since dam construction, winter steelhead have been restricted to the area below Big Cliff Dam, spawning in the mainstem both upstream of the Minto weir (to Big Cliff Dam) and downstream of the weir and in tributaries, including the Little North Santiam River, Mad Creek, and Rock Creek. Tributaries to the upper Little North Santiam River, such as Elkhorn Creek and Sinker Creek, are also used extensively. Because spawning takes place primarily in May, it is separated in time from that of spring Chinook salmon (which takes place primarily in September). Some spatial separation occurs as well (winter steelhead typically spawn in smaller streams than spring Chinook salmon), but there is considerable spatial overlap in larger streams such as the mainstem North Santiam and the Little North Santiam River.

South Santiam Subbasin. Winter steelhead spawned historically in the upper South Santiam subbasin, above the sites of Foster and Green Peter dams. Buchanan et al. (1993) estimated that 2,600 winter steelhead spawned in the upper mainstem of the South Santiam River and in Thomas, Crabtree, McDowell, Wiley, Canyon, Moose, and Soda Fork creeks. However, inadequate downstream passage at Foster and Green Peter dams and inadequate upstream passage at the latter facility are believed to have caused a drastic reduction of native winter steelhead in the upper subbasin. For these reasons, ODFW has not passed adult winter steelhead above Green Peter Dam since 1987. An average of 296 winter steelhead trapped in the Foster ladder were released above the dam during 1996 to 2000; the number rose to 728 in 2001 (Chilcote, 2001). Moose and Canyon creeks, which are tributaries to the South Santiam River above Foster Reservoir, are important areas for natural spawning (U.S. Army Corps of Engineers, 2000). Current key spawning areas in the South Santiam Subbasin include Rock, Crabtree, Wiley, Canyon, and Moose creeks (Wevers et al., 1992).

Nonnative Populations. Nonnative populations of winter steelhead are found in several westside tributaries and in the McKenzie River.

Westside Tributaries (Tualatin, Yamhill, Rickreall, and Luckiamute Rivers). Naturally spawning winter steelhead are currently found in several westside tributaries of the Willamette River; however, there is considerable debate on the origin of these fish. Surveys in 1940 reported anecdotal information of steelhead spawning in Gales Creek, a tributary to the Tualatin River (Parkhurst et al., 1950). Numerous introductions of early-run winter steelhead (Big Creek Hatchery stock) and late-run (North Santiam stock) winter steelhead have been made into the Tualatin River; this makes it difficult to determine whether the existing fish represent native or introduced lineages. Parkhurst et al. (1950) did not report the presence of any salmon or steelhead in the Yamhill, Rickreall, Luckiamute, and Marys rivers (although the surveys were conducted during the summer months when only juveniles would be present).

Hatchery records indicate that large numbers of early-run winter steelhead were stocked in the Luckiamute and Yamhill rivers. ODFW suggests that, based on spawn timing, late-run winter steelhead may have recently colonized the Yamhill River (National Marine Fisheries Service, 1999).

Recent genetic analysis of presumptive steelhead from the westside tributaries indicates that fish from the Yamhill River and Rickreall Creek were most similar to hatchery populations from the Lower Columbia River. The fish sampled from the Luckiamute River had no clear affinity with any other steelhead populations and may be representative of an isolate resident *O. mykiss* population.

Table 3-39 shows winter steelhead hatchery releases in westside tributaries.

Table 3-39: Winter Steelhead Hatchery Releases in Westside Tributaries, 1958-1996

Watershed	Duration	Years	Source	(Within ESU)	(Outside ESU)	Run
Tualatin River (Gales Creek)	**1991-1996**	**6**	**Gnat Creek**		**117,543**	**W**
	1991-1996	**6**	**Big Creek**		**60,055**	**W**
	1975-1990	**16**	**Big Creek/Gnat Creek**		**554,666**	**W**
Yamhill River	**1958-1991**	**18**	**Big Creek**		**429,497**	**W**
	1968	1	Marion Forks	9,976		W
Luckiamute River	**1979**	**1**	**Big Creek**		**55,211**	**W**
	1957	**1**	**Sandy Hatchery**		**119,211**	**W**
				9,976	**1,336,183**	

Source: Northwest Fisheries Science Center, 2003.

McKenzie and Middle Fork Willamette Rivers. There is general agreement that steelhead did not ascend the Willamette River beyond the Calapooia River. There are numerous theories on the factors affecting the distribution of steelhead. These vary from the occurrence of *Ceratomyxa shasta* in the lower portion of the river to passage problems in the historically highly braided river reaches above the Calapooia River. There are native *O. mykiss* populations in the upper portion of the Willamette Basin; however, these appear to be resident in nature (Kostow, 1995). The steelhead, both summer and winter, that currently are found in the McKenzie and Middle Fork Willamette rivers are the descendants of hatchery introductions. They are included here because of the potential risk they present to native populations downstream associated with the out-of-ESU origin of most introductions.

Hatchery releases of winter steelhead in the McKenzie and Middle Fork are shown in Table 3-40.

Table 3-40: Winter Steelhead Hatchery Releases in the McKenzie and Middle Fork

Watershed	Duration	Years	Source	(Within ESU)	(Outside ESU)	Run
McKenzie River	**1970-1976**	**3**	**Foster Res (Skamania)**		**107,650**	**S**
	1980-1992	**13**	**McKenzie R (Skamania)**	0	**1,139,387**	**S**
	1978-1985	**8**	**S. Santiam H**		**677,723**	**S**
McKenzie H.	**1913**	**1**	**Trask H fing**		**90,551**	**NA**
	1911	1	Unknown	35,000		NA
	1983-1996	**9**	**McKenzie R (Skamania)**		**513,197**	**S**
	1982-1992	**10**	**S. Santiam H (Skamania)**		**811,307**	**S**
	1991-2002	**12**	**Leaburg (Skamania)**		**1,386,686**	**S**
Fall Creek	**1994-2000**	**6**	**Dexter Ponds (Skamania)**		**123,327**	**S**
	1992	**1**	**McKenzie H. (Skamania)**		**9.940**	**S**
	1999	**1**	**Willamette H. (Skamania)**		**22,483**	**S**
	1995-1997	2	North Santiam	42,608		W
Middle Fork Willamette River	**1994-1998**	**5**	**Willamette H. (Skamania)**		**719,811**	**S**
	2000-2002	**3**	**Dexter Ponds (Skamania)**		**317,269**	**S**
Willamette Hatchery	**1957-1959**	**3**	**Alsea R and Tributaries**		**182,218**	**NA**
	1956	1	Oak Springs	1,069		NA
	1995-1999	3	North Santiam	117,034		W
	1972	1	Unknown	20,936		NA
	1954-1961	6	WILL+MF+BONN	Unknown		NA
	1955, 1957	2	Willamette R	102,271		NA
	1984-2002	**4**	**S. Santiam H (Skamania)**		**266,152**	**S**
	1991-1992	**2**	**McKenzie H. (Skamania)**		**133,511**	**S**
	1987	1	Big Cr.	82,211		W
			Total	412,953	**182,218**	

Source: Northwest Fisheries Science Center, 2003.

Historical Hatchery Production and Distribution of Winter Steelhead

North Santiam. A winter-run hatchery stock, developed primarily from North Santiam wild fish, but with some fish from the Big Creek and Klaskanine River stocks, was released into the Santiam Subbasin beginning in 1952 (ODFW, 1990). Approximately 100,000 steelhead smolts were released each year, mostly in the mainstem North Santiam River and Big Cliff Reservoir, until the program was discontinued in 1998 (NMFS 1999a) . Traps installed at Stayton in the North Santiam River caught 42 percent marked winter steelhead in 1993 and 85 percent in 1994 (Kostow, 1995). Hatchery strays from outside the system represented 2 percent of the catch in both years.

Native winter steelhead were artificially propagated at the North Santiam Hatchery beginning in 1930, when a record 2.8 million eggs (686 females at 4,170 eggs/female) were taken (Wallis, 1963). Beginning in 1952, ODFW tried to compensate for the loss of wild production areas above Detroit and Big Cliff dams by releasing hatchery winter steelhead, but these attempts were generally unsuccessful (ODFW, 1990). ODFW ended the winter steelhead hatchery program in the Santiam in 1998 because of concerns over the potential effects of residualized steelhead on the native population,[7] interbreeding and genetic interactions with the native population, and the cost-effectiveness of the program[8] (Mamoyac, 2003).

Introduced late-winter and Skamania summer-run steelhead are both present in the North Santiam River (Chilcote, 1997), but ODFW discontinued the release of the late-winter run in 1998 (NMFS 1999a). Now the only hatchery steelhead released into the North Santiam are 161,000 summer-run fish. The purpose of this hatchery program is to augment the sport fishery while minimizing natural production (that is, straying) by summer steelhead (NMFS, 2000).

South Santiam. Winter steelhead returning to the South Santiam River were reared at the former South Santiam Hatchery on Coal Creek from 1926 through 1944. After 1944, the South Santiam stock was infrequently reared in a hatchery (ODFW, 1986). It was often supplemented with fish from the Marion Forks Hatchery in the North Santiam Subbasin (ODFW, 1990). Less than 2 percent of the steelhead that ODFW released above Green Peter as presmolts migrated past the dam as smolts, and less than 50 percent of the juveniles released as smolts emigrated. By 1997, Chilcote (1997) estimated that the natural production of hatchery-origin steelhead spawning naturally in the South Santiam River was less than 5 percent (Chilcote, 1997). Releases of hatchery-origin winter steelhead above Green Peter were discontinued in 1989, although summer steelhead continue to be released with the intent of augmenting the sport fishery. ODFW ended the winter steelhead hatchery program in the Santiam in 1998 because of concerns over the potential effects of residualized steelhead on the native population, interbreeding and genetic interactions with the native population, and the cost-effectiveness of the program (Mamoyac, 2003).

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[7] Cold water at the Marion Forks Hatchery precluded the accelerated growth typical of most hatchery programs, and all smolts were released at age 2 instead of age 1. The protracted development period resulted in a high percentage of precocial males (up to 25 percent), which residualized in the system.

[8] Cost-effectiveness was low, in part, because of the residualism mentioned above.

3.2.4.3 Cutthroat Trout Life History, Population Status, and Trends

Cutthroat have the widest distribution of any trout in the Willamette Basin. Cutthroat trout are present in all the subbasins of the Willamette. Cutthroat trout are the only trout native to westside tributaries draining the Coast Range. In the eastside tributaries draining the Cascade Range, cutthroat trout coexist with rainbow trout and have higher population densities in the smaller headwater streams. Southwest Washington/Columbia River coastal cutthroat trout previously were considered a “candidate” species for federal ESA listing by the USFWS. In June 2002, USFWS determined that the population did not warrant protection under the ESA based on trends in population abundance; recently USFWS enacted fish and habitat protections.

Two life history patterns of cutthroat trout are native to the Willamette Basin; these are generally referred to as the sea-run (anadromous) and the resident forms, which exhibit various migration strategies within freshwater. Sea-run anadromous forms of cutthroat trout are thought to exist only below the Willamette Falls (RM26). As with other anadromous salmonids, the Willamette Falls presented an obstacle to movement. The primary life history form of cutthroat trout in the Willamette Basin appears to be freshwater migratory. Upper Willamette cutthroat trout are highly heterogeneous genetically, but they do not appear to form groupings of isolated and semi-isolated populations (Johnson et al., 1999). In 1945, Dimmick noted that except for differences in size (of adults), no morphological differences were noted between the two races (anadromous and resident) of cutthroat.

Life History Patterns and Diversity. This section presents life history patterns and diversity of resident and anadromous cutthroat, both of which are found in the Willamette Basin.

Adult Migration and Spawning. Cutthroat trout exhibit a variety of life strategies, including fish that do not migrate from their resident stream and those that migrate from larger streams and lakes into smaller tributaries. Many fish reside and spawn in small tributaries (this is a resident life history), while other fish reside in larger tributaries and move in and out of small streams (this is a fluvial life history). For both resident and migratory life history types, spawning occurs primarily, if not exclusively, in small tributaries.

Resident Cutthroat. Resident cutthroat trout can include two population types: fish that can move and breed within an interconnected stream system and fish that exist in isolated populations above impassible natural barriers (for example, waterfalls) or fish passage barriers resulting from land use practices (such as road crossing culverts or dams). For cutthroat trout that are restricted to small tributaries, the youngest age classes (ages 0, 1, and 2) predominate in the age structure (Wevers et al., 1992).

The fluvial cutthroat trout life history is common in the Willamette River system (Sumner, 1972). For example, a population of cutthroat trout resides in the Willamette River between Corvallis and the mouth of the McKenzie and spawns in small streams in the lower McKenzie River watershed, including tributaries to the Mohawk River (Jeff Ziller, ODFW, personal communication, 2002). Cutthroat trout movement from larger rivers and streams into small tributaries takes place from November through June (Wyatt, 1959; Nicholas, 1978). In contrast to resident cutthroat trout, the fluvial form grows larger and has a higher percentage of older fish. In rivers and larger streams, the 2- and 3-year-old cutthroat trout are the most prevalent (Wevers et al., 1992). This observation supports the belief that portions of tributary cutthroat trout populations migrate and reside in eastside and westside rivers and the Upper Willamette River for most of their growth.

Cutthroat trout in the Willamette Basin exhibit a long period of spawning that extends from January through July, depending on the location. Spawning takes place earlier in tributaries in the valley floor and later in the high mountain tributaries, with the timing pattern related to temperature regimes and runoff patterns (Nicholas, 1978). The resident form resides and spawns in the same stream. For example, 97 percent of the cutthroat trout in the Cascade Range tributary Lookout Creek appear to exhibit a nonmigratory strategy (Wyatt, 1959).

Sea-Run (Anadromous) Cutthroat. The current distribution of sea-run (anadromous) cutthroat trout in the lower Willamette is unknown. Anecdotal evidence suggests the presence of sea-run cutthroat in very small numbers in the Clackamas River and Johnson Creek (Dick Caldwell, personal communication). No systematic population abundance and distribution data are available.

Historically, sea-run cutthroat migrated into the mainstem Willamette River in the spring, reared throughout the summer, and then migrated to ocean in the fall or early winter. Notably, their use of the mainstem reaches included not spawning but rather spring, summer, fall, and early winter rearing. Sea-run cutthroat were predominantly noted residing near tributary confluence regions of the lower mainstem area.

Dimmick (1945) noted that sea-run cutthroat spawned in January, February, and March, while resident cutthroat spawned in May, June, and July. Sea-run cutthroat returned to their natal freshwater streams (and moved out of the mainstem Willamette) before juvenile Chinook emigrating seaward and used lower mainstem habitats.

Emergence and Juvenile Out-Migration or Movement. Fry move downstream to larger streams from June through November (Wyatt). Cutthroat trout are sexually mature at age 2 to 3 (Nicholas, 1978). Adult cutthroat trout in higher elevation tributaries generally mature at smaller sizes than trout found in lower elevation tributaries and the Willamette River. Based on scale collections from cutthroat trout in the McKenzie, Santiam, and Willamette rivers, there appears to be an increase in growth rates in the third and fourth year that is attributed to movement from small tributaries into rivers where there is a more abundant food supply (Nicholas, 1978).

Rearing, Refuge, and Forage. Cutthroat trout residing in headwater streams are generally smaller at each age than those inhabiting areas lower in the drainage (Nicholas, 1978). Populations that are isolated, as a result of natural or human-caused fish passage barriers, tend to have smaller fish than do populations below barriers (Hunt, 1982). For example, cutthroat trout above the falls on the Little Luckiamute River are generally smaller than those found in streams of similar size below barriers (Wevers et al., 1992). Cutthroat trout also will use seasonal streams for rearing, refuge, and forage habitat. In the Calapooia Subbasin, cutthroat trout were observed in seasonal streams during high flow periods in the winter and early spring (Randy Colvin, Oregon State University, personal communication, 2004). Artificial barriers, such as road crossing culverts, keep cutthroat trout from accessing spawning and rearing areas in both perennial and seasonal streams.

Population Distribution: Historical and Current Capacity. Compared to historical conditions, there have been dramatic changes to the distribution of cutthroat trout in the Upper Willamette Subbasin and the ability of the habitat to support abundant and genetically diverse populations. Dams, road crossing culverts, and other fish passage barriers have limited the distribution of cutthroat and their access to spawning and rearing habitat. For example, in the Long Tom River below Fern Ridge Dam, younger cutthroat are absent and larger adults appear only seasonally (Connolly et al., 1992). In addition, Brownsville Dam on the Calapooia River appears to hinder the movement of migrating adult and juvenile fluvial cutthroat trout during the spring high flow periods (Gary Galovich, ODFW, personal communication, 2003).

A number of studies have shown that adult and juvenile salmonids, including cutthroat trout do not pass through a majority of culverts at road crossings. Fish passage at culverts is a concern regarding both adult and juvenile fish. Juvenile cutthroat trout are weak swimmers and can be stopped by less than a 6-inch drop at the outlet of a culvert. Fish passage guidelines developed by ODFW specify that culverts need to be installed at a gradient of less than 0.5 percent and have no more than a 6-inch drop at the culvert outlet. The majority of culverts throughout the Upper Willamette Basin do not meet these criteria for fish passage; this has affected cutthroat trout distributions. For example, in an inventory of more than 80 culverts in the Calapooia Subbasin, more than 90 percent of the culverts did not meet the ODFW fish passage criteria (Runyon et al., 2004).

It appears that the forested upper portions of the Willamette Subbasin have higher quality cutthroat habitat than do lowland streams. Lowland streams that flow through the floor of the Willamette Valley have been disproportionately affected by agriculture and urban/residential development. The forested upland streams draining the Coast and Cascade ranges have been modified through timber harvest, road building, and other activities, but the impact on aquatic habitat has not been as dramatic as in the lowland systems. Historically, lowland streams, which were characterized by abundant side channels, large wood jams, and other complex and diverse habitats, provided the most productive fish habitat (IMST, 2002).

Other evidence points to the significant loss of cutthroat trout habitat capacity in lowland streams. In a study of 2nd- to 4th-order streams in the Willamette Basin, Baker et al. (2002) developed a cutthroat Habitat Suitability Index based on key aquatic/riparian conditions and other watershed characteristics (see Table 3-41).

Table 3-41: Aquatic/Riparian Conditions and Other Metrics Used to Develop a Cutthroat Trout Habitat Suitability Index for 2nd- to 4th-Order Streams in the Willamette Basin

Metric
Stream gradient
Annual mean flow
Valley floor width index
Wood potential
Percent of natural vegetation in riparian network
Watershed road density
Closed forest in watershed
Percent of human development in riparian network
Percent of agriculture in riparian network

Source: Baker et al., 2002.

The percent of human development (urban and residential land use) in the riparian network has a disproportionate impact on stream habitat quality and suitability for cutthroat trout. In a measure of biological indicators, the most developed riparian areas had the lowest invertebrate richness (mayflies, stoneflies, and caddis flies). Moreover, there appears to be a dramatic loss of fish species with development of riparian areas. The median number of fish species lost through development was 0.1 in upland streams and 1.8 in lowland streams. Compared to historical conditions, there was almost a twofold difference in the decline in the cutthroat Habitat Suitability Index between the upland and lowland streams: 0.14 decline in upland streams and 0.25 decline in lowland streams.

Similar studies underscore the aquatic habitat differences between upland and lowland systems. Thom et al. (1999) reported that streams on private, nonforested lands had much lower stream habitat quality. The lowland streams were characterized by a lack of riparian conifers, slightly higher fine sediments, less large wood in the channel, lower densities of deep pools, and reduced levels of shading in comparison to upland areas managed for timber production. Of the private, nonforested lowland streams that were in unconstrained, wide valley floor settings, only 13 of 55 reaches had high-quality habitat (Thom et al., 1999).

Riparian areas, which provide shade, wood to the channel, and other functions that relate to the quality of cutthroat trout habitat, have also undergone dramatic changes. By 1990, forests along major Willamette Valley tributaries were reduced to one-third of their 1850 extent, occupying just 26 percent of the riparian area, with agricultural and developed lands occupying the greatest amount of riparian area (Pacific Northwest Ecosystem Research Consortium, 2002). Historically, older conifer forests (more than 80 years old) made up almost one-third of the riparian areas in the Willamette Valley lowlands. As of 1990, these forests made up only 5 percent of the riparian area (Pacific Northwest Ecosystem Research Consortium, 2002).

Abundance and Population Trends. There have been very few systematic studies of Upper Willamette River cutthroat trout population trends. Most of the information presented here is qualitative and descriptive, rather than quantitative. There are reports from the 1920s and 1930s of good cutthroat trout sport fishing in the mainstem Willamette River above Independence. It appears that pollution in the river during the 1920s and 1930s eliminated this fishery. Cutthroat trout populations appear to be stable or increasing in the Upper Willamette above Corvallis. Populations of cutthroat tout are limited in the lower Willamette River below its confluence with the Marys River as a result of high summer water temperatures and the presence of the fish parasite *Certomyxa shasta*. Increasing numbers of cutthroat trout in the Willamette River between Corvallis and the mouth of the McKenzie River were noted in a 1992 to 1998 inventory (U.S. Army Corps of Engineers, 2002). Over the 7 years of sampling, the numbers of fish caught increased by 11 percent to 82 percent per year, depending on the location. In electrofishing sampling results from the lower McKenzie River between 1988 and 1993, the estimated number of river-migrating cutthroat trout longer than 20 centimeters ranged from 113 to 333 fish per mile of shoreline (U.S. Army Corps of Engineers, 2002).

There appears to be considerable variability in cutthroat trout population densities within the subbasins of the Upper Willamette. In some cases, fish passage barriers have led to reduced cutthroat trout population densities. The construction of Fern Ridge Dam isolated the upper Long Tom Subbasin cutthroat trout population, which resulted in reduced numbers of adult and juvenile fish residing in the river below the dam (Connolly et al., 1992). Cutthroat trout populations in small headwater streams that were isolated above impassible culverts have been extirpated when the streams have gone dry (Lorensen, ODF, personal communication, 2003). In other cases, it is difficult to understand the mechanisms controlling the variability in cutthroat trout population densities. Combined counts of cutthroat trout and rainbow trout in index pools in the North Fork of the Middle Fork Willamette River increased between 1975 and 1991, and the counts have remained stable since then. The abundance of juvenile cutthroat trout in an index reach of Dead Horse Creek, a tributary to the Molalla River, was stable from 1981 to 1991 (U.S. Army Corps of Engineers, 2002). Numbers of cutthroat trout in streams draining the Coast Range ranged from 166 fish per mile, in the North Yamhill River, to more than 1,700 per mile, in the Luckiamute Subbasin (Hooton, 1997; Johnson et al., 1999).

All of these population counts of cutthroat trout were completed after the major changes to river and stream habitat. By the 1950s, most of the stream systems in the Willamette Basin had already been altered through removal of large wood, channel straightening, loss of riparian forests, and other modifications (Pacific Northwest Ecosystem Research Consortium, 2002). Pollution in the Willamette River below Corvallis during the 1920s and 1930s and the current presence of the fish parasite *Certomyxa shasta* has eliminated the fluvial population of cutthroat trout from this portion of the river.

3.2.4.4 Bull Trout Life History, Population Status, and Trends

Prior to 1978, Dolly Varden (*Salvelinus malma)* were classified into an anadromous and an interior form. Cavender (1978) classified the interior form as a distinct species, *Salvelinus confluentus*—the bull trout. Bull trout are large char weighing up to 18 kilograms and growing to more than 1 meter in length (Goetz, 1989). They are distinguished by a broad flat head; large, downward-curving maxillaries that extend beyond the eye; a well-developed fleshy knob and a notch in the lower terminus of the snout; and light colored spots normally smaller than the pupil of the eye (Cavender, 1978).

Bull trout are found throughout northwestern North America from latitude 41°N to latitude 60°N. In Oregon, bull trout were once distributed throughout 12 basins in the Klamath and Columbia River systems, including the Clackamas, Santiam, McKenzie, and Middle Fork Willamette subbasins west of the Cascades (Buchanan et al., 1997). However, it is believed that bull trout have been extirpated from west of the Cascades with the exception of the McKenzie subbasin.

Buchanan et al. (1997) listed the bull trout population in the mainstem McKenzie as "of special concern," the South Fork McKenzie population as "high risk," and the bull trout above Trail Bridge Reservoir as "high risk." Bull trout in the Middle Fork Willamette are listed as "probably extinct." On June 10, 1998, USFWS listed the Columbia River bull trout population segment (including the McKenzie subbasin) as threatened under the federal Endangered Species Act.

Bull Trout Life History Patterns and Diversity. This section presents life history patterns and diversity of bull trout in the Willamette Basin.

Adult Migration and Spawning. Adult bull trout overwinter in the McKenzie River and are distributed throughout the river as far downstream as the confluence with the Willamette River. Typically, adult bull trout begin to move upstream from overwintering sites in the mainstem McKenzie or Cougar Reservoir in the late spring. The fish move upstream throughout the summer, stage within several miles of spawning tributaries in August, and enter spawning tributaries in late August or early September. Spawning occurs from September through the middle of October, with peak spawning in the middle of September. Bull trout remain in the spawning tributaries for up to 1 month before quickly migrating downstream to overwintering sites lower in the river in October.

Abundance and Population Trends

North Santiam Subbasin. Bull trout were last observed in the North Santiam in 1945. No abundance or trend data available.

McKenzie Subbasin. There are populations of bull trout in the mainstem McKenzie, Trail Bridge Reservoir, and the South Fork.

Mainstem McKenzie River. The McKenzie River local population occurs from the confluence of the McKenzie River with the Willamette River upstream to Trail Bridge Dam, in the South Fork McKenzie River below Cougar Dam, and in portions of Gate Creek, Blue River, Horse Creek, Deer Creek, Olallie Creek, and Anderson Creek. A total of 170 kilometers (105.6 miles) of stream habitat have been identified as being used by bull trout in the McKenzie River subbasin downstream of Trail Bridge Dam (Ziller and Taylor, 2000). Spawning activity is confined to just 5.8 RKm of Anderson and Olallie Creeks.

This population of bull trout appears to be the largest and most secure in the Willamette Basin. Anderson and Olallie creeks are key spawning and juvenile rearing areas and are relatively protected by USFS land management. An estimated 100 to 200 bull trout spawn annually in Anderson Creek. Recent redd surveys in Anderson and Olallie creeks indicate a decreasing trend in Anderson Creek but a stable to increasing trend in Olallie (see Table 3-42). Anderson Creek may be at carrying capacity for rearing juvenile bull trout, based on the number of adults spawning and the number of both fry and juvenile bull trout migrating from the creek. This population is expected to remain stable or to slowly increase in the foreseeable future.

Table 3-42: Number of Bull Trout Redds Observed in Spawning Areas of the McKenzie River, 1989–2003

	Anderson Creek		Olallie Creek	McKenzie River	Sweetwater Creek	Roaring River	Basin Total
	Index Area	Total					
Year							
1989	7	-	-	-	-	-	-
1990	9	-	-	-	-	-	-
1991	7	-	-	-	-	-	-
1992	13	-	-	-	-	-	-
1993	15	-	-	-	-	1	-
1994	22	30	-	0	-	1	-
1995	30	74	10	7	-	2	93
1996	26	82	7	7	-	0	96
1997	18	85	9	3	-	0	97
1998	29	79	7	2	-	6	94
1999	47	77	6	0	-	13	96
2000	44	83	9	0	2	25	119
2001	23	72	6	0	2	34	114
2002	31	60	10	3	1	25	99
2003	23	56	17	9	4	27	113

Trail Bridge Reservoir. This population was cut off from the mainstem McKenzie in 1963 by the construction of Trail Bridge Dam. Spawning for the Trail Bridge Reservoir local population occurs in two locations: the McKenzie River upstream of Trail Bridge Reservoir provides approximately 1.1 kilometers (0.68 miles) spawning and rearing habitat and Sweetwater Creek provides 2.4 kilometers (1.49 miles) of spawning and rearing habitat (Ziller and Taylor, 2000). A total of 6,377 bull trout fry were transferred from Anderson Creek to Sweetwater from 1993 to 1999. Subsequently, small numbers of redds have been identified in Sweetwater Creek from 2000 to 2003 (see Table 3-42). Monitoring indicates approximately 20 adult bull trout present in this population. It is estimated that the population using the mainstem above Trail Bridge is between 20 and 30 adults.

South Fork McKenzie River. This population was cut off from the mainstem McKenzie in 1963 by the construction of Cougar Dam. Bull trout inhabit approximately 29 RKm of stream in the South Fork McKenzie from Cougar Reservoir up to approximately the Three Sisters Wilderness Area boundary. Spawning activity has been documented in 5 RKm of Roaring River. Spawning surveys conducted in Roaring River have shown a sharp increase in bull trout redds over the past 5 years (see Table 3-42). It is estimated that this population numbers from 25 to 75 adults.

Middle Fork Subbasin. No bull trout were identified during extensive surveys of the Middle Fork Willamette Subbasin in the early to mid-1990s. Buchanan et al. (1997) listed bull trout as “probably extinct.” A plan to rehabilitate bull trout to the upper Middle Fork Willamette River was completed and approved by the Willamette Basin Bull Trout Working Group in 1997 (ODFW, 1997). Beginning in 1997 and continuing through 2004, bull trout fry from Anderson Creek in the McKenzie River Subbasin were reintroduced by USFS and ODFW to four cold-water springs and four creeks above Hills Creek Reservoir as part of the rehabilitation plan (ODFW and USFS, 1998). Monitoring has revealed good growth and survival of juvenile bull trout in the release sites. Information on survival and dispersal of the nearly 9,696 fry to the Middle Fork Willamette is limited, although distribution in 2001 was documented to be at least 5.5 miles in the Middle Fork Willamette, from approximately Chuckle Springs downstream to Sacandaga Campground (ODFW, 2001). ODFS and USFS personnel observed 28 bull trout and sampled approximately 25 percent of available habitat in the survey reach. Juvenile abundance in the Middle Fork was estimated at approximately 250 individuals (ODFW, 2001a).

In 2003, ODFW personnel captured a subadult bull trout in Hills Creek Reservoir.

The current abundance of bull trout in the Middle Fork Willamette River is believed to be, at most, a handful of adults (ODFW, 2001a). The population size that the Middle Fork Willamette River can support is not known, but local biologists believe the potential is similar to that of the South Fork McKenzie River (ODFW and USFS, 1998).

Emergence and Juvenile Out-Migration or Movement. Data from a downstream migrant fish trap that has operated seasonally since 1993, and that is located immediately downstream of the culvert passing under Highway 126 (approximately 0.4 kilometer or 0.25 mile upstream from the mouth of Anderson Creek) (Ziller and Taylor, 2000), indicates that the majority of bull trout fry and juveniles migrate from Anderson Creek to the McKenzie River between February and June (ODFW, 2001a). Peak fry and juvenile out-migration occurs from the middle to the end of March (ODFW, 2001a).

Habitat: Rearing, Refuge, and Forage. McKenzie River streams used by bull trout for spawning and rearing are characterized by abundant large wood, high channel complexity, and a mature conifer canopy. Adult bull trout predominantly use large pools, side channels and river margins. Taylor (2001) characterized juvenile bull trout rearing habitat in the mainstem McKenzie using eight quantitative measurements. Bull trout occupied shallow (mean total depth was 1.3 feet ± 0.2), low-velocity habitat (mean = 0.08 ft/sec. ± 0.05) near the stream margins. Mean water temperature was 47 º F. The predominant substrate identified was cobble followed by sand, organic debris, and bedrock. Ninety-one percent of juvenile bull trout observed were in micro-backwater pools associated with boulders, and 9 percent of the bull trout were in small, lateral scour pools associated with boulders.

Population Distribution: Historical and Current Capacity. Maps showing the distribution of bull trout are presented in Appendix E. The following section addresses the population distribution of bull trout in the Willamette Basin.

North Santiam Subbasin. The last verified sighting of a bull trout in the North Santiam subbasin, according to Goetz (1989), was in 1945. Buchanan et al. (1997) in a statewide assessment considered the current status of bull trout in the North Santiam as "probably extinct." Furthermore, presence and absence surveys conducted in the North Santiam Subbasin during the 1990s by personnel from USFS and ODFW failed to detect bull trout, affirming the likelihood that bull trout have been extirpated from this subbasin.

McKenzie Subbasin. The McKenzie River local population occurs from the confluence of the McKenzie River with the Willamette River upstream to Trail Bridge Dam, in the South Fork McKenzie River below Cougar Dam, and in portions of Gate Creek, Blue River, Horse Creek, Deer Creek, Olallie Creek, and Anderson Creek. A total of 170 kilometers (105.6 miles) of stream habitat has been identified as being used by bull trout in the McKenzie River Subbasin downstream of Trail Bridge Dam (Ziller and Taylor, 2000). Although the majority of the population resides upstream of Leaburg Dam in the McKenzie River, color video equipment added to the dam's monitoring facility in 1995 facilitated identification of bull trout and provided documentation of bull trout migrating through the facility. Bull trout have been observed passing the facility annually from 1995 to 2002, with a minimum of four and a maximum of 28 passing annually (EWEB et al., 2001; ODFW, 2001a).

In March 1999, a 74-centimeter (29-inch) bull trout was captured by ODFW crews while seining near the confluence of the McKenzie and Willamette rivers (WRUT, *in litt.*, 1997b). The capture of this individual provided the first evidence that bull trout are using the lower McKenzie River, and perhaps the upper Willamette River, seasonally for foraging. Blue River Dam on Blue River, Cougar Dam on the South Fork McKenzie River, and Trail Bridge Dam on the upper McKenzie River limit movement of bull trout from the McKenzie River local population to historical habitat above these dams.

Middle Fork Subbasin. Little information exists on the historical distribution and abundance of bull trout in the Middle Fork Willamette subbasin. Buchanan et al. (1997) reported that historical distribution included the mainstem Middle Fork Willamette Subbasin from its confluence with the Willamette River upstream to its headwaters, including Salmon Creek and Salt Creek below Hills Creek Reservoir; and the Middle Fork Willamette River above Hills Creek Reservoir, including Swift and Staley creeks. It is likely that historical overwintering and foraging would have extended bull trout distribution into many other tributaries in the subbasin, including the North Fork of the Middle Fork Willamette River. Current known distribution of bull trout in the Middle Fork Willamette extends from Chuckle Springs to Hills Creek Reservoir.

3.2.4.5 Oregon Chub Life History, Population Status, and Trends

Oregon chub are endemic to the Willamette River drainage of western Oregon (Markle et al., 1991). This species was formerly distributed throughout the Willamette River Valley in off-channel habitats such as beaver ponds, oxbows, side channels, backwater sloughs, low-gradient tributaries, and flooded marshes (Snyder, 1908). Historical records show that Oregon chub were found as far downstream as Oregon City and as far upstream as Oakridge.

Historical records also report that Oregon chub were collected from the Clackamas River, Molalla River, South Santiam River, North Santiam River, Luckiamute River, Long Tom River, McKenzie River, Mary's River, Coast Fork Willamette River, Middle Fork Willamette River, and the mainstem Willamette River from Oregon City to Eugene (Markle et al., 1991).

The current distribution of Oregon chub is limited to 24 known naturally occurring populations and eight recently reintroduced populations. The naturally occurring populations are found in the Santiam River, Middle Fork Willamette River, Coast Fork Willamette River, McKenzie River, and several tributaries to the mainstem Willamette River downstream of the Coast Fork/Middle Fork confluence. Only 10 of these populations exceed 1,000 fish, and nine populations contain fewer than 100 individuals. Introduced populations of Oregon chub exist within the Willamette River watershed at Foster Pullout Pond, Finley Display Pond, Cheadle Pond, Wicopee Pond, Fall Creek Spillway Pond, Russell Pond, Herman Pond, and Dunn Wetland (Scheerer et al., 2004).

In the last 100 years, backwater and off-channel habitats have disappeared rapidly because of changes in seasonal flows resulting from the construction of dams throughout the basin, channelization of the Willamette River and its tributaries, removal of snags for river navigation, and agricultural practices. A variety of nonnative aquatic species were introduced to the Willamette Valley over the same period. Consequently, these activities reduced available Oregon chub habitat, isolated the existing Oregon chub populations, restricted mixing between populations, reduced the probability of successful recolonization by Oregon chub, and introduced new competitors and predators into Oregon chub habitat. In 1983, Carl Bond and James Long of Oregon State University noted that Oregon chub were becoming rare in the Willamette River and suggested that some efforts might be necessary to protect this species (Bond and Long, 1984). In 1989, Pearsons surveyed historical locations of Oregon chub populations and documented the decline of this species (Pearsons, 1989). This prompted the petition for listing Oregon chub as a federal endangered species in 1990 (U.S. Fish and Wildlife Service, 1998), and the subsequent federal listing in 1993.

Oregon chub in the Willamette River drainage are not separated into distinct population segments. Historically there was downstream mixing and limited upstream mixing of chub populations throughout the basin. Currently the species is distributed among five subbasins of the Willamette River: the mainstem Willamette, Middle Fork Willamette, Coast Fork Willamette, McKenzie, and Santiam. Preliminary genetic studies are being conducted to provide information regarding the amount of variability or distinctness between populations.

Of the 32 known Oregon chub populations, the sites with the highest diversity of native fish, amphibian, and reptile species have the largest populations of Oregon chub (Scheerer and Apke, 1998). Beaver (*Castor canadensis*) appear to be especially important in creating and maintaining habitats that support these diverse native species assemblages (Scheerer and Apke, 1998).

Life History Patterns. The reproductive and feeding habits of Oregon chub are described below, along with reasons for the species' decline.

Reproduction. Oregon chub spawn from April through September. Before and after spawning season, chub are social and nonaggressive. As described by Pearsons (1989), spawning behavior begins with the male establishing a territory in or near dense aquatic vegetation. If an adult male enters the territory of another male, aggressive skirmishes occur. When an adult female enters the territory the courting begins with head rubbing behavior, where the male rubs his head in the ventral region of the female between the pectoral and anal fins. The female is then directed into the aquatic vegetation by slight changes in the angle and pressure of the head on the lateral undersides of the female. Twirling of both fish, arranged head to head and tail to tail, follows and eggs and sperm are released. Twirling behavior is rarely observed; however, the territorial behavior, head rubbing, and directing occur only during spawning (Pearsons, 1989). Observation of these behaviors is recorded as spawning activity. Spawning activity has been observed only at temperatures exceeding 16 degrees Celsius (61 degrees Fahrenheit). Males longer than 35 millimeters (1.4 inches) have been observed exhibiting spawning behavior.

Feeding Habits. Oregon chub are obligatory sight feeders (Davis and Miller, 1967). They feed throughout the day and stop feeding after dusk (Pearsons, 1989). Chub feed mostly on water column fauna. The diet of Oregon chub adults collected in a May sample consisted primarily of minute crustaceans including copepods, cladocerans, and chironomid larvae (Markle et al., 1991). The diet of juvenile chub also consisted of minute organisms such as rotifers, copepods, and cladocerans (Pearsons, 1989).

Reasons for Decline. It is likely that a variety of factors are responsible for the decline of the Oregon chub. These include habitat alteration; the proliferation of nonnative fish and amphibians; accidental chemical spills; runoff from herbicide or pesticide application on farms and timberlands or along roadways, railways, and power line rights-of way; the application of rotenone to manage sport fisheries; desiccation of habitats; unauthorized water withdrawals, diversions or fill and removal activities; sedimentation resulting from timber harvesting in the watershed; and possibly the demographic risks that result from a fragmented distribution of small, isolated populations.

Habitat Alteration. Based on a 1987 survey (Markle et al., 1989) and compilation of all known historical records, at the time of the petition for listing in 1991, viable populations of the Oregon chub occurred in the following locations: Dexter Reservoir, Shady Dell Pond, Buckhead Creek near Lookout Point Reservoir, Elijah Bristow State Park, William L. Finley National Wildlife Refuge, Greens Bridge, and East Fork Minnow Pond. These locations represented a small fraction—estimated as 2 percent, based on stream miles—of the species' formerly extensive distribution within the Willamette River drainage.

The decline of Oregon chub has been correlated with the construction of dams. Based on the date of last capture at a site, Pearsons (1989) estimated that the most severe decline occurred during the 1950s and 1960s. Eight of 11 flood control projects in the Willamette River drainage were completed between 1953 and 1968 (U.S. Army Corps of Engineers, 1970). Other structural changes along the Willamette River corridor such as revetment and channelization, diking and drainage, and the removal of floodplain vegetation, have eliminated or altered the slackwater habitats of the Oregon chub (Willamette Basin Task Force, 1969; Hjort et al.,1984; Sedell and Froggatt, 1984; Li et al., 1987). Channel confinement, isolation of the Willamette River from the majority of its floodplain, and elimination or degradation of both seasonal and permanent wetland habitats within the floodplain began as early as 1872 and, as an example, have reduced the 25-kilometer (15.5-

mile) reach between Harrisburg and the McKenzie River confluence from more than 250 kilometers (155 miles) of shoreline in 1854 to less than 64 kilometers (40 miles) currently (Sedell and Froggatt, 1984; Sedell et al., 1990).

Predation and Competition with Nonnative Species. The establishment and expansion of nonnative species in Oregon have contributed to the decline of the Oregon chub and limits the species' ability to expand beyond its current range. Many species of nonnative fish have been introduced and are common throughout the Willamette Valley, including largemouth bass (*Micropterus salmoides*), smallmouth bass *(Micropterus dolomieui*), crappie (*Pomoxis* sp.), bluegill (*Lepomis macrochirus*), and western mosquitofish (*Gambusia affinis*). The bullfrog (*Rana catesbiana*), a nonnative amphibian, also occurs in the valley and breeds in habitats preferred by the Oregon chub (Willamette Basin Task Force, 1969; Hjort et al.,1984; Li et al., 1984; Scheerer et al., 1992). The period of severe decline of the Oregon chub does not coincide well with the initial dates of introduction of nonindigenous species. However, many sites formerly inhabited by the Oregon chub are now occupied by nonnative species (Markle et al., 1989). Formerly successful Oregon chub populations, whether natural or introduced, have declined in sites where nonnatives have become established (Scheerer, pers. comm., 2004). The 1996 flooding in the Santiam River was probably responsible for several of these movements of nonnative fish. Other sites, located in the Middle Fork Willamette River drainage, were likely the result of unauthorized introductions or spread of nonnative fish from reservoirs (Scheerer and Jones, 1997).

Specific interactions responsible for the exclusion of Oregon chub from habitats dominated by nonnative species are not clear in all cases. While information confirming the presence of Oregon chub in stomach contents of predatory fishes is lacking, many nonnative fishes, particularly adult centrarchids (bass, for example) and ictalurids (catfish, for example) are documented piscivores (fish eaters) (U.S. Fish and Wildlife Service, 1998). These fishes are frequently the dominant inhabitants of ponds and sloughs within the Willamette River drainage and may constitute a major obstacle to Oregon chub recolonization efforts. Adult bullfrogs prefer habitat similar in characteristics (that is, little to no water velocity, abundant aquatic and emergent vegetation) to the habitat preferred by Oregon chub and are known to consume small fish as part of their diet (U.S. Fish and Wildlife Service, 1998). Nonnative fishes may also serve as sources of parasites and diseases; however, disease and parasite problems have not been studied in the Oregon chub.

In many cases the observed feeding strategies and diet of introduced fishes, particularly juvenile centrarchids (bass and crappie, for example) and adult mosquitofish (Li et al.,1987) and bullfrogs (U.S. Fish and Wildlife Service, 1998), overlap with the diet and feeding strategies described for Oregon chub (Pearsons, 1989). This suggests that direct competition for food between Oregon chub and introduced species may further impede chub's survival and chub recovery efforts. The rarity of finding Oregon chub in waters also inhabited by mosquitofish may reflect many negative interactions, including but not limited to food-based competition, aggressive spatial exclusion, and predation on eggs and larvae (Dr. Douglas Markle, Oregon State University, pers. comm., 1997; Meffe, 1984).

Water Quality. Many of the known extant populations of Oregon chub occur near rail, highway, and power transmission corridors and within public park and campground facilities. These populations are threatened by chemical spills from overturned truck or rail tankers;

runoff or accidental spills of vegetation control chemicals; overflow from chemical toilets in campgrounds; sedimentation of shallow habitats from construction activities; and changes in water level or flow conditions from construction, diversions, or natural desiccation. Oregon chub populations near agricultural areas are subject to poor water quality as a result of runoff laden with sediment, pesticides, and nutrients. Logging in the watershed can result in increased sedimentation and herbicide runoff.

Population Distribution: Historical and Current Capacity. The following is a summary of the historical and current distribution of Oregon chub (Paul Scheerer, Oregon Department of Fish and Wildlife, pers. comm., 2004).

Calapooia River. Oregon chub were found historically in the Calapooia River. One record exists for chub presence in Oak Creek near Albany (1894). Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish and loss of habitat limit Oregon chub recovery in this subbasin.

Clackamas River. Oregon chub were found historically in the Clackamas River. Records exist for chub presence in lower Clear Creek (1899) and near the mouth of the Clackamas (1953). Currently no known populations exist in the Clackamas drainage. Recent surveys at the historical locations yielded no chub.

Coast Fork Willamette River. Oregon chub were found historically in the Coast Fork Willamette River. Three record exists for chub presence near Cottage Grove (1950), Saginaw (1967), and Dorena (1958). Currently, there is one natural and one introduced population in the Coast Fork Subbasin (near Creswell and in the upper Layng Creek drainage). Nonnative fish and loss of off-channel habitats (two flood control dams, revetments) limit Oregon chub recovery in this subbasin.

Long Tom River. Oregon chub were found historically in the Long Tom River. One record exists for chub presence near Monroe (1899). Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish and loss of habitat limit Oregon chub recovery in this subbasin.

Luckiamute River. Oregon chub were found historically in the Luckiamute River. One record exists for chub presence in Cooper Creek near its confluence with the Luckiamute River (1949). Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish limit Oregon chub recovery in this subbasin.

McKenzie River. Oregon chub were found historically in the McKenzie River. One record exists for chub presence near Eugene (1899). Currently, there are two natural and one introduced populations in the McKenzie Subbasin (near Marcola and Springfield). Nonnative fish and loss of off-channel habitats (two flood control dams, revetments) limit Oregon chub recovery in this subbasin.

Middle Fork Willamette River. Oregon chub were found historically in the Middle Fork Willamette River. Seven records exist for chub presence between Lowell and Oakridge. Currently, there are 14 natural and two introduced populations in the Middle Fork Willamette Subbasin (Jasper to Wicopee). Nonnative fish and loss of off-channel habitats (four flood control dams, revetments) limit Oregon chub recovery in this subbasin.

Molalla River. No records for Oregon chub exist in the historical records. Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish limit Oregon chub recovery in this subbasin.

North Santiam River. Oregon chub were found historically in the North Santiam River. One record exists for chub presence near Green's Bridge (1983). Currently, there are four known populations in the North Santiam Subbasin, including Green's Bridge, Geren Island, Gray Slough (near Stayton), and Pioneer Park (near Stayton). Nonnative fish and loss of off-channel habitats (two flood control dams, revetments) limit Oregon chub recovery in this subbasin.

Rickreall Creek. No records for Oregon chub exist in the historical records. Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish limit Oregon chub recovery in this subbasin.

Santiam River. No records for Oregon chub exist in the historical records. Recent ODFW surveys located one Oregon chub population in this subbasin (near Interstate I-5). Nonnative fish and loss of off-channel habitats (four flood control dams in tributaries, revetments) limit Oregon chub recovery in this subbasin.

South Santiam River. Oregon chub were found historically in the South Santiam River. Three records exist for chub presence near Lebanon (1957). Currently, there is one introduced population in the South Santiam subbasin (near Foster Dam). Nonnative fish and loss of off-channel habitats (two flood control dams, revetments) limit Oregon chub recovery in this subbasin.

Tualatin River. No records for Oregon chub exist in the historical records. No known populations currently exist. Nonnative fish may limit Oregon chub recovery in this subbasin.

Willamette River (Mainstem). Oregon chub were found historically in the Willamette River. Four records exist for chub presence near Junction City (1967), Eugene (1894), Oregon City (1897), and Corvallis (1899). Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish and loss of habitat limit Oregon chub recovery in this subbasin.

Yamhill River. No records for Oregon chub exist in the historical records. Recent ODFW surveys have not located any Oregon chub populations in this subbasin. Nonnative fish limit Oregon chub recovery in this subbasin.

3.2.4.6 Pacific Lamprey

Two species of lamprey are known to be distributed in all subbasins of the Willamette Basin. The Pacific lamprey (*Lampetra tridentata*) is a large, anadromous, and parasitic species and has received the most research and management attention. The western brook lamprey (*L. richardsoni*) is smaller, nonanadromous, and nonparasitic. There is little information on the life history or population status of western brook lamprey in the Willamette Basin. River lamprey (*L. ayresi*) may reside in the system, but little information exists on the species, and its continued existence is not certain (Kostow, 2002). This description of lamprey life history, population status, and trends is from Kostow (2002).

Pacific and western brook lamprey were listed as an Oregon State sensitive species in 1993 because a serious decline in abundance had been observed since the 1950s; both species were given further legal protective status by the state in 1997 (OAR 635-044-0130).

Life History Patterns and Diversity. This section presents life history patterns and diversity of anadromous Pacific lamprey and resident western brook lamprey, both of which are found in the Willamette Basin.

Adult Migration and Spawning

Pacific Lamprey. Pacific lampreys enter saltwater and become parasitic, feeding on a wide variety of fish. It is not known how long they reside in the ocean. Pacific lamprey return to freshwater in the lower Columbia River as early as February, with peak numbers passing over Willamette Falls in May and June. They do not feed after entering freshwater. After completing part of their migration into the Willamette system, Pacific lamprey generally over-winter before spawning in the spring. Pacific lampreys select gravel substrate for spawning, usually near pools and ammocoete habitat. Most adults die after spawning, but there have been observations of repeat spawners and out-migration after spawning.

Western Brook Lamprey. The western brook lamprey is a nonparasitic, resident species. These lampreys spawn and live in smaller tributaries. Upon becoming adults, they go dormant until late winter or spring, when spawning occurs. Spawning takes place in small gravels upstream of riffles. Fecundity measured in the Willamette Basin ranged from about 2,500 to 5,500 eggs per female. Adults die after spawning.

Emergence and Juvenile Out-Migration and Movement

Pacific Lamprey. Most downstream movement occurs at night. After rearing for 5 to 7 years in the river or lower tributaries, the ammocoetes begin out-migrating as macropthalmia, eventually returning to the ocean. Out-migration to the ocean occurs November through June, peaking in the spring.

Western Brook Lamprey. Western brook lampreys probably move very little from spawning areas in tributary streams, with most of the movement passive downstream drift.

Rearing, Refuge and Forage

Pacific Lamprey. Pacific lampreys may live as ammocoetes in freshwater for a number of years as filter feeders living in the substrate. Pacific lamprey ammocoetes move progressively downstream, eventually accumulating in the lower parts of the subbasins and in the Willamette River, preferring low-gradient areas in the river and tributaries.

Western Brook Lamprey. Western brook lamprey ammocoetes distribute in the stream system based on size, with the smaller ammocoetes further upstream in areas with fewer silt deposits and shallower waters. The ammocoetes are filter feeders that metamorphose into nonfeeding adults after 4 to 6 years.

Population Distribution: Historical and Current Capacity. There have been no systematic inventories of lamprey distribution within the Willamette Basin. Most observations of lamprey have been incidental observations noted during stream habitat inventories or spawning surveys. Most observations are of juvenile lamprey (ammocoetes). Because ammocoetes from western brook and Pacific lamprey are difficult to distinguish, distribution observations tend to generalize across the species. These limited observations suggest that lampreys are still well distributed through the Willamette Coast Range subbasins, in the Molalla/Pudding system, and in the lower Santiam and Calapooia rivers. However, lamprey distribution has been substantially restricted by barriers at U.S. Army Corps of Engineers dams, other dams, and fish passage barriers at culverts and other structures. There is evidence that lamprey cannot pass above many fish ladders. For example, lampreys are restricted below the North Fork Dam on the Clackamas River, even though the dam is equipped with a functional fish ladder. Culverts at road crossings, weirs, and other instream structures can block upstream passage for lamprey. Any barrier that has a sharp lip, a high-velocity current, a smooth downstream surface, or a hanging drop more than a few inches high will be a passage problem. Diversions and dams also can contribute to lamprey mortality during downstream migration.

Abundance and Population Trends. The Willamette Basin is probably the most important production area for Pacific lamprey in the Columbia system. This was probably true historically as well as currently. Anecdotal historical observations indicate that lamprey were very abundant in the Willamette Basin. In the 1880s an observer from the United States Fish Commission at Willamette Falls stated that “the rocks at the particular point of the Falls where salmon ascend were at times completely covered with lampreys. In places where the force of the current was least, they were several layers deep, and at a short distance the rock appeared to be covered with a profuse growth of kelp or other water plants” (McDonald 1884, as quoted in Kostow, 2002).

Limited data from the Willamette Basin indicate that Pacific lamprey abundance has declined, yet the Willamette remains the most important production area in the Columbia Basin. Even with large yearly fluctuations, it appears that more lampreys pass over Willamette Fall annually than are counted at Bonneville Dam.

Harvest of Pacific lamprey at Willamette Falls provides the best estimate of trends in Pacific lamprey abundance. Hundreds of thousands of adult lamprey were harvested at Willamette Falls during the 1940s and early 1950s, and it is unlikely that this number currently passes Willamette Falls. Since completion of the Willamette Valley Project and the 13 U.S. Army Corps of Engineers dams in 1967, the annual commercial harvest has decreased considerably from the estimated average of more than 312,000 lampreys from 1943 to 1949. Lampreys continue to be harvested (by permit) at Willamette Falls. In 2001, about 15,500 lampreys were harvested.

Lamprey abundance can vary dramatically from one stream to the next. This variability in abundance is reflected in juveniles collected in smolt traps in 2001 on tributaries to the lower Clackamas River (not identified to species). Clear Creek had extremely large numbers of juvenile lamprey (9,480), while far fewer were observed in Deep Creek (173) and Eagle Creek (101). ODFW recently completed surveys of urban stream within the City of Portland (Tinus et al., 2003a) and streams within Clackamas County (Tinus et al., 2003b). Lampreys were observed throughout a number of watersheds. Although most lampreys were not identified to species, both Pacific and western brook lamprey were observed in the streams. In some streams, a relatively high abundance of lampreys was observed.

3.2.4.7 Aquatic Introductions, Artificial Production, and Captive Breeding Programs

Hatchery operations have had a number of direct and indirect effects on focal fish species in the Willamette Basin. One of the most important influences has involved heavy supplementation of naturally reproducing populations with hatchery-origin spawners. Willamette Basin populations of spring Chinook salmon and winter steelhead all have been influenced in this way. Most of these naturally reproducing populations are currently at critically low levels of abundance.

Native winter steelhead were artificially propagated in hatcheries in the South Santiam River beginning in 1926 (Wallis, 1961) and in the North Santiam River beginning in 1930 (Wallis, 1963). However, Willamette Basin hatchery production of native winter steelhead was discontinued in 1998.

Introduced Skamania Hatchery summer steelhead is now the only stock produced and released from Willamette Basin hatcheries. However, hatchery releases of steelhead have not occurred in the South Santiam River since 1989. Chilcote (1997) estimated that the proportion of naturally spawning fish that are of hatchery origin in this subbasin is less than 5 percent.

Differences in the run timing of returning adult spawners may limit, but does not eliminate, the potential for interbreeding of the native winter steelhead stock with the introduced hatchery summer steelhead stock. These stocks are genetically distinct. Genetic monitoring in the Clackamas Subbasin has indicated that hatchery-origin summer steelhead spawning in natural production areas above North Fork Reservoir have replaced a significant proportion of the natural production once provided by native winter steelhead. The extent to which this problem may also occur in the North Santiam River is unknown.

A healthy population must be able to sustain itself naturally. That is, naturally reproduced spawners must be able to replace themselves in subsequent generations. Hatchery fish that are left unharvested stray into natural production areas and spawn, competing with naturally produced spawners in those areas in many important ways, some of which are discussed below.

Where naturally reproducing populations are heavily supplemented with hatchery fish, it is important to know the relative contributions that fish of natural origin and of hatchery origin are making to subsequent generations of naturally produced spawners. This is necessary to determine whether the population is self-sustaining. If most naturally produced spawners in a population originate from parents that are hatchery fish, closure of the hatchery (because of, say, dysfunction, disease problems, or financial hardship) and subsequent loss of the hatchery-origin spawners could put the local population at risk of extirpation. If relatively few naturally produced spawners originate from parents that are hatchery fish, then most originate from parents of natural origin and the population is more likely to be self-sustaining. Consequently, lack of knowledge about the proportion of natural spawners that are of hatchery origin and the contribution of these fish to subsequent generations can substantially increases the risks to persistence of a local population.

Before 2000, most spring Chinook salmon of hatchery origin that returned to the Willamette River were unmarked, making it difficult or impossible to determine the proportion of natural spawners that were of hatchery origin. In 2000 and 2001, ODFW estimated that more than 94 percent and 98 percent, respectively, of spring Chinook spawning naturally in the North Santiam River were of hatchery origin (Schroeder et al., 2002). Likewise, Schroeder et al. (2002) found that more than 84 percent of spring Chinook spawning in the South Santiam River and more than 77 percent of spring Chinook spawning in the Middle Fork Willamette River in 2002 were of hatchery origin. The recoveries of marked (that is, fin-clipped) hatchery fish upon which these estimates were made tend to underestimate the actual proportion of hatchery-origin spawners because marking is not 100 percent effective.

Given the high contributions of hatchery-origin spawners to natural production in these areas, it is unlikely that any of these local populations are currently self-sustaining. Development of natural production sanctuary areas, where natural spawning of hatchery-origin fish can be reduced or eliminated, is essential if these local populations are ever to recover to a point where they are once again self-sustaining.

Recovering the use of high-quality spawning and rearing habitat located above major dams in the Willamette Basin through adult spawner trap-and-transport programs has the additional advantage of providing the opportunity to sort the transported fish and remove those of known hatchery origin. Thus, natural production sanctuaries could be developed above these dams. Although there is often a challenge in providing sufficient passage downstream for juveniles produced in areas above dams, the development of a natural production sanctuary in the South Santiam River above Foster Dam has worked relatively well for production of native winter steelhead.

The only remaining local population of spring Chinook in the Willamette Basin that may still be naturally self-sustaining is the population located above Leaburg Dam in the McKenzie Subbasin. In 1994 and 1995, ODFW estimated that 52 percent and 55 percent, respectively, of spring Chinook spawners passing Leaburg Dam were of natural origin (Willis et al., 1995). From 1998 through 2001, the average proportion of natural-origin spawners passing above Leaburg Dam was estimated at about 74 percent (Schroeder et al., 2002).

The straying rate of hatchery fish into this natural production area, which is in excess of 20 percent, is still threatening to the long-term persistence of the local population. For example, based on a hatchery-origin fish spawning at a rate of just 40 percent of all natural spawners, Neeley (1996) showed that if a particular gene (that is, the “hatchery” gene type) were just half as effective with respect to survival of hatchery-parent offspring as the same gene (that is, the “wild” gene type) was for wild fish, the frequency of the “wild” gene type would diminish within the population from 100 percent to just below 20 percent after only 25 years. If the natural spawning rate of hatchery-origin fish were then reduced to only 10 percent, the “wild” gene frequency within the population would slowly recover to just more than 60 percent after 70 years.

Under conditions of low to moderate numbers of fish passing at Leaburg Dam, an effort is made to capture and remove marked hatchery spring Chinook. The existing capture and handling facilities at Leaburg Dam are inadequate to safely handle large numbers of fish, so many hatchery-origin spawners escape to spawn naturally above the dam during the peak of the run.

A Biological Opinion developed by NOAA Fisheries and issued to BPA and the Portland District of the U.S. Army Corps of Engineers in July 2002 directed the Corps to provide improved fish trapping and handling facilities at Leaburg Dam in an effort to provide a natural production sanctuary above the dam. To date, multiple challenges and problems have prevented development of these facilities. The Biological Opinion will be updated in 2004.

Additional adverse effects resulting from hatchery programs in the Willamette Basin have included genetic change to populations through extensive interbasin stock transfers at Willamette Project hatchery facilities and subsequent interbreeding between naturally produced (wild) and hatchery-origin fish.

Originally, life history characteristics among local populations of salmonid species in the Willamette Basin originally markedly (Willis et al., 1995). For example, the timing of spring Chinook spawning was different in the Clackamas (early July to late August), Santiam (late August to the last week in October), and McKenzie (mid-August to the third week in October) subbasins. Currently, the time of spawning throughout the Willamette Basin for spring Chinook is truncated and uniform, beginning in early September and extending through mid-October with a peak around the third week in September (Willis et al., 1995).

Other adverse effects artificial production include increased competition between artificially and naturally produced juveniles for food and rearing habitat. Juvenile rearing habitat has been substantially reduced in the basin. For example, juvenile spring Chinook rear in complex habitat such as that found in braided stream channels and in near-shore areas that contain rooted aquatic vegetation and large wood. Much of this type of habitat was lost in the upper Willamette Basin, and elsewhere, between 1854 and 1946 as a result of deforestation and large wood removal from streams for boat navigation and agricultural development (Maser and Sedell, 1994). Usually, hatchery fish are larger at release than comparably aged, naturally produced fish and thus have a competitive advantage.

Production of large numbers of hatchery fish, which can be sustainably harvested at a much higher rate than naturally produced fish, has encouraged the over-harvesting of wild stocks. For example, cohort analysis of Willamette spring Chinook salmon by Cramer et al. (1996) showed that early ocean survival (to age 2) and consequent overall smolt-to-adult survival varied five- to twelvefold for the 1975-1989 brood years, ranging from 1 percent to 5 percent for subyearling emigrants and from 1 percent to 12 percent for yearling emigrants. However, harvest rates remained high every year, ranging between 70 percent and 80 percent for nearly all broods. At these high harvest rates, over-harvesting of naturally produced fish in low survival years would have been substantial. Marking and selective harvest of hatchery fish has substantially reduce this problem in recent years.

In July 2000, the NOAA Fisheries developed a Biological Opinion under Section 7 of the Endangered Species Act in consultation with BPA and the U.S. Army Corps of Engineers on the effects of Willamette Basin hatcheries on species listed under the act. (NMFS, 2000). Hatcheries considered in the Biological Opinion are listed in Table 3-43.

The U.S. Army Corps of Engineers and BPA fund more than 90 percent of the artificial propagation programs that potentially affect listed spring Chinook and winter steelhead in the upper Willamette River ESUs. However, all of the hatcheries included in the consultation are operated and maintained by ODFW. The area considered in the Biological Opinion encompasses the entire Willamette Basin from the mouth to the uppermost range of the defined ESUs.

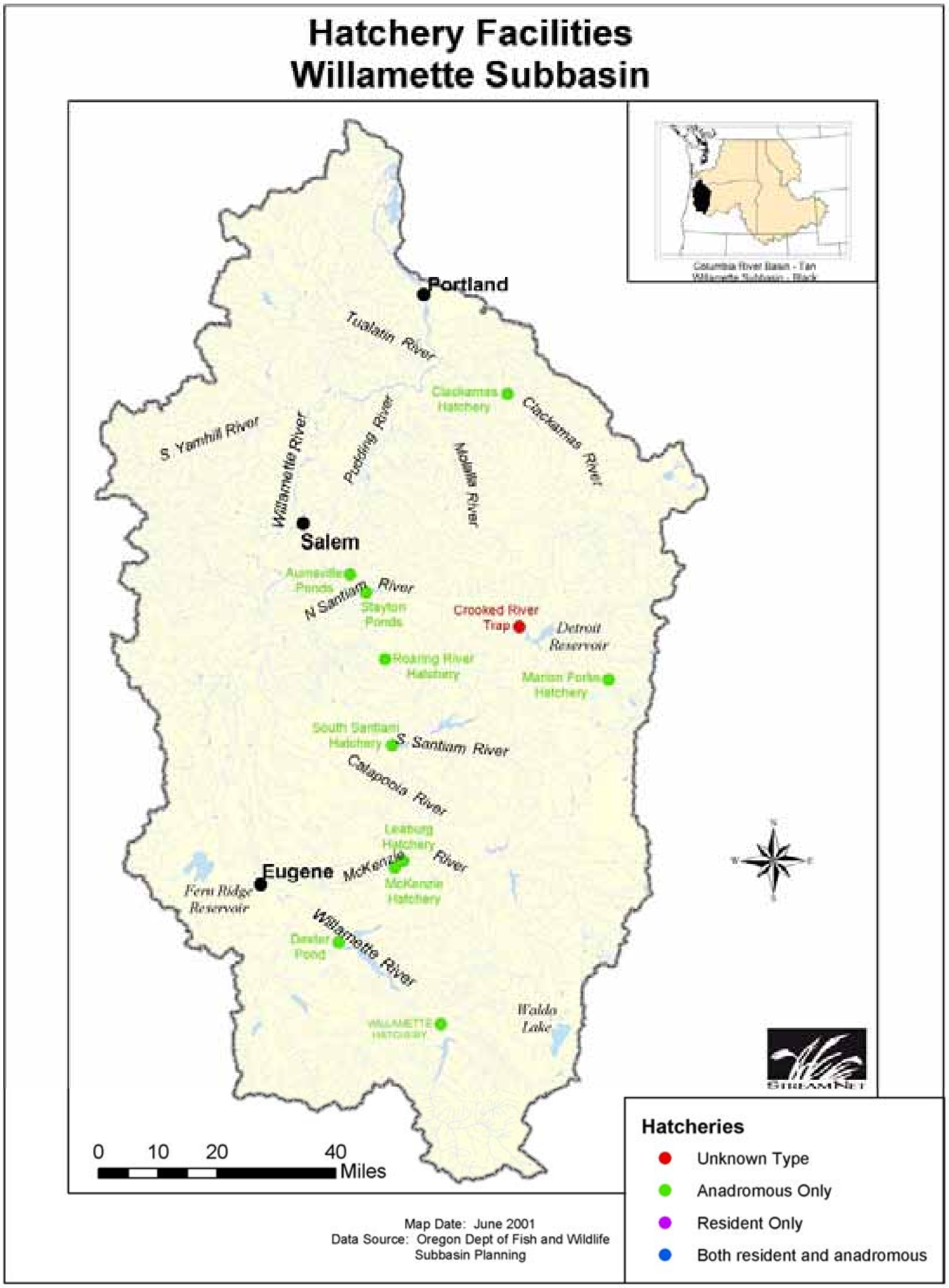
The effects of hatchery program activities in the upper Willamette River ESUs were cited by NOAA Fisheries' status reviews as potential factors for the decline of these ESUs (Busby et al., 1996; Myers et al., 1998). Interbreeding among hatchery-origin and natural-origin fish and the incidental harvest of listed fish in commercial and recreational fisheries targeting abundant hatchery runs were identified as particular concerns.

Table 3-43: Willamette Subbasin Hatcheries

Clackamas Hatchery	The Clackamas Hatchery is located at approximately RM 23 on the Clackamas River, which flows into the Willamette River approximately 2 miles downstream from Willamette Falls. The purpose of this spring Chinook hatchery program is to mitigate for fisheries losses associated with hydropower development and habitat degradation within the subbasin.
Marion Forks Hatchery	The purpose of this hatchery program is to mitigate for the loss of spring Chinook production associated with the construction of Big Cliff and Detroit dams on the North Santiam River, which blocked all upstream fish passage. The Marion Forks Hatchery is located above Detroit Dam, on the North Santiam River at RM 73.
South Santiam Hatchery	The purpose of the hatchery program is to mitigate for fishery losses associated with the construction of Foster and Green Peter dams on the South Santiam River. The South Santiam Hatchery is located adjacent to Foster Dam at RM 38. The South Santiam River is a tributary to the Santiam River, which flows into the Willamette River.
McKenzie Hatchery	The purpose of this hatchery program is to mitigate for fish production losses associated with the development and operation of Blue River and Cougar dams on the McKenzie River. The McKenzie Hatchery is located on the McKenzie River approximately 22 miles east of Springfield, Oregon. The proposed smolt production goal is 1.485 million fish.
Leaburg Hatchery	The purpose of this hatchery program is to mitigate for lost trout habitat caused by the construction of Blue River and Cougar dams and other Willamette Valley projects. Leaburg Hatchery is located on the McKenzie River approximately 23 miles east of Springfield, Oregon, and is used for egg incubation and rearing of summer steelhead and rainbow trout.
Willamette Hatchery	The purpose of the hatchery program is to mitigate for fishery losses caused by the Hills Creek, Lookout Point, and Dexter hydroelectric/flood control projects. The Willamette Hatchery is located along Salmon Creek, approximately 3 miles upstream from its confluence with the Middle Fork Willamette River.

Source: NMFS, 2000.

Willamette Basin Hatchery and Genetic Management Plans (HGMPs) required under NMFS 4(d) rule will be completed in 2004. HGMPs are described in the final salmon and steelhead 4(d) rule (July 10, 2000; 65 FR 42422) as a mechanism for addressing the take of certain listed species that may occur as a result of artificial propagation activities. A number of "mini" HGMPs based on early NOAA Fisheries guidance have been completed for spring Chinook programs at the Clackamas, Marion Forks, South Santiam, McKenzie, and Willamette hatcheries (see Figure 3-31). A prototype HGMP also was developed for the summer steelhead hatchery program at Leaburg Hatchery.



Map Date: June 2001
Data Source: Oregon Dept of Fish and Wildlife
Subbasin Planning

Figure 3-31: Willamette Subbasin Hatcheries

The July 2000 NOAA Fisheries Biological Opinion considered the impacts of proposed actions by BPA, the U.S. Army Corps of Engineers and ODFW, including the release of a total of 5.7 million artificially propagated spring Chinook, 570 thousand summer steelhead, and 325 thousand rainbow trout in the upper Willamette Basin. Table 3-44 lists annual release goals of hatchery fish in the upper Willamette ESUs. Consequently, the Biological Opinion identified three key issues regarding hatchery management in the Willamette Basin:

- Hatchery spring Chinook cannot be differentiated from naturally produced fish on the spawning grounds and in hatchery broodstocks.
- There is the possibility of significant interbreeding between hatchery fish and natural fish in the wild, which results in the loss of local adaptation among the wild populations. The actual level of hatchery fish straying is uncertain.
- The majority of hatchery production in the basin is to mitigate for habitat loss and degradation from federal dams. However, the abundance of hatchery fish promotes fisheries that may significantly affect the remaining listed fish populations.

Table 3-44: Annual Release Goals of Hatchery Fish by Location and Species from Artificial Propagation Programs in the Upper Willamette River ESUs

Release Location (Subbasins Except Where Noted)	Spring Chinook	Fall Chinook	Winter Steelhead	Summer Steelhead	Coho Salmon	Rainbow Trout	Total
Coast Fork Willamette	0	0	0	0	0	200,000	200,000
Middle Fork Willamette	1,427,240	0	0	157,000	0	0	1,584,240
Upper Willamette	0	0	0	0	0	0	0
McKenzie	985,000	0	0	108,000		125,000	1,218,000
South Santiam	1,021,000	0	0	144,000	0	0	1,165,000
North Santiam	667,000	0	0	161,500	0	0	828,500
Middle Willamette	0	0	0	0	0	0	0
Yamhill	0	0	0	0	0	0	0
Molalla	100,000	0	0	0	0	0	100,000
Tualatin	0	0	0	0	0	0	0
Clackamas	1,257,700	0	0	0	0	0	1,257,700
mainstem Lower Willamette River	260,000	n/a	0	0	n/a	0	260,000
Columbia River estuary*	900,000	n/a	n/a	n/a	n/a		900,000
TOTAL	6,617,940	0	0	570,500	0	325,000	7,513,440

* Juvenile releases in the estuary are from broodstock collected in the Upper Willamette spring Chinook ESU.

Notes: Subbasins are listed from upstream to downstream based on 4th-field HUCs. “N/A” represents hatchery production addressed.

The Biological Opinion concluded that the proposed actions will likely result in changes in the abundance, productivity, population structure, and/or genetic integrity of the Upper Willamette River spring Chinook and winter steelhead ESUs. NOAA Fisheries found the following:

- The hatchery programs as described in the proposed actions appreciably reduce both the survival and recovery of listed spring Chinook and thus jeopardize the continued existence of the Upper Willamette spring Chinook ESU.
- The proposed actions do not appreciably reduce the survival and recovery of listed winter steelhead; thus, they do not jeopardize the continued existence of the Upper Willamette River winter steelhead ESU.
- The proposed actions will not result in the destruction or adverse modification of critical habitat for the listed Upper Willamette River ESUs.
- The proposed actions do not jeopardize the continued existence of or result in adverse modification of critical habitat for the following listed ESUs: Lower Columbia River Chinook and steelhead, Columbia River chum, Middle Columbia River steelhead, Snake River spring/summer Chinook, fall Chinook, steelhead, and sockeye, and Upper Columbia River spring Chinook and steelhead.

The reasonable and prudent alternative contained in the Biological Opinion identifies four measures that will avoid jeopardy of the Upper Willamette River spring Chinook ESU:

- Immediately reducing the number of hatchery fish spawning naturally
- Modifying the numbers and release locations of hatchery fish to reduce adverse ecological effects
- Developing locally adapted hatchery stocks
- Facilitating the identification of hatchery and naturally produced fish.

NMFS developed several additional conservation recommendations related to hatcheries:

- Recommendations for All Agencies:
    - Fund and/or continue to collaboratively develop Hatchery and Genetic Management Plans (HGMPs) for hatchery programs in the Upper Willamette River spring Chinook and winter steelhead ESUs (before September 30, 2003, with spring Chinook the highest priority).
    - Develop distinguishable marks (or a representative sample) for hatchery spring Chinook within each of the subbasins.
    - Develop production plans that minimize transfers of fish among hatcheries for rearing.
    - Consider relocating some of the mitigation hatchery production to Lower Columbia River “select areas” to reduce the number of surplus fish returning to hatcheries in the Willamette Basin.
- Agency-Specific Recommendations:
    - The U.S. Army Corps of Engineers should develop contingency plans for production goals (and release strategies) if future monitoring and evaluation suggest that

hatchery mitigation is not being used in fisheries and that the percentage of hatchery fish on the spawning grounds is high.

- ODFW should recycle adult hatchery (of known origin) salmon and steelhead captured at hatchery facilities within the Willamette Basin to promote the maximum harvest of hatchery fish in recreational fisheries and reduce the number of surplus fish at the end of the season.

3.2.5 Terrestrial Focal Species Population Delineation and Characterization

As described in Section 3.2.3, this plan uses focal habitats as an organizing concept to discuss the terrestrial focal species in the Willamette Basin. Both focal habitats and the populations of their associated terrestrial focal species are characterized below.

Much of the terrestrial analysis described in this plan, and the data tools included herein for application to conservation decisionmaking, originated with five types of data:

- Land cover (or vegetation) maps
- Species distributional data and maps
- Species-habitat relationship models
- Species attribute databases
- Conservation priority maps

Details regarding the manner in which these were used together are described, as are their individual and collective assumptions and limitations, in Section 1.4 of Appendix T.

At the project outset the Technical Technical Advisory Group (TTAG), after weighing the strengths and limitations of numerous sources of information for the above, recommended that for the first three items the spatial data layers and biological databases of the PNW-ERC be used as the primary source, and that for item #4 the IBIS database could be used after review and minor modification by the TTAG. For item #5, the primary sources suggested were the Priority Conservation Areas (PCAs) identified through application of the SITES model by TNC's *Ecoregional Assessment* (Floberg et al. 2004) and the Conservation-Restoration Opportunity Areas (CROAs) identified with extensive stakeholder input by the PNW-ERC's *Alternative Futures* analysis (Hulse et al. 2002). The TTAG reached this decision for the following reasons:

- The PNW-ERC maps are the only source that maps the predominant land cover or vegetation over the *entire* subbasin at fine (0.22 acre) resolution.

- The PNW-ERC database identifies species distributions at the sub-county scale. This information Moreover, we updated and refined this information using ORNHIC's Element of Record (EOR) database (the standard repository for documented records of most threatened, endangered, and sensitive species) and the Oregon Breeding Bird Atlas (Adamus et al. 2001) database.

- Of species-habitat models currently available for the subbasin, those of the PNW-ERC (Adamus et al. 2001) provide the greatest level of technical sophistication. Specifically, they recognize 34 land cover types and for each species they score these on a 0-10 scale. An alternative source (IBIS, Johnson and O'Neil 2002) recognizes just 14 cover types in this subbasin and scores them on a 4-level scale. Moreover, the PNW-ERC models are unique in that the scoring regime for each species takes into account the adjacency of a particular pixel (patch of potential habitat) to other pixels, as determined through an automated (GIS) process for each of the 2 million-plus pixels that comprise the Willamette subbasin.

- All the above sources had previously undergone extensive peer review.

The terrestrial habitat analysis presented in this plan (and incorporated in its data tools) encompasses all terrestrial vertebrates, but the narrative accounts for practical reasons are limited to 55 focal species. The process used to select these species is described in Section 3.2.3.2.

Appendix F contains historical and current range maps. These maps are based on occurrence of habitat "associations." The maps only predict habitat associations and do not ensure the species is or could be present. The maps are intended to show overall distribution patterns and should not be used without field data to infer possible presence of a species or its habitat on a particular land parcel. Models used to plot these maps were peer-reviewed but not field-validated. The maps themselves have not been peer reviewed or field-verified. The maps have not incorporated all observations of sensitive species from specific locations, as reported to the ORNHIC. Alternative maps showing finer gradations of habitat suitability could be generated by alternative existing models but were not, due partly to time and resource constraints of this project.

3.2.5.1 Focal Habitat: Oak Woodlands

Definition. For purposes of this plan, oak woodland is defined as stands of Oregon white oak (*Quercus garryana*), with either closed canopies (oak forest) or with open canopy but tree densities of generally greater than about 100 trees per acre (oak woodland). At least during recent decades, oak woodlands have increasingly become oak forests with Doug-fir (*Pseudotsuga menziesii*) as a common co-dominant. Oak woodlands may include the following seven plant communities recognized by TNC’s *Ecoregional Assessment*:

- Oregon white oak—Oregon ash/common snowberry
- Oregon white oak—long-stolon sedge—common camas
- Oregon white oak—wedgeleaf ceanothus—Roemer’s fescue
- Oregon white oak—Roemer’s fescue
- Oregon white oak—common snowberry—long-stolon sedge
- Oregon white oak—common snowberry—sword fern
- Oregon white oak—oval-leaf viburnum—poison-oak

Recognition of Importance. Oak woodland has been identified explicitly as a priority for protection and restoration in nearby regions and specifically in the Willamette Basin. Although no legally-listed threatened or endangered species use oak woodland predominantly, several may use it periodically or as part of an overall mosaic of natural habitats. Several occur along oak woodland edges. These include the following legally listed species: Kincaid’s lupine and Fender’s blue butterfly (both federal—endangered); vesper sparrow (state—critical); and sharptail snake, western rattlesnake, and western bluebird (state-vulnerable). Wildlife species that may have used oak woodland regularly before vanishing (as breeders) from the Willamette Basin include: Lewis’s woodpecker, black-billed magpie, and lark sparrow. Thirteen of 27 plant associations listed as occurring in oak woodlands in the National Vegetation Classification are considered globally imperiled or critically imperiled by the Oregon Natural Heritage Program.

Status and Distribution. No maps showing oak woodlands are available for the entire basin. Thus, no completely reliable data are available on the present extent of this habitat type. Nonetheless some existing vegetation and land cover maps use categories that include oak to a varying and uncertain extent (herein termed “mixed oak”). The Eugene BLM office also has mapped oak woodlands, but just in southern portions of the Willamette Basin. In some assessments, one of the maps of current mixed oak has been overlaid on a map of historical distribution of oak woodlands (from General Land Office records of the 1800s) in order to discern “true” (presumably the most sustainable) patches of remaining oak woodland. However, the actual “purity” of the historical oak categories is unknowable.

Table 3-45 shows acreage estimates of land cover types in the Willamette Basin that include oak woodlands.

Table 3-45: Acreage Estimates of Land Cover Types That Include Oak Woodland

Source	Map Categories That Include Oak Woodland	Estimated Area (Acres)	Percent of Mapped Area
EC1850	“oak savanna”	527,136	7.23
EC90	“hardwood semiclosed upland”	106,448	1.46
IBIS—1850	“westside oak & dry Douglas-fir forest and woodlands”	1,864,879	25.98
IBIS -1990	“westside oak & dry Douglas-fir forest and woodlands”	285,280	4.00
ODFW*	“oak—Douglas fir >50 percent oak”	61,580	3.18

* Valley only—not entire basin.

Past Impacts, Limiting Factors, and Future Threats. Setting aside the data limitations described above, a rough comparison of the historical distribution of oak woodland with current distribution of mixed oak suggests that more than 1.5 million acres have been converted to other vegetation or land cover types over the past 150 years. Both the historical and current oak woodland occurs mostly in the southern and western portions of the Willamette Basin. Most of the mixed oak map category exists on private land.

Much of the remaining oak woodland exists in the foothills where expanding vineyards and Christmas tree plantations, as well as residential developments, have been removing oak woodlands. Ironically, land use regulations may be one of the largest causes of oak woodland loss because policies tend to direct development to oak woodlands, inasmuch as oak woodland in its natural state generates little income from agriculture or forestry (Steve Smith, pers. comm.).

In many of the oak woodlands that remain, oaks are stunted due to overcrowding and production of mast (acorn) may consequently decline. This has occurred largely as a result of decades of fire suppression. Overcrowding of oaks and invasion of oak stands by faster-growing Douglas-fir has reduced the amount of light reaching the woodland floor of most oak woodlands, thus reducing the percent cover and diversity of understory plants. This trend toward structural simplification and smaller-diameter trees has been documented as having adverse effects on at least 12 bird species (Hagar & Stern 2001). Unfortunately, in oak woodlands that are regulated by the Oregon Forest Practices Act, harvested oaks must be replaced with conifers (150/ac) unless prior exemption is requested. In running computer simulations of future environmental conditions in the Willamette Basin, one researcher (Payne 2002) assumed the maximum rate at which Douglas-fir might invade oak stands to be about 100 lateral feet per 15 years, as opposed to an expansion rate for oak of 100 ft per 100 years. Oak stands that are perhaps least vulnerable to Douglas-fir dominance are those in the driest settings.

Surely the most potent future threat to oak woodland is Sudden Oak Death, a disease that is decimating California oaks and has begun spreading to Oregon. Depending on accompanying changes in precipitation patterns, global warming has the potential to create microclimates in the Willamette Basin that are even more favorable for oak woodlands. Especially near urban areas and roads, oak woodlands are vulnerable to invasive plants such as English ivy (*Hedera helix*), false-brome (*Brachypodium sylvaticum)*, and scotch broom *(Cytiscus scoparius).* Minor harvesting of oaks for firewood and lumber also occurs.

Contribution of Oak Woodlands to Regional Biodiversity. Compared with other Willamette habitat types, oak woodlands in good condition provide the best habitat for 37 wildlife species, and are used regularly by at least an additional 100 wildlife species. The oak woodland avifauna includes 27 birds whose numbers appear to be declining regionally.

Selected Focal Species in Oak Woodlands. The following wildlife species are proposed as focal species for this habitat type: acorn woodpecker, chipping sparrow, western wood-pewee, white-breasted nuthatch, southern alligator lizard, sharptail snake, and western gray squirrel.

On a scale of 0 to 10, these species' average degree of association with oak woodlands[9] is a 9.2. Compare this with HEP "loss assessment" species[10] used in many previous mitigation calculations and land acquisitions in the Willamette Basin. Of the "hardwood forest" species used in HEP applications, the average degree of association with oak woodlands is only 7.5. This suggests there may have been an unintentional but systematic bias against oak woodlands in previous mitigation land dealings in the Willamette Basin.

Acorn Woodpecker

Special Designations: "Species of Concern" (USFWS). Partners In Flight focal species.

Distribution, Status, and Trends: In the Willamette Basin this non-migratory, cavity-nesting species seldom occurs above 1000 ft elevation. Application of simple species-habitat models to aerial imagery (that did not delineate oak woodlands specifically) using GIS suggests 5.75 percent of the basin might contain habitat that could be at least marginally suitable and 0.26 might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed

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[9] Calculated from file HABTYPE, using the "Hardwood Open" class as a surrogate for oak woodland, which could not be mapped.

[10] HEP = Habitat Evaluation Procedure (USFWS 1980). HEP is the procedure that has been used most often by Bonneville Power Administration and other agencies to determine the amount of mitigation required for loss of habitat in the region due to construction of reservoirs.

nesting in 17 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 13 percent of the units[11] Along Willamette Basin BBS routes[12], the species was detected at 0.25 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 0.86 percent in 1976. Wintering birds are found by most basin CBCs; numbers are generally 10-30 birds per count area. Acorn woodpecker apparently was absent in the Willamette Basin until about 1920. Its spread northward has coincided with disappearance of the closely-related Lewis' woodpecker. BBS data covering the period 1968-2003 show a decrease in the Willamette Valley and western Oregon-Washington generally, with possibly a slight increase since 1980 in the Willamette. Several pairs may nest in the same oak stand, forming a loose colony. Populations may fluctuate in response to semi-annual cycles in acorn production, so several years of monitoring data are needed to infer trends.

Key Environmental Correlates: A main requirement seems to be a relatively open area, such as lawn or heavily grazed pasture, beneath a high canopy that contains some oaks (Simmons 2003). Occupied oak stands in Benton County had a mean density of 107 trees/ac and 167 trees/home range, with a mean diameter of 19.2 inches and 2 dead limbs per tree (Doerge 1978). Granary trees (required for storing acorns) are generally of large diameter. Generally not found within the interior of short, dense oak stands. Occupies patches of oak woodland of less than 1 acre in size provided additional oak stands are not too distant and other structural requirements are met (personal observation).

Threats, Limiting Factors, Population Viability: Although it seems to thrive where oaks are large, its increase in the basin also has coincided with increased canopy closure and stunting of oaks within remaining oak stands. Possibly the greatest threats are the gradual loss (due to fire suppression) of oak stands having at least a few larger-diameter trees, and increased traffic on roads between suitable oak stands thus endangering dispersing birds. This woodpecker sometimes nests along lightly-trafficked roads in suburbs and does not appear to be extremely sensitive to human presence, but its flycatching behavior may put it at greater risk around roads with high-speed traffic. No estimates are available of population size or viability.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- Maintain a mean oak tree diameter of at least 15 inches, with >20 percent of the trees larger than 22 inches.
- Maintain canopy cover of douglas-fir at less than 5 percent
- Maintain or create a deciduous (predominantly oak) canopy cover of less than 75 percent and a subcanopy cover of less than 50 percent

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[11] The area of each survey unit was 245 square miles, and obviously no unit could be surveyed in its entirety. Species occurrence in a unit means it was found in at least one spot within the unit—not necessarily throughout the unit—during at least one year (late spring and summer) 1995-1999. About 53 units were located entirely or mainly within the Willamette Basin.

[12] Beginning in 1968, an average of 8 Breeding Bird Survey (BBS) routes have been run each year in the Willamette Basin (range = 2 to 14), with 50 point counts conducted per route. As a result of this relatively small sample size none of the species trends reported herein and using the BBS data are statistically, unless noted otherwise.

Conservation Needs: Table 3-46 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-46: HUC6 Units with the Most Suitable Habitat for Acorn Woodpecker

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	1105	99	2.27
170900090101	Aurora	1	837	30	1.81
170900070306	W. Salem	1	780	211	1.68
170900090102	Woodburn; Hubbard	1	747	83	1.65
170900070305	Keizer; Spring Valley Cr.	1	1895	230	1.60

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Chipping Sparrow

Special Designations: Partners In Flight focal species.

Distribution, Status, and Trends: Application of simple species-habitat models to aerial imagery (that did not delineate oak woodlands specifically) using GIS suggests 5.75 percent of the basin might contain habitat that could be at least marginally suitable and 0.21 percent might contain higher-suitability habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 4` percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 54 percent. Along Willamette Basin BBS routes the species was detected at 2.25 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 10.80 percent in 1968. BBS data show a decrease for both the Willamette Valley and western Oregon-Washington generally over the period 1968-2003, with a possible increase in the larger region during 1980-2003. The Willamette Valley trends are statistically significant. At Finley NWR, this species was present on all surveyed plots in 1968 but was absent from all in 1994-96 (Hagar & Stern 1997).

Key Environmental Correlates: Within oak woodlands, the presence of a native shrub and herbaceous (especially grassy) understory appears to be important (Altman 2000), and the species is more common near edges and openings in oak woodlands or where trees are widely-spaced. Not correlated with oak height or diameter (Manuwal 1997).

Threats, Limiting Factors, Population Viability: Habitat loss and degradation is the greatest threat, with loss of an open grassy ground cover in oak woodlands being a likely limiting factor. Habitat degradation consists of increased density of oaks within stands as a consequence of fire suppression. Other limiting factors may include cowbird parasitism of nests. No estimates are available of population size or viability.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- Maintain or create multiple patches of native shrub cover (for example, snowberry, poison oak) and herbaceous openings within oak woodlands such that cover of native shrubs is 10-40 percent, cover of blackberries is <10 percent, and cover of herbaceous plants is 30-70 percent

And the following population objectives:

- Reverse declining BBS trends to achieve stable populations (trends of <2 percent/year) or increasing trends by 2020. Maintain cowbird parasitism rates below 5 percent within specific woodlands.

Conservation Needs: Table 3-47 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-47: HUC6 Units with the Most Suitable Habitat for Chipping Sparrow

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080601	Yamhill	1	2520	1	1.89
170900090102	Woodburn; Hubbard	1	1667	0	1.75
170900070303	Chehalem Cr.	1	3427	0	1.64
170900070301	Saint Paul	1	1838	0	1.54
170900110103	Sandy	2	4363	0	1.45

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Western Wood-Pewee

Special Designations: Partners In Flight focal species.

Distribution, Status, and Trends: This migratory species is fairly common in wooded and partly wooded landscapes of the Willamette Basin, except in moderate- and high-density residential areas and in landscapes with unbroken conifer forests. Application of simple species-habitat models to aerial imagery (that did not delineate oak woodlands specifically) using GIS suggests 9.95 percent of the basin might contain habitat that could be at least marginally suitable and 1.61 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 37 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 59 percent. Along Willamette Basin BBS routes the species was detected at 20 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 23 percent in 1974. BBS data covering the period 1968-2003 and 1980-2003 show a decrease in the Willamette Valley, but possibly an increase in western Oregon-Washington generally.

Key Environmental Correlates: A main requirement seems to be a somewhat open canopy of oaks or other deciduous trees, with few or no conifers (Schrock 2003). The understory may contain herbaceous plants or shrubs.

Threats, Limiting Factors, Population Viability: Possibly the greatest threats are the gradual loss (due to fire suppression) of oak stands having at somewhat open canopy, and increased conversion of its habitat to agriculture, conifer forest, or residential use. The species' flycatching behavior may put it at higher risk around roads with heavy traffic. Sometimes nests along lightly-trafficked roads in suburbs. No estimates are available of population size or viability.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- maintain canopy cover of Douglas-fir at less than 5 percent
- maintain or create a deciduous canopy cover of 40-85 percent of which more than 80 percent is oak

And the following population objective:

- reverse declining BBS trends to achieve stable populations (trends of <2 percent/year) or increasing trends by 2020.

Conservation Needs: Table 3-48 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-48: HUC6 Units with the Most Suitable Habitat for Western Wood-Pewee

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900090201	S. Canby	1	1263	99	2.91
170900090101	Aurora	1	960	30	2.46
170900010302	Fall & Delp Cr.	4	1871	235	2.29
170900040301	Blue River Reservoir & Cook Cr.	3	1775	359	2.23
170900010803	Waldo Lake; Black & Salmon Cr.	6	982	289	2.21

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

White-breasted Nuthatch

Special Designations: Partners In Flight focal species.

Distribution, Status, and Trends: In the Willamette Basin this non-migratory, cavity-nesting species diminishes rapidly above about 1000 ft elevation. Along Willamette Basin BBS routes the species was detected at 2.25 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 6.29 percent in 1971. BBS data covering the period 1968-2003 and 1980-2003 show a decrease in the Willamette Valley, but possibly an increase in western Oregon-Washington generally. Data from Willamette CBCs also suggest a long-term regionwide decline. Has nearly been extirpated from oak woodlands in Washington. Nesting densities of 3-6 birds/40 ac have been noted in Willamette oak woodlands (Hagar & Stern 2001). Of Willamette oak woodland birds, it is perhaps the most dependent on large-diameter oaks in semi-open stands (Hagar & Stern 2001). Application of simple species-habitat models to aerial imagery (that did not delineate oak woodlands specifically) using GIS suggests 4.93 percent of the basin might contain habitat that could be at least marginally suitable and 0.21 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 30 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 43 percent. Wintering birds are found by most basin CBCs.

Key Environmental Correlates: Strongly tied to the presence of large-diameter oak or ponderosa pine in semi-open stands, and occasionally associated with other hardwoods, uncommonly in floodplain deciduous forests. Generally not found within the interior of short, dense oak stands. May be sensitive to oak woodland patch size (stands larger than 90 ac had >0.8 birds/ac compared with 0.6 birds/ac in smaller patches; Hagar & Stern 1997).

Threats, Limiting Factors, Population Viability: Habitat loss and degradation is the greatest threat, and large-diameter oaks in semi-open stands are a likely limiting factor. Habitat degradation consists of conifer invasion of oak woodlands as a consequence of fire suppression. No estimates are available of population size or viability.

Biological Objectives: As adapted from the *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), habitat objectives should include the following, applied mainly to areas where oak woodland predominated historically, i.e., where elevation, soil, and other factors can support oak woodland:

- oak canopy cover within woodlands of 40-80 percent
- non-oak canopy cover within woodlands of less than 10 percent
- mean oak tree diameter of >22 inches with 20 percent of the oaks larger than 28 inches
- at a landscape scale, oak woodland patches should be at least 100 ac in size, with at least one patch per watershed (fifth-field HUC) being larger than 300 acres if soil and elevation conditions are suitable for this

And the following population objective:

- achieve stable or increasing populations within 10 years

Conservation Needs: Table 3-49 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-49: HUC6 Units with the Most Suitable Habitat for White-Breasted Nuthatch

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	1105	99	2.38
170900090101	Aurora	1	837	30	1.96
170900070306	W. Salem	1	780	211	1.76
170900060101	Crabtree Cr. & Onehorse Slough	1	1084	0	1.67
170900070305	Keizer; Spring Valley Cr.	1	1895	230	1.59

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Sharptail Snake

Special Designations: "Vulnerable" (ODFW). "Rare, threatened, or uncommon" (ONHP).

Distribution, Status, and Trends: Based on information from other states, this species probably occurs in suitable habitat in all parts of the Willamette Basin, but documented records are few. The ORNHIC database contains documented records from 8 of the 170 Willamette watersheds. Little is known of status or trends. Some evidence suggests the Willamette population may be a separate race or species (Hoyer 2001).

Key Environmental Correlates: South-facing talus slopes provide critical sites for egg incubation and hibernation. The relatively few records from the Willamette Basin are mainly from lowland oak woodlands. However, data from other areas suggest that if ground cover (logs, boulders, etc.) is adequate this snake may occur in conifer forests, clearcuts, deciduous riparian areas, low-density residential areas, and grasslands at any elevation (Nussbaum et al. 1983, Leonard & Ovaska 1998). Feeds largely on slugs.

Threats, Limiting Factors, Population Viability: No estimates are available of population size or viability, but among the snake species currently inhabiting the basin its rarity appears to be second only to that of western rattlesnake. Threats might include conversion of woodlands to agriculture land cover; fragmentation of habitat by roads; mining near talus slopes; decimation of invertebrate foods by pesticides; influence of non-native soil invertebrates on soil leaf litter and slugs; reduced subsoil moisture (required by slugs) as a result of agricultural drainage, global warming, and groundwater extraction; and removal of downed wood by landowners (for example, for fire risk reduction or landscaping).

Biological Objectives:

- Maintain or increase downed wood (especially large-diameter logs) within oak woodlands
- Survey and maintain or increase present population in the basin.

Conservation Needs: Table 3-50 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-50: HUC6 Units with the Most Suitable Habitat for Sharptail Snake

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080502	Amity	1	3274	3133	3.03
170900070102	Independence; Monmouth	1	3606	3191	2.80
170900030602	Soap Cr.	1	2287	1714	2.45
170900030101	W. Eugene; Junction City	1	5345	3820	2.03

Table 3-50: HUC6 Units with the Most Suitable Habitat for Sharptail Snake

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900020301	Cottage Grove Reservoir N.	2	2635	2120	1.00

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Southern Alligator Lizard

Special Designations: None

Distribution, Status, and Trends: Apparently uncommon to common within lower elevations of the basin. Found at 1 of 10 oak woodland sampling sites in 1997-1998 (Vesely et al. 1999). No trends information is available.

Key Environmental Correlates: Reported from “open, dryer hillsides and oak woodlands, usually where there are clumps of poison oak and other brush” (St. John 1987).

Threats, Limiting Factors, Population Viability: Threats might include fragmentation of habitat by roads; decimation of invertebrate foods by pesticides; and removal of downed wood by landowners (for example, for fire risk reduction or landscaping).

Biological Objectives:

- Maintain or increase semi-open oak woodlands, especially near rocky areas..
- Maintain or increase present population in the basin.

Conservation Needs: Table 3-51 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-51: HUC6 Units with the Most Suitable Habitat for Southern Alligator Lizard

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	3482	1947	3.89
170900080601	Yamhill	1	3900	2110	3.63
170900090101	Aurora	1	2398	1343	3.60

Table 3-51: HUC6 Units with the Most Suitable Habitat for Southern Alligator Lizard

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900070301	Saint Paul	1	2444	1463	3.44
170900080702	Lafayette	1	2412	1131	3.36

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Western Gray Squirrel

Special Designations: ODFW “status uncertain.”

Distribution, Status, and Trends: Widely distributed within the basin’s deciduous woodlands, especially at lower elevations. No data on density or trends are available, but in southern Oregon a density of 3/ac was documented in one area over a 2-year period (Cross 1969). Populations fluctuate partly in response to semi-annual cycles in acorn production so several years of monitoring data are needed to infer trends.

Key Environmental Correlates: Acorns comprise a major portion of diet so this species inhabits oak woodlands extensively but not exclusively. Also occurs in riparian woodlands, orchards, and mixed forest. Nests (dreys) are constructed in tall trees but large tree cavities also are apparently important for birthing, sleeping, and shelter.

Threats, Limiting Factors, Population Viability: Loss of contiguous oak woodland and degradation of remaining tracts (i.e., reduced occurrence of large oaks suitable for nest cavities) may limit populations. Populations also have been impacted by disease (mange), at least in Washington (Larsen & Morgan 1998). Increased fragmentation of woodlands with heavily trafficked roads may be having a substantial impact, as roadkill of dispersing squirrels appears to be common.

Biological Objectives:

- Maintain or increase conditions supportive of sustaining a supply of large oaks within woodlands
- Survey and maintain (or increase) the present population in the basin.

Conservation Needs: Table 3-52 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate oak woodlands specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-52: HUC6 Units with the Most Suitable Habitat for Western Gray Squirrel

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	6282	3646	4.66
170900030503	Mary’s R. -upper	2	7081	6591	4.47
170900120202	S. Milwaukie; Happy Valley; Lake Oswego; W	1	2987	2454	4.43
170900110103	Sandy	2	12366	7984	4.24
170900060701	Sweet Home; Foster Reservoir	3	12649	12497	4.15

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

3.2.5.2 Focal Habitat: Upland Prairie, Savanna, and Rock Outcrops

Description. For purposes of this plan, upland prairie is defined as communities where native grasses (especially bunchgrasses) and forbs predominate, with little or no woody vegetation, and not dominated by hydric soils or plant communities characteristic of wetland environments. When shrubs and/or trees are also present but make up less than 30 percent canopy cover, the habitat is termed “savanna” and some authors have grouped this with oak woodland rather than with upland prairie. Likewise, some authors have grouped upland (dry) prairie with wetland prairie. This plan includes herbaceous balds, bluffs, talus slopes, and rock outcrops under the upland prairie-savanna category, although rocky conditions sometimes occur within other cover types, and certainly not all upland prairie occurs in rocky areas. Also included are caves, which are generally rare in the Willamette Basin.

Upland prairie/savanna occurs primarily on hillslope meadows and forest clearings at generally low elevations, where soils are mostly shallow, well-drained, and subject to chronic natural disturbance. At least historically, prairies, savanna, and oak woodlands formed a successional mosaic throughout lower-elevation parts of the Willamette Basin. Many such areas were maintained by fire, often set intentionally by indigenous tribes. The major native dominant bunchgrass is Roemer’s fescue (*Festuca idahoensis* var. *roemeri*). More locally, red fescue (*F. rubra*), California oatgrass (*Danthonia californica*) sometimes are dominant or co-dominant. Common camas (*Camassia quamash*) is a frequent forb, as is bracken fern (*Pteridium aquilinum*). The presence of several native slow-growing, colorful forbs also is characteristic of upland prairies. The scattered native shrubs include common snowberry (*Symphoricarpos albus*), Nootka rose (*Rosa nutkana*), poison- oak (*Toxicodendron* *diversilobum*), and serviceberry (*Amelanchier alnifolia*), and trees are typically Oregon white oak and (especially in presettlement times) ponderosa pine (*Pinus ponderosa*).

Recognition of Importance. Upland native prairie is among the rarest of North American ecosystems. Upland prairie-savanna has been identified explicitly as a priority for protection and restoration in nearby regions and in the Willamette Basin specifically. Much of the recent attention directed at this habitat has been due to its hosting three federally listed species: Golden Paintbrush (*Castilleja levisecta*, now extirpated from the basin), Kincaid's lupine (*Lupinus sulphureus var kincaidii*), and Fender's blue butterfly (*Icaricia icarioides fenderi*). In addition, this habitat hosts the streaked race of the horned lark (currently being considered for federal listing); vesper sparrow (state-listed as "critical"); and sharptail snake, western rattlesnake, and western bluebird (all state-listed as "vulnerable"). Wildlife species that may have used savanna regularly before vanishing as breeders from the Willamette Basin include Lewis's woodpecker, black-billed magpie, lark sparrow, and Oregon spotted frog. Literature pertaining to wildlife of grasslands and including the Willamette Basin was reviewed by Altman et al. (2001), and two useful web sites provide bibliographies, botanical information, and research news on Willamette prairies:

http://oregonstate.edu/~wilsomar/Index.htm and http://www.appliedeco.org/reports.html

Status and Distribution. No maps showing upland prairie and/or savanna are available for the entire basin. Thus, no completely reliable data are available on the present extent of this habitat type. Nonetheless, some existing vegetation and land cover maps use categories that include upland prairie/savanna to a varying and uncertain extent (see Tables 3-53 and 3-54).

Table 3-53: Acreage Estimates of Land Cover Types That Include Upland Prairie-Savanna

Source	Map Categories that Include Upland Prairie and/or Savanna	Estimated Area (Acres)	Percent of Mapped Area
EC1850	"oak savanna" + "grass natural"	1,294,450	17.76
EC90	"grass natural"	22,041	0.30
IBIS	--		
ODFW*	"unmanaged pasture"	171,558	8.84
TNC	"Upland prairie & savanna" "Herbaceous balds & bluffs"		

* Valley only—not entire basin

Table 3-54: Remaining Upland Prairies of the Willamette Valley*

Site	County	Ownership	Quality
Bald Hill	Benton	Corvallis	Medium-high
Baldy (Finley NWR)	Benton	FWS	Low
Baskett Butte	Polk	FWS	Low- high

Table 3-54: Remaining Upland Prairies of the Willamette Valley*

Site	County	Ownership	Quality
Butterfly Meadows	Benton	Private, OSU	Medium-very high
Camassia Natural Area	Clackamas	TNC	Medium
Carson Prairie	Benton	OSU	High
Coburg Ridge	Lane	Private	Medium-very high
Dallas	Polk	Private	Medium
Dolph Corner Hills	Polk		Low
Dorena Prairie	Lane	BLM	Medium
Edison Road Grassland	Marion		Medium
Fern Ridge	Lane	COE	Low-medium
Fir Butte	Lane	Eugene	Low
Fire Knob	Marion		Medium
Forest Peak	Benton	OSU/BLM	Medium-high
Grand Ronde Strip	Polk	Private?	Low
Henkle Way	Benton		Unknown
Hidden Oaks	Marion		Medium
Hilaire Rd.	Lane	Private	Low
Horse Rock Ridge	Linn	BLM	Low-very high
Jackson Prairie	Benton	OSU	Low
Kingston Meadows	Linn	Private	Low-very high
McKenzie Drive	Lane	Private	Medium
Mill Creek	Polk	ODOT	Low-medium
Mt. Pisgah	Lane	Lane Co	Medium
NE of Estacada	Clackamas		Low
Noble Pasture	Benton	Private	Low-high
Oak Ridge	Yamhill	Private	Low-medium
Open Space Park	Benton	County	Medium-high
Peterson Butte	Linn	Private	Low
Philomath Prairie	Benton	Private	Low-high
Pigeon Butte	Benton	FWS	Low-medium
Rattlesnake Butte	Lane	TNC, US Bank	Medium
Riches Road	Marion	Private	Low

Table 3-54: Remaining Upland Prairies of the Willamette Valley*

Site	County	Ownership	Quality
Row Point	Lane	COE	Medium
Sanford Drive	Lane	Private	Medium
Shafer Creek	Benton		Unknown
Shoulder-to-Shoulder Farm	Benton	Private	Medium
Spencer Butte Summit	Lane	Eugene	Medium
Sublimity Grassland Preserve	Marion	TNC Easement	Medium-high
Tower Ridge	Marion		Low
Twin Buttes	Linn		Low
Unnamed Butte	Yamhill		Low
West Hills Road	Benton	Private	Medium
Willow Creek	Lane	TNC	Low-medium
Wisner Cemetery	Linn	Private	Low
Wren	Benton	TNC	Medium-high

Source: Wilson (1998)

* Savanna, roadside, and very small sites are excluded, as are sites that formerly were prairie but now are dominated by non-native vegetation.

Past Impacts, Limiting Factors, and Future Threats. Upland prairies were among the first habitats to be plowed by early settlers of the Willamette Valley. Plowing altered the native plant and animal communities, but not nearly as severely as later development would. Grazing also occurred, first with free-ranging livestock and eventually within fenced prairies. This, along with increasing size of farms as farm machinery became more effective, changed the early landscape from a patchwork of small scattered farms interspersed with prairies to the monocultural expanses that prevail today. In the 1990s, many landowners established hybrid poplar plantations on former prairies. Most of these plantations are now being cut and not replanted. Because it is generally infeasible to convert them to cropland (due to extensive left-over stumps and roots), this may pose an opportunity for restoration to prairie habitat.

Both the historical and present upland prairie/savanna occurring mostly in the southern and western portions of the basin. Most exists on private land.

Much of the upland prairie-savanna that remains exists in the foothills. There, the acreage of vineyards and Christmas tree plantations, as well as residential neighborhoods, has been expanding As is true of oak woodlands, land use regulations and property tax policies contribute to loss of this habitat type because upland prairie-savanna, unless planted with trees or crops, generates little income. A few of the rare plants characteristic of upland prairie-savanna persist as well along shoulders of rural roads and other rights-of-way, but are vulnerable there to routine herbicide applications.

Most of the few remaining areas of upland prairie-savanna, if not being planted with trees on purpose, are changing to upland forest through natural succession. This has occurred largely as a result of decades of fire suppression. It is mainly the sites located in extremely rocky, steep terrain that have not succumbed to this or to development pressures. Upland prairie-savanna is vulnerable to invasion by a wide variety of plants, both herbaceous (for example, tall oatgrass, *Arrhenatherum elatius*) and woody (for example, scotch broom), and both native (for example, snowberry) and non-native (for example, Himalayan blackberry). These form dense patches that exclude most native plant species, consequently altering habitat structure. In some situations grazing may help check the spread of invasive shrubs (for example, short-duration, high-intensity grazing by goats) whereas in other situations it can serve as a vector for introduction or spread of non-native grasses and forbs. If global warming results in increased frequency and severity of drought in the basin, the area of upland prairie might eventually increase, provided seed banks in the soil are still viable.

Contribution of Upland Prairie-Savanna to Regional Biodiversity. In the Willamette Basin, this habitat includes the most endemic species (species that occur nowhere else in the world). Upland prairie in good condition provides the best reproductive habitat for 22 wildlife species, and is used regularly by at least an additional 56 breeding wildlife species. Adding the list of oak savanna species to the upland prairie list brings the total number of potentially-occurring wildlife species in upland prairie-savanna to 135. Several species associated with upland prairie also use wetland prairie. Some use agricultural lands as well, perhaps at some cost to reproductive success and survival. The upland prairie-savanna habitat type supports several birds whose numbers appear to be declining regionally, based on BBS data.

Selected Focal Species in Upland Prairie, Savanna, and Rock Outcrops. The following are proposed as focal species for this habitat type:

- Plants: golden paintbrush, white rock larkspur, white-topped aster, Kincaid’s lupine
- Wildlife: Fender’s blue butterfly, Taylor’s checkerspot butterfly, horned lark (streaked subspecies), vesper sparrow (Oregon subspecies), western meadowlark, western bluebird, western rattlesnake, black-tailed jackrabbit

On a scale of 0 to 10, these species’ average degree of association with upland prairie is a 7.0, and their association with savanna[13] is 8.3. Compare this with HEP “loss assessment” species used in many previous mitigation credit calculations and land acquisitions in the Willamette Basin. Of the “grass-forb” species used in HEP applications, the average degree of association with upland prairie is 4.6 and the association of HEP’s “hardwood forest” species is 7.7. This suggests there may have been an unintentional but systematic bias against upland prairie-savanna in previous mitigation land dealings in the Willamette Basin.

Golden Paintbrush (Castilleja levisecta)

Special Designations: “Threatened” (federal). “Endangered” (ODA). “Possibly Extirpated” (ONHP).

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[13] Calculated from file HABTYPE, using the “Oak Savanna” class as a surrogate for savanna, which could not be mapped, and the “Grassland Natural” as a surrogate for upland prairie.

Distribution, Status, and Trends: Attempts are currently being made to re-establish this apparently extirpated species which occurs only in the Pacific Northwest. This species is an herbaceous perennial that may reproduce only by seed, although clumps may spread vegetatively over short distances.

Key Environmental Correlates: Occurs in shallow soils at unshaded or partly shaded locations in lowlands or foothills. Also probably once occurred on edges of wetland prairies.

Threats, Limiting Factors, Population Viability: Its extirpation apparently has been caused by loss and degradation of upland prairie-savanna habitat. Some types of controlled burns and mowing may benefit this species. Other factors that have been cited as contributing to its disappearance include gravel mining and grazing by both livestock and by wildlife.

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management. The species recovery plan (USFWS 2000) describes objectives and identifies population reintroduction and development of propagation methods as high priority actions to meet the recovery objectives.

Important References: Kaye 2001, Kaye & Lawrence 2003

White Rock Larkspur (Delphinium nuttallii ssp. ochroleucum)

Special Designations: “Endangered” (ODA). “Imperiled” (ONHP).

Distribution, Status, and Trends: Occurs in the northern part of the basin and at one Washington location. Currently exists at fewer than 20 locations. The ORNHIC database contains documented records from 9 of the 170 Willamette watersheds.

Key Environmental Correlates: Requires relatively dry prairies.

Threats, Limiting Factors, Population Viability: Its extirpation apparently has been caused by loss and degradation of upland prairie-savanna habitat. Drift of herbicides applied during agricultural operations and roadside maintenance may also be having an effect.

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-55 contain records of this species in the ORNHIC database.

Table 3-55: HUC6 Units with ORNHIC Database Records for White Rock Larkspur

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900070301	Saint Paul	1	yes	yes
170900070403	Oregon City; West Linn	1	no	no
170900120202	S. Milwaukie; Happy Valley; Lake Oswego; W	1	no	no
170900070402	N. Canby; E. Wilsonville	1	no	yes
170900070403	Oregon City; West Linn	1	no	yes

Table 3-55: HUC6 Units with ORNHIC Database Records for White Rock Larkspur

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900100102	Hillsboro	1	no	yes
170900110101	Estacada; E. Gladstone	1	no	yes
170900110102	Clear Cr.	1	no	yes
170900090401	Scotts Mills Senecal Cr. & Mill Cr.	2	no	yes
170900090501	Molalla	2	no	yes
170900090501	Molalla	3	no	yes

Elevation zones (Elev) are:
1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft
PCA = Priority Conservation Area.

White-topped (Curtus's) Aster (Aster curtus = Sericocarpus rigidus)

Special Designations: "Threatened" (ODA). "Imperiled" (ONHP).

Distribution, Status, and Trends: Restricted to the Pacific Northwest. The ORNHIC database documents records from 8 of the 170 Willamette watersheds.

Key Environmental Correlates: Requires relatively dry prairies.

Threats, Limiting Factors, Population Viability: Its extirpation apparently has been caused by loss and degradation of upland prairie-savanna habitat. Other threats include the continued loss or degradation of habitat due to development, grazing, and off-road vehicle use.

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-56 contain records of this species in the ORNHIC database.

Table 3-56: HUC6 Units with ORNHIC Database Records for White-Topped (Curtus's) Aster

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900030101	W. Eugene; Junction City	1	yes	yes
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	yes	yes
170900090702	Drift Cr.	2	no	no
170900090704	Silverton S.	2	no	no
170900030103	Coyote Cr.	3	no	no
170900030101	W. Eugene; Junction City	1	no	yes

Table 3-56: HUC6 Units with ORNHIC Database Records for White-Topped (Curtus's) Aster

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	no	yes
170900030103	Coyote Cr.	1	no	yes
170900070403	Oregon City; West Linn	1	no	yes
170900020102	Creswell W.; Camas Swale	2	no	yes
170900030103	Coyote Cr.	2	no	yes
170900050601	Jefferson; Lyons; Bear Branch	2	no	yes
170900090702	Drift Cr.	2	no	yes

Elevation zones (Elev) are:
1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft
PCA = Priority Conservation Areas

Kincaid's Lupine (Lupinus sulphureus var. kincaidii)

Special Designations: "Threatened" on both federal and state lists. "Imperiled" (ONHP).

Distribution, Status, and Trends: Occupies 51 sites comprising 357 acres and located within 21 of the 170 watersheds in the Willamette Basin (ORNHIC data). It persists in the areas where upland prairie has been protected but future survival will require active management within these areas and probably the protection of additional upland prairies.

Key Environmental Correlates: The species is restricted almost entirely to upland prairie. Although sometimes found on steep grassy slopes and rock outcrops, these habitats are usually too dry to sustain significant populations. The lupine is a long-lived (up to 25 years) perennial that requires pollination by insects. Populations have been invigorated by controlled burns, fall mowing, and other measures to reduce shading (Clark & Wilson 1998). The species is amenable to re-establishment in suitable habitats using seeding or transplants.

Threats, Limiting Factors, Population Viability: Habitat loss and degradation are the main limiting factors. Long-term viability depends largely on control of shading plants, reducing competition from invasive herbaceous plants, and maintaining pollinator populations.

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-57 contain records of this species in the ORNHIC database.

Table 3-57: HUC6 Units with ORNHIC Database Records for Kincaid's Lupine

HUC6	Watershed Name (Not Comprehensive)	Elevation	Public Land?	In PCA?	Habitat Suitability Score
170900080601	Yamhill	1	no	no	2.49
170900070102	Independence; Monmouth	1	no	no	1.54
170900030601	Luckiamute R.4	1	no	no	1.24
170900030606	Little Luckiamute R.—lower	1	no	yes	0.75
170900080603	Panther & Haskins Cr.	1	no	no	0.75
170900030504	Finley NWR; Muddy & Hammer Cr.	1	no	yes	0.74
170900080403	Deer Cr.	1	no	no	0.74
170900030602	Soap Cr.	1	no	yes	0.73
170900030604	Luckiamute R.2.	1	no	no	0.65
170900030103	Coyote Cr.	1	no	yes	0.55
170900030103	Coyote Cr.	2	no	no	0.53
170900030501	Corvallis; Philomath; Mary's R.-lower	1	no	yes	0.50
170900030603	Luckiamute R.1.	1	no	no	0.49
170900070101	Baskett Slough NWR	1	yes	yes	0.41
170900030502	Mary's R -middle	2	no	no	0.33
170900080403	Deer Cr.	1	no	yes	0.32
170900030101	W. Eugene; Junction City	1	no	yes	0.25
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	no	yes	0.21
170900030504	Finley NWR; Muddy & Hammer Cr.	1	yes	yes	0.16
170900030502	Mary's R -middle	2	no	yes	0.12
170900080301	Mill & Gooseneck Cr.	1	no	yes	0.10
170900080603	Panther & Haskins Cr.	2	no	yes	0.08
170900080604	Turner Cr.	2	no	yes	0.07
170900030201	Corvallis N.; Adair Village	2	no	no	0.04
170900030101	W. Eugene; Junction City	1	yes	yes	0.03
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	yes	yes	0.03
170900030501	Corvallis; Philomath; Mary's R.-lower	3	no	yes	0.02
170900040201	Horse & Parsons & Cash & Mill Cr.	3	no	yes	0.01

Table 3-57: HUC6 Units with ORNHIC Database Records for Kincaid's Lupine

HUC6	Watershed Name (Not Comprehensive)	Elevation	Public Land?	In PCA?	Habitat Suitability Score

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Important References: Kaye & Kuykendall 2001, Kaye & Cramer 2002

Fender's Blue Butterfly

Special Designations: "Endangered" (federal). "Critically Imperiled" (ONHP).

Distribution, Status, and Trends: Once thought extirpated from the Willamette Basin, it was rediscovered in 1989. The population fluctuates annually but current estimates are of about 3,000 to 4,000 individuals at about 32 sites in 12 (of 170) watersheds in the Willamette Basin.

Key Environmental Correlates: Distribution parallels that of Kincaid's lupine (see above), upon which it is completely dependent. Thus, it is restricted to upland prairie and shares the same requirements as the lupine. Biological information is summarized in Schultz et al. (2003).

Threats, Limiting Factors, Population Viability: Habitat loss and degradation are the main limiting factors. Of 12 sites identified as having this species in 1991, agricultural or urban development had caused habitat loss in six sites by 1997 (Hammond 1998). Habitat destruction is the largest threat to the survival of both the Fender's blue butterfly and Kincaid's lupine (USFWS 1998). Pesticide drift has the potential to imperil local populations in some instances. Population viability is discussed by Schultz & Hammond (2003).

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-58 contain records of this species in the ORNHIC database.

Table 3-58: HUC6 Units with ORNHIC Database Records for Fender's Blue Butterfly

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?	HS
170900070102	Independence; Monmouth	1	no	no	1.63
170900030101	W. Eugene; Junction City	1	no	no	1.10
170900030606	Little Luckiamute R.—lower	1	no	yes	0.89
170900080403	Deer Cr.	1	no	no	0.84
170900030604	Luckiamute R.2.	1	no	no	0.76

Table 3-58: HUC6 Units with ORNHIC Database Records for Fender's Blue Butterfly

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?	HS
170900030501	Corvallis; Philomath; Mary's R.-lower	1	no	yes	0.58
170900070101	Baskett Slough NWR	1	yes	yes	0.44
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	no	yes	0.24
170900030502	Mary's R -middle	2	no	yes	0.17
170900070102	Independence; Monmouth	2	no	yes	0.15
170900030606	Little Luckiamute R.—lower	2	no	no	0.12
170900080301	Mill & Gooseneck Cr.	1	no	yes	0.12
170900080604	Turner Cr.	2	no	yes	0.09
170900070102	Independence; Monmouth	2	no	no	0.07
170900040101	E. Springfield; Camp & Ritchie Cr.	3	no	yes	0.05
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	yes	yes	0.03
170900030501	Corvallis; Philomath; Mary's R.-lower	3	no	yes	0.03

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

PCA = Priority Conservation Areas.

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Taylor's Checkerspot Butterfly

Special Designations: "Candidate" for listing (federal). "Critically Imperiled" (ONHP).

Distribution, Status, and Trends: Only five sites are known for this subspecies. The ORNHIC database contains documented records from just 3 of the 170 Willamette watersheds.

Key Environmental Correlates: Requires relatively dry prairies.

Threats, Limiting Factors, Population Viability: Habitat loss and degradation are the main limiting factors. Fire, even from prescribed burns, has contributed to loss of this subspecies. Drift of pesticides—even the relatively benign BTK formulation—has the potential to imperil local populations in some instances. The viability of the few remaining populations is questionable.

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-59 contain records of this species in the ORNHIC database.

Table 3-59: HUC6 Units with ORNHIC Database Records for Taylor's Checkerspot Butterfly

HUC6	Watershed Name (Not Comprehensive)	Elevation	Public land?	In PCA?
170900030501	Corvallis; Philomath; Mary's R.-lower	2	yes	yes
170900030501	Corvallis; Philomath; Mary's R.-lower	2	no	yes
170900030502	Mary's R -middle	2	no	yes
170900030602	Soap Cr.	2	yes	yes

PCA = Priority Conservation Area.

American Kestrel

Special Designations: Partners In Flight focal species.

