1 Columbia Lower and Columbia Estuary Subbasins

Figure 1-1. Location of the Columbia River estuary and mainstem subbasin within the Lower Columbia River Basin.

1.1 Basin Overview

The Columbia River estuary has formed over geologic time by the forces of glaciation, volcanism, hydrology, and erosion and accretion of sediments. Circulation of sediments and nutrients throughout the estuary are driven by river hydrology and coastal oceanography. Sea levels have risen since the late Pleistocene period, which has submerged river channels and caused deposition of coarse and fine sands. An abundance of fish and wildlife species are known to occur in the Columbia Estuary and Columbia Lower Subbasins, either as year-round residents, seasonal residents, or migratory visitors.

The Columbia River estuary and lower mainstem span over two ecological provinces as defined by the Northwest Power and Conservation Council (NPCC): Columbia River Estuary (river mouth, including nearshore waters and Columbia River plume, to RM 34) and the Lower Columbia River (RM 34 to Bonneville Dam). The historical (circa 1880) total surface area of the Columbia River estuary has been estimated from 160-186 square miles, with extensive sand beds and variable river flow. The current estuary surface area has been estimated as 101,750 acres, which is equivalent to 159 square miles. The Willamette River is the largest tributary to the lower Columbia River. Major tributaries originating in the Cascades include the Sandy River in Oregon and the Washougal, Lewis, Kalama and Cowlitz rivers in Washington. Major Coast Range tributaries include the Elochoman and Grays rivers in Washington and the Lewis and Clark, Youngs, and Clatskanie rivers in Oregon. Numerous other minor tributaries drain small watersheds but do not have substantial influence on the Columbia River because of their small size.

In the Columbia River, tidal impacts in water level have been observed as far upstream as Bonneville Dam (RM 146) during low flow, reversal of river flow has been measured as far upstream as Oak Point (RM 53), and intrusion of salt water is typically to Harrington Point (RM 23) at the minimum regulated monthly flow, although at lower daily flows saltwater intrusion can extend past Pillar Rock (RM 28) (Neal 1972). The lowest river flows generally occur during September and October, when rainfall and snowmelt runoff are low. The highest flows occur from April to June, resulting from snowmelt runoff. High flows also occur between November and March, caused by heavy winter precipitation. The discharge at the mouth of the river ranges from 100,000 to 500,000 CFS, with an average of about 260,000 CFS. Historically, unregulated flows at the mouth ranged from 79,000 CFS to over 1 million CFS, with average flows about 273,000 CFS.

The climate conditions vary across the subbasins; in general, coastal areas receive more precipitation and experience cooler summer temperatures and warmer winter temperatures than inland areas. In the lower part of the subbasin, climate data has been collected in Astoria, Oregon, since 1953. Total average annual precipitation is 68 inches, ranging from 1.04 inches in July to 10.79 inches in December. January is the coldest month in Astoria with an average maximum temperature of 48.2°F and an average minimum temperature of 36.5°F; August is the warmest month with an average maximum temperature of 68.7°F and an average minimum temperature of 52.8°F. In the middle part of the subbasin, climate conditions have been recorded at St. Helens, Oregon, since 1976. Total average annual precipitation is 44 inches, ranging from 0.79 inches in July to 6.77 inches in December. January is the coldest month in St. Helens with an average maximum temperature of 46.9°F and an average minimum temperature of 33.5°F; August is the warmest month with an average maximum temperature of 82.7°F and an average minimum temperature of 55.6°F. In the upper part of the subbasin, climate conditions have been recorded at Bonneville Dam since 1948. Total average annual precipitation is 77 inches, ranging from 0.90 inches in July to 12.91 inches in December. January is the coldest month at Bonneville with an average maximum temperature of 42.4°F and an average minimum temperature of 32.7°F; August is the warmest month with an average maximum temperature of 78.7°F and an average minimum temperature of 56.4°F.

The region is rich with history characterized by extensive human use of the natural resources in the subbasins. As early as 1792, European explorers sailed across the Columbia River bar, beginning an era of exploration and European settlement. By the early 1800s, approximately 50,000 Native Americans inhabited villages scattered along the banks of the Columbia River; records indicate that people in the region harvested Pacific salmon as early as 9,000 years ago. Timber and fisheries became the driving forces behind European settlement of the region. Earliest accounts of European exploitation of salmon date around 1830; the salmon industry began to realize its full potential when the first cannery began operating in Eagle Cliff, WA, in 1867. Initially, Chinook salmon were the primary catch, but fisheries began harvesting other salmon by the late 1800s; catch of all species peaked at 47 million pounds in 1911.

Concomitant to the growth of the fishing industry, the timber industry was experiencing a boom. Timber industry practices included the removal of stream debris, temporary construction of splash dams to store timber, and log drives that flushed timber through the system as freshet flows blasted the splash dams. Although efficient and inexpensive, such practices destroyed instream and riparian habitat. Log drive practices were eliminated by 1914, but other logging practices (such as the lack of riparian buffers) continued to negatively affect fish and wildlife habitat, including that of salmonids.

Introductions of exotic fish species had substantial impacts on early fisheries. For example, American shad were introduced to San Francisco in 1871; by 1903, Columbia River fisherman reported that shad had become so numerous they were a nuisance. Other species (i.e., warm-water fish such as bluegill, crappie, and bass) were becoming increasingly abundant in the lower reaches of many Columbia River tributaries and slough habitats of the lower mainstem Columbia River; these sloughs are ideal habitats for these warmwater species.

By the late 1800s, a substantial amount of acreage in the subbasin had been cleared of trees, burned, and converted to agricultural land; much of this land conversion was occurring in the lower Columbia River floodplain and the interior valleys. Many of these floodplain areas remain in agricultural use today.

Since the late 1800s, the US Army Corps of Engineers has been responsible for maintaining navigation safety on the Columbia River. In 1878, Congress directed the Corps to maintain a 20-foot minimum channel depth, authorizing the Columbia River navigation channel project. Since that time, Congress has periodically increased the approved channel depth to the current level of 43 ft. To maintain channel depth, the Corps has performed periodic maintenance dredging, constructed jetties at the mouth of the river, and used pile dikes to assist in channel depth (the existing dike system consists of 256 dikes totaling 240,000 linear feet).

In the early 1930s, the Columbia River was slated for development of the next major federal hydropower project; Bonneville Dam began operation in the late 1930s, affecting salmonid access to spawning habitat above Bonneville Dam. With extensive hydroelectric development, the lower Columbia River was quickly viewed as a production zone for salmon. Mitigation for the loss of habitat caused by dams came in the Mitchell Act of 1948, which created a system of hatcheries on the Columbia River. Although some of the first hatcheries where generally unsuccessful, hatcheries were viewed as the solution to overfishing, habitat loss, and hydroelectric development.

The Columbia Estuary and Columbia Lower Subbasins will play a key role in the recovery of salmon and steelhead. The subbasins serve as critical juvenile rearing pathways for fall Chinook and chum salmon; the importance of the estuary and mainstem to other anadromous salmonids is not completely understood. Chum salmon and fall Chinook have recently been observed spawning in multiple mainstem locations between Vancouver, WA, and Bonneville Dam; these areas are thought to be important in the recovery of these species. The subbasins also serve as a migratory route for all anadromous adult salmonids in the Columbia River basin. In the Columbia River basin today, there are 12 salmonid ESUs listed as threatened or endangered under the Endangered Species Act (ESA), as well as other candidates for listing. The deterioration of habitat conditions in the Columbia River mainstem, estuary, and plume affect all anadromous salmonids within the Columbia Basin. Other fish species of interest are sturgeon, Pacific Lamprey, and eulachon – these species are also expected to benefit from salmon protection and restoration measures. Wildlife species of interest in the subbasins are Columbian white-tailed deer, bald eagle, and sandhill crane; because of the federal or state listed status of these species, management plans have already been developed to address the protection and recovery needs of these species. As a result, these species will not be addressed further because the Lower Columbia Fish Recovery Board (LCFRB) supports the recommendations of the existing management plans.

Salmon and steelhead in the estuary and mainstem are affected by a variety of in-basin and out-of basin factors. Analysis has demonstrated that recovery cannot be achieved by addressing only one limiting factor. Recovery will require action to reduce or eliminate all manageable factors or threats. Key ecological interactions of concern include effects of nonnative species and predation by species affected by development including Caspian terns, northern pikeminnow, seals, and sea lions. Discussions of out-of-basin factors, strategies, and measures common to all subbasins may be found in Volume I, Chapters 4 and 7. This subbasin chapter focuses on habitat and other factors of concern specific to the Columbia Estuary and Columbia Lower Subbasins.

Human population in the Columbia Estuary and Columbia Lower Subbasins is expected to increase; a substantial part of this growth is a result of the expansion of the Vancouver metropolitan area. Development pressure is expected to increase along riparian and floodplain areas, having the potential to seriously degrade watershed processes and habitat conditions.

