Table 3.8 Proposed Ecosystem Research Actions

Research Task	Justification	Duration	Data Analysis
Add two additional transects in different habitat types similar to those being done for the NMFS studies currently under way with annual fish evaluation process.	Provide additional habitat and salmonid distribution information for the estuary. Useful in establishing inventory information for future monitoring or restoration.	Begin before construction and for 3 years after completion of the Project.	Record value and use of different habitat types for juvenile salmonids and cutthroat trout.
Evaluate cutthroat trout use of the estuary and river areas.	Little is known about the species use of this habitat. Research to provide additional information regarding salmonids use of this habitat.	Conduct study for 2 years before construction and 2 years during construction.	Record value and use of different habitat types for juvenile salmonids and cutthroat trout.
Conduct bank-to-bank hydrographic surveys of the estuary.	Has not been done in 20 years and is needed to assess available habitat and restoration actions.	Once, before construction.	Bathymetry will be available for shallow water areas in the estuary.
In conjunction with ongoing studies of juvenile salmonids habitat utilization in the Lower Columbia River, collect and analyze juvenile salmonids and their prey for concentrations of chemical contaminants.	Provide additional data on contaminants in listed salmonids and their prey. Useful in establishing inventory information for future monitoring or restoration.	Begin before construction and for 3 years after construction, depending on the results.	Record concentrations of persistent contaminants (*e.g.*, DDTs, PCBs, PAHs, dioxin-like compounds) in juvenile salmonids and prey.
In conjunction with above contaminant study, assess sublethal effects of contaminants (*e.g.*, growth, disease resistant) on salmonids.	Provide additional data for established contaminants thresholds effect levels to ensure that guidelines are Protective of salmonids; to better characterize performance of juvenile salmonids in the estuary.	Begin before construction and for 3 years after construction, depending on the results.	Record health status of juvenile salmonids Collected above.
Estuarine Turbidity Maximum (ETM) workshop.	To further the knowledge of the ETM and the listed stocks.	Once.	Not Required.

4. BIOLOGICAL INFORMATION

4.1 General Status of ESA-Listed Salmonids

NMFS has determined that the proposed action has the potential to adversely affect ESA-listed salmonids. Based on migratory timing, ESA-listed salmonids will be present in the action area during Project construction and operation and maintenance of the 43-foot channel. A general discussion of species status can be found in the November 2004 FCRPS Hydropower Biological Opinion, Chapter 4.0, Range-wide Status of the Listed Species.

4.2 Biological Requirements of Salmonids as Defined by the Conceptual Ecosystem Model

The Lower Columbia River, estuary and river mouth play a critical role in the survival and recovery of ESA-listed salmonids by providing refugia, nutrients, and conditions in which juvenile salmon undergo the physiological change from fresh-water to saltwater. NMFS' recently developed Cumulative Risk Initiative (CRI) modeling supports this conclusion. The CRI estimates population growth rates and uses this measure to assess the risk of extinction or of species decrease in abundance. The CRI analysis suggests that significant opportunities exist for securing additional improvements in overall population trends of ESA-listed salmonid stocks by reducing the substantial mortality in the estuarine and early ocean life stages (Kareiva *et al*., 2000).

In discussions of the importance and complex nature of the Lower Columbia River, estuary and river mouth to salmonids, the SEI panel identified the need for a consistent framework for understanding this ecosystem. The BRT worked with the SEI panel to develop a conceptual ecosystem model of the Lower Columbia River, estuary and river mouth ecosystem relationships that are significant for ESA-listed salmonids. The conceptual ecosystem model describes the physical and biological interactions of the Lower Columbia River and estuary in a manner that characterizes properly functioning habitat conditions for the system. The 2001 BA (Chapter 5 and Appendix E) provides an extensive presentation and discussion of the conceptual ecosystem model, and describes the historic and current conditions of the Lower Columbia River, estuary, and river mouth using the model. These descriptions are incorporated herein by reference.

In NMFS' 1999 biological opinion for this Project, we determined that the biological requirements NMFS considered to be most relevant to ESA-listed and salmonids were: (1) Habitat characteristics in the Lower Columbia River and estuary ecosystems that function to support successful migration, smoltification, and rearing; and (2) water quality that supports survival and recovery of ESA-listed salmonids. For the purposes of this reinitiation analysis, these biological requirements for ESA-listed salmonids have been included into the conceptual ecosystem model developed for the Project.

The following is a summary, based on the conceptual ecosystem model, of the Lower Columbia River, estuary and river mouth's ecosystem components, and how these factors collectively influence the growth and survival of the salmonid species rearing in and migrating through the Columbia River and estuary. Table 2-1 of the 2001 BA, Conceptual Model Pathways and Indicators for Juvenile Salmonid Production in the Lower Columbia River, is incorporated by reference.

