FINAL REPORT

LOWER COLUMBIA RIVER BI-STATE PROGRAM

CONTAMINANT ECOLOGY OF FISH AND WILDLIFE OF THE LOWER COLUMBIA RIVER

Summary and Integration

APRIL 1996

ACKNOWLEDGEMENTS

This report builds on the earlier reports that were completed by the Columbia Basin Fish and Wildlife Authority's subcontractor - Nora and Steven Berwick of WILDSystems. These reports are: Lower Columbia River Basin Bi-State Water Quality Program Fish and Wildlife Literature Review (July 29, 1994) and Contamination Ecology of Selected Fish and Wildlife of the Lower Columbia River (draft - October 14, 1994). WILDSystems completed a first draft of this report, which integrates all of the Bi-State fish and wildlife studies, on November 17, 1995, and a second draft in February 1996. We express our deep appreciation to the WILDSystems staff.

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LOWER COLUMBIA RIVER CONTAMINANT ECOLOGY - COMBINED BI-STATE FISH AND WILDLIFE REPORT

SUMMARY AND INTEGRATION

The Bi-State Water Quality Program's goals include an assessment of the impacts of contaminants on fish and wildlife in the Lower Columbia River (LCR). Our objective was to compile and synthesize available published, unpublished reports, and observations of experts on key fish and wildlife species, and selected trophic representatives. Potential impacts of contaminants to fish and wildlife may include chemical effects, biological effects, and habitat-related effects. This report attempts to analyze and synthesize these data, identify weaknesses in the data base, and formulate recommendations for further activities.

Four target species were selected by the fish and wildlife working group of the Bi-State Steering Committee: largescale sucker (*Catostomus macrocheilus*), bald eagle (*Haliaeetus leucocephalus*), mink (*Mustela vison*), and northern river otter (*Lutra canadensis*). Mink, river otter, and bald eagle are resident carnivores in the LCR from the top of the aquatic web that feed mainly on fish. The largescale sucker was selected because it is a long-living resident fish and is the prey of numerous bird and mammalian predators. Its feeds by sieving through bottom sediments where many contaminants persist. In the LCR, all of these target species are exposed to relatively high levels of pollutants and subject to the biomagnification of several contaminants.

Studies on the target species funded by the Bi-State Program were conducted by the U.S. Fish and Wildlife Service (USFWS 1996) on bald eagles and by the National Biological Service on the mink and otter (Henny *et al.* 1996). The largescale sucker studies were not exclusive to that species. The National Marine Fisheries Service (Collier *et al.* 1996) assessed the exposure of largescale suckers to aromatic compounds. Tetra Tech (1996a) assessed the health of fish species and communities in the LCR by three methods. LCR habitat was addressed by the U.S. Army Corps of Engineers (1996) and the Columbia River Estuary Task Force (Graves *et al.* 1995). Changes in the physical characteristics of the LCR were evaluated using old surveys, maps, and aerial photographs.

In addition to the four target species a phytoplankton (*Asterionella formosa*), zooplankton (*Eurytemora affinis*), benthic/epibenthic gammarid amphipod (*Corophium salmonis*), and chinook salmon (*Onchorynchus tshawytscha*) were selected to represent other significant trophic levels in the LCR for the characterization and analysis because of their importance to energy flows between populations in the LCR food web.

The literature for hundreds of reports on the eight species were reviewed, assessed, and summarized (Columbia River Basin Fish and Wildlife Authority and WildSystems 1996). However, the field studies are somewhat disparate, and correlations, consistencies, and links between all of the species studied were not always easy to discern.

BIOCIDE ISSUES AND ECOLOGY

Chemical pollutants can affect fish and wildlife in the water itself, sediment on the bottom, or in the tissues of prey that have assimilated pollutants. Many contaminants tend to concentrate in sediments and because of their chemical nature tend to concentrate in animal tissues even more than sediments. Not only the health of individual fish and wildlife species are of concern. The overall health, community structure, range, and breeding success of a species may be at risk. The most serious impacts to fish and wildlife may be from habitat loss or degradation. Several species that migrate through or inhabit the LCR are listed pursuant to the Endangered Species Act of 1973, including Snake River sockeye salmon, Snake River fall chinook salmon, Snake River spring/summer chinook salmon, and bald eagle.

Dioxins, DDT and many other compounds do not readily breakdown into other less harmful chemical compounds and can accumulate in the fatty tissues of animals when ingested. Routes of contaminant uptake include direct uptake of dissolved constituents from the water column, uptake of dissolved constituents via exposure to contaminated sediment, and uptake via ingestion of contaminated food. When animals are eaten by others, the concentrations of these compounds increase rapidly. Therefore, animals at the upper end of the food chain tend to have much higher concentrations of contaminants in their tissues. This effect is called biomagnification.

CONTAMINANT SOURCES: Contaminants enter the LCR through waste water, discharges to the air from combustion sources, storm water runoff, or by seeping from landfills that contain contaminated waste. Tetra Tech (1995) identified a total of 54 point sources discharging directly into the LCR. There are also 102 point sources in the lower 16 miles of the LCR tributaries (U.S. Geological Survey 1995). These contaminant sources include 19 municipal waste water treatment plants, 3 fish hatcheries, and 32 industrial sites, including 3 aluminum, 2 chemical, and 6 pulp and paper plants. The lower 25 miles of the Willamette River has 38 combined sewage overflow outfalls.

LCR contaminant non-point sources include surface runoff, sewer overflows, atmospheric inputs of polluted air, spills, agriculture, etc. A number of minor point and non-point sources of waste water range from small factories to individual residences. Seventeen hazardous waste and Superfund sites and eighteen landfills are potential sources of pollutants within a mile of the lower river. Over half of the waste water discharged is from pulp and paper mills, one-third is from municipal discharge, and eight percent is from major chemical industries. The increase in trace metal concentrations in the environment is largely due to coal burning, fungicides, chlorine production, and mining. Increases in the use of such products as electrical equipment, agricultural fungicides, and chlorine has led to four-fold increases in mercury in some river systems.

The Bi-State program has tested for nearly 80 chemical compounds and trace elements in the LCR. Concentrations of pesticides in water are controlled by solubility, adsorption -

desorption, partitioning, hydrodynamics and other factors. However, patterns of contaminant distribution, dispersal, and fixing, which could concentrate contaminants, are not well understood.

Concern about dioxins and furans in the LCR began when the U.S. Environmental Protection Agency reported high concentrations in fish collected in 1978. Sources of dioxins in the Columbia River include pulp and paper mill waste water treatment plants that use chlorine compounds to bleach wood pulp; municipal waste water treatment plants; combustion processes, such as cars, wood stoves, fireplaces, and incinerators; and wood treatment facilities. PCBs and chlorinated hydrocarbons (DDT, endrin, chlordane) originate from paint, tire wear, coolants and plastic production. Heavy metals originate from sewage, fuels, and industrial processes, and pesticides (DDT, malathion) from agricultural applications.

EFFECTS: The primary insidious carcinogenic, behavioral, cirrhotic and other effects of such organochlorine compounds are cumulative and long-term. For example, PCBs produce numerous effects including weight loss, edema, hepatotoxicity, immunotoxicity, decreased reproductive success, teratogenicity, promotion of cancer and enzyme induction (Sanderson *et al.* 1994). This brief list of potential effects of contaminants on the LCR and its fish and wildlife resources is by no means complete.

Mercury is concentrated between 10,000 and 80,000 times in fish and subsequently consumed by wildlife such as eagles, mink, and river otter. LCR common carp (*Cyprinus carpio*) were found to average 219 ug/kg (219 ppb, Tetra Tech 1995), about 100 times the permissible level for aquatic organisms. Even at low concentrations, mercury and its organic compounds present potential hazards on nervous system tissue due to enrichment in the food chain.

The most potent form of dioxin is 2,3,7,8-TCDD. Several studies report that it and related toxic halogenated aromatics elicit a number of toxic responses similar to PCBs, which include weight loss, thymic atrophy, impairment of immune responses, hepatotoxicity and porphyria, cloracne and related dermal lesions, tissue-specific hypo- and hyperplastic responses, carcinogenesis, teratogenicity, and reproductive toxicity (Safe 1990).

Much of the gentle-sloping land in Columbia River Basin is devoted to agricultural production. In addition to land disturbing activities, reduced fertility and associated soil chemistry change associated with pesticides may accelerate erosion and sedimentation rates. Ecosystem effects may also include reduced soil fertility through depressing microorganism populations which generate the fertility. Nitrification is crucial for the content of inorganic nitrogen in soil and hence is of considerable ecological importance. The first step in the nitrification process in soil, the oxidation of ammonium to nitrate, is particularly sensitive to chemicals. Dithiocarbamate fungicides have been found to have the most pronounced inhibition of ammonium oxidation (Hansson *et al.* 1991).

Pesticides which are applied to the soil become enmeshed in the transport and degradation processes. The transport process includes the movement of dissolved or particulate-sorbed pesticides in water by leaching, convection, and diffusion. Saiki *et al.* (1992) demonstrated that survival and growth of juvenile chinook salmon and striped bass (*Morone saxatilis*) were reduced when exposed to agricultural subsurface drainwater which contained elevated concentrations of major ions and trace elements.