County land use regulations will provide moderate protection. All Washington counties not currently operating under the state Growth Management Act (GMA) must have the GMA in place by the end of 2005. Clark County, which is operating under the GMA, is pursuing an ESA Section 4(d) limit by developing additional protective measures. All Washington counties within the subbasins will need to adopt measures to protect watershed processes and habitat from degradation resulting from land use conversions. While improved land use regulation can make a significant contribution to habitat protection, it will not and, in all likelihood, cannot effectively prevent any further deterioration of habitat conditions. Seemingly minor unregulated activities such as application of fertilizers and pesticides and removal of riparian vegetation can cause incremental deterioration of habitat conditions. These impacts must be addressed through public information and outreach efforts that promote appropriate practices and landowner incentive programs.

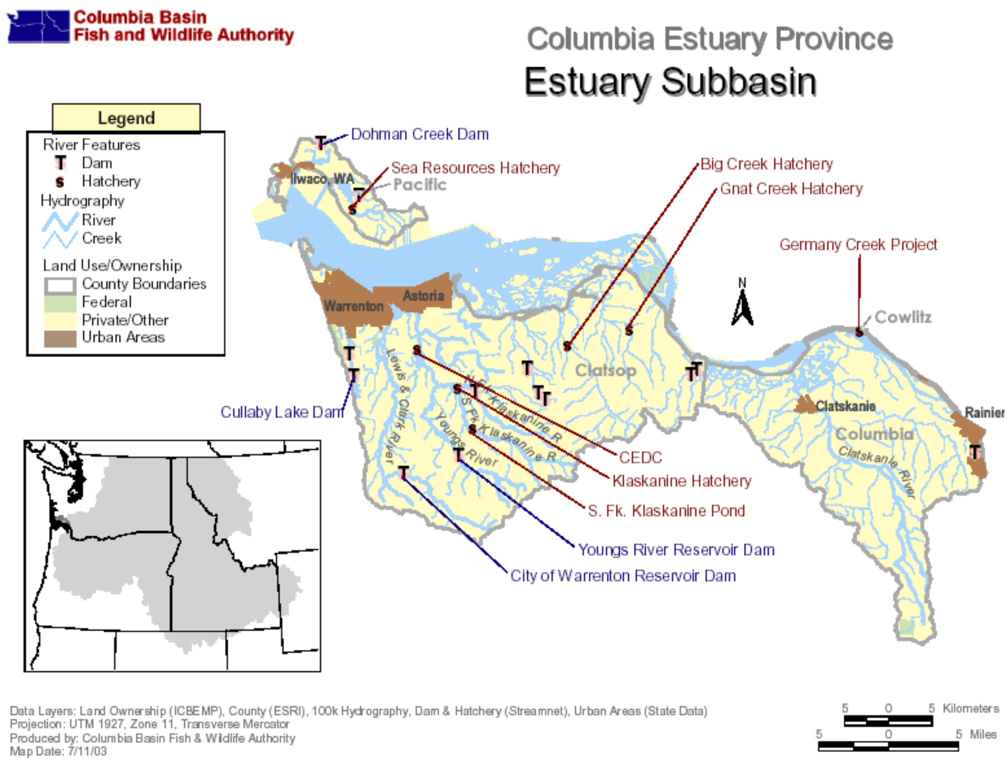

Figure 1-2. Boundaries of the Columbia Estuary Subbasin as defined by the Northwest Power and Conservation Council.

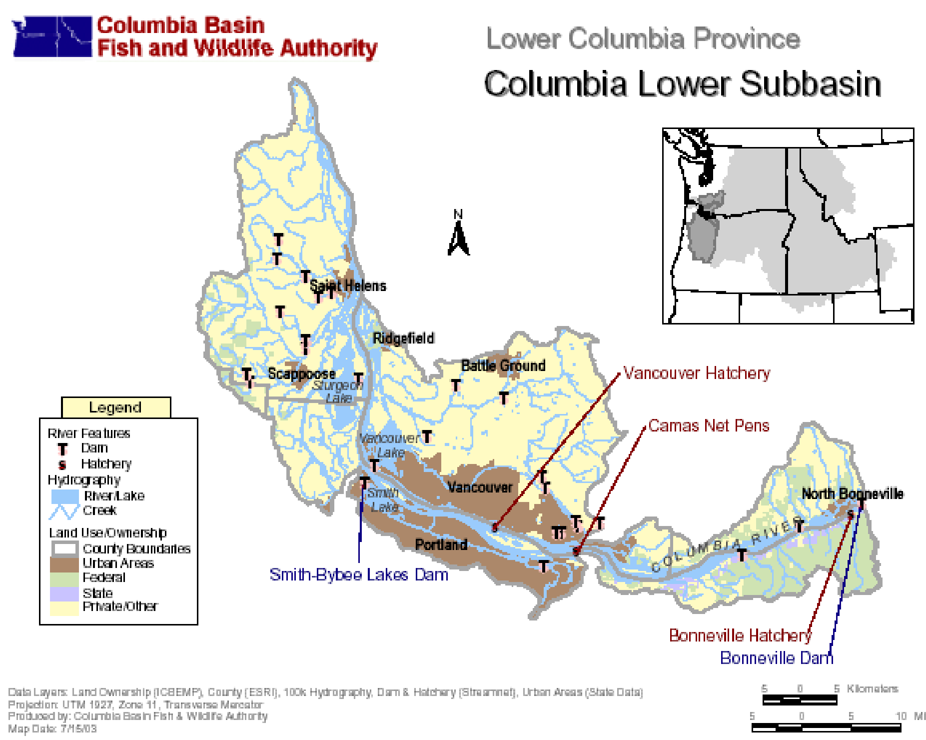

Figure 1-3. Boundaries of the Lower Columbia Subbasin as defined by the Northwest Power and Conservation Council.

1.2 Species of Interest

Focal salmonid species in the estuary and mainstem subbasins include fall Chinook, spring Chinook, winter steelhead, summer steelhead, chum, and coho. The health or viability of these populations is currently very low to moderate, as addressed in the following subbasin chapters. Focal populations need to improve to a targeted level that contributes to recovery of the species (see Volume I, Chapter 6). Other species of interest in the estuary and mainstem subbasins include sturgeon, Pacific lamprey, and eulachon. Regional objectives for these species are described in Volume I, Chapter 6. Recovery actions targeting focal salmonid species are also expected to provide significant benefits for these other species. Sturgeon, Pacific lamprey, and eulachon are expected to benefit from restoration of hydrologic conditions and sediment transport processes, as well as restrictions on non-native species.

All Columbia Basin anadromous fish utilize the lower Columbia migration corridor and the estuary habitat as departing juveniles and returning adults. Historical abundance has declined significantly, however the current abundance of juvenile salmon and steelhead migrating through the lower Columbia to the estuary remains significant as a result of Columbia Basin hatchery production. In 1990, the combined wild and hatchery juvenile salmon and steelhead produced in the Columbia Basin was estimated at about 350 million fish. Recent year returns of combined wild and hatchery salmon and steelhead, including adults and jacks, to the Columbia River ranges from 700,000 to 3 million fish.

The abundance of wild lower Columbia white sturgeon and eulachon (smelt) has fluctuated over the past century, but current abundance may be within the range of historical levels. There are no hatchery programs for lower Columbia white sturgeon or eulachon.

1.3 Potentially Manageable Impacts

Estuary and mainstem habitat conditions have contributed to reduced salmonid productivity, numbers, and population viability as fish rear or migrate through the subbasins. Based on an analysis of potentially manageable factors (harvest, hatcheries, subbasin and mainstem habitat, hydrosystem, and predation) of lower Columbia salmonid populations, degraded mainstem and estuary habitat conditions contribute to mortality as summarized in Table 1-1. The current mortality levels, as well as the estimated mortality level at population recovery levels, are presented. Thus, to contribute to recovery, the mainstem and estuary habitat mortality factor should be reduced from current to recovery goal levels. The difference between current estuary mortality and goals does not necessarily reflect the magnitude of improvement needed for each population to meet recovery goals. The estuary and mainstem mortality reductions are influenced by the relative proportion of mortalities associated with other limiting factors. For example, chum recovery is dominated by the need to improve freshwater habitat, which skews the reflected estuary recovery need to a smaller level in comparison. These results should not be interpreted to reflect a lack of importance in estuary and mainstem improvements for chum recovery.

Table 1-1. Estimated mainstem and estuary mortality factors, by species.

	Current		Recovery Goal	
Species	**Range**	**Average**	**Range**	**Average**
Tule Fall Chinook	0.29-0.38	0.33	0.16-0.36	0.27
Bright Fall Chinook	0.39	na	0.26	na
Spring Chinook	na	0.20	insufficient data	
Winter Steelhead	0.10-0.18	0.14	0.10-0.18	0.10
Summer Steelhead	0.04-0.59	0.16	0.04-0.59	0.16
Chum	0.28-0.59	0.46	0.23-0.58	0.42
Coho	insufficient data			

Mortality is based on preliminary analysis by the LCFRB based on comparison of EDT estimates of mainstem and estuary habitat effects on lower Columbia River salmonid populations, current population abundance estimates, and population abundance recovery goals.

1.4 Threats and Actions

Decades of human activity have significantly altered watershed processes and reduced both the quality and quantity of habitat needed to sustain viable populations of salmon and steelhead.

