Volume II, Chapter 13
Lewis River Subbasin—East Fork

TABLE OF CONTENTS

13.0 Lewis River Subbasin—East Fork

13.1 Subbasin Description

13.1.1 Topography & Geology

The East Fork Lewis River has its headwaters in Skamania County and flows generally west, with most of the basin lying within Clark County. It enters the mainstem (North Fork) Lewis at approximately river mile 3.5, about 4,000 feet downstream of the I-5 Bridge. The basin covers an area of approximately 150,635 acres (235 mi^2). The East Fork has its source near Green Lookout Mountain in the Gifford Pinchot National Forest. Elevation ranges from near sea level at the mouth to 4,442 feet. The headwaters are very steep, with narrow valleys, and are dominated by bedrock and boulder substrates. Copper Creek and upper Rock Creek are the two largest tributaries in the upper basin. Lucia Falls at RM 21.3 blocks passage of anadromous fish except steelhead and an occasional chinook and coho. Upstream migration for steelhead was essentially blocked at Sunset Falls (RM 32.7) until 1982 when the falls were notched, lowering the falls from 13.5 to 8 feet; approximately 12% of the steelhead run now spawns above Sunset Falls. Below Lucia Falls, the river flows through a narrow valley, forming a canyon in places, until it opens up around RM 14 into a broad alluvial valley. Stream gradient dramatically drops off within this reach causing large sediment aggradations. Extensive meandering, braiding, and channel shifting occurs in the lower river, particularly between RM 6 and RM 10. Backwater effects from the Columbia extend up to RM 6.

The East Fork Lewis basin has developed from volcanic, glacial, and erosional processes. Glaciation has shaped the valleys in upper portions of the basin as recently as 13,000 years ago. Oversteepened slopes as a result of glaciation, combined with the abundance of ash, pumice, and weathered pyroclastic material, have created a relatively high potential for surface erosion throughout the basin.

13.1.2 Climate

The climate is typified by mild, wet winters and warm, dry summers. Mean annual precipitation is 52 inches at Battle Ground, which is along the lower river (WRCC 2003). Precipitation in the upper basin is considerably greater. Although most of the basin is rainfall dominated, much of the upper basin receives abundant snowfall, with a significant portion of the upper basin in the rain-on-snow zone. The basin is subject to winter freshets and flooding.

13.1.3 Land Use/Land Cover

The bulk of the land is forested and a large percentage is managed as commercial forest. Agricultural and residential activities are found in valley bottom areas. Recreation uses and residential development have increased in recent years. The population in the basin was approximately 24,400 persons in 2000 (LCFRB 2001). Most of the land is private (63%), with about 20% of the basin area lying within the Gifford Pinchot National Forest. Stand replacement fires, which burned large portions of the basin between 1902 and 1952, have had lasting effects on basin hydrology, sediment transport, soil conditions, and riparian function. The largest of these fires was the Yacolt Burn in 1902. Subsequent fires followed in 1927 and 1929. Severe flooding in 1931 and 1934 likely was exacerbated by the effect of the fires on vegetation and soils. A breakdown of land ownership and land cover in the EF Lewis basin is presented in Figure 13-1 and Figure 13-2. Figure 13-3 displays the pattern of landownership for the basin. Figure 13-4 displays the pattern of land cover / land-use.

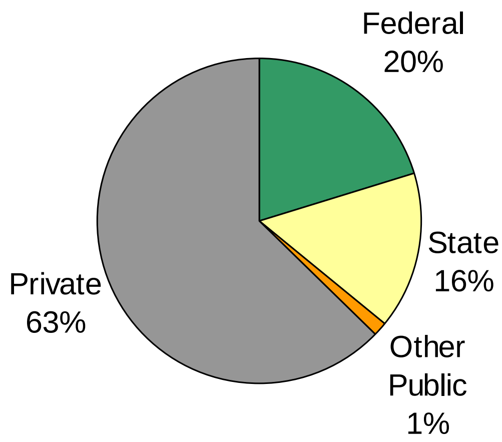


Figure 13-1. East Fork Lewis River basin land ownership

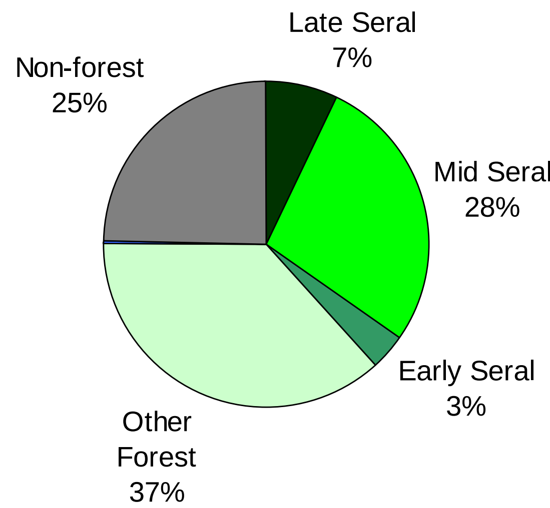


Figure 13-2. East Fork Lewis River basin land cover

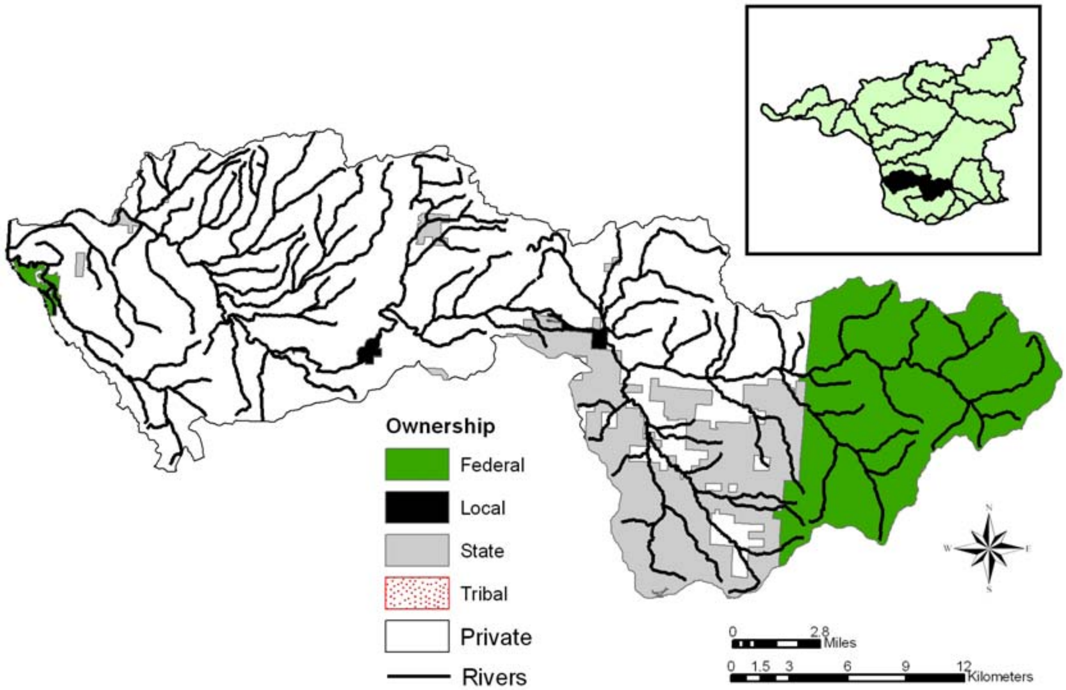


Figure 13-3. Landownership within the East Fork Lewis basin. Data is WDNR data that was obtained from the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

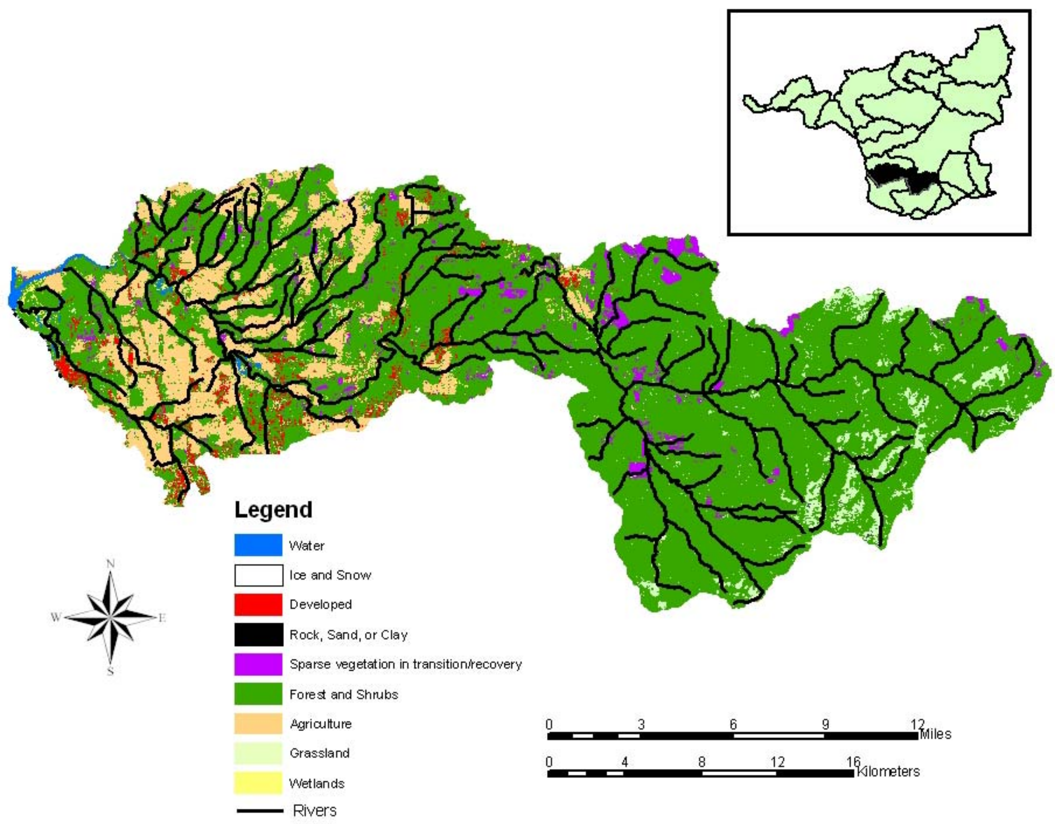
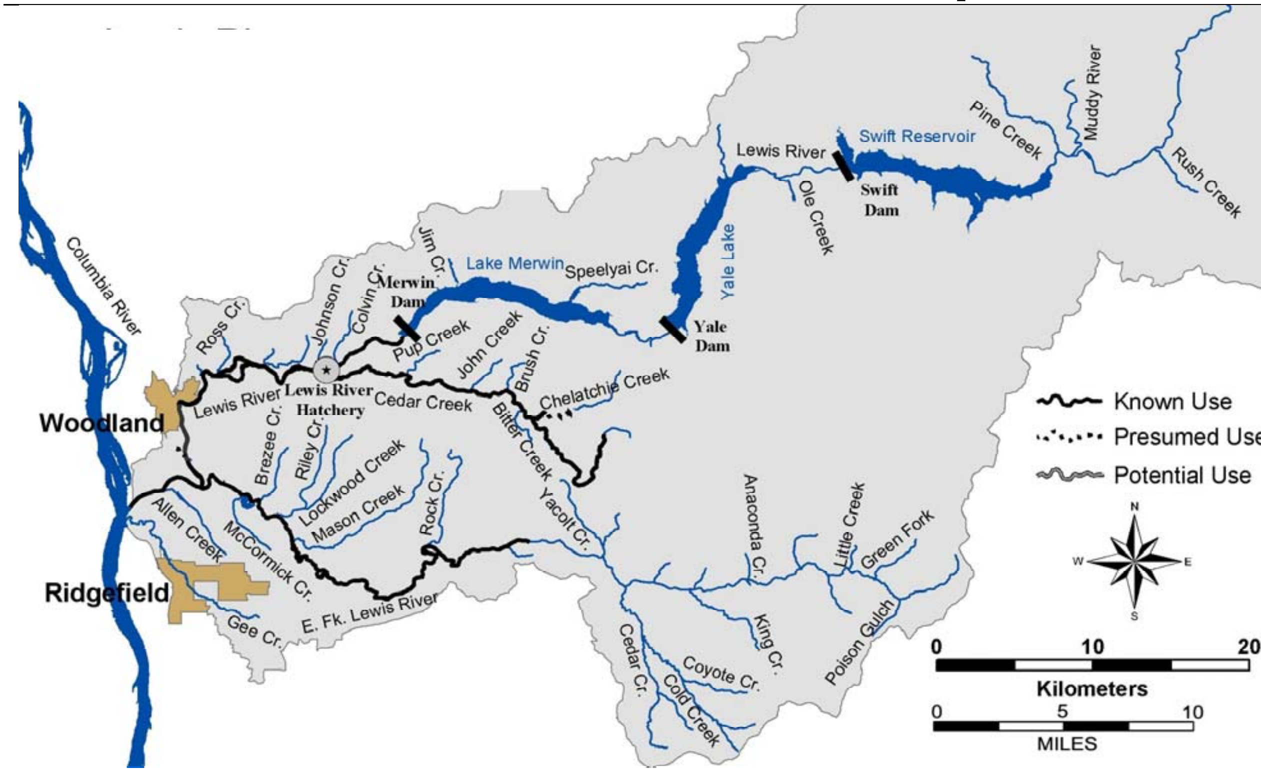


Figure 13-4. Land cover within the East Fork Lewis basin. Data was obtained from the USGS National Land Cover Dataset (NLCD).

13.2 Focal Fish Species

13.2.1 Fall Chinook—Lewis Subbasin (East Fork)

ESA: Threatened 1999	**SASSI: Depressed 2002**

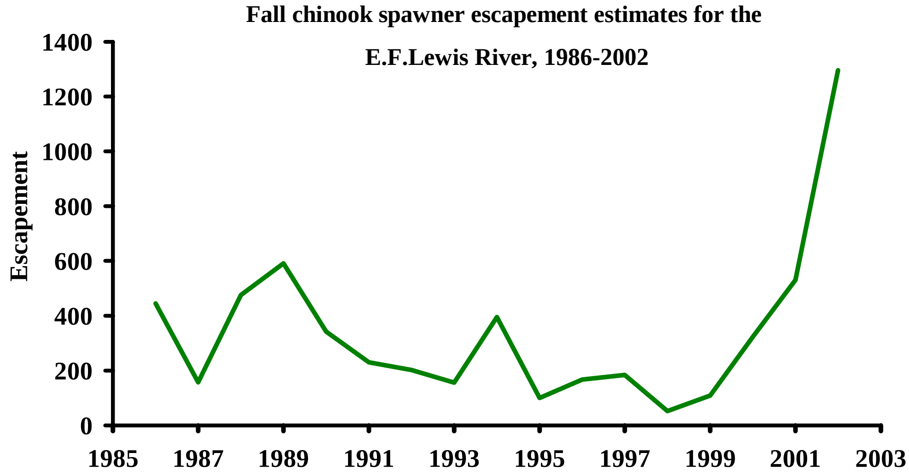


Diversity

- Late spawners in the North Fork and EF Lewis are considered a lower river wild stock within the lower Columbia River ESU
- Early spawners in the EF Lewis are considered lower Columbia tules
- The EF Lewis River fall chinook stock designated based on distinct spawning distribution and timing
- Genetic analysis of EF Lewis River fall chinook indicated they were genetically distinct from other lower Columbia River chinook stocks, except North Lewis River fall chinook

Life History

- Fall chinook enter the Lewis River from August to November, depending on early fall rain
- Natural spawning in the EF Lewis River occurs in two distinct segments: the early segment in October and the late segment from November through January
- Age ranges from 2-year-old jacks to 6-year-old adults, with dominant adult ages of 3, 4, and 5 (averages are 20.5%, 48.5%, and 22.7%, respectively)
- Fry emerge from March to August (peak usually in April), depending on time of egg deposition and water temperature; fall chinook fry spend the spring in fresh water, and emigrate in the summer as sub-yearlings



Distribution

- Spawning occurs primarily from Lewisville Park downstream to Daybreak Feeders (approx. 6 miles); the late spawning segment also spawns in areas upstream of Lewisville Park
- The EF Lewis late spawning fall chinook along with North Lewis and Sandy River late spawning fall chinook comprise the lower Columbia River wild management unit

Abundance

- Fall chinook escapement estimates by WDFW (1951) were about 4,000 into the EF Lewis River
- EF Lewis River spawning escapement from 1986-2001 ranged from 52 to 591 (average 279)

Productivity & Persistence

- NMFS Status Assessment for the EF Lewis River fall chinook indicated a 0.0 risk of 90% decline in 25 years, a 0.06 risk of 90% decline in 50 years, and a 0.0 risk of extinction in 50 years
- The EF Lewis early and late components of natural produced fall chinook have been sustained at low levels with minimal influence from hatchery fish

Hatchery

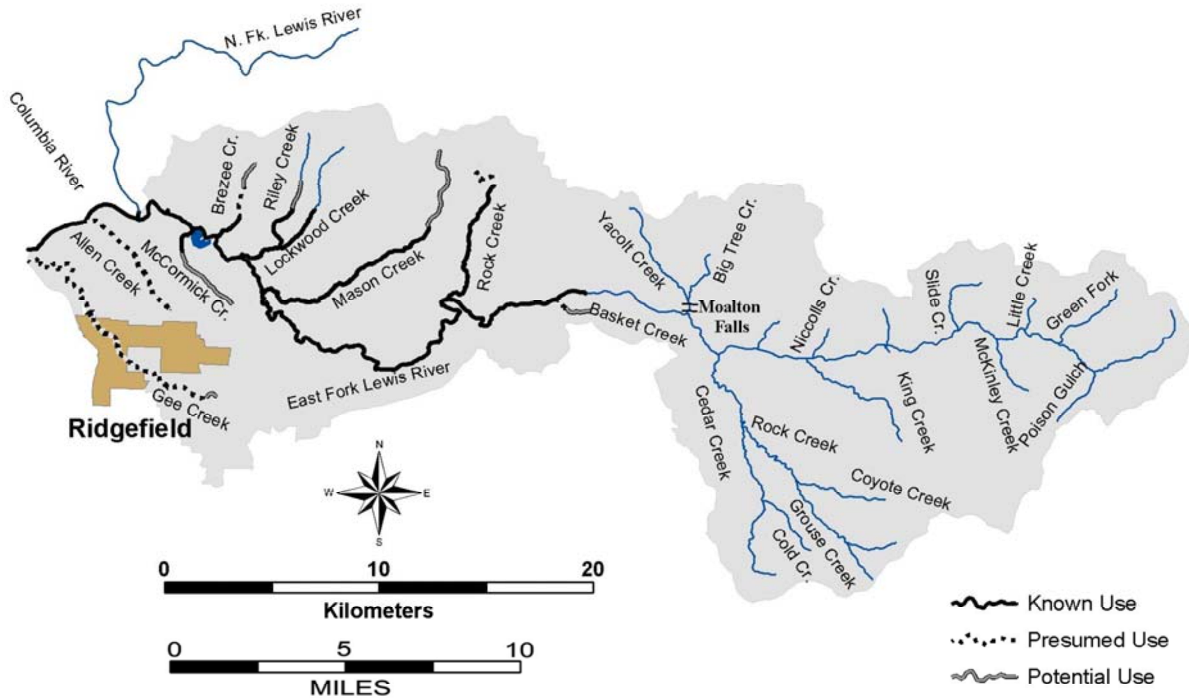
- There are no hatcheries on the EF Lewis River
- Hatchery fish have never been released into the East Fork; hatchery releases of fall chinook in the North Lewis began as early as 1909 and continued through 1985; there may have been some straying of North Lewis hatchery fish to the EF Lewis in past years