LOWER COLUMBIA RIVER AQUATIC HABITAT CHANGES

The LCR has experienced a variety of human impacts that have profoundly changed its physical, chemical and biological characteristics. Since the beginning of this century, these impacts include dredging for river transport, diking for land reclamation, dams for hydropower, irrigation, forestry and grazing on erodible slopes and riparian areas. For the past 25 years, between 5 and 10 million cubic meters of material have been dredged annually (Sherwood 1990; Simenstad *et al.* 1984).

LCR flows are a function of the health and storage in the 30 subbasins that contribute to the Columbia River. The upper basins contribute about 75 percent of the river's discharge. About 25 percent of the total runoff enters the river below Bonneville Dam by tributaries including the Sandy, Willamette, Lewis, Kalama, and Cowlitz rivers (Tetra Tech 1996b). From 1900 to 1980, the area under irrigation in the Columbia River Basin has increased from 2,000 to 32,000 km^2. The Yakima River, which is typical of many of the Columbia River tributaries, goes from about 6,000 cfs in spring to 100 cfs during the fall peak of irrigation withdrawals (USGS 1992), reducing both water quantity and quality. About half of the water withdrawn for irrigation is returned to the Yakima River with a new burden of agricultural chemicals.

The construction of over 200 dams on the Columbia River and tributaries has also had a fundamental effect on the quality, quantity, flow, and timing of water along the river (Figure 1). Additionally, upstream land uses such as forestry and the clearing of willow/dogwood/cottonwood riparian meadows for hay production has a fundamental influence on water temperature, pumping, storage and provision. Reducing flows to estuaries, particularily during the spring when flows are greatest, also decreases their productivity. Rozengurt and Haydock (1981) indicate that no more than 24-30 percent of historical river flow to an estuary can be diverted without ecological consequences to the receiving estuary. Daily flows at Bonneville Dam have decreased by about half since 1950, when they averaged about 500,000 cfs. Water temperatures have also increased from 65 to 70^0F (Northwest Power Planning Council 1994).

CHANGES TO HISTORIC LCR FISH AND WILDLIFE HABITAT: The Columbia River Estuary Task Force (Graves *et al.* 1995) and the Corps of Engineers (Corps - 1996) compared historical and existing wetlands, riparian, vegetation, and important and critical fish and wildlife habitat areas within two miles (3.2 km) of the mainstem LCR using 19th

Figure 1. Some of the major dam and reservoir projects in the Columbia River Basin.

century government surveys and 20th century aerial photographs. The results of the interpretation were digitized into a geographic information system (GIS) and analyzed to determine losses and gains of the interpreted habitat classes, between the 1880s and 1991 and from 1948 through 1991. Additionally, the Corps identified significant disturbed and undisturbed habitats with the potential for rehabilitation or enhancement.

Approximately 267,000 acres of natural vegetation and water types of the LCR estuary have been altered from the historic land type (Corps 1996). The amount of land in the LCR corridor that is now utilized for agriculture has increased from zero to 58,000 acres. Over half of the LCR tidal swamp and marsh areas have been lost. Wetlands, grasslands, and deciduous forest have decreased substantially, while barren, scrub, coniferous, and urban land have increased substantially. Over 75 percent of the tidal marshlands in the Columbia estuary have been lost over the last century. Since 1948, the most notable habitat changes seem to have occurred from RM 46.5 to 146.8, with a rapid increase in urban/developed.

These changes represent such a large proportion of the LCR estuary that some functions of wetlands may be affected, such as its ability to detoxify and cleanse water-borne contaminants and provide nurseries, forage and cover for fish and wildlife. The role of wetlands to detoxify contaminants has not well studied in the LCR. An assessment of the effect of these habitat losses (modifications) and changes to flows and water quality on fish and wildlife have also not been adequately evaluated. However, the relative abundance of resident and introduced warm water species has increased at the expense of cold water species such as salmon.

ECOLOGY AND CONTAMINATION OF REPRESENTATIVE SPECIES

PHYTOPLANKTON- *Asterionella formosa*

As primary producers, phytoplankton capture sunlight and convert it into a usable form within the food chain. They are grazed on by water-column suspension feeders such as small micro-crustaceans. Columbia River estuary phytoplankton are composed primarily of freshwater diatoms and *Asterionella formosa* is the most abundant species (Frey *et al.* 1984). Timing of the spring bloom may vary depending on factors such as freshwater flows, residence time of dam trapped water, and day-length, turbidity, nutrient and temperature differences (Amspoker and McIntire 1986).

In the LCR estuary, the annual water column primary production of phytoplankton is low compared to other estuaries. Light appears to be the principal limiting factor on primary production because of the frequent occurrence of turbidity and cloud cover. However, the LCR estuary appears to have high rates of productivity. Phytoplankton biomass is supported by import more than in-estuary production. The residence time of Columbia River waters and phytoplankton is between two and five days, while in the Delaware or Narragansett Bay resident time can be up to three months (Lara-Lara *et al.* 1990). Only one percent of the phytoplankton biomass is consumed by zooplankton and most of the rest settles at the salt wedge where salinity causes mortality (Frey *et al.* 1984). However, as detritus they are an important diet item for primary consumers.

Microflora can incorporate and accumulate metals, such as mercury, and other toxins, such as PCBs or DDT, into their cells from the aquatic environment. *Asterionella formosa* effectively ab/adsorbs some pollutants. Depending on pH, up to 50 percent of the zinc in the water is removed by this species (Reynolds and Hamilton-Taylor 1992).

ZOOPLANKTON - *Eurytemora affinis*

Although the Columbia River has substantial tidal influence, high river flow rates, and therefore, high flushing rates, the epibenthic copepod *Eurytemora affinis* is present in the LCR estuary mixing zone throughout the year in relatively high abundance. It is important in the diets of many juvenile fish and larger invertebrates. Peak survivorship is between low salinity and 20 parts per thousand. *E. affinis* abundance can be explained by a high reproductive rate, refuge in bays and other inlets, vertical migration, or passive transport in water moving upstream (Bottom and Jones 1984; Hough and Naylor 1991).

E. affinis appear to move up the estuary during low flows of late summer and are important in the diet of many juvenile fish and large invertebrates (Simenstad *et al.* 1984). *E. affinis* grazes on phytoplankton and other water born organic particles and can remove up to 1.2 percent of the total phytoplanktonic carbon available per day (Frey et al. 1984).

Dawson (1979) indicates that the degree of toxicity of heavy metals on *E. affinis* depends on the form of the metal in the water, the presence of other metals acting synergistically, environmental conditions, and life history stage of the organism. Effects can be lethal or sublethal. Feeding rate and egg production appear to be the factors most sensitive to sublethal quantities of heavy metals. The implications of sublethal effects in copepods can include morphological change, inhibitory effects on growth and development, and behavioral change.

Mercury has been identified as moving through the food chain from nearshore phytoplankton to offshore consumers. There appears to be little difference in copepod sensitivity to mercury nearshore or offshore. Copper and mercury can act synergistically to multiply the effects of heavy metal concentrations in copepods (Dawson 1979).

PCBs do not appear to be concentrated from zooplankton to fish up the trophic structure. DDT is concentrated through trophic levels from plankton to birds, although other evidence suggests DDT concentration depends on species-specific trophic interactions (Dawson 1979). *E. affinis* is also very sensitive to tibutyltin (TBT)(Bushong *et al.* 1988).

CRUSTACEAN AMPHIPOD - *Corophium salmonis*

Epibenthic zooplankton are crucial components of the estuarine food web through their transfer of water column borne particles to higher trophic levels. In the LCR, they produce approximately 64.7 mt C yr^{-1}. Thirty-nine percent of production occurs in tidal flats, 36 percent in dermersal slope, and 25 percent in channel bottom. The high production of epibenthic zooplankton in the mixing zone is an important food source for motile macroinvertebrates and other secondary consumers (Simenstad *et al.* 1984).

The benthic/epibenthic amphipod crustacean, *Corophium salmonis,* is found in high densities in fine sediments located in shallow bays and shoaling areas of the central and upper LCR estuary. *C. salmonis* distribution may be highly dependent on sediment type and salinity. It prefers salinity less than 10 parts per thousand and is more frequent in the central and upper estuary in riverine areas than near the estuary mouth or bays near the river mouth (Williams 1983; Holton *et al.* 1983). Some areas of the LCR may produce two generations a year - spring and fall. Reproduction appears to be stimulated at temperatures above 7^0C (Holton *et al.* 1984).

Corophium are deposit feeders that scavenge and consume diatoms and detritus (Holton et al. 1984). They are an important food item for many fishes, including juvenile chinook salmon, and invertebrates, waterfowl, and other consumers (Holton *et al.* 1984; Vermeer et al. 1993). At two sample sites in the LCR, the huge majority of production (>90 precent) was contributed by *C. salmonis* (Holton *et al.* 1984). Male *C. salmonis*, which are significantly shorter than the females, are sampled in higher densities in the water column. Because of the behavior of leaving their tubes to look for mates, the males may also be eaten more by predators than females (Williams 1983).

Some copepods have been found to metabolize DDT (Addison 1976), but no literature was located that documented this in C. salmonis. *Corophium* appear to be very sensitive to chlorinated hydrocarbons and heavy metals, especially DDT, PCBs, mercury and copper (Reish 1993). However, it seemed to tolerate and concentrate dioxins near a Vancouver Island pulp and paper mill, generating bioaccumulated levels in avian predators such as mergansers and grebes (Vermeer *et al.* 1993). Vermeer *et al.* (1993) found the ratios and concentrations of dioxin and furans similar in *Corophium* and the contaminated sediment samples where they lived.