1.4.1 Limiting Factors

The limiting factors have been formulated based on known or suspected biological relationships in the estuary and mainstem ecosystem. We have provided a qualitative metric of the importance and certainty level of each limiting factor as described below.

In an attempt to rank limiting factors, a subjective evaluation was conducted based on what is known or suspected regarding the present status of each species in relation to historical conditions. Throughout this document, the qualitative terms of "High", "Medium", and "Low" have been used to provide a relative level of importance for the limiting factors identified for each species. It is important to note that, because of the subjective nature of this evaluation, no two scientists will likely qualify each limiting factor in precisely the same manner. The purpose of the evaluation is to identify the most important limiting factors for each species; thus, actions intended to improve those limiting factors are expected to have the greatest benefit for the species population. In the context of species-specific limiting factors, the qualitative terms are defined as:

- High – The factor currently limits population viability because of effects on mortality rates or productivity. The limiting factor is of primary importance in maintaining current levels of population abundance/productivity. Or the limiting factor must be addressed to promote recovery of the species.
- Medium – The factor currently effects population viability, but at present impact levels, may not be significantly reducing population abundance or productivity. The limiting factor does effect current levels of population abundance/productivity or recovery of the species, however, addressing this factor will have less impact on overall population viability than the high impact factors.

- Low – The factor exists, but unlikely effects population viability at present impact levels. The limiting factor should be recognized but will unlikely produce measurable effects on population viability until the high and medium limiting factors have improved.

The level of impact of each limiting factor is further qualified based on the current level of certainty in the impact designation. Thus, the qualitative terms of "High", "Medium", and "Low" are again used and, in the context of certainty, are defined as:

- High – Considerable research has been performed on the subject and has repeatedly produced similar results.
- Medium – Considerable research has been performed on the subject and results have been inconclusive or contradictory. Or, some research has been performed on the subject and preliminary results suggest a relationship exists.
- Low – Some research has been performed on the subject and preliminary results are inconclusive or contradictory. Or, little to no research has been performed on the subject and any relationships are assumed based on other related scientific data or relationships.

Table 1-2. Salmonid limiting factors by life stage.

Life Stage	Limiting Factors	Impact	Certainty	Species
Juvenile Rearing (within and out-of-subbasin populations)	**Sa.LF.1** Availability of preferred habitat (i.e., shallow water, low velocity, peripheral habitats). Ocean-type salmon are closely associated with peripheral habitats. There has been extensive loss of peripheral wetland and side channel habitat throughout the mainstem and estuary, as a result of water regulation, dike construction, and urban and agricultural development.	High	High	Fall Chinook, Chum
	Sa.LF.2 Microdetritus-based food web. The current microdetritus-based food web is expected to be less productive than the historical macrodetritus-based food web. Loss of wetland and side channel habitat identified above has reduced the local macrodetritus inputs from terrestrial and riparian habitats that supported the historical food web. Present detrital inputs to the food web are dominated by microdetritus from upriver sources and are controlled primarily by reservoir production and flow rates from Bonneville Dam. Further, the microdetritus-based food web is thought to be less available to chum salmon because it is pelagic in nature and may be focused on the spatially-confined estuary turbidity maximum region.	High	Medium	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho

	Sa.LF.3 Loss of habitat connectivity. 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 ocean-type salmon that rear in the estuary for extended time periods, a broad range of habitat types in the proper proximities to one another may be critical to satisfy feeding and refuge requirements within each salinity zone.	High	High	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
	Sa.LF.4 Predation mortality. Current sources of predation on salmonids are substantial, however, how current predation levels compare to those experienced historically is unknown. Primary predation sources include Caspian terns and northern pikeminnow; both have increased in abundance as a result of habitat change in the mainstem and estuary. Caspian tern predation is higher for larger emigrating salmonids (i.e., stream-type).	Medium	High	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
	Sa.LF.5 Contaminant exposure. Contaminants have been documented throughout the lower mainstem and estuary. Contaminants are known to have detrimental effects on salmonids. Ocean-type juveniles are closely associated with peripheral, side channel habitats where contaminants commonly accumulate.	Medium	Medium	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
	Sa.LF.6 Interaction with introduced species. Hundreds of species introductions, both intentional and unintentional, have occurred in the lower Columbia mainstem and estuary. Effects on salmonids are unknown but are expected to be negative.	High	Low	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
	Sa.LF.7 Density dependence. Density dependent mechanisms in the lower mainstem, 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.	Medium	Low	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
	Sa.LF.8 Fitness and timing of juvenile salmonids entering the subbasin. Juveniles entering the subbasin from upriver via barge releases or dam passage experience lower survival than historical mainstem emigration prior to hydrosystem development.	High	High	Fall/ Spring Chinook, Winter/ Summer Steelhead, Coho
Adult Migration (within and out-of-subbasin populations)	**Sa.LF.9** Dam passage. Bonneville Dam has blocked most upstream migration of chum salmon to historical spawning areas. Other salmonids experience mortality and delay associated with mainstem dam passage. For lower Columbia River mainstem dams, average per dam survival rate estimate for fall Chinook, spring Chinook, and steelhead was 94%, 89%, and 95%, respectively; these estimates include fallback and re-entry.	High	High	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho

	Sa.LF.10 Migration barriers/ lack of resting habitats. 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.	Low	High	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
	Sa.LF.11 Predation losses. Marine mammals (pinnipeds) prey on adult salmon, but the significance is unclear.	Low	Medium	Fall/ Spring Chinook, Winter/ Summer Steelhead, Chum, Coho
Adult Spawning (within subbasin)	**Sa.LF.12** Availability of spawning habitat (i.e., accessibility/ quantity). Chum and fall Chinook salmon have been observed spawning in multiple lower mainstem locations between the I-205 Bridge and Bonneville Dam. These spawning aggregations represent an important component of current natural production. Water regulation at Bonneville Dam substantially effects water level in these mainstem spawning locations. Low flow may limit access to spawning areas while high flow may decrease the quality of these spawning locations (i.e., depth or velocity too high).	High	High	Fall Chinook, Chum
	Sa.LF.13 Decreased flows during spawning and incubation. Water regulation at Bonneville Dam substantially effects water flow in these mainstem spawning locations. Low flow may decrease the delivery of nutrients and dissolved oxygen to incubating eggs, thereby decreasing survival.	High	Medium	Fall Chinook, Chum
	Sa.LF.14 Dewatering of redds. Water regulation at Bonneville Dam substantially effects water level in these mainstem spawning locations. Flow reductions to the point of dewatering redds will result in substantial mortality of incubating eggs or pre-emergent alevins.	High	Medium	Fall Chinook, Chum

Table 1-3. Sturgeon, Pacific lamprey, and eulachon limiting factors by life stage. (Note: All factors apply to white sturgeon; only the adult abundance factors apply to green sturgeon.)

Life Stage	Limiting Factors	Impact	Certainty	Species
Egg Incubation	**OS.LF.1** Sedimentation of spawning substrates. Deposition of fine sediments in the preferred spawning habitats (i.e., deepwater, rocky substrates for sturgeon; i.e. coarse sands for eulachon) results in egg suffocation. Fine sediment sources include adjacent tributary subbasins as well as migration of sediments from mainstem deposits.	Medium	High	Sturgeon, Eulachon
	OS.LF.2 Egg hypoxia. Hypoxia may have disproportionate negative effects on sturgeon compared to other fish because of their 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.	Medium	High	Sturgeon, Eulachon
	OS.LF.3 Predation mortality. Demersal white sturgeon embryos are vulnerable to predation. Research on the upper Columbia indicated that 12% of naturally-spawned white sturgeon eggs were subject to predation, although the research suggests that predation was likely underestimated. Eulachon eggs have been documented as an important food item of juvenile sturgeon in the lower mainstem. Eulachon eggs comprised up to 25% of stomach contents for sturgeon $\leq$350mm; the percentage increased to 51% for sturgeon 351-724mm. If predation mortality is substantial, recruitment failure can result.	Medium	Medium	Sturgeon, Eulachon
	OS.LF.4 Direct dredging mortality. Although, white sturgeon prefer to spawn in rocky substrates with sufficient interstitial spaces, spawning has been observed in sands and fine sediments. Additionally, eggs broadcast among rocky substrates may disperse downstream and settle among sands or fine sediments. Dredging activities in areas where embryos are present results in direct mortality. Also, evidence suggests that dredging activity in the vicinity of eulachon spawning areas makes the substrate too unstable for egg incubation.	Medium	Low	Sturgeon, Eulachon
	OS.LF. Contaminant/parasite exposure. Contaminants have been documented throughout the lower mainstem and estuary. Contaminants are known to have detrimental effects on development and physiological processes.	Medium	Low	Sturgeon, Eulachon
Juvenile Rearing and Migration	**OS.LF.6** Flow alteration. Juvenile Pacific lamprey are poor swimmers and rely on flow to carry them toward the ocean. Flow alterations in the Columbia River basin (hydrosystem operations, water withdrawal) have decreased peak flows in the lower Columbia River mainstem, as well as created inundated habitats throughout the basin. Flow reductions may delay downstream migration, disrupting the synchrony of physiological development and downstream migration timing.	Medium	Medium	Pacific Lamprey