Distribution, Status, and Trends: This resident species once bred commonly in savanna and forest edges in the Willamette Basin, and is still moderately common. Application of simple species-habitat models to aerial imagery using GIS suggests 4 percent of the basin might contain habitat that could be at least marginally suitable and less than 1 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 28 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 48 percent. Along Willamette Basin BBS routes the species was detected at fewer than 1 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 3.25 percent in 1968. BBS data covering the period 1968-2003 and 1980-2003 show decreases in the Willamette Valley and western Oregon-Washington generally, but perhaps not in the Cascades. At least 525 were present almost simultaneously in January 2004 in farmlands of Lane-Linn-Benton-Polk-Yamhill-Marion Counties (J. Fleischer, pers. comm.).

Key Environmental Correlates: For nest sites, kestrels require tree cavities excavated by other species, but will occasionally use nest boxes. Nests are within or along the edge of clearcuts, pastures, or other open areas dominated by grasses and forbs. Kestrels generally do not nest or forage in closed-canopy forest or in fields totally overgrown by shrubs. At all seasons, requires elevated perch within or along a field.

Threats, Limiting Factors, Population Viability: Habitat loss and degradation have been the greatest contributors to decline of the species in the basin. Being largely insectivorous, kestrels are vulnerable to pesticide-related reductions in their prey. Also, increases in residential development are typically accompanied by increases in European starling and house sparrow, non-native species that usurp nesting cavities. Increased high-speed traffic on rural roads also may contribute to mortality.

Biological Objectives:

- Manage woodlands to provide a sustained supply of cavities (especially in oaks) in trees of at least 24 inch diameter and located either along forest edges that adjoin open areas or within the open areas themselves, i.e., areas with <30 percent canopy.

Population objectives should include:

- Achieve stable populations (negative trends of less than 2 percent per year) or increasing trends by 2010.

Conservation Needs: Table 3-60 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-60: HUC6 Units with the Most Suitable Habitat for American Kestrel

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080601	Yamhill	1	2096	1	1.00
170900070301	Saint Paul	1	1510	0	0.96
170900050103	Pyramid Cr.	5	315	49	0.91
170900090201	S. Canby	1	2190	0	0.90
170900080702	Lafayette	1	1232	0	0.87

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Horned Lark (strigata subspecies)

Special Designations: The streaked (*strigata*) subspecies of horned lark was proposed for federal listing in 2002. “Critical” (ODFW). “Critically Imperiled” (ORHP). Partners In Flight focal species.

Distribution, Status, and Trends: The horned lark occurs in large numbers throughout much of eastern Oregon, but the resident population in the Willamette Basin is a different subspecies and has declined dramatically over the past 50 years. The current breeding population in the basin is estimated at under 200 pairs (Altman 2003). Research on the wintering population is currently underway (R. Moore and D. Robinson, pers. comm.). The ORNHIC database contains documented records from 18 of the 170 Willamette watersheds. Along Willamette

Basin BBS routes the species was detected at 1 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 6.4 percent in 1981. Application of simple species-habitat models to aerial imagery using GIS suggests 0.78 percent of the basin might contain habitat that could be at least marginally suitable and 0.46 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 11 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 15 percent. BBS data covering the period 1968-2003 and 1980-2003 show a decrease in the Willamette Valley, but possibly an increase in western Oregon-Washington generally. The Willamette decrease is statistically significant.

Key Environmental Correlates: Formerly bred in upland and wetland prairies, but as the area of these has diminished the species has adapted to nesting in some types of agricultural lands, including row crops, conifer plantations, ryegrass fields, grazed pastures, burned fields) as well as road and railroad rights-of-way, wetland prairies, and mudflats. In all cases, prefers large open expanse with short, sparse grass/forb cover and patches of bare ground (mean = 17 percent). Mean territory size is 1.9 ac. (Altman 2003).

Threats, Limiting Factors, Population Viability: Habitat loss and degradation have been the greatest contributors to decline of the species in the basin. Nest failures also occur as a result of trampling by livestock and farm machinery, and possibly from increased predator densities (cats, raccoons) associated with residential development. Pesticides potentially affect feeding and reproduction. Increased high-speed traffic on rural roads also may contribute to mortality.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

Maintain or create patches of suitable habitat (individually less than an acre in extent) throughout native and agricultural grasslands; the patches should have these characteristics:

- Vegetation shorter than 1 ft
- 20-50 percent bare or sparsely vegetated
- Located where disturbance from people, animals, and vehicles is minimal

Population objectives should include:

- Maintain more than 20 distinct breeding populations in the basin by 2010

Conservation Needs: Table 3-61 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-61: HUC6 Units with the Most Suitable Habitat for Horned Lark

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900030602	Soap Cr.	1	933	474	0.90
170900030302	Brownsville	1	513	269	0.93
170900030504	Finley NWR; Muddy & Hammer Cr.	1	2029	1271	0.81
170900030402	S. Albany; Tangent.	1	613	421	1.59
170900030202	Monroe; Muddy Cr. E.	1	1488	1130	1.48

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Vesper Sparrow (affinis subspecies)

Special Designations: "Critical" (ODFW). "Imperiled" (ONHP). Partners In Flight focal species.

Distribution, Status, and Trends: Like the horned lark, the vesper sparrow is common throughout much of eastern Oregon but the population in the Willamette Basin (which is migratory) is a different subspecies and has declined dramatically over the past 50 years. The current breeding population in the basin is estimated at under 200 pairs (Altman 2003). The ORNHIC database contains documented records from 24 of the 170 Willamette watersheds. Along Willamette Basin BBS routes the species was detected at 0.75 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 3.2 percent in 1981. Application of simple species-habitat models to aerial imagery using GIS suggests 0.71 percent of the basin might contain habitat that could be at least marginally suitable and 0.20 percent might contain higher-suitability habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 20 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 26 percent. BBS data covering the period 1968-2003 show a decrease in the Willamette Valley and in western Oregon-Washington generally.

Key Environmental Correlates: Formerly bred in upland prairie-savanna, but as this habitat has diminished the species has adapted to nesting in two environments: (1) lightly grazed pastures with generally short grass and scattered shrubs, and (2) conifer plantations younger than 5 years old with extensive weeds and grasses. Mean territory size is 3.1 ac (Altman 2003). Along with other grassland species, this species may be impacted by increases in predator densities associated with urbanization, as well as by diminished inclusion of hedgerows in croplands as farm parcel sizes increase, i.e., agricultural intensification.

Threats, Limiting Factors, Population Viability: Probably similar to horned lark, above. The current breeding population in the basin is estimated at under 200 pairs (Altman 2003).

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- Maintain or provide patches of suitable habitat individually greater than 20 acres and having these characteristics, which apply mainly to pasture, native prairie, and fallow fields:
- Grass of variable heights, generally less than 18 inches tall
- Some areas of bare or sparsely vegetated ground
- Shrub cover of 5 to 15 percent
- Located where disturbance from people, animals, and vehicles is minimal
- Population objectives should include:
- Maintain more than 20 distinct breeding populations in the basin by 2010

Conservation Needs: Table 3-62 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-62: HUC6 Units with the Most Suitable Habitat for Vesper Sparrow

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	514	26	0.73
170900090702	Drift Cr.	2	799	4	0.58
170900010101	Rattlesnake & Hills Cr.	2	247	68	0.54
170900090501	Molalla	1	1273	127	0.51
170900070202	Aumsville & Beaver Cr.	2	231	8	0.49

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Western Meadowlark

Special Designations: "Critical" (ODFW) just in the Willamette Valley ecoregion. Partners In Flight focal species.

Distribution, Status, and Trends: Like the above two species (horned lark and vesper sparrow) the western meadowlark is common throughout much of eastern Oregon but the Willamette Basin population (which is mostly resident) has declined dramatically over the past 50 years. The current breeding population in the basin is estimated to be less than 300 pairs (Altman 2003). Along Willamette Basin BBS routes the species was detected at a maximum of 14.3 percent surveyed points (in 1974), but none during 2003. Application of simple species-habitat models to aerial imagery using GIS suggests 0.25 percent of the basin might contain habitat that could be at least marginally suitable and 0.20 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 11 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 30 percent.. BBS data covering the period 1968-2003 show a decrease in the Willamette Valley as well as in western Oregon-Washington generally. These declines are statistically significant. Willamette CBC data show a decline from about 100 birds per CBC in the late 1970s to about 50 birds per CBC in the mid 1990s.

Key Environmental Correlates: Formerly bred in upland prairie-savanna, but as this habitat has diminished the species has adapted to nesting in some fallow fields and lightly grazed pastures. Prefers large open expanse (greater than 100 ac) of uncultivated grassland with grass-forb cover of 1-2 ft height and scattered shrubs (less than 10 percent cover) or artificial perches (fences, telephone poles). Only 24 percent of the Willamette territories included cultivated grass fields and none contained more than 50 percent cultivated grass. Mean territory size is 14.3 ac (Altman 2003).

Threats, Limiting Factors, Population Viability: Probably similar to horned lark and vesper sparrow, above. The current breeding population in the basin is estimated to be less than 300 pairs (Altman 2003).

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- Maintain or create patches of suitable habitat (individually less than 200 acres in extent) throughout native and agricultural grasslands; the patches should have these characteristics:
  - Variable grass heights, generally shorter than 30 inches
  - Containing some shrubs, trees, or other perches, but over less than 10 percent of area
  - Located where disturbance from people, animals, and vehicles is minimal

Guidance on Willamette grassland management for this species is provided in ODFW (2001).

Population objectives should include:

- Reverse the declining BBS trends to achieve stable populations (negative trends of less than 2 percent per year) or increasing trends by 2010.

Conservation Needs: Table 3-63 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-63: HUC6 Units with the Most Suitable Habitat for Western Meadowlark

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080501	Ash Swale & Deer Cr.	1	69	64	2.16
170900030402	S. Albany; Tangent.	1	99	59	2.04
170900070101	Baskett Slough NWR	1	20	20	1.99
170900080402	Salt Cr.	1	21	18	1.93
170900030202	Monroe; Muddy Cr. E.	1	246	206	1.79

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Western Bluebird

Special Designations: “Vulnerable” (ODFW). Partners in Flight focal species.

Distribution, Status, and Trends: This species is currently absent as a breeder from nearly all of the valley floor, and is an uncommon breeder in foothills. Along Willamette Basin BBS routes the species was detected at 0.5 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of only 0.8 percent in 1968. Application of simple species-habitat models to aerial imagery using GIS suggests 8.3 percent of the basin might contain habitat that could be at least marginally suitable but less than 1 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 60 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 32 percent. Wintering birds are found by most basin CBCs. Local increases have been documented in response to extensive placements of nest boxes. This species once bred commonly in savanna and forest edges in the Willamette Basin. Declines were first noted in the 1950s and 1960s. BBS data covering the period 1968-2003 and 1980-2003 show a decrease in western Oregon-Washington generally.

Key Environmental Correlates: For nest sites, bluebirds require artificial nest boxes or tree cavities excavated by other species. Nests are within or along the edge of upland prairies, clearcuts, pastures, or other open areas, especially those dominated by native grasses and forbs. Bluebirds do not nest in closed-canopy forest or in fields overgrown by shrubs but may feed in such areas during winter, especially where mistletoe, madrone, and other berries are available.

Threats, Limiting Factors, Population Viability: Habitat loss and degradation have been the greatest contributors to decline of the species in the basin. May be more sensitive to changes in forest practices (rotation ages, patterns) than other focal species inhabiting this habitat type. Also, increases in residential development are typically accompanied by increases in European starling and house sparrow, non-native species that usurp nesting cavities. This may be less a problem at higher-elevation forested areas. Increased high-speed traffic on rural roads also may contribute to mortality.

Biological Objectives: Habitat objectives should include:

- Manage woodlands to provide a sustained supply of snags (at least 10 ft tall and 15 inch diameter) located along edges that adjoin open areas, i.e., areas with fewer than 5 trees/ac (Hansen et al. 1995)
- Following forest fires, leave larger snags whenever feasible.

Population objectives should include:

- Achieve stable populations (negative trends of less than 2 percent per year) or increasing trends by 2010.

Conservation Needs: Table 3-64 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-64: HUC6 Units with the Most Suitable Habitat for Western Bluebird

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900010302	Fall & Delp Cr.	4	2800	0	1.66
170900050103	Pyramid Cr.	5	4367	0	1.59
170900011101	Groundhog Cr: S.Fork	5	3005	0	1.49
170900110402	Timothy Lake; Dinger Lake	5	9977	0	1.46
170900060501	Pyramid Cr. & Quartzville Cr.-lower	5	9141	0	1.42

Table 3-64: HUC6 Units with the Most Suitable Habitat for Western Bluebird

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Black-tailed Jackrabbit

Special Designations: none

Distribution, Status, and Trends: Jackrabbits once were abundant on the valley floor and foothills, but anecdotal evidence suggests a long term population decline has occurred (Verts & Carraway 1998). ORNHIC databases contain no records from the last 20 years. Incidental to avian surveys conducted during summers 1996-1999, the species was noted at 15 rural locations in the Willamette Valley (Altman et al. 2001). Apparently extirpated from the greater Portland area (Metro 2003) and generally more common in southern parts of the basin.

Key Environmental Correlates: Historically this species inhabited upland prairie-savannah with scattered shrubs. Most recent observations have been from the vicinity of conifer plantations.

Threats, Limiting Factors, Population Viability: Habitat loss and fragmentation have been the greatest contributors to decline of the species in the basin. Other factors that might be contributing to decline include hunting, disease (tularemia), increases in predator densities, increases in farming efficiency and field size (i.e., fewer hedgerows), and roadkill due to increased high-speed traffic on rural roads. Home range is about 500 acres.

Biological Objectives: Survey, then maintain or increase present densities and distribution in the basin, consistent with minimizing potential damage to nearby crops.

Conservation Needs: Table 3-65 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-65: HUC6 Units with the Most Suitable Habitat for Black-Tailed Jackrabbit

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080501	Ash Swale & Deer Cr.	1	16810	0	5.24
170900030402	S. Albany; Tangent.	1	27257	0	5.22
170900080402	Salt Cr.	1	7986	0	4.96
170900070101	Baskett Slough NWR	1	10697	0	4.86
170900030203	Coburg; Halsey; Little Muddy R.; Pierce Cr	1	59165	0	4.41

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Western Rattlesnake

Special Designations: “Vulnerable” (ODFW, Willamette Valley ecoregion only).

Distribution, Status, and Trends: Formerly common on the valley floor and in foothills, rattlesnakes now persist at fewer than a dozen locations in the basin.

Key Environmental Correlates: Historically this species inhabited upland prairie-savannah as well as rock outcrops, but as this habitat has declined the remaining populations have become restricted to rock outcrops, especially ones on grassy south-facing slopes below 2000 ft elevation (Alan St. John, pers. comm.).

Threats, Limiting Factors, Population Viability: Loss, fragmentation, and degradation of upland prairie-savanna has been a major contributor to decline of the species in the basin. Persecution surely has also been a major contributor, especially around ranches and residential areas. Animal burrows are important for refuge during inclement weather and have diminished as prairies have been converted to cropland.

Biological Objectives: Survey present densities in the basin and then formulate biological objectives.

Conservation Needs: Table 3-66 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery (that did not delineate upland prairie specifically), so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-66: HUC6 Units with the Most Suitable Habitat for Western Rattlesnake

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090702	Drift Cr.	2	2933	2933	0.73
170900090703	Silverton N.	2	764	764	0.46
170900060102	E. Lebanon; Hamilton Cr.	2	1445	1445	0.46
170900080604	Turner Cr.	2	594	594	0.44
170900060301	Lower Thomas Cr. -lower; Scio	2	1063	1063	0.40

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

3.2.5.3 Focal Habitat: Wetland Prairie and Seasonal Marsh

Description. The wetland prairie and seasonal marsh (hereinafter termed simply "wetland prairie") includes areas that are outside of the annual floodplain of rivers, are inundated or saturated for only part of the year by lentic (non-flowing) water, are dominated by the types of herbaceous vegetation that are characteristically associated with wetlands according to USFWS databases, and show evidence of reducing conditions in the upper soil horizon or contain soils considered by the NRCS to be "hydric." In the Willamette Basin most such areas exist (or existed) on the valley floor, but this definition also includes some springs and seeps on the valley margin and foothills if these are dominated by herbaceous vegetation—that is, marsh. This definition includes vernal pools but not *Sphagnum*-dominated bogs. Many wetland prairies appear to be isolated, meaning that they are not permanently connected to other water bodies by surface water. Wetland prairies are classified as "slope" or "flats" wetland according to the classification scheme used by Oregon Division of State Lands (Brinson 1993, Adamus 2001) and includes "emergent wetland" (with semipermanent, seasonal, or temporarily inundated hydroperiod) as defined by the Cowardin et al. (1978) classification and used in maps published by the National Wetland Inventory.

Recognition of Importance. Wetlands included under this definition have been identified explicitly as a priority for protection and restoration in other regions and specifically in the Willamette Basin (Titus et al. 1996, Morlan 2000). Legally listed species that are strongly associated with this habitat include Bradshaw's lomatium (federal "endangered,"); Willamette Valley daisy and Nelson's checker-mallow (federal "threatened"); streaked horned lark (proposed for federal listing, and state-listed as "critical"); red-legged and Cascades frogs (both ODFW "vulnerable"), and western toad (now almost extirpated, ODFW "vulnerable").

Many species that are associated strongly or partially with wetland prairie have disappeared from the basin. These include at least one plant (water howellia, federally listed as “threatened”), one amphibian (Oregon spotted frog), and three breeding birds (sandhill crane, black-crowned night-heron, short-eared owl). Two other birds—Wilson’s snipe and golden eagle—are probably close to extirpation as breeders in the basin.

At a continental scale, the Willamette Valley’s wetland prairies are recognized as being particularly important for shorebirds and waterfowl during migration and winter. More than 20,000 dunlin and 10,000 killdeer winter in seasonal wetlands here, comprising a significant component of Pacific Coast populations of these shorebirds (Sanzenbacher & Haig 2001, Taft & Haig 2003). Although enormous declines have occurred over the past 100 years among waterfowl using the basin, the seasonal marshes, ponds, and reservoirs of the Willamette Valley still host up to 300,000 wintering waterfowl.

Status and Distribution. Compared with the other focal habitats, wetlands have been well-mapped (see Table 3-67), although wetland prairies generally have not been distinguished from seasonal marshes. Also, the aerial imagery used to construct wetland maps may not allow wetland prairies and other seasonal marshes to be distinguished consistently from permanently-inundated wetlands, which are included under ponds and sloughs. Many seasonal marshes are too small to be detected at all from aerial imagery. Wetlands remain unmapped in much of the higher-elevation portion of the basin, and the level of agreement among map sources can vary significantly. Several communities in the Willamette Basin have conducted finer-scale mapping of wetlands—with more field verification—as part of Oregon DSL’s legally-mandated support for “Local Wetland Inventories” (see: http://statelands.dsl.state.or.us/lwi.htm).

Table 3-67: Acreage Estimates of Land Cover Types That Include Wetland Prairie and Seasonal Marsh

Source	Map Categories that Include Wetland Prairie	Estimated Area (Acres)	Percent of Mapped Area
EC1850	“seasonal wetlands”	309,360	4.24
EC1990	“seasonal wetlands”	27,081	0.37
IBIS 1850	--	--	--
IBIS 1990	“herbaceous wetlands”	10,757	0.15
ODFW*	“hairgrass prairie” “cattail-bulrush” “reed canary grass”	7,200	0.37

* Valley area only.

Past Impacts, Limiting Factors, and Future Threats. Along with upland prairies and oak woodlands, wetland prairies were a prominent feature of the lower elevations of the Willamette Basin until the late 1800s. As was true of the upland prairies, the predominance of herbaceous vegetation was maintained largely by frequent fires set by indigenous tribes. Loss of wetland prairie in the Willamette Valley since presettlement times has been estimated at 99 percent, and loss of other herbaceous wetlands (probably including some perennially-inundated ones) is estimated at 57 percent (Titus et al. 1996, Morlan 2000).

Despite laws that regulate some activities in wetlands, the net (uncompensated) loss and degradation of wetlands—and especially of wetland prairie and seasonal marsh in the Willamette Basin—continues. For example, destruction of 546 wetland acres per year between 1982 and 1994 was measured in the Willamette Valley (Daggett et al. 1998, Bernert et al. 1999). Probably the largest contributing factor to wetland destruction in the basin has been legally-exempted agricultural activities (Shaich 2000). Remaining wetland prairies have become so fragmented and separated by roads carrying high-speed traffic that populations of wildlife, and especially reptiles and amphibians, may not be self-sustaining in some areas of the basin. And being supported by only a seasonal water regime, wetland prairies are particularly vulnerable to potential effects of global warming (Graham 2000).

Wetland prairies also are being ecologically degraded. Many are being gradually invaded by shrubs, especially Oregon ash (*Fraxinus latifolia*) and Himalayan blackberry, due to altered local water regimes and long term suppression of fires. In running computer simulations of future environmental conditions in the Willamette Basin, one researcher (Payne 2002) assumed the maximum rate at which ash might invade wet prairies and other open areas to be about 100 lateral feet per 40 years. Within the past few decades, highly invasive reed canary grass (*Phalaris arundinacea*) also has come to dominate many, if not most ,of the basin’s seasonal marshes, choking out large numbers of native species and profoundly altering wildlife habitat structure and food sources.

Pesticides, toxic substances, and excessive loads of sediment from roads, logging, and suburban and agricultural lands reach wetlands and diminish their capacity to support wildlife and rare plants. Some recent evidence suggests that nitrate fertilizers potentially impact the reproduction of native amphibians (Marco et al. 1999). Near residential areas, increased predator densities (cats, raccoons) may be significantly impacting some birds that nest in wetland prairies. Scientific literature on all of these impacts to wetland plants and animals was reviewed by Adamus & Brandt (1990) and Adamus et al. (2001).

Contribution of Wetland Prairies to Regional Biodiversity. Compared with other Willamette habitat types, wetland prairies in good condition provide the best reproductive habitat for 38 wildlife species, and are used regularly by at least an additional 54 breeding wildlife species. Many of these species are associated as well with upland prairie. Some use seasonally-inundated agricultural lands, perhaps at some cost to reproductive success and survival. The wetland prairie—seasonal marsh avifauna includes several nesting bird species whose numbers appear to be declining regionally. Many plant species found in the Willamette Basin’s wetland prairies are rare and found in none of the other 5 habitat types featured in this plan (Titus et al. 1996, Wilson 1998b).

Selected Focal Species in Wetland Prairie. The following are proposed as focal species for this habitat type:

- Plants: Bradshaw’s lomatium, Nelson’s checker-mallow (sidalcea), Willamette Valley daisy, peacock larkspur
- Wildlife: red-legged frog, sora, northern harrier, common yellowthroat, dunlin

On a scale of 0 to 10, these species' average degree of association with wetland prairies and seasonal marshes is a 8.43. Compare this with HEP "loss assessment" species used in many previous mitigation calculations and land acquisitions in the Willamette Basin. Of the "grass-forb" species used in HEP applications, the average degree of association with wetland prairie or seasonal wetland is only 2.78. This suggests there may have been an unintentional but systematic bias against the wetland prairie habitat type in previous mitigation land dealings in the Willamette Basin.

Bradshaw's Lomatium (Lomatium bradshawii)

Special Designations: "Endangered" (federal). "Imperiled" (ONHP).

Distribution, Status, and Trends: This species occurs only in the Willamette Valley and southern Washington. Once abundant, there now are documented records from just 13 of the 170 Willamette watersheds.

Key Environmental Correlates: This species occurs mainly on clayey soils with seasonally high water tables and little or no shade.

Threats, Limiting Factors, Population Viability: Habitat loss to development and succession of wetland prairies to woodland as a result of fire suppression and altered soil moisture regimes pose the greatest threat (Kagan 1980). Insects are essential for pollinating this plant and may be impacted by pesticides drifting from residential, forest (gypsy moth control), and agricultural areas.

Biological Objectives:

- Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-68 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-68: HUC6 Units with the Most Suitable Habitat for Bradshaw's Lomatium

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900030101	W. Eugene; Junction City	1	2177	1008	1.26
170900030504	Finley NWR; Muddy & Hammer Cr.	1	1253	612	1.20
170900030302	Brownsville	1	364	154	1.18
170900030403	Sodaville	1	169	59	1.05
170900020102	Creswell W.; Camas Swale	2	175	121	0.89

Table 3-68: HUC6 Units with the Most Suitable Habitat for Bradshaw's Lomatium

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Nelson's Checkermallow (Sidalcea nelsoniana)

Special Designations: "Threatened" (federal); "Imperiled" (ONHP).

Distribution, Status, and Trends: Once common, this species remains at fewer than 48 sites in just 5 portions of the basin, plus one area in southern Washington. Most sites have fewer than 100 plants, and only 5 have more than 1000.

Key Environmental Correlates: Typically occurs in moist unshaded soils that are not regularly plowed or mowed. Found mostly in remnant patches of native prairie such as along roadsides, fencerows, along streams or ditches, and in cemeteries. Also occurs in relatively open ash swales and on somewhat gravelly well-drained soils. Some sites contain standing water for long periods.

Threats, Limiting Factors, Population Viability: The greatest threats are of habitat loss to development, and habitat degradation as a result of succession of wetland prairies to woodland, following fire suppression and alteration of soil moisture regimes by agricultural drainage and residential development. Specific examples of loss through conversion to agricultural or other unsuitable land cover include known sites at Lewisburg, Philomath, Dallas, Corvallis (Starker Park), and the Salem Municipal Airport Additional habitat losses have been reported from habitat loss has been reported in Polk County at Van Well Road, Dyck Road, McTimmonds Valley, and Hess Road (CH2M Hill 1991). The species is thriving in several areas where regular burning and/or cutting of woody plants continues. Plants at some locations have been impacted by plowing, deposition of fill and yard debris, improvement of tile drain networks in wet fields, competition with invasive non-native plants, trampling by livestock and recreationists, and intense roadside vegetation management (regrading, mowing, herbicide applications). Especially in past decades, improvements in field drainage and stream channelization have harmed the species by reducing the seasonal persistence of water on the land. Mowing adversely impacts the plants if it takes place before the plants set seed. Insects essential for pollinating this plant may be impacted by pesticides. In the Coast Range, a proposed reservoir threatens the largest population of this species, containing one-third of the species population. Although the area is currently protected under the state Scenic Waterway System, there have been attempts in the Oregon Legislature to remove this designation so reservoir construction can proceed. In addition, a proposed capacity increase of an existing reservoir in Washington County would destroy some plants.

Biological Objectives: Maintain or expand existing numbers and geographic distribution of this plant through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-69 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-69: HUC6 Units with the Most Suitable Habitat for Nelson's Checkermallow

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080402	Salt Cr.	1	5723	86	3.80
170900070101	Baskett Slough NWR	1	6904	61	3.17
170900070102	Independence; Monmouth	1	18375	457	3.16
170900070201	Sublimity & Turner	1	10566	270	3.12
170900080502	Amity	1	15988	247	3.06

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Willamette Valley Daisy (Erigeron decumbens var. decumbens)

Special Designations: "Endangered" (federal). "Critically Imperiled" (ORNHIC).

Distribution, Status, and Trends: This very rare plant is known only from the Willamette Valley. The ORNHIC database contains records from 14 of the 170 Willamette watersheds.

Key Environmental Correlates: Similar to preceding species.

Threats, Limiting Factors, Population Viability: Similar to preceding species.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-70 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-70: HUC6 Units with the Most Suitable Habitat for Willamette Valley Daisy

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900030203	Coburg; Halsey; Little Muddy R.; Pierce Cr	1	1957	230	1.96
170900070101	Baskett Slough NWR	1	62	12	1.57
170900030504	Finley NWR; Muddy & Hammer Cr.	1	813	168	1.13
170900030101	W. Eugene; Junction City	1	1325	654	0.97
170900020102	Creswell W.; Camas Swale	2	190	134	0.84

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Peacock Larkspur (Delphinium pavonaceum)

Special Designations: “Endangered” (ODA). “Critically Imperiled” (ONHP). Not recognized as a species by some authorities because of its propensity to hybridize..

Distribution, Status, and Trends: The ORNHIC database contains documented records from 10 of the 170 Willamette watersheds.

Key Environmental Correlates: Native prairies, especially wetland prairies.

Threats, Limiting Factors, Population Viability: Its extirpation apparently has been caused by loss and degradation of upland prairie-savanna habitat. Drift of herbicides applied during agricultural operations and roadside maintenance may also be having an effect.

Biological Objectives: Maintain and increase current numbers and distribution through habitat protection, restoration, and management.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-71 contain records of this species in the ORNHIC database.

Table 3-71: HUC6 Units with ORNHIC Database Records for Peacock Larkspur

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900030504	Finley NWR; Muddy & Hammer Cr.	1	yes	yes
170900050601	Jefferson; Lyons; Bear Branch	1	yes	yes

Table 3-71: HUC6 Units with ORNHIC Database Records for Peacock Larkspur

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900070103	Ankeny NWR	1	yes	yes
170900070301	Saint Paul	1	yes	yes
170900030201	Corvallis N.; Adair Village	1	no	no
170900030602	Soap Cr.	1	no	no
170900070102	Independence; Monmouth	1	no	no
170900070103	Ankeny NWR	1	no	no
170900090202	Molalla R. -middle	1	no	no
170900030501	Corvallis; Philomath; Mary’s R.-lower	1	no	yes
170900030601	Luckiamute R.4	1	no	yes
170900030602	Soap Cr.	1	no	yes

Elevation zones (Elev) are:
1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft
PCA = Priority Conservation Area.

*Water Howellia (***Howellia aquatilis***)*

Special Designations: “Threatened” (federal). “Extirpated” (ONHP).

Distribution, Status, and Trends: This species once occurred widely in the Pacific Northwest. Currently, the remaining individuals are clustered mainly at two locations, one in eastern Washington and one in Montana, with a third cluster in Mendocino County, California.

Key Environmental Correlates: Historically this plant occurred in vernal wetlands with consolidated mud bottoms. These probably included edges of some oxbows and sloughs in portions of the floodplains of the Willamette and other rivers.

Threats, Limiting Factors, Population Viability: Reasons for its apparent disappearance are unclear, but could be related to river regulation, reduction in riparian shade, and increased water pollution (particularly increased deposition of sediment).

Biological Objectives: Determine limiting factors through research and seek opportunities to reintroduce if and where suitable habitat is found.

Red-legged Frog

Special Designations: “Vulnerable” (ONHP).

Distribution, Status, and Trends: The ORNHIC database contains documented records from 34 of the 170 Willamette watersheds. This frog potentially occurs at all elevations but is more common in the foothills and in southern parts of the basin.

Key Environmental Correlates: Although listed here as a focal species for wetland prairie and seasonal marshes, red-legged frogs often prefer ponds and sloughs with more-permanent water, especially when they are bounded by partly inundated shrubs and are relatively free of predatory bass and bullfrogs (Kiesecker & Blaustein 1998). The presence of a surrounding riparian area that is wooded enhances the habitat suitability of a pond, slough, or wetland where this species lays its eggs. Eggs are attached to sedges, cattails, or narrow stems of flooded shrubs when available, but flooded reed canary grass is also used. Isolated wooded pools that contain at least a foot of water through April (or longer) may be used for egg deposition, especially if they are located somewhat close to perennial water. Predation pressure from bullfrogs and especially bass may be less in such pools than in deeper perennial waters. Occasionally eggs are laid in the emergent vegetation of slow-flowing streams and rivers, or along wave-washed shores of reservoirs, but stagnant waters with relatively predictable springtime water levels are more typical. Velocity thresholds for successful egg hatching and tadpole survival are not known. During the summer some frogs move into woodland burrows or bury themselves under moist leaf litter up to 65 ft from water, and during heavy rains they can move overland up to 300 ft from ponds and wetlands.

Threats, Limiting Factors, Population Viability: Predation by bullfrogs and bass is the most commonly cited current threat to this species in the Willamette Basin. However, there are wetlands where these species appear to coexist, so the interaction of these species is complex and possibly mediated by emergent vegetation density, water temperature, and other factors. Threats include continued destruction or drainage of seasonal wetlands (some of it not subject to regulatory review), as well as water pollution, airborne pesticides, ultraviolet radiation, parasites, and disease.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-72 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-72: HUC6 Units with the Most Suitable Habitat for Red-Legged Frog

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS*
170900030504	Finley NWR; Muddy & Hammer Cr.	1	3235	2305	0.72
170900030101	W. Eugene; Junction City	1	3399	1825	0.69
170900050601	Jefferson; Lyons; Bear Branch	1	3834	2650	0.62
170900030202	Monroe; Muddy Cr. E.	1	2448	1650	0.45
170900100102	Hillsboro	1	1071	827	0.37

Table 3-72: HUC6 Units with the Most Suitable Habitat for Red-Legged Frog

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS*

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Common Yellowthroat

Special Designations: none.

Distribution, Status, and Trends: Fairly common in the basin's lowland wetlands. Along Willamette Basin BBS routes the species was detected at 9 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 17 percent in 1993. Application of simple species-habitat models to aerial imagery suggests 10.2 percent of the basin might contain habitat that could be at least marginally suitable and 0.38 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 52 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 35 percent. BBS data show statistically significant increases in the Willamette Valley for both the periods 1968-2003 and 1980-2003, but a decline in western Oregon-Washington generally during these periods.

Key Environmental Correlates: Nests in a wide variety of marsh vegetation types, including reed canary grass. Especially thrives in marshes with scattered plants that are more robust, for example, cattail, bulrush, shrubs.

Threats, Limiting Factors, Population Viability: Like other low-nesting marsh birds, this species might be especially vulnerable to feral cats, raccoons, snakes, and all-terrain vehicles. Nests are destroyed when fields are mowed before mid-July. Pesticides potentially affect the insects it consumes. As a neotropical migrant, its abundance could be limited by factors along its migration route or in its wintering range. Prairie restoration activities that feature complete removal of shrubs might adversely affect this common species.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-73 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-73: HUC6 Units with the Most Suitable Habitat for Common Yellowthroat

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900080501	Ash Swale & Deer Cr.	1	7572	259	4.31
170900070101	Baskett Slough NWR	1	5130	171	4.08
170900030402	S. Albany; Tangent.	1	8783	192	4.02
170900030202	Monroe; Muddy Cr. E.	1	16338	624	3.92
170900080402	Salt Cr.	1	3257	125	3.87

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Dunlin

Special Designations: none

Distribution, Status, and Trends: This arctic-nesting shorebird resides in the Willamette Basin from autumn to late spring. Largest wintering concentrations (more than 10,000 individuals) are regularly reported from the vicinity of Fern Ridge Reservoir, Halsey, Junction City, Tangent, and in parts of the national wildlife refuges that are managed for shorebirds. Trends are unmeasured, but widespread loss of wetland prairie over the last century seems likely to have had a major adverse impact.

Key Environmental Correlates: Flocks of dunlin feed in vernal pools and other seasonal wetlands with very short grass (<6 inches) or with bare saturated soils. Dunlin generally avoid wetlands bordered by woody vegetation (especially tall trees) unless such wetlands are very large. Pools or wet soils that are richest in earthworms, fly larvae, and other soil invertebrates are probably favored. Because invertebrate productivity of wet soil shows enormous temporal and spatial variability, dunlin flocks frequently wander large portions of the landscape (over 100 square miles per day) searching for food (Haig et al. 1998). When not feeding, dunlin flocks roost in bare or short-grass areas relatively free from constant human activity, such as gravel islands in rivers, sewage treatment plants, and large agricultural fields.

Threats, Limiting Factors, Population Viability: Improvements in agricultural drainage probably pose the greatest immediate threat to this species. Other threats include pesticides, invasion of wet prairies by woody shrubs as a result of fire suppression, conversion of favored roosting sites to other cover types or uses, and harassment of flocks by dogs and humans. Mowing, burning, plowing, and grazing probably benefit this species to some degree.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Northern Harrier

Special Designations: Partners In Flight focal species.

Distribution, Status, and Trends: Also called "marsh hawk," this species nests throughout most lowland regions of Oregon. It is not known if wintering birds are raised locally or migrate from other regions. Application of simple species-habitat models to aerial imagery suggests 1.16. percent of the basin might contain habitat that could be at least marginally suitable and 0.38 percent might contain good habitat. Breeding population in the Willamette Valley probably is less than about 100 birds (Altman 2000). The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 13 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 41 percent. Along Willamette Basin BBS routes the species was detected at 0.5 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 1.5 percent in 1989. BBS data covering the period 1968-2003 and 1980-2003 show increases in the Willamette Valley, but a decrease in western Oregon-Washington generally during 1980-2003. Populations vary significantly from year to year in response to rodent population fluctuations. This species is also fairly common in the basin in winter. At least 127 were present almost simultaneously in January 2004 in farmlands of Lane-Linn-Benton-Polk-Yamhill-Marion Counties (J. Fleischer, pers. comm.)

Key Environmental Correlates: Resident year-round in both upland prairie and wetland prairie, as well as in other types of non-forested wetlands, irrigated hayfields, wet meadows, lightly-grazed pastures, and possibly some ryegrass fields if not mowed before mid-July.

Threats, Limiting Factors, Population Viability: Has been impacted by loss of prairie and wetland habitat in the Willamette Basin, but possibly more adaptable to some types of agricultural land cover than short-eared owl, which otherwise has similar habits but is nearly extirpated. Like other low-nesting marsh birds, this species might be especially vulnerable to feral cats, raccoons, snakes, and all-terrain vehicles. Like most raptors, it requires large blocks of suitable habitat (not necessarily contiguous) and when nesting is sensitive to mere presence of livestock, humans, and domestic pets. Nests are destroyed when fields are mowed before mid-July.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- Maintain a mosaic of non-managed grasslands in blocks of larger than 400 ac located at least one-quarter mile from human development or recreational activities
- Where nests are located, provide a no-activity buffer of at least 400 ft radius around nests

Conservation Needs: Table 3-74 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-74: HUC6 Units with the Most Suitable Habitat for Northern Harrier

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900030402	S. Albany; Tangent.	1	1001	602	1.54
170900080501	Ash Swale & Deer Cr.	1	766	447	1.54
170900060101	Crabtree Cr. & Onehorse Slough	1	754	227	1.52
170900070101	Baskett Slough NWR	1	481	265	1.45
170900030203	Coburg; Halsey; Little Muddy R.; Pierce Cr	1	2788	1067	1.41

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Sora

Special Designations: none

Distribution, Status, and Trends: At least historically, this species occurred throughout lowlands of the Willamette Basin. Due to its secretive nature it is seldom detected on BBS routes so local trends are unknown. Application of simple species-habitat models to aerial imagery suggests 0.57 percent of the basin might contain habitat that could be at least marginally suitable. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 7 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 31 percent. On BBS routes in the Willamette Basin, soras have seldom been detected.

Key Environmental Correlates: This species inhabits taller denser marsh vegetation than may be typical of some wetland prairies, but perhaps not as tall as that used by two other secretive marsh species (American bittern and Virginia rail). Marshes of sedge or cattail, flooded either seasonally or year-round, are frequently used, as are (occasionally) irrigated hayfields, wet meadows, and lightly-grazed pastures on poorly-drained soils.

Threats, Limiting Factors, Population Viability: This species apparently has not been recorded nesting in reed canary grass so the recent proliferation of that invasive throughout the basin’s marshes may be having an effect. Populations may also decline as woody plants invade wet prairies, inasmuch as soras do not tolerate much tree cover. Soras may be more sensitive to marsh water quality and pesticide drift than some other species due to its consumption of aquatic invertebrates. Also may be more likely to suffer collision mortality due to habit of migrating at low elevations at night.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-75 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-75: HUC6 Units with the Most Suitable Habitat for Sora

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900090201	S. Canby	1	326	298	0.73
170900060101	Crabtree Cr. & Onehorse Slough	1	311	301	0.70
170900030101	W. Eugene; Junction City	1	1644	1426	0.55
170900030204	E. Eugene; Harrisburg; Springfield	1	639	565	0.49
170900090101	Aurora	1	256	232	0.48

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

3.2.5.4 Focal Habitat: Perennial Ponds and Their Riparian Areas

Description. In this report, this focal habitat includes all lentic (non-flowing) areas that are inundated year-round, extending spatially to include basically lentic areas that are inundated seasonally by other lentic water bodies or by rivers (“sloughs”). This focal type includes natural ponds, sloughs, lakes, and perennially-inundated marshes as well as regulated reservoirs, farm ponds, gravel-pit ponds, irrigation ponds, beaver-created ponds, and ponds constructed for wildlife, fire control, or as visual amenities in developed areas. Vegetation (woody or herbaceous) within one tree-length of the lentic waters at the time of annual maximum inundation is included. As such, this type includes some of the systems included in TNC’s *Ecoregional Assessment* “depressional wetland broadleaf forests” and “depressional wetland shrublands.”

Recognition of Importance. Compared with other focal habitat types featured in this report, ponds and most other lentic waters have not been accorded high priority in other ecological assessments of the Willamette Basin. This may be due to their relative abundance, lack of evidence of major decline from historical extent (see below), apparent absence of any endemic species, and lack of ecological survey effort, for example, of aquatic plants and lentic invertebrates. Nonetheless, ponds and their riparian areas provide a remarkable contribution to regional biodiversity, as described further below.

Status and Distribution. Defined broadly, the acreage of perennially inundated lentic water bodies in the Willamette Basin probably has not diminished since presettlement times and if anything, has increased. Maps of their current distribution (from NHI and other sources) are probably quite accurate and relatively complete. However, historical maps and accounts of vegetation almost surely do not adequately depict the distribution of very small sloughs, ponds, and perennial marshes. Rough estimates suggest they may have occupied at least 40,000 acres (0.55 percent of the basin) (see Table 3-76).

Table 3-76: Acreage Estimates of Land Cover Types That Include Lentic Habitat

Source	Map Categories that Include Lentic Habitats	Estimated Area (Acres)	Percent of Mapped Area
EC1850	“lakes & permanent wetlands”	40,693	0.55
EC90	“lakes, reservoirs, & permanent wetlands”	53,191	0.72
IBIS 1850	“lakes, rivers, and streams”	23,009	0.32
IBIS 1990	“lakes, rivers, and streams”	77,710	1.09
ODFW*	“water”	30,728	1.58

*Valley area only.

Past Impacts, Limiting Factors, and Future Threats. Regardless of possible change in total area of the basin’s lentic waters, the size distribution of these waters has changed. Prior to colonial settlement, very large bodies of lentic perennial water may have been virtually nonexistent on the valley floor, and existed at higher elevations only as scattered lakes, for example, Waldo Lake. As more settlers arrived, small perennial sloughs along the Willamette River were isolated from the river with berms to improve river navigation. Some were subsequently drained to provide additional agricultural land (IMST 2002). More dramatically, new lentic waters were created by damming rivers, for example, Fern Ridge Reservoir, Foster Reservoir, Bull Run Reservoir. This may have had the effect of increasing the mean size and depth of lentic waters in the basin, and decreasing the mean water temperature within this habitat type. These changes would be expected to have caused shifts in the composition of wildlife communities that historically used the basin. Species that are more likely to occur in wooded lowland ponds (for example, hooded merganser, river otter, red-legged frog) than in large reservoirs (or for which only the shoreline of reservoirs counts as suitable habitat) may now have less habitat. In contrast, species that are more likely to use large and/or marsh-fringed water bodies than wooded ponds (for example, Canada goose, black tern) may now have more habitat available.

Ponds, lakes, sloughs, and other lentic waters of the Willamette Basin have been ecologically degraded to varying degrees. Alien species of fish (especially bass, carp) and wildlife (bullfrog, nutria) intentionally released into lentic waters are believed to be at least partly responsible for decline of some native species (for example, Oregon spotted frog) unaccustomed to new predators or competitors. Some scientists have suggested that construction of perennial ponds for farm use or wetland mitigation, as well as construction of large reservoirs, has facilitated the establishment and spread of some harmful non-native animals (Gwin et al. 1999). Many of the basin's lentic waters have become degraded by invasive aquatic weeds and abnormal blooms of algae. Although some invasive aquatic plants provide food for waterfowl, they can deprive small lentic water bodies of light and oxygen, thus diminishing or changing communities of bottom-dwelling invertebrates important to many birds and amphibians, reducing the diversity of native aquatic plants, and harming larval amphibians.

Pesticides, toxic substances, and excessive loads of sediment from roads, logging, motorboats, and suburban and agricultural lands reach lentic waters and potentially diminish their capacity to support wildlife and rare plants. In some cases, changes in physical characteristics of receiving waters (temperature, oxygen, pH) triggered by drought, reservoir drawdown, or land clearing in adjoining watersheds can mobilize heavy metals and other contaminants lying latent in sediments, accelerating their bioconcentration in food chains.

Increased frequency and duration of human visits can cause some wildlife species to avoid lentic waters, at least temporarily. Local waterbird populations can be harmed when this occurs in smaller bodies of lentic water, and/or during sensitive times (for example, nesting), and/or when it involves chronic visitation and/or highly disturbing activities (for example, use of jet-skis).

Riparian areas associated with lentic waters in the Willamette Basin are being completely cleared in some instances, and degraded by several factors in other instances (IMST 2002). Consequently, the associated lentic waters can be degraded by increased water temperature, excessive sediment, and nutrient runoff. The supply of partly-submerged woody material important to turtles and a few other wildlife inhabitants also has been reduced (IMST 2002).

Contribution of Ponds and Their Riparian Areas to Regional Biodiversity. Whether natural or man-made, lentic water bodies and their riparian areas support a fauna quite unlike that found in other habitats. However, introduced animals—such as bullfrogs, bass, carp, and nutria—have increased the direct or indirect loss of native wildlife and especially native plants (such as wapato, *Sagittaria latifolia*) in many lentic waters of the Willamette Basin.

Selected Focal Species in Perennial Ponds and Their Riparian Areas. The following species are proposed as focal species for this habitat type: western pond turtle, Cascades frog, Oregon spotted frog, purple martin, green heron, wood duck, and yellow warbler.

On a scale of 0 to 10, these species' average degree of association with pond and pond riparian habitat is 8.5. Compare this with HEP "loss assessment" species used in many previous mitigation calculations and land acquisitions in the Willamette Basin. Of the "reservoir" species used in HEP applications, the average degree of association with pond and/or pond riparian is 7.8. This suggests there may have been an unintentional but systematic bias against pond and pond riparian habitat in previous mitigation land dealings in the Willamette Basin.

Western Pond Turtle

Special Designations: "Critical" (ODFW).

Distribution, Status, and Trends: Most turtle population centers are in lowlands of the central and southern parts of the basin. The ORNHIC database contains documented records from 78 of the 170 Willamette watersheds, covering over 400 sites. Several biologists have noted the rarity of reports of hatchlings and sub-adult turtles in the Willamette Basin in recent years (Holland 1993, Adamus 2003a). This is perhaps only partly due to the difficulties in locating turtle nests and detecting young. There is growing concern that it may largely reflect declining reproductive success and diminished subadult survival. Naturalists in the early 1900s reported turtles to be abundant in the region, with hundreds present in some sloughs. At least initially, precipitous declines were a result of habitat loss (near-extirpation of beaver which where responsible for creating productive pond habitat), habitat alteration (especially channelization of rivers), and intensive commercial collecting. Most current populations are on private lands below about 2000 ft elevation. Public lands that appear to host the most individuals are within the Willamette River Greenway, Fern Ridge Reservoir, Fall Creek Reservoir, and scattered holdings of the US Bureau of Land Management (Adamus 2003b).

Key Environmental Correlates: Pond turtle habitat is not limited to ponds, but potentially includes nearly all water bodies with stagnant or slow-flowing water, whether seasonal or perennial. Turtles use sloughs and wetlands that contain surface water only seasonally if perennially inundated areas are nearby. Pools, alcoves, and backwater sloughs along rivers such as the mainstem Willamette, McKenzie, Calapooia, and Row contain many turtles. Some seasonal movement may occur between habitats, with some turtles (especially juveniles) tending to use warmer, invertebrate-rich vernal pools and shallow wetlands more often during spring when river currents are too swift, and then moving to cooler and more permanent waters of rivers, deep ponds, and reservoirs during late summer. Turtles are frequently sighted where ponds or rivers are situated near relatively open areas—including natural gaps in the forest canopy, agricultural lands, golf courses, sewage treatment facilities, and prairies—especially if these are not far from wooded areas. Turtles lay eggs on land, and apparently the open land provides warmth needed for egg development and thermoregulation. The understory of wooded areas is at least equally important to turtles when it provides a thick mat of leaves suitable for hibernation.. Riparian wood, when it enters rivers and ponds, provides important basking sites. Nest and hibernation sites are generally within about 100 ft of surface water, but can be over 300 ft away. Within rivers and large reservoirs, movements of over 1 mile are common.

Threats, Limiting Factors, Population Viability: Threats to this species include the following in no particular order: habitat loss and fragmentation, habitat degradation (for example, channel downcutting, blanketing of floodplains with Himalayan blackberry), roads (collisions with vehicles), water pollution (Henny et al. 2003), predation of juveniles, illegal shooting/ collecting, and introduction of exotic turtles (Holland 1994, Adamus 2003b). Increased residential or recreational use of an area can imperil turtles because of associated increases in road traffic, trampling of nest and hibernation sites, introduction of warmwater fish, illegal shooting, accidental take on fish hooks, garbage that attracts predators such as raccoons, and lethal puncturing of turtle carapaces (shells) by curious dogs.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. Specific suggestions for habitat enhancement techniques and conservation strategies are provided by Adamus (2003b) and ODFW (www.dfw.state.or.us/ODFWhtml/springfield/W_Pond_Turtle.htm).

Conservation Needs: Table 3-77 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-77: HUC6 Units with the Most Suitable Habitat for Western Pond Turtle

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900030601	Luckiamute R.4	1	48	46	2.32
170900080501	Ash Swale & Deer Cr.	1	26	24	1.68
170900070201	Sublimity & Turner	1	120	75	1.62
170900030402	S. Albany; Tangent.	1	72	48	1.47
170900030403	Sodaville	1	59	40	1.43

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Cascades Frog

Special Designations: "Vulnerable" (ONHP). "Vulnerable" (ODFW).

Distribution, Status, and Trends: There are about 70 locations of this species in Oregon. The ORNHIC database contains records from 8 of the 170 Willamette watersheds. In some mountain meadows in Oregon, hundreds were estimated to be present within an area of just a few acres (Nussbaum et al. 1983). Although little information is available on trends, at a series of surveyed sites in Oregon where it was known to have existed historically, 22 percent of the sites were found to be no longer occupied (Fite et al. 1998). Severe declines have been documented in California.

Key Environmental Correlates: This species occurs mainly in montane ponds and lakes, but also uses slow-flowing streams, wet mountain meadows, sphagnum bogs, and open moist coniferous forests.

Threats, Limiting Factors, Population Viability: Factors potentially responsible for the declines include introductions of non-native predatory fishes, gradual loss of open wet meadows and associated aquatic habitats due to grazing-caused downcutting of outlet channels, drying of the forest floor microclimate as a result of logging-related forest fragmentation and global warming, spread of pathogenic fungi and parasites as perhaps accelerated by fish stocking, food chain contamination by airborne chemicals, and increased exposure to ultraviolet radiation resulting from atmospheric ozone layer depletion.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-78 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-78: HUC6 Units with the Most Suitable Habitat for Cascades Frog

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900110402	Timothy Lake; Dinger Lake	5	293	155	0.05
170900040803	Roaring R. & Elk Cr.	6	283	269	0.04
170900011001	Salt & Gold & Eagle Cr.	6	197	182	0.03
170900050102	Marion Lake	6	163	148	0.03
170900040501	Boulder Cr. & Smith R.	6	89	86	0.01
170900040802	French Pete Cr.	5	9	8	0.00
170900090601	Molalla R. N. Fk.	5	3	2	0.00
170900110401	Harriet Lake	3	--	--	--

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Oregon Spotted Frog

Special Designations: “Candidate species” (federal). “Imperiled” (ONHP).

Distribution, Status, and Trends: The ORNHIC database contains documented records from just two of the 170 Willamette watersheds. Both records are from the upper McKenzie watershed:

170900040803	Roaring R. & Elk Cr.
170900011001	Salt & Gold & Eagle Cr.

Drastic declines in distribution and abundance have occurred in much of its range, which is limited to the Pacific Northwest. Apparently it once occupied much of the Willamette Valley, but now is confined to higher elevations.

Key Environmental Correlates: Similar to the Cascades frog, this species occurs along grassy edges of ponds and lakes as well as slow-flowing streams and wet mountain meadows. A thick layer of dead leaves beneath the water surface, in areas shallower than 1 ft, may be important.

Threats, Limiting Factors, Population Viability: Similar to Cascades frog, but reasons for its more-dramatic decline are unknown. Nitrate contamination, e.g. from fertilizers, may be at least partly responsible inasmuch as tadpoles of this species were found to be 4 times more sensitive to nitrate than was another frog (Pacific tree frog) that has healthy populations throughout the basin (Marco et al. 2001, Hatch et al. 2001). Lower-elevation populations are aggressively preyed on by bullfrogs.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: See above.

Purple Martin

Special Designations: “Critical” (ODFW sensitive species). “Imperiled” (ONHP). Partners in Flight focal species.

Distribution, Status, and Trends: Formerly common in this region, the martin is now an uncommon to rare and localized colonial nester, occurring mainly at Fern Ridge Reservoir and at scattered locations in the foothills. Statewide, there are about 784 pairs (Horvath 1999). The ORNHIC database contains documented records from 13 of the 170 Willamette watersheds. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 28 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 7 percent. Along Willamette Basin BBS routes the species was detected at a maximum of 0.4 percent of surveyed points (1981). BBS data covering the period 1968-2003 and 1980-2003 show increases in western Oregon-Washington generally, but there were too few detections in the Willamette Valley to calculate trends for there.

Key Environmental Correlates: Martins historically nested in cavities of enormous old-growth trees located near water bodies or other open areas. With widespread reduction of this habitat element, the species has adapted to nesting in artificial structures (bird houses, hollow gourds, hollow pilings in rivers) erected for its use by humans.

Threats, Limiting Factors, Population Viability: The greatest threats are continued loss of old growth snags of the proper proportions situated in suitable landscapes, and lack of maintenance of artificial nesting structures. In addition, the artificial nest sites are sometimes usurped by exotic species (European starling, house sparrow). Like other swallows, martins are wide-ranging aerial foragers and consequently are vulnerable to collisions with vehicles and reductions in insect prey as a result of severe weather and contaminants.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-79 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-79: HUC6 Units with the Most Suitable Habitat for Purple Martin

HUC6	Watershed Name (Not Comprehensive)	Elevation	Habitat Suitability Score
170900030605	Luckiamute R.3.	3	0.43
170900030607	Little Luckiamute R. -upper	4	0.32
170900030607	Little Luckiamute R. -upper	3	0.30
170900030502	Mary’s R -middle	3	0.19
170900020301	Cottage Grove Reservoir N.	2	0.15

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Green Heron

Special Designations: none

Distribution, Status, and Trends: This small heron is an uncommon to fairly common breeder at lower elevations in much of the basin. Application of simple species-habitat models to aerial imagery suggests about 1.6 percent of the basin might contain habitat that could be at least marginally suitable. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 24 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 35 percent. Along Willamette Basin BBS routes the species was detected at 0.7 percent of surveyed points (1986), with none found in 2003. The species appears to have increased since the 1920s (Stryker 2003). However, BBS data covering the period 1968-2003 and 1980-2003 show decreases in the Willamette Valley.

Key Environmental Correlates: This species is strongly associated with wooded or brushy ponds and channels, especially those that contain water year-round.

Threats, Limiting Factors, Population Viability: A diet comprised mainly of small fish and frogs may make this species especially vulnerable to bioaccumulation of pesticides. Destruction of riparian areas by residential development, agricultural and forestry operations also is detrimental.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-80 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-80: HUC6 Units with the Most Suitable Habitat for Green Heron

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	806	0	2.02
170900060101	Crabtree Cr. & Onehorse Slough	1	841	0	1.32
170900090102	Woodburn; Hubbard	1	599	0	1.30
170900090101	Aurora	1	650	0	1.30
170900070301	Saint Paul	1	668	0	1.17

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Wood Duck

Special Designations: none

Distribution, Status, and Trends: This colorful duck is fairly common year-round mostly at lower elevations of the basin. Application of simple species-habitat models to aerial imagery suggests 2.3 percent of the basin might contain habitat that could be at least marginally suitable. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 56 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 26 percent. Along Willamette Basin BBS routes the species was detected at 1 percent of surveyed points (1989), and at none in 2003. Although this species was extirpated from much of its continental range by the early 1900s, it has since recovered. BBS data covering the periods 1968-2003 and 1980-2003 show increases in the Willamette Valley and in western Oregon-Washington generally.

Key Environmental Correlates: As their name indicates, wood ducks prefer wooded sloughs, shaded ponds, shallow portions of reservoirs, and slow-water sections of wooded rivers and wide streams. They nest in large tree cavities as well as artificial nest boxes placed for their use. They feed extensively on acorns, but also on aquatic invertebrates, berries, seeds of aquatic plants, and even hazelnuts.

Threats, Limiting Factors, Population Viability: River regulation and floodplain development have diminished their favored feeding habitat—flooded stands of trees—as well as reduced the sustained supply of natural nesting cavities. At some locations water quality may limit the aquatic invertebrates upon which they feed.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-81 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-81: HUC6 Units with the Most Suitable Habitat for Wood Duck

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900090201	S. Canby	1	806	0	2.02
170900060101	Crabtree Cr. & Onehorse Slough	1	841	0	1.32
170900090102	Woodburn; Hubbard	1	599	0	1.31
170900090101	Aurora	1	650	0	1.30
170900070306	W. Salem	1	502	0	1.17

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Yellow Warbler

Special Designations: Designated as a focal species by Partners In Flight.

Distribution, Status, and Trends: This species is currently uncommon (to locally fairly common) in the Willamette Basin. Application of simple species-habitat models to aerial imagery suggests 0.8 percent of the basin might contain marginally-suitable habitat and 0.6 percent might contain good habitat. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 19 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 67 percent. Along Willamette Basin BBS routes the species was detected at 2.5 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 6.4 percent in 1969. This species may have been the most abundant warbler in the Willamette Valley up until the mid-1900s, but has since declined dramatically. BBS data covering the period 1968-2003 show a decrease in the Willamette Valley and in western Oregon-Washington generally, with a possible increase in the Willamette during the 1980-2003 period.

Key Environmental Correlates: This neotropical migrant prefers deciduous shrubs or trees within a few dozen feet of standing or flowing water. In western Oregon it occurs mostly in lowland riparian areas containing willow and/or cottonwood.

Threats, Limiting Factors, Population Viability: Nests of yellow warblers are often parasitized by brown-headed cowbirds, which occur mostly within a few miles of livestock. Thus, fragmentation of riparian forests is likely to threaten this species the most in such agricultural landscapes. In contrast, dispersed (patch-like) removal of riparian forest canopy in low-density residential or forested landscapes might be beneficial, especially if a subcanopy layer of native shrubs is encouraged. As insectivores, yellow warblers are particularly vulnerable to pesticides. They also appear to fair poorly in high-density residential areas (Hennings 2001), perhaps partly because of heightened predation by feral cats and raccoons associated with such development.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), the habitat objectives should include:

- Maintain or create at least 70 percent deciduous shrub cover, of which at least 40 percent is beneath a forest canopy
- Maintain or create a mosaic of shrub or wetland patches amid a larger landscape of forest or other land devoid of cattle

The ultimate objective is to expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-82 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-82. HUC6 Units with the Most Suitable Habitat for Yellow Warbler

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900060101	Crabtree Cr. & Onehorse Slough	1	450	430	1.20
170900090101	Aurora	1	328	308	1.03
170900070301	Saint Paul	1	324	284	0.93
170900090201	S. Canby	1	238	204	0.84
170900030602	Soap Cr.	1	1771	1738	0.74

Table 3-82. HUC6 Units with the Most Suitable Habitat for Yellow Warbler

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

3.2.5.5 Focal Habitat: Riparian Areas of Rivers and Streams

Description. In this plan all lotic (flowing water) areas and their adjoining riparian areas are included under this focal habitat type. This focal type includes natural as well as artificial channels, for example, rivers, streams, and ditches. Vegetation (woody or herbaceous) within one tree-length of the lotic waters at the time of annual maximum inundation is included.

Recognition of Importance. The importance of the Willamette Basin’s streams, rivers, and riparian areas for aquatic animals (notably salmon and trout) is widely recognized by laws, policies, and science (for example, Gregory et al. 1991, IMST 2002). Less often noted is the importance of this habitat type for wildlife. In its analysis of “Freshwater Systems and Species,” TNC’s Ecoregional Assessment did not explicitly (by use of a “fine filter”) address the habitat needs of riverine wildlife species such as bald eagle, osprey, American merganser, and mink. Associations of riverine wildlife species with salmon—and presumably other fish—are catalogued and described by Cedarholm et al. (2001). Wildlife of riparian areas in Oregon and Washington are similarly described by Kauffman et al. (2001). “Riparian habitat” is one of just four habitat types targeted as priorities in the Willamette Valley by the Partners In Flight *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000)

Status and Distribution. Various estimates of the extent of riparian habitat are shown in Table 3-83.

Table 3-83: Acreage Estimates of Land Cover Types That Include Stream Riparian Habitat

Source	Map Categories that Include Stream Riparian	Estimated Area (Acres)	Percent of Mapped Area
EC1850	“streams”	42,937	0.59
EC90	“streams”	36,806	0.51
IBIS 1850	“lakes, rivers, and streams” “westside riparian—wetlands”	23,009 362,181	0.32 5.05
IBIS 1990	“lakes, rivers, and streams” “westside riparian—wetlands”	77,710 114,117	1.09 1.60

Table 3-83: Acreage Estimates of Land Cover Types That Include Stream Riparian Habitat

Source	Map Categories that Include Stream Riparian	Estimated Area (Acres)	Percent of Mapped Area
ODFW*	“ash-cottonwood-bottomland pasture”	86,559	4.46

*Valley area only.

Past Impacts, Limiting Factors, and Future Threats. As a result of river regulation and land development, major changes in wildlife habitat have occurred within the channels and riparian zones of many of the basin’s rivers and streams. One of the most extreme examples is the Willamette River itself (see Tables 3-84 and 3-85).

Table 3-84: Changes in Acres of Channel Habitat of the Willamette River, Eugene to Portland.

Year	Primary Channel	Side Channels	Alcoves	Islands
1850	35.2	1.6	8.9	54.2
1895	42.8	1.7	9.7	45.7
1932	45.9	1.1	9.5	43.5
1995	55.0	1.9	7.1	36.0

Source: Adapted from Gregory et al. (2002)

Table 3-85: Area of the Willamette Valley Inundated by Major Floods Since 1860

Year(s)	Acres Inundated by Major Floods
1861 & 1890	320,337
1943 & 1945	149,797
1964	152,789
1996	194,533

Source: Adapted from Gregory et al. (2002)

Information on past impacts and future threats to the basin’s riverine systems is provided in the section of the Willamette Basin plan dealing with aquatic habitat, and in IMST (2002). In the basin’s riverine and riparian systems, factors most likely to limit wildlife in particular include:

- Decline of fish stocks and their spatial and temporal distribution in some watersheds
- Food chain contamination with agrochemicals and industrial pollutants

- Other water quality effects (for example, Excessive sedimentation affecting frog eggs, waterfowl food plants, and riparian plant germination);
- Simplification of channel complexity and consequently riparian vegetation as a result of river regulation, altered runoff regimes, and channelization
- Increased disturbance of wildlife and vegetation due to increased frequency and duration of human visits
- Increased cover of invasive plants within riparian areas, largely in response to all of the above

Potential incompatibilities of listed threatened or endangered species with specific types of activities subject to Oregon's Removal-Fill laws are analyzed in a Division of State Lands report.

Contribution of Stream Riparian Areas to Regional Biodiversity. No wildlife species are restricted entirely to streams or stream riparian areas, but several are restricted to aquatic habitats generally, and/or use streams or stream riparian areas predominantly (Kauffman et al. 2001). Hundreds of plant and invertebrate species, none of them listed as threatened or endangered, reside exclusively in flowing water. Many introduced plants and animals—such as bass, bullfrogs, nutria, and reed canary grass—have increased the direct or indirect loss of native wildlife in streams and stream riparian areas.

Selected Focal Species in Stream Riparian Habitat. The following wildlife species are proposed as focal species for this habitat type: American dipper, bald eagle, harlequin duck, red-eyed vireo, willow flycatcher, American beaver, river otter, coastal tailed frog.

On a scale of 0 to 10, these species' average degree of association with riverine riparian is a 4.86. Compare this with HEP "loss assessment" species used in many previous mitigation calculations and land acquisitions in the Willamette Basin. Of the "riparian" species used in HEP applications, the average degree of association with riverine riparian is only 2.65. This suggests there may have been an unintentional but systematic bias against riverine riparian in previous mitigation land dealings in the Willamette Basin.

American Dipper

Special Designations: none

Distribution, Status, and Trends: Dippers are fairly common year-round residents of streams in forested parts of the Willamette Basin. Along the basin's BBS routes, dippers were detected at 0.5 percent of surveyed points in 2003, with a maximum over the period 1968-2003 of 0.8 percent (in 1969). The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 52 percent of the 53 survey units in the basin and found evidence of possible or probable nesting in 19 percent. BBS data covering the period 1968-2003 show a decrease in western Oregon-Washington generally, but a possible increase during 1980-2003. It can be hypothesized that dippers were once present (perhaps even common) along the Willamette River and are now absent there due to water pollution, river regulation, and accompanying reduction in gravel bars and downed wood. However, historical data are insufficient to determine this.

Key Environmental Correlates: Dippers occur mostly in larger streams (third order and greater) with noticeable current and exposed boulders, partly submerged logs, and/or gravel bars.

They also nest along the shores of mountain ponds and lakes. They feed almost entirely on larval aquatic invertebrates and nest within 1 ft of the water's edge (Loegering & Anthony 1999). Characteristics of adjoining riparian areas do not appear to directly influence the local distribution of this species.

Threats, Limiting Factors, Population Viability: Water pollution from forest roads and logging operations potentially affects the food base of this species. Nest wash-outs from severe water level fluctuations are also a likely limiting factor. Reservoir operations (flow regulation) could either help or hurt this.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. Stream restoration actions that benefit salmon and trout are likely to benefit this species.

Conservation Needs: Table 3-86 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-86: HUC6 Units with the Most Suitable Habitat for American Dipper

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900030502	Mary's R -middle	2	446	446	0.39
170900010101	Rattlesnake & Hills Cr.	2	120	120	0.35
170900090601	Molalla R. N. Fk.	3	233	233	0.30
170900080602	McMinnville N.	2	70	70	0.25
170900030503	Mary's R. -upper	2	431	431	0.24

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Harlequin Duck

Special Designations: "Species of Concern" (USFWS). "Imperiled" (ONHP).

Distribution, Status, and Trends: Within the Willamette Basin, this strikingly-patterned duck breeds mainly along larger streams in the Cascades (major tributaries to the McKenzie, North and South Santiam, Clackamas, Molalla, and Middle Fork of the Willamette). Fewer than 50 nesting pairs are present statewide. The ORNHIC database contains records from 27 of the 140 sixth-field watersheds. The Oregon BBA Project confirmed nesting in 9 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 17 percent. Birds spend the winter in coastal waters.

Key Environmental Correlates: Similar to those of American dipper, above. Nests are placed within 1 to 82 ft of water, generally under shrubs or on logs or rock ledges (Bruner 1997).

Threats, Limiting Factors, Population Viability: Similar to those of American dipper, above. Wintering populations are vulnerable to oil spills.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-87 are documented in the ORNHIC database.

Table 3-87: HUC6 Units with ORNHIC Database Records for Harlequin Duck

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900010301	Fall Cr. Reservoir N.	3	yes	no
170900010302	Fall & Delp Cr.	3	yes	no
170900010801	Oakridge E.	3	yes	no
170900011001	Salt & Gold & Eagle Cr.	3	yes	no
170900011101	Groundhog Cr: S.Fork	3	yes	no
170900011301	Oakridge W.; Hills Creek Reservoir	3	yes	no
170900040101	E. Springfield; Camp & Ritchie Cr.	2	no	yes
170900040301	Blue River Reservoir & Cook Cr.	3	yes	yes
170900040401	Blue River Reservoir & Elk Cr.	3	yes	no
170900040401	Blue River Reservoir & Elk Cr.	3	no	no
170900040501	Boulder Cr. & Smith R.	3	yes	yes
170900040501	Boulder Cr. & Smith R.	4	yes	yes
170900040502	White Branch	3	yes	yes
170900040502	White Branch	3	no	yes
170900040802	French Pete Cr.	4	yes	yes
170900040803	Roaring R. & Elk Cr.	4	yes	yes
170900050102	Marion Lake	4	yes	no
170900050102	Marion Lake	4	no	no
170900050201	Breitenbush R.	4	yes	no
170900050301	Detroit Reservoir	3	yes	no
170900050301	Detroit Reservoir	3	no	no

Table 3-87: HUC6 Units with ORNHIC Database Records for Harlequin Duck

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900050401	Gates; Lyons; Mill City	2	no	no
170900050401	Gates; Lyons; Mill City	2	no	yes
170900060201	Beaver Cr.	1	no	yes
170900060401	Greenpeter Reservoir	3	yes	no
170900060402	Quartzville Cr.-upper	3	yes	no
170900060402	Quartzville Cr.-upper	3	no	no
170900060601	Sevenmile & Soda & Squaw Cr.	3	yes	no
170900090601	Molalla R. N. Fk.	4	yes	no
170900090603	Table Rock Fk.	3	yes	no
170900090603	Table Rock Fk.	3	no	no
170900090604	Copper & Henry Cr.	3	yes	no
170900110302	Fish Cr. W.	2	yes	no
170900110302	Fish Cr. W.	3	yes	no
170900110601	Nohorn Cr.	3	yes	yes
170900110602	Dickey & Elk Cr.	4	yes	yes

Elevation zones (Elev) are:
1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft
PCA = Priority Conservation Area.

Bald Eagle

Special Designations: “Threatened” (federal). Proposed for delisting in 1999. “Vulnerable” (ONHP).

Distribution, Status, and Trends: Breeds and resides year-round in the Willamette Basin, although some seasonal turnover of individual birds occurs. The number of occupied territories in the Willamette Basin in 2003 was 59, with an average of 1.11 young produced per occupied territory (F. Isaacs, pers. comm.), and the USFWS-sponsored surveys show the nesting population has been increasing. Documented records maintained by ORNHIC indicate nesting in 46 of the 170 Willamette watersheds during at least one of the past 20 years. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in 52 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 28 percent. The nesting population is mainly stable. BBS data covering the period 1968-2003 show an statistically significant increase in western Oregon-Washington generally. During winter, many birds roost communally (DellaSalla et al. 1989). About 93 were present almost simultaneously in March 2004 in farmlands of Lane-Linn-Benton-Polk-Yamhill-Marion Counties (J. Fleischer, pers. comm.). Counts of wintering birds from the

USFWS mid-winter survey are depicted in Table 3-88. The wintering population is stable or increasing.

Table 3-88: Mean and Maximum (Among-Year) Counts of Bald Eagles from USFWS Mid-Winter Survey Routes in the Willamette Basin, 1988-2000

Survey Area	Mean	Maximum	Mean Ratio of Immatures to Adults	Maximum Ratio of Immatures to Adults
Fern Ridge Reservoir	1.67	4	0.44	3.00
Lookout Point Reservoir	1.92	7	0.19	1.00
Muddy Creek (Cabell Marsh)	2.38	6	0.78	5.00
Muddy Creek (McFadden Marsh)	1.69	5	0.69	4.00
North Santiam River (Reservoirs)	1.00	4	0.25	1.00
South Santiam River (Reservoirs)	5.09	8	0.17	0.60
Odell Lake	7.50	21	0.51	2.00
Upper Middle Fork Willamette	3.62	6	0.40	1.00
Willamette River (Calapooya R. 1)	14.09	31	1.29	6.00
Willamette River (Calapooya R. 2)	12.00	21	1.65	3.20
Willamette River (Calapooya R. 3)	6.60	21	0.63	2.67

Key Environmental Correlates: Mostly associated with forested rivers and lakes, but during some months occurs extensively in open areas with livestock. Nests mainly in large Douglas-fir (mean diameter = 42 inches, Anthony et al. 1982) or cottonwood, either live or dead. Home range during breeding encompasses 1-10 square miles, and is manyfold larger in winter. During summer, Oregon eagles feed mainly on fish (live or dead), then augment this in at other seasons with waterfowl and sheep (carrion and afterbirth). Very sensitive to human disturbance at all seasons, but some individuals adapt somewhat, for example, Jackson Bottom eagle nest near urban Hillsboro. The increased nesting success and population increase in recent years can be attributed largely to reduction of some persistent contaminants (DDT) and to increased protection of nest and roosting sites from harvesting and human visitation (Isaacs and Anthony 2001).

Threats, Limiting Factors, Population Viability: Illegal killing of eagles continues, as evidenced by recent discovery of 17 intentionally poisoned eagles in the Willamette Valley. Long term survival of the Willamette eagle population depends on managing forests so they are capable of providing a continuous supply of large-diameter open-branched trees near water, and on improving water quality.

Biological Objectives: See the species Recovery Plan (USFWS 1986).

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-89 contain records of this species in the ORNHIC database.

Table 3-89: HUC6 Units with ORNHIC Database Records for Bald Eagle

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900010101	Rattlesnake & Hills Cr.	2	no	yes
170900010401	Fall Cr. Reservoir S.; Winberry Cr.	4	yes	no
170900010501	Dexter Reservoir	2	no	yes
170900010501	Dexter Reservoir	3	no	no
170900010502	Hemlock; Lookout Point Reservoir	3	yes	no
170900010901	Waldo Lake; Cayuse & Fisher Cr.	6	yes	yes
170900011001	Salt & Gold & Eagle Cr.	6	yes	no
170900011101	Groundhog Cr: S.Fork	4	yes	no
170900011301	Oakridge W.; Hills Creek Reservoir	3	yes	no
170900020101	Creswell E. Bear & Gettings Cr.	1	no	yes
170900020101	Creswell E. Bear & Gettings Cr.	2	yes	yes
170900020301	Cottage Grove Reservoir N.	3	no	yes
170900020401	Dorena Reservoir	3	yes	no
170900020401	Dorena Reservoir	4	yes	no
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	1	yes	yes
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	3	yes	yes
170900030201	Corvallis N.; Adair Village	1	no	yes
170900030202	Monroe; Muddy Cr. E.	1	no	yes
170900030203	Coburg; Halsey; Little Muddy R.; Pierce Cr	3	no	yes
170900030204	E. Eugene; Harrisburg; Springfield	1	no	yes
170900030301	Courtney Cr..	2	no	yes
170900030302	Brownsville	3	no	no
170900030302	Brownsville	3	no	yes
170900030501	Corvallis; Philomath; Mary’s R.-lower	2	yes	yes
170900030504	Finley NWR; Muddy & Hammer Cr.	1	yes	yes
170900040101	E. Springfield; Camp & Ritchie Cr.	3	yes	yes
170900040401	Blue River Reservoir & Elk Cr.	3	yes	no
170900040501	Boulder Cr. & Smith R.	5	yes	yes

Table 3-89: HUC6 Units with ORNHIC Database Records for Bald Eagle

HUC6	Watershed Name (Not Comprehensive)	Elev	Public Land?	In PCA?
170900040501	Boulder Cr. & Smith R.	6	yes	yes
170900050102	Marion Lake	6	yes	no
170900050301	Detroit Reservoir	4	no	no
170900050601	Jefferson; Lyons; Bear Branch	1	no	no
170900050601	Jefferson; Lyons; Bear Branch	1	no	yes
170900060101	Crabtree Cr. & Onehorse Slough	1	no	yes
170900060102	E. Lebanon; Hamilton Cr.	1	no	no
170900060103	Waterloo; Sweet Home; McDowell Cr.	2	no	no
170900060401	Greenpeter Reservoir	3	yes	no
170900060401	Greenpeter Reservoir	3	no	no
170900060701	Sweet Home; Foster Reservoir	2	no	no
170900070102	Independence; Monmouth	1	no	no
170900070103	Ankeny NWR	1	no	yes
170900070302	Dundee; Newberg	1	no	no
170900070302	Dundee; Newberg	1	no	yes
170900070304	Lincoln	1	no	yes
170900070305	Keizer; Spring Valley Cr.	1	no	yes
170900070307	Salem	1	no	no
170900090101	Aurora	1	yes	yes
170900100101	Tigard; Tualatin; Sherwood; King City	1	no	yes
170900100102	Hillsboro	1	no	yes
170900100202	Diary Cr. E.	2	yes	yes
170900100301	Gales & Clear Cr.	1	no	yes
170900100302	Sain & Scoggins Cr.	2	no	no
170900110101	Estacada; E. Gladstone	1	no	yes
170900120201	Portland; Forest Hills; Multnomah Channel	1	no	yes
170900120202	S. Milwaukie; Happy Valley; Lake Oswego; W	1	no	no

Elevation zones (Elev) are:
1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft
PCA = Priority Conservation Area.

Red-eyed Vireo

Special Designations: none.

Distribution, Status, and Trends: Probably fewer than a dozen pairs of this neotropical migrant songbird currently nest in the Willamette Basin, mainly on the valley floor and Cascade foothills. Breeding is erratic—a site may be occupied one year but often not the next. It is common in other parts of North America. The Oregon BBA Project (Adamus et al. 2001) confirmed nesting in just one of the 53 survey units in the basin and found evidence of possible or probable nesting in 19 percent. BBS data covering the period 1968-2003 show a decrease in western Oregon-Washington generally, but the species is seldom encountered on BBS routes in the Willamette Basin.

Key Environmental Correlates: In western Oregon this species is mainly associated with large (>100 ft tall) canopy trees in cottonwood stands near water.

Threats, Limiting Factors, Population Viability: Loss of mature riparian habitat has probably limited this species, although its historical abundance in the region is unclear. Another bird species—yellow-billed cuckoo—that uses generally similar habitat is now extirpated from the basin presumably due to habitat loss. As insectivores, both species are potentially vulnerable to pesticides.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-90 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-90: HUC6 Units with the Most Suitable Habitat for Red-Eyed Vireo

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900090201	S. Canby	1	399	383	2.09
170900060101	Crabtree Cr. & Onehorse Slough	1	665	665	1.41
170900070301	Saint Paul	1	110	106	1.33
170900090101	Aurora	1	408	403	1.12
170900070305	Keizer; Spring Valley Cr.	1	583	566	0.93

Table 3-90: HUC6 Units with the Most Suitable Habitat for Red-Eyed Vireo

HUC6	Watershed Name (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Willow Flycatcher

Special Designations: "Vulnerable" (ODFW sensitive species). Partners In Flight focal species.

Distribution, Status, and Trends: As its name implies, this uncommon migratory songbird is associated with willows and similar deciduous shrubs. Along Willamette Basin BBS routes the species was detected at 6.8 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 22.4 percent in 1970. Application of simple species-habitat models to aerial imagery suggests 11 percent of the basin might contain habitat that could be at least marginally suitable and 0.6 percent might contain good habitat. The Oregon BBA Project confirmed nesting in 41 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 54 percent.. Historical accounts suggest it was once much more abundant in the basin. BBS data covering the periods 1968-2003 and 1980-2003 show a decrease both in the Willamette Valley and in western Oregon-Washington generally. Declines have been most noticeable on the valley floor.

Key Environmental Correlates: In addition to using riparian alder, willow, and vine maple, this species regularly uses clearcuts (4 to 15 years post-harvest); patches of scotch broom, hawthorn, trailing blackberry, and bracken fern; and Himalayan blackberry. It tends to prefer shrubs in the open rather than ones beneath an extensive forest canopy, and fragmenting of large shrub stands with paths may benefit the species. One local study found no difference in nest success in native vs. non-native shrubs (Altman 2003). Mean nest height was 3.9 ft. This species is not typically found in higher-density residential areas.

Threats, Limiting Factors, Population Viability: Loss of riparian habitat as a result of agriculture, forest practices, and urban development is possibly the greatest threat. Regulation of the Willamette River has probably diminished the extent of riverine willow habitat as well. The species' flycatching behavior may put it at higher risk around roads with heavy traffic. Pesticides and other contaminants potentially diminish its insect foods. Nests are sometimes parasitized by cowbirds. Pesticides can diminish the primary foods of this species. Territory size averages 1.1 ac at lower elevations and 0.6 ac at higher elevations.

Biological Objectives: As proposed in *Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington* (Altman 2000), habitat objectives should include the following:

- Maintain or provide a patchy deciduous shrub layer with several scattered herbaceous openings (i.e., 30-80 percent shrub cover)
- Do not allow tree canopy cover to exceed 20 percent
- Provide the above at a distance of no less than 0.6 mi from residential areas and not less than 3 miles from areas with livestock (due to cowbird threat)

And the following population objective:

- Reverse declining BBS trends to achieve stable populations (trends of <2 percent/year) or increasing trends by 2020.

Conservation Needs: Table 3-91 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-91. HUC6 Units with the Most Suitable Habitat for Willow Flycatcher

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900070301	Saint Paul	1	1832	326	1.45
170900010302	Fall & Delp Cr.	4	2630	0	1.45
170900011101	Groundhog Cr: S.Fork	5	2809	0	1.41
170900090101	Aurora	1	1697	325	1.32
170900060501	Pyramid Cr. & Quartzville Cr.-lower	5	8743	0	1.31

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Coastal Tailed Frog

Special Designations: “Vulnerable” (ODFW sensitive species). “Imperiled” (ONHP).

Distribution, Status, and Trends: Occurs at all elevations where habitat is suitable. The ORNHIC database contains records from 15 of the 170 Willamette watersheds.

Key Environmental Correlates: Occurs in cold streams with moderate to high gradients in moist forests, usually in forests with a full canopy and scattered logs within the channel.

Threats, Limiting Factors, Population Viability: Water temperature and suspended sediment may be key limiting factors. Thus, logging and associated road building can degrade habitat, especially when landslide-prone areas near steep-gradient streams are harvested (Bury 1983, Corn & Bury 1989, Aubry & Hall 1991). Being dependent on invertebrates for food, this species is vulnerable to effects of pesticide applications. It also might be vulnerable to pathogenic fungi perhaps spread by fish stocking. Bullfrog predation is an unlikely limiting factor due to the cold water temperatures and steep channel gradients preferred by this species.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-92 are the only ones that contain records of this species in the ORNHIC database.

Table 3-92: HUC6 Units with ORNHIC Database Records for Coastal Tailed Frog

HUC6	Watershed Name (Not Comprehensive)	Elevation	Public Land?	In PCA?
170900020503	Sharps & Martin Cr.	4	yes	no
170900030101	W. Eugene; Junction City	3	yes	no
170900030102	Veneta; Poodle & Swamp Cr.; Fern Ridge Res	3	yes	no
170900040101	E. Springfield; Camp & Ritchie Cr.	3	yes	yes
170900040102	Gate Cr. S. Fk.	3	yes	yes
170900040102	Gate Cr. S. Fk.	4	yes	yes
170900040802	French Pete Cr.	4	yes	yes
170900050401	Gates; Lyons; Mill City	4	yes	no
170900060202	Roaring R.	4	yes	yes
170900060202	Roaring R.	5	yes	yes
170900070204	Rickreall Cr. -upper	3	no	no
170900080301	Mill & Gooseneck Cr.	3	no	yes
170900080602	McMinnville N.	3	yes	no
170900080602	McMinnville N.	3	no	no
170900090601	Molalla R. N. Fk.	4	no	no
170900090603	Table Rock Fk.	5	yes	no
170900090604	Copper & Henry Cr.	5	yes	no
170900110402	Timothy Lake; Dinger Lake	5	yes	no

Table 3-92: HUC6 Units with ORNHIC Database Records for Coastal Tailed Frog

HUC6	Watershed Name (Not Comprehensive)	Elevation	Public Land?	In PCA?

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

PCA = Priority Conservation Area.

American Beaver

Special Designations: None. Included because it is widely considered by ecologists to be a keystone species due to its capacity to modify habitat in ways that benefit many other species, as documented for example by Perkins (2000) in studies in Coast Range portions of the Willamette Basin.

Distribution, Status, and Trends: Beavers occur throughout wooded and partly wooded portions of the basin. Densities in the Coast Range may be somewhat greater than in the Cascades and valley, and over the entire basin average about 10 per acre. Unregulated trapping almost eliminated the beaver from Oregon by the early 1900s, but populations have recovered significantly, to the point of being a primary source of damage complaints (due to their impounding water and felling trees).

Key Environmental Correlates: Beavers inhabit wooded rivers, streams, lakes, and sloughs. They generally do not reside in wave-swept portions of reservoirs, intermittent streams, and very steep montane channels. Beavers select relatively low-gradient channels whose geomorphic characteristics make them suitable for dam and lodge placement (see Suzuki & McComb 1998), but in wide channels and lakes will tunnel into bank and place lodges against the bank.

Threats, Limiting Factors, Population Viability: Densities probably are regulated by availability of suitable dam sites, trapping, and disease.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat, consistent with minimizing ecological and economic damages.

Conservation Needs: Table 3-93 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-93: HUC6 Units with the Most Suitable Habitat for American Beaver

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900030204	E. Eugene; Harrisburg; Springfield	1	3057	903	1.28
170900060101	Crabtree Cr. & Onehorse Slough	1	1243	717	1.12
170900090201	S. Canby	1	930	499	1.04
170900070402	N. Canby; E. Wilsonville	1	1256	736	1.00
170900070301	Saint Paul	1	1217	722	0.87

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

River Otter

Special Designations: none.

Distribution, Status, and Trends: Occurs mainly in aquatic and riparian areas throughout the basin. Application of simple species-habitat models to aerial imagery suggests about 3 percent of the Willamette Basin might contain habitat that could be at least marginally suitable. Unregulated trapping decimated river otters in the 1800s but populations have recovered significantly.

Key Environmental Correlates: May be associated with relatively clean waters with adequate streamside cover (for example, downed wood, forest canopy). Often occurs in beaver flowages. Regularly reported from urban waterways and from upland forested areas.

Threats, Limiting Factors, Population Viability: This species is vulnerable to reproductive problems associated with chemical contamination (for example, pesticides, endocrine disrupters) of its largely aquatic foods.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: Table 3-94 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-94: HUC6 Units with the Most Suitable Habitat for River Otter

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900070402	N. Canby; E. Wilsonville	1	1591	1591	3.19
170900030204	E. Eugene; Harrisburg; Springfield	1	3539	3539	2.82
170900090501	Molalla	1	1453	1453	2.63
170900090201	S. Canby	1	685	685	2.32
170900070403	Oregon City; West Linn	1	1160	1160	2.19

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

3.2.5.6 Focal Habitat: Old-Growth Conifer Forest

Description. For this report, old-growth forests were defined as multi-layered (structurally complex) forests generally older than 200 years. Some publications include forests as young as 150 years, but this plan uses 200 years because that is the oldest forested category specified in the spatial layer available for wildlife habitat modeling (the next oldest was 80-200 years). Most old-growth forests are “virgin” forests that have never been subject to logging. Usually, it is not forest stand age that directly accounts for use of old growth by certain wildlife species, but rather specific features of such stands that correlate (to varying degrees) with stand age. Depending on species, this can include canopy closure, abundance and diversity of downed wood and snags, and extent of deciduous trees within a stand.

Recognition of Importance. The subject of years of debate and litigation, old-growth conifer forest is among the most famous of endangered ecosystems. Public attention to the importance of this habitat was initially raised by legal listing of the spotted owl as a threatened species, with concomitant restrictions on timber harvest in the old-growth conifer forests that comprise its primary habitat. Literature reviews and summaries documenting the importance of old growth to wildlife are compiled in the Northwest Forest Plan, specifically in reports of the Scientific Panel on Late-Successional Forest Ecosystems (Johnson et al. 1991, Thomas et al. 1993), the subsequent *Record of Decision* and *Standards and Guidelines*, as well as in Kellogg (1992), Haynes & Perez (2001), reports of the CLAMS project, and many other documents.

Status and Distribution. Reliable information on the extent of old-growth forest, especially on private lands, is difficult to obtain. Several maps exist that include categories which incorporate old-growth conifer forest, but vary in their geographic coverage and definition of this habitat type. The CLAMS Project mapped coastal conifer forest, with the largest diameter category being “greater than 30 inches.” Those data were not obtained for this report. For this plan we used the category “Forest Closed Conifer older than 200 years” in the EC90 layer. This indicates a total of 709,948 acres of old-growth conifer forest on both public and private land within the basin in the early 1990s, and is undoubtedly an overestimate due to limitations of imagery classification. Distribution is shown in Table 3-95.

Table 3-95: Watersheds with the Most Old-Growth Conifer Forest in the Early 1990s, Based on The EC90 Land Cover Layer

HUC6	Name of HUC5	Name of HUC6	Acres	Percent of HUC6
170900040501	McKenzie R.	Boulder Cr. & Smith R.	36274	22.66
170900011201	Willamette R. Middle Fk.	Staley & Swift & Spruce Cr.	33462	29.58
170900011301	Willamette R. Middle Fk.	Oakridge W.; Hills Creek Reservoir	28914	26.31
170900011001	Willamette R. Middle Fk.	Salt & Gold & Eagle Cr.	26205	36.33
170900110502	Clackamas R.—Eagle Cr.	Berry & Cub & Lowe Cr.	18678	31.36
170900050102	North Santiam R.—upper	Marion Lake	18592	30.95
170900040502	McKenzie R.	White Branch	18326	26.16
170900040803	McKenzie R.—S. Fk.	Roaring R. & Elk Cr.	17992	28.2
170900040601	McKenzie R./ Mohawk R.	Separation Cr.	17734	29.08
170900110402	Clackamas R.—middle	Timothy Lake; Dinger Lake	17384	30.46
170900010901	Willamette R. Middle Fk.	Waldo Lake; Cayuse & Fisher Cr.	16980	24.18
170900050201	North Santiam R.	Breitenbush R.	16353	23.5
170900110602	Clackamas R.—lower.	Dickey & Elk Cr.	16091	31.29
170900060402	South Santiam R.	Quartzville Cr.-upper	15268	27.4
170900050501	North Santiam R.	Little North Santiam R.	14125	19.53
170900050301	North Santiam R.	Detroit Reservoir	13125	17.7
170900050103	North Santiam R.—upper	Pyramid Cr.	13050	30.84
170900060601	South Santiam R.	Sevenmile & Soda & Squaw Cr.	12930	18.98
170900040602	McKenzie R./ Mohawk R.	Horse & Eugene Cr.	12881	33.25
170900010502	Willamette R. Middle Fk.	Hemlock; Lookout Point Reservoir	12829	24.76
170900040401	McKenzie R.	Blue River Reservoir & Elk Cr.	12717	21.53

Past Impacts, Limiting Factors, and Future Threats. Around 1850, old growth and mature (>80 year-old) conifer forest may have occupied about 4.1 million acres (58 percent) of the Willamette Basin. Loss of old-growth conifer forest throughout the Pacific Northwest is ongoing and has been widely documented, for example, Wimberly et al. (2000).

Logging and fire clearly have been responsible for most losses of old-growth forest in the Willamette Basin during the past century, and will likely continue to dominate in the future. Nonetheless, harvest levels of timber generally (not necessarily old growth) are at about half the levels of the late 1980s, especially in the Cascades. Past harvesting of old growth was probably greater at lower elevations and (at least recently) greater on private than on public lands. Largely due to Oregon's strong land use laws, relatively little forest in the Willamette Basin has been converted to residential or agricultural use since the 1970s (Azuma 1999).

Old-growth conifer forests are thought to have once been a major component of the valley floor, especially prior to the annual setting of large fires by indigenous tribes. Nearly all of the low-elevation conifer forest has now been converted to agriculture or residential development. In the Coast Range and Cascades, infrequent but large fires during the pre-settlement era resulted in extensive even-aged stands, forming much of what today is old growth.

Some experts have expressed concern that current government and private industry policies are creating a strongly bimodal landscape pattern in the Cascades and Coast Range, with mainly old forests on public land, young forests on private land, and little mid-aged forest. Growth and harvest on private timberlands in Oregon generally are believed to be in balance (Johnson 2001) but location-specific data are typically not available. Rotation ages on most private lands are shorter than the ages that would result in maximum growth rates. Rotations may continue to shorten if present corporate management strategies persist. The net effect of current forest management practices may be that, by 2050, the average age of conifers may fall from about 70 years to around 58 years, assuming an even distribution of age within each conifer age group (Payne 2002). Shorter rotation lengths may not allow development of structural complexity comparable to that found in mature or old-growth forests. Structural features such as snags and downed wood are often removed from harvested stands for logistical reasons or to reduce fire or safety hazards.

As world trade continues to expand, increased transnational transport of pathogens and insect pests may increase, and thus threaten plants and animals not adapted to new types of plagues. At the same time spreading urbanization and global warming, if accompanied by prolonged drought, will lower the resistance of forests to insects and diseases, and possibly increase the frequency of fires.

Contribution of Old-Growth Forest to Regional Biodiversity. In Oregon, old-growth and late-successional conifer forests are closely associated with occurrence of 16 amphibians, 38 birds, and 21 mammals (Thomas et al.,1993). Many of these species use few other habitat types.

Selected Focal Species in Old-Growth Conifer Forest. The following wildlife species are proposed as focal species for this habitat type: marbled murrelet, spotted owl, great gray owl, olive-sided flycatcher, pileated woodpecker, Vaux's swift, Oregon slender salamander, American marten, red tree vole, and Townsend's big-eared bat.

On a scale of 0 to 10, these species' average degree of association with old-growth conifer forest is 9.1. Compare this with HEP "loss assessment" species used in many previous mitigation calculations and land acquisitions in the Willamette Basin. Of the "conifer" species used in HEP applications, the average degree of association with old-growth conifer forest is only 7.0. This suggests there may have been an unintentional but systematic bias against old-growth forest in previous mitigation land dealings in the Willamette Basin.

Pileated Woodpecker

Special Designations: "Vulnerable" (ODFW sensitive species). Partners In Flight focal species.

Distribution, Status, and Trends: This large, uncommon, resident woodpecker occurs throughout forested parts of the Willamette Basin. Along basin BBS routes, the species was detected at 1.5 percent of surveyed points in 2003, with a maximum over the period 1968-2003 of 2.4 percent in 1981. Application of simple species-habitat models to aerial imagery suggests about 10 percent of the basin might contain habitat that could be at least marginally suitable. The Oregon BBA Project confirmed nesting in 44 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 52 percent.. BBS data covering the periods 1968-2003 and 1980-2003 show an increase in the Willamette Valley, and in western Oregon-Washington generally during the latter period. It is not known what part of these reports might be attributed to birds that formerly inhabited old growth shifting to new areas and habitats as old growth is logged. Wintering birds are found by most basin CBCs.

Key Environmental Correlates: Strongly associated with old-growth conifer forest (Mannan et al. 1980, Nelson 1989, Carey et al. 1991, Mellen et al. 1992, McGarigal and McComb 1995). Also uses large-diameter stands of deciduous trees (for example, large cottonwoods and maples) in riparian areas and even in low-density residential neighborhoods. The mean diameter of snags on which it fed in the Coast Range was 41 inches (range 8-73 inches). Forages on both standing and fallen trees, and will use less mature forests if a few large-diameter trees are present or if mature stands are present nearby. Feeds extensively on carpenter ants. Home range on individual birds during the course of a year encompasses over 2000 acres, and birds commonly travel up to 4 miles.

Threats, Limiting Factors, Population Viability: This species faces several threats, including conversion of forests to non-forest habitats; shift to shorter-rotation even-aged forests; and removal of downed wood (for fuels reduction) that is important as a foraging substrate. Because they feed extensively on the ground, woodpeckers are vulnerable to being killed by several mammalian predators and by vehicles. For this reason downed wood should not be placed near roads.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. The density of breeding pairs should be an average of one pair per 1500 acres within the percent of the landscape that is suitable habitat (Altman 1999). As proposed in *Conservation Strategy for Landbirds in Coniferous Forests of Western Oregon and Washington* habitat objectives should include the following in managed stands older than 60 years:

- Maintain >70 percent canopy closure and >70 percent conifer species canopy trees
- Maintain 2 nest snags per 10 ac, each being >30 inches in diameter
- Retained snags should be spatially well distributed and mostly hard snags, but some may be defective live trees.

- Provide an average of 12 foraging snags per acre (mix of hard and soft snags) in the following size classes:
    - 10-20 in dbh = 7/ac
    - 20-30 in dbh = 3/ac
    - >30 in dbh = 2/ac (may include the nest snags)
- Maintain a 5 acre no-harvest buffer around known nest or roost sites.
- Extend rotation ages to >80 years to provide potential snags of sufficient size, and retain these snags and recruit replacement snags (large live trees) at each harvest entry.
- Retain large live trees with defective or dying conditions such as broken tops, fungal conks, and insect infestations.
- If snags have not been retained (or are insufficient in number), create snags through blasting tops or inoculation with heart rot if size of trees meets species requirements.
- Retain known or suitable nesting and roosting snags from all harvest and salvage activities and restrict access for fuelwood cutters.
- During harvest operations, retain large logs and stumps in various stages of decay for foraging sites.
- Avoid use of pesticides near retained snags

Conservation Needs: Table 3-96 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-96: HUC6 Units with the Most Suitable Habitat for Pileated Woodpecker

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900010802	Black & Salmon & Wall Cr.	6	14448	4102	5.86
170900040602	Horse & Eugene Cr.	6	27068	9805	5.51
170900010803	Waldo Lake; Black & Salmon Cr.	6	12510	5297	5.48
170900011001	Salt & Gold & Eagle Cr.	6	39473	19719	4.99
170900040601	Separation Cr.	6	29711	11630	4.94

Table 3-96: HUC6 Units with the Most Suitable Habitat for Pileated Woodpecker

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Olive-sided Flycatcher

Special Designations: “Vulnerable” (ODFW sensitive species). Partners In Flight focal species.

Distribution, Status, and Trends: This neotropical migrant songbird is uncommon throughout the basin. Application of simple species-habitat models to aerial imagery using GIS suggests about 0.8 percent of the basin might contain suitable habitat. Along Willamette Basin BBS routes it was detected at 5.5 percent of surveyed points in 2003. The Oregon BBA Project confirmed nesting in 28 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 65 percent. BBS data covering the periods 1968-2003 and 1980-2003 show a decrease both in the Willamette Valley and in western Oregon-Washington generally. The regional trends are statistically significant.

Key Environmental Correlates: In the Willamette Basin this species is strongly associated with old-growth conifer forest (Carey et al. 1991, McGarigal and McComb 1995). However, it is not an indicator of old-growth conifer forest per se, but rather is associated with canopy gaps created by blowdowns, mudflows, lightning strikes, beaver impoundments, and other natural processes or from human-related activities (logging, low-density residential development, controlled burns). In fact, it is one of the few species that appear to benefit from some types of fragmentation of conifer forests. However, the continuing increase in logged forest runs contrary to the documented overall decline in numbers of this species Habitat requirements were described by Altman (1999):

> Optimal habitat is edges and forest openings where tall trees and snags are present for singing and foraging perches, and varying sized conifers for nesting. This may include harvest units, post-fire habitat, natural edges of bodies of water, or old-growth forest with extensive areas of broken canopies. It is more abundant in two-story (green-tree retention) treatments than small (0.1 ac) patch cuts, modified clearcuts, or unharvested control stands. Optimal habitat in early-seral forest appears to be stands larger than 50 acres with an open canopy and retained green-trees and snags. The most important variable for nest success in managed early successional forest may be the presence of snags taller than 40 ft. Successful nesting in harvest units occurs in both small clumps of trees (aggregates) with canopy closure less than 50 percent, and in singular, dispersed trees throughout the harvest unit. Successful nesting also occurs in understory suppressed trees and in young plantation trees.

Threats, Limiting Factors, Population Viability: As is true of all neotropical migrants, numbers currently may be limited as much or more by conditions on wintering grounds in the tropics than by habitat on breeding grounds, but evidence is lacking. An insectivore, this species is potentially vulnerable to pesticides. Fire suppression, dead wood removal (for example, for fuels reduction and "forest health" programs), and low beaver populations undoubtedly limit the acreage of available habitat (snags in open-canopy forests and forest gaps).

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. The density of breeding pairs should be an average of one pair per 50 acres within the percent of the landscape that is suitable habitat (early successional with conditions described below or old growth with large canopy gaps) (Altman 1999). As proposed in *Conservation Strategy for Landbirds in Coniferous Forests of Western Oregon and Washington* habitat objectives should include the following, applied within harvest units larger than 50 acres:

- Retain >2.5 ac areas (aggregate clumps) with 4-12 trees/ac) that are >40 ft high and are within the harvest unit, not adjacent to the forest edge.
- The remainder of the harvest unit should average 1-2 trees/ac that are >40 ft high, dispersed relatively equally throughout the harvest unit
- Retained trees should be >50 percent hemlocks or true firs to provide preferred nest trees, and have at least 25 percent foliage volume (canopy lift) for nesting substrate.
- Retain or provide suppressed or plantation trees throughout the harvest unit (>5/ac) that are 10-40 ft high.

In addition to green-tree retention, seed tree, shelterwood, or group selection cuts may be used to meet the biological objectives.

- In reforestation units, include at least 10 percent hemlock or true fir seedlings, and retain these trees through thinnings and harvest.
- Retain residual clumps of older forest in association with retained green-trees to increase edge and reduce effects of wind-throw on retained green-trees.
- Retain large trees in association with retained large snags where snags can serve as guard and foraging perches.
- Maintain retained large canopy trees through stand development and recruit replacement green-trees at each harvest entry.

Conservation Needs: Table 3-97 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-97: HUC6 Units with the Most Suitable Habitat for Olive-Sided Flycatcher

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900010802	Black & Salmon & Wall Cr.	6	7069	243	4.40
170900110402	Timothy Lake; Dinger Lake	5	18764	1279	4.09
170900040602	Horse & Eugene Cr.	6	15900	73	3.89
170900010803	Waldo Lake; Black & Salmon Cr.	6	7086	149	3.77
170900011001	Salt & Gold & Eagle Cr.	6	25342	630	3.74

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Vaux’s Swift

Special Designations: Partners In Flight focal species.

Distribution, Status, and Trends: This aerial-foraging neotropical migrant traditionally nested only in large snags, but with the disappearance of many of these has adapted to nesting mostly in uncapped unused brick chimneys. The Oregon BBA Project confirmed nesting in 37 percent of the large survey units in the basin and found evidence of possible or probable nesting in an additional 5 percent. Along Willamette Basin BBS routes the species was detected at 2.5 percent of surveyed points in 2003, with a maximum during the period 1968-2003 of 6.3 percent in 1972. BBS data covering the periods 1968-2003 show a decrease both in western Oregon-Washington generally but possibly not in the Willamette Valley. Tall chimneys are also used as staging and roosting areas by enormous numbers of swifts just prior to migration. As many as 20,000 birds roost annually in one tall chimney at a school in Portland, and a total of 55,000 were estimated to be roosting in the few chimneys in the Willamette Valley used for this purpose in mid-September 2000 (Bull 2003).

Key Environmental Correlates: In forested areas it prefers old growth but will use logged areas if snags suitable for nesting are available (Manuwal 1991, Carey et al. 1989, 1991). It is more common in old growth on moist soils than on dry soils, and preferentially selects streams and wetlands for aerial foraging (Manuwal 1991, Bull and Beckwith 1993). Swifts also forage in the multi-layered, broken canopy of old-growth forests, and over agricultural fields, lakes, rivers, and residential neighborhoods. Snags used for nesting by pairs or colonies of swifts generally have a diameter of at least 27 inches and contain holes excavated by pileated woodpeckers or resulting from detached limbs or rot.

Threats, Limiting Factors, Population Viability: As is true of all neotropical migrants, numbers currently may be limited as much or more by conditions on wintering grounds in the tropics than by habitat on breeding grounds, but evidence is lacking. Loss of old-growth forest, however, is probably a major contributor to its decline. Fire suppression, dead wood removal (for example, for fuels reduction and "forest health" programs), shorter harvest rotations, and low beaver populations undoubtedly limit the acreage of available habitat (i.e., snags in open-canopy forests and forest gaps). In developed areas, fewer new houses are being built with brick chimneys and where they are, they typically are partially capped to exclude swifts and other wildlife. At the same time some of the older, taller brick chimneys have been torn down or are being used to vent heat and gases at times when they are most-needed by staging swifts. As insectivores, swifts also are potentially vulnerable to pesticides.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. To accomplish this, the *Conservation Strategy for Landbirds in Coniferous Forests of Western Oregon and Washington* (Altman 1999) recommends the following habitat objectives for managed forests:

- Increase the length of harvest rotations to greater than 100 years;
- Retain or create nest structures with diameter greater than 27 inches and height greater than 82 ft, that are in different stages of decay and in stands with less than 60 percent canopy closure (for example, canopy gaps) so they are accessible to flying swifts;
- Provide an average of 5 of these potential nest/roost structures per square mile at any point in time, with up to 30 percent being live trees with broken tops (created or natural), and up to 20 percent being snags;
- Maintain a 5 acre no-harvest buffer around known nest or roost sites.

Conservation Needs: Table 3-98 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-98: HUC6 Units with the Most Suitable Habitat for Vaux's Swift

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900120202	S. Milwaukie; Happy Valley; Lake Oswego; W	1	13669	13669	4.57
170900100103	Beaverton & Rock & Cedar Mill Cr.	1	20904	20904	4.45
170900120203	Gresham; Portland; N. Milwaukie	1	13256	13256	4.34
170900120201	Portland; Forest Hills; Multnomah Channel	1	15623	15623	3.51
170900010802	Black & Salmon & Wall Cr.	6	4102	4102	3.28

Table 3-98: HUC6 Units with the Most Suitable Habitat for Vaux's Swift

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Marbled Murrelet

Special Designations: "Threatened" (federal and state). "Imperiled" (ONHP).

Distribution, Status, and Trends: This forest-nesting seabird breeds mostly within about 36 miles of the Oregon coast, so its occurrence in the Willamette Basin is very limited. The ORNHIC database contains records from just 3 of the 170 Willamette watersheds. Locational data are also available from: http://www.reo.gov/gis/data/gisdata/index.htm. During the mid-1990s the Oregon population was estimated at 6,600—20,000 individuals (Nelson 2003). Predators and other factors have caused failure of two-thirds of the nests, and the Pacific population may be declining at a rate of 4-7 percent per year.

Key Environmental Correlates: Requires a natural platform high in a conifer tree for laying its eggs (it does not build a nest). The platform, generally of moss or dwarf mistletoe based on a stout horizontal limb beneath the forest canopy, must be at least 4 inches wide (preferably 10) and located at least 30 ft up (preferably 185) in a large conifer. Unlike spotted owls, whose territories encompass hundreds of acres of well-connected old growth stands, marbled murrelets do not defend large territories and even tend to nest in loose colonies. Presence of nearby river corridors may facilitate daily movements between nesting trees and marine waters. Populations might be influenced as much or more by ocean conditions (where murrelets feed and winter) as by the availability of suitable nest sites.

Threats, Limiting Factors, Population Viability: Populations of this species are experiencing very low recruitment rates, due partly to nest predation and partly to high mortality in young prior to reaching the ocean (USFWS 1994, 1996). Harvest of old-growth forest not only removes suitable egg placement sites, but also—by fragmenting the forest—increases habitat suitability for and search efficiency of ravens, other corvids, and raptors that prey on murrelet eggs and/or young. Although the Northwest Forest Plan established late-successional reserves, the habitat in large areas within these reserves will not be suitable for 50-100 years. Meanwhile, harvest of suitable habitat continues under the umbrella of Habitat Conservation Plans, land exchanges, and misidentification of habitat suitability during surveys of sites slated for timber sales (Nelson 2003). Moreover, the "survey and manage" requirements that apply to many rare species on federal lands may soon be eliminated. In marine waters, murrelets face a wide arrange of threats, including oil spills, marine pollutants, incidental mortality from gill nets, incidental harvest of some of their fish prey, and effects of mariculture facility operations (for example, alteration of local food base due to pollution).

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

Conservation Needs: See: USFWS 1996, 1997.

For Further Information See:

US Departments of Agriculture and Interior 1993
Nelson 2003
Nelson et al. 1992
Nelson & Hamer 1995a
Nelson 1997
ODF 1995
USFWS 1996, 1997
Ralph et al. 1994
Evans et al. 2000

Spotted Owl

Special Designations: “Threatened” (federal). “Vulnerable” (ONHP).

Distribution, Status, and Trends: This legendary owl occurs rarely but widely in the Willamette Basin. The ORNHIC database contains records from 96 of the 170 Willamette Basin watersheds. The relatively large number is attributable partly to implementation of extensive surveys for this species. Potential habitat for this species was mapped by McComb et al. (2002). Locational data are also available from: http://www.reo.gov/gis/data/gisdata/index.htm.

A population decline (but not necessarily a decline in survival or reproductive rates) during the period 1985-1998 was documented partly by an analysis of banding data (Franklin et al. 1999).

Key Environmental Correlates: Spotted owls nest and roost within or very near old-growth conifer forest, feeding on forest mammals (primarily flying squirrels and red tree voles) beneath the forest canopy, and sometimes along edges of canopy gaps and clearcuts. The requirement of this species for large (>3000 acre) blocks of old-growth conifer forest has been well-documented (for example, Forsman et al. 1984, Thomas et al. 1990, Carey et al. 1992, Ripple et al. 1997, Swindle et al. 1999). Younger forests are used as well, although secondarily and mainly when they contain relict patches of old growth in locations where no old-growth forest otherwise exists. Nests are placed on natural platforms in trees (for example, formed by deformed or broken tops) or in cavities of live or dead trees, generally 72-99 ft above the ground. Diameter of nest trees averages 42–53 inches in Oregon (Forsman et al. 1984).

Threats, Limiting Factors, Population Viability: Although the Northwest Forest Plan established late-successional reserves, much of the potential habitat within these reserves will not be optimal for 50-100 years. Meanwhile, harvest of old growth conifers continues on some forest lands. Simultaneously, the integrity of spotted owl as a species may be threatened by increasing numbers of barred owls which have displaced spotted owls from some areas and occasionally hybridize with them (Forsman 2003).

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat.

For Further Information: Thomas et al. 1990, USDA & USDI 1994, Thrailkill et al. 1997, Marcot & Thomas 1997, Meyer et al. 1998, Irwin et al. 2000, Forsman et al. 2002, Noon & Franklin 2002, Glenn et al. 2004.

Great Gray Owl

Special Designations: "Vulnerable" (ODFW sensitive species).

Distribution, Status, and Trends: Although this is Oregon's largest owl, it is difficult to survey and consequently little is known of its status or trends in the Willamette Basin. In Oregon it resides mainly on the east slope of the Cascades and in the Blue Mountains, but there are scattered reports of birds breeding within the basin, especially at higher elevations (for example, Goggans and Platt 1992). NHI models and data project that this species has a close association with land cover in less than 1 percent of the basin. Since 1850, suitable habitat for this species in the basin may have decreased by 95-100 percent (Payne 2002).

Key Environmental Correlates: Like spotted owls, great gray owls nest and roost in old-growth conifer forest, but appear to feed to a greater degree than other owls in montane meadows. They also forage in natural forest gaps and clearcuts if they support a vigorous herbaceous layer. Flightless fledglings may benefit from partially downed wood which they use as perches.

Threats, Limiting Factors, Population Viability: Loss of old-growth conifer forests, through logging and fire, is probably the greatest immediate threat. Succession of montane meadows into forest as a potential result of global warming may be a longer-term problem.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. Lengthen the usual harvest rotation period to sustain the supply of old growth trees.

For Further Information See: Quintana-Coyer et al. 2004.

Conservation Needs: Table 3-99 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-99: HUC6 Units with the Most Suitable Habitat for Great Gray Owl

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900010802	Black & Salmon & Wall Cr.	6	7593	77	2.95
170900040602	Horse & Eugene Cr.	6	15867	54	2.34
170900011001	Salt & Gold & Eagle Cr.	6	25511	331	2.32

Table 3-99: HUC6 Units with the Most Suitable Habitat for Great Gray Owl

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900011101	Groundhog Cr: S.Fork	6	9914	236	1.97
170900040802	French Pete Cr.	6	10491	18	1.97

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Oregon Slender Salamander

Special Designations: “Critically Imperiled” (ONHP).

Distribution, Status, and Trends: This salamander is reported to be locally common in parts of the eastern (Cascade) portion of the basin, and its range is confined entirely to Oregon. The ORNHIC database contains documented records from 18 of the 170 Willamette watersheds.

Key Environmental Correlates: Moist coniferous forests, especially mature and old growth stands, appear to provide the primary habitat for this species. Nests have been found under bark and in large rotten logs. Tall, multi-layered canopies of old growth retain humidity and intercept fog, which maintains ground-level moisture essential to this species.

Threats, Limiting Factors, Population Viability: Habitat loss and degradation (i.e., reduced soil moisture) is the major threat. The accumulations of large-diameter moist woody debris required by this species are much less available in younger managed forests, especially with the implementation of fuels reduction programs and shorter harvest rotations. Fragmentation of forests with roads and clearcuts potentially decreases soil moisture in the adjoining forest. Global climate warming also could potentially diminish soil moisture and result in more frequent fires, with negative impacts on salamanders.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. Lengthen the usual harvest rotation period to sustain the supply of old growth trees.

Conservation Needs: Of the 170 sixth-field watersheds in the basin, each subdivided by elevation zones, the watershed-elevation zone units in Table 3-100 contain records of this species in the ORNHIC database.

Table 3-100: HUC6 Units with ORNHIC Database Records for Oregon Slender Salamander

HUC6	Watershed Name (Not Comprehensive)	Elevation	Public Land?	In PCA?
170900030302	Brownsville	3	yes	no
170900040802	French Pete Cr.	5	yes	yes
170900040803	Roaring R. & Elk Cr.	4	yes	yes
170900050101	Detroit; Idanha	4	yes	no
170900050101	Detroit; Idanha	5	yes	no
170900050201	Breitenbush R.	4	yes	no
170900050301	Detroit Reservoir	4	yes	no
170900050301	Detroit Reservoir	5	yes	no
170900050401	Gates; Lyons; Mill City	4	yes	no
170900050501	Little North Santiam R.	4	yes	no
170900050601	Jefferson; Lyons; Bear Branch	4	yes	no
170900060302	Upper Thomas & Neil Cr. & Indian Prairie	3	yes	no
170900060401	Greenpeter Reservoir	3	yes	no
170900060401	Greenpeter Reservoir	3	no	no
170900060401	Greenpeter Reservoir	4	yes	no
170900090303	Woodcock Cr.	2	yes	yes
170900090401	Scotts Mills Senecal Cr. & Mill Cr.	4	yes	no
170900090402	Abiqua Cr.	3	yes	no
170900090604	Copper & Henry Cr.	4	yes	no
170900110301	Big Cliff Reservoir	3	yes	no
170900110301	Big Cliff Reservoir	4	yes	no
170900110303	Fish Cr. E.	3	yes	no
170900110601	Nohorn Cr.	4	yes	yes

Elevation zones (Elev) are:
1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft
PCA = Priority Conservation Area.

American (Pine) Marten

Special Designations: "Vulnerable" (ODFW sensitive species).

Distribution, Status, and Trends: Mainly resides in higher-elevation portions of the basin. The ORNHIC database contains 3 documented records of this species. All were from one watershed within the upper Middle Fork of the Willamette River, in the mid-1990s. Application of simple species-habitat models to aerial imagery suggests about 6 percent of the basin might have contained (in the early 1990s) habitat that could be at least marginally suitable and 0.7 percent might contain good habitat. Historically, unregulated trapping for pelts eliminated martens from some areas.

Key Environmental Correlates: Martens are usually found in dense old-growth conifer forests, possibly favoring those closer to water. To a lesser degree they use dense deciduous or mixed forest, and rocky alpine areas.

Threats, Limiting Factors, Population Viability: Continued loss of unmanaged old growth stands may threaten this species. Its requirement for accumulations of woody debris makes it less likely to survive in younger managed forests, especially with the implementation of fuels reduction programs and shorter harvest rotations.

Biological Objectives:

- Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat, particularly as:
    - Tracts of greater than 640 acres that contain >45 percent mature and old-growth forest.
    - Riparian areas or other corridors wider than 600 ft wide
- Lengthen the usual harvest rotation period to sustain the supply of old growth trees and create and maintain uneven-aged stands of timber
- Retain downed dead wood to the maximum extent (ideally covering >20 percent of the ground) consistent with fuel reduction needs and in a spatially dispersed pattern

Conservation Needs: Table 3-101 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-101: HUC6 Units with the Most Suitable Habitat for American (Pine) Marten

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score
170900040602	Horse & Eugene Cr.	6	19120	239	3.37
170900040501	Boulder Cr. & Smith R.	6	44810	3752	2.91
170900040802	French Pete Cr.	6	13940	414	2.87
170900050103	Pyramid Cr.	6	12596	2377	2.43
170900011201	Staley & Swift & Spruce Cr.	6	24943	4681	2.13

Table 3-101: HUC6 Units with the Most Suitable Habitat for American (Pine) Marten

HUC6	Watershed Name (Not Comprehensive)	Elevation	HabAcOK	HabAcBest	Habitat Suitability Score

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a “10.”

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6’s, and electronic files accompanying the plan for ranking of all watersheds and units.

Red Tree Vole

Special Designations: “Vulnerable” (ONHP).

Distribution, Status, and Trends: This small, highly specialized rodent resides mainly in the Cascade and Coast Range portions of the basin. From 650 surveys in potentially suitable habitat on national forests and BLM lands in western Oregon, a total of over 254 sites were discovered (Biswell et al. 2000). Survey data suggest the species may be less frequent in the more northerly part of the Cascades (for example, Clackamas and North Santiam watersheds).

Key Environmental Correlates: The preferred habitat of this vole appears to be moist, old-growth coniferous forest, especially Douglas-fir. To a lesser degree this vole uses mid-aged closed-canopy forests that have significant stands of large-diameter (>21 inch) trees. It spends nearly its entire life high in conifer trees (Meiselman and Doyle 1996). Tall, multi-layered canopies of old growth retain humidity and intercept fog, which functions as a climatic buffer and a source of free water. Large branches provide stable support for nests, protection from storms, and travel routes (Biswell et al. 2000).

Threats, Limiting Factors, Population Viability: Continued loss of unmanaged old growth stands due to logging and fire will threaten this species. Changes in forest microclimate (drying) as a result of adjoining clearcuts, roads, and global warming also could adversely it.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. Lengthen the usual harvest rotation period to sustain a supply of old growth trees.

Conservation Needs: Table 3-102 shows the sixth-field HUC units that may contain the most suitable habitat for this species. The estimates are from application of simple species-habitat models to early 1990s aerial imagery, so they are very approximate. For more information on HUC6 units with suitable habitat for this species, such as units that are publicly owned, privately owned, or identified by the The Nature Conservancy as Priority Conservation Areas, see Appendix D.

Table 3-102: HUC6 Units with the Most Suitable Habitat for Red Tree Vole

HUC6	Watershed Nam (Not Comprehensive)	Elev	HabAcOK	HabAcBest	HS
170900110402	Timothy Lake; Dinger Lake	5	15565	10823	3.16
170900040301	Blue River Reservoir & Cook Cr.	3	3063	1111	2.80
170900020102	Creswell W.; Camas Swale	2	2500	290	2.73
170900030103	Coyote Cr.	2	12864	1456	2.36
170900110301	Big Cliff Reservoir	4	9847	2759	2.35

Elevation zones (Elev) are:

1= <500 ft, 2= 500-1000 ft, 3= 1000-2000 ft; 4= 2000-3000 ft; 5= 3000-4000 ft, 6= >4000 ft

HabAcOK is the acres of possible habitat, i.e., scored >5 for habitat suitability on a 0-10 scale.

HabAcBest is the acres of habitat scored a "10."

The habitat suitability score is a relative index that represents the proportional extent (not acres) of higher-suitability habitat in the unit defined by the HUC6 and elevation zone; see Appendix D for more explanation, map files accompanying this plan for location of the HUC6's, and electronic files accompanying the plan for ranking of all watersheds and units.

Townsend's (Pacific Western) Big-eared Bat

Special Designations: "Vulnerable" (ONHP).

Distribution, Status, and Trends: This is one of the least common of the bats that use old-growth conifer forest. The ORNHIC database contains documented records from 16 of the 170 Willamette watersheds. It may be more common in the Coast Range than Cascades; numbers in northwestern Oregon were coarsely estimated at 300-400 individuals in 1987 but reliable survey data are too few to determine trends or densities.

Key Environmental Correlates: This species may not be highly dependent on old growth coniferous forests, but neither does it appear to be strongly associated with other forested cover types. Like many bats, its main requirement is for cool roosting and hibernation sites, and for these the bark and cavities of very large trees provides suitable sites. This need is also met by caves, large rock outcrops, and some abandoned buildings or mine tunnels. This bat forages primarily over water, riparian areas, wetlands, and small canopy gaps in forests.