Harvest

- East Fork Lewis wild fall chinook are harvested in ocean commercial and recreational fisheries from Oregon to Alaska, and in Columbia River commercial and sport fisheries
- East Fork Lewis late spawning fall chinook migration patterns are likely similar to North Lewis fall chinook and more northerly distributed than other lower Columbia chinook populations, primarily along the coasts of British Columbia and Alaska
- East Fork Lewis early spawning fall chinook migration patterns are likely similar to lower Columbia tule populations, primarily along the coasts of Washington and Southern British Columbia
- Columbia River commercial and sport harvest of late East Fork Lewis fall chinook is constrained by ESA limits on Snake and Coweeman wild fall chinook and the North Lewis spawning escapement goal
- Using North Lewis wild fall chinook as a surrogate for late spawning East Fork Lewis chinook suggests a harvest rate of 49% in the 1980s to early 1990s and a reduced harvest rate of 28% in the mid to late 1990s
- The EF Lewis River is closed to sport fishing for fall chinook

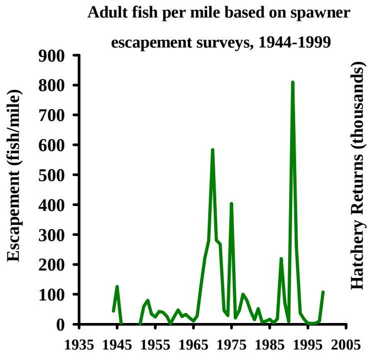
13.2.2 Coho—Lewis Subbasin (East Fork)

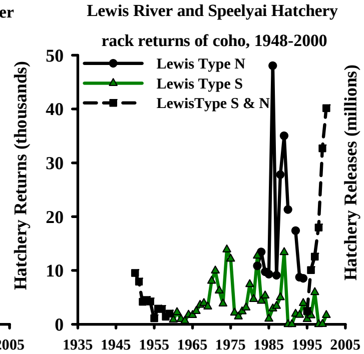
ESA: Candidate 1995	**SASSI: Unknown 2002**

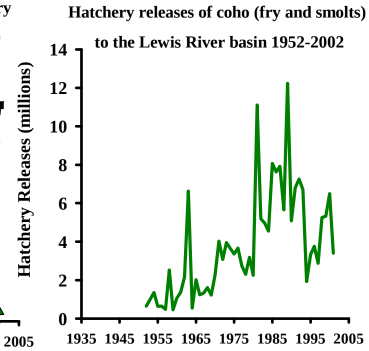


Distribution

- Managers refer to early coho as Type S due to their ocean distribution generally south of the Columbia River
- Managers refer to late coho as Type N due to their ocean distribution generally north of the Columbia River
- Coho historically spawned throughout the basin, including headwater tributaries now upstream of dams, such as Muddy River and Pine, Clearwater, and Clear Creeks
- Natural spawning is thought to occur in most areas accessible to coho; coho currently spawn in the North Lewis tributaries below Merwin Dam including Ross, Cedar, North and South Fork Chelatchie, Johnson, and Colvin Creeks; Cedar Creek is the most utilized stream on the mainstem
- On the East Fork, spawning occurs primarily below Lucia Falls (RM 21); Lockwood, Mason, and Rock Creeks are extensively used
- Construction of Merwin Dam was completed in 1932; coho adults were trapped and passed above Merwin Dam from 1932-1957; the transportation of coho ended after the completion of Yale Dam (1953) and just prior to completion of Swift Dam (1959)
- As part of the current hydro re-licensing process, reintroduction of coho into habitat upstream of the three dams (Merwin, Yale, and Swift) is being evaluated







Life History

- Adults enter the Columbia River from August through January (early stock primarily from mid-August through September and late stock primarily from late September through November)
- Peak spawning occurs in late October for early stock and December to early January for late stock
- Adults return as 2-year-old jacks (age 1.1) or 3-year-old adults (age 1.2)
- Fry emerge in the spring, spend one year in fresh water, and emigrate as age-1 smolts the following spring

Diversity

- Late stock coho (or Type N) were historically present in the Lewis basin with spawning occurring from late November into March
- Early stock coho (or Type S) were historically present in the Lewis basin with spawning occurring from late October to November
- Columbia River early and late stock coho produced at Washington hatcheries are genetically similar

Abundance

- Lewis River wild coho run is a fraction of its historical size
- An escapement survey in the late 1930s observed 7,919 coho in the North Fork and 1,166 coho in the East Fork
- In 1951, WDF estimated coho escapement to the basin was 15,000 fish; 10,000 in the North Fork (primarily early run) and 5,000 in the East Fork (primarily late run)
- Escapement surveys from 1944-1999 on the North and South Fork Chelatchie, Johnson, and Cedar Creeks documented a range of 1-584 fish/mile
- Hatchery production accounts for most coho returning to the Lewis River

Productivity & Persistence

- Natural coho production is presumed to be generally low in most tributaries
- Juvenile sampling in Lockwood Creek in 1994-95 found a low level of coho
- A smolt trap at lower Cedar Creek has shown recent year coho production to be fair to good in North and South forks of Chelatchie Creek (tributary of Cedar Creek) and in mainstem Cedar Creek
- Hatchery coho adults released above Swift Reservoir successfully spawned in upper basin tributaries

Hatchery

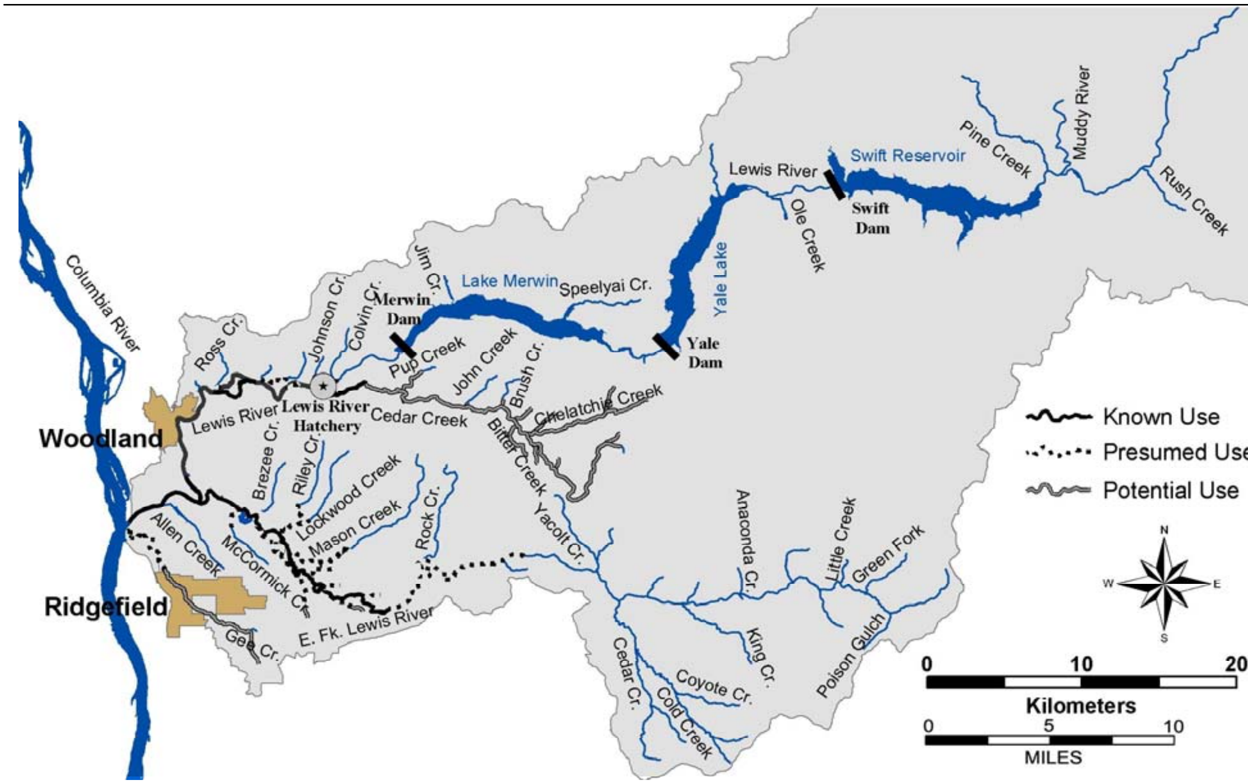
- The Lewis River Hatchery (completed in 1932) is located about RM 13; the Merwin Dam collection facility (completed in 1932) is located about RM 17; Speelyai Hatchery (completed in 1958) is located in Merwin Reservoir at Speelyai Bay; these hatcheries produce early and late stock coho and spring chinook
- Merwin Hatchery (completed in 1983) is located at RM 17 and rears steelhead, trout, and kokanee
- Coho have been planted in the Lewis basin since 1930; extensive hatchery coho releases have occurred since 1967
- The current Lewis and Speelyai hatchery programs include 880,000 early coho and 815,000 late coho smolts reared and released annually

Harvest

- Until recent years, natural produced Columbia River coho were managed like hatchery fish and subjected to similar harvest rates; ocean and Columbia River combined harvest rates ranged from 70% to over 90% from 1970-83
- Ocean fisheries were reduced in the mid 1980s to protect several Puget Sound and Washington coastal wild coho populations
- Columbia River commercial coho fisheries in November were eliminated in the 1990s to reduce harvest of late Clackamas River wild coho
- Since 1999, Columbia River hatchery coho returns have been mass marked with an adipose fin clip to enable fisheries to selectively harvest hatchery coho and release wild coho
- Natural produced lower Columbia coho are beneficiaries of harvest limits aimed at Federal ESA listed Oregon Coastal coho and Oregon State listed Clackamas and Sandy River coho
- During 1999-2002, fisheries harvest of ESA listed coho was less than 15% each year
- Hatchery coho can contribute significantly to the lower Columbia River gill net fishery; commercial harvest of early coho is constrained by fall chinook and Sandy River coho management; commercial harvest of late coho is focused in October during the peak abundance of hatchery late coho
- A substantial estuary sport fishery exists between Buoy 10 and the Astoria-Megler Bridge; majority of the catch is early hatchery coho, but late hatchery coho harvest can also be substantial
- An average of 3,500 coho (1980-98) were harvested annually in the North Lewis River sport fishery
- An average of 40 coho (1982-1989) were harvested annually in the EF Lewis sport fishery
- CWT data analysis of the 1995-97 brood early coho released from Lewis River hatchery indicates 15% were captured in a fishery and 85% were accounted for in escapement
- CWT data analysis of the 1995-97 late coho released from Lewis River Hatchery indicates 42% were captured in a fishery and 58% were accounted for in escapement
- Fishery CWT recoveries of 1995-97 brood Lewis early coho were distributed between Washington ocean (58%), Columbia River (21%), and Oregon ocean (21%) sampling areas
- Fishery CWT recoveries of 1995-97 brood Lewis late coho were distributed between Columbia River (56%), Washington coast (31%), and Oregon ocean (21%) sampling areas

13.2.3 Chum—Lewis Subbasin

ESA: Threatened 1999 **SASSI: NA**



Distribution

- Spawning occurs in the lower reaches of the mainstem NF and EF Lewis River.
- Historically, chum salmon were common in the lower Lewis and were reported to ascent to the mainstem above the Merwin Dam site and spawn in the reservoir area
- Chum were also abundant in Cedar Creek, with at least 1,000 annual spawners (Smoker et al 1951)

Life History

- Lower Columbia River chum salmon run from mid-October through November; peak spawner abundance occurs in late November
- Dominant age classes of adults are age 3 and 4
- Fry emerge in early spring; chum emigrate as age-0 smolts, generally from March to mid-May

Abundance

- 1951 report estimated escapement of approximately 3,000 chum annually in the mainstem Lewis and East Fork and 1,000 in Cedar Creek
- 96 chum observed spawning downstream of Merwin Dam in 1955
- In 1973, spawning population of both the Lewis and Kalama subbasins estimated at only a few hundred fish
- Annually, 3-4 adult chum are captured at the Merwin Dam fish trap

Productivity & Persistence

- Harvest, habitat degradation, and construction of Merwin, Yale, and Swift Dams contributed to decreased productivity
- WDFW consistently observed chum production in the North Lewis in March-May, 1977-1979 during wild chinook seining operations

Hatchery

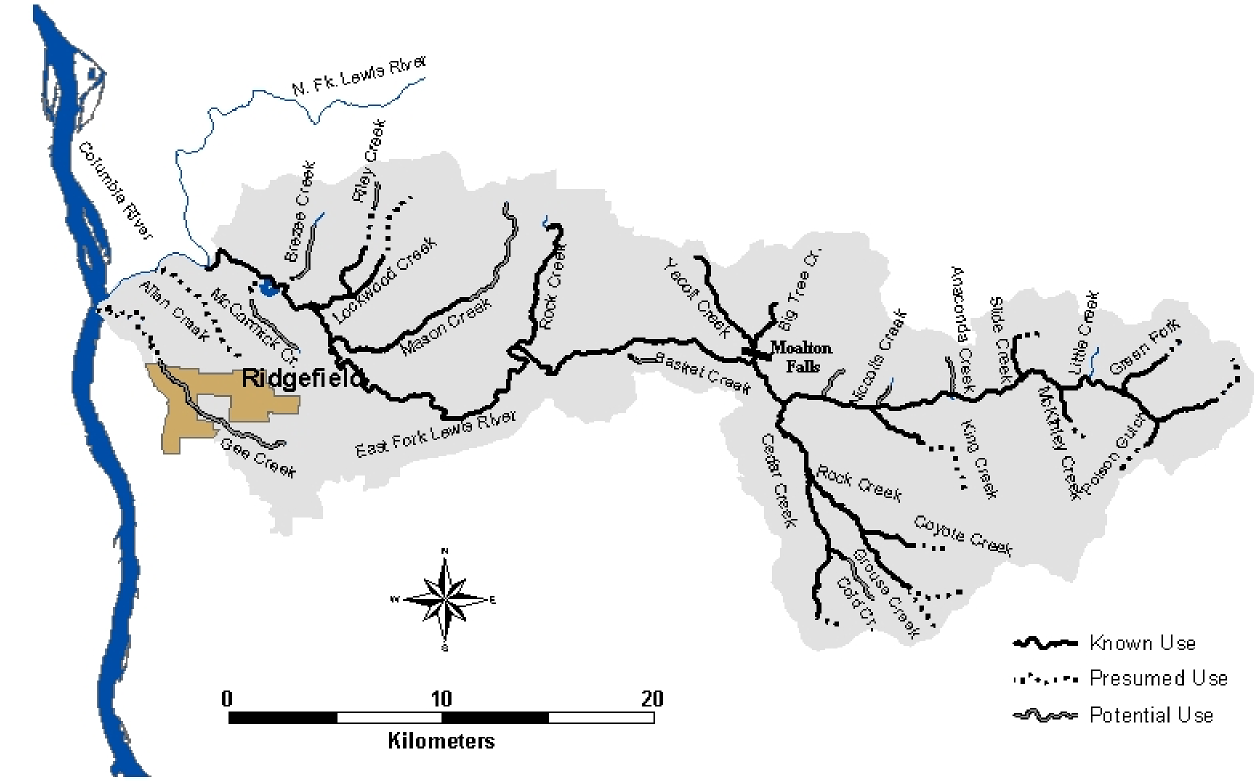
- Chum salmon have not been produced/released in the Lewis River

Harvest

- Currently very limited chum harvest occurs in the ocean and Columbia River and is incidental to fisheries directed at other species
- Columbia River commercial fishery historically harvested chum salmon in large numbers (80,000 to 650,000 in years prior to 1943); from 1965-1992 landings averaged less than 2,000 chum, and since 1993 less than 100 chum
- In the 1990s November commercial fisheries were curtailed and retention of chum was prohibited in Columbia River sport fisheries
- The ESA limits incidental harvest of Columbia River chum to less than 5% of the annual return