4.2.1 Habitat-Forming Processes

Habitats are formed primarily by the interaction of hydrodynamic forces and sediment supply. In the Lower Columbia River, estuary and river mouth, both the river and the ocean influence the riverine and estuarine hydrodynamics. Ocean processes, including tidal action and waves, interact with river processes, including currents and sediment transport, in the Lower Columbia River, estuary and river mouth to produce complex hydrodynamics. The net result is deposition (accretion) of suspended sediments to form flats and carving (erosion) to form shallow and deep channels. These habitats may be colonized by marsh and swamp vegetation, as controlled by bathymetry (elevation of substrate) and, in the estuary, salinity. Because plants and animals are adapted to certain salinity ranges, the salinity level, as well as seasonal and spatial patterns, strongly influences where species occur in the Lower Columbia River and estuary. If the turbidity levels are low enough to allow sufficient light penetration for plant growth, certain areas may develop submerged vegetation such as eelgrass. Woody debris, deposited on the flats, along channel edges, and in marshes and swamps, creates a complex, vertical structure. Habitats in deeper riverine and estuarine areas are formed by bedload transport, which shapes portions of the river and estuary bed into a series of sand waves. All of these dynamics and interactions culminate in the expression of habitat types important to salmon in the Lower Columbia River and estuary.

4.2.2 Habitat Types

The basic riverine and estuarine habitat-forming processes—physical forces of the ocean and river—create the conditions that define habitats. Key habitat types (*i.e.*, tidal marsh and swamp, shallow water and flats, and water column), in turn, provide an opportunity for the primary plant production that gives rise to complicated food webs. All of these pathways combine to influence the growth and survival and, ultimately, the production and ocean entry of juvenile salmonids moving through the Lower Columbia River and estuary.

The Lower Columbia River and estuary extends the freshwater habitat of salmon and expands habitat available for rearing (Wissmar and Simenstad, 1998). The estuary serves as a conduit to the ocean, transporting fish from the river to the ocean, and provides critical adult holding, spawning, incubation, juvenile rearing habitat and migration corridors for ESA-listed salmonids. Estuary conditions have an important effect on salmon survival (Emmett and Schiewe, 1997; Hinrichsen *et al*., 1997), and on the number of salmon that can be supported in the Columbia River system.

Structural and biological features of estuarine habitats that provide refugia from predators and off-channel areas protected from strong tidal and river currents are important to salmon survival. Important features that can minimize effects of predators and strong flows include: Complex dendritic tidal channel systems and other landforms (islands, peninsulas, *etc*.); wood, emergent vegetation, or other structural components; and connections between mainstem channels and floodplains. Availability of refugia under variable tidal and river flow levels is necessary to support diverse rearing and migratory behaviors and thereby spread the physical and biological risks to salmon through time and space.

Persistence and resilience of Pacific salmon are linked to the quantity and quality of habitats throughout the range of their life history, from freshwater spawning to oceanic rearing environments. But salmonid ecosystems are not static; freshwater, estuarine and ocean conditions vary over many time scales, but seldom in synchrony. To compensate for such uncertainty, salmon have evolved a diversity of life-history traits that allow them to function in a variable environment (Wissmar and Simenstad, 1998; Bottom *et al*., 2001).

The quality and diversity of estuarine rearing habitats are important factors influencing the diversity of salmon life-history types that enter a variable ocean environment. For example, salmon populations within and among species enter the Columbia River estuary at different times, reside for varying periods, and select different habitats in time and space. This variety of rearing strategies minimizes the risk of brood failure, since not all individuals behave identically under the same set of environmental conditions. Slightly different patterns of migration and rearing in the estuary are advantageous in different years depending, for example, on the timing of flood events, the onset of the spring transition, the distribution of coastal upwelling, the timing of prey production, and the distribution of predators.

Continued survival of juvenile salmon in the ocean is often dependent on prior growth in the estuary, which is largely supported by detrital food chains and prey species from a variety of estuarine habitats. Important rearing habitats for juvenile salmon include those that produce, retain, and concentrate macrodetritus in the high-flow environment of the Columbia River estuary. Among areas of production and accumulation of organic matter are dendritic tidal channels and backwater sloughs, estuarine and tidal-freshwater marshes and swamps, vegetated riparian habitats, mud and sandflats of shallow peripheral bays, and the microdetrital producing estuarine turbidity maximum zone in the mainstem channels.

The habitats most directly linked to salmonids in the Lower Columbia River and estuary include the tidal marshes and swamps, shallow water and flats, and the water column. The position and extent these habitats that allow juvenile salmon gradually to adapt to saltwater are particularly important to their performance and survival.