JUVENILE CHINOOK SALMON - *Onchorynchus tshawytscha*

The two forms of chinook salmon (*Onchorynchus tshawytscha*) have different life histories and vulnerability to contaminants. Juvenile spring/summer chinook spend a year or more in fresh water and then range far to sea until returning to natal streams to spawn and die (Healey 1991). About 3 months after emergence, juvenile fall chinook migrate downstream. Fall chinook salmon fry concentrate near shore in shallow water during the day and migrate off shore at night. In most estuaries, juvenile fall chinook salmon rear for several months, gaining 3 to 10 percent of body weight per day, and adapt physiologically to ocean salinity (Healey 1982). The main prey items for juvenile chinook and chum salmon (*O. keta*) in the estuary are benthic and epibenthic insects, crustaceans and copepods (Simenstad *et al.* 1982).

The effects of contaminants reflect both pollution level and resident times of the fish - i.e. fall chinook may be at higher risk in the estuary whereas spring chinook depend upon the quality of the upper watershed. Losses to other predators such as salmonids, birds, and seals is proportional to habitat complexity and alterations. The importance of Northern squawfish (*Ptychocheilus oregonensis*) as a salmon smolt predator reflects conditions such as transit time and visibility, now increased by extensive (up to 76 miles long) reservoirs behind the mainstem Columbia River dams. Likewise, the reservoir-favoring Cladoceran water flea, *Daphnia* has replaced the amphipod *Corophium* in importance as a food item (Rondorf *et al.* 1990). They are found more at the surface resulting in higher predation of salmon. *Corophium* are the major food item for juvenile salmon in the intertidal areas of many estuaries throughout the northwest (McCabe *et al.* 1983, Reimers et al. 1978).

Heavy metals and pesticides are very toxic to young salmon and concentrations of PCBs and aromatic hydrocarbons in amphipod prey are up to 4 and 650 times controls (McCain *et al.* 1990). More recently, the National Marine Fisheries Service has published a number of papers on the potential for DNA damage, cytochrome P450 activity, and impaired immunocompetence in juvenile salmon and other estuarine fish species urban estuaries as a result of contaminant exposure.

LARGESCALE SUCKER

Largescale suckers are very mobile and distributed throughout the LCR down into brackish water (Reimers et al. 1967). They live to about 20 years and can achieve a length of 61 cm and a weight of 3.2 kg (McPhail and Lindsey 1970). Therefore, they can accumulate contaminants over a long period. In the Hanford Reach largescale sucker are the dominant resident fish species with densities up to almost 15,000/km. Largescale suckers are sexually dimorphic (Dauble 1986). Salmon, bald eagles, river otter, and mink all prey on largescale suckers.

LARGESCALE SUCKER HABITAT: Mass spawning occurs in May and June at water temperatures of 12-15°C in areas characterized by rapid flow over gravel where freshets are common (Nelson 1968). The larval stage is pelagic and common in nearshore areas of low velocity. Yearlings are found to be most abundant in backwater areas at depths less than one meter or cobble bottoms of a main river (Dauble 1986).

LARGESCALE SUCKER DIET: Largescale suckers sieve bottom sediments for insect larvae, salmon eggs, and benthic plankton. They are opportunistic and omnivorous, feeding almost entirely on benthic organisms and organisms associated with bottom vegetation. Juveniles eat plankton and aquatic insect larvae mixed with small quantities of bottom ooze (Dauble 1986).

CONTAMINATION LEVELS IN LARGESCALE SUCKER: Schmitt *et al.* (1985) and Schmitt *et al.*(1990) measured levels of organochlorine residues in largescale sucker in 1980-81 and 1984, respectively, that had dropped since the 1970s. At 22 of 32 stations sampled for largescale sucker, Tetra Tech (1994b) detected PCBs above reference levels, indicating the potential for adverse effects on fish-eating wildlife. However, levels of contaminants measured in aquatic biota in the reconnaissance surveys are generally lower than corresponding levels measured nationwide. Two organic compounds exceeded the highest concentrations measured in any sample in the U.S. They detected arsenic, cadmium, chromium, lead, mercury, and selenium in largescale suckers at various LCR backwater sites. Relative proportions of DDT, DDE, and DDD measured in the reconnaissance surveys were consistent with proportions in various other studies. Relatively high levels of dioxins were also measured.

CURRENT HEALTH OF THE LCR FISH COMMUNITY: Tetra Tech (1996a) main objectives were to characterize the health of LCR fish assemblages and resident indicator species and to evaluate impacts of water quality and/or habitat loss on fish health in the LCR. Fish health was characterized by evaluating fish from the community level by applying the U.S. Environmental Protection Agency's Rapid Bioassessment Protocol V (Plafkin *et al.* 1989), which is based on the Index of Biological Integrity (IBI - Karr *et al.* 1986). Additionally, Tetra Tech conducted autopsy-based fish health/condition evaluations of largescale sucker (Goede 1993) and summarized data as Health Assessment Indexes (HAI - Adams *et al.* 1995) and assessed potential juvenile fish skeletal abnormalities.

In the fish community and health studies the LCR was divided into 4 segments:

1. Mouth to Tenasillahe Island (37 river miles).
2. Tenasillahe Island to the Cowlitz River (35 river miles).
3. Cowlitz River to the Willamette River (downstream of the Portland-Vancouver area)(30 river miles).
4. Willamette River to Bonneville Dam (44 river miles).

LCR INDEX OF BIOLOGICAL INTEGRITY (IBI): The IBI is a broadly based multiparameter tool for the assessment of biological integrity in running waters that has been applied widely in North America to evaluate the overall health of fish communities (Karr 1991). It was conceived to provide a broadly based and ecologically sound tool to evaluate biological conditions in streams. It incorporates many attributes of fish communities to evaluate human effects on a stream and its watershed. Those attributes cover the range of ecological levels from the individual through population, community, and ecosystem. IBI employs 12 biological metrics, including number of fish species, presence of native *vs* exotic species, percent anomalies, and species tolerance, to assess integrity based on the fish community's taxonomic and trophic composition and the abundance and condition of fish. Intended for streams and small rivers, Tetra Tech (1993a, 1994a) modified and successfully used the IBI on the Willamette River.

Because sampling in the LCR was conducted much later in the year than planned (December 1994) Tetra Tech (1996a) captured too few fish to calculate meaningful IBIs in some habitats. Most of these studies have been conducted in late summer or early fall, when fish are in shallower water and more active. There was no statistical effect of habitat type on IBI scores. However, IBI scores from segment 3 were significantly lower, indicating poorer community health, than in segments 2 and 4.

FISH HEALTH ASSESSMENT INDEXES (HAI): The *Fish Heath/Conditions Assessment Procedure* (Goede 1993) is well suited to comparing the health of a single species across time and location. Largescale suckers were chosen because they are distributed throughout the entire length of the LCR in quantities suitable for use with this technique (Tetra Tech 1996a). Field analysis of fish included sampling of blood, length and weight measurements, external observations (eyes, gills pseudobranchs, thymus), and an internal examination (mesenteric fat, spleen, kidney, liver).

An insufficient number of largescale suckers were captured in main channel habitat to test the effects of habitat type in the fish autopsy assessment. All mean HAI scores were lower, indicating better condition, than at sites known to be associated with chemical contamination. The HAI scores for urban/industrial sites, which are generally located along the main LCR channel, were significantly lower than the HAI scores for backwater stations. The slower flowing water at the backwater stations promote the deposition of fine sediments, which are thought to be more frequently associated with contamination (Tetra Tech 1995).

Analysis of water, sediments, and tissue collected near fish health stations during the reconnaissance surveys did not indicate a higher degree of contamination at either urban/industrial or backwater habitats. In addition to the IBI work, the results of this study were very preliminary. Health criteria for largescale suckers are not well known. Most previous HAI studies have focused on other species from other regions. However, HAI scores indicate that a healthier population of largescale suckers reside in the LCR than in the Willamette River (Tetra Tech 1996a).

SKELETAL ABNORMALITIES: Juvenile largescale suckers were the primary target species in looking for skeletal abnormalities because it is a primary prey item for bald eagles and it was also used in the fish health assessment study. Secondary target species were peamouth chub (*Mylocheilus caurinus*) and Northern squawfish. Only backwater habitat was targeted for sampling where juveniles could be collected. Very few juvenile fish were captured and the fish used to compare between segments were three-spine stickleback (*Gasterosteus aculeatus*). Incidence of skeletal abnormalities could not be tested against river segment because of the small number of fish captured in segments 3 and 4. However, the incidence was very low (less than 2.3 percent) for all species and river segments. The incidence on the LCR was within the range reported for unstressed natural fish populations and laboratory stocks.

Tetra Tech (1996a) believes that the lack of any meaningful relationships between river segments and incidence may be due to: 1) the overall low incidence of skeletal abnormalities; 2) the timing of sampling (mid-November 1994 to March 1995); 3) the use of species whose response to stressors is unknown; and 4) the larger size of the fish examined in the study compared to the range for which this assessment technique has proven most useful. Three-spine stickleback are relatively larger than fish that had been used previously for this technique. Additionally, few three-spine stickleback reach a maximum size of about 10 cm (Hart 1973). It is possible that many younger fish that were deformed could have already died or become prey by the time of year that the study was conducted. For these reasons, Tetra Tech (1996a) believes that conclusions about the health of fish populations on the LCR are premature.

