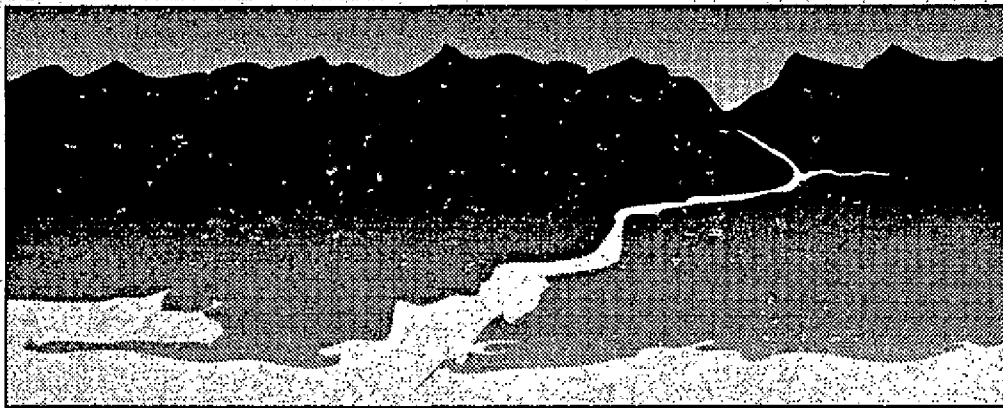# LOWER COLUMBIA RIVER

BI-STATE PROGRAM

OVERVIEW AND SYNTHESIS OF FISH AND WILDLIFE STUDIES IN THE LOWER COLUMBIA RIVER

JUNE 28, 1996

Prepared By:

TETRA TECH

TETRA TECH

FINAL REPORT
TC 0941-01

OVERVIEW AND SYNTHESIS OF FISH AND WILDLIFE STUDIES IN THE LOWER COLUMBIA RIVER

JUNE 28, 1996

Prepared For:

The Lower Columbia River
Bi-State Water Quality Program

Prepared By:

TETRA TECH, INC.
15400 NE 90th Street
Redmond, WA 98052

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

The objective of this report is to summarize the fish and wildlife studies that have been conducted under the supervision of the Lower Columbia River Bi-State Water Quality Program (Bi-State Program) and to integrate the results of these studies into an overall assessment of the health of selected target species. This section provides a brief history of the Bi-State Program and its efforts to address fish and wildlife issues, and a description of the lower Columbia River study area.

1.1 LOWER COLUMBIA RIVER BI-STATE WATER QUALITY PROGRAM

The Bi-State Program was formed in 1990 by an Interstate Agreement of the Oregon and Washington state legislatures. This Agreement directed the Bi-State Program to characterize water quality in the lower Columbia River, identify water quality problems, determine whether legally defined beneficial uses of the river are impaired, and develop solutions to problems identified in the river below Bonneville Dam; the Bi-State Program was placed under the direction of a Bi-State Committee which included a broad representation of public and private interests in the River, and was coordinated by the two state environmental agencies (Bi-State Steering Committee 1990). Since its inception, the Bi-State Program has conducted a number of studies to accomplish this legislative mandate. These studies have documented beneficial uses of the river; characterized historical and current contaminant levels in water, sediment, and a small number of fish species and crayfish throughout the river; quantified the amounts and sources of pollutants entering the river; assessed human health risks from the consumption of fish; and studied the health of fish and wildlife species and communities along the River.

To decide what studies might best address concerns relating to these beneficial uses, the Bi-State Committee convened a work group of fish and wildlife experts to guide the Committee in selecting studies. This work

1

group produced a long list of recommended fish and wildlife studies related to water quality in the lower Columbia River (see Appendix A). These studies were organized into four groups: 1) contaminant assessments, 2) habitat status, 3) population status and trends, and 4) long-term sampling to identify trends.

The work group members prioritized the studies and recommended those they felt had the greatest applicability to the objectives of the Bi-State Program. The Bi-State Program Coordinators decided which studies could be accomplished within the resources available to the Bi-State Program, and developed scopes of work for these studies. With the help of the fish and wildlife work group, the studies described in detail in section 2 were conducted by private contractors and public agencies.

1.2 LOWER COLUMBIA RIVER STUDY AREA

The Lower Columbia River Bi-State Program study area includes the Columbia River from Bonneville Dam at river mile (RM) 146 [river kilometer (RK) 235] to the mouth, including the basins of the lower river tributaries (Figure 1). The study focused primarily on the river's mainstem, but also considered inputs of contaminants from major tributaries. The five largest tributaries to the lower river are the Willamette, Cowlitz, Kalama, Sandy, and Lewis rivers.

The Columbia River basin below Bonneville Dam makes up about 7 percent of the total drainage area of the Columbia River (Figure 1). At Bonneville Dam the river is relatively narrow, as little as 0.2 mi (0.3 km) wide directly below the dam. A number of large islands along its course separate the main channel from backwater areas. The channel widens to a mile (1.6 km) or more at some locations. At RM 46 (RK 74) the river separates into two channels that pass around Puget Island, with the navigation channel following the Oregon side. Below Puget Island [RM 37 (RK 60)] the river opens into a broad estuary with a number of islands and interconnected channels. Below about RM 25 (RK 40) the estuary opens into an even wider expanse of bays and tide flats with distances between the Oregon and Washington shores ranging to about 5 mi (8 km) in some locations. At its mouth the river passes between two jetties approximately 2 mi (3 km) apart as it enters the Pacific Ocean.
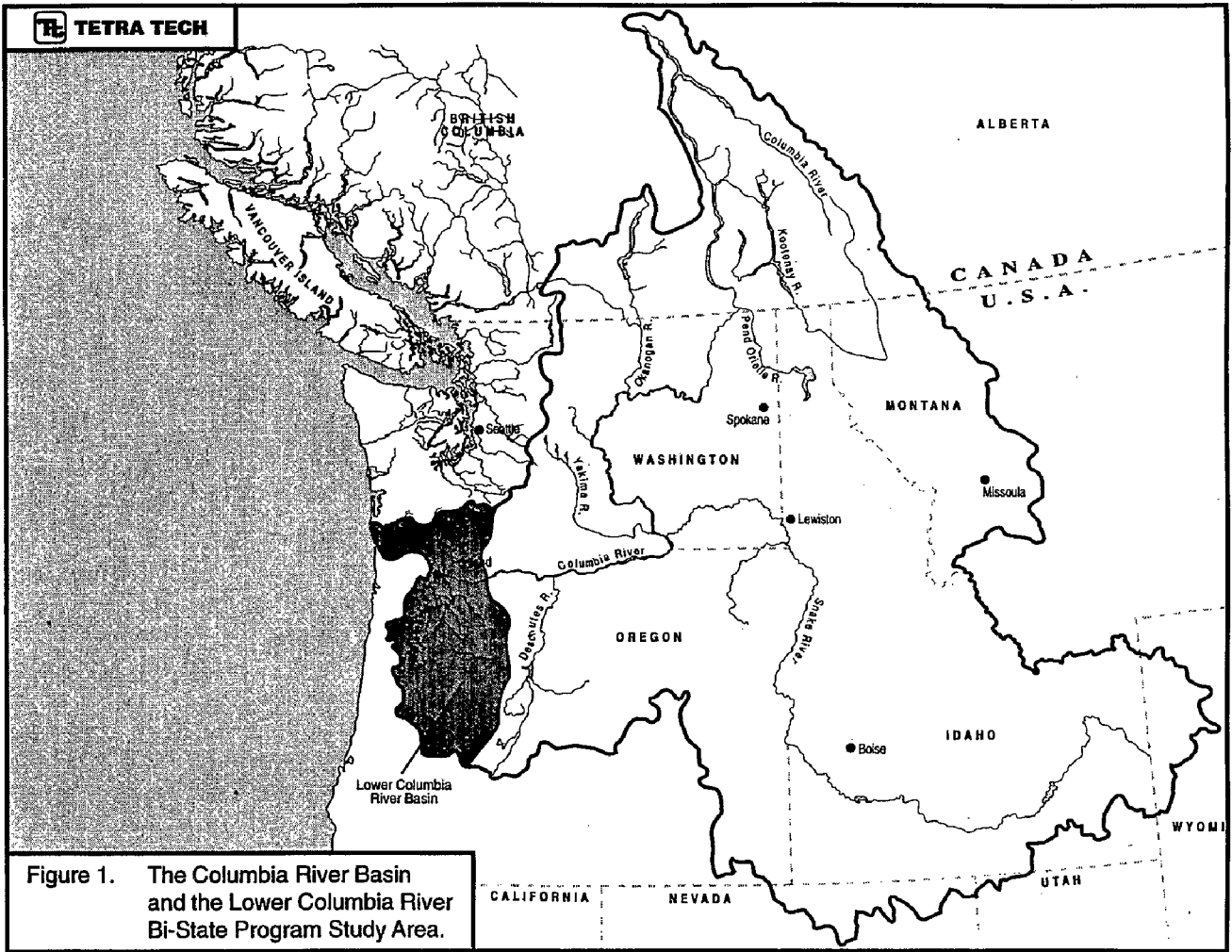
Figure 1. The Columbia River Basin and the Lower Columbia River Bi-State Program Study Area.

The flow of the lower Columbia River is strongly influenced by climatic variations and tides. The tidal influence on water surface elevation is evident all the way to the base of Bonneville Dam. During periods of low flow, tides may cause river flow to reverse up to about RM 80 (RK 128). However, the upstream limit of tidal salinity intrusion is approximately RM 23 (RK 37). The lowest river flows generally occur during September and October, when rainfall and snowmelt runoff are low. Highest flows occur in spring (April to June) due to snowmelt runoff from the Cascade and Rocky Mountains to tributaries of the upper Columbia. High flows also occur between November and March due to heavy winter precipitation in the tributary basins of the lower river, primarily the Willamette in Oregon and the Cowlitz in Washington.

Historically, inhabitants of the Columbia River basin have exploited the river for its bounty of salmon and its readily available water for irrigation. In the 1870s the first regulations directed at controlling the commercial salmon fishery were enacted by the state of Oregon and the Washington Territory, and in 1877 the first salmon hatchery opened (and soon closed) on the Clackamas River, tributary to the Willamette River in Oregon. By 1883 there were forty canneries operating on the Columbia River, packing 634,300 cases or approximately 35 million pounds of canned Chinook salmon that year.

Along with fish processing and agriculture, lumber mills and wood pulping and papermaking plants were established in the basin. The first pulp mill along the lower Columbia River was established in 1884 in Camas, Washington. This plant was followed by others in Vancouver, Washington (1923); St. Helens, Oregon (1926 and 1930); and Longview, Washington (1927 and 1931). Today, six pulp and paper mills are located along the lower Columbia River: Camas, Vancouver, and Longview (two plants), Washington, and St. Helens and Wauna, Oregon.

Another significant development in the basin was the extensive dredging, diking, and filling of the river which began in the late 19th century. Pile dikes (typically grouped timber pile structures) were constructed in the river to create a single channel for navigation and to minimize the need for costly dredging operations. Earthen dikes were constructred primarily for land use and flood protection purposes by state and local interests. The impact of dredging and filling was greatest in the broad estuary, where over half of the tidal swamp and marsh areas have been lost since 1870.

Development and exploitation of the basin's resources entered a new phase in the 1930s when the federal government began constructing dams for irrigation, flood control, river transportation, and hydropower

production in the basin. In 1935 a 35 ft (11 m) deep navigation channel was completed from the mouth of the river to Portland, Oregon. [The channel depth is currently maintained at 40 ft (12 m).] In 1937 the Bonneville Power Administration was formed and in 1938 the Bonneville Dam, the first federal dam on the Columbia River mainstem, was completed by the U.S. Army Corps of Engineers at a site 146 mi (235 km) from the mouth of the river. By 1970 the federal dam system of over 40 dams in the Columbia River basin was essentially complete. The current system has a storage capacity of 20 million acre-ft of water, produces more than 19,000 megawatts of electricity, and provides passage for commercial shipping as far as Lewiston, Idaho on the Snake River, over 460 miles (740 km) from the Pacific Ocean.

In spite of various salmon protection regulations enacted over the past decades by Oregon and Washington, salmon stocks have continued to decline. In 1980 the U.S. Congress passed the Pacific Northwest Electric Power Planning and Conservation Act, which reshaped the management of power production in the basin and legislated the protection, mitigation, and enhancement of salmon and steelhead stocks. The act also created the Northwest Power Planning Council, an eight-member body formed of appointed representatives of the states of Idaho, Oregon, Montana, and Washington. But salmon stocks continue to decline, and several Columbia River salmon species have been listed as endangered. The National Marine Fisheries Service has proposed a recovery plan to restore declining salmon runs.

Water pollution problems started to become evident in the Willamette River and the lower Columbia as development accelerated through the early decades of this century. The discharge of untreated organic-rich industrial and municipal wastewaters resulted in lowered levels of dissolved oxygen, which can be fatal to fish, and aesthetically unpleasant filamentous bacterial growth. A number of regulations were enacted by the states to control organic pollution in the lower river and its tributaries. Primarily as a result of secondary wastewater treatment requirements established in the Federal Water Pollution Control Act of 1972, the conventional water pollution problems of oxygen-demanding organic wastes were controlled in the Willamette and lower Columbia rivers by the mid-1970s.

Increased awareness of and concern for the potential harmful effects of less visible toxic pollutants, including metals, synthetic organic compounds, and radionuclides, has led to additional studies and regulations. Most recently, the Columbia River basin has been graded "water quality limited" by the U.S. Environmental Protection Agency due to the discharge of the chemical commonly referred to as dioxin, actually a group of related chemicals, from nine chlorine-bleaching pulp mills in the basin, including 7

5

mills in the lower basin. Discharge limits for dioxin have been established at the pulp mills that use the chlorine bleaching process.

The growing population of the lower Columbia River basin places increasing demands on the area's land and water for industrial, agricultural, forestry, commercial, and residential uses. The river supports a commercial, recreational, and tribal fishery that has expanded beyond salmon and steelhead to include sturgeon and a number of native and introduced freshwater species. People share the lower Columbia River with a variety of wildlife, including state- and federally-listed threatened and endangered species of mammals, fish, birds, amphibians, reptiles, insects, and plants. A number of locations along the lower river have been set aside for wildlife protection, including the Lewis and Clark National Wildlife Refuge [RM 16-36 (RK 26-58)], Julia Butler Hansen Wildlife Refuge for the Columbian White-tailed Deer [RM 35-38 (RK 56-61)], Ridgefield National Wildlife Refuge [RM 87-93 (RK 140-150)], and the Sauvie Island Wildlife Management Area [RM 86-100 (RK 138-161)]. These refuges provide protected tidelands, marshes, and riparian areas for wildlife habitat. However, the U.S. Fish and Wildlife Service has expressed concern about organic contaminants found in lower Columbia River water, sediments, and biota, and the effects these contaminants may have on fish-eating wildlife.

1.3 REPORT ORGANIZATION

Section 2 of this document describes each of the fish and wildlife studies performed for the Bi-State Program and provides a conceptual diagram identifying the relationships among the studies and the type of measurement data produced by each. In section 3, the study results from section 2 are integrated into an overall assessment of the health of selected target species. Section 4 provides recommendations for addressing the uncertainties that still remain at the conclusion of these studies.

This section summarizes the objectives, results, and conclusions of each of the fish and wildlife studies. These summaries are primarily narrative. The reader should refer to the original documents (cited in the following subsections) for tables and figures of raw data.

2.1 STUDY TOPICS

The fish and wildlife studies summarized in this report are shown in Figure 2. The studies are divided into the following four categories: 1) literature review, 2) habitat mapping, 3) fish assessment, and 4) wildlife assessment. Literature review and habitat mapping are placed at the bottom of the figure because these studies provide a foundation for the assessment studies.

Except for the literature review, which summarizes a variety of existing information on contaminant ecology, all the studies present measurement data at levels of biological organization ranging from the individual to the ecosystem. Three types of measurement data are considered in these studies: 1) measures of effects, 2) measures of exposure, and 3) measures of characteristics (U.S. EPA 1995). Measures of effects evaluate the response of an organism to a stressor. Most of the fish and wildlife assessment studies provide data on the effects of stressors to target organisms or populations. Measures of exposure describe how exposure may be occurring. An example of this type of measurement is the determination of toxic chemical concentrations in water, sediment, or tissue. Both of the wildlife assessment studies provide data of this type. Measures of characteristics influence the relationship between organisms and stressors. Ecosystem and population characteristics may influence the behavior and location of an organism. Both the wildlife assessment studies, one fish assessment study, and the habitat mapping studies provide characteristics of the target population or ecosystem. Ecosystem characteristics may also determine the

FISH

Skeletal Abnormalities[d]
Effects on Individuals

Community Assessment[d]
Effects on Population
Characteristics of Population

Autopsy-based Assessment[d]
Effects on Individuals

Biochemical Markers[e]
Exposure of Individuals

Contaminant Ecology[a]
Literature Review

WILDLIFE

Mink and River Otter[f]
Characteristics of Population
Effects on Individuals
Exposure of Individuals

Bald Eagles[g]
Characteristics of Population
Effects on Individuals
Exposure of Individuals

Habitat Mapping[b,c]
Characteristics of Ecosystem

Figure 2. Conceptual Diagram of Bi-State Program Fish and Wildlife Studies.
(*Types of Measurement Given in Italics Beneath Each Title*)

a	WILD Systems
b	CREST
c	ACOE (Portland)
d	Tetra Tech
e	NMFS (Seattle)
f	NBS (Corvallis)
g	USFWS (Portland)

location of a stressor. Life-history characteristics may affect exposure or reponse to a stressor. A recognition of the type of measurement data provided in a given study allows for a clearer understanding of the types of conclusions that are and are not possible.

2.2 CONTAMINANT ECOLOGY LITERATURE REVIEW

The primary objective of this literature review (Columbia Basin Fish and Wildlife Authority and WILDSystems 1996) was to review and summarize the available literature on the effects of contaminants and habitat changes on selected target species. Four target species were selected by the Bi-State Program as representative indicators of ecosystem health: largescale sucker (*Catostomus macrocheilus*), bald eagle (*Halieetus leucocephalus*), mink (*Mustela vison*), and river otter (*Lutea canadensis*). With the exception of largescale suckers, which serve as prey for the other three species, these animals are predators which feed at the top of the food chain. In order to more completely characterize contaminant bioaccumulation throughout the food chain, WILDSystems also included four other representative species: phytoplankton (freshwater diatom, *Asterionella formosa*), estuarine zooplankton (*Eurytemora affinis*), benthic/epibenthic amphipod (*Corophium salmonis*), and chinook salmon smolt (*Oncorhynchus tshawytcha*).

WILDSystems summarized the available literature in separate sections for each species. Each section included information on life history, habitat requirements, diet, contaminant distribution, and population dynamics. Potential data gaps for each species were also identified. The review of the literature is not repeated in this report. Selected citations are included in section 3, where appropriate. The impact of habitat alteration and contaminant concentrations on population levels and general population health was discussed for each selected species. In some cases, the authors presented conclusions using best professional judgement because specific studies documenting these relationships had not been performed. These discussions are summarized below.