13.2.4 Summer Steelhead—Lewis Subbasin (East Fork)

ESA: Threatened 1998	SASSI: Unknown 2002

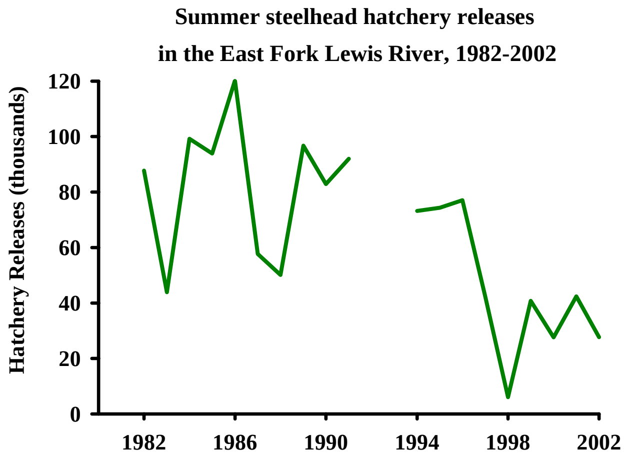


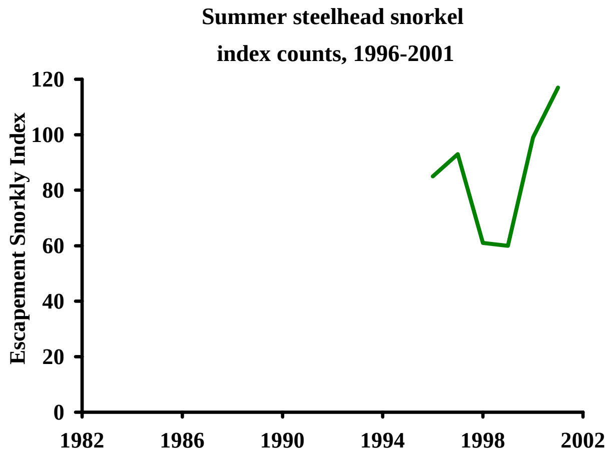
Distribution

- Spawning occurs in the EF Lewis River as well as Rock Creek and other tributaries; rearing habitat is available throughout most of the basin
- Upstream migration was essentially blocked at Sunset Falls until 1982 when the falls were “notched”, lowering the falls from 13.5 to 8 feet; approximately 12% of the run now spawns above Sunset Falls

Life History

- Adult migration timing for EF Lewis River summer steelhead is from May through November
- Spawning timing on the EF Lewis River is generally from early March through early June
- Age composition data are not available for EF Lewis River summer steelhead
- Wild steelhead fry emerge from late April through July; juveniles generally rear in fresh water for two years; juvenile emigration occurs from March to May, with peak migration in early May





Diversity

- Stock designated based on distinct spawning distribution and early run timing
- Progeny from Elochoman, Chambers Creek, Cowlitz, and Skamania Hatcheries have been planted in the Lewis basin; interbreeding among wild and hatchery stocks has not been measured
- After Mt. St. Helens 1980 eruption, straying Cowlitz River steelhead may have spawned with native Lewis stocks
- Genetic analysis in 1996 provided little information in determining stock distinctiveness

Abundance

- From 1925-1933, run size was estimated at 4,000 summer steelhead
- In 1936, steelhead were reported in the Lewis River during escapement surveys
- From 1963-1967, run size estimates averaged 6,500 summer steelhead
- Wild summer steelhead escapement to the EF Lewis River was estimated at 600 fish in 1984
- Average wild summer steelhead escapement to the EF Lewis River from 1991-1996 was 851
- Snorkel index escapement surveys have been conducted since 1996
- The escapement goal for the EF Lewis River is 814 wild adults

Productivity & Persistence

- Wild fish production is believed to be moderate

Hatchery

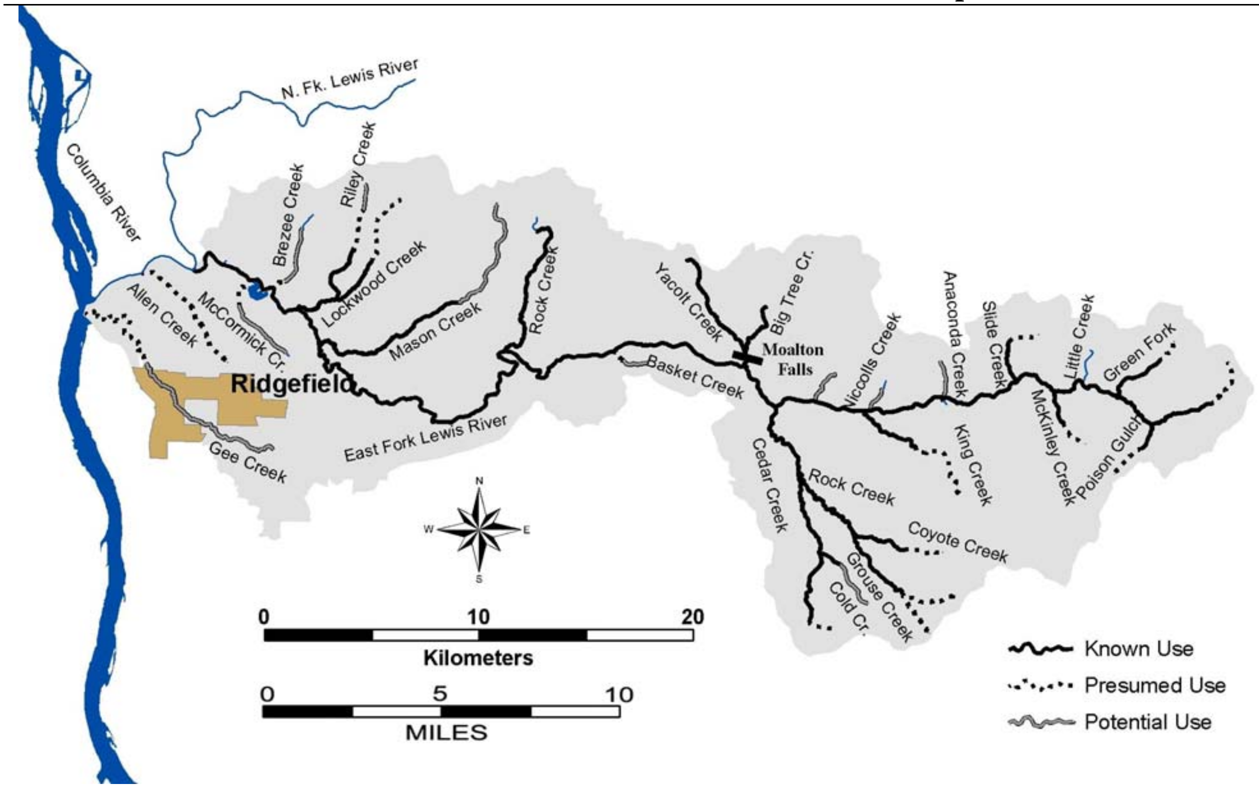
- The Lewis River Hatchery (about 4 miles downstream of Merwin Dam) and Speelyai Hatchery (Speelyai Creek in Merwin Reservoir) do not produce summer steelhead
- A net pen system has been in operation on Merwin Reservoir since 1979; annual average smolt production has been 60,000 summer steelhead; release data are available from 1982-2002; current annual stocking levels in the East Fork are around 40,000 smolts
- The portion of wild summer steelhead in the run at Lucia Falls averaged 27% from 1974-1983
- Recent snorkel surveys indicate hatchery summer steelhead comprise about 70% of the spawning escapement on the EF Lewis River

Harvest

- No directed fisheries target EF Lewis River summer steelhead; incidental mortality currently occurs during the Columbia River fall commercial fisheries and summer sport fisheries
- Summer steelhead sport harvest (wild and hatchery) in the Lewis River basin from 1980-1989 ranged from 3,001 to 8,700; historically, more fish in the sport fishery were caught in the East Fork but currently North Fork harvest exceed East Fork harvest; since 1986, regulations limit harvest to hatchery fish only
- ESA limits fishery impact on wild EF Lewis summer steelhead in the mainstem Columbia River and in the EF Lewis River

13.2.5 Winter Steelhead—Lewis Subbasin (East Fork)

ESA: Threatened 1998 **SASSI: Depressed 2002**

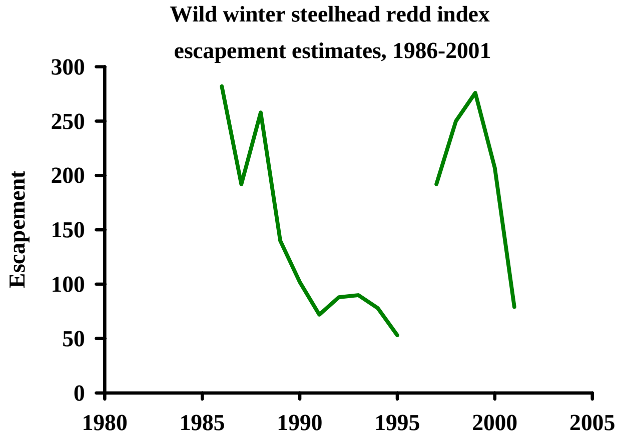


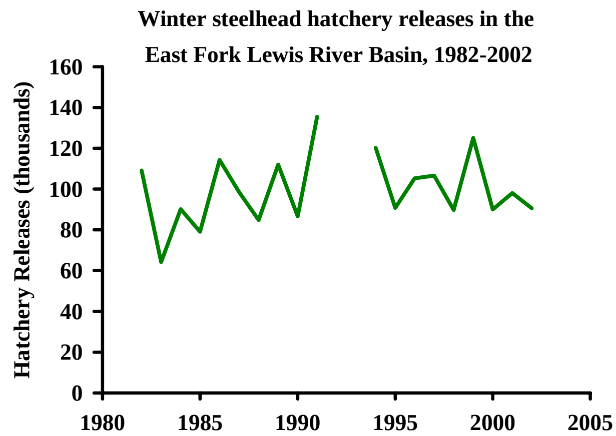
Distribution

- Spawning occurs in the EF Lewis River as well as Rock Creek and other tributaries; rearing habitat is available throughout most of the basin
- Upstream migration was essentially blocked at Sunset Falls until 1982 when the falls were "notched", lowering the falls from 13.5 to 8 feet; approximately 12% of the run now spawns above Sunset Falls

Life History

- Adult migration timing for EF Lewis winter steelhead is from December through April
- Spawning timing on the EF Lewis is generally from early March to early June
- Limited age composition data for Lewis River winter steelhead suggest that most steelhead are two-ocean fish
- Wild steelhead fry emerge from March through May; juveniles generally rear in fresh water for two years; juvenile emigration occurs from April to May, with peak migration in early May





Diversity

- EF Lewis winter steelhead stock designated based on distinct spawning distribution and late run timing
- Concern with wild stock interbreeding with hatchery brood stock from the Elochoman River, Chambers Creek, and the Cowlitz River
- After 1980 Mt. St. Helens eruption, straying Cowlitz River steelhead likely spawned with native Lewis stocks
- Allele frequency analysis of EF Lewis winter steelhead in 1996 was unable to determine the distinctiveness of the stock compared to other lower Columbia River steelhead stocks

Abundance

- In 1936, steelhead were reported in the Lewis River during escapement surveys
- Historical winter steelhead annual escapement in the Lewis River ranged from 1,000 to 11,000 fish
- Redd index escapement counts from 1986-2001 ranged from 53 to 282 (average 157); a new escapement index was instituted in 1997 and the relationship to the previous index is unknown
- Escapement goal for the EF Lewis River is 875 wild adult steelhead
- The portion of wild winter steelhead at Lucia Falls found in the creel ranged from 35% to 74% from 1974-1983
- Recent data suggests that 51% of spawning steelhead in the East Fork are of hatchery origin

Productivity & Persistence

- NMFS Status Assessment for the EF Lewis River winter steelhead predicted a risk of 1.0 for the risk of 90% decline in both 25 and 50 years; the risk of extinction in 50 years was not applicable
- Winter steelhead natural production is unknown

Hatchery

- There are no hatcheries on the EF Lewis River
- The Ariel (Merwin) Hatchery is located below Merwin Dam the NF Lewis River; the hatchery has been releasing winter steelhead in the Lewis basin since the early 1990s, but does not release steelhead in the EF Lewis

- Annual winter steelhead hatchery smolt releases into the EF Lewis during 1982-2002 have ranged from about 60,000—140,000
- Currently program releases about 90,000 winter steelhead smolts from Skamania Hatchery into the EF Lewis. Hatchery program has changed acclimation sites to the lower East Fork to reduce hatchery/wild interactions in the upper watershed

Harvest

- No directed commercial or tribal fisheries target EF Lewis winter steelhead; incidental harvest currently occurs during the lower Columbia River spring chinook tangle net fisheries
- Treaty Indian harvest does not occur in the Lewis River basin
- Winter steelhead sport harvest (hatchery and wild) in the Lewis River from 1980-1990 ranged from 2,245 to 6,766 (average 4,385); the portion of this harvest from the East Fork is unknown; since 1992, regulations limit harvest to hatchery fish only
- ESA limits fishery impact on wild winter steelhead in the mainstem Columbia River and in the EF Lewis River

13.3 Potentially Manageable Impacts

In Volume I of this Technical Foundation, we evaluated factors currently limiting Washington lower Columbia River salmon and steelhead populations based on a simple index of potentially manageable impacts. The index incorporated human-caused increases in fish mortality, changes in habitat capacity, and other natural factors of interest (e.g. predation) that might be managed to affect salmon productivity and numbers. The index was intended to inventory key factors and place them in perspective relative to each other, thereby providing general guidance for technical and policy level recovery decisions. In popular parlance, the factors for salmon declines have come to be known as the 4-H's: hydropower, habitat, harvest, and hatcheries. The index of potentially manageable mortality factors has been presented here to prioritize impacts within each subbasin.

- Loss of habitat quantity and quality has the highest relative impact on populations in the EF Lewis.
- Loss of estuary habitat quantity and quality has high relative impacts on chum and moderate impacts on fall chinook and winter steelhead. Impacts to summer steelhead are minor.
- Harvest has relatively high impacts on fall chinook, but impacts to chum, steelhead, and coho are relatively minor.
- Hatchery impacts are high to moderate for summer steelhead and coho, but are low for chum, fall chinook, and winter steelhead.
- Impacts of predation are moderately important to winter and summer steelhead, coho and chum, but are relatively minor for fall chinook.

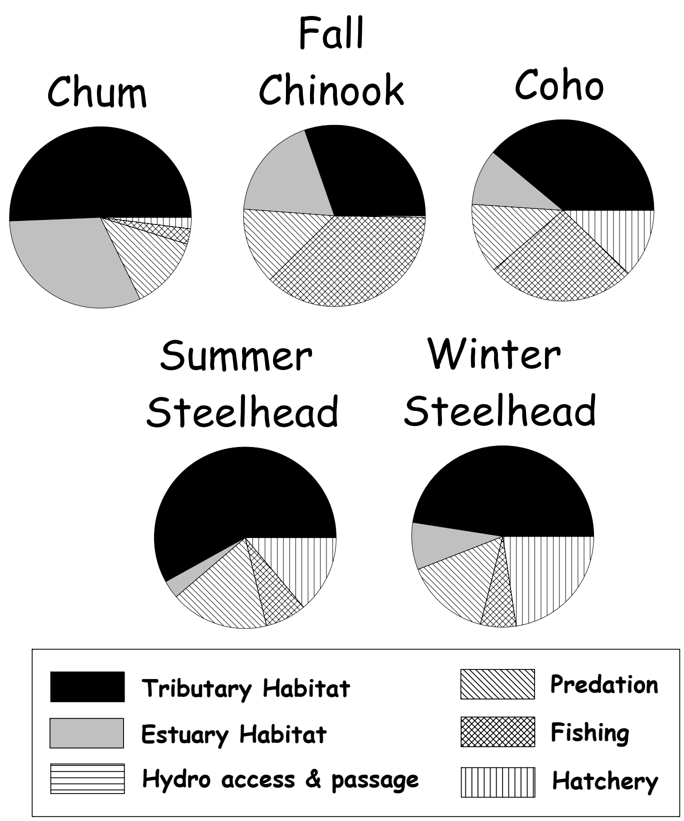


Figure 13-5. Relative index of potentially manageable mortality factors for each species in the East Fork Lewis subbasin.

13.4 Hatchery Programs

Please see Vol II, Chapter 11 for a dicussion of the hatcheries in the Lewis basin.

13.5 Fish Habitat Conditions

13.5.1 Passage Obstructions

No artificial barriers exist on the mainstem of the East Fork Lewis. Lucia Falls at RM 21.3 is believed to block access to anadromous species except for steelhead and an occasional coho. Sunset Falls at RM 32.7 was notched in 1982, allowing for easier passage of this natural feature. Artificial passage obstructions within the watershed include culverts, road crossings, and small dams. More than 10 miles of habitat are believed to be blocked by these obstructions (see Wade 2000 for more details).

13.5.2 Stream Flow

The EF Lewis River watershed is primarily a low to mid-elevation, rain dominated system with extensive rain-on-snow conditions present in the upper reaches. Peak stream flows are generated by fall, winter, and spring rains with flows augmented by snowmelt in the spring and early summer (Figure 13-6).

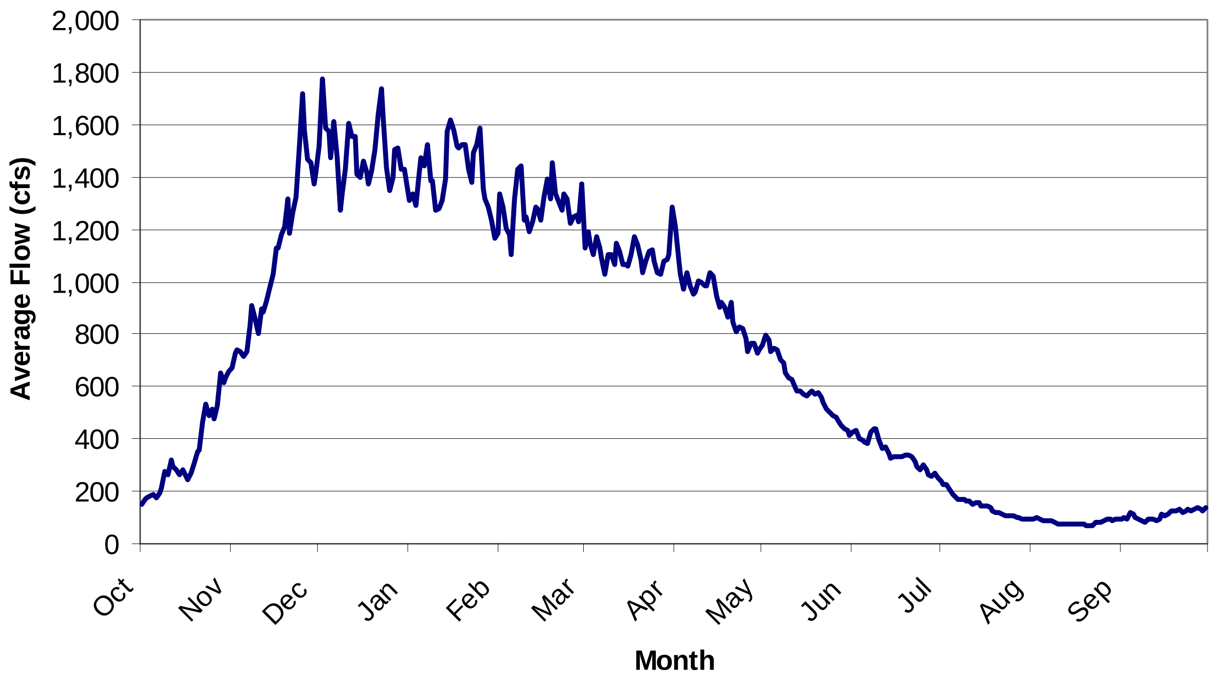


Figure 13-6. Daily average stream flow for the period 1929-2002. USGS Gage #14222500; East Fork Lewis River Near Heisson, WA.