AROMATIC COMPOUNDS IN LCR LARGESCALE SUCKERS: There is considerable evidence that aromatic compounds (ACs) and their derivatives are responsible for a variety of serious biological effects in fish exposed to such compounds. Certain classes of ACs are subject to extensive metabolism and depuration in fish. Using the same largescale suckers collected for the autopsy-based fish health/condition assessment, Collier et al. (1996) used biochemical means to determine exposure to ACs of LCR largescale sucker. Fluorescent antibodies of PAHs (polynuclear aromatic hydrocarbons) are excreted via the hapatobiliary system in fish. Two methods were used to assess exposure of largescale suckers to aromatic compounds: levels of biliary fluorescent aromatic compounds (FACs), and hepatic AHH (aryl hydrocarbon hydroxylase) activities (induction of P4501A enzymes).

Collier et al. (1996) found no differences in either of the two methods, and no significant difference between industrial/urban and backwater sites. Their tests did not provide evidence of marked exposure of LCR largescale suckers to ACs. However, the levels of biliary FACs were comparable to levels previously measured in other fish species from moderately contaminated areas. Induction of hepatic AHH activity has been shown to be one of the most sensitive biomarkers of organic contaminant exposure in benthic fish species. Hepatic AHH activities in largescale sucker were considerably lower than previously reported for other benthic fish species from moderately and severely contaminated sites.

BALD EAGLE

Oregon has one the largest bald eagle populations in the United States. Of the three Oregon subpopulations, the LCR birds are among the least productive (Anthony *et al.* 1993). They mature at 5 years and can live 30 years, and mortality of young is about 90 percent (Green 1985). In the three Oregon populations, bald eagles begin nesting in March, hatch in May, and fledge in August (Issacs *et al.* 1983).

BALD EAGLE HABITAT: Bald eagle habitat choices are limited by nesting site requirements and by prey abundance. Frenzel (1983) estimated that breeding pairs of Oregon bald eagles have an average home range of 660 hectares and an average distance between nesting territories of 3.2 km, with an average of 0.5 km of shoreline within each territory. In the LCR, most eagle nests are situated in conifer stands bordering the estuary and on river islands. Tidal flats allow for scavenging and foraging of prey in shallow water, which may be particularly important for subadults not yet adept at efficient foraging strategies and hunting (Hansen 1987; Garrett *et al.* 1988). As documented by the Corps these habitat features have been substantially altered in the LCR.

BALD EAGLE DIET: In the LCR, fish is the most common prey item, with freshwater catostomids (largescale sucker), cyprinids (common carp, peamouth), clupeids (American shad - *Alosa sapidissima*), and salmonids (salmon, steelhead) being the most frequent species (Watson *et al.* 1991). Bald eagles also prey on waterfowl, seabirds, and medium-sized mammals. In the LCR, Garret *et al.* (1988) noted a dietary shift in winter to waterfowl, reflecting a seasonal change in prey availability. In the mid-Columbia River area, waterfowl availability is dependent on the numbers of sick and injured birds not the healthy bird count and can be enhanced by human hunting (Fitzner *et al.* 1981).

RECENT STATUS OF LCR BALD EAGLES: Bald eagles have declined nationwide either through direct mortality or from reductions in productivity as a result of the organochlorine pesticide DDT, dieldrin, and their metaobolites. In the LCR from 1985 to 1987, Anthony *et al.* (1993) found elevated concentrations of DDE and PCBs in bald eagle eggs, in blood obtained from eight- to ten-week-old nestlings and in eagle carcasses collected near the river. Eggshell thinning, which is commonly observed with DDE, was also observed and prey items, primarily fish, exhibited detectable levels of DDE, PCBs, and other organochlorines. Although banned, large quantities of DDT were used in orchard crops prior to 1974 and it is very persistent. PCBs were used in electrical transformers and as dust suppressants. It was suspected that dredging activities to maintain a navigation channel in the Columbia River could be resuspending these compounds and increasing their bioavailability.

Anthony *et al.* (1993) also detected elevated concentrations of 2,3,7,8-tetrachloridibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachloribenzofuran (TCDF) in LCR bald eagles in 1987 and 1991. The TCDD levels were higher than that known to cause poor reproductive success. Additionally, the U.S. Environmental Protection Agency (1986) detected TCDD levels in fish that exceeded human health guidelines, which led to the establishment of a Total Maximum Daily Load for TCDD.

CURRENT STATUS OF THE LCR BALD EAGLE POPULATION: Bald eagle nesting territories and productivity of eagles along the LCR have been monitored since the early 1970s. The USFWS (1996) found that LCR eagles occupied 40 nesting territories in 1994 and 41 in 1995, and produced 0.70 and 0.54 young per occupied territory, respectively. Productivity of LCR eagles was considered very low in 1995. Annual productivity of nesting LCR eagles was 23 to 28 percent and 37 to 44 percent lower than statewide values in 1994 and 1995, respectively.

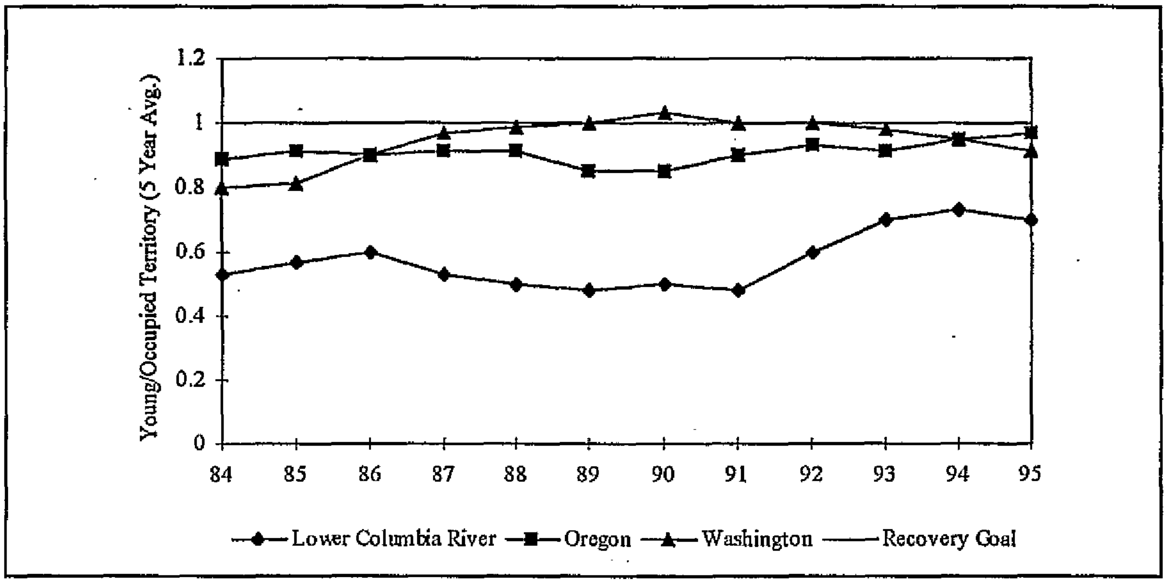

Figure 2. Five-year average productivity (young produced/occupied territory with known outcome) for bald eagles nesting in Washington, Oregon, and the LCR. Statewide values for Washington from 1993 to 1995 are estimates. Statewide data include values from the Columbia River (USFWS 1996).

Although, since 1993 five-year averages have been higher than during any previous five-year time period, productivity in Oregon and Washington statewide is much higher (Figure 2). Productivity in other areas of Oregon and Washington is nearing some of the recovery guidelines required to remove the species from the endangered species list. Eagle productivity in the LCR is at 50 to 75 percent of the population recovery goal. Elsewhere, productivity of bald eagles in Chesapeake Bay has been increasing about 13 percent per year and is now over 90 percent (Buehler *et al.* 1991).

CURRENT HEALTH OF LCR BALD EAGLES: The USFWS (1996) compared contaminant residues for bald eagle eggs collected in 1994 only. Analytical chemistry has not been completed on the eggs collected in 1995. In one or more eagle eggs collected in 1994, they detected residues of 12 organochlorine compounds and mercury. Mercury was detected in all of the bald eagle eggs tested. The compounds p,p'-DDE and total PCBs, were above levels considered high enough to impair reproduction. Concentrations of DDE and total PCBs were highest in one egg collected near the mouth of the river.

Eggshell thinning over a period of years is associated with poor reproductive success. All but one of the eggshells collected by the USFWS (1996) in 1994 showed some degree of eggshell thinning. Eggshells were up to 25 percent thinner than the mean of eggs collected prior to the use of DDT. However, breeding success of LCR eagles was quite variable and was not correlated with eggshell thickness. Some nesting pairs with a history of relatively high breeding success also produced thin-shelled eggs.

The USFWS (1996) detected dioxins and furan residues fairly consistently in the bald eagle eggs sampled along the LCR. All eggs contained PCDD dioxin and PDDF furans. TCDD and TCDF were the most elevated congeners in eggs. The potency of these planar compound mixtures has been correlated to the hatching success in double-crested cormorants (*Phalacrocorax auritus*) in the Great Lakes (Tillitt *et al.* 1992). Planar PCB residues were elevated in all egg tissue from bald eagles.