2.2.1 Largescale Sucker
Loss of habitat and habitat degradation may not directly impact largescale suckers due to their opportunistic, omnivorous feeding habits (Columbia Basin Fish and Wildlife Authority and WILDSystems 1996). The effects of toxic contaminants on largescale sucker populations have not been determined. The authors state that there has been a generally decreasing trend in the concentration of contaminants, except

for PCBs, in this species from 1967 to 1986. However, data collected during the last 10 years were not summarized. Contaminant concentrations in largescale suckers have been determined in at least 5 studies (including 3 Bi-State Program studies) during this time period. Some of these data will be referenced in section 3 in discussing the evidence for largescale sucker exposure to toxic substances.

2.2.2 Bald Eagle

Little empirical evidence exists which demonstrates causal effects of contaminants on reduced productivity, breeding success, and population viability of bald eagles in the lower Columbia River (Columbia Basin Fish and Wildlife Authority and WILDSystems 1996), although no Bi-State study has been designed to test these relationships. The authors explored other possibilities for the observed population decline, including the impacts of habitat alteration on prey choice and food web dynamics, and the interaction of habitat alteration with contaminantion resulting from human economic activities.

Habitat alteration which changes food supply may be at least as important as the effects of habitat alteration on nest and roost sites (Columbia Basin Fish and Wildlife Authority and WILDSystems 1996). Bottom-feeding largescale suckers form the largest part of the eagles' fish diet in the Columbia River. Bottom-feeders and resident fish, such as the largescale sucker, accumulate more contaminants from the Columbia River than anadromous salmonids (USGS 1992). The authors (Columbia Basin Fish and Wildlife Authority and WILDSystems 1996) hypothesize that the effects of habitat alteration on the base of the food web (plankton and benthic fauna) may have adversely impacted bald eagle breeding success relative to other locations where more stable populations exist. No comparisons between plankton and benthic fauna productivity in the lower Columbia River and other regions were offered as evidence, however.

The authors conclude that bald eagles are at greater risk of contamination than other bird species because of three factors: 1) their consumption of contaminated waterfowl, piscivorous birds, and fish, 2) their year-round residency on the river, and 3) their long reproductive lives. Some bird species which serve as prey for bald eagles (e.g., western grebes and double-crested cormorants) may be more highly contaminated than the fish which comprise the bulk of the eagles' diet because they feed higher on the food chain and are thus more likely to biomagnify organic pollutants.

2.2.3 Mink and River Otter

Little is known about the population size, productivity, contaminant burdens, and habitat utilization of mink and river otter in the lower Columbia River (Columbia Basin Fish and Wildlife Authority and WILDSystems 1996). The authors state that mink habitat is similar to river otter habitat, both of which have declined significantly in the last 100 years. The discussion of contamination of the diet of these species was limited to a theoretical discussion of bioaccumulation potential and the presentation of several contaminant concentrations in potential prey items from the Lower Columbia River Backwater Reconnaissance Survey (Tetra Tech 1995a).

2.3 HISTORICAL HABITAT CHARACTERIZATION

The health of fish and wildlife resources in the Columbia River basin is intertwined with the characteristics of the habitats they live in. For an area as large as the lower Columbia River Basin, comprehensive field evaluations of habitat quality are not likely to occur given the financial limitations of natural resource agencies. By using aerial photographs and maps of historical habitat distribution, some level of complete coverage of the study area is possible without additional field verification. This mapping project was a large cooperative effort among state and federal agencies and other organizations involved in the Bi-State Program. It included developing maps and a geographical information system (GIS) of historical and existing wetlands, riparian vegetation, and important fish and wildlife areas within two miles of the mainstem of the lower Columbia River (U.S. ACOE 1996). The goals of this task were as follows:

- Compile existing wetland, riparian habitat, wildlife habitat, and fish habitat mapping data.

- Review historical and current aerial photos to define habitat changes through time.

- Expand existing GIS mapping of the Columbia River estuary to extend coverage up to Bonneville Dam.

- Prepare a report summarizing results of habitat mapping and identifying significant riparian and wetland habitats.

11

- Make updated and expanded GIS habitat map database available to agencies and public bodies.

These tasks were undertaken as separate work projects led by the Columbia River Estuary Study Taskforce (CREST) and the U.S. Army Corps of Engineers (U.S. ACOE). The CREST study team expanded the map coverage of historical (1851-1887) wetlands habitats of the estuary developed by Thomas (1983) (RM 0-46.5) to include the area of the river to RM 105 (RK 168) and a portion of the Willamette River (Graves et al. 1995). The U.S. ACOE developed PC ARC/INFO (computer-based mapping) data layers for a number of habitat types found within two miles (3.2 km) of the river mainstem (where possible) from aerial photographs taken in 1948, 1961, 1973, 1983, and 1991 (U.S. ACOE 1996). These data were analyzed to produce estimates of changes in the expanse of these habitats from 1948 through 1991.

Habitat changes in the Columbia River Estuary (RM 0-46.5) between the 1880s and 1991 were also estimated. The U.S. ACOE study team identified significant undisturbed habitats and areas with the potential for habitat rehabilitation or enhancement. The database was expanded to include the 18 ft (5.5 m) water depth contour (believed to be important in delineating juvenile salmon habitat) and National Wetland Inventory maps developed by the U.S. Fish and Wildlife Service (USFWS). The U.S. ACOE also surveyed 15 other state, regional, and federal resource management and mapping agencies and concluded that no other agency had mapping data that would be redundant to that produced for the Bi-State Water Quality Program. A brief summary of the approaches to and results from the CREST and U.S. ACOE studies is provided below.

2.3.1 Analysis of Historical Habitats Using U.S. Coast Guard Survey Charts

The CREST study effort (Graves et al. 1995) was based on six U.S. Coast Survey charts published in 1870-1888. These charts were based on field surveys of the river from the mouth to Portland conducted in 1851-1887. Thomas (1983) used these charts to map seven habitat types in the estuary [river mouth to RM 46.5 (RK 74.4)]:

- Deep Water - Areas of water depth greater than 18 ft (5.5 m).

- Medium Depth Water - Areas of water depth between 6 and 18 ft (1.8-5.5 m).

12

- <u>Shallows and Flats</u> - Water depths of 6 ft (1.8 m) or less extending to the edge of tidal marsh or swamp vegetation or to mean higher high water (MHHW).

- <u>Tidal Marshes</u> - Emergent vegetation and low shrubs.

- <u>Tidal Swamps</u> - Shrub and forest-dominated wetlands extending up to the line of non-aquatic vegetation.

- <u>Non-tidal Water/Wetlands</u> - Floodplain lakes and non-tidal emergent or forested wetlands.

- <u>Upland</u>-Uplands without wetland vegetation.

The maps developed by Thomas (1983) were converted to digital coverage in PC ARC/INFO. The habitat types above RM 46.5 to 105 (RK 74.4-168) were delineated by Christy (Graves et al. 1995) into 18 types using Thomas' (1983) types as coarse definitions. Two final work products were produced (Table 1). The first was a complete PC ARC/INFO map and database of the seven habitat types (coarse definition) from the river mouth to Portland. A second ARC/INFO map and database contained information on the 18 habitat types in the area from Puget Island (RM 46) to Portland (RM 105).

2.3.2 Analysis of Historical Habitats Using Aerial Photographs

The U.S. ACOE study team reviewed aerial photographs dating back as far as 1929 to select five photographic record dates that would be most suitable for comprehensive coverage of the river from the mouth to Bonneville Dam. The dates selected were September/October 1948, November 1961, August/September 1973, September 1983, and September/October 1991. Habitats were then delineated using a hybrid system of two classification schemes: 1) the scheme developed for the U.S. ACOE study of riparian habitats and wildlife along the Columbia and Snake Rivers (U.S. ACOE 1976) and 2) the Cowardin classification scheme used for the USFWS's National Wetlands Inventory. The hybrid system included the following categories:

- **Barren Land (1):** Unvegetated sandy beaches, quarries, dunes, rock lands, etc. (At least 95 percent barren).

13

Table 1. Historic (1880s) Habitats of the Lower Columbia River [a]					
Habitat Type (based on Thomas) [b]	Acres	Percentage of Total	Habitat Type (based on Thomas and Christy) [c]	Acres	Percentage of Total
Shallows and Flats	44,832	16.76	Tidal flats and shallow water	44,832	16.76
			Sand bank, unvegetated	45	0.02
Medium Depth Water	59,261	22.16	Medium Depth Water	59,261	22.16
Deep Water	54,055	20.21	Deep Water	54,055	20.21
Non-Tidal Water/Wetland	29,696	11.10	Cottonwood and ash riparian forest	16,051	6.00
			Floodplain lake	6,397	2.39
			Emergent marsh, non-tidal	3,791	1.42
			Willow swamp, non-tidal	3,457	1.29
Tidal Marshes	25,555	9.56	Tidal Marshes	25,555	9.56
Uplands	19,651	7.35	Prairie and pasture	15,439	5.77
			Upland	2,553	0.95
			Oak and fir forest	1,332	0.50
			Oak, fir, and ash savannah	202	0.08
			Urban	81	0.03
Tidal Swamps	34,399	12.86	Tidal swamp	22,932	8.57
			Tidal willow swamp	4,257	1.59
			Tidal cottonwood swamp	4,069	1.52
			Tidal spruce swamp	3,140	1.17
Total	267,449			267,449	

[a] Data from Graves et al. (1995) and Graves, J., 20 May 1996, personal communication
[b] Seven habitat types defined by Thomas (1983)
[c] Seven types of Thomas subdivided into eighteen habitat types by Christy (Graves et al. 1995)

- **Open Water (2):** At least 6.6 ft (2 m) deep. Further sub-classifications are possible and include marine subtidal (2Ms), marine intertidal (2Mi), estuarine subtidal (2Es), estuarine intertidal (2Ei), riverine tidal (2Rt), riverine lower perennial (2Rl), riverine upper perennial (2Ru), lacustrine limnetic (2Ll), lacustrine littoral (2Lt), and palustrine (2P).

- **Grassland (3):** At least 95 percent grassland.

- **Wetland/Marsh (4):** Tidal and non-tidal cattail, sedge, grass, salt or freshwater marsh, and water shallow enough to support emergent marsh vegetation [less than 6.6 ft (2 m) deep]. Further subclassifications are possible and include marine subtidal (4Ms), marine intertidal (4Mi), estuarine subtidal (4Es), estuarine intertidal (4Ei), riverine tidal (4Rt), riverine lower perennial (4Rl), riverine upper perennial (4Ru), lacustrine limnetic (4Ll), lacustrine littoral (4Lt), and palustrine (4P).

- **Shrub/Scrub (5):** At least 95 percent shrub/scrub.

- **Savanna-like (6):** Grassland with less than 25 percent scattered trees.

- **Coniferous Forest, Low (7L):** Forest density between 26 and 70 percent cover.

- **Coniferous Forest, High (7H):** Forest density greater than 70 percent cover.

- **Broadleaf Forest, Low (8L):** Forest density between 26 and 70 percent cover.

- **Broadleaf Forest, High (8H):** Forest density greater than 70 percent cover.

- **Mixed Forest, Low (9L):** Greater than 20 percent mixed with low (26-70 percent cover) forest density.

- **Mixed Forest, High (9H):** Greater than 20 percent mixed with high (greater than 70 percent cover) forest density.

15

- **Agricultural Land (10):** Field crops, orchards, and pasture.

- **Urban/Developed (11):** Residential, industrial, transportation, etc.

- **Forested Wetland (12):** Palustrine.

The expanses of these 33 delineated habitat types (including subclassifications) were digitized, attributed, and georeferenced in a PC ARC/INFO GIS database. The GIS was then used to summarize the expanse of each habitat type in three river units [Lower Unit (mouth to RM 46.5), Middle Unit (RM 46.5 to 105.5), and Upper Unit (RM 105.5 to RM 146.8)] for each of the five photographic records analyzed.

The U.S. ACOE study team also defined and identified significant existing habitats that were either undisturbed (no apparent human impacts), or candidates for rehabilitation or enhancement to improve their value as habitat. These areas of minimally-disturbed habitat were estimated to cover approximately 194,790 acres (77,915 ha) or 31 percent of the total habitat mapped.

To make comparisons between the CREST-defined habitats in the estuary (RM 0-46.5) for the 1880s and the U.S. ACOE-defined habitats, the CREST-defined habitats were lumped into one of the 12 major U.S. ACOE categories. However, none of the CREST habitat classifications fell into either the Shrub/Scrub or Agricultural habitat categories of the U.S. ACOE. Comparing estuarine habitat in the 1880s with that in 1991 indicates significant losses of Wetland/Marsh, Broadleaf Forest, Grassland, and Forested Wetland, mostly countered by increases in Urban/Developed Land and Open Water (Figure 3). The current level of agricultural habitat is also undoubtedly much greater than that existing within the estuary during the late 1800s.

Interpretation of the reported differences between habitat coverage in the 1880s and 1991 should be made cautiously. The accuracy of areal and boundary delineations made more than 100 years ago is likely not as high as modern measurements made using a GIS system. The process of lumping several precise categories into a more general category could lead to errors since the definitions of the older categories were not always given in much detail.

16

TETRA TECH

Columbia River Estuary Habitats (RM 0-46.5)
1880s vs. 1991

Legend: ■ 1880s □ 1991

Habitat Area in Acres

Categories: Barren Land, Open Water, Grassland, Wetland/Marsh, Shrub/Scrub, Savanna-Like, Coniferous Forest, Broad Leaf Forest, Mixed Forest, Agricultural, Urban/Developed, Forested Wetland
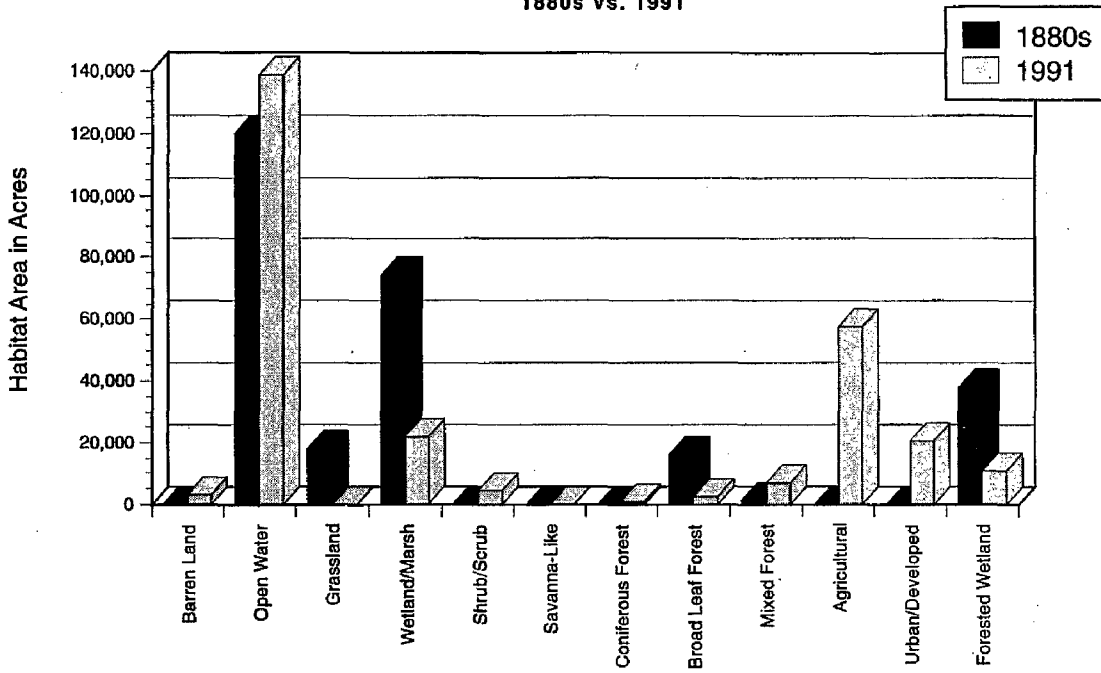
Source: U.S. ACOE (1996)

Figure 3.   Changes in Habitat Coverage in the Lower Columbia River Estuary, 1880s vs. 1991.

The U.S. ACOE habitat data can also be compared for each study unit to evaluate habitat trends between 1948 and 1991 (Figure 4). Since 1948, the most notable habitat changes seem to have occurred in the Middle and Upper Units of the lower Columbia River. For example, rapid rises are evident in the coverage of Urban/Developed habitat in both the Middle and Upper Units. Decreases in other habitat types are most notable for Open Water, Wetland/Marsh, Shrub/Scrub (Upper Unit only), Coniferous Forest, Broadleaf Forest, and Agricultural habitat. Only the coverage of Forested Wetland habitat appears to be increasing.

2.4 FISH ASSESSMENTS

The health of resident fish species in the lower Columbia River was assessed in two studies. Tetra Tech (1996a) performed a fish health assessment using three different techniques and NMFS personnel (Collier et al. 1996) performed a study on biomarkers of aromatic compound exposure in largescale suckers.

2.4.1 Fish Health Assessment

The fish health assessment had two main objectives:

- Characterize the health of fish assemblages and resident indicator fish species in the lower Columbia River, and

- Draw conclusions, if possible, about the impacts of water quality and/or habitat loss on fish health in the lower Columbia River.

Fish health was characterized by applying the following three biological assessment techniques:

- Fish community assessment based on the Index of Biotic Integrity (IBI) (Karr et al. 1986) and U.S. EPA Rapid Bioassessment Protocol V (RBP V) (Plafkin et al. 1989);

- Autopsy-based fish health/condition assessment of largescale sucker (Goede 1993) and Health Assessment Index (HAI) procedure outlined by Adams et al. (1993); and

18

Lower Unit (RM 0-46.5)

Middle Unit (RM 46.5 - 105.5)

Upper Unit (RM 105.5 - 146.8)

Legend:
- 1948
- 1961
- 1973
- 1983
- 1991

Habitat categories: Barren Land, Open Water, Grassland, Wetland/Marsh, Shrub/Scrub, Savanna-like, Coniferous Forest, Broadleaf Forest, Mixed Forest, Agricultural Land, Urban/Developed, Forested Wetland

Source: U.S. ACOE (1996)
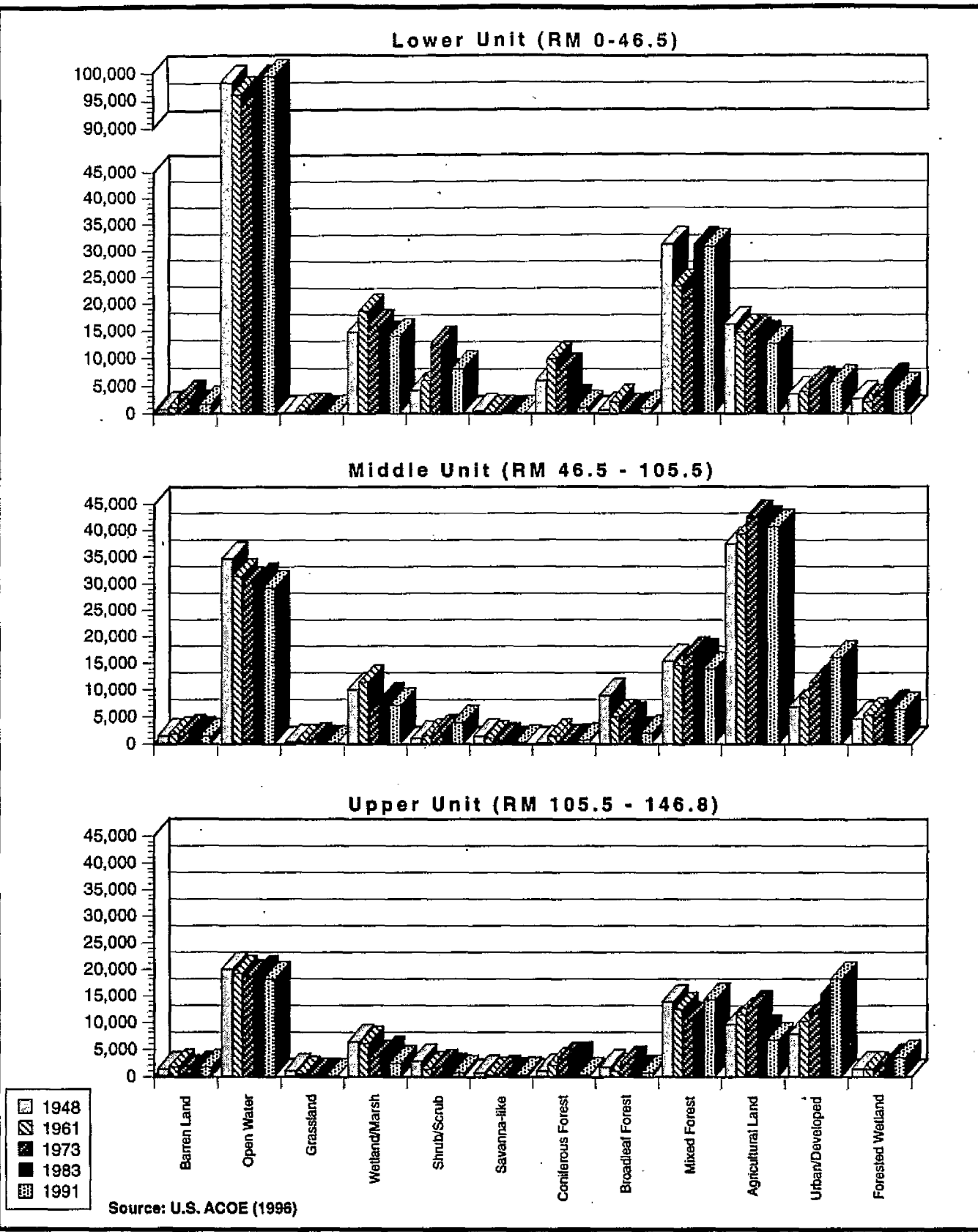
Figure 4.   Changes in Habitat Coverage (acres) in the Lower Columbia River - 1948, 1961, 1973, 1983, and 1991.