The potential exists for impaired runoff conditions in certain areas due to past fires, the presence of young forest stands, high road densities, and impervious surfaces. The Integrated Watershed Assessment (IWA), which is presented in greater detail later in this chapter, indicates that 18 of the 36 subwatersheds (7^{th} field) in the basin are "impaired" with respect to landscape conditions influencing runoff; 14 are rated as "moderately impaired"; and only 4 are considered "functional". The greatest impairments are located in the lower and middle elevation subwatersheds. These subwatersheds are primarily private agricultural, residential, or commercial forest. Runoff conditions improve in the upper watershed, which is predominantly composed of public forest land. In the uppermost, federally managed, portion of the basin, the USFS conducted a peak flow analysis that modeled the effect of vegetation removal on the 2-year peak flow. The Slide Creek, Rock Creek (upper), and Copper Creek basins show susceptibility to flow increases of greater than 10%. These basins show "moderately impaired" conditions according to the IWA. The USFS assessment also indicated that many basins have a significant increase in the length of the channel network due to roads and road ditches, which can also increase peak flows (USFS 1995).

DOE conducted an instream flow study on the EF Lewis and 13 tributaries. The Instream Flow Incremental Methodology (IFIM) was used to model flow-habitat conditions on the mainstem while the toe-width method was used to assess flow-habitat conditions on tributaries. The IFIM results revealed that flows at certain times of the year may be below optimal for fish at various life history stages. Flows for chinook spawning, which starts in October, were only 25% of the optimal flow in October but reached 80% of the optimal flow by November 1. Flows necessary for chinook and steelhead juvenile rearing were only about 30% of optimum in August and September (Caldwell 1999).

Comparing spot flow measurements with flow requirements determined from the Toe-Width method revealed that spawning and rearing habitat was limited for most species in McCormick, Brezee, Lockwood, Mason, and Yacolt Creeks during the fall of 1998. The results in Rock creek suggested insufficient flows for fall spawning but optimum fall rearing conditions (Caldwell 1999).

Based on predictions of future population growth in the basin, total water use is estimated to increase from 10% (2000) to 20% (2020) of late summer flow, assuming full hydraulic continuity between ground water and stream flow. The watershed is near closure for surface water rights and for some existing surface water rights, low flow restrictions are in place in order to protect aquatic biota (LCFRB 2001). The potential for ground and/or surface water withdrawal impacts to salmonids needs further investigation.

13.5.3 Water Quality

The mainstem from the mouth to RM 24.6 was listed on the 1998 WA state 303(d) list of impaired waterbodies due to exceedance of temperature and fecal coliform standards (WDOE 1998). Stream temperatures in the mainstem East Fork commonly exceed the 64°F (18°C) state standard, and occasionally exceed 73.4ºF (23ºC), at locations from Daybreak Park down. In the Ridgefield gravel pits (RM 8), which the stream avulsed into in 1996, temperatures may be warming as a result of large water surface areas within the former gravel pits. Temperature effects in this reach are of particular concern for salmonids (Sweet et al. 2003). USFS monitoring has showed exceedances of the 60.8ºF (16ºC) standard on the mainstem East Fork above and below Sunset Falls as well as on the Green Fork (Wade 2000).

Stream temperatures are also a concern in McCormick Creek, Lockwood Creek and lower Dean Creek. Temperatures in excess of 82.4ºF (28ºC) in lower Dean Creek have been recorded near the outlet of the J.L. Storedahl & Sons - Daybreak gravel mining pits, and conditions are believed to be generally unsuitable for salmonids during the summer (Sweet et al. 2003).

Turbidity is also a concern in portions of the basin. In lower Dean Creek, turbid water has been discharged from the gravel processing ponds owned by J. L. Storedahl and Sons. Measurements associated with the evaluation of a new effluent treatment system, which was implemented in 1999, showed considerable improvements in turbidity levels from pre-project measurements. Recent data from the mainstem East Fork Lewis shows no significant difference in fines between the first riffle above and the first riffle below the Dean Creek confluence (Sweet et al. 2003). Limiting Factors Analysis TAG members noticed turbidity problems in Cedar Creek, potentially from wastewater releases from Larch Mountain Corrections Facility and roads leading to the facility (Wade 2000). An unnamed tributary to the East Fork Lewis, sometimes referred to as Manley Road Creek, has turbidity problems resulting from Teboe processing/mining operations (Donna Hale, personal communication).

Turbidity measurements in lower Rock Creek exceeded state standards in 30% of the samples. Fecal coliform standards were exceeded in 55% of samples and D.O. standards were exceeded 10% of the time. These water quality problems may be due to farming operations (Hutton 1995 as cited in Wade 2000).

Low nutrient levels are assumed to exist in the East Fork Lewis basin due to the lack of sufficient salmonid carcasses as a result of low escapement numbers for most species. However, nutrient enhancement projects have planted numerous carcasses into tributary streams over the past several years (Wade 2000).

13.5.4 Key Habitat

In the lower mainstem, pool abundance and quality are concerns between RM 6 and RM 16.2, partly as a result of the 1996 avulsion of the mainstem into the Ridgfield Pits near RM 8. This avulsion resulted in the abandonment of approximately 3,200 lineal feet of riffle habitat (used primarily for spawning) in exchange for low velocity pool habitat (used primarily for rearing). Portions of the upstream end of the avulsed reach are slowly converting to riffle habitat as the pools fill with coarse sediments (Sweet et al. 2003).

As part of the 2000 Limiting Factors Analysis, the TAG expressed concerns with the availability of suitable pool habitat on the mainstem between lower Rock Creek (RM 16.2) and Sunset Falls (RM 32.7).

USFS surveys in the upper basin, conducted as part of the 1995 watershed analysis, identified substandard pool frequency in approximately 58% of surveyed streams (USFS 1995). Pools suitable for summer steelhead holding exist on the upper mainstem below the Green Fork confluence, though many of these lack adequate cover. Good holding pools are rare on Slide, Green Fork, and the mainstem above Green Fork (USFS 1999).

Historically available side channel habitat has been reduced in the lower river due to draining of wetlands for agricultural uses and conversion to a single thread channel as a result of channel confinement projects (Sweet et al. 2003). Off-channel habitat in the upper basin is sparse and is only accessible during the highest flows (USFS 1999).

13.5.5 Substrate & Sediment

A large portion of sediment delivery in the lower river is from in-channel bed and bank erosion related to channel migration and avulsions. Analysis of historical aerial photos indicates that movement of the channel is a natural process in the lower mainstem alluvial reaches; however, between RM 7 and RM 10, natural rates of channel adjustment have been influenced by the presence of stream-adjacent gravel pits, which have captured the mainstem in a few locations within the past 10 years. These avulsions have altered rates of sediment generation and accumulation. The most notable avulsion occurred near RM 8 in November, 1996, when the mainstem was captured by the abandoned gravel ponds known as the Ridgefield Pits. This avulsion alone abandoned approximately 3,200 feet of riffle habitat. The previous riffle habitat was replaced by pools that are rapidly filling with sediment. In the Ridgefield Pit reach, the former gravel ponds have been filling with fine sediments that are believed to originate primarily from a high sandy bank just upstream of the avulsed reach. In some areas, riffle habitat suitable for spawning is being re-created as the pools fill. Sediment sampling downstream of the Ridgefield Pits in 2001 indicated that fine sediment volumes were less than 10% (Sweet et al. 2003).

Basin-wide sediment supply conditions were evaluated as part of the IWA watershed process modeling, which is presented later in this chapter. The results indicate that 28 out of the 36 subwatersheds in the basin are "moderately impaired" with respect to conditions that influence sediment supply. The remainder of the basin was rated as "functional" with respect to sediment supply. Most of the functional subwatersheds were concentrated in the Rock Creek basin (Upper). Sediment supply impairment is related to a number of factors, including primarily naturally unstable slopes and high road densities. The total road density in the basin is 4.13 mi/mi2 (greater then 3 mi/mi2 is considered high by most standards). The upper watershed, dominated by National Forest lands, has a relatively low overall road density of 1.79 mi/mi2. The USFS Watershed Analysis reports an estimated sediment yield due to roads of 400 tons/mi2/year, with 3 out of 23 of the subbasins in the upper watershed (portion primarily in National Forest) having high rates of surface erosion from roads (USFS 1995).

Despite the effects of roads, the Pacific Watershed Institute completed a sediment budget for the upper watershed and determined that the sediment supply is limited, primarily due to most available material having already eroded following early 20th century fires. The lack of supply of gravels may limit spawning habitat in the upper basin. Furthermore, low large woody debris (LWD) concentrations combined with the steep gradient and confinement of most upper basin channels probably results in transport of most gravels out of the upper basin (USFS 1999).

Sediment production from private forest roads is expected to decline over the next 15 years as roads are updated to meet the new forest practices standards, which include ditchline disconnect from streams and culvert upgrades. The frequency of mass wasting events should also decline due to the new regulations, which require geotechnical review and mitigation measures to minimize the impact of forest practices activities on unstable slopes.

13.5.6 Woody Debris

LWD recruitment potential is of concern throughout the basin due to past forest fire impacts and harvest of riparian areas. A 1995 aerial photo analysis conducted by the USFS noted that 87% of riparian stands in the upper basin had either young, sparse hardwood stands or were burned in the early part of the century and now contained mature, dense hardwoods, with low to moderate potential for LWD recruitment (USFS 1995). In-stream LWD levels are very low also as a result of salvage logging following large fires in the early 20th century and from removal of log jams in the 1980s that were incorrectly assumed to be fish passage barriers (USFS 1999).

USFS stream surveys in the 1990s found that 92% of the surveyed streams had less than 40 pieces per mile (a poor rating), and at least 98% of the streams surveyed had concentrations of LWD less than 80 pieces per mile (USFS 1995). Limiting Factors Analysis TAG members felt that overall, LWD concentrations in the lower basin were low (Wade 2000).

13.5.7 Channel Stability

Bank stability is a major concern along portions of the lower 14 miles of the mainstem, particularly in areas that have received extensive alteration due to agricultural, residential, and mining development. In the broad alluvial valley between RM 7 and RM 10, dramatic channel adjustments including avulsions and lateral meander migration have occurred since 1858 (Sweet et al. 2003). Current rates of channel adjustment may be altered from their historical condition due to confinement of the river by levees and removal of riparian forests. Recent avulsions into stream-adjacent gravel pits occurred near RM 9 in 1995 and near RM 8 (Ridgefield Pits) in 1996. These adjustments abandoned a combined total of 4,900 feet of spawning habitat and have altered sediment transport dynamics in the lower river. A comprehensive evaluation of the effects of these events can be found in Sweet et al. (2003).

Reconnaisance surveys in 1999 indicated that high stream-adjacent bluffs near Daybreak Park may be contributing large amounts of fine sediment to the river, much of which is collecting in the Ridgefield Pits (Sweet et al. 2003). There are other areas of bank instability near RM 10.5 and RM 11.3. All of these conditions have dramatically altered channel stability and rates of sediment supply in the lower river. In particular, aggradation of sediments in some areas is believed to be causing erosion of lateral banks, therefore increasing width-to-depth ratios.

Bank stability problems in East Fork tributaries include streambank erosion along a segment of Mason Creek, cattle impacts on Rock Creek, and chronic mass wasting sites on upper Rock Creek and upper Lockwood Creek (Wade 2000).

13.5.8 Riparian Function

Riparian conditions in the lower river below RM 10 have been substantially impacted by residential, agricultural, and mining development. This area is believed to have been a gallery-type forest consisting of multiple age classes of willow, alder, ash, and cottonwood, but now consists only of widely dispersed cottonwoods, willow, and ash, with abundant reed canary grass, Himalayan blackberry, and Scotch broom in the disturbed areas. Substantial restoration efforts have involved the planting of thousands of native trees and shrubs in the past few years (Wade 2000).

An analysis of 1996 aerial photos indicated that the majority of the mainstem has lost substantial portions of riparian forest, many having been replaced by lawns. Most of the tributaries also have poor riparian conditions (Wade 2000). Riparian forests in the upper watershed have been altered by fire history, with only 4% of riparian reserves in late-successional stages and a total riparian hardwood composition of 23%. Large segments of the upper mainstem and Copper Creek have canopies that cover less than 50% of the stream channel (USFS 1995).

According to IWA watershed process modeling, which is presented in greater detail later in this chapter, 8 of the 36 subwatersheds in the basin are “impaired” with respect to riparian function. The remainder fall primarily in the “moderately impaired” category, with only 4 subwatersheds rated as “functional”. The greatest impairments are in the low elevation portions of the basin, which have received the greatest impacts to riparian areas due to agricultural and residential development. Fully functional conditions exist only in a handful of headwaters subwatersheds.

Riparian function is expected to improve over time on private forestlands. This is due to the requirements under the Washington State Forest Practices Rules (Washington Administrative Code Chapter 222). Riparian protection has increased dramatically today compared to past regulations and practices.

13.5.9 Floodplain Function

The lower river flows through a broad alluvial valley that has been extensively diked to protect agricultural, residential, and mining activities. Historically, nearly the entire lower river valley bottom was wetlands, with extensive channel braiding from RM 7 to RM 10. By 1937, the mainstem was mostly a single-thread channel with ephemeral floodplain sloughs where the braids once were. This simplification of the channel has reduced a substantial amount of side channel and backwater habitat that was historically used for chum spawning and could provide important overwintering habitat for juvenile coho. Limiting Factors Analysis TAG members estimated that over 50% of the off-channel habitat and wetlands in the historical lower river floodplain have been disconnected from the river (Wade 2000).

13.6 Fish/Habitat Assessments

The previous descriptions of fish habitat conditions can help identify general problems but do not provide sufficient detail to determine the magnitude of change needed to affect recovery or to prioritize specific habitat restoration activities. A systematic link between habitat conditions and salmonid population performance is needed to identify the net effect of habitat changes, specific stream sections where problems occur, and specific habitat conditions that account for the problems in each stream reach. In order to help identify the links between fish and habitat conditions, the Ecosystem Diagnosis and Treatment (EDT) model was applied to East Fork Lewis River winter steelhead, summer steelhead, fall chinook, chum, and coho. A thorough description of the EDT model, and its application to lower Columbia salmonid populations, can be found in Volume VI.

Three general categories of EDT output are discussed in this section: population analysis, reach analysis, and habitat factor analysis. Population analysis has the broadest scope of all model outputs. It is useful for evaluating the reasonableness of results, assessing broad trends in population performance, comparing among populations, and for comparing past, present, and desired conditions against recovery planning objectives. Reach analysis provides a greater level of detail. Reach analysis rates specific reaches according to how degradation or restoration within the reach affects overall population performance. This level of output is useful for identifying general categories of management (i.e. preservation and/or restoration), and for focusing recovery strategies in appropriate portions of a subbasin. The habitat factor analysis section provides the greatest level of detail. Reach specific habitat attributes are rated according to their relative degree of impact on population performance. This level of output is most useful for practitioners who will be developing and implementing specific recovery actions.

13.6.1 Population Analysis

Population assessments under different habitat conditions are useful for comparing fish trends and establishing recovery goals. Fish population levels under current and potential habitat conditions were inferred using the EDT model based on habitat characteristics of each stream reach and a synthesis of habitat effects on fish life cycle processes.

Habitat-based assessments were completed in the EF Lewis basin for summer steelhead, winter steelhead, fall chinook, chum and coho. Model results indicate an estimated 61- 88% decline in adult productivity for all species compared to historical estimates (Table 13-1). Estimated historical-to-current trends in adult abundance show a decline of 49-90% for all species (Figure 13-7). Fall chinook adult abundance has declined the least, to an estimated 51% of historical levels. Adult abundance of coho, winter and summer steelhead has declined by

75%, 75%, and 79%, respectively. Chum abundance has witnessed the most severe decline. Current estimates of chum abundance are at only 10% of historical levels. Diversity (as measured by the diversity index) has remained relatively constant for fall chinook, chum and summer steelhead (Table 13-1). However, coho and winter steelhead diversity has declined by 29% and 23%, respectively.

Smolt productivity has also declined from historical levels for each species in the EF Lewis basin (Table 13-1). For fall chinook and chum, smolt productivity has decreased by 58% and 43% respectively. For both coho and winter steelhead the decrease was estimated as approximately 80%. Summer steelhead smolt productivity has declined by 72%. Smolt abundance in the EF Lewis has declined most dramatically for chum and coho, with respective 79% and 80% changes from historical levels (Table 13-1). Current fall chinook, winter steelhead, and summer steelhead smolt abundance levels are modeled at approximately half of their historical numbers (Table 13-1).

Model results indicate that restoration of properly functioning habitat conditions (PFC) would achieve significant benefits for all species (Table 13-1). Adult abundance of both chum and coho would increase by more than 200%. Adult returns of fall chinook, winter steelhead, and summer steelhead would increase by more than 60%. Smolt numbers are also estimated to increase dramatically for all species, especially for coho, which shows a 287% increase in smolt abundance with restoration of PFC.

Table 13-1. EF Lewis River— Population productivity, abundance, and diversity (of both smolts and adults) based on EDT analysis of current (P or patient), historical (T or template), and properly functioning (PFC) habitat conditions.

	Adult Abundance			Adult Productivity			Diversity Index			Smolt Abundance			Smolt Productivity		
Species	P	PFC	T[1]	P	PFC	T[1]	P	PFC	T[1]	P	PFC	T[1]	P	PFC	T[1]
Fall Chinook	1,380	2,223	2,690	3.5	7.0	8.8	0.96	1.00	1.00	194,805	323,012	411,593	384	725	913
Chum	4,652	16,540	45,517	2.0	6.7	10.4	0.97	1.00	1.00	2,200,608	6,194,596	10,474,620	641	960	1,122
Coho	1,066	3,306	4,280	2.6	8.8	12.6	0.71	1.00	1.00	20,097	77,730	102,601	56	206	294
Winter Steelhead	631	1,109	2,517	3.7	10.4	29.9	0.77	0.84	1.00	10,560	18,414	22,539	69	188	292
Summer Steelhead	187	338	893	2.6	5.3	17.4	0.94	1.00	1.00	3,500	6,247	8,797	48	97	170

[1] Estimate represents historical conditions in the basin and current conditions in the mainstem and estuary.

