Supplement to the Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan

Prepared for the

Northwest Power and Conservation Council

November 22, 2004

Prepared by the

Lower Columbia River Estuary Partnership

Contents

Acronyms and Abbreviations

APRE	Artificial Production Review and Evaluation
BMPs	best management practices
CWT	Columbian white-tailed (deer)
DIP	demographically independent population
EDT	Ecosystem Diagnosis and Treatment
EMA	Estuary and Mainstem Assessment
ESA	Endangered Species Act
ETM	estuary turbidity maximum
HGMP	Hatchery and Genetics Management Plan
LCFRB	Lower Columbia Fish Recovery Board
LCREP	Lower Columbia River Estuary Partnership
LF	limiting factor
NOAA	National Oceanic and Atmospheric Administration
NPCC	National Power and Conservation Council
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PO	physical objective
RM&E	research, monitoring, and evaluation
TMDL	total maximum daily load
WOTs	western Oregon tributaries

SECTION 1

Introduction

This document is a supplement to the *Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan* prepared by the Lower Columbia River Estuary Partnership in May 2004 as part of Columbia River subbasin planning efforts requested by the Northwest Power and Conservation Council. This supplement does not replace or substitute for any part of the original subbasin plan. Rather, it is a companion document that is intended to clarify key elements of the *Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan,* particularly Chapter 4 (the management plan) and the relationships among limiting factors, physical objectives, and strategies for the focal species covered in the subbasin plan. This document was prepared by the Estuary Partnership with the assistance of the Lower Columbia Fish Recovery Board, which participated in planning meetings and helped draft portions of the text.

A Unique Resource

The Columbia River estuary and lower mainstem provide a diversity of interconnected and interacting habitat types, from tidal marsh and swamp to open water of varying depths and salinities to riparian forests and freshwater wetlands. These habitats support a correspondingly diverse assemblage of hundreds of fish and wildlife species, including more than a dozen rare or endangered species; non-focal species such as cutthroat trout, river otter, osprey, and wintering sandhill cranes; one of the world's largest and most productive sturgeon populations; breeding bald eagles; and some of the last remaining populations of Columbian white-tailed deer.

The Columbia River estuary is particularly important for anadromous salmonids, who use it for critical life stages. The estuary serves as a vital transition zone during the physiological acclimation from freshwater to saltwater, it provides juvenile salmonids an opportunity to achieve the critical growth needed to survive in the ocean, and estuarine habitats serve as a productive feeding area, free of marine predators. In addition, the estuary provides olfactory cues needed for successful return migrations.

Unlike the tributaries, the Columbia River estuary is an essential part of the life history of <u>all</u> the salmonids in the Columbia River system that successfully migrate to the ocean and return to their natal streams to spawn. Because all salmonids in the Columbia use the estuary during their juvenile life stage (and when they return from the ocean), conditions in the estuary have direct bearing on the health of upriver migratory stocks. In other words, if the estuary is not functioning optimally, the biological performance of upriver salmonids will be compromised, even if the tributaries where those fish originate <u>are</u> functioning optimally. For this reason, increasing habitat productivity and access in the estuary and lower mainstem can be expected to benefit not just local salmon populations, but populations throughout the Columbia River Basin. In addition, improving habitat conditions and habitat-forming processes is likely to contribute to the biological performance of the hundreds of other species that use the unique resource that is the Columbia River estuary and lower mainstem.

Geographic Scope

The geographic scope of this supplement is the same as that of the original subbasin plan. The subbasin includes the Columbia River plume, the Columbia River estuary, and the mainstem lower Columbia to Bonneville Dam, a stretch of 146 river miles. The subbasin does not extend past the confluence of the tributaries that drain into the Columbia River, with the exception of the westernmost Oregon tributaries, including the watersheds of Young's Bay, Nicolai-Wikiup, Lower Columbia-Clatskanie River, and Scappoose Bay. These tributaries are included in the Columbia River estuary and lower mainstem subbasin plan because they are not addressed in other subbasin plans.

Washington tributaries, such as the Grays, Elochoman, Kalama, Cowlitz, are addressed in the Lower Columbia Fish Recovery Board's *Lower Columbia Salmon and Steelhead Recovery and Subbasin Plan,* prepared for the Northwest Power and Conservation Council in May 2004. Smaller Washington tributaries are also addressed in the Lower Columbia Fish Recovery Board's recovery/subbasin plan as part of the larger, Council-designated subbasins in southwest Washington. This has been done to avoid duplication between the Lower Columbia Fish Recovery Board's plan and the Estuary Partnership's plan and to be consistent with National Oceanic and Atmospheric Administration (NOAA) Fisheries' identifications of salmon populations. Table 1 shows the smaller Columbia River tributaries, the Council-designated subbasin that they fall within, and the Lower Columbia Fish Recovery Board subbasin (within the Lower Columbia Fish Recovery Board's recovery/subbasin plan) where they are addressed.

Table 1
Washington Lower Columbia Tributaries by Northwest Power and Conservation Council Subbasin and Lower Columbia Fish Recovery Board Subbasin

Columbia Tributary	**Northwest Power and Conservation Council Subbasin**	**Lower Columbia Fish Recovery Board Subbasin** (Lower Columbia Fish Recovery Board, 2004, Volume II: Subbasin Plans)
Wallacot	Estuary	Estuary Tributaries
Chinook River	Estuary	Estuary Tributaries
Salmon Creek	Lower Columbia	Salmon Creek
Burnt Bridge Creek	Lower Columbia	Salmon Creek
Gibbons	Lower Columbia	Bonneville Tributaries
Lawton Creek	Lower Columbia	Bonneville Tributaries
Duncan Creek	Lower Columbia	Bonneville Tributaries
Hardy Creek	Lower Columbia	Bonneville Tributaries
Hamilton Creek	Lower Columbia	Bonneville Tributaries

Focal Species Selection

Focal species for this supplement and the original subbasin plan were selected following guidance in the Northwest Power and Conservation Council's *Technical Guide for Subbasin Planners* (Northwest Power and Conservation Council, 2001), which recommends the following four criteria for selection of focal species: federal designation as a threatened or endangered species, ecological significance, cultural significance, and local significance (which in this case has been interpreted as economic and recreational significance). The focal species for this supplement and their basis for selection are shown in Table 2.

Table 2
Focal Species Selection

Species	ESA Designated	Ecologically Significant	Culturally Significant	Economically Significant	Recreationally Significant
Fall Chinook	X	X	X	X	X
Chum	X	X	X	X	X
Spring Chinook	X	X	X	X	X
Winter Steelhead	X	X	X	X	X
Summer Steelhead	X	X	X	X	X
Coho	X	X	X	X	X
Pacific Lamprey	X	X	X		
Bald Eagle	X	X	X		
Columbian white-tailed deer	X	X	X		
Green Sturgeon		X	X		
White Sturgeon		X	X	X	X

ESA = Endangered Species Act.

It should be noted that the subbasin plan addresses not just focal species but several aquatic and terrestrial species of ecological, management, and recreational interest, namely northern pikeminnow, American shad, eulachon, river otter, osprey, Caspian tern, yellow warbler, red-eyed vireo, dusky Canada goose, sandhill crane, walleye, smallmouth bass, and channel catfish. Management actions for focal species must take interactions with these non-focal species into account. In addition, the existing bald eagle and Columbian white-tailed deer management plans, which are operating successfully, should be consulted before any actions arising from this supplement or the subbasin plan are taken, to ensure that actions do not undo elements of the existing plans or have unintended consequences for bald eagles or Columbian white-tailed deer.

Single- vs. Multi-Species Benefits

The Northwest Power and Conservation Council criterion of federal designation as a threatened or endangered species has led to an emphasis on salmonids in this supplement and, to a lesser extent, in the subbasin plan. However, the strategies recommended in both documents are not necessarily salmonid-specific. To improve the biological performance of salmonids over the long term, it is necessary to address the underlying causes of ecological problems, not just their symptoms. This means improving ecological processes and conditions—such as flow regimes, access to productive habitat, and water quality—throughout the watershed. In the Columbia River estuary and lower mainstem, addressing these fundamental ecological issues would benefit a variety of species, from eulachon to river otter to osprey and sandhill crane. In addition, improving ecological processes and conditions has the potential to shift the ecosystem toward its predevelopment state—one that is more complex and resilient and favors native species over exotics. In recognition of the hundreds of species that use the subbasin and the value of addressing underlying ecological issues, preference has been given in the subbasin plan and this supplement to strategies that are likely to have multi-species rather than single-species benefits.

SECTION 2

Strategies

The subbasin-wide strategies in this supplement were developed by compiling focal species-specific strategies from Chapter 5 of the subbasin plan, eliminating duplication from one species to the next, and—from the resulting strategies—grouping related strategies that address the same or similar physical objectives and limiting factors. The result is five action-oriented strategies and one supporting strategy that, because they address fundamental issues throughout the Columbia River estuary, lower mainstem, and western Oregon tributaries, are likely to benefit multiple species, including terrestrial focal species and non-focal species. These strategies incorporate the eight “upper-tier” strategies from p. 4-42 of the subbasin plan, plus additional strategies from Section 4.4.1 of the subbasin plan

The five action-oriented strategies, in order of priority, are as follows:

1. Reduce the effects of the Columbia River hydrosystem.
2. Protect and restore habitat.
3. Address toxic contaminants.
4. Slow introductions of non-native species.
5. Reduce predation on focal species.

The supporting strategy is to manage uncertainty, through research and the monitoring and evaluation of on-the-ground projects. This strategy is not ranked in terms of priority because it is not discrete. Rather, it informs and is part of all the other five strategies and should be implemented concurrently with them. One of the most significant findings of the assessment in Section 2 of the subbasin plan was that the estuary and mainstem are understudied and poorly understood. Much more needs to be known about estuarine processes and species' habitat needs and interactions, and this is expressed in the key assumptions, strategies, limiting factors, and measures in Chapter 4 of the subbasin plan. Yet actions to improve conditions for fish and wildlife cannot wait until after key questions about species, habitat, and ecosystem processes have been answered. For this reason, managing uncertainty is presented as a supporting strategy to be implemented along with the other strategies. It is described in more detail at the end of this section.

Prioritizing strategies was the most challenging aspect of the subbasin planning process. In Chapter 4 of the subbasin plan (the management plan) an effort was made to generalize the multi-species benefits of each strategy and infer priorities based on the number of species potentially affected. While this approach resulted in the identification of eight strategies that supported the most species (see p. 4-42 of the subbasin plan), the approach fell short in factoring in other key considerations, such as whether a strategy addressed a short-term need or a long-term solution.

Prioritization of the strategies presented in this supplement was derived in part by considering the four criteria in the management plan: ability to address key objectives, relationship to threatened or endangered species, relationship to focal species of the subbasin, and socioeconomic considerations as stated in the vision (see Section 4.2.1 of the subbasin plan and Section 5 of this supplement). However, the final priorities were qualitative, based on findings in the estuary and mainstem assessment and what this revealed about the extent of the strategies' effects. For example, hydrology, which is governed largely by the Columbia River hydrosystem, affects nearly every aspect of ecosystem functioning, particularly habitat formation and maintenance, which in turn help determine water quality, which affects the composition of biological communities. Thus the dominant effect of flow places this strategy at the top. (In other words, it does not make sense to expend great effort altering species interactions, such as predation, without also improving habitat conditions and, ultimately, habitat-forming processes.) Essentially, top priority is given to the two strategies that address fundamental ecological problems in the estuary and lower mainstem: the availability, diversity, and quality of habitat and the role of flow in habitat creation and maintenance.