Tidal marshes and swamps generally occur between Mean Higher High Water (MHHW) and the Mean Lower Low Water (MLLW). Tidal marshes begin at lower tidal elevations, slightly above MLLW, and swamps occur at or above MHHW. Juvenile salmonids use the edges of these marshes to feed, and the edges of shallow channels within the marshes as refugia and feeding areas. Tidal marshes can be divided into saltwater marshes and freshwater marshes, each characterized by a distinctive vegetation type.

Tidal marshes include tidally-influenced areas all the way up to Bonneville Dam, as well as extensive tidal freshwater marshes in the Lower Columbia River, particularly those in Cathlamet Bay. Availability of feeding habitats and refugia within the oligohaline or brackish zones of the estuary constitute a critical transition area for smaller salmon juveniles when they first enter saline waters. The proper function of habitats in this area and their linkage to adjacent habitats require that salmon can move freely upstream and downstream as needed to adjust their distribution with changes in the salinity gradient.

Shallow water and flats occur throughout the intertidal zone and into the shallow subtidal zone in waters up to six feet deep. Benthic algae (largely benthic diatoms) develop on tidal flats and in the shallow subtidal zone within the system. Juvenile salmonids use shallow water and flats habitats for feeding and movement.

Water column habitat refers to waters that are greater than 6 feet deep. Freshwater plankton dominate the fresh and oligohaline portions of the water column upstream, and plankton tolerant of greater salinity dominate the estuary and the river mouth of water column habitats. Juvenile salmonids utilize water column habitat for feeding and movement.

Habitat Primary Productivity Pathway. A major function of the habitats is to produce food used by organisms in the ecosystem. Habitat primary productivity refers to the amount of material (biomass) produced over time during plant growth that occurs within each habitat type. Primary productivity is driven by light and is supported by inorganic nutrients (*e.g*., nitrate, phosphate). Inorganic nutrients enter the system from the upstream watershed and the downstream ocean currents and through the breakdown and recycling of organic matter within the system. Live plant material and detritus are the primary sources of organic matter in the food web used by salmonids in the Lower Columbia River, estuary and river mouth.

Primary productivity within water column habitat results from imported and resident phytoplankton. Imported phytoplankton are freshwater species produced in large quantities in the upstream watershed (particularly in the reservoirs behind the mainstem Columbia River and tributary dams), whereas resident phytoplankton are produced within the Lower Columbia River and estuary.

Primary productivity within the shallow water and flats habitat results mostly from benthic algae. Shallow water habitats can also produce filamentous algae and flowering grasses such as eelgrass, however, the majority of primary productivity within the river's shallow water areas comes from benthic algae.

Primary productivity within tidal marsh and swamp habitat comes from the marsh and swamp vegetation, which includes emergent plants, shrubs, and trees.

Food Web Pathway. The base of any food web is the plant material produced over time or the primary productivity within each habitat type. The food web described in the conceptual ecosystem model includes macrodetritus, the large, complex forms of dead plants, primarily from tidal marsh plants. Macrodetrital webs are supported by tidal channels and backwater sloughs, marshes and swamps, vegetated riparian habitats, and other shallow water and low velocity habitats. This food web also includes microdetritus, the material from simple-celled plant or organic particles. Microdetritus can be in the form of imported microdetritus if they are derived from imported phytoplankton, or resident microdetritus if they are derived from resident phytoplankton. Small animals that shred the larger plant matter and microbes, including bacteria, protozoa, and fungi, facilitate the breakdown of detritus. In addition to making the organic matter useful to the food web, these breakdown processes recycle inorganic nutrients needed by the plants for primary production.

Fish and invertebrate community surveys in the Lower Columbia River and estuary provide strong evidence that physical processes that concentrate organic matter and maintain zooplankton populations in the estuary control the feeding environment for estuarine fishes (Bottom and Jones, 1990). Salmonids eat invertebrate prey species that are supported by resident and imported microdetritus, and macrodetritus from tidal marsh and swamp plant material. The relative amount of food and food energy depends on the abundance of each habitat type (*e.g*., tidal marshes) and the input of nonresident material from upstream sources. Several types of invertebrate prey species make up the next level up the food chain from the primary producers and their detritus.

Mobile macroinvertebrates are large epibenthic organisms, such as sand shrimp, mysids, and Dungeness crab, that reside on the river bottom and feed on bottom sediments and byproducts of primary productivity. Mysids are the primary macroinvertebrates that are relevant to the salmonid food web. Floating insects (larvae and adults) also appear to be important in the diet of most of the salmonid species and age classes in the salmonid food web. Many of these insect types feed on live tidal marsh plants.