The USFWS (1996) summarized the overall dioxin-like potency of polychlorinated hydrocarbons (PCHs) in bald eagle egg tissues as TCDD toxic equivalents (TEQs). TEQs are determined by normalizing concentrations of individual PCHs relative to the potency of 2,3,7,8-TCDD using toxic equivalency factors. For evaluation, TEQs reduce many individual congener concentrations of dioxin-like compounds that act in a similar manner (but with different potencies) to one value. The USFWS calculated both international TEFs (I-TEFs) and chicken TEFs (C-TEFs), which are represented as I-TEQ for the mammalian based TEFs and C-TEQ for the avian based TEF values, respectively. LCD bald eagle and fish TCDD-EQ were comparable to less contaminated sites in the Great Lakes. However, the USFWS cautions that the adverse effects these concentrations of TCDD-EQ may elicit on bald eagle embryos is uncertain because the relative potency of planar halogenated compounds to cause early life stage toxicity in bald eagles is currently unknown. They intend to further evaluate TCDD-EQs in LCR eagle eggs collected in 1995.

The USFWS (1996) also tested two prey items (starry flounder and common carp) that were collected at two bald eagle nest sites. Organochlorine pesticide, total PCB, and mercury residues were near or below detectable limits. TCDD and TCDF, dioxin and furan congeners, were detected in both prey items. The amount of theses residues in the carp was about double that of the flounder.

TRENDS OF CONTAMINATION IN LCR BALD EAGLES: The USFWS (1996) found that p,p'-DDD, p,p'-DDE, total PCBs and hexachlorobenzene values were lower in 1994 eggs than in eggs collected from 1985 to 1987 in the LCR. However, total PCB concentrations were higher in the 1985 eggs than estimated bald eagle threshold values and no-adverse-effect- concentrations. The p,p'-DDE values in LCR eagle eggs also were nearly double the value associated with reduced productivity from other areas (Wiemeyer *et al.* 1993). Thin bald eagle eggshells are closely related with high levels of DDE. In the LCR, the current level of thin bald eagle eggshells are thought to be biologically significant and may be causing the population decline, even though eggshell thinning was not found to be correlated with breeding success. Mercury was also found in at about the same levels as in 1985 to 1987, and not exceeding concentrations associated with adverse effects. Lead and cadmium levels also remain below levels thought to have deleterious effects on the bald eagle population (USFWS 1996).

With the mean level of DDE found in the LCR eagle eggs (6.84 μg/g), the USFWS (1996) predicts that the five-year average productivity for eagles will be only 0.49 young/occupied territory. This productivity level is similar to the historical five-year average for these birds.

The increase in 19 bird territories since 1990 reflected the recently observed higher breeding success. However, these newly established pairs (six in the past two years) may not yet have accumulated DDE or other oganochlorines to the extent of older pairs along the river.

Mean TCDD concentrations in the 1984 eggs greatly exceeded established "lowest observable adverse effect level" and "no observable adverse effect level" LOAEL/NOAELs, indicating that dioxins are contributing to the reduced reproductive success of LCR bald eagles. TCDD contribution of the TEQ values in LCR bald eagles (70%) were very similar to the TCDD contribution (69%) of the average I-TEQs that found in wood ducks (*Aix sponsa*) nesting near a Superfund site highly contaminated with dioxins and furans. Comparisons of TEQ concentrations and how they reflect toxicity in eagle embryos will be better discerned when the 1995 eggs are analyzed.

Contaminants analyzed in the two prey items had values similar to 1986 fish samples in the LCR (USFWS 1996, Anthony *et al.* 1993) and within the range of other LCR fish species sampled by the USFWS. A biomagnification factor (BMF) is a ratio that is calculated from contaminant concentrations in prey items and in the predator. The current USFWS (1996) bald eagle study found a BMF from prey found in the nest to eagle eggs of 54 (27/0.5) for TCDD and 57 (6.8/0.12) for p,p'-DDE, values which are similar to that found elsewhere for these compounds.

The USFWS (1996) indicate that analysis of additional data from the 1995 field season will be useful in further elucidating relationships between toxics and reproductive effects in LCR bald eagles.

RIVER OTTER

Northern river otter mature sexually and mate at two years and have long reproductive lives (up to 16 years)(Tabor 1974). Age class 0 river otter are still in family groups with their mothers. Age class 1 begins a period in their lives of dispersal and wandering. Age class 2+ represents a relatively sedentary population that lives within an established home range, although the home range is relatively large for adult males (Melquist and Hornocker 1983). Males commonly move 10 km/night, families less. Home ranges vary from about 7 km (females) to 15 km (males) in diameter although they cover up to 100 km in a year (Liers 1951)

LCR RIVER OTTER HABITAT: River otter are generally most abundant along food rich coastal areas, including the lower portions of streams, rivers and estuaries, and in areas with extensive non-polluted waterways and minimal human impact. Otter are scarce in heavily settled areas, in polluted waterways, and in food-poor mountain streams (Melquist and Hornocker 1983; Toweill and Tabor 1982). Adaptation to freshwater habitats is determined by barriers in dispersal including; arid areas, mountain ranges, glaciated areas, and salt water straits. Otters make extensive use of estuarine areas (Toweill and Tabor 1982).

Habitat preference is based on the availability of adequate escape cover, shelter and sufficient food and minimal human activity (Melquist and Hornocker (1983). In the LCR, critical habitat for river otter are sloughs and tidal creeks associated with willow-dogwood and sitka spruce habitats. Aquatic habitats associated with these vegetated habitats may be important feeding sites as they contain substantial populations of crayfish (*Pacifastacus leniusculus* and *P. trowbridgii*), sculpin, and carp. The concentration of otter sign in these habitats may reflect their importance to otter feeding activity (Dunn *et al.* 1984).

Habitat destruction is the most serious cause of river otter mortality, including impacts of waterway development, destruction of riparian habitat caused by home-sites or farmland, and declines in water quality due to increased siltation or introduction of chemical residues (Melquist and Hornocker 1983; Toweill and Tabor 1982). Mortality of the river otters studied in west central Idaho (Melquist and Hornocker 1983) were strongly related to human activities, accidents on roads and railroads were responsible for 6 of the 9 known otter deaths.

LCR RIVER OTTER DIET: Northern river otters general primary prey consists of fish and crustaceans, with amphibians, insects, birds (particularly carrion waterfowl), and mammals (particularly muskrats - *Ondatra zibethicus*, or carrion) comprising otter diet in lesser portions (Larsen 1984; Toweill 1974; Dunn *et al.* 1984; Melquist and Hornocker 1983; Merker 1983; Stenson *et al.* 1984). Major foods of LCR river otter (in the summer) are carp, crayfish, suckers (*Catostomus* spp.) and centrarchid fishes. Minor prey species included Northern squawfish, salmon, birds, mammals, insects, and mollusks (Tabor *et al.* 1980).

In important prey items of LCR river otters, contaminant reference levels were exceeded in tissue samples from largescale sucker and crayfish in six sites along the lower Columbia River. Dioxin and furan reference levels were exceeded in largescale sucker at Youngs Bay (RM 14), and in crayfish at Elochoman Slough (RM 36). Total PCB reference levels were exceeded in largescale sucker at Youngs Bay, Cathlamet Bay (RM 21), Scappoose Bay (RM 88), Bachelor Island Slough (RM 90) and Camas Slough (RM 120)(Tetra Tech 1994b).

RECENT STATUS OF LCR RIVER OTTERS: Although not common, river otter are stable or increasing in Oregon and Washington (Toweill and Tabor 1982). In 1978-1979, Henny *et al.* (1981) detected PCBs in LCR river otter and mink more frequently than had been detected in other sites in Oregon at the highest concentrations reported in North America. River otter contained even higher concentrations of PCBs than the mink, but their relative sensitivity to PCBs is not known. Mink are among the most sensitive species to the toxic effects of TCDD and related compounds such as PCBs (Hochstein *et al.* 1988; Plantonow and Karstad 1973). However, no laboratory studies have been conducted on the relative biophysical sensitivity of the river otter to PCB concentrations. Additionally, the diet of river otter is varied and localized. Therefore, different trophic levels are utilized to an extent that prey from each of these levels would have to be analyzed in order to determine a realistic dietary exposure to PCBs (Henny *et al.* 1981).

RECENT STATUS OF THE LCR RIVER OTTER POPULATION: In the LCR, the present distribution and abundance of river otter remains unknown. Likewise, the role of habitat change and the role of pollutants on the present distribution (Henny *et al.* 1996). Henny *et al.* (1996) determined that in late summer 1994 the average family (5.81) contained 2 adults, 2.28 young of year, and 1.53 1-year olds. From these counts, they estimated that at the end of the fall-winter 1994-1995 trapping season, the LCR contained 244±47 river otters and another 42 were harvested.

The river otter population appears to be well distributed throughout the LCR, has the highest density reported in the literature, and is considered to be "abundant". It is even well distributed in the Portland-Vancouver (P-V) area which is the most polluted. However, Henny *et al.* (1996) indicated that other populations in the literature were from rivers much smaller than the Columbia River and they also believed that population estimates elsewhere may be quite conservative.

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Henny *et al.* (1996) reported that livers of LCR river otters showed a pattern of increased concentrations with age for all organochlorine insecticides and metabolites, but the change was only statistically significant for oxychlordane. At age 0, LCR river otters already had higher levels of DDE, DDD, heptachlor epoxide, β-HCH, dieldrin, and mirex significantly higher than in the reference area. Nearly every PCB congener was also higher in the 0-age class. Additionally, concentrations of several co-planar PCBs, dioxins and furans were significantly higher in all river otter age classes than the reference area. Higher dioxin and furan concentrations were found in age class 0 than in older river otters. Six dioxins and furans were significantly higher in age class 0 in the LCR than in the reference area. In the LCR, TEQs were significantly higher in all river otter age classes than the reference area and the TEQs did not show a significant increase with age.