That said, it must be kept in mind that none of these strategies is discrete. There is a high degree of interdependence among the strategies, and taking action on any individual strategy will have significant impacts on the others.

The six strategies are presented below, along with the focal species, limiting factors, and physical objectives that each strategy addresses. Limiting factors are described individually in Appendix A, grouped by degree of impact on focal species. Appendix B presents biological objectives from the management portion of the subbasin plan. For a complete list of physical objectives and the species they apply to, see pages 4-34 through 4-41 of the subbasin plan.

Strategy 1: Reduce Effects of the Columbia River Hydrosystem

Implementing this strategy would involve adjusting Columbia River flows to simulate peak seasonal discharge, increase the variability of flows during focal species emigration, and restore tidal complexity in the estuary; maintaining adequate water flows during spawning, incubation, and migration periods; restoring connectivity between the river and the floodplain; restoring impaired sediment transport processes; and maintaining deep-water, rocky substrate spawning habitat for sturgeon in the estuary and lower mainstem.

Reducing the effects of the Columbia River hydrosystem is fundamental to increasing the abundance and productivity of all focal and many non-focal aquatic and terrestrial species in the lower Columbia mainstem and estuary, as well as the entire Columbia River Basin. While direct changes in the Columbia River hydropower system are complicated by a wide range of social, economic, political, and biological issues, the potential benefits of a healthy lower mainstem and estuary ecosystem cannot be overstated and should be factored into hydrosystem decision making. Some aspects of flow should be changed to improve habit-forming processes. The ability to alter other aspects of flow is more constrained. For these aspects of flow, sufficient mitigation efforts should be directed to activities that have a high correlation to threats posed by hydrosystem operations.

This strategy affects salmonids and white sturgeon during the egg incubation, juvenile, and adult life stages; juvenile and adult Pacific lamprey; and bald eagle. The strategy is consistent with the following key assumptions, which are based on assessment data and analysis in Chapter 2 of the subbasin plan:

- Complex and dynamic interactions between physical river and oceanographic processes, as modulated by climate and human activities, affect the general features of fish and wildlife habitat in the Columbia River estuary and lower mainstem. (See p. 2-150 of the subbasin plan.)
- Human activities have altered how the natural processes interact, changing habitat conditions in the Columbia River estuary and lower mainstem. (See p. 2-152 of the subbasin plan.)
- Construction and operation of the Columbia River hydropower system have contributed to changes in Columbia River estuary and lower mainstem habitat conditions that have reduced salmonid population resilience and inhibited recovery. (See p. 2-163 of the subbasin plan.)

Strategy Component

- Strive to understand, protect, and restore habitat-forming processes in the Columbia River lower mainstem, western Oregon tributaries, estuary, and plume.[1]

Explanation

Hydrology is arguably the most significant force that structures aquatic and riparian habitats in riverine and estuarine ecosystems. In the case of the Columbia River estuary and lower mainstem, habitat conditions for fish and wildlife species are governed largely by two opposing hydrologic forces: ocean tides and Columbia River discharges. Because ocean tides are largely outside the realm of potential management actions, it is the flow patterns of the Columbia River that are discussed here.

Flow patterns in the lower Columbia region are affected primarily by construction and operation of the Columbia hydropower system and tributary flows below Bonneville Dam (see Sections 2.1.3.1.1 and 2.1.3.2.2 of the subbasin plan). Columbia mainstem and tributary hydropower dams affect watershed-scale processes that govern the hydrology, food web, and sediment budget in the lower Columbia mainstem and estuary (see Section 2.1.4.2.1 in the subbasin plan). In turn, these processes directly and indirectly influence focal species by creating and eliminating habitat types, altering freshwater and saltwater balances, changing food availability for different species, and influencing migratory patterns for anadromous and resident species.

Flow regulation and irrigation withdrawals have changed the timing and magnitude of Columbia River flows, particularly maximum flows (see Section 2.1.3.1.1 of the subbasin plan). Winter drawdown of reservoirs and the filling of reservoirs during spring runoff have reduced spring freshet flows by 50 percent since 1969 and increased flows during the rest of the year such that peak flows can now occur during winter, rather than in spring, as historically was the case. Maximum flows have been reduced; this, combined with diking and the deposition of dredged material along the shoreline, have all but eliminated overbank flows in the lower Columbia. Historically such flows created a variety of habitats of value to focal species by connecting the river with its floodplain, increasing channel

[1] This corresponds to Strategy 2 in Chapter 4 of the subbasin plan.

complexity through the deposition of large woody debris, and transporting crucial riverine sediment to the estuary.

Sand sediments are vital to the natural formation and maintenance of habitat in the estuary, yet the transport of riverine sediments has decreased as a result of dam construction (see Section 2.1.3.1.2 of the subbasin plan). The largest single factor in reduced sediment transport appears to be the reduction of spring freshet flow as a result of water regulation and irrigation withdrawal. In addition, reservoirs restrict bedload movement and trap upstream supplies of sediments. Flow-related changes in the estuary sediment budget affect focal species by altering estuarine habitat formation, reducing habitat diversity, and disrupting turbidity patterns that aid in predator avoidance. Additionally, the decreased capacity of the lower Columbia River to transport sediments translates to less flushing and more sand and fine sediment deposition; to the extent that sedimentation occurs in areas used for sturgeon or salmonid spawning and incubation, spawning success and incubation survival may decrease.

Flow alterations also affect the salinity distribution in the estuary, particularly the location, size, shape, and salinity gradients of the estuary turbidity maximum zone, which migrates upstream during low flows and increases in size with high river flow (see Section 2.1.3.1.3 in the subbasin plan). Alterations in the estuary turbidity maximum zone can affect seasonal species distributions and the structure of entire fish, epibenthic, and benthic invertebrate prey species assemblages throughout the estuary. Small changes in the distribution of salinity gradients can change the type of habitats available when juvenile salmon make the critical physiological transition from fresh to brackish water. These changes affect salmon through alterations of salinity patterns and food webs, effects on the physiology of smoltification, and influences on predator and prey species distributions.

Lack of overbank flow has reduced the amount and accessibility of shallow-water, low-velocity wetland and side-channel habitat that juvenile salmonids depend on for food and cover (see Sections 2.1.3.2.2 and 2.1.3.2.3 in the subbasin plan) and that bald eagles use for feeding. Chum and fall Chinook in particular prefer these habitats, but evidence suggests that stream-type salmonids also use peripheral, shallow-water areas of the estuary and mainstem and that shallow-water habitats are important to sturgeon at night (Parsley et al., 2004). Columbian white-tailed deer rely on overbank flows for the creation of tidal lowlands and forested swamps—habitat types that have sharply declined in the last century. (See Table 2-11 in the subbasin plan.)

Another effect of flow-related habitat loss is the reduction of macrodetritus inputs (that is, coarse nutrients such as leaf litter and spruce needles) to the food web (see Section 2.1.4.2.8 in the subbasin plan). Historically the macrodetritus-based food web was distributed throughout the lower mainstem and estuary and supported a variety of native species. Currently detrital inputs are dominated by microdetritus (such as phytoplankton) from upriver sources. Micronutrients tend to remain suspended in the water column and, in the estuary, are concentrated in the spatially confined estuary turbidity maximum zone. They create a food web that is less accessible to species using peripheral habitats and that benefits exotic species such as American shad over native species, thus changing species assemblages, predator-prey relationships, and other species interactions. Microdetrital inputs are controlled primarily by reservoir production and flow rates.

Low peak flows and low sustained flood flows exacerbate the effects of contaminant exposure on fish and wildlife because lower water volumes translate to less dilution and higher concentrations of pollutants in Columbia River water. Also, contaminants associated with fine sediments are more likely to settle out and remain in slack-water habitats under low flow conditions. (See Section 2.1.3.2.5 in the subbasin plan.)

In addition, low water levels associated with daily hydrosystem operations can do the following (see Sections 2.1.4.4 and 2.1.4.2.7 in the subbasin plan):

- Reduce the delivery of nutrients and dissolved oxygen to incubating salmonid and sturgeon eggs, thus decreasing survival
- Dewater redds
- Decrease access to sturgeon and salmonid spawning areas and reduce the quality of existing spawning habitat
- Reduce the amount of resting habitat
- Strand juvenile salmonids during downstream migration
- Raise water temperatures, which can delay adult salmonid migrations, alter spawn timing for sturgeon and salmonids, and reduce the duration of egg incubation, thereby altering sturgeon and salmonid spawning, emergence, and juvenile rearing synchrony with environmental conditions
- Create still-water environments that favor introduced species and predation

Lastly, the migration behavior and travel rates of Pacific lamprey and juvenile and adult salmonids are closely tied to flow patterns. Because juvenile Pacific lamprey are poor swimmers, they rely on flow to carry them toward the ocean. Flow reductions may delay the downstream migration of lampreys and disrupt the timing of their physiological development. Among salmonids, fluctuations in flow can stimulate or delay juvenile emigration or adult migration, affecting the timing of juvenile arrival in the estuary or adult arrival at spawning grounds. Greater flows increase velocity, which increases juvenile travel rates and decreases adult travel rates. Higher flows generally increase the survival of juveniles as they pass through the dams, because more fish can pass over the spillways (where mortality is low) than through the powerhouses (where turbine passage mortality can be significant). In contrast, increased flow and spill can increase mortality and delay upstream passage of adults at dams as fish have a more difficult time locating the entrances to fishways and also are more likely to fall back after exiting the fish ladder.

Non-focal species that would benefit from this strategy include eulachon, osprey, yellow warbler, red-eyed vireo, dusky Canada goose, smallmouth bass, and channel catfish.

Key Limiting Factors This Strategy Addresses

Availability of peripheral rearing habitat and channel spawning habitat (LF.1[2] and LF.13), microdetritus-based food web (LF.2), lack of large woody debris and associated channel complexity (LF.9), flow-related migration barriers (LF.11), low flows during spawning (LF14.), dewatering of redds (LF.15), flow alterations affecting migration behavior (LF.31), and availability of preferred riparian habitat for Columbian white-tailed deer (LF.55).

[2] "LF" refers to the numbered limiting factors in Table 4-4 of the subbasin plan. The table is organized by species and life stage and includes working hypotheses and the level of certainty about the impact of each limiting factor.

Key Physical Objectives This Strategy Addresses

- Increase shallow-water peripheral and side-channel habitats toward historical levels.
- Restore connectivity between the river and floodplain, as well as in-river habitats.
- Maintain favorable water flow and temperature throughout mainstem incubation, spawning, and migration periods (August through March, depending on life stage).
- Restore spring peak flows in the lower Columbia River.

Strategy 2: Protect and Restore Habitat

Implementing this strategy would involve development of an estuary and mainstem model at the reach scale that organizes existing data and estimates productivity by habitat factor, protecting and restoring riparian and wetland habitat conditions and functions, restoring tidal swamp and marsh habitat, maintaining deep-water rocky substrates for white sturgeon spawning, improving access to productive spawning and rearing habitat, improving lamprey passage at dams, mitigating channel dredging activities, and restoring (1) the connectivity between the river and the floodplain, (2) sediment transport processes, and (3) spring peak flows.

There are significant challenges in implementing this strategy, among them the difficulties in modifying Columbia River flows and dredging activities to restore habitat-forming processes and floodplain connectivity. Although current programs and projects may be adequate to protect existing habitats, more needs to be done to restore tidal swamps, marshes, floodplains, and riparian areas so as to provide additional resting, feeding, breeding, and rearing habitat for focal species. Currently, conflicts with floodplain land uses and a lack of funds to acquire lands preclude large-scale habitat reclamation (through dike breaching, for example). Yet species simply cannot exist without habitat. Given the extent of habitat loss in the lower Columbia system, habitat restoration—and not just protection—is essential to improving the biological performance of focal species.