■   Juvenile fish skeletal abnormality assessment.

The fish health assessment was designed to characterize fish health and community differences among three habitat types (main channel, urban/industrial, and backwater) and the following four major river segments, which are based on physical and hydrologic characteristics:

■   Segment 1 (37 river miles) — from the mouth to Tenasillahe Island

■   Segment 2 (35 river miles) — from Tenasillahe Island to the Cowlitz River

■   Segment 3 (30 river miles) — from the Cowlitz River to the Willamette River

■   Segment 4 (44 river miles) — from the Willamette River to Bonneville Dam.

Due to delays in issuing fish collection permits for endangered salmon species, sampling was conducted much later in the year than proposed in the sampling plan (December rather than late summer/early fall). This delay resulted in smaller catches of fish (at some stations no fish were captured) than in previous surveys on large river systems which employed similar methods (e.g., Hughes and Gammon 1987, Sanders 1992, Tetra Tech 1995b). These other surveys were conducted in late summer or early fall. It is likely that many Columbia River resident fish species are more easily captured during the warmer months when they are more active.

2.4.1.1 Fish Community Assessment. Unlike the other two components of the fish health assessment, which focused on morphological features of individual fish, the fish community study attempted to characterize the entire population of fish in a given location. Although not all fish species can be collected with the same degree of efficiency using electrofishing, this technique is widely used for making generalizations about the health of fish communities in rivers and streams. Just as the characteristics of benthic invertebrate communities can be used to evaluate sediment quality, the characteristics of fish communities can be used to evaluate the integrated effects of water, sediment, and habitat quality. The abundance results at each station are compiled into an IBI score which consists of the sum of 13 individual metrics.

A stratified random sampling design was employed whereby 3 stations from each habitat/land use type (main channel, urban/industrial, and backwater) were sampled in each of the 4 river segments, for a total of 36 stations. At 12 of the 36 stations, including all 9 of the Segment 1 stations, no fish were captured. Ten or more fish were captured at 12 of the remaining 24 stations. Individuals from 21 different fish species were captured. As many as 8 different species from 6 different families were collected at a single station. Because of the relatively small number of fish collected, a revised sampling design (Figure 5) was created *a posteriori* whereby abundance data from related stations were combined to allow statistical tests of both habitat type and river segment to be performed. No fish were collected from river segment 1, so the effects of this segment could not be tested.

The results of analysis of variance (ANOVA) tests on the pooled data indicated no significant effect of habitat on IBI scores. IBI scores from river segment 3 were significantly lower (indicating poorer community health) than the IBI scores from river segments 2 and 4. The station groups in river segment 3, particularly group 3-B (backwater) differed from the other station groups by having a greater number of centrarchid (bass family) and cyprinid (minnow family) species and fewer number of salmonids. One possible explanation for the lower IBI scores in river segment 3 is the variable water quality, as measured by toxic pollutant concentrations, in the 3 segments. Based on data collected during two reconnaissance surveys of the lower Columbia River (Tetra Tech 1993, 1995a), river segment 3 had more frequent exceedances of reference levels for pollutants in water, sediments, and tissues than did segments 2 or 4.

To evaluate which of the 13 metrics used in calculating the IBI had the greatest effect on the overall score, a step-wise multiple regression was performed on the pooled individual metric data. By far the most predictive metric in this survey was the number of pollution intolerant species (e.g., salmonids). Approximately two-thirds of the variance ($R^2 = 0.66$) in IBI scores was explained by this metric. This metric plus 5 others (percentage carp, total biomass, percentage insectivores, number native species, and number individuals) accounted for all the variance. The significantly lower IBI scores for river segment 3 may be explained by noting that the two most predictive metrics for this survey (number intolerant species and percentage carp) were both lower (indicating poorer water quality) for the river segment 3 station groups compared to the other station groups.

2.4.1.2 Fish Autopsy Assessment. This technique is useful for evaluating the health of individuals of a single species, as measured by the incidence of external and internal abnormalities (Goede 1993). External

```
                    ┌─────────────────────────────────────────┐
                    │  Columbia River Fish Community Assessment │
                    └─────────────────────────────────────────┘
```

Habitat Comparisons			River Segment Comparisons		
Backwater	**Urban Industrial**	**Main Channel**	**River Segment 2**	**River Segment 3**	**River Segment 4**
• 2-B	• 2-U	• 2-M	• 2-B	• 3-B	• 4-B
• 3-B	• 3-U	• 3-M	• 2-U	• 3-U	• 4-U
• 4-B	• 4-U	• 4-M	• 2-M	• 3-M	• 4-M

H_0 = No difference in IBI scores among habitat types/land uses. H_0 = No difference in IBI scores among river segments.
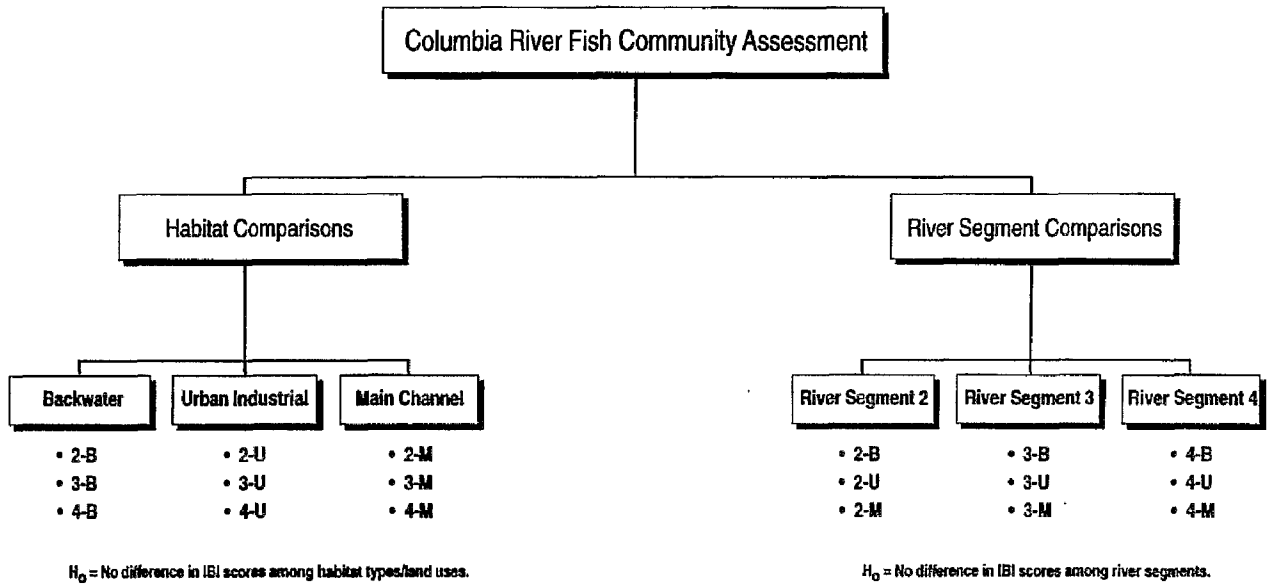
Figure 5.   Revised Sampling Design for the Fish Community Assessment Data for the Lower Columbia River, 1994.

features evaluated include gills, eyes, thymus, pseudobranch, fins, and opercles. Internal features evaluated include kidneys, spleen, mesenteric fat, and hindgut. In addition, blood samples are taken and measured for hematocrit (percentage of red blood cells), leucocrit (percentage of white blood cells), and plasma protein.

The original sampling design called for the collection of up to 20 largescale suckers at each of 15 stations located in all three of the habitat types (urban/industrial, main channel, and backwater). Ten or more fish were collected at only 6 stations, which were split evenly between urban/industrial and backwater habitats. No largescale suckers could be collected at main channel stations. The results were compiled by assigning a Health Assessment Index (HAI) to each fish, which consisted of numerical representations of the codes used in the autopsy assessment. At each station, a mean HAI was calculated.

Mean HAI scores did not significantly differ within habitat type. The mean HAI scores for the urban/industrial stations were significantly lower (indicating better condition) than the HAI scores for backwater stations. However, all mean HAI scores from this study were lower than at sites known to be associated with chemical contamination (Adams et al. 1993). Analyses of water, sediments, and tissue collected near fish health stations during the reconnaissance surveys (Tetra Tech 1993, 1995a) did not show one habitat type to be more highly contaminated than the other.

2.4.1.3 Juvenile Fish Skeletal Abnormality Assessment. While the fish autopsy assessment attempted to document the health of adult fish, this technique focused on juvenile fish. Many authors have noted that increased incidence of skeletal abnormalities in juvenile fish can be associated with many stressors, including heavy metals and bleached kraft mill effluents (e.g., Bengtsson and Larsson 1986, Bengtsson 1988). The sampling design called for the collection of juvenile fish using a 50-m beach seine at 4 stations in each of the four river segments. The target species were Northern squawfish, largescale sucker, and peamouth chub, although all fish except salmon smolts (which were released without handling) were collected and preserved in formalin.

A total of 596 fish were collected at the 16 stations. Due to the delay in sampling noted above, very few small juvenile fish were captured. Only small numbers of the original target species were obtained. Over 90 percent of the fish captured were three-spined sticklebacks (72 percent) or banded killifish (18 percent). Five species of fish were analyzed for skeletal abnormalities: three-spined stickleback, banded killifish,

23

bluegill, peamouth, and largescale sucker. Because less than 35 fish were collected at all but 3 stations, the results for each station within a river segment were lumped to provide an overall percentage of skeletal abnormalities.

The percentage of deformed fish observed in each of the four river segments ranged from zero (segment 4) to 2.2 percent (segment 3). No statistical comparisons between river segments were made because the sample size in segments 3 and 4 (46 and 60, respectively) were judged to be insufficient (target sample size was 200 of a single species) to provide meaningful results. The incidence of skeletal abnormalities observed is within the range of 2-5 percent reported for unstressed natural fish populations and laboratory stocks (Gill and Fisk 1966, Wells and Cowan 1982).

Conclusions about the health of fish populations on the lower Columbia River are probably premature due to the species sampled and the time of year sampling took place. Using the limited data available, the incidence of skeletal abnormalities was compared with contaminant level data; no meaningful relationships were observed. This lack of a statistical relationship could be due to 1) the overall low incidence of skeletal abnormalities, 2) the timing of sampling, 3) the use of species (e.g., three-spine stickleback) whose response to stressors is unknown, and 4) the larger size of the fish examined in this study (due to the timing of sampling) compared to the range for which this assessment technique has been used. It is possible that many of the more deformed fish would have died or become prey by this time of year.

Interpretation of the results from all three of the fish health assessment techniques performed by Tetra Tech (1996a) is hampered by the small numbers of fish that could be collected. The authors recommended that the study be repeated during the summer months when a larger number of fish could be collected.

2.4.2 Biomarkers of Aromatic Compound Exposure

The National Marine Fisheries Service (NMFS) conducted an assessment of exposure to polynuclear aromatic hydrocarbons (PAHs) in the same largescale suckers collected as part of the autopsy-based fish health/condition assessment described above (Collier et al. 1996). This was done by measuring cytochrome P4501A (CYP1A)-dependent enzyme activities (i.e., AHH, aryl hydrocarbon hydroxylase) and biliary levels of fluorescent aromatic compounds (FACs). Both CYP1A activities and FAC concentrations are indicative of exposure to aromatic organic compounds. These PAH-exposure assessment methods have been developed and field tested by the staff of the Environmental Conservation Division of the Northwest

Fisheries Science Center.

No overall site differences were noted for levels of biliary FACs or hepatic CYP1A, nor was there a significant linear relationship between individual measurements of bile and AHH activities. Many of the female fish showed signs of ovarian development, and significant sex differences were noted, with females having significantly lower AHH activity than males. In general, the largescale sucker data did not indicate marked exposure to PAHs. AHH activities were lower than previously reported values for other benthic fish in moderately and severely contaminated environments. However, the levels of biliary FACs were relatively high compared to reference levels measured in lower Columbia River white sturgeon upstream of an oil spill (Krahn et al. 1986). In the absence of adequate dose-response data for largescale sucker, the FAC data cannot be interpreted as showing evidence of exposure.

Problems encountered in the fish enzyme activation study led the researchers to recommend changes to improve future studies. Note that several of the suggestions address the difficulties in collecting suitable numbers of fish caused by the fish collection permitting delays described in section 2.4.1 above. These suggestions are:

- *A priori* determination of suitable reference sites for comparison

- Sampling earlier in the year to avoid sampling females undergoing gonadal maturation

- Collection of fish from main channel locations to determine if these sites are suitable as reference sites

- Collection of more fish and fish of both sexes at each site

- Chemical analyses of stomach contents and surficial sediments to determine the presence of PAHs in the fish's habitat.

2.5 WILDLIFE ASSESSMENTS

Two wildlife assessment studies were performed to evaluate the health of the three target wildlife species selected by the Fish and Wildlife Work Group. In late summer of 1994 and winter of 1994-95, the National Biological Service (NBS) undertook an assessment of mink and river otter habitat, body condition, and contaminant concentrations (Henny et al. 1996). The U.S. Fish and Wildlife Service initiated a two year study in 1994 with partial funding from the Bi-State Program to assess bald eagle nesting success and contaminants in bald eagle eggs found along the lower Columbia River (USFWS 1996). These studies are discussed in separate sections below.

2.5.1 Mink and River Otter Assessment

Mink and river otter are both predatory mammals associated with aquatic systems. As carnivores, they are expected to accumulate organochlorine pollutants, which tend to biomagnify at each level of the food chain. Mink are among the most sensitive species to the toxic effects of TCDD and related compounds such as PCBs (Henny et al. 1996). Measured TCDD concentrations in fish prey species during surveys in the last 10 years are within the range associated with reproductive failure in this species. The effects of organochlorine compounds on river otter have yet to be determined, but PCB concentrations in river otter at the lower Columbia River are even higher than they are for mink (Henny et al. 1981).

The objectives of the mink and river otter study were to:

- Collect mink and river otter and their scat along the lower Columbia River and at a reference area to determine present contaminant burdens

- Evaluate contaminant distribution by comparing residue concentrations with river mile for different age classes

- Evaluate possible contaminant effects by comparing body and organ measurements and weights with contaminant concentrations

26

- Determine the abundance and distribution of mink and river otter from surveys, interviews of local trappers, and harvest records

- Evaluate mink and river otter habitat along the lower Columbia River by collecting information for the Mink Habitat Suitability Index (HSI) Model (Allen 1986).

During the winter, licensed fur trappers were contracted to provide skinned frozen mink and river otter carcasses trapped along the lower Columbia River [within approximately 400 m (1,310 ft) of the river] between RM 11.0 and 119.5 for necropsy, tissue histopathology, and contaminant analysis. A few mink and river otter scats were also collected in the study for analysis. Reference mink and river otter carcasses and scats were collected in Idaho and Oregon and analyzed for comparison with the study results for the lower Columbia River. Canine teeth were extracted from all animals for aging.

A total of 30 river otter were collected from the Columbia River between RM 11.0 and 119.5. Six otter were collected from a reference area located in the Coast Range of Oregon. Two mink were collected from the lower Columbia (both in the vicinity of RM 88) and four reference mink were collected at Malheur National Wildlife Refuge in eastern Oregon. The small number of mink collected greatly restricted interpretation of residue accumulation. Mesentery fat and livers from the animals were analyzed for 20 organochlorine (OC) pesticides and their metabolites, 43 non-orthosubstituted PCB congeners, PCB Aroclors, and 15 dioxin and furan compounds. Liver and kidney from the same animals were analyzed for 10 metals (aluminum, cadmium, chromium, copper, lead, manganese, mercury, nickel, vanadium, and zinc). River otter scats were pooled into five samples representing several animals at each location along the Columbia River between RM 27 and 134. Reference area scats were collected from the Wizard Falls Fish Hatchery on the Metolius River in central Oregon and along the Clearwater River in northern Idaho.

In age class 0 river otters, most OC compound concentrations were already significantly higher in the lower Columbia River compared to the reference area. OC pesticide concentrations were rarely correlated with river mile (RM) for age class 0 or 1 animals, but almost always correlated with RM for age class 2+ (adults). In all significant relationships, concentrations decreased from Portland-Vancouver to the river mouth. Age class 2+ animals represent a relatively sedentary population that have established a home range. For dioxin-like compounds (co-planar PCBs, dioxins and furans), significant relationships between concentration and RM were noted for only 2 of 4 co-planar PCBs, 2 dioxin congeners, and 7 furan

congeners. In most cases where significant relationships were found (except for age class 1), the concentrations were again higher near Portland-Vancouver and decreased downstream toward the mouth of the river.

Body and organ weights were compared between the lower Columbia River and the reference area. Only baculum (penis bone) length and weight of lower Columbia River age class 0 were significantly different (smaller or shorter) than the reference area animals of the same age class. Young river otters from the Columbia River represent the first free-living mammal population showing dose-response (xenobiotics measured in the liver) hypoplasia of male reproductive organs. Most contaminants were intercorrelated (correlated with each other) making it extremely difficult to identify contaminants with respect to their potential for causing the observed effects. Several dozen significant inverse relationships in age class 0 were noted between contaminant concentrations and baculum weight (6 OC pesticides, 35 PCB congeners, 2 dioxins, and 5 furans) and baculum length (3 OC pesticides, 16 PCB congeners, 1 dioxin, 2 furans, and chromium). Male river otters in each age class were evaluated with respect to liver parameters, spleen weight and contaminant concentrations. A large number of significant direct relationships were found with liver and spleen weights and contaminant concentrations.