Threats, Limiting Factors, Population Viability: Major threats include disturbance of cave roosts (especially maternity colonies and hibernation sites) by recreationists; blockage of cave entrances from intentional or natural events; and loss of mature and old-growth forest from logging and fire. Pesticide spraying can potentially affect the insect populations upon which this bat feeds.

Biological Objectives: Maintain or expand existing numbers and geographic distribution through protection, restoration, and management of suitable habitat. Lengthen the usual harvest rotation period to sustain a supply of old growth trees.

3.2.6 Future Conditions with No New Actions

3.2.6.1 Plan Trend 2050

Given the timeline and budget for development of this *Willamette Subbasin Plan*, it is not possible to provide a detailed characterization of future environmental conditions with no new actions for each of the focal species and habitats selected for assessment. However, the Pacific Northwest Ecosystem Research Consortium recently analyzed three alternative future scenarios for the Willamette Basin. The results are published in the *Willamette River Basin Planning Atlas* (Oregon State University Press, 2002).

PNERC evaluated the impacts of plausible actions on aquatic and terrestrial species by using ecological response models keyed to highly detailed land cover information. The scenarios each identified changes through the year 2050, and each assumed a common 2050 population of 3.9 million residents—about a doubling of the 1990 human population.

One of the scenarios, Plan Trend 2050, assumes that existing long-term plans and policies (such as the federal Northwest Forest Plan, Oregon's land use planning system) will be unchanged and fully implemented; the scenario also projects recent trends in human population growth, land use, and water use through 2050. By combining long-term plans and recent trends, the scenario portrays forest and agricultural land uses along with residential, industrial, and commercial development. The analysis of the Plan Trend 2050 scenario, therefore, offers insight into the trajectory of Willamette basin environmental conditions and can approximate environmental conditions absent new actions.

Before describing environmental conditions under Plan Trend 2050, this scenario's assumptions and settings need to be specified. Plan Trend 2050 has about 93 percent of the 2050 population living inside compact urban growth boundaries (UGBs), with residential densities increased significantly over current levels. To accommodate the larger basin population, in 2050 UGBs have expanded 51,000 acres beyond their 1990 extent. Nearly two-thirds of this expansion occurs in the cities of Portland, Salem, Eugene/Springfield, Albany, and Corvallis.

Consistent with current land use planning regulations, no additional rural residential zones are established; however, new rural residences built after 1990 are located on vacant rural parcels existing today. Using densities consistent with each county's zoning, Plan Trend 2050 shows complete rural residential build-out by 2020.

The amount of prime farmland in the Plan Trend 2050 scenario remains about the same as today, but about 40,000 acres have been converted to urban uses. Plan Trend 2050 shows increases in the nursery sector and in hybrid poplar plantations, while grass seed, orchards, berries, and Christmas trees remain major crops. Plan Trend 2050 increases the amount of riparian vegetation along currently regulated water-quality limited streams (Oregon Senate Bill 1010 and Clean Water Act section 303d) by approximately 10 percent over today's conditions.

Federally managed public forest lands in this scenario follow the Northwest Forest Plan. Old growth forests remain concentrated on federal lands. No changes occur in national wildlife refuge management. State and private forest lands in Plan Trend 2050 follow the 1995 Oregon Forest Practices Act.

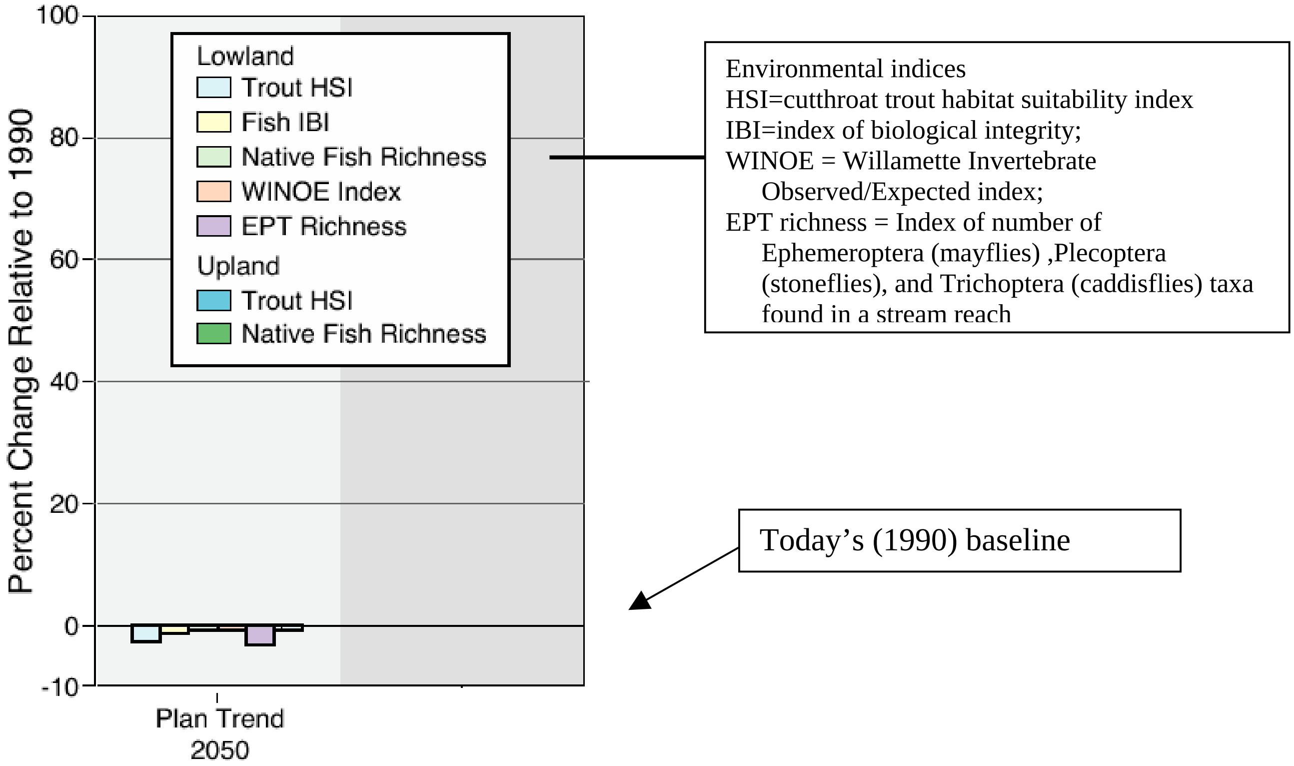
3.2.6.2 Environmental Conditions in 2050

Aquatic Habitats and Species. Water use has a direct impact on aquatic habitats and populations of aquatic species. In Plan Trend 2050, growing surface water demand reflects population and economic growth, with municipal demands nearly doubling from the year 2000 and an increased demand for agricultural irrigation. Under Plan Trend 2050, increases in agricultural, municipal, industrial, and domestic water consumption would result in the loss of nearly an additional 8 percent of current habitat volume.

However, local impacts of water use on habitat quantity can be more significant. For example, in the mid-Willamette subbasin, model results suggest that under Plan Trend 2050, habitat volume could decline an additional 19 percent. While all 2nd- to 4th-order streams in the basin maintained some flow historically, according to PNERC’s models, currently, an estimated 82 miles of stream have gone dry as a result of water withdrawals, and this number would double to 169 miles under Plan Trend 2050.

Under Plan Trend 2050, conditions for cutthroat trout would improve slightly in streams draining federally managed forest lands but would continue to decline in streams draining privately managed and state-managed forest lands. Overall, however, all indices of environmental condition decline under the Plan Trend 2050 scenario, this includes the Index of Biological Integrity, a native fish richness index, and invertebrate indices) (see Figure 3-32).

Nevertheless, overall, the models’ projected environmental conditions for Plan Trend 2050 (and even a more development-oriented scenario) are not significantly different from today for all indicators of stream condition. This is in part because most of the land converted to urban and residential use under Plan Trend 2050 is in agriculture today, and the environmental effects of urban development and agricultural land use appear to be equivalent.



Environmental indices
HSI=cutthroat trout habitat suitability index
IBI=index of biological integrity;
WINOE = Willamette Invertebrate Observed/Expected index;
EPT richness = Index of number of Ephemeroptera (mayflies) ,Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa found in a stream reach

Today's (1990) baseline

Figure 3-32: Change Likely from Plan Trend 2050 Scenario

Source: Adapted from PNERC's Willamette River Basin Planning Atlas, 2002.

Terrestrial Habitats and Species. Using median percent change as a measure, the area of wildlife habitat for native species does not change dramatically in any of the future landscapes relative to today. However, the percentage of species that gained or lost habitat do show substantial differences between landscapes. Under the Plan Trend 2050 scenario,10 percent more species would experience decreased habitat than would experience increased habitat. Three species increase more than 10 percent under the Plan Trend 2050 scenario.

Specifically, in Plan Trend 2050, for 17 modeled terrestrial species, populations of coyotes, red fox, bobcat, and Cooper's hawk increase by 7 to more than 50 percent compared to today's levels. On the other hand, populations of black-capped chickadee, blue grouse, Douglas squirrel, gray jay, great horned owl, marsh wren, mourning dove, Northern goshawk, Northern spotted owl, pileated woodpecker, raccoon, red-tailed hawk, and western meadowlark decline by 1 to 25 percent compared to today's levels (see Figure 3-33).

In general, in all future scenarios, the urban fringes and forested uplands have fewer numbers of species than today. Areas that are now urban, agriculture, or in riparian zones in the Willamette Valley generally had greater numbers of species in the pre-Euro-American landscape than they do currently.

In terms of wildlife population viability, the pre-EuroAmerican and three alternative future scenarios represent significant departures from today's landscape conditions. In the modeling, wildlife populations respond in remarkably similar ways for both Plan Trend 2050 and the development scenario: both scenarios result in declines for a majority of the modeled species. In contrast, a conservation scenario enhanced all but three of the populations.

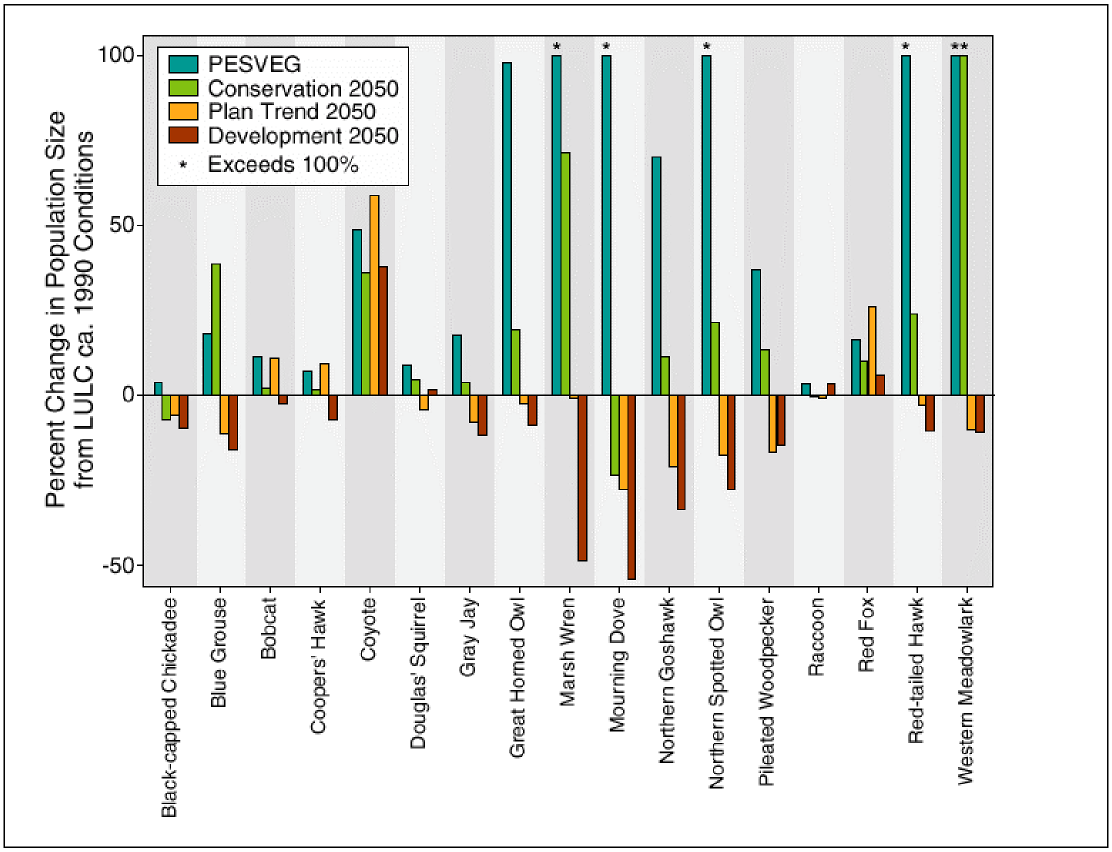


Figure 3-33: Change in Terrestrial Species Populations under Alternative Future Scenarios

Source: PNERC's Willamette River Basin Planning Atlas, 2002.

3.3 Out-of-Subbasin Effects

Both aquatic and terrestrial species in the subbasin are affected by habitat conditions and features that occur outside of the subbasin.

3.3.1 Aquatic

Spring Chinook salmon, winter steelhead, and coho salmon spend the majority of their life histories in the Ocean outside of the Willamette Basin. Pacific lamprey also migrate to the ocean but the majority of their life histories occur in freshwater streams.

3.3.1.1 Estuary

Habitat losses in estuarine environments have resulted from hydropower system operations. Dams on the Columbia system have altered the hydrograph. This alteration has resulted in a reduction in average sediment supply to the estuary, an increase in the residence time of water in the estuary and corresponding decrease in salinity, an increase in detritus and nutrient residence, and a decrease in vertical mixing (Sherwood, as cited in Ecovista, 2004).

These changes have converted the estuary to a less energetic system with high organic sedimentation rates. The changes have caused an overall loss of estuarine habitat used for rearing and has contributed to the decline in habitat quantity and quality (Ecovista, 2004)

3.3.1.2 Nearshore

El Niño events, combined with other climatic and oceanic phenomenon, have caused a shift in ocean conditions over the past two decades; impacting Columbia Basin salmon returns (NMFS, 2000). Based on the cyclic nature of the oceanic and climatic regimes, conditions are likely going to become more favorable for fish in the next decade (NMFS, 2000).

3.3.1.3 Marine[14]

Ocean conditions strongly affect overall salmon survival. Salmon spend most of their life in the ocean and early ocean survival is widely considered to be a time of particularly high mortality. In recent years, a growing body of evidence from field, tagging, and correlation studies shows that Pacific salmon experience large year-to-year fluctuations in survival rates of juvenile fish making the transition from freshwater to marine environment (Hare et al. 1999). Climate-related changes have the most affect on salmon survival very early in the salmon's marine life history (Pearcy 1992, Francis and Hare 1994).

The Pacific Decadal Oscillation is a pan-Pacific, recurring pattern of ocean-atmospheric variability that alternates between climate regimes every 20-30 years (Hare et al. 1999). The PDO affects water temperatures off the coast of Oregon and Washington and has cold (negative) and warm (positive) phases (Hare et al. 1999). A positive PDO phase brings warmer water to the eastern North Pacific, reducing upwelling of nutrient-rich cooler water off the coast of North America and decreasing juvenile salmon survival (Hare et al. 1999). The negative phase of the PDO has the opposite effect, tending to increase salmon survival.

Climatic changes are manifested in both returns and harvests. Mantua et al. (1997) found evidence of an inverse relationship between harvests in Alaska and off the coast of Oregon and Washington. The negative phase of the PDO resulted in larger harvests of Columbia River stocks and lower harvests of Alaskan stocks. In the positive phase, warmer water resulted in lower harvests (and runs) in the Columbia River, but higher harvests in Alaska. Phase reversals occurred around 1925, 1947, 1977, and possibly 1999. The periods from 1925-1947 and from 1977-1999 were periods of low returns to the Columbia River, while periods from 1947-1977 and the current period are periods of high returns.

El Nino/Southern Oscillation. The El Nino-Southern Oscillation (ENSO), commonly referred to as El Nino and La Nina), like the PDO, affects water temperatures off the coast of Oregon and Washington and has both a cold (negative) and warm (positive) phase. ENSO events are much shorter than PDO events in that events typically occur every 2-7 years and last 12-18 months. Positive ENSO events occur more frequently during positive PDO phases and less frequently during negative PDO phases (Hare et al. 1999). ENSO events intensify or moderate the effects of PDO changes on salmon survival.

A positive ENSO (El Nino) event also results in higher North Pacific Ocean temperatures, while a negative ENSO (La Nina) results in lower temperatures. Positive ENSO events occur

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[14] This information is taken from TOAST, February 2004.

more frequently during positive PDO phases and less frequently during negative PDO phases (Hare et al. 1999).

PDO and ENSO also affect freshwater habitat of salmon. Positive PDO and ENSO events generally result in less precipitation in the Columbia Basin. Lower stream flows result in higher water temperatures and a longer outmigration. It is likely that less water will be spilled over mainstem Columbia and Snake river dams to assist smolt outmigration (Hare et al. 1999).

Climate Change. Climate change on a longer term than the PDO could have a large impact on the survival of Columbia Basin salmon. Finney et al. (2000) used lake sediment elemental composition to find evidence of very long term cycles of abundance of sockeye salmon in the Bristol Bay and Kodiak Island regions of Alaska over the past 300 years. No doubt there have been similar variations in the abundance of Columbia Basin salmon.

Computer models generally agree that the climate in the Pacific Northwest will become, over the next half century, gradually warmer and wetter, with an increase of precipitation in winter and warmer, drier summers (USDA Forest Service 2004). These trends mostly agree with observed changes over the past century. Wetter winters would likely mean more flooding of certain rivers, and landslides on steep coastal bluffs (Mote et al. 1999) with higher levels of wood and grass fuels and increased wildland fire risk compared to previous disturbance regimes (USDA Forest Service 2004). The region’s warm, dry summers may see slight increases in rainfall, according to the models, but the gains in rainfall will be more than offset by losses due to increased evaporation. Loss of moderate-elevation snowpack in response to warmer winter temperatures would have enormous and mostly negative impacts on the region’s water resources, forests, and salmon (Mote et al. 1999). Among these impacts are a diminished ability to store water in reservoirs for summer use, and spawning and rearing difficulties for salmon.

Climate models lack the spatial resolution and detailed representation of critical physical processes that would be necessary to simulate important factors like coastal upwelling and variation in currents. Different models give different answers on how climate change will affect patterns and frequencies of climate variations such as ENSO and PDO.

For the factors that climate models can simulate with some confidence, however, the prospects for many Pacific Northwest salmon stocks could worsen. The general picture of increased winter flooding and decreased summer and fall streamflows, along with elevated stream and estuary temperatures, would be especially problematic for in-stream and estuarine salmon habitat. For salmon runs that are already under stress from degraded freshwater and estuarine habitat, these changes may cause more severe problems than for more robust salmon runs that utilize healthy streams and estuaries.

While it is straightforward to describe the probable effects of these environmental patters individually, their interaction (PDO, ENSO, climate change) is more problematic. The main question appears to be the duration of the present favorable (for salmon) PDO period and the timing and intensity of the subsequent unfavorable period. Prudence suggests planning for a shorter favorable period and a subsequent longer, if not more intense, unfavorable period.

3.3.1.4 Mainstem Habitat

Predation seems to be a major impact on juveniles and may be an important factor on adults. Heavy predation by birds on outmigrating juveniles has recently been documented in the Columbia River Estuary. It is also likely that fish predators and marine mammals are turning to salmonids as a response to the very low smelt runs. Marine mammal impacts appear to be important for adult winter steelhead and spring chinook. Human caused factors such as constructing protected nesting islands or causing the spring outmigration flows to be lower and clearer than normal (due to storage of spring flows) can exacerbate predation problems. Large aggregations of hatchery fish can also attract predators to hit wild fish also (Martin et. al. 1998)

3.3.1.5 Hydropower

Dams on the Columbia system have altered the hydrograph which may impact spring outmigration flows and habitat (see Sections 3.4.1.1 and 3.4.1.4). No hydroelectric dams occur between the mouth of the Willamette and the ocean.

3.3.1.6 Out-of-Subbasin Harvest

Historic production, release and harvest of large numbers of hatchery produced fish encouraged the incidental over-harvest of wild stocks prior to marking programs (see Section 3.2.4.7). Harvest rates in the past have been too high for wild stocks to sustain. Ocean and in river harvest rates may have been 50-70% for spring chinook and as high as 25% for steelhead. Steelhead are currently unaffected by lower Columbia gillnet seasons and are subject to selective sport fisheries due to fin-clipping. Spring chinook harvest rates have been substantially reduced in the Columbia (Martin et. al. 1998). Marking (fin-clipping) enables selective harvest of hatchery fish and has substantially reduced this problem in recent years, but historic harvest pressure on naturally produced fish likely further contributed to genetic simplification. Reductions in North Pacific Ocean fisheries impacts on Willamette chinook would be helpful, but appear to be unlikely in the near term (Martin et. al. 1998).

3.3.1.7 Hatcheries

Hatchery-reared salmon and steelhead have impacts on wild anadromous salmonids through competitive interaction, genetic introgression, and disease transmission (see Section 3.2.4.7). Recent efforts to decrease the likelihood of negative impacts from hatchery competition and interbreeding have been undertaken through Hatchery and genetics management plans. The large runs of salmonids currently seen in the Willamette are expected to be largely of hatchery origin (WLCTRT 2002). The impact of non-Willamette hatchery fish in out-of-subbasin life history stages is unknown. Hatchery and genetics management plans are currently under development for upper Willamette Pacific salmonid stocks. Implementation of these plans will guide management to address many of the issues associated with risks resulting from decline of genetic diversity. Increased habitat capacity throughout the basin will, over time, improve the likelihood that new life history strategies will develop in response to more diverse and well distributed habitat characteristics.

3.3.2 Terrestrial

In general, most mammals, amphibians, reptiles, and rare plant species are not strongly and directly affected by factors outside the Willamette subbasin. This is because, except for a few large predators and scavengers, their seasonal and annual movements are constrained to areas entirely within the subbasin. Thus, external factors most likely to affect these groups are ones that occur over broad regions, such as global warming, spread of invasive species, and long-distance movement of airborne contaminants and food sources (such as fish). In contrast, many bird species (like fish) migrate or forage beyond the subbasin and thus can be limited more strongly by factors elsewhere. However, sound information is lacking with regard to which species are being limited by which particular external factors, and whether factors beyond the subbasin are more limiting than those within.

3.4 Environment/Population Relationships

Overall, stream management activities, such as restoration and enhancement, provide enormous benefits to stream- and riparian-associated wildlife, both directly by increasing the productivity of fish and other aquatic organisms upon which some terrestrial animals feed, and indirectly by improving habitat complexity and quality. Approximately six terrestrial vertebrates of the Willamette Basin (four of which are residents) have been documented as having a "strong and consistent association" with salmonid fish (see Table 3-103). An additional 70 terrestrial vertebrates (including 44 residents) have been documented as having a "recurrent," "indirect," or "rare" association with salmonids (Cedarholm et al., 2001). No population trends data are available for the mammals or amphibians listed in Table 3-103, and for birds, trends are known only for the period beginning in 1968, from Breeding Bird Survey data. Those data, which mainly cover roadsides, do not show any statistically significant regional decreases for any bird species having a "strong and consistent" or "recurrent" relationship to salmonids; and in fact, some of the species (such as osprey) have had significant increases.

Table 3-103: Wildlife Species of the Willamette Basin Documented to Feed on (Or Are Otherwise Functionally Linked to) Live or Dead Salmonid Fish*

Species Grouped by Degree of Association with Salmonids	Species Status	How or When Associated with Salmonids
STRONG AND CONSISTENT ASSOCIATION:		
Bald Eagle	Resident	Carcasses
Bald Eagle	Resident	Spawning—freshwater
Black Bear	Resident	Carcasses
Black Bear	Resident	Spawning—freshwater
Common Merganser	Resident	Freshwater rearing—fry, fingerling, and parr
Common Merganser	Resident	Incubation—eggs and alevin
Northern River Otter	Resident	Carcasses
Northern River Otter	Resident	Freshwater rearing—fry, fingerling, and parr
Northern River Otter	Resident	Spawning—freshwater
Harlequin Duck	Seasonal	Incubation—eggs and alevin

Table 3-103: Wildlife Species of the Willamette Basin Documented to Feed on (Or Are Otherwise Functionally Linked to) Live or Dead Salmonid Fish*

Species Grouped by Degree of Association with Salmonids	Species Status	How or When Associated with Salmonids
Osprey	Seasonal	Freshwater rearing—fry, fingerling, and parr
Osprey	Seasonal	Spawning—freshwater
RECURRENT ASSOCIATION:		
American Crow	Resident	Carcasses
American Crow	Resident	Freshwater rearing—fry, fingerling, and parr
American Dipper	Resident	Carcasses
American Dipper	Resident	Freshwater rearing—fry, fingerling, and parr
American Dipper	Resident	Incubation—eggs and alevin
Barrow’s Goldeneye	Resident	Carcasses
Barrow’s Goldeneye	Resident	Freshwater rearing—fry, fingerling, and parr
Barrow’s Goldeneye	Resident	Incubation—eggs and alevin
Belted Kingfisher	Resident	Freshwater rearing—fry, fingerling, and parr
Belted Kingfisher	Resident	Spawning—freshwater
Bobcat	Resident	Carcasses
Bobcat	Resident	Spawning—freshwater
Common Merganser	Resident	Carcasses
Common Raven	Resident	Carcasses
Common Raven	Resident	Freshwater rearing – fry, fingerling, and parr
Common Raven	Resident	Spawning—freshwater
Coyote	Resident	Carcasses
Great Blue Heron	Resident	Freshwater rearing—fry, fingerling, and parr
Mink	Resident	Carcasses
Mink	Resident	Freshwater rearing—fry, fingerling, and parr
Mink	Resident	Spawning—freshwater
Pacific Giant Salamander	Resident	Freshwater rearing—fry, fingerling, and parr
Pacific Giant Salamander	Resident	Incubation—eggs and alevin
Pied-billed Grebe	Resident	Freshwater rearing—fry, fingerling, and parr
Raccoon	Resident	Carcasses
Raccoon	Resident	Freshwater rearing—fry, fingerling, and parr
Steller’s Jay	Resident	Carcasses

Table 3-103: Wildlife Species of the Willamette Basin Documented to Feed on (Or Are Otherwise Functionally Linked to) Live or Dead Salmonid Fish*

Species Grouped by Degree of Association with Salmonids	Species Status	How or When Associated with Salmonids
Virginia Opossum	Resident	Carcasses
Water Shrew	Resident	Carcasses
Water Shrew	Resident	Freshwater rearing—fry, fingerling, and parr
Water Shrew	Resident	Incubation—eggs and alevin
California Gull	Seasonal	Carcasses
Common Goldeneye	Seasonal	Carcasses
Common Goldeneye	Seasonal	Freshwater rearing—fry, fingerling, and parr
Common Goldeneye	Seasonal	Incubation—eggs and alevin
Common Loon	Seasonal	Freshwater rearing—fry, fingerling, and parr
Double-crested Cormorant	Seasonal	Freshwater rearing—fry, fingerling, and parr
Forster’s Tern	Seasonal	Freshwater rearing—fry, fingerling, and parr
Glaucous Gull	Seasonal	Carcasses
Glaucous-winged Gull	Seasonal	Carcasses
Glaucous-winged Gull	Seasonal	Incubation—eggs and alevin
Glaucous-winged Gull	Seasonal	Spawning—freshwater
Golden Eagle	Seasonal	Carcasses
Golden Eagle	Seasonal	Spawning—freshwater
Herring Gull	Seasonal	Carcasses
Herring Gull	Seasonal	Freshwater rearing—fry, fingerling, and parr
Ring-billed Gull	Seasonal	Carcasses
Ring-billed Gull	Seasonal	Freshwater rearing—fry, fingerling, and parr
Turkey Vulture	Seasonal	Carcasses
Western Grebe	Seasonal	Freshwater rearing—fry, fingerling, and parr
INDIRECT ASSOCIATION:		
American Dipper	Resident	Carcasses
Bald Eagle	Resident	Carcasses
Bald Eagle	Resident	Freshwater rearing—fry, fingerling, and parr
Bald Eagle	Resident	Incubation—eggs and alevin
Fog Shrew	Resident	Carcasses
Killdeer	Resident	Carcasses

Table 3-103: Wildlife Species of the Willamette Basin Documented to Feed on (Or Are Otherwise Functionally Linked to) Live or Dead Salmonid Fish*

Species Grouped by Degree of Association with Salmonids	Species Status	How or When Associated with Salmonids
Pacific Shrew	Resident	Carcasses
Pacific Water Shrew	Resident	Carcasses
Peregrine Falcon	Resident	Carcasses
Peregrine Falcon	Resident	Freshwater rearing—fry, fingerling, and parr
Spotted Sandpiper	Resident	Carcasses
Trowbridge’s Shrew	Resident	Carcasses
Vagrant Shrew	Resident	Carcasses
Water Shrew	Resident	Carcasses
Cliff Swallow	Seasonal	Carcasses
Harlequin Duck	Seasonal	Carcasses
Northern Rough-winged Swallow	Seasonal	Carcasses
Tree Swallow	Seasonal	Carcasses
Violet-green Swallow	Seasonal	Carcasses
Willow Flycatcher	Seasonal	Carcasses
RARELY ASSOCIATED:		
American Marten	Resident	Carcasses
American Robin	Resident	Incubation—eggs and alevin
Canvasback	Seasonal	Carcasses
Common Garter Snake	Resident	Freshwater rearing—fry, fingerling, and parr
Common Loon	Seasonal	Carcasses
Deer Mouse	Resident	Carcasses
Douglas’ Squirrel	Resident	Carcasses
Fog Shrew	Resident	Carcasses
Franklin’s Gull	Seasonal	Freshwater rearing—fry, fingerling, and parr
Gray Fox	Resident	Carcasses
Gray Jay	Resident	Carcasses
Great Egret	Seasonal	Freshwater rearing—fry, fingerling, and parr
Greater Scaup	Seasonal	Carcasses
Greater Scaup	Seasonal	Incubation—eggs and alevin
Greater Yellowlegs	Seasonal	Incubation—eggs and alevin

Table 3-103: Wildlife Species of the Willamette Basin Documented to Feed on (Or Are Otherwise Functionally Linked to) Live or Dead Salmonid Fish*

Species Grouped by Degree of Association with Salmonids	Species Status	How or When Associated with Salmonids
Green Heron	Seasonal	Freshwater rearing—fry, fingerling, and parr
Green-winged Teal	Resident	Incubation—eggs and alevin
Hooded Merganser	Resident	Carcasses
Hooded Merganser	Resident	Freshwater rearing—fry, fingerling, and parr
Hooded Merganser	Resident	Incubation—eggs and alevin
Long-tailed Weasel	Resident	Carcasses
Mallard	Resident	Carcasses
Mallard	Resident	Incubation—eggs and alevin
Mew Gull	Seasonal	Incubation—eggs and alevin
Mountain Lion	Resident	Spawning—freshwater
Northern Flying Squirrel	Resident	Carcasses
Pacific Shrew	Resident	Carcasses
Pacific Water Shrew	Resident	Carcasses
Red Fox	Resident	Carcasses
Red-tailed Hawk	Resident	Carcasses
Song Sparrow	Resident	Carcasses
Spotted Towhee	Resident	Carcasses
Striped Skunk	Resident	Carcasses
Trowbridge’s Shrew	Resident	Carcasses
Trumpeter Swan	Seasonal	Carcasses
Trumpeter Swan	Seasonal	Freshwater rearing—fry, fingerling, and parr
Trumpeter Swan	Seasonal	Incubation—eggs and alevin
Vagrant Shrew	Resident	Carcasses
Varied Thrush	Seasonal	Carcasses
Varied Thrush	Seasonal	Incubation—eggs and alevin
Western Grebe	Seasonal	Carcasses
Western Pond Turtle	Resident	Carcasses
Western Pond Turtle	Resident	Freshwater rearing—fry, fingerling, and parr
Winter Wren	Resident	Carcasses
Wolverine	Resident	Carcasses

Table 3-103: Wildlife Species of the Willamette Basin Documented to Feed on (Or Are Otherwise Functionally Linked to) Live or Dead Salmonid Fish*

Species Grouped by Degree of Association with Salmonids	Species Status	How or When Associated with Salmonids

*This table is adapted from an IBIS database file provided by the Northwest Habitat Institute. Most of these species may feed as much or more on other types of fish. Among birds whose status is “seasonal,” only those that occur regularly in the Willamette Basin are included.

Most of the wildlife species shown may feed as much or more on other types of fish than they do on salmon, including all nonnative fish. Predation rates probably depend on the seasonal availability of salmonids, size, and habitat use. No data are available to adequately quantify predation rates in the Willamette Basin. In addition to these species that consume fish, one species (American beaver) has a profound and usually positive effect on stream environments. Beavers are recovering from near-extirpation as a result of trapping in the early 1900s. Also, native ungulates that use riparian areas can, under extreme conditions, reduce canopy cover (shade) that is important to fish. Wildlife also transport nutrients across riparian-upland boundaries, thus increasing the functional connectivity of habitats. Virtually every environmental correlate important to fish populations is at least indirectly important to some wildlife populations. For this plan, environmental correlate data for fish habitats in the Willamette Basin were not available for the entire basin at the watershed (sixth-field HUC) scale, as would be necessary to allow a geographically comprehensive and detailed description of linkages between fish and wildlife.

Stream management activities likely to benefit wildlife the most are perhaps those that restore riparian vegetation, those that restore natural flow regimes to rivers, those that provide a long-term supply of wood to the channel, and those that improve water quality (especially sediment runoff). Nonetheless, some stream restoration activities could potentially have adverse effects on some wildlife species in certain situations. These activities are discussed below—not to discourage their use, because in most instances their benefits to wildlife exceed their detriments, but to call attention to the need for multispecies wildlife analysis on a project-by-project basis when stream restoration programs are implemented.

3.4.1 Riparian Planting

Streambanks frequently are planted to help streams meet legal criteria for water temperature. However, increases in tree canopy cover can shade out some rare plants, such as Willamette Valley daisy. Riparian planting should never extend into areas that are (or were, historically) wetland or upland prairies. Also, complete shade can diminish the suitability of habitat for several stream-associated species that normally prefer early-successional conditions, such as willow flycatcher, common nighthawk, killdeer, common yellowthroat, and most waterfowl. Historically, these species relied on major floods to reset succession and provide unshaded conditions in a semi-random manner. Natural disturbances of that type are now subdued as a result of dams regulating flow on many rivers. In addition, planting of forests in urban or agricultural landscapes has the potential to increase the spread of some invasive species and predators, as well as increasing native wildlife as a result of improving canopy connectivity.

3.4.2 Riparian Buffers

Riparian buffers are nearly always beneficial to both fish and wildlife. The main difference is that many wildlife species prefer wider buffers than those commonly recommended for protecting fish and water quality. There is no particular width threshold below which woodland wildlife will fail to use a buffer. Generally speaking, “the wider the better.” Acceptable widths depend on the density and type of riparian vegetation, the harshness of adjoining unbuffered landscape (impervious surfaces versus native, nonforest vegetation), the wildlife species, and distance to its source populations. For protecting individual wildlife species or wildlife generally, buffer widths (measured on one side of a channel) ranging from 100 to more than 1,000 ft have been documented (McComb and Hagar, 1992; Washington Department of Fish and Wildlife, 1995).

3.4.3 Fencing Streams

Because riparian areas support habitat for salmon and trout by cooling stream water, fences are sometimes erected to protect riparian areas from overgrazing. Depending on their design and location, fences also can unintentionally restrict movements of some wildlife species (large mammals), but overall their benefits are more likely to be positive than negative.

3.4.4 Stabilizing Streambanks

Steep, eroding streambanks potentially degrade water quality, so they are often the focus of remedial measures. However, a few wildlife species use this habitat exclusively or opportunistically, to create burrows where they then nest or breed. These include belted kingfisher, northern rough-winged swallow, bank swallow (rare in the Willamette Basin), barn owl, mink, beaver, and otter. Placement of riprap or planted willows on all eroding banks potentially can diminish local populations of these species.

3.4.5 Reconnecting Isolated Sloughs, Side Channels, and Oxbows

Many backwater sloughs and oxbows were originally connected to rivers year-round or during high water but became isolated through intentional human activities (such as those to improve river navigation) or because of natural events such as beaver dams, flood deposits, or channel meandering. When barriers (debris jams, beaver dams, concrete dams, etc.) that block fish access to these areas are removed, it increases habitat for several fish species, especially nursery habitat and flood refugia. As a result, several fish-feeding bird and mammal species will reap some benefits. However, other rare aquatic plants and listed aquatic amphibians and turtles could be harmed under the following conditions:

- Current velocities become excessive—for example, they exceed thresholds for frog and salamander egg deposition, juvenile maturation, aquatic plant metabolism, or waterfowl foraging.

- Water temperatures in the newly reconnected slough rise or fall below optimal temperatures for particular amphibians or turtles during critical periods.

- Conversion from seasonal to permanent inundation degrades the habitat of some plants that thrive only in seasonally wet soils.

- Reconnecting increases the isolated slough's vulnerability to waterborne seeds of invasive plants or to fish (especially exotic species) that prey on juvenile turtles and amphibians.
- Newly increased boat access to isolated areas increases disturbance of wildlife significantly.

Wildlife species most likely to be directly harmed by the reconnection of isolated sloughs include red-legged frog, Oregon spotted frog, northwestern salamander, western pond turtle, and several dabbling ducks.

3.4.6 Removing Barriers; Culvert Replacement

Similar to the above (see Appendix G for fish barrier maps).

3.5 Identification and Analysis of Limiting Factors/Conditions

3.5.1 Historical Factors Leading to Decline of Aquatic Species and Ecological Functions and Processes

This section presents information on the limiting factors for focal species in the various subbasins within the Willamette Basin. The section is organized by subbasin, with those subbasins not having undergone EDT analysis presented first, as follows:

- Calapooia Subbasin
- Coast Fork Willamette Subbasin
- Long Tom Subbasin
- Luckiamute/Rickreall Subbasin
- Marys Subbasin
- Middle Fork Willamette Subbasin
- Molalla/Pudding Subbasin
- North Santiam Subbasin
- Salem-area watersheds
- South Santiam Subbasin
- Tualatin Subbasin
- Upper Willamette Mainstem
- Yamhill Subbasin

For each of these subbasins, the geographic setting and environmental conditions are described with respect to the aquatic focal species for this plan, along with limiting factors in the lower and upper subbasins. Appendixes H, E, and G contain overview maps, fish distribution maps, and fish barrier maps, respectively, for the Willamette Basin.

This is followed by subbasins that have undergone EDT analysis to identify limiting factors for the aquatic focal species of this plan:

- Clackamas Subbasin
- Johnson Creek Subbasin
- McKenzie Subbasin
- Tryon Creek Subbasin

- Lower Willamette

The information on the limiting factors in these EDT-analyzed subbasins is lengthier and, in most cases, includes detailed results from the EDT analysis.

3.5.1.1 Limiting Factors in the Calapooia Subbasin

This section describes the Calapooia Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: winter steelhead, spring Chinook, and Oregon chub.

Focal species present:

- Winter steelhead trout
- Spring Chinook salmon
- Cutthroat trout

Focal species present historically:

Oregon chub (all life stages)

Geographic Setting. The Calapooia Subbasin covers an area of 329 square miles on the western slope of the Cascade Range and the floor of the Willamette Valley. The Calapooia River is approximately 80 miles long and enters the Willamette River within the city of Albany at RM 122. Approximately 94 percent of the land in the subbasin is privately owned. Most of the private lands are in forestry, agricultural, and rural residential land uses. Urban lands cover about 2 percent of the watershed, primarily within the cities of Albany and Lebanon (Runyon et al., 2004). The Willamette National Forest manages a small area in the river's headwaters, while the Eugene District of the BLM manages a portion of the lower subbasin.

The Calapooia River's headwaters are in the western Cascade Range. The river's headwaters flow through Willamette National Forest and industrial forestlands, small-acreage farms, and rural residential areas until the river reaches the floor of the Willamette Valley near the community of Holley (RM 48). Major tributaries in the forested upper subbasin include the North Fork Calapooia River, and Biggs, McKinley, and Potts creeks. The lower Calapooia River flows through the city of Brownsville, agricultural lands, scattered rural residential areas, and the city of Albany, where it joins the Willamette River. Brush, Butte, Courtney, and Oak creeks are major tributaries in the lower subbasin.

The upper subbasin drains the western Cascade Range, but most of the river and the larger tributaries flow through the Willamette Valley's recent alluvial deposits. The subbasin's high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. As a result of the subbasin's low elevations and the western Cascade geology, summertime stream flows are not supplemented by large amounts of snowmelt or numerous spring-fed sources.

The headwaters and tributaries of the upper Calapooia Subbasin flow steeply off the Cascade Range. The upper river's gradient ranges from nearly 2.0 percent in the headwaters to 1.0 percent at RM 60. After the river and tributaries enter the Willamette Valley the gradient decreases and the river meanders through the alluvial deposits of the Willamette River. The gradient of the Calapooia River decreases from 0.44 near Holley to less than 0.06 percent near the river's confluence with the Willamette River. Most of the spring Chinook salmon prespawning holding and spawning takes place in the upper river above Holley.

Environmental Conditions. Altered watershed processes, riparian and aquatic habitat, and access to historical spawning and rearing areas in the Calapooia Subbasin have affected the productivity, capacity, and diversity of cutthroat trout, juvenile spring Chinook salmon, and winter steelhead populations. Table 3-104 summarizes changes in the subbasin's environmental conditions and how these changes have affected cutthroat trout, juvenile spring Chinook, and winter steelhead life stages.

Upper and Lower Subbasins. Relative to the lower subbasin, the forested upland portions of the upper subbasin have aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Runyon et al., 2004; Baker et al., 2002). Impacts to aquatic and riparian habitats have been greater in the lower Calapooia Subbasin than in the forested upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because the largest proportion of unconstrained river and stream channels were in the area where the Calapooia River flowed across the flat Willamette Valley (Pacific Northwest Ecosystem Research Consortium, 2002; Runyon et al., 2004).

Table 3-104. Calapooia Subbasin: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Naturally low flows in the basin are aggravated by water withdrawals, which increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the watershed, are aggravated by loss of riparian cover, reduced wetland areas, and channel simplification.	Brownsville Dam presents an obstacle to upstream movement of adults. Numerous culverts throughout the watershed serve as barriers to adult refuge habitat.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of adult holding areas.	
	Adult spawning/ egg incubation		Numerous culverts throughout the watershed serve as barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-104. Calapooia Subbasin: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the basin are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the watershed, do not provide optimal conditions for juvenile rearing.	Numerous culverts throughout the watershed present barriers to juvenile access to rearing and refuge habitat.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.

Table 3-104. Calapooia Subbasin: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Spring Chinook Salmon	Adult migration and holding	Naturally low flows in the basin are aggravated by water withdrawals, which increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the watershed, are aggravated by loss of riparian cover, reduced wetland areas, and channel simplification.	Brownsville Dam presents an obstacle to upstream movement of adult prespawners. The dams and water diversions within the Thompson's Mill complex delay adult migration.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of adult holding areas.	Adult prespawners are delayed at the base of the dams within the Thompson's Mill complex and at Brownsville Dam, subjecting the fish to possible harassment and poaching. Recreational use in the upper basin and limited large wood for cover results in harassment of adult prespawners holding in pools.
	Adult spawning/ egg incubation			Limited wood in tributary streams has reduced retention of spawning gravels.	Recreational use in the upper basin and limited large wood for cover results in harassment of adult spawners.

Table 3-104. Calapooia Subbasin: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the basin are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the watershed, do not provide optimal conditions for juvenile rearing.	Numerous culverts throughout the watershed present barriers to juvenile access to rearing and refuge habitat. Culverts on seasonal streams in the lower subbasin may be limiting access to winter refuge habitat.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.

Table 3-104. Calapooia Subbasin: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Winter Steelhead Trout	Adult migration and holding	Naturally low flows in the basin are aggravated by water withdrawals, which increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the watershed, are aggravated by loss of riparian cover, reduced wetland areas, and channel simplification.	Brownsville Dam presents an obstacle to upstream movement of adults. The dams and water diversions within the Thompson's Mill complex may delay adult migration. Numerous culverts throughout the watershed present barriers to adult refuge habitat.	Channels in the lower portions of the River and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. Loss of wetland, floodplain and off-channel habitats have affect the quantity and quality of adult holding areas.	
	Adult spawning/ egg incubation		Numerous culverts throughout the watershed serve as barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-104. Calapooia Subbasin: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the basin are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the watershed, do not provide optimal conditions for juvenile rearing.	Numerous culverts throughout the watershed present barriers to juvenile access to rearing and refuge habitat.	Channels in the lower portions of the River and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. Loss of wetland, floodplain and off-channel habitats have affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.

Source: USACE 1989; ODFW 1992; Mamoyac, ODFW, personal communication, 2004; Runyon et al. 2004.

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood. While there are areas along the lower river with extensive floodplain forests, the extent and composition of riparian vegetation has been modified along the river's middle reaches and tributaries (Runyon et al., 2004). Over time, a number of historical practices (such as log drives and stream cleaning) have reduced the quantity of large wood in the Calapooia River and tributary channels (Runyon et al., 2004). While riparian areas in the forested upper subbasin have greater numbers of conifer trees than the lower subbasin does, historical riparian harvests and wood removal from streams have reduced large wood in these channels. Reduced large wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat. Reduced wood in the river, particularly large log jams, has reduced hiding cover for fish and led to increased harassment of adult spring Chinook salmon holding the upper river's pools.

Water Quality Changes. Water quality has been modified throughout the subbasin. Water temperatures exceed criteria in the Calapooia River and some tributaries, particularly in the lower subbasin. Natural low flows in the subbasin are aggravated by water withdrawals, which could increase water temperatures (Runyon et al., 2004). In general, water temperatures are lower in the forested upper subbasin than in the lower subbasin (Runyon et al., 2004). High water temperatures in the lower subbasin are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces (Runyon et al., 2004).

Changes in Flow Regimes. There have been some impacts to the subbasin's hydrologic regimes. Changes in land use in the lower subbasin have affected hydrologic regimes in the tributaries. Channelization of tributaries in the lower subbasin; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows (Mamoyac, ODFW, personal communication, 2004).

Fish Passage Barriers. Fish passage barriers are an issue throughout the subbasin. There are several dams and diversions that limit upstream migration. The dams and diversions within the Thompson's Mill complex (RM 19.5 to 28.5) have the greatest impact on fish passage. While Sodom Dam is equipped with a fish ladder, migrating spring Chinook salmon are delayed at the base of the dam, which subjects them to additional stress and possible harassment and poaching (Runyon et al., 2004). Brownsville Dam (RM 36) is equipped with a fish passage ladder but its effectiveness is limited, particularly during high flow periods when spring Chinook salmon, winter steelhead, and cutthroat trout are moving through the river (Gary Galovich, ODFW, personal communication, 2003). In addition, there are numerous unscreened small diversions within the subbasin (Mamoyac, ODFW, personal communication, 2004).

There are large numbers of road crossing culverts in the lower and upper subbasin that block or limit fish passage. In an inventory of more than 80 culverts in the middle portions of the subbasin (for example, Brush and Courtney creeks), more than 90 percent of the culverts did not meet the ODFW fish passage criteria (Runyon et al., 2004). Access into seasonal streams in the lower subbasin provides important fish refuge habitat during high flow periods.

Cutthroat trout, and juvenile winter steelhead and spring Chinook salmon were observed in seasonal streams in the lower subbasin (for example, Butte and Lake creeks) during high flow periods in the winter and early spring (Randy Colvin, Oregon State University, personal communication, 2004). No fish were observed in seasonal streams where there were downstream culverts blocking fish passage. Limiting the fish passage above culverts restricts the amount of habitat available for all cutthroat trout life stages and important rearing habitat for juvenile winter steelhead and spring Chinook salmon.

Appendix G shows specific fish passage barriers on the Calapooia, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river and tributaries through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats (Runyon et al., 2004). Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout and juvenile spring Chinook salmon and winter steelhead. These habitats provide fish with habitat for foraging and refuge from winter flood events.

Key Factors Limiting Fish Populations. The upper and lower portions of the Calapooia Subbasin are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower Calapooia Subbasin. In the lower Calapooia Subbasin, the productivity, capacity, and diversity of cutthroat trout, spring Chinook salmon, and winter steelhead populations are limited by the following:

- **Flow Regime Change and Channel Structure.** Modification of tributary high flow regimes from urbanization, land use changes, channel and bank confinement and water withdraws have reduced interactions between aquatic and terrestrial environments reducing terrestrial inputs of wood, nutrients, and sediment. This dynamic interaction is essential for habitat formation and maintenance. Flow regime and channel structure influence virtually all aspects of habitat quality and quantity.
- **Key Habitat Loss**. Modifications to key habitats and the natural processes that form and maintain them have affected all life stages of fish. Changes in interactions between the rivers and streams with their floodplain have reduced the delivery and transport of large wood, modified gravel deposition patterns, reduced the frequency and depth of pools, minimized hiding cover for adult and juvenile fish and reduced available spawning areas.
- **Habitat Connectivity.** Flow modifications and channel confinement and in-stream barriers have reduced access to off-channel habitats essential for juvenile rearing and winter refuge and decreased connectivity between habitats throughout the watershed and the dynamic processes needed to form and maintain habitat diversity.
- **Habitat Modification**. Modifications of key aquatic habitats have affected all life stages. Limited spawning areas and reduced levels of gravels/small cobbles have reduced the areas available for spawning.

- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Withdrawals**. Unscreened water withdrawals affect juvenile fish.
- **Water Temperature**. Changes in summertime water temperature regimes limit the capacity of river and tributary streams to support adult and juvenile fish.
- **Fish Passage Barriers**. Two dams on the river and fish passage barriers at road crossings on tributary streams limit the capacity of the Calapooia to support spring Chinook salmon, winter steelhead, and cutthroat trout migration and limit juvenile access to rearing and refuge habitat.
- **Additional Factors**. Other factors limiting cutthroat trout, spring Chinook salmon, and winter steelhead populations include competition with hatchery and introduced fish; lower numbers of salmon carcasses, which reduces nutrient inputs and thus food availability; and harassment of adult migrating and holding prespawning fish by recreational activities such as boating and fishing. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Table 3-105 shows the EDT attributes related to these limiting factors for cutthroat trout, spring Chinook salmon and winter steelhead in the lower Calapooia Subbasin. The lower subbasin is largely on the floor of the Willamette Valley and in private ownership. The priorities for restoration are qualitative ratings based on the information in Table 3-104 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-105: Qualitative Rating of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook, and Cutthroat Trout in the Lower Calapooia Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	There have been changes in the interannual variability of low and high flows as a result of land use changes. This has affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Harassment	Possible harassment and poaching below the dams.	**HIGH**
Obstructions	Dams delay migration into the upper subbasin; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	**HIGH**

Table 3-105: Qualitative Rating of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook, and Cutthroat Trout in the Lower Calapooia Subbasin

EDT Attribute Class	Description	Priority for Restoration
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation) and primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels has reduced channel stability.	Medium
Competition with hatchery fish	Surplus hatchery fish from South Santiam Hatchery have been released into the system (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Food	Salmon carcasses are reduced from historical levels, thus limiting nutrient inputs to the system and food availability for rearing fish.	Medium
Pathogens	Hatchery fish have been introduced, thus increasing the potential for disease (Mamoyac, ODFW, personal communication, 2004).	Medium
Withdrawals	Some unscreened diversions could affect juvenile rearing and juvenile out-migration.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Oxygen	Oxygen levels are adequate to support all life stages.	Low
Sediment load	Although there are periodic high turbidity levels, there does not appear to be increased sediment deposition (Mamoyac, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Calapooia Subbasin. Historically the upper subbasin was an important spawning and juvenile rearing area for all three of the focal species in the Calapooia. In contrast to the large-scale modification of the lower subbasin, most of the impacts to habitat and water quality in the upper subbasin are localized. Currently, limiting factors for spring Chinook, winter steelhead, and cutthroat in the upper Calapooia are as follows:

- **Channel Structure**. The road that parallels the upper river and other roads next to tributary channels have increased channel confinement and reduced riparian vegetation and canopy cover, but not to the extent of the lower subbasin.
- **Habitat Modification and Large Wood**. There have been systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have reduced large wood loads in the aquatic system. Reduced in-channel wood has resulted in modified gravel

deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.

- **Additional Factors**: Other, more moderate impacts to fish habitat and populations in the upper subbasin include partial and complete barriers to fish passage on tributary streams, changes in water temperature regimes as a result of reduced canopy cover, competition with hatchery introductions, and lower numbers of salmon carcasses, which reduces nutrient inputs and thus food availability.

Table 3-106 shows the EDT attributes related to limiting factors for cutthroat, spring Chinook, and winter steelhead in the forested upper Calapooia Subbasin, and area that consists primarily of industrial timberlands, although a small area in the headwaters is under U.S. Forest Service management. Again, the table presents qualitative ratings based on information in Table 3-104 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-106: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Winter Steelhead, and Spring Chinook in the Upper Calapooia River Subbasin.

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Habitat quality has been affected by moderate channel confinement through the river corridor road that parallels the mainstem and secondary roads and limited large wood.	**HIGH**
Harassment	High levels of recreational use of the upper river pools and limited hiding cover have increased the potential for harassment of adult spring Chinook salmon.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood.	**HIGH**
Channel stability	In some areas limited in-channel wood and reduced riparian function has destabilized channels.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas, thus increasing competition with native fish for habitat and food (Mamoyac, ODFW, personal communication, 2004).	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Obstructions	Some complete and partial barriers on tributary streams.	Medium
Pathogens	Hatchery fish have been introduced, which increases the potential for disease (Mamoyac, ODFW, personal communication, 2004).	Medium
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Competition with other species	Very low number of introduced fish species present in the Upper subbasin.	Low

Table 3-106: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Winter Steelhead, and Spring Chinook in the Upper Calapooia River Subbasin.

EDT Attribute Class	Description	Priority for Restoration
Flow	There have not been significant changes in the interannual variability of low and high flows.	Low
Oxygen	Oxygen levels are adequate to support all life stages	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	Minimal water withdrawals.	Low

3.5.1.2 Limiting Factors in the Coast Fork Willamette Subbasin

This section describes the Coast Fork Willamette Subbasin in terms of geographic and environmental conditions and presents information on the limiting factors for focal species in the subbasin: cutthroat trout and spring Chinook.

Focal species present:

- Spring Chinook salmon
- Cutthroat trout

Geographic Setting. The Coast Fork Willamette Subbasin covers an area of approximately 665 square miles within the Calapooya Mountains and the floor of the Willamette Valley. The river is 40 miles long and joins the Middle Fork Willamette River near Eugene to form the mainstem Willamette River. Only a third of the land in the Coast Fork Willamette Subbasin is managed by federal agencies. The U.S. Forest Service’s Umpqua National Forest and the Eugene District of the BLM manage a portion of the subbasin. The communities of Cottage Grove and Creswell are in the subbasin.

The Row River, the largest tributary, drains nearly 60 percent of the subbasin and joins the Coast Fork just below the city of Cottage Grove. Sharps and Mosby creeks are important tributaries to the Row River, which flows through a complex mixture of sedimentary and volcanic rocks, including tuffs, mudflow and lahar deposits, and basalt flows. Mineral-bearing layers intrude into bedrock in the headwaters of the Row River, and the area continues to be mined both commercially and recreationally. Mercury has been mined intensively in the Black Butte area, in the upper reaches of the mainstem Coast Fork Willamette River, and in the Bohemia Mining District, in the upper Row River drainage. Bedrock in the western portion of the basin, including the majority of the Coast Fork Willamette River and Mosby Creek drainages, is composed of marine sand and siltstones of the Eugene Formation.

Several dams managed by the U.S. Army Corps of Engineers divide the subbasin, including Cottage Grove Dam on the Coast Fork (at RM 29) and Dorena Dam on the Row River (at RM 7.5). These dams limit upstream fish passage and exert strong control over downstream hydrologic regimes, temperature patterns, sediment and bedload transport, and large wood delivery to the lower reaches. The upper subbasin is primarily forested with a mix of private industrial timberlands and areas managed by the federal government.

The upper subbasin drains the lower elevations of the western Cascade Range and the Calapooya Mountains. The subbasin’s high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. As a result of the subbasin’s low elevations, summertime stream flows are not supplemented by large amounts of snowmelt or numerous spring-fed sources.

Lower Mosby Creek and the Row and Coast Fork Willamette rivers downstream of the dams flow through narrow valleys filled with erodible alluvial sediments. Slopes are gentle relative to the volcanic parent materials to the east. The valley widens considerably downstream of the confluence of these three streams. Sand and gravel are mined in the lower basin, and much of the area is heavily farmed and developed for agriculture. The Row River downstream of Dorena Dam has an average slope of 0.2 percent but is much steeper upstream of the reservoir, where the river flows through narrow, incised valleys (U.S. Army Corps of Engineers, 2001).

Environmental Conditions. Alterations to subbasin processes, aquatic habitat, and access to historical spawning and rearing areas in the Coast Fork Willamette Subbasin have affected the productivity, capacity, and diversity of cutthroat trout and spring Chinook populations. Also, Oregon chub have lost habitat as backwater and off-channel areas have disappeared as a result of changes in seasonal flows associated with the construction of dams throughout the Coast Fork Willamette Subbasin. Table 3-107 summarizes changes in the subbasin’s environmental conditions and how these changes have affected cutthroat trout and spring Chinook salmon, while Table 3-108 summarizes the effects of environmental changes on Oregon chub.

The U.S. Army Corps of Engineers dams have restricted fish access to the upper subbasin and changed downstream hydrologic processes, water quality, and processes influencing habitat formation. There are no fish passage facilities at the Cottage Grove or Dorena dams. Cottage Grove Dam does not block access to historical spring Chinook salmon spawning areas, but Dorena Dam does block access to some historical habitat in the Row River. Both dams limit the movement of cutthroat trout.

Table 3-107. Coast Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	The mainstem of the Coast Fork (mouth to RM 31) is listed as impaired for fish passage because of the high mercury levels. There are water quality criteria exceedences of summer maximum temperatures below Cottage Grove and Dorena dams and in Camas Swale Creek. The Coast Fork is used only lightly to supply water for domestic, industrial, and agricultural uses; increased summer flows below the dams contribute to better water quality. There are reduced canopy shade levels on many tributary streams, which leads to increased water temperatures. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats.	Cottage Grove and Dorena dams are complete barriers to adult movement. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit adult upstream movement into foraging and refuge habitat.	The lower subbasin has reduced floodplain forest extent and connectivity. Roads have reduced the extent of riparian vegetation. Historically, most of the riparian areas were harvested; currently, many have reduced levels of conifers. Patches of floodplain forest are interspersed with areas with little floodplain vegetation. Reduced pool frequency, depth, and cover have affected the quality of adult habitat in the river and tributaries. Three species of nonnative invasive shrubs dominate riparian areas, particularly in the lower subbasin: Himalayan blackberry, Scotch broom, and reed canary grass. Limited wood in the river and tributaries has affected the quality of pools and backwater habitats. Revetments along the Lower Coast Fork and Row River have reduced habitat complexity.	

Table 3-107. Coast Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Maximum temperatures for incubation and emergence have been exceeded in the lower Coast Fork Willamette River and Row River.	Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, reducing spawning areas and gravels. Limited in-channel wood to capture spawning gravels. There appears to be a coarsening of substrate below the dams, which reduces spawning habitat.	
	Fry and juvenile rearing and migration	Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. There are water quality criteria exceedences of summer maximum temperatures for rearing below Cottage Grove and Dorena dams and in Camas Swale Creek. Dissolved oxygen concentrations do not meet criteria for rearing in Camas Swale Creek. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Flow fluctuations below the dams occur at rates rapid enough to entrap and strand juvenile fish.	Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity limiting rearing and refuge habitat. Cottage Grove and Dorena dams are complete barriers to juvenile fish movement. There are revetments along large portions of the Coast Fork Willamette and Row rivers downstream of the dams; this has reduced floodplain connectivity. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit juvenile upstream movement into refuge habitat.	Reaches of the Coast Fork Willamette River and Row river below dams have limited large wood, which reduces the formation of pools and side channels. As a result of historical wood removal and riparian harvests, there are significant reductions in large wood levels in tributary streams. This has reduced pools, cover, and other rearing habitats.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels. This limits nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, thus increasing competition with native fish for habitat and food.

Table 3-107. Coast Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Spring Chinook Salmon	Adult migration and holding	The mainstem of the Coast Fork (mouth to RM 31) is listed as impaired for fish passage because of the high mercury levels. There are water quality criteria exceedences of summer maximum temperatures below Cottage Grove and Dorena dams and in Camas Swale Creek. The Coast Fork is used only lightly to supply water for domestic, industrial, and agricultural uses; increased summer flows below the dams contribute to better water quality. There are reduced canopy shade levels on many tributary streams, which leads to increased water temperatures. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats.	Cottage Grove and Dorena dams are complete barriers to adult movement.	The lower subbasin has reduced floodplain forest extent and connectivity. Roads have reduced the extent of riparian vegetation. Historically, most of the riparian areas have been harvested; currently, many have reduced levels of conifers. Patches of floodplain forest are interspersed with areas with little floodplain vegetation. Reduced pool frequency, depth, and cover have affected the quality of adult habitat in the river and tributaries. Three species of nonnative invasive shrubs dominate riparian areas, particularly in the lower subbasin: Himalayan blackberry, Scotch broom, and reed canary grass. Limited wood in the river and tributaries has affected the quality of pools and backwater habitats. Revetments along the Lower Coast Fork and Row River have reduced habitat complexity.	

Table 3-107. Coast Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Maximum temperatures for incubation and emergence have been exceeded in the lower Coast Fork Willamette River and Row River.		Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, which reduces spawning areas and gravels. Limited in-channel wood to capture spawning gravels. There appears to be a coarsening of substrate below the dams, which reduces spawning habitat.	Boating, fishing, and other recreational activities harass adults moving and holding in pools.

Table 3-107. Coast Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. There are water quality criteria exceedences of summer maximum temperatures for rearing below Cottage Grove and Dorena dams and in Camas Swale Creek. Dissolved oxygen concentrations do not meet criteria for rearing in Camas Swale Creek. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Flow fluctuations below the dams occur at rates rapid enough to entrap and strand juvenile fish.	Floodplain is not frequently inundated, with less over-bank flow and side channel connectivity limiting rearing and refuge habitat. Cottage Grove and Dorena dams are complete barriers to juvenile fish movement. There are revetments along large portions of the Coast Fork Willamette and Row Rivers downstream of the dams; this has reduced floodplain connectivity. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit juvenile upstream movement into refuge habitat.	Reaches of the Coast Fork Willamette River and Row river below dams have limited large wood, which reduces the formation of pools and side channels. As a result of historical wood removal and riparian harvests, there are significant reductions in large wood levels in tributary streams. This has reduced pools, cover, and other rearing habitats.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels. This limits nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, thus increasing competition with native fish for habitat and food.

Source: U.S. Army Corps of Engineers, 2001; ODFW 1992; Fernauld et al., 2001; Landers et al., 2001.

Table 3-108: Coast Fork Willamette Subbasin: Subbasin Attributes Affecting Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Oregon chub	All	Camas Swale Creek, which once contained Oregon chub, has been so degraded as a result of industrial influences that Oregon chub no longer exist in this creek. The frequency and magnitude of high flows is not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas.	Loss of connectivity to floodplain and wetland habitats has affected availability of suitable habitat. Dams and other structures have changed river hydrology and reduced the amount of side channel habitat.	Three species of nonnative invasive shrubs dominate riparian areas, particularly in the lower subbasin: Himalayan blackberry, Scotch broom, and reed canarygrass. The lower subbasin has reduced floodplain forest extent and connectivity.	The presence of exotic fish in this system inhibits Oregon chub recolonization of formerly occupied habitat. Exotic fish such as bluegills and smallmouth bass likely caused the failure of an Oregon chub introduction into Schwarz Pond in the Row River in 1990.

Source: Oregon Department of Fish and Wildlife, 2004.

Upper and Lower Subbasins. Relative to the lower subbasin, the forested upper subbasin above the dams has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, the largest amounts of large wood in the river and tributary channels, and the highest quality spawning areas. The dams have altered the links between the upper and lower subbasin, thus reducing the transport and delivery of large wood and substrate to downstream reaches. Changes in the abundance and distribution of gravels, small cobbles and large wood (particularly in large jams) have reduced suitable spawning areas and limited areas for adult cutthroat trout and juvenile rearing habitat for spring Chinook salmon. In addition, the dams have changed flow regimes and water temperature patterns. Compared to historical conditions, water temperatures in the river below the dam are cooler in the summer and warmer in the fall and winter, which affects the upstream distribution of spring Chinook salmon adults, alters the timing of spawning, and affects the period of egg incubation. The change in flow regimes has also altered the availability and quality of Oregon chub habitat in backwater sloughs, floodplain ponds, and other slow-moving side-channel habitat. Among other things, warmer water temperatures in these areas encourage the persistence and dispersal of exotic predaceous fish species.

Appendix G shows specific fish passage barriers on the Coast Fork, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Water Quality Changes. Water quality has been affected throughout the subbasin. Mining in the upper subbasin has increased mercury concentrations in the drainage over the naturally high background levels. In addition, mercury has been found in fish from the Cottage Grove and Dorena reservoirs at levels that are potentially hazardous to humans (U.S. Army Corps of Engineers, 2001). The mainstem of the Coast Fork (mouth to RM 31) is listed as impaired for anadromous fish passage because of the high mercury levels (Oregon Department of Environmental Quality, 2004). Water temperatures in the river below the dams do not meet water quality criteria (Oregon Department of Environmental Quality, 2004). The low dissolved oxygen levels in Camas Swale Creek in the lower subbasin do not meet water quality criteria (U.S. Army Corps of Engineers, 2001).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced transport of wood below the dams, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries. Approximately 97 percent of the Upper Row River drainage has been harvested, and 76 percent of the Upper Coast Fork Willamette River drainage has been harvested at least once, which has contributed to riparian areas being having primarily younger aged conifers and hardwoods (U.S. Army Corps of Engineers, 2001). Many of the upper subbasin tributaries do not provide adequate shading or large wood recruitment. The lower subbasin contains extensive agricultural, urban, and residential development that has limited the extent and composition of riparian vegetation. In the lower subbasin, further loss of riparian vegetation and function was caused by the U.S. Army Corps of Engineer’s construction of 5 miles of revetments along the banks of the lower Coast Fork Willamette River to protect agricultural development from flood damage, and another mile of revetments along the lower Row River (U.S. Army Corps of Engineers, 2000). The construction of I-5 reduced riparian vegetation along parts of the lower 25 miles of the Coast Fork. Historically, logjams and other large wood were removed from stream channels on both public and private land in a misdirected effort to improve fish passage, for timber salvage, and to reduce downstream damage to bridges during floods (U.S. Army Corps of Engineers, 2001). Limited wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. Large sections of the Coast Fork Willamette and Row rivers have revetments (U.S. Army Corps of Engineers, 2001). In addition, changes in the frequency and magnitude of high flow events below the dams have altered the formation of these complex habitats. Backwater areas in the river and lower tributaries serve as key habitats for adult and juvenile cutthroat trout and juvenile spring Chinook salmon, providing opportunities for fish to forage and take refuge from high flow events. In addition, backwater habitats are essential for the establishment and survival of Oregon chub at all life stages.

Key Factors Limiting Fish Populations. The U.S. Army Corps of Engineers dams divide the Coast Fork Willamette Subbasin, and the upper and lower subbasins are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors on the Lower Coast Fork Willamette Subbasin. In the lower Coast Fork Willamette Subbasin, the productivity, capacity, and diversity of cutthroat trout and spring Chinook populations are limited by the following factors:

- **Habitat Connectivity**. Modification of the river’s high flow regime from dam regulation, channel and bank confinement through riprap and other actions, and reduced large wood in the channels have interacted to reduce backwater habitats important for juvenile rearing and winter refuge.
- **Habitat Modification**. Limited spawning areas and reduced levels of gravels/small cobbles have reduced the areas available for spawning.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries have modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. Changes in high and low water temperature regimes have affected adult spawning success and egg incubation and have limited the capacity of river and tributary streams to support juvenile fish.
- **Fish Passage Barriers**. The U.S. Army Corps of Engineers dams on the river and fish passage barriers at road crossings on tributary streams prevent access into historical spring Chinook salmon spawning areas, block the interchange between the upper and lower subbasin cutthroat trout populations, and limit juvenile access into rearing and refuge habitat.
- **Additional Factors**. Other factors that are limiting cutthroat trout and spring Chinook salmon populations include competition with hatchery and introduced fish; lower

numbers of salmon carcasses, which reduces nutrient inputs and thus food availability; and harassment of adult migrating and holding prespawning fish by recreational activities such as boating and fishing. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Limiting factors for Oregon chub include modification of key habitats and the presence of exotic, warm-water fish. These factors have affected Oregon chub at all life stages.

Table 3-109 shows the EDT attributes related to the limiting factors for cutthroat and spring Chinook in the lower Coast Fork Willamette Subbasin, while Table 3-110 shows the EDT attributes for Oregon chub limiting factors. The area in question is below the U.S. Army Corps of Engineers dams, and most of the lower subbasin is in private ownership. The priorities for restoration are qualitative ratings based on information in Table 3-107 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-109: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Spring Chinook Salmon and Cutthroat Trout in the Lower Coast Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	Changes in the interannual variability of low and high flows from dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams prevent migration into the upper subbasin; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	The dams have modified high and low water temperature regimes in the river. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation); primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels has reduced channel stability.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas below the dams, increasing competition with native fish for habitat and food (Ziller, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish.	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium

Table 3-109: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Spring Chinook Salmon and Cutthroat Trout in the Lower Coast Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Harassment	Extensive recreational use of the lower river (boating and fishing) harasses migrating, holding, and spawning fish.	Medium
Oxygen	Some issues with oxygen levels in Camas Swale Creek.	Medium
Pathogens	Hatchery fish have been introduced to areas below the dams, increasing the potential for disease.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	There are few unscreened diversions to affect adult and juvenile rearing habitat.	Low

Table 3-110: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower Coast Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition w/sp.	Exotic fish species pose a significant threat through predation and competition.	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low-velocity waterways.	**HIGH**
Flow	There have been changes in the interannual variability of low and high flows from dam regulation. This affects the quantity of habitat and disrupts the processes that create a complex array of habitats.	Medium
Chemicals	Camas Swale no longer contains suitable Oregon chub habitat because water quality has degraded as a result of nearby industrial operations.	Low
Oxygen	Low dissolved oxygen in Camas Swale Creek has reduced water quality.	Low

Limiting Factors on the Upper Coast Fork Willamette Subbasin. Historically the upper subbasin provided spawning and juvenile rearing habitat for both cutthroat and spring Chinook. In contrast to the large-scale modification of the lower subbasin, most of the impacts to habitat and water quality in the upper subbasin are localized. Currently, limiting factors for cutthroat and spring Chinook in the upper subbasin are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover, but not to the extent as in the lower subbasin.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors**. Other, more moderate factors limiting fish populations include partial and complete barriers to fish passage on tributary streams, changes in water temperature regimes as a result of reduced canopy cover, competition with hatchery introductions, and lower numbers of salmon carcasses, which reduces nutrient input and thus food availability.

Limiting factors for Oregon chub include modification of key habitats and the presence of exotic, warm-water fish. These factors have affected Oregon chub at all life stages.

Table 3-111 shows the EDT attributes related to the limiting factors for spring Chinook and cutthroat life in the upper Coast Fork Willamette Subbasin, while Table 112 shows the EDT attributes for Oregon chub limiting factors. The area in question is above the U.S. Army Corps of Engineers dams and is primarily under U.S. Forest Service management. Again, the tables present qualitative ratings based on the information in Table 3-107 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-111: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Spring Chinook Salmon in the Upper Coast Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Moderate channel confinement through the river corridor as a result of bank riprap, secondary roads, and limited large wood has affected the quality of habitat.	HIGH
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood.	HIGH
Channel stability	In some areas limited in-channel wood and reduced riparian function has destabilized channels.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas above the dams, increasing competition with native fish for habitat and food.	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Obstructions	Some complete and partial barriers on tributary streams.	Medium
Pathogens	Hatchery fish have been introduced to areas above the dams, increasing the potential for disease.	Medium

Table 3-111: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Spring Chinook Salmon in the Upper Coast Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids.	Low
Competition with other species	Very low number of introduced fish species present.	Low
Flow	There have not been significant changes in the interannual variability of low and high flows.	Low
Harassment	Moderate recreational use of the upper river (boating and fishing) harasses migrating, holding, and spawning fish.	Low
Oxygen	Oxygen levels are adequate to support all life stages	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	Minimal water withdrawals.	Low

Table 3-112: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Upper Coast Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Exotic fish species pose a significant threat through predation and competition.	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low-velocity waterways.	**HIGH**
Flow	There have been changes in the interannual variability of low and high flows from dam regulation. This affects the quantity of habitat and disrupts the processes that create a complex array of habitats.	Medium

3.5.1.3 Limiting Factors in the Long Tom Subbasin

This section describes the Long Tom Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species found in the subbasin: cutthroat and spring Chinook.

Focal Species Present:

- Cutthroat trout
- Spring Chinook salmon (juvenile rearing and refuge; lower basin only)

Focal Species Historically Present:

- Oregon chub

Geographic Setting. The Long Tom Subbasin covers an area of 410 square miles on the eastern slope of the Coast Range and the floor of the Willamette Valley. The Long Tom River is approximately 55 miles long and enters the Willamette River at RM 146, approximately 25 miles downstream of the confluence with the McKenzie River. More than 90 percent of the land in the Long Tom Subbasin is privately owned, with most of the private lands in forestry (approximately 50 percent), agricultural, and rural residential land uses. Urban lands cover about 8 percent of the subbasin, primarily within the city of Eugene (Thieman, 2000). The Eugene District of the BLM, the U.S. Army Corps of Engineers, and the Oregon Department of Forestry manage a small portion of the subbasin (Thieman, 2000).

Neither the Long Tom River nor its tributaries have spawning populations of anadromous fish, but juvenile Chinook salmon have been observed using the lower portions of the river as rearing and winter refuge habitat (Jeff Ziller, ODFW, personal communication, 2002). Cutthroat trout exist in all of the subbasin’s streams, and historically there was a population that moved between the Long Tom River and the Willamette River mainstem (Connolly et al., 1992).

The Long Tom River’s headwaters are on the east side of the Coast Range near Noti. Fern Ridge Reservoir (RM 26) divides the subbasin. The headwaters of the river flow through industrial forestlands, small-acreage farms, and rural residential areas until the river reaches the Willamette Valley floor near Veneta. The river then flows several more miles through rural residential areas and small farms and empties into Fern Ridge Reservoir. Major tributaries in the upper subbasin include Amazon (through diversion into the reservoir), Elk, Coyote, and Noti creeks. Most of the headwaters of Amazon Creek are within Eugene’s city limits. Below Fern Ridge Dam, the Long Tom River flows through primarily agricultural lands, with some rural residential areas. Ferguson and Bear creeks are major tributaries below the dam.

Most of the subbasin lies below 1,000 feet in elevation. The upper subbasin drains the Coast Range, but most of the river and the larger tributaries flow through the Willamette Valley’s recent alluvial deposits. The Coast Range bedrock in the upper subbasin is predominantly medium- to fine-grained marine sandstones of the Tyee Formation. These sedimentary rocks do not have the permeability of volcanic rock and thus have limited groundwater storage capacity. Consequently, the streams within the Long Tom Subbasin have lower summertime flows and higher water temperatures than do Cascade Range streams. The subbasin’s high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin; this leads to rapid delivery of water to the stream network. As a result of the Long Tom Subbasin’s low elevations and the Coast Range geology, summertime streamflows are not supplemented by snowmelt or spring-fed sources.

The headwaters and tributaries of the upper Long Tom Subbasin flow steeply off the Coast Range. After the river and tributaries enter the Willamette Valley, the gradient decreases and the river meanders through the alluvial deposits of the Willamette River. Prior to construction of upstream flood control dams, flood flows from the Long Tom and Willamette rivers inundated the entire lower portions of the Long Tom River Valley (U.S. Army Corps of Engineers, 1947).

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas have affected the productivity, capacity, and diversity of cutthroat trout (at all life stages) and juvenile spring Chinook salmon in the Long Tom Subbasin. Table 3-113 summarizes changes in the subbasin’s environmental conditions and how these impacts have affected cutthroat trout (at all life stages) and juvenile spring Chinook salmon life stages.

Fern Ridge Dam. The U.S. Army Corps of Engineers’ Fern Ridge Dam has restricted fish access to the upper subbasin and changed downstream hydrologic regimes, water quality, and processes influencing habitat formation. Construction of the dam in 1941 blocked fish passage and eliminated the downstream transport of sediment and large wood from more than 60 percent of the subbasin (U.S. Army Corps of Engineers, 2000). Fish passage structures were not included during construction of Fern Ridge Dam because anadromous salmonids were considered to be absent from the system (Willis et al., 1960). Fern Ridge Dam has affected the fluvial population of cutthroat trout that moved between the upper subbasin and the Willamette River. In the Long Tom River below the dam, younger cutthroat trout are absent and larger adults appear only seasonally (Connolly et al., 1992).

Table 3-113: Long Tom Subbasin: Subbasin Attributes Affecting Cutthroat Trout And Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Naturally low flows in the subbasin are aggravated by water withdrawals, which increase water temperatures. Naturally high water temperatures have been increased by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces. Fern Ridge Reservoir functions as a huge heat sink in the summer. This results in increased river temperatures below the dam and a temperature regime that favors exotic fish. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows. Nutrient and toxic runoff from agricultural and urban areas may be a problem. The loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows). Portions of Coyote Creek and Amazon Creek do not meet water quality criteria for dissolved oxygen. Stormwater from urbanized Eugene containing oil residue and other toxics flows into upper Amazon Creek.	The U.S. Army Corps of Engineers fishway at Monroe (RM 6) is functional but of marginal design and structurally suspect. The Stroda structure (RM 9) was recently modified by the U.S. Army Corps of Engineers. It passes fish at certain flows but does not meet ODFW fish passage criteria. A segment of the original Long Tom channel functions as a potential bypass for fish encountering the Ferguson structure, but fish must locate the bypass channel, which is problematic, and the structure is occasionally blocked. Fern Ridge Dam (RM 26) was not equipped with fish passage, so it blocks migration and interchange between the upper and lower subbasin cutthroat populations. Numerous culverts throughout the subbasin serve as barriers to adult refuge and forage habitat.	Reductions in the magnitude and frequency of high flows in the river below Fern Ridge Dam have altered the processes that form side channels and other complex habitats. Straightening of the river channel below the dam and the addition of the control structures have reduced complex habitats and pools. Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality.	

Table 3-113: Long Tom Subbasin: Subbasin Attributes Affecting Cutthroat Trout And Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
				Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. Loss of wetland, floodplain, and off-channel habitats have affected the quantity and quality of adult holding areas.	
	Adult spawning/ egg incubation		Numerous culverts throughout the subbasin serve as barriers to spawning habitat. Fern Ridge Dam was not equipped with fish passage, so it blocks spawning by fluvial cutthroat trout populations in the upper subbasin.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-113: Long Tom Subbasin: Subbasin Attributes Affecting Cutthroat Trout And Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the basin are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the subbasin, do not provide optimal conditions for juvenile rearing. High water temperatures, particularly in the river below the dam, have extended the range of nonnative fish.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (such as large-mouth bass) may affect juvenile survival.
Spring Chinook Salmon	Fry and juvenile rearing and refuge		Culverts in the lower subbasin present barriers to juvenile access refuge habitat. Loss of connections to floodplain and wetland areas has reduced the quality and quantity of high flow refuge habitat.	The loss of wetland, floodplain, and off-channel habitats in the lower subbasin has affected the quantity and quality of juvenile rearing and refuge areas.	

Source: Connoly et al., 1992; Thieman, 2000; U.S. Army Corps of Engineers, 2000; Mamoyac, ODFW, personal communication, 2004.

Fish Passage Barriers. In addition to Fern Ridge Dam there are other fish passage issues in the subbasin. Three structures on the lower Long Tom River serve as at least partial fish passage barriers (Mamoyac, ODFW, personal communication, 2004): the fishway at Monroe, the Stroda structure, and the Ferguson structure. These structures are designed to control the gradient on the river, and all of them effectively act as dams. The fishway at Monroe (RM 6) has not been thoroughly assessed for fish passage, but it probably is a partial barrier. The Stroda structure (RM 9) was recently modified for passage and probably passes fish at certain flows but still does not meet ODFW's fish passage criteria. A segment of the original Long Tom River channel functions as a potential bypass for fish encountering the Ferguson structure; however, fish must first locate this bypass channel, which requires that they drop downstream 600 feet to enter the bypass. In addition to these barriers on the mainstem Long Tom River, many of the road culverts on tributaries throughout the subbasin act as partial or total fish passage barriers (Thieman, 2000). Limiting the fish passage above culverts restricts the amount of habitat available for all cutthroat trout life stages.

Appendix G shows specific fish passage barriers on the Long Tom, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Upper and Lower Subbasins. Compared to the lower subbasin, the primarily forested upper subbasin above the Fern Ridge Dam has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Baker et al., 2002; Thieman, 2000). Impacts to flow regimes and aquatic-riparian habitats have been greater in the lower subbasin than in the upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because it contains the largest proportion of unconstrained river and stream channels (Thieman, 2000; Pacific Northwest Ecosystem Research Consortium, 2002). Many of these channels have been affected by changes in flow and temperature regimes and channelization.

Changes in Flow Regimes. Fern Ridge Dam (RM 26) has altered the links between the upper and lower subbasin, reducing the transport and delivery of large wood and altering flow regimes. Changes in the abundance and distribution of large wood (particularly in large jams) have reduced the quantity and quality of habitat for adult cutthroat trout and juvenile spring Chinook salmon in the lower river. Flows in the Long Tom River are regulated by Fern Ridge Dam and affected by other water diversions and withdrawals. A structure was converted in 1951 to divert flows (up to 1,250 cfs) from Amazon Creek into Fern Ridge Reservoir, and residual flow in lower Amazon Creek enters the Long Tom River about 6 miles downstream of the dam. There are also several small diversions upstream of Monroe (U.S. Geological Survey, 1997). ODFW has indicated that "excessive water withdrawals" have negatively affected fish (Connolly et al., 1992). Flood control operations at Fern Ridge Dam have decreased the magnitude and frequency of extreme high flow events, although the overall reduction has been less than has been observed for the other Willamette River projects. Post-project summer flows are greater than occurred historically because storage is available to redistribute flood volumes and release water later in the year for flow augmentation purposes. Since dam construction, the average daily flows in August and September have increased to 81 cfs 228 cfs, respectively (Moffatt et al., 1990).

In addition to changes in flow regimes from Fern Ridge Dam, runoff has accelerated and peak flows in tributaries have increased as a result of channelization of tributaries and modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development. Increased peak flows have been exacerbated further by extensive loss of wetlands and functioning floodplains, which have reduced the subbasin's capacity to store and gradually release floodwaters.

Water Quality Changes. Water quality has been modified throughout the subbasin. Water quality monitoring indicates that that there are low levels of suspended solids in runoff from agricultural fields and potentially high levels of nitrate and phosphorous (Thieman, 2000). Almost none of the streams that have been monitored in the subbasin meet water quality criteria for temperature (Thieman, 2000). Water warming within Fern Ridge Reservoir and its release into the river, loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces aggravate high water temperatures. Compared to historical conditions, water temperatures in the river below the dam are warmer in the summer. The Long Tom River between Fern Ridge Dam and the mouth can exceed 80° F during the summer (U.S. Army Corps of Engineers, 2001). Warm water temperatures in the Lower Long Tom River favor nonnative fish species (large-mouth bass, for example) over native fish (Mamoyac, ODFW, personal communication, 2004). Cutthroat trout move out of Fern Ridge Reservoir in late July and early August, probably because of water warming in the reservoir (Connolly et al., 1992). The subbasin's natural summertime low flows are aggravated by water withdrawals, which increase water temperatures. Portions of Coyote and Amazon creeks do not meet water quality criteria for dissolved oxygen (Oregon Department of Environmental Quality, 1998). In addition, stormwater from urbanized Eugene delivers oil residue and other toxics to upper Amazon Creek (Thieman, 2000).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced transport of wood below Fern Ridge Dam, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries. Riparian areas throughout the subbasin have been modified, with more changes occurring in the lower subbasin than in the upper. There has been an extreme loss of riparian function from approximately 46 percent of the lower subbasin's valley bottom areas and 10 percent of the upper subbasin's forested areas (Thieman, 2000). Reduced wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced compared to historical levels. Historically the lower Long Tom River was characterized by numerous wetlands and oxbows, with abundant large wood in the channel (U.S. Army Corps of Engineers, 2001). Almost the entire length of the mainstem, from its mouth to Fern Ridge Dam, has been channelized, straightened, leveed, or otherwise modified by projects related to drainage and irrigation (Thieman, 2000). Portions of Coyote Creek, Amazon Creek, and other tributaries also have been channelized (U.S. Army Corps of Engineers, 2001). The majority of wetlands in the lower subbasin have been converted to other land uses (Thieman, 2000). In addition, changes in the frequency and magnitude of high flow events below the dam have altered the formation of these complex habitats. Large wood has been removed from many of the streams within the subbasin (Thieman, 2000).

Typically, backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout and juvenile spring Chinook salmon. These habitats provide fish with habitat for foraging and refuge from high flow events.

Key Factors Limiting Fish Populations. Fern Ridge Dam divides the Long Tom Subbasin at RM 26. The upper and lower subbasins are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower Long Tom. In the lower Long Tom Subbasin, the productivity, capacity, and diversity of cutthroat trout and juvenile spring Chinook salmon populations are limited by the following factors:

- **Flow Modification**. Modification of the river's high flow regime from dam regulation; channel and bank confinement through channelization, riprap and other actions; and reduced large wood in the channels have interacted to reduce floodplain connectivity and backwater habitats important for juvenile Chinook salmon rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile cutthroat trout and affected juvenile Chinook salmon rearing areas in the lower river.
- **Water Temperature.** Increased summertime water temperature regimes have affected adult cutthroat trout populations and limited the capacity of river and tributary streams to support juvenile fish.
- **Fish Passage Barriers.** Fern Ridge Dam, other dams on the lower Long Tom River, and fish passage barriers at road crossings on tributary streams block the interchange between the upper and lower subbasin cutthroat trout populations and limit juvenile access to rearing and refuge habitat.
- **Additional Factors**. Other factors affecting fish populations include competition with introduced fish, runoff of toxics from urban and agricultural areas, and some unscreened water diversions.

Table 3-114 shows the EDT attributes limiting cutthroat trout and juvenile spring Chinook salmon in the Lower Long Tom Subbasin (below Fern Ridge Dam). The priorities for restoration are qualitative ratings based on the information in Table 3-113and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-114: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Juvenile Spring Chinook in the Lower Long Tom Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	There have been extreme changes in the interannual variability of low and high flows from dam regulation, affecting the quantity of habitat and disrupting the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams on the river prevent migration into the upper subbasin; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Releases from the reservoir have modified high water temperature regimes in the river. Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function has reduced channel stability.	Medium
Chemicals	Increased toxics, particularly from urban and agricultural runoff, may affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Oxygen	Oxygen levels have been affected in some tributaries.	Medium
Withdrawals	Some problems from unscreened diversions (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although turbidity levels are periodically high, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Long Tom. Historically the upper subbasin was an important spawning area for both resident and fluvial cutthroat trout. In contrast to the large-scale modification of the lower subbasin resulting from Fern Ridge Dam and extensive channelization of the river, there is higher quality habitat in the upper subbasin, particularly in the forested upland areas. Currently, key limiting factors for cutthroat in the upper Long Tom are as follows:

- **Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover.
- **Large Wood**. There have been systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. Changes to riparian canopy have increased summertime water temperatures.
- **Fish Passage Barriers**. Numerous partial and complete fish passage barriers on tributary stream have limited cutthroat trout populations.
- **Additional Factors**. Other, more moderate impacts to fish habitat and populations include increased toxic runoff from urban and agricultural areas, decreased oxygen levels in some tributaries, unscreened water diversions, and competition with nonnative fish.

Table 3-115 shows the EDT attributes related to the limiting factors for cutthroat in the upper Long Tom Subbasin, above Fern Ridge Dam. Again, the table presents qualitative ratings based on information in Table 3-113 and professional opinions from individuals familiar with the subbasin (primarily ODFW biologists).

Table 3-115: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Long Tom River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Extensive channel confinement through the river corridor and on tributaries as a result of revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Numerous complete and partial barriers on tributaries.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures in some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have affected channel stability.	Medium
Chemicals	Increased toxics, particularly from urban and agricultural runoff, may affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Medium

Table 3-115: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Long Tom River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Fish community richness is high and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Flow	There have been changes in the variability of low and high flows as a result of land use changes and withdrawals.	Medium
Oxygen	Oxygen levels have been impacted in some tributaries.	Medium
Withdrawals	Some problems from unscreened diversions (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although turbidity levels are periodically high, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

3.5.1.4 Limiting Factors in the Luckiamute/Rickreall Subbasin

This section describes the Luckiamute/Rickreall subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the basin: cutthroat, spring Chinook, and winter steelhead.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon (juvenile rearing and refuge; lower basin only)
- Winter steelhead (unknown origin)

Focal species present historically:

- Oregon chub

Geographic Setting. The Luckiamute/Rickreall Subbasin covers an area of approximately of 546 square miles on the eastern slope of the Coast Range and the floor of the Willamette Valley. The Luckiamute River is approximately 58 miles long and enters the Willamette River at RM 108. Rickreall Creek is approximately 32 miles long and joins the Willamette River at RM 88. Approximately 85 percent of the land in the subbasin is privately owned (Ecosystems Northwest, 2001; Earth Design Consultants, 2004). Most of the private lands are in forestry, agricultural, and rural residential land uses. Urban lands cover a very small portion of the subbasin, primarily within the cities of Monmouth and Dallas. The Salem District of the BLM, the Siuslaw National Forest, and the Oregon Department of Forestry manage a small portion of the forested upper subbasin. Baskett Slough National Wildlife Refuge is in the Rickreall Creek drainage.

Neither the Luckiamute River nor Rickreall Creek has spawning populations of native anadromous fish, but juvenile Chinook salmon have been observed using the lower portions of the Luckiamute as rearing and winter refuge habitat (Gary Galovich, ODFW, personal communication, 2003). Cutthroat trout exist in all of the subbasin’s streams, and historically there was a population that moved between the Luckiamute River and Rickreall Creek and the mainstem of the Willamette River (Wevers et al., 1992). Naturally spawning winter steelhead are present in both the Luckiamute and Rickreall Creek. It appears that these fish are strays or from introduced populations, and there is little evidence to suggest that self-sustaining spawning aggregations of winter steelhead existed historically in the Luckiamute/Rickreall subbasin (Myers et al., 2003). In general, cutthroat trout and winter steelhead have similar habitat requirements.

The headwaters of the Luckiamute River and Rickreall Creek are on the forested east side of the Coast Range. In the upper subbasin land use is primarily private industrial forestlands. As the Luckiamute River and Rickreall Creek enter the Willamette Valley they flow past small-acreage farms and rural residential areas. The Luckiamute River enters the floor of the Willamette Valley near the community of Hoskins (RM 40). Rickreall Creek reaches the floor of the valley near the city of Dallas, but Mercer Dam (RM 23) divides the upper and lower portions of the subbasin. Major tributaries in the upper subbasin of the Luckiamute River include the Little Luckiamute River, Pedee Creek, and Price Creek. Major tributaries in the forested upper Rickreall Creek include the North and South Fork Rickreall Creeks, Rockhouse Creek, and Canyon Creek. Soap Creek is a major tributary to the Luckiamute River in the lower subbasin.

The Coast Range bedrock in the upper subbasin is composed predominantly of Seltz River basalts with some sedimentary formations. Most of the subbasin lies below 1,000 feet in elevation. The upper subbasin drains the Coast Range, but most of the river and the larger tributaries flow through the Willamette Valley’s recent alluvial deposits. The Coast Range sedimentary rocks have lower groundwater storage capacity than is the case in the Cascade Mountains, and the streams within the Luckiamute/Rickreall subbasin experience lower summertime flows and higher water temperatures than do Cascade Range streams. The subbasin’s high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper-elevations and rain-dominated flow patterns in the lower subbasin; this leads to rapid delivery of water to the stream network. As a result of the subbasin’s low elevations and the geology of the Coast Range, summertime stream flows are not supplemented by snowmelt or spring-fed sources.

The headwaters and tributaries of the upper subbasin flow steeply off the Coast Range, with the gradient rapidly decreasing once the streams enter the lower subbasin areas within the flat Willamette Valley (see Table 3-116). The lower Luckiamute River channel is very sinuous as it flows through the old fluvial deposits of the Willamette Valley. Rickreall Creek is more entrenched and less sinuous (Ecosystems Northwest, 2001).

Table 3-116: Percent Gradient for Major Segments of the Lower and Upper Luckiamute River and Rickreall Creek

Subbasin Location	River Mile (RM)	Percent Gradient
Rickreall: lower subbasin	0 to 24	0.43
Rickreall: upper subbasin	25 to 32	5.74
Luckiamute: lower subbasin	0 to 40	0.08
Luckiamute: upper subbasin	40 to 58	2.12

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the Luckiamute/Rickreall Subbasin have affected the productivity, capacity, and diversity of cutthroat tout and juvenile spring Chinook salmon populations. Table 3-117 summarizes changes in the subbasin's environmental conditions and how these changes have affected cutthroat trout and juvenile spring Chinook salmon life stages.

Upper and Lower Subbasins. Relative to the lower subbasin, the upper subbasin, which is primarily forested, has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, the largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Ecosystems Northwest, 2001; Baker et al., 2002). There have been greater impacts to aquatic and riparian habitats in the lower subbasin than in the upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because the largest proportion of low-gradient, unconstrained river and stream channels were in the area where the Luckiamute River and Rickreall Creek flowed across the flat Willamette Valley (Ecosystems Northwest, 2001; Earth Design Consultants, 2004).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin (Ecosystems Northwest, 2001). Over time, a number of practices (such as splash dams and stream cleaning) removed large wood from the Luckiamute River, Rickreall Creek, and tributary channels (Ecosystems Northwest, 2001; Earth Design Consultants, 2004). While riparian areas in the forested upper subbasin have greater numbers of conifer trees, historical wood removal from streams and riparian harvest have reduced large wood in the channels. Reduced wood in the river and tributary channels limits the formation of pools, thus reducing hiding and feeding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Table 3-117: Luckiamute/Rickreall subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Naturally low flows in the subbasin are aggravated by water withdrawals, which increase water temperatures. High water temperatures in the subbasin are aggravated by the loss of riparian cover, reduced wetland areas, and channel simplification. Water diversions in Rickreall Creek have reduced water flows, contributing to increased water temperatures. Channelization of tributaries; modification of runoff patterns through agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows. Loss of wetlands and floodplain habitats, especially in the lower subbasin, have affected water quality and quantity (storage and timing of peak and low flows). The City of Dallas discharges municipal effluent into Rickreall Creek (RM 10), which contributes a significant proportion of the summer streamflow.	Numerous culverts throughout the subbasin present barriers to adult refuge habitat.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of adult holding areas.	

Table 3-117: Luckiamute/Rickreall subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/egg incubation		Numerous culverts throughout the subbasin present barriers to spawning habitat. Mercer Dam (RM 24) on Rickreall Creek blocks access to approximately 11 miles of habitat, affecting access to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels. Mercer Dam on Rickreall Creek (RM 24) blocks the transport and delivery of spawning gravels and substrate to the lower reaches.	
	Fry and juvenile rearing and migration	Naturally low flows in the lower subbasin have been aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the lower subbasin, do not provide optimal conditions for juvenile rearing. The City of Dallas diverts a significant proportion of Rickreall Creek's summer flow for municipal use, reducing rearing habitat below the point of diversion.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin. Mercer Dam (RM 24) on Rickreall Creek blocks access to approximately 11 miles of habitat, affecting access to rearing habitat.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Mercer Dam on Rickreall Creek (RM 24) blocks the transport and delivery of large wood to the lower reaches. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.

Table 3-117: Luckiamute/Rickreall subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Spring Chinook Salmon	Fry and juvenile rearing and refuge		Culverts in the lower Luckiamute River present barriers to juvenile access refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat in the lower Luckiamute River.	The loss of wetland, floodplain and off-channel habitats in the lower reaches of the Luckiamute River and Rickreall Creek has affected the quantity and quality of juvenile rearing and refuge areas. The loss of connections to floodplain and wetland areas has reduced the quality and quantity of high flow refuge habitat.	

Source: ODFW 1992, Mamoyac, ODFW, personal communication, 2004.

Water Quality. Water quality has been modified throughout the subbasin. Water temperatures exceed criteria in the lower portions of the Luckiamute River and Rickreall Creek. May of the tributaries, particularly in the lower subbasin, have elevated water temperatures (Ecosystems Northwest 2001, Earth Design Consultants 2004). The subbasin's natural summertime low flows are aggravated by water withdrawals, which increase water temperatures. There are a number of water withdrawals in the subbasin, particularly in the lower portions as a result of agriculture and urbanization (Ecosystems Northwest, 2001; Earth Design Consultants, 2004). The City of Dallas diverts a significant proportion of the Rickreall Creek's summer flow for municipal use, thus reducing rearing habitat below the point of diversion. In general, water temperatures are lower in the forested portions of the upper subbasin. High water temperatures in the lower subbasin are aggravated by the loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces. In addition to temperature issues, Soap Creek, which drains into the lower Luckiamute River, does not meet water quality criteria for dissolved oxygen (Earth Design Consultants, 2004), and lower Rickreall Creek appears to be nutrient enriched (Ecosystems Northwest, 2001).

Flow Modifications. Peak- and low-flow regimes have been modified. While Mercer Dam (Rickreall Creek, RM 24) and other small reservoirs in the subbasin do not exert strong controls on peak or low flows, changes in land use have affected hydrologic regimes in the tributaries. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows (Mamoyac, ODFW, personal communication, 2004). There has been extensive loss of wetlands throughout the subbasin (Ecosystems Northwest, 2001; Earth Design Consultants, 2004).

Fish Passage Barriers. Fish passage is restricted throughout the subbasin. Mercer Dam in upper Rickreall Creek blocks fish passage and access to 11 miles of habitat (Ecosystems Northwest, 2001). In addition there are numerous culverts at road crossings throughout the lower and upper subbasin that block or limit fish passage (Mamoyac, ODFW, personal communication, 2004). Limiting the fish passage above culverts restricts the amount of habitat available for juvenile spring Chinook rearing and all cutthroat trout life stages.

Appendix G shows specific fish passage barriers on the Luckiamute, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Water Temperature and Parasites. The fluvial population of cutthroat trout in the lower Luckiamute River and Rickreall Creek has been affected by the lower subbasin's altered aquatic habitat and water quality (Ecosystems Northwest 2001). In addition, changes in water quality and the presence of a fish parasite probably restrict the movement of cutthroat trout between the subbasin and the Willamette River. In the lower Willamette River below the confluence with the Luckiamute/Rickreall River, populations of cutthroat tout are limited as a result of high summer water temperatures and the presence of the fish parasite *Certomyxa shasta* (Wevers et al., 1992).

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. Large portions of the lower Luckiamute River and Rickreall Creek and sections of tributary streams have confined channels as a result of the placement of riprap and actions that restrict channel movement. Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout and juvenile spring Chinook salmon. These habitats provide fish with habitat for foraging and refuge from winter flood events.

Key Factors Limiting Fish Populations. The upper and lower Luckiamute/Rickreall subbasins are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasin.

Lower Luckiamute/Rickreall Subbasin. In the lower Luckiamute/Rickreall Subbasin, cutthroat trout and juvenile spring Chinook salmon populations are limited by the following:

- **Habitat Connectivity**. Modification of river and tributary habitat through channel and bank confinement and reduced large wood in the channels has interacted to reduce floodplain connectivity and backwater habitats important for all cutthroat trout life stages and juvenile Chinook salmon rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile cutthroat trout and affected juvenile Chinook salmon rearing areas in the lower river.
- **Water Temperature**. Increased summertime water temperature regimes have affected adult cutthroat trout populations and limited the capacity of river and tributary streams to support juvenile fish.
- **Fish Passage Barriers**. Fish passage barriers at road crossings on tributary streams block the interchange between cutthroat trout populations and limit adult and juvenile access into rearing and refuge habitat.
- **Additional Factors**. Other factors limiting focal species populations include competition with introduced fish, runoff of toxics from urban and agricultural areas, and some unscreened water diversions.

Table 3-118 shows the EDT attributes related to these limiting factors for cutthroat trout and juvenile spring Chinook in the lower Luckiamute/Rickreall Subbasin. The lower subbasin is largely on the Willamette Valley floor (below RM 40 on the Luckiamute and the RM 24 on Rickreall Creek) and consists primarily of private land with agricultural, rural residential, and urban land uses. The priorities for restoration are qualitative ratings based on information presented in Table 3-117 and professional opinions from individuals familiar with the subbasin, primarily ODFW biologists.

Table 3-118: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Juvenile Spring Chinook in the Lower Luckiamute/Rickreall Subbasin

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels and reduced riparian function have reduced channel stability.	**HIGH**
Flow	There have been impacts to the interannual variability of low and high flows as a result of land use practices and water diversions.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor from bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Mercer Dam prevents migration into upper Rickreall Creek; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Competition with other species	Fish community richness is high and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Mamoyac, ODFW, personal communication, 2004).	Medium
Chemicals	There is little evidence that toxics are affecting salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels where they are susceptible to harassment.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Luckiamute/Rickreall Subbasin. Historically the upper subbasin was an important spawning and rearing area for both resident and fluvial cutthroat trout. In contrast to the large-scale modification of the lower subbasin, there is higher quality habitat in the upper subbasin, particularly in the forested upland areas. Currently, limiting factors for cutthroat trout in the upper subbasin are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have lead to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. Changes to riparian canopy have increased summertime water temperatures.
- **Fish Passage Barriers**. Numerous partial and complete fish passage barriers on tributary stream have limited cutthroat trout populations.

Table 3-119 outlines the EDT attributes limiting cutthroat trout life stages in the Luckiamute/Rickreall Subbasin, an area that is primarily private land with forestry and rural residential land uses. Again, the table presents qualitative ratings based on the information in Table 3-117 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-119: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Luckiamute/Rickreall Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Some channel confinement through the river corridor as a result of revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have affected channel stability.	Medium
Obstructions	Numerous complete and partial barriers on tributaries.	Medium
Withdrawals	Limited impacts because most of the unscreened diversions are in the lower subbasin.	Medium
Chemicals	Toxics are probably not an issue because of the limited urban and agricultural land uses in the upper subbasin.	Low
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low

Table 3-119: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Luckiamute/Rickreall Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	There is some competition with introduced fish in the river, but competition in the tributaries is minimal (Mamoyac, ODFW, personal communication, 2004).	Low
Flow	There is less area in agricultural and urban land uses that contributes to changes in flow regimes.	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

3.5.1.5 Limiting Factors in the Marys Subbasin

This section describes the Marys Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: cutthroat, spring Chinook, and Oregon chub.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon (juvenile rearing and refuge; lower subbasin only)
- Oregon chub (lower subbasin only)

Geographic Setting. The Marys Subbasin covers an area of 329 square miles on the eastern slope of the Coast Range and the floor of the Willamette Valley. The Marys River is approximately 40 miles long and enters the Willamette River at RM 132. Approximately 90 percent of the land in the subbasin is privately owned. Most of the private lands are in forestry, agricultural, and rural residential land uses (Ecosystems Northwest, 1999). Urban lands cover about 1 percent of the subbasin, primarily within the city of Corvallis (Ecosystems Northwest, 1999). The Salem District of the BLM, the Siuslaw National Forest, and the Oregon Department of Forestry manage a small portion of the subbasin. Muddy Creek, the largest tributary to the lower Marys River, flows through Finley National Wildlife Refuge.

Neither the Marys River nor its tributaries have spawning populations of anadromous fish, but juvenile Chinook salmon have been observed using the lower portions of the river as rearing and winter refuge habitat (Gary Galovich, ODFW, personal communication, 2003). Cutthroat trout exist in all of the subbasin's streams, and historically there was a population that moved between the Marys River and the Willamette River mainstem (Wevers et al., 1992). Populations of Oregon chub exist on Finley National Wildlife Refuge, in the Muddy Creek and in Beaver Creek tributaries (Scheerer, 2004).

The Mary River's headwaters are on the east side of the Coast Range near Summit and Nashville. The river's headwaters flow through industrial forestlands, small-acreage farms, and rural residential areas until the river reaches the floor of the Willamette Valley near Philomath. Major tributaries in the forested upper subbasin include Norton, Woods, and Greasy creeks and the Tum Tum River. Below Philomath, the Marys River flows through agricultural lands, scattered rural residential areas, and the city of Corvallis, where it joins the Willamette River. Muddy and Oak creeks are major tributaries in the lower subbasin below Philomath.

The Coast Range bedrock in the upper subbasin is composed predominantly of sedimentary rocks with some volcanic formations. Most of the subbasin lies below 1,000 feet in elevation. The upper subbasin drains the Coast Range, but most of the river and the larger tributaries flow through the Willamette Valley's recent alluvial deposits. The Coast Range sedimentary rocks have lower groundwater storage capacity than is the case in the Cascade Mountains, and the streams within the Marys Subbasin have lower summertime flows and higher water temperatures than do Cascade Range streams. The subbasin's high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. As a result of the subbasin's low elevations and the Coast Range geology, summertime stream flows are not supplemented by snowmelt or numerous spring-fed sources.

The headwaters and tributaries of the upper Marys Subbasin flow steeply off the Coast Range. After the river and tributaries enter the valley, the gradient decreases and the river meanders through the alluvial deposits of the Willamette Valley. The gradient of the Marys River decreases from 0.26 at RM 40 to 0.15 at RM 20.

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas have affected the productivity, capacity, and diversity of cutthroat tout and juvenile spring Chinook salmon populations in the Marys Subbasin.

Table 3-120 summarizes changes in the subbasin's environmental conditions and how these impacts have affected cutthroat trout and juvenile spring Chinook salmon life stages, while Table 3-121 summarizes how changes in the subbasin's environmental conditions have affected all life stages of Oregon chub.

Table 3-120: Marys Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Naturally low flows in the basin are aggravated by water withdrawals, which increase water temperatures. High water temperatures are aggravated by the loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces, particularly in the lower subbasin. Channelization of tributaries; modification of runoff patterns through agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows in the lower subbasin. Nutrient and toxic runoff from agricultural and urban areas may be a problem in the lower subbasin. Loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows), particularly in the lower subbasin.	Numerous culverts throughout the subbasin present barriers to adult refuge habitat.	Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of adult holding areas.	
	Adult spawning/ egg incubation		Numerous culverts throughout the subbasin present barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-120: Marys Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Salmon Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the basin are aggravated by water withdrawals in the lower subbasin, which may increase water temperatures. High water temperatures, particularly in the lower subbasin, do not provide optimal conditions for juvenile rearing.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. Loss of wetland, floodplain and off-channel habitats have affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.
Spring Chinook Salmon	Fry and juvenile rearing and refuge		Culverts in the lower subbasin present barriers to juvenile access refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat in the lower river.	The loss of wetland, floodplain, and off-channel habitats in the lower subbasin has affected the quantity and quality of juvenile rearing and refuge areas.	

Source: Wevers et al., 1992; Ecosystems Northwest 1999; Mamoyac, ODFW, personal communication, 2004.

Table 3-121: Marys Subbasin: Subbasin Attributes Affecting Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Oregon chub	All	Nutrient and toxic runoff from agricultural and commercial forestry areas may be a problem in the lower subbasin. In particular, Oregon chub populations at Finley National Wildlife Refuge may be declining as a result of poor water quality and low dissolved oxygen in Gray Creek Swamp and Display Pond. Likely sources of nutrient enrichment of these ponds are nearby forestry operations. Loss of wetlands and floodplain habitats has affected water quality and quantity.	Numerous diversions and water barriers may protect Oregon chub from the influx of exotic fish species; however, the natural dispersal of Oregon chub is also limited by these structures. Loss of connectivity to floodplain and wetland habitats has affected the availability of suitable habitat.	Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat. Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions.	Presence of exotic fish in this system inhibits Oregon chub recolonization of formerly occupied habitat.

Source: Scheerer, ODFW, personal communication, 2004.

Upper and Lower Subbasins. Relative to the lower subbasin, the forested upland portions of the upper subbasin has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Baker et al., 2002; Ecosystems Northwest, 1999). Impacts to aquatic and riparian habitats have been greater in the lower Marys Subbasin than in the upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because the largest proportion of unconstrained river and stream channels were in the area where the Marys River flowed across the flat Willamette Valley (Pacific Northwest Ecosystem Research Consortium, 2002).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin (Ecosystems Northwest, 1999; Pacific Northwest Ecosystem Research Consortium, 2002). Over time, a number of practices have reduced the quantity of large wood in the Marys River and tributary channels (Ecosystems Northwest, 1999). While riparian areas in the forested upper subbasin have greater numbers of conifer trees than the lower subbasin does, historical riparian harvests and wood removal from streams have reduced large wood in these channels. Reduced large wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Water Quality Changes. Water quality has been modified throughout the subbasin. Water temperatures exceed criteria in the Marys River and many of its tributaries. Naturally low flows in the subbasin are aggravated by water withdrawals, which increase water temperatures (Ecosystems Northwest, 1999). In general, water temperatures are lower in the forested upper subbasin than in the lower subbasin. High water temperatures in the lower subbasin are aggravated by the loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces (Ecosystems Northwest, 1999). Toxic runoff from urban and agricultural land uses may affect fish populations (Mamoyac, ODFW, personal communication, 2004).

Changes in Flow Regimes. There have been moderate impacts to the subbasin’s hydrologic regimes. Rock Creek Reservoir, which supplies water to the city of Corvallis, does not control the river’s peak or low flows. Changes in land use have affected hydrologic regimes in the tributaries. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows (Mamoyac, ODFW, personal communication, 2004).

Fish Passage Barriers. There are no dams restricting fish passage on the mainstem of the Marys River. However, numerous road crossing culverts throughout the lower and upper subbasin that block or limit fish passage. Limiting the fish passage above culverts restricts the amount of habitat available for juvenile spring Chinook rearing and all cutthroat trout life stages. For example, there is restricted passage of fish into Oak Creek in the lower subbasin, which affects cutthroat trout and historical rearing and refuge habitat for juvenile spring Chinook salmon (Ecosystems Northwest, 1999).

Appendix G shows specific fish passage barriers on the Marys River, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Habitat Modification. Backwater habitats, including pool margins, side channels, and alcoves, have been reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. Large portions of the lower Marys River (below Philomath) and sections of tributary streams have confined channels as a result of the placement of riprap and streamside roads (Ecosystems Northwest, 1999). Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat trout, juvenile spring Chinook salmon, and Oregon chub. These habitats provide fish with habitat for foraging and refuge from winter flood events.

Key Factors Limiting Fish Populations. The upper and lower portions of Marys Subbasin are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower portions of the subbasin.

Limiting Factors in the Lower Marys Subbasin. In the lower Marys Subbasin, the productivity, capacity, and diversity of cutthroat trout and juvenile spring Chinook salmon populations are limited by the following factors:

- **Habitat Connectivity**. Modification of river and tributary habitat through channel and bank confinement and reduced large wood in the channels has interacted to reduce floodplain connectivity and backwater habitats important for all cutthroat trout life stages and juvenile Chinook salmon rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile cutthroat trout and affected juvenile Chinook salmon rearing areas in the lower river.
- **Water Temperature**. Increased summertime water temperature regimes have affected adult cutthroat trout populations, and limited the capacity of river and tributary streams to support juvenile fish.
- **Fish Passage Barriers**. Fish passage barriers at road crossings on tributary streams block the interchange between cutthroat trout populations, and limit adult and juvenile access into rearing and refuge habitat.
- **Additional Factors**. Other factors limiting cutthroat and juvenile Chinook populations include competition with introduced fish, runoff of toxics from urban and agricultural areas, and some unscreened water diversions.

Key limiting factors for Oregon chub in the lower Marys Subbasin are as follows:

- **Habitat Diversity.** Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.

- **Water Quality.** Increased toxics, particularly from urban, agricultural, and commercial forestry runoff, may affect water quality for Oregon chub.
- **Competition with Exotic Species**. Exotic fish species pose a significant threat through predation and competition.
- **Fish Passage Barriers**. Numerous culverts are complete and partial barriers on tributary streams.
- **Additional Factors.** Other factors limiting Oregon chub populations in the lower Marys Subbasin include levels of dissolved oxygen in certain ponds and water withdrawals, particularly near the Finely National Wildlife Refuge.

Table 3-122 shows the EDT attributes related to these limiting factors for cutthroat trout and juvenile spring Chinook in the lower Marys Subbasin, while Table 3-123 shows the EDT attributes for Oregon chub limiting factors. The area of the subbasin being considered is largely on the Willamette Valley floor, below the city of Philomath, and consists primarily of private land with agricultural, rural residential, and urban land uses. The priorities for restoration are qualitative ratings based on the information in Tables 3-120 and 3-121 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-122: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Juvenile Spring Chinook in the Lower Marys Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	There have been impacts to the interannual variability of low and high flows from land use practices and water diversions.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor from bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Numerous culverts are complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have reduced channel stability.	Medium
Chemicals	Increased toxics, particularly from urban and agricultural runoff, may affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Medium

Table 3-122: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Juvenile Spring Chinook in the Lower Marys Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Fish community richness is high and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels where they are susceptible to harassment.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

Table 3-123: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower Marys Subbasin

EDT Attribute Class	Description	Priority for Restoration
Chemicals	Increased toxics, particularly from urban, agricultural, and commercial forestry runoff, may affect water quality for Oregon chub (Scheerer, ODFW, personal communication, 2004).	**HIGH**
Competition with other species	Exotic fish species pose a significant threat through predation and competition (Scheerer, ODFW, personal communication, 2004).	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water (Scheerer, ODFW, personal communication, 2004).	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low- velocity waterways (Scheerer, ODFW, personal communication, 2004).	**HIGH**

Table 3-123: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower Marys Subbasin

EDT Attribute Class	Description	Priority for Restoration
Oxygen	Low dissolved oxygen in some ponds contributes to reduced water quality for Oregon chub (Scheerer, ODFW, personal communication, 2004).	Medium
Withdrawals	It is important to work with water rights holders near Finley National Wildlife Refuge to manage flows effectively.	Medium
Flow	There have been impacts to the interannual variability of low and high flows as a result of land use practices and water diversions.	Low
Pathogens	Pathogens are not thought to be limiting (Scheerer, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Scheerer, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Marys Subbasin. Historically the upper subbasin was an important spawning and rearing area for both resident and fluvial cutthroat trout. In contrast to the large-scale modification of the lower subbasin, there is higher quality habitat in the upper subbasin, particularly in the forested upland areas. Currently, limiting factors for cutthroat trout in the upper subbasin are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Historical management of riparian areas and stream cleaning practices has led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. Changes to the riparian canopy have increased summertime water temperatures.
- **Fish Passage Barriers**. Numerous partial and complete fish passage barriers on tributary streams have limited cutthroat trout populations.

Table 3-124 outlines the EDT attributes limiting cutthroat life stages in the upper Marys Subbasin, above Philomath, in an area that is primarily privately owned, with land uses being forestry and rural residential. Again, the table presents qualitative ratings based on information in Table 3-120 and professional opinions from individuals familiar with the subbasin (primarily ODFW biologists).

Table 3-124: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Marys Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Some channel confinement through the river corridor and on tributaries by revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Numerous complete and partial barriers on tributaries.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have affected channel stability.	Medium
Withdrawals	Limited impacts because most of the unscreened diversions are in the lower subbasin.	Medium
Chemicals	Toxics are probably not an issue because of the limited urban and agricultural land uses in the upper subbasin.	Low
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Competition with other species	There is some competition with introduced fish in the river, but competition in the tributaries is minimal (Mamoyac, ODFW, personal communication, 2004).	Low
Flow	There is less area in agricultural and urban land uses that contributes to changes in flow regimes.	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

3.5.1.6 Limiting Factors in the Middle Fork Willamette Subbasin

This section describes the Middle Fork Willamette Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: spring Chinook salmon, cutthroat trout, Oregon chub, and bull trout.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon
- Bull trout (upper subbasin only)
- Oregon chub (lower subbasin only)

Geographic Setting. The Middle Fork Willamette Subbasin covers an area of approximately 1,360 square miles on the western slope of the Cascade Mountains and the floor of the Willamette Valley. The river is 84 miles long and joins the Coast Fork Willamette River near Eugene to form the mainstem Willamette River. Approximately 75 percent of the land in the subbasin is publicly owned and managed by federal agencies, including the U.S. Forest Service's Willamette National Forest, which manages most of the upper subbasin. The Eugene District of the BLM manages a smaller proportion of the lower subbasin below Dexter Dam. The headwaters of the Middle Fork Willamette River originate in the Diamond Peak and Waldo Lake Wilderness areas on the Willamette National Forest. The city of Oakridge is in the upper subbasin, and the lower subbasin includes portions of the cities of Springfield and Eugene.

The geology of the western Cascades characterizes the mountainous areas of the subbasin. This area has deeply weathered rocks, steep and highly dissected hill slopes, and significant erosion. Stream runoff patterns in the subbasin are dominated by the western Cascade geology, with a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. The High Cascades geology in the upper subbasin, which is characterized by deep lava deposits, contributes spring-feed flows to the system, particularly in some tributaries above Hills Creek Reservoir. These spring-fed sources are not of sufficient volume to significantly influence flow patterns or water temperature regimes in the mainstem river reaches below the dams. The headwater elevations are high enough to form a seasonal snowpack, which influences summer stream flows and water temperatures.

The Dexter and Lookout Point Dam complex (approximately 8 miles above the confluence with the Coast Fork) divides the subbasin, limiting upstream fish passage and greatly influencing downstream hydrologic regimes, temperature patterns, sediment and bedload transport, and large wood delivery to the lower reaches. The North Fork Middle Fork Willamette River and Salt and Salmon creeks are major tributaries in the upper subbasin that historically supported anadromous fish populations. The upper Middle Fork Willamette River flows through a narrow, steep forested canyon. Hills Creek Dam on the upper Middle Fork Willamette River (approximately 36 miles above the confluence with the Coast Fork) further divides the upper subbasin. The river's gradient decreases from 2.6 percent upstream of Hills Creek Reservoir to approximately 0.5 percent between Hills Creek Dam and Lookout Pont Reservoir.

Downstream of Dexter Dam, the Middle Fork Willamette River flows into the wide, alluvial Willamette Valley. Fall, Little Fall, and Lost creeks are major tributaries in the lower subbasin. Fall Creek Dam (RM 7) limits fish access to upper Fall Creek and controls downstream flows and other processes. The lower portion of the river below the Dexter Dam is low gradient (less than 0.2 percent) and flows through a relatively wide valley with an extensive floodplain. More than 60 percent of land in the lower subbasin is privately owned, primarily as industrial forestlands. The remainder of the lower river valley consists of agricultural land and urban areas.

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the Middle Fork Willamette Subbasin have affected the productivity, capacity, and diversity of cutthroat trout, bull trout, and spring Chinook populations. In addition, Oregon chub have lost habitat as backwater and off-channel areas have disappeared as a result of changes in seasonal flows associated with the construction of dams throughout the basin, channelization of the Willamette River and its tributaries, removal of snags for river navigation, and agricultural practices. Table 3-125 summarizes changes in the subbasin’s environmental conditions and how these changes have affected cutthroat trout, spring Chinook salmon, bull trout, and Oregon chub life stages.