This strategy affects salmonids and white sturgeon at the egg incubation, juvenile, and adult life stages; juvenile and adult Pacific lamprey; bald eagle; and Columbian white-tailed deer. The strategy is consistent with the following key assumptions, which are based on assessment data and analysis in Chapter 2 of the subbasin plan:

- Human activities have altered how the natural processes interact, changing habitat conditions in the Columbia River estuary and lower mainstem. (See p. 2-152 of the subbasin plan.)
- Rates of obvious physical habitat change in the Columbia River estuary and lower mainstem have slowed in recent years; current physical and biological processes are likely still changing such that habitat conditions represent a degraded state. (See p. 2-155 of the subbasin plan.)
- Habitat restoration efforts are capable of significantly improving conditions for fish and wildlife species in the Columbia River estuary and lower mainstem. (See p. 2-167 of the subbasin plan.)

- If habitat diversity and channel stability in high-priority reaches of the western Oregon tributaries subarea are protected and restored, salmonid production and abundance will increase. (See W.H1 on p. 4-5 of the subbasin plan, where there are additional assumptions dealing with specific western Oregon tributaries, including the Lewis and Clark, Klaskanine, and Clatskanie rivers; Scappoose Bay; and Jackson and Joy creeks.)

Strategy Components

- Assess the Columbia River estuary and lower mainstem by discrete geographic reaches to aid in the development of restoration and protection priorities; develop an approach for determining expected outcomes of research, monitoring, and evaluation activities.[3]
- Protect functioning habitats while also restoring impaired habitats to properly functioning conditions.
- Use a combination of active and passive habitat restoration measures to provide near-term and long-term benefits.
- Maximize the efficiency of habitat restoration activities by concentrating on currently productive areas with significant scope for improvement, adjacent areas of marginal habitat where realistic levels of improvement can restore conditions suitable for fish, and areas where multiple species benefit.
- Mitigate small-scale local habitat impacts such that no net loss occurs, and avoid large-scale habitat changes where risks to salmonids, white sturgeon, and Pacific lamprey are uncertain.
- Protect and restore habitat diversity and channel stability attributes in the western Oregon tributaries to complement salmonid life-history requirements.
- Evaluate and improve downstream and upstream passage conditions for lamprey at mainstem and tributary dams—ensuring no negative effects on salmonid passage.
- Open access to productive habitat by removing or mitigating passage barriers.[4]

Explanation

Both aquatic and terrestrial species need a broad range of habitat types in the proper proximities to one another, at the right time, to satisfy feeding, refuge, breeding, and rearing requirements. Disconnected habitat, a lack of habitat, lack of habitat diversity, or lack of access to habitat obviously reduces the spatial structure, abundance, productivity, and life history diversity of species.

Over the last 130 years, human activities have altered the Columbia River estuary, lower mainstem, and western Oregon tributaries such that significant amounts of fish and wildlife habitat have been lost (see Sections 2.1.3.3.4 and 2.1.3.3.5 in the subbasin plan). From 1870 to 1983, for example, the amount of tidal swamp has declined by an estimated 77 percent and marsh habitat has declined by approximately 43 percent; ocean- and stream-type salmonids, Pacific lamprey, bald eagle, Columbian white-tailed deer, and non-focal species such as

[3] These components correspond to Strategies 7, 10, and 23 in Chapter 4 of the subbasin plan.

[4] These components correspond to Strategies 1, 6, 5, 3, 4, 20, 17, and 18 in Chapter 4 of the subbasin plan.

river otter rely on these and other wetland and riparian habitat types for spawning, rearing, and foraging (see Table 2-11 in the subbasin plan or Appendix C of this supplement). In many cases, access to functioning spawning and rearing habitat is blocked by tide gates, culverts, hatchery weirs, and dams. Dams are a particular challenge to Pacific lamprey who, as adults, have difficulty navigating fish ladders designed for salmonid passage (see Section 5.2.1.1.9.4 in the subbasin plan). Chum salmon also are often unable or unwilling to migrate through fish ladders (see Table 5-3 in the subbasin plan).

Habitat loss can be attributed to the conversion of wetlands and estuaries to other uses, such as urban and agricultural development, and the effects of flow alterations, dams, dikes, and dredging (see Section 2.1.3.2.2 in the subbasin plan). Diking is particularly detrimental because it completely removes habitat from the estuarine system. Dikes also reduce overbank flow, further disconnecting the river from its floodplain and altering flow-related processes that otherwise would create off-channel and peripheral habitat (see Section 2.1.3.2.3 in the subbasin plan). In addition, a lack of connectivity with the floodplain contributes to the microdetritus-based food web, as opposed to the more natural macrodetritus food web.

Dredging activities, too, have reduced habitat availability and quality through disturbance, sediment delivery, and alteration of habitat-forming sediment transport to the estuary. Placement of dredge spoils in the historical floodplain eliminates opportunities for protection and restoration of habitat, and it has contributed to predation of salmonids by Caspian terns. Concentrating flow in one main shipping channel has reduced flow to side channels and peripheral bays and changed the bathymetry of the estuary (see Section 2.1.3.2.4 in the subbasin plan). This, in turn, alters tidal flow, salinity gradients, and the estuary turbidity maximum, all of which influence habitat conditions for salmonids, sturgeon, and lamprey.

Habitat loss also can contribute to increased density of focal species, which in the case of juvenile salmonids may limit survival and productivity. Overcrowding of Columbian white-tailed deer has increased their vulnerability to parasites and foot-rot disease and made them more susceptible to population losses from flooding (see Section 5.2.2.1.4 in the subbasin plan). For bald eagles, human encroachment on nesting sites is known to reduce breeding success. Habitat loss and recreational and development pressures can exacerbate this problem.

In the western Oregon tributaries, channelization and the lack of spring freshets and large woody debris have simplified habitat and reduced refugia and resting areas. In addition, culverts, weirs, and other passage barriers block access to potentially productive salmonid spawning and rearing habitat.

Protecting existing functioning fish and wildlife habitat usually is more cost-effective than restoring degraded habitat, and protection provides a base level of production and diversity of focal species. In the Columbia River estuary, lower mainstem, and western Oregon tributaries, productive salmonid spawning and rearing habitat, riparian habitat used by Columbian white-tailed deer, and deep-water, rocky substrates that sturgeon use for spawning are candidates for protection. It also is important to remove or mitigate passage barriers so that focal species can reach functioning but currently inaccessible habitat. For aquatic species, passage barriers include levees, tide gates, culverts, weirs, and dams. For

Columbian white-tailed deer, river channels and structures cause useful habitat to be disconnected and therefore less available.

With regard to restoration, active restoration (such as installing engineered log jams in streams to compensate for the absence of large woody debris) should be used where there is an immediate need for near-term improvements in habitat conditions. However, passive restoration measures also should be employed to reinstate habitat-forming processes that will address the underlying causes of ecological problems and thus provide long-term and self-sustaining benefits.

Important habitats that are isolated or impaired should be restored when this would provide benefits to fish and wildlife species as habitat-forming processes are allowed to improve. It also makes sense to focus on restoring currently marginal areas where the gap between existing degraded conditions and suitable conditions is relatively small. Although some substantially degraded areas will be candidates for restoration, large-scale restoration of severely degraded areas is unlikely because of the relatively high cost-benefit ratio.

A key step in protecting and restoring habitat is determining which areas or reaches are in greatest need of protection or restoration. In many watersheds, analytical tools such as Ecosystem Diagnosis and Treatment (EDT) are used to quantify relationships between habitat conditions and species response and thus identify those reaches where the need for protection or restoration is most pressing. Currently, no such model exists that is appropriate for use in the Columbia River estuary and lower mainstem. However, the data and working hypotheses in Chapter 2 of the subbasin plan describe basic assumptions about life history requirements, habitat needs, watershed-scale processes, and species interactions in the subbasin, and this information could be used as the basis of an estuary-specific model that relates habitat conditions at the reach level to species performance. In developing the assessment in Chapter 2 of the subbasin plan, planners stressed the importance of describing these estuary and mainstem assumptions to (1) facilitate a transparent dialog among the scientific community that would provide direction for future data collection, (2) serve as the basis for EDT-like models appropriate to the estuary and lower mainstem, and (3) identify and prioritize habitat restoration and protection projects.

Non-focal species that would benefit from this strategy include eulachon, osprey, yellow warbler, red-eyed vireo, dusky Canada goose, and sandhill crane.

Key Limiting Factors This Strategy Addresses

Availability of preferred habitat (LF.1 and LF.55), loss of habitat connectivity (LF.3 and (LF.57), density dependence (LF.7), sedimentation of substrates (LF.18), migration barriers (LF.11), lack of resting habitats (LF.11), and dam passage (LF.10).

Key Physical Objectives This Strategy Addresses

- Protect existing rearing and spawning habitat to ensure no further net degradation.
- Increase shallow-water peripheral and side-channel habitats toward historical levels.
- Restore connectivity between the river and floodplain, as well as in-river habitats.

- Develop an understanding of emigrating juvenile salmonid life history diversity, white sturgeon spawning characteristics, and Pacific lamprey habitat use in the lower mainstem, western Oregon tributaries, estuary, and plume.
- Maintain favorable water flow and temperature throughout mainstem incubation, spawning, and migration periods (August through March, depending on life stage).
- Restore spring peak flows in the lower Columbia River.
- Improve dam passage for Pacific lamprey.
- Eliminate and mitigate access barriers for migrating adult salmonids, creating additional spawning and rearing habitat.
- Restore habitat diversity and geomorphology to tidally influenced reaches in the western Oregon tributaries.
- Protect existing Columbian white-tailed deer foraging habitat to ensure no further net degradation.
- Increase forested areas in lowlands and floodplain with hardwood and some coniferous riparian species (for use by Columbian white-tailed deer).
- Increase the availability of Columbian white-tailed deer habitat, including pasture and wood lots.

Strategy 3: Address Toxic Contaminants

Implementing this strategy would involve (1) extensive sampling to determine the locations and concentrations of contaminants in the lower mainstem and estuary, and (2) reducing uncertainty about exposure risks to salmonids, sturgeon, and lamprey. The effects of toxic contaminants could be addressed through the removal, treatment, or containment of hot spots or by addressing contaminants at their source, such as through the establishment of total maximum daily loads and best management practices that address stormwater and point sources. In either case, more specific data are needed on contaminant sources and the location and extent of contaminant effects before specific management actions can be taken.

This strategy affects juvenile salmonids and Pacific lamprey, white sturgeon in the egg incubation and juvenile stages, and bald eagle. The strategy is consistent with the following key assumptions, which are based on assessment data and analysis in Chapter 2 of the subbasin plan:

- Human activities have altered how the natural processes interact, changing habitat conditions in the Columbia River estuary and lower mainstem. (See p. 2-152 of the subbasin plan.)
- Changes in the Columbia River estuary and lower mainstem habitat have decreased the productivity of the ecosystem and contributed to the imperiled status of salmon and steelhead. (See p. 2-161 of the subbasin plan.)