	OS.LF.7 Predation mortality. Juvenile white sturgeon losses to predation are probably low because of the protective scutes, benthic habitats, and fast growth. Juvenile lamprey and eulachon losses to predation are unknown and need to be evaluated. Predation could be substantial because juvenile lamprey and eulachon have poor swimming ability and emigrate at the mercy of river currents.	Medium	Low	Sturgeon, Pacific Lamprey, Eulachon
	OS.LF.8 Direct dredging mortality. White sturgeon, lamprey, and eulachon association with benthic habitats make them susceptible to suction dredging effects. There is speculation that dredging operations may attract white sturgeon, compounding potential losses. Dredging activities in areas where juveniles are present can result in direct mortality.	Medium	Low	Sturgeon, Pacific Lamprey, Eulachon
	OS.LF. Contaminant/parasite exposure. Contaminants have been documented throughout the lower mainstem and estuary. Contaminants are known to have detrimental effects on growth and physiological processes. Juvenile sturgeon, lamprey, and eulachon are closely associated with fine sediments where contaminants commonly accumulate.	Medium	Low	Sturgeon, Pacific Lamprey, Eulachon
	OS.LF.10 Interaction with introduced species. Hundreds of species introductions, both intentional and unintentional, have occurred in the lower Columbia mainstem and estuary. Effects on native species are unknown and may be offsetting. For example, shad have become an important food source for adult sturgeon while shad and gamefish may compete for food sources with juvenile sturgeon.	Medium	Low	Sturgeon, Pacific Lamprey, Eulachon
	OS.LF.11 Near ocean survival. Mortality upon ocean entry is unknown, but may be substantial.	High	Low	Eulachon
Adult Abundance	**OS.LF.12** Fishing mortality. At present, size restrictions in the sport fishery are allowing for sturgeon survival to older ages, thus maintaining adequate abundance of spawning adults. 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 (Deschutes River). Because of limitations on lamprey harvest (i.e., fishing effort, legal gear types, area closures, seasonal restrictions, diel restrictions), harvest may not be a major mortality factor. At present, eulachon fishery regulations, fishing effort, and harvest levels appear to be at sustainable levels. Fishery regulations, fishing effort, harvest levels, and population response needs to be monitored closely to ensure abundance is maintained.	Low	High	Sturgeon, Pacific Lamprey, Eulachon
	OS.LF.13 Interaction with introduced species. Hundreds of species introductions, both intentional and unintentional, have occurred in the lower Columbia mainstem and estuary. Effects on white sturgeon are unknown and may be offsetting. For example, shad have become an important food source for adult sturgeon while shad and gamefish may compete for food sources with juvenile sturgeon.	Medium	Low	Sturgeon, Pacific Lamprey, Eulachon

	OS.LF.14 Incidental mortality. Operations at Bonneville Dam, specifically dewatering of turbines, can strand white sturgeon and result in mortality. Significance of this mortality factor needs to be evaluated.	Low	Low	Sturgeon
	OS.LF.15 Predation losses. Because of their high caloric value, Pacific lamprey are an important food source for marine mammals (pinnipeds) and sturgeon (and potentially others) in the lower Columbia River. Eulachon are an important food item for many estuary and lower mainstem species. Large congregations of avian predators accompany eulachon runs into spawning areas. Pinnipeds prey on eulachon as they migrate through the estuary; pinnipeds may also follow eulachon runs to spawning areas. The significance of predation on lamprey and eulachon needs to be quantified.	Medium	Medium	Pacific Lamprey, Eulachon
	OS.LF.16 Dam passage/ migration barriers. Pacific lamprey and eulachon are often unable or unwilling to migrate through fish ladders. Thus, Bonneville Dam has limited upstream migration of Pacific lamprey and eulachon to historical upriver spawning areas; many tributary or other mainstem dams have also limited lamprey access. Optimal water temperature for eulachon upstream migration is about 40 °F; below this temperature, migration will be delayed.	High	High	Pacific Lamprey, Eulachon

1.4.2 Strategies

Because of our current level of understanding of the links between physical conditions and species' biological response in the estuary and lower mainstem ecosystem, we are limited in the degree of specificity that can reasonably be included in habitat strategies and measures. As a result, the strategies and measures presented in Volume I, Chapter 6, Regional Strategies and Measures, as well as Chapter 7, Research, Monitoring, and Evaluation, apply to the salmonid and other species physical objectives presented above. In particular, the sections pertaining to the estuary and lower mainstem, hydropower, ecological interactions, and research address most biological and physical objectives in the Columbia Estuary and Columbia Lower subbasins. Thus, to avoid repetition, those measures and strategies are not included here. In this section, we have presented only those strategies that differ from the regional strategies because of the unique characteristics of sturgeon, Pacific lamprey, and eulachon.

Because of the diversity of estuary and mainstem species of interest and their subsequent life history requirements, the potential for conflict exists among suggested strategies and measures among the focal species. If conflicts arise, planning and policy decisions will dictate which strategies and measures are implemented, based on species prioritization. However, the strategies and measures suggested within this management plan have been formulated to minimize conflict among species-specific strategies and measures. For example, lamprey and eulachon experience challenges with Columbia River mainstem migration and dam passage. Thus, strategies and measures promote lamprey and eulachon migration. However, because of the differential swimming capabilities between these two species and most salmonids, passage improvements for eulachon and lamprey are challenged by potential negative effects on salmonids.

1.4.2.1 Predators

S1. Evaluate the level of predation mortality during the embryo and juvenile life stages of sturgeon and eulachon to determine the extent of predation-related recruitment failure.

S2. Evaluate the level of predation mortality during the adult life stages of lamprey and eulachon to determine estuary and mainstem survival.

Explanation: In an unaltered natural system, predator and prey populations generally establish an equilibrium that does not pose a long-term threat to the viability of either. Where natural systems have been substantially altered by human activities or other disturbances, this equilibrium can be disturbed to the detriment of one species or another. Increased predation and risks are typically a symptom of some more pervasive cause. Predator-prey interactions are also complex and difficult to understand or manage. However, in selected cases it is possible to temporarily limit risks through management of predators or predation. Predator management need not rely on predator control; a variety of predator management alternatives exist.

1.4.2.2 Other Mortality Factors

S3. Avoid incidental mortality of embryos and juveniles during dredging operations.

Explanation: Developing embryos or juvenile sturgeon, eulachon, or lamprey may be present among sand or fine substrates throughout the lower Columbia River. Suction dredging in these areas results in direct mortality. Dredge operations should avoid areas of known embryo or juvenile presence.

S4. Manage Columbia River fisheries at sustainable levels, maintaining a viable population through adequate spawner abundance.

Explanation: Longevity, slow growth, and delayed maturation make sturgeon susceptible to fishery overexploitation. Columbia River sturgeon fisheries should continue to be managed in such a way as to ensure sufficient abundance of fish attaining older ages, thus maintaining adequate spawner abundance. Columbia River eulachon fisheries should continue to be managed in such a way as to ensure population viability while meeting the needs of commercial, tribal, and recreational fisheries. At present levels of fishing effort and fishery restrictions, current lamprey harvest is relatively low but should be monitored as fishery effort and restrictions change.

S5. Avoid incidental mortality as a result of Bonneville Dam operations.

Explanation: Dewatering of turbines at Bonneville Dam has been documented to strand white sturgeon, resulting in mortality. Operations at Bonneville, and elsewhere in the subbasins, need to be evaluated to minimize sturgeon mortality.

S6. Evaluate and improve passage conditions at mainstem and tributary dams, ensuring no negative effects on salmonid passage.

Explanation: Adult Pacific lamprey and eulachon have difficulty in dam passage and juveniles migrating downstream do not appear to benefit from juvenile salmonid passage systems. Bonneville Dam has blocked access to historical spawning and rearing areas. Potential improvements to lamprey or eulachon passage need to be evaluated for potential negative effects on salmonids.

1.4.3 Measures

As discussed in the Strategies Section 1.4.2, regional measures presented in Volume 1, Chapters 6 and 7 apply to the biological and physical objectives of salmonids in the Columbia Estuary and Lower Columbia subbasins and are not repeated here. In this section, we have presented only those measures that differ from the regional measures because of the unique characteristics of sturgeon, Pacific lamprey, and eulachon. The measures identified in this section represent a list of potential actions or categories of actions. Habitat actions vary substantially from location to location and more specific direction needed to develop implementation plans is necessary.

1.4.3.1 Habitat

M1. Maintain sturgeon and eulachon preferred spawning habitat in the estuary and tidal freshwater portion of the lower Columbia River.

Explanation: Spawning substrate used by white sturgeon varies considerably, although they appear to prefer deepwater, rocky habitats with sufficient interstitial spaces to provide adequate water flow and predator protection during embryonic development. Spawning substrate used by eulachon is characterized by coarse sand substrate. At present, there is limited information as to the available acreage of preferred spawning habitat or as to whether acreage of this habitat type is increasing or decreasing. Based on the recent productivity of the white sturgeon population, there is currently no indication that white sturgeon are spawning habitat limited. Because of our present lack of information regarding the lower Columbia sturgeon and eulachon, an inventory of spawning locations, habitat characteristics, and habitat availability would be beneficial.