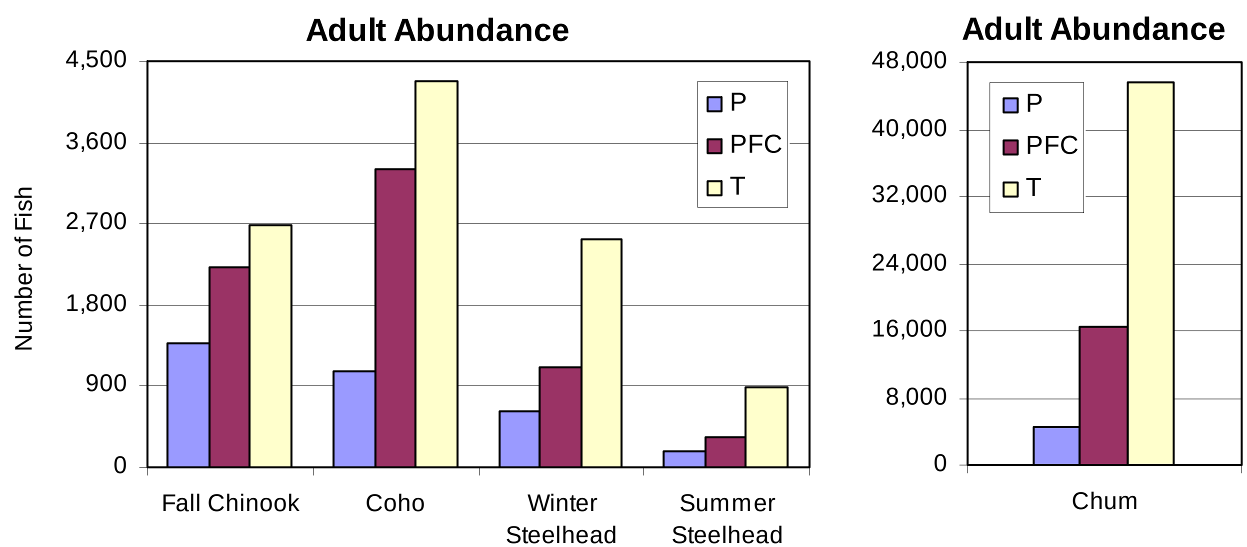


Figure 13-7. Adult abundance of EF Lewis fall chinook, coho, winter steelhead, summer steelhead and chum based on EDT analysis of current (P or patient), historical (T or template), and properly functioning (PFC) habitat conditions.

13.6.2 Restoration and Preservation Analysis

Habitat conditions and suitability for fish are better in some portions of a subbasin than in others. The reach analysis of the EDT model uses estimates of the difference in projected population performance between current/patient and historical/template habitat conditions to identify core and degraded fish production areas. Core production areas, where habitat degradation would have a large negative impact on the population, are assigned a high value for preservation. Likewise, currently degraded areas that provide significant potential for restoration are assigned a high value for restoration. Collectively, these values are used to prioritize the reaches within a given subbasin.

Summer steelhead, which are able to ascend Sunset Falls at RM 32.7, ascend the furthest up the EF Lewis. Winter steelhead, whose distribution stops at Sunset Falls, make greater use of mainstem tributary habitats. Fall chinook distribution ends at Lucia Falls (RM 21.3) and chum distribution ends approximately at lower Rock Creek. See Figure 13-8 for a map of EDT reaches within the EF Lewis basin.

The high priority reaches for winter steelhead are the mainstem reaches (EF Lewis 12 and 13) and reaches in the Rock Creek basin (Rock 1-4) (Figure 13-9). These reaches represent the primary spawning and rearing areas for this population. As such, all of these reaches, except Rock Creek 4, show a preservation emphasis. High priority reaches for summer steelhead are also located in the most productive spawning and rearing reaches of the headwaters (EF Lewis 17-19) and the upper mainstem (EF Lewis 15) (Figure 13-10). These reaches, with the exception of EF Lewis 15, all show a combined preservation and restoration recovery emphasis.

For both fall chinook and chum, the high priority reaches are located lower in the basin. High priority reaches for fall chinook include lower and middle mainstem reaches (EF Lewis 5-7 and 9) (Figure 13-11). Reaches EF Lewis 5-7 show a combined preservation and restoration emphasis, while EF Lewis 9 only has a preservation emphasis. For chum, the high priority reaches are EF Lewis 4-8 (Figure 13-12). All of these reaches, except for EF Lewis 4, have a combined preservation and restoration emphasis.

High priority reaches for coho in the EF Lewis are similar to those for fall chinook. Coho high priority reaches include EF Lewis 5-8 and EF Lewis 10 (Figure 13-13). For coho, all of these reaches have a restoration emphasis, suggesting degradation to key coho habitat in these areas.

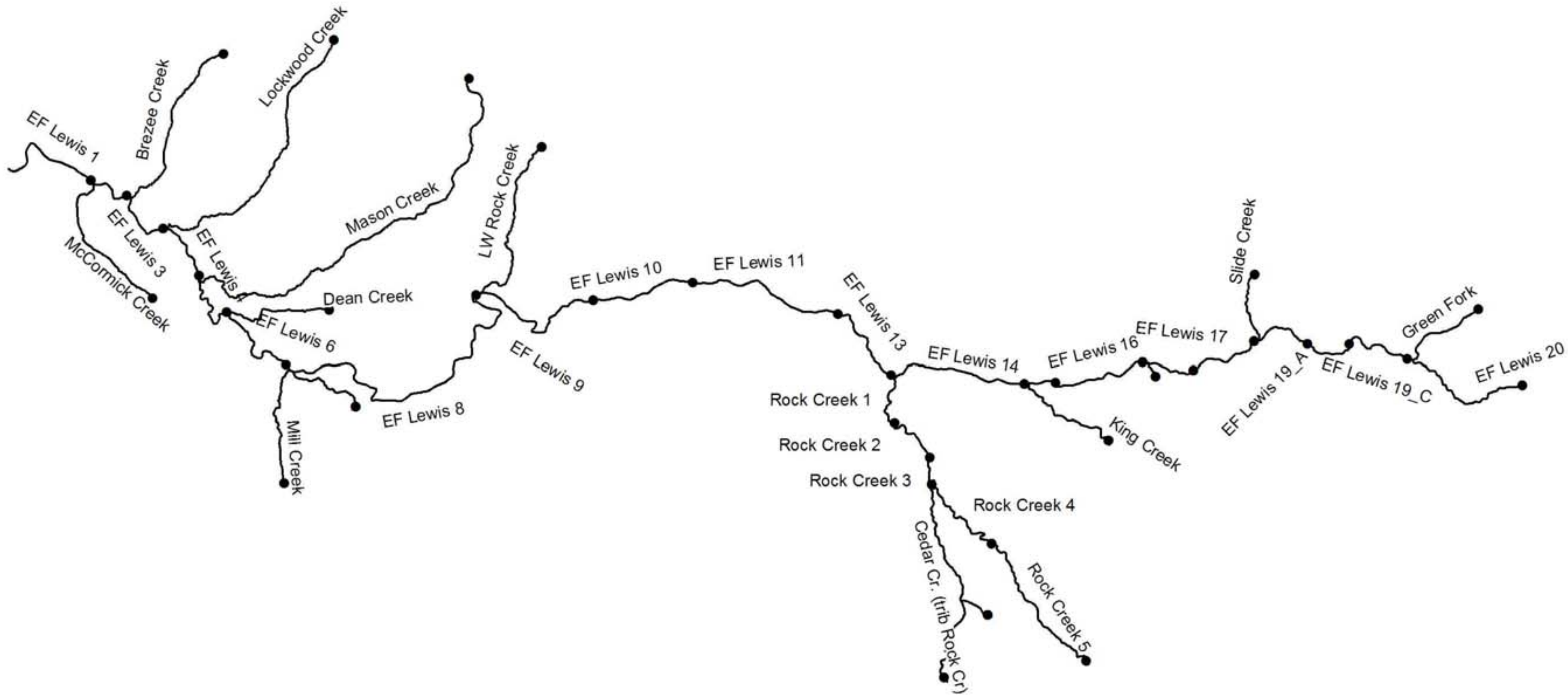


Figure 13-8. EF Lewis EDT reaches. Some reaches are not labeled for clarity.

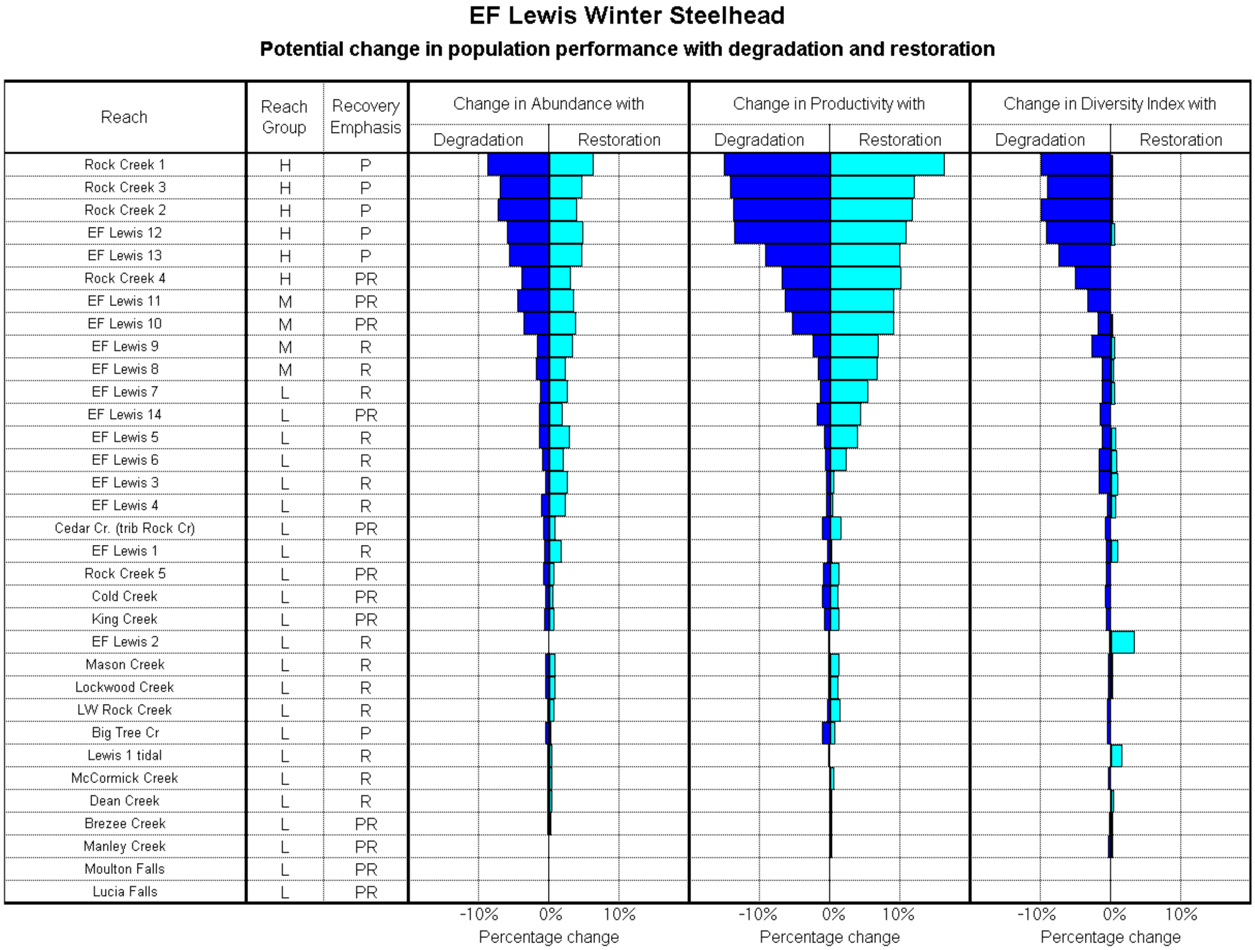


Figure 13-9. EF Lewis winter steelhead ladder diagram. The rungs on the ladder represent the reaches and the three ladders contain a preservation value and restoration potential based on abundance, productivity, and diversity. The units in each rung are the percent change from the current population. For each reach, a reach group designation and recovery emphasis designation is given. Percentage change values are expressed as the change per 1000 meters of stream length within the reach. See Volume VI for more information on EDT ladder diagrams.

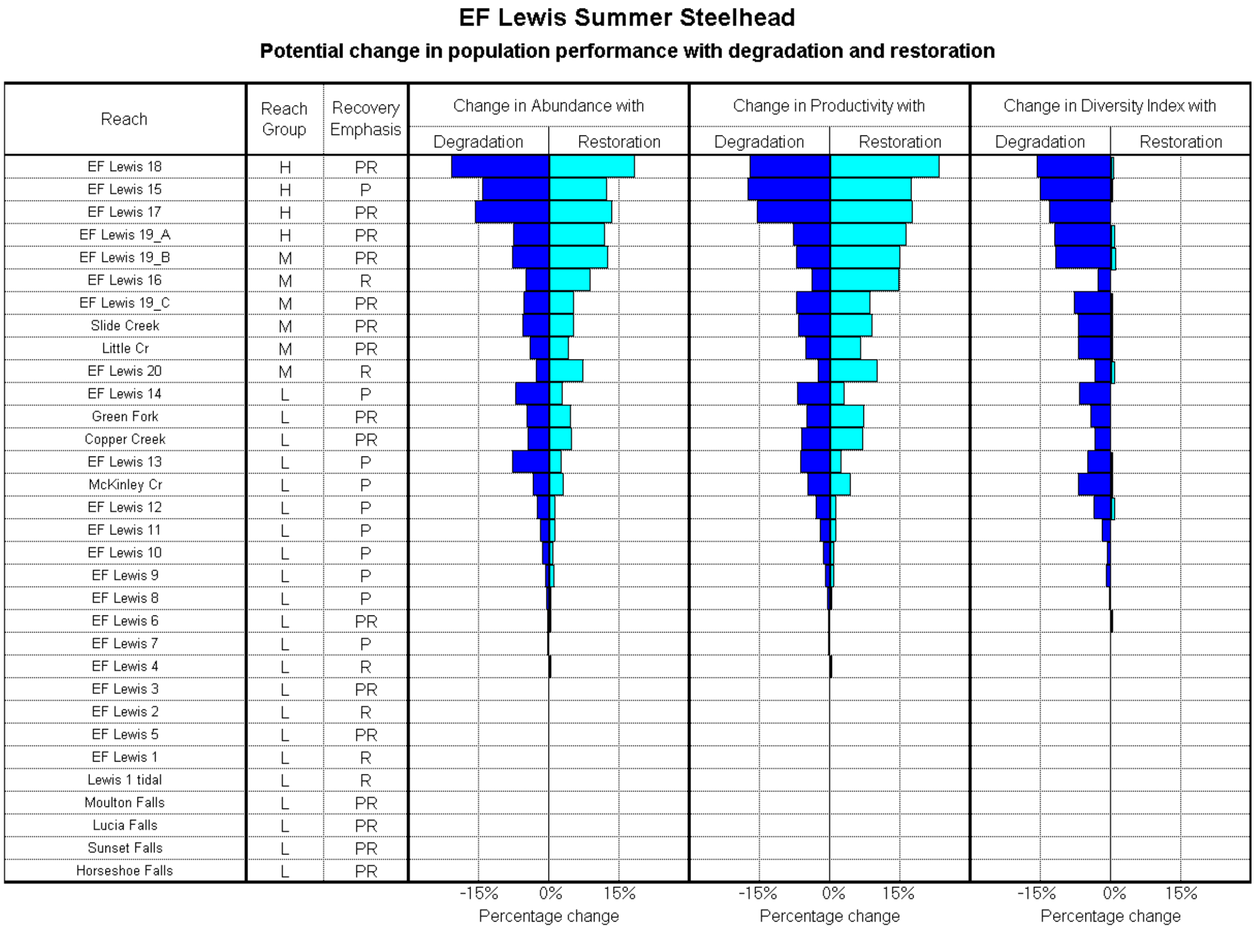


Figure 13-10. East Fork Lewis summer steelhead ladder diagram.

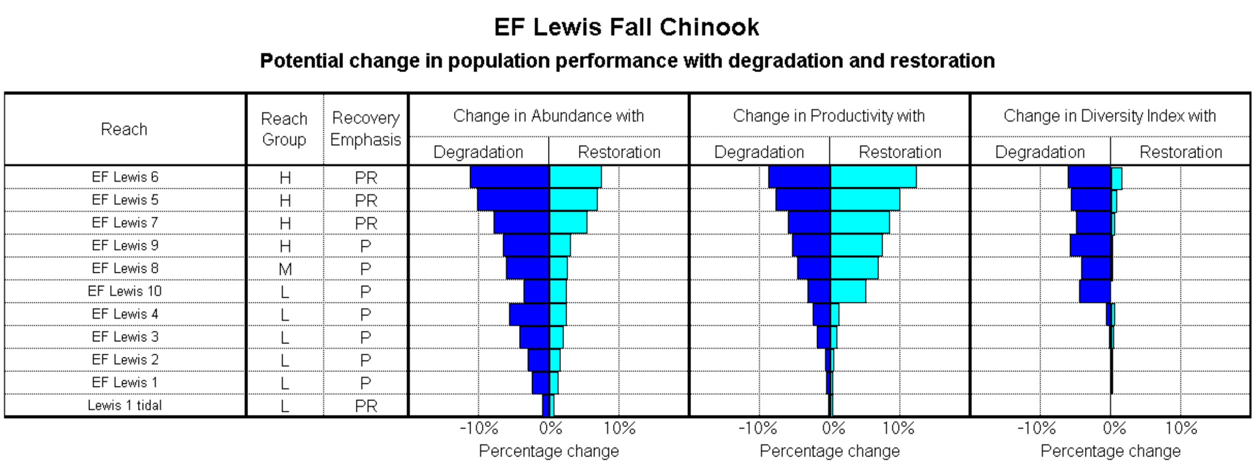


Figure 13-11. East Fork Lewis fall chinook ladder diagram.