Strategy Component

- Limit the effects of toxic contaminants in the Columbia River estuary, lower mainstem, and near-shore ocean.[5]

Explanation

Agricultural practices and industrial and urban development in the lower Columbia region have resulted in the accumulation of toxic contaminants such as DDT, DDE, polychlorinated biphenyls (PCBs), and metals in sediments, fish tissue, and bald eagle eggs in the lower mainstem and estuary (see Section 2.1.3.2.5 of the subbasin plan). DDT and PCBs have been detected at elevated concentrations in juvenile salmonids, and a variety of organochlorines (including aldrin, dieldrin, trichlorobenzene, and polycyclic aromatic hydrocarbons [PAHs]) and toxic metals (including mercury, cyanide, and arsenic) have been found to be above guidance levels in fish tissue and sediment in the lower 150 miles of the mainstem Columbia. In fact, the Oregon and Washington health departments have issued advisories regarding consumption of certain fish species (carp, peamouth, and sucker) because of elevated levels of PCBs, DDT, and DDE in the Columbia. Other contaminants of concern in the lower mainstem include dioxins, furans, and various pesticides.

Sublethal concentrations of contaminants affect the survival of aquatic and terrestrial species by increasing stress, predisposing organisms to disease, delaying development, and disrupting physiological processes, including reproduction (see Section 2.1.3.2.5 in the subbasin plan). In juvenile salmonids, contaminant exposure can result in decreased immune function and generally reduced fitness. Fall Chinook and chum may be particularly susceptible to contaminant exposure because they prefer peripheral shallow-water habitats where contaminants are known to accumulate. Pacific lamprey, too, may be susceptible because contaminants collect in the fine sediments where lamprey burrow. Toxic contaminants may also be affecting white sturgeon.

In the case of bald eagles, concentrations of PCBs, pesticides, and dioxins in eggs collected along the lower Columbia were at levels associated with reduced breeding success. Contaminants such as DDE and PCBs, which bioaccumulate in adult birds over time, are known to decrease eggshell thickness and reduce the number of young produced per occupied nest. Although studies show that levels of DDE and total PCBs declined from the mid-1980s to the mid-1990s, values still exceed estimated no-effect levels for bald eagles (see Section 2.1.3.2.5 in the subbasin plan). Productivity at new breeding sites along the Columbia is much higher than at old breeding sites (particularly those in the lower 60 miles of the river), suggesting that pairs at the older sites are more affected by contaminants than pairs at the newer sites. Productivity is lowest for bald eagles nesting between River Miles 13 and 31 (see Sections 2.1.3.2.5 and 2.1.4.10 in the subbasin plan).

Non-focal species that would benefit from this strategy include eulachon and osprey.

Key Limiting Factors This Strategy Addresses

Contaminant exposure of salmonids, sturgeon, lamprey, and bald eagle (LF.5, LF.22, LF.26, LF.33, and LF.51).

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[5] This corresponds to Strategy 12 in Chapter 4 of the subbasin plan.

Key Physical Objectives This Strategy Addresses

- Reduce contaminant exposure of emigrating salmonid and Pacific lamprey juveniles and white sturgeon eggs and juveniles.
- Continue to reduce, monitor, and understand contaminant sources in the lower Columbia River.

Strategy 4: Slow the Introduction of Non-native Species

Implementing this strategy would involve instituting regulatory, control, and education measures to prevent additional species invasions; establishing a moratorium on intentional introductions of non-native species; and evaluating and managing the impacts of American shad on salmonids and sturgeon.

The benefits of this strategy would be high because of the numerous negative impacts of introduced species on both native species and the ecosystem (see explanation below). Currently state and federal fish and wildlife agencies have the authority to prevent intentional introductions of non-native species, although differing agency goals and opinions on the importance, desirability, and impact of certain introduced gamefish, such as shad, make a moratorium on introduced species difficult to implement at this time.

A larger issue is the unintentional and thus uncontrolled introduction of non-native species—a topic that requires additional research to understand and address directly. However, to the extent that introduced species proliferate because they are able to capitalize on a degraded or altered ecosystem, efforts to mimic historical habitat conditions and ecosystem processes (such as by implementing the first two strategies described in this section) can be expected to reduce the impacts of unintentionally introduced species.

This strategy addresses juvenile salmonids, juvenile and adult white sturgeon and Pacific lamprey, and Columbian white-tailed deer. The strategy is consistent with the following key assumption, which is based on assessment data and analysis in Chapter 2 of the subbasin plan:

- Exotic species are capitalizing on the Columbia River estuary and lower mainstem habitats, and they have affected ecosystem processes and relationships. (See p. 2-156 of the subbasin plan.)

Strategy Component

- Do not intentionally introduce new species; take aggressive measures to avoid inadvertent introductions of new species or expansions of existing introduced species.[6]

Explanation

Numerous fish, wildlife, and plant species have been introduced into the Columbia estuary and lower mainstem ecosystem. Historically, game or food fish species, such as walleye and American shad, were introduced intentionally; today, however, introductions of non-native species are increasingly the result of world trade, which unintentionally transports a variety of species to new ecosystems, where they alter food web dynamics, transmit diseases and

[6] This corresponds to Strategy 8 in Chapter 4 of the subbasin plan.

parasites, and may outcompete native species. Non-native species are particularly adept at capitalizing on altered habitats such as those in the lower Columbia and estuary that have been affected by hydrosystem development and water regulation (see Section 2.1.5.2 in the subbasin plan). Once established, introduced species are extremely difficult to control or eliminate. They represent permanent alterations of the biological integrity of the ecosystem. The introduction of non-native species, combined with habitat alteration, can deplete or eliminate populations of native species.

In the Columbia River estuary and lower mainstem, non-native species number more than 70, including 37 fish species and 16 plants (see Section 2.1.5.2 in the subbasin plan). Non-native noxious weeds include purple loosestrife, which spreads aggressively; Eurasian water milfoil, which shades out native aquatic vegetation, decreases oxygen levels, and increases phosphorous and nitrogen loading, pH, and water temperature; parrot feather, which provides mosquito larvae habitat and shades algae, thus altering the aquatic food web; and Brazilian elodea, whose dense stands restrict water movement and trap sediments, affecting water quality (see Section 2.1.5.2.3 in the subbasin plan).

Exotic fish species in the lower Columbia system include walleye, smallmouth bass, channel catfish, and American shad. American shad are particularly abundant, in part because they prefer the microdetritus-based food web now prominent in the lower mainstem and estuary. Recent shad returns have reached nearly 4 million, and shad can live to be 11 years old, spawning multiple times during their lifetimes. Although shad have become an important food source for adult sturgeon, the habitat use and diet of juvenile shad overlap with those of juvenile salmonids (and possibly juvenile sturgeon), presumably creating competition. American shad also crowd fish ladders during salmonid upstream migration, which can cause migration delays. It is likely that the sheer abundance and consumption rates of American shad have already modified the estuarine food web. (See Section 2.1.5.2.2 in the subbasin plan).

In addition, introduced plant species such as purple loosestrife affect Columbian white-tailed deer by crowding out preferred forage.

Non-focal species that would benefit from this strategy include eulachon, smallmouth bass, and channel catfish.

Key Limiting Factors This Strategy Addresses

Interaction of introduced species with salmonids, sturgeon, lamprey, and Columbian white-tailed deer (LF.6, LF.27, LF.34, LF.39, and LF.59).

Key Physical Objectives This Strategy Addresses

- Document the interaction between introduced species and emigrating salmonid juveniles, white sturgeon adults and juveniles, and Pacific lamprey adults and juveniles; minimize negative interactions.
- Develop an understanding of emigrating juvenile salmonid life history diversity, white sturgeon spawning characteristics, and Pacific lamprey habitat use in the lower mainstem, western Oregon tributaries, estuary, and plume.

Strategy 5: Reduce Predation on Focal Species

Implementing this strategy would involve, among other things, evaluating and possibly managing shad impacts on salmonids; managing established populations of pikeminnow and introduced gamefish to reduce risks to salmonids, sturgeon, and lamprey; continuing management of predation by Caspian terns; establishing regulatory flexibility to manage seals and sea lions; and identifying predators of sturgeon embryos and juvenile lamprey.

Predation has the potential to have a high impact on juvenile salmonids, but some of that impact has been lessened through successful pikeminnow and Caspian tern programs, which can be continued with little difficulty. More challenging would be to define predation effects on sturgeon and lamprey—particularly the effects of gamefish, about which there is disagreement among state and federal wildlife agencies—and translate that new understanding into management actions. The Marine Mammal Protection Act limits the regulatory control of seals and sea lions that prey on salmonids, but some level of management is possible if warranted for salmon recovery. Reducing predation poses moderate challenges but is likely to be highly beneficial to focal species.

This strategy addresses juvenile and adult salmonids, incubating white sturgeon eggs, adult Pacific lamprey, and Columbian white-tailed deer. The strategy is consistent with the following key assumption, which is based on assessment data and analysis in Chapter 2 of the subbasin plan.

- Predation has always been a significant source of juvenile salmonid mortality in the lower Columbia River mainstem and estuary, but habitat changes resulting from human activities have substantially altered predator concentration and distribution, particularly Caspian terns and northern pikeminnow. (See p. 2-164 of the subbasin plan.)

Strategy Components

- As an interim recovery measure until more suitable habitat conditions are restored for salmon, consider management of predators and predation by selected species where corresponding threats have been exacerbated by human activities.
- Evaluate the level of predation mortality during the embryo and juvenile life stages of white sturgeon and the juvenile and adult migration stages of Pacific lamprey to determine the extent of predation-related recruitment failure.[7]

Explanation

Salmon, sturgeon eggs, lamprey, and Columbian white-tailed deer in the Columbia estuary and lower mainstem subbasin all are vulnerable to increased predation as a result of changes to the ecosystem that have altered predator-prey interactions. Predation of juvenile salmonids by Caspian terns and northern pikeminnow in particular has increased (see Section 2.1.5.1.1 in the subbasin plan). Although Caspian terns are native to the region, they did not nest in the Columbia River estuary until 1984, when they moved to East Sand Island and, later, Rice Island, which was created by Columbia River dredge spoils. Terns are a migratory species whose nesting season coincides with salmonid outmigration, making them a major predator of juvenile salmonids in the estuary. In 1997, terns and other avian

[7] These components correspond to Strategies 9 and 13 in Chapter 4 of the subbasin plan.

predators consumed 10 to 30 percent of the total estuarine salmonid smolt population. Since then, nesting has been encouraged on East Sand Island, where non-salmonid food sources are more plentiful; although this may decrease predation on juvenile salmonids, predation by terns remains a limiting factor. Larger emigrating salmonids, such as steelhead, are particularly vulnerable to Caspian tern predation, while chum appear to be least vulnerable.

Pikeminnows (a native fish) consume up to 9 million juvenile salmonids each year in the estuary and lower mainstem (see Table 2-17 in the subbasin plan). It is likely that this represents an increase in pikeminnow numbers over historical figures, as reservoirs and flow regulation have created slack-water habitats favored by pikeminnow. Also, pikeminnows tend to congregate at dam bypass outfalls and hatchery release sites to feed on smolts, which make up the majority of their diet at these locations (see Section 2.1.5.1.1 in the subbasin plan). Although a pikeminnow management program has been instituted that rewards anglers for pikeminnows over a certain size, predation by pikeminnows remains a limiting factor for juvenile salmonids. Walleyes also are a significant predator of juvenile salmonids. On a fish-per-fish basis, walleyes are as damaging as pikeminnows, but their overall impact is less because they are less abundant (see Section 2.1.5.2.1 in the subbasin plan).

Other predators in the Columbia River estuary and lower mainstem include seals, sea lions, and coyotes. Seals and sea lions prey on adult salmon and steelhead (see Section 2.1.5.1.1 in the subbasin plan) and the highly caloric Pacific lamprey, while coyotes prey on Columbian white-tailed deer fawns. The impact of these predators is uncertain but may be significant.