M2. Allocate water within the annual water budget for the Columbia River Basin that simulates peak spring discharge.

Explanation: Flow affects from upstream dam construction and operation have significantly modified estuary and mainstem hydrologic conditions. Juvenile lamprey are poor swimmers and are at the mercy of currents to complete downstream migrations. Decreased spring flows in the lower Columbia River may have eliminated the synchrony between lamprey physiological development and emigration timing. Establishing flows in the Columbia River estuary and lower mainstem that emulate a more natural regime will help improve emigration conditions for juvenile Pacific lamprey.

1.4.3.2 Predators

M3. Identify predators of sturgeon, lamprey, and eulachon embryos and juveniles; reduce predation mortality.

Explanation: Predators of sturgeon embryos and juveniles in the lower Columbia River are unknown and need to be identified. Elsewhere in the Columbia River, substantial predation on sturgeon embryos has been observed. The potential for predation-related recruitment failure exists. Small white sturgeon (i.e. <725mm) are a substantial predator of eulachon eggs. Other predators of eulachon eggs and juveniles in the lower Columbia River are unknown and need to be identified. Predators of juvenile lamprey in the lower Columbia River are unknown and need to be identified. Juvenile lamprey and eulachon have poor swimming ability and are expected to be highly susceptible to predation.

1.4.3.3 Other Mortality Factors

M4. Evaluate and mitigate Bonneville Dam operations that result in direct sturgeon mortality.

Explanation: Dewatering of turbines at Bonneville Dam can result in direct sturgeon mortality through stranding. The degree and significance of this mortality factor needs to be identified. Measures to mitigate impacts resulting from these activities should be identified and implemented.

M5. Modify passage structures at dams to improve juvenile and adult passage efficiency for Pacific lamprey and eulachon.

Explanation: Pacific lamprey and eulachon access to historical spawning and rearing habitats has been limited because of their inability to navigate fish ladders designed for salmonid passage. Additionally, juvenile lamprey do not appear to benefit from juvenile salmonid passage systems. Passage modifications need to proceed with caution; negative effects on salmonid passage need to be prevented.

M6. Closely monitor Columbia River fisheries harvest levels to maintain sturgeon, lamprey, and eulachon abundance.

Explanation: Current fishery regulations, particularly size limits, have allowed sturgeon to survive to older ages, thereby maintaining the spawning portion of the population. Harvest levels and fishery regulations should be closely monitored to ensure that adequate spawning adult abundance is maintained. Current lamprey fishery restrictions and level of effort maintain harvest at relatively low levels. Harvest levels and fishery regulations should be closely monitored to insure that lamprey population viability is maintained. Current eulachon fishery regulations and harvest effort have maintained harvest at sustainable levels. Harvest levels and fishery regulations should be closely monitored to insure that population viability is maintained.

1.4.4 Physical Objectives and Actions

In an attempt to rank physical objectives, a subjective evaluation was conducted based on what is known or suspected regarding the present status of each species and the level to which the physical objective would address an important limiting factor. Throughout this document, the qualitative terms of “High”, “Medium”, and “Low” have been used to provide a relative benefit of each identified physical objective. It is important to note that, because of the subjective nature of this evaluation, no two scientists will likely qualify each physical objective in precisely the same manner. The purpose of the evaluation is to identify those physical objectives that address the most important limiting factors for each species; thus, achieving these physical objectives are expected to have the greatest benefit for the species population. In the context of species-specific physical objectives, these terms are defined as:

- High – The physical objective addresses a limiting factor that currently limits population viability because of effects on mortality rates or productivity. Achieving the physical objective is of primary importance in maintaining current levels of population abundance/productivity or in promoting recovery of the species.
- Medium – The physical objective addresses a limiting factor that currently effects population viability, but at present impact levels, may not be significantly reducing population abundance or productivity. Achieving this physical objective will have less impact on overall population viability than the high benefit objectives.
- Low – The physical objective addresses a limiting factor that exists, but unlikely effects population viability at present impact levels. Achieving the physical objective will unlikely produce measurable effects on population viability until the high and medium benefit physical objectives are implemented.

The physical objectives benefit level is further qualified based on the current level of certainty that the objective will address a limiting factors. The qualitative terms of “High”, “Medium”, and “Low” are defined similarly to the certainty terms applied to the limiting factors.

Table 1-4. Salmonid desired environmental conditions.

Life Stage	Physical Objective	Difficulty	Benefit/Certainty
Juvenile Rearing (all juveniles in the Columbia River Basin)	**Sa.PO.1** Protect existing rearing habitat to ensure no further net degradation. *Hypothesis Statement:* If current rearing habitat is protected, then juvenile rearing capacity and productivity in the lower mainstem, estuary, and plume can be maintained. *Justification:* Protection and maintenance of existing rearing habitat will provide a base level of juvenile salmonid production and diversity. Further, protection of existing habitat is often more cost effective than restoration of former habitat.	Medium	High/High
	Sa.PO.2 Increase shallow water peripheral and side channel habitats toward historic levels. *Hypothesis Statement:* If shallow water habitat is increased, then juvenile rearing capacity in the estuary and mainstem will increase. *Justification:* Rearing ocean-type juvenile salmon are closely associated with shallow water habitats in the estuary and lower mainstem.	High	High/High
	Sa.PO.3 Restore connectivity between river and floodplain, tidally influenced reaches of tributaries, as well as in-river habitats. *Hypothesis Statement:* If connectivity with the floodplain is restored, then juvenile salmon productivity in the estuary and mainstem will increase. *Justification:* Connectivity with the floodplain will restore macrodetrital inputs and alter the current food web. A macrodetritus-based food web will increase productivity and support greater life history diversity.	High	High/High
	Sa.PO.4 Reduce predation mortality on emigrating juveniles. *Hypothesis Statement:* If predation on juveniles is reduced, then juvenile survival in the lower mainstem, estuary, and plume will increase. *Justification:* Predation on juvenile salmonids in the lower Columbia River and estuary has increased as a result of increased predator populations, such as northern pikeminnow or Caspian terns.	High	Medium/Medium
	Sa.PO.5 Reduce contaminant exposure of emigrating juveniles. *Hypothesis Statement:* If contaminant exposure is reduced, then juvenile survival in the lower mainstem, estuary, and plume will increase. *Justification:* Contaminants have been shown to have detrimental effects on juvenile salmonids, such as decreased immune function, disrupted physiological processes, and generally reduced fitness. Numerous contaminants have been detected throughout the lower Columbia River and estuary at concentrations known to have detrimental effects on aquatic organisms. Ocean-type salmon may be particularly susceptible to contaminant exposure because they are closely associated with peripheral, shallow water habitats where contaminants are known to accumulate.	High	Medium/Medium

	Sa.PO.6 Document the interaction between emigrating juvenile salmonids and introduced species; minimize negative interactions. *Hypothesis Statement:* If introduced species continue to thrive, then juvenile salmonid survival in the lower mainstem, estuary, and plume will be negatively affected. *Justification:* Introduced species, both purposeful and unintentional, have altered the lower mainstem, estuary, and plume ecosystem. Effects on native species are generally unknown, may be significant, and need to be quantified.	High	High/Low
	Sa.PO.7 Develop an understanding of emigrating juvenile salmonid life history diversity and habitat use in the lower mainstem, estuary, and plume. *Hypothesis Statement:* If our understanding of salmonid integration with the ecosystem increases, then management and recovery actions will proceed with greater certainty. *Justification:* Our current understanding of life history diversity and salmonid interaction with the lower mainstem, estuary, and plume ecosystem is limited; ongoing research continues to increase our knowledge and reduce uncertainty.	High	High/Medium
Adult Migration (all adults in the Columbia River Basin)	**Sa.PO.8** Maintain favorable water flow and temperature throughout migration period. *Hypothesis Statement:* If extreme water flows or temperatures exist during migration, then spawning may be delayed or averted. *Justification:* Extreme (i.e., both high and low) water flow and temperature can serve as a migration barrier that generally results in one of three outcomes: delayed arrival to spawning grounds, spawning activity in less than desirable locations, or no spawning. Each of these scenarios often results in decreased juvenile fitness or productivity.	Medium	Medium/High
	Sa.PO.9 Reduce predation mortality on migrating adults. *Hypothesis Statement:* If predation on adults is reduced, then survival in the estuary and mainstem will increase. *Justification:* Marine mammal predation on adult salmonids in the lower Columbia River and estuary has been observed. Predation mortality may be significant and needs to be quantified.	High	Low/High
Adult Spawning (adult spawners in estuary and lower mainstem)	**Sa.PO.10** Protect existing spawning habitat to ensure no further net degradation. *Hypothesis Statement:* If current spawning habitat is protected, then adult spawning capacity and productivity in the estuary and mainstem can be maintained. *Justification:* Protection and maintenance of existing spawning habitat will provide a base level of chum and fall Chinook salmon production. Further, protection of existing habitat is often more cost effective than restoration of former habitat.	Medium	High/High

	Sa.PO.11 Maintain favorable water flow and temperature throughout mainstem spawning period. *Hypothesis Statement:* If extreme water flows or temperatures exist during spawning, then chum and fall Chinook may not have access to current spawning areas. *Justification:* Extreme (i.e., both high and low) water flow and temperature can serve as a migration barrier and prevent access to current spawning areas. Further, extreme flow and temperature may decrease the quality of existing spawning habitat.	Medium	High/High
	Sa.PO.12 Maintain favorable water flow and temperature throughout mainstem incubation period. *Hypothesis Statement:* If extreme water flows or temperatures exist during incubation, then egg mortality will be unacceptably high. *Justification:* Extreme (i.e., both high and low) water flow and temperature can decrease egg to fry survival. High flow can cause bed scour and subsequent egg loss. Low flow reduces nutrient and oxygen transport to developing eggs; extreme low flow can result in redd dewatering. High temperature can increase egg mortality. Low temperature delays emergence and subsequent emigration. Each of these scenarios often results in decreased juvenile fitness.	Medium	High/High

Table 1-5. Sturgeon, Pacific lamprey, and eulachon desired environmental conditions.