River otters collected at RM 119.5 (Portland-Vancouver) typically contained the highest concentrations of most contaminants (the exception being dioxins and furans). Three of the 4 animals collected at this location showed gross abnormalities. The authors conclude that river otter in the vicinity of RM 119.5 are in a critical or almost critical category based on reference level comparisons, abnormalities noted during necropsy, and histopathological observations of individuals collected from this area. There was no evidence for fewer animals in the Portland-Vancouver vicinity where the highest contaminant concentrations were found. A population estimate for the entire study area was 286 ± 47 animals. This is the highest published estimate of river otter density in North America, although estimates of river otter density in other similar habitats (large rivers) were not available.

No population estimates were made for mink, although the population is apparently quite small (Henny et al. 1996). A mink HSI was determined for 25 percent of the river. The HSI scores were excellent for many segments of the lower Columbia River, although few mink were detected. Based on a series of published criteria developed for interpreting organ residue concentrations in mink, the few mink captured contained relatively low contaminant concentrations. The authors hypothesize that the mink sampled

during the study may be individuals that have recently entered the lower Columbia River in an attempt to recolonize.

Comparison to historical tissue contaminant data on mink and river otter of the lower Columbia River collected over 15 years ago (Henny et al. 1981) indicates a major decline in PCB concentrations over time. Historically, some individual mink contained PCB concentrations known to make adult female mink in laboratory studies incapable of producing young. The environmental significance of the current contaminant levels measured in tissue and scat samples from mink and river otter in the lower Columbia River was assessed by comparing these data to effects-based contaminant reference levels developed by other investigators. Although the two mink contained contaminant levels below threshold effects concentrations, some river otter contained concentrations that exceeded threshold and even critical levels in tissue or levels of concern in scat. However, these reference levels may not be appropriate for river otter. The reference levels for tissue were developed for mink, which are generally considered extremely sensitive to PCBs, dioxins, furans, and other dioxin-like compounds. The levels of concern for scat concentrations were derived for European otter (*Lutra lutra*), a related species of unknown sensitivity compared to *Lutra canadensis*.

Several future research areas are proposed. Animals were not live-captured in this study which eliminated the option of collecting blood to evaluate steroid concentrations, as well as the option for histopathology of unaltered (non-frozen) organs and tissue. Additional research is planned with trapper-caught and live-captured animals from the Columbia River and elsewhere throughout the Pacific Northwest and includes further studies with the contaminants initially investigated plus other known endocrine disrupters (e.g., alkylphenols, phthalate esters). This research will emphasize a general evaluation of health, hormone concentrations, hormone receptor characteristics, and sperm counts and quality. Analysis of river otters from other locations with differing contaminant combinations will allow further evaluation of contaminants that appear to be related to the observed reproductive organ hypoplasia in young males, and future evaluation of the distribution and magnitude of the problem in the Northwest.

2.5.2 Contaminant Study of Bald Eagle Eggs

Previous studies have indicated that although the number of nesting pairs of bald eagles along the Columbia River estuary has increased each year since 1980, the five-year average productivity has been about half that of the state-wide averages for bald eagles nesting in Oregon and Washington (Isaacs and Anthony

29

1993). However, the productivity estimates for the Columbia River from 1993 to 1995 are higher than estimates for any year assessed since 1984. Eggs collected in 1985-1987, and in 1991 near the river revealed elevated concentrations of PCBs, DDE, and 2,3,7,8-TCDD (Anthony et al. 1993). Elevated concentrations of PCBs and DDE were also measured in blood obtained from eight- to ten-week-old nestlings and eagle carcasses collected near the river (Garret et al. 1988; Anthony et al. 1993). Prey items (primarily fish) collected from the river also had detectable concentrations of DDE, PCBs, and other chlorinated organic compounds (Anthony et al. 1993). Concentrations of DDE, PCBs, and 2,3,7,8-TCDD in eggs were high enough to cause lowered breeding success. Eggshell thinning, commonly attributed to DDE, was prevalent in most eggs and shell fragments collected from eagles along the river. The amount of eggshell thinning was negatively correlated with breeding success (Anthony et al. 1993). However, eggshell thinning in the present study did not correlate with lowered breeding success.

Analyses of fresh and addled eggs collected in April and May 1994 indicate that concentrations of DDD, DDE, total PCBs, and hexachlorobenzene are lower than mean concentrations measured before 1988 (USFWS 1996). However, the measured DDE and total PCB concentrations were still above levels associated with reduced productivity of bald eagles in other areas. The concentrations of dioxins and furans and individual PCB congeners in the 1994 sample were also higher than adverse effects levels. The mean mercury residue level in these eggs was similar to the mean concentration found in 13 eggs collected along the river in 1985 to 1987. However, mercury levels did not exceed concentrations associated with adverse effects on bald eagle productivity.

The relative dioxin-like toxic contribution of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and planar PCBs was made by means of an additive model of toxicity using toxic equivalency factors (TEFs) and toxic equivalents (TEQs); both mammalian (I-TEF; Ahlborg et al. 1992) and avian (C-TEF; Bosveld et al. 1995) TEF models were used. This analysis indicated that much of the dioxin-like toxicity of PCDDs and PCDFs was due to 2,3,7,8-TCDD; 69 percent for the mammalian model and 40 percent for the avian model. Measuring the TEFs for PCB congeners indicated that PCB 118 (2,3',4,4',5-PCB) contributed the most dioxin-like toxicity (33 percent) in the mammalian model and PCB 126 (3,3',4,4',5-PCB) contributed the most toxicity (54 percent) in the avian model.

The H4IIE rat hepatoma cell bioassay was used to assess exposure to planar halogenated hydrocarbons (PHHs), a class that includes PCBs, PCDDs, and PCDFs. This bioassay was used to screen bald eagle

30

eggs for total dioxin-like activity (i.e., 2,3,7,8-TCDD equivalents or TCDD-EQ). The potency of PHH mixtures in the H4IIE cells has been correlated to the hatching success in double-crested cormorants from the Great Lakes (Tillitt et al. 1992). The analyses conducted on tissue samples collected in 1994 indicated PHH levels comparable to less contaminated sites in the Great Lakes. However, the levels of PHHs that might cause early life stage toxicity in bald eagles is unknown at this time. Further analysis and assessment of TCDD-EQs will be conducted on eagle eggs collected in 1995.

Eggshell thinning has been associated with environmental contamination and with reduced reproductive success of birds. Mean eggshell thickness measured in 1994 and 1995 was less than the mean thickness of eggs collected in the Pacific Northwest prior to the use of DDT, although one egg was 12 percent thicker than the pre-DDT average. Linear regression analysis indicated no significant relationship between breeding success and eggshell thickness among breeding pairs ($r=-0.06$, $n=19$, $p=0.79$) (USFWS 1996).

The general trend in the annual mean concentration of DDD, DDE, total PCBs, and hexachlorobenzene concentrations in bald eagle eggs has been a decrease from concentrations measured in the lower Columbia River from 1985 to 1987. Five-year productivity (measured as the five-year running average number of young bald eagles per occupied territory) for the lower Columbia River region from 1993 to 1995 was higher than in any previous year assessed since 1984. This level of reproductive success is higher than predicted using a regression relationship between productivity and DDE concentration in bald eagle eggs. A number of nesting sites have been established by newly arrived breeding pairs since 1990. The youth and recent arrival of these birds could cause them to have lesser contaminant accumulations, explaining some of the equivocal relationships among productivity, eggshell thickness, and contaminant levels measured at these sites. Analysis of contaminant levels in eggs of newly established breeding pairs collected in 1995 will provide positive or negative evidence of this influence.

In summary, the relationship between organochlorine compounds and reproduction of bald eagles nesting along the lower Columbia has not yet been fully evaluated. Preliminary data indicate that eagles nesting along the river continue to accumulate levels of DDE and PCBs that have been associated with impaired reproduction. Data also indicate that eagles are accumulating PCDD and PCDF compounds, but additional information is needed to assess their relative contribution to overall toxic effects. No correlation was found between reproductive success and eggshell thickness, and reproductive success did not fit the prediction based on the measured concentration of DDE in eggs. The extent to which these equivocal findings are

influenced by the presence of newly established nesting pairs that have not yet accumulated contaminants at levels that affect reproduction has not yet been determined. A complete analysis of five-year productivity averages, eggshell thickness, and contaminant levels will be included in the final USFWS report due to be completed in 1996.

3.0 HEALTH OF FISH AND WILDLIFE IN THE LOWER COLUMBIA RIVER

The state of Oregon lists wildlife as a beneficial use and the state of Washington lists wildlife habitat as a characteristic use of the lower Columbia River. Both states have recognized the importance of healthy fish and wildlife populations as a measure of the value of the Columbia River. The studies summarized in section 2 have attempted to assess the health of the target species selected by the Bi-State Program's fish and wildlife work group. The status of each of these four target species (largescale sucker, mink, river otter, and bald eagle) is an indicator of the overall health of the aquatic ecosystem of the lower Columbia River.

A stressor can be defined as any substance or condition that can, in certain circumstances, constrain the well-being of an organism. Most of the fish and wildlife assessment studies described in section 2 have focused on environmental contaminants as stressors. Environmental contaminants are relatively easy to measure, and the relationship between exposure and effects (i.e., dose-response) has been the subject of a considerable body of research. Although habitat is undoubtedly an important factor in the overall health of each target species, the cause-effect relationship between quality of habitat and species health is nearly impossible to quantify and not completely understood.

Each of the target species may be exposed to toxic chemicals from the Columbia River via several exposure pathways, including uptake of water through drinking and transport across membranes, uptake of sediment in conjunction with feeding activities, and uptake through prey items. Precisely quantifying the actual environmental concentrations to which an individual is exposed in the field is impossible because of the dynamic nature of the river system and the mobility of the target species. The amount of chemical accumulated in the body represents an integration of all exposure pathways. The measurement of body burdens provides definitive evidence that exposure has occurred.

Each of the target species relies on other species at lower levels of the food chain for survival. Many of the contaminants of concern for fish and wildlife species are organic compounds which tend to biomagnify

at each higher level of the food chain. Thus the evidence of exposure to these contaminants is more easily observed in larger predator species than in the planktonic and benthic invertebrate species on which the ecosystem is based.

As indicated in Figure 2, the fish and wildlife assessment studies may include measurements of exposure or effects (or both). These two types of measurements are interrelated. There can be no direct effect of toxic contaminants without exposure to them; however, exposure to toxic chemicals is not always associated with adverse effects. In order to develop a cause-effect relationship between toxic chemicals and adverse effects, both exposure and effects must be demonstrated.

Documenting exposure to toxic chemicals is more straightforward than documenting effects. A critical task in documenting effects is establishing a biologically meaningful endpoint. An ideal endpoint is sensitive to and uniquely associated with the stressor under consideration, relates to the stressor in a dose-response fashion, and is easy to measure. In some cases, what appears to be an ideal endpoint in an experimental setting using a single chemical may not be as suitable in field experiments, where mixtures of chemicals can complicate the dose-response relationship because of antagonisitc or synergistic effects. In field studies, correlations between exposure and effects may be the best obtainable data to demonstrate dose-response. While correlations may not offer definitive proof of a significant relationship, the weight-of-evidence approach can be used to make useful conclusions (U.S. EPA 1992a).

Figure 2 also indicates that assessments can be made at the level of the individual or population. Each level of measurement may yield valuable information. Documented adverse effects to individuals can be incorrectly extrapolated to entire populations in cases where the presence of the stressor is localized or characteristics of the population are not uniform. Conversely, documentation of population changes that does not include testable hypotheses of mechanisms by which individuals are affected does not assist natural resource managers charged with protecting those populations.

This section presents an analysis of the health of fish and wildlife species of the lower Columbia River, as represented by the four target species. The analysis focuses on two types of measurement (exposure and effect) at two different levels (individual and population). For each of the four target species, all available evidence of exposure to and effects of toxic contaminants will be summarized. Many of these data are from the fish and wildlife assessment studies described in sections 2.4 and 2.5 and are at the level of the

34

individual. Where appropriate, citations from the literature review task (section 2.2) will be used to support the presentation. At the population level, the effects of all stressors, including toxic contaminants, are integrated so that attributing available evidence to individual stressors is difficult. Population estimates made as part of the fish and wildlife assessment studies are presented in conjunction with variables that describe the entire study area, such as habitat characteristics (section 2.3). The target species health analyses are presented succinctly in a single matrix, which is then used in a summary section to indicate the degree to which the lower Columbia River supports fish and wildlife as a beneficial use.

3.1 LARGESCALE SUCKER

Evidence of largescale sucker exposure to toxic contaminants, as measured by body burdens, has been presented in several studies (e.g., Tetra Tech 1993, 1995a). The biomarker study (Collier et al. 1996) was also designed to look for evidence of exposure to toxic chemicals. Several of the fish assessment studies were focused on the largescale sucker. The autopsy-based fish health assessment (section 2.4.1.2) and the skeletal abnormality study (section 2.4.1.3) used largescale sucker as a target species. Both of these studies were designed to measure the effects of stressors, primarily toxic contaminants, on individual fish. Largescale sucker were collected as part of the fish community study (section 2.4.1.1), but the sampling design was not focused on this species. Recent quantitative population estimates for this species have not been made, but general observations can be made about abundance and habitat requirements.

3.1.1 Exposure

Largescale sucker has been the target species for a number of studies within the last 10 years of contaminant burdens in Columbia River fish (Beak Consultants 1989; U.S. EPA 1992b; Schuler 1994; Tetra Tech 1993, 1995a, 1996b). This species is well suited for this type of study because it is resident year-round and relatively easy to capture, and because its feeding habits bring it in close contact with potentially contaminated sediment. These studies collected and analyzed either whole-body or filet samples. Neither type of sample alone is ideal for determining the target species' maximum level of exposure to contaminants. The objective of whole-body samples is to characterize the degree to which fish-eating wildlife that consume the target species are exposed to contaminants; the objective of filet samples is to characterize the degree to which humans that consume fish are exposed to contaminants. To determine the maximum level of exposure in the target species, liver or kidney samples are often collected

35

because these are areas in which xenobiotic toxicants are metabolized. In spite of the differing objectives, the data from the studies referenced above can provide useful indications of exposure. Table 2 presents the concentrations of selected chemicals from these studies. The analyte list in Table 2 includes all chemicals measured in three or more of the six studies. Because of differences in sample type (whole-body versus filet), sampling locations, and analytical techniques, a statistical presentation of these results is not appropriate. The discussion of these data will be limited to qualitative observations of detection frequency, maximum values, and temporal trends.

3.1.1.1 Dioxins and Furans. Dioxins and furans were measured in all six of the studies, although only two congeners (2,3,7,8-TCDD and 2,3,7,8-TCDF) were reported by Beak Consultants (1989). With the exception of the 1991 whole-body samples collected by Tetra Tech (1993), several of the congeners in each of the studies were never detected above detection limits, which varied between studies. The most consistently detected congener was 2,3,7,8-TCDF. The concentrations of the most toxic congener (2,3,7,8-TCDD) in whole-body samples declined from 1987 (U.S. EPA 1992b) to 1993 (Tetra Tech 1995a). A similar decline was noted for filet samples from 1989 (Beak Consultants 1989) to 1995 (Tetra Tech 1996b). These temporal trends should not be overemphasized, however, because the fish sampling locations were different in each of the studies.

The concentrations of 2,3,7,8-substituted dioxin and furan congeners are often presented as Toxicity Equivalents (TEQs)(e.g., Newell et al. 1987), whereby each congener is assigned a Toxicity Equivalent Factor (TEF) relative to the most toxic congener. The range of TEQs (in ng/kg, wet weight) for each of the studies is given below:

- U.S. EPA (1992b)   4.4 to 5.8 (n=4)
- Beak Consultants (1989)   0.36 to 0.82 (n=5, tetra congeners only)
- Schuler (1994)   1.8 to 3.8 (n=6, all congeners)
                            0.55 to 3.9 (n=11, tetra congeners only)
- Tetra Tech (1993)   1.5 to 3.8 (n=12)
- Tetra Tech (1995a)   0.92 to 3.1 (n=16)
- Tetra Tech (1996b)   0.38 to 1.6 (n=9)

The TEQs for the whole-body samples (U.S. EPA 1992b; Schuler 1994; Tetra Tech 1993, 1995a) were