Dams. The U.S. Army Corps of Engineers dams have restricted access to the upper subbasin and changed downstream hydrologic processes, water quality, and processes that influence habitat formation. The construction of Dexter and Lookout Point dams limited access to an estimated 80 percent of the historical production area for spring Chinook salmon and eliminated the interchange between the upper and lower subbasin cutthroat trout populations (U.S. Army Corps of Engineers, 2001). Relative to the lower subbasin, the upper subbasin above the dams has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, the largest amounts of large wood in the river and tributary channels, and the highest quality spawning areas. The dams have altered the links between the upper and lower subbasin, thus reducing the transport and delivery of large wood and substrate to downstream reaches. Because the dams capture material, delivery of large wood to the lower Middle Fork Willamette River is blocked from 90 percent of the subbasin (U.S. Army Corps of Engineers, 2001). Changes in the abundance and distribution of gravels, small cobbles, and large wood (particularly in large jams) have reduced suitable spawning areas and limited areas for adult cutthroat trout and juvenile rearing habitat for spring Chinook salmon. The dams have also changed flow regimes and water temperature patterns. Compared to historical conditions, water temperatures in the river below the dam are cooler in the summer and warmer in the fall and winter, which affects the upstream distribution of spring Chinook salmon adults, alters the timing of spawning, and affects the survival of eggs.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Maximum temperatures for adult migration have been exceeded in the mainstem of the river and Fall Creek below the dams. Maximum temperatures for adult migration have been exceeded in the upper Middle Fork Willamette above Hills Creek Reservoir, Salt Creek, the North Fork of the Middle Fork Willamette, Lost Creek, Fall Creek above Fall Creek Dam, and other tributaries. No criteria exceedences for toxics, nutrients, or turbidity.	Dams block access to an estimated 80 percent of the historical habitat. Fall Creek and Dexter dams prevent movement of cutthroat trout between the upper and lower subbasin. Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	The lower subbasin contains only a small fraction of the original extent of floodplain forest; many remaining patches of floodplain forest are interspersed with areas with little floodplain vegetation. The frequency of flows is not of sufficient magnitude to create and maintain channel complexity and provide nutrients, organic matter, and sediment inputs from floodplain areas. Riparian vegetation within 100 feet of the small tributaries of the lower Middle Fork Willamette is generally in poor condition. The highway along much of the Middle Fork and Salt Creek and roads along tributaries have compromised the ability of channels to meander, recruit large wood, and create new surfaces for establishment of riparian trees.	
	Adult spawning/ egg incubation		Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	There is limited in-channel wood in tributaries to capture spawning gravels.	

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	The frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Reduced recruitment of large wood has limited the creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats. Maximum temperatures for adult migration have been exceeded in the upper Middle Fork Willamette above Hills Creek Reservoir, Salt Creek, the North Fork of the Middle Fork Willamette, Lost Creek, Fall Creek above Fall Creek Dam, and other tributaries. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Low summer flows in tributaries from water withdrawals may reduce the juvenile rearing habitat area.	All of the dams have reduced downstream juvenile migrant survival. The floodplain is not inundated frequently; thus, the reduced over-bank flow and side channel connectivity limit rearing and refuge habitat. Much of the lower Middle Fork Willamette River has revetments. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit juvenile upstream movement into refuge habitat.	Many of the remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development 74 percent of riparian forests along the lower Middle Fork have reduced function and are limited in extent and connectivity. There is a large extent of mature and old-growth conifer in the upper subbasin riparian areas. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. Large wood into the lower Middle Fork Willamette River is blocked from 90 percent of the subbasin. Large wood in the reaches of the river below the dams is limited, which reduces the formation of pools and side channels. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity. Revetments protect 50 percent of the lower 8 miles of the river, which limits habitat complexity. Lower river reaches have lost sinuosity, side-channel length, alcoves, and gravel bars.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Spring Chinook Salmon	Adult migration and holding	Compared to historical conditions, cooler summer mainstem temperatures and warmer fall temperatures below the dams disrupt normal migration and spawning behaviors. Maximum temperatures for adult migration have been exceeded in the mainstem of the river and Fall Creek below the dams. Maximum temperatures for adult migration have been exceeded in the upper Middle Fork Willamette above Hills Creek Reservoir, Salt Creek, the North Fork of the Middle Fork Willamette, Lost Creek, Fall Creek above Fall Creek Dam, and other tributaries. No criteria exceedences for toxics, nutrients, or turbidity.	Dams block access to an estimated 80 percent of the historical habitat. Fall Creek Dam is a barrier to fish movement. A trapping facility is in place by upstream migrants could experience abrasion, mechanical injury, and stress and experience delay in migration and disease when water temperatures are above maximum. The Dexter and Lookout Point dams were built without fish passage facilities. Upstream migrants are trapped at Dexter Dam and held in a pond until they are trucked to the upper subbasin. Hills Creek Dam was built without upstream or downstream fish passage facilities. ODFW began releasing adult spring Chinook salmon above Hills Creek Reservoir in 1993 to increase nutrient inputs and provide a prey base for bull trout.	The lower subbasin contains only a small fraction of the original extent of floodplain forest; many remaining patches of floodplain forest are interspersed with areas with little floodplain vegetation. The frequency of flows is not of sufficient magnitude to create and maintain channel complexity and provide nutrients, organic matter, and sediment inputs from floodplain areas. Riparian vegetation within 100 feet of the small tributaries of the lower Middle Fork Willamette is generally in poor condition. The highway along much of the Middle Fork and Salt Creek and roads along tributaries have compromised the ability of channels to meander, recruit large wood, and create new surfaces for establishment of riparian trees.	

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Warmer fall temperatures resulting from dam regulation have shortened the emergence timing of Chinook fry. Maximum temperatures for incubation emergence have been exceeded in the lower river, leading to egg mortality.		Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. Limited in-channel wood to capture spawning gravels. Substrate has coarsened in the Middle Fork downstream of Dexter Dam, reducing spawning habitat. Removal of gravel from floodplain gravel mining reduces the availability of substrate for in-channel habitat.	Boating, fishing, and other recreational activities harass adults moving and holding in pools.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Winter and spring flow reductions below the dams may reduce rearing area and the survival of fry. Flow fluctuations now occur at rates rapid enough to entrap and strand juvenile anadromous fish. Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Reduced recruitment of large wood has limited the creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats. Maximum temperatures for adult migration have been exceeded in the upper Middle Fork Willamette above Hills Creek Reservoir, Salt Creek, the North Fork of the Middle Fork Willamette, Lost Creek, Fall Creek above Fall Creek Dam, and other tributaries. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Low summer flows in tributaries from water withdrawals may reduce the juvenile rearing habitat area.	All of the dams have reduced downstream juvenile migrant survival. The floodplain is not inundated frequently; thus, the over-bank flow and side channel connectivity limit rearing and refuge habitat. Much of the lower Middle Fork Willamette River has revetments. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit juvenile upstream movement into refuge habitat.	Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development 74 percent of riparian forests along the lower Middle Fork have reduced function and are limited in extent and connectivity. There is a large extent of mature and old-growth conifer in the upper subbasin riparian areas. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. Large wood into the lower Middle Fork Willamette River is blocked in 90 percent of the subbasin. Large wood in reaches of the river below the dams is limited, which reduces the formation of pools and side channels. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity. Revetments protect 50 percent of the lower 8 miles of the river, which limits habitat complexity. Lower river reaches have lost sinuosity, side-channel length, alcoves, and gravel bars.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Bull Trout	Adult migration and holding	Middle Fork Willamette below Hills Creek and Dexter Dams: The frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. No documented affect from winter and spring flow reductions below Hills Creek and Dexter dams on migrating bull trout; however, flow management that more closely approaches the natural hydrograph would benefit bull trout. Spring and summer releases from Hills Creek and Dexter dams are cooler than inflow; winter releases are warmer than inflow DEQ's 2002 CWA 303(d) database indicates that the Middle Fork Willamette above Hills Creek Reservoir (Sand Prairie Campground) exceeds the temperature standard for bull trout (50°F). The 7-day average of daily maximums ranged from 63°F (1964) to 72°F (1980). Water temperatures limit bull trout distribution. DEQ's 2002 CWA 303(d) database indicates that the Middle Fork Willamette below Dexter Dam exceeds the temperature standard for bull trout (50°F). Water temperatures limit bull trout distribution.	Upstream adult movement is confined to entering Dexter Ponds Hatchery Facility from June through September at Dexter Dam (RM 203). Complete barriers to upstream adult movement are Lookout Point Dam (RM 206) and Hills Creek Dam (RM 233). No designed downstream fish passage. All downstream fish passage is through turbines or regulating outlets.	Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat Large wood does not meet USFS targets in most low-gradient upper Middle Fork tributaries, most of the North Fork Middle Fork, Salmon Creek, Hills Creek, and the mainstem Fall Creek Large wood into the lower Middle Fork is blocked in 90 percent of the subbasin U.S. Army Corps of Engineers reservoirs block sediment into the lower Middle Fork from 90 percent of the Middle Fork subbasin Construction of Fall Creek, Dexter, Lookout Point, and Hills Creek Reservoir have replaced 40 miles of free-flowing stream in the Middle Fork Willamette Basin with reservoir habitat.	Boating and other recreational activities harass adults migrating and holding in pools. Poaching of bull trout occurs. Bull trout captured and released during trout, steelhead, or salmon fisheries suffer an unknown level of hooking mortality. Reduction of spring Chinook salmon production above Dexter, Lookout Point, and Hills Creek dams has decreased the availability of a historical prey base important for bull trout. Hatchery rainbow trout have been introduced to areas above and below dams, potentially competing with bull trout for food and habitat.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
				Streambank protection has limited habitat complexity, reducing the number of pools and side channels available for holding and rearing fish. Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development.	
	Adult spawning/egg incubation	Spawning has not been documented in the Middle Fork basin since reintroduction of juvenile bull trout began in 1997. It is assumed that bull trout will spawn in cool-water springs where juveniles were reintroduced or in portions of the mainstem Middle Fork where water temperatures are not currently limiting.		Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat Large wood does not meet USFS targets in most low-gradient upper Middle Fork tributaries, most of the North Fork Middle Fork, Salmon Creek, Hills Creek, and the mainstem Fall Creek	There is the potential for hybridization with nonnative brook trout.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	ODEQ’s 2002 CWA 303(d) database indicates that the Middle Fork Willamette above Hills Creek Reservoir (Sand Prairie Campground) exceeds the temperature standard for bull trout (50°F). The 7-day average of daily maximums ranged from 63°F (1964) to 72°F (1980). Water temperatures limit juvenile bull trout distribution.	Complete barriers to upstream juvenile movement are Dexter Dam (RM 203), Lookout Point Dam (RM 206), and Hills Creek Dam (RM 233). No designed downstream fish passage. All downstream fish passage is through turbines or regulating outlets. Numerous partial and complete passage barriers at culverts on tributary streams may limit movement into refuge habitat.	Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat Large wood does not meet USFS targets in most low-gradient upper Middle Fork tributaries, most of the North Fork Middle Fork, Salmon Creek, Hills Creek, and the mainstem Fall Creek	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Oregon chub	All	Logging practices in the upper watersheds of the Middle Fork Willamette tributaries contribute sediment to ponds that contain Oregon chub. Over time, these ponds may fill in completely. Sedimentation taking place at East Fork Minnow Creek pond may be partially influenced by logging in the watershed. Logging practices in the upper watersheds of the Middle Fork Willamette tributaries may, through runoff, contribute pesticides and herbicides to ponds containing Oregon chub. Water quality can be subsequently affected through increased nutrients and low dissolved oxygen. Several Oregon chub populations that occur near roadways may be subject to pollution from road runoff and chemical spills.	Numerous diversions and water barriers may protect Oregon chub from the influx of exotic fish species; however, the natural dispersal of Oregon chub is also limited by these structures. For example, the Dexter Reservoir alcoves allow passage of exotic fish species between the reservoir and the alcoves, which contain Oregon chub. The loss of connectivity to floodplain and wetland habitats has affected the availability of suitable habitat. Dams and other structures have changed river hydrology and reduced the amount of side-channel habitat.	Frequency of flows is not of sufficient magnitude to create and maintain channel complexity and provide nutrients, organic matter, and sediment inputs from floodplain areas. Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development There has been significant loss of wetland, floodplain and off-channel habitats and associated habitat complexity. Lower river reaches have lost sinuosity, side-channel length, alcoves, and gravel bars.	The presence of exotic fish in this system inhibits Oregon chub recolonization of formerly occupied habitat.

Table 3-125: Middle Fork Willamette Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, Bull Trout, and Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
		Oregon chub populations, such as those at Hospital Pond and the Dexter Reservoir alcoves, are vulnerable to fluctuations in Dexter and Lookout Point reservoirs. Low reservoir levels draw down water in the adjacent alcoves containing Oregon chub. The U.S. Army Corps of Engineers has worked extensively with USFWS to remedy this problem. The City of Oakridge sewage treatment facility is adjacent to the Oakridge population of Oregon chub. This population has declined drastically in recent years. USFWS has conducted preliminary water quality tests to determine whether the treatment plant operations are adversely affecting this population of Oregon chub. Tests to date (February 2004) have been inconclusive.	The floodplain is not inundated frequently; thus, reduced over-bank flow and side-channel connectivity limits Oregon chub habitat.		

Source: MWC, 2002; U.S. Army Corps of Engineers, 2001; ODFW, 1992; Fernauld et al., 2001; Landers et al., 2001; ODEQ, 2004; ODFW, 2004.

Appendix G shows specific fish passage barriers on the Middle Fork, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Large Wood. Historical removal of large wood from the river and tributary streams, reduced transport of wood below the dams, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries. Approximately 74 percent of the riparian forests along the lower Middle Fork have reduced functions, including delivery of large wood Limited wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. There has been significant loss of sinuosity, side channel length, and numbers of alcoves in the lower river reaches (Andrus and Walsh, 2002). More than 50 percent of the channel length of the lower Middle Fork Willamette River has revetments (U.S. Army Corps of Engineers, 2001). Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. In addition, changes in the frequency and magnitude of high flow events below the dams have altered the formation of these complex habitats. Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout and juvenile spring Chinook salmon and Oregon chub. These habitats provide fish with habitat for foraging and refuge from high flow events.

Key Factors Limiting Fish Populations. The U.S. Army Corps of Engineers dams divide the Middle Fork Willamette Subbasin into upper and lower portions that are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Lower Middle Fork Willamette Subbasin. In the lower Middle Fork Willamette Subbasin, the population productivity, capacity, and diversity of cutthroat trout and spring Chinook salmon, populations are limited by the following (no bull trout populations occur in the lower subbasin):

- **Habitat Connectivity**. Modification of the river’s high flow regime as a result of dam regulation, channel and bank confinement, and reduced large wood in the channels have interacted to reduce backwater habitats important for juvenile rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages. Limited spawning areas and reduced levels of gravels/small cobbles have reduced the areas available for spawning.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. Changes in high and low water temperature regimes have affected adult salmonid spawning success and egg incubation and have limited the capacity of river and tributary streams to support juvenile fish.

- **Fish Passage Barriers**. The U.S. Army Corps of Engineers dams on the river and fish passage barriers at road crossings on tributary streams prevent access to historical spring Chinook salmon and cutthroat trout spawning areas, block the interchange between the upper and lower subbasin cutthroat trout populations, and limit juvenile access into rearing and refuge habitat.
- **Additional Factors**. Other, more moderate factors that are limiting cutthroat trout and spring Chinook salmon populations include competition with hatchery and introduced fish; lower numbers of salmon carcasses, which reduce nutrient inputs and thus food availability; and harassment of adult migrating and holding prespawning fish by recreational activities such as boating and fishing. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Oregon chub populations are severely limited by the presence of exotic fish species in many habitats, reduced water quality from upslope commercial timber operations, and reductions in essential floodplain and backwater habitats that have been reduced from historical levels as a result of the hydrologic regimes associated with dams on the Middle Fork.

Table 3-126 shows the EDT attributes related to the limiting factors for cutthroat trout and spring Chinook salmon life stages in the lower Middle Fork Willamette Subbasin, while Table 3-127 shows the EDT attributes for Oregon chub limiting factors. (No bull trout populations occur in the lower Middle Fork subbasin.) The area in question is below the U.S. Army Corps of Engineers dams and is primarily in private ownership. The priorities for restoration are qualitative ratings based on information in Table 3-125 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-126: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Spring Chinook Salmon and Cutthroat Trout in the Lower Middle Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	Changes in the interannual variability of low and high flows from dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams prevent migration into the upper subbasin; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	The dams have modified high and low water temperature regimes in the river. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation); primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**

Table 3-126: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Spring Chinook Salmon and Cutthroat Trout in the Lower Middle Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels has reduced channel stability.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas below the dams, thus increasing competition with native fish for habitat and food (Ziller, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish.	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Harassment	Extensive recreational use of the lower river (boating and fishing) harasses migrating, holding, and spawning fish.	Medium
Pathogens	Hatchery fish have been introduced to areas below the dams, increasing the potential for disease.	Medium
Withdrawals	Unscreened diversions on some tributaries affect adult and juvenile rearing habitat.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids.	Low
Oxygen	Oxygen levels are adequate to support all life stages.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low

Table 3-127: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower Middle Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Chemicals	Oregon chub habitats are susceptible to reduced water quality from commercial timber operations, sewage treatment plants, and highway runoff.	**HIGH**
Competition with other species	Exotic fish species pose a significant threat through predation and competition.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low-velocity waterways.	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.	**HIGH**

Table 3-127: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower Middle Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	Changes in the interannual variability of low and high flows from dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	Medium
Sediment load	Sediment from logging activities in the upper watershed may be contributing to filling in and reducing the amount of habitat.	Medium
Withdrawals	Water levels in Dexter and Lookout Point reservoirs affect available habitat in side alcoves to the reservoirs.	Medium
Oxygen	Low dissolved oxygen levels in some habitats may contribute to reduced water quality.	Low
Pathogens	Pathogens are not thought to be limiting.	Low

Limiting Factors in the Upper Middle Fork Willamette Subbasin. Historically the upper subbasin was an important spawning and juvenile rearing area for cutthroat trout, spring Chinook salmon, and bull trout. In contrast to the large-scale modification of the lower subbasin, most of the impacts to habitat and water quality in the upper subbasin are localized. Currently, limiting factors for cutthroat, Chinook, and bull trout in the upper subbasin are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover, but not to the extent as in the lower subbasin. A highway parallels the river for much its length and there are numerous forest roads along tributary streams.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors**. Other, more moderate limiting factors include partial and complete barriers to fish passage on tributary streams, changes in water temperature regimes as a result of reduced canopy cover, competition with hatchery introductions, and lower numbers of salmon carcasses, which reduces nutrient inputs and thus food availability.

Table 3-128 shows the EDT attributes related to limiting factors for cutthroat trout, spring Chinook salmon, and bull trout life stages in the upper Middle Fork Willamette Subbasin, an area that is primarily under U.S. Forest Service management. Again, the table presents qualitative ratings based on information in Table 3-125 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-128: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Spring Chinook Salmon, and Bull Trout in the Upper Middle Fork Willamette River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Moderate channel confinement through the river corridor as a result of bank riprap, the highway and secondary roads, and limited large wood has affected the quality of habitat.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood.	**HIGH**
Channel stability	In some areas, limited in-channel wood and reduced riparian function have destabilized channels.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas above the dams, increasing competition with native fish for habitat and food.	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Juvenile Chinook salmon were an important prey item for bull trout.	Medium
Obstructions	Some complete and partial barriers on tributary streams.	Medium
Pathogens	Hatchery fish have been introduced to areas above the dams, increasing the potential for disease.	Medium
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams inhabited historically by bull trout.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids.	Low
Competition with other species	Very low number of introduced fish species present.	Low
Flow	There have not been significant changes in the interannual variability of low and high flows.	Low
Harassment	Moderate recreational use of the upper river (boating and fishing) harasses migrating, holding, and spawning fish.	Low
Oxygen	Oxygen levels are adequate to support all life stages	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	Minimal water withdrawals.	Low

3.5.1.7 Limiting Factors in the Molalla/Pudding Subbasin

This section describes the Marys subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: winter steelhead, cutthroat trout, and spring Chinook.

Focal species present:

- Winter steelhead trout
- Spring Chinook salmon
- Cutthroat trout

Focal species present historically:

- Oregon chub

Geographic Setting. The Molalla/Pudding Subbasin covers an area of approximately 900 square miles. The Molalla River begins in the western slope of the Cascade Mountains, while the Pudding River's headwaters begin in the low elevation Waldo Hills east of Salem. The Molalla River is approximately 49 miles long and enters the Willamette River at RM 36; the Pudding Rive is 62 miles long and enters the Molalla River at RM 0.75. Approximately 87 percent of the land in the subbasin is privately owned. Agriculture and rural residential development are the dominant land uses in the lower subbasin, with most of the development concentrated in the Pudding drainage. There are numerous small communities and growing urban areas within the lower subbasin, including the cities of Canby, Silverton, Molalla; in addition, portions of the cities of Salem and Woodburn are within the lower subbasin. Forestland uses predominate in the upper Molalla River drainage and on tributaries to the Pudding River that drain the Cascade Range (Butte and Abiqua creeks, for example). The Salem District of the BLM manages a block of land in the upper Molalla River, which includes the Table Rock Wilderness.

The Molalla River enters the floor of the Willamette Valley near the community of Shady Dell (RM 20). Major tributaries in the forested upper Molalla drainage include the North Fork Molalla and Table Rock Creek. Milk and Woodcock creeks are major tributaries to the lower Molalla River. Almost the entire Pudding River drainage is on the floor of the Willamette Valley. Major tributaries in the primarily forested upper portions of the upper Pudding River drainage include Abiqua, Butte, and Silver creeks. The Little Pudding River and Drift Creek drain into the lower Pudding River drainage in the Willamette Valley.

The Molalla/Pudding Subbasin has variable stream flow regimes. Stream runoff patterns in the Molalla drainage are dominated by the western Cascade geology, with a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the river leading to rapid delivery of water to the stream network. Snowmelt from the low-elevation western Cascades contributes to flows in the Molalla drainage but not in the quantities of the higher Cascade drainages. The Pudding drainage begins at very low elevations with no summer snowmelt to affect stream flows. Because the Pudding drainage is underlain with Willamette Valley alluvium, which has little water storage capacity, stream flows follow seasonal rainfall patterns. The mainstem Pudding River has lower flows and higher water temperatures than the Molalla River drainage. Butte, Abiqua and Silver creeks in the Pudding drainage and the headwaters of the Molalla River are underlain with volcanic basalts, which store water, thus helping to maintain flows and cooler water temperatures in the summer and early fall.

The headwaters and tributaries of the upper subbasin flow steeply off the Cascade Range, and the gradient rapidly decreases once the river enters the lower subbasin areas within the flat Willamette Valley. The lower 20 miles of the Molalla River has a gradient of 0.2 percent.

Almost the entire Pudding River channel is within the flat Willamette Valley floor, with a gradient of 0.04 percent for the first 50 miles.

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the Molalla/Pudding Subbasin have affected the productivity, capacity, and diversity of winter steelhead, spring Chinook, and cutthroat population. Table 3-129 summarizes changes in the subbasin's environmental conditions and how these changes have affected cutthroat trout, spring Chinook salmon, and winter steelhead life stages.

Upper and Lower Subbasins. Relative to the lower Molalla/Pudding Subbasin, the upper subbasin, which is primarily forested, has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, the largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Baker et al., 2002). Impacts to aquatic and riparian habitats have been greater in the lower subbasin than in the upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because largest proportion of low gradient, unconstrained river and stream channels were in the area where the Molalla and Pudding rivers and tributaries flowed across the flat Willamette Valley (Pacific Northwest Ecosystem Research Consortium, 2002).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin (Pacific Northwest Ecosystem Research Consortium, 2002). Over time, a number of practices (such as splash dams and stream cleaning) removed large wood from the Molalla and Pudding rivers and tributary channels. While riparian areas in the forested upper subbasin have greater numbers of conifer trees than the lower subbasin does, historical wood removal from streams and riparian harvest has reduced large wood in the channels. Reduced wood in the river and tributary channels limits the formation of pools, thus reducing hiding and feeding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat. The loss of large wood and other structures that provide hiding cover has reduced the quality of adult spring Chinook salmon holding pools in the Molalla River (Stahl, ODFW, personal communication, 2004).

Table 3-129: Molalla/Pudding Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Naturally low flows in the lower Pudding drainage are aggravated by water withdrawals, which increase water temperatures. High water temperatures are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces, particularly in the Pudding drainage. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands—particularly in the Pudding drainage—have accelerated runoff and increased peak flows. Nutrient and toxic runoff from agricultural and urban areas is an issue in the Pudding drainage. Loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows).	The fish ladder at Silverton's water diversion on Abiqua Creek has an inadequate entrance and is a partial fish passage barrier. Numerous culverts throughout the subbasin present barriers to adult refuge habitat. There are unscreened diversions on the mainstem Molalla River near Shady Cove. Labish Ditch is an unscreened diversion that provides an interbasin connection between Claggett Creek and the Little Pudding River.	Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. There is some high-quality floodplain forest remaining along the lower Pudding River. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of adult holding areas.	Stocked summer steelhead interact with native fish.
	Adult spawning/egg incubation		Numerous culverts throughout the subbasin present barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-129: Molalla/Pudding Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the Pudding drainage are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the lower subbasin, do not provide optimal conditions for juvenile rearing. The agricultural and urban land uses in the subbasin, particularly in the Pudding drainage, have changed peak and low flows. Small diversions, ditches, and drainage tiling in the lower subbasin have reduced storage capacity, contributing to flashy peak flows and lower flows during the summer and early fall.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin.	Channels in the lower portions of the Molalla River, particularly near the city of Molalla (RM 20), and some tributaries have been simplified as a result of revetments and other actions. Revetments have simplified channels throughout the lower Pudding River and tributaries as a result of rural residential development and small-community build-out near the stream channels. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.

Table 3-129: Molalla/Pudding Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Spring Chinook Salmon	Adult migration and holding	Naturally low flows in the lower Pudding drainage are aggravated by water withdrawals, which increase water temperatures. High water temperatures are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces, particularly in the Pudding drainage. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands—particularly in the Pudding drainage—have accelerated runoff and increased peak flows. Nutrient and toxic runoff from agricultural and urban areas is an issue in the Pudding drainage. Loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows).	The fish ladder at Silverton's water diversion on Abiqua Creek has an inadequate entrance and is a partial fish passage barrier.	Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. The loss of large wood and other structures that provide hiding cover has reduced the quality of adult holding pools in the Molalla River. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. There is some high-quality floodplain forest remaining along the lower Pudding River. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of adult holding areas.	Stocked summer steelhead interact with native fish.
	Adult spawning/egg incubation			Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-129: Molalla/Pudding Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the Pudding drainage are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the lower subbasin, do not provide optimal conditions for juvenile rearing. The agricultural and urban land uses in the subbasin, particularly in the Pudding drainage, have changed peak and low flows. Small diversions, ditches, and drainage tiling in the lower subbasin have reduced storage capacity, contributing to flashy peak flows and lower flows during the summer and early fall.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin.	Channels in the lower portions of the Molalla River, particularly near the city of Molalla (RM 20), and some tributaries have been simplified through revetments and other actions. Revetments have simplified channels throughout the lower Pudding River and tributaries as a result of rural residential development and small-community build-out near the stream channels. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.

Table 3-129: Molalla/Pudding Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Winter Steelhead Trout	Adult migration and holding	Naturally low flows in the lower Pudding drainage are aggravated by water withdrawals, which increase water temperatures. High water temperatures are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces, particularly in the Pudding drainage. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands—particularly in the Pudding drainage—have accelerated runoff and increased peak flows. Nutrient and toxic runoff from agricultural and urban areas is an issue in the Pudding drainage. Loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows).	The fish ladder at Silverton's water diversion on Abiqua Creek has an inadequate entrance and is a partial fish passage barrier. Numerous culverts throughout the subbasin present barriers to adult refuge habitat. There are unscreened diversions on the mainstem Molalla River near Shady Cove. Labish Ditch is an unscreened diversion that provides an interbasin connection between Claggett Creek and the Little Pudding River.	Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. There is some high-quality floodplain forest remaining along the lower Pudding River. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of adult holding areas.	Stocked summer steelhead interact with native fish.
	Adult spawning/egg incubation		Numerous culverts throughout the subbasin present barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-129: Molalla/Pudding Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the Pudding drainage are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the lower subbasin, do not provide optimal conditions for juvenile rearing. The agricultural and urban land uses in the subbasin, particularly in the Pudding drainage, have changed peak and low flows. Small diversions, ditches, and drainage tiling in the lower subbasin have reduced storage capacity, contributing to flashy peak flows and lower flows during the summer and early fall.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin.	Channels in the lower portions of the Molalla River, particularly near the City of Molalla (RM 20), and some tributaries have been simplified through revetments and other actions. Revetments have simplified channels throughout the lower Pudding River and tributaries as a result of rural residential development and small-community build-out near the stream channels. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.

Source: Stahl, ODFW, personal communication, 2004; Oregon Department of Environmental Quality, 2004.

Water Quality Changes. Water quality has been modified throughout the subbasin, particularly in the Pudding River. The Pudding River's low summertime flows contribute to concentrating nonpoint-source runoff (toxics and nutrients) and aggravate naturally higher water temperatures (Oregon Department of Environmental Quality, 2004). Water temperatures exceed criteria throughout the Pudding drainage. Many of the tributaries, particularly in the lower subbasin, have elevated water temperatures (Oregon Department of Environmental Quality, 2004). The Pudding River's natural summertime low flows are aggravated by water withdrawals, which increase water temperatures. There are a number of water withdrawals in the subbasin, particularly in the Pudding drainage as a result of agriculture and other land uses (Stahl, ODFW, personal communication, 2004). In general, water temperatures are lower in the forested portions of the upper subbasin tributaries (for example, Butte, Silver, and Abiqua creeks) and the Molalla River. High water temperatures in the lower subbasin are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces.

Changes in Flow Regimes. Peak- and low-flow regimes have been modified, particularly in the Pudding drainage. While the Silverton Reservoir, Silverton Creek, and other small reservoirs in the subbasin do not exert strong controls on peak or low flows, changes in land use have affected hydrologic regimes in the tributaries. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows (Stahl, ODFW, personal communication, 2004). There has been extensive loss of wetlands throughout the subbasin.

Fish Passage Barriers. Fish passage is restricted throughout the subbasin, in part by a number of small dams on Butte, Abiqua, and Silver creeks. Many of these dams are laddered for fish passage, but the effectiveness of the fish ladders is unknown (Stahl, ODFW, personal communication, 2004). In addition, numerous culverts at road crossings throughout the lower and upper subbasin block or limit fish passage (Stahl, ODFW, personal communication, 2004). When fish passage above culverts is limited, the amount of habitat available for juvenile spring Chinook rearing and all cutthroat trout life stages is restricted.

Appendix G shows specific fish passage barriers on the Mollala, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. Large portions of the lower Pudding River and sections of tributary streams have confined channels as a result of the placement of riprap and actions that restrict channel movement (Stahl, ODFW, personal communication, 2004). Revetments, roads, and other structures constrain sections of the lower Molalla River. Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat trout and juvenile spring Chinook salmon. These habitats provide fish with habitat for foraging and refuge from winter flood events.

Key Factors Limiting Fish Populations. The upper and lower portions of the Molalla/Pudding Subbasin are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower Molalla/Pudding Subbasin. In the Lower Mollala/Pudding Subbasin, the productivity, capacity, and diversity of cutthroat trout, winter steelhead, and spring Chinook populations are limited by the following factors:

- **Habitat Connectivity**. Modification of the river's high flow regime as a result of land use changes, channel and bank confinement from riprap and other actions, and reduced large wood in the channels have interacted to reduce backwater habitats important for juvenile rearing and winter refuge.
- **Habitat Modification**. Modifications in key aquatic habitats have affected all life stages. Limited spawning areas and reduced levels of gravels/small cobbles have reduced the areas available for spawning.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries have modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. Changes in high water temperature regimes can affect adult spawning success and limit the capacity of river and tributary streams to support juvenile fish. Water Withdrawals. Unscreened water withdrawals affect juvenile fish.
- **Additional Factors**: Other factors that are limiting cutthroat trout, spring Chinook salmon, and winter steelhead populations include competition with hatchery and introduced fish; lower numbers of salmon carcasses, which reduces nutrient inputs and thus affects food availability; and harassment of adult migrating and holding prespawning fish by recreational activities such as boating and fishing. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Table 3-130 shows the EDT attributes related to these limiting factors for cutthroat trout, spring Chinook salmon, and winter steelhead in the lower Molalla/Pudding Subbasin. The area in question includes portions of the Molalla drainage within the valley floor and the entire mainstem Pudding River and Valley tributaries—this is primarily in private ownership. The priorities for restoration are qualitative ratings based on the information in Table 3-129 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-130: Qualitative Ratings of EDT Attributes for Winter Steelhead, Spring Chinook, and Cutthroat Trout in the Lower Molalla/Pudding Subbasin

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels and reduced riparian function have reduced channel stability.	**HIGH**
Flow	There have been impacts to the interannual variability of low and high flows as a result of land use practices and water diversions.	**HIGH**

Table 3-130: Qualitative Ratings of EDT Attributes for Winter Steelhead, Spring Chinook, and Cutthroat Trout in the Lower Molalla/Pudding Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Small dams my prevent migration into upper tributaries; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Chemicals	There are increased toxics (Stahl, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	There is some competition with stocked summer steelhead (Stahl, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high, and there is competition with introduced fish (Stahl, ODFW, personal communication, 2004).	Medium
Food	The abundance of salmon carcasses is reduced from historical levels.	Medium
Harassment	Prespawning spring Chinook salmon are susceptible to harassment, and there is reduced cover on adult holding pools (Stahl, ODFW, personal communication, 2004).	Medium
Sediment load	There is an increase sediment deposition, particularly in the Pudding drainage (Stahl, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Stahl, ODFW, personal communication, 2004).	Medium
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Stahl, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Molalla/Pudding Subbasin. Historically the forested upper subbasin was an important spawning and juvenile rearing area for all of three of the focal species. In contrast to the large-scale modification of the lower subbasin, most of the impacts to habitat and water quality in the upper subbasin, which is primarily forested, are localized. Currently, limiting factors for cutthroat, spring Chinook, and winter steelhead are as follows:

- **Channel and Habitat Modification.** Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover, but not to the extent in the lower subbasin.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led reduced large wood loads in the aquatic system. Reduced in-channel wood has resulted in modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors**. Other, more moderate limiting factors include partial and complete barriers to fish passage on tributary streams, changes in water temperature regimes as a result of reduced canopy cover, competition with hatchery introductions, and lower numbers of salmon carcasses, which reduces nutrient inputs and thus affects food.

Table 3-131 shows the EDT attributes related to limiting factors for spring Chinook, winter steelhead, and cutthroat in the upper Molalla/Pudding Subbasin. This portion of the subbasin is predominately privately held land with forestry land uses, although BLM manages a portion of the upper Mollala River drainage. Again, the table present qualitative ratings based on information in Table 3-129 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-131. Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Winter Steelhead, and Spring Chinook in the Upper Molalla/Pudding Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Some channel confinement through the river corridor as a result of revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Numerous complete and partial barriers on tributaries.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have affected channel stability.	Medium
Competition with hatchery fish	Competition with hatchery summer steelhead (Stahl, ODFW, personal communication, 2004).	Medium
Food	Abundance of salmon carcasses is reduced from historical levels.	Medium
Harassment	Adult spring Chinook salmon hold in the river and are subject to harassment; reduced hiding cover over holding pools (Stahl, ODFW, personal communication, 2004).	Medium

Table 3-131. Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Winter Steelhead, and Spring Chinook in the Upper Molalla/Pudding Subbasin

EDT Attribute Class	Description	Priority for Restoration
Temperature	Changes in riparian canopy cover have increased summer high water temperatures but not to the level of the lower subbasin.	Medium
Chemicals	Toxics are probably not an issue because of the limited urban and agricultural land uses in the upper subbasin.	Low
Competition with other species	There is some competition with introduced fish in the river, but competition in the tributaries is minimal (Stahl, ODFW, personal communication, 2004).	Low
Flow	There is very little area in the upper subbasin in agricultural and urban land uses that contribute to changes in flow regimes.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Stahl, ODFW, personal communication, 2004).	Low
Sediment load	Although turbidity levels are periodically high, sediment deposition does not appear to be affecting spawning areas (Stahl, ODFW, personal communication, 2004).	Low
Withdrawals	Limited impacts because most of the unscreened diversions are in the lower subbasin.	Low

3.5.1.8 Limiting Factors in the North Santiam Subbasin

This section describes the North Santiam Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: cutthroat trout, spring Chinook, winter steelhead, and Oregon chub.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon
- Winter steelhead trout
- Oregon chub (lower subbasin only)

Focal species present historically:

- Bull trout

Geographic Setting. The North Santiam Subbasin covers an area of approximately 730 square miles on the western slope of the Cascade Mountains and the floor of the Willamette Valley, including the small subbasin that drains to the 12-mile reach of the mainstem Santiam River. The North Santiam and mainstem Santiam rivers together are about 100 miles long and enter the Willamette River at RM 108. Approximately 75 percent of the land in the North Santiam Subbasin is publicly owned and managed by federal or state agencies. The Willamette National Forest manages most of the upper subbasin. The Salem District of the

BLM manages a smaller proportion of the subbasin. The Oregon Department of Forestry manages the 75-square-mile Santiam State Forest between Stayton and Detroit Dam. The headwaters of the North Santiam River originate in the Mount Jefferson Wilderness area of the Willamette National Forest.

The geology of the western Cascades characterizes the mountainous areas of the subbasin. This area has deeply weathered rocks; steep, highly dissected hill slopes; and significant erosion. Stream runoff patterns in the subbasin are dominated by the western Cascade geology, with a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. The High Cascades geology in the upper subbasin, which is characterized by deep lava flows and the Mount Jefferson volcano, contributes some spring-feed flows to the system, although not in sufficient volume to significantly influence downstream flow patterns or water temperature regimes.

Detroit and Big Cliff dams (RM 58) divide the subbasin, limiting upstream and downstream fish passage and exerting strong control over downstream hydrologic regimes, temperature patterns, sediment and bedload transport, and large wood delivery to the lower reaches. The Breitenbush River and Blowout Creek are major tributaries in the upper subbasin that supported anadromous fish populations. The upper North Santiam flows through a narrow, steep, forested canyon. Numerous ancient, deep-seated landslides have been mapped in the upper subbasin, and these features probably continue to contribute large amounts of sediment to the North Santiam River (U.S. Army Corps of Engineers, 2001).

Downstream of Mehama (RM 37), the North Santiam River flows into the wide alluvial Willamette River Valley. The Little North Fork Santiam River is the major tributary in the lower subbasin. The lower 27 miles of the North Santiam is low gradient (less than 0.3 percent) and flows through a relatively wide valley with an extensive floodplain. Below this point, the channel becomes sinuous; historically it was described by the U.S. Army Corps of Engineers (1947) as “crooked and frequently divided by large islands.” More than 70 percent of land in the reach from Mehama to the mouth of the South Santiam River, including the 12-mile mainstem Santiam River, is used for agriculture. The remainder of the lower river valley consists of urban areas, coniferous forests, and mixed deciduous forests.

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the North Santiam Subbasin have affected the productivity, capacity, and diversity of cutthroat trout, spring Chinook, and winter steelhead populations. Table 3-132 summarizes changes in the subbasin’s environmental conditions and how these changes have affected cutthroat trout, spring Chinook salmon, and winter steelhead life stages.

Bull trout are no longer present in the North Santiam, although the USFWS recovery plan calls for reintroduction of bull trout as part of its draft recovery plan. Most of the same environmental issues challenging cutthroat trout, spring Chinook, and winter steelhead also affect bull trout (personal communication Greg Taylor, May 7, 2004). Because no bull trout population currently exists, no specific environmental analysis is included in this subbasin description.

The amount and quality of habitat for Oregon chub in the North Santiam Subbasin has been limited by altered subbasin processes, modified riparian and aquatic habitat, and the presence of exotic warm-water fish, and the Santiam River has been identified as a recovery subbasin in the *Oregon chub Recovery Plan* (U.S. Fish and Wildlife Service, 1998). Establishing successful Oregon chub populations in the lower subbasin has been challenging because exotic fish species often have easy access to chub habitat in backwater sloughs and other slow water habitats. Table 3-133 summarizes changes in the subbasin’s environmental conditions and how these changes have affected Oregon chub life stages.

Dams. The U.S. Army Corps of Engineers dams have restricted fish access to the upper subbasin and changed downstream hydrologic regimes, water quality, and processes influencing habitat formation. The dams block access to an estimated 71 percent of the historical production area for spring Chinook salmon, thus limiting access to historical winter steelhead spawning and rearing areas and eliminating interchange between the upper and lower subbasin cutthroat trout populations (Oregon Department of Fish and Wildlife, 1992). Relative to the lower subbasin, the upper subbasin above the dams has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, the largest amounts of large wood in the river and tributary channels, and the highest quality spawning areas. The dams have altered the links between the upper and lower subbasin, reducing the transport and delivery large wood and substrate to downstream reaches. Changes in the abundance and distribution of gravels, small cobbles, and large wood (particularly in large jams) have reduced suitable spawning areas and limited areas for adult cutthroat trout and juvenile rearing habitat for spring Chinook salmon and winter steelhead.

The dams also have changed flow regimes and water temperature patterns. Compared to historical conditions, water temperatures in the river below the dam are cooler in the summer and warmer in the fall and winter, which affects the upstream distribution of spring Chinook salmon adults, alters the timing of spawning, and affects the period of egg incubation. The change in flow regimes also has altered the availability and quality of Oregon chub habitat in backwater sloughs, floodplain ponds, and other slow-moving side channel habitat. Warmer water temperatures encourage the persistence and dispersal of exotic predaceous fish species.

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce adult passage to upstream spawning areas. Maximum temperatures for adult migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10. Average daily temperatures of less than 52°F during May through late June delay the upstream migration of adults. Dissolved oxygen concentrations do not meet criteria for salmonid spawning at RM 9.3 and RM 11.2 in the mainstem Santiam River. No criteria exceedences for toxics, nutrients, or turbidity.	Complete barriers to adult movement: Detroit and Big Cliff dams (RM 58.1) and Minto Dam (RM 60.9). Partial barriers to adult movement: upper Bennett Dam (RM 31.5) and lower Bennet Dam (RM 29). Unscreened diversions (partial barriers): SWCD power and irrigation canals and Salem ditch; Sidney ditch (RM8). Numerous partial and complete fish passage barriers at culverts on tributary streams may limit adult upstream movement into foraging and refuge habitat.	The lower subbasin contains only 25 percent of the original extent of floodplain forest; many remaining patches of floodplain forest are interspersed with areas with little floodplain vegetation. Reduced pool frequency, depth, and cover have affected the quality of adult habitat in the river and tributaries. Limited wood in the river and tributaries has affected the quality of pools and backwater habitats. Moderate channel confinement in the upper subbasin through the river corridor as a result of bank riprap along the highway and secondary roads.	

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Detroit and Big Cliff dams: Increased fall flows may allow spawning in areas that will be dewatered during active flood control operations. Indirect evidence suggests that warmer fall temperatures resulting from dam regulation have shortened the incubation and emergence timing of Chinook salmon fry. Maximum temperatures for incubation emergence have been exceeded in the lower North Santiam River and in the Santiam River.	Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. Limited in-channel wood to capture spawning gravels. Removal of gravel from floodplain gravel mining reduces availability of substrate for in-channel habitat.	

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Detroit and Big Cliff dams: Winter and spring flow reductions may reduce rearing area and the survival of fry. Frequency and magnitude of high flows not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce juvenile rearing habitat areas. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats. Maximum temperatures for rearing and juvenile migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10. Dissolved oxygen concentrations do not meet criteria rearing at RM 9.3 and RM 11.2 in the mainstem Santiam River. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Channelization of tributaries and changes in runoff patterns on agricultural and developed lands have caused accelerated runoff.	Unscreened diversions: SWCD power and irrigation canals and Salem ditch; numerous unassessed, small, unscreened diversions from RM 29 to Willamette River. Floodplain is not inundated frequently; reduced over-bank flow and side channel connectivity limit rearing and refuge habitat. Much of the lower North Santiam River downstream of Mehama has been diked. The U.S. Army Corps of Engineers installed revetments along 3.2 miles, primarily along the lower 20 miles above the confluence with the South Santiam River. Significant amount of revetment in place above and below Stayton Bridge. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit juvenile upstream movement into refuge habitat.	Approximately 65 percent of riparian areas in smaller tributaries of the upper North Santiam Subbasin above Detroit Reservoir (including Marion Creek) are in early- to mid-successional stages, while 25 percent are old-growth or mature forests. 86 percent of riparian areas within 50 feet of the mainstem between Niagara and Mehama (including the small tributaries that enter within this reach) are characterized by small trees less than 12 inches in diameter. 33 percent of Little North Santiam riparian areas have “high” large wood recruitment potential, while 52 percent have “low” recruitment potential (within 30 feet of the channel). Dams reduce transport of large wood. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
				Reaches of the North Santiam River below Detroit and Big Cliff dams have limited large wood, thus reducing the formation of pools and side channels. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity, reducing habitat quality.	
Spring Chinook Salmon	Adult migration and holding	Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce adult passage to upstream spawning areas. Compared to historical conditions, cooler summer mainstem temperatures and warmer fall temperatures below the dams disrupt normal migration and spawning behaviors. Maximum temperatures for adult migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10. Average daily temperatures of less than 52°F during May through late June delay the upstream migration of adults. Dissolved oxygen concentrations do not meet criteria for salmonid spawning at RM 9.3 and RM 11.2 in the mainstem Santiam River. No criteria exceedences for toxics, nutrients, or turbidity.	Complete barriers to adult movement: Detroit and Big Cliff dams (RM 58.1) and Minto Dam (RM 60.9). Dams block access to an estimated 71 percent of the historical habitat. Partial barriers to adult movement: upper Bennett Dam (RM 31.5) and lower Bennet Dam (RM 29). Unscreened diversions (partial barriers): SWCD power and irrigation canals and Salem ditch; Sidney ditch (RM 8).	The lower subbasin contains only 25 percent of original extent of floodplain forest; many remaining patches of floodplain forest are interspersed with areas with little floodplain vegetation. Moderate channel confinement in the upper subbasin through the river corridor as a result of bank riprap along the highway and secondary roads.	Extensive recreational use of the lower river (boating and fishing) harasses migrating and holding fish.

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Detroit and Big Cliff dams: Increased fall flows may allow spawning in areas that will be dewatered during active flood control operations. Warmer fall temperatures resulting from dam regulation have shortened the emergence timing of Chinook fry. Maximum temperatures for incubation emergence have been exceeded in the lower river.		Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. Limited in-channel wood to capture spawning gravels. Removal of gravel from floodplain gravel mining reduces availability of substrate for in-channel habitat.	Extensive recreational use of the lower river (boating and fishing) harasses spawning fish.

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Detroit and Big Cliff dams: Winter and spring flow reductions may reduce rearing area and the survival of fry. Frequency and magnitude of high flows not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce juvenile rearing habitat areas. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats. Maximum temperatures for rearing and juvenile migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10. Dissolved oxygen concentrations do not meet criteria rearing at RM 9.3 and RM 11.2 in the mainstem Santiam River. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Channelization of tributaries and changes on agricultural and developed lands have caused accelerated runoff.	Detroit Dam and Cliff Dam juvenile downstream passage (combined survival rates): 35 percent to 42 percent. More monitoring is needed. Unscreened diversions: SWCD power and irrigation canals and Salem ditch; numerous unassessed, small, unscreened diversions from RM 29 to Willamette River. Floodplain is not inundated frequently; reduced over-bank flow and side channel connectivity limit rearing and refuge habitat. Much of the lower North Santiam River downstream of Mehama has been diked. The U.S. Army Corps of Engineers installed revetments along 3.2 miles, primarily along the lower 20 miles above the confluence with the South Santiam River. Significant amount of revetment in place above and below Stayton Bridge. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit juvenile upstream movement into refuge habitat.	Approximately 65 percent of riparian areas in smaller tributaries of the upper North Santiam Subbasin above Detroit Reservoir (including Marion Creek) are in early- to mid-successional stages, while 25 percent are old-growth or mature forests. 86 percent of riparian areas within 50 feet of the mainstem between Niagara and Mehama (including the small tributaries that enter within this reach) are characterized by small trees less than 12 inches in diameter. 33 percent of Little North Santiam riparian areas have “high” large wood recruitment potential, while 52 percent have “low” recruitment potential (within 30 feet of the channel). Dams reduce transport of large wood. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. Reaches of the North Santiam River below Detroit and Big Cliff dams have limited large wood, thus reducing the formation of pools and side channels.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
				There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity.	
Winter Steelhead Trout	Adult migration and holding	Diversions in the lower subbasin (see habitat connectivity): Low summer flows in specific reaches may reduce adult passage to upstream spawning areas. Maximum temperatures for adult migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10. No criteria exceedences for toxics, nutrients, or turbidity. No evidence of excessive water diversions in the upper subbasin.	Complete barriers to adult movement: Detroit and Big Cliff dams (RM 58.1) and Minto Dam (RM 60.9). Partial barriers to adult movement: upper Bennett Dam (RM 31.5) and lower Bennet Dam (RM 29). Unscreened diversions (partial barriers): SWCD power and irrigation canals and Salem ditch; Sidney ditch (RM 8).	The lower subbasin contains only 25 percent of the original extent of floodplain forest; many remaining patches of floodplain forest are interspersed with areas with little floodplain vegetation. Loss of large wood and other cover and pool filling have affected the success of holding by prespawning adults. Moderate channel confinement in the upper subbasin through the river corridor as a result of bank riprap along the highway and secondary roads.	

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Maximum temperatures for incubation emergence have been exceeded in the lower North Santiam River and in the Santiam River.	Numerous partial and complete fish passage barriers at culverts on lower and upper subbasin tributary streams limit adult upstream movement.	Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. Limited in-channel wood to capture spawning gravels. Removal of gravel from floodplain gravel mining reduces availability of substrate for in-channel habitat.	

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Detroit and Big Cliff dams: Winter and spring flow reductions may reduce rearing area and the survival of fry. Frequency and magnitude of high flows not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce juvenile rearing habitat areas. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats. Maximum temperatures for rearing and juvenile migration have been exceeded in the mainstem Santiam River and in the North Santiam River up to RM 10. Dissolved oxygen concentrations do not meet criteria rearing at RM 9.3 and RM 11.2 in the mainstem Santiam River. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Detroit Dam and Cliff Dam juvenile downstream passage (combined survival rates): 35 percent to 42 percent. Unscreened diversions: SWCD power and irrigation canals and Salem ditch; numerous unassessed, small, unscreened diversions from RM 29 to Willamette River. Floodplain is not inundated frequently; reduced over-bank flow and side channel connectivity limit rearing and refuge habitat. Much of the lower North Santiam River downstream of Mehama has been diked. The U.S. Army Corps of Engineers installed revetments along 3.2 miles, primarily along the lower 20 miles above the confluence with the South Santiam River. Numerous partial and complete fish passage barriers at culverts on upper and lower subbasin tributary streams limit juvenile upstream movement into rearing and refuge habitat.	Large wood is lacking in most small tributaries in the lower subbasin; few meet the ODFW benchmarks, limiting juvenile rearing and refuge habitat. Approximately 65 percent of riparian areas in smaller tributaries of the upper North Santiam Subbasin above Detroit Reservoir (including Marion Creek) are in early- to mid-successional stages, while 25 percent are old-growth or mature forests. 86 percent of riparian areas within 50 feet of the mainstem between Niagara and Mehama (including the small tributaries that enter within this reach) are characterized by small trees less than 12 inches in diameter. 33 percent of Little North Santiam riparian areas have “high” large wood recruitment potential, while 52 percent have “low” recruitment potential (within 30 feet of the channel). Dams reduce transport of large wood.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-132: North Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
				Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. Reaches of the North Santiam River below Detroit and Big Cliff dams have limited large wood, thus reducing the formation of pools and side channels.	

Source: U.S. Army Corps of Engineers, 1989; ODFW, 1992; WNF, 1994; WNF DRD, 1995; BLMS, 1998a; Fernauld et al., 2001; Landers et al., 2001; E&S, 2002; ORDEQ, 2003; Mamoyac, ODFW, personal communication, 2004.

Table 3-133: North Santiam Subbasin: Subbasin Attributes Affecting Oregon Chub

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Oregon chub	All	Frequency and magnitude of high flows not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas.	A SWCD fish screen and water diversion project in Stayton in 2003 removed a backwater slough area previously used by Oregon chub. The lower Santiam Subbasin tends to interact with its floodplain relatively frequently compared to other basins that contain Oregon chub populations (the major dams are farther up the basin compared to other systems). While this is a benefit for the dispersal of Oregon chub and colonization of new habitat, it also allows nonnative predaceous fish to access Oregon chub habitats. Some sites in the Santiam, such as the I-5 backwaters, have managed to maintain Oregon chub despite the presence of exotics; however, exotics remain a significant threat to the long-term persistence of Oregon chub at these sites.	The lower subbasin contains only 25 percent of original extent of floodplain forest; many remaining patches of floodplain forest are interspersed with areas that have little floodplain vegetation. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity, thus reducing habitat quality.	Exotic warm-water predaceous fish are a significant threat to Oregon chub survival. Several sites formerly occupied by Oregon chub have been reduced to unsustainable levels or eliminated completely by exotic predators (Santiam Conservation Easement, Geren Island North, Green’s Bridge, and Stayton Public Works Pond).

Source: USFWS, 1998; ODFW, 2004.

Appendix G shows specific fish passage barriers on the North Santiam, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Large Wood. Historical removal of large wood from the river and tributary streams, reduced transport of wood below the dams, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries. Mature riparian forests make up less than 7 percent of the vegetation in the lower subbasin (E&S, 2002). Limited wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. In addition, changes in the frequency and magnitude of high flow events below the dams have altered the formation of these complex habitats. Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout, juvenile spring Chinook salmon, and winter steelhead. These habitats provide fish with habitat for foraging and refuge from high flow events. Backwater habitats also are essential for the establishment and survival of Oregon chub at all life stages.

Key Factors Limiting Fish Populations. The U.S. Army Corps of Engineers dams divide the North Santiam Subbasin at RM 58, with the upper and lower portions of the subbasin having different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower North Santiam Subbasin. In the lower North Santiam Subbasin, the productivity, capacity, and diversity of cutthroat trout, spring Chinook, and winter steelhead populations are limited by the following factors:

- **Habitat Connectivity**. Modification of the river's high flow regime from dam regulation, channel and bank confinement, and reduced large wood in the channels have interacted to reduce backwater habitats important for juvenile rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages. Limited spawning areas and reduced levels of gravels/small cobbles have reduced the areas available for spawning.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Flow Diversions**. Flow diversions in the river impede upstream movement of adult fish and can contribute to juvenile mortality.
- **Water Withdrawals**. Unscreened water withdrawals affect juvenile fish.
- **Water Temperature**. Changes in high and low water temperature regimes have affected adult spawning success and egg incubation and limited the capacity of river and tributary streams to support juvenile fish.

- **Fish Passage Barriers**. The U.S. Army Corps of Engineers dams on the river and fish passage barriers at road crossings on tributary streams prevent access to historical spring Chinook salmon and winter steelhead spawning areas, block the interchange between the upper and lower subbasin cutthroat trout populations, and limit juvenile access into rearing and refuge habitat.
- **Additional Factors**. Other, more moderate factors that are limiting cutthroat trout, spring Chinook salmon, and winter steelhead populations include competition with hatchery and introduced fish; lower numbers of salmon carcasses, which reduces nutrient inputs and thus affects food availability; and harassment of adult migrating and holding prespawning fish by recreational activities such as boating and fishing. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Table 3-134 shows the EDT attributes related to the limiting factors for cutthroat trout, spring Chinook, and winter steelhead in the lower North Santiam Subbasin, while Table 3-135 outlines the attributes limiting Oregon chub populations in the lower North Santiam Subbasin. The area in question is below the U.S. Army Corps of Engineers dams; it is primarily private land with forestry, agricultural, rural residential, and urban land uses. The priorities for restoration are qualitative ratings are based on the information in Tables 3-132 and 3-133 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-134: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, and Cutthroat Trout in the Lower North Santiam River

EDT Attribute Class	Description	Priority for Restoration
Competition with hatchery fish	Hatchery fish have been introduced to areas below the dams, increasing competition with native fish for habitat and food (Mamoyac, ODFW, personal communication, 2004).	**HIGH**
Flow	Changes in the interannual variability of low and high flows from dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams prevent migration into the upper subbasin; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	The dams have modified high and low water temperature regimes in the river. Changes in riparian canopy cover have increased summer high water temperatures in some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation); primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels has reduced channel stability.	Medium

Table 3-134: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, and Cutthroat Trout in the Lower North Santiam River

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Harassment	Extensive recreational use of the lower river (boating and fishing) harasses migrating, holding, and spawning fish.	Medium
Pathogens	Hatchery fish have been introduced to areas below the dams, increasing the potential for disease (Mamoyac, ODFW, personal communication, 2004).	Medium
Withdrawals	Unscreened diversions within the river affect adult migration, juvenile rearing, and juvenile out-migration.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Oxygen	Oxygen levels are adequate to support all life stages.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition (Mamoyac, ODFW, personal communication, 2004).	Low

Table 3-135: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower North Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Exotic fish species pose a significant threat through predation and competition.	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.	**HIGH**
Withdrawals	Diversions within the river have caused destruction of Oregon chub habitat.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low-velocity waterways.	**HIGH**
Flow	Changes in the interannual variability of low and high flows as a result of dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	Medium
Oxygen	Low dissolved oxygen levels in some habitats may contribute to reduced water quality.	Low

Table 3-135: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower North Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Pathogens	Pathogens are not thought to be limiting.	Low

Limiting Factors in the Upper North Santiam Subbasin. Historically the upper subbasin was an important spawning and juvenile rearing area for cutthroat, spring Chinook salmon, and winter steelhead in the upper North Santiam Subbasin. However, Oregon chub have not been found—and are not expected to occur—above the dams. In contrast to the large-scale modification of the lower subbasin, most of the impacts to habitat and water quality in the upper subbasin are localized. Currently, limiting factors for cutthroat, spring Chinook, and winter steelhead are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover, but not to the extent as in the lower subbasin.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors.** Other, more moderate impacts to fish populations include partial and complete barriers to fish passage on tributary streams, changes in water temperature regimes as a result of reduced canopy cover, competition with hatchery introductions, and lower numbers of salmon carcasses, which reduces nutrient inputs and thus food availability.

Table 3-136 shows the attributes limiting cutthroat, spring Chinook, and winter steelhead in the in the upper North Santiam Subbasin, above the U.S. Army Corps of Engineers dams. This area is primarily under U.S. Forest Service management. Again, the table presents qualitative ratings based on the information in Table 3-132 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-136: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat, Spring Chinook, and Winter Steelhead in the Upper North Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	The quality of habitat has been affected by limited large wood and moderate channel confinement through the river corridor as a result of bank riprap along the highway and secondary roads.	**HIGH**

Table 3-136: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat, Spring Chinook, and Winter Steelhead in the Upper North Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood.	**HIGH**
Channel stability	In some areas, limited in-channel wood and reduced riparian function has destabilized channels.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas above the dams, increasing competition with native fish for habitat and food (Mamoyac, ODFW, personal communication, 2004).	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Obstructions	Some complete and partial barriers on tributary streams.	Medium
Pathogens	Hatchery fish have been introduced to areas above the dams, increasing the potential for disease (Mamoyac, ODFW, personal communication, 2004).	Medium
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Competition with other species	Very low number of introduced fish species present.	Low
Flow	There have not been significant changes in the interannual variability of low and high flows.	Low
Harassment	Moderate recreational use of the upper river (boating and fishing) harasses migrating, holding, and spawning fish.	Low
Oxygen	Oxygen levels are adequate to support all life stages	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	Minimal water withdrawals.	Low

3.5.1.9 Limiting Factors in Salem-Area Watersheds

This section describes Salem-area watersheds in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the watersheds: cutthroat trout, spring Chinook, and winter steelhead.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon
- Winter steelhead trout

Focal species historically present:

- Oregon chub

Geographic Setting. The Mill, Claggett, Pringle, and Glenn-Gibson Creek watersheds all drain the mid-Willamette Valley and flow into the Willamette River within the Salem city limits. The combined land area for the watersheds is 153 square miles, located entirely within the lower Willamette Valley and foothills. Mill, Clagget, and Pringle creeks flow into the Willamette River from the east side, while Glenn-Gibson drains into the river from the west.

Mill Creek, which begins in the foothills of the Cascades, is the largest of the Salem-area watersheds, covering approximately 110 square miles. Water is diverted from the North Santiam River into Mill Creek. Diversions off of Mill Creek carry water into Pringle Creek (Shelton Ditch) and Salem Mill Race. Mill Creek's headwaters primarily drain agricultural lands, with some forested and rural residential areas. The watershed encompasses the Salem urban growth boundary and several smaller communities, including Turner, Aumsville, and Stayton. Claggett Creek watershed covers approximately 20 square miles. This watershed drains most of east Salem, the city of Keizer, and agricultural lands in the upper watershed. The Pringle Creek watershed covers a little more than 13 square miles and drains a large portion of South Salem.

Cutthroat trout have been documented residing in all four of the watersheds. Mill Creek historically had minor runs of spring Chinook salmon and winter steelhead, and there is a run of introduced fall Chinook salmon (Hemesath and Nunez, 2002). Juvenile winter steelhead have been observed in Pringle and Glenn-Gibson creeks. Juvenile spring Chinook salmon and winter steelhead probably use the lower portions of all of the streams as rearing and refuge habitat during winter high flow periods (Hemesath and Nunez, 2002).

The majority of the land in the combined Salem-area watersheds is in private ownership, with less than 6 percent managed by public agencies. A portion of each of the watersheds is within the Salem-Keizer urban growth boundary (UGB) (Hemesath and Nunez, 2002). Sixty percent of the Pringle Creek watershed is within the UGB, 46 percent of the Glaggett Creek watershed is within the UGB, 33 percent of the Glenn-Gibson Creek watershed is within the UGB, and 6 percent of Mill Creek is within the boundary.

Mill Creek begins near the 2,400-foot elevation in the foothills of the Cascade Mountains, while Pringle and Glenn-Gibson creeks begin in the hills surrounding Salem. The Eola Hills in West Salem (Glenn-Gibson Creek watershed) and the Ankeny Hills of South Salem (Pringle Creek watershed) are blocks of Columbia River basalts uplifted along faults. Claggett Creek begins in the mostly flat terrain of East Salem, Keizer, and the western portion of Lake Labish, an old meander channel of the Willamette River that has been drained and now is used primarily for agriculture (Hemesath and Nunez, 2002).

High and low flows in the Salem-area watersheds follow seasonal rainfall patterns. All of the watersheds begin at very low elevations with no summer snowmelt to influence stream flows. Mill Creek is supplemented by water diverted from the North Santiam. From June through September, 130 to 150 cfs of North Santiam water is diverted into Mill Creek, which influences water temperatures and other water quality characteristics (Hemesath and Nunez, 2002). Urban land uses influence the hydrologic patterns in all of the watersheds. Impervious surfaces, drainage pipes, and stream cleaning for the conveyance of flood flows all act to accelerate storm runoff and increase peak flows. Drainage off of impervious surfaces also affects water quality by increasing summer water temperatures and contributing to the delivery of toxics to waterways.

Environmental Conditions. Altered watershed processes, modified riparian and aquatic habitat, and limited access to portions of the streams have affected the productivity, capacity, and diversity of cutthroat trout, spring Chinook, and winter steelhead populations in the Salem-area watersheds. Table 3-137 summarizes changes in the watersheds' environmental conditions and how these affected have affected cutthroat trout, spring Chinook salmon, and winter steelhead life stages.

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood. The City of Salem continues to clean large wood and other debris out of streams to accelerate the conveyance of floodwaters (Hemesath and Nunez, 2002). Most of the riparian areas—particularly in the urban portions of the watersheds—are narrow and discontinuous with reduced numbers of trees, which affects the delivery of wood and canopy cover levels (Hemesath and Nunez, 2002).

Table 3-137: Salem Area Watersheds: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead	Adult migration and holding	Increased water temperatures, particularly in the urban areas of Pringle, Mill, and Claggett creeks. Most of Glenn-Gibson Creek meets water temperature criteria but portions exceed. Most of Claggett Creek does not meet dissolved oxygen criteria. Lower Glenn-Gibson Creek sometimes does not meet the dissolved oxygen criteria. Battle Creek, a tributary to Mill Creek, has reduced dissolved oxygen. The West Fork Pringle Creek can exceed the dissolved oxygen criteria. Extensive tiling of agricultural lands, channelization, and stream cleaning has contributed to increased and flashy peak flows.	Pringle Creek (percent fish passage barriers): Culverts (48 percent); dams (77 percent). Glenn-Gibson Creeks (percent fish passage barriers): Culverts (27 percent); all 12 dams inventoried (100 percent). Upper Claggett Creek (percent fish passage barriers): Culverts (43 percent); no dams identified. Mill Creek Watershed (percent fish passage barriers): Culverts – all in Battle Creek (29 percent); dams (43 percent). Diversion ditches in the Turner area may divert adult fish traveling upstream. There are many obstacles to fish passage in the Mill Race (Mill Creek).	Extensive channel confinement from channelization, revetments, and roads—particularly in the urban portions of the watersheds—prevents formation of high-quality habitats. Loss of riparian trees and extensive stream cleaning, particularly in urban areas, have reduced the amount of large wood in streams, which affects pool depth and cover. Large portions of Mill Creek and its tributaries (such as Battle and Powell creeks) are channelized.	

Table 3-137: Salem Area Watersheds: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning / egg incubation	Increased peak flows from urbanization scour gravel, reducing spawning areas and affecting redds. Elevated suspended sediment in the urban portions of the watersheds may affect spawning success.	Impassable culverts and dams limit access into spawning areas.	High sediment loads reduce suitable spawning gravels. Limited wood in most stream reaches to retain spawning substrate. Large portions of Glenn and Gibson creeks do not provide adequate spawning habitat because suitable gravels are limited and water levels are shallow.	

Table 3-137: Salem Area Watersheds: Watershed Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Low summer flows from urbanization and lost storage capacity have increased summer water temperatures. Reduced shade on most of the urban portions of the streams has increased water temperatures. In the classified stream reaches, the percent with minimal shade cover is as follows: Pringle Creek, 52 percent; Glenn-Gibson, 25 percent; Claggett, 43 percent; and Mill 16 percent. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams. Channelization of tributaries and changes in runoff patterns on agricultural and developed lands have caused accelerated runoff. Oil, lead, and other toxic substances have been noted in the urban portions of the watersheds. Draining of wetlands has contributed to loss of water storage capacity. Most existing wetlands are small and isolated, particularly in the Claggett Creek watershed where there has been extensive wetland loss in the valley bottom.	Because of fish passage barriers, juvenile fish cannot access upstream habitat to escape high water temperatures or for refuge from winter high flows. Revetments and channelization keep floodplains from being inundated frequently; reduced over-bank flow and side-channel connectivity limit rearing and refuge habitat. Many irrigation diversions, particularly in Mill Creek, may not be screened.	Low summer flows from lost storage capacity (for example, lost wetlands) and urbanization have reduced the amount of high-quality habitat available to rearing fish. Accelerated flows and increased peak flows in urban areas reduce habitat quality during the winter high flow periods. Reduced deep pools and wood in stream channels limit juvenile rearing habitat. During the summer and early fall, Claggett Creek has very low flows and stagnant water.	Introduced fish species (small- and large-mouth bass) may prey on juveniles.

Source: Hemesath and Nunez, 2002.

Water Quality Changes. Water quality has been modified throughout the Salem-area watersheds (Hemesath and Nunez, 2002). The urban portions the four watersheds have particularly poor water quality. Impervious streets and parking lots drain into streams, contributing oils, lead, and other toxics to the system. Reduced riparian canopy cover, particularly in the urban portions of the watersheds, contributes to increased water temperatures, which often exceed water quality criteria. Summer and early fall water temperatures are elevated. Claggett Creek is warm through its entire length. Glenn-Gibson and Pringle creeks are warm in the lower reaches and cooler in the upper portions. Water diverted into Mill Creek from the North Santiam helps to maintain cooler water temperatures. Toxic spills in Pringle Creek (1996 and 2000) and Mill Creek (1989) resulted in fish kills (Hemesath and Nunez, 2002). Nutrient levels are high at a majority of the sites sampled in the four watersheds, and numerous stream reaches have dissolved oxygen levels that are lower than the criteria. Increased sediment deposition has been noted in all of the watersheds, particularly in the urban areas.

Flow Regime and Channel Structure. Peak and low flow regimes have been modified, particularly in the urban areas. In the four watersheds, more than 450 miles of pipes and almost 18 miles of culverts convey water underground (Hemesath and Nunez, 2002). In addition, there are more than 50 miles of open ditches. Loss of wetlands and extensive channelization have disconnected the floodplain from the streams, reducing flood storage capacity and summertime low flows. There is extensive use of drainage tiling in the agricultural portions of all four watersheds (Hemesath and Nunez, 2002). Claggett Creek drains portions of Lake Labish, a drained lake and wetland area that is now largely agricultural lands (Hemesath and Nunez, 2002). The peak runoff volume of Claggett Creek is 100 percent higher than predicted, largely because of extensive tiling in the watershed (Hemesath and Nunez, 2002). Irrigation withdrawals occur in all four watersheds.

Fish Passage Barriers. Fish passage is restricted in all four watersheds by impassible culverts and dams (Hemesath and Nunez, 2002). In Pringle Creek, 48 percent of the surveyed culverts and 77 percent of the dams were classified as fish passage barriers. All of the 12 dams surveyed and 27 percent of the culverts in the Glenn-Gibson Creek watershed were classified as fish passage barriers. There are a number of barriers on Claggett Creek and Battle Creek, a tributary to Mill Creek. Water diversions and irrigation withdrawals also affect fish passage. The area south of Turner on Mill Creek has a number of ditches that may divert adult fish traveling upstream (Hemesath and Nunez, 2002). Other diversions in Mill Creek and the Mill Race may have a need for fish screens.

Appendix G shows specific fish passage barriers in the Salem-area watersheds, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Habitat Quality. Channelization, loss of large wood, increased peak flows, and reduced low flows have degraded fish habitat quality in the four watersheds (Hemesath and Nunez, 2002). Many of the reaches within upper Pringle Creek and tributaries (such as Clark Creek) are channelized and have poor aquatic habitat quality. Most stream reaches in the four watersheds have low amounts and reduced size of large wood, which reduces pool frequency and depth and limits the retention of gravels. Large portions of Glenn and Gibson creeks do not provide adequate spawning habitat because suitable gravels are limited and water levels are shallow (Hemesath and Nunez, 2002). During the summer and early fall, Claggett Creek has very low flows and stagnant water, which suggests poor habitat quality. Much of the mainstem of lower Mill Creek has adequate fish habitat, but in the upper reaches the stream widens, there is little cover, and instream habitat is poor. Large portions of Mill Creek and its tributaries (such as Battle and Powell creeks) are channelized (Hemesath and Nunez, 2002).

Key Factors Limiting Fish Populations. In the Salem-area watersheds, the productivity, capacity, and diversity of cutthroat trout, spring Chinook salmon, and winter steelhead populations are limited by the following factors:

- **Habitat Connectivity**. Channel and bank confinement through riprap (and other actions) and reduced large wood in the channels have interacted to limit backwater habitats important for juvenile rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages. Limited spawning areas and reduced levels of gravels/small cobbles have reduced the areas available for spawning.
- **Large Wood**. Changes in the delivery and transport of large wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **High Flow Regimes.** Increased peak flows from loss of wetlands, tiling of agricultural lands, and impervious surfaces in urban areas have scoured channels and changed processes that maintain complex stream habitats.
- **Flow Diversions and Withdrawals**. Flow diversions in the river impede upstream movement of adult fish and can contribute to juvenile mortality. Unscreened water withdrawals impact juvenile fish.
- **Water Quality**. Water quality impacts, including increased temperature regimes and toxic runoff, have affected the capacity of the streams to support adult and juvenile fish.
- **Additional Factors.** Other, more moderate that are limiting cutthroat trout, spring Chinook salmon, and winter steelhead populations include competition with hatchery and introduced fish and predation from nonnative fish. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Table 3-138 shows the EDT attributes related to these limiting factors in the Mill, Claggett, Pringle, and Glenn-Gibson watersheds. The priorities for restoration are qualitative ratings based on information in Table 3-137.

Table 3-138: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Winter Steelhead, and Spring Chinook in the Salem-Area Watersheds: Mill, Claggett, Pringle, and Glenn-Gibson Creeks

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels has reduced channel stability.	**HIGH**

Table 3-138: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout, Winter Steelhead, and Spring Chinook in the Salem-Area Watersheds: Mill, Claggett, Pringle, and Glenn-Gibson Creeks

EDT Attribute Class	Description	Priority for Restoration
Chemicals	Evidence of levels of toxics sufficient to affect salmonids, including aromatic hydrocarbons and lead; toxic spills have resulted in fish mortality.	**HIGH**
Flow	There have been changes in the variability of low and high flows as a result of impervious surfaces and changes in the storage capacity of other land uses; this disrupts the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the stream corridors as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the stream channels.	**HIGH**
Obstructions	Numerous culverts, dams, and water diversions prevent movement by adult and juvenile fish.	**HIGH**
Oxygen	A number of stream reaches have dissolved oxygen levels that do not meet criteria.	**HIGH**
Temperature	Changes in riparian canopy cover and heated water off of impervious surfaces have increased summer high water temperatures in all four of the watersheds.	**HIGH**
Withdrawals	Unscreened diversions affect adult migration, juvenile rearing, and juvenile out-migration.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation); primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Competition with hatchery fish	Hatchery fish have been introduced to Mill Creek, increasing competition with native fish for habitat and food.	Medium
Competition with other species	Fish community richness is high and there is competition with introduced fish.	Medium
Pathogens	Hatchery fish have been introduced to Mill Creek, increasing the potential for disease.	Medium
Sediment load	There is increased sediment deposition, particularly in the urban portions of the watersheds.	Medium
Food	Historically there were not large runs of spring Chinook salmon that would have contributed salmon carcasses.	Low
Harassment	Very few prespawning spring Chinook salmon are present.	Low

3.5.1.10 Limiting Factors in the South Santiam Subbasin

This section describes the South Santiam Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: cutthroat trout, spring Chinook, and winter steelhead.

Focal species present:

- Winter steelhead trout
- Spring Chinook salmon
- Cutthroat trout
- Oregon chub (lower subbasin only)

Focal species present historically:

- Bull trout
- Oregon chub

Geographic Setting. The South Santiam Subbasin covers an area of approximately 1,000 square miles on the western slope of the Cascade Mountains and the floor of the Willamette Valley. The South Santiam River is about 68 miles long and enters the Santiam River at RM 12. Approximately 32 percent of the land in the South Santiam Subbasin is publicly owned and managed by federal agencies. The Willamette National Forest manages 54 percent of the upper subbasin above Foster Dam, while the Salem District of the BLM manages a small portion of the lower subbasin. The Middle Santiam River, the largest tributary to the South Santiam River, flows through the Middle Santiam Wilderness. Most of the city of Lebanon is within the subbasin.

The geology of the western Cascades characterizes the mountainous areas of the upper subbasin. This area has deeply weathered rocks and steep, highly dissected hill slopes. Large portions of this landscape are prone to erosion and frequent landslides. Stream runoff patterns in the subbasin are dominated by the western Cascade geology, with a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network.

Foster Dam on the South Santiam mainstem (RM 39) and Green Peter Dam on the Middle Santiam River (RM 6) divide the South Santiam Subbasin, limiting upstream and downstream fish passage and greatly influencing downstream hydrologic regimes, temperature patterns, sediment and bedload transport, and large wood delivery to the lower reaches. Above Foster Dam the river flows though a steep, forested canyon with gradients of more than 0.4 percent. Quartzville and Canyon creeks are major tributaries in the upper subbasin. The upper South Santiam flows through a narrow, steep forested canyon. Numerous ancient, deep-seated landslides have been mapped in the upper subbasin, and these features probably continue to contribute large amounts of sediment to the South Santiam River (U.S. Army Corps of Engineers, 2001).

In the lower subbasin downstream of Foster Dam, the South Santiam River flows into the wide alluvial Willamette River Valley. Wiley, Thomas, and Crabtree creeks are major tributaries in the lower subbasin. The lower 30 miles of the South Santiam is low gradient (less than 0.1 percent) and flows through a relatively wide valley with an extensive floodplain. In 1947, the lower South Santiam River was described as very sinuous and divided by large islands (U.S. Army Corps of Engineers, 2001). Most of the land in the lower subbasin is in private ownership, primarily in agricultural, forestry, and rural residential land uses.

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the South Santiam

Subbasin have affected the productivity, capacity, and diversity of cutthroat trout, spring Chinook, and winter steelhead populations. Table 3-139 summarizes changes in the subbasin's environmental conditions and how these changes have affected cutthroat trout, spring Chinook salmon, and winter steelhead life stages.

The amount and quality of habitat for Oregon chub has been limited by altered subbasin processes, modified riparian and aquatic habitat, and the presence of exotic warm-water fish. In fact, the Santiam River has been identified as a recovery subbasin in the *Oregon Chub Recovery Plan* (U.S. Fish and Wildlife Service, 1998). Establishing successful Oregon chub populations in the lower subbasin has been challenging because exotic fish species often have easy access to chub habitat in backwater sloughs and other slow water habitats. Table 3-140 summarizes changes in the subbasin's environmental conditions and how these changes have affected Oregon chub life stages.

Dams. The U.S. Army Corps of Engineers dams have restricted access to the upper subbasin and changed downstream hydrologic regimes, water quality, and processes influencing habitat formation. The dams block or limit access to an estimated 85 percent of the historical production area for spring Chinook salmon, thus limiting access to historical winter steelhead spawning and rearing areas and eliminating interchange between the upper and lower subbasin cutthroat trout populations (U.S. Army Corps of Engineers, 2001). Relative to the lower subbasin, the upper subbasin above the dams has aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas the largest amounts of large wood in the river and tributary channels, and the highest quality spawning areas. The dams have altered the links between the upper and lower subbasin, reducing the transport and delivery of large wood and substrate to downstream reaches. Changes in the abundance and distribution of gravels, small cobbles, and large wood (particularly in large jams) have reduced suitable spawning areas and limited areas for adult cutthroat trout and juvenile rearing habitat for spring Chinook salmon and winter steelhead.

The dams also have changed flow regimes and water temperature patterns. Compared to historical conditions, water temperatures in the river below the dam are cooler in the summer and warmer in the fall and winter, which affects the upstream distribution of spring Chinook salmon adults, alters the timing of spawning, and affects the period of egg incubation (U.S. Army Corps of Engineers, 2001). The change in flow regimes has altered the availability and quality of Oregon chub habitat in backwater sloughs, floodplain ponds, and other slow-moving side channel areas. Warmer water temperatures encourage the persistence and dispersal of exotic predaceous fish species.

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Flow reductions associated with diversions for irrigation, domestic, and industrial water uses contribute to low flow conditions in the river and its tributaries, particularly in late summer and early fall. Operation of U.S. Army Corps of Engineers reservoirs reduced spring/summer temperatures in the South Santiam River and increased temperatures during most of the rest of the year. Water temperatures in the South Santiam River exceed water quality criteria for summer maxima adult migration (64°F) during most of the rest of the year.	Foster and Green Peter dams are complete barriers to upstream movement by adult cutthroat trout. Numerous partial and complete fish passage barriers at culverts on tributary streams may limit adult upstream movement into foraging and refuge habitat. The 8-foot-tall Lebanon Dam at RM 21 diverts water into the unscreened Lebanon-Albany this dam is equipped with several fish ladders that allow passage of adult fish, but, because of the older, ineffective design of the fish ladders, they probably cause some migration delay.	Some forests in the upper subbasin are dominated by early- to mid-successional stages, but up to 39 percent of the Middle Santiam and 43 percent of the Quartzville drainages contain late-successional forests. Riparian areas in upper subbasin tributaries are dominated by late-successional vegetation on federal land and early-successional vegetation on private lands. Width and continuity of riparian areas are good along Thomas and Crabtree creeks in the lower South Santiam Subbasin, but almost all vegetation is less than 80 years old. Less than 30 percent of the riparian forest along the mainstem South Santiam River is more than 100 feet wide. Reaches of the South Santiam River below Green Peter and Foster dams are deprived of large wood. There is inadequate recruitment of large wood from riparian areas along the mainstem South Santiam and tributaries downstream from Foster Dam.	

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
				Reduced pool frequency, depth, and cover have affected the quality of adult habitat in the river and tributaries. Limited wood in the river and tributaries has affected the quality of pools and backwater habitats.	
	Adult spawning/ egg incubation		Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. There is limited in-channel wood to capture spawning gravels.	

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Water temperatures in the South Santiam River exceed water quality criteria for summer maximum for juvenile rearing and migration. Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce juvenile rearing habitat areas. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats.	Foster and Green Peter dams are complete barriers to downstream movement by juvenile cutthroat trout. The floodplain is not inundated frequently, which causes reductions in over-bank flow and side-channel connectivity, nutrient exchange, sediment exchange, and flood refugia for fish. In addition, new riparian forests are established. Numerous partial and complete fish passage barriers at culverts on tributary streams limit juvenile upstream movement into rearing and refuge habitat.	Frequency of flows not of sufficient magnitude to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes in the lower subbasin. Reaches of the river below Foster Dam have limited large wood, thus reducing the formation of pools and side channels. There has been significant loss of wetland, floodplain and off-channel habitats and associated habitat complexity, reducing habitat quality.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Spring Chinook Salmon	Adult migration and holding	Flow reductions associated with diversions for irrigation, domestic, and industrial water uses contribute to low flow conditions in the river and its tributaries, particularly in late summer and early fall. Operation of U.S. Army Corps of Engineers reservoirs has reduced spring/summer temperatures in the South Santiam River and increased temperatures during most of the rest of the year. Water temperatures in the South Santiam River exceed water quality criteria for summer maximum adult migration (64°F) during most of the rest of the year.	Several older fish ladders allow passage of adult spring Chinook salmon but probably cause some migration delay. Irrigation diversions on the lower tributaries of Crabtree and Thomas creeks pose migration barriers to adult spring Chinook. Foster Dam: While there is probably mortality at the dam, there are no estimates of upstream passage mortality at the dam. Foster Dam's dated design does not allow facilities for holding, handling, examining, and sorting hatchery- from natural-origin fish. Green Peter Dam does not allow passage of adult fish.	Some forests in the upper subbasin are dominated by early- to mid-successional stages, but up to 39 percent of the Middle Santiam and 43 percent of the Quartzville drainages contain late-successional forests. Riparian areas in upper subbasin tributaries are dominated by late-successional vegetation on federal land and early-successional vegetation on private lands. Width and continuity of riparian areas are good along Thomas and Crabtree creeks in the lower South Santiam Subbasin, but almost all vegetation is less than 80 years old. Less than 30 percent of the riparian forest along the mainstem South Santiam river is more than 100 feet wide. Reaches of the South Santiam River below Green Peter and Foster dams are deprived of large wood.	Extensive recreational use of the lower river (boating and fishing) harasses migrating, and holding fish.

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
			The 8-foot-tall Lebanon Dam at RM 21 diverts water into the unscreened Lebanon-Albany this dam is equipped with several fish ladders that allow passage of adult fish, but the older, ineffective design of the fish ladders probably results in some migration delay. A number of irrigation diversions on the lower tributaries of Crabtree and Thomas creeks pose migration barriers to adult spring Chinook salmon (such as the Lacomb Dam at RM 25 of Crabtree Creek).Creek) due to the use of push-up dams to capture water during low late summer flows.	There is inadequate recruitment of large wood from riparian areas along the mainstem South Santiam and tributaries downstream from Foster Dam. Reduced pool frequency, depth, and cover have affected the quality of adult habitat in the river and tributaries. Limited wood in the river and tributaries has affected the quality of pools and backwater habitats.	

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation	Maximum temperatures for incubation emergence have been exceeded in the lower South Santiam River.		Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. There is limited in-channel wood to capture spawning gravels. There appears to be a coarsening of gravels below the dams. Removal of gravel from floodplain gravel mining reduces the availability of substrate for in-channel habitat.	Extensive recreational use of the lower river (boating and fishing) harasses spawning fish.

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Flow fluctuations blow Green Peter Dam now occur at rates rapid enough to entrap and strand juvenile anadromous fish. Water temperatures in the South Santiam River exceed water quality criteria for summer maximums for juvenile rearing and migration. Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce juvenile rearing habitat areas. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats.	Juveniles are entrained into the unscreened Lebanon Dam (RM 21), which diverts water into the Lebanon-Albany power canal for irrigation, hydropower, and municipal use. The floodplain is not inundated frequently, which results in reductions in over-bank flow and side-channel connectivity, nutrient exchange, sediment exchange, and flood refugia for fish. In addition, new riparian forests are established. Numerous partial and complete fish passage barriers at culverts on tributary streams limit juvenile upstream movement into rearing and refuge habitat.	Frequency of flows not of sufficient magnitude to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes in the lower subbasin. Large wood in reaches of the river below Foster Dam is limited, which reduces the formation of pools and side channels. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity, which reduces habitat quality.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Winter Steelhead Trout	Adult migration and holding	Flow reductions associated with diversions for irrigation, domestic, and industrial water uses contribute to low flow conditions in the river and its tributaries, particularly in late summer and early fall. Operation of U.S. Army Corps of Engineers reservoirs has reduced spring/summer temperatures in the South Santiam River and increased temperatures during most of the rest of the year. Water temperatures in the South Santiam River exceed water quality criteria for summer maxima adult migration (64°F) during most of the rest of the year.	Several older fish ladders allow passage of adult spring Chinook salmon but probably cause some migration delay. Irrigation diversions on the lower tributaries of Crabtree and Thomas creeks pose migration barriers to adult spring Chinook. Foster Dam: While there is probably mortality at the dam, there are no estimates of upstream passage mortality at the dam. Foster Dam's dated design does not allow facilities for holding, handling, examining, and sorting hatchery- from natural-origin fish. Green Peter Dam does not allow passage of adult fish. The 8-foot-tall Lebanon Dam at RM 21 diverts water into the unscreened Lebanon-Albany this dam is equipped with several fish ladders that allow passage of adult fish, but the fish ladders' older, ineffective design probably results in some migration delay.	Some forests in the upper subbasin are dominated by early- to mid-successional stages, but up to 39 percent of the Middle Santiam and 43 percent of the Quartzville drainages contain late-successional forests. Riparian areas in upper subbasin tributaries are dominated by late-successional vegetation on federal land and early-successional vegetation on private lands. Width and continuity of riparian areas are good along Thomas and Crabtree creeks in the lower South Santiam Subbasin, but almost all vegetation is less than 80 years old. Less than 30 percent of the riparian forest along the mainstem South Santiam River is more than 100 feet wide. Reaches of the South Santiam River below Green Peter and Foster dams are deprived of large wood. There is inadequate recruitment of large wood from riparian areas along the mainstem South Santiam and tributaries downstream from Foster Dam.	

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
			A number of irrigation diversions on the lower tributaries of Crabtree and Thomas creeks pose migration barriers to adult spring Chinook salmon (such as the Lacomb Dam at RM 25 of Crabtree Creek). Creek) due to the use of push-up dams to capture water during low late summer flows. Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	Reduced pool frequency, depth, and cover have affected the quality of adult habitat in the river and tributaries. Limited wood in the river and tributaries has affected the quality of pools and backwater habitats.	
	Adult spawning/ egg incubation		Numerous partial and complete fish passage barriers at culverts on tributary streams limit adult upstream movement into spawning habitat.	Dams reduce channel substrate movement: cobble and boulder bars have replaced many of the sand and gravel bars, and numerous areas of the river have been scoured down to bedrock with scattered boulders, thus reducing spawning areas and gravels. Limited in-channel wood to capture spawning gravels. There appears to be a coarsening of gravels below the dams. Removal of gravel from floodplain gravel mining reduces the availability of substrate for in-channel habitat.	

Table 3-139: South Santiam Subbasin: Subbasin Attributes Affecting Cutthroat Trout, Spring Chinook Salmon, and Winter Steelhead Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Flow fluctuations blow Green Peter Dam now occur at rates rapid enough to entrap and strand juvenile anadromous fish. Water temperatures in the South Santiam River exceed water quality criteria for summer maxima for juvenile rearing and migration. Diversions (see habitat connectivity): Low summer flows in specific reaches may reduce juvenile rearing habitat areas. Reduced recruitment of large wood has limited creation of new gravel bars; hyporheic flow through gravel bars can cool water, which provides cool-water rearing habitats.	Juveniles are entrained into the unscreened Lebanon Dam (RM 21), which diverts water into the Lebanon-Albany power canal for irrigation, hydropower, and municipal use. Floodplain is not inundated frequently, which reduces over-bank flow and side-channel connectivity, nutrient exchange, sediment exchange, and flood refugia for fish. In addition, new riparian forests are established. Numerous partial and complete fish passage barriers at culverts on tributary streams limit juvenile upstream movement into rearing and refuge habitat.	Frequency of flows not of sufficient magnitude to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes in the lower subbasin. Large wood in reaches of the river below Foster Dam is limited, which reduces the formation of pools and side channels. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity, which reduces habitat quality.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles. Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish. Hatchery fish have been introduced to areas above and below the dams, increasing competition with native fish for habitat and food.

Source: U.S. Army Corps of Engineers, 2001; Wevers et al., 1992; E&S, 2000; ORDEQ, 2003; Mamoyac, ODFW, personal communication, 2004.

Table 3-140: South Santiam Subbasin: Subbasin Attributes Affecting Oregon Chub

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Oregon chub	All	Low dissolved oxygen may be a contributing factor in suppressed population numbers at Foster Pullout Pond. Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas.	The lower South Santiam Subbasin tends to interact with its floodplain relatively frequently compared to other basins that contain Oregon chub populations (the major dams are farther up the basin compared to other systems). While this is a benefit for the dispersal of Oregon chub and colonization of new habitat, it also allows nonnative predaceous fish to access Oregon chub habitats.	Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. There has been significant loss of wetland, floodplain, and off-channel habitats and associated habitat complexity, reducing habitat quality.	Exotic warm-water predaceous fish are a significant threat to Oregon chub survival.

Source: USFWS, 1998; ODFW, 2004.

Fish Passage Barriers. While Green Peter and Foster Dams are equipped with fish passage facilities, there are fish passage issues at both dams. The facility at Green Peter Dam is no longer in use, effectively blocking all upstream access. The trap and haul facility at Foster Dam is still in use, but there is no accurate measure of spring Chinook salmon or steelhead mortality (U.S. Army Corps of Engineers, 2001). The fishway and trap for upstream migrating adults, while functional, is labor intensive and requires fish be transported above the dam to prevent fallback (Mamoyac, ODFW, personal communication, 2004). There appears to be fairly good survival at the dam for out-migrating juvenile steelhead and Chinook salmon, although there is some mortality and injury.

In addition to the dams that block fish access to the upper subbasin, other dams, diversions, and road crossing culverts are obstacles to fish passage. Numerous culverts throughout the subbasin act as partial or complete fish passage barriers (Mamoyac, ODFW, personal communication, 2004). In the lower subbasin, Lebanon Dam, which diverts water for municipal and other uses, delays upstream passage of fish. The diversion associated with this dam has not been screened and can entrain juveniles, although the City of Albany is working on improvements to the diversion and fish ladder (Mamoyac, ODFW, personal communication, 2004). A number of irrigation diversions on the lower tributaries of Crabtree and Thomas creeks pose migration barriers to adult spring Chinook salmon (such as the Lacomb Dam at RM 25 of Crabtree Creek) as a result of the use of push-up dams to capture water during low late summer flows (E&S 2000).

Appendix G shows specific fish passage barriers on the South Santiam, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Water Quality Changes. Water quality has been modified throughout the subbasin, with most of the impacts in the lower subbasin. Water temperatures exceed criteria in the South Santiam River and many of the tributaries. In general, water temperatures are lower in the forested upper subbasin. High water temperatures in the lower subbasin are aggravated by loss of riparian cover, reduced wetland areas, and channel simplification (E&S, 2000). Although landslides and erosion in the subbasin have contributed to pulses of turbidity, sedimentation levels do not appear to be affecting fish populations (U.S. Army Corps of Engineers, 2001; Oregon Department of Environmental Quality, 2004). Toxic runoff does not appear to affect fish populations (Mamoyac, ODFW, personal communication, 2004).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced transport of wood below the dams, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries. Mature riparian forests make up a very small proportion of the floodplain and riparian vegetation along the river and tributaries in the lower subbasin (E&S, 2000). There is a greater extent and more connectivity of riparian vegetation in the upper subbasin than in the lower, but levels of mature and old-growth coniferous forests are reduced (U.S. Army Corps of Engineers, 2001). Foster and Green Peter dams block transport of large wood from 50 percent of the subbasin (U.S. Army Corps of Engineers, 2001). Limited wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. More than 35 percent of the lower river's channel is constrained by revetments (U.S. Army Corps of Engineers, 2001). In addition, changes in the frequency and magnitude of high flow events below the dams have altered the formation of these complex habitats (U.S. Army Corps of Engineers, 2001). Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout, juvenile spring Chinook salmon, and winter steelhead. These habitats provide fish with habitat for foraging and refuge from high flow events. Backwater habitats are essential for the establishment and survival if Oregon chub at all life stages.

Key Factors Limiting Fish Populations. The U.S. Army Corps of Engineers dams divide the South Santiam Subbasin, with the upper and lower portions of the subbasin being characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower South Santiam Subbasin. In the lower South Santiam subbasin, the productivity, capacity, and diversity of cutthroat trout, winter steelhead, and spring Chinook populations are limited by the following factors:

- **Habitat Connectivity**. Modification of the river's high flow regime from dam regulation, channel and bank confinement through riprap and other actions, and reduced large wood in the channels have interacted to reduce backwater habitats important for juvenile rearing and winter refuge.

- **Habitat Modification**. Modified key aquatic habitats have affected all life stages. Limited spawning areas and reduced levels of gravels / small cobbles have reduced the areas available for spawning.

- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.

- **Flow Diversions**. Flow diversions in the river impede upstream movement of adult fish and can contribute to juvenile mortality.

- **Withdrawals**. Unscreened water withdrawals affect juvenile fish.

- **Water Temperatures**. Changes in high and low water temperature regimes have affected adult spawning success, impacted egg incubation, and limited the capacity of river and tributary streams to support juvenile fish.

- **Fish Passage Barriers**. The U.S. Army Corps of Engineers dams on the river and fish passage barriers at road crossings on tributary streams prevent access into historical spring Chinook salmon and winter steelhead spawning areas, block the interchange between the upper and lower subbasin cutthroat trout populations, and limit juvenile access into rearing and refuge habitat.

- **Additional Factors**. Other, more moderate factors limiting the populations of cutthroat trout, spring Chinook salmon, and winter steelhead include competition with hatchery and introduced fish; lower numbers of salmon carcasses impacting food availability due to reduced nutrient inputs; and harassment of adult migrating and holding prespawning fish by recreational activities such as boating and fishing. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Limiting factors for Oregon chub include modification of key habitats and the presence of exotic warm-water fish. These factors have affected Oregon chub at all life stages.

Table 3-141 shows the EDT attributes related to the limiting factors for cutthroat, spring Chinook, and winter steelhead in the lower South Santiam Subbasin, while Table 3-142 shows the EDT attributes for Oregon chub limiting factors. The area in question is below the U.S. Army Corps of Engineers dams, and most of the lower subbasin is in private ownership, with forestry, agricultural, rural residential, and urban land uses. The priorities for restoration are qualitative ratings based on information in Tables 3-139 and 3-140 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-141: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, and Cutthroat Trout in the Lower South Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with hatchery fish	Hatchery fish have been introduced to areas below the dams, increasing competition with native fish for habitat and food (Mamoyac, ODFW, personal communication, 2004).	**HIGH**
Flow	Changes in the interannual variability of low and high flows from dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams prevent migration into the upper subbasin; numerous complete and partial barriers on tributary streams.	**HIGH**
Withdrawals	Unscreened diversions within the river affect adult migration, juvenile rearing, and juvenile out-migration.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation); primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels has reduced channel stability.	Medium
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium

Table 3-141: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, and Cutthroat Trout in the Lower South Santiam River Subbasin

Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Harassment	Extensive recreational use of the lower river (boating and fishing) harasses migrating, holding, and spawning fish.	Medium
Pathogens	Hatchery fish have been introduced to areas below the dams, increasing the potential for disease (Mamoyac, ODFW, personal communication, 2004).	Medium
Temperature	The dams have modified high and low water temperature regimes in the river. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Oxygen	Oxygen levels are adequate to support all life stages.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition (Mamoyac, ODFW, personal communication, 2004).	Low

Table 3-142: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon Chub in the Lower South Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Exotic fish species pose a significant threat through predation and competition.	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.	**HIGH**
Withdrawals	Diversions within the river have caused destruction of Oregon chub habitat.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low-velocity waterways.	**HIGH**
Flow	Changes in the interannual variability of low and high flows as a result of dam regulation affect the quantity of habitat and disrupt the processes that create a complex array of habitats.	Medium
Oxygen	Low dissolved oxygen levels in some habitats may contribute to reduced water quality.	Low
Pathogens	Pathogens are not thought to be limiting.	Low

Limiting Factors in the Upper South Santiam Subbasin. Historically the upper subbasin was an important spawning and juvenile rearing area for cutthroat trout, spring Chinook, and winter steelhead, although Oregon chub have not been found—and are not expected to occur—a above U.S. Army Corps of Engineers dams. In contrast to the large-scale modification of the lower subbasin, most of the impacts to habitat and water quality in the upper subbasin are localized. Currently, limiting factors for cutthroat, spring Chinook, and winter steelhead in the upper subbasin are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover, but not to the extent as in the lower subbasin.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors**. Other, more moderate factors limiting fish populations include partial and complete barriers to fish passage on tributary streams, changes in water temperature regimes from reduced canopy cover, competition with hatchery introductions, and lower numbers of salmon carcasses, which reduces nutrient inputs and thus food availability.

Table 3-143 shows the attributes limiting cutthroat, spring Chinook, and winter steelhead in the upper South Santiam Subbasin, above the U.S. Army Corps of Engineers dams. This area is primarily under U.S. Forest Service management. Again, the table presents qualitative ratings based on the information in Table 3-139 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-143: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, and Cutthroat Trout Life Stages in the Upper South Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	The quality of habitat has been affected by limited large wood and moderate channel confinement through the river corridor as a result of bank riprap along the highway and secondary roads.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood.	**HIGH**
Channel stability	In some areas limited in-channel wood and reduced riparian function has destabilized channels.	Medium
Competition with hatchery fish	Hatchery fish have been introduced to areas above the dams, increasing competition with native fish for habitat and food (Mamoyac, ODFW, personal communication, 2004).	Medium

Table 3-143: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, and Cutthroat Trout Life Stages in the Upper South Santiam River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Obstructions	Some complete and partial barriers on tributary streams.	Medium
Pathogens	Hatchery fish have been introduced to areas above the dams, increasing the potential for disease (Mamoyac, ODFW, personal communication, 2004).	Medium
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Low
Competition with other species	Very low number of introduced fish species present.	Low
Flow	There have not been significant changes in the interannual variability of low and high flows.	Low
Harassment	Moderate recreational use of the upper river (boating and fishing) harasses migrating, holding, and spawning fish.	Low
Oxygen	Oxygen levels are adequate to support all life stages.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	Minimal water withdrawals.	Low

3.5.1.11 Limiting Factors in the Tualatin Subbasin

This section describes the Tualatin Basin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species found in the subbasin: cutthroat trout and spring Chinook.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon (juvenile rearing and refuge; lower basin only)
- Winter steelhead

Focal species present historically:

- Oregon chub

Geographic Setting. The Tualatin Subbasin covers an area of 707 square miles on the eastern slope of the Coast Range and the floor of the Willamette Valley. The Tualatin River is approximately 80 miles long and enters the Willamette River at RM 29. Approximately 93 percent of the land in the subbasin is privately owned. Most of the private lands are in forestry, agricultural, rural residential, and urban land uses. About half of the subbasin is forested (Murtagh et al., 1992). Urban lands cover a substantial portion of the lower subbasin, including the cities of Forest Grove, Tigard, Lake Oswego, and West Linn and the southwest portion of Portland. The Salem District of the BLM and the Oregon Department of Forestry manage a small portion of the upper subbasin.

The Tualatin River, primarily in Gales Creek, has a small number of naturally spawning winter steelhead. There is evidence that winter steelhead are native to the subbasin, but they are not considered a self-sustaining population (Myers et al., 2003). In addition, juvenile Chinook salmon have been observed using the lower portions of the river as rearing and winter refuge habitat. Cutthroat trout exist in all of the subbasin's streams, and historically there was a population that moved between the river and the Willamette River mainstem (Murtagh et al., 1992). Cutthroat trout and winter steelhead have similar habitat requirements.

The Tualatin River's headwaters are on the forested east side of the Coast Range. The river's headwaters flow through private industrial, state, and federal forestlands, small-acreage farms, and rural residential areas until the river reaches the floor of the Willamette Valley near Cherry Grove (RM 68). Major tributaries in the forested upper subbasin include Scoggins, Gales, and Dairy creeks. In the lower subbasin, the Tualatin River flows through agricultural lands and scattered rural residential areas and near numerous small communities and cities. McKay, Rock, and Fanno creeks are major tributaries in the lower subbasin.

The Coast Range bedrock in the upper subbasin is composed predominantly of sedimentary rocks with some volcanic formations. Most of the subbasin lies below 1,000 feet in elevation. The upper subbasin drains the Coast Range, but most of the river and the larger tributaries flow through the Willamette Valley's recent alluvial deposits. The Coast Range sedimentary rocks have lower groundwater storage capacity than is the case in the Cascade Mountains, and the streams within the Tualatin Subbasin have lower summertime flows and higher water temperatures than do Cascade Range streams. The subbasin's high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. As a result of the subbasin's low elevations and the Coast Range geology, summertime stream flows are not supplemented by snowmelt or numerous spring-fed sources.

The headwaters of the Tualatin River and tributaries of the upper subbasin flow steeply off the Coast Range. After the river and tributaries enter the Willamette Valley the gradient decreases and the river meanders through the alluvial deposits of the Willamette Valley. These low-gradient areas in the lower subbasin create reaches with slow-moving water that are prone to high temperatures during the summer and early fall (Murtagh et al., 1992).

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the Tualatin Subbasin have affected the population productivity, capacity, and diversity of cutthroat trout and juvenile spring Chinook salmon. Table 3-144 summarizes changes in the subbasin's environmental conditions and how these changes have affected cutthroat trout and juvenile spring Chinook salmon life stages.

Upper and Lower Subbasins. Relative to the lower subbasin, the forested upland portions of the upper subbasin have aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Baker et al., 2002; Murtagh et al., 1992). In the lower Tualatin Subbasin, with its extensive agricultural and urban land uses, impacts to aquatic and riparian habitats have been greater than in the forested upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because largest proportion of unconstrained river and stream channels were in the area where the Tualatin River flowed across the flat Willamette Valley (Pacific Northwest Ecosystem Research Consortium, 2002).

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin (Pacific Northwest Ecosystem Research Consortium, 2002). Most of the riparian areas in the lower subbasin are fragmented, have limited tree cover, or have been converted to other land uses (CleanWater Services, 2004). Over time, a number of practices have reduced the quantity of large wood in the Tualatin River and tributary channels throughout the subbasin (Murtagh et al., 1992). There is very little large wood in the channels, particularly in the form of large wood jams (Clean Water Services, 2004). While riparian areas in the forested upper subbasin have greater numbers of conifer trees than the lower subbasin does, historical riparian harvests and wood removal from streams have reduced large wood in these channels. Reduced large wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Table 3-144: Tualatin Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	Naturally low flows in the subbasin are aggravated by water withdrawals, which increase water temperatures. High water temperatures are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows. Nutrient and toxic runoff from agricultural and urban areas may be a problem. Loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows). The effects of low summer flows and high nutrient loads combine to create a poor environment for fish passage and production.	Numerous culverts throughout the subbasin present barriers to adult refuge habitat. Oregon Iron and Steel Dam on the lower Tualatin River is a partial fish passage barrier (requires improvement of the fish ladder). Henry Hagg Dam on Scoggins Creek is a fish passage barrier.	Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of adult holding areas.	
	Adult spawning/egg incubation		Numerous culverts throughout the subbasin present barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-144: Tualatin Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Spring Chinook Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the subbasin are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the lower subbasin, do not provide optimal conditions for juvenile rearing.	Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. The loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, thus limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality, particularly in the lower subbasin. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.
Spring Chinook salmon	Fry and juvenile rearing and refuge		Culverts in the lower subbasin present barriers to juvenile access refuge habitat. Oregon Iron and Steel Dam on the lower Tualatin River may prevent juvenile fish from accessing rearing and refuge habitat.	The loss of wetland, floodplain, and off-channel habitats in the lower subbasin has affected the quantity and quality of juvenile rearing and refuge areas.	

Source: Murtagh et al., 1992; Stahl, ODFW, personal communication, 2004; Clean Water Services, 2004.

Water Quality Changes. Water quality has been modified throughout the subbasin, with most of the dramatic impacts occurring in the lower subbasin. Water temperatures exceed criteria in the Tualatin River and many of the tributaries. Naturally low flows in the subbasin are aggravated by water withdrawals, which increase water temperatures (Murtagh et al., 1992). In general, water temperatures are lower in the forested upper subbasin than in the lower subbasin. High water temperatures in the lower subbasin are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces (Clean Water Services, 2004). Phosphorous and ammonia-nitrogen pollution has been an ongoing issue in the subbasin. The effects of low summer flows and high nutrient loads combine to create a poor environment for fish passage and production (Murtagh et al., 1992). There is a TMDL process and other management practices in place to address excess phosphorous and nutrient loads (Oregon Department of Environmental Quality, 2004), but toxic runoff from urban and agricultural land uses may affect fish populations (Stahl, ODFW, personal communication, 2004).

Changes in Flow Regimes. There have been extensive impacts to the subbasin's hydrologic regimes. Changes in land use have affected hydrologic regimes in the tributaries. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows (Stahl, ODFW, personal communication, 2004). Consumptive uses from agricultural, industrial, and urban uses throughout the subbasin seriously delete summertime low flows (Murtagh et al., 1992).

Fish Passage Barriers. Obstacles to fish passage are an issue throughout the subbasin. Of the several dams that limit upstream migration, Oregon Iron and Steel Dam on the lower river (RM 3.9) has the greatest impact on fish passage. This dam has a fish ladder but its effectiveness appears to be limited (Stahl, ODFW, personal communication, 2004). The largest dam in the subbasin—on Scoggins Creek, forming Henry Hagg Lake—is not equipped for fish passage (Murtagh et al., 1992). The largest diversion in the system is the Lake Oswego canal (RM 6.8), which is unscreened. There are also numerous unscreened small diversions within the subbasin (Stahl, ODFW, personal communication, 2004). In addition to dams and diversions, numerous road crossing culverts in the lower and upper subbasin block or limit fish passage. When fish passage above culverts is limited, the amount of habitat available for all cutthroat trout life stages is restricted.

Appendix G shows specific fish passage barriers on the Tualatin, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. Large portions of the lower Tualatin River and sections of tributary streams have confined channels as a result of riprapping, revetments, and roads along streams (Clean Water Services, 2004). Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout and juvenile spring Chinook salmon. These habitats provide fish with habitat for foraging and refuge from winter flood events.

Key Factors Limiting Fish Populations. The upper and lower portions of the Tualatin Subbasin are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower Tualatin Subbasin. In the lower Tualatin Subbasin, the productivity, capacity, and diversity of cutthroat trout and juvenile Chinook salmon populations are limited by the following factors:

- **Habitat Connectivity**. Modification of river and tributary habitat through channel and bank confinement and reduced large wood in the channels have interacted to reduce floodplain connectivity and backwater habitats important for all cutthroat trout life stages and juvenile Chinook salmon rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile cutthroat trout and affected juvenile Chinook salmon rearing areas in the lower river.
- **Water Temperature**. Increased summertime water temperatures have affected adult cutthroat trout populations and limited the capacity of river and tributary streams to support juvenile fish.
- **Fish Passage Barriers**. Fish passage barriers at road crossings on tributary streams block the interchange between cutthroat trout populations and limit adult and juvenile access into rearing and refuge habitat.
- **Additional Factors**. Other factors limiting focal species include competition with introduced fish, runoff of toxics from urban and agricultural areas, and some unscreened water diversions.

Table 3-145 shows the EDT attributes related to these limiting factors for cutthroat trout and spring Chinook in the lower Tualatin Subbasin, which is located largely on the Willamette Valley floor and is held primarily in private ownership. The priorities for restoration are qualitative ratings based on the information in Table 3-144 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-145: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Juvenile Spring Chinook in the lower Tualatin Subbasin

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels and reduced riparian function has reduced channel stability.	**HIGH**
Flow	There have been impacts to the interannual variability of low and high flows as a result of land use practices and water diversions.	**HIGH**

Table 3-145: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout and Juvenile Spring Chinook in the lower Tualatin Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams on the river and Scoggins Creek prevent upstream and downstream movement; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Competition with other species	Fish community richness is high and there is some competition with introduced fish (Stahl, ODFW, personal communication, 2004).	Medium
Chemicals	There is little evidence that toxics are directly affecting salmonids, although there are some high levels noted in monitoring (see Table 1; Stahl, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Stahl, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Stahl, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Stahl, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Stahl, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Tualatin Subbasin. Historically the upper subbasin was an important spawning and rearing area for both resident and fluvial cutthroat trout. In contrast to the large-scale modification of the lower subbasin, there is higher quality habitat in the upper subbasin, particularly in the forested upland areas. Currently, limiting factors for cutthroat trout in the upper subbasin are as follows:

- **Channel and Habitat Modification**. Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover.

- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have led to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperature**. In addition, changes to riparian canopy have increased summertime water temperatures.
- **Fish Passage Barriers**. Numerous partial and complete fish passage barriers on tributary stream have limited cutthroat trout populations.

Table 3-146 outlines the EDT attributes limiting cutthroat trout life stages in the upper Tualatin Subbasin, which is largely privately owned. Again, the table presents qualitative ratings based on information in Table 3-144 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-146: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Tualatin Subbasin.

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Some channel confinement through the river corridor as a result of revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Numerous complete and partial barriers on tributaries.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have affected channel stability.	Medium
Food	Salmon carcass abundance is reduced from historical levels.	Medium
Temperature	Changes in riparian canopy cover have increased summer high water temperatures but not to the level of the lower subbasin.	Medium
Chemicals	Toxics are probably not an issue because of the limited urban and agricultural land uses in the upper subbasin.	Low
Competition with hatchery fish	Limited competition with hatchery fish (Stahl, ODFW, personal communication, 2004).	Low
Competition other species	There is some competition with introduced fish in the river, but competition in the tributaries is minimal (Stahl, ODFW, personal communication, 2004).	Low
Flow	There is very little area in the upper subbasin in agricultural and urban land uses that contribute to changes in flow regimes.	Low
Harassment	Prespawning fish do not hold in the river channels (Stahl, ODFW, personal communication, 2004).	Low

Table 3-146: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the Upper Tualatin Subbasin.

EDT Attribute Class	Description	Priority for Restoration
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Stahl, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Stahl, ODFW, personal communication, 2004).	Low
Withdrawals	Limited impacts because most of the unscreened diversions are in the lower subbasin.	Low

3.5.1.12 Limiting Factors in the Upper Willamette River Mainstem

This section describes the subbasin of the upper Willamette River mainstem in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species found in the subbasin: spring Chinook salmon, cutthroat trout, bull trout, and Oregon chub.

Focal species present:

- Spring Chinook salmon
- Oregon chub
- Bull trout
- Cutthroat trout

Geographic Setting. The mainstem Willamette River begins at the confluence with the Columbia River (Columbia RM 100) at Portland, Oregon, and extends approximately 187 miles almost due south. The river originates near Eugene at the confluence of the Coast Fork and Middle Fork Willamette rivers. The river drains an area of 11,478 square miles and is the 13th largest river in the United States and the largest tributary to the Columbia below the Snake River. This description focuses on the general habitat conditions and trends in the Willamette River, with most of the emphasis on the upper river above Willamette Falls (RM 26). A separate description outlines habitat and other factors influencing fish populations for the lower Willamette River below Willamette Falls.

The Willamette River lies within a broad trough between the Cascade Mountains to the east and the Coast Range to the west (Orr et al., 1976). This trough has been partially filled by deep sediments deposited by the Missoula floods—a series of immense glacial floods that originated in Montana at the end of the last glacial period some 15,000 years ago. The valley has also been formed by volcanic activity associated with the Cascade Mountains. This includes extensive basalt formations in the northern end of the valley that form Willamette Falls, along with relatively recent volcanic formations in the headwaters of the Clackamas and McKenzie drainages and elsewhere.

Land uses along the Upper Willamette River are a mix of agricultural, rural residential, and urban lands. In an analysis of land uses and land cover along the river (within 393 feet of the river), Gregory et al (2002) found that agricultural lands occupy more than 30 percent of the area along the Upper Willamette River, followed by developed land (nearly 10 percent of the area). The Willamette River above Willamette Falls and its floodplain intersect with numerous small and large communities, including five cities with populations of more than 40,000 (PSU, 2003): Springfield (54,720), Eugene (143,910), Corvallis (52,950), Albany (43,600), and Salem (142,940).

In contrast to most of the tributaries that rise in the Cascade or Coast mountain ranges and begin as very steep headwater streams, the Willamette River maintains a low gradient throughout its length. Over its 263 miles, the river rises only 400 feet, for an overall gradient of 0.03 percent (Pacific Northwest Ecosystem Research Consortium, 2002). The channel of the meandering upper Willamette River has changed much more dramatically than the simpler, tidally influenced channel below Willamette Falls. The upper Willamette River cuts through the deep deposits of gravels and sediments deposited on the valley floor by the Missoula Floods and major tributaries. Before development, most of the upper Willamette River, particularly in the section above Corvallis, meandered across the valley, creating a highly braided channel with multiple side channels, alcoves, and oxbows (Pacific Northwest Ecosystem Research Consortium, 2002).

Average annual discharge of the Willamette River is 21,542 million gallons per day. Although the headwaters of many tributaries lie above elevations that accumulate the winter snowpack, for the most part flow follows seasonal precipitation patterns. The Willamette's discharge peaks in December, and low flow usually occurs in August (Figure 3-34). Dams on the major tributaries, including the Clackamas, Santiam and McKenzie rivers, largely regulate flow in the Willamette River. Regulation has moderated winter flooding by causing winter precipitation to be stored and then released later, which results in an increase in summer low flow (Figure3-34).

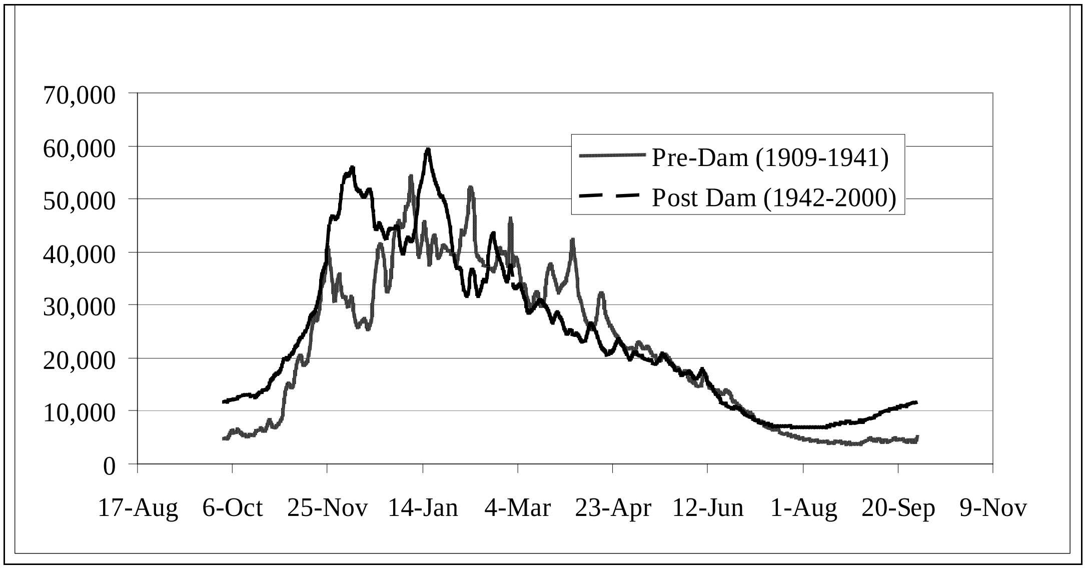


Figure 3-34: Daily Average Flow in the Willamette River at Salem, Oregon

Key Conclusions. Altered flow regimes, modified delivery and transport of large wood and sediment, and extensive changes to the riparian and aquatic habitat in the Willamette River have affected the productivity, capacity, and diversity of the focal fish species populations. Unconstrained, low-elevation river and stream reaches in the Willamette Valley have the greatest abundance and diversity of salmonid and other fish species, probably because of the greater habitat diversity. The Willamette River, along with the lowland portions of its tributaries, is rich in species diversity. Historically, the Willamette River and other lowland tributary reaches contained abundant slow water habitats – side channels, backwaters, alcoves, and sloughs – that contributed to species diversity (Pacific Northwest Ecosystem Research Consortium, 2002). The Willamette River contains 31 native fish species, while only 10 species occupy the headwater tributaries in the Cascade and Coast ranges (Pacific Northwest Ecosystem Research Consortium, 2002).

Since the mid-19th century, much of the Willamette River's channel has been constrained and simplified. Large portions of the river are now confined to a single broad channel. Channel area and length, which are key measures of habitat complexity, have dramatically declined. Since 1850, it is estimated that diking, straightening, and channelization have led to the wetted area of the river declining by 22 percent and the total channel length of the Willamette River being reduced by about 26 percent (see Tables 3-147 and 3-148). The most dramatic change in habitat complexity has been in the upper river. In the section of the river between Harrisburg and Eugene, for example, more than 60 percent of the channel length has been lost (Pacific Northwest Ecosystem Research Consortium, 2002). Alcoves, side channels, and other slow-water habitats have also declined throughout the river (Tables 3-147 and 3-148). Islands within the river channel, which create shallow water edges and other aquatic habitats, have been reduced by more than 60 percent (Table 3-147).

Table 3-147: Percent Changes* in Channel Habitat Features from 1850 to 1995 for the Willamette River from Portland to Eugene.

	Channel Habitat Type				
Year	Primary channel	Side channel	Alcoves	Islands	Total Area
1895	12.3	-0.9	0.3	-22.1	9.5
1932	4.7	-46.5	-14.7	-35.5	-0.9
1995	-13.3	-35.1	-55.6	-63.1	-22.3

* Changes are calculated using 1850 as the baseline (Pacific Northwest Ecosystem Research Consortium, 2002).

Table 3-148: Percent Changes in Length for Channel Habitat Features from 1850 to 1995 for the Willamette River from Portland to Eugene

	Channel Habitat Type			
Year	Primary channel	Side channel	Alcoves	Total Length
1895	-7.3	-0.9	-24.5	-13.8
1932	-7.1	-27.8	-21.8	-14.7
1995	-6.1	13.1	-57.7	-25.8

* Changes are calculated using 1850 as the baseline (Pacific Northwest Ecosystem Research Consortium, 2002).

Most of the length of the Willamette River is now isolated from the floodplain and seasonal tributary streams, with revetments and dikes preventing the river from accessing the floodplain during high flow periods. More than 25 percent of the length of the river has revetments on one or both banks (Pacific Northwest Ecosystem Research Consortium, 2002). Most of the revetments are on the most geomorphically active portions of the river, such as bends and openings to side channels. More than 65 percent of meander bends have revetments (Pacific Northwest Ecosystem Research Consortium, 2002), which limit the interaction of high lows with the floodplain and contribute to the loss of sloughs, alcoves, and side channels. The river’s connection with seasonal streams also has been altered. Seasonal streams along the floor of the valley provide refuge from high flows for over-wintering juvenile spring Chinook salmon and important rearing and spawning habitat for other native species (such as the three-spine stickleback). Culverts and other fish passage barriers limit juvenile Chinook salmon and other fish access to large portions of seasonal streams during winter high flow periods (Randy Colvin, Oregon State University, personal communication, 2004).

Slow water and winter refuge areas provide important habitats for many fish species, including rearing and refuge areas for juvenile spring Chinook salmon. Bradford et al. (1990) found that juvenile spring Chinook salmon use slow-water habitats in the lower Willamette River. During winter high flow periods, juvenile spring Chinook salmon will reside in floodplain ponds (Bayley and Baker, 2000). Juveniles also have been observed in higher density in alcoves (Andrus, Water Work Consulting, personal communication, 2004).

Historically, the floodplain and riparian areas along the Willamette River were heavily forested. These areas contributed large amounts of large wood to the river and provided floodplain habitats that helped maintain and create channel complexity. Land use conversion and other actions have altered vegetation and other features along the river. In 1850, more than 64 percent of the area next to the river was hardwood forest. By 1990, only a little more than 17 percent of the area was occupied by hardwood forests (see Table 3-149). Agriculture and development occupy one-third of the area that formerly was floodplain forest (Pacific Northwest Ecosystem Research Consortium, 2002). The former extensive floodplain forests have been reduced to a narrow, discontinuous strip along the river, with remnant patches scattered across the floodplain.

Table 3-149: Percent Composition of Land Use/Land Cover along the Willamette River* from Portland to Eugene, 1850 to 1990

Total River Percent Composition as Percent of Length										
	Vegetation or Land Use Type								Total	
Year	Devlp.	Ag.	Nat. Grass	Nat. Shrub	Hdwd. Forest	Mix. Forest	Conifer Forest	Wetlands	km	miles
1850	0.0	0.0	5.0	6.2	67.6	13.5	6.6	1.1	444.5	276.2
1895	12.8	20.8	0.3	0.0	34.8	26.6	0.7	0.0	479.3	297.8
1932	10.8	43.5	3.0	14.5	13.5	2.2	5.8	0.1	480.2	298.4
1990	16.4	29.5	0.6	8.9	17.4	18.2	1.5	3.6	421.5	261.9

*Within 393 feet of both sides of the channel.