Lastly, white sturgeon embryos are vulnerable to predation by various aquatic species. Research indicates that, in the upper Columbia River, 12 percent of naturally spawned white sturgeon eggs are subject to predation. This is likely an underestimate. Predation rates in the lower Columbia are unavailable.

Non-focal species that would benefit from this strategy include eulachon.

Key Limiting Factors This Strategy Addresses

Predation of juvenile and adult salmonids (LF.4 and LF.12), sturgeon eggs (LF.20), juvenile and adult lamprey (LF.35 and LF.37), and Columbian white-tailed deer (LF.58).

Key Physical Objectives This Strategy Addresses

- Reduce predation mortality on developing embryos, emigrating juveniles, and migrating adults.
- Manage predator populations to maintain or decrease current levels of abundance.
- Encourage Caspian tern breeding colony distribution among multiple sites, preferably in locations where non-salmonid food sources are plentiful.

Supporting Strategy: Manage Uncertainty

Implementing this strategy would involve the testing and refining of assumptions and hypotheses found in the estuary and mainstem assessment in Chapter 2 of the subbasin plan, additional clarification and resolution of key questions that need to be answered, and the initiation of additional research to help answer key questions.

This strategy affects salmonids and white sturgeon at the egg incubation, juvenile, and adult life stages; juvenile and adult Pacific lamprey; bald eagle; and Columbian white-tailed deer. The strategy is consistent with the following key assumptions, which are based on assessment data and analysis in Chapter 2 of the subbasin plan:

- Our current understanding of the interrelationships among fish, wildlife, and limiting habitat conditions in the estuary and lower mainstem is not robust and introduces substantial uncertainty in decisions intended to benefit recovery and sustainability of natural resources. (See p. 2-156 of the subbasin plan.)
- Density-dependent factors affect salmonid productivity in the Columbia River estuary and lower mainstem. However, the relationships of the quantity and quality of habitat in relation to the expression of life history strategies of salmonids requires further clarification. (See p. 2-165 of the subbasin plan.)

Strategy Component

- Improve understanding of the relationships among salmonids, white sturgeon, and Pacific lamprey and the lower mainstem, western Oregon tributaries, estuary, and plume ecosystems; recognize the significance of salmon to the productivity of other species and the salmon themselves.

Explanation

Subbasin planning efforts in the lower Columbia mainstem and estuary were challenged by the lack of documented understanding about the life history requirements of focal species, their habitat needs, how watershed-scale processes affect those habitats, and how species interact. This is in sharp contrast to the level of understanding about how tributaries function, where, in many cases, significant data have been collected and models such as EDT are available to organize data and hypothesize relationships between habitat conditions and productivity.

In the estuary, research, monitoring, and evaluation needs include mapping, quantifying, and comparing current and pre-twentieth century aquatic habitats in the estuary to better understand the restoration potential of specific geographic areas; establishing goals, objectives, and scientific principles for restoration; and establishing a habitat monitoring program for use in an adaptive management process.

Additional research is needed to understand how physical processes affect habitat conditions in the estuary and mainstem, how focal species use those habitats, and how focal species are affected by predators, introduced species, and contaminants. For example, it would of value to develop a better understanding of the following:

- How emigrating juvenile salmonids use the estuary
- Pacific lamprey habitat use in the lower mainstem
- Spawning habitat characteristics for white sturgeon
- The bioaccumulation of contaminants in bald eagles
- The role of salmonids in stimulating primary and secondary productivity

Non-focal species that would benefit from this strategy include eulachon, osprey, yellow warbler, red-eyed vireo, dusky Canada goose, Caspian tern, smallmouth bass, channel catfish, walleye, and northern pikeminnow.

Key Limiting Factors This Strategy Addresses

This strategy addresses virtually all of the limiting factors for aquatic focal species (see Appendix A), particularly those related to predation, toxins, introduced species, habitat use, and species interactions.

Key Physical Objectives This Strategy Addresses

- Document the interaction between emigrating salmonid juveniles, white sturgeon adults and juveniles, and Pacific lamprey adults and juveniles and introduced species; minimize negative interactions.
- Develop an understanding of emigrating juvenile salmonid life history diversity, white sturgeon spawning characteristics, and Pacific lamprey habitat use in the lower mainstem, western Oregon tributaries, estuary, and plume.
- Evaluate and improve the survival of upriver juvenile salmonids emigrating via barge or dam passage.
- Develop an understanding of white sturgeon juvenile and adult and Pacific lamprey habitat use in the lower mainstem and estuary.
- Continue to reduce, monitor, and understand contaminant sources in the lower Columbia River.

SECTION 3

Status of a Framework for Prioritizing Future Projects

Throughout the subbasin planning process, planners' ability to prioritize habitat restoration and protection projects, research-related activities, and monitoring efforts in the Columbia River estuary and lower mainstem has been hampered by a lack of information about and understanding of the relationships among biological processes, physical conditions, and habitat-shaping processes, both at the reach level and on a watershed scale. In the absence of such information, planners have attempted to reduce uncertainty in future management decisions by doing the following:

- Collecting and organizing existing data on ecological conditions and processes in the estuary and lower mainstem and presenting that data in the estuary and mainstem assessment that appears in Chapter 2 of the subbasin plan.
- Formulating key assumptions (referred to in the subbasin plan as working hypotheses) about ecological conditions and processes in the estuary and lower mainstem, based on the data and analysis in the assessment.
- Developing strategies that are consistent with the assessment (which represents the best available science) and that address key limiting factors and physical objectives for focal species. The prioritized strategies are presented in Section 2 of this supplement.

Given the fact that current understanding about the interrelationships among fish, wildlife, and habitat conditions in the estuary and lower mainstem is not robust, a framework for prioritizing future projects has yet to be developed. However, in the interim, the relative merits of potential habitat protection and restoration projects, research-related activities, and monitoring efforts can be evaluated within the context of the prioritized strategies, with success measured in terms of achievement of the biological and physical objectives identified in the subbasin plan and this supplement (see Section 2 of this supplement, and Appendix B).

In addition, the Estuary Partnership, Lower Columbia Fish Recovery Board, and Oregon Watershed Enhancement Board currently apply detailed evaluation processes for potential projects—processes that use rigorous scientific criteria and best professional judgment to identify projects that are both scientifically sound and that can be implemented successfully. Although these processes could be improved, they are useful in evaluating proposed subbasin projects on a finer scale. Such an approach would be likely to enhance communication and coordination among the Northwest Power and Conservation Council, Estuary Partnership, Lower Columbia Fish Recovery Board, and Oregon Watershed Enhancement Board on habitat restoration and protection projects, research-related activities, and monitoring efforts.

A key step in developing a prioritization framework would be creation of an EDT-type model, appropriate to the estuary and lower mainstem, that quantifies relationships between habitat conditions and species response. This would involve identifying reaches at the appropriate scales, correlating data to the reaches, and defining relationships in the model that predict life-stage species responses to habitat conditions. While no such model currently exists for the estuary and mainstem, past efforts (such as Johnson et al., 2003) have produced defined reaches. In addition, the assessment in Chapter 2 of the subbasin plan organized much of the existing data and established hypotheses and assumptions that would be useful in defining the model parameters.

The outputs of such a model would be similar to those of EDT and could help identify the most important restoration and protection reaches in the estuary and mainstem and the relative importance of habitat attributes. Outputs also could be useful in helping to identify data gaps and research needs. The development of such a model for the estuary and lower mainstem should be as transparent as possible to ensure that the scientific community participates in crafting the underlying assumptions used to correlate habitat conditions to biological responses. If this occurs, the resulting prioritization framework would yield useful results that reflect and extend current scientific knowledge.

SECTION 4

Artificial Production

Current anadromous salmon runs are dominated by hatchery fish, which are being produced to enhance fisheries and at least partially mitigate for the reduced ability of habitat to produce natural fish at historical levels (Lichatowich, 1999). However, hatcheries have captured only a small portion of the historical life history diversity of salmonids. Large-scale hatchery releases may have increased the potential for detrimental interactions with declining wild fish populations, especially in critical estuary habitats. Potential risks of hatchery fish are exacerbated by estuary habitat loss and hydropower-related changes in the dynamic physical processes that shape estuary habitats and their suitability for salmon.

More than 200 hatchery programs currently produce salmon, steelhead, or trout in the U.S. portion of the Columbia River Basin, with hatchery stocks representing 175 of 264 of the basin's anadromous salmon and steelhead stocks (Northwest Power and Conservation Council, 2003). Each year, approximately 208 million salmon and steelhead juveniles are released into the Columbia River Basin below the Chief Joseph and Hells Canyon dams. The largest portion of these releases (42 percent) occurs in the lower Columbia River Province (see Figure 1), where many hatchery programs have been concentrated to take advantage of abundant water supplies and to avoid dam passage mortalities.

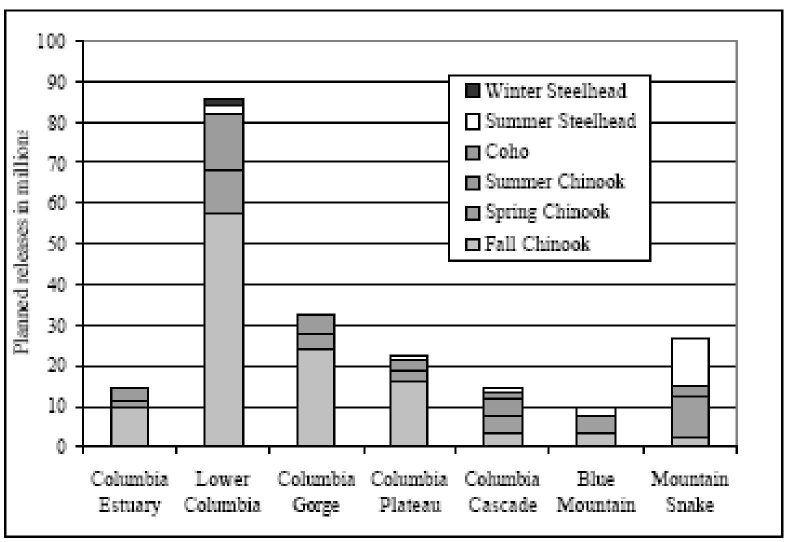

Figure 1
Distribution of Planned Hatchery Releases of Salmon and Steelhead
in the Columbia Basin by Province
(Source: Northwest Power and Conservation Council, 2003)

Effects of Artificial Production

Hatchery effects on wild fish can be both positive and negative. On the one hand, hatcheries are a useful conservation tool. They can temporarily preserve populations where habitat has been lost, bolster numbers through bottlenecks caused by poor ocean conditions, and supplement naturally spawning production where mortality factors are severe. On the other hand, hatcheries may increase extinction risks through a variety of mechanisms (National Research Council, 1996; Brannon et al., 2004). In the Columbia River estuary and lower mainstem these mechanisms include the following:

- **Competition.** The significance of density-dependent competition during juvenile emigration is unknown (Hard, 1994). However, because salmonid smolts actively feed during their downstream migration (Muir and Emmett, 1988; Sagar and Glova, 1988), it is possible that increased density from hatchery releases could increase competition with wild smolts; this effect is likely to have been exacerbated by habitat loss and degradation in the estuary over time. In 1990, the total hatchery and wild combined juvenile salmonid production was estimated to be 347.7 million, compared to an estimated historical wild juvenile abundance of 264.5 million (Kacynski and Palmisano, 1992). However, the current number of juveniles reaching the estuary may be less than historical numbers as a result of dam passage and post-release mortality suffered by hatchery fish.
- **Predation.** Hatchery fish can prey on wild fish and affect rates of predation by birds, other fish, and marine mammals. Large hatchery smolts or residual fish may eat smaller wild juveniles, especially of smaller species. Hatchery fish effects on other predators are complex and can be both positive and negative. Large numbers of hatchery fish might exacerbate predation by attracting increased predation (a functional response) or by enhancing predator populations (a numerical response). There is evidence that prey availability immediately below mainstem dams on the Columbia River affects predation rates by northern pikeminnow on juvenile salmonids (Peterson and DeAngelis, 1992). Conversely, Cada et al. (1994) note that the importance of predation by northern pikeminnow and other predators at the hydroelectric projects may be lessened by the possibility that many fish being consumed are hatchery smolts.
- **Mixed-stock harvest.** Because hatchery and naturally produced salmon and steelhead are often co-mingled, when hatchery production stimulates harvest effort, the catch of naturally produced fish can increase. Current harvest management strategies have transitioned to selective fishery and other regulatory methods that provide harvest opportunity for hatchery fish and strong wild stocks but minimize impacts to weak natural populations.
- **Genetic effects.** Hatcheries may also reduce wild salmon diversity and productivity through genetic effects. Domestication of hatchery stocks over time, founder effects, selective breeding, and the use of non-local broodstock can reduce the fitness of hatchery fish in the wild relative to locally adapted and diverse wild populations. In this case, interbreeding of hatchery and wild fish may reduce the success of the wild population. Genetic effects are not directly related to estuary alterations, but effects may be expressed throughout the salmon life cycle.