Table 2. Chemical Concentrations in Largescale Sucker From the Lower Columbia River																		
Chemical	Beak Consultants 1989 (Filets from 1989)			Schuler 1994 (Whole-body from 1990-91)			Tetra Tech 1993 (Whole-body from 1991)			Tetra Tech 1995a (Whole-body from 1993)			Tetra Tech 1996b (Filets from 1995)			U.S. EPA 1992b (Whole-body from 1987)		
	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)
Dioxins and Furans (ng/kg, wet weight)																		
TCDD2378	4 of 5	0.57	0.34	13 of 17	2.60	1.09	12 of 12	1.56	0.99	2 of 16	0.90	0.40	0 of 9	--	0.19	4 of 4	2.78	2.41
PeCDD2378	--	--	--	0 of 6	--	0.49	12 of 12	1.10	0.61	1 of 16	0.50	0.37	0 of 9	--	0.28	3 of 4	0.68	0.57
HxCDD3478	--	--	--	0 of 6	--	0.49	12 of 12	0.53	0.24	3 of 16	0.50	0.34	1 of 9	0.21	0.18	0 of 4	--	1.23
HxCDD3678	--	--	--	0 of 6	--	0.49	12 of 12	1.42	0.71	2 of 16	0.60	0.34	1 of 9	0.35	0.20	4 of 4	0.90	0.70
HxCDD3789	--	--	--	0 of 6	--	0.50	12 of 12	0.92	0.38	0 of 16	--	0.28	0 of 9	--	0.19	2 of 4	0.19	0.44
HpCDD4678	--	--	--	1 of 6	1.25	0.62	12 of 12	4.36	2.40	16 of 16	2.60	1.02	3 of 9	0.90	0.34	3 of 4	5.86	3.33
OCDD	--	--	--	4 of 6	5.65	2.57	12 of 12	21.30	8.32	16 of 16	36.90	6.77	3 of 9	3.26	1.11	--	--	--
TCDF2378	5 of 5	2.50	1.45	16 of 17	14.00	6.30	12 of 12	11.40	7.06	15 of 16	6.50	3.85	9 of 9	2.42	1.26	4 of 4	16.39	13.50
PeCDF2378	--	--	--	0 of 6	--	0.49	12 of 12	0.49	0.25	12 of 16	9.90	2.22	3 of 9	1.82	0.88	1 of 4	0.28	0.38
PeCDF3478	--	--	--	0 of 6	--	0.49	12 of 12	1.21	0.58	2 of 16	1.80	0.41	0 of 9	--	0.17	3 of 4	0.44	0.43
HxCDF3478	--	--	--	0 of 6	--	0.49	12 of 12	0.45	0.22	0 of 16	--	0.27	0 of 9	--	0.34	1 of 4	0.60	1.21
HxCDF3678	--	--	--	0 of 6	--	0.49	12 of 12	0.36	0.21	1 of 16	5.20	0.56	2 of 9	1.59	0.53	0 of 4	--	1.42
HxCDF3789	--	--	--	0 of 6	--	0.49	12 of 12	0.60	0.19	15 of 16	4.50	1.98	3 of 9	1.81	0.62	0 of 4	--	1.39
HxCDF4678	--	--	--	0 of 6	--	0.49	12 of 12	2.77	1.45	13 of 16	5.20	0.90	1 of 9	0.64	0.33	0 of 4	--	0.98
HpCDF4678	--	--	--	1 of 6	1.07	0.59	12 of 12	1.79	0.70	4 of 16	5.50	0.92	2 of 9	2.67	0.60	4 of 4	0.76	0.48
HpCDF4789	--	--	--	0 of 6	--	0.49	12 of 12	0.43	0.15	0 of 16	--	0.29	0 of 9	--	0.17	0 of 4	--	1.31
OCDF	--	--	--	0 of 6	--	0.99	12 of 12	10.60	1.82	6 of 16	2.70	0.69	4 of 9	5.96	1.04	--	--	--
Metals (µg/kg, wet weight)																		
Antimony	--	--	--	--	--	--	0 of 18	--	244.72	0 of 16	--	5.81	6 of 9	1.00	1.11	--	--	--
Arsenic	--	--	--	--	--	--	0 of 18	--	213.61	1 of 16	385.00	40.63	9 of 9	181.00	148.33	--	--	--
Barium	--	--	--	--	--	--	18 of 18	5400.00	2733.33	16 of 16	3500.00	1690.63	9 of 9	185.00	110.78	--	--	--
Cadmium	--	--	--	--	--	--	18 of 18	60.00	38.33	16 of 16	66.00	36.38	1 of 9	4.00	2.83	--	--	--
Copper	--	--	--	--	--	--	18 of 18	1230.00	986.67	16 of 16	1230.00	828.13	9 of 9	770.00	528.89	--	--	--
Lead	--	--	--	--	--	--	14 of 18	860.00	178.89	8 of 16	507.00	161.50	6 of 9	20.00	12.83	--	--	--
Mercury	--	--	--	--	--	--	18 of 18	137.00	80.72	16 of 16	264.00	167.88	9 of 9	193.00	153.00	2 of 3	90.00	55.00
Nickel	--	--	--	--	--	--	4 of 18	1360.00	540.00	6 of 16	2260.00	287.38	7 of 9	60.00	26.56	--	--	--
Selenium	--	--	--	--	--	--	0 of 18	--	213.61	6 of 16	207.00	39.84	9 of 9	260.00	168.89	--	--	--
Silver	--	--	--	--	--	--	0 of 18	--	96.39	2 of 16	6.00	2.44	0 of 9	--	0.50	--	--	--
PCBs (µg/kg, wet weight)																		
PCB1221	--	--	--	--	--	--	0 of 18	--	25.00	0 of 16	--	26.00	0 of 9	--	0.93	--	--	--
PCB1232	--	--	--	--	--	--	0 of 18	--	25.00	0 of 16	--	26.00	0 of 9	--	0.93	--	--	--
PCB1248	--	--	--	--	--	--	0 of 18	--	25.00	0 of 16	--	26.00	4 of 9	18.33	6.42	--	--	--
PCB1254	--	--	--	--	--	--	17 of 18	380.00	127.00	16 of 16	2700.00	230.25	0 of 9	--	0.93	--	--	--
PCB1260	--	--	--	--	--	--	1 of 18	130.00	30.83	8 of 16	56.00	39.28	9 of 9	57.66	33.55	--	--	--
Pesticides (µg/kg, wet weight)																		
Aldrin	--	--	--	0 of 3	--	5.00	3 of 17	5.60	1.97	0 of 16	--	2.36	0 of 9	--	0.01	--	--	--
BHC-alpha	--	--	--	0 of 21	--	5.00	2 of 17	3.70	2.42	0 of 16	--	1.25	0 of 9	--	0.01	1 of 2	2.74	2.00
BHC-beta	--	--	--	0 of 21	--	5.00	1 of 17	4.10	1.95	0 of 16	--	1.27	0 of 9	--	0.01	--	--	--

Chemical	Beak Consultants 1989 (Filets from 1989)			Schuler 1994 (Whole-body from 1990-91)			Tetra Tech 1993 (Whole-body from 1991)			Tetra Tech 1995a (Whole-body from 1993)			Tetra Tech 1996b (Filets from 1995)			U.S. EPA 1992b (Whole-body from 1987)		
	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)	Detection Frequency	Maximum Detected	Mean of All Values (half for ND)
BHC-delta	--	--	--	0 of 3	--	5.00	0 of 17	--	1.50	0 of 16	--	2.77	0 of 9	--	0.01	--	--	--
BHC-gamma	--	--	--	0 of 21	--	5.00	3 of 17	7.70	2.20	0 of 16	--	1.25	0 of 9	--	0.01	0 of 2	--	1.25
Chlordane-alpha	--	--	--	3 of 21	10.00	5.71	--	--	--	0 of 16	--	1.45	0 of 9	--	0.01	0 of 2	--	1.25
Chlordane-gamma	--	--	--	0 of 21	--	5.00	--	--	--	0 of 16	--	3.49	0 of 9	--	0.01	0 of 2	--	1.25
DDD-op'	--	--	--	6 of 21	20.00	7.86	6 of 17	29.00	9.53	0 of 16	--	18.53	--	--	--	--	--	--
DDD-pp'	--	--	--	3 of 3	70.00	56.67	15 of 17	30.00	16.37	16 of 16	47.00	24.84	9 of 9	18.37	8.77	--	--	--
DDE-op'	--	--	--	3 of 21	10.00	5.71	9 of 17	42.00	10.88	0 of 16	--	10.78	--	--	--	--	--	--
DDE-pp'	--	--	--	21 of 21	340.00	86.19	0 of 17	--	23.85	16 of 16	180.00	97.00	9 of 9	44.63	28.66	2 of 2	89.20	85.05
DDT-op'	--	--	--	15 of 21	30.00	15.24	0 of 17	--	2.26	0 of 16	--	15.40	--	--	--	--	--	--
DDT-pp'	--	--	--	20 of 21	40.00	16.43	13 of 17	16.00	6.56	16 of 16	56.00	13.98	6 of 9	6.93	1.70	--	--	--
Dicofol	--	--	--	--	--	--	0 of 18	--	15.00	0 of 16	--	13.00	0 of 0	--	0.00	0 of 2	--	1.25
Dieldrin	--	--	--	6 of 21	20.00	8.33	1 of 17	4.50	1.74	0 of 16	--	4.38	0 of 9	--	0.02	0 of 2	--	1.25
Endosulfan1	--	--	--	--	--	--	1 of 17	3.30	1.61	0 of 16	--	1.25	0 of 9	--	0.01	--	--	--
Endosulfan2	--	--	--	--	--	--	0 of 17	--	1.50	0 of 16	--	2.50	0 of 9	--	0.02	--	--	--
Endosulfan sulfate	--	--	--	--	--	--	1 of 17	3.50	1.79	0 of 16	--	2.50	0 of 9	--	0.02	--	--	--
Endrin	--	--	--	0 of 21	--	5.00	2 of 17	12.00	2.86	0 of 16	--	2.50	0 of 9	--	0.02	0 of 2	--	1.25
Endrin-aldehyde	--	--	--	--	--	--	1 of 17	4.20	1.75	0 of 16	--	2.56	0 of 9	--	0.02	--	--	--
Heptachlor	--	--	--	0 of 3	--	5.00	0 of 17	--	1.50	0 of 16	--	1.25	0 of 9	--	0.01	0 of 2	--	1.25
Heptachlor epoxide	--	--	--	1 of 21	10.00	5.24	0 of 18	--	1.50	0 of 16	--	2.27	0 of 9	--	0.01	0 of 2	--	1.25
Hexachlorobenzene	--	--	--	0 of 21	--	5.00	0 of 18	--	100.00	0 of 16	--	122.88	9 of 9	1.53	0.50	1 of 2	1.49	1.37
Methoxychlor	--	--	--	--	--	--	1 of 17	65.00	17.94	0 of 16	--	12.50	0 of 9	--	0.09	0 of 2	--	1.25
Methyl parathion	--	--	--	--	--	--	0 of 18	--	3.28	0 of 16	--	13.00	0 of 9	--	0.18	--	--	--
Mirex	--	--	--	0 of 21	--	5.00	0 of 17	--	1.50	--	--	--	0 of 9	--	0.02	0 of 2	--	1.25
cis-Nonachlor	--	--	--	7 of 21	20.00	8.57	--	--	--	--	--	--	--	--	--	0 of 2	--	1.25
Oxychlordane	--	--	--	1 of 21	10.00	5.24	--	--	--	--	--	--	--	--	--	0 of 2	--	1.25
Toxaphene	--	--	--	0 of 3	--	5.00	0 of 17	--	75.00	0 of 16	--	125.00	0 of 9	--	4.63	--	--	--
Semi-volatiles (µg/kg, wet weight)																		
124-Trichlorobenzene	--	--	--	--	--	--	0 of 18	--	100.00	0 of 16	--	122.88	0 of 9	--	5.00	0 of 2	--	1.25
14-Dichlorobenzene	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	122.88	0 of 9	--	5.00	--	--	--
24-Dinitrotoluene	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	615.31	0 of 9	--	5.00	--	--	--
2-Chlorophenol	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	122.88	0 of 9	--	5.00	--	--	--
bis-2(Ethylhexyl)phthalate	--	--	--	--	--	--	8 of 18	1100.00	350.56	2 of 16	760.00	189.28	2 of 9	1101.00	239.56	--	--	--
4-Methylphenol	--	--	--	--	--	--	0 of 18	--	100.00	0 of 16	--	122.88	4 of 9	11.00	7.33	--	--	--
4-Nitrophenol	--	--	--	--	--	--	0 of 18	--	500.00	0 of 16	--	615.31	3 of 9	99.00	29.56	--	--	--
Acenaphthene	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	4.82	0 of 9	--	5.00	--	--	--
Chrysene	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	4.82	0 of 9	--	5.00	--	--	--
Hexachlorobutadiene	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	122.88	0 of 9	--	0.01	0 of 2	--	1.25
Isophorone	--	--	--	--	--	--	0 of 17	--	50.00	0 of 16	--	122.88	0 of 9	--	5.00	--	--	--
Phenol	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	122.88	3 of 9	23.00	12.06	--	--	--
Pyrene	--	--	--	--	--	--	0 of 18	--	50.00	0 of 16	--	4.82	0 of 9	--	5.00	--	--	--

slightly higher than the TECs for the filet samples, although the values from the Beak Consultants (1989) study were based on only the two tetra congeners. A reference value of 3.0 ng/kg (TEQ) has been suggested by New York State (Newell et al. 1987) to be protective of fish-eating wildlife. This threshold was exceeded by all of the U.S. EPA (1992b) samples, two of the Schuler (1994) samples, four of the Tetra Tech (1993) samples and one of the Tetra Tech (1995a) samples. This reference level may be useful in determining the potential risk to predators of largescale sucker but it is not applicable for the determination of ecological risks to the largescale suckers themselves.

3.1.1.2 Metals. Ten metals were measured in the three Tetra Tech studies (1993, 1995a, 1996b) and mercury was measured by U.S. EPA (1992b). Only barium, copper, and mercury were detected in all samples (Table 2). Silver was rarely detected in both whole-body and filet samples, while antimony and arsenic were rarely detected in whole-body samples. For many metals, particularly barium, cadmium, copper, lead, and nickel, the concentration in filet samples was considerably lower than the concentrations in whole-body samples.

3.1.1.3 PCBs. PCB Aroclor mixtures were measured in the three Tetra Tech studies. Aroclors 1248, 1254, and 1260 were detected in one or more of the studies (Table 2). The most dramatic difference between whole-body and filet PCB concentrations is for Aroclor 1254, which was found at concentrations as high as 2,700 μg/kg in 1993, but was never detected (detection limit approximately 2 μg/kg) in filet samples in 1995. A similar trend between 1993 and 1995 was not evident for Aroclor 1260 (Table 2).

3.1.1.4 Organochlorine Pesticides. Pesticides were measured in all of the six studies except Beak Consultants (1989). Most pesticides were detected rarely, with the exception of DDT and its metabolites (Table 2). The concentrations of these analytes were generally lower in filet samples than in whole-body samples.

3.1.1.5 Semi-volatiles. Semi-volatile organics were measured in all three Tetra Tech studies and by U.S. EPA (1992b). Only bis-2(ethylhexyl)phthalate was detected consistently (Table 2). Three phenols were also detected in filet samples in 1995. No temporal trends or differences between whole-body and filet samples were noted.

39

3.1.1.6 Biomarkers. In general, the biomarker data for largescale sucker did not indicate marked exposure to PAHs. Enzyme (AHH) activities were lower than previously reported values for other benthic fish in moderately and severely contaminated environments. In the absence of adequate dose-response data for largescale sucker, these data cannot be interpreted as showing evidence of exposure to toxic chemicals.

3.1.2 Effects

The two fish assessment techniques which included largescale sucker as a target species focused on specific morphological characteristics of individual fish as indicators of fish health (Tetra Tech 1996a). The fish autopsy technique used as endpoints qualitative observations of the health of individual organ systems. These endpoints stray from the ideal endpoint described above because their sensitivity to and unique association with the stressors under consideration (toxic chemicals) has not been determined. It is likely that there are multiple causes of abnormal organ systems in largescale sucker. The skeletal abnormality endpoint is closer to the ideal endpoint because there is an extensive literature base which describes the relationship of toxic chemicals with skeletal abnormalities. However, the dose-response relationship for largescale suckers has not been determined.

3.1.2.1 Fish Autopsy. A total of 71 fish from 6 stations were evaluated using a variety of endpoints associated with the fish autopsy. Although abnormalities in some organ systems were noted, the frequency and severity of abnormalities were lower than at sites known to be associated with chemical contamination (Adams et al. 1993) in other river systems. These endpoints did not provide any evidence of adverse effects of toxic chemicals to largescale sucker.

3.1.2.2 Skeletal Abnormalities. Although juvenile largescale sucker were one of the target species for the skeletal abnormality study (Tetra Tech 1996a), only 6 individual fish were collected and analyzed. No skeletal abnormalities were observed in any of these fish. Due to the small sample size, conclusions about the interpretation of this assessment endpoint are premature.

3.1.3 Population

Quantitative population estimates for largescale sucker in the lower Columbia River have not been made. Reimers and Bond (1967) noted that large populations of largescale sucker were spread throughout the lower Columbia River down into brackish water. In the Hanford Reach of the Columbia River, population estimates as high as $14,961 \pm 9,422$ have been made (Dauble 1986). Largescale sucker are relatively easy

to capture in all areas of the lower Columbia River by electrofishing (Tetra Tech 1993, 1995a, 1996b).

Largescale sucker generally inhabit shallow, slow-moving regions of rivers (Wydoski and Whitney 1979). Due to their opportunistic feeding habits, the substrate is not likely to be a critical factor in their distribution. The decrease in the abundance of open water and other wetland habitat types (Figure 4) has not adversely impacted the largescale sucker. With the advent of the dams in the upper regions of the river, the current velocities in the lower river have tended to decline.

3.2 MINK

Investigations on the contaminant burdens of wild mink in the lower Columbia River region have been conducted by Henny et al. (1981, 1996). Because of their status as a ranch species for fur farming, the effects of contaminants on mink have received considerable attention. Henny et al. (1996) attempted to evaluate the measured chemical concentrations in lower Columbia River mink in the context of effects-based reference levels derived by others in laboratory feeding experiments. The recently completed study conducted by Henny et al. (1996) suffered from small sample size; population estimates could not be made. The general status of the mink population can be assessed using habitat assessment data.

3.2.1 Exposure

Henny et al. (1996) collected and analyzed a single male and a single female specimen from RM 88 on the lower Columbia River. Two reference samples (composite samples of 2 males and 2 females) from the Malheur National Wildlife Refuge in Eastern Oregon were also analyzed. Organochlorine pesticides were found in the livers from both areas, usually at higher levels in the mink from the lower Columbia River. The highest detected concentrations for Columbia River mink were for p,p'-DDE (152 μg/kg) and oxychlordane (58 μg/kg). Concentrations of PCB congeners were also higher in the Columbia River mink, often by a factor of at least 3. The estimated total PCB concentrations (from the sum of congeners) were 549 and 151 μg/kg for the Columbia River male and female, respectively, compared to 119 and 34 μg/kg for the reference area male and female samples, respectively. Only one liver from Columbia River mink was measured for co-planar PCBs, dioxins, and furans. Several congeners were detected in this sample that were not detected in the two reference area samples. The most notable Columbia River result was 6.24 ng/kg for 2,3,4,7,8-PeCDF. This congener is second in toxicity only to 2,3,7,8-TCDD (TEF = 0.5).

41

Metal concentrations between the two areas were similar, with the exception of nickel, which was 4-8 times higher in Columbia River kidney samples.

Mink were also collected and analyzed by Henny et al. (1981). Samples were collected from the lower Columbia River and coastal streams in the Columbia River basin, as well as inland locations in the Blue and Wallowa mountains and the Klamath basin. Six of the nine mink livers collected from the lower Columbia River contained detectable levels of PCBs (total PCB concentration range 0.55 to 2.1 mg/kg). PCBs and pesticides were seldom detected in mink livers from the other locations.

3.2.2 Effects

Research on the effects of toxic chemicals on mink has focused on PCBs, but other organochlorine compounds have been included as well. Mink may be the most sensitive mammalian wildlife species to these contaminants (Aulerich and Ringer 1977, Jensen et al. 1977). Laboratory experiments have been performed in which captive mink are fed contaminated diets (e.g., Jensen et al. 1977). A variety of endpoint data are typically collected, primarily concerning reproduction. The specific endpoints examined, such as litter size and kit survival, are not uniquely associated with the contaminants under investigation, but the experimental setting usually permits a determination of cause-and-effect since extraneous environmental variables can be controlled.

3.2.2.1 Contaminants in Organs and Tissues. Concentrations of PCBs detected in Columbia River mink in the late 1970's were equivalent to concentrations in mink that survived long-term feeding tests, but failed to produce kits that survived (Henny et al. 1981). Since that time, PCB concentrations appear to have declined. The highest PCB concentration in the mink analyzed in the recent study (Henny et al. 1996) was several times lower than the highest concentration reported by Henny et al. (1981), although the sample size in the recent study was much smaller than in the earlier study.

The dioxin/furan and co-planar PCB data collected in Henny et al. (1996) can be evaluated using TEQs. A recent study where mink were fed contaminated carp (*Cyprinus carpio*) provides a good baseline against which to measure the concentrations from the Columbia River (Heaton et al. 1995a, 1995b; Tillitt et al. 1996). In this study, it was estimated that the threshold dose (TEQ; both dioxins/furans and PCBs) for reproduction effects, based on liver concentrations, was 60 ng/kg wet weight (Tillitt et al. 1996). The control mink in the study had a TEQ of 18 ng/kg, while the 10% carp group (lowest treatment) had TEQs

of 207 and 495 ng/kg. The 10% carp diet fed to females for two months prior to breeding resulted in decreased body weights and kit survival. For the single Columbia River mink sample analyzed by Henny et al. (1996), the calculated TEQ was 17.67 ng/kg. This value and the TEQs for the reference area (12.09 and 1.68 ng/kg) were below the control TEQ for the Saginaw Bay study (Tillitt et al. 1996). Thus, the one Columbia River sample available does not provide evidence that body burdens of organochlorine compounds are adversely impacting reproduction of mink.