Devlp. = Developed urban or rural residential lands.

Ag. = Agriculture.

Nat. Grass = Natural grasslands, such as prairie.

Nat. Shrub = Natural shrublands, such as willow thickets.

Hdwd. Forest = Forests dominated by deciduous species (cottonwoods, alder, etc.).

Mix. Forest = Forests with a mixture of hardwoods and conifers

Conifer Forest = Forests dominated by conifers.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Dams in the major tributaries have modified the flow regime and the transport of large wood and sediment into the Willamette River, and this has affected the processes that create and sustain habitats. The construction of the U.S. Army Corps of Engineers dams in the Middle Fork Willamette, McKenzie, Santiam, and other drainages has resulted in a dramatic reduction in the frequency and magnitude of high flow events (Table 3-150). The U.S. Army Corps of Engineers's 13-reservoir Willamette Project controls runoff from 27 percent of the Willamette Basin (U.S. Army Corps of Engineers, 2000). Sustained high flows and sediment transport maintain and create habitats such as side channels and islands (Pacific Northwest Ecosystem Research Consortium, 2002). Changes in the flow regime and the transport of large wood and sediments have influenced the distribution and abundance of islands and gravel bars. For example, Dykaar and Wigington (2000) observed an 80 percent reduction in gravel bar and island area in the upper Willamette River between Harrisburg and Eugene between 1910 and 1988. The tributary dams effectively block the transport of wood into the Willamette River from large areas of the basin, much of it National Forest land with most of the remaining old-growth and mature conifer forests that could contribute large pieces of wood (U.S. Army Corps of Engineers, 2000). Historically there were large amounts of wood and numerous logjams in the river. Between 1870 and 1950, 550 snags per kilometer were removed from the upper Willamette River above Albany (Sedell and Foggat, 1984).

Appendix X shows specific fish passage barriers on the upper Willamette, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Table 3-150: Maximum Discharges Recorded at the Albany Gage for Four Major Willamette River Floods

Peak Flows				
1861	**1890**	**1943/1945**	**1964**	**1996**
340,000 cfs	291,000cfs	210,000 cfs	180,000cfs	117,000 cfs

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Water quality in the Willamette River has affected fish populations. There are reports from the 1920s and 1930s of good cutthroat trout sport fishing in the mainstem Willamette River above Independence. It appears that pollution in the river during the 1920s and 1930s eliminated abundant cutthroat trout populations in the river above Independence. Currently, populations of cutthroat tout are limited in the lower Willamette River below the confluence with the Marys River as a result of high summer water temperatures and the presence of the fish parasite *Certomyxa shasta*. Water temperatures in the river can exceed the maximum for salmonid rearing and spawning (Oregon Department of Environmental Quality, 2004). High water temperatures in the river have probably been exacerbated by changes in large wood and gravel recruitment. Reduced recruitment of large wood and sediment has limited creation of new gravel bars. Hyporheic flow through gravel bars can cool water, which can provide areas with cool-water rearing habitats (Fernauld et al., 2001*)*. Toxics in the river below Salem from urban runoff and other sources may be affecting native fish populations. Aromatic hydrocarbons, for example, have exceeded water quality criteria (Oregon Department of Environmental Quality, 2004). Sediment appears not to be limiting salmonid fish populations, but dissolved oxygen levels have fluctuated below the water quality criteria in this portion of the river (Oregon Department of Environmental Quality, 2004).

Introduced fish probably limit the abundance of native fish. Almost half of the total richness of 60 fish species found in the Willamette Basin is attributable to introduced species. The Willamette River Basin contains 31 native fish species and 29 exotic or introduced species (Pacific Northwest Ecosystem Research Consortium, 2002). Most of these introduced fish species are found in the Willamette River, including large- and small-mouth bass, brown bullheads, and western mosquito fish (Pacific Northwest Ecosystem Research Consortium, 2002). Large numbers of introduced hatchery fish (spring Chinook salmon and winter steelhead, for example) also use the river corridor for migration and rearing.

Environmental Conditions. The three reaches (lower, middle, and upper) described in the *Willamette River Basin Planning Atlas* (Pacific Northwest Ecosystem Research Consortium, 2002) are used to describe the environmental conditions in the upper Willamette River. Because this assessment focuses on the river above Willamette Falls, only a portion of the lower reach (between Willamette Falls and Newburg) is within the upper Willamette River. For this reason, most of the description is of the middle and upper reaches.

The reaches in the *Willamette River Basin Planning Atlas* (Pacific Northwest Ecosystem Research Consortium, 2002) do not correspond directly to reaches used in the EDT assessment. For the EDT assessment, 14 river reaches were used to describe the river between Willamette Falls and the confluence of the McKenzie River at Eugene These reaches were defined on the basis of the confluence of major tributaries or other geographic features, including major cities. The 14 river reaches were grouped into three geographic areas corresponding to an upper Willamette area (Eugene), a mid-Willamette area (Salem), and a lower Willamette area (Newberg). A fourth area, Portland, contained 26 additional reaches and described the river from Willamette Falls to the Columbia River. Table 3-151 lists the *Willamette River Basin Planning Atlas* (Pacific Northwest Ecosystem Research Consortium, 2002) reaches and the corresponding EDT reaches and geographic areas.

Table 3-151: Willamette River Basin Planning Atlas Reaches (Lower, Middle, and Upper) and the Corresponding EDT Assessment Reaches and Geographic Areas

Planning Atlas Reach	Description	Corresponding EDT Reaches and Geographic Areas
Lower	Columbia River to Newberg	WR1—WR26 (Lower Willamette Reaches to Willamette Falls) WR27—WR29 (Newberg Geographic Area)
Middle	Newberg to Albany	WR30 (Newberg Geographic Area) WR31—WR35 (Salem Geographic Area) WR36 (Eugene Geographic Area)
Upper	Albany to Eugene	WR37—WR40 (Eugene Geographic Area)

Environmental Conditions in the Lower/Middle Reach. This section of the Willamette River encompasses a portion of the lower reach from the top of Willamette Falls and the entire middle reach from Newberg to Albany. Key tributaries that enter the river along this section include the Tualatin, Yamhill, Pudding, Luckiamute, and Santiam rivers. In this portion the river confined channel sections are interspersed broad floodplain areas. In the Newberg and Salem areas, hills comprised of Columbia River basalts uplifted along faults constrain the river and limit the development of a wide floodplain.

This section of the river has lost habitat complexity, although not to the degree of the upper reach. The total area of river, channel and island decreased by about 14 percent from 1850 to 1995 (Table 3-152). The total length of the channel was largely unchanged (Table 3-153), although there were substantial losses of important slow-water habitats. Between 1850 and 1995 there was a 33 percent change in the alcove area and more than a 15 percent change in side channel area.

Table 3-152: Percent Changes* in Channel Habitat Features from 1850 to 1995 for the Middle Reach of the Willamette River from Newberg to Albany.

	Channel Habitat Type				
Year	Primary channel	Side channel	Alcoves	Islands	Total Area
1895	22.8	53.8	19.0	7.1	23.2
1932	8.3	-9.6	20.2	0.0	9.1

Table 3-152: Percent Changes* in Channel Habitat Features from 1850 to 1995 for the Middle Reach of the Willamette River from Newberg to Albany.

	Channel Habitat Type				
Year	Primary channel	Side channel	Alcoves	Islands	Total Area
1995	-12.1	-15.5	-33.1	-8.6	-14.5

*Changes are calculated using 1850 as the baseline.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Table 3-153: Percent Changes* in Length for Channel Habitat Features from 1850 to 1995 for the Middle Reach of the Willamette River from Newberg to Albany

	Channel Habitat Type			
Year	Primary channel	Side channel	Alcoves	Total Length
1895	-2.5	62.5	34.7	10.9
1932	-0.1	-27.8	10.9	0.0
1995	-0.9	10.8	-2.1	-0.2

* Changes are calculated using 1850 as the baseline.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Many of the most dramatic changes in habitat complexity occur at tributary junctions. The Luckiamute and North Santiam rivers enter the Willamette River on opposite sides (RM 108). This section of the river is particularly dynamic with major shifts in channel position over time and a broad floodplain forest. While aquatic and floodplain habitats have been lost over time at this tributary confluence, high-quality habitats still remain (Pacific Northwest Ecosystem Research Consortium, 2002).

Scattered revetments, often on curves of the river, constrain channel movements along this section of the river. Along the middle reach, revetments occupy 13.5 percent of the river on one side and constrain both sides along 1.1 percent of the river’s length (Pacific Northwest Ecosystem Research Consortium, 2002). Most of the revetments are located roughly equally along urban, agricultural, and forest lands.

Floodplain and riparian vegetation been modified along this section of the river. In the middle reach of the river, combined urban and agricultural lands make up 40 percent of the riparian system (see Table 3-154). Hardwood floodplain forests were reduced from more than 76 percent in 1850 to about 23 percent by 1990.

Table 3-154: Percent Composition of Land Use/Land Cover along the Middle Reach of the Willamette River (within 393 feet of both sides of the channel) from Newberg to Albany, 1850 to 1990.

	Vegetation or Land Use Type								Total	
Year	Devlp.	Ag.	Nat. Grass	Nat. Shrub	Hdwd. Forest	Mix. Forest	Conifer Forest	Wetlands	km	miles
1850	0.00	0.00	4.50	4.44	76.23	13.42	0.00	1.41	198.14	123.12
1895	8.42	23.15	0.05	0.00	52.56	12.83	0.17	0.00	203.26	126.30
1932	5.20	47.43	0.00	7.33	23.69	5.05	3.36	0.26	199.36	123.88
1990	10.19	29.69	0.49	8.84	23.13	20.02	0.41	3.42	192.14	119.39

Devlp. = Developed urban or rural residential lands.

Ag. = Agriculture.

Nat. Grass = Natural grasslands, such as prairie.

Nat. Shrub = Natural shrublands, such as willow thickets.

Hdwd. Forest = Forests dominated by deciduous species (cottonwoods, alder, etc.).

Mix. Forest = Forests with a mixture of hardwoods and conifers.

Conifer Forest = Forests dominated by conifers.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Environmental Conditions in the Upper Reach. The upper reach of the Willamette River extends from Albany through Eugene to the confluence of the Middle and Coast Fork Willamette rivers. Large tributaries that enter this reach include the Calapooia, Marys, Long Tom, and McKenzie rivers. This is the most unconstrained and complex reach along the Willamette River. Historically, the river meandered over large areas of the floor of the valley (Benner and Sedell, 1997).

The upper reach of the Willamette River has experienced the greatest loss of habitat complexity and floodplain function. The river is largely confined to a single channel with a few remnants of the braided network. Almost 40 percent of the channel area has been lost (see Table 3-155). From 1850 to 1995 there has been almost an 80 percent decline in island area and a dramatic reduction in the slow-water habitats. More than 73 percent of the area in alcoves, and 41 percent of the side channel area has been lost. The total length of the channel has declined by nearly 40 percent (see Table 3-156).

Historically, the section of the upper reach between Harrisburg and Eugene, which includes the confluence with the McKenzie River, was the most dynamic section of the Willamette River. There has been substantial loss of habitat quantity and diversity in this section of the river since 1850, with the river changing from a complex braided network to the simple, straightened channel of today. The total length of channels and islands is less than one-fifth of the comparable area in 1850 (Pacific Northwest Ecosystem Research Consortium, 2002).

The upper reach of the Willamette River is constrained by numerous revetments, which occupy 19 percent of the river on one side and constrain both sides along 4.7 percent of the reach's length (Pacific Northwest Ecosystem Research Consortium, 2002). Most of the revetments are located adjacent to farm lands, at meander bends or side channels. This limits the ability of the channel to interact with the floodplain.

Table 3-155: Percent Changes* in Channel Habitat Features from 1850 to 1995 for the Upper Reach of the Willamette River from Albany to Eugene.

	Channel Habitat Type				
Year	Primary channel	Side channel	Alcoves	Islands	Total Area
1895	8.3	-21.8	-11.4	-31.2	0.1
1932	-4.3	-60.3	-31.8	-46.6	-16.5
1995	-21.3	-41.4	-73.5	-79.5	-39.8

*Changes are calculated using 1850 as the baseline.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Table 3-156: Percent Changes* in Length for Channel Habitat Features from 1850 to 1995 for the Upper Reach of the Willamette River from Albany to Eugene.

	Channel Habitat Type			
Year	Primary channel	Side channel	Alcoves	Total Length
1895	-16.0	-24.0	-39.2	-29.9
1932	-15.9	-21.7	-32.2	-25.7
1995	-14.7	21.7	-74.0	-45.4

*Changes are calculated using 1850 as the baseline.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Historically, the upper reach had the most extensive floodplain forests adjacent to the Willamette River. Loss of side channels, sloughs, alcoves, and islands within the upper reach was accompanied by changes in the composition and distribution of floodplain and riparian vegetation. In 1850, more than 87 percent of the riparian system in this reach was hardwood forest (see Table 3-157). By 1990, hardwood forests were reduced to a remnant, occupying only about 14 percent of the riparian system. Combined agricultural and urban land uses cover almost 50 percent of the riparian area along the upper reach. Although dramatically reduced in extent, there are existing fragments of floodplain forest along the this reach, primarily above Harrisburg and near the confluence of McKenzie River.

Table 3-157: Percent Composition of Land Use/Land Cover along the Upper Reach of the Willamette River (within 393 feet of both sides of the channel) from Albany to Eugene, 1850 to 1990

	Vegetation or Land Use Type								Total	
Year	Devlp.	Ag.	Nat. Grass	Nat. Shrub	Hdwd. Forest	Mix. Forest	Conifer Forest	Wetlands	km	miles
1850	0.00	0.00	10.14	0.35	87.58	0.31	0.51	1.11	131.84	81.92
1895	7.91	11.19	0.71	0.00	33.01	44.60	0.00	0.00	157.43	97.82
1932	4.63	37.43	0.00	12.39	21.73	6.13	12.04	0.08	168.09	104.45
1990	8.70	41.82	1.14	10.59	14.52	14.70	0.04	5.20	124.30	77.24

Devlp. = Developed urban or rural residential lands.

Ag. = Agriculture.

Nat. Grass = Natural grasslands, such as prairie.

Nat. Shrub = Natural shrublands, such as willow thickets.

Hdwd. Forest = Forests dominated by deciduous species (cottonwoods, alder, etc.).

Mix. Forest = Forests with a mixture of hardwoods and conifers.

Conifer Forest = Forests dominated by conifers.

Source: Pacific Northwest Ecosystem Research Consortium, 2002.

Key Factors Limiting Fish Populations The lower/middle and upper reaches of the Willamette River are characterized by different patterns of aquatic and riparian habitat and water quality characteristics. For this reason, factors limiting populations for the focal fish species are assessed separately for the lower/middle and upper reaches.

Limiting Factors in the Lower/Middle Reach. In the lower/middle reach of the upper Willamette River Subbasin, cutthroat trout, spring Chinook salmon, winter steelhead, and Oregon chub are limited by the following factors:

- **Habitat Connectivity**. Modification of the river’s high flow regime through dam regulation, channel and bank confinement, and reduced large wood in the channels has interacted to reduce backwater habitats important for juvenile rearing and winter refuge.
- **Flow Regimes and Habitat Modification**. Changes in flow regimes and modification of key habitats have greatly affected the range of life stages – migration, adult holding, and juvenile rearing.
- **Large Wood**. Reduced delivery and transport of large wood in the river and tributaries have modified gravel deposition patterns, reduced the quality and quantity of slow-water habitats, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors**. Other, more moderate factors limiting the populations of focal species in the lower/middle reach of the upper Willamette are competition with hatchery and introduced fish; lower numbers of salmon carcasses, which reduces nutrient input and thus food availability; and changes in water quality. These factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Table 3-158 shows the EDT attributes related to these limiting factors for the focal species in the lower/middle reach of the Willamette River, along with qualitative ratings for restoration priorities.

Table 3-158: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, Cutthroat Trout, and Oregon Chub Life Stages in the Lower Middle Reach of the Willamette River

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels has reduced channel stability.	**HIGH**
Competition with hatchery fish	Hatchery fish have been introduced to areas below the dams, increasing competition with native fish for habitat and food.	**HIGH**
Flow	There have been changes in the interannual variability of low and high flows from dam regulation. This affects the quantity of habitat and disrupts the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects important life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Chemicals	Toxics may be at levels that affect salmonids.	Medium
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish.	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Oxygen	Oxygen levels have fluctuated below the criteria.	Medium
Pathogens	Hatchery fish have been introduced, increasing the potential for disease.	Medium
Temperature	The dams have modified high and low water temperature regimes in the river, and high temperatures can exceed criteria. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams that may provide refugia from higher temperatures in the river.	Medium
Withdrawals	There are some unscreened diversions within the river that many affect fish (Michael Mattick, Oregon Water Resources Dept., personal communication, 2004).	Medium
Harassment	While there is extensive recreational use of the lower river (boating and fishing), water depths probably limit harassment of holding fish.	Low
Obstructions	The are no obstructions above the Willamette Falls fish ladder.	Low

Table 3-158: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Winter Steelhead, Spring Chinook Salmon, Cutthroat Trout, and Oregon Chub Life Stages in the Lower Middle Reach of the Willamette River

EDT Attribute Class	Description	Priority for Restoration
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low

Limiting Factors in the Upper Reach. Historically, the upper reach was the most complex and dynamic section of the Willamette River. Currently, limiting factors for the focal species in the upper reach are as follows:

- **Habitat Connectivity**. Modification of the river's high flow regime from dam regulation, channel and bank confinement, and reduced large wood in the channels has interacted to reduce backwater habitats important for juvenile rearing and winter refuge.
- **Flow Regimes and Habitat Modification**. Modified flow regimes and changes in key habitats have greatly affected the range of life stages – migration, adult holding, and juvenile rearing.
- **Large Wood**. Reduced delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the quality and quantity of slow-water habitats, and minimized hiding cover for adult and juvenile fish.
- **Additional Factors**. Other, more moderate factors limiting the populations of focal species include competition with hatchery and introduced fish; lower numbers of salmon carcasses, which reduces nutrient inputs and thus food availability; and changes in water quality. All of these factors interact with modified habitats and other impacts to the aquatic system to limit fish populations.

Table 3-159 shows the EDT attributes related to the limiting factors for cutthroat trout, spring Chinook salmon, winter steelhead, and Oregon chub in the upper reach of the Willamette River, along with qualitative ratings for restoration priorities.

Table 3-159: Qualitative Ratings of EDT Attributes Related to Limiting Factors For Winter Steelhead, Spring Chinook Salmon, Cutthroat Trout, And Oregon Chub in the Upper Reach of the Willamette River

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels has reduced channel stability.	**HIGH**
Competition with hatchery fish	Hatchery fish have been introduced to areas below the dams, increasing competition with native fish for habitat and food.	**HIGH**
Flow	There have been changes in the interannual variability of low and high flows as a result of dam regulation. This affects the quantity of habitat and disrupts the processes that create a complex array of habitats.	**HIGH**

Table 3-159: Qualitative Ratings of EDT Attributes Related to Limiting Factors For Winter Steelhead, Spring Chinook Salmon, Cutthroat Trout, And Oregon Chub in the Upper Reach of the Willamette River

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects important life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Competition with other species	Fish community richness is high in the lower river and there is competition with introduced fish.	Medium
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Medium
Oxygen	Oxygen levels have fluctuated below the criteria.	Medium
Pathogens	Hatchery fish have been introduced, increasing the potential for disease.	Medium
Temperature	The dams have modified high and low water temperature regimes in the river, and high temperatures can exceed criteria. Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams that may provide refugia from higher temperatures in the river.	Medium
Withdrawals	There are some unscreened diversions within the river that many affect fish (Michael Mattick, Oregon Water Resources Dept., personal communication, 2004).	Medium
Chemicals	Toxics are probably not at levels that affect salmonids.	Low
Harassment	While there is extensive recreational use of the lower river (boating and fishing), water depths probably limit harassment of holding fish.	Low
Obstructions	The are no obstructions above the Willamette Falls fish ladder.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low

3.5.1.13 Yamhill Subbasin

This section describes the Yamhill Subbasin in terms of geographic setting and environmental conditions and presents information on the limiting factors for focal species in the subbasin: cutthroat trout and spring Chinook.

Focal species present:

- Cutthroat trout

- Spring Chinook salmon (juvenile rearing and refuge)

Focal species present historically:

- Oregon chub

Geographic Setting. The Yamhill Subbasin covers an area of approximately 919 square miles on the eastern slope of the Coast Range and the floor of the Willamette Valley. The North and South Forks join to form the Yamhill River, which flows for 11 miles before entering the Willamette River at RM 55. Approximately 96 percent of the land in the subbasin is privately owned. Most of the private lands are in forestry, agricultural, and rural residential land uses. Urban lands cover a very small portion of the subbasin, primarily within the city of McMinnville. The Salem District of the BLM and the Oregon Department of Forestry manage a small proportion of the forested upper subbasin.

The Yamhill River does not have spawning populations of native anadromous fish, but juvenile Chinook salmon have been observed using the lower portions of the river as rearing and winter refuge habitat (Gary Galovich, ODFW, personal communication, 2003). Cutthroat trout exist in all of the subbasin's streams, and historically there was a population that moved between the Yamhill River and the mainstem of the Willamette River (Wevers et al., 1992). Naturally spawning winter steelhead are present in the Yamhill Subbasin. It appears that these fish are strays or from introduced populations, and there is little evidence to suggest that self-sustaining spawning aggregations of winter steelhead existed historically in the Yamhill Subbasin (Myers et al., 2003). Cutthroat trout and winter steelhead have similar habitat requirements.

The headwaters of the Yamhill River are on the east side of the Coast Range. Private industrial forestlands are the primary land use in the upper subbasin. As the North and South Forks of the Yamhill River enter the Willamette Valley they flow past small-acreage farms and rural residential areas. Major tributaries in the upper subbasin of the North Fork Yamhill River include Haskins, Panther, and Turner Creeks. Mill, Willamina, and Deer Creeks are important upper subbasin tributaries to the South Fork. The lower South and North Forks, the mainstem Yamhill River, and lower subbasin tributaries flow through agricultural lands and rural residential areas and near the city of McMinnville and numerous small communities, including Carlton, Laftette, Sheridan, Amity, and Dundee. Important tributaries in the lower subbasin include Salt, Ash Swale, Palmer, and Chehalem creeks.

The Coast Range bedrock in the upper subbasin is composed predominantly of sedimentary rocks with some volcanic formations. Most of the subbasin lies below 1,000 feet in elevation. The upper subbasin drains the Coast Range, but most of the Yamhill River, North and South Forks, and larger tributaries flow through the Willamette Valley's recent alluvial deposits. The Coast Range sedimentary rocks have lower groundwater storage capacity than is the case in the Cascade Mountains, and the streams within the Yamhill Subbasin have lower summertime flows and higher water temperatures than do Cascade Range streams. The subbasin's high flow runoff patterns are dominated by a rain-on-snow hydrology in the mid- to upper elevations and rain-dominated flow patterns in the lower subbasin, which leads to rapid delivery of water to the stream network. As a result of the subbasin's low elevations and the Coast Range geology, summertime stream flows are not supplemented by snowmelt or numerous spring-fed sources.

The headwaters and tributaries of the upper subbasin flow steeply off the Coast Range, and the gradient rapidly decreases once the streams enter the lower subbasin areas within the flat Willamette Valley. For example, the lower 20 miles of the North Yamhill River, which flows through the valley, has a gradient of nearly 0.1 percent, while the upper portions of the river exceed 3.5 percent gradient (see Table 3-160). Historically, the lower Yamhill River channel was very sinuous as it flowed through the old fluvial deposits of the Willamette Valley (YBC, 2001b).

Table 3-160: Percent Gradient for Major Segments of the North and South Yamhill River

Subbasin Location	River Mile (RM)	Percent Gradient
North Yamhill	0 to 20	0.11
North Yamhill	20 to 32	3.44
South Yamhill	0 to 30	0.03
South Yamhill	30 to 60	0.22

Environmental Conditions. Altered subbasin processes, modified riparian and aquatic habitat, and limited access to historical spawning and rearing areas in the Yamhill Subbasin have affected the productivity, capacity, and diversity of cutthroat tout and juvenile spring Chinook salmon populations in the Yamhill Subbasin. Table 3-161 summarizes changes in the subbasin's environmental conditions and how these changes have affected cutthroat trout and juvenile spring Chinook salmon.

Upper and Lower Subbasins. Relative to the lower subbasin, the forested upland portions of the upper subbasin have aquatic habitat that is closer to the historical baseline, with the highest proportion of functioning riparian areas, the largest amounts of large wood in the river and tributary channels, and higher quality aquatic habitats (Baker et al., 2002; YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002a). Impacts to aquatic and riparian habitats have been greater in the lower Yamhill Subbasin than in the upper subbasin. Historically, the lower subbasin was characterized by very complex and productive fish habitat because the largest proportion of unconstrained river and stream channels were in the area where the Yamhill River and the lower portions of the South and North Forks flowed across the flat Willamette Valley (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002).

Table 3-161: Yamhill Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Chinook

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	Adult migration and holding	The management of Haskins Dam contributes to the extremely low summertime flow levels. Naturally low flows in the basin are aggravated by water withdrawals, which increase water temperatures. High water temperatures are aggravated by the loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces. Channelization of tributaries and modification of runoff patterns as a result of agriculture (drainage tiling, for example), impervious surfaces, and urban/residential development have increased peak flows in tributaries and accelerated runoff, thus reducing storage capacity. Nutrient and toxic runoff from agricultural and urban areas may be a problem. The loss of wetlands and floodplain habitats has affected water quality and quantity (storage and timing of peak and low flows).	Numerous culverts throughout the subbasin present barriers to adult refuge habitat. Haskins Dam (City of McMinnville) is a fish passage barrier to upstream habitat. Baker Creek Dam is a fish passage barrier to upstream habitat. Removal is planned for this dam.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover. Limited large wood in channels is particularly pronounced in the lower subbasin. Riparian areas along the river and tributaries, especially in the lower subbasin, are reduced in width, connectivity, and quality. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain and off-channel habitats has affected the quantity and quality of adult holding areas.	
	Adult spawning/ egg incubation		Numerous culverts throughout the subbasin present barriers to spawning habitat.	Limited wood in tributary streams has reduced retention of spawning gravels.	

Table 3-161: Yamhill Subbasin: Subbasin Attributes Affecting Cutthroat Trout and Juvenile Chinook

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Fry and juvenile rearing and migration	Naturally low flows in the basin are aggravated by water withdrawals, which may increase water temperatures. High water temperatures, particularly in the river and tributaries in the middle and lower portions of the subbasin, do not provide optimal conditions for juvenile rearing.	Haskins Dam (City of McMinnville) is a barrier to juvenile downstream movement. Numerous culverts throughout the subbasin present barriers to juvenile access to rearing and refuge habitat. Loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat, particularly in the lower subbasin. Unscreened diversions are present in the lower subbasin, especially in Salt Creek, Ash Swale, and Palmer creeks.	Channels in the lower portions of the river and some tributaries have been simplified through revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools, limiting juvenile rearing and refuge habitat. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of juvenile rearing and refuge areas.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.
Spring Chinook Salmon	Fry and juvenile rearing and refuge		Culverts in the lower subbasin present barriers to juvenile access to refuge habitat. The loss of connectivity to floodplain and wetland habitats has affected juvenile rearing and refuge habitat in the lower river.	The loss of wetland, floodplain, and off-channel habitats in the lower subbasin have affected the quantity and quality of juvenile rearing and refuge areas.	

Source: Wevers et al., 1992; Stahl, ODFW, personal communication, 2004; YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002.

Large Wood. Historical removal of large wood from the river and tributary streams, reduced delivery and transport of wood through channels, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries. Mature riparian forests make up a small proportion of the riparian areas in the lower subbasin (Pacific Northwest Ecosystem Research Consortium, 2002). Most of the riparian areas in the lower subbasin are fragmented, have limited tree cover, or are covered by other land uses such as urban or residential (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002). For example, more than 15 percent of the riparian areas along the Lower Yamhill River and tributaries are characterized as consisting of bush, grass, or no vegetation (YBC, 2001c). Over time, a number of practices have reduced the quantity of large wood in the Tualatin River and tributary channels throughout the subbasin (Wevers et al., 1992). While riparian areas in the forested upper subbasin have greater numbers of conifer trees than do lower subbasin areas, historical riparian harvests and wood removal from streams have reduced large wood in these channels (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002). Reduced large wood in the river and tributary channels limits the formation of pools, thus reducing hiding areas for adult fish and restricting the quality and quantity of juvenile rearing habitat.

Water Quality Changes. Water quality has been modified throughout the subbasin, and currently water temperatures exceed criteria in the Yamhill River and many of the tributaries. Naturally low flows in the subbasin are aggravated by water withdrawals, which increase water temperatures (Stahl, ODFW, personal communication, 2004). In general, water temperatures are lower in the forested upper subbasin than in the lower subbasin (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002). High water temperatures in the lower subbasin are aggravated by loss of riparian cover, reduced wetland areas, channel simplification, and increased impervious surfaces (YBC, 2001a). Phosphorous pollution has been an ongoing issue in the subbasin. The effects of low summer flows and high nutrient loads can combine to create a poor environment for fish passage and production (Murtagh et al., 1992). There is a TMDL process and other management practices in place to address excess phosphorous loads (Oregon Department of Environmental Quality, 2004).

Changes in Flow Regimes. There have been extensive impacts to the subbasin’s hydrologic regimes. Changes in land use have affected hydrologic regimes in the tributaries. Channelization of tributaries; modification of runoff patterns as a result of agriculture, impervious surfaces, and urban/residential development; and loss of storage capacity in floodplains and wetlands have accelerated runoff and increased peak flows (Stahl, ODFW, personal communication, 2004). In up to 80 percent of the agricultural lands in the lower subbasin, tiles are used to drain excess water (YBC, 2000a), and there has been a significant loss of wetlands in the subbasin as a result of ditching, draining, and tiling (YBC, 2002). Consumptive uses from agricultural, industrial, and urban uses throughout the subbasin seriously delete summertime low flows. Most of the larger tributaries in the subbasin are have more water appropriations that exceed flows during the summer months (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002).

Fish Passage Barriers. Obstacles to fish passage are an issue throughout the subbasin. There are several dams that limit upstream migration (Stahl, ODFW, personal communication, 2004). Haskins Dam (City of McMinnville) is a fish passage barrier to upstream habitat, as is Baker Creek Dam; removal of Baker Creek Dam is planned. In addition, there are large numbers of road crossing culverts in the lower and upper subbasin that block or limit fish passage (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002). Limiting the fish passage above culverts restricts the amount of habitat available for all cutthroat trout life stages.

Appendix G shows specific fish passage barriers on the Yamhill, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Habitat Connectivity. Backwater habitats, including pool margins, side channels, and alcoves, are reduced from historical levels. Actions to stabilize the lower river through the placement of riprap along banks (and other actions) and limited large wood in the channel have interacted to reduce the quantity and quality of backwater habitats. Large portions of the Yamhill River, North and South Forks, and sections of tributary streams have confined channels as a result of riprapped banks, revetments, and roads (YBC, 1999a, 1999b, 2000a, 2000b, 2001a, 2001b, 2001c, and 2002). Backwater areas in the river and lower tributaries provide key habitats for adult and juvenile cutthroat tout and juvenile spring Chinook salmon. These habitats provide fish with habitat for foraging and refuge from winter flood events.

Key Factors Limiting Fish Populations. The upper and lower portions of the Yamhill Subbasin are characterized by different patterns of aquatic and riparian habitat, hydrologic regimes, water quality characteristics, and fish species distributions. For this reason, factors limiting populations for the focal fish species are assessed separately for the upper and lower subbasins.

Limiting Factors in the Lower Yamhill Subbasin. In the lower Yamhill Subbasin, the productivity, capacity, and diversity of cutthroat trout and juvenile spring Chinook are limited by the following factors:

- **Habitat Connectivity**. Modification of river and tributary habitat through channel and bank confinement and reduced large wood in the channels have interacted to reduce floodplain connectivity and backwater habitats important for all cutthroat trout life stages and juvenile Chinook salmon rearing and winter refuge.
- **Habitat Modification**. Modification of key aquatic habitats has affected all life stages.
- **Large Wood**. Changes in the delivery and transport of large wood in the river and tributaries has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile cutthroat trout and affected juvenile Chinook salmon rearing areas in the lower river.
- **Water Temperature**. Increased summertime water temperature regimes have affected adult cutthroat trout populations and limited the capacity of river and tributary streams to support juvenile fish.
- **Fish Passage Barriers**. Fish passage barriers at road crossings on tributary streams block the interchange between cutthroat trout populations and limit adult and juvenile access into rearing and refuge habitat.

- **Additional Factors**. Other factors limiting the populations of focal species include competition with introduced fish, runoff of toxics from urban and agricultural areas, and some unscreened water diversions.

Table 3-162 shows the EDT attributes related to these limiting factors for cutthroat trout and juvenile spring Chinook salmon life stages in the lower Yamhill Subbasin. The area of the subbasin being considered is largely on the Willamette Valley floor, where the majority of the land is privately owned, with agricultural, rural residential, and urban land uses. The priorities for restoration are qualitative ratings based on the information in Table 3-161 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-162: Qualitative Rating of EDT Attributes for Cutthroat Trout and Juvenile Spring Chinook in the Lower Yamhill Subbasin

EDT Attribute Class	Description	Priority for Restoration
Channel stability	Limited wood in channels and reduced riparian function have reduced channel stability.	**HIGH**
Flow	There have been impacts to the interannual variability of low and high flows as a result of land use practices and water diversions.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams on tributary streams prevent upstream and downstream movement; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Chemicals	There is little evidence that toxics are affecting salmonids, although there are some high levels noted in monitoring (see Table 3-161; Stahl, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high and there is some competition with introduced fish (Stahl, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Stahl, ODFW, personal communication, 2004).	Medium

Table 3-162: Qualitative Rating of EDT Attributes for Cutthroat Trout and Juvenile Spring Chinook in the Lower Yamhill Subbasin

EDT Attribute Class	Description	Priority for Restoration
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Stahl, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Stahl, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Stahl, ODFW, personal communication, 2004).	Low

Limiting Factors in the Upper Yamhill Subbasin. Historically the upper subbasin was an important spawning and rearing area for both resident and fluvial cutthroat trout. In contrast to the large-scale modification of the lower subbasin, there is higher quality habitat in the upper subbasin, particularly in the forested upland areas. Currently, limiting factors for cutthroat trout in the upper subbasin are as follows:

- **Channel and Habitat Modifications.** Roads next to stream channels have increased channel confinement and reduced riparian vegetation and canopy cover.
- **Large Wood**. There are systematic changes to the levels of large wood in the river and stream channels of the upper subbasin. Past management of riparian areas and stream cleaning practices have lead to reduced large wood loads in the aquatic system. Reduced in-channel wood has modified gravel deposition patterns, reduced the frequency and depth of pools, and minimized hiding cover for adult and juvenile fish.
- **Water Temperatures**. In addition, changes to riparian canopy have increased summertime water temperatures.
- **Fish Passage Barriers**. Numerous partial and complete fish passage barriers on tributary stream have limited cutthroat trout populations.

Table 3-163 outlines the EDT attributes limiting cutthroat life stages in the upper Yamhill Subbasin. The area in question is primarily privately owned, with forestry and rural residential land uses. Again, the table presents qualitative ratings based on information in Table 3-161 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-163: Qualitative Rating of EDT Attributes for Cutthroat Trout Life Stages in the Upper Yamhill Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Some channel confinement through the river corridor as a result of revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Numerous complete and partial barriers on tributaries.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have affected channel stability.	Medium
Withdrawals	Limited impacts because most of the unscreened diversions are in the lower subbasin.	Medium
Chemicals	Toxics are probably not an issue because of the limited urban and agricultural land uses in the upper subbasin.	Low
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Stahl, ODFW, personal communication, 2004).	Low
Competition with other species	There is some competition with introduced fish in the river, but competition in the tributaries is minimal (Stahl, ODFW, personal communication, 2004).	Low
Flow	There is less area in agricultural and urban land uses that contributes to changes in flow regimes.	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting focal species.	Low
Pathogens	Pathogens are not thought to be limiting (Stahl, ODFW, personal communication, 2004).	Low
Sediment load	Although there are periodic high turbidity levels, sediment deposition does not appear to be affecting spawning areas (Stahl, ODFW, personal communication, 2004).	Low

3.5.1.14 Limiting Factors in the Clackamas Subbasin (with EDT Analysis)

This section describes the geographic setting of the Clackamas Subbasin and limiting factors for the focal species in the subbasin: Chinook and coho salmon and winter steelhead. The limiting factors were determined by using EDT to analyze habitat conditions on a reach-by-reach basis throughout the Clackamas Subbasin.

Focal species present:

- Chinook salmon
- Coho salmon
- Winter steelhead

Focal species for the assessment were chosen to characterize the environment and to capture habitat issues of concern to managers. We chose three anadromous salmonid focal species: coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*O. tshawytscha*) and winter steelhead (*O. mykiss*). These species are native to the system, although all are influenced by hatchery releases within the basin. We assume that robust, naturally spawning populations of these species are consistent with the normative condition for the Clackamas and that constraints on their performance within the EDT reflect anthropogenic changes to the normative condition.

Populations were defined for each focal species (see Table 3-164). The term “population” in EDT does not necessarily imply a genetic connotation. EDT populations are regions within a watershed composed of reaches that are delineated from other areas because of management interest (including possible genetic concerns) and to contrast different areas of the watershed. EDT begins life history trajectories for each population from reaches within the defined area. This group of trajectories may traverse several geographic areas over the course of the life history. For example, assessment results for the upper Clackamas coho population represent trajectories that began in reaches in the upper Clackamas and extended downstream through the middle and lower geographic areas in the Clackamas, the Willamette River, and so on to complete a life history.

Table 3-164: Focal Species and EDT Populations in the Clackamas River

Species	Population
Chinook	Clackamas Fall Chinook Clackamas Spring Chinook
Coho	Upper Clackamas Coho Lower Clackamas Coho
Winter steelhead	Upper Clackamas Steelhead Lower Clackamas Steelhead

Chinook salmon in the Clackamas were divided into two populations on the basis of differences in adult and juvenile behavior and distribution within the system (see Table 3-164). Fall Chinook in the Clackamas spawn in the lower reaches of the mainstem and lower tributaries. They display an ocean-type life history and out-migrate as juveniles in the spring and summer following emergence. Spring Chinook potentially use the entire watershed, including the entire length of the mainstem and many tributaries. Spring Chinook display a stream-type life history and remain as juveniles in the system for their first year and then out-migrate in their second spring.

Coho and steelhead were divided into two populations for each species using the PGE mainstem dams as the point of demarcation (see Table 3-164). Both species are potentially present in almost all reaches of the Clackamas and tributaries. They have both been heavily influenced by management actions, including hatchery programs that differ in the upper and lower sections of the river. For this reason and in order to contrast habitat conditions between the upper and lower portions of the river, we delineated the two populations for each species.

The two coho populations were based on the biological characteristics of the Clackamas early-run coho population. Managers have defined two coho populations in the Clackamas based on differences in return timing, spawning area and origin (Cramer and Cramer, 1994). Native coho in the Clackamas River are the late-run coho that spawn mainly in the reaches between the PGE dams and Roaring River (Doug Cramer, personal communication). The Lower Columbia River Technical Review Team has designated this late-returning life history as Type N coho (WLC-TRT, 2003b). They enter the river late and spawn as late as February and March (Doug Cramer, personal communication). Early-run coho spawn throughout the river but originate from hatchery outplants. These fish spawn in late fall and are designated at Type S coho life history (WLC-TRT, 2003b). While the late-run coho probably originated from native Clackamas River coho, their late spawning time may have been skewed by intense harvest pressure in the past years (Doug Cramer, personal communication). Because our intent was to characterize habitat conditions and not , at this time, to explore the implications of habitat effects on coho life histories, we used the early returning, Type N life history to characterize coho habitat in the Clackamas River.

Geographic Setting. The Clackamas River drains a watershed of 941 square miles and is the fourth largest watershed within the Willamette Basin. The Clackamas enters the Willamette at RM 25.1 and is the largest watershed in the Willamette River below Willamette Falls (RM 26.8). The river has several major tributaries, including Deep, Clear and Eagle creeks in the lower Clackamas and Collowash River and Oak Grove Fork in the upper basin (see Appendix X). The upper two-thirds of the watershed consists of relatively high-gradient mountainous reaches, while the lower section drains a gentler topography. The upper sections of the river are heavily forested, and much of the upper watershed is within the Mt. Hood National Forest. The lower portion of the watershed is more developed and becomes increasingly urbanized toward the mouth of the river. The city of Estacada is the largest city entirely within the watershed, although the Portland suburbs of Glastone, Johnson City, and Oregon City are located at the mouth of the river.

PGE operates dams on the mainstem not far above the city of Estacada at Clackamas RM 23. The PGE operation consists of River Mill Dam, Faraday Diversion Dam, and North Fork Dam (see Appendix H for a map of the Clackamas Subbasin showing these dams). These dams operate as a complex, with the main reservoir located behind North Fork Dam. Migrating juvenile and adult fish are passed around these dams through a system of pipes and ladders (Cramer and Cramer, 1994). PGE also operates a power production facility on the Oak Grove Fork. Harriet Lake Dam diverts most of the stream flow from Oak Grove out of the watershed to Three Lynx Powerhouse near Frog Lake. Anadromous fish passage is blocked below Harriet Lake Dam by a natural waterfall at River Mile 3.8 (USFS, 1996).

The Clackamas River drains the lower east side of the Willamette Valley, which is a broad, north-south trending valley formed by the Coast Range to the west and the Cascade Mountains to the east. The floor of the valley has been filled by alluvial deposits of the Willamette drainage and by deposits from Missoula Floods that occurred at the close of the last glaciation (Orr and others, 1976). The Clackamas arises from the flanks of Mt. Hood in the Cascade Mountains in the High Cascades geological province (Orr and others, 1976). This consists of relatively young volcanic deposits that have not yet developed a complete drainage network (Grant, 1997). The rocks are highly porous, and much of the area's precipitation is absorbed within the bedrock. This water is released through springs that maintain relatively high summer flow in the Clackamas compared to other streams in the Willamette (Grant, 1997). As the river flows to the west, it drains the older Western Cascades province. These volcanic rocks are less porous and have a well-developed drainage network. As a result, streamflow in the lower watershed largely tracks rainfall precipitation patterns (USFS, 1995), such that summer flow in the upper Clackamas basin is relatively high compared to summer low flow in the lower basin (see Figure 3-35).

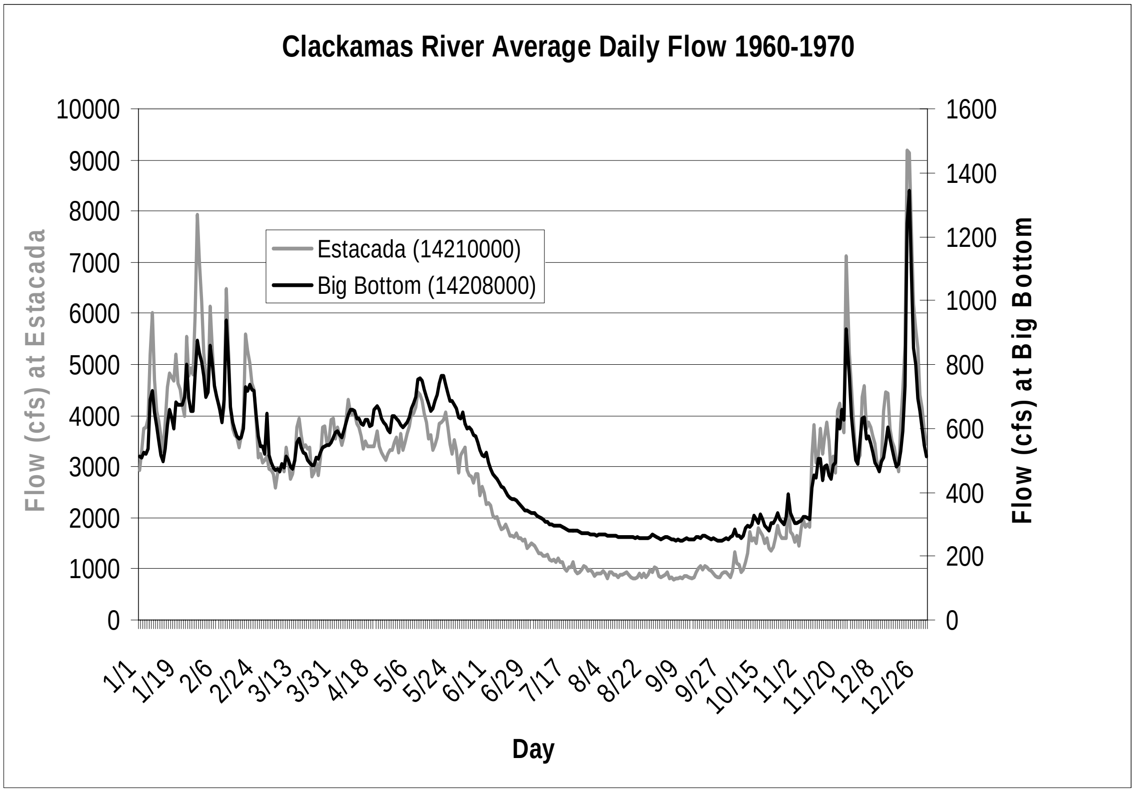


Figure 3-35: Flow in the Clackamas River in the Upper Watershed (Big Bottom) and Lower Watershed (Estacada)

Key Findings. Figure 3-36 displays the results of the EDT analysis for all the EDT geographic areas in the Clackamas for all species and populations combined. The figure shows the effect of degrading conditions further (protection priority) and of restoring conditions (restoration priorities) in each geographic area on the equilibrium abundance of each of the six populations. Protection priorities describe how the Clackamas system currently operates. Restoration priorities describe the potential of each area in terms of what might be possible with restoration. Table 3-165 shows the relative ranking of each EDT geographic area with regard to overall protection and restoration potential for all six populations combined.

Table 3-165: Overall Protection and Restoration Ranks for Each of 15 Geographic Areas in the Clackamas River Across Three Species and Six Populations

Geographic Area (15 total areas)	Protection Rank	Restoration Rank
Portland	15	2
Lower Clackamas	1	1
Deep Cr.	10	5
Clear Cr.	8	4
Eagle Cr.	5	6
North Fork Eagle Cr.	7	7
Lower Clackamas Tributaries	14	12
Middle Clackamas	3	3
Fish Cr.	12	13
Roaring R.	13	14
Middle Clackamas Tributaries	11	15
Upper Clackamas	2	8
Collowash R.	4	10
Hot Springs Fork	9	11
Upper Clackamas Tributaries	6	9

Generally, upper Clackamas areas had higher protection value than restoration value (see Figure 3-36). This indicates that habitat conditions in the upper Clackamas areas are generally good, making protection a priority over restoration. In the lower Clackamas areas, the reverse was the case. Conditions are generally poor and restoration of habitat was a greater priority than was protection of current conditions. However, areas can have both a high protection and a high restoration priority. This indicates that even though current conditions are degraded (and therefore there is restoration potential), these areas are still key to the current biological performance of the population (and therefore have a high protection value).

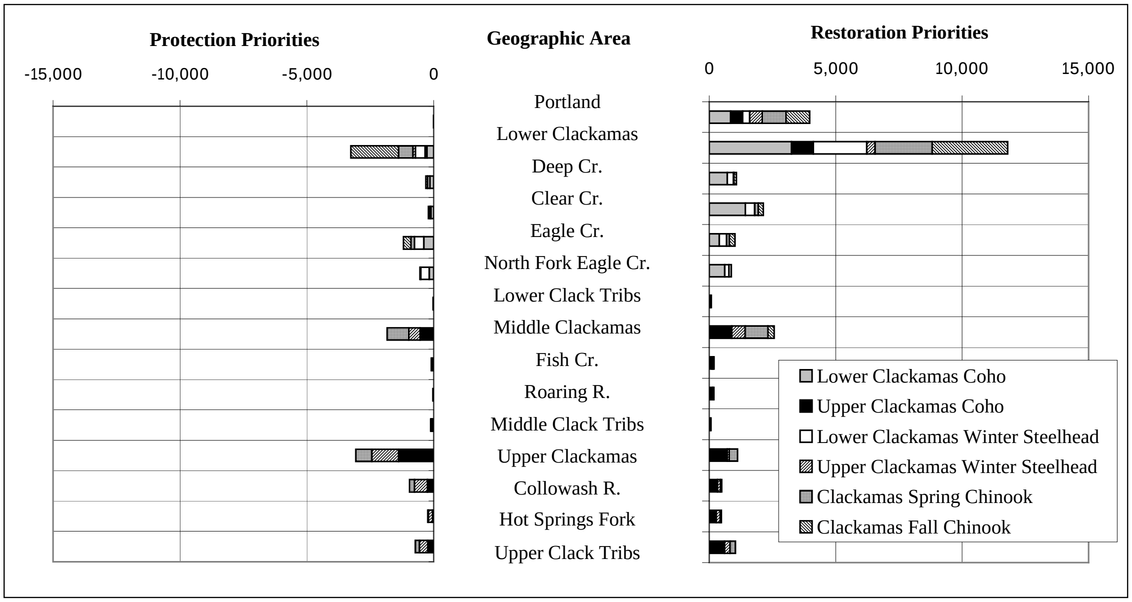


Figure 3-36: Protection and Restoration Priorities for Each Geographic Area in the Clackamas River in Regard to Abundance of All Six Focal Populations

The lower Clackamas mainstem is a good example of this. The lower Clackamas mainstem area had the number one rank in the entire assessment for both protection and restoration (see Table 3-162). Conditions in the lower mainstem are clearly important to all six populations (see Figure 3-36). As will be discussed later, the lower mainstem area is degraded but has a key biological function for all six populations. The Portland area (lower Willamette) had the lowest protection ranking of all areas in the assessment but was ranked second in terms of overall restoration benefit for the Clackamas River (see Table 3-165).

Currently, because of habitat limitations, adults and juveniles appear to use the lower Willamette largely as a migration corridor for which current habitat conditions are not limiting—life histories that might use the lower river for juvenile growth and rearing are trimmed out of the model because of current habitat conditions, leaving only those that move through the area quickly. However, under the EDT restoration scenario, the lower Willamette added considerable juvenile rearing capacity to the Clackamas and significantly increased potential abundance of the Clackamas populations.

To summarize, key conclusions of the EDT analysis are as follows:

- The current potential of habitat in the Clackamas River with respect to the six focal species is about 16 percent of that under the reference condition.
- Habitat constraints in the Clackamas River are most severe in the lower portion of the river (below the PGE dams). As a result, most of the restoration opportunities in the Clackamas River lie in the lower reaches.
- With the exception of the reaches inundated by the PGE dams, habitat in the upper basin (above the PGE dams) is in relatively good shape; most protection opportunities, as a result, lie in the upper watershed.

EDT Approach. EDT (Mobrand Biometrics, 2004) was the primary tool used to assess habitat conditions in the Clackamas River with regard to three native salmonid fish species: coho salmon, Chinook salmon, and steelhead trout. EDT relates a reach-level environmental description to the life stage and population performance of the focal species. The purpose of the assessment was threefold:

- To estimate the potential of the focal species in the Clackamas River given current habitat conditions
- To prioritize areas within the Clackamas in regard to their potential protection and restoration value
- To identify specific factors constraining the current performance of the focal species in the Clackamas River

The assessment was based on existing data sources, including habitat assessments from USFS, ODFW, the Clackamas River Basin Council, and others. Information was gathered and reviewed by a technical team composed of technical representatives from Clackamas County, ODFW, PGE, and the basin council.

This assessment was conducted to determine the potential of habitat in the Clackamas River and lower Willamette River with respect to the three focal species. It is a guide to restoration, rather than a predictor of future events. The abundance of fish that actually return to the Clackamas River is the result of many factors in addition to local habitat conditions. These broader factors include conditions in the ocean, where the fish spend the majority of their lives, and a host of anthropogenic factors, including harvest rates and hatchery practices. Fish populations are constantly being adjusted by natural selection to adapt to these nonhabitat factors, in addition to the conditions in the Clackamas River. Over the last several decades, fish have been affected by dramatic changes in ocean climatic regimes, wide fluctuations in harvest, and changing hatchery policies. As a result, current populations may be “out of sync” and still trying to adapt to their rapidly changing conditions and rebuilding from past events. For these reasons, this assessment should be used as a guide to habitat constraints and opportunities in the Clackamas River; expectations of benefits should be moderated by the realization of the complex environment that determines actual fish abundance and persistence over time.

EDT was used to characterize the potential biological performance of the focal species under two scenarios: the current condition scenario and the restored reference condition scenario. The current condition scenario was based on empirical data and expert observations of environmental conditions in the Clackamas River today. The restored reference condition scenario provided a point of comparison. This is a representation of the Clackamas River in a fully restored condition and is analogous to a presettlement condition that might have existed in the early 19th century. The intent, however, was not to recreate a specific historical condition but to describe the inherent potential of the system if it were unencumbered by anthropogenic modifications. The change in potential performance of the focal species in the current condition relative to the idealized reference condition described the constraints on the system is due to anthropogenic factors. A third scenario, the degraded condition scenario, is automatically generated from EDT by setting most environmental attributes to a fully degraded condition. Conditions were assessed with respect to the focal species by comparing the current condition of the Clackamas at reach and larger scales to the degraded and restored conditions.

Following the assessment of conditions, we used EDT to characterize a fourth condition, termed PFC, or properly functioning conditions. PFC is a set of attribute ratings in EDT that define an environmental condition that is consistent with productive salmon populations in the Pacific Northwest. The PFC condition lies between the current condition and the restored reference condition. PFC conditions for EDT have been developed by an interagency team organized by the Washington Department of Fish and Wildlife and the Northwest Indian Fisheries Commission. The use of the PFC scenario in this analysis is intended to illustrate an environmental condition that is likely to result in robust fish populations in the Clackamas River but that is still not equal to the historical potential of the river or the restored reference scenario. PFC is not, however, necessarily advocated by any group as a feasible or target condition for the Clackamas River.

The assessment of the Clackamas was organized hierarchically. At the finest scale, information was developed for stream reaches that described the physical and biological environment of the stream. A total of 215 stream reaches were described throughout the Clackamas system (see Appendix I for reach-break maps). Reaches were defined by the technical team based on geomorphic and land use criteria. In some portions of the watershed, the team used reaches that had been defined for other stream surveys, especially those conducted in the watershed by the Oregon Department of Fish and Game as part of its Aquatic Inventory Project (Moore and others, 1997). Stream reaches for the EDT assessment also included 51 obstruction reaches. In EDT, an obstruction such as culvert or dam is treated as a reach and hydrologically routed to other reaches. Each obstruction was rated by the technical committee as to its impediment to upstream or downstream movement of adult and juvenile fish.

Reaches were grouped into 14 geographic areas (see Table 3-166) throughout the Clackamas watershed. An additional area (the Portland area) added the Willamette River from the mouth of the Clackamas to the Columbia River. Geographic areas are groupings of stream reaches that are used to summarize the detailed stream reach results. Areas corresponded to major tributaries or sections of the mainstem. Smaller tributaries were grouped into separate groups (see Table 3-166). Geographic areas were organized into three sections corresponding to the major geomorphic divisions of the river. For this subbasin plan, information is presented at the level of the geographic areas in Table 3-166. However, reach-level assessment of conditions for each life stage in each reach are available from the EDT assessment.

Table 3-166: Geographic Structure of EDT Assessment of the Clackamas River

Clackamas River EDT Structure

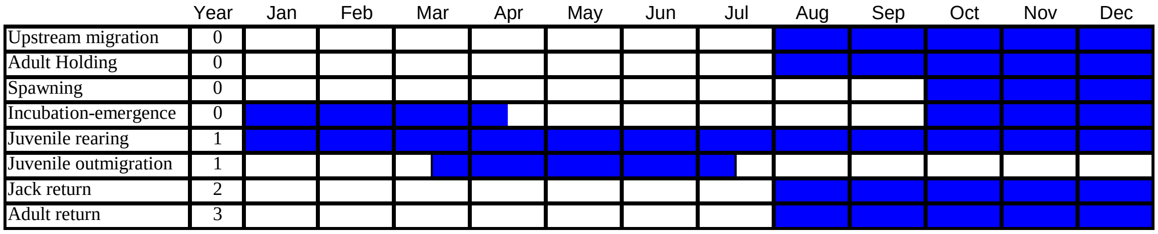
Section	Geographic Areas	Included streams
Lower Clackamas	Lower Clackamas	
	Lower Clack Tribs	
		Rock Cr.
		Richardson Cr.
		Foster Cr.
		Goose Cr.
		Cow Cr.
		Sieben Cr.
	Clear	
	Eagle	
	N. Fork Eagle	
	Deep	
		Tickle Cr.
PGE Dam complex (RM 23)		
Middle Clackamas	Middle Clackamas	
	Middle Clack Tribs	
		N. Fork Clackamas
		S. Fork Clackamas
		Sandstone Cr.
		Big Cr.
		Whale Cr.
		Cripple Cr.
		S. Fork Cripple Cr.
	Fish	
	Roaring	
Oak Grove Fork (RM 49)		
Upper Clackamas	Upper Clackamas	
	Upper Clackamas Tribs	
		Oak Grove Fork
		Tag Cr.
		Trout Cr.
		Pot Cr.
		Wolf Cr.
		Kansas Cr.
		Pinhead Cr.
		Last Cr.
		Lowe Cr.
		Rhododendron Cr.
		Fawn Cr.
		Hunter Cr.
		Cub Cr.
		Berry Cr.
	Collawash	
	Hot Springs	

EDT Results. EDT assesses habitat in terms of four output parameters: biological capacity (quantity of habitat), biological productivity (quality of habitat), equilibrium abundance (quantity and quality of habitat), and life history diversity (breadth of suitable habitat). These output parameters assess habitat in regard to three assessment products:

- **Population Potential**. This is the four output parameters for each of the six populations (Table 3-164) as a function of the habitat in the Clackamas River and the lower Willamette River.
- **Protection and Restoration Priorities.** Spatial differences between geographic areas within the Clackamas River were summarized as the protection and restoration value of each geographic area (Table 3-166 plus the Portland area) for each population. Protection priority is defined as the percent change in an EDT output parameter when the current values for all attributes in a geographic area are set to a highly degraded condition, whereas restoration priority is the percent change in an EDT output parameter when the current values for all attributes in a geographic area are set to a restored condition.
- **Attribute Effects (Limiting Factors).** The effect of individual attributes was assessed as the change in an EDT output parameter that occurred when the value for an individual attribute in a geographic area was set to its value in the restored condition. The results are summarized in "dot diagrams" in which the size of a dot is proportional to the change in productivity as a result of setting the EDT attribute to its restored value.

EDT Habitat Assessment by Population

Lower Clackamas Coho. The lower Clackamas River coho population was defined to spawn in the mainstem and all tributaries below River Mill Dam. Coho in the lower river are mainly early-run fish of hatchery origin, although a few late-run fish may be present (Doug Cramer, personal communication). For purposes of this habitat assessment, we have focused only on the early-run portion. The life history of this population is based on Clackamas early-run coho as described in Cramer and Cramer (1994). Early-run coho in the Clackamas are a Type S population (WLC-TRT 2003b) because they enter the Clackamas River in August and spawn in October and November (Cramer and Cramer 1994) (Figure 3-37). Natural spawners have been observed throughout the Clackamas basin below River Mill Dam (Cramer and Cramer 1994). Early-run coho in the Clackamas are of hatchery origin and the returns to the river are predominantly of hatchery origin. Fish are released from Eagle Creek National Fish Hatchery and in other lower river tributaries.



	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upstream migration	0								■	■	■	■	■
Adult Holding	0								■	■	■	■	■
Spawning	0										■	■	■
Incubation-emergence	0	■	■	■	◧						■	■	■
Juvenile rearing	1	■	■	■	■	■	■	■	■	■	■	■	■
Juvenile outmigration	1			◨	■	■	■	◧					
Jack return	2								■	■	■	■	■
Adult return	3								■	■	■	■	■

Figure 3-37: Generalized Early Returning (Type S) Coho Life History

Coho fry emerge from eggs around April. They spend the next year in the tributaries and mainstem and out-migrate from the Clackamas the following spring after one year in freshwater. Precocious males (jacks) return the next fall after less than 1 year in the ocean. The remaining adults spend one more year in the ocean to return to spawn as 3-year old fish.

Coho is not a federally listed species in the Willamette or lower Columbia River. No ESU is applicable to this population and the Lower Columbia TRT has not designated populations. In its status review of lower Columbia River coho, NOAA Fisheries designated a single Clackamas River coho population (Myers and others, 1998). The lower river population used in this assessment would be a part of the NOAA Fisheries population.

The most complete enumeration of returning salmon in the Clackamas River is the ladder count at North Fork Dam (Figure 3-38). While this count applies to coho that have passed the lower river reaches that apply to the lower Clackamas coho population, the trend in early-returning coho at North Fork provides an indication of the trend in abundance of this population. No clear trend in the count in Figure 3-38 is evident, although counts since the mid-1970s have are generally greater than the count in the previous decade. This is likely the result of a decrease in commercial harvest rates over the period and precipitous drop in harvest in 1994 as a result of more restrictive harvest regulation. During the 1960s and 70s, harvest rates on were around 85 to 95 percent; after 1994, rates have been between 10 and 20 percent (WLC-TRT, 2003b). Return of coho to at North Fork Dam since 1970 has averaged 720 adults and has varied widely from a low of a 54 to a high of 2,196.

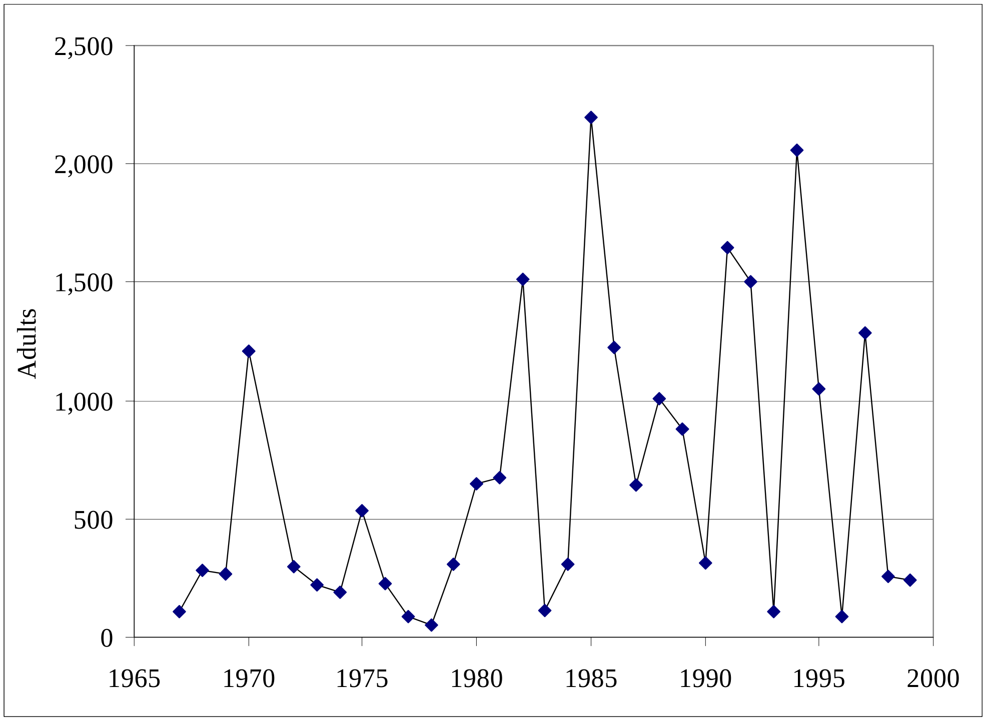


Figure 3-38: Count of Adult Early Returning Coho at North Fork Dam

Source: StreamNet

For the lower Clackamas population specifically, the Oregon Department of Fish and Game (ODFW) estimated 2,402 natural spawners in the area below North Fork Dam in 2002. As noted above, early-run coho are released from Eagle Creek Hatchery; ODFW estimated that 78 percent of the naturally spawning fish were of hatchery origin (WLC-TRT, 2003b).

The habitat potential for coho in the lower Clackamas has been greatly reduced as a result of habitat modification relative to the EDT reference condition (Figure 3-39). Current abundance potential is 91 percent less than the potential under the reference condition. Productivity, a measure of habitat quality, is reduced by 86 percent. With harvest, current productivity is estimated to be only 1.6 (Figure 3-39). Given the expected ranges of natural environmental variation and events, it is questionable whether natural production of coho is sustainable in the lower Clackamas River under the present habitat condition. In fact, much of the observed current natural production of coho in the lower Clackamas River is of hatchery origin (WLC-TRT 2003b). Potential coho life history diversity, as a function of the breadth of suitable habitat conditions, has been reduced by more than half. This indicates a considerable narrowing of the area and time (within a year) for suitable coho habitat in the lower river.

Lower Clackamas Coho

Scenario	Diversity index	Productivity	Abundance
Current without harvest	41%	1.8	704
Current with harvest	38%	1.6	492
Reference potential	99%	13.4	8,262

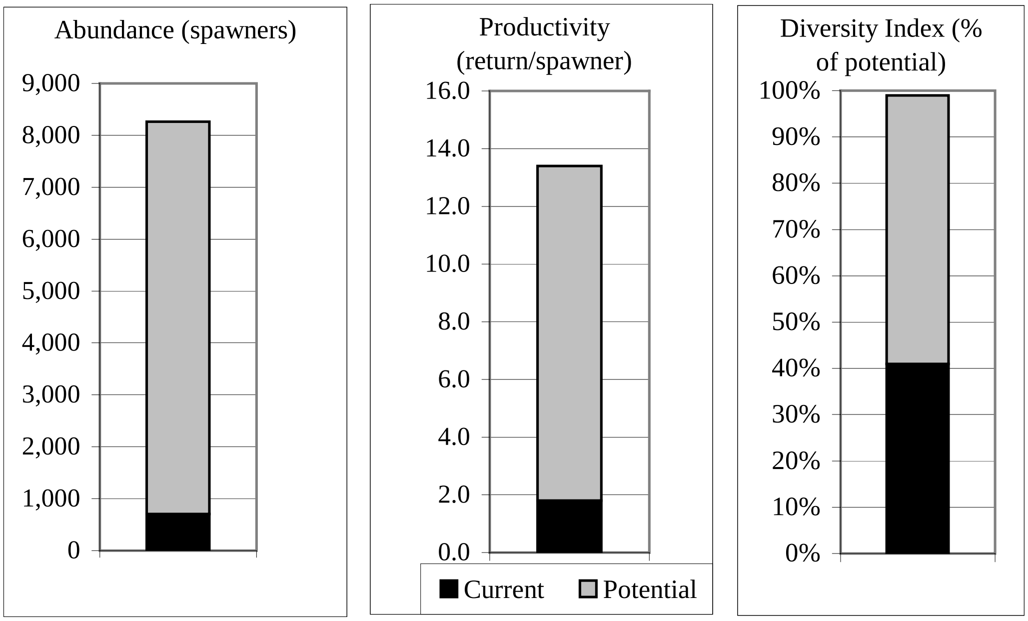


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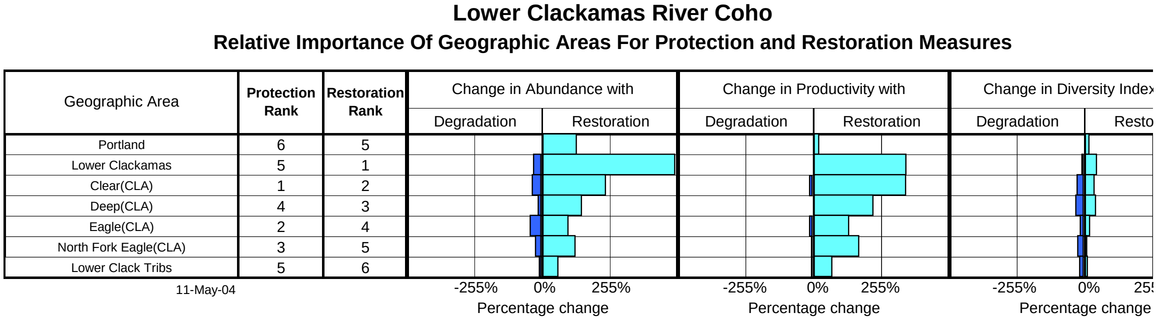
Figure 3-39: EDT Estimates of Habitat Potential in the Lower Clackamas River for Coho Salmon

Numbers in graphs are without harvest.

All reaches used by this population had low protection value (Figure 3-40), indicating that current conditions are degraded and that coho potential is greatly restricted in the current habitat condition. Clear Creek has the greatest current habitat potential (therefore greatest protection value), followed by Eagle and North Fork Eagle creeks. The pattern of protection priorities with respect to the diversity index also stressed the value of the tributary reaches.

Lower Clackamas, Deep Creek, and Clear Creek appear to support most of the present diversity of habitat and range of potential coho life histories (Figure 3-40).



Geographic Area	Protection Rank	Restoration Rank
Portland	6	5
Lower Clackamas	5	1
Clear(CLA)	1	2
Deep(CLA)	4	3
Eagle(CLA)	2	4
North Fork Eagle(CLA)	3	5
Lower Clack Tribs	5	6

Figure 3-40: Lower Clackamas River Coho Habitat Priorities

Protection priorities are determined by the change in a performance attribute with degradation while restoration priories are given by the change in performance with restoration.

Restoration of the lower mainstem area has the greatest potential to increase abundance and productivity of coho in the lower Clackamas population (Figure 3-40). Not only does this area have the potential to provide coho spawning habitat, but conditions in the lower mainstem also affect trajectories started from all upstream reaches. Restoration of conditions in Clear, Deep, and North Fork Eagle creeks also has high potential to increase coho abundance and productivity.

The results in Figure 3-40 also indicate the close relationship between coho potential in the Clackamas and conditions in the lower Willamette. Restoration of the Portland reach had the fifth greatest impact on abundance of coho for all the reaches affecting this population and was on par with most of the major lower river tributaries in terms of its impact on coho abundance in the lower Clackamas River. This primarily reflects the potentially large capacity of the lower Willamette for juvenile life stages that can add to the Clackamas populations.

Figure 3-41 shows the relative contribution of individual habitat attributes to the restoration benefits in Figure 3-40. The quantity of habitat for coho in the lower Clackamas area has declined in every area (key habitat quantity in Figure 3-41). This is the result of loss of off-channel areas (important overwintering habitat for juvenile coho) and the narrowing of the channel as a result of diking and encroachment of roads and other development along the streambank.

Lower Clackamas River Coho
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration																
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Portland		∘		●	•		•	•	⬤	•			•	•		•		●
Lower Clackamas	∘	◯	●	•	●	•	•	•	⬤	•			•	●	●	•		●
Clear(CLA)	◯	○		•	•		•	•	●		⬤		•	•	•	•		●
Deep(CLA)	∘	○		•			•	•	●		⬤			•	●	●		●
Eagle(CLA)	○	∘			•		•	•	⬤		●		•	•	•	•		•
North Fork Eagle(CLA)	○	∘			•		•	•	●		●				•	•		●
Lower Clack Tribs	∘		•	•		•	•	•	●	•					●	•		●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority

◯ ⬤	High	○ ●	Medium	∘ •	Low		Indirect or General

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Figure 3-41: Lower Clackamas River Coho Habitat Attribute Priorities

The change in productivity with restoration of an attribute is given by the size of the black dot, which is proportional to the overall restoration value given by the open circles to the left. A large black dot in an area with little overall restoration value (given by the size of the open circle) indicates little change in performance with restoration of the attribute.

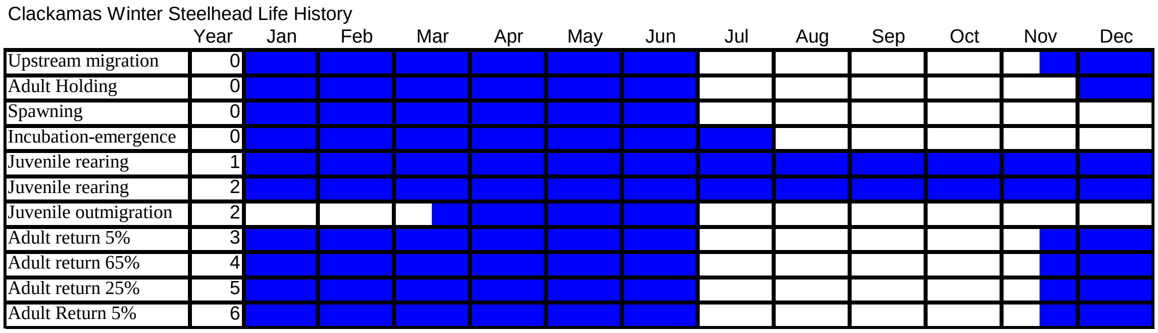
The quality of habitat in the lower Clackamas has declined primarily as a result of reduced habitat diversity, increased sediment, and increased temperature in summer (Figure 3-41). Habitat diversity is a function of the decline in large woody debris and channel simplification as a result of artificial confinement of the channel behind dikes. Summer water temperature was a limitation on summer rearing of coho in all areas of the lower Clackamas, especially in Deep Creek. Sediment was an important limiting factor in most areas in the lower Clackamas area but especially in Deep Creek and the lower Clackamas mainstem, as well as in other lower river tributaries.

Limiting factors for Clackamas coho in the lower Willamette (Portland) area were chemicals, habitat diversity, and loss of key habitat. The effect of chemicals reflects pollutants from a variety of local and upriver sources. The loss of habitat diversity and key habitat is a result of the overall channelization of the lower Willamette, the loss of wood and other structure, and elimination of much of the shallow water habitat (McConnaha 2003).

Obstructions (culverts) were key limitations in the tributaries. Obstructions were particularly important in Deep Creek and Clear Creek. This assessment included nine culverts in Deep Creek and five culverts in Clear Creek. Obstructions were a lesser problem in Eagle Creek, including the North Fork of Eagle Creek. This system has three natural waterfalls that have been laddered and two artificial obstructions.

Lower Clackamas Steelhead. The lower Clackamas River steelhead population was defined for this assessment to potentially spawn in all accessible reaches below River Mill Dam. This population displays the winter-run life history and is considered native to the Clackamas River (WLC-TRT 2003c).

Life history is based on the description of the Clackamas population provided by Hansen and others (2001). In contrast to coho, steelhead have a complex life history with a variety of patterns existing in the same populations. Figure 3-42 depicts the general winter steelhead life history. Winter steelhead return to the Clackamas in late fall. Spawning occurs through the first quarter of the year mainly into the spring. Fry emerge in the spring and summer. Juvenile steelhead rear from 1 to 4 years in the Clackamas, although the majority emigrate after a 2-year rearing period (Hansen and others, 2001). Steelhead spend from 1 to 4 years in the ocean. In the Clackamas, most return after 2 years (as 4-year-old fish) or 3 years (as 5-year-old fish) in the ocean (Hansen and others, 2001).



Clackamas Winter Steelhead Life History

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upstream migration	0	🟦	🟦	🟦	🟦	🟦	🟦					◨	🟦
Adult Holding	0	🟦	🟦	🟦	🟦	🟦	🟦						🟦
Spawning	0	🟦	🟦	🟦	🟦	🟦	🟦						
Incubation-emergence	0	🟦	🟦	🟦	🟦	🟦	🟦	🟦					
Juvenile rearing	1	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Juvenile rearing	2	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Juvenile outmigration	2			◨	🟦	🟦	🟦						
Adult return 5%	3	🟦	🟦	🟦	🟦	🟦	🟦					◨	🟦
Adult return 65%	4	🟦	🟦	🟦	🟦	🟦	🟦					◨	🟦
Adult return 25%	5	🟦	🟦	🟦	🟦	🟦	🟦					◨	🟦
Adult Return 5%	6	🟦	🟦	🟦	🟦	🟦	🟦					◨	🟦

Figure 3-42: Generalized Life History of Winter Steelhead in the Clackamas River

Clackamas River winter steelhead are part of the Lower Columbia River steelhead ESU (Busby and others, 1996). Within this ESU the TRT has recognized the Clackamas River winter steelhead population (WLC-TRT, 2003c). The lower Clackamas River steelhead population used in this analysis is the portion of the TRT population below River Mill Dam.

The return of winter steelhead to the Clackamas River has been in a general decline for the past several decades (Figure 3-43). Since 1970, the abundance at North Fork Dam as averaged 1,479 steelhead but has varied from 4,439 in 1970 to a low of 189 in 1998.

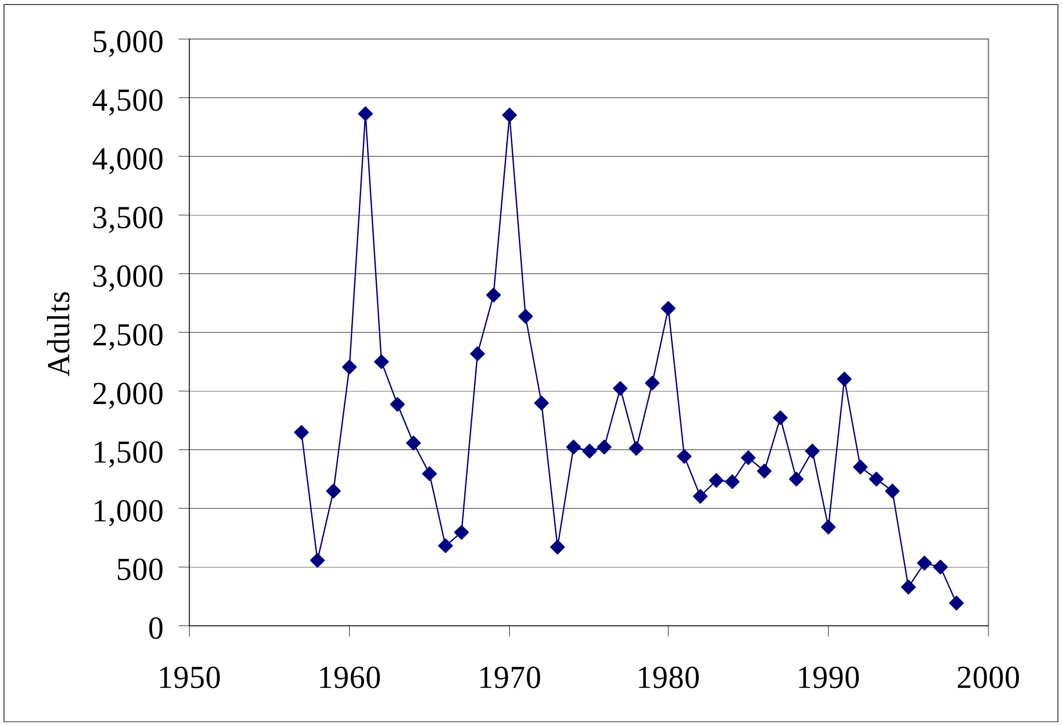


Figure 3-43: Abundance of Winter Steelhead at North Fork Dam

Source: StreamNet

Current habitat potential for steelhead is significantly constrained in the lower Clackamas River relative to the EDT reference condition (Figure 3-44). Current abundance potential is 86 percent less than the potential under the reference condition. Productivity, a measure of habitat quality, is reduced by 88 percent. Potential steelhead life history diversity, as a function of the breadth of suitable habitat conditions in the lower Clackamas, has been reduced by 54 percent.

Lower Clackamas Winter Steelhead

Scenario	Diversity index	Productivity	Abundance
Current without harvest	43%	2.4	833
Current with harvest	43%	2.4	833
Reference potential	93%	20.9	5,129

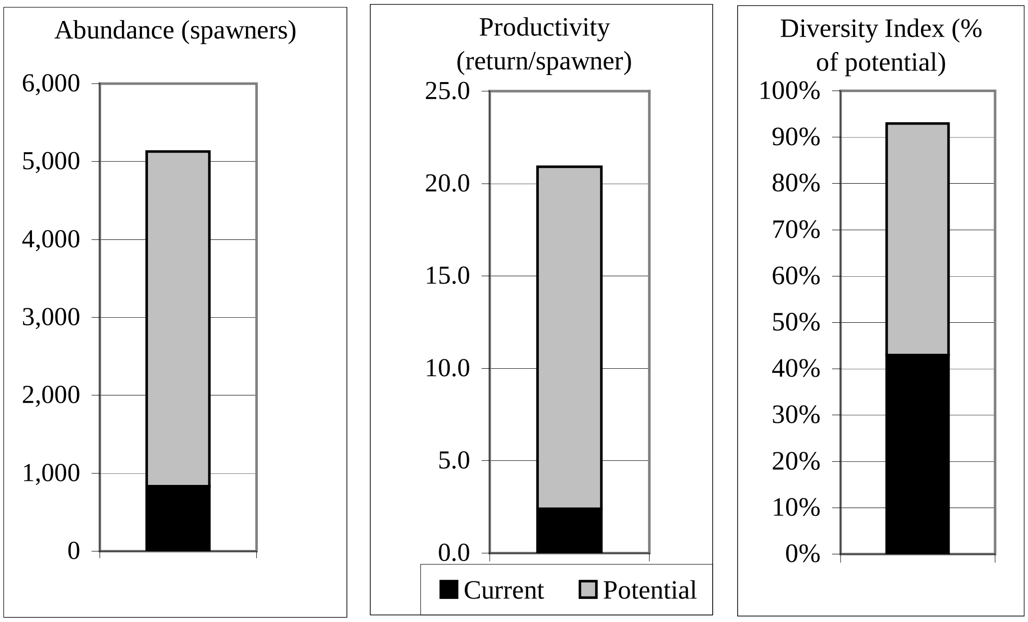


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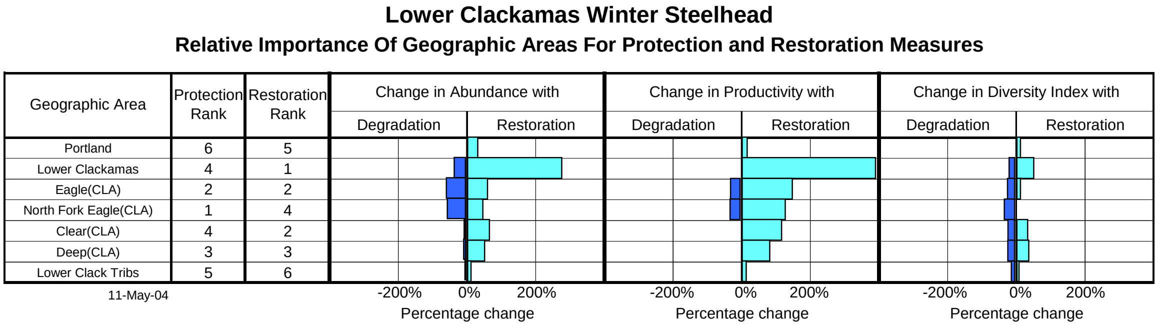
Figure 3-44: EDT Estimates of Habitat Potential in the Lower Clackamas River for Winter Steelhead

Steelhead harvest outside the Willamette Basin is considered to be zero.

Most areas used by this population had relatively low protection values in the EDT assessment, indicating that conditions are generally degraded in the lower Clackamas with respect to winter steelhead (Figure 3-45). The change to the current potential that occurred when conditions in each geographic area were degraded in the model indicates that the current abundance potential of steelhead in the lower Clackamas is heavily dependent on conditions in the lower Clackamas mainstem and the Eagle Creek watershed. The pattern of change in the diversity index with degradation (Figure 3-45) emphasizes the importance of conditions in the tributaries, especially Deep Creek, Eagle Creek and the North Fork Eagle Creek, in maintaining the current potential for life history diversity.



Lower Clackamas Winter Steelhead

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection Rank	Restoration Rank
Portland	6	5
Lower Clackamas	4	1
Eagle(CLA)	2	2
North Fork Eagle(CLA)	1	4
Clear(CLA)	4	2
Deep(CLA)	3	3
Lower Clack Tribs	5	6

11-May-04

Figure 3-45. Lower Clackamas River Winter Steelhead Habitat Priorities

Protection priorities are determined by the change in a performance attribute with degradation while restoration priories are given by the change in performance with restoration.

When conditions were set to the restored reference condition in each area, the greatest restoration value appeared in the lower Clackamas mainstem reaches (Figure 3-45). Clackamas tributaries and the Portland reach of the Willamette had lesser but collectively important restoration values for steelhead. Restoration of Clear Creek produced the greatest increase in steelhead life history diversity (diversity index) of any area in the lower Clackamas River.

Temperature was a limiting factor for steelhead in every area of the lower Clackamas River (Figure 3-46). The primary temperature impact on survival was on the egg incubation and early rearing stages during the spring and summer. Similar limitations were seen for juvenile coho (although not the egg incubation stage) in the lower Clackamas (Figure 3-41). Conditions in the lower Clackamas mainstem reaches, where overall restoration potential was the greatest, were limited by almost every survival factor, especially sediment and temperature (Figure 3-46). Factors associated with hatcheries, such as competition with hatchery fish and pathogens, were also significant for steelhead in the lower mainstem reaches. As with coho, obstructions in Deep Creek and especially Clear Creek were limiting. Clear Creek was also adversely affected by pathogens because of the presence of whirling disease in a trout hatchery on the stream.

Lower Clackamas River Winter Steelhead
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Portland	∘	∘		●	•		•		•	•			•	•				•
Lower Clackamas	○	◯	•	•	●	•	•	•	•	•			●	●	●	●		•
Eagle(CLA)	◯	○			•		•		•		●		•	•	•	●		•
North Fork Eagle(CLA)	◯	∘			•		•				●		•	•	●	•		●
Clear(CLA)	○	○		•			•	•	•		⬤		●	•	•	●		•
Deep(CLA)	○	○		•			●		•		⬤		•	•	●	●		●
Lower Clack Tribs	∘			•			●	•	•	•			•	•	●	●		●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority

◯ ⬤	High	○ ●	Medium
∘ •	Low		Indirect or General

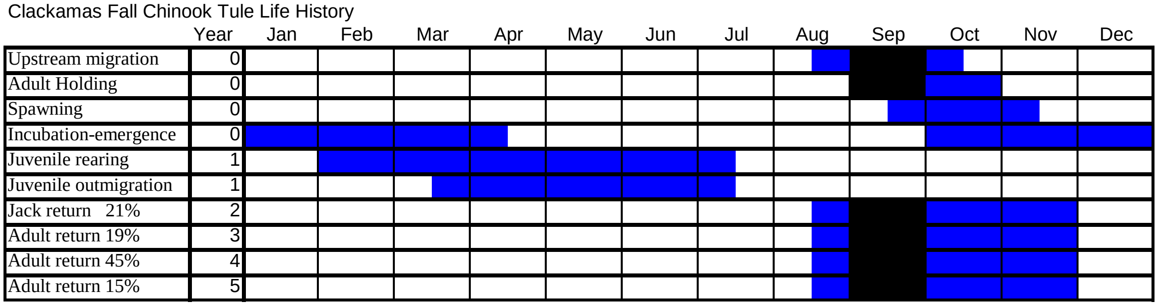
11-May-04

Figure 3-46: Lower Clackamas River Steelhead Habitat Attribute Priorities

The change in productivity with restoration of an attribute is given by the size of the black dot, which is proportional to the overall restoration value given by the open circles to the left. A large black dot in an area with little overall restoration value (given by the size of the open circle) indicates little change in performance with restoration of the attribute.

Lower Clackamas Fall Chinook. Fall Chinook in the Clackamas River are largely confined to the mainstem below River Mill Dam and the lower reaches of the major tributaries in the lower river (Doug Cramer, PGE, personal communication). Historically they probably extended up through the Middle Clackamas reaches. Fall Chinook are native to the Clackamas River; however, the population was extirpated in the mid-1930s because of poor water quality in the lower Willamette. The run was reestablished from lower Columbia River hatchery stocks; however, stocking ceased in the early 1980s and the run is now supported by natural production (WLC-TRT 2003a).

The population is part of the lower Columbia River fall Chinook group (Howell and others, 1985) and is considered a tule life history. Columbia River tule fall Chinook are an important component of commercial harvest off Oregon, Washington, and southern British Columbia. Fall Chinook are released in large numbers from several lower Columbia River hatcheries to support these fisheries (Mobrand Biometrics, 2003), although fall Chinook in the Clackamas are natural spawners. In contrast to other salmonid species considered in this assessment, fall Chinook spend a relatively short time in freshwater (Figure 3-47). Adults enter the river in August with peak returns in September. Spawning commences soon after entry to the Clackamas in September and October. Chinook fry emerge in the spring. Juvenile fall Chinook spend relatively little time in the Clackamas and begin moving downstream toward the estuary during the spring and summer.



Clackamas Fall Chinook Tule Life History

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upstream migration	0								⬜🟦	⬛⬛	🟦⬜		
Adult Holding	0									⬛⬛	🟦🟦		
Spawning	0									⬜🟦	🟦🟦	🟦⬜	
Incubation-emergence	0	🟦🟦	🟦🟦	🟦🟦	🟦⬜						🟦🟦	🟦🟦	🟦🟦
Juvenile rearing	1		🟦🟦	🟦🟦	🟦🟦	🟦🟦	🟦🟦	🟦⬜					
Juvenile outmigration	1			⬜🟦	🟦🟦	🟦🟦	🟦🟦	🟦⬜					
Jack return 21%	2								⬜🟦	⬛⬛	🟦🟦	🟦🟦	
Adult return 19%	3								⬜🟦	⬛⬛	🟦🟦	🟦🟦	
Adult return 45%	4								⬜🟦	⬛⬛	🟦🟦	🟦🟦	
Adult return 15%	5								⬜🟦	⬛⬛	🟦🟦	🟦🟦	

Figure 3-47: Generalized Life History of Clackamas River Tule Fall Chinook

Source: Howell and others, 1985.

Clackamas River fall Chinook are included in the Lower Columbia Chinook ESU (Myers and others 1998).

Fall Chinook are counted by ODFW in the lower Clackamas River (Figure 3-48). Since the mid-1960s, returns to the Clackamas River have generally declined. The estimated return has varied widely from a high of 1,385 fish in 1974 to a low of 20 fish in 1999. Returns over the period averaged 469 fish.

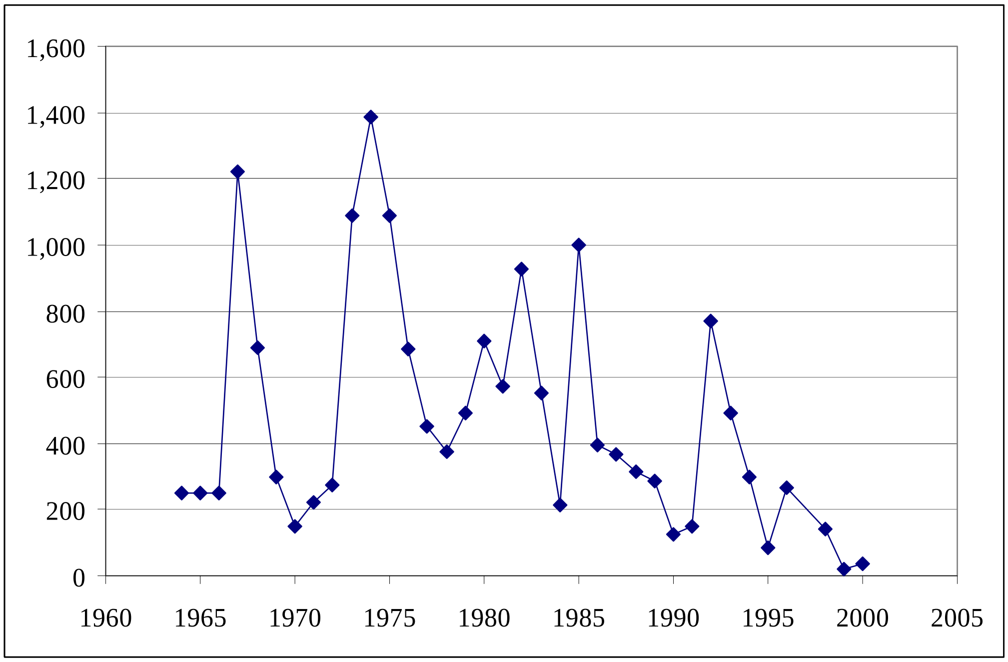


Figure 3-48: Estimated Abundance of Clackamas River Fall Chinook Below River Mill Dam

Source: StreamNet.

Current habitat potential of the lower Clackamas River for fall Chinook (without harvest) is about 24 percent of the potential under the restored reference condition (Figure 3-49). Harvest further reduces the estimated abundance potential of the habitat to 6 percent of the reference condition. Current estimated productivity with harvest is only 1.3—barely above replacement. With normal environmental variation and events, it is unlikely that the current habitat can support a sustainable natural population of fall Chinook in the Clackamas River. The life history diversity (diversity index) that could be expected from the current habitat breadth is about 62 percent of that expected under the reference condition. The current restriction on the diversity index is less than what was seen for other lower Clackamas salmon populations. This is because fall Chinook mainly use the mainstem and do not ascend far up the tributaries. The mainstem is a relatively uniform habitat unit that would be expected to produce a relatively uniform life history response compared to the varied solutions used by other species to exploit tributary and mainstem habitats. Although the habitat quality and quantity of the mainstem has declined, reducing productivity and capacity, the range of potential life histories has declined to a lesser degree.

Lower Clackamas Fall Chinook

Scenario	Diversity index	Productivity	Abundance
Current without harvest	62%	2.2	1,904
Current with harvest	49%	1.3	466
Reference potential	100%	9.5	7,816

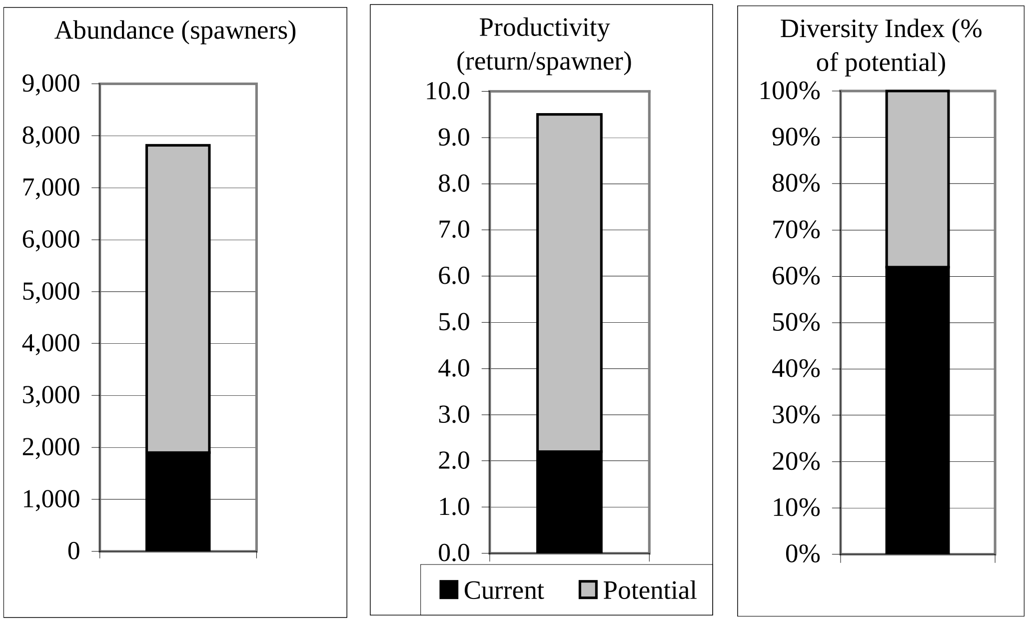


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Figure 3-49: EDT Estimates of Habitat Potential in the Lower Clackamas River For Fall Chinook

Numbers in graphs are without harvest.

Because fall Chinook typically spawn in larger tributaries and rivers, it is not surprising that the lower Clackamas area (lower mainstem reaches) had almost all of the protection value under current conditions (Figure 3-50); degradation of conditions in the lower mainstem in the model eliminated almost all fall Chinook. The lower reaches of the tributaries added some value for the diversity index.

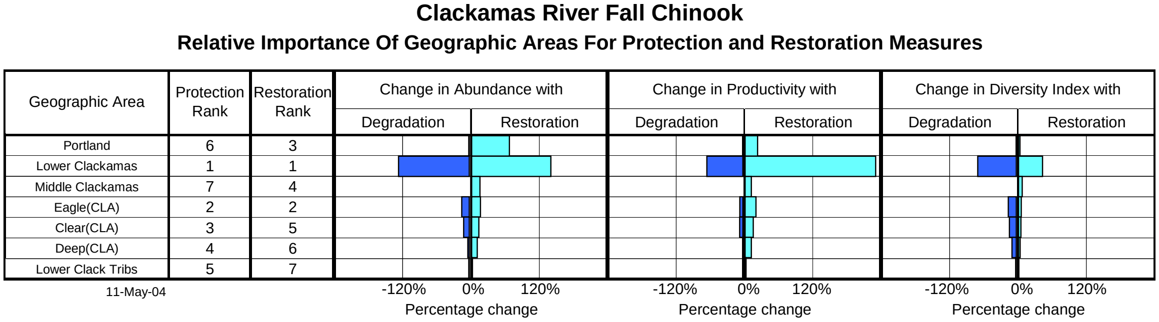

Figure 3-50: Clackamas River Fall Chinook Habitat Priorities

Protection priorities are determined by the change in a performance attribute with degradation while restoration priories are given by the change in performance with restoration.

Restoration value was similar, with almost all of the restoration value being in the lower mainstem area (Figure 3-50). The Portland area of the Willamette provided the second highest restoration value for Clackamas fall Chinook. Under a restored condition, the lower Willamette adds considerable rearing habitat that would be used by juvenile fall Chinook as they move toward the estuary.

The major factor limiting fall Chinook production in the Clackamas River is water temperature during the late summer and fall (Figure 3-51). Water temperature in the lower Clackamas during September, when fall Chinook spawn, was rated high enough to preclude successful spawning of fall Chinook until temperatures moderated in October. Sediment, habitat diversity and channel stability were also rated as important limiting factors for fall Chinook in the lower mainstem.

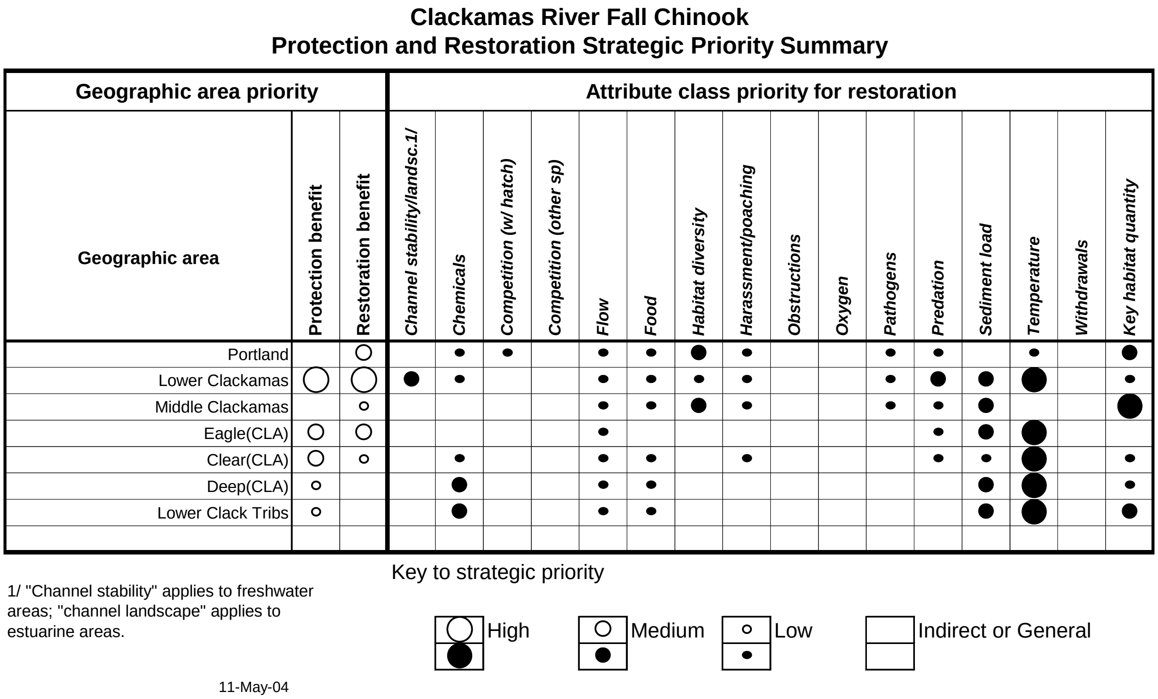

Figure 3-51: Clackamas River Fall Chinook Habitat Attribute Effects

The change in productivity with restoration of an attribute is given by the size of the black dot, which is proportional to the overall restoration value given by the open circles to the left. A large black dot in an area with *little overall restoration value (given by the size of the open circle) indicates little change in performance with restoration of the attribute.*

Upper Clackamas Coho. Upper Clackamas coho were defined to potentially spawn in the mainstem and tributaries above North Fork Dam. Naturally spawning coho in the upper Clackamas River are almost entirely composed of the early-returning life history (Cramer and Cramer, 1994). The native late-returning segment does not appear to do well in the upper basin, perhaps because water temperatures are too low in the upper basin by the time the later fish arrive (Cramer and Cramer, 1994). Population characteristics of the early returning coho were described above and in Cramer and Cramer (1994).

Coho is not a federally listed species in the Willamette or lower Columbia River. No ESU is applicable to this population, and the Lower Columbia TRT has not designated populations. In its status review of lower Columbia River coho, NOAA Fisheries designated a single Clackamas River coho population (Myers and others 1998). The upper river population used in this assessment would be a part of the NOAA Fisheries population.

Figure 3-38 shows the count of adult coho at North Fork Dam as an index of population trend. Although counts have varied widely over the period, the trend is generally positive, probably reflecting the large decrease in commercial harvest on coho in 1994 (WLC-TRT 2003b). In contrast to the lower Clackamas population that receives considerable supplementation from hatcheries, the ODFW estimated in 2002 that the count of coho at North Fork Dam was only 12 percent hatchery fish (WLC-TRT 2003b).

Although significantly habitat constraints exist for coho in the upper Clackamas River, habitat is less degraded than it is in the lower river. The current abundance potential of upriver habitat is 32 percent of the reference (Figure 3-52) compared to about 8.5 percent for the lower river population (Figure 3-39). Productivity of coho in the upper basin is about 4.0, compared to 1.3 in the lower river; the upper basin likely has the potential to sustain a naturally producing population in contrast to the lower basin. Potential life history diversity (diversity index) for the coho in the upper basin is 73 percent compared to 41 percent for coho in the lower river. This indicates that the general structure of habitat in the upper basin, in terms of times and areas of suitable habitat conditions, remains relatively intact, even though the quality and quantity of habitat is reduced compared to the reference condition.

Upper Clackamas Coho

Scenario	Diversity index	Productivity	Abundance
Current without harvest	70%	4.7	2,202
Current with harvest	68%	4.0	1,829
Reference potential	96%	13.1	6,785

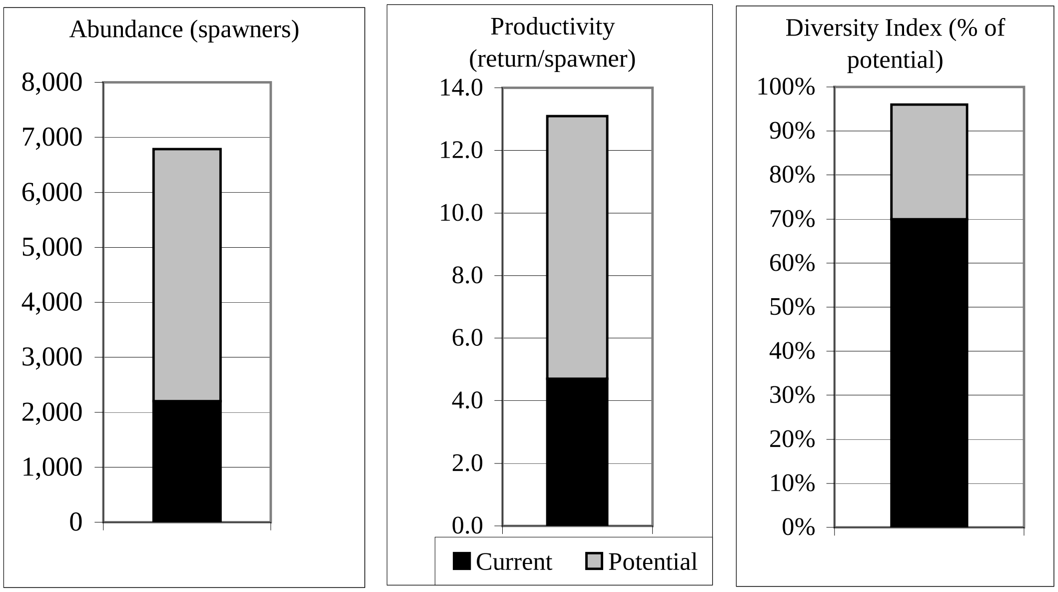

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Figure 3-52: EDT Estimates of Habitat Potential in the Upper Clackamas River for Coho Salmon

Numbers in graphs are without harvest.

Current habitat potential for coho in the upper Clackamas area is concentrated in the upper Clackamas mainstem (above Oak Grove Fork), Middle Clackamas mainstem (Oak Grove Fork to North Fork Dam), and Collowash River areas (Figure 3-53). The upper Clackamas area includes the Big Bottom area that is generally considered to be the most intact habitat in the Clackamas River (USFS 1995). The present life history diversity (diversity index) reflects the diversity of habitats areas in the upper Clackamas afforded by mainstem and tributaries, especially the Collowash and Hot Springs tributaries and the collection of smaller tributaries in the upper basin (upper Clackamas tributaries). As with the other populations discussed above, the current value of the tributary areas is less in regard to increasing overall abundance than it is in protecting the potential life history diversity afforded by a diversity of areas and times with suitable habitat conditions.

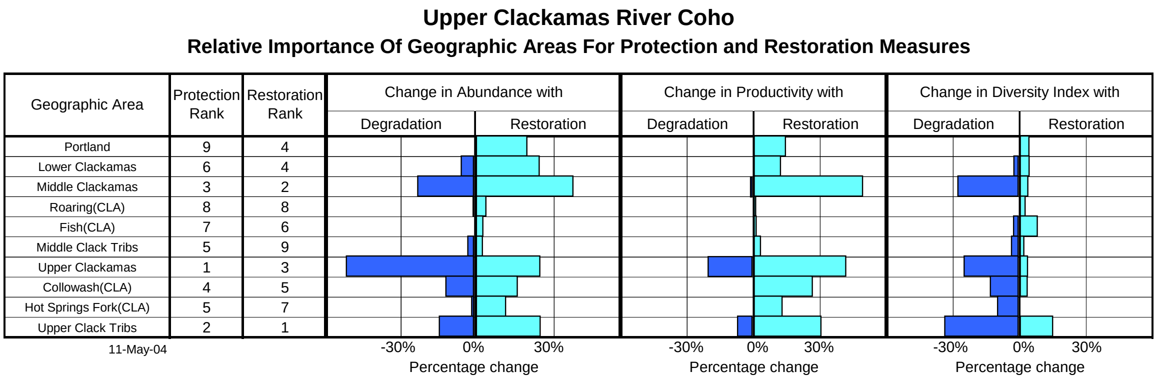


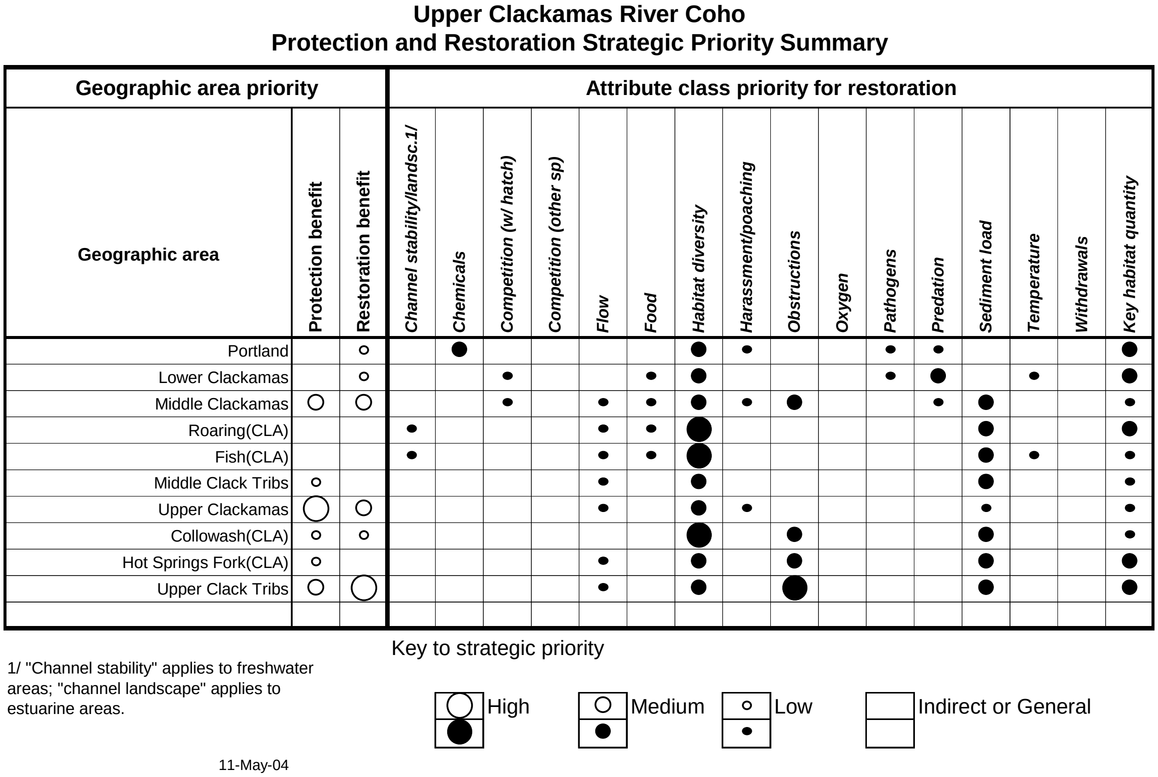
Figure 3-53: Upper Clackamas River Coho Habitat Priorities

Protection priorities are determined by the change in a performance attribute with degradation while restoration priories are given by the change in performance with restoration.

The greatest restoration value for coho in the upper Clackamas lies in the middle Clackamas area (Figure 3-53). This is largely a function of the PGE dam complex and reservoir and illustrates the constraints on production in the upper basin as a result of the shift from riverine habitat in the reference condition to the dams and reservoir in the current condition. The important restoration value of the lower Clackamas arises because all coho life history trajectories generated from the upper basin must pass through the lower river as adults and juveniles; restoration of conditions in these lower reaches provided considerable benefit to the upriver population.

The Portland area of the Willamette had significant restoration value for upper Clackamas coho, again emphasizing the close relationship between the Clackamas and the lower Willamette (Figure 3-53). Restoration of water quality in the lower Willamette improved survival for all populations; restoration of shallow water habitat in the Portland area greatly increased the rearing capacity for coho originating in both the lower and upper portions of the Clackamas.

The primary factors limiting coho in the upper Clackamas reaches are habitat diversity and loss of key habitat quantity (Figure 3-54). The loss of habitat diversity is almost entirely a function of the decline in large wood in the stream and river as a result of changes in riparian forests and overt removal. The loss of habitat quantity reflects a general narrowing of the channel (therefore loss of habitat area). In the upper basin this generally is due to roads that follow the stream course and impinge on the channel dynamics.



Upper Clackamas River Coho
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration																
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Portland		∘		●					●	•			•	•				●
Lower Clackamas		∘			•			•	●				•	●		•		●
Middle Clackamas	○	○			•		•	•	●	•	●			•	●			•
Roaring(CLA)			•				•	•	⬤						●			●
Fish(CLA)			•				•	•	⬤						●	•		•
Middle Clack Tribs	∘						•		●						●			•
Upper Clackamas	◯	○					•		●	•					•			•
Collowash(CLA)	∘	∘							⬤		●				●			•
Hot Springs Fork(CLA)	∘						•		●		●				●			●
Upper Clack Tribs	○	◯					•		●		⬤				●			●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority

◯ ⬤ High

○ ● Medium

∘ • Low

Indirect or General

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Figure 3-54: Upper Clackamas River Coho Habitat Attribute Effects

The change in productivity with restoration of an attribute is given by the size of the black dot, which is proportional to the overall restoration value given by the open circles to the left. A large black dot in an area with little overall restoration value (given by the size of the open circle) indicates little change in performance with restoration of the attribute.

Habitat limitations in the lower Clackamas mainstem and the lower Willamette (Portland) area for upper river coho were similar to the limitations seen for lower river coho (Figure 3-54). Decline in habitat diversity, high summer water temperature, and decline in key habitat quantity were key factors in the lower Clackamas. In the Willamette, chemicals (pollutants), habitat diversity, and key habitat quantity limited production of upper river coho.

Obstructions (culverts) are key factors in the upper basin (Figure 3-54). Within this analysis, the smaller tributaries to the Clackamas (Upper Clack Tribs) had 11 culverts with varying degrees of passage. Obstructions were also important in the Collowash River and Hot Springs Fork. In the middle Clackamas mainstem, obstructions showed up as a problem as a result of the passage mortality at the three PGE dams.

Upper Clackamas Winter Steelhead. The upper Clackamas River steelhead population was defined for this assessment to potentially spawn in all accessible reaches above North Fork Dam and is otherwise identical to the lower Clackamas steelhead population. This population displays the winter-run life history and is considered native to the Clackamas River (WLC-TRT, 2003c). The life history is based on the description of the Clackamas population provided by Hansen and others (2001). Life history information is summarized above and in Figure 3-42.

Clackamas River winter steelhead are part of the Lower Columbia River steelhead ESU (Busby and others, 1996). Within this ESU the TRT has recognized the Clackamas River winter steelhead population (WLC-TRT, 2003c). The upper Clackamas River steelhead population used in this assessment is the portion of the TRT population above North Fork Dam.

Figure 3-43 shows the count of steelhead at North Fork Dam as an index of population trend. Counts have varied widely but, overall, the return of steelhead to the upper basin shows a declining trend over the period. ODFW estimated that about 52 percent of the recent steelhead returns at North Fork Dam were of “wild” origin (WLC-TRT, 2003b).

Population potential of winter steelhead in the upper Clackamas River is limited at the present time by habitat constraints (Figure 3-55). Abundance potential of steelhead in the upper Clackamas River under the current habitat condition is about 52 percent of the potential under the reference habitat condition. However, this is better than the condition of habitat in the lower basin, where current potential for steelhead is only 16 percent of the potential under the reference condition (Figure 3-44). Potential productivity of steelhead under the present habitat configuration is a relatively healthy value of 8.7 returns/spawner. Although the habitat quality and quantity have declined and reduced the abundance potential for steelhead, the structure of the habitat (the places and times within a year where suitable conditions exist for steelhead) appears relatively intact in the upper basin. Winter steelhead in the upper Clackamas had the highest diversity index of any population in this assessment; current diversity was only 10 percent less than the diversity under the reference condition (Figure 3-55).

Upper Clackamas Winter Steelhead

Scenario	Diversity index	Productivity	Abundance
Current without harvest	90%	8.7	2,693
Current with harvest	90%	8.7	2,693
Reference potential	100%	20.6	5,208

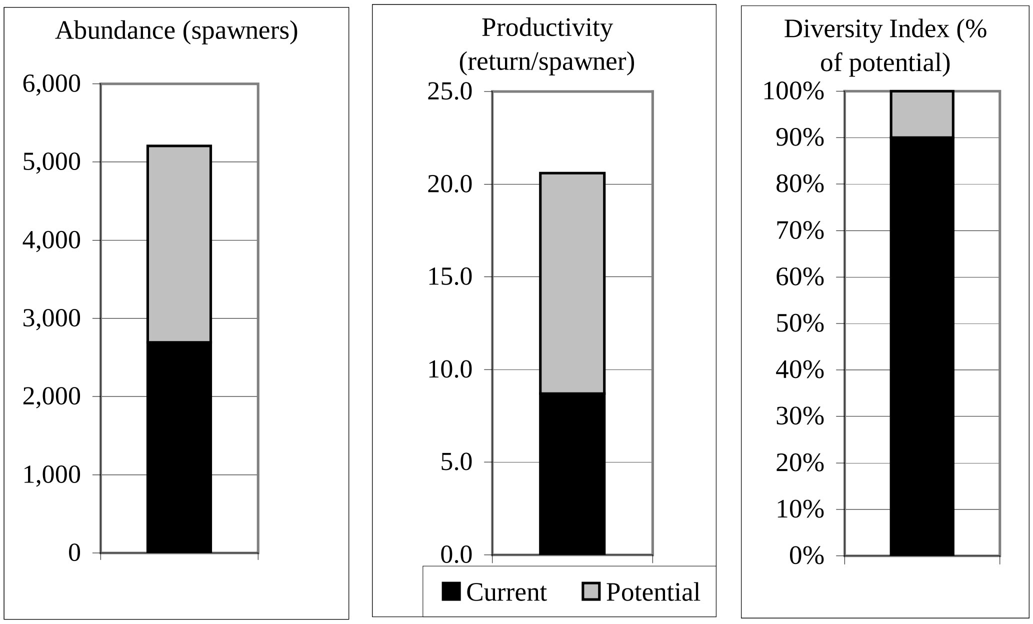

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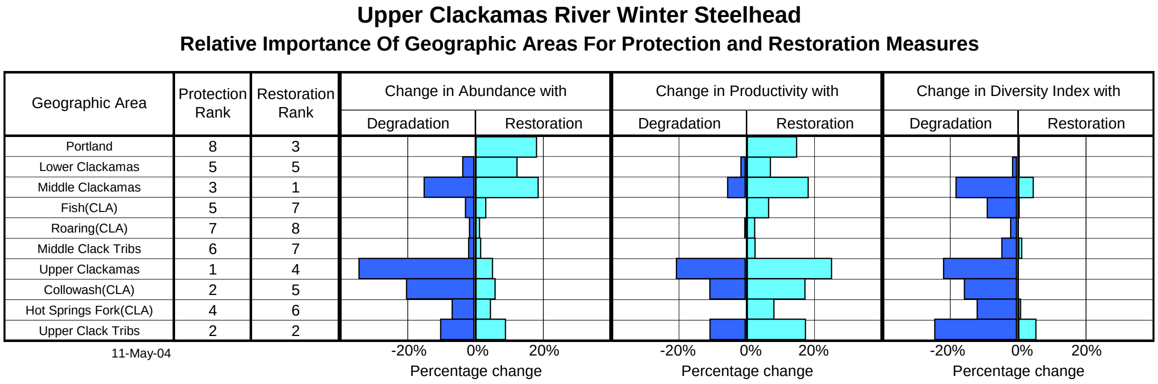
Figure 3-55: EDT Estimates of Habitat Potential in the Upper Clackamas River for Winter Steelhead

Steelhead harvest outside the Willamette Basin is considered to be zero.

The pattern of protection priorities in Figure 3-56 indicate that much of the current potential for steelhead in the upper Clackamas River is in the upper mainstem, middle mainstem, and Collowash River. As with other populations considered so far, the existing breadth of suitable habitat conditions indexed by the diversity index depends greatly on tributaries, especially the collection of upper Clackamas tributaries (Figure 3-56).



Geographic Area	Protection Rank	Restoration Rank
Portland	8	3
Lower Clackamas	5	5
Middle Clackamas	3	1
Fish(CLA)	5	7
Roaring(CLA)	7	8
Middle Clack Tribs	6	7
Upper Clackamas	1	4
Collowash(CLA)	2	5
Hot Springs Fork(CLA)	4	6
Upper Clack Tribs	2	2

Figure 3-56: Upper Clackamas River Winter Steelhead Habitat Priorities

Protection priorities are determined by the change in a performance attribute with degradation while restoration priories are given by the change in performance with restoration.

Restoration priorities for steelhead in the upper Clackamas (Figure 3-56) indicate that abundance is currently limited largely by conditions in the middle Clackamas mainstem, the lower Clackamas mainstem, and the lower Willamette (Portland). The upper Clackamas mainstem and all tributaries had relatively low restoration values, indicting that conditions are generally good for steelhead in these areas. In the middle Clackamas, which had the highest restoration value, the high restoration priority reflects the effect of the PGE dams and reservoirs. Restoration of the lower Willamette added considerable capacity to all populations in the Clackamas, including upper river steelhead. The restoration priority for the lower Clackamas is because all steelhead trajectories generated from the upper basin had to pass through the lower Clackamas during the juvenile and adult life stages.