Heavy metals were analyzed in river otter livers and kidneys. Cadmium significantly increased with age but zinc did not. Chromium, copper, iron, manganese, mercury, and vanadium levels were not significantly higher in the LCR than the reference area for all age classes. Nickel was seldom detected in LCR river otters. Aluminum was detected in river otters (3 liver and 4 kidneys), and was at the highest concentration in a 3 year old that was captured downstream of an aluminum smelter. Lead was detected in 9 of 30 river otter kidneys. Lead was detected in all four of the river otters in the P-V area. With respect to river mile (RM) and dioxin and furan Henny *et al.* (1996) found few significant relationships because of the potentially important point sources downstream from the P-V area. Of the metals tested in river otter and compared to RM, only manganese (age class 2+) showed a direct relationship and chromium (age class 1) showed a inverse relationship.

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MINK

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Mink are generally solitary, unsociable animals except during the breeding season. Mink reach sexual maturity in their first year and they only live about three years in the wild. There can be up to 10 young in a litter (average = 4 to 5)(Linscombe *et al.* 1982).

Mink are territorial and in mink populations, the greatest movement is associated with dispersal of juveniles during summer and fall. Male mink are mainly nocturnal during all seasons, with the level of activity increasing with the length of the night and decreasing temperature. Female have very low activity rates during pregnancy, but activity increased while caring for litters and is primarily diurnal. Home ranges of adult and juvenile males are similar. Home ranges of female mink are smaller than that of males, but are used more intensely (Linscombe *et al.* 1982). Most movements occur in, or along, linear habitat features, such as lake shores, river banks, stream courses, or hedge-rows (Birks and Linn 1982).

Knowledge of the effects of environmental contaminants on mink is essential to the mink farming industry. Therefore, mink are available for experimentation without interfering with the wild mink population. However, data obtained from experiments with farmed mink neglects the potential compounded effects of contaminants that mink may suffer in the wild. Mink are able to store and concentrate DDT, DDD, and DDE, which indicates they may be somewhat tolerant of these compounds (Aulerich and Ringer 1970). They are very sensitive to the toxicological effects of PCBs and dioxins (Hochstein *et al.* 1988).

LCR MINK HABITAT: Mink inhabit many types of wetland areas, including banks of rivers, streams, lakes, ditches, swamps, marshes, and backwater areas (Banfield 1974; Mason and MacDonald 1983). They depend on aquatic prey for a large portion of the year but transient use of upland cover may occur if terrestrial prey becomes more important. Mink generally avoid exposed or open areas, hence habitats associated with small streams are preferred to those associated with large, broad rivers (Allen 1986).

Mink dens (temporary or permanent) are usually located close to water, commonly within cavities beneath tree roots at the water's edge, within cavities or piles of rock above the water line, in areas with a large number of dead-falls and stumps, or in fallen branches, brush, and other debris (Allen 1986).

LCR MINK DIET: Both river otter and mink are resident carnivores in the LCR watershed that feed largely on fish and other aquatic invertebrates and vertebrates. Therefore, they can be exposed to relatively high levels of pollutants. Prey include small mammals (e.g. muskrat), fish (crayfish, sculpin, carp, and largescale sucker, and salmonids), and birds (Tabor *et al.* 1980). Females are smaller than males and are able to subsist on smaller prey. The larger male can easily prey on relatively larger small mammals. Mink are opportunistic predators and their diet is highly variable by season (Allen 1986). Since the diet of wild mink is varied and localized, different trophic levels are utilized to an extent that prey from each of these levels would have to be analyzed in order to determine a realistic dietary exposure to PCBs (Henny *et al.* 1981).

RECENT STATUS OF THE LCR MINK POPULATION: The percentage of Oregon's mink harvest in the two counties bordering the Columbia River decreased from 15.4 percent from 1949-1952 to 9.1 percent in 1973-1976 (Henny *et al.* 1981). In 1992, only 7 mink were taken in the 2-county area of Oregon that includes the Columbia River, but most of these counties are not associated with the Columbia River (Oregon Department of Fish and Wildlife files).

Of the mink and river otter tested for contaminant residues in Oregon in 1978-1979, PCBs were most frequently encountered in the LCR animals and the levels were within the range of concentration that kill or depress reproduction in experimental mink. PCB concentrations in LCR mink and river otter were some of the highest found in North America.

In four days Henny *et al.* (1996) was able to count mink in the LCR on only one side of the river. Therefore, their count is a minimum population number. Although the Habitat Suitability Index for mink in many portions of the LCR was excellent (Allen 1986), few mink were trapped. Mink sign was seldom located and only one mink family and four lone animals were documented. Of 219 mink scent box nights distributed throughout the one side of the river, only one mink was attracted to a box at RM 108. Another 57 mink trap nights during the same period yielded no mink captures. No population estimates were attempted.

CURRENT HEALTH OF LCR MINK: In the LCR, the present distribution and abundance of mink also remains unknown and likewise, the role of habitat change and the role of pollutants on the present distribution (Henny *et al.* 1996). From licensed trappers, Henny *et al.* (1996) obtained only two mink from the LCR and four from a reference area, which was the Malheur National Wildlife Refuge in eastern Oregon. Fresh scats were also collected for analysis of environmental contaminants.

With a sample size of only two mink, Henny *et al.*'s (1996) ability to discuss residue accumulation and concentration was greatly limited. Agricultural pesticides were usually found at higher levels in mink from the LCR than from the reference area. PCB congeners were also almost always higher, usually 3 to 5-fold, or higher. Many more of co-planar PCBs, dioxins, and furans were found in the one LCR mink liver that was tested. Nickel was considerably higher in the kidney of a LCR mink.

PCB and DDE concentrations in river otter were much higher in the LCR in 1978-79 (Henny *et al.* 1981; 1996). PCB and DDE concentrations were also probably higher in mink 15 years ago. Estimated effects on kit survival and productivity based on the residue criteria available most likely underestimate effects in the past. PCB concentrations in some LCR mink from the late 1970s were equivalent to mink that survived PCB tests, but failed to produce any kits that survived. It seems conceivable that PCBs nearly extirpated the mink in the LCR and that the few mink seen in 1994-95 may be animals pioneering back into the watershed in an attempt to recolonize it.

Henny *et al.* (1996) also note that synergistic and antagonistic effects between PCB congeners and dioxins and furans in combination with PCBs on reproduction and kit survival of minks is poorly understood. Valuable information would be lost if only TEQs were reported using an additive model.

TYPES, PATTERNS, AND EFFECTS OF SELECTED CONTAMINANTS IN THE LCR

Tables 1 through 3 summarize data from several of the studies selected because they permitted an analysis of location (river mile) and contamination level. The primary sources were the USGS (1995) Analysis of Current and Historical Water Quality Data, and reviews and data in Henny *et al.* (1996). Several sources such as the Tetra Tech (1995) Human Health study had very extensive data on fish tissue contamination, but from the presentation it was not possible to identify where the contaminated individual specimens came from. It is clear from the identification numbers that a review would render such an analysis possible. This brief summary presents ambient and tissue data in a rough trophic hierarchy - water, sediments, fish tissue, and predator.

The sampling sites which provided the information used in these tables are well distributed along the LCR. However, different contaminants were inventoried in different sites, with some omissions and consequent data gaps. For example, very little quantitative examination of the estuary was done. The USGS inventory did not address many of the pesticides of interest (such as DDE), PCBs or Dioxins. Tetra Tech did not identify the river miles for their extensive Human Health Study samples which characterize many of the contaminants. The excellent time series data of fish tissue from the National Contaminant Monitoring Program does not capture any sites between RM 149 which is above Bonneville Dam, and RM 18-22, making the identification of contaminant contributors and hot spots along the

Table 1. Water quality in the ambient aquatic environment of the Lower Columbia River[1] (USGS 1995).

Contaminant -(Acceptable Standard)	**River Mile**					
	53.8	**82.4**	**86.3**	**102**	**141**	**101.5**
Suspended Sediment (1.4)	21.0	15.0	25.0	15.0	12.0	146.0
Temperature (<20°C)	>20	>20		>20	>20	
Total dissolved gases (<110 percent of saturation)	over 110-120 most of river					
Atrazine (3.0 ppb)	0.03	0.02	0.16	.003	.006	0.17
Arsenic (190 ppb)	1.0	1.0		1.0	1.0	
Iron (300 ppb)	20.0	18.0	46.3	10.5	9.0	103.5
Zinc (58.19 ppb)	3.0		2.5	1.5	<1.0	2.0

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[1] in μg/L unless otherwise noted

Table 2. Organochlorines in prey (detritivore fish) tissues[2] (Schmitt *et al.* 1983, 1985, 1990; and Anthony *et al.* in Henny *et al.* 1996).