Hatchery Evaluations

A key element in managing artificial production for the recovery of natural populations will be to align hatchery priorities to be consistent with conservation objectives, such as conserving natural populations, enhancing natural fish recovery, and avoiding impeding progress toward recovery while continuing to provide fishery mitigation benefits. Hatchery operating agencies, which include states, tribes, and the U.S. Fish and Wildlife Service, have implemented a number of actions to enhance the benefits of artificial production while minimizing the risks. Conservation hatchery programs are being developed to enhance natural populations and assist them in meeting recovery objectives through supplementation, reintroduction, separation of hatchery and natural fish, or a merged hatchery/natural conservation strategy.

Regional hatchery programs have been subjected to regional reviews and requirements by NOAA Fisheries and the Northwest Power and Conservation Council. NOAA Fisheries must analyze the effects of a hatchery's propagation actions to determine whether listed fish may be taken and whether the continued existence of listed fish is jeopardized (Hard et al., 1992). NOAA Fisheries also can authorize a hatchery program by approving a Hatchery and Genetics Management Plan that addresses the potential risks and benefits of hatchery programs relative to the species conservation goals of the Endangered Species Act. The Northwest Power and Conservation Council completed a Columbia River Basin Artificial Production Review and Evaluation (APRE) in 2003 in response to a request from Congress. The goal of the APRE was to develop coordinated policies for the use of artificial production in the basin so as to increase the social benefits of artificial propagation programs while minimizing risks to naturally spawning populations (Northwest Power and Conservation Council, 2003). With respect to artificial propagation programs, NOAA Fisheries' Endangered Species Act regulatory authorities have objectives similar to those of the Northwest Power and Conservation Council's Columbia Basin Fish and Wildlife Program. The Hatchery and Genetics Management Plan template was developed in concert with Council efforts.

Estuary/Mainstem Implications

Given the limited understanding of the links between physical conditions and species' biological responses in the estuary and lower mainstem ecosystem, it is difficult to identify specifically the relationship between estuary habitat measures and lower Columbia River Basin hatchery measures. However, it can reasonably be assumed that competition between hatchery and natural juvenile salmonids, predation, and mixed-stock harvest are the focus of integrated hatchery and estuary habitat recovery strategies. Future research and monitoring of fish and habitat in the estuary will be key to understanding the interaction of hatchery and habitat effects on wild fish and in developing appropriate remedies.

The Estuary Partnership and Lower Columbia Fish Recovery Board are willing to assist with future efforts by the Northwest Power and Conservation Council to integrate artificial production with the various subbasin plans at a regional level.

SECTION 5

Conclusion

The Columbia River estuary and lower mainstem is a fascinating, complex, productive ecosystem whose biological workings we do not yet fully understand. We do know, though, that if the current levels of biological diversity and ecosystem functioning in the subbasin are to be maintained, action must be taken to improve conditions for fish and wildlife species. The need for action is even greater if the vision for the estuary and lower mainstem set forth in the subbasin plan is to be achieved:

> **Vision**: Fish and wildlife resources and their habitats are maintained at healthy levels; clean, safe water is available for people, fish, and wildlife. The lower Columbia River and estuary nourish all communities.

The subbasin plan and this supplement are intended to help make this vision a reality. Toward that end, the supplement presents, explains, and prioritizes strategies that are expected to improve conditions for a host of fish and wildlife species throughout the subbasin; the supplement also clarifies the relationship between the strategies, on one hand, and the physical objectives and limiting factors for the selected focal species, on the other.

In this supplement each strategy is described discretely, as if it could be implemented independently to improve individual components of the ecosystem. Clearly this is a simplification. In reality the strategies are interconnected and the components of the ecosystem they address are different parts of an integrated whole. Implementing one strategy is likely to alter conditions and functions that, in the supplement, are described in connection with another. This is particularly true of the two top-priority strategies: "reduce the effects of the Columbia River hydrosystem" and "protect and restore habitat," which are interdependent. Because these two strategies jointly address fundamental ecological problems, they have the potential to provide far-reaching benefits for multiple species throughout the subbasin.

As noted in Section 2 of this supplement, some strategies may be challenging to implement because of social, economic, or political constraints. Also, given the sometimes conflicting needs of different species, implementing the strategies could result in ecosystem changes that benefit some species but are detrimental to others. This might be the case even among the selected focal species, such as sturgeon and salmonids, which could be affected quite differently by alterations in flow regimes. However, we do not yet know enough about estuarine processes and species' habitat needs and interactions to be able to predict the effects of management actions with a high degree of certainty.

All of this argues for being aware of complexities and as informed as possible when implementing the strategies in the subbasin plan and this supplement. Answering key questions through research and monitoring and evaluating on-the-ground projects will facilitate course corrections in the event that the projects have unintended results or reveal significant new information about species, habitats, or ecosystem processes. Neither this supplement nor the management plan in Chapter 4 of the subbasin plan is a step-by-step "how-to" manual for fish and wildlife restoration. Rather, potential projects need to be considered in the context of the entire ecosystem and the realities of the social and political environment.

What does this mean? In part it means continuing what is currently working, using existing processes and programs to implement aspects of the strategies described in this supplement. For example, the Estuary Partnership and the Lower Columbia Fish Recovery Board currently are implementing numerous habitat restoration and protection projects that are consistent with the strategies; funding for these efforts should continue and, where appropriate, be expanded. Existing environmental and land use laws and regulations should be enforced and, where appropriate, strengthened. Support for current research into estuarine processes and species' habitat needs and interactions should continue. The results of research, monitoring, and evaluation efforts should be incorporated into the conceptual models and key assumptions in the subbasin plan and applied to current projects using adaptive management. That way, protection and restoration approaches will reflect the most current scientific knowledge and will improve continuously over time.

What are the next steps in improving conditions for fish and wildlife in the Columbia River estuary and lower mainstem? Based on the information in this supplement, which reflects the data, analysis, and management elements in the subbasin plan, the next steps are as follows:

- Improve our understanding of estuarine processes and species' habitat needs and interactions so that the impacts of potential management actions can be anticipated with a greater degree of certainty (see the supporting strategy, "manage uncertainty," in Section 2 of this supplement).
- Develop an EDT-type model specific to the estuary and lower mainstem that quantifies relationships between habitat conditions and species response (see Section 3 of this supplement).
- Use the model to (1) conduct reach-by-reach assessments of habitat conditions in the estuary and lower mainstem, and (2) identify those reaches that have the greatest protection or restoration needs and potential (see Section 3 of this supplement and the supporting strategy, "manage uncertainty," in Section 2).
- Address protection and restoration needs in high-priority reaches by using on-the-ground projects that are consistent with the strategies presented in this supplement, particularly Strategies 1 and 2, which are the highest priority strategies (see Section 2 of this supplement).

In essence, the subbasin plan and this supplement set the stage for protection and restoration actions to proceed in a precise, informed manner—one that is likely to yield benefits for a wide variety of aquatic and terrestrial species in the Columbia River estuary and lower mainstem.

SECTION 6
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APPENDIX A

Limiting Factors

APPENDIX A

Limiting Factors

Limiting factors for the focal species were identified by analyzing the following:

- Factors or conditions that historically led to the decline of each focal species and of associated ecological functions and processes
- Key factors or conditions that currently inhibit populations and ecological processes and functions relative to the populations' potential
- Current threats or risks for focal species and their habitats
- Opportunities that directly reduce these threats

For the purposes of this supplement, limiting factors have been grouped to indicate general level of impact, as follows:

- **High-impact limiting factors**, about which there is a high or medium level of certainty regarding the impact.[1] These factors currently limit population viability because of effects on mortality rates or productivity. High-impact limiting factors are of primary importance in maintaining current levels of population abundance or productivity, or they must be addressed to promote recovery of the species. Certainty about the Priority 1 limiting factors is high, except in the case of three limiting factors: the microdetritus-based food web, decreased flows during spawning and incubation, and dewatering of redds. The certainty level for these three factors is medium.
- **Medium-impact limiting factors.** These factors currently affect population viability but may not be significantly reducing population abundance or productivity.
- **Low-impact limiting factors.** These factors exist but are unlikely to affect the population viability at current impact levels.

One limiting factor—interaction with introduced species—does not fall easily into the categories above. Numerous species have been introduced into the lower Columbia mainstem and estuary, both intentionally and unintentionally, and they undoubtedly affect focal species; for example, non-native plant species such as purple loosestrife crowd out Columbian white-tailed deer's preferred forage. However, in many cases the level and dynamics of the impacts of introduced species are not clear. Effects on some species may be offsetting. For example, shad (an introduced species) has become an important food source for adult sturgeon, but shad and gamefish may compete with juvenile sturgeon for food sources. The effects of introduced species on salmonids are thought to be negative, and

[1] A "high" level of certainty indicates that considerable research has been performed on the subject and this research has repeatedly produced similar results. A "medium" level of certainty indicates that considerable research has been performed on the subject and results have been inconclusive or contradictory, or some research has been performed and preliminary results suggest that a relationship exists. A "low" level of certainty indicates that limited research has been performed and preliminary results are inconclusive or contradictory, or little to no research has been performed and any relationships are assumed based on other related scientific data or relationships.

effects on Pacific lamprey are unknown. Introduced species are discussed in more detail in the Section 2 of the supplement.

High-Impact Limiting Factors

Availability of preferred habitat: juvenile rearing habitat, spawning habitat, and riparian habitat (LF.1,[2] LF.13, LF.16, LF.55)

Affected species: Chum, fall Chinook, Columbian white-tailed deer.

A lack of adequate quantities of accessible, high-quality habitat limits both salmonid and terrestrial focal species in the estuary, lower Columbia mainstem, and western Oregon tributaries. In the Coast Range stratum, barriers such as culverts and hatchery weirs reduce fall Chinook's access to what historically were productive spawning areas used by demographically independent populations. Throughout the estuary, mainstem, and western Oregon tributaries, activities such as water regulation, dike construction, and urban and agricultural development have caused extensive losses of shallow-water, low-velocity peripheral wetland and side-channel habitats. These losses limit the potential of chum salmon (which are closely associated with peripheral habitats) and fall Chinook during juvenile rearing. Both subbasin and out-of-subbasin populations are affected.