Deposit feeders are benthic animals that feed by consuming organic matter in sediments. The term deposit feeders refers to both surface and subsurface deposit feeders, which include marine annelids (polychaetes), and freshwater annelids (oligochaetes), and benthic crustaceans. Suspension feeders are organisms that feed from the water column itself. For zooplankton and benthic/epibenthic organisms, this is accomplished primarily through 'filter feeding' (extracting organic matter from the water column by pumping or siphoning the water through their systems). Among the most abundant species found in the stomachs of salmonids is the planktonic cladocera suspension feeder *Daphnia pulex*.

Suspension/deposit feeders are benthic and epibenthic organisms that feed on or at the interface between the sediment and the water column. Because of the shift in the Lower Columbia River to more of a 'microdetrital' food web (*see* discussion below), the suspension/deposit feeder *Corophium salmonisis* now perhaps the most abundant species found in the stomachs of salmonids. However, nutritionally, *Corophium* may not be as desirable as other food sources for young salmon. According to Higgs, *et al*. (1995), gammarid amphipods such as *Corophium* are high in chitin and ash and low in available protein and energy relative to daphnids and chironomid larvae.

Thus, there has been a shift in the food web within the Lower Columbia River. Tidal marsh and swamp vegetation and macrodetritus have declined. The benthic/epibenthic food web, which was a prominent feature of the historical Lower Columbia River ecosystem, no longer produces as varied or rich a food web (Sherwood, *et al*., 1990). The current ecosystem is now more dependent on a 'microdetrital' food web supported by the Estuarine Turbidity Maximum (ETM) zone in the mainstem channels.

The ETM results from the combination of two processes, strong tidal forces and its interaction with the salt wedge in the Lower Columbia River. This combination results in elevated levels of suspended particulate matter. The physical process occurs when strong tidal forces push salinity upriver beneath the outflowing river water. The turbulence caused by this tidal forcing results in resuspension of sediment and other particulate material present on the riverbed. Concurrently, dissolved material in the river water flocculates when it comes into contact with the salt wedge pushing its way up river. The interaction of these forces results in the ETM.

The ETM supports the detrital food chain and salmon production, and in the current estuary the ETM sustains the highest secondary productivity (Simenstad *et al*., 1990). Fish and invertebrate community surveys in the Columbia River estuary provide strong evidence that physical processes that promote concentration of organic matter and the maintenance of zooplankton populations within the estuary control the feeding environment for estuarine fishes (Bottom and Jones, 1990). With the degradation of the macrodetrital food chain, the ETM has assumed an important role in providing food for salmon that enables them to mature properly and enhances their ability to survive.

Growth Pathway. Salmonids are adapted for using a complex mosaic of many habitat areas as they migrate downstream, and during their residence in the Lower Columbia River, estuary and river mouth. This mosaic of habitats used by salmonids is referred to as habitat complexity. An absence or reduction in the natural complexity of habitats available may affect the salmonids' ability to reach food resources needed for growth. Habitat conveyance is the opportunity for salmonids to move over flats and into tidal marsh systems as the water level rises and falls with the tide and with river flow. Connectivity refers to links and spatial arrangements among habitats in the mosaic of changing habitat areas. Feeding habitat opportunity reflects the variable access among feeding, rearing, and refuge habitats along the migratory corridor. Habitat-specific food availability needs to exist for salmonids to feed within the set of habitats. Lastly, low current velocity, shallow water areas provide productive feeding areas for salmonids. However, because salmonids are visual predators, turbidity and uneven bathymetry may influence their ability to successfully capture prey items.

Survival Pathway. Besides growth, a variety of factors interact to affect the ultimate survival of salmonids in the Lower Columbia River, estuary and river mouth. Factors that can negatively affect survival include contaminants, predation, suspended solids, temperature and salinity extremes, stranding, entrainment, and competition.

Contaminants may affect the health (physiological integrity) of salmonids and may result in disease as well as a reduced ability to physiologically adapt to saltwater, avoid predators, forage effectively, and seek and find shelter. Contaminants can be taken up directly through the water column or through contaminated prey. Predation is a major factor affecting salmonid survival in the Lower Columbia River, estuary and river mouth. Birds, including Western grebes, cormorants, gulls, terns, and great blue herons, are known to prey on salmonids. Piscine and pinniped predators also may prey salmonids. Suspended solids, which can be a major contributor to turbidity, may affect survival by reducing the ability of salmonids to see prey, and indirectly cause mortality via starvation. Temperature and salinity extremes typically stress fish, which may lead directly or indirectly to mortality. Stranding can occur when fish are washed up onto higher ground by waves or ship wakes, or if they are caught for extended periods of time in a shallow pool during an extended low tide. Fisheries biologists have observed stranding of salmonids in the Lower Columbia River system. Entrainment refers to the uptake of fish during dredging. Finally, competition between and among members of the outmigrating salmonid populations may play a role in survival, however, little is understood or documented regarding the effects of competition in the Lower Columbia River, estuary and river mouth.