Overall, habitat conditions for steelhead in the upper Clackamas appear to be good. The major constraint in the upper mainstem area in this assessment was some loss of habitat quantity, probably as a result of a narrowing of the channel from road building next to the channel, and a small loss of habitat diversity resulting from a decline in large wood (Figure 3-57). These problems were present in the tributaries as well; however, the biggest limitation in the upper basin tributaries was obstructions (Figure 3-57). Although these same obstructions were problems for coho, they were an even greater impediment to the movement of steelhead into potentially productive habitat.

Upper Clackamas River Winter Steelhead
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration																
Geographic area	Protection benefit	Restoration benefit	*Channel stability/landsc.1/*	*Chemicals*	*Competition (w/ hatch)*	*Competition (other sp)*	*Flow*	*Food*	*Habitat diversity*	*Harassment/poaching*	*Obstructions*	*Oxygen*	*Pathogens*	*Predation*	*Sediment load*	*Temperature*	*Withdrawals*	*Key habitat quantity*
Portland		○		●					•	•				•				•
Lower Clackamas	∘	∘			•								•	●				•
Middle Clackamas	○	◯						•	●	•	•			•	●			•
Fish(CLA)	∘						•		•					•	●	•		•
Roaring(CLA)							•		•						●			●
Middle Clack Tribs							•		•		⬤				●			•
Upper Clackamas	◯	∘							•	•				•	●			•
Collowash(CLA)	○	∘									●				●			•
Hot Springs Fork(CLA)	∘						•		•		⬤				●			●
Upper Clack Tribs	○	○							•		⬤			•	●			●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority

◯ ⬤	High	
○ ●	Medium	
∘ •	Low	
	Indirect or General	

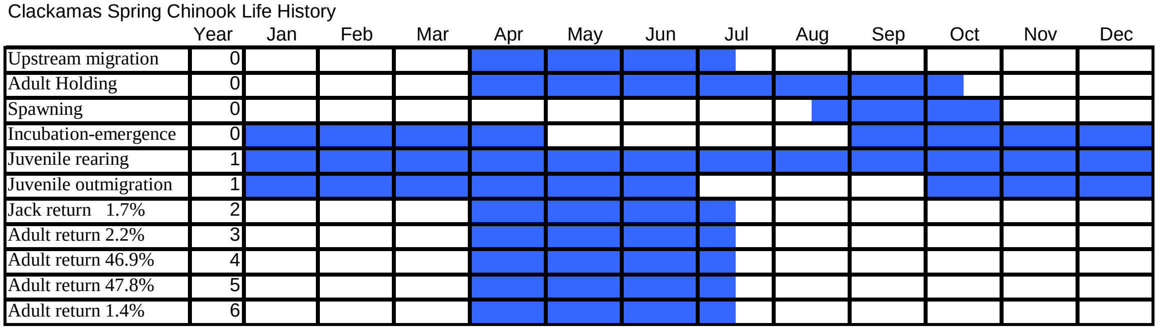
11-May-04

Figure 3-57: Upper Clackamas River Steelhead Habitat Attribute Effects

The change in productivity with restoration of an attribute is given by the size of the black dot, which is proportional to the overall restoration value given by the open circles to the left. A large black dot in an area with little overall restoration value (given by the size of the open circle) indicates little change in performance with restoration of the attribute.

Most of the habitat constraints on steelhead in the upper basin occur downstream in the middle and lower mainstem reaches and the lower Willamette. The problems in these areas have been discussed previously in connection with other populations. The major constraint in the middle Clackamas have to do with the PGE dams and reservoirs and the loss of spawning habitat and passage mortality at the dams. In the lower Clackamas, channel straightening, confinement, and loss of habitat complexity limit steelhead and coho. Constraints in the lower Willamette include chemicals (pollutants) and loss of shallow water habitat.

Upper Clackamas Spring Chinook. The Clackamas River spring Chinook population was defined to spawn in reaches throughout the Clackamas Subbasin. This spring Chinook population was modeled with a stream-type life history, meaning that after emergence in their first spring, juveniles spend an entire year in freshwater and out-migrate from the Clackamas in their second spring. Life history characteristics for this assessment were based on Howell and others (Howell and others, 1985). Adults enter in the early spring and hold in deep pools over the summer before moving to spawning areas in the fall (Figure 3-58). After emergence the next spring, the juveniles rear for a year generally tributaries and margins of the mainstem. They have a pronounced spring out-migration as 1-year-olds. Most adults return to the Clackamas after 3 or 4 years in the ocean (Figure 3-58).



Clackamas Spring Chinook Life History

	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upstream migration	0				🟦	🟦	🟦	🟦					
Adult Holding	0				🟦	🟦	🟦	🟦	🟦	🟦	🟦		
Spawning	0								🟦	🟦	🟦		
Incubation-emergence	0	🟦	🟦	🟦	🟦					🟦	🟦	🟦	🟦
Juvenile rearing	1	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Juvenile outmigration	1	🟦	🟦	🟦	🟦	🟦	🟦				🟦	🟦	🟦
Jack return 1.7%	2				🟦	🟦	🟦	🟦					
Adult return 2.2%	3				🟦	🟦	🟦	🟦					
Adult return 46.9%	4				🟦	🟦	🟦	🟦					
Adult return 47.8%	5				🟦	🟦	🟦	🟦					
Adult return 1.4%	6				🟦	🟦	🟦	🟦					

Figure 3-58: Generalized Spring Chinook Life History in the Clackamas River

Clackamas spring Chinook are part of the Upper Willamette River spring Chinook ESU (Myers and others, 1998).

Estimated return of spring Chinook to the Clackamas River is shown in Figure 3-59. Returns of spring Chinook have increased in the Clackamas River since the mid-1970s. Since that time, returns have ranged from to a low of 900 in 1975 to a high of 9,700 in 2001. Return of spring Chinook to the Clackamas River since the mid-1970s has averaged 4,691 fish.

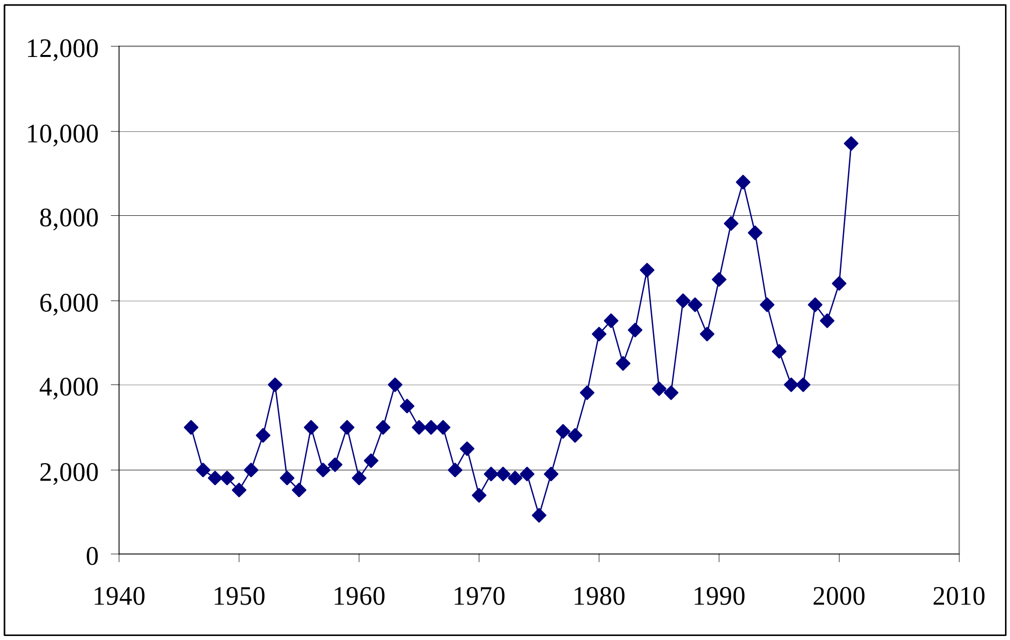


Figure 3-59: Estimated Return of Spring Chinook to the Clackamas River

Source: StreamNet.

The overall potential of habitat in the Clackamas River for spring Chinook has been greatly reduced relative to the restored reference condition. Current abundance potential is about 23 percent of the potential under the reference condition (Figure 3-60). Overall productivity as a function of habitat has been reduced by about 7 percent relative to the reference but remains about 3.5 returns/spawner even with harvest. On the other hand, the habitat retains about 80 percent of the potential life history diversity. This is higher than for most other populations in this assessment and reflects the heavy use of the mainstem by spring Chinook (especially the upper mainstem reaches), with less use of the diversity of habitats in the tributaries.

Upper Clackamas Spring Chinook

Scenario	Diversity index	Productivity	Abundance
Current without harvest	76%	4.7	2,434
Current with harvest	73%	3.5	1,620
Reference potential	96%	17.9	10,716

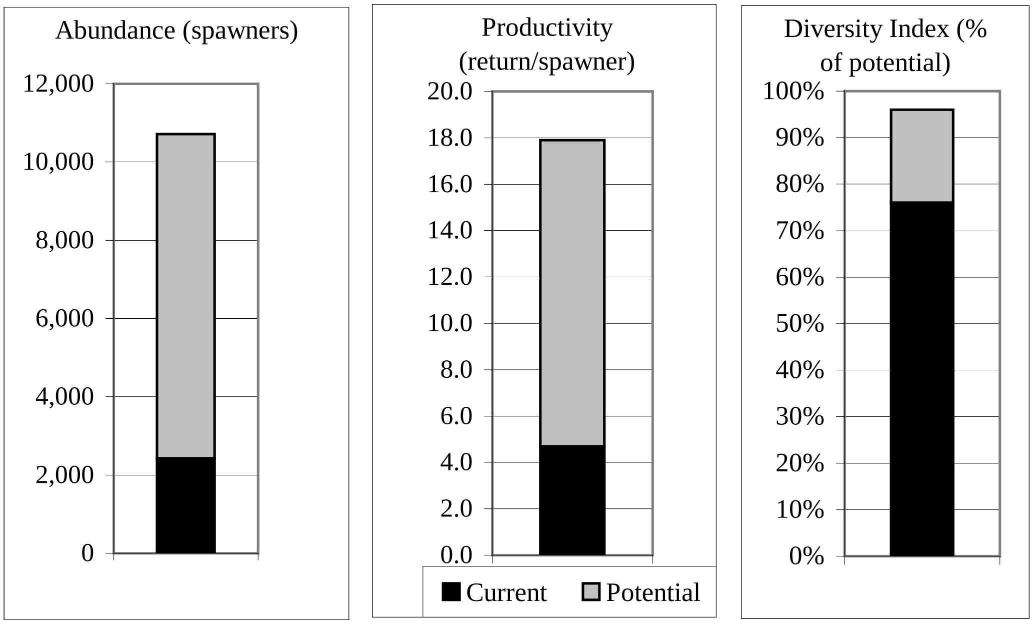


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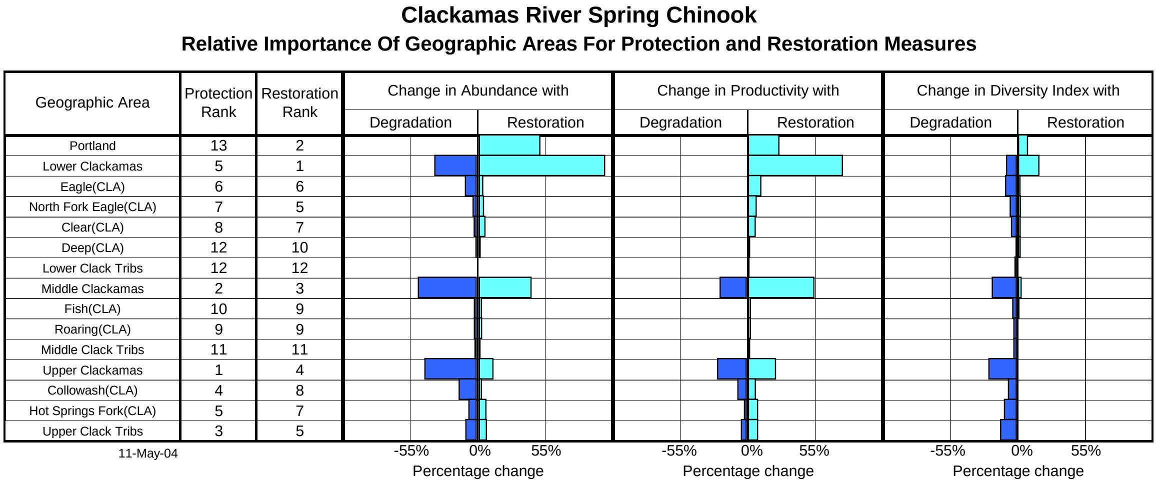
Figure 3-60. EDT Estimates of Habitat Potential in the Clackamas River for Spring Chinook

Graphs show figures without harvest.

Current habitat potential for spring Chinook in the Clackamas is mainly in the mainstem areas, especially the middle Clackamas area (reaches from above North Fork Reservoir to Oak Grove) and the upper Clackamas (Figure 3-61). Similarly, most of the protection value for the diversity index under the current habitat condition was in the middle and upper mainstem reaches of the Clackamas.



Geographic Area	Protection Rank	Restoration Rank
Portland	13	2
Lower Clackamas	5	1
Eagle(CLA)	6	6
North Fork Eagle(CLA)	7	5
Clear(CLA)	8	7
Deep(CLA)	12	10
Lower Clack Tribs	12	12
Middle Clackamas	2	3
Fish(CLA)	10	9
Roaring(CLA)	9	9
Middle Clack Tribs	11	11
Upper Clackamas	1	4
Collowash(CLA)	4	8
Hot Springs Fork(CLA)	5	7
Upper Clack Tribs	3	5

Figure 3-61: Clackamas River Spring Chinook Habitat Priorities

Protection priorities are determined by the change in a performance attribute with degradation while restoration priories are given by the change in performance with restoration.

The greatest habitat restoration value for spring Chinook in the Clackamas was in the lower Clackamas mainstem (Figure 3-61). The second restoration value for spring Chinook was the lower Willamette area (Portland). The high restoration value of these lower reaches in part reflects the benefits afforded by improving conditions for adult and juvenile migrants that pass through the lower Willamette and lower Clackamas reaches. Conditions for spring Chinook spawning in the lower Clackamas mainstem were also reduced by habitat constraints. The third restoration priority is the middle Clackamas (Figure 3-61). As noted above for other populations, this refers to the effect of the PGE reservoir and dam. Restoration of this area in the model extended the high-priority habitat in the reaches above North Fork Reservoir down to the location of River Mill Dam.

Major limiting factors on spring Chinook potential in the Clackamas River were temperature in the lower tributaries and lower mainstem, habitat diversity in almost all areas, and loss of key habitat quantity as a result of the narrowing and straightening of the channel (Figure 3-61). Water temperature was a particularly important limiting factor in the lower Clackamas mainstem, where it limited spawning success. This was also a problem for fall Chinook spawning in the lower mainstem (Figure 3-51). Spring Chinook spawning begins in September when temperatures in the lower river, including the lower basin tributaries, are at high levels.

As discussed for other populations, the decline in habitat diversity in almost all cases reflects a reduction in the amount of large wood as a result of changes in riparian forests and stream clearing. Obstructions were an important limiting factor for spring Chinook in the middle Clackamas area because of the survival impacts of the PGE dams.

In the lower Willamette (Portland) area, chemicals (pollutants), habitat diversity, and key habitat quantity were important limiting conditions for Clackamas spring Chinook (Figure 3-62). These limitations have been discussed above for other populations. Pathogens, however, were an additional important factor in the lower Willamette. Pathogens showed up as a limiting factor for coho in the lower Willamette as well. The Willamette River has *Certatomyxis shasta*, and its virulence is proportional to temperature in the EDT analysis.

The timing of adult and juvenile Chinook (and coho) migrants through the lower Willamette is such that they are exposed to the disease as temperature is increasing in the spring.

Clackamas River Spring Chinook
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Portland		◯		●			•	•	●				•	●		•		●
Lower Clackamas	∘	◯	●	•	•		•	•	•	•			•	●	●	⬤		•
Eagle(CLA)	∘	∘			•		•						•	•	●	⬤		•
North Fork Eagle(CLA)	∘	∘			•								•		●	⬤		•
Clear(CLA)	∘	∘		•	•		•	•	•	•		•	•	•	•	⬤		•
Deep(CLA)				●			•	•					•		●	⬤		●
Lower Clack Tribs				•			•		•			•			●			●
Middle Clackamas	◯	○						•	•	•	●			•	●			•
Fish(CLA)			•				•	•	•						●	●		•
Roaring(CLA)									•						•			●
Middle Clack Tribs							•		•						●			•
Upper Clackamas	◯	○							•	•					•			•
Collowash(CLA)	○	∘													•			•
Hot Springs Fork(CLA)	∘	∘							•		●				•			●
Upper Clack Tribs	○	∘					•							•	•			●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority

◯ ⬤	High
○ ●	Medium
∘ •	Low
	Indirect or General

11-May-04

Figure 3-62: Clackamas River Spring Chinook Attribute Effects

The change in productivity with restoration of an attribute is given by the size of the black dot, which is proportional to the overall restoration value given by the open circles to the left. A large black dot in an area with little overall restoration value (given by the size of the open circle) indicates little change in performance with restoration of the attribute

EDT Habitat Assessment by Geographic Area

The assessment of the Clackamas River addressed habitat conditions for three salmonid species and six populations. The preceding discussion focused on how habitat conditions across the Clackamas affect potential performance of each of the six populations, that is, geographic areas within populations. This section will discuss each of the 15 geographic areas in the Clackamas River (Table 3-165) and the conditions that limit populations within each area, that is, populations within geographic areas. In this way, limiting conditions that occur across one or more populations can be identified while geographic areas can be prioritized in terms of their potential impact on the mix of salmonid populations in the Clackamas River.

Of course, not all geographic areas are relevant to each population. Conditions in the Eagle Creek geographic area, for example, have no impact on upper Clackamas steelhead, while conditions in the Collowash area have no impact on lower Clackamas steelhead. Any geographic area can affect up to six populations, depending on how anadromous salmonids use the Clackamas River within the EDT assessment.

This brings up an important caveat: this study assessed only the effect of conditions within a reach on fish survival and capacity within that reach. It did not deal with causes of conditions. While some habitat limitations are proximal, meaning that they originate at a local level, others are systemic and are the result of cumulative conditions throughout the watershed. Large wood and channel form are examples of proximal limiting factors (although arguments can be made that these are influenced by the accumulation of upriver conditions as well). Flow, sediment, and temperature are examples of systemic problems that are perceived by fish at a local level (and would be identified in this assessment) but develop as a result of the accumulation of conditions upstream. For example, temperature is an important limiting factor in the lower Clackamas area, but conditions in the lower Clackamas area have only a minor impact on the summer water temperature. Instead, water temperature in the lower Clackamas is the result of decreased riparian forests in the tributaries and mainstem, ponding of water behind dams, and other upriver factors.

The point is that, even though many of the smaller tributaries were ranked low in terms of their overall contribution to abundance of the focal species, these areas may be the source or origin of conditions that are identified as limiting factors in larger downstream areas. In addition, the discussion above for each population noted that these smaller streams can make important contributions to the life history diversity of the population even if they do not contribute greatly to abundance. Restoration of lower ranked areas may be entirely appropriate as solutions to problems limiting fish production in higher ranked areas and to increase diversity.

Limiting Factors in Portland: Lower Willamette

Overall Protection Rank: 15
Overall Restoration Rank: 2

Conditions in the lower Willamette River affect the performance of all six populations in the Clackamas River. This assessment showed that conditions in the lower Willamette can contribute significantly to the potential biological performance of fish in the Clackamas River. In fact, it is apparent that the Clackamas River and the lower Willamette River form a contiguous habitat unit. This expanded view of the Clackamas can form a useful focus for restoration and management of coho, Chinook, and steelhead in the Clackamas River.

Current conditions in the Portland (lower Willamette) area are degraded, and the area had almost no protection value for the six Clackamas populations. The assessment found that salmon and steelhead used the area almost entirely as a migration corridor. This is consistent with studies of fish use of the lower Willamette River that found that most juvenile salmonids move through the area in less than two weeks (Friesen and others, 2002). However, restoration of conditions in the lower Willamette illustrated the potential of the area to contribute to tributary populations such as those from the Clackamas. For all six populations combined, the Portland area was the second-ranked restoration priority. The Portland area had a moderate overall restoration ranking and relatively high rankings for Clackamas spring Chinook (restoration rank 2 out of 13), fall Chinook (restoration rank 3 out of 7), and upper Clackamas steelhead (restoration rank 3 out of 8).

Limiting environmental attributes in the Portland area included chemical pollutants, loss of habitat diversity, pathogens, predation (the result of large numbers of introduced fish species), and loss of key habitat (Figure 3-63). The lower Willamette River has a host of water pollutant problems from local and upriver sources. Loss of habitat diversity and the quantity of key habitat types are the result of channelization and dredging of the lower river that has eliminated much of the shallow water habitat that would provide rearing habitat for juvenile life stages (McConnaha 2003). Harassment from boating and other encroachment of human activities on salmonids is pervasive within an urbanized area. Predation is suggested as a limiting factor because of the presence of numerous nonnative fish species in the lower Willamette River (Farr and Ward 1993). The limiting effect of pathogens reflects the presence of large numbers of hatchery fish in the lower Willamette and endemic *C. shasta* (a fish pathogen).

Geographic Area: Portland (Lower Willamette)

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	6	5	6		●	•		•	•	⬤	•			•	•		•		●
Upper Coho	9	4	9		●					●	•			•	•				●
Lower Steelhead	6	5	6		●	•		•		•	•			•	•				•
Upper Steelhead	8	3	8		●					•	•				•				•
Fall Chinook	6	3	7		•	•		•	•	●	•			•	•		•		●
Spring Chinook	13	2	13		●			•	•	●				•	●		•		●
Average Area Rank	8.0	3.7	8.2																

Figure 3-63: Protection and Restoration Rankings for the Portland (Lower Willamette) Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Limiting Factors in the Lower Clackamas River

Protection Priority: 1
Restoration Priority: 1

The lower Clackamas River mainstem influences performance of all six populations. With all six populations combined, the lower Clackamas was the number-one ranked area in the Clackamas River for both protection and restoration (Figure 3-36). Conditions are relatively degraded, and protection ranks for all populations except fall Chinook were low. Because this area has virtually all potential spawning habitat in the Clackamas for fall Chinook, it was the number one protection priority for this population, despite the current habitat limitations. All six populations use the lower Clackamas to varying degrees and would benefit from improved conditions in this area; as a result, the lower Clackamas area had the top restoration rating for four of the six populations. Upper river coho and steelhead used the lower river mainly for migration, so restoration was a lesser priority for these populations.

Limiting factors include predation (resulting from the large number of introduced fish species present), sediment (for those populations that potentially use the lower river for spawning), and degraded channel stability (Figure 3-64). The latter factor is the result of diking and channelization of the lower river and the restricted connection between the river and the floodplain. Narrowing of the channel between dikes also has decreased key habitat quantity in the lower Clackamas area (Figure 3-64). Temperature was a major limiting factor for both Chinook populations that commence spawning in September, when water temperatures are extremely high. Chemical pollutants and hatchery impacts (competition with hatchery fish and pathogens) were also important limiting factors in the lower Clackamas. Changes in the sediment patterns and storage are also affecting fish populations. The river channel in the first two miles below the River Mill dams is coarsening and downcutting, which affects the quality and quantify of spawning habitats. Sediments, nutrients, and toxins also flow in the lower river from urbanizing tributaries, such as Deep, Rock and Richardson creeks.

Geographic Area: Lower Clackamas

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	5	1	6	●	•	●	•	•	•	⬤	•			•	●	●	•		●
Upper Coho	6	4	9			•			•	●				•	●		•		●
Lower Steelhead	4	1	6	•	•	●	•	•	•	•	•			●	●	●	●		•
Upper Steelhead	5	5	8			•								•	●				•
Fall Chinook	1	1	7	●	•			•	•	•	•			•	●	●	⬤		•
Spring Chinook	5	1	13	●	•	•		•	•	•	•			•	●	●	⬤		•
Average Area Rank	4.3	2.2	8.2																

Figure 3-64: Protection and Restoration Rankings for the Lower Clackamas Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Limiting Factors in Deep Creek

Overall Protection Priority: 10
Overall Restoration Priority: 5

In the context of the Clackamas River as a whole and for all six populations, Deep Creek received a moderately low protection rank (10 of 15) but a moderately high restoration rank (5 of 15). The Deep Creek watershed provides valuable habitat for four of the six populations but especially for lower Clackamas coho, lower Clackamas steelhead, and spring Chinook (Figure 3-65).

Geographic Area: Deep Creek

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	4	3	6		•			•	•	●		⬤			•	●	●		●
Upper Coho																			
Lower Steelhead	3	3	6		•			●		•		⬤		•	•	●	●		●
Upper Steelhead																			
Fall Chinook	4	6	7		●			•	•							●	⬤		•
Spring Chinook	12	10	13		●			•	•					•		●	⬤		●
Average Area Rank	5.8	5.5	8.0																

Figure 3-65: Protection and Restoration Rankings for the Deep Creek Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

The Deep Creek watershed has an abundance of nursery operations and some urbanization. Presumably as a result, major limiting factors for all populations present were sediment and chemicals (pollutants). Summer water temperature was also a major factor, especially for the two Chinook populations that are exposed to high September temperatures during spawning. Obstructions from culverts and their impacts on adult and juvenile passage are a key factor limiting winter steelhead and coho salmon.

Limiting Factors in Clear Creek

Overall Protection Priority: 8
Overall Restoration Priority: 4

Conditions in Clear Creek affect four of the six populations (Figure 3-66). Fall Chinook spawn in the lower reaches while coho, steelhead, and spring Chinook use most of the accessible reaches. For the entire Clackamas Basin and for all six populations, Clear Creek received a moderate rating for protection (8 of 15) and a relatively high rank for restoration (4 of 15). There are some remaining areas within the Clear Creek watershed, particularly in the upper watershed, that retain high quality riparian and stream habitats that warrant protection.

Geographic Area: Clear Creek

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	1	2	6		•	•		•	•	●		⬤		•	•	●	•		●
Upper Coho																			
Lower Steelhead	4	2	6		•			•	•	•		⬤		●	•	●	●		•
Upper Steelhead																			
Fall Chinook	3	5	7		•			•	•		•				•	•	⬤		•
Spring Chinook	8	7	13		•	•		•	•	•	•		•	•	•	•	⬤		•
Average Area Rank	4.0	4.0	8.0																

Figure 3-66: Protection and Restoration Rankings for the Clear Creek Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Temperature was an important limiting factor for all four populations, especially the two Chinook populations that spawn in September when water temperatures are at their maximum. Obstructions in the form of culverts and road crossings are a key factor limiting winter steelhead and coho salmon. Other important factors affecting fish populations in Clear Creek and its tributaries are habitat diversity (from limited large wood in stream channels) and loss of key habitat quantity as a result of channelization and channel restrictions. Whirling disease has been identified in a private hatchery in the watershed, although no recent outbreaks in natural populations have been identified. However, because of its potential impact on fish, disease in Clear Creek warrants continued monitoring.

Limiting Factors in Eagle Creek

Protection Priority: 5
Restoration Priority: 6

Conditions in Eagle Creek affect four of the six populations. Eagle Creek includes Eagle Creek National Fish Hatchery. Three natural waterfalls occur. These have been laddered to allow fish passage into the upper watershed. Overall, protection of conditions in Eagle Creek received a moderately high rating (5 of 15) and a similar restoration rating (6 of 15). For individual populations, Eagle Creek was ranked as a number two priority for protection for coho, steelhead, and fall Chinook and a 6 (out of 13) for spring Chinook (Figure 3-67).

Geographic Area: Eagle Creek

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	2	4	6			•		•	•	⬤		●		•	•	●	•		•
Upper Coho																			
Lower Steelhead	2	2	6			•		•		•		●		•	•	●	●		•
Upper Steelhead																			
Fall Chinook	2	2	7					•							•	●	⬤		
Spring Chinook	6	6	13			•		•						•	•	●	⬤		•
Average Area Rank	3.0	3.5	8.0																

Figure 3-67: Protection and Restoration Rankings for the Eagle Creek Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

High water temperature and sediment were the major limiting factors in Eagle Creek. Obstructions were a lesser problem in Eagle Creek compared to the other lower river tributaries. This system has three natural waterfalls that have been laddered and two artificial obstructions.

Limiting Factors in North Fork Eagle Creek

Protection Priority: 7
Restoration Priority: 7

Conditions in North Fork Eagle Creek affected three of the six populations (Figure 3-67). Overall, this area received a moderate rank for both protection and restoration (7 of 15). However, North Fork Eagle Creek was ranked number one for protection in regard to lower Clackamas winter steelhead, although it received only moderate rankings for the other populations (Figure 3-68).

Geographic Area: North Fork Eagle Creek

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	3	5	6			•		•	•	●		●				●	•		●
Upper Coho																			
Lower Steelhead	1	4	6			•		•				●		•	•	●	•		●
Upper Steelhead																			
Fall Chinook																			
Spring Chinook	7	5	13			•								•		●	⬤		•
Average Area Rank	3.7	4.7	8.3																

Figure 3-68: Protection and Restoration Rankings for the North Fork Eagle Creek Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Limiting factors in North Fork Eagle Creek are similar to those in other lower watershed tributaries. High water temperature was a key factor for spring Chinook, while increased fine sediment has affected spawning success of all three populations. Coho and steelhead—species that would use the upper reaches of the stream—are affected by obstructions from culverts and road crossings.

Limiting Factors in Lower Clackamas Tributaries

Overall Protection Priority: 14
Overall Restoration Priority: 12

The collection of small streams making up the Lower Clackamas tributary area includes Rock, Richardson, Foster, Goose, Cow and Sieben creeks. Overall, this area received low rankings for both protection (14 of 15) and restoration (12 of 15). Conditions in these tributaries directly affect four of the six populations but also received low protection and restoration rankings for each of the populations (Figure 3-69).

Geographic Area: Lower Clackamas River Tributaries

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho	5	6	6	•	•		•	•	•	●	•					●	•		●
Upper Coho																			
Lower Steelhead	5	6	6		•			●	•	•	•			•	•	●	●		●
Upper Steelhead																			
Fall Chinook	5	7	7		●			•	•							●	⬤		●
Spring Chinook	12	12	13		•			•		•			•			●			●
Average Area Rank	6.8	7.8	8.0																

Figure 3-69: Protection and Restoration Rankings for the Lower Clackamas Tributaries Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Although the lower Clackamas tributaries were ranked near the bottom in regard to protection and restoration priorities, this may be underestimating their impact on the Clackamas River. As was discussed above, many problems in the lower Clackamas mainstem (ranked first in overall protection and restoration priorities), such as temperature and sediment, originate upstream and in tributaries like those included in this area. Solutions to problems in the lower Clackamas mainstem may lie in these smaller tributaries.

Habitat problems in these streams are common to all the lower basin tributaries: high summer water temperature, increased fine sediment, and loss of key habitat quantity. Surprisingly, obstructions did not show up as a limiting survival factor in the lower tributaries, although it is emphasized that this assessment did not include all obstructions and it is likely that culverts and other obstructions exist in these streams.

Limiting Factors in the Middle Clackamas River

Protection Priority: 3
Restoration Priority: 3

The Middle Clackamas area consists of the mainstem of the Clackamas River from North Fork Dam to Oak Grove Fork, including North Fork Reservoir. At the scale of the entire Clackamas River and all six species, the middle mainstem reach ranked third for both protection and restoration. Habitat in the middle mainstem affects four of the six populations (Figure 3-70). The aquatic and riparian habitats within and along the upper Middle Clackamas have high protection values, particularly for spring Chinook salmon (protection rank 2 out of 13 possible). The area had high restoration values for coho (restoration rank 2 out of 9), winter steelhead (restoration rank 1 out of 8), and spring Chinook (restoration rank 3 out of 13). Within this analysis, fall Chinook were hypothesized to spawn historically in the river reaches currently inundated by North Fork Dam. This area has no protection value because of the reservoir and a moderate restoration value for fall Chinook (restoration rank 4 out of 7).

Geographic Area: Middle Clackamas

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	3	2	9			•		•	•	●	•	●			•	●			•
Lower Steelhead																			
Upper Steelhead	3	1	8						•	●	•	•			•	●			•
Fall Chinook	7	4	7					•	•	●	•			•	•	●			⬤
Spring Chinook	2	3	13						•	•	•	●			•	●			•
Average Area Rank	3.8	2.5	9.3																

Figure 3-70: Protection and Restoration Rankings for the Middle Clackamas Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Key factors limiting fish populations in the middle Clackamas River are loss of habitat diversity, increased fine sediment, and loss of key habitat quantity. Most of the loss of habitat diversity is the result of reductions in large wood in the river, channel confinement from roads and other actions, impacts to riparian areas, and loss of spawning habitat within the North Fork Reservoir. Forest Service Road 46, which parallels large sections of the river, prevents river meandering and restricts the channel, all of which increases channel velocities and scour and minimize complex, slow-water habitats such as side channels. The river cannot meander through the road and cannot access historical side-channels and other floodplain habitats.

There are also issues with low flows below the Oak Grove Reservoir to Three Lynx Creek. In addition, the highway narrows the channel, resulting in a decline in the quantity of habitat. North Fork Reservoir eliminated all spawning habitat in the lower portion of this area. However, it also greatly increased the amount of potential rearing habitat for juvenile salmonid life stages. It is unclear how much spawning habitat was lost as a result of the reservoir because the dams inundated a fairly steep, confined canyon area that may have provided limited spawning potential. The three-dam complex operated by PGE that forms the downstream boundary of this area also forms obstructions and decreases survival of adult and juvenile migrants.

Limiting Factors in Fish Creek

Protection Priority: 12
Restoration Priority: 13

Fish Creek is a tributary entering the Clackamas River at about RM 41.5. The creek has a low overall protection priority (12 of 15) and restoration priority (13 of 15). Three of the six populations are potentially directly affected by conditions in Fish Creek. The area also received a low ranking for protection and restoration for coho, Chinook, and steelhead.

Restoration priorities include sediment, temperature, and habitat diversity (Figure 3-71). These factors can be largely traced to logging and road-building activities in the watershed. There has been extensive harvest and associated road-building activity in the Fish Creek Watershed. Over the past several decades, the Forest Service has pursued extensive road, riparian, and in-channel restoration actions. Increased water temperatures and sediment deposition are key factors affecting winter steelhead survival.

Geographic Area: Fish Creek

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	7	6	9	•				•	•	⬤						●	•		•
Lower Steelhead																			
Upper Steelhead	5	7	8					•		•					•	●	•		•
Fall Chinook																			
Spring Chinook	10	9	13	•				•	•	•						●	●		•
Average Area Rank	7.3	7.3	10.0																

Figure 3-71: Protection and Restoration Rankings for the Fish Creek Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Limiting Factors in Roaring River

Protection Priority: 13

Restoration Priority: 14

Roaring River enters the middle Clackamas River at about RM 44. Much of the watershed is inaccessible to anadromous fish because of a natural barrier about 3 miles from the mouth. The accessible portion of the river is a narrow, steep-sided gorge. The Roaring River area received nearly the lowest protection (13 of 15) and restoration (14 of 15) rankings in the Clackamas River across all six populations. Conditions in the Roaring River affect three of the six populations. The area received low rankings for protection and restoration for the three individual populations (Figure 3-72).

The low rankings for Roaring River are due to the fact that the accessible length of the stream is quite short (about 3 miles); also, the accessible portion is a high-gradient, naturally confined canyon. The area does have decreased habitat diversity (lack of large wood) and increased levels of fine sediment (Figure 3-72).

Geographic Area: Roaring River

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	8	8	9	•				•	•	⬤						●			●
Lower Steelhead																			
Upper Steelhead	7	8	8					•		•						●			●
Fall Chinook																			
Spring Chinook	9	9	13							•						•			●
Average Area Rank	8.0	8.3	10.0																

Figure 3-72: Protection and Restoration Rankings for Roaring River Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Limiting Factors in the Middle Clackamas Tributaries

Protection Priority: 11
Restoration Priority: 15

This area consists of the smaller tributaries in the area between North Fork Dam and Oak Grove Fork, including the North Fork Clackamas, South Fork Clackamas, and Sandstone, Big, Whale, and Cripple creeks. Overall, these tributaries ranked low for both protection and restoration. For the Clackamas River as a whole, these tributaries were ranked 11 (out of 15) for protection and 15 (out of 15) for restoration. Conditions in these tributaries potentially affect three of the six populations. For the individual populations they ranked moderately low for protection but nearly last for restoration (Figure 3-73).

Geographic Area: Middle Clackamas Tributaries

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	5	9	9					•		●						●			•
Lower Steelhead																			
Upper Steelhead	6	7	8					•		•		⬤				●			•
Fall Chinook																			
Spring Chinook	11	11	13					•		•						●			•
Average Area Rank	7.3	9.0	10.0																

Figure 3-73: Protection and Restoration Rankings for the Middle Clackamas Tributaries Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Increased fine sediment was a limiting factor for all species. Most of these tributaries are within watersheds that have recent or active logging and associated road building. Obstructions that limit fish movement are an important limiting factor for steelhead in these tributaries. Sediment, habitat diversity, and key habitat quantity are also degraded, all of which reflect logging and road building in the watersheds.

Limiting Factors in the Upper Clackamas River

Overall Protection Priority: 2
Overall Restoration Priority: 8

The Upper Clackamas River area is the mainstem of the Clackamas River from Oak Grove Fork to headwaters. This portion of the river is a key spawning and rearing area for the Upper Clackamas coho salmon and winter steelhead populations, and it provides important habitat for spring Chinook salmon as well. The area includes the Big Bottom, which is generally considered the highest quality coho salmon habitat in the Clackamas River Subbasin.

Conditions in the upper Clackamas mainstem are generally good to excellent. The area ranked number two for protection priority for the whole of the Clackamas River across all six populations. The upper mainstem had a moderate overall rank for restoration (8 of 15). The area benefits three of the six populations and received the number one rank for protection for each population (Figure 3-74). Restoration priority was moderately high for coho (3 of 9) and spring Chinook (4 of 13) and moderate for steelhead (4 of 8).

Geographic Area: Upper Clackamas

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	1	3	9					•		●	•					•			•
Lower Steelhead																			
Upper Steelhead	1	4	8							•	•				•	●			•
Fall Chinook																			
Spring Chinook	1	4	13							•	•					•			•
Average Area Rank	1.0	3.7	10.0																

Figure 3-74: Protection and Restoration Rankings for the Upper Clackamas Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Habitat limitations for salmon in the upper Clackamas mainstem include loss of habitat diversity (decline in large wood and decreased riparian forests), harassment (proximity of human activities to salmon), increased sediment, and decline in the quantity of key habitat types. Riparian forests have been decreased as a result of highway construction along the river, and many areas have stands of young and deciduous trees that provide inferior instream wood other riparian benefits. Sediment in the upper river has increased as a result of logging and road building (USFS 1995). The quantity of key habitats for various salmonid life stages has decreased because of the narrowing and straightening of the channel that has been a consequence of the highway that parallels much of the upper river. This also has decreased river side-channels and simplified the channel structure.

Limiting Factors in the Collowash River

Overall Protection Priority: 4
Overall Restoration Priority: 10

The Collowash River is the largest tributary in the upper Clackamas River. The Collowash River watershed is managed by the Forest Service and contains areas with high-quality riparian and stream habitats. Upper parts of the watershed are in the Bull of the Woods Wilderness Area. While the area does not support large numbers of spawning and rearing fish, it does provide diverse habitats, primarily for coho salmon and winter steelhead.

The Collowash ranked fourth (of 15) in overall protection priority within the Clackamas River and 10th (of 15) in regard to restoration. The river provides benefits to three of the six populations in the Clackamas River. It is especially important to winter steelhead in the upper basin and ranked second (of 8) in regard to protection. Restoration priorities for all three populations were moderately low (Figure 3-75).

Geographic Area: Collowash River

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	4	5	9							⬤		●				●			•
Lower Steelhead																			
Upper Steelhead	2	5	8									●				●			•
Fall Chinook																			
Spring Chinook	4	8	13													•			•
Average Area Rank	3.3	6.0	10.0																

Figure 3-75: Protection and Restoration Rankings for the Collowash River Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

The potential of the habitat in the Collowash is limited primarily by obstructions, which are culverts under logging and other roads (Figure 3-75). There is some increase in sediment as a result of roads and logging. In addition, roads and logging have narrowed the channel in places and decreased the quantity of key habitat. Habitat diversity has decreased, with the primary impact on juvenile rearing for coho salmon. This is the result of some decrease in riparian forest and a decline in large wood deliver to the stream.

Limiting Factors in Hot Springs Fork

Overall Protection Priority: 9
Overall Restoration Priority: 11

Hot Springs Fork is the largest tributary to the Collowash River. The lower part of the watershed is in the Mt. Hood National Forest while the upper portion is in the Bull of the Woods Wilderness area.

Although habitat in the Hot Springs Fork is of high quality, the stream has only moderate protection and restoration rankings for the Clackamas River as a whole. Conditions in the Hot Spring Fork potentially affect three of the six populations. The stream received a moderately low protection ranking for upriver coho (5 of 9) and a low ranking for restoration (7 of 9). The Hot Springs Fork has a relatively high gradient (3 percent) and is more suited to steelhead than coho. However, rankings for steelhead and spring Chinook were also moderately low (Figure 3-76). Overall, the Hot Springs ranked low in this assessment because of (1) its relatively small size and resulting low biological capacity and (2) its extreme upriver location and the resulting effects of all the habitat constraints below its confluence with the Collowash River.

Geographic Area: Hot Springs Fork

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	5	7	9					•		●		●				●			●
Lower Steelhead																			
Upper Steelhead	4	6	8					•		•		⬤				●			●
Fall Chinook																			
Spring Chinook	5	7	13							•		●				•			●
Average Area Rank	4.7	6.7	10.0																

Figure 3-76: Protection and Restoration Rankings for the Hot Springs Fork Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

Habitat constraints in the Hot Springs Fork were obstructions, habitat diversity, sediment, and key habitat quantity (Figure 3-76). Obstructions (culverts and road crossings) were a key limiting factor for winter steelhead that would use the upper reaches with better access. Less robust riparian forests and lack of large wood have decreased habitat diversity. Sediment reflects some logging and road building in the watershed, while the stream has narrowed somewhat, resulting in a loss of the quantity of key habitats.

Limiting Factors in Upper Clackamas Tributaries

Protection Priority: 6
Restoration Priority: 9

This area consists of smaller tributaries in the Clackamas River above Oak Grove Fork, including Tag, Trout, Pot, Wolf, Kansas, Pinhead, Last, Lowe Rhododendron, Fawn, Hunter, Cub and Berry creeks. This portion of the Clackamas Subbasin is managed by the Forest Service and contains areas with high-quality riparian and stream habitats. While the area does not support large numbers of spawning and rearing fish, it does provide diverse habitats, primarily for coho salmon and winter steelhead.

The upper Clackamas tributaries had moderate overall restoration and protection rankings for the entire Clackamas River. The streams potentially affect three of the six populations. Relative to the small tributaries in the middle and lower Clackamas, the upper Clackamas tributaries were ranked high for the three relevant populations (Figure 3-77). For upriver coho, the tributaries were ranked number two (of 9) for protection and were ranked number one for restoration. For upriver winter steelhead, the tributaries were ranked number 2 (of 8) for both protection and restoration.

Geographic Area: Upper Clackamas River Tributaries

	Area Rank			Survival Factor Priority for Restoration															
Population	**Protection Rank**	**Restoration Rank**	**Out of**	***Channel stability/landsc.1/***	***Chemicals***	***Competition (w/ hatch)***	***Competition (other sp)***	***Flow***	***Food***	***Habitat diversity***	***Harassment/poaching***	***Obstructions***	***Oxygen***	***Pathogens***	***Predation***	***Sediment load***	***Temperature***	***Withdrawals***	***Key habitat quantity***
Lower Coho																			
Upper Coho	2	1	9					•		●		⬤				●			●
Lower Steelhead																			
Upper Steelhead	2	2	8							•		⬤			•	●			●
Fall Chinook																			
Spring Chinook	3	5	13					•							•	•			●
Average Area Rank	2.3	2.7	10.0																

Figure 3-77: Protection and Restoration Rankings for the Upper Clackamas Tributaries Area and Restoration Effects of Survival Attributes on Six Populations from the Clackamas River

The primary habitat limitation in the upper Clackamas tributaries is obstructions (Figure 3-77) that limit access to upper reaches by coho and steelhead. Increased levels of fine sediment and a decline in the quantity of habitat also limited potential performance.

3.5.1.15 Limiting Factors in the Johnson Creek Subbasin (with EDT Analysis)

This section describes the geographic setting of the Johnson Creek Subbasin and limiting factors for two of the focal species in the subbasin: coho salmon and winter steelhead. The limiting factors were determined by using EDT to analyze salmonid habitat conditions on a reach-by-reach basis throughout the Johnson Creek Subbasin.

Focal Species present:

- Coho salmon
- Winter steelhead
- Cutthroat trout

Because their health, abundance, and productivity are linked to terrestrial and aquatic watershed conditions, salmonids (salmon and trout) are a good indicator of watershed health. Salmon are sensitive to all components of watershed processes and functions (hydrology, habitat, water quality, and biological communities). More is known about the life histories of salmon and the relationships between stream conditions and population abundance and productivity than is known about many other aquatic species in the Willamette River Basin. Chinook, coho, and steelhead have complex life histories that involve resident and anadromous life history traits and as such can be important indicators of environmental condition.

Historical data characterizing the presence and distribution of salmonids are generally more quantitative and comprehensive than data on other native fish communities, hence reference conditions and existing habitat conditions and associated population status can be better evaluated. In addition to past and present data availability, salmon populations will continue to be evaluated in the near and long-term future, as a result of federal Endangered Species Act listings. However, the ability to acquire biological data in the future is critical in evaluating trends in habitat condition and thus is needed to effectively inform decisionmaking and to evaluate the success of implemented actions. For these reasons, other, non-ESA-listed native fish communities, such as rainbow, cutthroat, and sculpin, may in the future play an important role in helping to evaluate habitat conditions.

For now, Johnson Creek coho and steelhead were chosen as focal species to be evaluated using EDT. Both are native to Johnson Creek and experience freshwater conditions that affect other native fish communities in the subbasin. Cutthroat trout, rainbow trout, and Pacific lamprey are likewise considered important species in the Johnson Subbasin, but these species were not evaluated in EDT. Neither resident fish population dynamics nor or lamprey life history strategies have been substantively defined in EDT; thus, they were not evaluated using this tool.

Johnson Creek Coho

Population Description. The Johnson Subbasin coho population was defined to spawn and rear throughout the entire mainstem Johnson Creek and its tributaries. No natural fish barriers were identified. Life history of this population is based on similar populations in the lower Willamette River, most prominently the Clackamas River and Tryon Creek populations. Coho return as 3-year-age adults and 2-year-age jacks. Lower Willamette coho are an early-run population, reaching Willamette Falls from late August through early November. Peak migrations occur from middle to late September, following periods of considerable rainfall, and peak spawning generally occurs soon afterwards, from September through December. Fry emerge from mid-January through April, yielding a 4-month emergence period. While a small proportion of fry emigrate during the first year, most fingerling smolts emigrate during the second spring, beginning in March and extending through mid-July.

Relationship to ESU or Other Population Designations. The Johnson Creek coho population is part of the Lower Columbia River coho ESU, which were listed on the state ESA in July 1999. This population was previously considered for federal listing. On July 25, 1995, NMFS determined that the listing was unwarranted; however, the population remains a “candidate” for listing on the federal ESA. The Willamette River Basin, up to Willamette Falls and including the Clackamas River, contains major spawning and rearing habitat for this population.

Historical Abundance and Present Status. Willamette Basin coho are believed to be native only to subbasins below Willamette Falls—notably, the Clackamas River Basin, Johnson Creek (Fulton, 1970), and Tryon Creek (WMSWCD, 2003d)—and were reported occupying tributaries to Multnomah Channel from 1951 to 1959 (Willis et al, 1960). Notably, the lower Willamette River Basin provided the third most important spawning grounds for coho salmon throughout the entire Columbia River basin (Fulton, 1970).

In Johnson Creek, adults migrated through and occupied lower, middle, and upper areas of the watershed; however, the best spawning habitat was believed to be in the upper watershed (Fulton, 1970).

Presently, Johnson Creek’s biological communities have been greatly reduced from historical conditions. Many native fish populations, including salmon, have declined significantly.

Biotic integrity is severely impaired basinwide (ODFW, 2002); however, native fish communities continue to populate and dominate fish community structure in the basin: redside shiners, reticulate sculpin, and speckled dace.

Observations of adult and juvenile coho in lower Johnson Creek and Crystal Springs suggests within population recruitment and production and/or use by other Willamette Basin populations.

Johnson Creek Winter Steelhead

Population Description. The Johnson Creek winter steelhead population was defined to spawn in mainstem Johnson Creek and its tributaries. No natural fish barriers were identified. The life history of this population is based on other lower Willamette winter steelhead populations, notably the Clackamas and Tryon Creek populations. Both are believed to be a late-run population returning to freshwater to spawn during their fifth and sixth years. Native, late-run winter steelhead entered the Willamette River from October through May (Dimmick, 1945), with spawning beginning in March and peaking in April through May. Juvenile steelhead generally spend 2 years in freshwater before smolting, with peak emigration beginning early April and extending through early June. Larger steelhead generally emigrate sooner than their smaller cohorts (ODFW, 2000).

Relationship to ESU or Other Population Designations. Johnson Creek winter steelhead are part of the Lower Willamette River ESU and are believed to be most closely associated with populations below Willamette Falls: Clackamas River and Tryon Creek.

Historical Abundance and Present Status. Small wild winter steelhead runs have populated Johnson Creek since the 1950s (ODFW, 2000). Prior to the mid-1960s, key spawning and rearing habitat was believed to be located in the lower portion of Johnson Creek basin. Since then, winter steelhead are believed to have extended their distribution up to the middle section of the basin (Fulton, 1970).

Johnson Creek's biological communities have been greatly reduced from historical conditions. Many native fish populations, including salmon, have declined significantly. Biotic integrity is severely impaired basinwide (ODFW, 2002); however, native fish communities continue to populate and dominate the basin: redside shiners, reticulate sculpin and speckled dace. Large-scale suckers are notably abundant in the lower reach. Observations of adult and juvenile steelhead/rainbow in lower Johnson Creek and Crystal Springs suggests within-population recruitment and production and/or use by other Willamette Basin populations.

Geographic Setting. Johnson Creek is a third-order stream draining a watershed of approximately 54 square miles. The stream is 24-miles long and includes eight named tributaries. It is a low-gradient stream that drops some 660 feet over its 24-mile course for an average mainstem gradient of 0.5 percent. A number of volcanic vents and domes – such as the Boring Lava Domes – influence the topography of the Johnson Creek watershed. Elevations range from high point of 1,129 feet at the Boring Hills to near sea level at the confluence. The topography of the watershed consists of a moderate-gradient upper segment (0.6 percent gradient), a flat middle segment (0.2 percent), and a moderate-gradient lower segment (0.8 percent). Terrain on the north side of the watershed is typically less steep than on the southern side. Hillslopes typically range between 1 and 25 percent, although Mt. Scott has hillslopes as high as 50 percent.

Surficial geology in the Johnson Creek watershed is based on two major formations. Most of upper Johnson Creek watershed is characterized by Troutdale Gravel, a Miocene formation of Columbia River deposits characterized by rounded cobbles and gravel (Orr and others, 1976). In the middle and lower portions of the basin, Willamette Silt overlies the Troutdale Formation. This consists of unconsolidated silts deposited by the Missoula Floods in the late Pleistocene.

Soils in the northern portion of the watershed are of low to moderate erodibility and are generally more porous, with moderate to high permeability; however, this is also where impervious surfaces predominate. Soils in the southern portion of the watershed are moderately erodible. They are largely clay, and therefore have low porosity. Soils are primarily Multnomah and Latourell-Urban Land Complex (Type B hydrologic group) or Cascade Silt Loam (Type C hydrologic group). Type B comprises 71 percent of the watershed, while Type C comprises 21 percent.

Key Findings. For the Johnson Creek coho salmon population, the current potential is about 6 percent of that under the reference habitat conditions, while steelhead populations are about 4 percent of that under the reference habitat conditions. The percent change is a measure of the overall degradation of habitat conditions in the Johnson Creek watershed, primarily as a result of anthropogenic changes throughout the watershed and in the lower Willamette River.

Present habitat conditions in the Johnson Creek Subbasin are symptomatic of both impaired watershed processes and discrete actions that have occurred in the subbasin. For example, lining the creek with Works Progress Administration (WPA) tiles significantly altered natural hydraulic processes throughout the middle and lower portions of Johnson Creek. Tiles constrain creek flows into the main channel, reduce floodplain and riparian connectivity, and hydrologically disconnect historical floodplain wetlands from mainstem flows. This has resulted in a creek that is highly channelized and—where natural bank form is present—eroded. In addition, urbanization throughout the watershed has altered hydrologic regimes draining the subbasin; storm flows are more frequent and of higher velocities than they were historically. The cumulative effect has been a reduction in habitat diversity, high sediment loading, a loss of key habitats, and impaired fish passage basinwide. Table 3-167 summarizes key habitat attributes limiting Johnson Creek steelhead and coho populations.

Table 3-167: Summary of Key Problems in Johnson Creek

Habitat Attribute	Symptomatic Habitat Features
Habitat complexity	Lack of large wood, large and medium-sized substrate, overhanging vegetation, and stream bank diversity (for example, undercut banks). Simplified and hardened channel morphology (WPA lining). Shorter stream length with fewer meanders.
Key Habitats	Lack of high-quality riffles, deep pools, side channels, secondary channels, and off-channel and backwater habitats critical for spawning and rearing.
Fine Sediment	High sediment loads smother spawning habitats (riffle gravels) and subsequent egg

Table 3-167: Summary of Key Problems in Johnson Creek

Habitat Attribute	Symptomatic Habitat Features
	incubation environment and fill pools, thus reducing the quality of depth refugia. High silt cover reduces areas for macroinvertebrate production and subsequent food sources. Indirect effects of prolonged suspended sediments on native fish communities include reduced feeding, avoidance reactions, and delayed (or ceased) migrations.
Riparian and Floodplain Condition	Lack of native conifers and hardwoods as source wood limit the longevity and function of wood in the creek. Lack of overhanging vegetation along streambanks destabilizes the creek and minimizes potential protective cover to fish and wildlife. Lack of mature native trees and shrubs increases the potential for elevated water temperatures in the summer and limits the amount and type of future sources of woody debris.
Flow	Low summer flows increase potential for elevated water temperatures and reduce potential habitat function (for example, depth refugia). High storm flows in fall, winter, and spring.
Stream Temperature	Elevated summer temperatures stress fish communities, resulting in lethal and sublethal effects.
Stream Connectivity	Artificial obstructions impair juvenile migrations in Middle Johnson Creek, Crystal Springs Creek, and Kelley Creek. Artificial obstructions at key tributary confluences limit adult and juvenile movement.
Chemical Contamination	Chronic and acute chemical toxicity may result in lethal and/or sublethal effects to aquatic communities, including macroinvertebrate production.

EDT Approach

Information Sources. Wherever possible, existing data were used to rate EDT attributes, and the use of expert opinion in rating attributes was minimized. Flow attributes were rated using USGS gauges and hydrology models. Habitat attributes were rated using an ODFW habitat survey (ODFW, 2000). Water quality attributes were rated using City of Portland Bureau of Environmental Services monitoring data and USGS water quality investigations (Edwards, 1994). Biological attributes were rated using a Portland State University study of macroinvertebrates (Pan et al., 2001) and a collection of technical studies on Johnson Creek (Johnson Creek Corridor Committee, 1994).

The purpose of the EDT assessment of the Willamette River below Willamette Falls was to evaluate the affect of the lower Willamette River on Johnson Creek coho and steelhead population productivity. One limitation in the EDT analysis of the lower Willamette River that should be addressed in future work is the need to include additional habitat types and species rules to account for the complexity of the large river environment. EDT is based on the existing scientific literature regarding salmonid-habitat relationships. The great bulk of that literature focuses on “wadeable” streams. Large-river habitats used by salmon have not been extensively studied not only because of the difficulties in studying these environments, but also because large rivers are often viewed as simple migration corridors, rather than complex spawning and rearing areas. Habitat types developed for smaller streams are inadequate to evaluate the habitat functions provided in large-river habitats. The complexity of the alluviating Willamette environment represents considerable habitat complexity and should be included in future EDT analyses.

Scenario Development. Three scenarios were described to evaluate coho and steelhead productivity in Johnson Creek Subbasin. The first describes the current conditions based on existing empirical and expert knowledge regarding hydrology, water quality, physical habitat, and biological communities in Johnson Creek. The second scenario describes a reference or template condition. This reference condition defines fully restored conditions in Johnson Creek, its tributaries, and the lower Willamette River, as they relate to salmonid life history, spawning, and rearing. The third scenario describes a fully degraded condition for the subbasin. Placing the current condition between the two “bookends” (that is, the reference condition and the fully degraded condition) allows evaluation of each population and its reliance on basinwide protection and restoration measures (such as reducing sedimentation) and measures at specific areas (fish passage improvements, for example).

Reach Structure and Geographic Areas. Mainstem Johnson Creek, Kelley Creek, and Crystal Springs Creek were evaluated using EDT, and six smaller tributaries were evaluated for their cumulative importance in providing important habitat functions. The lower Willamette River (from Willamette Falls downstream to the confluence with the Columbia River) also was evaluated for its effect on life-history diversity and juvenile rearing of Johnson Creek salmon populations.

Stream reaches in the Johnson Creek Subbasin are coincident with those of the ODFW Aquatic Inventory Project. Generally reaches are defined by functional characteristics such as tributary confluences, changes in valley form and channel form, major changes in vegetation, and/or changes in land-use ownership (Moore et. al., 1997). In addition to these landscape attributes, unique channel forms such as culverts and fish barriers were identified as unique reaches so that each could be rated as to its potential impact on coho and steelhead productivity. Table 3-168 shows the number of stream reaches per watershed in the Johnson Creek Subbasin.

Table 3-168: Number of Stream Reaches in the Johnson Creek Subbasin

Subbasin Name	Total Number of Stream Reaches Evaluated	Number of Grouped Stream Reaches
Johnson Creek (mainstem)	23	3
Crystal Springs Creek	4	
Kelley Creek	2 (mainstem) 3 tributaries	1
Johnson Creek Tributaries	6	1
Lower Willamette Mainstem	5	1

Mainstem Johnson Creek was further grouped into three geographic areas that reflect watershed function and land-use. Kelley and Crystal Springs creeks were evaluated as individual subwatersheds draining the Johnson Creek Subbasin. Additional small tributaries were evaluated as an entire habitat function, and the lower Willamette mainstem was evaluated as an entire mainstem reach affecting salmonid productivity in the Johnson Creek Subbasin.

Lower Willamette River. The lower Willamette River reach includes five distinct river segments. From upstream to downstream they are Sellwood, Ross Island, Downtown, Harbor, and Industrial.

Lower Johnson. Lower Johnson Creek begins at the Willamette confluence and extends upstream to SE 82nd (5.56 river miles). Crystal Springs Creek enters mainstem Johnson Creek near the downstream segment of the reach, and Errol Creek enters the mainstem just upstream of Tideman Johnson Park. Critical habitat features include the confluence of Johnson Creek and the Willamette River.

Middle Johnson. Middle Johnson Creek begins at SE 82nd and extends upstream to the Springwater Corridor bridge (trail), just upstream of Main City Park in Gresham (9.72 river miles). Veterans, Wahoo, Kelley, and Butler creeks enter the mainstem Johnson through this reach.

Upper Johnson. Upper Johnson Creek begins at the Springwater Corridor bridge (trail), just upstream of Main City Park in Gresham and extends upstream through the headwaters (8.7 river miles). Surface water draining agricultural lands provide source flows to Johnson Creek. Hogan and McDonald creeks enter mainstem Johnson in this reach.

Kelley Creek. Kelley Creek enters Middle Johnson Creek and extends upstream to the north side of Kelley Creek Farms. The Kelley Creek subwatershed drains Mitchell, Clatsop, and Church creeks.

Crystal Springs Creek. Crystal Springs reach begins at the confluence of Kelley and Johnson creeks and extends upstream to Reed College Lake.

Johnson Tributaries. Six tributaries were included in Johnson Creek Tributaries: Errol, Veterans, Wahoo, Butler, Hogan, and McDonald creeks.

EDT Results. EDT was used to assesses habitat in terms of four population output parameters:

1. Biological capacity (quantity of habitat)
2. Biological productivity (quality of habitat)
3. Equilibrium abundance (quantity and quality of habitat)
4. Life history diversity (breadth of suitable habitat)

Capacity and productivity are parameters of a Beverton-Holt production function; abundance is calculated from this relationship. Life history diversity is listed as a Diversity Index that is the percentage of viable trajectories sustainable under the current condition relative to the reference condition.

Population potential provides an assessment of the “size” and quality of the Johnson Creek coho salmon population. Figure 3-78 compares the estimated current abundance potential to the abundance potential of the habitat under the reference or template condition. Note that this is an index of habitat potential and that the actual abundance of fish observed in Johnson Creek will vary greatly from year to year as a result of factors within and outside the subbasin, especially variation in ocean conditions.

For the Johnson Creek coho salmon population, the current potential is about 6 percent of that under the reference habitat conditions. The percent change is a measure of the overall degradation of habitat conditions in the Johnson Creek watershed, primarily as a result of anthropogenic changes throughout the watershed and in the lower Willamette River.

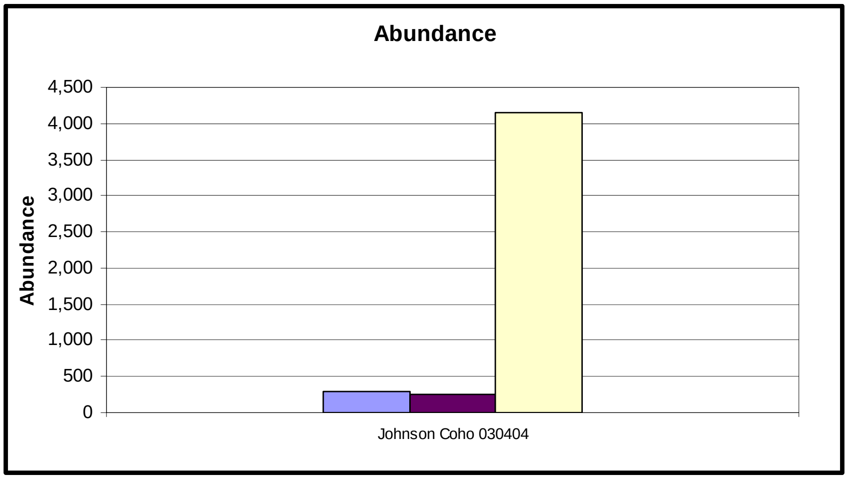


Figure 3-78: Estimated Coho Abundance Potential as a Function of Habitat in the Current and Reference Conditions for the Johnson Creek Coho Population

Figure 3-79 provides an assessment of the “size” and quality of the Johnson Creek steelhead population. For the Johnson Creek steelhead salmon population, the current potential is about 4 percent of that under the reference habitat conditions.

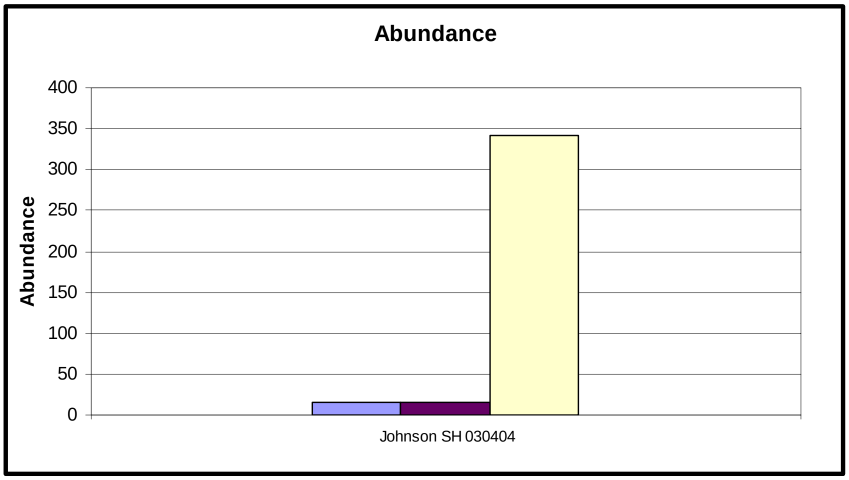
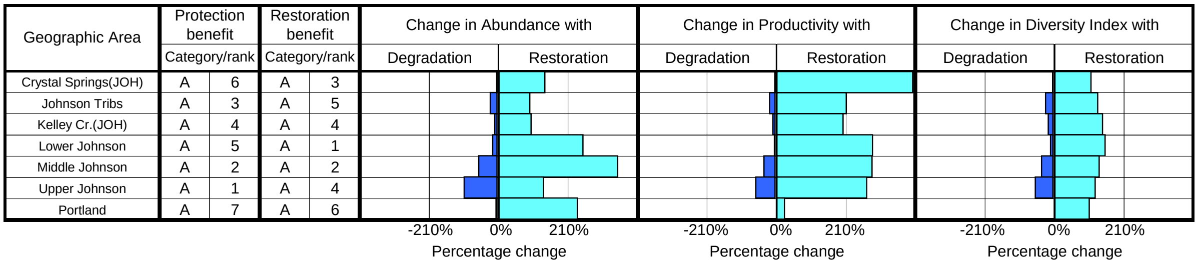


Figure 3-79: Estimated Steelhead Abundance Potential as a Function of Habitat in the Current and Reference Conditions for the Johnson Creek Steelhead Population

Geographic Area Habitat Priorities for Protection and Restoration. The results of the EDT reach analysis were aggregated to provide an estimate of the changes in the abundance, productivity, and diversity of Johnson Creek coho and winter steelhead populations for each geographic area. The changes in the Johnson coho and winter steelhead populations' attributes provide an estimate of the relative importance of the geographic areas for habitat protection and restoration measures. The priorities for the geographic areas are based on the following:

- An estimate in the changes in population abundance, productivity, and diversity at each life stage under conditions of habitat degradation from the current state (protection benefit) and habitat restoration to the historical potential (restoration benefit)
- The extent to which the geographic area is used by each of the life stages

Johnson Creek Coho. Figure 3-80 illustrates the changes in coho population parameters at each geographic area and the coincident restoration and protection value. Table 3-169 further shows the relative protection value for each geographic area, or what would be lost if ecological functions in these areas are not conserved. Table 3-170 shows the relative restoration value for each geographic area, or the relative benefit that could be realized if this geographic area were restored to reference conditions



Geographic Area	Protection benefit		Restoration benefit	
	Category/rank		Category/rank	
Crystal Springs(JOH)	A	6	A	3
Johnson Tribs	A	3	A	5
Kelley Cr.(JOH)	A	4	A	4
Lower Johnson	A	5	A	1
Middle Johnson	A	2	A	2
Upper Johnson	A	1	A	4
Portland	A	7	A	6

Figure 3-80: Johnson Creek Coho Habitat Priorities

Protection Value. Based on this analysis, upper Johnson Creek provides the greatest opportunities for protection value to coho salmon (Table 3-169). Protection value in the upper watershed comes almost entirely from a portion of Johnson Creek that contains large wood, deep pools, backwater areas, and more complex channel form, all of which are important to coho productivity. This area is most important in that it provides higher quality spawning and early life history rearing habitat than do other areas. In addition, Hogan Creek flows into this portion of the reach and may provide important flow and temperature refugia.

Table 3-169: Estimated Protection Value of Each Geographic Area for Johnson Creek Coho

Geographic Area	Restoration Rank	Percent Change in Coho Parameters with Protection		
		Abundance	Productivity	Diversity
Lower Johnson	5	13 percent	2 percent	8 percent
Middle Johnson	2	56 percent	34 percent	34 percent
Upper Johnson	1	100 percent	58 percent	54 percent
Crystal Springs	6	1 percent	0 percent	1 percent
Kelley Creek	4	7 percent	6 percent	14 percent
Johnson Tributaries	3	21 percent	17 percent	23 percent

Table 3-169: Estimated Protection Value of Each Geographic Area for Johnson Creek Coho

Geographic Area	Restoration Rank	Percent Change in Coho Parameters with Protection		
		Abundance	Productivity	Diversity
Lower Willamette River	7	3 percent	0 percent	0 percent

Middle Johnson Creek provides the second greatest benefit for protection. Notably, the reach running through Tideman Johnson Park is believed to be a key habitat core, with higher quality and rearing habitat. Key Johnson Creek tributaries also provide important protection value, likely resulting from their influence on water quality and provision of potential off-channel refugia during winter and summer rearing.

The lower protection values in lower Johnson, Crystal Springs, and the lower Willamette reflect poor habitat conditions in these areas that are greatly influenced by past and present urban land uses and management. Notably, under restored conditions, these habitat areas provide some of the most important areas for spawning and rearing. Specifically, lower Johnson Creek and Crystal Springs Creek provide the first and third greatest restoration potential, respectively. These areas were historically important for winter rearing, and it is likely that Crystal Springs Creek used to provide important cool water refugia throughout the summer.

Restoration Value. Lower Johnson Creek provides the best overall restoration potential for improving coho productivity, abundance, and diversity in Johnson Subbasin (Table 3-170). Notably, middle Johnson Creek provides the best restoration potential for increasing population abundance, while Crystal Springs Creek provides the greatest restoration potential for improving population productivity. Life history diversity and genetic diversity are equally affected under restored habitat conditions in nearly all reaches of Johnson Creek Subbasin.

Middle Johnson is low gradient and, as it did historically, currently contains key habitats such as floodplain wetlands that coho use and often prefer, particularly for rearing and refuge. The confluence area of Kelley Creek also is low gradient and historically contained numerous seasonal wetlands throughout its broader floodplain area with Johnson Creek. These habitats provide important overwintering habitat and would significantly influence overwinter survival, from juvenile to smolt.

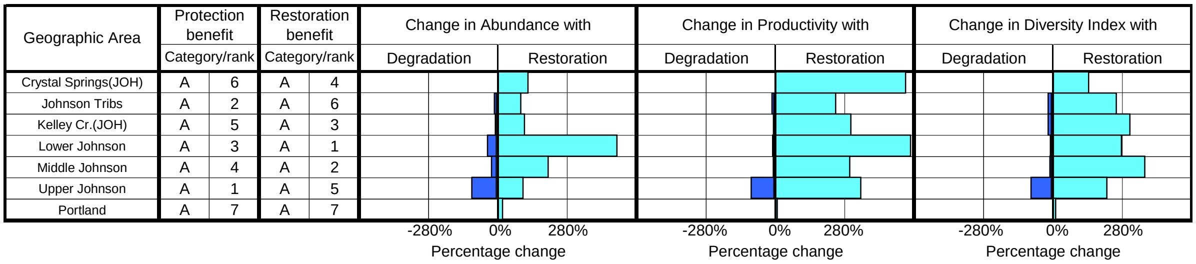
Table 3-170: Estimated Restoration Value of Each Geographic Area for Johnson Creek Coho

Geographic Area	Restoration Rank	Percent Change in Coho Parameters with Restoration		
		Abundance	Productivity	Diversity
Lower Johnson	1	257 percent	292 percent	254 percent
Middle Johnson	2	364 percent	291 percent	135 percent
Upper Johnson	4	136 percent	275 percent	124 percent
Crystal Springs	3	140 percent	416 percent	111 percent
Kelley Creek	4	98 percent	202 percent	146 percent

Table 3-170: Estimated Restoration Value of Each Geographic Area for Johnson Creek Coho

Geographic Area	Restoration Rank	Percent Change in Coho Parameters with Restoration		
		Abundance	Productivity	Diversity
Johnson Tributaries	5	94 percent	212 percent	131 percent
Lower Willamette River	6	240 percent	23 percent	105 percent

Johnson Creek Steelhead. Figure 3-81 illustrates the changes in steelhead population parameters at each geographic area and the coincident restoration and protection value. Table 3-171 further shows the relative protection value for each geographic area, or what would be lost if ecological functions in these areas are not conserved. Table 3-172 shows the relative restoration value for each geographic area, or the relative benefit that could be realized if this geographic area were restored to reference conditions.



Geographic Area	Protection benefit Category/rank		Restoration benefit Category/rank	
Crystal Springs(JOH)	A	6	A	4
Johnson Tribs	A	2	A	6
Kelley Cr.(JOH)	A	5	A	3
Lower Johnson	A	3	A	1
Middle Johnson	A	4	A	2
Upper Johnson	A	1	A	5
Portland	A	7	A	7

Figure 3-81: Johnson Creek Steelhead Habitat Priorities

Protection Value. Based on this analysis, upper Johnson Creek provides the greatest opportunities for protection value to steelhead (Table 3-171). Protection value in the upper watershed comes almost entirely from a portion of Johnson Creek (Reach 16) that contains large wood, deep pools, complex channel forms, and good substrate composition, all of which provide important spawning and rearing areas. In addition, Hogan Creek flows into this portion of the reach and may provide important flow and temperature refugia, and this portion of the creek has good shade cover. Notably, Reach 16 (which bounds the downstream end of upper Johnson Creek) contains the greatest refuge potential and is the most natural and least disturbed area in mainstem Johnson Creek (ODFW, 2000).

Table 3-171: Estimated Protection Value of Each Geographic Area for Johnson Creek Steelhead

Geographic Area	Protection Rank	Percent Change in Steelhead Parameters with Protection		
		Abundance	Productivity	Diversity
Lower Johnson	3	36 percent	5 percent	4 percent
Middle Johnson	4	19 percent	3 percent	6 percent
Upper Johnson	1	100 percent	92 percent	83 percent
Crystal Springs	6	0 percent	0 percent	0 percent
Kelley Creek	5	4 percent	2 percent	13 percent
Johnson Tributaries	2	8 percent	7 percent	13 percent

Table 3-171: Estimated Protection Value of Each Geographic Area for Johnson Creek Steelhead

Geographic Area	Protection Rank	Percent Change in Steelhead Parameters with Protection		
		Abundance	Productivity	Diversity
Lower Willamette River	7	0 percent	0 percent	0 percent

Johnson Creek tributaries (Errol, Veterans, Wahoo, Butler, Hogan, and McDonald creeks) provide the second greatest benefit for habitat protection. These tributaries augment summer low flows and may provide important cool water refugia in the summer and off-channel refugia in the winter. Errol Creek originates from wetland springs and provides cooler and less turbid water into middle Johnson Creek. Wahoo Creek is surrounded by an intact riparian buffer and fish passage is not a concern; this area likely provides important off-channel refugia to fish residing in middle Johnson Creek in the winter. MacDonald Creek also contains a relatively good riparian corridor, based upon canopy cover, riparian width, and the presence of native conifers and hardwoods. In addition, channel complexity is good and pools and riffles are present. MacDonald Creek flows into upper Johnson Creek. Lower Johnson Creek likewise provides important protection benefit, most notably by providing spawning and rearing grounds.

The lower protection values in the lower Willamette River, Crystal Springs Creek, and Kelley Creek reflect the habitat type and use that these areas would naturally provide to winter steelhead. Notably, Crystal Springs Creek is low gradient, with low flows, and may not have historically provided a high quantity of spawning and rearing grounds relative to mainstem Johnson Creek; however, this subwatershed undoubtedly provided key habitat that supported key habitat. The lower Willamette River did not provide substantive spawning or long-term juvenile rearing grounds, but it is very important during adult steelhead migrations and juvenile emigrations.

Restoration Value. Lower Johnson Creek provides the best opportunity to restore important spawning and rearing grounds in the Johnson Creek Subbasin. Restoration of these habitats—most notably riffles for spawning and summer rearing (and feeding) and deep pools for cover—could substantively increase steelhead abundance and productivity in the Johnson Creek Subbasin. Notably, Crystal Spring Creek flows into lower Johnson Creek. Although this subwatershed historically did not provide a high quantity of spawning and rearing habitat (relative to mainstem Johnson Creek), it likely provided cool water refugia during the summer. This significantly affects steelhead productivity and juvenile rearing because steelhead spend 2 to 3 years in freshwater before emigrating seaward. Kelley Creek provides important restoration potential for similar reasons as does Crystal Springs Creek; however, Kelley Creek likewise contains quality spawning and rearing habitat in the form of riffle gravels and pools.

Table 3-172: Estimated Restoration Value Each of the Geographic Area for Johnson Creek Steelhead

Geographic Area	Restoration Rank	Percent Change in Steelhead Parameters with Restoration		
		Abundance	Productivity	Diversity
Lower Johnson	1	485 percent	551 percent	279 percent
Middle Johnson	2	204 percent	302 percent	375 percent
Upper Johnson	5	101 percent	341 percent	219 percent
Crystal Springs	4	121 percent	531 percent	144 percent
Kelley Creek	3	107 percent	307 percent	313 percent
Johnson Tributaries	6	92 percent	245 percent	258 percent
Lower Willamette River	7	17 percent	5 percent	10 percent

Middle Johnson Creek provides important restoration potential. It contains key habitats in the form of deep pools and riffle area. Core habitats such these support varied life history strategies expressed by steelhead, including adult holding, spawning, fry colonization, and summer and winter juvenile rearing.

Notably, for both coho and steelhead, upper Johnson Creek, middle Johnson Creek, and Johnson Creek tributaries (not including Kelley and Crystal Springs creeks) were identified as higher priority reaches for protection. These areas are likely functioning in a manner that closer to their natural state than are other reaches, such as the lower Willamette River and Crystal Springs, which have been more greatly altered and affected by urban constructs and human uses. Notably, these areas with high protection value are strongholds for population productivity.

It is also worth noting that lower Johnson, middle Johnson, Crystal Springs, and Kelley Creek were identified as having higher priority for restoration. These areas currently have more urban influences but historically were very important for salmonid spawning and rearing.

Assessment of Habitat Constraints

Habitat Complexity. One of the most significant factors in determining habitat complexity is the abundance and composition of large wood. ODFW findings generally indicate that Johnson Creek has extremely low wood volumes instream, particularly large wood that is necessary for pool formation. Wood volume is extremely low throughout Johnson Creek. ODFW considers values higher than 30 cubic meters per 100m to be desirable, and values of less than 20 cubic meters per 100m to be undesirable. All values throughout Johnson Creek are well below the undesirable benchmark (see Figure 3-82). This is due to the lack of large, mature riparian trees, as well as active removal of woody debris from the creek by citizens and officials from city agencies trying to prevent obstruction of flows downstream.

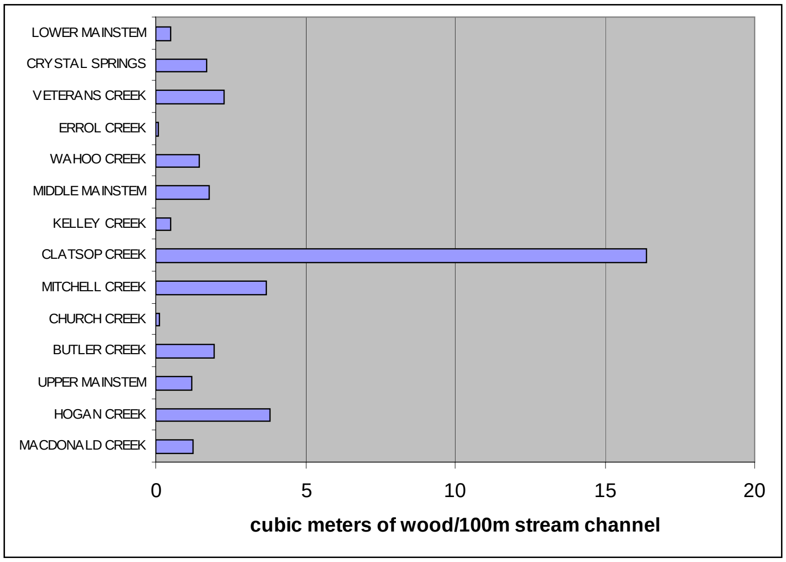


Figure 3-82: Volume of Wood per 100 Meters of Channel Length

Source: ODFW, 2000.

Another factor reducing habitat complexity is the reduction in total stream length that has occurred as Johnson Creek has urbanized over the last 150 years. Analyses indicate that the current watershed has less than half the stream kilometers of the historical stream. Up to 75 kilometers of stream have been filled, piped, or otherwise eliminated from the Johnson Creek drainage, leaving a much simpler system that retains only 62 stream kilometers (Metro, 2000). Metro topographic modeling analysis suggests the historical presence of a large tributary entering the middle section of Johnson Creek from the north side that could have added approximately 41 stream kilometers and was likely an extensive wetland complex, as well as other smaller tributaries throughout the watershed.

Key Rearing Habitats. Key habitat relates to the amount of deep pools, side channels, secondary channels, off-channel and backwater habitats, and high-quality riffles in the watershed. Pools are relatively abundant and well dispersed through the watershed. However, pool quality, as measured by residual pool depth and the number of complex pools, is fair or poor throughout much of the watershed (see Figure 3-83). This is largely due to the lack of large wood associated with pools, and inadequate residual pool depth.

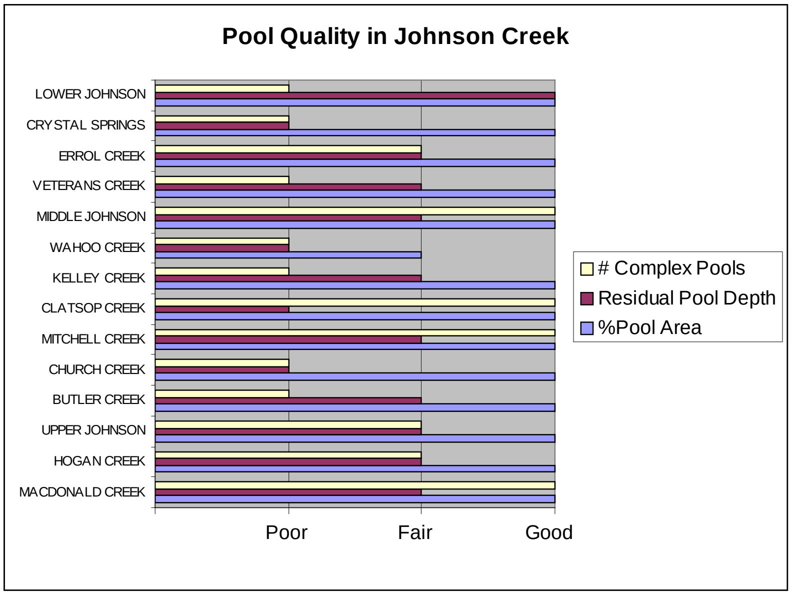


Figure 3-83: Amount and Quality of Pool Habitat Throughout Johnson Creek

Good, fair, and poor ratings are based on ODFW habitat benchmarks.

Source: ODFW, 2000.

ODFW also found that glides, which are generally uncommon in natural, healthy creeks, are widespread throughout Johnson Creek. This is an indication of the quality of instream habitat and is likely due to the deficiency of instream wood, a key element in breaking glides into pools and riffles. Existing pools and riffles are created not by woody debris but by existing geomorphic features that have evolved as energy is dispersed along the stream course (McConnaha, 2002).

Side channels, alcoves, and backwater areas are present in some reaches of Johnson Creek, but extensive bank hardening and channel alterations have greatly reduced the number, quality, and accessibility of off-channel habitats. Crystal Springs and Kelley Creek provide much of the remaining off-channel habitat (Figure 3-84).

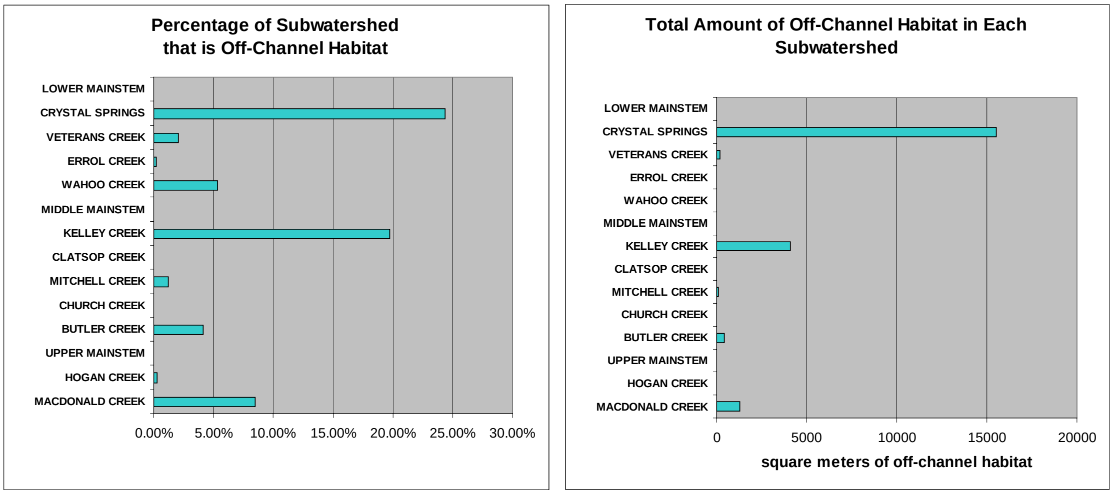


Figure 3-84: Percentage of Each Subwatershed That Is Off-Channel Habitat (Right) and Total Amount of Off-Channel Habitat That Each Subwatershed Provides (Left)

Crystal Springs and Kelley Creek provide much of the off-channel habitat in Johnson Creek.

Source: ODFW, 2000

Riffles make up 18 percent of the overall habitat throughout Johnson Creek and its tributaries, an amount that is moderately low for fish-bearing streams. Spawning and rearing grounds may be a limiting factor affecting population abundance and species diversity. However, riffle quality (substrate composition and proportion of fine sediments) is moderate to poor. Most of the tributaries have at least 50 percent riffle habitats with more than 35 percent gravel composition (see Figure 3-85)—considered optimal for fish-bearing habitat—while the mainstem has less than 50 percent meeting this benchmark. However, the proportion of substrate and gravels covered or embedded with fine sediments and organics is high basinwide, as described below.

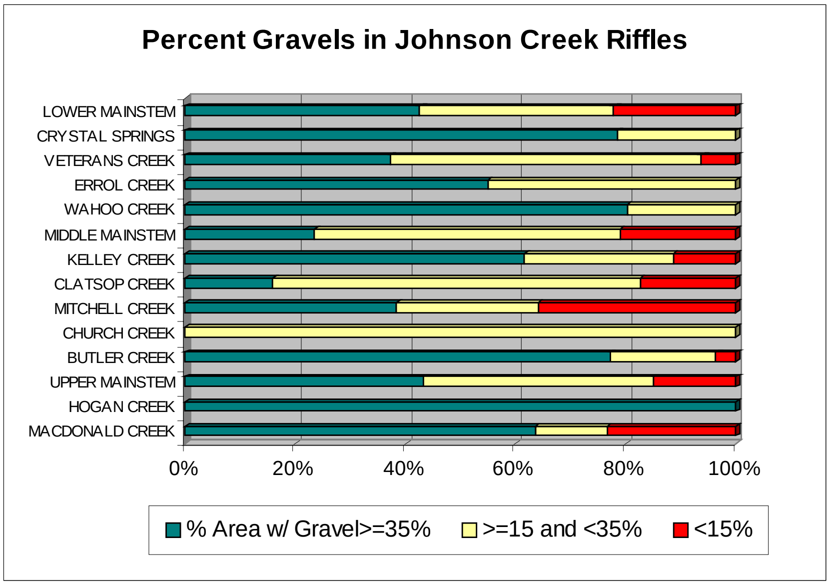


Figure 3-85: Percentage of Riffle Area in Johnson Creek Where Gravel Is Below 35 Percent

Source: ODFW, 2000.

Fine Sediment. The proportion of substrate and gravels covered or embedded with fine sediments and organics is high basinwide. Only Butler and Hogan creeks have a majority of riffles with less than 12 percent fines (see Figure 3-86), which is considered desirable habitat conditions for fish-bearing streams (GWEB, 1999). Spawning and rearing grounds may be a limiting factor affecting population abundance and species diversity.

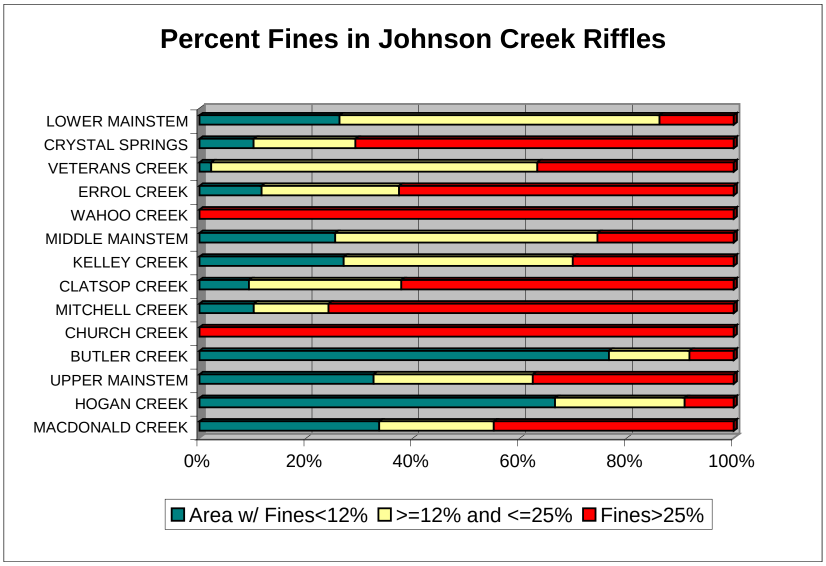


Figure 3-86: Percentage of Riffle Area in Johnson Creek Where Fines Exceed 12 Percent

Source: ODFW, 2000

Riparian and Floodplain Forest. The riparian corridor along Johnson Creek and its tributaries varies in width, from extensively vegetated areas more than 600 feet in width to reaches with little or no vegetation along the bank. Thirty-four percent of the watershed has little or no riparian vegetation present; an additional 32 percent has riparian vegetation less than 100 feet wide. The remaining remnants of riparian vegetation are primarily along the small, steep, southern tributaries where development has been less intensive. The tributaries with the most heavily forested riparian areas are Mitchell, Badger, Sunshine, and Deardorf/Wahoo creeks. Crystal Springs and the lower reaches of Johnson Creek (near the Milwaukie/Portland boundary) have the least extensive riparian vegetation. The Boring Lava Domes area is more heavily forested than most of the rest of the watershed. By comparison, the headwater streams flowing through rural agricultural lands in the upper watershed have very little riparian vegetation.

Riparian areas within the Johnson Creek watershed consist primarily of mixed forest with some coniferous forest and shrub areas. Dominant tree species in forested riparian areas within the watershed are Douglas fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*), black cottonwood (*Populus balsamifera trichocarpa*), and red alder (*Alnus rubra*). Other common tree species within the watershed include Oregon ash (*Fraxinus latifolia*), big-leaf maple (*Acer macrophyllum*), and Pacific willow (*Salix lasiandra*). Shrub habitats within the watershed include Himalayan blackberry (*Rubus discolor*), red-osier dogwood (*Cornus sericea*), hardhack (*Spiraea douglasii*), red elderberry (*Sambucus racemosa*), and salmonberry (*Rubus spectabilis*).

Flow. Seasonal patterns of flow in Johnson Creek reflect patterns of rainfall. High flows occur in December, January, and February in response to abundant rainfall and high amounts of runoff as soils become saturated through the rainy season. Summer low flows in July, August, and September reflect groundwater contributions to stream flow throughout the watershed.

High Flow Regime. Statistical evaluation of flow since 1940 indicates some increase in the flashiness of peak flows over the period of record. While increases in absolute peak flows are not evident, the amount of rainfall needed to produce a peak flow has decreased over time (Clark, 1999). Currently approximately 23 percent of the watershed is covered by impervious surfaces, which may be a key reason why high flows have become flashier.

Significant impacts on peak flows in Johnson Creek also appear to be affected by alterations in the stream channel and floodplain that have diminished the ability of the creek and floodplain to accommodate flood flows. Because of channel alterations, the historical floodplain of Johnson Creek is minimally accessible or inaccessible to creek waters through much of its length. The lack of floodplain access means that flood flows cannot spread out and slow down on the floodplain; instead they are directed and concentrated into the main channel, increasing scour and degrading instream habitat.

Low Flow Regime. Flow monitoring in Johnson Creek indicates that low flow conditions in Johnson Creek may adversely affect aquatic life. ODFW has set minimum flow targets to protect salmonids in Johnson Creek (Meross, 2000). Flows in the middle and upper watershed frequently do not meet those minimum flows, particularly in spring and summer months (see Figure 3-87). Below Crystal Springs, which provides consistent and abundant groundwater flows, minimum instream flows are typically met.

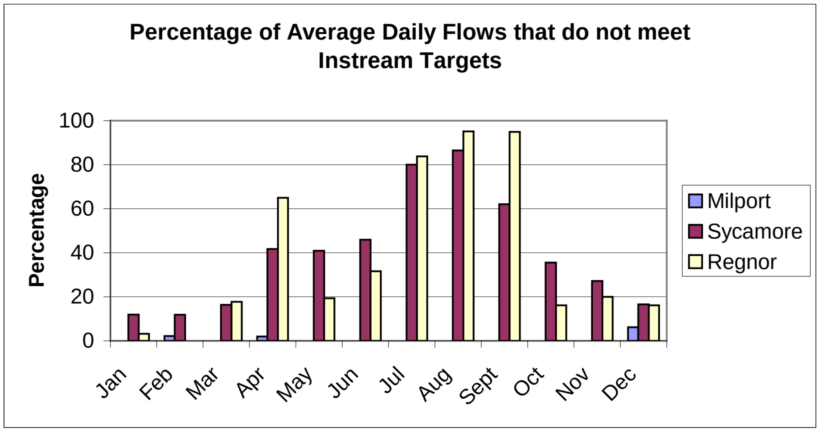


Figure 3-87: Percentage of the Average Daily Flow at the Milport, Sycamore, and Regnor Gauges That Do Not Meet ODFW Flow Targets

Source: USGS flow gauge data.

Stream Temperature. Numerous investigations of temperature in Johnson Creek over the years have consistently indicated that elevated temperatures are a problem throughout the watershed. Temperatures throughout Johnson Creek exceed water quality standards during the summer months (see Figure 3-88). Temperatures begin to exceed the spawning and incubation standard in April, although data are lacking to determine whether eggs and fry are still present within the gravel during this period. Temperatures at the mouth of Johnson Creek are consistently higher than temperatures in the middle and upper watershed.

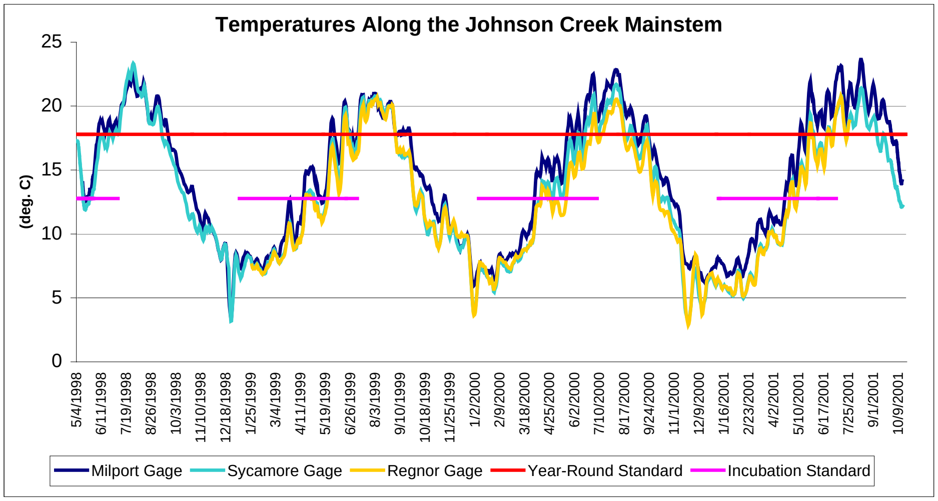


Figure 3-88: Temperatures along the Johnson Creek mainstem. Data source: USGS continuous temperature gauges.

Stream Connectivity. Culverts are present on nearly all of the tributaries to Johnson Creek. Much of the habitat that has been least encroached upon by development in the watershed is above culverts that partially or completely block salmon passage. Although there are no culverts on the mainstem until high in the watershed, they are present on nearly all the tributaries to Johnson Creek (see Figure 3-89). Crystal Springs, an area used by local and migratory Willamette salmonids, has a series of partially impassable culverts along its length, and some of the least developed tributaries along the southern side of the middle watershed also have culverts along their confluences with the mainstem.

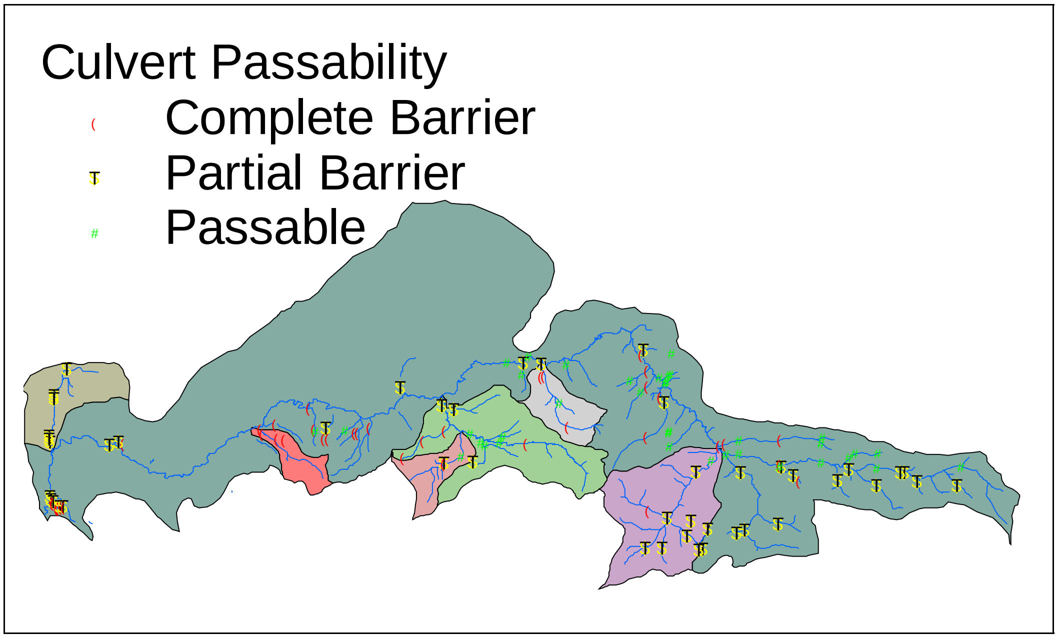
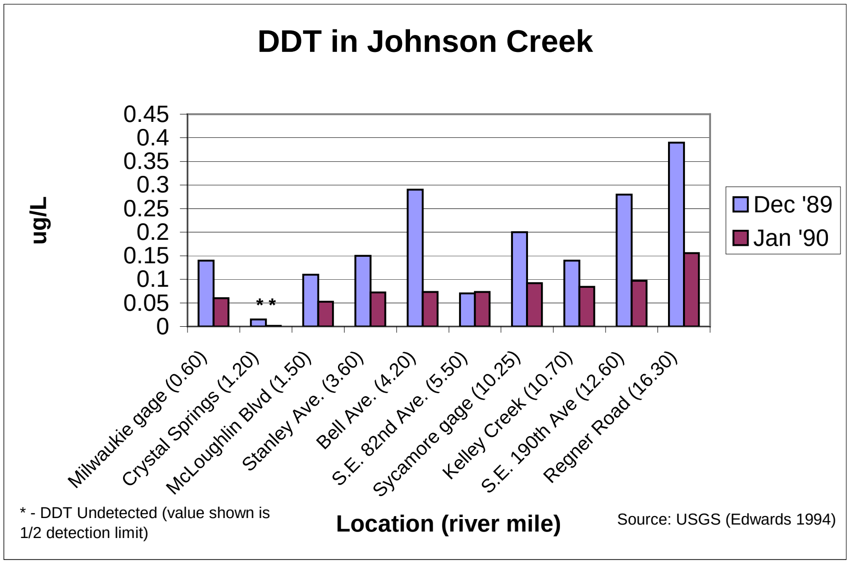


Figure 3-89: Culverts and Their Ratings for Passability in Johnson Creek

Source: Joint Johnson Creek Crossings data, 2000.

Chemical Contamination. Johnson Creek is on the 303(d) list for DDT and dieldrin, as both have been measured in concentrations that exceed state standards for chronic toxicity. DDT was identified as a problem based on the results of a USGS investigation; instream DDT concentrations are among the highest measured in the region (Edwards, 1994; see Figure 3-90). Additional investigations of DDT are planned to determine whether DDT concentrations have changed over time and to provide further evaluation of the nature and sources of DDT concentrations throughout the watershed.



* - DDT Undetected (value shown is 1/2 detection limit)

Source: USGS (Edwards 1994)

Figure 3-90: DDT Concentrations in Johnson Creek.

Source: Edwards, 1994.

Habitat Priorities by Geographic Area. The following sections describe key habitat attributes limiting coho and steelhead productivity in each geographic area. This assessment evaluates species productivity by life stage and associated habitat needs during development (or use).

Lower Willamette River

Coho	**Rank**	**Steelhead**	**Rank**
Protection benefit	7	Protection benefit	7
Restoration benefit	6	Restoration benefit	7

Coho were most affected by lack of habitat diversity and lack of key habitats in the lower Willamette River. The persistence of chemical contaminants year-round and warm temperatures in the summer likewise impair potential coho productivity in the lower Willamette.

The most vulnerable life stages and life history strategies affected include juvenile winter rearing, spring and summer rearing, and smolt emigration. Of these life stages, 0+ winter rearing is most vulnerable, followed by smolt emigration and spring and summer active rearing.

Juvenile Rearing (winter). Lack of shallow, low-velocity shoreline habitats (key habitats) and lack of complex shoreline structure and cover such as overhanging vegetation, large wood, and large substratum (habitat diversity) most prominently affect overwintering rearing and refuge habitat in the lower Willamette River. The lack of these critical overwintering habitats poses the greatest risk to successful coho production. The presence of chemicals, particularly those in close to shoreline and alcove areas, pose a potential risk to coho throughout the winter.

Active Rearing. As for juvenile overwintering, coho rely on shallow, slack-water habitats with complex shoreline structure and protective cover during the spring to rear and feed. These off-channel, shoreline, and alcove habitats provide areas where coho can feed and grow as they physiologically mature and smolt. Without these habitats, juvenile coho may move into the lower Columbia River at a smaller size, before they are physiologically ready to rear in saltwater environs. As result, juveniles may be more vulnerable to predators and may be at a disadvantage for surviving in the ocean.

Smolt Emigration. During emigration, coho smolts are most prominently affected by chemical contaminants and lack of key habitats. Although off-channel or marginal shoreline habitats remain important, once juvenile coho begin emigrating, moving out of the overwintering habitats and actively moving through the lower mainstem channel, they become less reliant on key habitat areas, thus becoming more sensitive to other environmental conditions that affect there ability to move downstream. In the lower Willamette, chemical contamination poses a great risk to coho as they emigrate seaward to the lower Columbia estuary.

Steelhead were most affected by chemicals and lack of key habitats in the lower Willamette River. The most vulnerable life stages and life history strategies affected include smolt emigration and prespawning adult migrations.

Smolt Emigration. Steelhead migrants are most prominently affected by chemical contaminants and lack of key habitats to temporarily rear and reside. As with coho, alcoves, tributary confluences, and off-channel areas are important to juvenile steelhead as they head seaward into the lower Columbia River. These areas are most prominently used for temporary refuge during storm flows and for temporary rearing. In addition to these areas, chemical contamination in the lower Willamette River prominently affects Johnson Creek steelhead productivity. As steelhead become less reliant on key habitat areas, they become more sensitive to environmental conditions that affect their ability to move downstream. In the lower Willamette, chemical contamination poses a critical risk to steelhead as they emigrate seaward from March through June.

Prespawning Adult. Adult steelhead enter the lower Willamette River from late fall through spring and are most prominently affected by lack of key holding areas, such as deeper pools, and chemical contamination.

Lower Johnson Creek

Coho	**Rank**	**Steelhead**	**Rank**
Protection benefit	5	Protection benefit	3
Restoration benefit	1	Restoration benefit	1

Coho were most affected by lack of habitat diversity and lack of key habitats. High sediment loading during storm flows, warm stream temperatures in the summer, and poor channel stability likewise impair potential coho productivity in lower Johnson Creek.

Most vulnerable life stages and life history strategies (for example, habitat preferences) affected include egg incubation, fry colonization, and juvenile rearing (winter and summer). Of these life stages young-of-the-year juvenile rearing and egg incubation are most vulnerable, followed by winter rearing and fry colonization.

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation and subsequent egg-to-fry survival. High storm flows through fall, winter, and spring erode unprotected banks along Johnson Creek, while WPA-lined creek portions prevent high flows from accessing the floodplain. This results in increased bed scour, increased bank erosion, and high sediment loading throughout the lower reach.

Fry Colonization. Fry colonization is most prominently influenced by lack of habitat diversity, lack of large wood, and lack of key habitats such as off-channel ponds, floodplain wetlands, and instream shallow-water habitats. In addition, lack of aquatic insects as food source adversely affects fry-to-juvenile survival.

Juvenile Rearing (Summer and Winter). Lack of large wood and large substratum (habitat diversity), lack of key habitats such as deep pools and riffles, and high stream temperature most prominently affect juvenile production through the summer. Lack of aquatic insects likewise limits coho productivity in lower Johnson Creek during active, summer rearing.

Lack of off-channel and slack-water habitats and instream structure (large wood, overhanging vegetation) are primary limiting factors affecting juvenile coho during winter rearing. Notably, the lack of critical overwintering habitats likely poses the greatest risk to successful coho production. Slack-water environs are most important during winter rearing and are critically important as high flow refugia during peak and prolonged high flows, which have also been identified as a key limiting factor in lower Johnson Creek.

Steelhead were most affected by lack of habitat diversity and key habitats and high sediment loading during early life history rearing. Warm stream temperatures in the summer and fish passage obstructions, most notably at Tideman Johnson Park and at tributary confluence areas, likewise impair potential steelhead productivity in lower Johnson Creek.

The most vulnerable life stages and life history strategies (for example, habitat preferences) most prominently affected include egg incubation and juvenile rearing (winter and summer). Of these life stages, egg incubation and juvenile spring/summer (active) rearing are most vulnerable, followed by winter (inactive) rearing.

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation and subsequent egg-to-fry survival. High storm flows through fall, winter, and spring erode unprotected banks along Johnson Creek, while WPA-lined creek portions prevent high flows from accessing the floodplain. This results in increased bed scour, increased bank erosion, and high sediment loading throughout the lower reach. Elevated stream temperatures potentially adversely affect incubation beds. Effects on egg incubation are most prominently noted in the middle and upper reaches of lower Johnson Creek.

Juvenile Rearing (Summer and Winter). The lack of large wood and large substratum (habitat diversity), low summer flows coincident with high stream temperature, and lack of primary food sources most prominently affect juvenile production through the summer in lower Johnson Creek. Notably, these habitat attributes affect both 0+ and 1+ age steelhead and are common throughout the lower reach; however, young-of-the-year steelhead are more vulnerable to habitat limitations compared to older aged juveniles that are likely to be more competitive for food and space.

Lack of instream structure such as large wood and overhanging vegetation primarily limits steelhead productivity (and survival) through the winter. Complex habitat forms provide important high flow refugia and protective cover during higher storm flows. Lack of these types of important habitats likely results in fish being swept downstream.

Middle Johnson Creek

Coho	Rank	Steelhead	Rank
Protection benefit	2	Protection benefit	4
Restoration benefit	2	Restoration benefit	2

Coho were most affected by lack of habitat diversity and lack of key habitats. High sediment loading during storm flows, warm stream temperatures in the summer, and poor channel stability likewise impair potential coho productivity in middle Johnson Creek.

The most vulnerable life stages and life history strategies (for example, habitat preferences) most prominently affected include egg incubation, fry colonization, and juvenile rearing (winter and summer). Of these life stages, egg incubation and young-of-the-year juvenile rearing are most vulnerable, followed by winter rearing and fry colonization.

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation and subsequent egg-to-fry survival. High storm flows through fall, winter, and spring erode unprotected banks in middle Johnson Creek, while WPA-lined creek portions prevent high flows from accessing the floodplain. This results in increased bed scour, increased bank erosion, and high sediment loading in this reach and in downstream reaches.

Fry Colonization. Fry colonization is most prominently influenced by lack of habitat diversity, lack of large wood, and lack of key habitats such as off-channel ponds, floodplain wetlands, and instream shallow-water habitats. In addition, poor channel stability and high peak flows affect the ability of fry to colonize, seek refuge, and thrive in middle Johnson Creek.

Juvenile Rearing (Summer and Winter). Lack of large wood and large substratum (habitat diversity), lack of key habitats such as deep pools and riffles, and high stream temperature most prominently affect juvenile production potential through the summer. In addition, food sources are lacking and low summer flows limit coho productivity during active, summer rearing.

Lack of off-channel and slack-water habitats and instream structure (large wood, overhanging vegetation) are primary limiting factors affecting juvenile survival and productivity through the winter. Notably, the lack of critical overwintering habitats likely poses the greatest risk in the upper portion of middle Johnson Creek (Reach 14 and Reach 15).

Steelhead were most affected by high sediment loading, lack of habitat diversity, and lack of key habitats. Most vulnerable life stages and life history strategies (for example, habitat preferences) affected include egg incubation and juvenile rearing (winter and summer). Of these life stages, juvenile spring/summer (active) rearing and winter (inactive) rearing are most vulnerable, followed by egg incubation.

Egg Incubation. Lack of key habitats such as high-quality riffle beds with low embedded fines significantly impair the egg incubation environment and subsequent egg-to-fry survival. High silt loads atop riffle beds result in low dissolved oxygen concentration reaching the eggs, which subsequently affects embryonic development, fry maturation, and total egg-to-fry survival.

Juvenile Rearing (Summer and Winter). Lack of large wood and large substratum (habitat diversity), low summer flows coincident with high stream temperature, and lack of primary food sources most prominently affect juvenile production through the summer in middle Johnson Creek. Notably, these habitat attributes affect both 0+ and 1+ age steelhead and are common limitations throughout the middle reach.

Lack of instream structure such as large wood and overhanging vegetation, along with high flows, primarily limit steelhead productivity (and survival) through the winter. Complex habitat forms provide important high flow refugia and protective cover during high storm flows, and the lack of these habitat niches results in fish being swept downstream.

Upper Johnson Creek

Coho	Rank	Steelhead	Rank
Protection benefit	1	Protection benefit	1
Restoration benefit	4	Restoration benefit	5

Coho were most affected by lack of habitat diversity and lack of key habitats. High sediment loading during storm flows and poor channel stability likewise impair potential coho productivity in upper Johnson Creek.

The most vulnerable life stages and life history strategies (for example, habitat preferences) most prominently affected include egg incubation, fry colonization, and juvenile rearing (winter and summer). Of these life stages, egg incubation and young-of-the-year juvenile (active) rearing are most vulnerable, followed by fry colonization and inactive winter rearing.

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation and subsequent egg-to-fry survival. High storm flows through fall, winter, and spring erode unstable channel banks in upper Johnson Creek. This results in increased bank scour and high sediment loading in this reach and in subsequent downstream reaches.

Fry Colonization. Fry colonization is most prominently influenced by lack of habitat diversity (for example, instream structure such as wood) and lack of key habitats, such as off-channel wetlands and instream shallow water habitats. In addition, high peak flows affect the ability of fry to colonize, seek refuge (instream as well as off-channel), and—ultimately—persist.

Juvenile Rearing (Summer and Winter). Lack of large wood and large substratum (habitat diversity), lack of key habitats such as deep pools and riffles, and high stream temperature most prominently affect juvenile production potential through the summer. In addition, food sources are lacking and low summer flows limits coho productivity during active, summer rearing.

Lack of key habitats (off-channel and slack water habitats) and low habitat diversity (instream structure such as large wood and overhanging vegetation) are primary limiting factors affecting juvenile survival and productivity through the winter. Notably, the lack of critical overwintering habitats likely poses the greatest risk near the headwaters of upper Johnson Creek (Reach 23).

Steelhead are most affected by lack of habitat diversity, lack of key habitats, and high sediment loading during early life history rearing. In addition, warm stream temperatures and low flows in the summer impair potential steelhead productivity in upper Johnson Creek. The most vulnerable life stages and life history strategies (for example, habitat preferences) affected include egg incubation and juvenile spring/summer (active) rearing.

Egg Incubation. High sediment loading and potentially high stream temperatures significantly affect the egg incubation environment and subsequent egg-to-fry survival. Impacts on egg incubation are prevalent throughout upper Johnson Creek.

Juvenile Rearing (Summer). Lack of large wood and large substratum (habitat diversity), low summer flows coincident with high stream temperature, and lack of primary food sources most prominently affect juvenile production through the summer in upper Johnson Creek. Notably, these habitats attributes affect both 0+ and 1+ age steelhead and are common throughout the lower reach; however, young-of-the year steelhead are more vulnerable to habitat limitations compared to older aged juveniles that are likely to be more competitive for food and space.

As in lower and middle Johnson Creek, the lack of instream structure and flow-associated refugia are not considered a limiting factor in upper Johnson Creek.

Crystal Springs Creek

Coho	**Rank**	**Steelhead**	**Rank**
Protection benefit	6	Protection benefit	6
Restoration benefit	3	Restoration benefit	4

Coho were most affected by lack of habitat diversity and lack of key habitats. High sediment loading during storm flows and poor channel stability likewise impair potential coho productivity in upper Johnson Creek.

The most vulnerable life stages and life history strategies (for example, habitat preferences) most prominently affected include egg incubation, fry colonization, and juvenile rearing (winter and summer). Of these life stages, egg incubation and young-of-the-year juvenile (active) rearing are most vulnerable, followed by fry colonization and inactive winter rearing.

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation and subsequent egg-to-fry survival. High storm flows through fall, winter, and spring erode unstable channel banks in upper Johnson Creek, resulting in increased bank scour and high sediment loading in this reach and in subsequent downstream reaches.

Fry Colonization. Fry colonization is most prominently influenced by lack of habitat diversity (for example, instream structure such as wood) and lack of key habitats, such as off-channel wetlands and instream shallow-water habitats. In addition, high peak flows affect the ability of fry to colonize, seek refuge (instream as well as off-channel), and—ultimately—persist.

Juvenile Rearing (Summer and Winter). Lack of large wood and large substratum (habitat diversity), lack of key habitats such as deep pools and riffles, and high stream temperature most prominently affect juvenile production potential through the summer. In addition, food sources are lacking and low summer flows limit coho productivity during active, summer rearing.

Lack of key habitats (off-channel and slack-water habitats) and low habitat diversity (instream structure such as large wood and overhanging vegetation) are primary limiting factors affecting juvenile survival and productivity through the winter. Notably, the lack of critical overwintering habitats likely poses the greatest risk near the headwaters of upper Johnson Creek (Reach 23).

Steelhead are most affected by lack of habitat diversity and fish passage obstructions in Crystal Springs Creek. The lack of key habitats and high sediment loading during early life history rearing likewise impair potential steelhead production. Existing habitat conditions significantly affect different life history strategies in different parts of the subbasin; however, poor summer rearing habitat and areas for fry to colonize and rear in are common throughout. Lack of habitat diversity and key habitats for adults to hold and spawn likewise affect steelhead productivity in Crystal Springs Creek.

Fry Colonization. Fry colonization is most prominently influenced by lack of habitat diversity (for example, instream structure such as wood) and poor channel stability. In addition, high peak flows affect the ability of fry to successfully colonize and occupy refuge habitat (instream as well as off-channel) and ultimately affect their ability to persist within the subbasin. Fry colonization is a critical life history strategy that currently is impaired in Crystal Springs Creek.

Juvenile Rearing (Summer). Lack of suitable habitat for 0+ and 1+ age steelhead to rear throughout the spring and summer is the primary limiting factor in Crystal Springs Creek. Specifically, lack of instream cover and habitat complexity (large wood), low summer flows coincident with high stream temperature, and lack of primary food sources most prominently affect juvenile production through the summer. Young-of-the-year (0+) steelhead are most vulnerable to habitat limitations compared to older aged juveniles that are likely to be more competitive for food and space and may (at this age) have moved out of Crystal Springs into lower Johnson Creek.

Adult Holding and Spawning. Crystal Springs Creek lacks deep, complex pools that provide important holding areas to migrant adult winter steelhead. Adult winter steelhead return to their natal stream in the winter, when flows are high; thus they are particularly reliant on key holding habitats, such as deep pools.

Kelley Creek

Coho	**Rank**	**Steelhead**	**Rank**
Protection benefit	4	Protection benefit	5
Restoration benefit	4	Restoration benefit	3

Coho were most affected by fish passage obstructions, lack of habitat diversity, and high sediment loads. Lack of off-channel and slack-water habitats, poor channel stability, and high storm flows likewise impair potential coho productivity in Kelley Creek.

The most vulnerable life stages and life history strategies (for example, habitat preferences) most prominently affected include egg incubation, fry colonization, and summer rearing. Of these life stages, egg incubation and fry colonization are most vulnerable, followed by juvenile summer rearing.

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation and subsequent egg-to-fry survival. High storm flows through fall, winter, and spring erode unstable channel banks in Kelley Creek. This results in increased bank scour and high sediment loading in this reach and in subsequent downstream reaches.

Fry Colonization. Fry colonization is most prominently influenced by high storm flows coincident with lack of key habitats and in-channel habitat diversity (for example, instream structure such as wood). The lack of off-channel slack-water areas, such as floodplain wetlands and backwater pools, and the lack of instream structure to provide protective cover (for example, deep pools and large wood) leave fry vulnerable to being swept downstream during high storm flows. Without these important refugia habitats, fry may not be able colonize and residualize in the subbasin.

Juvenile Rearing (Summer). Lack of suitable habitat for 0+ age coho to rear throughout the spring and summer limits coho productivity in Kelley Creek. Specifically, the lack of key habitats, such as high-quality riffle areas with low fines and deep pools with cool stream temperatures, affect survivorship through the summer.

Steelhead are most affected in Kelley Creek by fish passage obstructions and excessive sediment loading. Altered hydrologic cycles and lack of key habitats and habitat diversity likewise affect potential steelhead production in Kelley Creek. Habitat conditions affect different life history strategies throughout the subbasin, particularly lower Kelley Creek, which is lower gradient and has more fish passage obstructions than do other parts of the creek. Basinwide, the lack of high-quality summer rearing habitat and high-quality riffle – gravel beds limits potential steelhead productivity during active rearing. In addition, lack of instream cover to protect adults before spawning and to protect fry as they emerge from riffle beds affects potential steelhead productivity in Kelley Creek. Of these life stages, summer rearing by age 0+ and 1+ juvenile steelhead is most limiting, followed by egg incubation and fry colonization.

Egg Incubation. High sediment loading most prominently impairs the egg incubation environment and subsequent egg-to-fry survival. High sedimentation atop riffle beds can smother eggs, reducing dissolved oxygen concentrations to eggs and ultimately compromising egg-to-fry survival. High sediment loads throughout the winter are affected by high stream flows that bring sediment in from the surrounding uplands, and by high erosive flows that scour the stream channel, sending bank materials instream. In addition, the lack of key riffle areas affects total egg incubation area and ultimately limits the potential productivity of steelhead originating from Kelley Creek.

Fry Colonization. Fry colonization is most prominently influenced by lack of habitat diversity (for example, instream structure such as wood) and poor channel stability. These conditions are exacerbated by high winter and spring flows that erode streambanks and send fry downstream from natal rearing grounds.

Juvenile Rearing (Summer). Lack of suitable habitat for 0+ and 1+ age steelhead to rear throughout the spring and summer is the primary limiting factor affecting steelhead productivity in Kelley Creek. More specifically, lack of instream cover (large wood) and key rearing habitats such as riffles and deep pools affect steelhead productivity throughout the spring and summer. In addition, low summer flows and lack of primary food sources affect juvenile production. Young-of-the-year (0+) steelhead are most vulnerable to habitat limitations compared to older aged juveniles that are likely to be more competitive for food and space and may (at this age) have moved out of Kelley Creek into middle and lower Johnson Creek.

Johnson Creek Tributaries

Coho	Rank	Steelhead	Rank
Protection benefit	3	Protection benefit	2
Restoration benefit	5	Restoration benefit	6

Clatsop, Mitchell, Butler, Hogan, and MacDonald creeks were evaluated for their contribution to potential steelhead productivity in the Johnson Creek Subbasin. The combination of habitat value that these tributaries provide is significant. For both coho and steelhead, these areas rank relatively high for protecting existing habitat condition and functions.

Fish passage obstructions are a key limiting factor in all creeks except MacDonald Creek, which does not have a barrier to fish passage. All others have human constructs very near the confluence: Mitchell Creek at RM 0.20, Clatsop Creek at RM 0.12, Butler Creek at RM 0.0 and again at RM 0.34, and Hogan Creek at RM 0.21. These barriers affect both adult and juvenile fish passage. Notably, MacDonald Creek is free flowing for at least 3.0 river miles, with no fish passage barriers.