3.2.2.2 Contaminants in Prey Species. Several studies on contaminant levels in mink prey species (e.g., crayfish, carp, and largescale sucker) have been performed in recent years (e.g., Tetra Tech 1993 and 1995a). As mentioned in section 3.1.1, the objective of the tissue collection component of some of these studies was to characterize the potential for adverse impacts to fish-eating wildlife species such as mink, river otter, and bald eagle. The potential for impacts can be evaluated by comparing prey body burdens with tissue residue guidelines (TRGs) designed to protect fish-eating wildlife. TRGs for organochlorine compounds such as pesticides, PCBs, and dioxins/furans have been developed for New York state (Newell et al. 1987) and British Columbia (Pommen 1989, Nagpal 1992). These TRGs are given in Table 3. More recently, Leonards et al. (1994) reviewed PCB toxicity data for mink. They extrapolated risk levels expressed on the basis of mink tissue residues to concentrations in prey organisms. The no-effect level for litter size for total PCB in the diet was 145 μg/kg (wet weight). This value is higher than the lowest TRG for total PCBs given in Table 3. The diet-based no-effects levels expressed as TEQs (both dioxins/furans and coplanar PCBs) were 50 ng/kg for relative litter size and 17 ng/kg for kit survival.

Whole-body concentrations of the chemicals listed in Table 3 in three typical prey species (carp, crayfish, and sucker) were compared to TRGs (Table 4). For carp, 18 of 460 measurements (3.9 percent) exceeded TRGs. Most of the exceedances were for 2,3,7,8-TCDD and PCBs. None of the 981 measurements for crayfish exceeded TRGs. For sucker, 22 of 1,142 measurements (1.9 percent) exceeded TRGs. Again, most of the exceedances were for 2,3,7,8-TCDD and PCBs. Overall, 1.5 percent of the measurements exceeded TRGs. This calculation probably slightly underestimates the true frequency of exceedances because some of the TRGs are based on total concentrations that were not reported in all the studies. This simple analysis does not account for interactions between chemicals, the bioaccumulation potential of each chemical compared to others, or the toxicity of the chemical. The comparison of Leonards' no-effects levels expressed as TEQs with the tissue data summarized in Table 4 is complicated by the fact that none of these studies measured PCB congeners. Nonetheless, none of the tissue samples exceeded the no-effects

43

Table 3. Summary of Tissue Residue Guidelines (TRGs) for the Protection of Piscivorous Wildlife				
Chemical	TRG (wet weight	Rationale	Jurisdiction	Reference
Aldrin/Dieldrin	0.02 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.12 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Benzo(a)pyrene	1 mg/kg	Maximum level in fish food organisms	British Columbia	Pommen 1989
Chlordane	0.37 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.5 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
DDT + DDE	0.27 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.2 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
2,3,7,8-TCDD	2.3 ng/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	3.0 ng/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Endrin	0.025 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Heptachlor and Heptachlor epoxide	0.21 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.2 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Hexachlorobenzene	0.2 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.33 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Hexachlorobutadiene	4.5 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	1.3 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Lindane	0.51 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.1 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Hexachloroethane	14.1 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Mirex	0.37 mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.33 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Octachlorostyrene	20 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
PCBs	0.1 mg/kg	Maximum level in whole fish to protect wildlife	British Columbia	Nagpal 1992
	0.11mg/kg	Carcinogenic (1 in 100 cancer risk level) fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
	0.13 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Pentachlorophenol	2 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Tetrachlorophenol	0.67 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Trichlorobenzenes	1.3 mg/kg	Non-carcinogenic fish flesh criterion for piscivorous wildlife	New York	Newell et al. 1987
Source: Henny et al. (1996)				

Table 4. Frequency of Exceedances of Tissue Residue Guidelines for the Protection of Piscivorous Wildlife by Whole-Body Concentrations Found in Carp, Crayfish, and Sucker in the Lower Columbia River, 1986-1996				
Chemical	Carp	Crayfish	Sucker	All species
1,2,3-Trichlorobenzene	0 of 1	0 of 0	0 of 3	0 of 4
1,2,4-Trichlorobenzene	1 of 12	0 of 33	0 of 37	1 of 82
1,3,5-Trichlorobenzene	0 of 1	0 of 0	0 of 3	0 of 4
2,3,7,8-TCDD	5 of 21	0 of 72	4 of 50	9 of 143
Aroclor 1242/1016	0 of 2	0 of 15	0 of 16	0 of 33
Aroclor 1016	0 of 9	0 of 18	0 of 18	0 of 45
Aroclor 1221	0 of 11	0 of 33	0 of 34	0 of 78
Aroclor 1232	0 of 11	0 of 33	0 of 34	0 of 78
Aroclor 1242	0 of 9	0 of 18	0 of 18	0 of 45
Aroclor 1248	0 of 11	0 of 33	0 of 34	0 of 78
Aroclor 1254	4 of 11	0 of 33	13 of 34	17 of 78
Aroclor 1260	1 of 11	0 of 33	1 of 34	2 of 78
Total Deca PCBs	0 of 1	0 of 0	0 of 3	0 of 4
Total Di PCBs	0 of 1	0 of 0	0 of 3	0 of 4
Total Hepta PCBs	1 of 1	0 of 0	0 of 3	1 of 4
Total Hexa PCBs	1 of 1	0 of 0	0 of 3	1 of 4
Total Mono PCBs	0 of 1	0 of 0	0 of 3	0 of 4
Total Nona PCBs	0 of 1	0 of 0	0 of 3	0 of 4
Total Octa PCBs	0 of 1	0 of 0	0 of 3	0 of 4
Total Penta PCBs	1 of 1	0 of 0	0 of 3	1 of 4
Total Tetra PCBs	1 of 1	0 of 0	0 of 3	1 of 4
Total Tri PCBs	0 of 1	0 of 0	0 of 3	0 of 4
Benzo(a)pyrene	0 of 11	0 of 33	0 of 34	0 of 78
Chlordane	0 of 30	0 of 49	0 of 60	0 of 139
DDE-op'	0 of 22	0 of 46	0 of 54	0 of 122
DDE-pp'	2 of 25	0 of 46	2 of 57	4 of 128
DDT-op'	0 of 22	0 of 46	0 of 54	0 of 122
DDT-pp'	0 of 24	0 of 46	0 of 54	0 of 124
Total DDT	1 of 5	0 of 3	2 of 3	3 of 11
Dieldrin	0 of 25	0 of 46	0 of 57	0 of 128
Endrin	0 of 25	0 of 46	0 of 57	0 of 128
Heptachlor	0 of 19	0 of 36	0 of 39	0 of 94
Heptachlor epoxide	0 of 25	0 of 46	0 of 58	0 of 129
Hexachlorobenzene	0 of 23	0 of 46	0 of 58	0 of 127
Hexachlorobutadiene	0 of 12	0 of 33	0 of 37	0 of 82
Lindane	0 of 25	0 of 46	0 of 57	0 of 128
Mirex	0 of 21	0 of 31	0 of 41	0 of 93
Octachlorostyrene	0 of 1	0 of 0	0 of 3	0 of 4
Pentachlorophenol	0 of 11	0 of 33	0 of 34	0 of 78
All Chemicals	18 of 460	0 of 981	22 of 1142	40 of 2583

TEQ of 17 ng/kg (Leonards et al. 1994) based on dioxins and furans alone. The relatively low frequency of TRG exceedances noted for three important prey species indicates that the average chemical concentration in prey items encountered by mink is probably well below the applicable TRG.

3.2.3 Population

Henny et al. (1996) attempted to make a population estimate for mink in the lower Columbia River, but the sample size was too small to allow a reasonable estimate to be made. During the late summer 1994, one mink family and four lone animals were documented in 5 of the 8 randomly selected 9-mile strata (Henny et al. 1996). There were no observed signs of mink in 3 of the strata. During the 1994-95 (fall-winter) trapping season, only 2 mink were captured.

Mink habitat was assessed in each of the 9-mile strata (Henny et al. 1996). The habitat suitability index (HSI) was lower in urban industrial areas. For many other regions of the lower Columbia River, the HSI was excellent. Thus, there appears to be the potential for a greater number of mink in this area. Henny et al. (1996) speculated that the high levels of PCBs measured in mink during the 1970's may have decimated the population and the few mink that are found now may be pioneers that are recolonizing the lower Columbia River system.

3.3 RIVER OTTER

Investigations on the contaminant burdens of river otter in the lower Columbia River region have been conducted by Henny et al. (1981, 1996). Only a very few studies of the effects of contaminants on river otter have been conducted. Effects data for other species in the same family, such as mink, may be useful for comparative purposes, but the relative sensitivity of the two species to contaminants is undetermined. A recent population estimate for river otter in the lower Columbia River was made by Henny et al. (1996).

3.3.1 Exposure

Henny et al. (1996) collected and analyzed 30 river otter from the lower Columbia River and 6 from the Malheur National Wildlife Refuge in Eastern Oregon (reference area). Concentrations of six organo-chlorine insecticides (DDE, DDD, heptachlor epoxide, β-HCH, dieldrin, and mirex) and almost all measured PCB congeners were significantly higher in Columbia River liver samples than in reference area

samples. The geometric mean DDE concentrations (maximum = 145 μg/kg, wet weight) were at least an order of magnitude higher than concentrations for all other insecticides. Concentrations of co-planar PCBs, dioxins, and furans were significantly higher in Columbia River samples for some congeners, but not for others. TEQs were calculated for each sample using both PCB and dioxin/furan data. Geometric mean TEQs (range 19.79 to 27.94 ng/kg, wet weight) were significantly higher than reference samples for all age classes, but they did not show a significant pattern of increase with age.

Metals were analyzed in both the liver and kidney for each animal (Henny et al. 1996). In general, there were no significant differences between lower Columbia River and reference area samples. Concentration changes with age were noted for cadmium, which increased significantly with age in both livers and kidneys of lower Columbia River animals. The highest concentrations of aluminum and lead (1.83 and 1.63 mg/kg, dry weight, respectively) were found in animals collected at RM 119.5, which is just downstream of an aluminum smelter.

The rat hepatoma cell line bioassay is based on the fact that there is an established dose-response relationship between dioxins and dioxin-like compounds and the expression of the detoxifying enzyme EROD. In Henny et al. (1996), extracts of lower Columbia River river otter liver failed to induce EROD activity. The authors offered two explanations for the observed results: 1) interference by other less potent PCB congeners by competitive binding and 2) concentrations of dioxin-like compounds were too low to induce EROD activity.

River otter were also collected and analyzed by Henny et al. (1981). Samples were collected from the lower Columbia River and coastal streams in the Columbia River basin, as well as inland locations in the Klamath basin. All of the otter from the lower Columbia River contained detectable levels of DDE and PCBs. PCB concentrations in livers of lower Columbia River otter ranged from 4.8 to 23 mg/kg. PCBs and pesticides were seldom detected in the other locations.

3.3.2 Effects

In conjunction with measurements of contaminant levels in lower Columbia River river otter, Henny et al. (1996) also collected data on the effects of the contaminants. Because the analyses were performed on animals captured in the wild, the association of effects with contaminant levels relied on correlation analysis. Henny et al. (1996) performed necropsies and histopathological observations on each animal.

47

3.3.2.1 Necropsy and Histopathology. Generally, river otter collected in the lower Columbia River were found during necropsy to be in good condition (Henny et al. 1996). Three of the four otter collected at RM 119.5 had gross abnormalities. Samples from this location contained the highest concentrations of most of the contaminants, with the exception of dioxins and furans. Approximately one-third of the river otter necropsied had enlarged spleens. For male river otters, the weight and length of the baculum and the weight of the testes were measured. For age 0 animals, the mean baculum length and weight was significantly smaller than measurements from the reference area (Henny et al. 1996). The mean testes weight was also much smaller in animals from the lower Columbia River, but the difference was not significant. Significant inverse relationships between measurements of reproductive fitness and contaminants were noted for a large number of organochlorine insecticides and PCBs and a smaller number of dioxin and furan congeners. Because many of these contaminants are significantly correlated with each other, it is difficult to determine which chemicals had the most profound effect on baculum and testes characteristics. Among metals, it appears that only chromium may be impacting baculum length.

The most striking result of the histopathological observations was the difference between seminiferous tubules of lower Columbia River and reference area animals (Henny et al. 1996). In the lower Columbia River animals, the tubules were small and usually lined by a single cell layer of sertoli cells. There was no evidence of spermatogenesis. In the reference area animals, tubules were large and lined by several cell layers and spermatogenesis was observed. The under-development or delayed development of the male reproductive tract observed in this study has not been previously documented in any free-living mammals.

3.3.2.2 Contaminants in Organs and Tissues. As described in section 3.2.2.1, contaminant concentrations expressed as TEQs can be compared to effects-based TEQs from laboratory experiments. Such experiments have not been performed for river otters, but the results of similar experiments with mink may provide useful comparisons (Tillitt et al. 1996). The geometric mean TEQs from lower Columbia River river otters in age classes 0, 1, and 2+ (both sexes) were 19.79, 22,37, and 27.94 ng/kg (wet weight), respectively, well below the 60 ng/kg threshold of Tillitt et al. (1996). One individual from RM 88 (TEQ 82.72) and two individuals from RM 119.5 (TEQs 83.17 and 115.24) did exceed the threshold TEQ. It should be noted that the threshold TEQ was developed for mink and the relative sensitivity of the two species to organochlorine contaminants has not been determined.

3.3.2.3 Contaminants in Prey Species. The presentation of contaminants in prey species in section 3.2.2.2 is applicable to river otter as well. Carp, crayfish, and sucker are among the primary prey items for this species (Tabor et al. 1980).

3.3.3 Population

Henny et al. (1996) estimated a population abundance of river otter on the lower Columbia River of 286 ± 47 animals. This estimate was based on field investigations of 8 of the 16 nine-mile strata on the lower river and extensive consultation with the knowledgeable local trappers that assisted in the collection of all animals. The population density reported by Henny et al. (1996) is the highest ever reported for river otter in North America.

The HSI scores applied to the lower Columbia River by Henny et al. (1996) are designed to assess mink habitat (Allen 1986). The habitat requirements of mink and river otter are similar, so the HSI may be useful for assessing river otter habitat as well. For most of the lower Columbia River, HSI scores were excellent. These results agree with the observation that river otter seemed to be evenly distributed throughout the lower Columbia River (Henny et al. 1996).

3.4 BALD EAGLES

Concentrations of contaminants in bald eagles have been the subject of a large number of studies in the past two decades, but only recently have such studies focused on the lower Columbia River (Anthony et al. 1993, USFWS 1996). Because of the protected status of the bald eagle, adverse effects of these contaminants cannot be determined experimentally. However, several researchers have estimated concentrations associated with adverse impacts (e.g., Wiemeyer et al. 1984, 1993; Giesy et al. 1995). Bald eagle nest sites can be easily identified and tracked from year to year, making population estimates for the lower Columbia River and elsewhere in Washington and Oregon possible.

3.4.1 Exposure

USFWS (1996) detected residues of 12 organochlorine pesticides or metabolites and mercury in 14 bald eagle eggs collected in 1994. Mean concentrations of most of these compounds were less than 1 mg/kg, with the exception of total PCBs and p,p'-DDE, which were 6.15 and 6.84 mg/kg, respectively. All egg

49

samples contained PCDD, PCDF, and planar PCB residues. TCDD and TCDF were the most elevated PCDD/PCDF congeners, averaging 27.6 and 21.1 ng/kg, respectively. The most elevated non ortho-substituted PCB congeners were PCB 77 and 126 and the most elevated mono ortho-substituted PCB congeners were PCB 118 and 105. Both mammalian TEQs (I-TEQs; Ahlborg et al. 1992) and avian TEQs (C-TEQs; Bosveld et al. 1995) were calculated. The mean I-TEQs were 40.2 ng/kg for PCDDs and PCDFs only and 637 ng/kg including planar PCBs. The corresponding values for C-TEQs were 68 and 301 ng/kg, respectively.

Extracts from bald eagle eggs were tested using the rat hepatoma cell (H4IIE) bioassay (USFWS 1996). The mean TCDD-EQ (TCDD equivalent) was 72 ng/kg.

Anthony et al. (1993) collected blood samples from 22 bald eagles (nestlings, subadults and adults) along the lower Columbia River. Contaminant concentrations were highest for adults. Mean concentrations of p,p'-DDE and total PCBs in adults (n=3) were 2.13 and 2.40 mg/kg, respectively. Mean concentrations of lead and mercury in adults were 0.43 and 3.07 mg/kg, respectively.

3.4.2 Effects

Characterization of the effects of contaminants on bald eagles has been limited to measurements of eggshell thickness and breeding success, and comparisons of measured contaminant concentrations with concentrations known to be associated with adverse effects.

3.4.2.1 Eggshell Thickness. With the exception of one egg, all bald eagle eggshells collected along the lower Columbia River by USFWS (1996) exhibited some degree of eggshell thinning. The mean eggshell thickness was 11 percent less than the mean thickness of eggs collected prior to the use of DDT. Eggshell thinning greater than 15-20 percent over a number of years is associated with poor reproductive success and a declining population (Anderson and Hickey 1972). Eggshells from five territories along the lower Columbia River were more than 15 percent thinner than the pre-DDT average and breeding success at these territories ranged from 0 to 0.93 young per breeding attempt (USFWS 1996). Overall, eggshell thickness was not correlated to breeding success for bald eagles along the lower Columbia River (USFWS 1996).

3.4.2.2 Contaminants in Eggs. Adverse effects from contaminants in eggs of bald eagles have been noted for several chemicals, including p,p'-DDE, total PCBs, and 2,3,7,8-TCDD. For the eggs collected by USFWS (1996), adverse effects levels were exceeded for p,p'-DDE, total PCBs, and 2,3,7,8-TCDD. The mean p,p'-DDE concentration (6.84 mg/kg) was almost double the concentration associated by Wiemeyer (1993) with impaired reproduction (3.6 mg/kg). The mean total PCB concentration (6.15 mg/kg) exceeded the no-effects level (4.0 mg/kg) derived by Wiemeyer et al. (1984). The mean 2,3,7,8-TCDD concentration (27.6 ng/kg) was several times higher than the no-effects level (7 ng/kg) derived by Giesy et al. (1995). The mean I-TEQ values (PCDD/PCDF only) in bald eagles along the lower Columbia River (USFWS 1996) were higher than I-TEQs in eggs of other bird species experiencing reproductive problems, including peregrine falcons (Jarman et al. 1993) and wood ducks (White and Seginak 1994).

3.4.2.3 Contaminants in Prey Species. USFWS (1996) reported unique contaminant data on prey items (carp and starry flounder) collected from bald eagle nests. The reported concentrations were generally at or below detection limits, with the exception of total PCBs, which were detected in the carp sample at 0.23 mg/kg. This concentration exceeds all the TRGs reported in Table 3 for total PCBs. The presentation of contaminants in prey species in section 3.2.2.2 is applicable to bald eagle as well, although crayfish are not normally a prey item (Watson et al. 1991), and other typical bald eagle prey items are not included in Table 4.