Life Stage	Physical Objective	Difficulty	Benefit/ Certainty	Species
Egg Incubation	**OS.PO.** Protect existing spawning habitat to ensure no future net degradation. *Hypothesis Statement:* If current spawning habitat is protected, then productivity and population recruitment in the estuary and mainstem can be maintained. *Justification:* Sturgeon: Protection and maintenance of existing deepwater, rocky substrate spawning habitat will maintain the current level of embryo survival and population productivity. Sedimentation and dissolved oxygen delivery are two important concerns with developing embryos; concerns are minimized in rocky substrates. Eulachon: Protection and maintenance of existing stable coarse sand substrate spawning habitat will maintain the current level of population productivity. Dredging in the vicinity of eulachon spawning areas can make the substrate too unstable for successful egg incubation.	Medium	High/High	Sturgeon, Eulachon
	OS.PO.2 Reduce predation mortality on developing embryos. *Hypothesis Statement:* If predation on embryos is reduced, then embryo survival in the estuary and mainstem will increase. *Justification:* Sturgeon: Predation on white sturgeon embryos has been observed at about 12% in the upper Columbia River; current levels of predation in the lower Columbia is unknown and needs to be quantified. Eulachon: Predation on eulachon eggs by white sturgeon can be substantial; other predators may exist. Eulachon eggs comprised 51% of stomach samples from sturgeon 351-724mm in the Skamania area.	Medium	Medium/ Medium	Sturgeon, Eulachon
	OS.PO. Reduce contaminant exposure. *Hypothesis Statement:* If contaminant exposure is reduced, then embryo survival in the estuary and mainstem will increase. *Justification:* Contaminants have been shown to have detrimental effects, such as delayed development or disrupted physiological processes. Numerous contaminants have been detected throughout the lower Columbia River and estuary at concentrations known to have detrimental effects on aquatic organisms.	High	Medium/ Low	Sturgeon, Eulachon

	OS.PO.4 Avoid direct dredging mortality. *Hypothesis Statement:* If suction dredging activities occur in the presence of embryos, then direct mortality will result. *Justification:* White sturgeon or eulachon embryos may be present among sand and fine sediments as a result of deposition and dispersal mechanisms. Suction dredging of these sands and fine sediments results in entrainment and mortality. Dredge operations should avoid known areas of developing embryos.	Low	Medium/ Low	Sturgeon, Eulachon
	OS.PO.5 Develop an understanding of spawning habitat characteristics in the lower mainstem and estuary. *Hypothesis Statement:* If our understanding of spawning habitat increases, then management actions will proceed with greater certainty. *Justification:* Our current understanding of known spawning sites and specific spawning habitat characteristics in the lower mainstem and estuary ecosystem is limited; research is needed to increase our knowledge and reduce uncertainty.	High	High/Low	Sturgeon, Eulachon
Juvenile Rearing/ Migration	**OS.PO.6** Restore spring peak flows in lower Columbia River. *Hypothesis Statement:* If peak flows are restored, then juvenile lamprey physiological development and downstream migration timing will remain synchronized. *Justification:* Restoration and maintenance of historical peak flows will provide a consistent mechanism for juvenile lamprey downstream migration.	High	Medium/ Medium	Pacific Lamprey
	OS.PO.7 Reduce predation mortality. *Hypothesis Statement:* If predation mortality is reduced, then juvenile survival in the lower mainstem, estuary, and plume will increase. *Justification:* Juvenile eulachon have poor swimming capability. Predation on emigrating juvenile eulachon may be substantial and needs to be quantified.	High	High/Low	Eulachon
	OS.PO.8 Reduce contaminant exposure. *Hypothesis Statement:* If contaminant exposure is reduced, then juvenile survival in the estuary and mainstem will increase. *Justification:* Contaminants have been shown to have detrimental effects, such as reduced growth or disrupted physiological processes. Numerous contaminants have been detected throughout the lower Columbia River and estuary at concentrations known to have detrimental effects on aquatic organisms.	High	Medium/ Low	Sturgeon, Pacific Lamprey, Eulachon

	OS.PO.9 Avoid direct dredging mortality. *Hypothesis Statement:* If suction dredging activities occur in the presence of juveniles, then direct mortality will result. *Justification:* Juveniles are closely associated with sand and fine sediments. Suction dredging of these sands and fine sediments results in entrainment and mortality. Dredge operations should avoid known areas of juveniles.	Low	Medium/ Low	Sturgeon, Pacific Lamprey, Eulachon
	OS.PO.10 Document the interaction between juveniles and introduced species; minimize negative interactions. *Hypothesis Statement:* If introduced species continue to thrive, then juvenile survival in the estuary and mainstem may be negatively affected. *Justification:* Introduced species, both purposeful and unintentional, have altered the lower mainstem, estuary, and plume ecosystem. Effects on native species are generally unknown, may be significant, and need to be quantified.	High	Medium/ Low	Sturgeon, Pacific Lamprey, Eulachon
	OS.PO.11 Develop an understanding of juvenile habitat use in the lower mainstem, estuary, and plume. *Hypothesis Statement:* If our understanding of sturgeon, Pacific lamprey, and eulachon integration with the ecosystem increases, then management actions will proceed with greater certainty. *Justification:* Our current understanding of species interaction with the lower mainstem, estuary, and plume ecosystem is limited; research is needed to increase our knowledge and reduce uncertainty.	High	High/Low	Sturgeon, Pacific Lamprey, Eulachon
Adult Abundance	**OS.PO.12** Improve migration conditions and dam passage. *Hypothesis Statement:* If dam passage conditions are improved, then populations will benefit basin-wide. *Justification:* Adult Pacific lamprey and eulachon navigate hydrosystem dams with poor efficiency; thus, access to historical spawning and rearing areas has been limited. Eulachon preferred migration water temperature is 40 °F; cooler temperatures will delay migration.	High	High/High	Pacific Lamprey, Eulachon

	OS.PO.13 Avoid incidental mortality at Bonneville Dam. *Hypothesis Statement:* If Bonneville Dam operations are properly managed, then sturgeon incidental mortality can be minimized. *Justification:* Turbine dewatering operations at Bonneville Dam have been observed to strand sturgeon and result in mortality. This, and other operations at Bonneville and elsewhere in the subbasins, needs to be monitored to determine the significance to the lower Columbia sturgeon population.	Medium	Low/Low	Sturgeon
	OS.PO.14 Reduce predation mortality. *Hypothesis Statement:* If predation mortality is reduced, then adult survival in the estuary and mainstem will increase. *Justification:* Marine mammals and sturgeon prey on adult lamprey in the lower Columbia River and estuary. Other predators may exist. Eulachon are an important food item for many estuary and mainstem species. Large congregations of avian predators have been observed in eulachon spawning areas and pinnepeds may follow eulachon runs in the mainstem.	High	Medium/ High	Pacific, Lamprey, Eulachon
	OS.PO.15 Protect population from overexploitation. *Hypothesis Statement:* If current fisheries are properly managed, then adult abundance in the estuary and mainstem can be maintained. *Justification:* Sturgeon: Longevity, slow growth, and delayed maturation make sturgeon susceptible to fishery overexploitation. Fishery restrictions (such as size limits) and constant population monitoring can help maintain the current level of spawner abundance. Lamprey: At present levels of fishing effort and fishery restrictions, lamprey harvest is relatively low and unlikely a major limiting factor. Eulachon: Fishery regulations and constant population monitoring can help maintain sustainable harvest levels.	Medium	High/High	Sturgeon, Pacific Lamprey, Eulachon
	OS.PO.16 Document the interaction between sturgeon, Pacific lamprey, and eulachon and introduced species; minimize negative interactions. *Hypothesis Statement:* If introduced species continue to thrive, then native species survival in the estuary and mainstem may be negatively affected. *Justification:* Introduced species, both purposeful and unintentional, have altered the lower mainstem, estuary, and plume ecosystem. Effects on native species are generally unknown, may be significant, and need to be quantified.	High	High/Low	Sturgeon, Pacific Lamprey, Eulachon