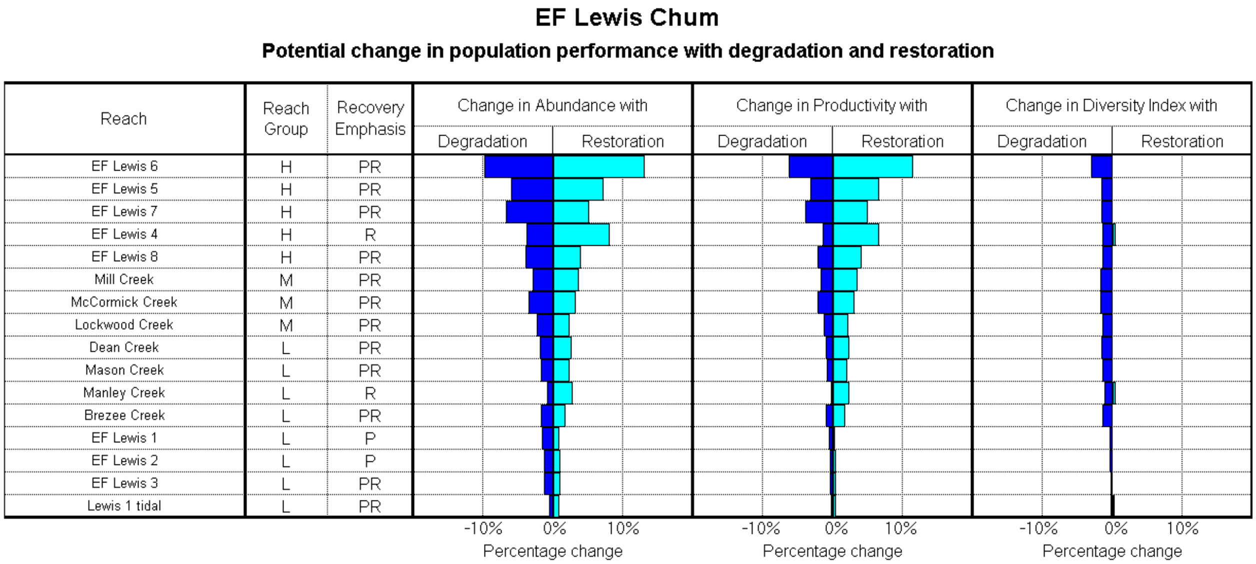


Figure 13-12. East Fork Lewis chum ladder diagram.

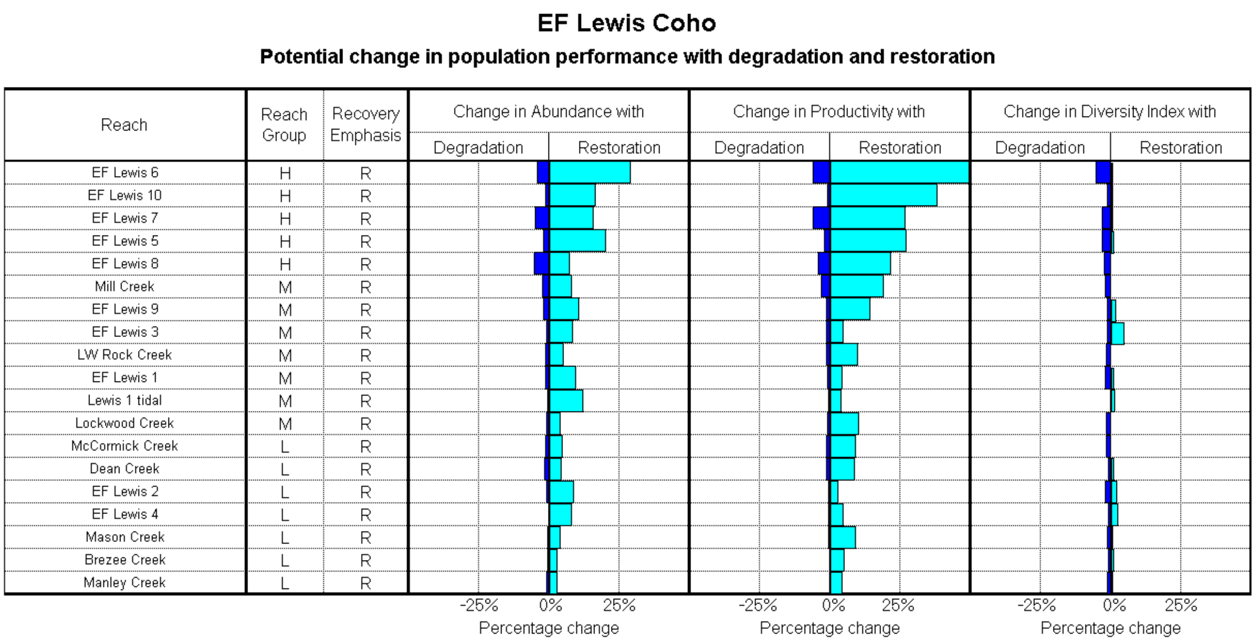


Figure 13-13. East Fork Lewis coho ladder diagram.

13.6.3 Habitat Factor Analysis

The Habitat Factor Analysis of EDT identifies the most important habitat factors affecting fish in each reach. Whereas the EDT reach analysis identifies reaches where changes are likely to significantly affect the fish, the Habitat Factor Analysis identifies specific stream reach conditions that may be modified to produce an effect. Like all EDT analyses, the reach analysis compares current/patient and historical/template habitat conditions. The figures generated by habitat factor analysis display the relative impact of habitat factors in specific reaches. The reaches are ordered according to their combined restoration and preservation rank. The reach with the greatest potential benefit is listed at the top. The dots represent the relative degree to which overall population abundance would be affected if the habitat attributes were restored to historical conditions.

As described in the reach analysis section above, the high priority reaches for winter steelhead are in the middle mainstem (EF Lewis 12 and 13) and reaches in the Rock Creek basin (Rock 1-4). In these areas, habitat diversity, sediment, flow, and temperature have had a negative impact on the population (Figure 13-14). Loss of key habitat and channel stability are also important factors. Key habitat has been lost due to recent channel avulsions into streamside gravel pits in the lower and middle mainstem. Sediment impacts are mostly from upriver sources. Habitat diversity impacts stem from degraded riparian zones and low LWD levels.

High priority reaches for summer steelhead are located in upper mainstem reaches that are affected mostly by degraded habitat diversity and flow (Figure 13-15). Sediment, loss of key habitat, and channel stability have also had negative impacts (Figure 13-15). Habitat diversity is low due to degraded riparian zones and low LWD levels. Flow and sediment impacts are related to upper basin forest and road conditions, with some effects still lingering from large fires and floods in the 1920s and 30s. The 1995 USFS watershed analysis (USFS 1995) rated nearly all of the headwater reaches occupied by summer steelhead (except for the Green Fork) as having poor (<40 pieces per mile) LWD abundance. The bulk of these reaches also have riparian canopy openings of greater than 50%. Sediment impacts in the channel below Sunset Falls (EF Lewis 17) and in Green Fork Creek stem largely from past fires and floods (USFS 1995). Flow is affected by hillslope vegetation and road conditions. The 1995 watershed analysis rated 14 of 23 upper basin subwatersheds as being impaired with regards to peak flows.

Important fall chinook reaches are located in the lower mainstem. The greatest impact here is sediment, key habitat, and temperature (Figure 13-16). There is a large influx of sediment from channel sources due to rapid channel migration rates and avulsions into streamside gravel pits. These conditions have served to decrease overall channel stability, increasing bank erosion and downcutting. Low LWD levels, channelization, and degraded riparian forests have contributed to a lack of habitat diversity. Key habitat has been lost due to channelization and channel avulsions. Temperature is impacted by low canopy cover levels and flow is impacted by upper basin conditions mentioned previously for steelhead.

The high priority areas for chum are similar to those for fall chinook. These reaches suffer from similar sediment problems and loss of key habitat (Figure 13-17). However, an additional impact to chum in these areas comes from lack of habitat diversity. These reaches have experienced much channelization (diking) and riparian zone degradation. LWD levels are low in these streams. Residential development and agriculture have altered sediment and flow regimes. Furthermore, the high density of people in the area increases the risk of harassment impacts from anglers and recreationists.

Key restoration areas for coho in the EF Lewis are generally located in middle and lower mainstem sections. In these areas, habitat impacts to coho come from sediment, loss of both key habitat and habitat diversity, and poor channel stability (Figure 13-18). The causes of impacts are similar to those discussed for fall chinook and chum.

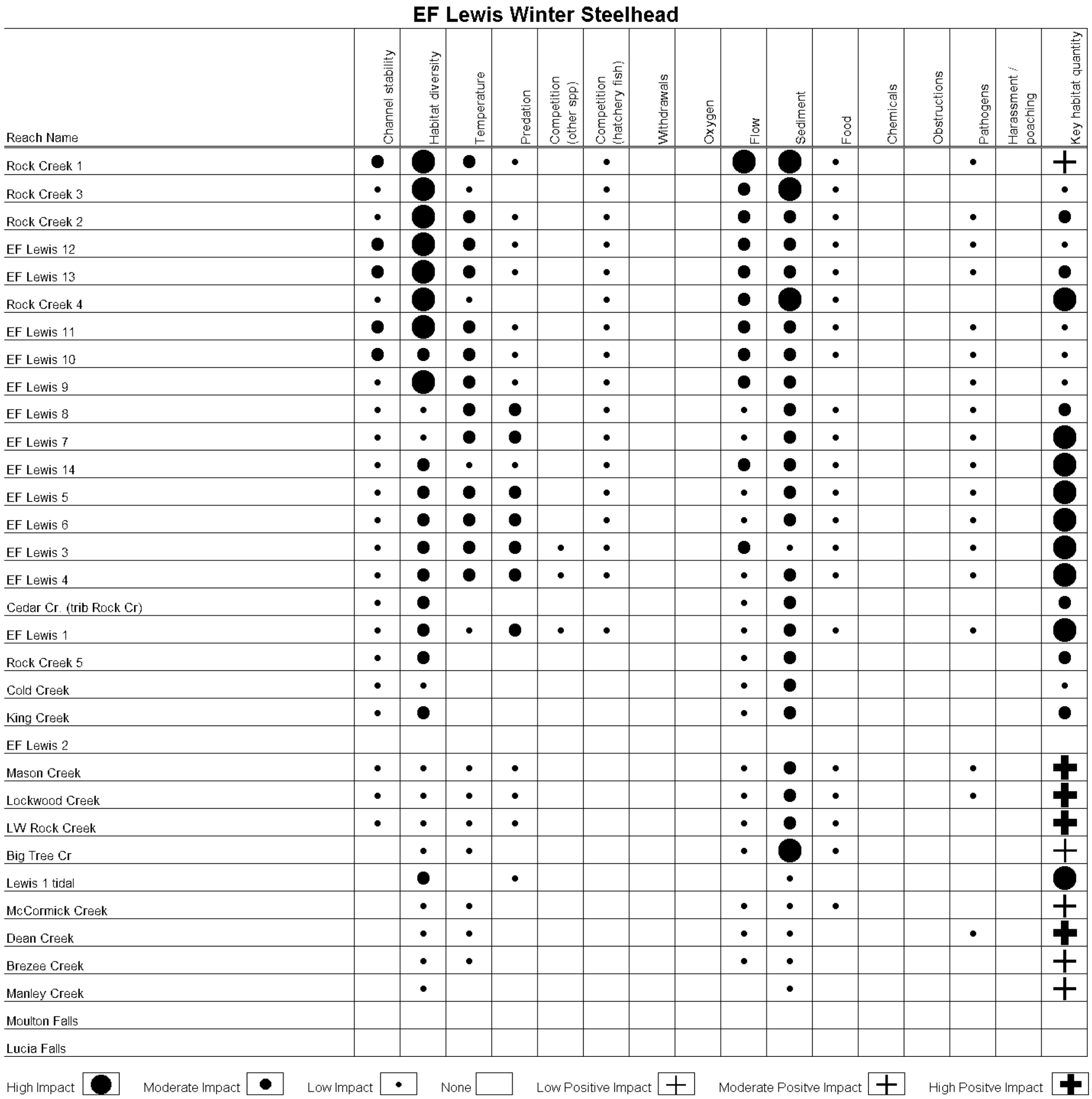


Figure 13-14. EF Lewis winter steelhead habitat factor analysis diagram. Diagram displays the relative impact of habitat factors in specific reaches. The reaches are ordered according to their restoration and preservation rank, which factors in their potential benefit to overall population abundance, productivity, and diversity. The reach with the greatest potential benefit is listed at the top. The dots represent the relative degree to which overall population abundance would be affected if the habitat attributes were restored to template conditions. See Volume VI for more information on habitat factor analysis diagrams.

EF Lewis Summer Steelhead

Reach Name	Channel stability	Habitat diversity	Temperature	Predation	Competition (other spp)	Competition (hatchery fish)	Withdrawals	Oxygen	Flow	Sediment	Food	Chemicals	Obstructions	Pathogens	Harassment / poaching	Key habitat quantity
EF Lewis 18	Moderate	High	Moderate	Low		Low			High	Moderate	Low			Low		High
EF Lewis 15	Moderate	High	Moderate	Low		Low			High	Moderate	Low			Low		Low
EF Lewis 17	Moderate	High	Moderate	Low		Low			High	Moderate	Low			Low		Moderate
EF Lewis 19_A	Moderate	High				Low			High	Moderate	Low					Moderate
EF Lewis 19_B	Moderate	High				Low			High	Moderate	Low					Moderate
EF Lewis 16	Moderate	High	Low	Low		Low			Moderate	High	Low			Low		High
EF Lewis 19_C	Moderate	Moderate	Low	Low		Low			Moderate	Moderate	Moderate					Low
Slide Creek	Moderate	Moderate				Low			Moderate	High	Low					High
Little Cr	Moderate	Moderate				Low			Moderate	High	Low					High
EF Lewis 20	Moderate	High	Low			Low			Moderate		Low					High
EF Lewis 14	Low	Moderate	Low	Low		Low			Moderate					Low		Low
Green Fork	Low	Moderate				Low			Moderate	High	Low					Moderate
Copper Creek	Low	Moderate	Low						Moderate	High						High
EF Lewis 13	Low	Moderate	Low						Low							Moderate
McKinley Cr	Moderate	Moderate							Moderate	High	Low					High
EF Lewis 12	Low	Moderate	Low						Low							
EF Lewis 11	Low	Moderate	Low						Low							
EF Lewis 10	Low	Low	Low						Low							
EF Lewis 9	Low	Low	Low	Low					Low							
EF Lewis 8			Low	Low												
EF Lewis 6			Low	Low												Low
EF Lewis 7			Low													
EF Lewis 4			Low	Low												Low
EF Lewis 3				Low												
EF Lewis 2		Low		Low												
EF Lewis 5																
EF Lewis 1				Low												
Lewis 1 tidal		Low														
Moulton Falls																
Lucia Falls																
Sunset Falls																
Horseshoe Falls																

High Impact ● Moderate Impact ● Low Impact • None Low Positive Impact + Moderate Positve Impact + High Positve Impact ✚

Figure 13-15. East Fork Lewis summer steelhead habitat factor analysis diagram.

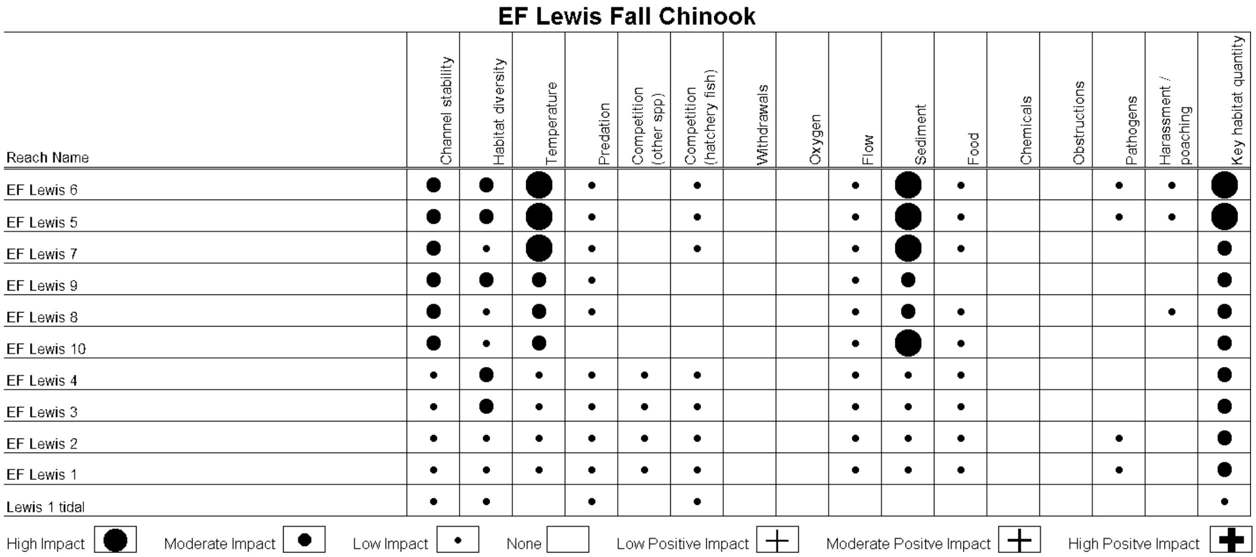


Figure 13-16. East Fork Lewis fall chinook habitat factor analysis diagram.