3.4.3 Population

USFWS (1996) reported the number of nesting territories along the lower Columbia River and the productivity (young/occupied territory). Bald eagles nesting along the lower Columbia River occupied 40 nesting territories in 1994 and 41 nesting territories in 1995, and produced 0.70 and 0.54 young/occupied territory, respectively. These productivity values were lower than statewide values by 23 to 28 percent in 1994 and 37 to 44 percent in 1995. Five-year average productivity was 0.73 young/occupied territory during the five-year period ending in 1994 and 0.70 for the five-year period ending in 1995. These values were higher than all previous estimates since 1984 (USFWS 1996), but were still approximately 25 percent lower than statewide averages. Since 1990, 19 new territories were established along the river, 6 within the past 2 years. The recent increase in five-year productivity averages reflects the higher breeding success observed from newly established pairs along the river.

3.5 SUMMARY

The status of each of the four target species was evaluated based on available data for levels of exposure to contaminants, adverse effects of those contaminants, and population levels. Table 5 presents a summary of these evaluations.

Table 5. Status of Each Lower Columbia River Target Species Based on Exposure and Effects of Contaminants and Population Levels				
	Largescale Sucker	Mink	River Otter	Bald Eagle
Levels of Exposure to Contaminants [a]	Low	Medium	Medium	High
Confidence [b]	High	Low	Medium	Medium
Evidence of Effects of Exposure to Contaminants [c]	Low	Low	Medium	Medium
Confidence	Low	Low	Medium	Medium
Status of Population	High	Low	High	Medium
Confidence	Medium	Medium	Medium	High
[a] These subjective values are largely relative to each other				
[b] Confidence is based on the weight-of-evidence and amount of available data				
[c] Based on frequency and magnitude of exceedances of effects-based concentrations				

A brief summary of the available evidence is provided below in separate sections for each species. These sections provide the rationale for the subjective ratings given in Table 5. Based on these ratings, the health of the target species can be ranked (in decreasing order) as largescale sucker, mink, river otter, and bald eagle. The available data indicate that the lower Columbia River does not fully support the legally protected beneficial use by fish and wildlife.

3.5.1 Largescale Sucker

As shown by body burden data, there is considerable evidence that largescale sucker are exposed to dioxins and furans, pesticides, PCBs, and metals. The concentrations of these contaminants are relatively low compared to the other target species. Based on the biomarker study results, there is little evidence that

exposure to PAHs has occurred. The available data on the effects of exposure to these chemicals do not indicate that adverse impacts are occurring. However, the effects studies that have been performed to date have not utilized endpoints that are uniquely associated with exposure to the toxic chemicals under consideration and have suffered from small sample sizes due to the sampling season. There is no evidence that the population of largescale sucker in the lower Columbia River is in decline due to the presence of toxic chemicals or changes in habitat. Other factors which could influence fish populations have not been evaluated.

3.5.2 Mink

The data on contaminant levels in mink in the lower Columbia River is very limited. Recently collected mink in the region had higher concentrations of PCBs and dioxins/furans than did mink from a reference area in Eastern Oregon. The concentrations detected in lower Columbia River mink were lower than levels known to cause adverse reproductive effects. Contaminant concentrations in common prey items (carp, crayfish, and sucker) infrequently exceeded tissue residue guidelines designed to protect piscivorous wildlife. The mink population in the lower Columbia River appears to be low, but a reliable quantitative estimate cannot be made at this time. The amount of suitable habitat should support greater numbers than currently exist.

3.5.3 River Otter

Recently collected river otter in the lower Columbia River had higher concentrations of PCBs, insecticides, and some dioxin and furan congeners than did river otter from a reference area in Eastern Oregon. Three of the four river otter collected from RM 119.5, just downstream of an aluminum smelter, had gross physiological abnormalities. Age 0 males from the lower Columbia River showed signs of under-development or delayed development of the reproductive tract. The geometric mean concentrations detected in lower Columbia River river otter were lower than levels known to cause adverse reproductive effects in mink, but TEQs for several individuals did exceed the threshold. An estimate of density of river otters in the lower Columbia River is higher than any previously reported in North America.

3.5.4 Bald Eagle

Measured concentrations for several contaminants (p,p'-DDE, total PCBs, and 2,3,7,8-TCDD) in bald eagle are higher than for any of the other three target species and are higher than concentrations associated with adverse reproductive effects in this species. Eggshell thinning, thought to be a major determinant in

reproductive failure, was noted for bald eagle eggs collected in 1994 and 1995, but was not correlated with contaminant concentrations. Population levels appear to be higher than they were during the 1980s, but productivity is lower along the lower Columbia River than in the rest of Oregon and Washington.

The conclusions reached in section 3.5 indicate that contaminants in the lower Columbia are associated with adverse impacts in the target species. These results warrant additional research to more clearly establish a dose-response relationship. Some of the recommendations made by the authors of the various reports are given below. In addition, Appendix B lists recommendations for further actions made by the Fish and Wildlife Work Group.

4.1 LARGESCALE SUCKER

Although the available evidence does not indicate that contaminants present in largescale sucker are adversely impacting individuals or population, the studies on which this conclusion did not provide clear answers due to limitations in sampling. The three fish health assessment techniques utilized by Tetra Tech (1996) all suffered from the small number of fish that could be captured. Repeating these studies during the summer when more of the target species can be captured would greatly reduce the uncertainty of the results.

In addition, Collier et al. (1996) suggested several ways in which the biomarker study could be improved:

- *A priori* determination of suitable reference sites for comparison

- Sampling earlier in the year to avoid sampling females undergoing gonadal maturation

- Collection of fish from main channel locations to determine if these sites are suitable as reference sites

- Collection of more fish and fish of both sexes at each site.

55

- Chemical analyses of stomach contents and surficial sediments to determine the presence of PAHs in the fish's habitat.

4.2 MINK AND RIVER OTTER

Henny et al. (1996) proposed several future research areas for mink and river otter. Animals were not live-captured in this study which eliminated the option of collecting blood to evaluate steroid concentrations, as well as the option for histopathology of unaltered (non-frozen) organs and tissue. Additional research is planned with trapper-caught and live-captured animals from the Columbia River and elsewhere throughout the Pacific Northwest and includes further studies with the contaminants initially investigated plus other known endocrine disrupters (e.g., alkylphenols, phthalate esters). This research will emphasize a general evaluation of health, hormone concentrations, hormone receptor characteristics, and sperm counts and quality. The addition of river otters from other locations with differing contaminant combinations will allow further evaluating of contaminants that do not appear to be related to the observed reproductive organ hypoplasia in young males, and future evaluation of the distribution and magnitude of the problem in the Northwest.

4.3 BALD EAGLE

Because of the interim nature of the bald eagle report (USFWS 1996), no recommendations for future research were made by the authors. Chemical analysis of the eggs collected in 1995 is currently underway. These results should provide a clearer picture of the relationship between organochlorine compounds and reproductive success in bald eagle.

5.0 REFERENCES

Adams, S.M, A.M. Brown, and R.W. Goede. 1993. A quantitative health assessment index for rapid evaluation of fish condition in the field. Transactions of the American Fisheries Society 122:63-73.

Ahlborg, U.G., A. Brouwer, M.A. Fingerhut, J.L. Jacobson, S.W. Kennedy, A.A.F. Kettrup, J.H. Koeman, H.Poiger, C. Rappe, S.H. Safe, R.F. Seegal, J. Tuomisto, and M. van den Berg. 1992. Impact of polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls on human and environmental health, with special emphasis on application of the toxic equivalency factor concept. Eur. J. Pharmacol. Environ. Toxicol. Pharmacol. Sec. 228:179-199.

Allen, A.W. 1986. Habitat suitability index models: mink. U.S. Fish and Wildlife Service, Biological Report 82 (10.127). Revised. Ft. Collins, CO. 23 pp.

Anderson, D.W. and J.J. Hickey. 1972. Eggshell changes in certain North American birds. Proc. Internat. Ornithol. Congr. 15:514-540.

Anthony, R.G., M.G. Garrett, and C.A. Schuler. 1993. Environmental contaminants in bald eagles in the Columbia River Estuary. J. Wildl. Manage. 57:10-19.

Aulerich, R.J. and R.K. Ringer. 1977. Current status of PCB toxicity to mink and effect on their reproduction. Arch. Environ. Contam. Toxicol. 6:279-292.

Beak Consultants, Inc. 1989. Columbia River fish study: fish collection, fish tissue sampling, and age of fish sampled. Prepared for Northwest Pulp & Paper Association, Portland, Oregon. Beak Consultants, Inc., Portland, Oregon.

Bengtsson, B.-E. 1988. Effects of pulp mill effluents on skeletal parameters in fish - a progress report. Wat. Sci. Tech. 20:87-94.

Bengtsson, B.-E. and A. Larsson. 1986. Vertebral deformities and physiological effects in fourhorn sculpin (*Myoxocephalus quadricornis*) after long-term exposure to a simulated heavy metal-containing effluent. Aquatic Toxicology. 9:215-229.

Bi-State Steering Committee. 1990. Lower Columbia River Water Quality Program: Four Year Program Plan (1990 to 1994). Prepared by Lower Columbia River Bi-State Steering Committee Members. 28 pp.

Bosveld, A.T.C., J. Gradener, A.J. Murk, A. Brouwer, M. van Kampen, E.H.G. Evers, and M. van den Berg. 1995. Effects of PCDDs, PCDFs, and PCBs in common terns (*Sterna hirundo*) breeding in estuarine and coastal colonies in the Netherlands and Belgium. Environ. Toxicol. Chem. 14:99-115.

Collier, T.K., B.F. Anulacion, J.E. Stein, B. Bill, T. Hom, S. Sol, and S. Spencer. 1996. Assessment of exposure to aromatic compounds in fish from the lower Columbia River, by use of appropriate biomarkers. Prepared for Lower Columbia River Bi-State Program. Environmental Conservation Division, Northwest Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, WA. 22 pp.

Columbia Basin Fish and Wildlife Authority/Wildlands In Landuse Development (WILD) Systems. 1996. Contamination ecology of selected fish and wildlife of the lower Columbia River. Prepared for Lower Columbia River Bi-State Program. Wildlands in Landuse and Development (WILD) Systems, Portland, Oregon. 224 pp.

Dauble, D.D. 1986. Life history and ecology of the largescale sucker (*Catostomus macrocheilus*) in the Columbia River. American Midland Naturalist 116(2):356-367.

Garrett, M., R.G. Anthony, J.W. Watson, and K. McGarigal. 1988. Ecology of bald eagles on the lower Columbia River. Final report submitted to the U.S. Army Corp of Engineers, Contract No. DACW57-83-C-0100. 189 pp.

Giesy, J.P., W.W. Bowerman, M.A. Mora, D.A. Verbrugge, R.A. Othoudt, J.L. Newsted, C.L. Summer, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, G.A. Dawson, T.J. Kubiak, D.A. Best, and D.E. Tillitt. 1995. Contaminants in fishes from the Great Lakes-influenced sections and above dams of three Michigan rivers: III. Implications for health of bald eagles. Arch. Environ. Contam. Toxicol. 28

Gill, C.D. and D.M. Fisk. 1966. Vertebral abnormalities in sockeye, pink, and chum salmon. Trans. Am. Fish. Soc. 95:177-182.

Goede, R.W. 1993. Fish health/condition assessment procedures. Unpublished. Utah Division of Wildlife Resources, Fisheries Experiment Station. 31 pp. + appendices.

Graves, J.K. 20 May 1996. Personal communication [Revised Table 3 from Graves et al. (1995) faxed to Tad Deshler, Tetra Tech, Redmond, Washington). Columbia River Estuary Study Taskforce, Astoria, Oregon.

Graves, J.K., J.A. Christy, P.J. Clinton, and P.L. Britz. 1995. Historic habitats of the lower Columbia River. Columbia River Estuary Study Taskforce, Astoria, Oregon. 11 pp. + appendices.

Heaton, S.N., S.J. Bursian, J.P. Giesy, D.E. Tillitt, J.A. Render, P.D. Jones, D.A. Verbrugge, T.J. Kubiak, and R.J. Aulerich. 1995a. Dietary exposure of mink to carp from Saginaw Bay. 1. Effects on reproduction and survival, and the potential risks to wild mink populations. Arch. Environ. Contam. Toxicol. 28:334-343.

Heaton, S.N., S.J. Bursian, J.P. Giesy, D.E. Tillitt, J.A. Render, P.D. Jones, D.A. Verbrugge, T.J. Kubiak, and R.J. Aulerich. 1995b. Dietary exposure of mink to carp from Saginaw Bay. 1. Hematology and liver pathology. Arch. Environ. Contam. Toxicol. 29:411-417.

Henny, C.J., L.J. Blus, S.V. Gregory, and C.J. Stafford. 1981. PCBs and organochlorine pesticides in wild mink and river otters from Oregon. Worldwide Furbearer Conference Proceedings, August 3-11,

1980. Frostburg, Missouri, pp. 1763-1780.

Henny, C.J., R.A. Grove, and O.R. Hedstrom. 1996. A field evaluation of mink and river otter on the lower Columbia River and the influence of environmental contaminants. Prepared for Lower Columbia River Bi-State Water Quality Program. Forest and Rangeland Ecosystems Science Center, National Biological Service, Corvallis, Oregon. 64 pp. + figures and tables.

Hughes, R.M. and J.R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society 116:196-209.

Isaacs, F.B. and R.G. Anthony. 1993. Bald eagle nest locations and history of use in Oregon 1971 through 1993. Oreg. Coop. Wildl. Res. Unit, Oregon State University, Corvallis, OR. 14 pp., 5 tables, 1 figure.

Jarman, W.M., S.A. Burns, R.R. Chang, R.D. Stephens, R.J. Norstrom, M. Simon, and J. Linthicum. 1993. Determination of PCDDs, PCDFs, and PCBs in California peregrine falcons (*Falco peregrinus*) and their eggs. Environ. Toxicol. Chem. 12:105-114.

Jensen, S., J.E. Kihlstrom, M. Olsson, C. Lundberg, and J. Orberg. 1977. Effects of PCB and DDT on mink (*Mustela vison*) during the reproductive season. Ambio 6:239.

Karr, J.R., K.K Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5, Urbana, IL.

Krahn, M.M., L.J. Kittle, Jr., and W.D. MacLoed, Jr. 1986. Evidence for exposure of fish to oil spilled into the Columbia River. Marine Environmental Research 20:291-298.

Leonards, P.E.G., M.D. Smit, A.W.J.J. deJongh, and B. van Hattum. 1994. Evaluation of dose-response relationships for the effects of PCBs on the reproduction of mink (*Mustela vison*). Institute Environ. Studies, Vrije Univ, Amsterdam, Holland. 50 pp.

Nagpal, N.K. Water quality criteria for polychlorinated biphenyls (PCBs). Ministry Environ., Lands and Parks, Victoria, British Columbia.

Newell, A.J., D.W. Johnson, and L.K Allen. 1987. Niagara River biota contamination project: fish flesh criteria for piscivorous wildlife. Tech. Report. 87-3, New York State Dept. Environ. Conversation, Albany, New York. 182 pp.

Plafkin, J.L, M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish. EPA 444/4-89-001. U.S. Environmental Protection Agency, Assessment and Watershed Protection Division, Washington, D.C.

Pommen, L.W. 1989. Approved and working criteria for water quality. Water Management Branch, British Columbia Ministry for the Environment, Victoria, British Columbia. 38 pp.

Reimers, P.E. and C.E. Bond. 1967. Distribution of fishes in tributaries of the lower Columbia River.

Copeia 3:541-550.

Sanders, R.E. 1992. Day versus night electrofishing catches from near-shore waters of the Ohio and Muskingum Rivers. Ohio J. Sci. 92:51-59.

Schuler, C. 1994. Unpublished data. Sent to Kimberle Stark, Tetra Tech, Inc., Redmond, Washington. U.S. Fish and Wildlife Service, Portland, Oregon.

Tabor, J.E., B. Thompson, C. Turner, R. Stocker, C. Detrick, and J. Howerton. 1980. Study of impacts of project modification and river regulation on riparian habitats and associated wildlife along the Columbia River. Washington Department of Wildlife, Olympia, Washington. 769 pp.

Tetra Tech. 1992a. City of St. Helens discharge monitoring report: Accumulation of dioxins and furans in sediment and biota. Prepared for City of St. Helens, Oregon. Tetra Tech, Inc., Bellevue, Washington.

Tetra Tech. 1992b. James River Wauna Mill discharge monitoring report: Accumulation of dioxins and furans in sediment and biota. Prepared for James River Corporation, Wauna, Oregon. Tetra Tech, Inc., Bellevue, Washington.

Tetra Tech. 1993. Lower Columbia River Bi-State Program. Reconnaissance survey of the lower Columbia River. Task 6: Reconnaissance report. Prepared for Lower Columbia River Bi-State Committee. Tetra Tech, Inc., Redmond, Washington.

Tetra Tech. 1995a. Lower Columbia River Bi-State Program. Lower Columbia River backwater reconnaissance survey. Volume 1: Reconnaissance report. Prepared for Lower Columbia River Bi-State Committee. Tetra Tech, Inc., Redmond, Washington.

Tetra Tech. 1995b. Willamette River Basin Water Quality Study. Phase II. Ecological Monitoring Component: Assessment of aquatic communities and biological indices. Draft report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, Washington. 125 pp. + appendices.

Tetra Tech. 1996a. Assessing health of fish species and fish communities in the lower Columbia River. Prepared for Lower Columbia River Bi-State Program. Tetra Tech, Inc., Redmond, Washington. 61 pp.

Tetra Tech. 1996b. Assessing human health risks from chemically contaminated fish in the lower Columbia River. Risk assessment. Prepared for Lower Columbia River Bi-State Program. Tetra Tech, Inc., Redmond, Washington.

Thomas, D.W. 1983. Changes in the Columbia River Estuary habitat types over the past century. Columbia River Estuary Study Taskforce, Astoria, OR. 51 pp. + appendices.

Tillitt, D.E., J.P. Giesy, J.P. Ludwig, H. Kurita-Matsuba, D.V. Weseloh, P.S. Ross, C.A. Bishop, L. Sileo, K. Stromberg, J. Larson, and T.J. Kubiak. 1992. Polychlorinated biphenyl residues and egg mortality in double-crested cormorants from the Great Lakes. Environ. Toxicol. Chem. 11:1281-1288.

Tillitt, D.E., R.W. Gale, J.C. Meadows, J.L. Zajicek, P.H. Peterman, S.N. Heaton, P.D. Jones, S.J. Bursian, T.J. Kubiak, J.P. Giesy, and R.J. Aulerich. 1996. Dietary exposure of mink to carp from Saginaw Bay. 3. Characterization of dietary exposure to planar halogenated hydrocarbons, dioxin equivalents, and biomagnification. Environ. Sci. Technol. 30:283-291.

U.S. Army Corps of Engineers (U.S. ACOE). 1976. Inventory of riparian habitats and associated wildlife along the Columbia and Snake Rivers. U.S. ACOE, Walla Walla District, Walla Walla, WA. Three volumes (I, IIA, and IIB).

U.S. Army Corps of Engineers (U.S. ACOE). 1996. Lower Columbia River Bi-State Water Quality Program Fish, Wildlife and Wetlands GIS Habitat Mapping. U.S. ACOE, Portland District, Portland, OR. 26 pp. + maps and appendices.

U.S. Environmental Protection Agency (U.S. EPA). 1992a. Framework for ecological risk assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, D.C. EPA/630/R-92/001. 41 pp.

U.S. Environmental Protection Agency (U.S. EPA). 1992b. National study of chemical residues in fish. Volumes I and II. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, D.C. EPA/823/R-92/008a,b.

U.S. Environmental Protection Agency (U.S. EPA). 1995. Draft proposed guidelines for ecological risk assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, D.C. EPA/630/R-95/002.