Species by Year & River Mile	**DDE**	**DDD**	**Dieldrin**	**HCB**	**PCBs**
Tissue Standard in ppm	0.27	w/DDE	0.02	0.2	0.1
River Mile 149 Cascade Locks, OR					
1970 Largescale Sucker	220	120	10	nd	440
Northern squawfish	1170	425	10	nd	1745
1971 Largescale Sucke	395	295	10	nd	625
Northern squawfish	895	215	10	nd	905
1972 Largescale Sucker	470	380	nd	nd	1400
1973 Largescale Sucker	250	140	nd	nd	865
Northern squawfish	240	nd	nd	nd	500
1974 Largescale Sucker	1010	nd	nd	nd	nd
Northern squawfish	1200	280	nd	nd	2600
1976 Largescale Sucker	135	55	10	10	1700
Northern squawfish	270	120	20	nd	2000
1978 Largescale Sucker	290	175	10	nd	320
Northern squawfish	360	30	nd	nd	800
1981 Largescale Sucker	540	210	10	10	300
Northern squawfish	640	140	10	nd	500
1984 Largescale Sucker	730	230	10	10	500
River Mile 18-22					
1986 Largescale Sucker	70	80	nd	nd	850
Northern squawfish	200	210	nd	nd	1700
Willamette River (Oregon City)					
1970 Largescale Sucker	605	745	nd	40	3490
1971 Largecale Sucker	250	335	15	nd	1510
Northern squawfish	350	325	10	nd	2425
1972 Largescale Sucker	450	225	20	nd	4100
Northern squawfish	570	130	20	nd	3000
1973 Largescale Sucker	260	130	nd	nd	2000
Northern squawfish	530	140	nd	nd	2800
1974 Largescale Sucker	325	90	nd	nd	2000
Northern squawfish	190	60	nd	nd	2300
1978 Northern squawfish	420	nd	nd	nd	830
1981 Largescale Sucke	210	50	10	nd	1200
Northern squawfish	280	30	10	nd	800
1984 Northern squawfish	130	20	nd	nd	300

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[2] ppb, wet wt. with same species/same year averaged

Table 3. Abridged tabulation of organochlorine contaminants in river otter from the lower Columbia River[3] (Henny *et al.* 1996).

Contaminant Standard	**Ref. site no. 2**	**RIVER MILE**				
		27	**28-33**	**63-69**	**87-108**	**134**
ΣPCBs-100	2966	3002	5776	14031	22545	9937
ΣArochlor-100	9408	8557	19200	45186	56495	32055
DDE (ΣDDE+DDD)-270	1371	1290	2457	6942	9230	6095
Dieldrin-20	69	106	253	321	561	132
(HCB)-200	53	131	222	281	209	273

LCR difficult to identify. We have combined the most extensive data from the above tables to attempt an analysis of hot spots.

Summed and normalized values for tissue organochlorines and the number of major permitted point sources were plotted against RM location (Figures 3 through 5). The largest data sets which identify river miles are used (Henny *et al.* 1996; Schmitt *et al.* 1983, 1985, 1990 in Henny *et al.* 1996). Although sample sizes are not given, they represent 30 river otter and hundreds of largescale suckers.

ANALYSIS: An overview of the data clearly indicates excessive sediment, temperature, and dissolved gases. Fish tissues are consistent over space and time in indicating concentrations of a thousand times or more of standard for organochlorine and related PCB contaminants. Henny *et al.*'s (1996) work indicate that LCR river otter have 2 to 8 times the levels of reference animals, and 4 to 30 times the level of the standard (with the exception of HCB which was in low levels in tissue). Although still far above healthy values, it appears that contaminant concentrations declined over the past 25 years of data collection.

The low contaminant values found downstream around RM 20 do not capture the impacts of the inputs to the estuary occurring below the sampling sites used to date. Clearly, pollution and contamination is a problem in the Portland-Vancouver area (roughly RM 90-110), due both to *in situ* products and those imported from the Willamette River basin. Although relatively little agricultural activity occurs in the LCR, DDE values are low in the input to the LCR near Bonneville Dam, peak near Portland, and decline to the mouth. The high mainstem numbers around Portland can come from the Willamette River with its high seasonal turbidity (5-10 times the Columbia near Portland), or from the dredging/port activities around Portland (or both).

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[3] In ppb. Reference controls from relatively clean environments outside of area.

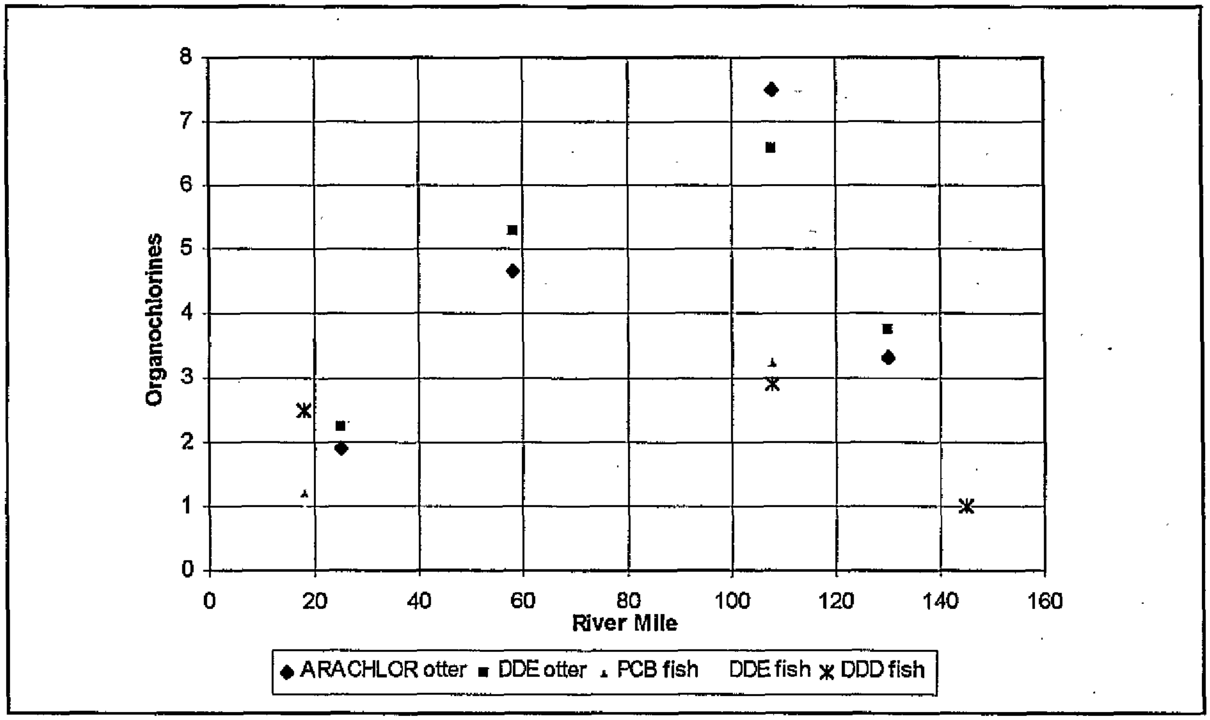

Figure 3. Normalized values for tissue organochlorines by river mile segment.

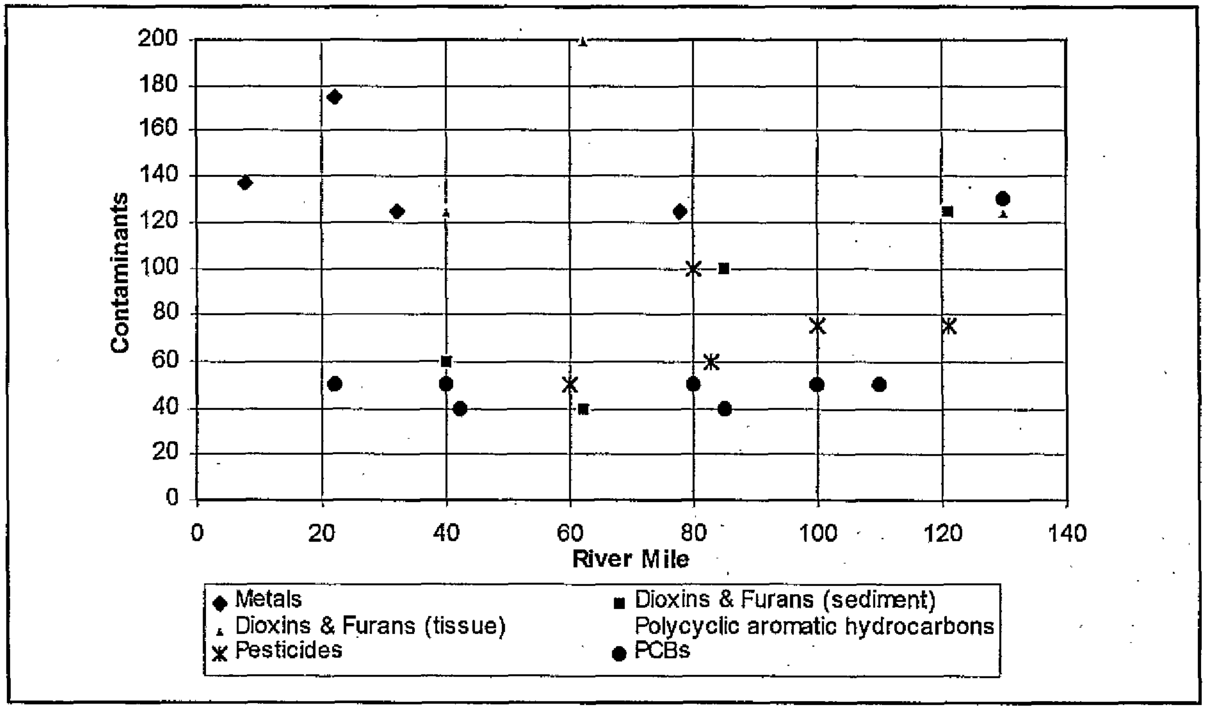

Figure 4. Sediment and tissue contaminants exceeding health standards (by river mile).