	OS.PO.17 Develop an understanding of habitat use in the lower mainstem, estuary, and plume. *Hypothesis Statement:* If our understanding of sturgeon, Pacific lamprey, and eulachon integration with the ecosystem increases, then management actions will proceed with greater certainty. *Justification:* Our current understanding of species interaction with the lower mainstem, estuary, and plume ecosystem is limited; research is needed to increase our knowledge and reduce uncertainty.	High	High/Low	Sturgeon, Pacific Lamprey, Eulachon

1.5 Program Gap and Sufficiency Analysis

The lower Columbia River mainstem and estuary incorporates the mainstem from Bonneville Dam (RM 146) to the mouth of the river; the estuary surface area is estimated at about 160 square miles. The subbasins span two ecological provinces as defined by the NPCC: the Columbia River Estuary (mouth to RM 34) and the Lower Columbia River (RM 34 to Bonneville Dam). There are multiple major tributaries to the lower mainstem and estuary in both Washington and Oregon; each Washington tributary is defined as a subbasin by NPCC and has been addressed separately in this Management Plan. Land ownership and jurisdictional authority are varied throughout the lower mainstem and estuary. The lower mainstem and estuary is inherently linked to the various lower Columbia tributaries, as well as the mainstem and tributaries above Bonneville Dam. Thus, programs discussed in the subsequent tributary subbasin chapters have general applicability to the mainstem and estuary subbasin. To avoid repetition, those tributary subbasin programs have not been included here; only those programs with specific applicability to the mainstem river corridor or estuary ecosystem have been identified.

Protection Programs

Protection programs in the mainstem and estuary subbasins are implemented by citizen volunteer groups, non-profit organizations, local counties, State of Washington departments, and federal agencies/corporations. Protection programs in this analysis include those programs that protect habitat conditions or watershed functions through regulatory measures, through the outright purchase or lease of property rights, or by applying standards to new development that protects resources by avoiding damaging impacts. Protection programs may also address ecological interactions, such as programs that seek to reestablish historical predator-prey relationships. Major programs implementing protection measures are identified below.

- *Columbia Land Trust:* Columbia Land Trust works exclusively with willing landowners to find ways to conserve the natural values of the land and water. Landowners donate the development rights or full ownership of their land to the Columbia Land Trust. The Land Trust in turn manages the land under a stewardship plan. The Columbia Land Trust also identifies priority conservation lands to purchase, using financial contributions from private donors.
- *The Lower Columbia River Estuary Partnership:* LCREP is a two-state, public-private initiative that works to protect and restore the lower Columbia River estuary with habitat improvements and education/information programs. LCREP produced a Comprehensive Conservation and Management Plan in 1999 that provides a vision for the estuary and

ensures that ongoing efforts remain consistent with this vision. Through collaboration, convening, and coordination, LCREP integrates 28 cities, nine counties, and the states of Oregon and Washington. LCREP supports a wide range of volunteer, education, protection, and restoration projects that seek to improve habitat and land use, heighten education, information, and coordination, and reduce pollutants in the estuary.

- ✓ *LCREP Habitat Monitoring Program*: The program involves "status monitoring" as outlined in the US Army Corps of Engineers (USACE)/Bonneville Power Administration (BPA) Research, Monitoring, and Evaluation (RME) Plan. Status monitoring is the "measurement of environmental characteristics over an extended period of time to determine status or trends in some aspect of environmental quality." The LCREP's Columbia River Estuary (CRE) Habitat Monitoring Program is consistent with the RME Plan and, in fact, the CRE may be treated as a pilot monitoring subbasin. The funding from BPA covers a three-year program with annual funding increments. The intent of the funding is to develop and establish a habitat monitoring program that can be initiated in year two, and sustained in year three and after. The three parts with their associated goals are as follows: 1. Population/Habitat Status Monitoring – monitoring for trends in the status of juvenile salmon and conditions in the habitats they use, 2. Ecosystem Status Monitoring – habitat classification using remote sensing, and 3. Invasive Species Monitoring – monitoring abundance and distribution of non-indigenous plants and animals.

- o *Columbia River Estuary Study Taskforce*: CREST is a council of local governments serving as a forum for collaboration and regional planning that provides technical assistance to local governments and implements restoration and protection of the Columbia River estuary from river mile 0 to 46. The program provides resource protection, restoration, and management for anadromous and resident fish. CREST assists local jurisdictions with permitting issues, zoning ordinances, comprehensive plan and shoreline master plan amendments, estuarine impact analysis, and wetland, dredging, and water quality issues.
- o *NOAA Fisheries Habitat Conservation Program*: NOAA Fisheries is responsible for habitat conservation through application of ESA Sections 4, 7, and 10. NOAA Fisheries regulates water quality, quantity, habitat, and wetlands for the management of anadromous fish. Conserving the habitat of ESA listed Pacific salmon is the Habitat Conservation Division's largest program area.
- o *USACE*: The USACE has regulatory protection authority over waters of the U.S. under the Rivers and Harbors Act and the Clean Water Act.
  - ✓ The USACE presides over permitting, mitigation, and enforcement of waters of the U.S. primarily in matters pertaining to Section 404 of the Clean Water Act and Sections 10 and 13 of the Rivers and Harbors Act. The Corps evaluates permit applications and enforcement work including wetlands and other special aquatic sites. Section 10 of the Rivers and Harbors Act requires authorization for the construction of any structure in or over any navigable water of the United States. This law applies to any dredging or disposal of dredged materials, excavation, filling, rechannelization, or any other modification of navigable water of the United States, and applies to all structures.
  - ✓ Section 404 of the Clean Water Act regulates the discharge of dredged or fill material into all waters of the United States, including wetlands, both adjacent and isolated. Discharges of fill material generally include, without limitation: placement of fill that is necessary for the construction of any structure or impoundment requiring rock, sand, dirt, or other material for its construction; site-development fills for recreational, industrial,

commercial, residential, and other uses; causeways or road fills; dams and dikes; artificial islands; property protection or reclamation devices such as riprap, groins, seawalls, breakwaters, and revetments; beach nourishment; levees; fill for intake and outfall pipes and subaqueous utility lines; fill associated with the creation of ponds; and any other work involving the discharge of fill or dredged material.

- *BPA Environment, Fish, and Wildlife Program*: BPA is responsible for protecting, mitigating, and enhancing fish and wildlife affected by the development and operation of hydroelectric dams in the Columbia River Basin. Through the guidance of the NPCC, BPA funds projects which protect and enhance salmon and other fish and wildlife populations impacted by regional hydroelectric development and operations.
- *State of Washington:* Numerous department within the State of Washington have protection program responsibilities.
  - ✓ Department of Fish and Wildlife (WDFW) manages land for fish, wildlife, and recreation needs. The Department is mandated to preserve, protect, and perpetuate fish and wildlife and their habitat. A goal of WDFW is to encourage and assist local governments in adopting policies and regulations to protect fish and wildlife habitat. The Priority Habitats and Species Program is the principal means by which WDFW provides important fish, wildlife, and habitat information to local governments, state and federal agencies, private landowners and consultants, and tribal biologists for land use planning purposes. The Department also provides a partnership-based information system that characterizes freshwater and estuary habitat conditions and distribution of salmonid stocks in Washington.
  - ✓ WDFW, in collaboration with Oregon Department of Fish and Wildlife (ODFW), is also responsible for fisheries management, and sets annual harvest regulations for salmon, sturgeon, eulachon, and lamprey in the estuary and lower Columbia mainstem.
  - ✓ Department of Natural Resources public lands are managed under the guidelines of a Habitat Conservation Plan. The Habitat Conservation Plan has protection mechanisms for riparian buffers.
  - ✓ *Washington State Department of Agriculture (WSDA) Water Quality Protection Program*: The goal of this program is to work together with the agricultural community and regulators to protect water resources. The program addresses a variety of surface and ground water issues that involve fertilizers and pesticides. The WSDA is also evaluating current pesticide use practices in conjunction with pesticide residue data in surface waters that provide habitat for ESA- listed species.
- *Local Governments:* Numerous programs are in place to assist urban or industrial development at the city or county level to proceed while minimizing negative environmental impacts.
  - ✓ The State *Growth Management Act (GMA)* requires cities and counties to plan for growth and development through a comprehensive, coordinated, and proactive land use planning approach.
  - ✓ *Critical Area Ordinances*: As part of the GMA, cities and counties are required to adopt policies and regulations that protect critical areas, such as fish and wildlife habitat conservation areas, wetlands, frequently flooded areas, aquifer recharge areas, geologically hazardous areas.
  - ✓ *Shoreline Management Act (SMA)*: The SMA governs proposed land uses within 200 ft. of shoreline areas and their associated wetlands and/or 100-year floodplain, including shorelines along saltwater, streams >20cfs, and lakes >20 acres.

- ✓ *State Environmental Policy Act (SEPA)*: SEPA aims to maintain and improve environmental quality through requiring government agencies to properly consider environmental matters during decision making, including the identification and evaluation of probable impacts to all elements of the built and natural environment.