U.S. Fish and Wildlife Service (USFWS). 1996. Interim report. Environmental contaminants in bald eagles nesting along the Columbia River estuary. Prepared for Oregon Department of Environmental Quality, Portland, OR. U.S. Fish and Wildlife Service, Oregon State Office. 29 pp. + attachment.

U.S. Geological Survey (USGS). 1992. Surface-water quality assessment of the Yakima River basin, Washington: Pesticide and other trace-organic-compound data for water, sediment, soil, and aquatic biota, 1987-1991. Open-File Report 92-644. U.S. Geological Survey, Portland, Oregon.

Watson, J.W., M.G. Garrett, and R.G. Anthony. 1991. Foraging ecology of bald eagles in the Columbia River estuary. J. Wildl. Manage. 55(3):492-499.

Wells, D.E. and A.A. Cowan. 1982. Vertebral dysplasia in salmonids caused by the herbicide trifluralin. Environmental Pollution (Series A). 29:249-260.

White, D.H. and J.T. Seginak. 1994. Dioxins and furans linked to reproductive impairment in wood ducks. J. Wildl. Manage. 58:100-106.

Wiemeyer, S.N., T.G. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.J. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs -- 1969-1979 -- and their relationships to shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 13(5):529-549.

Wiemeyer, S.N., C.M. Bunck, and C.J. Stafford. 1993. Environmental contaminants in bald eagle eggs-1980-1984 - and further interpretations of relations to productivity and shell thickness. Arch. Environ. Contam. Toxicol. 24:213-231.

Wydoski, R.S. and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle, Washington. 220 pp.

APPENDIX A

LIST OF RECOMMENDED FISH AND WILDLIFE STUDIES

PROPOSED BY

LOWER COLUMBIA RIVER BI-STATE WATER QUALITY PROGRAM

FISH AND WILDLIFE WORK GROUP

CONTAMINANT ASSESSMENTS -- STUDIES NEEDED

* Assessment of contaminant impacts on great blue herons. (1993-95) [USFWS, OSU]

* Evaluation of organic contaminants and impacts on nesting double-crested cormorants. (1993) [USFWS, EPA]

* Evaluation of impacts of organic contaminants and impacts on nesting bald eagles -- detailed food habits of this species need to be done to identify how, when, and where the pollution is causing problems. (1993-1994) [USFWS, EPA]

* Assessment of contaminants in mink and river otter -- detailed food habits of this species need to be done to identify how, when, and where the pollution is causing problems. [USFWS]

■ Detailed evaluation of bioaccumulation of contaminants in the fish and wildlife food chain -- best done by long-term study?

■ Detailed evaluation of bioaccumulation of contaminants in fish.

■ Fish health assessment above and below pollution sources.

■ Fish health assessment in regard for human consumption above and below pollution sources as well as river wide.

■ Evaluation of contaminant source by assessing contaminants in biota above and below pollution sources.

■ Fish and wildlife risk analysis.

■ Baseline data collected during different seasons.

■ Rapid bioassessment of health of the system.

■ Manipulation experiments to assess short-term bioaccumulation of contaminants relative to localized pollution sources.

■ Numerical modeling of sublethal pollution effects of prominent fish and wildlife populations, specifically carnivorous avifauna and anadromous juvenile salmonids.

A-1

- Nutrient loading from watershed, point and non-point sources and nutrient demand along mainstem river.

- Impacts of elevated water temperatures during the summer and fall months of both adult and juvenile salmonids.

HABITAT STATUS -- STUDIES NEEDED

* Quantification and analysis of habitats. [NOAA, NMFS, CREST]

- Assessment of habitat loss and its effect on fish and wildlife -- both quantification and assessment of habitat loss should be coupled and done together.

- Assessment of different habitat types and the importance of each.

- Assessment of methods to restore degraded and lost habitats.

- Effects of loss or degradation of habitat on fish and wildlife.

- Potential wetland and associated river floodplain habitat restoration sites.

- Evaluation of modern manipulation of river discharge on wetland function, particularly relative to restoration potential.

- Landscape ecology analysis of habitat fragmentation and corridor loss relative to fish and wildlife populations.

- Limitations of system productivity for resident and anadromous fishes based on understanding of limnology or trophic dynamics.

POPULATION STATUS AND TRENDS -- STUDIES NEEDED

* Status and trends of great blue heron populations. [USFWS]

- Population status of salmonids -- Specifically, migration demography and ecology of juvenile salmon from threatened and endangered stocks in the lower Columbia River.

- Population assessment of mink and river otter.

- Impacts of channel deepening.

- Impacts of regular dredging outside of the channel.

- Impacts of periodic dredging outside of the channel.

- Importance of shallow water (20 feet or less) areas.

- Impacts from creation of dredge soil islands.

- Importance of estuary to salmonids.

- Identification of critical habitats for fish and wildlife.

- Baseline biological information for important habitats.

- Inventory of slough and backwater habitats and impacts of developmental activities.

- Impacts of hybrid cottonwood farms on waterfowl foraging habitat and flood water retention.

- Expansion of shorebird population studies.

- Monitoring of colonial bird productivity.

- Monitoring of bald eagles: individuals, foraging, and territories.

- Distribution and population status of exotic species.

- Population status, movements and fisheries ecology of sturgeon.

- Food web relationships of prominent fish and wildlife populations.

LONG-TERM SAMPLING -- STUDIES NEEDED

The objective of the long-term program is to identify trends in various populations, changes in food webs, identification and effects of introduced exotics, relationships between physical factors and contaminants on biological population's health and food web integrity.

- Establish long-term sampling locations at representative habitats in the lower Columbia River and it's estuary:

  -Lower estuary bay habitat:
      Intertidal habitat
      Subtidal habitat

  -Lower estuary channel habitat:
      Intertidal habitat
      Subtidal habitat

  -Upper estuary bay habitat:
      Intertidal habitat
      Subtidal habitat

A-3

-Upper estuary channel habitat:
        Intertidal habitat
        Subtidal habitat

-Lower river channel habitat

-Lower river slough habitat

-Upper river (near Willamette River) channel habitat

-Upper river (near Willamette River) slough habitat

■   Long-term data collections at these habitats should include:

-Fish collections:
        Fish densities
        Fish species composition
        Fish food habits
        Fish contaminant loads by species

-Invertebrate collections (includes plankton, epibenthos, and benthos):
        Invertebrate densities
        Invertebrate species composition
        Invertebrate contaminant loads by species

-Bird and mammal surveys:
        Bird and mammal densities
        Bird and mammal species composition
        Bird and mammal contaminant loads by species

-Phytoplankton and macrophyte collections:
        Phytoplankton and macrophyte densities
        Phytoplankton and macrophyte species composition

-Major avifauna surveys:
        Food web studies -- what they consume as top predators

-Physical collections:
        Water quality

[a] Recommendations by Robert Emmett, NMFS; Ray Beamsderfer and Donn Bennett, ODFW; Charles Simenstad, University of Washington, FRI, and Jon Graves, CREST.

Note: * = Information needed, partially funded.
        ■ = Information needed.

APPENDIX B

LIST OF RECOMMENDED FURTHER ACTIONS PROPOSED BY THE

LOWER COLUMBIA RIVER BI-STATE WATER QUALITY PROGRAM

FISH AND WILDLIFE WORKGROUP

LOWER COLUMBIA RIVER BI-STATE
WATER QUALITY PROGRAM
-- DUPLICATE REDUCED RECOMMENDATIONS LIST
NEEDING FURTHER ACTIONS   --

WORK GROUP RECOMMENDED CATEGORIES
(December 4, 1995)

<u>FISH, WILDLIFE, AND HUMAN HEALTH</u>

1.   Technical Findings/Summary

2.   Bi-State Response:

    a.   Goals:

    b.   Priorities/Criteria:

    c.   Action Agenda -- Specific Recommendations:

    o   <u>Policies.</u>

    o   <u>Information (Monitoring/Data Management Needs).</u>

       1.   Summarize the status (population characteristics,
           potential problems, etc.) of migratory and resident
           fish.

       2.   Investigate induction of mixed-function oxygenase
           (MFO) enzymes in selected fish and avian species.

       3.   Monitor for exotic species (zebra mussels).

       4.   Estimate human and wildlife health risk using
           tissue data from the reconnaissance survey and
           other studies.

       5.   Expand tissue contaminant analysis to other
           species, emphasizing those commonly consumed by
           humans and wildlife.

6. Based on reconnaissance survey and the following years' studies, make recommendations for species to use for bioaccumulation monitoring for specific types of chemicals.

7. Conduct tissue contaminant studies of piscivorous wildlife; conduct studies on the diet of piscivorous wildlife and fish; estimate consumption rates; target diet species for bioaccumulation studies.

8. Conduct tissue contaminant studies for aquatic vascular plants and algae, emphasizing those known to be consumed by herbivores.

9. Conduct tissue contaminant studies on the amphipod **Corophuim**, a principal food species for salmon smolt.

10. Conduct "mussel watch" type bioaccumulation studies by placing "clean" freshwater clams (**Corbicula**) in cages at locations of interest for [a] period of time, and then collect and analyze tissues. Place upstream and downstream of major sources/source areas.

11. Conduct basic biology studies for bioaccumulation target species.

12. Develop sediment bioassay procedures using endemic test species.

13. Conduct additional studies to determine the current status of migratory and resident fish populations in the river.

14. Determine the fundamental processes regulating fisheries production in the river.

15. Sample the benthic boundary layer material and analyze for contaminants.

16. Prepare fish and wildlife risk assessment plan of study.

17. Rapid bioassessment in backwater areas.

18. Fish health assessments and evaluation of sources by assessing biota above and below.

19. Determine the carrying capacity of the lower river ecosystem.

20. Food web characterization and distribution and abundance evaluation of selected species.

21. Conduct tissue contamination analysis on salmonids, including juvenile fish migrating downstream.

22. The collection of fish consumption data should be a high priority for future data collection efforts.

23. Dioxins/furans and pesticides/PCBs may be quantified using only two different analytical methods. To maximize cost-effectiveness, future monitoring efforts directed toward the collection of data for human health risk characterization should focus only on these two analytical groups.

24. A comprehensive ecosystem approach to understanding the chemical contaminants impacting fish, wildlife, and human consumption must include the entire Columbia Basin throughout Oregon, Washington, Idaho, British Columbia and Montana.

25. Selection, development and data compilation for a GIS system for management of fish and wildlife issues.

26. For future studies using these assessment techniques, (fish autopsy and skeletal abnormality), either separate standardized sampling transect distances should be established or additional discretion given to field personnel to select sampling locations within a broader area to minimize sampling efforts in unsuitable locations.

27. The high bacterial densities observed at Stations 5 and 6 may require further investigation to determine the source of contamination and the potential human health risks.

28. Conduct additional sampling of sediments & tissues in the wildlife refuge areas of the upper estuary.

29. Future studies should continue to sample both sediments and tissue, in addition to water. The importance of this is shown by the fact that while PCBs are generally undetectable in water using standard laboratory methods, and were detected at only 3 of 69 stations sampled in the two surveys,

they were detected in all fish samples in both surveys.

30. To understand the interactions of contaminants, the lower trophic level of species (aquatic insects, clams, etc) should be included in the inventory and reconnaissance surveys.

31. The original study design (See Section 2.1) called for the collection of composite samples from two resident game species (smallmouth bass and walleye). Future sampling should be conducted in spring or summer so that these important game species can be evaluated.

32. The risk estimates provided for the three nonresident salmonid species were all based on data from three composite samples for each species. The collection of additional samples from these species could reduce the uncertainty in the mean chemical concentration calculated from the original three samples.

33. The individual sturgeon samples analyzed for this risk assessment were from fish less than 48 inches in length. Current fishery regulations allow individuals to keep one fish between 40 and 48 inches and one fish between 48 and 66 inches. Future sampling efforts should include the collection of fish from the larger size class.

34. The original study design called for the collection of 9 composite samples of carp. Only one sample was collected because of the season in which sampling took place. Future collection efforts should focus on collection of additional composite samples for carp.

35. There is a critical need for a regional assessment of fish consumption practices in the lower Columbia River Basin. Such an assessment should include information about the species consumed, the amounts consumed, and how the fish are prepared. ·

36. The carcinogenic and noncarcinogenic risk estimates for PCBs are based on a single slope factor and reference dose, respectively. Each of the seven Aroclor mixtures analyzed for this risk assessment are composed of a different assemblage of some of the 209 PCB congeners. Analysis of fish samples for these congeners should be considered for future

risk assessments so that a more precise estimate of risk from these toxic chemicals can be made.

37. The subject of risk from the consumption of fish is of great interest to many people. A monitoring program should be established to periodically sample lower Columbia River fish species which are consumed by people.

38. Research effort should be focused on the Portland-Vancouver area along the Lower Columbia river between RM 117-126 where the highest residues were found in river otter tissue collected during this study, and where 3 of 4 otter collected in the general vicinity had obvious physiological or pathological abnormalities.

39. Effort should be made to live-trap as many as 24 river otter estimated in this 9 mile segment, as well as an adequate number from a Reference Area. Proposed field research should be conducted over a 2-year period during the months of December through February in an attempt to minimize seasonal changes in physiological reproductive readiness which may complicate data interpretation. Proposed research would focus on five areas:
    (1) Blood samples will be taken from anesthetized (live) otters for complete blood chemistry work-up and differential blood cell count to characterize general animal condition, pertinent endocrine levels, and immunological competence.
    (2) A complete necropsy will be performed in the field to obtain morphometric data, and collection of tissues for enzyme assays, chemical analyses, and histopathy.
    (3) Analyze fat and liver samples collected for dioxins, furans, and PCBs, and kidney samples for metals.
    (4) Conduct assays to measure xenobiotic phase I and phase II metabolic enzyme activities (e.g., EROD, BROD, AHH) to identify possible induction of these enzymes resulting from contaminant exposure. Further character-ization of contaminant exposure could be evaluated using rat hepatoma cell enzyme bioassays to assess toxic potencies of residue extracts from river otter and fat samples.
    (5) Examine possible endocrine disruption of target tissues via currently accepted methodologies.

40. How much of the pollutant exposure of migratory fish occurs while in fresh water or in marine water?

41. NMFS should evaluate the potential for exotic invertebrate introduction into the Columbia River and its estuary and seek appropriate corrective measures.

42. NMFS should initiate a study to determine juvenile migration and area use patterns within migratory habitat.

43. The EPA should evaluate water quality in the mainstem and estuary habitats and develop or modify control mechanisms for protecting listed species.

44. NMFS, BPA, COE, and BOR should cooperate in investigating the environmental requirements of juvenile salmonids in the estuary and near shore ocean, including making an assessment of the relationship between fluctuations in estuary and ocean environments and salmon abundance.

45. BPA. Fund an evaluation of tributary, mainstem (including reservoirs), estuary, plume, near-shore ocean and marine salmon survival, ecology, carrying capacity and limiting factors.

46. BPA. Fund development of a study plan based on the critical uncertainties and research needs identified in the above evaluation.

47. Specific studies should be initiated to measure mortality occurring in salmon as they pass through the estuary and identifying estuarine factors affecting that mortality.

48. Current biological assessment efforts should be expanded.

49. A program of bioassays would help determine whether current patterns and levels of dissolved gases are causing deleterious effects.

50. Sturgeon population and ecology studies.

51. The transport, binding, and transformation of such contaminants (organochlorines) under conditions along the LCR (Lower Columbia River) have not been determined. Neither has the binding of heavy

metals and dioxin been determined, although a similar path (phytoplankton uptake) is not unlikely.

52. No work has been done on contaminants and zooplankton in the Columbia. As with *Asterionella*, movement and distribution patterns may help clarify related contaminant patterns in the LCR. These taxa may well include *Corophium*, a favored prey of suckers, juvenile chinook, and birds. the pathways of accumulation are still not empirically clear, however.

53. Juvenile chinook are an important prey resource for many LCR predators such as squawfish, walleye, bald eagles, bass, cormorants, mergansers, grebes, and other birds. The role they play in contaminant concentration and transfer has not been studied. Several studies address effects of heavy metals, but not the potentially critical sublethal effects.

54. Another area for investigation is the differences in habitat use and bioaccumulation of contaminants of hatchery versus wild salmon.

55. From such considerations, priority studies include:
    o contaminant concentrations in phyto/ zooplankton;
    o adsorption patterns of organochlorines and dioxins under varying physical environments;
    o toxic effects of contaminants on *A. formosa* and *E. affinus*;
    o the community structure of phyto/zooplankton at various river sites;
    o cycling, flushing, and sediment patterns of different patterns of different contaminants in the LCR;
    o retention of contaminants in *E. affinus* in the estuarine mixing zone;
    o contaminant uptake, abundance, and production of *C. salmonis* in polluted and unpolluted waters;
    o determinants of tube evacuation in *C. affinus*;
    o lethal and sublethal effects of contaminants on juvenile chinook (salmon);
    o factors (physical, morphological, physiological) influencing contaminant uptake in juvenile chinook (e.g. water temperature, residency and mobility);
    o food web energetics and efficiency;
    o stock distribution and relative vulnerability

of chinook;
  o   relationship of chinook contamination, rates
      of predation by chinook consumers, and
      contaminant profiles in these predators.

56. Recommendations (Bald Eagles):
  o   trophic web studies in selected sampling
      zones;
  o   determinants of bald eagle prey selection;
  o   effects of various contaminants on eagles and
      their prey under various controlled conditions
      of stress, metabolism, and environment;
  o   a system simulation of rates and variables in
      the LCR bald eagle ecosystem.

57. Recommendation (River Otter):
  o   current population densities and dynamics;
  o   sensitivity of different population segments
      to different contaminants;
  o   the seasonal contaminant burden;
  o   the extent of specific contaminant
      bioaccumulation.

58. Expand the current scope of studies to specifically
    address fish and wildlife issues in the Lower
    Columbia River.

59. A. priori determination of suitable reference sites
    for comparison. this might be helped by more
    sampling effort at main channel sites, to determine
    if these sites may serve as reference sites.

60. Earlier sampling, to minimize sampling of females
    undergoing gonadal maturation. This was the
    intention of this study, but unforeseen delays in
    obtaining sampling permits precluded earlier
    sampling. (And) Increased sampling effort, to
    assure collection of minimum numbers of fish of
    both sexes at each site.

61. Chemical analysis of stomach contents and surficial
    sediments, to determine the presence of aromatic
    contaminants in the fish's habitat.

62. Consideration of other species for sampling,
    including piscivorous species such as northern
    squawfish, which may have a greater potential for
    bioaccumulation of persistent halogenated aromatic
    contaminants.

63. Determine and establish long-term sampling locations at representative habitats. Long-term data collected at these sites should sample for fish, mammals, birds, etc.

o **Administrative Structures.**

o **Immediate Action.**

1. Develop a proposed policy to avoid introduction of exotic species (zebra mussels) into the Columbia River.

2. Washington Department of Health and the Oregon Health Division should determine whether a health advisory is necessary or appropriate.

3. NMFS should critically review proposals for in-water construction to ensure that no habitat destruction occurs, that methods are used where possible to increase habitat values, and that work will not adversely affect salmonids.

4. States and Federal Agencies. Based on existing information, identify management measures that can be implemented immediately to provide better protection and improve estuarine productivity.

5. Council. Begin rulemaking in December 1995 to identify measures aimed at improving estuary conditions and survival for salmon and steelhead.

SYNTHESIS / SUMMARY

CRRECCAT.WG3