Coho. If these creeks were passable year-round to adult and juvenile coho, high winter flows and low summer flows, high sedimentation, and lack of instream cover and key habitats would most prominently limit coho productivity in the five tributaries evaluated. Of these different life stages affected, the egg incubation environment is most vulnerable, followed by juvenile rearing and the ability of fry to colonize and hold through the spring.

Egg Incubation. Presuming that fish passage obstructions do not limit adult and juvenile coho migration, channel instability and subsequent sediment loading into the creek would most prominently affect potential coho productivity in the five tributaries. Notably, sedimentation impairs the egg incubation environment and subsequent egg-to-fry survival. High sedimentation atop riffle beds can smother eggs, reducing dissolved oxygen concentrations to eggs and ultimately inhibiting fry survival. High sediment loads throughout the winter are affected by high stream flows that bring sediment in from the surrounding uplands, and by high erosive flows that scour the stream channel, sending bank materials instream. In addition, lack of key riffle area affects the amount of spawning and egg incubation areas; ultimately this limits the potential productivity of coho originating from these five tributaries.

Fry Colonization. Fry colonization is most prominently influenced by high spring flows coincident with lack of habitat diversity (for example, instream structure such as wood) and lack of key habitats such as deep pools and off-channel areas. These two attributes are critically important to providing protective cover and refuge during spring storm flows when fry emerge from their gravel beds.

Juvenile Rearing. Lack of suitable habitat for coho to rear year-round limits potential coho productivity in all five tributaries; specifically, the lack of instream cover (large wood) and key rearing and refuge habitats such as deep pools, off-channel habitats, side channels, and seasonal wetlands affect coho productivity throughout the fall, winter, and spring. In addition, low summer flows and lack of primary food sources affect juvenile production.

Steelhead. If these creeks were passable year-round to adult and juvenile steelhead, high winter flows, low summer flows, high sedimentation, and lack of instream cover and key habitats would most prominently limit steelhead productivity throughout the five tributaries. Of the different life stages affected, the egg incubation environment is most vulnerable, followed by the ability of juveniles to survive through the summer and the ability of fry to colonize and hold in the spring.

Egg Incubation. Presuming that fish passage obstructions do not limit adult and juvenile steelhead migration, channel instability and subsequent sediment loading into the creek would most prominently affect potential steelhead productivity in the five tributaries. Notably, sedimentation impairs the egg incubation environment and subsequent egg-to-fry survival. High sedimentation atop riffle beds can smother eggs, reducing dissolved oxygen concentrations to eggs and ultimately inhibiting fry survival. High sediment loads throughout the winter are affected by high stream flows that bring sediment in from the surrounding uplands and by high erosive flows that scour the stream channel, sending bank materials instream. In addition, the lack of key riffle areas affects the amount of spawning and egg incubation areas, ultimately limiting the potential productivity of steelhead originating from these five tributaries.

Fry Colonization. Fry colonization is most prominently influenced by high spring flows coincident with lack of habitat diversity (for example, instream structure such as wood) and lack of key habitats such as deep pools. Deep pools and complex instream structure are critically important to providing protective cover and refuge during spring storm flows when fry emerge from their gravel beds.

Juvenile Rearing (Summer). Lack of suitable habitats for steelhead to rear in the summer limits potential productivity in all five tributaries; specifically, lack of instream cover (large wood, overhanging vegetation, and large cobbles and boulders) and lack of riffle areas affect steelhead productivity through the summer. In addition, low summer flows and lack of primary food sources affect juvenile production.

Basinwide. The assessment of Johnson Creek Subbasin included two species and two populations: coho and steelhead. This provided the opportunity to examine the subbasin in a multispecies context by putting all of the information together to create a more holistic depiction of habitat conditions in Johnson Creek watershed. This also provides another dimension for examining restoration and protection priorities for habitat in Johnson Creek.

Figure 3-91 displays the results of the EDT spatial analysis for coho and steelhead and the two populations combined. This figure shows the effect of degrading conditions further (protection priority) and of restoring conditions (restoration priorities) in each geographic area on the equilibrium abundance of each population. Protection priorities describe how Johnson Creek currently functions with regard to providing key fish-bearing habitat. In terms of abundance, most of the current habitat potential (for example, protection potential) is in upper Johnson Creek. However, the best restoration potential is realized in middle Johnson Creek; here the best opportunities to restore coho and steelhead abundance are realized. Lower Johnson Creek likewise provides great restoration potential. The upper section, which is in relatively better condition than the lower and middle portions of Johnson Creek, has less restoration potential.

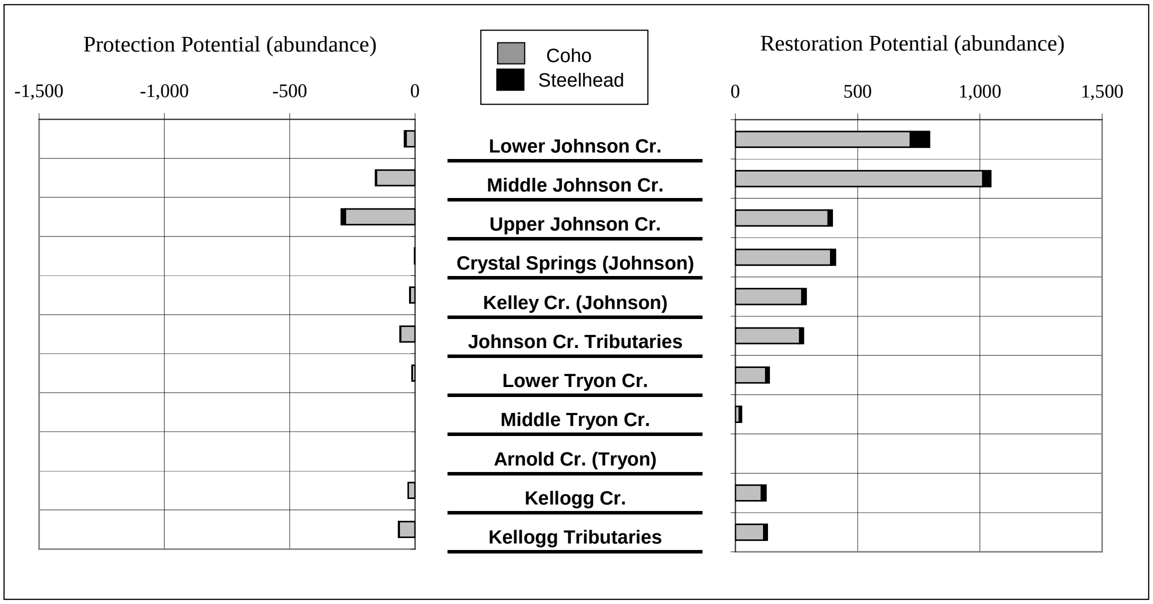


Figure 3-91: Combined Restoration and Protection Potential for Coho and Steelhead in the Lower Willamette

3.5.1.16 Limiting Factors in the Lower Willamette River Mainstem (with EDT Analysis)

This section describes the Lower Willamette River in terms of geographic setting and environmental conditions and presents information on limiting factors for the focal species in the river: cutthroat trout, winter steelhead, spring Chinook, and coho. The limiting factors for these species were determined by using EDT to analyze habitat conditions on a reach-by-reach basis.

Focal Species present:

- Cutthroat trout
- Winter steelhead
- Spring Chinook
- Coho salmon

Geographic Setting. The lower Willamette River is distinctly different from the middle and upper portions of the river, above Willamette Falls. Much of the upper portion is set within a wide valley floor where, historically, the river was composed of braided, meandering channels with extensive floodplains, side channels, islands, and off-channel habitats. As the Willamette approaches Willamette Falls, the landforms begin to constrain the channel and the course of the river is more typically confined to a single channel with narrow floodplains. Just below Willamette Falls the river is naturally incised deep into steep bedrock walls that strongly confine the narrow channel through this reach. The floodplain is very narrow or nearly nonexistent, and the river reaches some of its greatest natural depths (more than 100 feet) through this section.

As the Willamette approaches Portland, landform constraints become less severe, the channel widens, and conditions become increasingly influenced by the Columbia River. Historically the reduced landform constraints allowed the formation of floodplains and off-channel habitats through Portland, with large off-channel lakes such as Guilds, Doane, and Ramsey. Although floodplain widths in the lower Willamette were never as extensive as those in the middle and upper basin, their location at this dynamic transitional zone between the two major river systems and the scarcity of off-channel habitat for some distance upstream suggests that the ecological importance of these floodplains was high. In particular, the Columbia Slough and Sauvie Island formed a large floodplain wetland complex at the merging of the two rivers that provided extensive, high-quality habitat for large numbers and types of biota at this ecological crossroads.

It is also important to acknowledge that the Columbia River has always had a strong impact on conditions in the lower Willamette. The Missoula Floods more than 10,000 years ago scoured many of the morphological features that still define the structure of the channel through this section, and the hydrology of the lower Willamette is strongly influenced by flows coming from the upper Columbia Basin and the tidal effects transmitted up the lower Columbia from the coast.

Regional Geology. The dominant geological formation of the region is Columbia River basalt, which originated in lava flows from the eastern Columbia Basin. Underlying this is the Scappoose Formation—sandstone and shale deposited when the region was ancient ocean bottom 22 million years ago. These formations were subjected to volcanism and tectonic forces that formed the Cascade, Coast, and Tualatin mountain ranges. Subsequent weathering and erosion of Columbia River basalt has since shaped these mountains and exposed portions of the Scappoose Formation in Portland's West Hills.

The Columbia River basalt in this area is overlain by the Troutdale Formation, which consists of sandstone and gravel eroded from the Columbia Basin and Cascade Mountains. The Troutdale Formation was up to 1,500 feet thick (accumulated 10 to 2 million years ago) and was created as volcanic activity, mudflows, and continuing deformation repeatedly transformed the Willamette, Sandy, Clackamas, and Tualatin rivers into closed drainage basins, forming large lakes. Silt, sand, and gravel were deposited through this process and by the Columbia River. Relief features in east Portland (Mt. Tabor, Rocky Butte, and Kelly Butte) were formed more recently (3 to 0.5 million years ago) by localized volcanic intrusions know as the Boring volcanoes.

The erosion of the Troutdale Formation material by the Willamette, Clackamas, and Columbia rivers exposed these volcanic features further as the rivers migrated extensively across the area.

The most recent significant factor in the region's geology and soil formation was a series of events known as the Missoula Floods (16 to 12 thousand years ago). These floods were caused by cycles of advancing glacial ice that repeatedly dammed the Clarks Fork of the Columbia River, formed an enormous lake, and broke, releasing up to 600 cubic miles of water in a matter of days. These massive floods created erosion patterns on Portland's east side, most notably Sullivan's Gulch and the Alameda Ridge. As drainage of this water was restricted by topography to the west, large lakes up to 400 feet deep formed at the site of present-day Portland and the settling gravel, sand, silt, and clay formed the current soils. In addition, during this general period a 5-foot-thick layer of wind-blown silt (known as Portland Hills silt) was deposited on the upper portions of the West Hills. Local rivers have since eroded and migrated through these depositions, forming the current channels and floodplains.

Flow. Patterns of river flow in the Willamette River at Portland are similar to patterns of flow in the upper Willamette Basin, which in general reflect seasonal variation in precipitation. The basin has a temperate marine climate with dry summers and wet winters. Approximately 70 to 80 percent of precipitation falls between October and March, with less than 5 percent falling in July and August (Pacific Northwest Ecosystem Research Consortium, 2002).

This pattern is reflected in river flows in the lower Willamette River. USGS has measured flow at Portland since 1973. Annual minimum flows have typically occurred in August over the period of record (Figure 3-92). Median flow gradually increases in September, then rapidly increases from October to December. The highest average flows occur from December to January. Between January and February median flows begin to decrease, although flood flows greater than 150,000 cfs can occur any time between late November and March (Figure 3-92). The maximum flow over the period of record occurred on February 9, 1996, when flows reached 420,000 cfs during the flood of 1996. This flood produced the four highest daily average values ever measured in the Willamette River at Portland, from February 8 to 11. Average flow gradually decreases throughout the spring and summer to the August low.

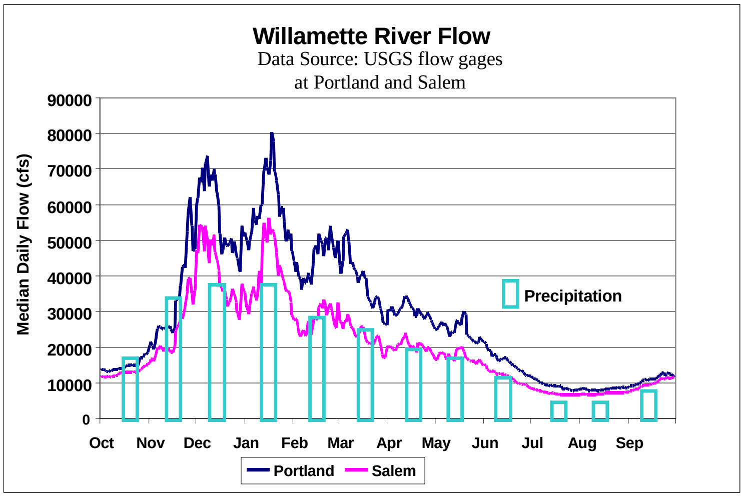


Figure 3-92: Median Flow over the Period of Record (1975-present) at the USGS Portland Gage (Blue Line)

Note: Seasonal patterns follow patterns of flow in the upper basin (pink line, using same time period for comparison) and generally reflect seasonal precipitation patterns.

In characterizing current flow conditions in the lower Willamette River it is important to note that patterns of flow in the Willamette River have changed dramatically over time, largely because of water management practices and the presence of dams. The effect of dams on flow patterns can be evaluated by comparing the “pre-dam” years (1909-1941) to “post-dam” years (1968-present) of record. One of the most dramatic changes evident in this comparison is the markedly higher median flows in the post-dam period over the summer and fall low flow periods; late summer and early fall flows are currently 2 to 2.5 times higher than pre-dam flows (Figure 3-93). Median post-dam flows also exhibit sharp peaks during the early winter period that are much higher than pre-dam median flows, presumably because of dam releases that provide flood storage capacity in the reservoirs in preparation for the periods that historically had the highest average flows. The effect of dam management on low flows is a profound change in seasonwide patterns of base flows.

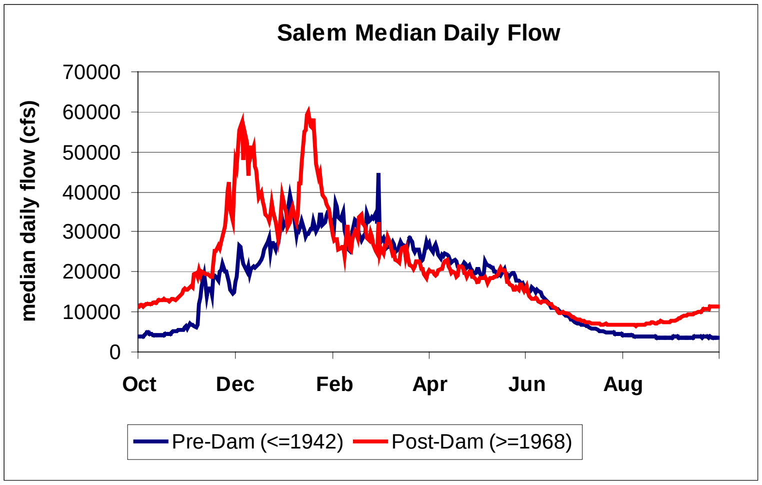


Figure 3-93: Changes in Median Daily Flow Before and After Dam Construction

Source: USGS flow gauge at Salem.

The presence of dams has also reduced the magnitude of peak flood events (see Figure 3-94). The annual 1-day, 3-day, and 7-day maximum flows prior to dam construction are significantly higher than after dam construction (City of Portland Bureau of Environmental Services, 2004). The1996 flood—which is a rare event under the current hydrologic regime—occurred every 6 to 10 years prior to dam construction.

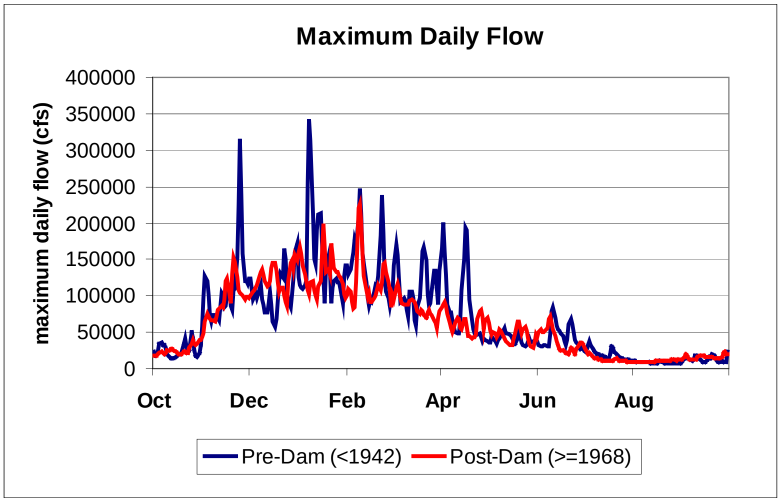


Figure 3-94: Changes in Maximum Flows Before and After Dam construction.

Data source: USGS flow gauge at Salem

Environmental Conditions. Conditions in the channel and floodplain in the lower Willamette River have changed dramatically over the last 150 years. The channel has been deepened, narrowed, and simplified; the banks have been hardened and lined. Floodplain and off-channel habitats have been filled and destroyed, and banks have been steepened throughout the length of the river within the City. Seasonal patterns of flow have changed such that winter and spring flood peaks have been reduced and summer base flows are now significantly higher than in the past. Urban pollutants have accumulated in the sediments of the lower river to levels significant enough to warrant Superfund listing.

Appendix X shows specific fish passage barriers on the lower Willamette, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Key Findings. Unlike most other portions of the Willamette River subbasin, the lower Willamette River does not have a unique, locally spawning population with which to evaluate local habitat conditions. Instead, the lower Willamette functions as a migration corridor and rearing grounds for populations throughout the entire Willamette subbasin, and the ecological effects of local conditions are best evaluated for their impact on focal species populations throughout the basin.

EDT analyses indicate that conditions in the lower Willamette River are an important bottle-neck for populations throughout the Willamette Basin. Although the lower Willamette is not typically the highest priority reach for restoration in any of the analyses of individual focal species populations, it is a relatively important reach for many of the populations. The fact that all the populations in the Willamette Basin must pass through the lower Willamette

River makes the lower Willamette's cumulative effect on the basin's populations a high priority.

The key limiting factors that arise from evaluation of these populations are habitat diversity, key habitat quantity, and chemicals. Throughout the lower Willamette through Portland, the channel has been deepened, narrowed and simplified; the banks have been hardened and lined. Floodplain and off-channel habitats have been filled and destroyed, and banks have been steepened. A long history of urban and industrial uses has elevated levels of contaminants in the sediments along this section.

EDT Analysis of Limiting Factors. The lower Willamette is one of the areas in the Willamette Basin to have undergone a detailed, reach-by-reach EDT analysis of its habitat conditions with respect to the focal species populations in this plan: cutthroat trout, spring Chinook salmon, winter steelhead, and coho. Appendix J presents a detailed description of the EDT analysis, including information sources, habitat attributes assessed, and hypotheses regarding restoration and protection strategies. The following subsection summarizes the information in the appendix.

EDT Approach. The EDT analysis was based on existing information, GIS analysis, observation, and expert opinion regarding flow, habitat, water quality, and biological attributes of the lower Willamette River. Three scenarios were part of the analysis: current conditions, a reference or template condition that defined a fully restored condition, and a fully degraded condition.

- The EDT assessment of the lower Willamette River was organized hierarchically into 23 stream reaches and four geographic areas, as follow:
- **North Segment**. The north segment begins at the confluence of the Columbia and Willamette rivers and extends upstream (south) 6 miles to the St. Johns Bridge. A portion of the Multnomah Channel, which runs along the south edge of Sauvie Island and joins the Columbia farther downstream, is included in this river segment. Land uses along this reach are predominantly industrial, with a large expanse of port facilities. There is some important open space along this segment (Kelley Point Park and Harborton Wetlands, for example). Other critical habitat features along this segment include the Multnomah Channel, the Columbia Slough, Miller and Doane creeks, and the Willamette-Columbia confluence.
- **Industrial Segment**. The industrial segment extends from the St. Johns Bridge to the Steel Bridge and encompasses most of Portland's working harbor. Industrial land uses dominate this segment also. Nearly all of the historical tributaries draining to this reach have been piped underground. Remaining key habitat features include Willamette Park and the Swan Island beach.
- **Downtown Segment**. The downtown segment extends from the Steel Bridge to the Ross Island Bridge. Land uses in this reach are a mix of commercial, industrial, and high-density residential. The few streams that historically discharged to this reach all have been piped underground, and the few remaining habitat features are limited and small scale (Eastbank Crescent beach, for example).

- **South Segment**. The south segment extends from the Ross Island Bridge to the Urban Services Boundary south of the Sellwood Bridge. This segment has considerable open space, as well as commercial and industrial land uses. The reach has lost some historical tributaries, but Stephens Creek provides high-quality tributary confluence habitat and Ross Island, Oaks Bottom, and Willamette Park provide important habitat features.

EDT Results. Because populations of the focal species do not spawn locally within the lower Willamette River, the impacts of conditions in this section on focal species populations are evaluated through the series of population analyses conducted through the Willamette Basin. The McKenzie River, Clackamas River, Johnson Creek, and Tryon Creek sections of this plan provide information on the impact of conditions in the lower Willamette on these populations.

EDT analysis indicates that the key limiting factors in the lower Willamette are habitat diversity, key habitat quantity, and chemicals. These are described in more detail below.

Habitat Diversity. Changes in the channel have decreased habitat diversity throughout the course of the lower river through Portland. Loss of shallow-water habitat, lack of wood, bank hardening and reconfiguration, and loss of off-channel habitats are some of the factors that have reduced habitat diversity. These conditions affect the migratory and rearing stages of Chinook, coho, and steelhead that use the lower river.

Historically, the Willamette River in the Portland area had an extensive and interconnected system of active channels, open slack waters, emergent wetlands, riparian forest, and adjacent upland forests on hill slopes and Missoula Flood terraces. Prior to settlement, the river was embedded in the regional forest network and intricately connected to the Columbia floodplains. Areas along the riverbank probably were difficult to distinguish from the surrounding green, forested environment.

Significant dredging, diking, and channeling of the mainstem Willamette has altered many of these historical conditions. The mainstem has been narrowed and deepened, and off-channel habitat has been virtually eliminated. The river’s banks have been hardened, which precludes important naturally caused channel changes and minimizes the interaction between the river and riparian and floodplain vegetation. Habitat has been simplified and large tracts of riparian vegetation have been cleared. As a result of these actions, significant amounts of shallow water, floodplain, and off-channel habitats have been lost.

The lower Willamette River historically had a number of large, off-channel lakes that provided high-quality rearing and refuge areas (Guilds, Kitteredge, Doane, and Ramsey lakes, for example). Over time, floodplain fill, vegetation removal, bank alterations, and channel clearing destroyed floodplain, off-channel, and riverine habitats and altered their physical structure. For example, Guilds Lake and Ramsey Lake were filled to provide land for downtown and port development, while Doane Lake was reduced in size and its connection to the river severed. Eighty-nine percent of the historical off-channel area was destroyed. These losses have been most extensive in the north and industrial sections of the lower Willamette, which historically had the highest amount of off-channel habitat (see Figure 3-95). The south segment is the only segment that retains a percentage of its former off-channel habitat, because of the presence of Ross Island.

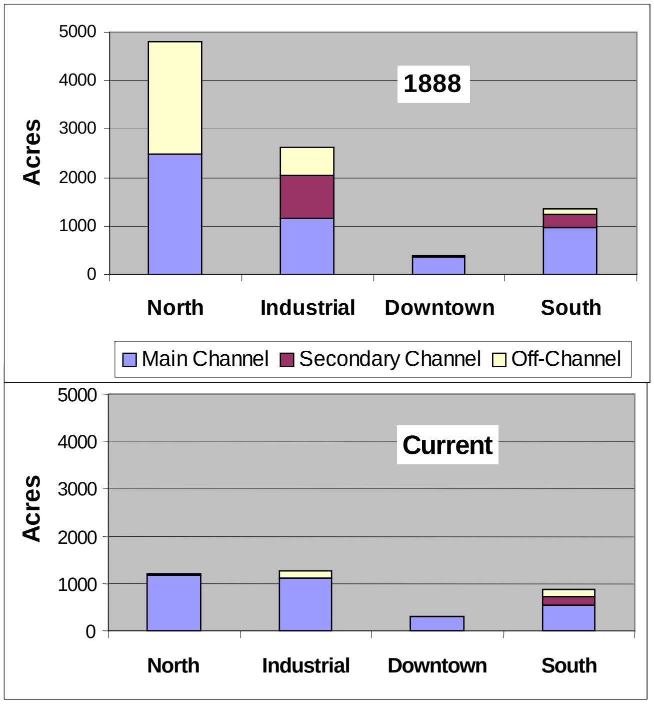


Figure 3-95: Changes in the Amount of Mainstem, Secondary and Off-Channel Habitat in the Lower Willamette River through Portland, 1888 – 2001

Over the same time period, the mainstem channel was undergoing many changes to improve conditions for navigation, port access to the channel, and—ostensibly—"flood control." As a result, the channel has been deepened and narrowed and its banks have been steepened over time. Seventy-nine percent of the shallow-water habitat through the lower river was lost through channel deepening (see Figure 3-96). Similar to the pattern in changes in off-channel habitat, these losses were most extensive in the north and industrial sections of the river, which historically had the largest amount of shallow-water habitats, while the south segment retains the highest proportion of its historical shallow-water habitat.

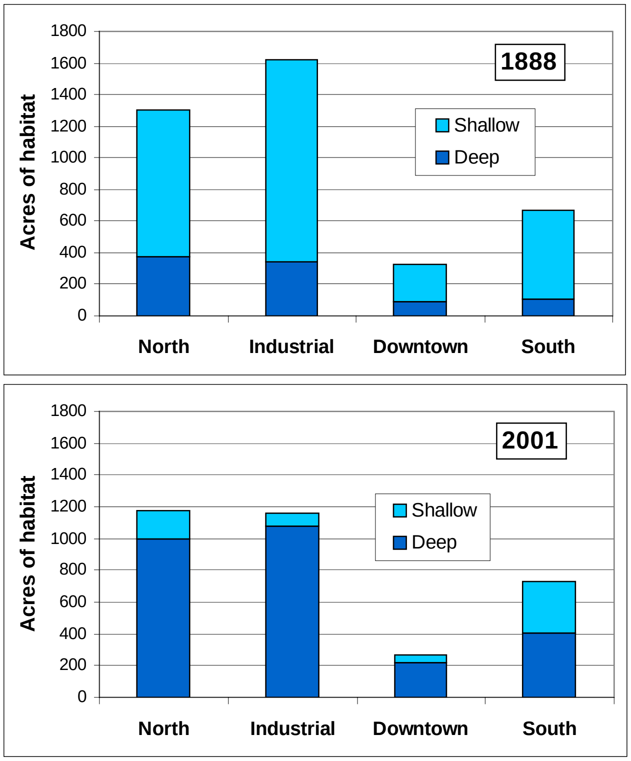


Figure 3-96: Changes in the Proportion and Total Amount of Shallow and Deep Water Habitat in the Lower Willamette River through Portland

To maintain these changes in channel configuration and support the infrastructure for port, industrial, and other urban uses, the banks of the lower river were "hardened" with riprap, sheet pile, and other human-made structures. These features alter the velocity and timing of river and stream flows, disconnect rivers and streams from their floodplains, and limit the establishment of native vegetation and the natural maintenance of gravel beds and other important habitats. Historically, river banks were dominated by beach, with significant components of wetland and vertical steep banks (see Figure 3-97). Currently, the majority of the banks are made up of artificial substrates of one type or another. Although beach habitats are still a significant component, riparian wetlands have been completely eliminated.

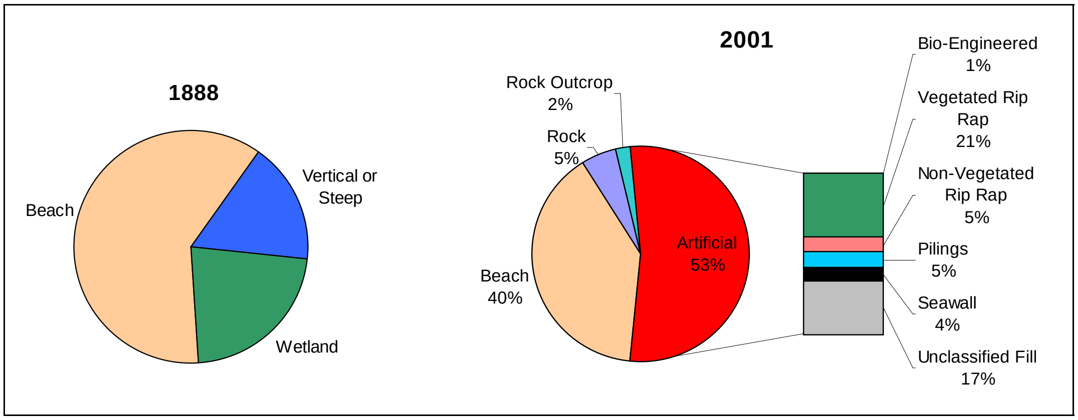


Figure 3-97: Changes in Bank Types Along the North Segment of the Lower Willamette River

There is no historical information on the amount of wood in the lower Willamette, and there have not been any quantitative surveys to assess current levels. It is likely that current levels of wood are dramatically lower than historical levels. The mouths of large rivers often accumulated huge debris jams. These jams have been cleared to support river navigation, and the channels and banks have continued to be cleared over time to protect urban infrastructure and maintain navigation.

Key Habitat Quantity. While habitat diversity refers to the quality of habitat available, it is clear that the quantity of habitat available for key life history stages also is limiting. Lack of off-channel habitat, low levels of wood and shallow-water habitat, and lack of channel and bank complexity all result in insufficient amounts of key habitat available for migration and rearing stages of Chinook, coho, and steelhead using the lower river.

Chemical Contamination. Because of the level of pollution in lower Willamette River sediments, the Portland Harbor was added to the federal Superfund cleanup list in December 2000. The Portland Harbor Superfund site currently covers a 5.7-mile section of the Willamette River from the upstream end of Sauvie Island (RM 3.5) and Swan Island (RM 9.2); the northern 2.5 miles of the site are in the north segment of the EDT study area, and the southern 3.2 miles of the site are in the industrial segment of the EDT study area. Pollutants introduced through industrial discharges, toxics carried by stormwater, and other sources have contributed to elevated levels of many urban pollutants. Preliminary assessments indicate that DDT, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and heavy metals are some of the key risk drivers in lower Willamette River sediment. More extensive analyses of patterns of chemical contamination are described in Weston (1998).

The Oregon 303(d) list divides the Willamette River into segments, including one that covers RM 0 to RM 24.8. The current 303(d) listings for that river segment are summarized in Table 3-173.

Table 3-173: 303(d)-Listed Water Quality Parameters for the Lower Willamette River

Parameter	Season(s)	Sample Matrix	Year Listed	Notes
Fecal Coliform	Winter/spring/fall	Water column	1998	
Dieldrin	All	Fish tissue	2002	
DDT	All	Fish tissue Water column	2002	
DDE	All	Fish tissue	2002	
PAHs	All	Water column	2002	
Biological Criteria	Not specified	Water column	1998	Listing based on skeletal deformities in juvenile squawfish.
Mercury	All	Fish tissue	1998	
Aldrin	All	Fish tissue	2002	
Temperature	Summer	Water column	1998	
PCBs	All	Fish tissue	2002	

Table 3-173: 303(d)-Listed Water Quality Parameters for the Lower Willamette River

Parameter	Season(s)	Sample Matrix	Year Listed	Notes
Manganese	All	Water column	2002	
Iron	All	Water column	2002	
Pentachlorophenol	Not specified	Sediment	1998	Listing basis is an Oregon State Health Department (OSHD) alert regarding fishing and swimming near the Baxter & McCormick Superfund site.

3.5.1.17 Limiting Factors in the McKenzie Subbasin (with EDT Analysis)

This section describes the geographic setting of the McKenzie Subbasin and limiting factors for the focal species in the subbasin: cutthroat trout, spring Chinook, Oregon chub, and bull trout. The limiting factors for spring Chinook were determined by using EDT to analyze habitat conditions on a reach-by-reach basis throughout the McKenzie Subbasin and in the Willamette River.

Focal species present:

- Cutthroat trout
- Spring Chinook salmon
- Oregon chub (lower subbasin only)
- Bull trout

Geographic Setting. The McKenzie River is approximately 90 miles long and drains an area of about 1,300 square miles in the western cascades and on the floor of the Willamette Valley (see Appendix H for a map of the McKenzie Subbasin). Horse Creek, the South Fork McKenzie River, and Blue River are major tributaries in the upper subbasin. Major tributaries in the lower subbasin include Quartz, Gate, and Martin creeks and the Mohawk River.

The McKenzie River begins at Clear Lake, and the headwaters are high in the Cascade Mountains, which are characterized by a broad, gently sloping volcanic ridge that extends west from the Three Sisters volcanoes. Elevations in the subbasin range from 375 near the McKenzie River’s confluence with the Willamette River to 10,358 feet at the summit of the South Sister. Below the lava field and summits of the High Cascades, the upper subbasin is mountainous, with steep ridges and a narrow band of level land in the valleys along the McKenzie River and larger tributaries. For the lower 40 miles, the McKenzie River meanders through the broad Willamette Valley. The river’s channel slope decreases from 1.2 percent upstream of Belknap Springs (RM 75) in the upper subbasin to less than 0.4 percent through the glacial valley just upriver from Blue River Downstream of the confluence of the McKenzie River and Blue River (RM 57), the channel slope remains between 0.2 percent and 0.4 percent, but the channel is more confined within a canyon for approximately 20 miles. The slope flattens to less than 0.2 percent when the river enters the wide, unconstrained floodplain in the Willamette Valley (RM 37).

The federal government manages approximately 70 percent of the land in the McKenzie Subbasin. The Willamette National Forest manages 99 percent of the upper McKenzie Subbasin (above Quartz Creek, RM 54), while the BLM manages tracts in the middle portions of the subbasin and the Mohawk Subbasin. The lower McKenzie Subbasin is primarily in private ownership and includes portions of the urban growth boundaries of Eugene and Springfield. Springfield is the largest town in the subbasin (population approximately 52,000; PSU, 1998). Many other small communities and rural residential areas are located along the McKenzie River within the Mohawk River Valley; these include the towns of Vida, McKenzie Bridge, and Marcola. Almost the entire floodplain of the lower McKenzie Subbasin is privately owned, primarily as agricultural or residential lands (MWC, 1996). The subbasin is heavily used for recreation and is one of the most popular rivers for fishing and boating in Oregon (U.S. Army Corps of Engineers, 2000).

The McKenzie River’s peak and low flow runoff patterns are controlled by the upper subbasin’s High Cascades geology. Vast areas of porous lava in the headwaters of the river store water in deep groundwater systems that are released through relatively constant-flowing springs. These springs and other groundwater sources in the upper subbasin provide most of the river’s volume. Because the river is dominated by these groundwater sources of flow, the McKenzie River exhibits more consistent summer flows, lower water temperatures, and higher water quality than do rivers in neighboring basins. In contrast to the groundwater dominated flow in the river’s mainstem and key tributaries (for example, Horse Creek and the South Fork), the hydrologic regime of tributaries in the lower portions of the subbasin and the Mohawk Subbasin is controlled by snow melt and rain-on-snow events, which results in quick flood responses, lower summer flows, and higher water temperatures.

The headwaters of both Horse Creek and the South Fork McKenzie River originate in the Three Sisters Wilderness area and are dominated by mature and old-growth conifers. In lower portions of the subbasin, younger conifers and deciduous trees make up much of the riparian vegetation along tributaries. Along most portions of the lower river, the extent of floodplain vegetation is restricted to a narrow band. While there are some large areas with floodplain forests, most of the remaining patches are interspersed with agricultural lands, highways, and urban and residential development.

Key Findings. For the McKenzie River spring Chinook salmon population, the current potential is about 18 percent of that under the reference habitat conditions. This change in the spring Chinook salmon population is a measure of the overall degradation of conditions in the McKenzie Subbasin, primarily as a result of anthropogenic changes to habitat and watershed processes in the McKenzie River, the South Fork McKenzie River, larger spawning tributaries, and the lower Willamette River. Major factors contributing to the decline in spring Chinook salmon populations are changes in riparian conditions, modified flow regimes, obstructions to fish passage, and impacts to the amount and quality of aquatic habitat.

Dams. The subbasin’s U.S. Army Corps of Engineers and Eugene Water & Electric Board (EWEB) dams have restricted access to historical spawning areas in the upper McKenzie River, Blue River, and the South Fork. These dams have also altered downstream hydrologic processes, water quality, and habitat formation, in part by trapping sediment and large wood from headwaters.

Appendix X shows specific fish passage barriers on the McKenzie, based on May 2004 data from ODFW; the information was compiled from existing ODFW databases.

Large Wood. Trail Bridge Dam in the Upper McKenzie River (RM 82) and, to a greater extent, Cougar Dam on the South Fork McKenzie River and Blue River Dam on the Blue River, intercept large wood and sediment from 35 percent of the McKenzie's headwaters. Historical removal of large wood from the river and tributary streams, reduced transport of wood below the dams, and changes in riparian vegetation all have interacted to reduce the quantity and distribution of large wood in the river and tributaries.

Water Temperature. Release patterns from Blue River and Cougar dams have changed the river's water temperature regime from historical conditions, such that cooler water released during the late spring and summer impedes the upstream migration of spring Chinook salmon and warmer fall and winter temperatures accelerate egg incubation and fry emergence. Improvements to the water release facilities at Cougar Dam are expected to improve water temperature conditions in the South Fork McKenzie River and enhance spring Chinook survival. In addition to modifying the river's flow patterns from the dams, flow diversions at EWEB's Leaburg and Walterville projects have altered summertime habitat by reducing flow for a number of reaches along the lower river.

Channel Modification. Much of the lower McKenzie River has been simplified and channelized. Flood control operations at the Cougar and Blue River dams have reduced the magnitude and frequency of peak flows. Reductions in the peak flows that historically maintained the dynamic river channel, in combination with reduced delivery of large wood in the channel, has resulted in fewer side channels and other backwater features in the lower river. The mainstem McKenzie below the Deerhorn Park (RM 32) has lost most of its islands and side channels. In addition, the river's channel substrate appears to have coarsened downstream of EWEB and U.S. Army Corps of Engineers projects, which may be affecting the availability of spawning gravel in the McKenzie River.

Limiting Factors for Cutthroat Trout. All cutthroat trout in the McKenzie Subbasin spawn in the smaller tributaries. McKenzie cutthroat trout exhibit three life history patterns (Howell et al., 1988):

- **Isolated Resident**: Populations above impassible barriers that have very restricted movement through their life cycle.
- **Resident**: Populations that reside below barriers and will move upstream and downstream and into smaller tributaries for spawning.
- **Fluvial**: Juveniles rear in the small to mid-sized tributaries, move down into the McKenzie or upper Willamette River to mature, and return to smaller tributaries to spawn.

Cutthroat trout are found throughout the McKenzie Subbasin, including in areas above Tamolitch Falls and in small, high-gradient tributaries above the distribution of rainbow trout. During the late spring and summer, cutthroat trout are more numerous than rainbow trout in the lower McKenzie River mainstem up to Hayden Bridge (RM 11.4). This lower McKenzie population of fluvial cutthroat trout declines in the fall and winter as fish move into lower McKenzie and Mohawk Watershed tributaries (Howell et al., 1988).

Cutthroat trout in the McKenzie Subbasin face similar challenges as they do in other subbasins in the Willamette Valley: loss of connectivity between habitats as a result of impassible dams, culverts, and other obstructions; modifications in habitat-forming process that create and sustain complex pools, cover, and other habitats; reduced key habitats from channelization and wood removal; and increased water temperatures from reduced riparian cover and water withdrawals. Table 3-174 summarizes how changes in the subbasin's environmental conditions have affected all life stages of cutthroat trout.

Table 3-174: McKenzie Subbasin: Subbasin Attributes Affecting Cutthroat Trout Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Cutthroat Trout	All life stages	Low flows in the basin are aggravated by water withdrawals, which increase water temperatures. High water temperatures, particularly in the Mohawk River and tributaries in the middle and lower portions of the watershed, are aggravated by loss of riparian cover, reduced wetland areas, and channel simplification.	Numerous culverts throughout the watershed present barriers to adult movement and juvenile access to rearing and refuge habitat. Cougar Dam, Blue River Dam, and the dams associated with the Carmen-Smith project restrict movement within the river channel and isolate populations.	Channels in the lower portions of the river and some tributaries have been simplified by revetments and other actions. Limited wood in the tributaries and river channel has reduced the frequency and depth of pools and limited adult hiding cover and the quality of juvenile rearing and refuge habitats. Riparian areas along the river and tributaries are reduced in width, connectivity, and quality; there are limited conifers along the middle portions of the river and most tributary streams. Reed canary grass and Himalayan blackberry in the aquatic and riparian area limit the growth of robust native vegetation needed for habitat and channel formation processes. The loss of wetland, floodplain, and off-channel habitats has affected the quantity and quality of adult holding areas and refuge habitats. Limited wood in tributary streams has reduced retention of spawning gravels.	Introduced fish species (small- and large-mouth bass, for example) may prey on juveniles.

Table 3-175 shows EDT attributes related to the limiting factors for all life stages of cutthroat trout in the lower McKenzie Subbasin, while Table 3-176 shows attributes for the upper subbasin. The priorities are based on information in Table 3-174 and professional opinions from individuals familiar with the subbasin.

Table 3-175: Qualitative Ratings of EDT attributes Related to Limiting Factors for Cutthroat Trout in the Lower McKenzie River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Flow	Changes in the interannual variability of low and high flows from dam regulation have affected the quantity of habitat and disrupted the processes that create a complex array of habitats.	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels.	**HIGH**
Obstructions	Dams prevent upstream and downstream movement and isolate populations; numerous complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: small cobble/gravel riffles in the river (spawning and incubation); primary pools, backwater areas, and large wood (0- and 1-age rearing and migration).	**HIGH**
Channel stability	Limited wood in channels has reduced channel stability.	Medium
Competition w/hatch.	Hatchery fish have been introduced to some areas below the dams, increasing competition with native fish for habitat and food.	Medium
Withdrawals	Water withdrawals and diversions within the river affect adult migration, juvenile rearing, and juvenile movement.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids.	Low
Competition w/sp.	Very low number of fish species present.	Low
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.	Low
Harassment	Harassment is not an issue for adult cutthroat trout.	Low
Oxygen	Oxygen levels are adequate to support all life stages	Low
Pathogens	Hatchery fish have been introduced to areas below the dams, increasing competition with native fish for habitat and food.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low

Table 3-176: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Cutthroat Trout in the McKenzie River Subbasin

EDT Attribute Class	Description	Priority for Restoration
Habitat diversity	Moderate channel confinement through the river corridor as a result of bank riprap along the highway and secondary roads. Limited large wood has affected the quality of habitat.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood.	**HIGH**
Competition w/hatch.	Hatchery fish have been introduced to areas above the dams, increasing competition with native fish for habitat and food.	Medium
Channel stability	In some areas, limited in-channel wood has destabilized channels.	Medium
Obstructions	Some complete and partial barriers on tributary streams.	Medium
Temperature	Changes in riparian canopy cover have increased summer high water temperatures on some tributary streams.	Medium
Chemicals	No evidence of levels of toxics sufficient to affect salmonids.	Low
Competition w/sp.	Very low number of fish species present.	Low
Flow	There have not been significant changes in the interannual variability of low and high flows.	Low
Food	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and food availability for rearing fish.	Low
Harassment	Harassment is not an issue for adult cutthroat trout .	Low
Oxygen	Oxygen levels are adequate to support all life stages.	Low
Pathogens	Hatchery fish have been introduced to areas above the dams, increasing competition with native fish for habitat and food.	Low
Sediment load	Although turbidity levels are periodically high, there does not appear to be increased sediment deposition.	Low
Withdrawals	Minimal water withdrawals.	Low

Limiting Factors for Oregon Chub. Oregon chub were found in the McKenzie River historically; one record exists for chub near Eugene in 1899. Currently, there are two natural and one introduced populations in this subbasin, two of which are in the Mohawk River. Oregon chub were introduced to Russell Pond (in the Mohawk near Marcola) in 2001 and were first documented in Shetzline Pond (in the Mohawk near Marcola) and Big Island (in the McKenzie River near Springfield) in 2002 (Paul Scheerer, ODFW, personal communication, 2004). These populations were discovered after the *Oregon Chub Recovery Plan* (U.S. Fish and Wildlife Service, 1998) was developed, so the McKenzie Subbasin was not factored into the recovery strategy at that time. However, since these new populations were discovered, the McKenzie Subbasin has received considerable attention and has been included in recovery planning for Oregon chub. To date, Oregon chub have not been documented in the upper McKenzie subbasin.

Oregon chub face similar challenges in the McKenzie subbasin as in the other subbasins of the Willamette Valley: habitat loss as a result of changes in seasonal flows associated with the construction of dams throughout the basin; channelization of the river and its tributaries; removal of snags for river navigation; the proliferation of nonnative fish and amphibians; accidental chemical spills; runoff from herbicide or pesticide application on farms, timberlands, or along roadways, railways, and power line rights-of-way; desiccation of habitats; unauthorized water withdrawals, diversions, or fill and removal activities; and sedimentation resulting from timber harvesting in the watershed. Table 3-177 summarizes how changes in the subbasin’s environmental conditions have affected all life stages of Oregon chub.

Table 3-177: McKenzie Subbasin: Subbasin Attributes Affecting Oregon Chub Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Oregon chub	All	Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas.	Loss of connectivity to floodplain and wetland habitats has affected availability of suitable habitat. Dams and other structures have changed river hydrology and reduced the amount of side-channel habitat necessary for Oregon chub.	Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat. Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Streambank protection has limited habitat complexity, reducing the number of pools and side channels available for Oregon chub. Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development.	Exotic warm-water predaceous fish are a significant threat to Oregon chub survival.

Table 3-178 shows the EDT attributes related to the limiting factors for Oregon chub in the lower McKenzie Subbasin. The priorities for restoration are based on the information in Table-177 and professional opinions from individuals familiar with the Subbasin, particularly ODFW biologists.

Table 3-178: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Oregon in the Lower McKenzie

EDT Attribute Class	Description	Priority for Restoration
Competition with other species	Exotic fish species pose a significant threat through predation and competition.	**HIGH**
Habitat diversity	Changes in hydrologic flow regimes have reduced the amount of off-channel habitat in side channels, sloughs, and other slow-moving water.	**HIGH**
Key habitats	Reduction of the following key channel habitats affects all life stages: backwater sloughs, channels, and other low-velocity waterways.	**HIGH**
Flow	Changes in the interannual variability of low and high flows as a result of dam regulation affect the quantity of habitat and disrupt the processes that create a complex array of habitats.	Medium
Withdrawals	Unauthorized withdrawals have the potential to disrupt flows and reduce the amount and quality of habitat.	Medium
Chemicals	Oregon chub habitats are susceptible to reduced water quality from commercial timber operations, agricultural, residential, and highway runoff.	Low
Oxygen	Oxygen levels are not known to be affecting Oregon chub in this subbasin.	Low
Pathogens	Pathogens are not thought to be limiting.	Low
Sediment load	Although turbidity levels are periodically high, sediment deposition does not appear to be affecting known Oregon chub populations.	Low

Limiting Factors for Bull Trout. There are currently three populations of bull trout in the McKenzie Subbasin, found in the following locations:

- The mainstem McKenzie River and tributaries up to Trail Bridge Dam
- The McKenzie River and tributaries from Trail Bridge Dam up to Tamolitch Falls

The South Fork McKenzie River above Cougar Dam.

These populations were formed artificially in the early 1960s when dam construction fragmented the original McKenzie population.

Of these, the population inhabiting the mainstem is the largest and most secure. Anderson and Olallie creeks are key spawning and juvenile rearing areas and are relatively protected by U.S. Forest Service land management direction. Anderson Creek may be at carrying capacity for rearing juvenile bull trout, based on the number of adults spawning and the number of both fry and juvenile bull trout migrating from the creek. Opening upstream passage for adult bull trout under Highway 126 on Olallie Creek in 1995 may have doubled the area available for rearing juvenile bull trout. This area had been inaccessible to bull trout since the highway was constructed in the early 1960s. This population is still vulnerable to incidental harvest in recreational fisheries; however, it is expected that the mainstem McKenzie population will continue to slowly increase in the foreseeable future.

Bull trout inhabiting the mainstem McKenzie above Trailbridge Reservoir are probably severely limited by a lack of juvenile rearing habitat, and their population is reduced because of angling, even though angling regulations requiring the release of bull trout in the Willamette Basin were adopted in 1990. Reestablishing bull trout spawning in Sweetwater Creek has increased juvenile rearing area for this population; however, the success of this introduction effort is still uncertain. Brook trout are well established in Trail Bridge Reservoir and the watershed above the reservoir, and competition and hybridization between brook trout and bull trout are a limiting factor for this population. It is unlikely that eliminating or even reducing brook trout is feasible. Little data exist on the number of bull trout passing downstream through Trailbridge Dam; however, it is likely that fish passage at Trailbridge Dam will need to be established to maintain this population.

Angling has probably limited the number of older fish in the South Fork McKenzie population. Regulations requiring the release of bull trout have generally been accepted, although some harvest still occurs as a result of misidentification and illegal taking. The popularity of this river for angling was due in part to the release of legal-sized rainbow trout, easy access, and numerous campsites. Beginning in 1997, legal-sized rainbow trout were no longer stocked in the South Fork McKenzie above Cougar Reservoir, so as to reduce incidental angling mortality on bull trout. Recent intensive monitoring of the local population of bull trout in the South Fork McKenzie by ODFW, in association with the U.S. Army Corps of Engineers' Cougar Dam Water Temperature Control Project, has shown a significant number of bull trout passing downstream of Cougar Dam. To maintain this population, it will be essential that fish passage at Cougar Dam be restored.

All bull trout in the McKenzie Subbasin are sensitive to habitat alteration from road construction and timber harvesting, loss of juvenile spring Chinook as a food source, mortality from angling, loss of migration corridors because of man-made obstructions, and competition with nonnative brook trout. Table 3-179 summarizes how changes in the McKenzie Subbasin's environmental conditions have affected all life stages of bull trout.

Table 3-179: McKenzie Subbasin: Subbasin Attributes Affecting Bull Trout Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
Bull Trout	Adult migration and holding	Cougar and Blue River dams: Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. No documented affect from winter and spring flow reductions below Cougar and Blue River dams on migrating bull trout; however, flow management that more closely approaches the natural hydrograph would benefit bull trout. Spring and summer releases from Cougar and Blue River dams are cooler than inflow; winter releases are warmer than inflow ODEQ's 2002 CWA 303(d) database indicates that the South Fork McKenzie below Cougar Dam exceeds the temperature standard for bull trout (50°F). The 7-day average of daily maximums of 59.0/59.9/59.0/54.7/59.9 exceeded the bull trout temperature standard in 1990/91/92/93/94, respectively. ODEQ 2002 CWA 303(d) database indicates that Blue River below Blue River Dam exceeds the temperature standard for bull trout (50°F).	Complete barriers to upstream adult movement: Cougar Dam on the South Fork McKenzie (RM 4.5), Blue River Dam (RM 1.5) on Blue River, and Trailbridge Dam on the mainstem McKenzie (RM 82). No designed downstream fish passage. All downstream passage is through turbine or regulating outlets.	Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat Cougar Dam: Frequency and magnitude of high flows are not sufficient to create and maintain channel complexity and provide nutrient, organic matter, and sediment inputs from floodplain areas. Construction of Cougar Dam has replaced 6.5 miles of free-flowing stream in the South Fork McKenzie subbasin with reservoir habitat. Streambank protection has limited habitat complexity, reducing the number of pools and side channels available for holding and rearing fish. The mainstem McKenzie below Trailbridge Dam, South Fork McKenzie below Cougar Dam, and Blue River below Blue River Dam are deprived of large wood from the headwaters. Inadequate recruitment of large wood from riparian areas below the dams. Many remaining patches of floodplain forest are interspersed with pastureland, highways, and residential development.	Boating and other recreational activities harass adults migrating and holding in pools. Poaching of bull trout occurs. Bull trout captured and released during trout, steelhead, or salmon fisheries suffer an unknown level of hooking mortality. Reduction of spring Chinook salmon production above Cougar Dam has decreased the availability of a historical prey base important to bull trout. Hatchery rainbow trout have been introduced to areas above and below dams, potentially competing with bull trout for food and habitat.

Table 3-179: McKenzie Subbasin: Subbasin Attributes Affecting Bull Trout Life Stages

Species	Life Stage	Water Quality and Quantity	Habitat Connectivity	Aquatic and Riparian Habitat Characteristics and Processes	Other Impacts
	Adult spawning/ egg incubation		Complete barriers to upstream adult movement: Cougar Dam on the South Fork McKenzie (RM 4.5), Blue River Dam (RM 1.5) on Blue River, and Trailbridge Dam on the mainstem McKenzie (RM 82). No designed downstream fish passage. All downstream passage is through turbine or regulating outlets. Numerous partial and complete passage barriers at culverts on tributary streams may limit movement into refuge habitat.	Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat	Hybridization with nonnative brook trout.
	Fry and juvenile rearing and migration	ODEQ 2002 CWA 303(d) database indicates that the South Fork McKenzie below Cougar Dam exceeds the temperature standard for bull trout (50°F). The 7-day average of daily maximums of 59.0/59.9/59.0/54.7/59.9 exceeded the bull trout temperature standard in 1990/91/92/93/94, respectively. ODEQ 2002 CWA 303(d) database indicates that Blue River below Blue River Dam exceeds the temperature standard for bull trout (50°F).	Complete barriers to upstream juvenile movement: Cougar Dam on the South Fork McKenzie (RM 4.5), Blue River Dam (RM 1.5) on Blue River, and Trailbridge Dam on the mainstem McKenzie (RM 82). No designed downstream fish passage. All downstream passage is through turbine or regulating outlets. Numerous partial and complete passage barriers at culverts on tributary streams may limit movement into refuge habitat.	Timber harvesting has increased sediment delivery to streams and decreased large wood input, resulting in degraded aquatic habitat Streambank protection has limited habitat complexity, reducing the number of pools and side channels available for holding and rearing fish.	Salmon carcasses are reduced from historical levels, limiting nutrient inputs to the system and thus food availability for rearing fish.

Table 3-180 shows the EDT attributes related to the limiting factors for bull trout in the lower McKenzie Subbasin, while Table 3-181 shows the attributes for limiting factors in the upper subbasin. The priorities for restoration are qualitative ratings based on the information in Table 3-179 and professional opinions from individuals familiar with the subbasin, particularly ODFW biologists.

Table 3-180: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Bull Trout in the Lower McKenzie

EDT Attribute Class	Description	Priority for Restoration
Flow	There have been impacts to the interannual variability of low and high flows from land use practices and water diversions (see Table 3).	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels (see Table 3).	**HIGH**
Obstructions	Numerous culverts are complete and partial barriers on tributary streams (see Table 3).	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams (see Table 3).	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration) (see Table 3).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have reduced channel stability (see Table 3).	Medium
Chemicals	Increased toxics, particularly from urban and agricultural runoff, may affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting bull trout.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although turbidity levels are periodically high, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

Table 3-181: Qualitative Ratings of EDT Attributes Related to Limiting Factors for Bull Trout in the Lower McKenzie

EDT Attribute Class	Description	Priority for Restoration
Flow	There have been impacts to the interannual variability of low and high flows from land use practices and water diversions (see Table 3).	**HIGH**
Habitat diversity	Extensive channel confinement through the river corridor as a result of bank riprap and revetments; loss of floodplain and riparian trees and limited wood in the river and tributary channels (see Table 3).	**HIGH**
Obstructions	Numerous culverts are complete and partial barriers on tributary streams.	**HIGH**
Temperature	Changes in riparian canopy cover and water withdrawals have increased summer high water temperatures on some tributary streams (see Table 3).	**HIGH**
Key habitats	Reduction of the following key channel habitats affects key life stages: primary pools, backwater areas, and large wood (0- and 1-age rearing and migration) (see Table 3).	**HIGH**
Channel stability	Limited wood in channels and reduced riparian function have reduced channel stability (see Table 3).	Medium
Chemicals	Increased toxics, particularly from urban and agricultural runoff, may affect salmonids (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with other species	Fish community richness is high and there is competition with introduced fish (Mamoyac, ODFW, personal communication, 2004).	Medium
Withdrawals	Some problems from unscreened diversions (Mamoyac, ODFW, personal communication, 2004).	Medium
Competition with hatchery fish	Competition with hatchery fish is not believed to be significant (Mamoyac, ODFW, personal communication, 2004).	Low
Food	Historically low salmon carcasses abundance.	Low
Harassment	Prespawning fish do not hold in the river channels.	Low
Oxygen	Oxygen levels are not known to be affecting bull trout.	Low
Pathogens	Pathogens are not thought to be limiting (Mamoyac, ODFW, personal communication, 2004).	Low
Sediment load	Although turbidity levels are periodically high, sediment deposition does not appear to be affecting spawning areas (Mamoyac, ODFW, personal communication, 2004).	Low

Limiting Factors for Spring Chinook. The McKenzie Subbasin is one of the few in the Willamette Basin to have undergone a detailed, reach-by-reach EDT analysis of its habitat conditions with respect to the population potential, capacity, productivity, abundance, and diversity of one of the focal species of this plan: spring Chinook salmon. The other focal species in the McKenzie—cutthroat, winter steelhead, bull trout, and Oregon chub—have not yet been analyzed using EDT.

Appendix K presents a detailed description of the EDT analysis, including information sources, assumptions, methodology, and limitations; results for specific geographic areas, including protection and restoration benefit rankings; and hypotheses regarding restoration and protection strategies The following subsection summarizes the information in the appendix.

EDT Approach. The EDT analysis was based on existing information on current and historical conditions in the McKenzie Subbasin and the upper Willamette River, from Eugene to Willamette Falls. These conditions included riparian and aquatic habitat, water quality, hydrologic regime, fish passage, and biological characteristics. For the upper Willamette reaches, the EDT-calculated survival rate of juvenile spring Chinook was calibrated using ODFW estimates of survival for wild yearling spring Chinook for the years 1999 to 2001; this provided initial insights into the effect of Willamette River conditions on spring Chinook potential in the McKenzie River.

Three scenarios were part of the EDT analysis:

- Current conditions, based on existing empirical and expert knowledge regarding physical and biological conditions in the McKenzie Subbasin. This scenario was described by the McKenzie Watershed Council technical team.
- A reference or template condition that defined a fully restored condition for the McKenzie River, its tributaries, and the downstream reaches of the Willamette River. This scenario also was described by the McKenzie Watershed Council technical team.
- A fully degraded condition for the system. This scenario is contained within the EDT model.

The EDT assessment of the McKenzie Subbasin and Willamette River was organized hierarchically into 276 stream reaches and 11 geographic areas, as shown in Table 3-182 (see also Appendix I).

Table 3-182: McKenzie Subbasin EDT Geographic Areas

Section	Geographic Area	Description
McKenzie Subbasin	Upper McKenzie River	The mainstem upstream of Quartz Creek (RM 54) to the end of historical salmon spawning habitat
	Upper McKenzie River Tributaries	Horse Creek, Lost Creek, and other tributaries that have historical Chinook salmon spawning at Tamolitch Falls (RM 85)
	South Fork McKenzie River	The South Fork and larger tributaries (French Pete, Roaring River and others)

Table 3-182: McKenzie Subbasin EDT Geographic Areas

Section	Geographic Area	Description
	Blue River	Blue River and key tributaries
	Lower McKenzie River	The mainstem from the Willamette River to Quartz Creek
	Lower McKenzie River Tributaries	Larger tributaries (Cedar, Gate, and Martin and others) up to and including Quartz Creek
	Mohawk Subbasin	Mohawk River, Mill Creek, and other larger tributaries
Willamette River	Eugene	From the confluence with the McKenzie River to the confluence with the Santiam and Luckiamute rivers
	Salem	Mainstem from the confluence with the Santiam/Luckiamute Rivers to the confluence with the Yamhill River
	Newberg	Mainstem from the confluence with the Yamhill River to Willamette Falls
	Portland	Willamette Falls to the confluence with the Columbia River

EDT Results. EDT assesses habitat in terms of four output parameters:

- Biological capacity (quantity of habitat)
- Biological productivity (quality of habitat)
- Equilibrium abundance (quantity and quality of habitat)
- Life history diversity (breadth of suitable habitat)

Parameters for McKenzie spring Chinook salmon population are provided in Table 3-183. Capacity and productivity are parameters of a Beverton-Holt production function; abundance is calculated from this relationship. Life history diversity is listed as a diversity index that is the percentage of viable trajectories sustainable under the current condition relative to the reference condition.

Table 3-183: Capacity, Productivity, Abundance, and Diversity of McKenzie River Spring Chinook Salmon, Estimated as a Function of Habitat

Scenario	Capacity	Productivity[1]	Abundance[2]	Diversity Index[3]
Current with harvest	18,914	8.3	16,648	68%
Reference (template condition)	95,179	29.3	91,929	97%

1 Productivity is the density independent survival rate in a Beverton-Holt production function measured as return / spawner.

2 Abundance is the equilibrium abundance in a Beverton-Holt production function.

3 Diversity index is the percentage of sustainable life history trajectories in the current condition relative to the reference condition.

Figure 3-98 compares the estimated current abundance potential to the abundance potential of the habitat under the reference or template condition. Population potential provides an assessment of the “size” and quality of the McKenzie River spring Chinook salmon population. (Note that this is an index of habitat potential and that the actual abundance of fish observed in the McKenzie River will vary greatly from year to year as a result of factors within and outside the subbasin, especially variation in ocean conditions.)

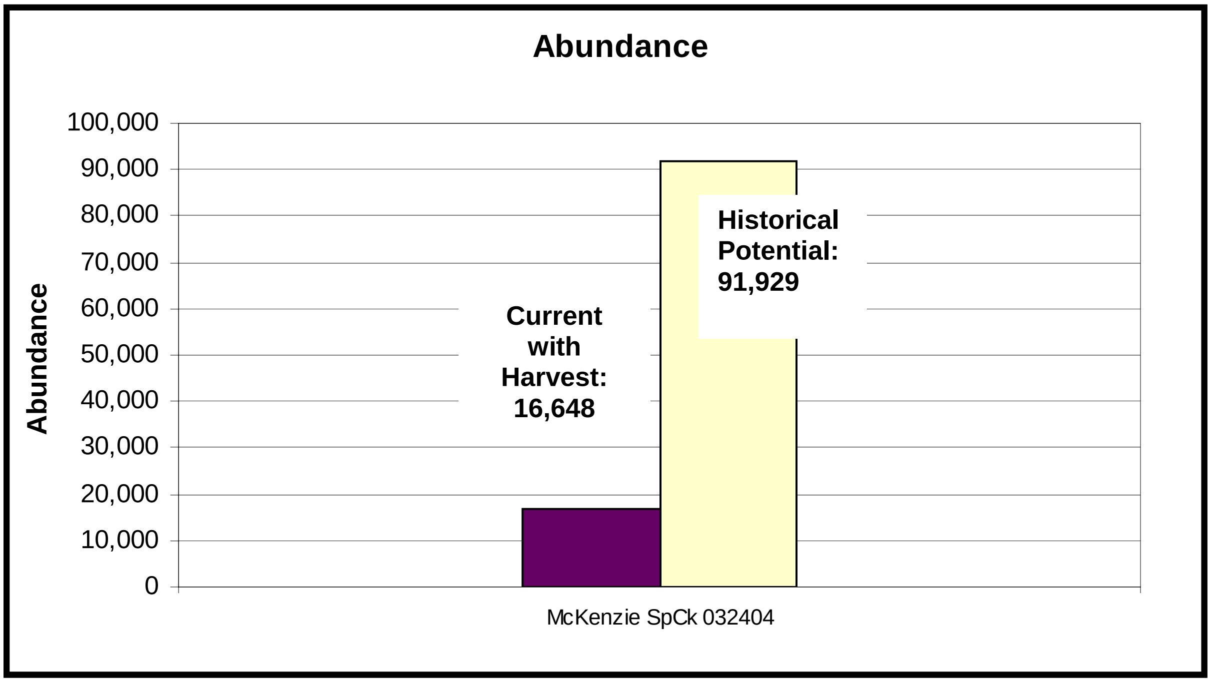


Figure 3-98: Estimated Fish Abundance Potential for Mckenzie River Spring Chinook as a Function of Habitat under Current and Reference Conditions

For the McKenzie River spring Chinook salmon population, the current potential is about 18 percent of that under the reference habitat conditions. The percent change is a measure of the overall degradation of habitat conditions in the McKenzie Subbasin, primarily as a result of anthropogenic changes to the habitat in the McKenzie River, the South Fork McKenzie River, larger spawning tributaries, and the lower Willamette River.

The results of the EDT reach analysis were aggregated to provide an estimate of the changes in the McKenzie River spring Chinook salmon population abundance, productivity, and diversity for each of the 11 geographic areas (see Table 3-184). Figure 3-99 illustrates the changes in the population attributes for the geographic areas within the McKenzie Subbasin and upper Willamette River.

The changes in McKenzie spring Chinook salmon population attributes provide an estimate of the relative importance of the geographic areas for habitat protection and restoration measures (see Table 3-184 and Figure 3-99). The geographic areas priorities are based on the following:

- An estimate of the changes in spring Chinook salmon population abundance, productivity, and diversity at each life stage under conditions of habitat degradation from the current state (protection benefit) and habitat restoration to the historical potential (restoration benefit)

- The extent to which the geographic area is used by each of the life stages

Table 3-184: Estimated Changes in Population Parameters for McKenzie River Spring Chinook, by Geographic Area

Geographic Area	Restoration Rank	Percent Change in Parameter with Restoration		
		Abundance	Productivity	Diversity
Lower McKenzie River	1	86%	52%	1%
South Fork McKenzie R. Subbasin	1	20%	13%	15%
Upper McKenzie River	2	22%	19%	3%
Willamette River, Eugene Reach	3	14%	9%	1%
Willamette River, Portland Reach	4	12%	11%	0%
Blue River Subbasin	5	5%	1%	8%
Willamette River, Salem Reach	6	8%	6%	0%
Upper McKenzie River Tributaries	7	7%	8%	0%
Mohawk River Subbasin	8	1%	0%	7%
Willamette River, Newberg Reach	9	6%	5%	0%
Lower McKenzie River Tributaries	10	1%	1%	0%

McKenzie Spring Chinook

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit		Restoration benefit	
	Category/rank		Category/rank	
Lower McKenzie River	A	1	A	1
Upper McKenzie River	B	2	B	2
South Fork McKenzie River Watershed	C	4	A	1
Eugene	C	5	B	3
Upper Watershed Tributary	B	3	D	7
Blue River Watershed	E	8	C	5
Portland	E	9	C	4
Salem	E	8	D	6
Mohawk Watershed	D	7	E	8
Lower Watershed Tributary	D	6	E	10
Newberg	E	9	E	9

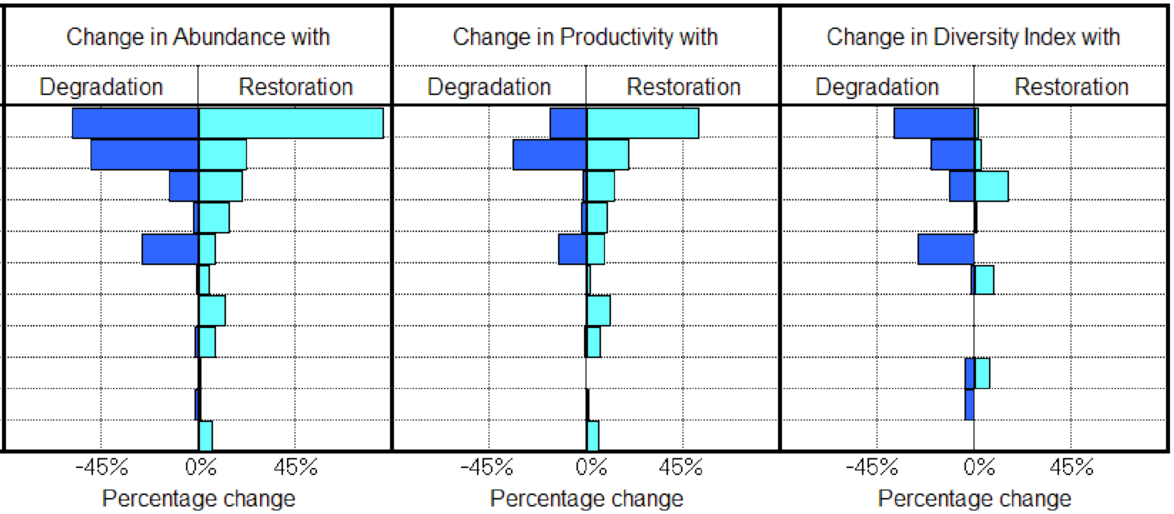


Figure 3-99: Relative Importance of Geographic Areas for Protection and Restoration Measures for McKenzie River Spring Chinook

Based on this analysis, the lower McKenzie River has the highest protection and restoration benefits (protection rank = 1, restoration rank = 1). All of the spring Chinook salmon population (as adults and juveniles) migrate through the lower McKenzie River, and it provides important habitats for juvenile rearing. While there have been significant losses of habitat within the lower McKenzie River, some high-quality aquatic and floodplain habitats still remain. The South Fork McKenzie watershed also is ranked as the highest restoration benefit priority (rank = 1) and receives a moderately high protection benefit priority (rank = 4). Cougar Dam on the South Fork has resulted in significant loss of access to historically productive spring Chinook salmon habitat. The South Fork's protection benefits are due to the large amounts of high-quality habitat remaining above the dam.

In contrast to the other parts of the subbasin, the lower McKenzie River tributaries were ranked last for restoration benefit (rank = 10) and near the bottom for protection benefit (rank = 6). There is almost no spring Chinook salmon spawning in the lower McKenzie River tributaries, and use by juveniles is confined to refuge habitat in the lower portions of the streams (e.g., lower Cedar Creek).

Summary. The EDT analysis of habitat, water quality, fish passage and other attributes influencing McKenzie River spring Chinook salmon provides a description of the factors limiting the population and the relative importance of the geographic areas for habitat improvement. This information is useful for developing habitat restoration strategies.

Figure 3-100 provides an overview of the EDT attribute classes and their relative influence (high, medium, or low) in limiting the abundance, productivity, and diversity of spring Chinook salmon in each of the geographic areas. The relative protection and restoration benefit rankings should be used to weight the priority restoration attribute ratings for each geographic area. For example, while obstructions have a large impact in the Mohawk watershed, there is very little relative restoration benefit to spring Chinook salmon populations because very few fish historically spawned in the watershed.

McKenzie Spring Chinook
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Upper McKenzie River	○	○						•	•		⬤				•			•
Upper Watershed Tributary	○							•	•									•
South Fork McKenzie River Watershed	∘	◯						•	•		●				•			●
Blue River Watershed		∘	•				•	•	●		⬤				●	•		
Lower McKenzie River	◯	◯	•				•	•	●	•						•		●
Lower Watershed Tributary			•				•	•	●							•		•
Mohawk Watershed			•		•		•	•	●		⬤				●	●		●
Eugene	∘	○			•		•	•	•				•	•		•		•
Salem									•					•		•		
Newberg				●					•					•				
Portland		∘		●					•					•				•

Key to strategic priority (corresponding Benefit Category letter also shown)

A	B	C	D & E
◯ ⬤ High	○ ● Medium	∘ • Low	Indirect or General

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Figure 3-100: Aquatic and Riparian Protection and Restoration Priorities by EDT Attribute Class for McKenzie River Spring Chinook

As shown in Figure 3-100, several EDT attribute classes have a disproportionate affect on McKenzie River spring Chinook salmon populations:

- **Habitat Diversity**. Altered habitat diversity (channel confinement, riparian function, wood in the channel, and other attributes) has affected all of the spring Chinook salmon life stages in the geographic areas, with larger impacts in the Blue River watershed, lower McKenzie River, lower subbasin tributaries, and Mohawk watershed.
- **Key Habitat Quality**. Key habitat quality also has a dominant impact on the population. Habitat changes that affect spawning (coarsening of channel substrate, for example) and juveniles (loss of backwater habitats, for example) affect most geographic areas, particularly in the South Fork McKenzie, lower McKenzie River, and Mohawk watershed.
- **Fish Passage Barriers**. Obstructions to fish passage have the greatest impact on the distribution and productivity of spring Chinook salmon in the Subbasin. Dams on the upper McKenzie River, South Fork, and Blue River restrict access to large amounts of historical habitat. To a lesser degree, culverts and other fish passage obstructions limit the population in the Mohawk Watershed.

3.5.1.18 Limiting Factors in the Tryon Creek Subbasin (with EDT Analysis)

This section describes the geographic setting of the Tryon Creek Subbasin and limiting factors for two of the focal species in the subbasin: coho salmon and winter steelhead. The limiting factors were determined by using EDT to analyze habitat conditions on a reach-by-reach basis throughout the Tryon Creek Subbasin.

Focal species present:

- Coho salmon
- Winter steelhead
- Cutthroat trout

Because their health, abundance and productivity are linked to terrestrial and aquatic watershed conditions, salmonids (salmon and trout) are a good indicator of watershed health. Salmon are sensitive to all components of watershed processes and functions (hydrology, habitat, water quality and biological communities). More is known about the life histories of salmon and the relationships between stream conditions and population abundance and productivity than is known about many other aquatic species in the Willamette River basin. Anadromous fish such as coho and steelhead have complex life histories that involve resident and anadromous traits. These unique life history strategies inform local freshwater habitat condition, as well as marine influenced rearing conditions.

In addition, historical data characterizing salmonid presence and distribution is generally more quantitative and comprehensive than other native fish communities, hence reference conditions and existing habitat conditions and associated population status can be better evaluated. In addition to past and present data availability, salmon populations will continue to be evaluated in the near and long-term future, as a result of federal ESA listings. However, the ability to acquire biological data in the future is critical in evaluating trends in habitat condition and thus is needed to effectively inform decision-making and to evaluate the success of implemented actions. For these reasons we perceive that other non-ESA listed native fish communities, such as rainbow, cutthroat and sculpin may in the future play an important role in helping to evaluate habitat conditions.

For now, Tryon Creek winter steelhead and coho were chosen as focal species to be evaluated using EDT. Both are native to Tryon Creek and experience freshwater conditions affecting other native fish communities in the subbasin. Cutthroat trout and rainbow trout are likewise considered important species in Tryon Creek Subbasin, however, non-ocean-going species are not presently defined (e.g. fish rules) in EDT; hence they were not evaluated using this tool.

Tryon Creek Winter Steelhead

Population Description. The Tryon Creek Subbasin winter steelhead population was defined to spawn in mainstem Tryon Creek up to Marshall Cascade, a natural fish barrier at rivermile 3.3. The life history of this population is based on other lower Willamette winter steelhead populations, notably the Clackamas and the Tualatin River populations. Both are believed to be a late-run population returning to freshwater to spawn during their fifth and sixth year. Native, late-run winter steelhead entered the Willamette River from October through May (Dimmick 1945), with spawning beginning in March and peaking in April through May. Juvenile steelhead generally spend two years in freshwater before smolting, with peak emigration beginning early April and extending through early June. Larger steelhead generally emigrate sooner than their smaller cohorts (ODFW 2000).

Relationship to ESU or Other Population Designations. Tryon Creek Subbasin winter steelhead are part of the Lower Willamette River ESU and are believed to be most closely associated with populations below Willamette Falls: Clackamas River and Johnson Creek.

Historical Abundance and Present Status. Winter steelhead populated Tryon Creek basin (WMSWCD 2003(d)). The upstream extent of their anadromy is not known; however based on channel geomorphology and valley hillslope, they likely spawned up to (and perhaps beyond) Marshall Cascades on mainstem Tryon Creek and perhaps up to Arnold Falls on Arnold Creek (RM 0.4).

Presently, the biotic integrity of Tryon Creek has been greatly reduced from historical conditions. Many native species of fish, wildlife and plants are extinct or are greatly reduced in number. Anadromous coho, steelhead and cutthroat have significantly declined in distribution, productivity and abundance. However, steelhead and rainbow trout continue to spawn and rear throughout the subbasin. Although HWY 43 significantly impedes adult migrations in the winter, it does not completely block steelhead anadromy. Steelhead are most abundant (and largest) in the spring and least abundant (and smallest) in the summer, indicating spring smolt emigration and anadromous population recruitment (ODFW 2003).

Tryon Creek Coho

Population Description. The Tryon Creek Subbasin coho population was defined to spawn and rear in mainstem Tryon Creek up to the Marshall Cascade on Tryon Creek (RM 3.3); however, habitat above the confluence of Arnold Creek (RM 2.6) likely did not provide substantive coho spawning and rearing grounds. Life history of this population is based on similar populations in the lower Willamette River: Clackamas River and Johnson Creek populations. Coho returned as 3-year age adults and 2-year age jacks. Lower Willamette coho are an early run population, reaching Willamette Falls from late August through early November. Peak migrations occur from middle to late September, following periods of considerable rainfall, and peak spawning generally occurs soon afterwards from September through December. Fry emerge from mid-January through April, yielding a four-month emergence period. While a small proportion of fry emigrate during the first year, most fingerling smolts emigrate during the second spring, beginning in March and extending through mid-July.

Relationship to ESU or Other Population Designations. Lower Columbia River coho salmon were listed on the state ESA in July 1999. This population was previously considered for federal listing. On July 25, 1995, NMFS determined that the listing was unwarranted; however, the population remains a “candidate” for listing on the federal ESA. Lower Columbia River coho are listed as endangered under the state ESA. The Willamette River basin, up to Willamette Falls including the Clackamas, contains major spawning and rearing habitat for this population.

Historical Abundance and Present Status. Willamette Basin coho are believed to be native only to subbasins below Willamette Falls, notably, the Clackamas River basin, Johnson Creek (Fulton 1970) and Tryon Creek (WMSWCD 2003d), and were reported occupying tributaries to Multnomah Channel from 1951 to 1959 (Willis et al., 1960). Notably, the lower Willamette River basin provided the third most important spawning grounds for coho salmon, throughout the entire Columbia River basin (Fulton 1970).

In Tryon Creek adults generally occupied the lower and middle basin. The upstream extent of their anadromy is not known; however based on channel geomorphology and valley hillslopes, they likely migrated up to the confluence of Tryon and Arnold Creek and possibly up to the bottom of Marshall Cascades, a natural fish barrier, during high water years.

Today, coho no longer populate Tryon Creek; HWY 43 completely impedes movement into the basin in the fall, when coho adults return to spawn. However, juvenile coho continue to use the lower confluence reach (up to RM 0.3) throughout much of the year (ODFW 2002)(ODFW 2003).

Geographic Setting. The mainstem of Tryon Creek is about 7 miles long from its headwaters near Multnomah Village (just north of Interstate 5 and Highway 99) to its confluence with the Willamette River in Lake Oswego at the Highway 43 crossing. Tryon Creek flows in a northwesterly to southeasterly direction from its headwaters to its confluence with the Willamette River.

Tryon Creek is primarily a low-moderate gradient stream system. The overall gradient averages 1.6 percent, although short sections with higher gradients from 10-25 percent exist at the Marshall and Arnold cascades. The lower portion is generally low gradient (1 percent or less) with a larger floodplain compared to the upper reaches. At Boones Ferry Road steep canyon walls restrict the stream while gradient increases (3 to 4 percent).

Arnold Creek and Falling Creek are Tryon Creek’s two main tributaries. Arnold Creek drains an area of 772 acres and joins Tryon Creek at the Boones Ferry Road crossing. Falling Creek drains an area of 325 acres and joins Tryon Creek at SW 26th Avenue and Taylor’s Ferry Road. Other smaller tributaries flow into Tryon Creek both within and outside Portland’s city limits. The 455-acre Tryon Creek State Park, managed by the Oregon Parks and Recreation Department, is a prominent feature in the watershed.

Tryon Creek was characterized and evaluated using EDT. Tryon Creek coho and winter steelhead were the focal species for the development of data sets that were used to derive habitat condition and inform attribute ratings in EDT. Stream reaches in Tryon subbasin are coincident with Oregon Department of Fish and Wildlife (ODFW) Aquatic Inventory Project. Generally reaches are defined by functional characteristics such as tributary confluences, changes in valley form and channel form, major changes in vegetation and / or changes in land-use ownership (Moore et. al 1997). In addition to these landscape attributes, unique channel forms such as culverts and fish barriers were identified as unique reaches in order to rate each to its potential impact on coho and steelhead productivity.

Key Findings. For the Tryon Creek Subbasin, the current coho salmon productivity potential is about 1.5 percent of that under the reference habitat conditions, and current steelhead productivity is about 1.0 percent of that under the reference habitat conditions. The percent change is a measure of the overall degradation of conditions in the Tryon Creek Subbasin primarily as a result of anthropogenic changes to fish passage in the lower watershed and habitat and watershed processes in the upper subbasin. Major factors contributing to the decline in both anadromous populations are obstructions to fish passage, modified flow regimes, changes in riparian and floodplain conditions, and impacts to the amount and quality of aquatic habitat.

Present habitat condition in Tryon Creek Subbasin is symptomatic of watershed processes as well as discrete actions that have occurred in the basin. For example, construction of HWY 43 and the culvert running under it has significantly impaired fish passage to middle and upper Tryon Creek. Deforestation of middle Tryon Creek in the 1940s sets the current vegetative template in the creek, riparian and floodplain area, and the uplands. Urbanization in the upper watershed has altered the hydrologic regime throughout the entire drainage area. These altered hydrologic regimes have functionally disconnected the creek from its riparian and floodplain area. Table 3-185 summarizes the key attributes limiting Tryon Creek steelhead and coho populations.

Table 3-185: Summary of Key Problems in Tryon Creek

Environmental Attribute	Symptomatic Habitat Features
Stream Connectivity	HWY 43 significantly blocks anadromous fish from accessing middle Tryon Creek Boones Ferry Rd. completely blocks anadromous and resident fish from accessing upper Tryon Creek.
Habitat complexity	Lacking large wood; large and medium sized substrate; overhanging vegetation; undercut banks and terraced banks Shorter stream length with fewer meanders and simplified channel morphology (channelization).
Key habitats	Lack of high quality riffles, deep pools, side channels, secondary channels, off-channel and backwater habitats.
Riparian and Floodplain forest	Second growth, even-aged deciduous riparian and floodplain forests in middle Tryon Creek do not provide large wood pieces and substantive volume of woody debris. Lack of native conifers as source woody debris will limit the longevity and function of wood forms in the creek. Lack of overhanging vegetation along the stream banks destabilizes the creek, and minimizes potential protective cover to fish and wildlife. Lack of mature native trees and shrubs in upper Tryon Creek contribute to increased stream temperatures in the summer.
Fine Sediment	High sediment loads smother spawning habitats (riffle gravels) and fill pools. Sediment associated pollutants prevalent throughout the basin. High silt cover reduces areas for macroinvertebrate production.
Hydrologic Regime	Surface runoff originating from the upper watershed alters the hydrologic regime throughout the Willamette Basin.
Stream Temperature	Elevated summer temperatures stress fish communities resulting in lethal and sublethal effects.
Chemical Contamination	Chronic and acute chemical toxicity results in lethal and / or sublethal effects to aquatic communities, including macroinvertebrate production.

The data on which this summary of conditions is based are described in greater detail later in this section, under “Assessment of Habitat Constraints on Population Potential.”

EDT Approach

Information Sources. Tryon Creek EDT analysis was based primarily upon a watershed characterization assessment by the City of Portland. The watershed characterization summarized information from existing data sources, such as the ODFW's Aquatic Inventory Program habitat surveys, to describe current conditions in Tryon Creek Subbasin. EDT habitat attribute ratings were based on knowledge of historical and current conditions that describe hydrologic regimes, physical habitat, water quality and biological communities native to the subbasin. The content of the watershed characterization was previously vetted through a City of Portland, Tryon and Fanno Creek Watershed Advisory Team, which include members from Clean Water Services, Neighborhood Associations, Oregon State Parks, and other City Bureaus.

The purpose of the EDT assessment of the Willamette River below Willamette Falls was to allow detailed analysis of the lower Willamette River as it influences Tryon Creek coho and steelhead productivity.

One limitations in the EDT analysis of the lower Willamette River that should be addressed in future work is the need to include additional habitat types and species rules to account for the complexity of the large river environment. EDT is based on the existing scientific literature regarding salmonid-habitat relationships. The great bulk of that literature focuses on "wadeable" streams. Large river habitats used by salmon have not been extensively studied not only because of the difficulties in studying these environments but also because large rivers are often viewed as simple migration corridors rather than complex spawning and rearing areas. Habitat types developed for smaller streams are inadequate to evaluate the habitat functions provided in large river habitats. The complexity of the alluviating Willamette environment represent considerable habitat complexity and should be included in future EDT analysis.

Scenario Development. Three scenarios were described to evaluate coho and steelhead productivity in Tryon Creek Subbasin. The first describes the current conditions were described based on existing empirical and expert knowledge regarding hydrology, water quality, physical habitat and biological communities in Tryon Creek. The second scenario describes a reference or template condition. This reference condition defines fully restored conditions in Tryon Creek, it's tributaries, and the lower Willamette River, as it relates to salmonid life history, and spawning and rearing. The third scenario describes a fully degraded condition for the subbasin. Placing the current condition between the two "bookends" (e.g., reference condition and fully degraded condition) allows us to evaluate each population and its reliance on protection and restoration measures basinwide (e.g., sedimentation) and at specific areas (e.g., fish passage improvements).

Reach Structure and Geographic Areas. Mainstem Tryon Creek was broken into 11 stream reaches, five culvert reaches and one natural barrier (Marshall Cascades). Arnold Creek and Falling Creek were also characterized and evaluated using EDT. Arnold Creek was broken into seven stream reaches, five culverts and one natural barrier (Arnold Falls); and Falling Creek was broken into three stream reaches and two culverts. Mainstem Tryon, Arnold and Falling Creek were further grouped into three geographic areas that reflect watershed function, and land-use (e.g., upper subbasin in urban land-use and middle subbasin in Tryon Creek State Natural Area).

Lower Willamette River. The lower Willamette River reach includes four distinct river segments. From upstream to downstream these river segments are the North Segment, Industrial Segment, Downtown Segment, and South Segment. Refer to Section 3.5.1.18 for additional details describing habitat conditions and functions in the lower Willamette River subbasin.

Lower Tryon Creek. The lower reach extends from the confluence of Tryon Creek and the Willamette River upstream to the west side of Boones Ferry Rd. culvert, which is coincident with the confluence of Arnold and Tryon creeks (RM 0.00 – 2.68). Stream gradient is generally low, averaging 2.3 percent. HWY 43 crosses the creek at RM 0.24. Below the culvert, habitat functions primarily as off-channel habitat to the Willamette River. Land use in this confluence area is predominately residential. The remainder of lower Tryon Creek is mostly protected with Tryon Creek State Natural Area. Key tributaries include Nettle Creek, Red Fox Creek, Palatine Hill Creek, Park Creek and Arnold Creek (at the upstream extent). Note, hillsides were logged (predominately clear cut) approximately 40-60 years ago. The forest stand is characteristic of second-growth, even-aged forest stand, and is dominated by large maples, alders and native firs. The area is relatively undisturbed with a few exceptions: 1) A sewer pipe runs along the valley bottom; and 2) Recreational trails used by hikers, equestrians and mountain bikers parallel and cross the creek.

Middle Tryon Creek. The middle reach begins at the confluence of Arnold and Tryon Creek and extends upstream to Marshall Cascade. Mature second growth forests surround the lower portion of this reach, with some low-density residential use in the uplands. The remainder of middle Tryon (including Falling Creek) is predominately enclosed in residential land-use, with several small city parks. Key tributaries include Arnold, Burlingame and Quail creeks; however, several other (unnamed) tributaries enter the mainstem and may provide important off-channel and cool water refugia.

EDT Results. EDT was used to assesses habitat in terms of four population output parameters:

1. Biological capacity (quantity of habitat)
2. Biological productivity (quality of habitat)
3. Equilibrium abundance (quantity and quality of habitat)
4. Life history diversity (breadth of suitable habitat)

Capacity and productivity are parameters of a Beverton-Holt production function; abundance is calculated from this relationship. Life history diversity is listed as a Diversity Index that is the percentage of viable trajectories sustainable under the current condition relative to the reference condition.

Estimated Population Potential. The following figures compare the estimated current abundance, productivity and life history diversity potential to similar reference or template potential based upon habitat conditions. Indices of habitat potential (and its influence on fish abundance) do not represent actual fish abundance, productivity or diversity as measured or observed in Tryon Creek. Actual abundance, productivity or diversity is not known in Tryon Creek, but presumably varies from year to year as a result of factors within and outside the subbasin, notably, changes in ocean conditions.

The percent change in population potential is a measure of the overall degradation of habitat conditions in the Tryon Creek Subbasin primarily as a result of anthropogenic changes to the habitat in Tryon Creek and in the lower Willamette River.

Current winter steelhead abundance is estimated to be only 1.0 percent of reference population size (Figure 3-101). Current productivity is likewise low at about 3.0 percent (Figure 3-102) of the reference conditions, and life history diversity is only 7.5 percent (Figure 3-103) of the reference condition.

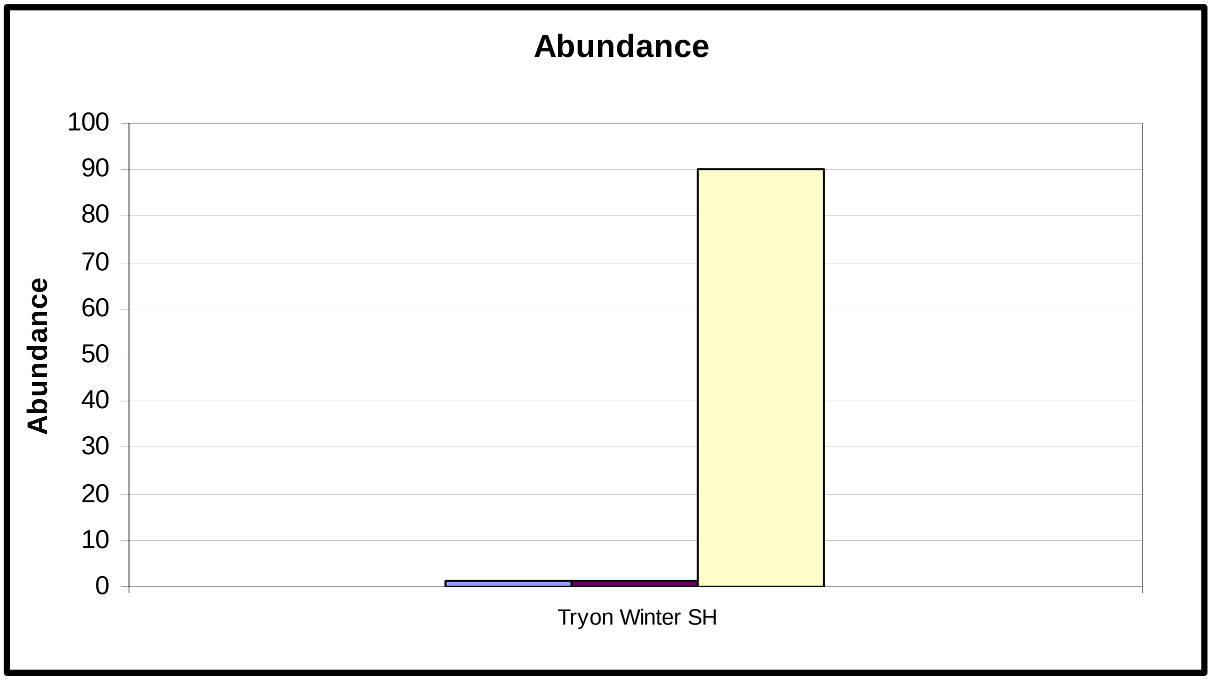


Figure 3-101: Estimated Fish Abundance Potential as a Function of Habitat in the Current and Reference Conditions for Tryon Creek Subbasin Winter Steelhead Population

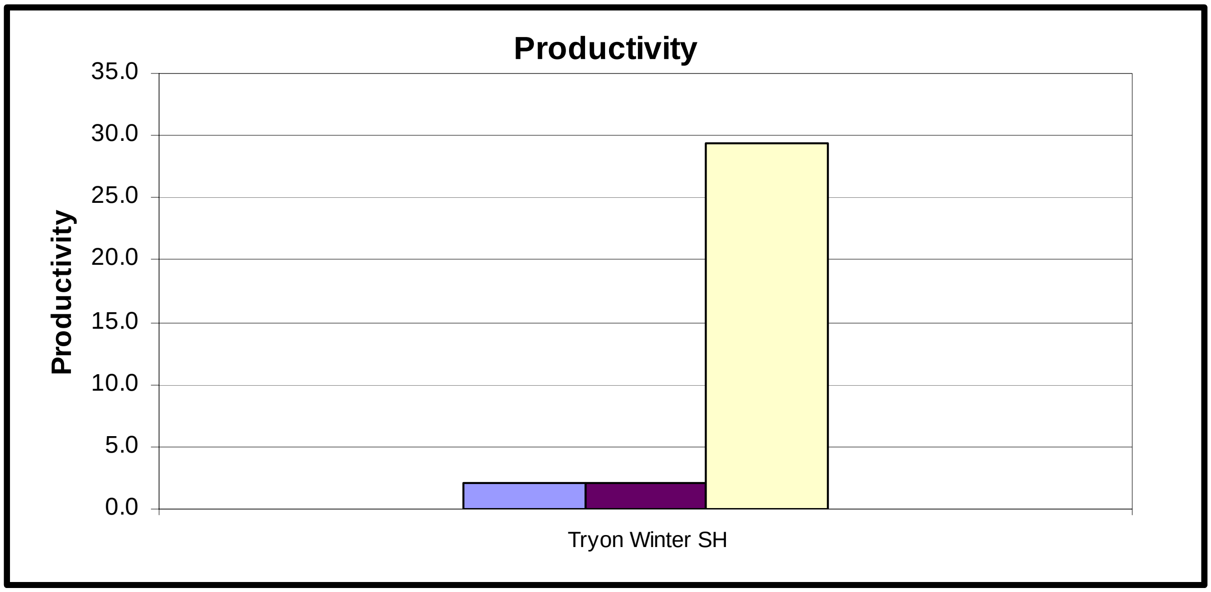


Figure 3-102: Estimated Fish Productivity Potential as a Function Of Habitat in the Current and Reference Conditions for Tryon Creek Subbasin Winter Steelhead Population

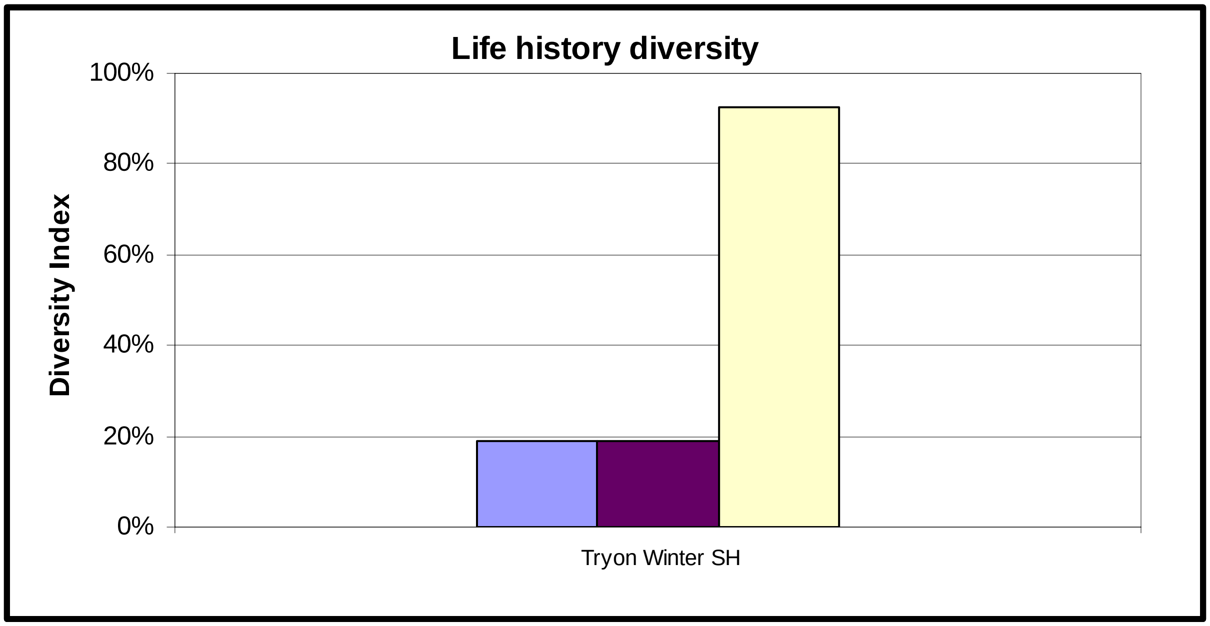


Figure 3-103. Estimated Species Diversity Potential as a Function of Habitat in the Current and Reference Conditions for Tryon Creek Subbasin Winter Steelhead Population

Coho abundance is extremely low in Tryon Creek Subbasin, estimated at only 1.5 percent of reference (or historical) numbers (Figure 3-104). In addition, coho productivity is only at about 3.5 percent of its reference potential (Figure 3-105); however, life history diversity is estimated at about 20 percent the reference potential (Figure 3-106).

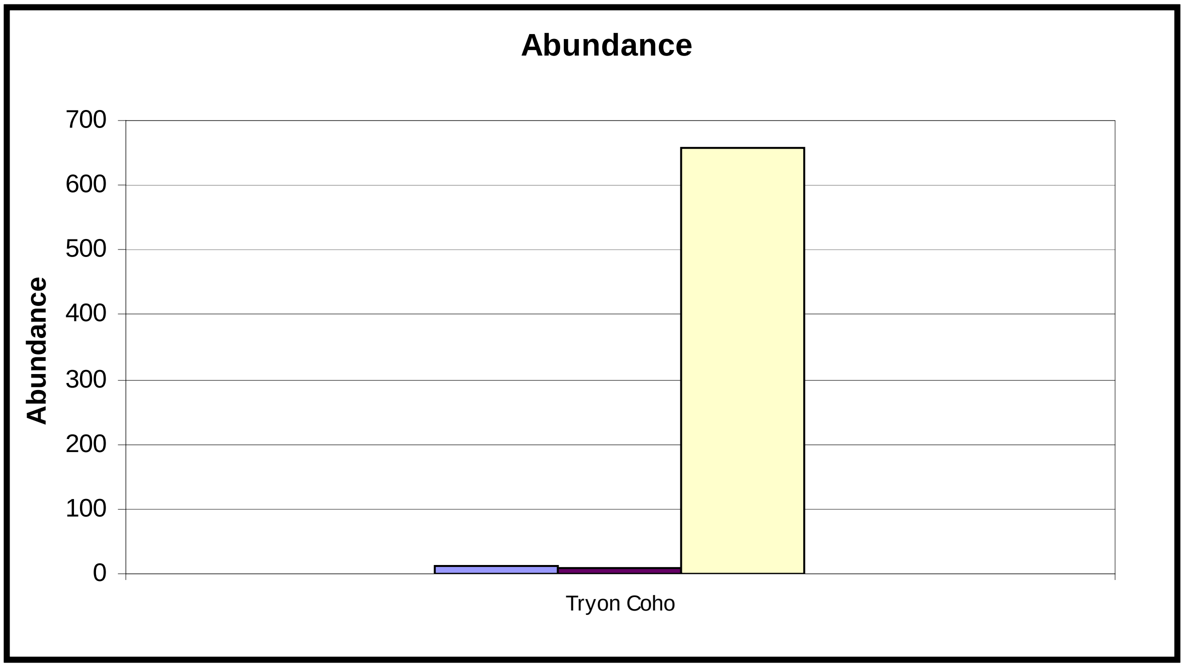


Figure 3-104: Estimated Fish Abundance Potential as a Function of Habitat in the Current and Reference Conditions for Tryon Creek Subbasin Coho Population

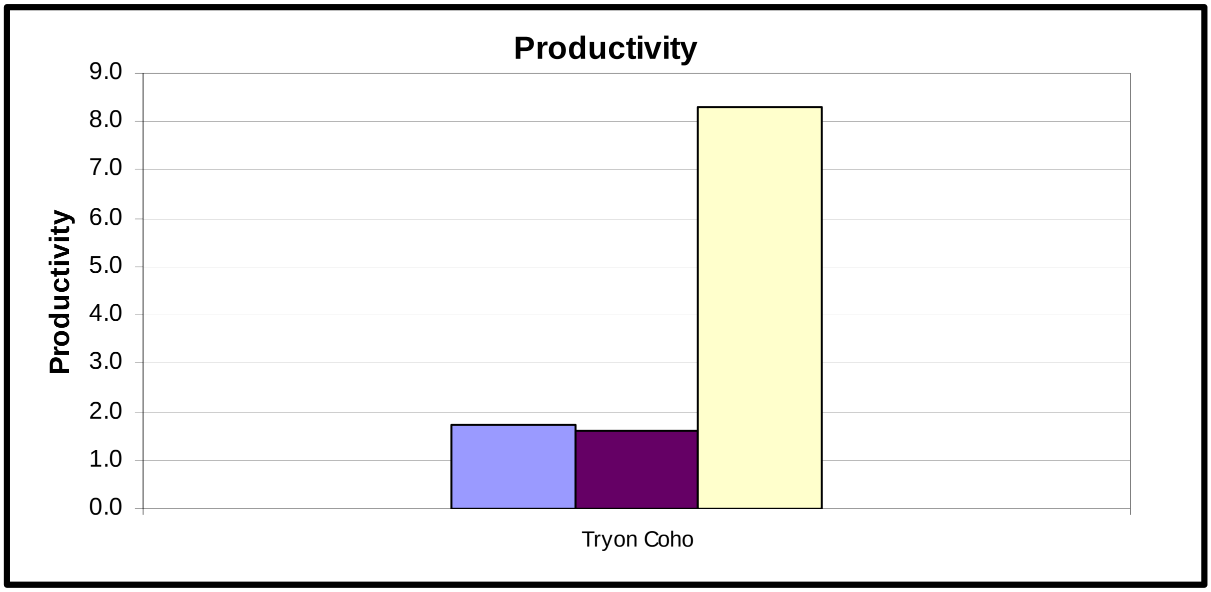


Figure 3-105: Estimated Fish Productivity Potential as a Function of Habitat in the Current and Reference Conditions for Tryon Creek Subbasin Coho Population

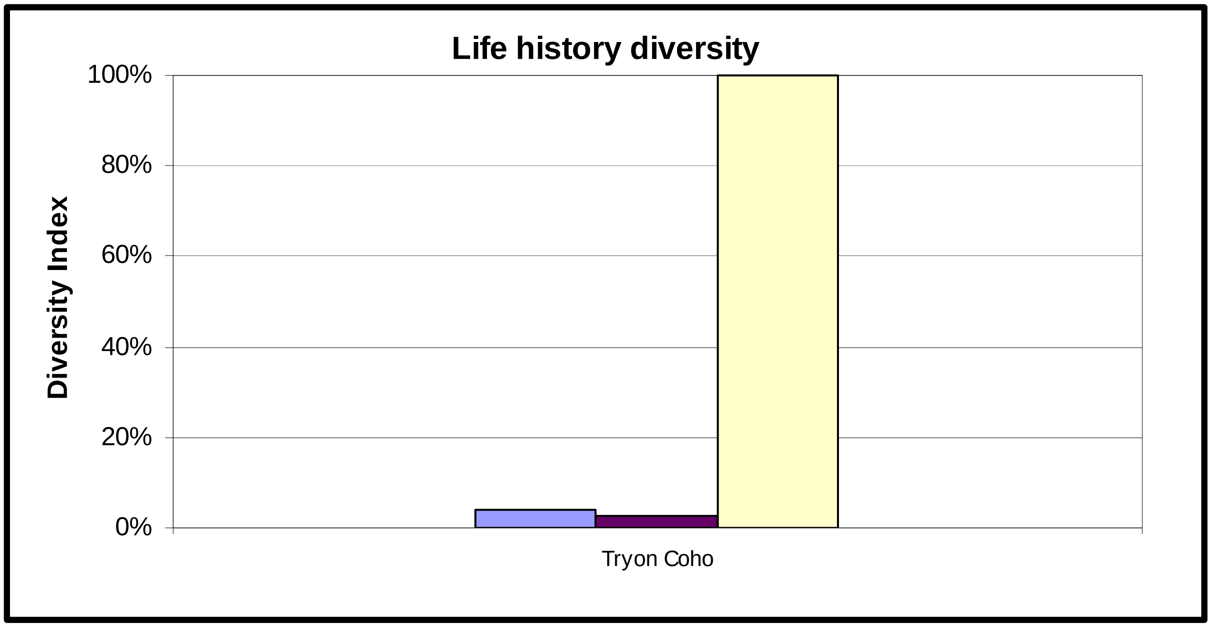
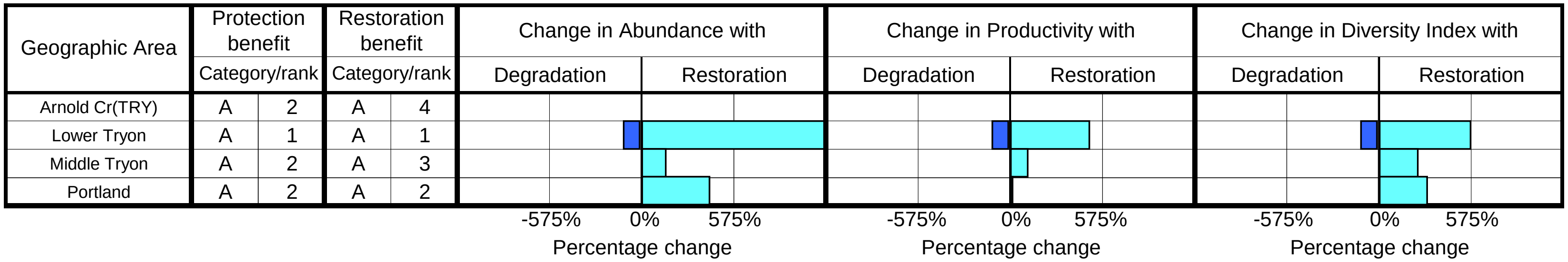


Figure 3-106: Estimated Species Diversity Potential as a Function of Habitat in the Current and Reference Conditions for Tryon Creek Subbasin Coho Population

Geographic Area Habitat Priorities for Protection and Restoration. The results of the EDT reach analysis were aggregated to provide an estimate of the changes in the Tryon Creek coho and winter steelhead population abundance, productivity, and diversity for each geographic area. The changes in the Tryon coho and winter steelhead populations' attributes provide an estimate of the relative importance of the geographic areas for habitat protection and restoration measures. The geographic areas priorities are based on (1) an estimate in the changes in population abundance, productivity, and diversity at each life stage under conditions of habitat degradation from the current state (protection benefit) and habitat restoration to the historical potential (restoration benefit) and (2) the extent to which the geographic area is used by each of the life stages. Figure 3-107 shows the relative restoration value for each geographic area, or the relative benefit that could be realized if the geographic area was restored to reference conditions. Table 3-186 also illustrates the changes in coho population attributes for the geographic areas within Tryon Creek Subbasin and the lower Willamette River.

Table 3-186: Estimated Restoration Value of Each of Geographic Area for Tryon Creek Coho

Geographic Area	Restoration Rank	Percent Change in Coho Parameters with Restoration		
		Abundance	Productivity	Diversity
Lower Tryon	1	1,150 percent	495 percent	576 percent
Middle Tryon	3	149 percent	106 percent	241 percent
Arnold Cr	4	0 percent	0 percent	0 percent
Lower Willamette River	2	425 percent	11 percent	300 percent



Geographic Area	Protection benefit		Restoration benefit	
	Category/rank		Category/rank	
Arnold Cr(TRY)	A	2	A	4
Lower Tryon	A	1	A	1
Middle Tryon	A	2	A	3
Portland	A	2	A	2

Figure 3-107: Relative Importance of the EDT Analysis Geographic Areas for Protection and Restoration Measures for the Tryon Creek Coho Salmon

Based on this analysis, lower Tryon Creek provides the greatest opportunities for protection and restoration value to coho salmon. This reach is well protected within Tryon Creek State Natural Area and provides the greatest tract of productive habitat within the subbasin. lower Willamette River provides the second greatest benefit for protection and restoration, followed by middle Tryon Creek and Arnold Creek. The lower protection and restoration values to coho salmon in middle Tryon and Arnold Creek primarily reflect low historical (and present) use of this portion of the subbasin for coho spawning and rearing.

Similar results for Tryon winter steelhead are depicted in Table 3-187 and Figure 3-108. As with coho salmon, lower Tryon provides the greatest protection and restoration benefit to steelhead. However, unlike coho, middle Tryon has significant protection value (rank 2) to steelhead; winter steelhead likely migrated, spawned and reared at least up to Marshal Cascade, whereas coho did not. The lower Willamette likewise shows important restoration value, likely associated with temporary refugia during adult and juvenile migrations.

Historically, it likely favored steelhead production, whereas middle Tryon Creek likely favored coho production.

Table 3-187: Estimated Restoration Value Each of Geographic Area for Tryon Creek Steelhead

Geographic Area	Restoration Rank	Percent Change in Steelhead Parameters with Restoration		
		Abundance	Productivity	Diversity
Lower Tryon	1	890 percent	658 percent	63 percent
Middle Tryon	2	585 percent	266 percent	76 percent
Arnold Cr	4	0 percent	0 percent	0 percent
Lower Willamette River	3	22 percent	10 percent	2 percent

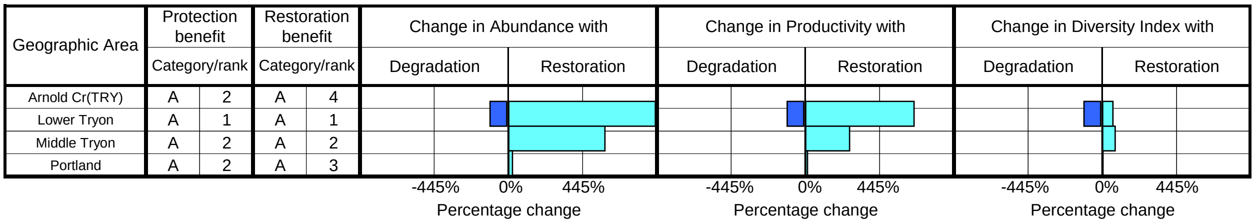


Figure 3-108: Relative Importance of the EDT Analysis Geographic Areas for Protection and Restoration Measures for the Tryon Creek Steelhead

Relative to coho and steelhead production in Tryon Creek, historically, middle Tryon would have favored steelhead production, whereas lower Tryon would have favored coho production.

Assessment of Habitat Constraints on Population Potential. The EDT analysis of habitat, water quality, fish passage and other attributes influencing Tryon Creek coho and steelhead provides a description of the factors limiting the population and the relative importance of each geographic area. This information is useful for developing habitat restoration strategies. Figure 3-109 and Figure 3-110 provides an overview of habitat attributes evaluated in EDT and the relative influence on coho and steelhead productivity in each geographic area. This analysis will ultimately inform habitat restoration and protection strategies.

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Arnold Cr(TRY)	◯	◯	•		•		●	•	⬤		⬤				●			•
Lower Tryon	◯	◯	•		•		•	•	●		⬤				⬤			●
Middle Tryon	◯	◯	•	•	•		●	•	⬤		⬤				●			●
Portland	◯	◯		●	●	•	•	•	⬤	•			●	•		•		⬤

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ ⬤	High	○ ●	Medium	◦ •	Low		Indirect or General

Figure 3-109: EDT analysis of aquatic and riparian protection and restoration priorities by attribute class for the Tryon Creek coho salmon.

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability/landsc.1/	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
Arnold Cr(TRY)	◯	◯			•		●	•	●		⬤				●			•
Lower Tryon	◯	◯			•		•	•	•		⬤				⬤			●
Middle Tryon	◯	◯		•	•		●	•	●		⬤				⬤			●
Portland	◯	◯		●					●	•			•	•				●

1/ "Channel stability" applies to freshwater areas; "channel landscape" applies to estuarine areas.

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ ⬤	High	○ ●	Medium	◦ •	Low		Indirect or General

Figure 3-110: EDT Analysis of Aquatic and Riparian Protection and Restoration Priorities by Attribute Class for the Tryon Creek Steelhead Population

Several habitat attributes evaluated using EDT most significantly affect Tryon Creek salmonid production. Fish passage obstructions (notably at HWY 43) most prominently affects both anadromous species. For coho, low habitat diversity, such as channel confinement, impaired riparian function, and lack of wood in the channel prominently affect potential coho productivity at every life stage. Lack of habitat diversity is prevalent throughout Tryon Creek Subbasin and the lower Willamette River and significantly affects coho productivity during early life history rearing. Lack of key habitats, such as off-channel rearing areas and slack water habitats are also lacking and could prominently affect potential coho production in lower and middle Tryon Creek, and the lower Willamette River.

Sediment loads in Tryon Creek most prominently affect steelhead production. This is associated with its adverse impact on spawning gravels, egg incubation environment, and summer rearing habitat. In addition, lack of key habitats prominently affects steelhead productivity in Tryon Creek and the lower Willamette River. In Tryon Creek these habitats are likely associated with lack of high quality spawning and rearing grounds, which are influenced by the amount of fine sediment loading overlaying these habitats, as well as the available amount of these habitats.

Fish Passage Obstructions. Obstruction to fish passage (at HWY 43) have the greatest impact on the distribution and productivity of both species in the Subbasin. This culvert severely limits anadromous fish from accessing spawning and rearing habitat in the subbasin. The culvert is a concrete box culvert, which has been retrofitted with baffles to improve passage for anadromous adults, yet it remains a partial barrier, particularly for fall spawning coho salmon. During this time flows are not high enough to allow access into the culvert (e.g., the jump height into the culvert remains too high) and passage through the long, baffled culvert is very inhospitable. Winter steelhead return to spawn in late winter – early spring when flows are higher, providing more advantageous opportunities for passage, however, passage likely remains impaired.

Although this culvert is most significant because of its proximity to the confluence and its impassability, other fish passage barriers exist and are a major factor limiting biological potential in the subbasin (Figure 3-111). For example, the culvert at Boones Ferry Rd. is impassable, precluding access to all of Arnold Creek and middle and upper Tryon Creek.

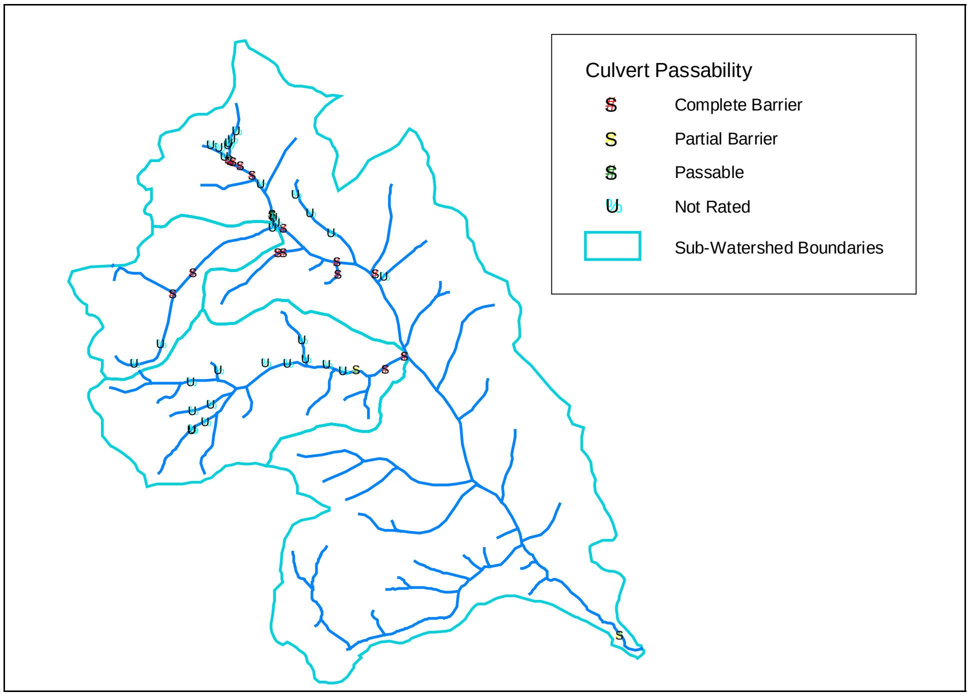


Figure 3-111: Culverts and Their Passability in Tryon Creek

Marshall Cascade and Arnold Cascades are the only documented natural barriers. Other natural (and man-made) channel forms (steps) may seasonally impede fish movement, but are not known to block fish passage year-round.

Habitat Complexity. Instream habitat conditions range from marginal to optimal (optimal only in a few areas), with most of the marginal habitat within the more heavily urbanized upper watershed. Highest quality instream and upland habitats are located within Tryon Creek State Natural Area (lower Tryon). Stream complexity and habitat quality have been greatly reduced by significant channelization, downcutting, lack of wood, lack of floodplain connectivity, underground piping of tributaries and bank erosion, particularly in the upper watershed.

One of the most significant factors determining habitat complexity is the abundance and composition of large wood. The National Riparian Services Team (NRST) (WMSWCD, 2003b) characterizes Tryon Creek as a wood dependent system, meaning that it developed in conjunction with a large conifer forest stand. The wood provided by larger conifer tree boles historically trapped sediment and formed floodplains, retaining flood flows and promoting rich, diverse riparian vegetation. They likewise concluded that “large wood material is the most important attribute in this stream type and the processes associated with it are the most important to the function of the watershed”. Large woody material is lacking basin-wide (ODFW 2001), (WMSWCD, 2003a), (WMSWCD, 2003b) (WMSWCD 2003d). Wood abundance is low upstream of Boones Ferry Rd., wood volume is low basin wide and key pieces are rare (ODFW 2001). In addition, most tributaries of Tryon Creek (excluding Iron Mt. Creek) lack enough wood to effectively store sediments and retain water. The NRST (WMSWCD 2003b) noted that upland and riparian vegetation is generally less than 60-years old and too young to contribute significant amounts of large woody material that is needed to rebuild floodplain and channel structure. Notably, wood pieces are indicative of riparian vegetation age and species; and the presence of smaller to mid-sized single pieces indicates that wood is falling into the creek, but it has not yet amassed enough to provide critical habitat function in the form of debris jams or clusters.

Past logging and tree removal during urban development, prolonged and acute peak flows and inadvertent (or planned) maintenance removal of large wood has resulted in low large wood abundance and volume basin-wide (Figure 3-112). Additionally, the combination of high flows, incised channels and lack of in-channel complexity, limits the amount of wood that is presently retained in-channel. The loss of accumulated large wood has resulted in channel erosion that has further converted the stream from one that often accessed its' floodplain, to one that cannot.

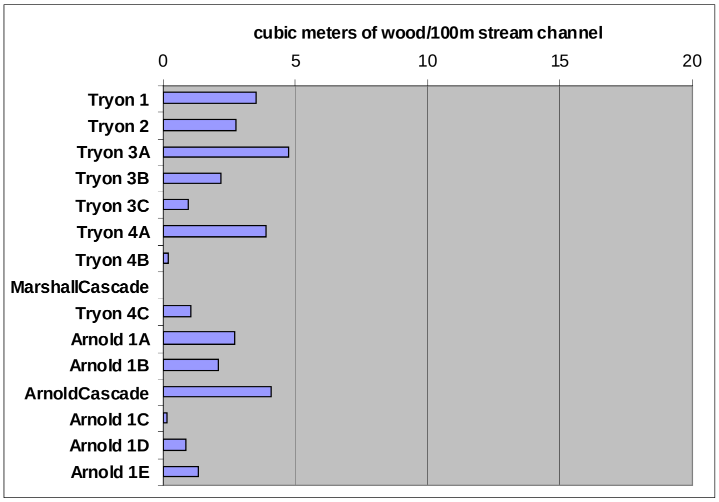


Figure 3-112: Volume of Wood per 100 Meters of Channel Length

Source: ODFW, 2001.

The lack of large wood combined with the prevalence of higher, flashy storm flows significantly affects habitat formations and maintenance of good quality spawning and rearing fish habitat in Tryon Creek. In addition to its role in helping stabilize and protect streamside habitats, buried, large wood complexes provide important overwintering habitat and high flow refugia to coho and steelhead. Without this protective cover fish can be swept downstream during high storm flows.