- o *Northern Pikeminnow Management Program:* The goal of the program is to manage annual pikeminnow predation on juvenile salmonids. The program pays rewards to anglers for harvesting pikeminnow over a prescribed size, thus providing an incentive to remove the large, predaceous pikeminnow from the population.
- o *Caspian Tern Management Programs*: Numerous programs/activities have recently occurred that address Caspian tern management in the Columbia River estuary.
  - ✓ *Caspian Tern Working Group*: Task force dedicated to establishing the needs of the Columbia River Caspian tern breeding population while minimizing negative effects on ESA-listed species.
  - ✓ *Caspian Tern Environmental Impact Statement (EIS)*: The USFWS, USACE, and NOAA Fisheries are jointly preparing the EIS; the purpose is to explore options to reduce the level of tern predation on Columbia River salmonids while insuring the protection and conservation of Caspian terns in the Pacific Coast/Western region (California, Oregon, Washington, Idaho, and Nevada).
  - ✓ *Caspian Tern Relocation Project*: The goal of the project was to relocate terns to another location in the estuary where tern predation on juvenile salmonids would be reduced but the viability of the tern population would be maintained.
- o *Pacific Flyway Council, Dusky Canada Goose Management*
  - ✓ A management plan for the Dusky Canada goose was developed by United States Fish and Wildlife (USFWS), ODFW, WDFW, Oregon State University (OSU), and Pacific Flyway representatives. This group developed harvest, nest survey, management and research tasks with the goal of improving the declining dusky population. If these tasks are funded, then the population of dusky geese will reach a level where special protection is not needed. Funding has been limited recently and many projects are not being implemented as planned.
  - ✓ *Agricultural Depredation Control Plan*: This plan is a list of strategies and tasks to reduce the agricultural depredation committed by geese on private property. The plan was developed by WDFW, ODFW, USFWS, APHIS-WS, OSU, and the Oregon and Washington Farm Bureaus. The funding for this plan is inconsistent and recent reductions have caused landowners to potentially suffer more crop damage. Assistance from agencies to landowners has also declined by lack of funding.
  - ✓ *Agricultural Waterfowl Incentive Program*: The program is designed to enhance waterfowl habitat by providing seeds, tubers, graze, and invertebrates. In 1998, 49 landowners participated to create 38,949 ac (15,769 ha) of waterfowl habitat, a 75% increase from the proceeding year. Enrolled landowners were predominantly rice producers in the northern Central Valley, with only one elsewhere. Much of this flooding is in addition to the 60,021 ac (24,300 ha) already being flooded before the program was initiated.

Restoration Programs

Restoration programs in the mainstem and estuary subbasins are implemented by citizen volunteer groups, non-profit organizations, local counties, State of Washington departments, and federal agencies/corporations. Many protection programs outlined above also have restoration components; these programs are not repeated here. Major programs implementing restoration measures include:

- *LCREP:* The purpose of LCREP has been described above under the 'Protection Programs' section.
  - ✓ *LCREP Habitat Restoration Program*: An effort to develop an ecosystem based approach to protecting existing habitat and restoring altered habitat has been initiated by the Estuary Partnership in association with the CREST. The outcome of this project will be a coordinated, ecosystem based habitat restoration program focused on increasing the survival of juvenile salmonids and monitoring habitat project success over time. The specific objectives of this project are to: (1) establish a habitat restoration program for the lower Columbia River and estuary (Bonneville Dam to mouth of river), and (2) develop monitoring and evaluation protocols for the lower river and estuarine habitats.
- *NOAA Fisheries.*
  - ✓ *Federal Columbia River Power System (FCRPS) and Channel Deepening Biological Opinions*: Numerous restoration actions have been identified through the BiOps; USACE, BPA, and the Bureau of Reclamation are responsible for implementing these restoration actions.
  - ✓ *Evaluating Cumulative Ecosystem Response To Restoration Projects in the Columbia River Estuary*: The goal of this study is to develop standardized techniques and protocols that will facilitate evaluation of the performance of salmon habitat restoration actions and support the decision-making process for said actions in the CRE aimed at increasing population levels of listed Columbia Basin salmonids. The management implications of this research are two-fold. It will provide techniques to: 1) obtain data to compare project results in order to support decisions regarding what projects to pursue for restoration of the ecosystem, and 2) to evaluate the ecological performance of the collective habitat restoration effort in the CRE and its effects on listed salmonids. The objectives of this study are to: 1) develop standard monitoring protocols and methods to prioritize monitoring activities that can be applied to CRE habitat restoration activities for listed salmonids; 2) develop the empirical basis for a cumulative assessment methodology, together with a set of metrics and a model depicting the cumulative effects of CRE restoration projects on key major ecosystem functions supporting listed salmonids; 3) design and implement field evaluations of the cumulative effects of restoration projects using standard methods, and sensors or remotely operated technologies, to measure the effects on listed salmonids through ecosystem response; and 4) develop an adaptive management system including data management and dissemination to support decisions by the Corps of Engineers and others regarding CRE habitat restoration activities intended to increase population levels of listed salmon.
- *USACE*: Under Section 206 of the Water Resources Development Act of 1996, the USACE has the authority to carry out an aquatic ecosystem restoration and protection project if the project will improve the quality of the environment, is in the public interest, and is cost-effective. Significant provisions of Section 206 include a cost-sharing requirement and an annual funding cap for programs nation-wide. A minimum of 35% of a project's costs must be contributed from non-federal sources and a maximum of $25 million dollars annually may be dedicated to projects nation-wide. Restoration and protection projects funded under Section 206 need not be tied to a hydrologic project.
- *USFWS Environmental Contaminants Program*: The program applies to all watersheds within the Columbia River Basin. The Environmental Contaminants Program conducts

studies that help to reveal the health of terrestrial and aquatic ecosystems. Wildlife and fish populations are assessed for the health of their habitats, populations and individual organisms. The purpose is to identify and prevent the harmful effects of contaminants on fish and wildlife, and to restore resources degraded by contamination. The Service provides technical assistance on a variety of issues including: pesticide use, mining, agriculture, industrial discharges, forestry practices, range management, urbanization, wastewater treatment system discharges, and non-point source discharges, crop production for waterfowl, and control of fish diseases at hatcheries.

- *USFWS Partners for Fish and Wildlife Program*: The program is the USFWS's primary mechanism for delivering voluntary on-the-ground habitat improvement projects on private lands for the benefit of federal trust species. The purpose of the program is to promote watershed based restoration of wetland, riparian, prairie, and other habitats essential to fish and wildlife resources. Restoration projects are intended to provide direct benefit to fish and wildlife resources. The program provides technical and financial assistance to landowners to help meet the habitat needs of federal trust species on private lands.

Gap Analysis

Protection-related Programs: The lower mainstem and estuary subbasins have protections through federal, state, and local regulatory authority. These protection programs can direct local subbasin actions, however, this remains only a portion of the protection challenges for the lower mainstem and estuary because all upstream activities and protection programs affect conditions in the lower mainstem and estuary.

Restoration-related Programs: Over a long period of time, improvements to the lower mainstem and estuary are possible, primarily through restoration action of LCREP and via the NOAA Fisheries BiOps. To the degree possible, programs should focus on restoring floodplain function and connectivity with the mainstem, as well as restoring off- and side-channel habitats.'

Table 1-6. Programmatic Actions to Address Gaps

Action No.	Lead Agency	Proposed Action
EST/M.1	Counties	Adequately protect riparian areas, wetlands, wetland buffers, and wetland function. Activities on the landscape must protect wetlands and the vegetation surrounding them to avoid disturbing soils, vegetation, and local hydrology. Utilize mitigation, where necessary, to offset unavoidable damage.
EST/M.2	Counties	Adequately protect historical stream meander patterns and channel migration zones and avoid hardening stream banks and shorelines.
EST/M.3	Counties	Remove or modify tide gates to restore floodplain connectivity with mainstem and floodplain function.
EST/M.4	Counties	Apply land use code enforcement across jurisdictions in a consistent manner, using appropriate funding levels and application.
EST/M.5	Columbia Land Trust, LCREP, WDFW, USFWS, USACE, BPA, Counties	Obtain wetland, riparian, off-channel, and floodplain habitats to restore connectivity between river and floodplain as well as floodplain function.
EST/M.6	USACE, BPA	Monitor/manage Bonneville Dam releases to evaluate effects on watershed functions, mainstem spawning habitats, and peripheral rearing habitats over time to evaluate hydrologic impacts.
EST/M.7	LCFRB, WDFW, NOAA, USFWS, USACE, BPA, SRFB, LCREP	Increase available funding for projects that implement measures and addresses underlying threats.
EST/M.8	Counties, LCREP	Utilize a combination of public outreach/education, incentives, and authority to positively influence landowner behaviors toward land stewardship in practices not covered by land use regulations.
EST/M.9	LCFRB, WDFW, Counties	Build institutional capacity for agencies and organizations to undertake additional protection and restoration projects (e.g., noxious weed control).
EST/M.10	LCFRB, WDFW, NOAA, USFWS, USACE, BPA, SRFB, LCREP, Counties	Address threats proactively by building agreement on priorities among the various program implementers.