In addition, changing flow levels associated with water regulation at Bonneville Dam affect chum and, to a lesser degree, fall Chinook by limiting access to lower mainstem spawning locations and potentially decreasing their quality. Chum salmon have been observed spawning at multiple locations between the I-205 Bridge and Bonneville Dam and in the lower reaches of the western Oregon tributaries, and these spawning aggregations represent an important component of current chum natural production. Fall Chinook also have been observed spawning in multiple mainstem locations, particularly in the Ives and Pierce Island area (although these spawning aggregations are believed to be derived from local hatchery strays, so their importance to the recovery of the evolutionarily significant unit is unclear). Low flow associated with water regulation is thought to limit access to spawning areas, while high flow may decrease the quality of these spawning locations by increasing the water depth or velocity beyond acceptable bounds.

A lack of preferred habitat also affects Columbian white-tailed deer, which need riparian habitat with plant communities that provide both forage and cover. In the lower Columbia, Columbian white-tailed deer forage for annuals, forbs, and shrubs in brushy woodlots associated with tidal lowlands that are characterized by cottonwood, willow, alder, spruce, and dogwood. Dense forested swamps and tall tidal shrubs are needed for suitable habitat. There has been extensive loss of riparian habitat throughout the mainstem and estuary as a result of water regulation, dike construction, and urban and agricultural development.

Habitat connectivity in the estuary and lower western Oregon tributaries (LF.3)

Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during juvenile rearing.

[2] "LF" refers to the numbered limiting factors in Table 4-4 of the subbasin plan. The table is organized by species and life stage and includes working hypotheses and impact certainty levels for each limiting factor.

Areas of adjacent habitat types distributed across the estuarine salinity gradient may be necessary to support annual migrations of juvenile salmonids. As juveniles grow, they move across a spectrum of salinities, depths, and water velocities. For species such as chum salmon that rear in the estuary and in tidally influenced areas of the western Oregon tributaries for extended time periods, a broad range of habitat types in the proper proximities to one another may be necessary to satisfy feeding and refuge requirements within each salinity zone. Species such as fall Chinook that rear in the estuary for extended time periods have similar needs for habitat connectivity among salinity zones. For stream-type salmonids, research suggests that proximity of feeding and refuge areas may be important for survival and to provide olfactory cues needed for a successful return migration.

Lack of large woody debris (LF.9)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during juvenile rearing.

Development and agricultural and timber practices have caused a loss of habitat diversity and channel stability by reducing recruitment of large woody debris into the systems throughout the subbasin. Habitat complexity is important for creating rearing opportunities for young-of-the-year coho.

Decreased flows during spawning and incubation (LF.14)
Affected species: Chum, fall Chinook, coho, and winter steelhead spawning within the subbasin.

Water regulation at Bonneville Dam substantially affects water flow in mainstem spawning locations and may also negatively affect flow in the lower reaches of the western Oregon tributaries. Low flow may decrease the delivery of nutrients and dissolved oxygen to incubating eggs, thereby decreasing survival. The level of certainty regarding the impact of decreased flows during spawning and incubation is medium.

Dewatering of redds (LF.15)
Affected species: Chum and fall Chinook spawning within the subbasin.

Water regulation at Bonneville Dam substantially affects water level in mainstem spawning locations. Flow reductions to the point of dewatering of redds result in substantial mortality of incubating eggs or pre-emergent alevins. The level of certainty regarding the impact of dewatering of redds is medium.

Microdetritus-based food web (LF.2)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during juvenile rearing.

Loss of wetland and side-channel habitat in the estuary, lower mainstem, and western Oregon tributaries has reduced the local macrodetritus inputs from terrestrial and riparian habitats that historically supported the food web. Currently, detrital inputs to the food web are dominated by microdetritus from upriver sources, and these inputs are controlled primarily by reservoir production and flow rates from Bonneville Dam. Unlike the historical macrodetritus-based food web, the microdetritus-based food web benefits exotic species over natives, thus changing a variety of species interactions. The level of certainty regarding the impact of the microdetritus-based food web is medium.

Fitness and timing of juvenile salmonids entering the subbasin (LF.8)
Affected species: Fall and spring Chinook, coho, and winter and summer steelhead (within-subbasin and out-of-subbasin populations) during juvenile rearing.

Juveniles entering the subbasin from upriver via barge releases or dam passage experience lower survival than juveniles historically did during mainstem emigration, before hydrosystem development.

Dam passage (LF.36)
Affected species: Adult lamprey during migration.

Pacific lamprey are often unable or unwilling to migrate through fish ladders. Thus, Bonneville Dam and many tributary or other mainstem dams have limited upstream migration of Pacific lamprey to historical upriver spawning areas.

High tides in undiked areas or failed dikes (LF.56)
Affected species: Columbian white-tailed deer.

Some of the greatest recent losses of deer have been the result of flooding in the estuary and along the lower mainstem.

Lack of continuity between suitable riparian habitats (LF.57)
Affected species: Columbian white-tailed deer.

Much of the habitat in the estuary and lower mainstem is unsuitable or disconnected because of channels and structures.

Predation mortality (LF.58)
Affected species: Columbian white-tailed deer.

The greatest losses of fawns in the estuary and lower mainstem are due to coyotes. Adult losses from predation are due to poaching.

Medium-Impact Limiting Factors

Dam passage (LF.10)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during adult migration.

Chum salmon are often unable or unwilling to migrate through fish ladders or inundated habitats. Thus, Bonneville Dam has blocked most upstream migration of chum salmon to historical spawning areas. Access to historical spawning areas also has been blocked in two major fall Chinook producing subbasins, the Cowlitz and Lewis, and in key areas of the western Oregon tributaries. Coho likely experience some mortality and delay associated with mainstem dam passage; however, an average per-dam survival rate estimate for coho was not available. For spring Chinook, the average per-dam survival rate estimate was 89 percent (this includes fallback and re-entry). The estimate for winter and summer steelhead was 95 percent.

Contaminant exposure (LF.5 and LF.51)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during juvenile rearing; Pacific lamprey during juvenile rearing and migration; white sturgeon egg incubation; bald eagle.

Contaminants have been documented throughout the lower mainstem and estuary. Contaminants are known to have detrimental effects on salmonids and the development and physiological processes of white sturgeon; they also decrease eggshell thickness among bald eagles, which affects survival. Juvenile chum and fall Chinook salmon are closely associated with peripheral, side-channel habitats where contaminants commonly accumulate. Exposure risks to stream-type salmonids are not clear, although contaminant uptake may occur through consumption of contaminated diet items. It is likely that juvenile Pacific lamprey also are affected by contaminants, as lamprey are closely associated with fine sediments where contaminants commonly accumulate. The greatest impact to bald eagles appears to occur at older breeding territories, which are located predominantly in the lower estuary below River Mile 60.

Hatchery impacts on diversity (LF.17)
Affected species: Coho spawning within the subbasin.

Early hatchery practices resulted in the proliferation of s-type coho populations, which are not ideally matched with the environmental characteristics of the Coast Range ecological zone.

Sedimentation of spawning substrates (LF.18)
Affected species: White sturgeon egg incubation.

Deposition of fine sediments in the preferred spawning habitats (deep-water, rocky substrates) in the estuary and lower mainstem results in egg suffocation. Fine sediment sources include adjacent tributary subbasins as well as migration of sediments from mainstem deposits.

Egg hypoxia (LF.19)
Affected species: White sturgeon egg incubation.

Hypoxia may have disproportionate negative effects on sturgeon compared to other fish because of sturgeon’s limited capacity to osmoregulate at low dissolved oxygen concentrations. Dissolved oxygen levels may be low for any number of reasons. Delivery of oxygenated water is decreased through sedimentation.

Predation (LF.20 and LF.37)
Affected species: White sturgeon egg incubation and Pacific lamprey.

Demersal white sturgeon embryos are vulnerable to predation. Research on the upper Columbia indicated that 12 percent of naturally spawned white sturgeon eggs were subject to predation, although the research suggests that predation was likely underestimated. If predation mortality is substantial, recruitment failure can result.

Additionally, because of their high caloric value, Pacific lamprey are an important food source for marine mammals, sturgeon, and possibly other species in the lower Columbia River. The significance of predation on Pacific lamprey needs to be quantified.

Direct dredging mortality (LF.21, LF.25, and LF.32)
Affected species: White sturgeon eggs during incubation and juveniles during rearing; Pacific lamprey during juvenile rearing and migration.

White sturgeon's association with benthic habitats makes them susceptible to suction dredging effects as both eggs and juveniles. Although white sturgeon prefer to spawn in rocky substrates with sufficient interstitial spaces, spawning has been observed in sands and fine sediments, and eggs broadcast among rocky substrates sometimes disperse downstream and settle among sands or fine sediments. Additionally, there is speculation that dredging operations may attract white sturgeon, compounding potential losses. Dredging activities in areas where embryos or juveniles are present result in direct mortality.

Juvenile Pacific lamprey also are closely associated with fine sediments, in which they burrow and filter feed. Dredging activities in areas where juveniles are present result in direct mortality; an estimated 3 to 26 percent of juvenile lamprey passed through a dredge survived.

Flow alteration (LF.31)
Affected species: Pacific lamprey during juvenile rearing and migration.

Juvenile Pacific lamprey are poor swimmers and rely on flow to carry them toward the ocean. Flow alterations in the Columbia River basin (as a result of hydrosystem operations and water withdrawal) have decreased peak flows in the lower Columbia River mainstem and inundated habitats throughout the basin. Flow reductions may delay downstream migration of lamprey, disrupting the synchrony of physiological development and downstream migration timing.

Density dependence (LF.7)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during juvenile rearing.

Density-dependent mechanisms in the lower mainstem, western Oregon tributaries, estuary, and plume may limit juvenile salmonid survival and productivity; however, the significance is unclear. NOAA Fisheries is currently conducting research intended to clarify this issue.

Persecution (primarily illegal shooting) (LF.54)
Affected species: Bald eagle.

Hybridization and competition with black-tailed deer (LF.61)
Affected species: Columbian white-tailed deer.

Direct competition with black-tailed deer affects Columbian white-tailed deer resources in the estuary and lower mainstem.

Low-Impact Limiting Factors

Migration barriers/lack of resting habitats (LF.11)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during adult migration.

Elevated water temperature or high water flow may act as a temporary adult migration barrier. Additionally, high water flow likely reduces available resting habitat for migrating adults. Hatchery weirs, culverts, and other passage barriers in the western Oregon tributaries can block access to potentially productive habitat.

Predation mortality (LF.4, LF.12, and LF.24)
Affected species: All salmonid focal species (within-subbasin and out-of-subbasin populations) during juvenile rearing; white sturgeon juveniles during rearing.

Current levels of predation on chum salmon are unknown but are thought to be lower than for other salmonids, possibly as a result of lower abundance, smaller size, or spatial segregation from predators. Levels of predation on fall Chinook are unknown but are thought to be higher than for chum but lower than for stream-type salmonids. The current primary sources of predation on stream-type salmonids are substantial. For example, Caspian tern predation is higher for larger emigrating salmonids, such as steelhead. Primary predation sources for stream-type salmonids include Caspian tern and pikeminnow. Also, because chum salmon spawn downstream of Bonneville Dam, emigrating chum do not encounter the known concentration of northern pikeminnow just below Bonneville Dam. Marine mammals also prey on adult salmon, but the significance is unclear.