Loss of transient and embedded wood in the channel and in the floodplain may have had the most adverse affect on stream habitat, and riparian and floodplain connectivity, and is likely a prominent factor limiting fish productivity in the subbasin.

Other forms of instream structure and cover are lacking throughout the subbasin. Most is found in the protected areas of the Park (lower Tryon and include): beaver ponds and associated wood clusters and debris jams; and undercut banks, large cobble and boulders.

Key Habitat. Key habitat relates to the amount of deep pools, side channels, secondary channels, off-channel and backwater habitats, and high quality riffles in the watershed. In Tryon Creek, pools are relatively abundant and well dispersed through the much of the watershed. However, pool "quality"—as measured by residual pool depth and the number of complex pools—is good in within the state park, but fair or poor throughout much of the upper watershed and Arnold Creek (Figure 3-113). Pool area is best in lower Tryon, with pool area (lateral scour pools) comprising about half the wetted area. Several beaver ponds and debris jams are present in lower Tryon, and comprise about 25 percent of the total pool area. Upstream of Boones Ferry Rd. (middle Tryon), the amount of pool habitat (as measured by surface area) declines.

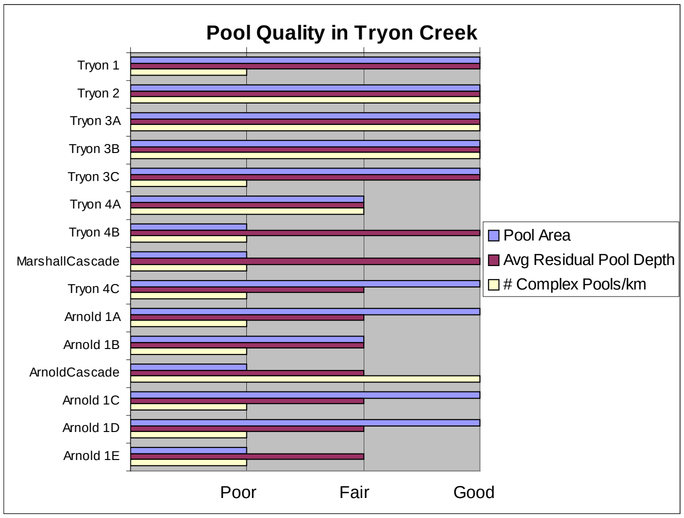


Figure 3-113: Amount and Quality of Pool Habitat Throughout Tryon Creek

Good, fair, and poor ratings are based on ODFW habitat benchmarks.

Source: ODFW 2001.

In addition to pool area, pool quality is relatively poor. The proportion of fine sediment amassed in pools ranges from 21 percent to 31 percent (reach average) in mainstem Tryon Creek and Arnold Creek. Sediment deposition greater than 20 percent generally signifies above normal deposition. Specifically, a disproportionate amount of amassed sediments implies that sediment recruitment, deposition, and transport is out of balance. This dynamic is descriptive of pool habitats in Tryon Creek indicating that sediments are disproportionately filling scoured areas in pools and effectively minimizing their functional capacity.

The lack of deep pools, relative to the prevailing channel depth likewise indicates that pools are not providing protective cover and depth refugia, compared to other channel habitats. Most deep pools are present in lower Tryon, but is lacking in middle and upper Tryon. Notably, pools are considered marginal (>= 0.2-m) or desirable (>= 0.5-m) in most mainstem reaches. More than half the pool area in the Park is at least 0.5-m deep, which is considered optimal for fish bearing streams. However, the average channel depth is quite deep for a stream of this size, yielding relatively shallow pools compared to the average channel depth within the reach; pools are rarely more than 25 percent deeper than the average channel depth. Notably, this channel structure is symptomatic of a stream that has deepened and is channelized—it does not functionally provide adequate cover and refugia, particularly during storm flows and throughout prolonged high flow periods. As with deep pools, complex pools are lacking throughout the basin; only a few were noted in middle Tryon.

Off-channel habitats are not common in Tryon subbasin (Figure 3-114). That which is present is associated with tributary junctions, backwater pools, side channels, and secondary channels. Notably, the lower confluence area of Tryon Creek functions as off-channel habitat to the Willamette River and is used year round by Willamette Basin salmonids.

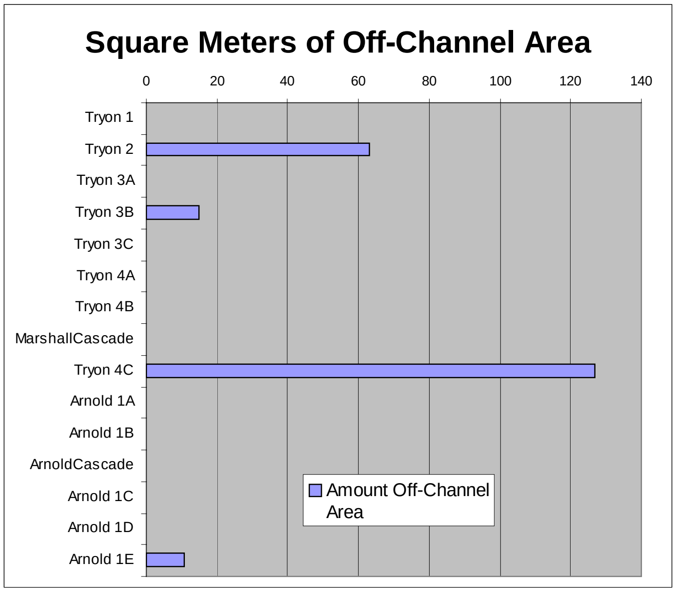


Figure 3-114: Amount of Off-Channel Habitat Through Tryon Creek

Source: ODFW, 2001.

Riffles comprise 17 percent to 29 percent of the wetted habitat in mainstem Tryon Creek, which is generally low for fish bearing streams. However, riffle quality (substrate composition and proportion of fine sediments) is moderately good. Nearly all reaches have at least half the riffle substratum comprised with 35 percent or more gravel, which is generally considered optimal for fish bearing habitat (Figure 3-115). However, the quality of this riffle habitat, as determined by the proportion of substrate covered or embedded with fine sediments and organics, is marginally high basinwide, as described in the *Fine Sediment* section below. Because riffle quantity is relatively low and because riffle quality may be compromised (due to high sediment loading), spawning and rearing grounds may be a limiting factor affecting population abundance and species diversity.

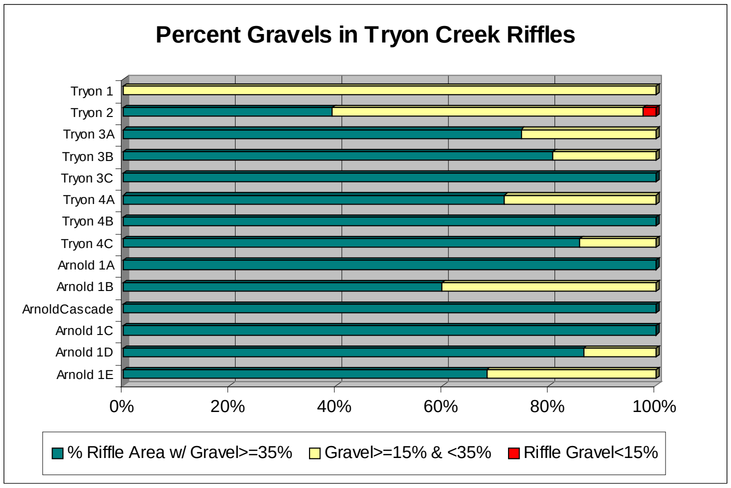


Figure 3-115: Percent of Gravels in Tryon Creek Riffles

Source: ODFW, 2001.

Riparian and Floodplain Forests. Approximately 72 percent of the Tryon Creek watershed is vegetated, 26 percent of the stream length has riparian vegetation greater than 250 feet in width, although most is located within middle Tryon; and 19 percent of the watershed has a vegetated riparian corridor between 100-250 feet.

Riparian condition is relatively good throughout middle Tryon. Here, riparian widths average 200’ or more, tree canopy cover is high, and well-established second growth forest dominates the landscape, averaging 15-30-cm dbh. In lower Tryon the riparian corridor is narrow, grasses and vines predominate and tree canopy cover is relatively low. In the Park riparian conditions improve. Notably, the forest has converted from a mixed conifer-deciduous forest to deciduous trees and shrubs. Red alder and big leaf maple predominate in streamside areas and large native conifers (western red cedar, Douglas-fir, and grand fir) are rare. Common understory species include vine maple, western wahoo, and salmonberry, with some streamside areas lined with blackberries.

Large conifers are most prevalent in lower Tryon, downstream from Iron Mt. Creek. This confluence region was noted by the National Riparian Services Team (WMSWCD, 2003b) to have the most developed (and functioning) floodplain than any other area of Tryon Creek. They partly attributed this to larger, more mature trees.

The forest stand structure (size, age and condition) within the protected areas in lower Tryon does not presently provide substantive sources of wood into the creek. Past logging and tree removal has reduced the supply of large wood into the channel (WMSWCD, 2003a), however, the potential for long-term sources is great. An older aged forest encompasses the lower canyon reach, while a younger forest stand encompasses the middle and upper Park reaches. This undoubtedly affects the ability of the stream to interact with its riparian and floodplain area.

With the exception of HWY 43 and Boones Ferry Rd, and recreational trails (and bridges), the riparian corridor is continuous through lower Tryon. As residential land-use becomes more common (in middle and upper Tryon), riparian integrity declines; corridors are fragmented (street crossings) and narrow, residential dwellings encroach onto the stream bank, vegetative cover diminishes and the proportion of impervious area increases.

Lower Arnold Creek, like lower Tryon, exhibits high riparian integrity, with riparian widths greater than 100'. Riparian condition declines upstream as the creek corridor leaves protected areas of the Park and enters upland residential development. Falling Creek exhibits poor riparian integrity; much of the stream corridor is surrounded by residential development.

Fine Sediment. The proportion of substrate and gravels covered or embedded with fine sediments and organics is marginally high basinwide (Figure 3-116). Fine sediments were least abundant in lower Tryon, with 15 percent and 21 percent riffle habitats having less than 12 percent fines and 65 percent and 55 percent having less than 25 percent fines, considered desirable and marginal habitat condition for fish bearing streams.

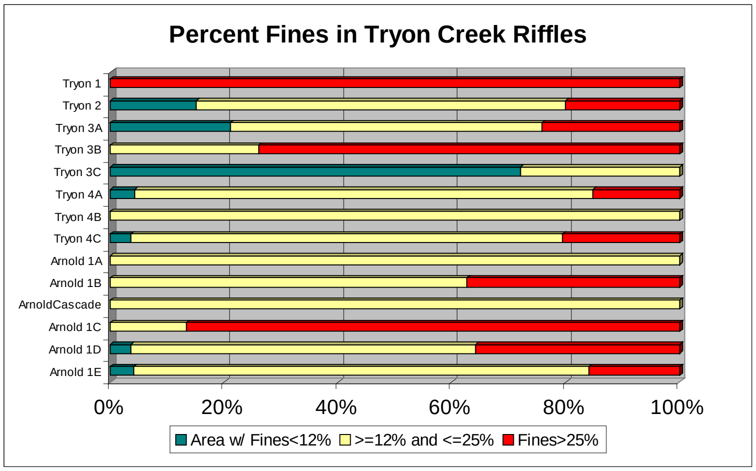


Figure 3-116: Percentage of Riffle Area in Johnson Creek Where Fines Exceed 12 Percent

Source: ODFW, 2001.

The proportion of fine sediments covering riffles was least desirable in the Willamette River confluence region (100 percent riffles with more than 25 percent fines). Remaining reaches exhibited marginal riffle quality based on the proportion of fine sediment covering stream bottom substrates: 12 percent-25 percent fines. Although riffle habitat in most reaches did not have significant (undesirable with > 25 percent) proportions of fine sediments, the majority of riffle habitat is considered sub optimal quality with >12 percent fine sediment overlaying riffle gravel substrates.

Tryon Creek drains a watershed that is characterized by a natural abundance of fine silt. Land use practices have likely exacerbated the natural condition of the stream to transport high levels of fine sediment. In addition, fine sediment originating from the steeper, more urbanized upper watershed settles out in the lower gradient reaches (in the Park). Stormwater run-off sediment loading, along with fine silts that slough into the creek during erosive flows has resulted in a constant layer of fine silt and sediment overlaying stream bottom substrates. These high silt loads overlaying spawning and rearing grounds may significantly impair the carrying capacity of Tryon Creek.

In addition to these above environmental attributes, changes to the hydrologic regime in Tryon Creek have significantly affected stream building process, habitat quantity, and habitat quality in the channel, and broader riparian and floodplain area. In addition, stream temperature and potential chemical contamination may significantly limit potential steelhead and coho productivity in the subbasin. These attributes were further discussed below.

Stream Temperature. Temperatures in Tryon Creek exceed state standards through the summer Figure 3-117). As seen in Figure 3-117, the monitoring results are consistent with the 303(d) listing and show the 7-day average of the daily maximum temperatures frequently exceeding the water quality standard of 17.8 C during the summer period. Maximum summer period daily temperatures ranged from 20.0 to 21.9 C and the 7-day average temperatures exceeded the standard from 27 to 42 days each summer. Also shown in Figure 3-117, is the temperature standard of 12.5 C for the protection of salmonid spawning, incubation and fry emergence. The applicable time periods for cutthroat trout, coho salmon and winter steelhead are shown at the bottom of the figure. Although the 303-(d) listing for temperature was not based on the 12.5 C criteria, the monitoring results show that the standard is exceeded during the months of May and June. This time period corresponds to spawning, incubation and fry emergence times for winter steelhead and cutthroat trout.

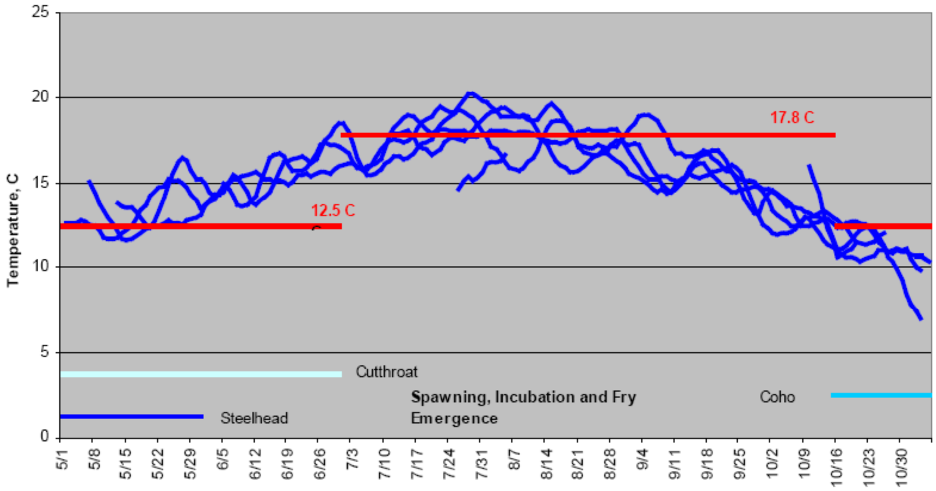
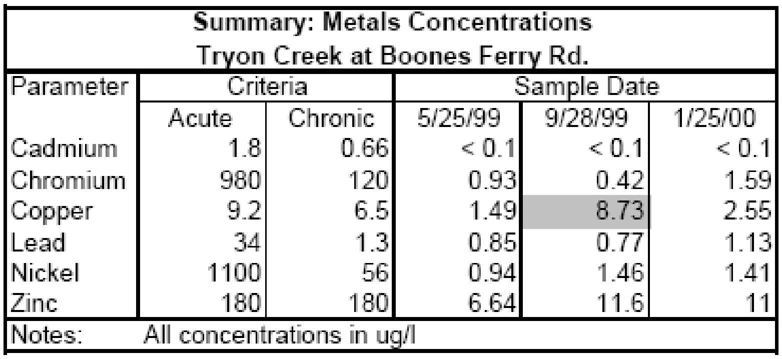


Figure 3-117: Seven-Day Average Daily Maximum Temperatures in Tryon Creek 1998-2000

Source: Portland Bureau of Environmental Services Continuous Temperature Gauges

Chemical Contamination. There is very limited water quality data available on toxics in Tryon Creek or its tributaries. Currently, no data is available on organic contaminants (pesticides, herbicides, etc.) for Tryon Creek. Available toxics data is limited to 6 metals that were sampled for three times in 1999 and early 2000 at the Boones Ferry site. The results of this monitoring are summarized in Table 3-188. Also shown are the chronic and acute water quality criteria for the protection of aquatic life for the respective metals. As shown, all samples met both the acute and chronic water quality criteria with the exception of a single sample, which exceeded the chronic criteria for copper.

Table 3-188: Metals Concentrations in Tryon Creek in 1999-20000



Summary: Metals Concentrations
Tryon Creek at Boones Ferry Rd.

Parameter	Criteria		Sample Date		
	Acute	Chronic	5/25/99	9/28/99	1/25/00
Cadmium	1.8	0.66	< 0.1	< 0.1	< 0.1
Chromium	980	120	0.93	0.42	1.59
Copper	9.2	6.5	1.49	8.73	2.55
Lead	34	1.3	0.85	0.77	1.13
Nickel	1100	56	0.94	1.46	1.41
Zinc	180	180	6.64	11.6	11
Notes:	All concentrations in ug/l				

Source: Portland Bureau of Environmental Services Monitoring.

Habitat Priorities by Geographic Area. The following sections describe key habitat attributes limiting potential coho and steelhead productivity in each geographic area. This assessment evaluates species productivity by life stage and associated habitat needs during development (or use).

Lower Willamette River

Coho Protection benefit rank:	2	Steelhead Protection benefit rank	3
Coho Restoration benefit rank:	2	Steelhead Restoration benefit rank:	3

Coho were most affected by lack of habitat diversity and lack of key habitats in the lower Willamette River. The persistence of chemical contaminants year-round and warm temperatures in the summer likewise impair potential coho productivity in the lower Willamette.

Most vulnerable life stages and life history strategies affected include juvenile winter rearing, spring and summer rearing and smolt emigration. Of these life stages 0+ winter rearing is most vulnerable, followed by smolt emigration and spring and summer active rearing.

Juvenile Rearing (Winter). Lack of shallow, low velocity, shoreline habitats (key habitats) and lack of complex shoreline structure and cover such as overhanging vegetation, large wood and large substratum (habitat diversity) most prominently affect overwintering rearing and refuge habitat in the lower Willamette River. Lack of these critical overwintering habitats pose the greatest risk to successful coho production. The presence of chemicals, particularly associated with shoreline and alcove areas likewise pose a great risk to coho throughout the winter.

Active Rearing. As for juvenile overwintering, coho rely on shallow, slack water habitats with complex shoreline structure and protective cover during the spring to rear and feed. These off-channel, shoreline, and alcove habitats provide areas where coho can feed and grow as they physiologically mature and smolt. Without these habitats, juvenile coho may move into the lower Columbia River at a smaller size, before they are physiologically ready to rear in saltwater environs. As result juveniles may be more vulnerable to predators, and may be at a disadvantage for surviving in the ocean.

Smolt Emigration. During emigration, coho smolts are most prominently affected by chemical contaminants and lack of key habitats. Although off-channel or marginal shoreline habitats remain important, once juvenile coho begin emigrating, moving out of the overwintering habitats and actively moving through the lower mainstem channel, they become less reliant on key habitat areas, thus becoming more sensitive to other environmental conditions that affect there ability to move downstream. In the lower Willamette, chemical contamination poses a great risk to coho as they emigrate seaward to the lower Columbia estuary.

Steelhead were most affected by chemicals and lack of key habitats in the lower Willamette River. Most vulnerable life stages and life history strategies affected include smolt emigration and prespawning adult migrations.

Smolt Emigration. Steelhead migrants are most prominently affected by chemical contaminants and lack of key habitats to temporarily rear and reside. As for coho, alcoves, tributary confluences and off-channel areas are important to juvenile steelhead as they head seaward into the lower Columbia River. These areas are most prominently used for temporary refuge during storm flows and for temporary rearing. In addition to these areas, chemical contamination in the lower Willamette River prominently affects Johnson Creek steelhead productivity. As steelhead become less reliant on key habitat areas, they become more sensitive to environmental conditions that affect their ability to move downstream. In the lower Willamette, chemical contamination poses a critical risk to steelhead as they emigrate seaward from March through June.

Prespawning Adult. Adult steelhead enter the lower Willamette River from late fall through spring and are most prominently affected by lack of key holding areas, such as deeper pools, and chemical contamination.

Lower Tryon Creek

Coho Protection benefit rank:	1	Steelhead Protection benefit rank	1
Coho Restoration benefit rank:	1	Steelhead Restoration benefit rank:	1

The confluence area of lower Tryon Creek functions as off-channel rearing and refuge habitat to lower Willamette and upper Willamette Basin coho, Chinook and steelhead year-round. The habitat value that these types of environs provide are critically important during early and juvenile life history rearing by Willamette basin salmonids; and key habitat priorities to enhance functional value provided by these areas are described in the lower Willamette River piece.

Coho were most affected by lack of habitat diversity, poor channel stability, lack of food, high peak flows in the winter and low flows in the summer and sediment loading. The combination of minimal off-channel habitat and high flows likely pose the greatest risk to successful coho production. Slack water habitats are most important during winter rearing and are likewise critically important as high flow refugia during peak and prolonged winter flows.

Most vulnerable life stages and life history strategies (e.g., habitat preferences) in middle Tryon Creek include egg incubation, fry colonization, and juvenile rearing (winter and summer). As stated previously, habitat evaluations in Tryon Creek presume that adults can pass HWY 43—adult holding and spawning were not considered limiting factors to coho production

Egg Incubation and Fry Colonization. Poor channel stability and high sediment loads most prominently affect egg incubation. Chemical contamination and lack of key habitat, such as stable riffle beds, likewise affect egg-to-fry survival. Winter flows and its affect on bed scour may be a potential concern in the reach immediately below Boones Ferry Rd.

Fry colonization is most prominently influenced by lack of habitat diversity, high spring flows and associated channel instability. Lack of aquatic insects for feeding, and poor water quality (chemical contamination and temperature) likewise adversely affect fry to juvenile survival.

Juvenile Rearing (Summer and Winter). Lack of deep pools (habitat diversity), lack of aquatic insects (for source food) and low summer flows (and stream temperature) most prominently affect juvenile production through the summer. In addition, chemical contamination remains a concern through the summer; and competition with other species could be a concern.

Lack of off-channel, and slack water habitats is the primary limiting factor for coho during winter rearing. Other significant influences on overwintering survival include channel stability and food. Peak flows and associated water quality (chemical contamination and high sediment loads) are likewise considered important attributes affecting juvenile survival (and rearing) through the winter.

Steelhead were affected most by flow, sediment and lack of habitat diversity. Low summer flows, and high winter flows combined with few off-channel areas, deep pools, and instream structure are likely prominent factors. In addition, high sedimentation in the winter and summer can smother eggs and inhibit macroinvertebrate production. Channel stability and chemical contamination are likewise key attributes affecting potential steelhead production.

Most vulnerable life stages and life history strategies (e.g., habitat preferences) in middle Tryon Creek include egg incubation and juvenile rearing (winter and summer).

Egg Incubation. High sediment loading during from late winter through early spring most prominently affect egg incubation. Chemical contamination and channel instability, such as unstable riffle beds, likewise affect egg-to-fry survival.

Juvenile Rearing (Summer and Winter). Low summer flow is the primary limiting factor affecting age 0+ and age 1+ productivity. Elevated stream temperature also affects summer rearing, particularly in the middle and upper portion of middle Tryon Creek, where stream gradient steepens. Lack of deep pools with logs and woody debris, and exposed riffle beds (habitat diversity) along with associated low aquatic insect production significantly affect steelhead productivity.

Lack of deep pools and large wood (habitat diversity), high flow refugia in the form of side-channels, terraced banks, and off-channel habitats (habitat diversity), high sediment loads, high peak winter flows, and channel instability impair steelhead productivity.

Middle Tryon Creek

Coho Protection benefit rank:	3	Steelhead Protection benefit rank	2
Coho Restoration benefit rank:	3	Steelhead Restoration benefit rank:	2

Coho were most affected by lack of habitat diversity, poor channel stability, lack of food, high peak flows in the winter and low flows in the summer and sediment loading. The absence of off-channel habitat, combined with high stream velocity would significantly limit coho production in this reach. Slack water habitats are most important during winter rearing and are likewise critically important as high flow refugia during peak and prolonged winter flows.

Note, historically upper Tryon Creek likely did not provide high quality coho rearing habitat. This reach is moderately steep and bound by steeper valley walls. Areas of low gradient, slack water likely existed, however, much of the coho production likely occurred in lower Tryon Creek.

Most vulnerable life stages and life history strategies (e.g., habitat preferences) in upper Tryon Creek include egg incubation and juvenile rearing (winter and summer).

Egg Incubation. Poor channel stability and high sediment loads most prominently affect egg incubation. Chemical contamination and lack of key habitat, such as stable riffle beds, likewise affect egg-to-fry survival.

Juvenile Rearing (Summer and Winter). Lack of deep pools and protective cover (habitat diversity), lack of aquatic insects (for source food) and low summer flows (and stream temperature) most prominently affect juvenile production through the summer. In addition, channel instability and chemical contamination remains a concern through the summer.

Lack of off-channel, and slack water habitats (key habitat) and diverse habitats (e.g., deep pools, beaver dams, and channel morphology) (habitat diversity) are the primary limiting factors for coho during winter rearing. Other significant influences on overwintering survival include channel instability and lack of food. Peak flows and associated water quality (chemical contamination and high sediment loads) are likewise considered important attributes affecting juvenile survival (and rearing) through the winter.

Steelhead were affected most by flow, sediment and lack of habitat diversity. Low summer flows, and high winter flows combined with few off-channel areas, deep pools, and instream structure are likely prominent factors. In addition, high sedimentation in the winter and summer can smother eggs and inhibit macroinvertebrate production. Channel instability and chemical contamination are likewise key attributes affecting potential steelhead production in this upper, urbanized reach.

Most vulnerable life stages and life history strategies (e.g., habitat preferences) affected in upper Tryon Creek include egg incubation and juvenile rearing (winter and summer).

Egg Incubation. High sedimentation of riffle habitat most prominently affect egg-to-fry survival (e.g., smothering and suffocation). High peak flows through the winter and spring, channel instability and chemical contamination likewise affect egg-to-fry survival.

Juvenile Rearing (Summer and Winter). Lack of deep pools (habitat diversity), lack of aquatic insects (for source food) and low summer flows (and stream temperature) most prominently affect juvenile production through the summer. In addition, chemical contamination remains a concern through the summer; and competition with other species could be a concern.

Lack of deep pools and off-channel refugia (key habitats) is the primary limiting factor for steelhead during winter rearing. Other significant influences on overwintering survival include lack of large wood to provide protective cover, channel stability and lack of food. Peak flows and associated water quality (chemical contamination and high sediment loads) are likewise considered important attributes affecting potential survival through the winter.

Basinwide. The assessment of Tryon Creek subbasin included two species and two populations: coho and steelhead. This provided the opportunity to examine the subbasin in a multi-species context by putting all of the information together to create a more holistic depiction of habitat conditions in Tryon Creek watershed. This also provides another dimension for examining restoration and protection priorities for habitat in Tryon Creek.

Figure 3-118 displays the results of the EDT spatial analysis for coho and steelhead and the two populations combined. This figure shows the effect of degrading conditions further (protection priority) and of restoring conditions (restoration priorities) in each geographic area on the equilibrium abundance of each population. Protection priorities describe how Tryon Creek currently functions, with regards to providing key fish bearing habitat. In terms of abundance, most of the current habitat potential (e.g., protection potential) is in lower Tryon Creek. Interestingly, the best restoration potential for both species is likewise realized in lower Tryon Creek. Although restoration (and protection) of middle Tryon Creek would undoubtedly improve habitat conditions in both middle and lower Tryon, this reach did not likely support substantive coho rearing. Under normative hydrologic regimes, steelhead would have likely thrived in this upper reach.

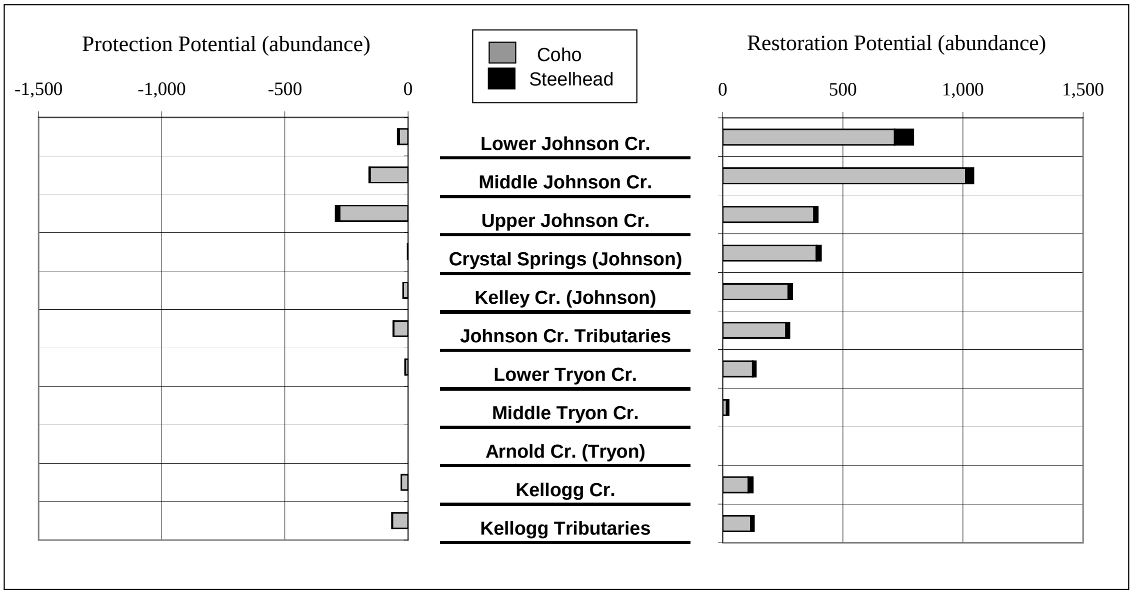


Figure 3-118: Combined Restoration and Protection Potential for Coho and Steelhead in the Lower Willamette

3.5.2 Historical Factors Leading to Decline of Terrestrial Species and Ecological Functions and Processes

Despite being Oregon’s most populated subbasin, the Willamette hosts a notable 281 wildlife species. Loss of suitable habitat has been and continues to be among the most important factors that limit wildlife populations in the subbasin. In particular, the loss of six vital habitats—upland prairie-savanna, oak woodlands, wetland prairie and seasonal marsh, ponds and their riparian zones, stream riparian zones, and old growth conifer forest—has been accompanied by the decline of many wildlife, plant, and butterfly species that use these habitat types. Other factors known or hypothesized to limit terrestrial species populations in this subbasin include roads and other barriers, vegetation change, diminished supply of dead wood, water regime change, pollution, temperature change, soil degradation, harassment, and invasive species, pathogens, and parasites. Agents and practices that contribute to these limiting factors are described in this section. Together, these limiting factors comprise habitat degradation, and often tend to fragment and simplify the internal structure of terrestrial habitats, making them less able to support viable plant and wildlife populations.

3.5.2.1 Status and Trends of Terrestrial Wildlife, Rare Plants, and Habitat in the Willamette Subbasin

Native wildlife and rare plants in the rapidly urbanizing Willamette subbasin face multiple threats. Chief among these is loss of suitable habitat. Since the mid-1800s at least 10 breeding species of wildlife and unknown numbers of plants have vanished from the region, most likely as a result of habitat loss. Currently in the Willamette Basin, four wildlife species (one of them extirpated), one butterfly, and six plants (two of them extirpated) are federally listed as threatened or endangered, and an additional 28 wildlife species and three plants are state-listed.

Quantitative trends data are available only for breeding bird species and a few non-bird species. For those nesting bird species for which breeding bird survey trends data are statistically significant, 12 native species declined and two increased in lowlands of the region during the periods 1968 to 2003 or 1980 to 2003, the longest periods for which data are available. Less definitively, trends can be surmised from known changes in the extent of different habitat types. For this, computer application of species-habitat models to current and mid-1800s land cover maps suggests that 75 percent of the subbasin's 281 native breeding wildlife species now have less extensive areas of suitable habitat than they did historically. Most native wildlife species have lost more than 12 percent of the area (and some have lost all the area) that likely provided habitat in the mid-1800s.

Except for a few listed species, no reliable predictions are available of future viability of species populations. The multi-partner Willamette "Alternative Futures" project (Baker et al., 2004; Hulse et al., 2004) inferred the future status of species by projecting and mapping future land cover under various scenarios of conservation and development. These investigators found that no plausible future scenario could completely restore wildlife to mid-1800s conditions. The project projected that 172 wildlife species (62 percent of the subbasin total) would lose habitat as a consequence of the most plausible "development" scenario for the Willamette subbasin, whereas under the most plausible "conservation" scenario only 82 wildlife species (29 percent of the total) might still lose habitat. The impacts of development or conservation on rare plants were not assessed.

Habitats important to wildlife and rare plants that have decreased the most within the Willamette Basin include oak woodland, upland prairie, savanna, wetland prairie, seasonal marsh, ponds and their riparian zones, streams/rivers and their riparian zones, and old-growth conifer forest. These are termed focal habitats in this plan. All Willamette Basin wildlife and plant species that are listed under the Endangered Species Act and all sensitive species listed by ODFW depend heavily on one or more of these focal habitats.

3.5.2.2 Factors Known or Hypothesized To Be Limiting Within the Willamette Basin

Wildlife limiting factors were identified by reference to several information sources and consultations with experts. For listed species, the published recovery plans and federal listing notices were a primary source. For Partners in Flight species, the regional conservation strategy documents were used. For other species, standard references such as Marshall et al. (2003), Verts and Carraway (1998), and NatureServe (the information base of the state natural heritage programs) were consulted first. Subsequently, scientific papers on Pacific Northwest populations of individual species were reviewed when available. Limiting factors for each of the focal *habitats* were identified partly through review of key regional documents, such as Hulse et al. (2002), Floberg et al. (2004), and Altman (1999, 2000). From knowledge of species life histories and associations with particular focal habitats, additional limiting factors for individual species were then identified. Subbasin vegetation change estimates also were used to gauge the relative importance of habitat loss as a possible limiting factor for each species. Finally, for each focal species a list of "management activities" associated with its primary habitats was generated from the IBIS database, and was scanned to check for important limiting factors that might have been overlooked by other sources.

With 281 wildlife species breeding in the Willamette Basin, each with specific needs and vulnerabilities that vary across time and space, the tools and data to determine which factors and causative agents are “generally” the most limiting are unavailable. Nonetheless, review of limiting factors for the 55 focal species included in this plan, as well as reviews completed by other biologists (for example, Floberg, 2004), suggests that the limiting factors in Tables 3-189 through 3-194 may currently be the most for the terrestrial focal species. The limiting factors themselves are described in more detail after the tables.

Table 3-189: Hypothesized Importance of the Limiting Factors to Focal Species in Oak Woodland

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water regime change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
Acorn woodpecker	1	2	1	1	--	2	--	--	--	1
Chipping sparrow	1	2	1	2	--	2	--	--	--	2
Western wood-pewee	1	2	1	2	--	2	--	--	--	2
White-breasted nuthatch	1	2	1	1	--	2	--	--	--	1
Southern alligator lizard	1	2	2	2	--	2	--	--	--	2
Sharptail snake	1	2	2	1	--	2	--	1	2	2
Western gray squirrel	1	1	2	1	--	2	--	--	--	2

1 = primary factor; 2= secondary factor, based on published opinions of other biologists, the author, or (least often, due to unavailability) field data from this region. For more explanation see Appendix D.

Table 3-190: Hypothesized or Documented Importance of the Limiting Factors to Focal Species in Upland Prairie

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water Regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
American kestrel	1	2	1	1	2	1	--	2	2	1
Horned lark	1	2	1	--	1	2	--	--	2	--
Vesper sparrow	1	2	1	--	2	2	--	2	2	--
Western meadowlark	1	2	1	--	2	2	--	2	2	--

Table 3-190: Hypothesized or Documented Importance of the Limiting Factors to Focal Species in Upland Prairie

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water Regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
Western rattlesnake	1	1	1	2	2	2	--	1	1	--
Black-tailed jackrabbit	1	1	1	--	2	2	--	2	2	2
Taylor’s checkerspot	1	1	1	--	--	1	--	2	--	1
Fender’s blue butterfly	1	1	1	--	--	1	--	2	--	1
Kincaid’s lupine	1	2	1	--	--	2	--	1	--	1
Golden paintbrush	1	2	1	--	--	2	--	1	--	1
White rock larkspur	1	2	1	--	--	2	--	1	--	1
White-topped aster	1	2	1	--	--	2	--	1	--	1

1 = primary factor; 2= secondary factor, based on published opinions of other biologists, the author, or (least often, due to unavailability) field data from this region. For more explanation see Appendix D.

Table 3-191: Hypothesized or Documented Importance and Prevalence of the Limiting Factors to Focal Species in Wetland Prairie and Seasonal Marsh

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
Dunlin	1	2	1	--	1	2	--	2	1	2
Common yellowthroat	1	2	2	--	2	2	--	2	2	2
Northern harrier	1	1	2	--	2	1	--	2	1	2
Sora	1	2	2	--	1	2	--	2	2	2
Red-legged frog	1	1	2	--	1	1	1	2	2	1
Water howellia	1	--	1	--	1	2	--	2	--	1
Bradshaw’s lomatium	1	--	1	--	1	2	--	1	--	1
Nelson’s checkermallow	1	--	1	--	1	2	--	1	--	1

Table 3-191: Hypothesized or Documented Importance and Prevalence of the Limiting Factors to Focal Species in Wetland Prairie and Seasonal Marsh

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
Willamette Valley daisy	1	--	1	--	1	2	--	1	--	1
Peacock larkspur	1	--	1	--	1	2	--	1	--	1

1 = primary factor; 2= secondary factor, based on published opinions of other biologists, the author, or (least often, due to unavailability) field data from this region. For more explanation see Appendix D.

Table 3-192: Hypothesized or Documented Importance and Prevalence of the Limiting Factors to Focal Species in Pond and Pond Riparian Habitat

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water Regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
Western pond turtle	1	1	2	1	2	1	1	1	1	2
Oregon spotted frog	1	1	2	2	1	1	1	2	--	1
Cascades frog	2	1	2	2	1	1	1	2	--	1
Purple martin	1	2	2	1	2	2	2	--	--	1
Green heron	1	2	2	2	2	2	2	--	2	--
Wood duck	1	2	2	1	2	2	2	--	2	--
Yellow warbler	1	2	2	--	--	2	2	--	2	1

1 = primary factor; 2= secondary factor, based on published opinions of other biologists, the author, or (least often, due to unavailability) field data from this region. For more explanation see Appendix D.

Table 3-193: Hypothesized or Documented Importance and Prevalence of the Limiting Factors to Focal Species in Stream and Stream Riparian Habitat

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water Regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
American dipper	--	--	--	2	1	2	--	--	--	--
Bald eagle	2	2	2	--	2	1	--	--	1	--
Harlequin duck	--	--	--	--	2	2	--	--	2	--
Red-eyed vireo	1	2	--	--	--	2	--	--	--	2
Willow flycatcher	1	2	1	--	2	2	--	--	--	2
Coastal tailed frog	2	--	--	2	--	1	1	--	--	2
American beaver	2	--	--	--	--	--	--	--	2	--
River otter	2	2	--	2	--	1	--	--	2	--

1 = primary factor; 2= secondary factor, based on published opinions of other biologists, the author, or (least often, due to unavailability) field data from this region. For more explanation see Appendix D.

Table 3-194: Hypothesized or Documented Importance and Prevalence of the Limiting Factors to Focal Species in Old-Growth Conifer Forest

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water Regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
Pileated woodpecker	1	--	--	1	--	--	--	--	2	--
Olive-sided flycatcher	2	--	2	2	--	2	--	--	2	--
Vaux's swift	1	--	--	1	--	2	--	--	2	--
Marbled murrelet	1	--	--	--	--	--	--	--	--	--
Spotted owl	1	2	--	1	--	--	--	--	2	2
Great gray owl	2	--	--	1	--	--	--	--	2	--
Oregon slender salamander	1	2	--	2	2	2	2	2	--	--

Table 3-194: Hypothesized or Documented Importance and Prevalence of the Limiting Factors to Focal Species in Old-Growth Conifer Forest

	Habitat Loss	Roads/Barriers	Vegetation Change	Deadwood Supply	Water Regime Change	Pollution	Warming	Soil Degradation	Harassment	Invasives Parasites Diseases
American marten	1	2	--	1	--	--	--	--	2	--
Red tree vole	1	1	--	2	--	--	--	--	--	--
Townsend's big-eared bat	2	--	--	1	--	2	--	--	2	--

1 = primary factor; 2= secondary factor, based on published opinions of other biologists, the author, or (least often, due to unavailability) field data from this region. For more explanation see Appendix D.

Habitat Loss. The factor most responsible for limiting the Willamette Basin's populations of terrestrial wildlife and rare plants is the loss of suitable habitat. Habitat loss includes changes that are long-term and that radically change habitat structure as perceived by wildlife, as follows:

- Conversion of any land cover type to impervious surface, such as pavement, buildings, or other infrastructure
- Permanent inundation of land, such as by large dams
- Permanent filling of seasonally or permanently inundated areas, such as by intentional or natural deposition of sediment, rock, or debris
- Conversion of naturally vegetated land to agricultural production
- Creation of persistently unvegetated surfaces, such as from gravel extraction
- Conversion of mature forests to very early successional land cover, such as clearcuts

Most of the Willamette Basin's historical losses of habitat are attributable to conversion of forested lands, wetlands, and prairies to agricultural and residential areas and conversion of old-growth forest to younger stands. Future habitat losses are most likely to involve conversion of the least productive forested and agricultural lands to residential areas (Hulse et al., 2004).

Habitat Degradation. Closely related to habitat loss is habitat degradation, which consists of physical and biological changes that are technically easier to reverse or mitigate than is habitat loss, or which can be reversed over shorter time periods, although there may be substantial socioeconomic constraints to doing so. Habitat degradation decreases the accessibility or suitability of food, water, and cover/substrate to wildlife populations—and therefore increases crowding, competition, predation, pathogen and parasite transmission, and ultimately mortality rates. Restoration of habitat provides only marginal net benefit to populations of terrestrial wildlife and rare plants if losses from a host of degrading factors are allowed to continue unimpeded. In the Willamette Basin, as elsewhere, degradation of habitat for native wildlife and rare plants most often involves the following:

- Roads and other barriers
- Vegetation change
- Diminished supply of dead wood
- Water regime change
- Pollution
- Temperature change
- Soil degradation
- Harassment
- Invasive species, pathogens, and parasites

Barriers. This includes all structures or terrains that kill or interfere with movement/dispersal of plants and/or wildlife. It includes roads (and vehicles), other paved surfaces, wind turbine towers, picture windows, and some types of communication towers, powerlines and transmission poles, fences, and unvegetated or very steep terrain. It includes factors that are directly lethal (collisions) as well as those that fragment otherwise suitable habitat and thus expose traveling animals to greater predation risk (for example, paved surfaces). The threat to wildlife posed by all of these structures has been well documented elsewhere, but the relative severity and extent of threat they individually pose in the Willamette Basin is unknown. Residential and industrial development is the largest source of physical barriers to wildlife movement. Roads occur throughout such development, but heavily trafficked roads pose the greatest hazard and are mostly concentrated near urban areas. Roads are probably most important as a limiting factor to amphibians and reptiles. The extent of future road construction will depend largely on the types of development that are proposed. By 2050, the total area of new roads within the subbasin's developable rural areas is anticipated to increase by 2376 acres (if development is clustered) or 5072 acres (if not clustered) (Payne, 2002).

Vegetation Change. This consists of changes in vegetative structural and species diversity, and in percent cover of live foliage and woody material. Vegetation change can be induced by fire, disease, insect damage, wind, ice storms, grazing of saplings, flood events, alteration of natural hydrologic regimes, soil compaction, and intentional removal or planting of vegetation by humans. Herbaceous (for example, prairie) vegetation is maintained by fire, other natural disturbances, soil health, high water table levels or grazing that limit woody cover establishment, and some types of human activities that reduce shading from trees and shrubs. Absence of contiguous tree canopy, especially at strategic locations, is the most prominent form of habitat fragmentation that is detrimental to some species, although evidence of fragmentation effects is much weaker in western U.S. forests than in eastern forests.

Vegetation is directly important for cover, nesting substrate, and support of food resources of wildlife. By providing shade and buffering wind, vegetation also moderates the microclimate near the ground that is important to many small mammals. Vegetation shields some species from the view of aerial predators, decreasing risks of dispersal to other habitat patches. However, there is no such thing as "generally good wildlife cover." Each species responds differently, with some prairie species avoiding all shaded areas. For such species, areas with tree canopy actually have the potential to fragment their habitat. Thus, habitat connectivity must be evaluated carefully and with regard to the particular species of interest. The absence of a woody canopy is of greatest concern in parts of the subbasin where tree canopy cover was previously the most extensive, such as along rivers and streams and in the mountains. The least amount of residual tree canopy remains in the lowlands, yet for centuries much of this area existed as open prairie, which allowed wildlife and plants adapted to open areas to colonize. Vegetation succession poses the greatest threat to wildlife and rare plants of upland prairies, oak woodlands, and wetland prairies (possibly in that order of priority). Additional information on this limiting factor is presented in Appendix D.

Diminished Supply of Dead Wood. Wildlife species are often limited by the supply and lack of diversity of standing (snag) or downed dead wood of various sizes. A few woodpecker species excavate cavities in snags, which are then used as nesting, roosting, and/or hibernation sites by dozens of other species. The presence of dense soil leaf litter (duff layer) also is important to some species, such as hibernating turtles. Soil organic matter also helps maintain soil invertebrate communities and biogeochemical processes crucial to sustaining productive habitat for rare plants and wildlife. A supply of dead wood is sustained by forest management than favors multi-aged stands at multiple spatial scales. Snag availability can increase as a result of disease, fire, flood events, wind or ice storms, water level changes, and climate change. A scarcity of dead wood is most limiting to wildlife where forest has been converted, at multiple scales, to other land cover types or to a nearly single-aged stand. Dead wood scarcities also arise where river regulation has largely eliminated sporadic tree mortality through flooding and channel migration. During much of the fall, winter, and spring, there is hardly a rural neighborhood in the region where the sight of burning “yard waste” is absent. Often this “waste” consists of downed limbs and other dead wood highly valued by wildlife and crucial to healthy forest soils. Dead wood is removed to reduce hazards to buildings from wildland fires, as well as for firewood and as part of general fuel reduction programs, forestry operations, and homeowner landscaping.

Water Regime Change. Even with implementation of aggressive water conservation programs, major water shortages are anticipated in the Willamette Basin before the year 2050 (Baker et al., 2004; Dole and Niemi, 2004). Drought and flood, low and high water, can both help and hurt wildlife and rare plant populations. And it is not only the severity of extreme events, but the frequency, duration, and variability of water on the landscape that imposes consequences. Increased water provides habitat space and feeding opportunities for amphibians and waterbirds while decreasing these elements for some other species. Surface water is essential as a drinking source for many wildlife species. Water levels alter plant cover and successional processes and the availability and type of soil invertebrates. Precipitation and runoff regimes can be altered by global climate change, pavement, land conversion, and water control infrastructure (dams, ditches, and tile drains). When water regimes consequently depart far outside the range to which plants and wildlife species are adapted, populations suffer. Altered water regimes are perhaps most limiting to wildlife and rare plants where naturally hydric soils have been paved, drained, or otherwise altered, and where dams have inundated areas that historically were not wetlands or lakes. Construction of dams on the upper Willamette permanently removed habitat for many forest species but created habitat for some waterbirds. Agricultural operations also have a potentially great effect on water availability and thus wildlife habitat. Crops differ with regard to their need for irrigation, and thus have potentially different offsite impacts, both on low flows in streams and on water table levels in adjoining wetlands. Row crops and landscape nurseries tend to have higher water demands than land used for grass seed, hay, Christmas trees, hops, orchards, vineyards, or pasture.

Pollution. In extreme concentrations many substances, both natural and manufactured, can adversely affect wildlife and plants. These include but are not limited to some synthetic hydrocarbons, heavy metals, and radiation. Some originate from local sources, while others are carried long distances (even from Asia) in aerosols or attached to airborne dust. Local sources include agricultural, mining, road maintenance, and forestry activities, as well as industrial effluent and stormwater runoff. Natural sources of toxic substances are sometimes locally common in the Willamette Basin and can be mobilized or immobilized by some types of land conversion or alteration (for example, mercury from abandoned mines near Dorena Reservoir) as well as by extreme weather events. Toxic effects on wildlife are observed directly only rarely, but sublethal effects (such as reduced fertility, increased vulnerability to predation, reduced disease-resistance, and increased metabolic demands as a result of having to search farther and longer for invertebrate foods) could be widespread and devastating to populations, while going largely unnoticed (Sparling et al., 2000).

Some pesticides used commonly in the Willamette Basin persist for months or longer after application (Field et al., 2003), and the Willamette Basin is a major contributor to problems with these substances in the Columbia River (McCarthy and Gale, 2001). There are significant differences among crop types in the amount, frequency, timing, persistence, and toxicity of pesticides (primarily herbicides and fungicides) used, and thus their relative risks to specific native plants and wildlife. Considerable data are available concerning pollution of surface and groundwater in the Willamette Basin, and much progress has been made in reducing the most toxic substances in the valley’s rivers and lakes. Nevertheless, very few measurements have been made of exposure levels of most terrestrial wildlife species to these contaminants, such as indicted by contaminant levels in eggs and tissues. Moreover, sublethal effects on native wildlife of the majority of contaminants are unknown, and the number of new and virtually untested compounds in the environment is growing daily, in the form of pharmaceuticals, nanotechnology “buckyballs,” and growth hormones.

Exposure of wildlife to pollutants is presumably greater near urban and industrial areas, but there are many exceptions. High Cascade lakes, for example, are exposed to elevated levels of ultraviolet radiation, as a result of the thinning of the earth’s protective ozone layer, and some evidence suggests that several frog species may be adversely affected by this radiation (Blaustein et al., 1994b and1998). Also of concern are nitrate fertilizers from suburban lawns, golf courses, and crop fields. These fertilizers are known to contaminate groundwater in parts of the subbasin and have been shown to be toxic to larvae of some Willamette frog species at routine exposure levels (Hatch et al., 2001; Marco et al., 2001), and even at levels considered safe for human drinking. Thus, nonpoint source control programs are as essential to wildlife as to fish.

Warming temperatures are potentially an outcome of globally changing climate, and partly a result of regional and local changes in land cover, such as the “heat sink” effect of urban environments. At a finer scale, the magnitude, seasonality, and variability of temperatures can change as a result of removing the forest canopy and altering the distribution of water on the landscape. Changes in air and water temperatures can have subtle but profound effects on wildlife. Warming temperatures can eliminate perennial snow packs in the Cascades, thus reducing or eliminating late-summer streamflow and depriving wildlife and vegetation of critical moisture. Diminished soil moisture and drought-killed trees then increase the risk of further habitat loss from wildfire. In contrast, reservoir regulation has brought generally cooler temperatures to some waterways downriver of reservoirs. Some evidence indicates that the composition and distribution of the Willamette Basin’s fauna might be shifting in a manner that suggests that progressive warming is occurring, but definitive proof is so far lacking.

Soil Degradation. Soil degradation consists mainly of soil compaction (that is, a reduction in space between soil particles), which is most often the result of the herding of livestock in a confined area or off-road vehicles employed for farming, forestry, or recreation. Compaction is of particular concern with respect to rare plants and burrowing mammals. Burrows are easily crushed and, although they are readily recreated, chronic travel over the same area may compact the soil to a point where it becomes unsuitable for burrowing. Soil compaction and associated traffic also kill vegetation directly and may limit the ability of natural seed banks to germinate and/or survive until they can develop sufficient root systems. By reducing the pore space in soils, compaction can reduce habitat space for soil invertebrate communities and sensitive plants upon which wildlife populations depend. Wet, clayey soils that typify much of the Willamette Valley are the most vulnerable to compaction, especially when they lack organic material. Compaction usually is a localized problem, concentrated mainly in developed areas, heavily grazed areas, and plowed lands.

Harassment. Harassment of wildlife includes the detrimental exposure of wildlife to the presence of humans, to loud noise and scents of humans, or to those of pets closely associated with humans, at greater-than-normal frequencies. Harassment need not be intentional. It also includes legal and illegal harvest of wildlife and is commonly associated with recreation and other outdoor activities. The simple presence of humans has been well documented to potentially increase physiological stress in wild mammals and birds. In some instances this results in increased metabolic demands and can cause some species to have to search longer for food, thus exposing them to greater risk from predators and adverse weather. Nests temporarily unattended by a parent that is moving away from approaching humans may be quickly predated or parasitized.

The point at which human presence becomes harassment is uncertain. Thresholds for inducing harassment (that is, the frequency, intensity, duration, distance, and type of human presence) are not well defined and depend partly on the species. Some species appear to adapt well to human presence while others do so slowly or not at all. At one extreme, a single intrusion into a cave harboring colonial bats during a critical period may cause the bats to completely abandon the site. At the other extreme, chipmunks at campgrounds often become so accustomed to humans that they feed directly out of the human hand. Most large birds and mammals flee when humans on foot approach within a few hundred feet, while smaller birds and mammals seem unaffected until humans are within a few feet.

Harassment depends not only on the species, but on timing. Many species are especially sensitive during the nesting season (mostly late spring and summer) and when they are roosting or congregating. Waterfowl are sensitive during their annual plumage molt. The willingness of an animal to leave a habitat patch completely may depend partly on the availability of refuges of suitable habitat nearby. The severity of harassment is generally proportional to the local population density of humans. Although extensive trail networks are important to fostering public understanding of wildlife, the routing of trails near sensitive features such as heron rookeries, bat caves, and turtle basking sites has the potential to exacerbate harassment of wildlife.

Invasive Species, Pathogens, and Parasites. These are organisms—especially ones not native to the Willamette subbasin—that do the following

- Spread rapidly
- Are unusually efficient competitors with or predators of native species
- Drastically modify habitat structure in ways that reduce native species diversity and abundance.
- Some combination of the above

Invasive plant species are one of the most widespread and serious threats to native plant populations in all of the focal habitat types, except perhaps old-growth conifer forest. Invasive species increase competition or predation on native species not adapted to coexisting with the invader, thus reducing population viability. Nonnative species tend to be less frequent and/or less invasive where natural drainage, thermal, fire, and nutrient regimes have not been widely altered, where native predators have not been decimated, and where access by humans and other dispersal agents is minimal.

Invasive species are most detrimental to wildlife when they physically alter habitat structure in a manner that eliminates or severely reduces particular habitat types. Unfortunately the effects of invasive plants on wildlife have seldom been studied, but anecdotal observations by local naturalists and scientists suggest both positive and negative effects. Probably the most prevalent invasive plants in the Willamette Basin are Himalayan blackberry, Scotch broom, reed canary grass, and English ivy. Some relatively recent additions of significant concern are Japanese knotweed and false-brome. Some of the better-known invasive wildlife species are nutria, European starling, and bullfrog.

Diseases and parasites also are a major factor limiting plants and wildlife. For example, deformities noted among native frogs in the Willamette subbasin have been linked circumstantially to parasites known as flukes. Although flukes have always parasitized frogs and caused a limited incidence of deformities, evidence is mounting that some additional factor—perhaps nitrate pollution—has indirectly caused an expansion of fluke populations and thus has possibly increased the incidence of frog deformities. The extent of deformities in Willamette frogs is unknown. Pathogenic fungi also may be affecting amphibians (Blaustein et al., 1994a). In addition, two diseases—sudden oak death, which largely affects oaks, and West Nile virus, which affects birds and people—are poised to invade the Willamette Basin. When they do, the damage to vegetation and wildlife could be catastrophic, judging from what has happened elsewhere in the United States.

3.5.2.3 Limiting Factors Outside the Subbasin

In general, most mammals, amphibians, reptiles, and rare plant species are not strongly and directly affected by factors outside the Willamette Basin. This is because, with the exception of a few large predators and scavengers, the seasonal and annual movements of mammals, amphibians, reptiles, and rare plants are constrained to areas entirely within the basin. Thus, external factors most likely to affect these groups are ones that occur over broad regions, such as global warming, the spread of invasive species, and long-distance movement of airborne contaminants and food sources (such as fish). In contrast, many bird species migrate or forage beyond the Willamette Basin and thus can be limited more strongly by factors elsewhere. However, sound information is lacking with regard to which species are being limited by which particular external factors, and whether factors beyond the Willamette Basin are more limiting than those within.

3.6 Synthesis and Interpretation

The Willamette Basin is a big and complex place. It is home for than 70 percent of Oregon's population and encompasses 12 percent of the total area of Oregon, including 11,500 square miles, 10 counties, 100 cities, 26 watershed councils, and 272 native fish and wildlife species. There was a lot of ground to cover in this subbasin plan. The landscape of the Willamette Basin has changed considerably in the last 100 years. Native habitats have been modified or converted to other land uses. Citizens have made use of the productive soils and mild climate of the Willamette Basin for a variety of agriculture and forest product, making the basin an important component of Oregon’s economy. Modifications to the Willamette River system have enabled cities and towns throughout the basin to develop, grow, and thrive in close proximity to the 13th largest river in the U.S., with relative security and insulation from the effects of seasonal flooding that once changed the landscape regularly. More than 2 million people live within 20 miles of the banks of the Willamette River.

With the positives have come some negatives. About one-third of the species in the basin are listed as threatened, endangered, or species of concern by state and federal fish and wildlife management agencies.

Much of the native habitat on which these species depend to complete important life history stages in the Willamette are no longer available, no longer accessible, or heavily degraded. With changes to the landscape have also come significant changes to the natural processes that form and maintain habitats. Construction of 13 major flood control dams, large-scale removal of snags for navigation, channelization and revetments, and the drainage of wetlands to increase the land available for agriculture have reduced the channel length and complexity of the Willamette River (PNERC, 2002; Sedell and Froggatt, 1984; Benner and Sedell, 1997). Flooding of the river valley was common in the winter and spring prior to the construction of the dams (1941-1969). On average, 14 floods above bankfull occurred each decade from about 1884 through 1969 (Corps of Engineers, 1970). What was considered a 10-year flood event prior to construction of the dams is now considered a 100-year flood event (Benner and Sedell, 1997). Channelization of rivers and streams and flow management by dams restricts or eliminates interactions between the river and its floodplain (Gabriel, 1993). These interactions are essential to the formation and maintenance of key habitats on which fish and wildlife depend (Bayley, 1991; Osmundson and Burnham, 1998; Modde et al., 2001, Scheerer, personal communication, 2004).

The abundance, diversity, and distribution of many native fish and wildlife species in the Willamette Basin are diminished from historical estimates. While cycles of abundance have occurred, particularly among anadromous salmonids, overall trends for focal species in this assessment are declining. The declining trends of focal species correspond with reduced access, quantity, and quality of native habitats and ecosystem functions (PNERC, 2002; USACE, 2002; Altman, 1997).

The data and tools to directly link biological performance of focal species in the Willamette Basin with specific habitat modifications are inadequately developed. Analysis of existing data, however, shows consistency in the sequence of observed declines in biological performance and the loss and degradation of habitats and habitat-forming processes. Based on the current state of knowledge about species and habitat relationships, the biological performance of focal species currently being observed and reported by fish and wildlife biologists is consistent with what would be expected (see Section 3.2.2). Review and analysis of species status and habitat conditions and current understandings of the relationships between biological performance and the key habitats and habitat diversity on which species depend affirm that the Willamette Basin presents significant challenges. As importantly, the basin also presents significant opportunities for habitat conservation and restoration efficiency.

Our assessment and analysis of existing conditions and data show that no one factor is singularly responsible for the decline in natural abundance, productivity, and diversity of fish and wildlife in the Willamette Basin. Rather, a combination of consequences derived from landscape-level conversion of native habitats to other uses and development of infrastructure to control and store water have disrupted ecosystem processes, functions, and dynamics. These changes have:

- Reduced the quantity of accessible habitat
- Reduced physical connectivity between habitats and habitat-forming processes
- Degraded the quality of the habitat that remains
- Decreased the functional ability of the ecosystem to form and maintain habitats

Together, these changes have had effects on the life stages of aquatic and terrestrial species that occur within the basin. It is important to keep in mind that a significant portion of the life histories of anadromous fish occur outside of the Willamette Basin. Much more needs to be known about these out-of-subbasin effects to associate habitat with total species abundance.

3.6.1 Subbasin-Wide Working Hypotheses

3.6.1.1 Aquatic Hypothesis

Working Hypothesis #1: Restoration of natural processes functions and dynamics in the Willamette Basin will improve the quantity, quality, and diversity of key habitats essential for the full range of life stages that occur within the basin.

Evidence. The natural processes, functions, and dynamics on which aquatic species in the Willamette Basin depend to form and maintain key habitats have been disrupted (PNERC, 2002; Sedell and Froggatt, 1984; Benner and Sedell, 1997; Bayley, 1991; Osmundson and Burnham, 1998; Modde et al., 2001; 2004; Altman, 1997). Modifications that disrupt these natural processes have also had significant effects on water temperature patterns and extremes and eliminated access to historical habitat (USACE, 2000). Reductions in the functional capacity of ecosystems have negatively affected the abundance, diversity, and quality of essential habitats for key life history stages of all aquatic focal species (Chapter 3).

While the specific causes, severity, and acuteness of habitat quantity, quality, and diversity of aquatic habitat degradation vary by geographic location, the linked attributes of key habitat and habitat diversity emerged as high priorities for restoration in every subbasin of the Willamette (see Table 3-195). Each salmonid life stage occupies and depends on different key habitats with distinct features (Hawkins and others, 1993). Oregon chub rely on many of the same lowland off-channel key habitat structural conditions important for salmonids (U.S. Fish and Wildlife Service, 1998). Key habitat refers to the quantity of the distinct habitat types needed for each life stage. Habitat diversity refers to the diversity of these key habitats. The quantity of the diverse key habitats needed to complete each life stage determines the capacity of a river system. A simple example: fish spawn and eggs incubate on gravel, juveniles rear and take refuge in riffles, shallow pools, and ponds, and adults hold in deep pools in larger reaches. To be successful, salmonids in particular need a string of suitable, connected habitats of adequate quality and quantity at times appropriate to each life stage (Independent Scientific Group, 2000).

Key habitats are formed and maintained by the dispersal of large wood and sediments and other structural components resulting from the natural interaction between flow and the structural components of a river channel and interactions between a river and its floodplain (Beechie and Sibley, 1997; Naiman and others, 1992, Washington Forest Practices Board, 1995). Large wood is a primary structural component influencing the formation of key habitat types and habitat diversity in the Willamette. The availability and recruitment of large wood has been reduced in every subbasin in the Willamette. Channel stability is the attribute in this analysis that captures large wood availability and it ranks as medium to high as a restoration priority in every subbasin (Table 3-195). Wood in the stream channel captures gravel, contributes to constant changes and sinuosity of river channels, provides cover for juvenile and adult fish, and enhances the productivity of aquatic insect populations (Bilby and Ward, 1998).

Reductions in large wood in rivers and streams throughout the Willamette Basin is a major contributor to reduced key habitats and habitat diversity (see Section 3.5.1). The extent and vegetative composition of riparian forests in the Willamette is reduced from historical levels (PNERC, 2002). Changes in riparian extent and composition have reduced the quantity and quality of wood available. Larger (older), coniferous trees provide longer-lasting benefits to stream habitat compared to younger, deciduous trees (Bilby and Ward, 1998). The reduction in riparian extent and subsequent availability of wood to rivers and streams in the Willamette Basin is exacerbated by:

- Decreased recruitment potential caused by reduced connectivity between rivers and streams and their floodplains as a result of flow regime changes and bank hardening and channelization activities

Table 3-195: Management Unit Attributes

LOWER WATERSHED ATTRIBUTES AND RATINGS FOR NON-EDT TREATED AREAS															
	Channel Stability	**Chemicals**	**Competition with Hatchery Fish**	**Competition with Introduced Species**	**Flow**	**Food**	**Habitat Diversity**	**Harassment**	**Obstructions**	**Oxygen**	**Pathogens**	**Sediment Load**	**Temperature**	**Withdrawals**	**Key Habitats**
Calapooia	Medium	Low	Medium	Medium	High	Medium	High	High	High	Low	Medium	Low	High	Medium	High
Coast Fork	Medium	Low	Medium	Medium	High	Medium	High	Medium	High	Medium	Medium	Low	High	Low	High
Long Tom	Medium	Medium	Low	Medium	High	Low	High	Low	High	Medium	Low	Low	High	Medium	High
Luckiamute/Rickreall	High	Low	Low	Medium	High	Low	High	Low	High	Low	Low	Low	High	Medium	High
Marys	Medium	Medium	Low	Medium	High	Low	High	Low	High	Low	Low	Low	High	Medium	High
McKenzie	High	Low	Medium	Medium	High	Medium	High	Medium	High	Low	Low	Low	High	Medium	High
Middle Fork	Medium	Low	Medium	Medium	High	Medium	High	Medium	High	Low	Medium	Low	High	Medium	High
Molalla/ Pudding	High	Medium	Medium	Medium	High	Medium	High	Medium	High	Low	Low	Medium	High	Medium	High
N. Santiam	Medium	Low	High	Medium	High	Medium	High	Medium	High	Low	Medium	Low	High	Medium	High
S. Santiam	Medium	Low	High	Medium	High	Medium	High	Medium	High	Low	Medium	Low	Medium	High	High
Tualatin	High	Medium	Low	Medium	High	Low	High	Low	High	Low	Low	Low	High	Medium	High
Yamhill	High	Medium	Low	Medium	High	Low	High	Low	High	Low	Low	Low	High	Medium	High
Willamette Mainstem	High	Medium	High	Medium	High	Medium	High	Low	Low	Medium	Medium	Low	Medium	Medium	High
Salem Area Tributaries	High	High	Medium	Medium	High	Low	High	Low	High	High	Medium	Medium	High	High	High

UPPER WATERSHED ATTRIBUTES AND RATINGS FOR NON-EDT TREATED AREAS															
	Channel Stability	**Chemicals**	**Competition with Hatchery Fish**	**Competition with Introduced Species**	**Flow**	**Food**	**Habitat Diversity**	**Harassment**	**Obstructions**	**Oxygen**	**Pathogens**	**Sediment Load**	**Temperature**	**Withdrawals**	**Key Habitats**
Calapooia	Medium	Low	Medium	Low	Low	Medium	High	High	Medium	Low	Medium	Low	Medium	Low	High
Coast Fork	Medium	Low	Medium	Low	Low	Medium	High	Low	Medium	Low	Medium	Low	Medium	Low	High
Long Tom	Medium	Medium	Low	Medium	Medium	Low	High	Low	High	Medium	Low	Low	High	Medium	High
Luckiamute/Rickreall	Medium	Low	Low	Low	Low	Low	High	Low	Medium	Low	Low	Low	High	Medium	High
Marys	Medium	Low	Low	Low	Low	Low	High	Low	High	Low	Low	Low	High	Medium	High
Middle Fork	Medium	Low	Medium	Low	Low	Medium	High	Low	Medium	Low	Medium	Low	Medium	Low	High
Molalla/ Pudding	Medium	Low	Medium	Low	Low	Medium	High	Medium	High	Low	Low	Low	Medium	Low	High
N. Santiam	Medium	Low	Medium	Low	Low	Medium	High	Low	Medium	Low	Medium	Low	Medium	Low	High
S. Santiam	Medium	Low	Medium	Low	Low	Medium	High	Low	Medium	Low	Medium	Low	Medium	Low	High
Tualatin	Medium	Low	Low	Low	Low	Medium	High	Low	High	Low	Low	Low	Medium	Low	High
Yamhill	Medium	Low	Low	Low	Low	Low	High	Low	High	Low	Low	Low	High	Medium	High
Willamette Mainstem	High	Low	High	Medium	High	Medium	High	Low	Low	Medium	Medium	Low	Medium	Medium	High

- Reduced downstream movement of wood caused by dams and other structures
- Removal of wood for navigation

Key habitats and habitat diversity are integrally linked to water regimes, channel form and structure, and habitat connectivity. Implementation of restoration actions must be informed by an understanding of natural hierarchies and processes. To be successful over time, restoration efforts should seek to improve the processes that form and maintain key habitats and habitat diversity (see Section 3.2.2). Restoration efforts should be logically sequenced and consider the systemic, interdependent nature of naturally functioning systems.

3.6.1.2 Aquatic and Terrestrial Hypotheses That Overlap

Working Hypothesis #2: Restoration of normative water regimes will improve the ability of the natural system to form and maintain quantity, quality, and diversity of key habitat components.

Evidence. The “water regime” of a stream, lake, pond, or wetland describes the magnitude, frequency, duration, and seasonal pattern of inundation or drought, as well as the rate at which water flows through it. Restoration of normative water regimes, particularly flow volumes, ranks as a high priority in the lowlands of every subbasin in the Willamette (Table 3-195). Stanford and others (1996) emphasize the primary importance of flow in the health of large rivers and regard it as one of the most pervasive effects on large rivers across the globe*.* Poff and others (1997) consider flow a “master variable” that regulates the ecological integrity of river ecosystems.

Water regime dynamics affect nearly every aspect of ecosystem functioning, including habitat formation and maintenance, the flow of energy and materials, temperature, the fate and transport of contaminants, and the composition of biological communities (Ziemer and Lisle, 2001). Both aquatic and terrestrial species have evolved to maximize their fitness under normative water regimes. When water regimes consequently depart far outside the range to which fish, plants, and wildlife species are adapted, populations suffer. (Precipitation and runoff regimes can be altered by global climate change, pavement, land conversion, and water control infrastructure such as dams, ditches, and tile drains.)

Water regimes potentially limit wildlife species by influencing aquatic foods, floodplain vegetation, and access to aquatic or terrestrial habitats and foods. Increased water provides habitat space and feeding opportunities for fish, amphibians, and waterbirds while decreasing these elements for some terrestrial species. Surface water is essential as a drinking source for many wildlife species. Water levels alter plant cover and successional processes, and availability and type of soil invertebrates. For example, riparian cottonwood habitat is important to many wildlife species in the Willamette Subbasin, and the germination and survival of seedling cottonwoods is intimately tied to water regimes (timing, drawdown rate, depth), both directly and at least hypothetically, in association with the effects of water regime on vegetation (such as Himalayan blackberry) that can exclude young cottonwoods through shading.

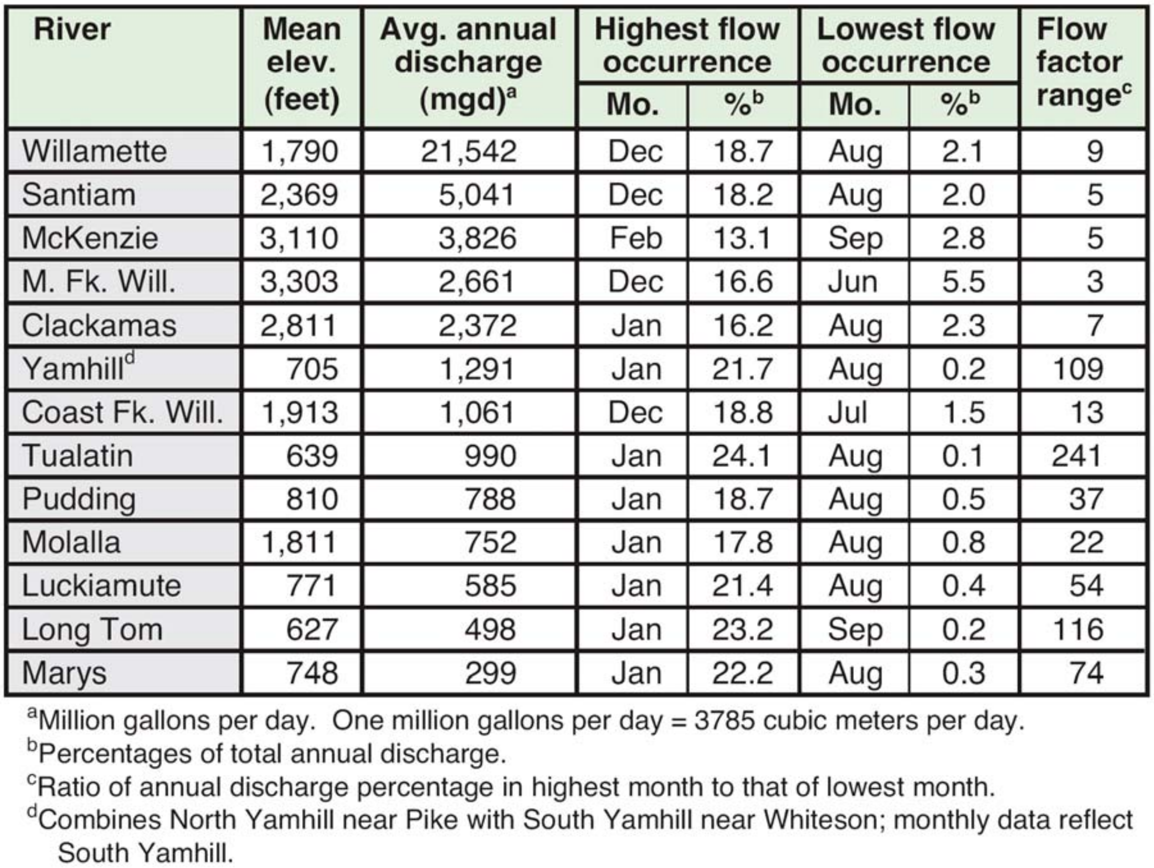
Increasing flows and water levels, by altering physical access, have the potential to introduce predatory fish into otherwise-isolated floodplain pools and cut-off channels, with sometimes detrimental effects on native amphibians (see Section 3.4 for further discussion). Increased flows and water levels also can isolate terrestrial habitat patches that were accessible to wildlife (and predators) when water levels were lower, with consequent benefits for some species and adverse effects for others (Hallock & Hallock, 1993; Jobin & Picman, 1997).

At least 74 native wildlife species feed on fish, either directly or indirectly (Table 3-103 in Section 3.4). Thus, they are potentially affected whenever fish are affected by changes in water regimes. An additional 31 native wildlife species that breed in the Willamette Subbasin and are not fish-associated are potentially influenced by water regimes because they use water or aquatic plants as their primary substrate (e.g., dabbling ducks). Yet another 55 breeding wildlife species find habitat in riparian areas to be generally more suitable than habitat in uplands (Adamus, 2001b), perhaps as a result of greater opportunities to forage on emerging aquatic insects or to generally greater habitat structural diversity. Including an additional 24 native riparian- or water-associated species that occur regularly in the subbasin only during winter or migration (and were not counted previously as fish-feeders), a total of 184 wildlife species are vulnerable to the effects of altered water regimes and degradation of riparian areas in the Willamette Subbasin. Restoration of normative water regimes could thus benefit at least 57 percent of the subbasin’s wildlife.

Natural Factors Influencing Water Regimes. Water regimes in streams, lakes, and wetlands are the direct result of the balance between water inputs and outputs. Climate, geology, and topography affect the delivery of this water to the habitat. Precipitation determines the amount of water (inches per year) delivered to a watershed. Temperature, along with precipitation patterns and geology, determines the schedule of delivery of this water to the stream within a year and the resulting flow characteristics. Long-term precipitation and climate patterns establish water regimes among years. In snow-melt systems, precipitation may peak with snowfall in winter but delivery of that water to the stream is delayed until warmer weather in spring. In rainfall-dominated systems, water regimes in streams and other water bodies closely follow precipitation patterns. Geology affects delivery of water through soil characteristics, topography, and subsurface water storage (Ziemer and Lisle, 2001). These natural factors are important to water regimes in the Willamette Basin. In snow-melt systems such as the Middle Fork, McKenzie, North and South Santiam, and Clackamas, precipitation may peak with snowfall in winter but delivery of that water to the stream is delayed until warmer weather in spring. In rainfall-dominated systems like Coast Range tributaries and lower elevation Cascade tributaries, water regimes closely follow precipitation patterns. Subsurface storage of water in aquifers or near-surface soils is the primary contributor to summer water availability in many water bodies and determines the annual low flow. The amount of storage is a function of precipitation and geological characteristics of the watershed (Grant, 1997). In spring-fed water bodies such as many of those at higher elevation in the Cascades, this delivery of groundwater is extreme and water regimes of streams and wetlands can significantly differ from precipitation patterns (Grant, 1997). Cascade tributaries have more subsurface storage capacity than Coast Range tributaries (PNERC, 2002).

Table 3-196 illustrates flow regimes for some of the major tributaries in the Willamette Basin. The difference between the ratio of discharge from the highest month to the lowest month illustrate the effect subsurface storage can have on summer base flow.

Table 3-196: Flow Regimes for Major Tributaries in the Willamette Basin



River	Mean elev. (feet)	Avg. annual discharge (mgd)[a]	Highest flow occurrence		Lowest flow occurrence		Flow factor range[c]
			Mo.	%[b]	Mo.	%[b]	
Willamette	1,790	21,542	Dec	18.7	Aug	2.1	9
Santiam	2,369	5,041	Dec	18.2	Aug	2.0	5
McKenzie	3,110	3,826	Feb	13.1	Sep	2.8	5
M. Fk. Will.	3,303	2,661	Dec	16.6	Jun	5.5	3
Clackamas	2,811	2,372	Jan	16.2	Aug	2.3	7
Yamhill[d]	705	1,291	Jan	21.7	Aug	0.2	109
Coast Fk. Will.	1,913	1,061	Dec	18.8	Jul	1.5	13
Tualatin	639	990	Jan	24.1	Aug	0.1	241
Pudding	810	788	Jan	18.7	Aug	0.5	37
Molalla	1,811	752	Jan	17.8	Aug	0.8	22
Luckiamute	771	585	Jan	21.4	Aug	0.4	54
Long Tom	627	498	Jan	23.2	Sep	0.2	116
Marys	748	299	Jan	22.2	Aug	0.3	74

[a] Million gallons per day. One million gallons per day = 3785 cubic meters per day.

[b] Percentages of total annual discharge.

[c] Ratio of annual discharge percentage in highest month to that of lowest month.

[d] Combines North Yamhill near Pike with South Yamhill near Whiteson; monthly data reflect South Yamhill.

Flows are adjusted to exclude the influence of upstream dams.

Source: PNERC, 2002.

Artificial Factors Influencing Water Regimes. Human modification of watersheds can result in dramatic changes in water regimes in streams and wetlands, with a cascading effect on most aspects of aquatic habitats (Ziemer and Lisle, 2001). Dams have a clear effect on water regimes and in many cases are specifically designed to alter streamflow to reduce flooding or to meet demand schedules for hydropower. Dams or diversion structures or both exist on every major tributary to the Willamette. The Willamette Basin has 371 dams. Thirteen USACE dams were constructed specifically to reduce the negative effects of seasonal flooding. Approximately 45 percent of the dams in the Willamette Basin are used to store water for irrigation (PNERC, 2002). Dams have significant influence over flow and profound effects on the ability of a stream system to deliver structural components of habitat such as wood and sediment downstream. Flow regulation also diminishes the essential habitat forming interaction between rivers and streams and their floodplains. The loss of this dynamic process has influence over all aspects of key habitat quality and quantity. Construction of dams on the upper Willamette permanently removed many miles of stream habitat and terrestrial habitat (Figure 3-119), while creating habitat for reservoir-associated fish and waterfowl species that typically find flowing water to be less suitable. It is hypothesized that flow regulation by these dams has not only affected species onsite, but also floodplain and in-channel habitat and species many miles downriver. Such changes are hypothesized to be the result of diminished base flows, higher or longer-duration low flows, altered seasonality of flow, cooler mean temperatures, and possibly other water characteristics.

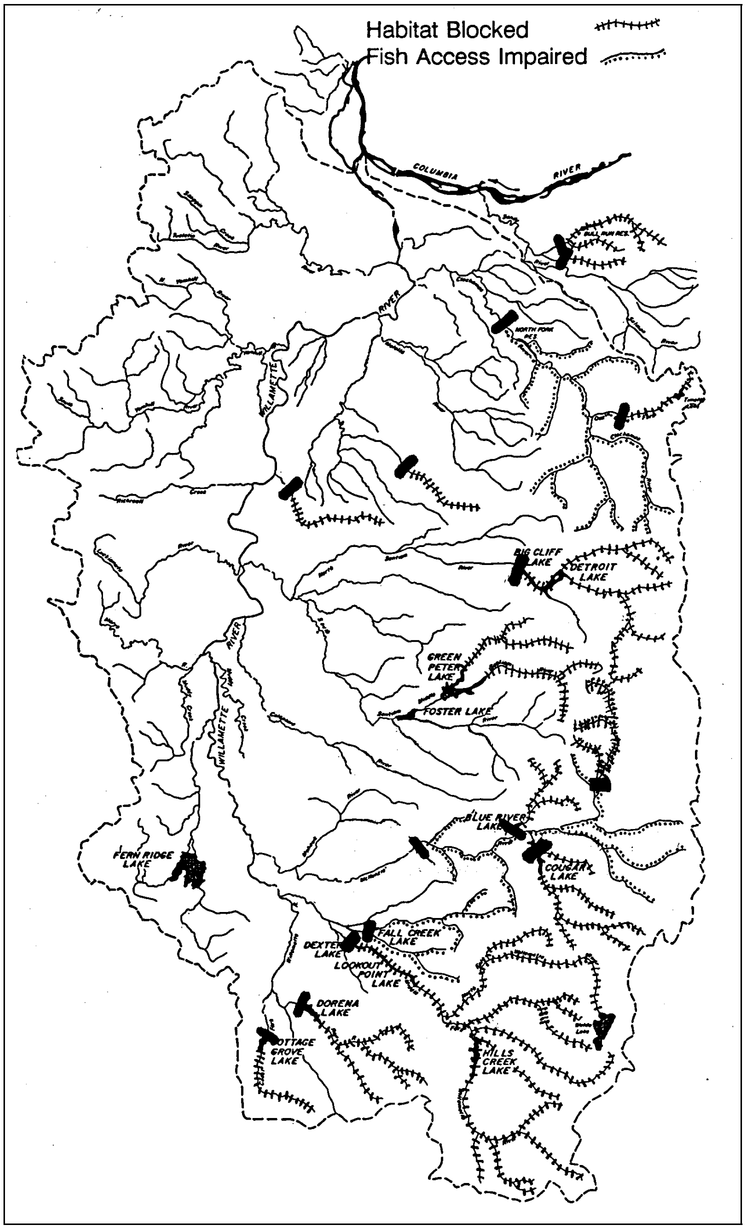


Figure 3-119: Spring Chinook Salmon Habitat Blocked By Major Willamette Dams

Source: Cramer et al., 1996.

The most obvious factor resulting in loss of water to streams is the withdrawal of streamflow for irrigation or human consumption. Water withdrawals are an important factor affecting key habitat quantity and quality. Low levels of rainfall during the summer months in the Willamette Basin result in naturally low streamflows and higher demand for scarce water for irrigation and human and industrial consumption. In 1995, 77 percent of the total withdrawals in the Willamette Basin were derived from surface flow and 23 percent from groundwater. Approximately 49 percent of the water withdrawals are for irrigation; 15 percent for domestic use; 13 percent for industrial use; and 19.5 percent for commercial use (Hulse et al., 2002).

Less obvious than dams and withdrawals is the effect of land use practices on water regimes. This is often because of increases in overland flow and channel modifications which lead to reductions in subsurface storage (Ziemer and Lisle, 2001). In small urban watersheds, a few researchers have documented a negative association of stream ecological condition with the increasing amount of watershed imperviousness, an association that is partly the result of the effect of impervious surfaces on watershed hydrology, specifically changes to overland flow and baseflow (Booth, 1991; Schueler, 1994; May and others, 1997). The end result is an increase in "flashiness," where streamflow responds quickly to rainfall and then quickly drops back as the precipitation is transferred downstream. Downcutting of stream channels owing to grazing or other practices also can disconnect stream channels from subsurface storage, leading to reductions in summer flow (Hicks and others, 1991).

Agricultural operations also have a potentially significant effect on water availability and thus fish and wildlife habitat. Both agricultural and urban development can affect the water regime in remaining wetlands and streams through installation of ditches and subsurface drainage tile intended to make managed lands more productive or buildable.

Where Do Altered Water Regimes Limit Salmonid Fish and Wildlife? The effects of landscape level modification on natural water régimes in the Willamette are cumulative and most acute in the lowlands. Acute, local flow problems occur with irrigation or other withdrawals. Altered water regimes are hypothesized to be most limiting to wildlife and rare plants where naturally hydric soils have been paved, drained, or otherwise altered, and where dams have inundated areas that historically were not wetlands or lakes.

Working Hypothesis #3: Reduced channel confinement in the lowland areas of the Willamette Basin will improve interactions between rivers and streams and their floodplains, enabling natural processes, functions, and dynamics responsible for the formation and maintenance of channel complexity and habitat diversity to occur.

Evidence. Channel form describes the physical form of the channel and the connection between the stream and its floodplain and valley. As such, it is one component of overall channel complexity. Channel form develops as a response to the dissipation of hydraulic energy of a stream and the underlying geology (Leopold and others, 1964). This energy dissipation affects the sinuosity of the channel, development of multiple channels and off-channel areas, as well as bed load mobility. As energy dissipates, the dynamic, naturally-occurring shift in location of meandering channels temporarily removes vegetation and resets vegetative succession. All of these factors help drive the development of a range of habitat types, diversity of energy regimes (fast water vs. slow water), food levels for fish and wildlife (productivity of aquatic insect communities) and, for salmonid fishes, spawning success as affected by bed movement and scour (Montgomery and others, 1996). Unless naturally constrained by valley form (canyon reaches, for example), natural stream channels typically grade into terrestrial areas through secondary channels, oxbows, and wetlands that have permanent or season connections to the main stream channel (Montgomery and

Buffington, 1998). These wetlands and oxbows provide diverse habitat for many species, including waterfowl and amphibians (Galat et al., 1998).

Other components of channel form complexity that are important to wildlife include eroding banks and gravel bars. In the Willamette Subbasin, the vertical, eroding banks that occur along short reaches of larger-order channels are required or preferred by belted kingfisher, northern rough-winged swallow, and several mammals which create burrows. Gravel bars are used for roosting and feeding by shorebirds and waterfowl, and for nesting by killdeer and (at least formerly) by common nighthawk. Gravel bars might provide relative isolation from mammals that prey on nests. Along some segments of the Willamette River, the area of unvegetated gravel bars has diminished, possibly as a consequence of vegetative succession related to water withdrawals and flow regulation (Gutowsky, 2000).

Natural Processes Contributing to Maintenance of Channel Form. In a natural setting, creation and maintenance of channel form is a dynamic ongoing process of destruction and formation. (Montgomery and Buffington, 1998). Flow quantities and patterns result in seasonal flooding that create and maintains channels, gravel bars, and floodplain wetlands. Flooding recharges aquifers and contributes to subsurface inflow to the stream during summer (Stanford and Ward, 1993). Geologic forces create valley form and natural confinement, set the susceptibility of stream banks to erosion, and determine the nature of the stream bedload (gravel, sand, and other sediment transported by the stream). Riparian vegetation potentially stabilizes stream banks while downed trees can affect the path and sinuosity of the stream channel (Gregory and others, 1991). Beaver impoundments can alter channel processes and riparian structure, usually locally and for limited periods of time. Effects on other wildlife are typically positive (Grover and Baldassare, 1995; Perkins, 2000).

Artificial Factors Affecting Channel Form. Human activities and structures limit or eliminate much of the dynamic process that results in channel form (Bolton and Shellberg, 2001). The connection between the stream and the floodplain is often severed by dikes to reduce flooding and increase the quantity of useable land. Dams potentially alter the natural water regimes needed to maintain channel form, thus degrading wildlife habitat in some instances (Nilsson and Dynesius, 1994, Johnson et al., 1996). Dikes constructed to protect property in floodplains sever the connection between the stream and the floodplain. Dredging to produce a single deep channel not only reduces habitat diversity within the floodplain, but can, under some geologic conditions, produce high levels of scour and streambed mobility. Stream water withdrawals and conversion of land to impervious surfaces can alter flows and increase flashiness, sometimes resulting in increased channel downcutting. Conversely, overloading of channels with sediment runoff as a result of erosion following vegetation removal in some cases can accelerate channel degradation (raising of elevation of the channel bottom), which also alters channel form. Removal of riparian forests also eliminates large wood that in many instances helps maintain natural variability in channel form. Urban streams are often heavily riprapped or even confined within concrete channels, obviously altering channel form.

Where Is Channel Form Typically Limiting? Channel form can be altered by human factors across a variety of landscapes. Typically, however, channel form is most altered and limiting in lowland areas. The floodplain is usually widest in lower reaches of streams. These areas are often diked to allow development and agriculture and to limit flooding. In lowlands, many other human activities have reduced the diversity of habitat types available to wildlife. Channel form in upper stream reaches can be altered by road building. Data on which particular Willamette locations have suffered the most biological effects from altered channel form are generally not available, except in some instances for salmonid habitat. Maps showing approximate channel alignments during different periods are available for some of the subbasin's rivers and can be compared to identify locations where channel location, and most likely channel form as well, has been altered the most.

Working Hypothesis #4: Improving access to historical habitat will improve the abundance, diversity, and quality of habitat available to aquatic species.

Evidence. Elements of aquatic habitat affect the survival and capacity of different life stages. However, to be successful, these life stages must be connected to form a complete life history from spawning of one generation to spawning of their progeny. Suitable habitat patches must be linked across time and space to enable each life stage to survive and move to the next stage (Independent Scientific Group, 2000). Within EDT, one measure of connectivity is the evaluation of life history trajectories. A successful life history trajectory is the habitat pathway along the stream and across months that results in an overall productivity greater than 1.0. Pathways with high quality habitat for one life stage but lacking habitat for another will be unsuccessful and discarded by the model. Similarly, many wildlife species use different habitat types during different life stages or for different functions. For example, early life stages of many amphibians are aquatic while adults are terrestrial. If quality of either aquatic or terrestrial habitats is impaired, or if their connectivity is interrupted by roads or other barriers, populations may decline.

An obvious impediment to connectivity is the presence of natural and artificial obstructions to the upstream and downstream movement of adult and juvenile life stages of aquatic animals. Natural obstructions include waterfalls, landslides, extreme low flow conditions, and (rarely) log jams. Beavers construct dams on small tributaries and side channels that may seasonally block fish passage. Obstructions are not always bad. In some cases, natural obstructions have enabled species to persist that would be eliminated through competition (Trotter, 1997), as is sometimes the case with Oregon cub and several frogs whose eggs and tadpoles are vulnerable to fish predation. For fish, artificial obstructions include culverts, diversions, and dams. For some wildlife species, obstructions include roads, other impervious surfaces, very wide channels, or extensive patches of highly unsuitable land cover (e.g., snowfields, burned cropland). These artificially shrink the size of the subbasin or home ranges of individuals and separate species and populations. The effect of barriers on fish and wildlife movement is often seasonal and variable by life stage. For fish and possibly for some aquatic wildlife species, culverts may be passable at moderate and high flows but "perched" and impassible at low flow. Obstruction may be impassible to upstream movement of juveniles but may still be passable to adults moving upstream. Dams and diversions often have screens, ladders, or other provisions for passing adult and juvenile fish with varying success.

Dams that block or impede fish passage also create reservoirs that inundate terrestrial habitats. Blockage of anadromous salmonids by dams eliminates an important food source for terrestrial species and halts the delivery of marine nutrients (from consumption of adult carcasses) to the watershed above the dam. Dams and ponds created by beaver form important summer rearing habitat for juvenile salmonids and also diversify wildlife habitat, with consequent benefits to many species (Grover and Baldassare, 1995; Perkins, 2000). These dams are usually seasonally passable to adult fish to allow spawning above the ponds while juveniles leave the ponds at high flow.

Artificial Factors Affecting Obstructions. Dams occur on every mainstem tributary to the Willamette River. A total of 371 dams in the Willamette Basin are used for irrigation, municipal water use, and flood control (PNERC, 2002). Major dams in the Willamette Basin block access to upstream habitat. Culverts installed to allow road crossings at tributaries have also created numerous fish passage barriers.

Major habitat blockages resulted from Big Cliff Dam (built in 1952) on the North Santiam River and from Green Peter Dam (built in 1967) on the South Santiam River. These dams, along with Dexter Dam, Dorena Dam, and Cougar Dam, were identified by NMFS as the upper limit of steelhead distribution for critical habitat designation (64 FR 5750).

Beginning 40 years ago, all Willamette Project dams (except Foster) completely blocked fish migration, either because no passage facilities were provided, or those provided did not work. Upper Willamette spring Chinook and winter steelhead are no longer found above these dams.

Fragmentation and isolation of bull trout populations have created a patchwork of remnant populations in the Columbia River basin (63 FR 31674). Barriers caused by the Willamette Project dams prevent bull trout from freely migrating between winter refuge areas and summer foraging areas, and prevent gene flow among the isolated populations. Fragmentation and isolation of fish populations resulting from dam operation have also been observed for resident cutthroat trout in the Long Tom River.

Oregon chub have also been affected by dams. Opportunities for migration may be limited to extreme flooding events; however, no data exist on either population structure or potential dispersal among populations. Dispersal (successful colonization) and genetic exchange among populations have likely been reduced substantially post-dams. In terms of dam influences, the Dexter/Lookout Point, Fall Creek, and Hills Creek projects appear to have the highest potential to affect Oregon chub populations. The Foster/Green Peter, Big Cliff/Detroit reservoirs have a moderate influence (USFWS, 1998a).

Where Are Obstructions Typically Limiting? There are 371 dams in the Willamette Basin. USACE dams and hydroelectric dams on Cascade tributaries and the Coast Fork and Long Tom River block access to significant portions of upland habitat. Obstruction is ranked as a high restoration priority in the lowlands of the basin. In lower elevation areas, irrigation diversions impede or block passage (see fish passage barrier maps in Appendix G). On larger rivers, hydroelectric dams are common. While most of these dams have facilities to pass juvenile and adult fish, they continue to impede passage to some degree. Other dams have been built on the Columbia and Snake rivers without passage facilities, resulting in significant reduction in the range of available habitat (Dauble and others, 2003).

Working Hypothesis #5: Temperature ranges and patterns approaching more normative conditions will improve aquatic habitat quality.

Evidence. Water temperature is a major issue for the lowland areas throughout the Willamette, especially rivers and streams regulated by dams (see Section 3.for a discussion of water quality in the Willamette Basin). The water quality in the Willamette Basin is affected by the effect of both high and low water temperature during important life history stages for salmonids. Temperature is a primary environmental factor affecting the physiology of all stream organisms (McCullough and others, 2001). Fish and invertebrates are cold-blooded and so their metabolic rates and functions are related to water temperature. Salmonids have a limited temperature range for metabolic functions, and temperatures outside this range lead to decreased performance and death. Water temperature also affects the growth and development of life stages such as developing eggs (Beer and Anderson, 2001). In addition to having a direct physiological effect on salmonids and other aquatic species, temperature affects other survival attributes as well, such as rates of predation and disease virulence. Increases in water temperature generally favor nonnative species to the detriment of native species, which is a primary factor affecting Oregon chub.

Connection to Terrestrial Habitat. Water temperature has only limited connection with most terrestrial species, except for species such as amphibians, which have a close connection to aquatic environments (Roni, 2002). However, factors contributing to water temperature such as climate, shading, and riparian conditions affect habitat conditions for floodplain terrestrial species in addition to aquatic habitats.

Natural Components Affecting Temperature. Water temperature is determined by thermal input to the stream. High temperature tends to increase downstream as temperature inputs accumulate. Thermal input is determined by a number of factors, including air temperature, exposure, aspect, shading, and inputs such as springs (Welch and others, 1998). Natural temperatures in Willamette streams are not necessarily always ideal for salmonids. Summer water temperatures may be inherently high as a result of climate and exposure in some areas. Similarly, winter temperatures may be quite low. However, for streams having native salmonid species, historical life history strategies, productivities, and abundance reflect these inherent environmental limitations.

Artificial Components Affecting Temperature. Many human actions in watersheds exacerbate natural temperature extremes and can modify seasonal temperature patterns (Coutant, 1999). Elimination or reduction of riparian forests decrease shade and expose the stream to direct solar warming. Dams increase surface area and decrease turnover of water, resulting in temperature increases. However, reservoirs can become stratified with respect to temperature and can decrease downstream water temperature if output from the dam is taken from the cold deep water layer. Land uses that lead to downcutting of stream channels and elimination of wetlands can decrease the inflow of cooler subsurface water that often provides important refuge areas from high summer water temperatures.

Where Is Temperature Typically Limiting for Salmonids? Because temperature is a cumulative problem and summer water temperature usually increases downstream, temperature problems in the Willamette are greatest in the lower reaches of watersheds and in the mainstem. However, it is important to emphasize that the sources of downstream temperature problems are usually upstream.

3.6.1.3 Terrestrial Hypotheses

Working Hypothesis #6: Conservation or restoration of the six focal habitat types — upland prairie-savanna, oak woodlands, wetland prairie and seasonal marsh, ponds and their riparian zones, streams/rivers and their riparian zones, and old growth conifer forest—will improve the quantity and quality of available habitats on which focal terrestrial species depend.

Evidence

All Willamette wildlife and plant species listed under the federal Endangered Species Act, and all sensitive species listed by the Oregon Department of Fish and Wildlife, depend strongly on one or more of these focal habitats. Relationships of individual species to each of these habitat types are described not only in Section 3.4 and Appendix D of this report, but also in several regional databases and habitat models, including those of IBIS, the PNW-ERC, and the ORNHIC. These secondary sources cite the primary literature that documents the importance of these particular habitats to the focal terrestrial species. In addition, several previous analyses have singled out these particular habitats as being of greatest overall importance to biodiversity in the Willamette Subbasin: Willamette Restoration Strategy (ODFW; Nov. 2000 draft); Ecoregional Assessment (TNC; Floberg et al., 2004); Conservation Strategy for Landbirds in Lowlands and Valleys of Western Oregon and Washington (Altman, 2000); Joint Venture Implementation Plan: Willamette Valley (Roth et al., 2002); Alternative Futures Assessment (PNERC, 2002); Payne, 2002).

Willamette Subbasin plant and wildlife species are affected by both habitat loss and habitat degradation. Habitat loss includes changes that are long-term and that radically change habitat structure as perceived by wildlife, such as:

- Conversion of any land cover type to impervious surface, e.g., pavement, buildings, other infrastructure
- Permanent inundation of land, e.g., by large dams
- Permanent filling of seasonally or permanently inundated areas, e.g., by intentional or natural deposition of sediment, rock, or debris
- Conversion of naturally vegetated land to monocultural agricultural cover
- Creation of persistently unvegetated surfaces, e.g., from gravel extraction

Habitat degradation is closely related and consists of physical and biological changes that are technically easier than habitat loss to reverse or mitigate, or which can be reversed over shorter time periods, although there may be substantial socioeconomic constraints to doing so. Habitat degradation decreases the accessibility or suitability of food, water, and cover/substrate to wildlife populations, therefore increasing crowding, competition, predation, pathogen and parasite transmission, and ultimately, mortality rates. Restoration of degraded habitat provides only marginal net benefit to populations of terrestrial wildlife and rare plants if habitat losses continue unimpeded. In the Willamette Subbasin, as elsewhere, degradation of habitat for native wildlife and rare plants most often involves, in no particular order:

- Roads and other barriers
- Vegetation change

- Diminished supply of dead wood
- Water regime change
- Pollution
- Temperature change
- Soil degradation
- Harassment
- Invasive species, pathogens, and parasites

From a spatial perspective, loss and degradation of habitat results in fragmentation of the remaining habitat. That is, there is:

- Increased distance between patches of remaining accessible habitat, e.g., decreased connectivity
- Increased simplification of habitat, i.e., fewer habitat types and structures at multiple scales

Natural Factors Contributing to Habitat Loss and Degradation. Natural events can degrade habitat for some wildlife species and enhance it for others. Examples are forest fires, major floods, drought, landslides, insect and disease infestations, wind, ice storms, grazing by wild herbivores, and natural vegetative succession. With the exception of regionwide catastrophic change to natural habitats, such as the Missoula Flood at the end of the last Ice Age, periodic habitat loss and degradation did not result in significant species loss. That is because:

- Such events were localized and occurred in a pattern largely dispersed in space and time
- Remaining natural areas within and beyond the subbasin provided temporary refuge for species capable of fleeing such events as well as a source of recolonizers following cessation of disturbance
- Escape and recolonization corridors were physically better-connected than is currently true.

Artificial Factors Contributing to Habitat Loss and Degradation. Artificial causes of habitat loss and degradation result largely from land conversion and management activities (see Appendix D for a detailed discussion of the approach used to identify and weight specific categories of change and degradation). Artificial factors can degrade habitat for some wildlife species and enhance it for others. Conversion of presettlement habitat has likely resulted in a net decline or disappearance of approximately 165 wildlife species, or about 59 percent of the total terrestrial fauna (White et al. 2002, Payne 2002). Because credible quantitative data are lacking on historical populations of all wildlife species, these conclusions are based on comparison of current with historical vegetation and application of peer-reviewed species-vegetation association models to each vegetation type. Limitations of this procedure are summarized in Table 2 of Appendix D.

The relative contributions of the various habitat degradation factors to wildlife population changes are unmeasured for most species, and likely depend on the species, location in the subbasin, and other factors discussed under the individual focal species in Section 3.2.4.5.

Multiple studies have concluded that conservation and restoration of native habitats have the potential to stabilize or improve trends of terrestrial species in the Willamette Basin (White et al. 2002; Payne 2002; Polasky et al., personal communication).

Conclusions from White et al. (2002) Analysis. Of several future scenarios examined in the Pacific Northwest Ecosystem Research Consortium's *Willamette Basin Planning Atlas* (PNERC 2002), the conservation scenario was projected to provide the most benefits to wildlife (31 percent gain compared to present), followed by the Plan Trend scenario (10 percent loss). A loosening of land use laws and other effects envisioned by the Development scenario resulted in 39 percent more species losing habitat than gaining habitat. Outcomes for each species are shown Table 50 of Appendix D. The conservation scenario was developed based on the following assumptions (for example) for the year 2050:

- To accommodate development, 54,000 acres (rather than 129,000) are added to UGBs.
- About half the new housing adjacent to the 1990 rural residential areas is in clustered developments (9.3 dwellings per acre vs. 6.2).
- Urban areas contain 94 percent of the population instead of 87 percent.
- All streams contain some wooded riparian habitat, and this occupies at least 100 feet on both sides of all streams crossing private land and 300 feet on both sides of streams on public land.
- Average clearcut size on public timberlands declines from 30 to 10 acres, and averages between 5.6 and 13 acres on private timberlands.

Conclusions from Application of PATCH Model. Computer simulations suggested that application of the same habitat conservation scenarios developed in the PNERC Conservation 2050 scenario could increase the populations of 14 of the 17 species whose populations were modeled.

Conclusions from Payne's (2002) Analysis. This investigator studied rural residential development patterns. Her models assumed restoration would be required as mitigation for all cluster developments within less productive areas of the subbasin. If such a policy were adopted, Payne's spatial analysis indicated it could result in restoration of 84,819 acres of habitat, specifically: 38,146 acres of oak savanna, 29,218 acres of conifer forest, 8,319 acres of upland prairie, 3,184 acres of wetland prairie, 2,394 acres of wetland, 2,340 acres of mixed forest, and 1,229 acres of riparian forest.

Preliminary Conclusions from Polasky et al. (pers. comm.) Analysis. The optimum solution of this simulation, using a hypothetical Willamette Valley landscape, indicated that perhaps 96 percent of the habitat suitability for the 97 terrestrial wildlife species examined could be maintained with (at most) a 7 percent economic loss to agricultural or forest use objectives. Residential development objectives were not examined. The researchers determined the optimum case to be one in which:

- The parcel presettlement vegetation had been 37 percent conifer forest, 26 percent prairie and other non-forest, 25 percent oak woodland and other deciduous forests, and 12 percent shrubland;

- Parcels whose most valuable activity is agriculture occupied 28 percent of the landscape with a mean per acre value of $3743 and standard deviation of 3762;
- Parcels whose most valuable activity is forestry occupied 72 percent of the landscape, with a mean per acre value of $3933 and standard deviation of 485

Taken together, the above four studies demonstrate the value for wildlife with modest habitat restoration proposals. At the same time they caution that restoration — unless undertaken much more extensively — cannot hope to (1) create a net benefit for wildlife if habitat destruction continues unabated, and (2) replace a significant fraction of the habitat losses that have occurred historically.

Where Does Habitat Loss and Fragmentation Limit Terrestrial Species? Habitat loss and fragmentation limit terrestrial species throughout the Willamette Basin. Habitat loss and degradation due to conversion has been most extensive in the lowlands (PNERC 2002).

3.6.2 Opportunities

3.6.2.1 Habitat for High-Priority Protection

Place a near-term priority on conserving remaining aquatic and terrestrial focal and key habitats in lowlands where habitat loss has been the greatest (PNERC 2002, WRI 2001). Anticipated population increases and urban expansion make conservation of existing habitats in the lowlands critically important. Conservation of key habitats with intact ecosystem dynamics, processes, and functions is much less expensive and more effective than restoration.

3.6.2.2 Habitat to Reestablish Access

Restore connectivity to historical habitats and among existing habitats. Restore connectivity to historical aquatic and terrestrial habitats by targeting restoration in areas that will link high quality key habitats in both the aquatic and terrestrial environment. Prioritize connectivity restoration activities to the highest quality habitats and the areas that have the potential to increase patch sizes of terrestrial habitats. Prioritize fish passage efforts at dams where improvements open up the greatest extent of high quality habitat**.** USACE dams have blocked access to large portions of historical habitat in the Willamette Basin (see evidence for Working Hypothesis #4). Restoring access to these historical habitats will increase the total system capacity by an average of 35 percent for salmon and steelhead.

3.6.2.3 Habitat for Restoration

Aquatic and Terrestrial. Restore river and floodplain interactions in appropriate areas to create and maintain aquatic and terrestrial habitats and improve water quality. The dynamic interactions between a river and its floodplain are essential to the creation and maintenance of riparian and aquatic habitat features. Natural flow regimes and periodic flooding are a mechanism of energy and nutrient exchange between terrestrial and aquatic environments that has been severely disrupted through water flow management and streambank hardening. Simplification of river and stream channels decreases floodplain interactions. The complex interactions of a river system with its floodplain need to be protected where they currently exist and restored where the combination of ecological potential and willing landowners occurs.

Restore linear integrity and species composition to lowland riparian areas. Riparian vegetation closest to rivers and streams has the greatest functional potential (PNERC 2002). While wide riparian habitat is important and serves a range of critical functions, the highest priority should be given to restoring riparian vegetation immediately adjacent to rivers and streams. Riparian areas provide essential habitat for many terrestrial wildlife species and are essential for the maintenance and creation of aquatic habitat. All natural riparian vegetation is beneficial. Forested riparian areas provide a greater range of benefits than non-forested areas and should be given conservation priority.

Aquatic. Restore channel complexity in the lowlands throughout the Willamette Basin. A key finding of this assessment is the importance of considering the Willamette Basin as a system of connected habitats. EDT analysis in the Clackamas and McKenzie subbasins indicate the highest restoration values are in the lowlands. That is not so surprising. What was surprising was the high restoration value of the lower Willamette for Clackamas River populations of anadromous fish species.

The analysis reveled that the Clackamas River and the lower Willamette River form a contiguous habitat unit. Current conditions in the Portland (lower Willamette) area are degraded from historical conditions. The lower Willamette mainstem has been largely converted from shallow-water habitats to deep water with virtually no large wood. The assessment found that salmon and steelhead currently use the area almost entirely as a migration corridor, and not for rearing. This is consistent with studies of fish use of the lower Willamette River that found most juvenile salmonids move through the area in less than two weeks (Friesen and others 2002). EDT analysis has shown that restoration of the complex network of shallow water habitats in the lower Willamette has the potential to contribute significantly as rearing habitat for tributary spawning populations such as those from the Clackamas. For all six populations combined, the Portland area had the second highest rank for restoration value.

It is important to keep in mind that the Willamette is a constrained natural system in which values for naturally functioning conditions must be considered within the context of the infrastructure that keeps the many people who live, work, and contribute to a thriving economy safe. While restoration of shallow water habitat in many portions of the lower Willamette is unlikely due to infrastructure development and economic and social constraints, this result highlights the value of considering an expanded view of the relationship between rearing habitats in lower elevation tributaries and the mainstem Willamette and total system capacity.

Terrestrial. Successful conservation planning necessitates a realistic and strategic approach that considers the needs of landowners while identifying the most biologically important places for investment. Without such an approach, there is a risk that scarce conservation resources will be expended on restoration projects or land acquisition that produce limited benefit to biodiversity. Faced with the reality that society will be unable to protect or restore all habitat required to sustain every species, efforts to identify good investments for conservation and restoration have been made.

Two major projects have used a systematic approach to prioritize particular areas of the Willamette Subbasin for wildlife habitat protection or restoration. These are the Alternative Futures project conducted by the Pacific Northwest Ecosystem Research Consortium (ERC), which identified “Conservation and Restoration Opportunity Areas” (CROAs)[15], and the Willamette Valley – Puget Trough – Georgia Basin (WPG) Ecoregional Assessment, coordinated by The Nature Conservancy (TNC), which identified “Priority Conservation Areas” (PCAs).

Willamette Valley-Puget Trough-Georgia Basin (WPG) Ecoregional Assessment (Floberg et al. 2004). This 4-year effort involved over 100 experts from Oregon and Washington. It did not cover the entire Willamette Subbasin, just the portion that comprises the Willamette Valley and adjoining foothills. Priority Conservation Areas are sites of biological significance warranting conservation attention. TNC’s portfolio of PCAs is selected by analyzing several layers of data, including the status, spatial distribution and ecological condition of species, natural communities and major habitat types (e.g., conservation targets). The delineation of PCAs also reflects the likelihood that each PCA will be able to meet minimum population or area goals set for individual conservation targets. TNC determines the number of occurrences or amount of area (representation goals) needed to ensure the survival of species or viability of habitats at the ecoregional and subecoregional (section, e.g., Willamette Valley) level. A computer algorithm selects the best combination of conservation areas based on the concentration and condition of targets, degree to which target representation goals are met and landscapes where the fewest impediments to successful conservation exist. Results of the computer model are independently peer-reviewed and refinements are made to the assessment to produce a final portfolio of PCAs. By design, the assessment did not address salmon. TNC ranked the biological value and the severity and urgency of threats of each PCA to further prioritize conservation investment at each site in the Willamette Valley. TNC considers this portfolio of PCAs “a first approximation of the most important places for conserving native species and ecosystems” in the Willamette Valley, Washington’s Puget Trough, and British Columbia’s Georgia Basin. The final list of PCAs includes a small percentage of the total Willamette Subbasin, almost entirely on private land. It does not include every location for every listed or sensitive species. The assessment does not address higher-elevation portions of the subbasin because these areas occur outside of ecoregional boundaries used by TNC.

Willamette River Basin Planning Atlas (Hulse et al. 2002, Hulse et al. 2004, Baker et al. 2004). For this project, a team of planners and scientists applied the same wildlife models used in this report (Adamus et al. 2000) to maps they constructed of Willamette Basin land use and land cover circa 1851 (“pre-settlement”) and 1990 (present). They then developed maps of three alternative ”futures” circa 2050, based on plausible changes in societal priorities for land management. The purpose was to evaluate net changes in species richness from past practices and provide a scientifically sound tool for evaluating the future ecological ramifications of contemporary policies and actions. The PNW-ERC (EC90) land cover map was used as the reference point. Subsequently, a graduate student (Susan Payne) created a refined “CC90” map of present-day land cover and applied it to predict the net effects on wildlife (basinwide) of cluster development vs. conventional development. Specific locations for restoration or conservation within the subbasin were not identified or prioritized. Also, recently a consortium of university scientists used a version of the EC90 layer and simplified

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[15] These were further differentiated as “Tier 1” and “Tier 2” areas. Tier 1 habitats are assumed to be managed for the purpose of achieving a naturally functioning landscape. Tier 2 habitats are habitats of comparatively lower habitat suitability (e.g., orchard, vineyard) set within a mosaic of more important habitats and assumed to be managed for sustainable production of goods and services compatible with more-limited conservation of habitat on site.

wildlife models to run scenarios involving alternative forest management practices in the Coast Range portion of the subbasin, and described likely net effects of each on species richness (Radosevich et al. 2004).

A key assessment activity of this subbasin plan was to identify the degree to which the priority areas from these two sources overlap (see the overlay in Appendix R).

- Approximately 60 percent of the area identified by The Nature Conservancy Ecoregional Assessment lies within the areas identified by the Consortium as Conservation and Restoration Opportunities. Conversely, approximately 13 percent of the area identified by the Consortium was identified by The Nature Conservancy (Table 3-197). The latter percentage is smaller mainly because The Nature Conservancy's Priority Conservation Areas were identified over a smaller region than were the Consortium's Opportunity Areas.

Table 3-197: Summary: Percent of ERC-identified Conservation and Restoration Opportunity Areas Included within TNC-identified Priority Conservation Areas

Feature	Acres Identified as PCA	Total Acres in Subbasin	Percent of Feature Identified as PCA
tier 1 oak	35210	55144	64
tier 1 prairie	24294	37870	64
tier 1 floodplain forest	39551	57638	69
tier 1 upland forest	4701	766765	1
tier 1 mid-elev forest	25930	53289	49
tier 1 forest rip prot zones	7630	496958	2
tier 1 wetlands	35661	87714	41
Willamette R. restored channels	39448	94846	42
SUBTOTAL Tier 1	(212,425)	(1,650,224)	(13)
tier 2 forests	42923	71388	60
tier 2 oak and prairie	11014	21450	51
tier 2 riparian protection zones	44443	743164	6
tier 2 wetland protection zones	15528	62563	25
SUBTOTAL Tier 2	(113,907)	(898,565)	(13)

Note: The PNW-ERC defined Tier 1 habitats as priority habitats managed for the purpose of achieving a naturally functioning landscape. Tier 2 habitats are habitats of comparatively lower habitat suitability (e.g., orchard, vineyard) set within a mosaic of more important habitats and managed for sustainable production of goods and services compatible with limited habitat conservation. Table compiled by Chris Robbins, Oregon Chapter of The Nature Conservancy.

- Overlap between PCAs and Tier-1 CROAs is greatest with regard to floodplain forest, oak woodland, and upland prairie. It is least with regard to upland forest and upland forest riparian areas (Table 3-197). This is largely due to the lowland ecoregional constraint of the TNC project. The degree of overlap between each PCA and CROA is depicted in Table 3 of Appendix D. This should be used in planning for conservation or restoration of specific sites.

Taken together, the PCAs and CROAs identified by previous projects appear to reasonably represent the best remaining habitat for the widest variety of species in the Willamette Subbasin

This report also examined the conservation effectiveness if only the Nature Conservancy's Priority Conservation Areas and public lands already protected from development are conserved or restored. Time and other constraints allowed quantified analysis of this question only with regard to the PCAs, not the CROAs or additional areas that might be prioritized for fish conservation and aquatic habitat restoration. It should be understood that the TNC and ERC assessments were never intended to capture all known occurrences or habitat of every species inhabiting the subbasin. In fact, the TNC assessment intentionally did not include a number of known occurrences of rare species within the boundaries of its PCAs where those occurrences were considered unlikely to be sustainable due to small local population size of the species, proximity to urban areas, and other factors. Nonetheless, this report examined the efficacy of the PCAs and public lands in order to identify explicitly the species and watersheds covered least-well by these areas, so future conservation and restoration activities can be extended to those when warranted. The analysis was based on two considerations:

1. To what degree are *actual occurrences* of EOR species being missed? Which species and watersheds have the highest incidence of omissions?

   To answer this, the EOR (element-of-occurrence records) database maintained by the Oregon Natural Heritage Information Center (ORNHIC) was queried. "EOR species" are ones tracked by ORNHIC because of their scarcity or vulnerability, and are within the scope of this report. It includes all federally-listed plant and wildlife species and some state-listed species. In the Willamette Subbasin a total of 35 are relevant to this terrestrial analysis. They include 9 amphibians, 3 reptiles, 14 birds, 4 mammals, 4 plants, and 1 butterfly. Caution is advised in interpreting results based on EOR data because the total number of records from the Willamette Subbasin in the EOR database, and consequently the number captured by the PCAs and public lands, depends largely on the extent of previous survey efforts for the species and the degree to which biologists contribute their observations of rare species to the ORNHIC, for many years now the official repository for such information in Oregon. Thus, the number of EORs is not necessarily a reliable indicator of a species' relative abundance or extent of its habitat.

   To answer this, the ERC species models were applied to ERC's "EC90" land cover layer using GIS, then ORNHIC species occurrence data were added where habitat did not predict occurrence, and final lists were generated of wildlife species both within and outside of the PCAs and public lands in each watershed. These lists were compared, and species that were predicted to occur only outside of the PCA+public land area were highlighted by watershed.

   The analysis showed that known occurrence of only one species – pallid bat – would fall completely outside of public lands and PCAs. That secretive species has been documented at only one location in the subbasin. Species with the smallest percentage of their documented breeding occurrences inside the combined area of the PCAs and the public lands are: mountain quail, Nelson's checkermallow, horned lark, western pond turtle, and vesper sparrow. These results suggest that special efforts should be made to enhance habitat for these species on private lands, and/or to extend PCA boundaries to include known locations. Among species, the median percentage of records incorporated within the PCA+public area is 70 percent, indicating the PCAs as drawn are fairly effective in capturing the EORs.

2. To what degree is possibly-suitable *habitat* of the 289 terrestrial species (and especially the 51 focal species) being missed? Which species and watersheds have the highest incidence of apparent omissions?

   Among the 104 watersheds that have PCAs, 92 watersheds have one or more EORs, for a total of 348 EORs. Of these EORs, half (49.7 percent) are from private lands not identified as PCAs. Based on exclusion of EORs, the watersheds where the need may be greatest to either enhance habitat on private land or extend PCA boundaries to include known locations are: 170900030302 (Brownsville), 170900030101 (W. Eugene; Junction City), 170900050601 (Jefferson; Lyons; Bear Branch), and 170900060103 (Waterloo; Sweet Home; McDowell Cr.). Efficacy in capturing the EORs was correlated somewhat with the proportion of the watershed comprised of PCAs and public lands.

   Considering the subbasin as a whole, the results show that the combination of PCAs plus public lands would include at least some amount of habitat for all wildlife and rare plant species. Taking a watershed-by-watershed approach, the results show that of the Willamette watersheds in which PCAs were identified, they would be adequate (when combined with public lands) to protect habitat of all species in the majority (53 percent) of watersheds.

A third question examined for this report is:

> *If conservation actions focus mainly on a limited set of focal species, which other species are most and least likely to benefit?*

The selection of 55 species (17 percent of the total) as "focal' was intentionally not based solely on their anticipated ability to serve either as "indicator" species (i.e., species most closely associated with the habitat type under which they are grouped) or "umbrella" species (i.e., species whose habitat requirements are broad enough to include those of many other species). Nonetheless, a need was identified to at least measure how well protection of habitat just for the focal species might address the requirements of other terrestrial wildlife species. This is important because:

- Restoration and preservation proposals are easier to support when it can be demonstrated that benefits will accrue to more than just a few target species whose habitat preferences overlap closely, i.e., inclusion of one species will "sweep" others;
- By identifying which species have the least overlap in their habitat preferences, one can identify which species need attention over-and-beyond that given to a particular target species. This allows for greatest efficiency in restoring or preserving complementary areas.

Determining the potential for overlap among any two species requires consideration of three primary factors:

1. the habitat types each associates with the most
2. the habitat structural conditions each associates with the most; and
3. overlap in the geographic/ elevation ranges of the species.

There is no “short answer” to the question posed above. Depending on species being compared, the maximum correlation between non-focal species and any focal species ranged 0.23 to 1.00 (median = 0.81) for habitat type and 0 to 1 (median = 0.76) for habitat structure. These relatively large and positive median correlations suggest a high likelihood that collectively speaking, protecting or restoring habitat for the focal species will tend to benefit many non-focal species as well.

A fourth question considered by this effort is:

> *If conservation actions focus mainly on just six focal habitat types and their associated species, which additional habitats are most necessary to address needs of other species?*

Largely by conducting a “sweep” analysis of the attribute data for species associated with the six focal habitats, we determined that protection or restoration of several additional habitat types will be required to adequately protect habitat for several other species. Table 30 of Appendix D shows species for which none of the six focal habitats provides ideally (or in some cases, any) suitable habitat.

The analysis conducted for this report shows there is great opportunity for conservation in the Willamette Basin for both terrestrial and aquatic habitats. Discussion in Section 5 of this report describes practical approaches to applying strategy to the opportunities in the Willamette.