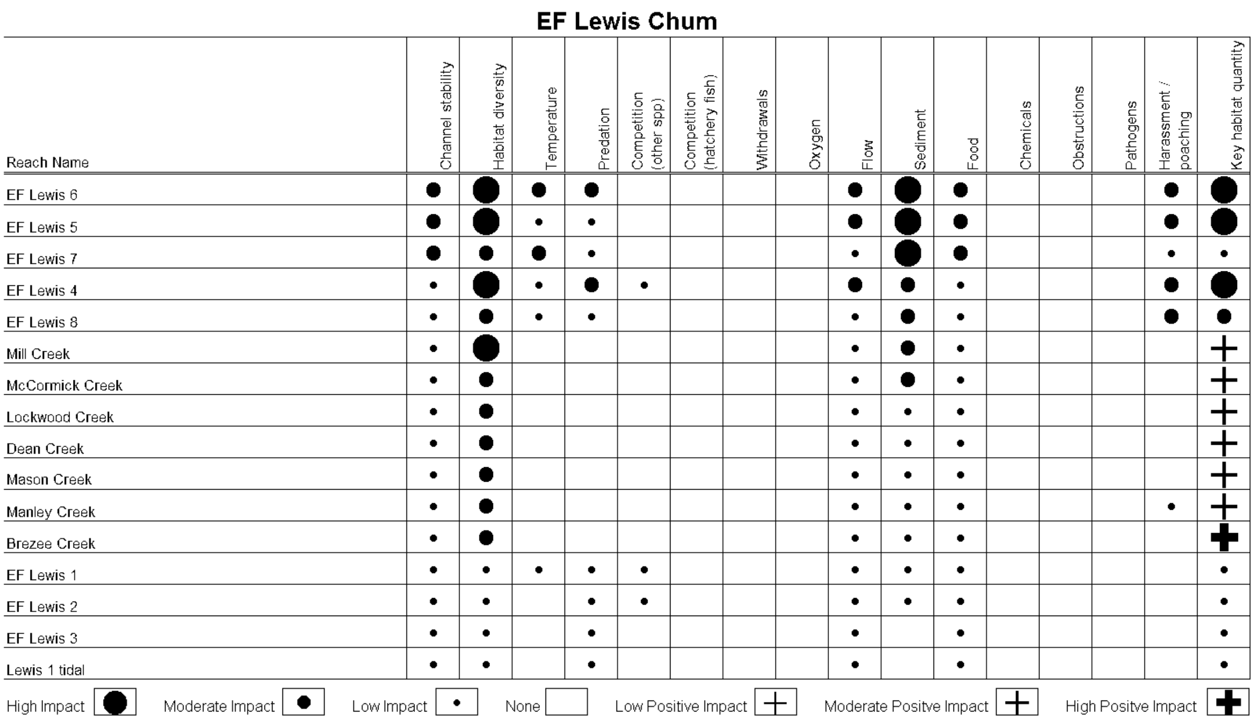


Figure 13-17. East Fork Lewis chum habitat factor analysis diagram.

EF Lewis Coho

Reach Name	Channel stability	Habitat diversity	Temperature	Predation	Competition (other spp)	Competition (hatchery fish)	Withdrawals	Oxygen	Flow	Sediment	Food	Chemicals	Obstructions	Pathogens	Harassment / poaching	Key habitat quantity
EF Lewis 6	High	High	Moderate	Moderate		Moderate			Low	High	Moderate			Low		High
EF Lewis 10	Moderate	High	Moderate	Low		Low			Low	Moderate	Low			Low		High
EF Lewis 7	Moderate	Moderate	Moderate	Moderate		Low			Low	High	Low			Low		High
EF Lewis 5	Moderate	Moderate	Moderate	Moderate		Low			Low	Moderate	Moderate			Low		High
EF Lewis 8	Moderate	Moderate	Moderate	Low		Low			Low	Moderate	Low			Low		High
Mill Creek	Moderate	Moderate	Low	Low		Low			Low	High	Low					Moderate
EF Lewis 9	Moderate	Moderate	Low	Low		Low			Low	Moderate						Low
EF Lewis 3	Low	Moderate	Low	Low		Low			Low		Low			Low		High
LW Rock Creek	Low	Moderate	Low						Low	Moderate	Low					Moderate
EF Lewis 1	Low	Moderate	Moderate	Moderate	Low	Low			Low	Low	Low			Low		High
Lewis 1 tidal	Low	High	+	Moderate		Low			Low	Low	Low			Low		High
Lockwood Creek	Low	Moderate	Low						Low	Moderate	Low					Moderate
McCormick Creek	Low	Moderate	Low						Low	Moderate	Low					Moderate
Dean Creek	Low	Moderate	Low						Low	Moderate	Low					Moderate
EF Lewis 2	Low	Moderate	Low	Moderate	Low	Low			Low	Low	Low			Low		High
EF Lewis 4	Low	Moderate	Low	Low		Low			Low	Low	Low			Low		High
Mason Creek	Low	Moderate	Low						Low	Low	Low					Moderate
Brezee Creek	Low	Moderate	Low						Low	Low	Low					Low
Manley Creek	Low	Low	Low						Low	Low	Low					Low

High Impact ● Moderate Impact ● Low Impact • None Low Positive Impact + Moderate Positve Impact + High Positve Impact ✚

Figure 13-18. East Fork Lewis coho habitat factor analysis diagram.

13.7 Integrated Watershed Assessment[1]

The East Fork Lewis River is composed of 34 subwatersheds within the East Fork proper, and two independent tributaries, Gee Creek and Allen Canyon Creek. Gee Creek discharges into the Columbia at the Lewis River confluence, whereas Allen Canyon Creek enters the lower Lewis between the East Fork/North Fork split and the Columbia. Lucia Falls marks a transition between high percentages of public ownership in the upper watershed—roughly 66%, with the headwater subwatersheds within the Gifford Pinchot National Forest—and dramatically lower rates of public ownership in the lower river totaling 5%.

13.7.1 Results and Discussion

IWA results were calculated for all subwatersheds in the EF Lewis River watershed. IWA results are calculated at the local level (i.e., within subwatershed, not considering upstream effects) and the watershed level (i.e., integrating the effects of the entire upstream drainage area as well as local effects). IWA results for each subwatershed are presented in Table 13-1. A reference map showing the location of each subwatershed in the basin is presented in Figure 13-19. Maps of the distribution of local and watershed level IWA results are displayed in Figure 13-20.

Table 13-2. IWA results for the EF Lewis River

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
50601	M	M	I	M	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502, 50501, 50616, 50605, 50604, 50615, 50614, 50613, 50604, 50603, 50612, 50611, 50608, 50602, 50609, 50607, 50606, 50610
50610	M	M	M	M	M	none
50606	M	M	M	M	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502, 50501, 50616, 50605, 50604, 50615, 50614, 50613, 50604, 50603, 50612, 50611, 50608, 50602, 50609, 50607
50607	M	M	M	M	M	none
50609	I	M	I	I	M	none

[1] Because of the complexity and size of the maps that illustrate these watersheds, the figure references in the Integrated Watershed Assessment section refer to maps in a separate file.

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
50602	M	M	M	I	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502, 50501, 50616, 50605, 50604, 50615, 50614, 50613, 50604, 50603, 50612, 50611, 50608, 50609, 50607
50608	I	M	I	I	M	none
50611	M	M	M	M	M	none
50612	I	F	M	I	M	50611
50603	I	M	I	I	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502, 50501, 50616, 50605, 50604, 50615, 50614, 50613, 50604, 50612, 50611
50613	I	M	M	I	M	none
50614	I	M	I	I	M	none
50615	I	M	M	I	M	none
50604	I	M	M	I	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502, 50501, 50616, 50605, 50615
50605	I	M	I	I	M	none
50616	I	M	M	M	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502, 50501
50501	I	M	M	M	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505, 50502
50505	I	M	I	I	M	None
50504	I	M	I	I	M	50506
50506	I	M	M	I	M	none
50401	M	F	M	F	F	50405, 50404, 50403, 50402
50402	F	F	M	M	F	50404
50403	I	F	M	I	F	none
50404	M	M	F	M	M	
50405	M	F	M	M	F	

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
50507	I	M	M	I	M	
50502	M	F	M	M	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505
	M	F	M	M	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509, 50503, 50502, 50507, 50405, 50404, 50403, 50402, 50401, 50506, 50504, 50505
50503	M	M	M	F	M	50101, 50203, 50201, 50202, 50302, 50301, 50508, 50509
50509	M	M	M	M	M	none
50508	I	M	M	I	M	none
50301	F	M	M	M	M	50302
50302	I	F	M	I	F	none
50202	F	F	F	F	F	none
50201	M	M	M	F	M	50203, 50101
50203	M	M	F	F	M	50101
50101	F	M	F	F	M	none

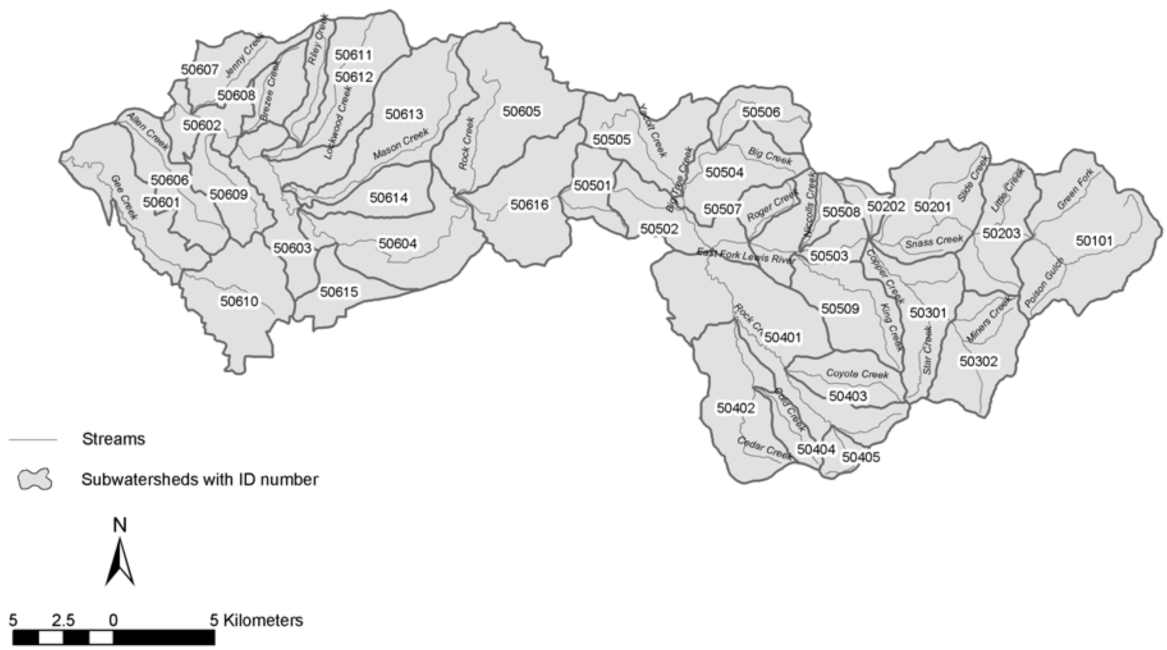


Figure 13-19. Map of the EF Lewis basin showing the location of the IWA subwatersheds

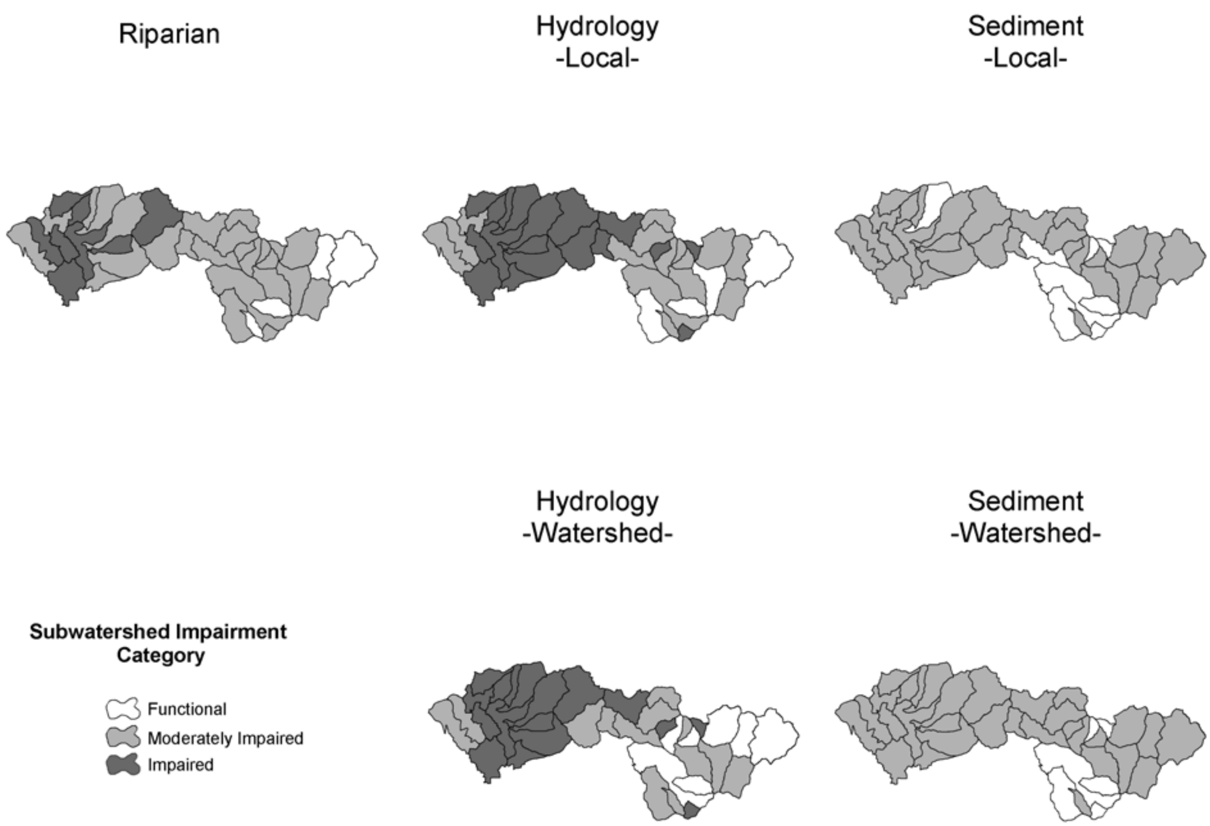


Figure 13-20. IWA subwatershed impairment ratings by category for the EF Lewis basin

13.7.1.1 Hydrology

There is a dramatic difference in hydrologic conditions between the upper and lower watershed. In the lower watershed, local hydrologic conditions are uniformly impaired, with the exception of the independent tributaries (Gee and Allen Canyon Creeks) as well as the mainstem subwatershed furthest downstream (50602).

Subwatersheds above Lucia Falls are for the most part rated moderately impaired at the local level, with the exception of three subwatersheds with more substantial impairment (50202 Anaconda Creek, 50507 Roger Creek, and 50505 Yacolt Creek), and four non-contiguous subwatersheds in the upper basin with functional conditions, including the headwaters of the mainstem (50101), Coyote Creek (50403, a tributary to upper Rock Creek), lower Copper Creek (50301), and Cedar Creek (50402, a tributary to Rock Creek).

Analysis of hydrologic conditions at the watershed scale produces a small number of changes in IWA ratings. For example, two upper mainstem subwatersheds (50201, 50203) earn a functional rating due to the influence of upstream functional conditions.

13.7.1.2 Sediment

Local sediment conditions fall primarily into the moderately impaired category, with no cases of impaired sediment condition and with nearly all functional subwatersheds occurring in the upper basin. Local sediment conditions are moderately impaired throughout the lower watershed, including the mainstem and tributaries Brezee Creek (50611), Lockwood Creek (50602) and Mason Creek (50613).

The change between natural and current erodability is similar for both the upper and lower portions of the basin, and therefore subwatersheds in these areas are rated similarly. However, on an absolute scale, erodability indices are much greater in the lower basin. This is an important distinction: while the IWA method rates sediment conditions as similarly degraded throughout the watershed due to the relative difference between natural and current conditions, the absolute levels remain very low throughout the upper watershed while the lower watershed is in the moderate to high category. Impaired conditions in the lower watershed are not surprising given the extremely low percentage of public ownership, mature forest cover of only 9%, very high road densities ranging from 4.8-7.7 mi/sq mi, and erodable soils.

Whereas rain-on-snow conditions are prevalent in most of the upper watershed, they are generally absent downstream of Lucia Falls. However, due to the stability of soils and much higher level of mature forest cover (57%), rain-on-snow events have less adverse impacts on upper subwatersheds. Road densities in the upper watershed range from 1.9-5.6 mi/sq mi, while stream crossing densities are moderately high.

Watershed level analysis results in few changes to local sediment condition ratings as all but one functional subwatershed are located in terminal areas (i.e., without effects from upstream subwatersheds).

13.7.1.3 Riparian

Riparian conditions are evenly divided in the lower watershed between impaired and moderately impaired categories. Riparian conditions in the upper watershed are for the most part moderately impaired, with localized areas of functional conditions in headwater areas. Riparian impairment in the upper basin is primarily the result of timber harvest and historical stand replacing fires. In the lower watershed, riparian impairment can be attributed to timber harvest, residential development, roadways, and agricultural uses.

13.7.2 Predicted Future Trends

13.7.2.1 Hydrology

In the lower portion of the basin, low levels of public ownership, low levels of mature forest cover, high road densities, and intense development pressure are likely to lead to downward trends in hydrologic conditions. More than 75% of areas zoned for development remain vacant, meaning this area may develop extensively over the next 20 years. As a result, impervious surfaces, road density, and stream crossing density will likely increase.

These trends will apply in low-elevation tributaries, which generally have low forest cover and increasing development. The tributaries to the East Fork—including Brezee, Lockwood, Mason and Mill Creeks, in addition to non-key subwatersheds—likely will become increasingly 'flashy', featuring higher, short-duration flows during the rainy season, while also suffering lower base flows during late summer months due to loss of riparian cover, increased watershed imperviousness, higher rates of surface water withdrawal, and depletion of groundwater resources due to withdrawal and reduced infiltration.

Mainstem subwatersheds in the lower East Fork may suffer similar consequences due to development pressure, but hydrologic effects will be substantially governed by conditions further upstream in the upper watershed. Hydrologic continuity has been substantially degraded by the loss of wetlands, gravel mining, and construction of levees. The East Fork avulsion through abandoned gravel pits in the lower river impacted spawning and rearing habitat.

Upper watershed hydrologic conditions are likely to maintain current conditions or gradually improve due to the high percentage of public ownership and low levels of anticipated development. Predicted improvements are based on improved forest management practices on both federal (GPNF) and state (WDNR) lands. Road and road-crossing removal as well as riparian restoration are likely to provide substantial hydrologic benefits.