Juvenile white sturgeon losses to predation are probably low because of the protective scutes, benthic habitats, and fast growth. Predation needs to be evaluated.

Fishing mortality (LF.28)
Affected species: Adult white and green sturgeon.

Currently, size restrictions in the sport fishery allow sturgeon to survive to older ages, thus maintaining adequate abundance of spawning adults. Fishery regulations, fishing effort, harvest levels, and population response need to be monitored closely to ensure that adult spawning abundance is maintained.

Incidental mortality (LF.30)
Affected species: Adult white and green sturgeon.

Operations at Bonneville Dam—specifically, the dewatering of turbines—can entrain white sturgeon and result in mortality. The significance of this mortality factor needs to be evaluated.

Harvest mortality (LF.38)
Affected species: Adult lamprey during migration.

Historically, tribes harvested lamprey throughout the Columbia basin for food, ceremonial, medicinal, and trade purposes. Today harvest is limited primarily to Willamette Falls and Sherars Falls (on the Deschutes River). Because of limitations on lamprey harvest (fishing effort, legal gear types, area closures, seasonal restrictions, diel restrictions), harvest may not be a major mortality factor.

Availability or disturbances to nesting habitat (LF.52)
Affected species: Bald eagle (and osprey).

Bald eagles typically prefer very old Douglas fir or Sitka spruce on shorelines and large cottonwoods or spruce on Columbia River islands. Osprey prefer mature forest habitats with adequate nest and roost trees close to abundant fish resources. Osprey appear to be adaptable and have been observed nesting on artificial structures such as channel markers or power poles**.**

Available habitat (LF.60)
Affected species: Columbian white-tailed deer. Overcrowding has led to higher numbers of parasites and diseases such as foot rot in the estuary and lower mainstem.

Collisions with cars (LF.62)
Affected species: Columbian white-tailed deer. Losses have resulted from automobile collisions.

APPENDIX B

Biological Objectives

APPENDIX B

Biological Objectives

Biological objectives, which represent desired future conditions for the focal species, are summarized in Table B-1. Spring Chinook and coho are not included in Table B-1 because it is likely that their biological performance is determined largely by out-of-subbasin effects, such as spawning conditions in tributaries and dam passage success.

Table B-1
Summary of Biological Objectives

Focal Species	Metric	Performance Level
Chum	Mortality [A]	Current estimates of annual mortality for different populations range from 0.28 to 0.59 and average 0.46. Mortality estimates at population recovery goals range from 0.23 to 0.58 and average 0.42.
	Productivity	>1 recruit per spawner
	Abundance[B]	I-205 1,250 Ives Island 6,400 Multnomah Falls 2,300
Fall Chinook	Mortality [A]	Current estimates of annual mortality for different populations range from 0.29 to 0.38 and average 0.33. Mortality estimates at population recovery goals range from 0.16 to 0.36 and average 0.27. The current mortality estimate for the Lewis River late fall population was 0.39; The mortality estimate at population recovery was 0.26.
	Productivity	>1 recruit per spawner
	Abundance[B]	Ives and Pierce Islands 12,000
Winter steelhead	Mortality [A]	Current estimates of annual mortality for different populations range from 0.10 to 0.18 and average 0.14. Mortality estimates at population recovery goals range from 0.10 to 0.18 and average 0.10.
Summer steelhead	Mortality [A]	Current estimates of annual mortality for different populations range from 0.04 to 0.59 and average 0.16. Mortality estimates at population recovery goals range from 0.04 to 0.59 and average 0.16.
White sturgeon	Productivity	>1 recruit per spawner
	Abundance of 36- to 72-inch size class	> 400,000; abundance estimates of this size class in the 1990s approached 450,000, which represents modern-day record numbers. [C]
	Harvest levels	Approximately 50,000; manage population to maintain recent harvest levels while maintaining spawner abundance.
Pacific lamprey	Adult abundance	Minimum of 100,000 adults passing Bonneville Dam annually (represents the 1938-1969 average).

Table B-1
Summary of Biological Objectives

Focal Species	Metric	Performance Level
CWT deer	Abundance	Julia Butler Hansen National Wildlife Refuge: Approximately 150
		Tenasillahe Island: Approximately 150
Bald eagle	Productivity	>1 young per occupied nest

Notes:

[A] Mortality is based on preliminary analysis by LCFRB based on comparison of Ecosystem Diagnosis and Treatment (EDT) estimates of mainstem and estuary habitat effects on lower Columbia River salmonid populations, current population abundance estimates, and population abundance recovery goals.

[B] Estuary/mainstem adult spawning only.

[C] Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife abundance estimates for the lower Columbia mainstem and estuary.

APPENDIX C

Species' Use of Habitat Types in the Columbia River Estuary and Lower Mainstem

APPENDIX C

Species' Use of Habitat Types in the Columbia River Estuary and Lower Mainstem

				Riverine/Estuarine Habitat			Transition Habitat			Upland Habitat		
				Estuary Habitat Classification (Thomas, 1983; Johnson et al., 2003)					WDFW Priority Habitat Classification			
				Deep Water	Medium Depth Water	Tidal Flats	Tidal Marsh	Tidal Swamp	Riparian	Old-Growth/ Mature Forest (see note below)	Freshwater Wetland (i.e., isolated from river corridor)	Rural Natural Open Space
				Percent Habitat Change from 1870 to 1983 (Thomas, 1983; Johnson et al., 2003)								
Species	Primary Life Stage	Level of Use	Primary Season of Use	-13	-19	+10	-49	-74	-	-	-	-
Ocean-type salmonid[a]	Subyearling juveniles	Migratory	Spring-fall	◓	◕	◕	●	●	●	○	○	○
Stream-type salmonid[a]	Yearling smolt	Migratory	Summer	◕	◕	◕	◕	◕	◕	○	○	○
Pacific Lamprey[b]	Ammocoetes or macrothalmia	Migratory or resident	Potentially year-round	◕	◕	◔	◕	◕	◕	○	○	○
White Sturgeon[c]	Juveniles and adults	Migratory or resident	Year-round	●	◓	◓	◔	◔	◔	○	○	○
Northern Pikeminnow[d]	Juveniles and adults	Migratory or resident	Year-round	◓	◕	◓	◕	◕	◕	○	○	○
River Otter[e]	Juveniles and adults	Resident	Year-round	◓	◓	◓	◕	◕	◕	◔	◕	◓
Caspian Tern[f]	Juveniles and adults	Resident	Spring to fall	◕	◕	◕	◔	◔	◔	○	○	◓
Bald Eagle/ Osprey[g]	Juveniles and adults	Resident	Spring to fall	◓	◓	◓	◔	◕	◕	◕	◓	◔
Yellow Warbler[h]	Juveniles and adults	Resident	Spring to fall	○	○	○	◔	●	●	◔	◕	◔
Red-eyed Vireo[i]	Juveniles and adults	Resident	Spring to fall	○	○	○	◔	●	●	◓	◕	◔
Sandhill Crane[j]	Juveniles and adults	Resident	Winter	○	○	◓	◕	○	◕	○	◕	◕
Columbian White-tailed Deer[k]	Juveniles and adults	Resident	Year-round	○	○	○	◓	◕	◕	◕	◓	◕

Qualitative Scale of Habitat Use:

- ● Critical
- ◕ High
- ◒ Medium
- ◔ Low
- ○ None

Note: The use of multiple habitat classification systems is problematic; considerable overlap occurs between habitat designations in different classifications. The habitat types used in the comparison of current and historical habitat conditions (Johnson et al., 2003) are very general and are not intended to fully describe the vegetation components of the habitat. The WDFW Priority Habitats may be general or specific, depending on the category. For example, old-growth/mature forests are described by specific tree diversity, density, and canopy layers but have no elevation specifications. Therefore, old-growth forests could be a subset of tidal swamps or part of the upland region. In fact, the 74 percent loss of tidal swamp habitat may have consisted primarily of old-growth tidal swamps, and the importance of old-growth habitats in the lower mainstem and estuary should not be underestimated. On the other hand, the WDFW riparian habitat category is very general and may encompass habitats categorized as tidal marsh or tidal swamp. Finally, use of the word "tidal" implies some influence of inflowing saltwater on the lower Columbia River mainstem and estuary habitats. In the Columbia River, the influence is generally realized as fluctuating water levels and not as substantial changes in salinity levels over the tidal cycle; many tidal areas in the lower Columbia River remain dominated by freshwater. In general, salinity can have an overriding influence on estuary and mainstem habitats; it controls plant and animal species assemblages that occur in specific areas because most species have very specific salinity tolerance.

[a] Estuary habitats are used primarily by outmigrating juvenile salmonids, except for cutthroat trout, which have been observed to occupy estuarine and tidewater habitats for the entire ocean residence period. The importance of the estuary and mainstem littoral habitats varies and is roughly equivalent to the amount of time each species uses the estuary and lower mainstem. Generally, salmonids that emigrate as fry or sub-yearlings (that is, ocean-type Chinook and chum salmon) use the estuary extensively for rearing, while salmonids that emigrate as yearlings spend less time in the estuary.

[b] Pacific lamprey do not feed during the transformation from ammocoetes to macrothalmia, which occurs around the time of migration from freshwater to saltwater. Although little is known about Pacific lamprey use of the estuary or lower mainstem habitats, lampreys are not thought to spend much time in the lower mainstem or estuary.

[c] White sturgeon have been observed congregating in the Columbia River estuary during summer, presumably in relation to food availability. However, it is likely that white sturgeon are present in the lower mainstem and estuary throughout much of the year. Estuary and lower mainstem habitat usage likely varies by age, with younger fish using near-shore or medium-depth habitats and adults using deep-water habitats.

[d] Northern pikeminnow are freshwater species and are not known to use estuarine habitats. Northern pikeminnow are warm-water species that inhabit the medium- and deep-water habitats of the Columbia River mainstem.

[e] River otter juveniles and adults are closely associated with aquatic habitats; pups are usually born in a subterranean burrow and begin to swim at about 2 months. River otters feed in water and on land; otters have been observed traveling long distances over land.

[f] Caspian terns can nest in a variety of substrates among an assortment of vegetation types; nests are commonly on sandy substrates that are close to abundant fish resources. Breeding Caspian terns almost exclusively eat fish; feeding occurs in near-shore and mid-channel habitats.

[g] Osprey may be found in various estuary and lower mainstem habitats. Their presence is most likely in tidal swamps or riparian areas where adequate nest sites exist in proximity to aquatic habitats where fish/birds are abundant and available for consumption.

[h] Possible breeding evidence of yellow warblers has been documented in the Columbia River estuary and along the lower mainstem. If present, yellow warblers would most likely be found in tidal swamp, riparian, or freshwater wetland habitats because they are a riparian obligate species most strongly associated with wetlands that contain Douglas spirea and deciduous tree cover.

[i] Red-eyed vireos are relatively abundant in Puget Sound and northeast Washington. There has been no confirmed breeding in the Columbia River estuary; however, possible breeding evidence has been documented along the mainstem near Bonneville. If present, red-eyed vireos would most likely be found in tidal swamp, riparian, or freshwater wetland habitats where woody species satisfy the canopy height and density requirements.

[j] The Columbia River estuary and lower mainstem is generally a migratory stop for sandhill cranes that breed in the Central Valley of California. In recent years up to 1,000 sandhill cranes have wintered on lower Columbia River bottomlands.

[k] Columbian white-tailed deer are generally associated with riparian and wetland habitats. Their strongest habitat association is with oak and Douglas fir forest close to a stream or river.