13.7.2.2 Sediment Supply

As with hydrologic trends, the lower watershed is not likely to experience substantial improvements in sediment conditions in the next 20 years due to development pressures. Furthermore, natural erodability is moderately high (due to geologic conditions) and road densities are unlikely to decrease.

Even with moderate impairment, geology in the upper watershed naturally limits the extent of deleterious, episodic sediment erosion. Sediment processes are likely to improve based on a trend towards improved forest and road management on public lands. Natural regeneration of previously harvested and burned areas will also yield improved sediment supply conditions.

13.7.2.3 Riparian Condition

Upper watershed riparian conditions are represented by a patchwork of functional and moderately impaired subwatersheds. Currently, functional riparian areas are found in only four subwatersheds in the entire basin, all located in the upper reaches of the watershed on publicly owned lands. Forest management by WDNR and the USFS are expected to result in improved riparian conditions.

Moderately impaired to impaired riparian condition ratings are most prevalent along the lower mainstem and tributaries. Historical riparian forests within the mainstem floodplain have been almost entirely removed, limiting LWD recruitment while also reducing channel roughness and stability, which results in higher rates of bank erosion during high flows. Absent restorative measures, episodic levee avulsion and bank erosion events may accelerate in the future. In the lower mainstem and tributary subwatersheds, currently degraded conditions are expected to persist due to existing road densities, channelization, and current land uses.

13.8 References

Access Opportunities. 1992. ADA Evaluation and Transitional Plan for Lewis River Recreation Area. Pacific Power and Light Company, Portland, OR.

Allen, R. 1963. Lake Merwin Juvenile Fish Collector Progress Report for July 1, 1962 to June 30, 1963. Washington Department of Fisheries (WDF), Research Division.

Allen, R. 1964. Lake Merwin Juvenile Fish Collector Progress Report July 1, 1963 to June 30, 1964. Washington Department of Fisheries (WDF), Research Division.

Allen, R.L.; Rothfus, L.O. 1976. Evaluation of a Floating Salmon Smolt Collector at Merwin Dam. Washington Department of Fisheries (WDF).

Amren,J. 1997. Operations Program Lewis River Complex for January 1, 1996 to December 31, 1996. Washington Department of Fish and Wildlife WDFW), Hatcheries Program, Olympia, WA.

Anderson, D.P., R.G. Anthony, Ichisaka. 1985. Wintering Ecology of Bald Eagles on the Lewis River, Washington 1984-1985. Pacific Power and Light Co., Portland, OR.

Anderson, D.P., R.G. Anthony, Ichisaka. 1986. Wintering Ecology of Bald Eagles on the Lewis River, Washington 1985-1986. Pacific Power and Light Co., Portland, OR.

Barker, B., P. Cavanaugh, P., D. Burdick. 1996. Floodway Hazard Assessment for Home Located at 4503 NW 416th Street Near the Lewis River. Washington State Dept of Ecology (WDOE).

Bryant, F.G. 1949. A survey of the Columbia River and its tributaries with special reference to its fishery resources--Part II Washington streams from the mouth of the Columbia to and including the Klickitat River (Area I). U.S. Fish and Wildlife Service (USFWS), Special Science Report 62.

Caldwell, B. 1999. East Fork Lewis River fish habitat analysis using the Instream Flow Incremental Methodology and Toe-Width Method for WRIA 27. Publication # 99-151. Washington State Department of Ecology. Olympia, WA.

Chambers, J.S. 1957. Report on the survey of the North Fork of the Lewis River above Yale Dam. Washington Department of Fisheries (WDF).

Clearwater BioStudies, Inc. 2002. Bull trout surveys and stream temperature monitoring conducted within selected watersheds on the Gifford Pinchot National Forest, Summer 2001. Clearwater BioStudies, Inc. Canby, OR.

Crawford, B.A. 1986. Recovery of game fish populations impacted by the May 18, 1980 eruption of Mount St. Helens. Part 11. Recovery of surviving fish populations within the lakes in the Mount St. Helens National Volcanic Monument and adjacent areas. Washington Department of Game (WDG), Fishery Management Report 85-9B.

Crawford, B.A., R. Pettit, R. Claflin. Study of juvenile steelhead densities and biomass in the wind and E.F. Lewis Rivers. Washington Department of Fish and Wildlife (WDFW).

EA Engineering, Science & Technology. 1999. Initial information package for the Lewis River hydroelectric projects. Prepared for PacifiCorp and PUD of Cowlitz County, EA Engineering, Science & Technology.

Hale, D. 2003. Personal communication with Donna Hale, Washington Department of Fish & Wildlife. Comments submitted.

Harlan, K. 1999. Washington Columbia River and tributary stream survey sampling results, 1998. Washington Department of fish and Wildlife (WDFW), Columbia River Progress Report 99-15, Vancouver, WA.

Harlan, L., R. Pettit. 2001. Forecasts for 2001 spring chinook returns to Washington Lower Columbia River tributaries. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 02-01, Vancouver, WA.

Hawkins, S. 1996. Lewis River wild stock fall Chinook tagging project, 1995. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 96-08, Battle Ground, WA.

Hawkins, S. 1996. Results of sampling the Lewis River natural spawning fall Chinook population in 1995. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 96-06, Battle Ground, WA.

Hawkins, S. 1997. Lewis River wild fall chinook tagging project. Washington Department of Fish and Wildlife (WDFW). Columbia Rive Progress Report 98-6, Vancouver, WA.

Hawkins, S. 1998. Residual hatchery smolt impact study: wild fall chinook mortality 1995-1997. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-8, Vancouver, WA.

Hawkins, S. 1998. Results of sampling the Lewis River natural spawning fall chinook population in 1997. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-7, Vancouver, WA.

Humer, J. 1989. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1988. Washington Department of Fish and Wildlife (WDFW). Columbia River Laboratory Progress Report 89-13, Battle Ground, WA.

Hutton, Robert. 1994. DRAFT East Fork Lewis River watershed action plan. Clark County Water Quality Division. pp. 56. Vancouver, WA.

Hutton, Robert. 1994. DRAFT East Fork Lewis River watershed characterization background Report. Clark County Water Quality Division, Vancouver, WA.

Hymer, J. 1990. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1989. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 90-19, Battle Ground, WA.

Hymer, J. 1992. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1991. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 92-23, Battle Ground, WA.

Hymer, J. 1993. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1992. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 93-18, Battle Ground, WA.

Hymer, J. 1993. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1992. Washington Department of Fish and Wildlife (WDFW). Columbia River Laboratory Progress Report. Vol:93-18. Battle Ground, WA.

Hymer, J., B. Woodard. 1991. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1990. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 91-11, Battle Ground, WA.

Hymer, J., R. Pettit, M. Wastel, P. Hahn, K. Hatch. 1992. Stock summary reports for Columbia River anadromous salmonids, Volume III: Washington subbasins below McNary Dam. Bonneville Power Administration (BPA), Portland, OR.

Kinney, J., S. Lampo. 2002. Summary of Gifford National Forest aquatic habitat surveys on the tributaries of the Lewis River watershed between Lower Falls and Swift Reservoir, including Drift and Siouxon Creeks. Gifford Pinchot National Forest. Amboy, WA. Report. Lewis River

Lavoy, L., G. Fenton. 1983. North Fork Lewis River Steelhead Study. Washington Department of Game, Olympia, WA.

LeFleur, C. 1987. Columbia River and tributary stream survey sampling results, 1986. Washington Department of Fisheries (WDF), Progress Report 87-8, Battle Ground, WA.

LeFleur, C. 1988. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1987. Washington Department of Fish and Wildlife (WDFW), Progress Report 88-15, Battle Ground, WA.

LeFleur, C. 1988. Columbia River and tributary stream survey sampling results, 1987. Washington Department of Fisheries (WDF), Progress Report 88-17, Battle Ground, WA.

Lewis County GIS. 1999. GIS Fish Distribution Maps and Analysis of Various Habitat Conditions within WRIA 27.

Lower Columbia Fish Recovery Board (LCFRB) 2001. Level 1 Watershed Technical Assessment for WRIAs 27 and 28, Longview, Washington. Prepared by GeoEngineers, Inc. (the prime contractor), WEST Consultants, Inc., and Hammond Collier Wade Livingstone for the LCFRB. Longview, Washington.

Lucas, B. 1985. Draft Analysis of creel check data at Lucia Falls, East Fork Lewis River. Washington Department of Wildlife (WDW).

Lucas, R.; Pointer, K. 1987. Wild steelhead spawning escapement estimates for southwest Washington streams--1987. Washington Department of Wildlife (WDW) 87-6.

Marriott, D. et.al. 2002. Lower Columbia River and Columbia River Estuary Subbasin Summary. Northwest Power Planning Council.

McIsaac, D., H. Fiscus. 1979. Relative value of North fork Lewis River spring chinook. Washington Department of Fisheries (WDF), Memo, Vancouver, BC

McIsaac, D.O. 1990. Factors affecting the abundance of 1977-1979 brood wild fall chinook salmon (Oncorhynchus tshawytscha) in the Lewis River, Washington. University of Washington, Ph.D. Dissertation, Seattle, WA.

Montgomery Watson. 1997. Hatchery Evaluation Report, Merwin Dam Hatchery - Winter Steelhead. Bonneville Power Administration. An Independent Audit Based on Integrated Hatchery Operations Team (IHOT) Performance Measures 95-2, Bellevue, WA.

Norman, G. 1984. Memo to Don McIsaac on North Lewis River wild stock fall chinook tagging project and post-tagging recapture, 1983. State of Washington, Department of Fisheries, Battle Ground, WA.

PacificCorp Environmental Services. 1995. Yale Hydroelectric Project Preliminary Water Quality Study. PacificCorp Environmental Services, FERC Project 2071, Portland, OR.

Pettit, R. 1993. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1993. Washington Department of Fisheries (WDF), Columbia River Laboratory Progress Report 93-23. Battle Ground, WA.

Pettit, R. 1994. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1994. Washington Department of Fisheries (WDF), Columbia River Laboratory Progress Report 94-30.

Pettit, R. 1995. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1995. Washington Department of Fish and Wildlife (WDFW), Columbia Rive Laboratory Progress Report 95-21, Battle Ground, WA.

Pettit, R. 1996. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1996. Washington Department of Fisheries (WDF), Columbia River Laboratory Progress Report 96-19, Battle Ground, WA.

Pettit, R. 1998. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1988. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-13, Vancouver, WA.

Pettit, R. 1998. Forecasts for 1999 spring chinook returns to Washington Lower Columbia river tributaries. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-11, Vancouver, WA.

Pettit, R. 2002. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-2001. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report, 02-06. Vancouver, WA.

Pettit, R. 2002. Forecasts for 2002 spring chinook returns to Washington Lower Columbia River tributaries. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 02-02, Vancouver, WA.

Quinn, T.P., K. Fresh. 1984. Homing and straying in chinook salmon (Oncorhynchus tshawytscha) from Cowilitz River Hatchery, Washington. Canadian Journal of Fisheries and Aquatic Sciences 41: 1078-1082.

Roler, R. 1990. North Lewis River wild stock fall chinook tagging and post tagging recapture project, 1989. Washington Department of Fisheries (WDF), Columbia River Laboratory Report 90-09, Battle Ground, WA.

Smoker, W.A., J.M. Hurley, R.C. Meigs. 1951. Compilation of information on salmon and steelhead losses in the Columbia River basin salmon and trout in the Lewis River. Washington Department of Fisheries (WDF).

Smoker, W.A., J.M. Hurley, R.C. Meigs. 1951. Compilation of Observations on the Effect of Ariel (Merwin) Dam on the Production of Salmon and Trout in the Lewis River. Washington Department of Fisheries and Washington Department of Game.

Sweet, H.R., R2 Resource Consultants, Inc., IT Corporation, WEST Consultants, Inc., Ecological Land Services, Inc., Maul, Foster, and Alongi, Inc., Janice Kelly, Inc., Perkins Coie, LLP. 2003. Habitat Conservation Plan - J.L. Storedahl & Sons, Inc. Daybreak Mine Expansion and Habitat Enhancement Project. R2 Resource Consultants, Inc. Redmond, Washington.

The ICM Core Team. 1996. Integrated landscape management for fish and wildlife: an evaluation of the planning process used to develop the Lewis-Kalama River watershed plan. Washington Department of Fish and Wildlife (WDFW), Draft Report 2, Olympia, WA.

Tracy, H.B., C.E. Stockley. 1967. 1966 Report of Lower Columbia River tributary fall chinook salmon stream population study. Washington Department of Fisheries (WDF).

U.S. Forest Service (USFS), Gifford Pinchot National Forest. 2000. Lewis River Hydroelectric Projects. U.S. Forest Service (USFS), Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1995. Middle Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1995. Upper East Fork of the Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1995. Upper Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1996. Lower Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1997. Muddy River Watershed Analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1999. East Fork Lewis River fish habitat rehabilitation project; environmental assessment. Gifford Pinchot National Forest.

Wade, G. 2000. Salmon and Steelhead Habitat Limiting Factors Water Resource Inventory Area 27. Washington State Conservation Commission.

Wahle, R.J., R.R. Vreeland, R.H. Lander. 1973. Bioeconomic contribution of Columbia River hatchery coho salmon, 1965 and 1966 broods, to the Pacific salmon fisheries. National Marine Fisheries Service (NMFS), Portland, OR.

Wahle, R.J., R.R. Vreeland, R.H. Lander. 1974. Bioeconomic contribution of Columbia River hatchery coho salmon, 1965 and 1966 broods, to the Pacific Salmon Fisheries. Fishery Bulletin 72(1).

Wahle, R.J., R.R. Vreeland. 1978. Bioeconomic contribution of Columbia River hatchery fall chinook salmon, 1961 through 1964. National Marine Fisheries Service (NMFS), Fishery Bulletin 1978(1).

Washington Department of Ecology (WDOE). 1998. Final 1998 List of Threatened and Impaired Water Bodies - Section 303(d) list. WDOE Water Quality Program. Olympia, WA.

Washington Department of Fish and Wildlife (WDFW). 1986. Operations Report: Lewis River Complex for January 1, 1995 to December 31, 1995. Washington Department of Fish and Wildlife (WDFW), Hatcheries Program.

Washington Department of Fish and Wildlife (WDFW). 1995. Annual Report 1994 for Speelyai Salmon Hatchery. Washington Department of Fish and Wildlife (WDFW), Hatcheries Program.

Washington Department of Fish and Wildlife (WDFW). 1996. Lower Columbia River WDFW hatchery records. Washington Department of Fish and Wildlife (WDFW).

Washington Department of Fish and Wildlife (WDFW). 1997. Preliminary stock status update for steelhead in the Lower Columbia River. Washington Department of Fish and Wildlife (WDFW), Vancouver, WA.

Washington Department of Fish and Wildlife (WDFW). 1998. Integrated landscape management plan for fish and wildlife in the Lewis-Kalama River watershed, Washington: a pilot project. Olympia, Washington. Washington Department of Fish and Wildlife (WDFW).

Washington Department of Fisheries (WDF) and U.S. Fish and Wildlife Service (USFWS). 1951. Lower Columbia River Fisheries Development Program: Lewis River Area, Washington. Washington Department of Fisheries (WDF).

Washington Department of Fisheries (WDF). 1951. Lower Columbia River Fisheries Development Program. Lewis River Area. Washington Department of Fisheries (WDF), Olympia, WA.

Washington Department of Fisheries (WDF). 1971. North Lewis River Surveys. Washington Department of Fisheries (WDF).

Washington Department of Fisheries (WDF). 1987. Speelyai Salmon Hatchery: August 1, 1986 through December 31, 1986. Washington Department of Fisheries (WDF). Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1988. Agreement Between the Department of Wildlife, Department of Fisheries, and Pacific Power and Light Company; Regarding Construction of a Fish Hatchery Near Merwin Dam. Washington Department of Fisheries (WDF).

Washington Department of Fisheries (WDF). 1989. Annual Report for Speelyai Salmon Hatchery Fiscal Year 1988. Washington Department of Fisheries (WDF). Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1990. Lewis River Salmon Hatchery Operations Report for January 1, 1990 through July 31, 1990. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1991. Lewis River Salmon Hatchery Operations Report for July 1, 1990 through December 31, 1990. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1991. Operation of Merwin Hydroelectric Project, FERC Project No 935: Proposed Changes of Article 49 Parts II and III. Washington Department of Fisheries (WDF), Columbia River Laboratory, Battle Ground, WA.

Washington Department of Fisheries (WDF). 1992. Lewis River Salmon Hatchery Operations Report for January 1, 1991 through December 31, 1991. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1992. Speelyai Salmon Hatchery: January 1, 1991 through December 31. 1991. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1993. Annual Report 1992 for Speelyai Salmon Hatchery. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1993. Lewis River Salmon Hatchery Operations Report for January 1, 1992 through December 31, 1992. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1994. Annual Report 1993 for Speelyai Salmon Hatchery. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1994. Lewis River Salmon Hatchery Operations Report for January 1, 1993 through December 31, 1993. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries; Washington Game Commission. 1948. A report on the fisheries problems in connection with the proposed hydroelectric development of the Cowlitz River, Lewis County, Washington. Washington Department of Fisheries and Washington Game Commission.

Washington Department of Game (WDG). 1973. Lewis Basin Study Fish and Wildlife Appendix. Washington Department of Game (WDG). Environmental Management Division.

Washington Department of Wildlife (WDW). 1990. Columbia Basin System Planning Salmon and Steelhead Production Plan, Lewis River Basin. Washington Department of Wildlife (WDW).

Weinheimer, J. 1995. Letter to Craig Burley of WDFW Regarding Bull Trout Capture Below Yale Dam, North Fork Lewis River. Washington Department of Fish and Wildlife (WDFW). Vancouver, WA.

Wendler, H.O., E.H. LeMier, L.O. Rothfus, E.L. Preston, W.D. Ward, R.E. Birtchet. 1956. Columbia River Progress Report, January through April, 1956. Washington Department of Fisheries (WDF).

Western Regional Climate Center (WRCC). 2003. National Oceanic and Atmospheric Organization - National Climatic Data Center. URL: http://www.wrcc.dri.edu/index.html.

Westley, R.E. 1966. Limnological Study of Merwin Upper Baker and Lower Baker Reservoirs. Washington Department of Fisheries WDF), Research Division.

Woodard, B. 1997. Columbia River Tributary sport Harvest for 1994 and 1995. Washington Department of Fish and Wildlife (WDFW), Battle Ground, WA.