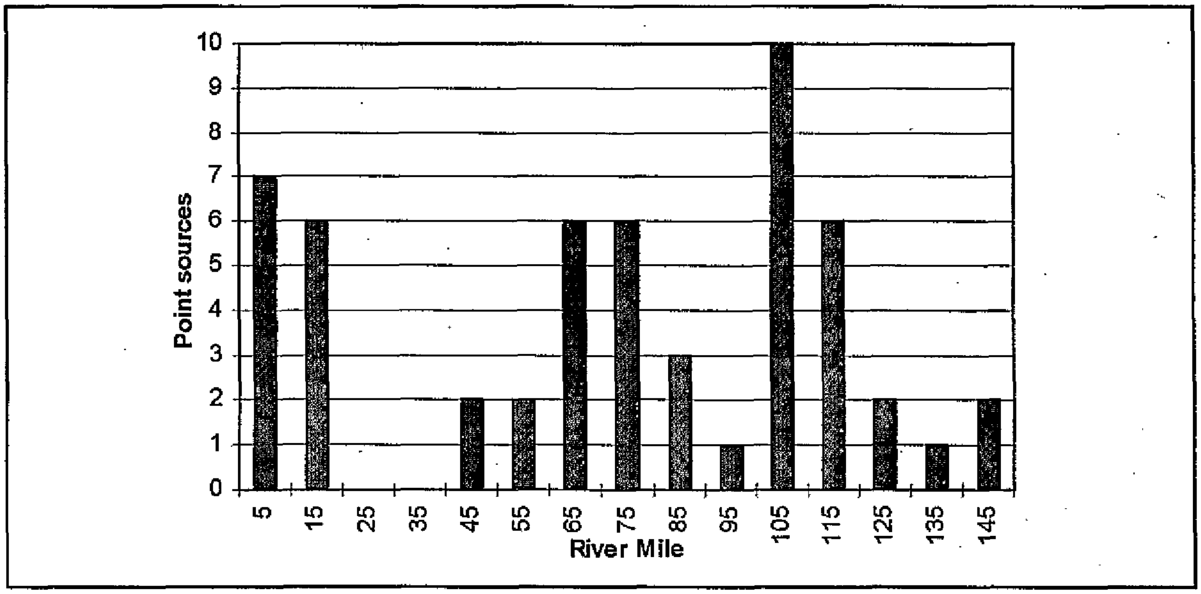

Figure 5. River mile of point sources of contaminants.

Tetra Tech (1996a) believe that the lower IBI scores calculated for river segment 3 (downstream of the Willamette River) are a result of the higher proportion of exceedances of contaminant reference levels measured in 1991 and 1993 (Tetra Tech 1993b; 1994b). For six of the analytical group/river segment combinations, the number of exceedances was highest in segment 3. The trend was most pronounced for sediment metals and pesticides/PCBs, for which the number of exceedances per station in segment 3 was double that in either segments 2 or 4.

In Figure 4, remarkable consistency can be seen in the repetition of the same locations for PCBs - i.e. around RM 20, RM 55-60, RM 80-110, and RM 120-130. The earlier work also found high levels around RM 38-40, but the sample was larger and more distributed. Over time and species this contaminant appears in unhealthy concentration in the same areas, suggesting a consistent and productive source.

Pesticides present much the same pattern and consistency as PCBs. The reconnaissance report notes the correlation of contaminants with sediment grain size and suggests the heavy contaminant loads 20 to 30 miles downstream from the many sources in the Portland-Vancouver area are a function of the transport and settling of the sediments and associated contaminants. The backwater reconnaissance study basically corroborated these patterns and concentrations of contaminants of the first survey. Furan congeners were higher in largescale sucker and one very high value for PCBs was found at Scapoose Bay (RM 88) within the cluster of PCB readings shown in Figure 4 for the 1991 study.

Although the data consistently show excessive contamination from the water to the top predators, some questions arise. For example, it is difficult to reconcile the high tissue levels of contaminants in river otter with an apparently thriving population, while ascribing the extirpation of mink to similar patterns of contamination.

The lack of agreement among the three techniques that were used to evaluate LCR fish health did not yield consistent results. River segment appears to influence fish health for the fish community technique, but not for the skeletal abnormality technique. Land use/habitat type appears to influence fish health for the fish autopsy technique, but not for the fish community assessment technique. This lack of agreement was also found on the Willamette River (Tetra Tech 1993a). The lack of agreement among techniques highlights the fact that sublethal effects of stressors on fish health can be manifested in many different ways, which a single technique might be unable to detect (Tetra Tech 1996a). The sensitivity of the skeletal abnormality technique for the LCR can not be fairly compared to its sensitivity on the Willamette River until the same target species, Northern squawfish, can be evaluated on the LCR.

CONCLUSIONS

Given the independent planning and conduct of the studies examined for this summary, the consistency of results is striking. The wetland habitats lost are important to each of the terrestrial species studied, bald eagle, mink, and river otter. The river contains each type of contaminant which was studied - dioxin, chlorinated hydrocarbons, PCBs, trace metals, as well as other classes such as aromatic hydrocarbons. Some species, such as the mink and river otter, apparently tolerate certain contaminants like chlorinated hydrocarbons. However, the same mink and otter are affected by the other contaminants such as dioxins and PCBs. In every instance in which dioxins were studied, they were present in harmful levels. The river otter, mink, eagle, and phytoplankton are all very sensitive to PCBs which are found in excess of risk thresholds. The primary variable which determined the presence and deleterious effects of the contaminants in question was simply whether it had been studied. In many important species and trophic levels, such as phytoplankton and zooplankton, relationships with contaminants are unknown in the LCR.

The results of the many studies reviewed do not indicate an incipient issue. They constitute a corroborative body of evidence that declining fish and wildlife populations in the Columbia are, in part related to contamination associated with human activities. Many of the studies referenced here are considered preliminary. What has been measured is reflected in poorly producing eagles, the near extirpation of mink, and impacted development of river otter male genitalia. The isolation of the contribution of contaminants to failures of salmon recovery have not really started. At this stage the threat, in outline and order-of-magnitude, appears real. Next steps can take two basic themes: priority research and immediate remedial actions.

RECOMMENDATIONS FROM THE FISH AND WILDLIFE STUDIES REVIEWED

Collier *et al.* (1996) Aromatic Compounds in LCR Largescale Sucker

- Work on aromatic compounds by NMFS was not conclusive and suggested several important improvements in the sampling regime such as earlier, increased sampling of species with a greater likelihood of bioaccumulation;

- Chemically analyze fish stomach contents and furficial sediments to determine the presences of aromatic contaminants in the fish's habitat

Corps (1996) - LCR Habitat Changes

- Complete the upper 40 miles of type mapping.

- Add several more GIS layers (primarily physical such as dredge-related, soils, topography) to their maps.

- Access newer false color infra-red imagery.

- Do more original image-processing.

- Enhance agency data swaps.

Henny *et al.* (1996) - Mink and River Otter

- Large differences may exist in sensitivity for PCBs between closely related species. Continue research on the sensitivity and toxicokinetics of PCBs for the river otter in comparison to the mink.
- Clarify the reasons for the relative differences in population trends in mink and river otter.
- Augment work on river otter in the nine mile segment of the P-V area which produced the highest residue values.
- Live-capture river otters to conduct blood chemistry to characterize general animal condition and immunological competence and to evaluate steroid concentrations.
- Conduct complete necropsies on live-captured river otters to obtain general morphometric data, obtain histopathology of unaltered (non-frozen) organs and tissue, and analyze enzyme activity and hormone receptors.
- Evaluate disease and parasite incidence from the tissues collected for histopathology to potentially provide evidence of immunocompetence. Gonadal morphology of male river otter will be characterized and correlated with sperm count and contaminant concentrations.

- Clarify the biochemical modes of contaminant effects in liver and kidney tissue by fluometric assays and western blotting. Hormones will be estimated by competitive binding assays.
- Analyze mink and river otter fat, kidney, and liver samples for organochlorine insecticides, total PCBs and congeners, other coplanar polyhalogenated hydrocarbons, pthalate esters, alkyphenols, and inorganics.
- Fecal samples taken from river otter during necropsy will be assessed for hormone concentrations as a potential bio-marker that could be compared to hormone levels in blood.
- LCR prey (fish) contamination data currently is too limited to determine diet-based no-effect levels for mink or river otter. PCB residue levels in LCR fish, which have usually been based on Aroclor 1254 or 1260, should be based on cumulative indices (total PCBs, PCB 153, TEQs).

Tetra Tech (1994b) - Backwater Reconnaissance Survey

- Evaluate the potential for adverse effects to aquatic biota and wildlife using screening level concentrations adopted for the measured levels of water sediment, and tissue contaminants.

- Expand and elaborate on the analysis of relationships between sediment and biota metal concentrations.

- Collect and analyze additional fish species with different life history patterns.

Tetra Tech (1996a) - Assessing Health of Fish Species and Communities

- Sampling problems plagued the Tetra-Tech fish health assessment, and suggestions turned on fixing the sampling regime. They propose to rectify tardy issuance of collection permits.

Tetra-Tech (1996b) - Integrated Technical Report, Summary and Synthesis

- Develop two types of physical models (sediment type, flow, salinity, etc.) for mathematical simulation to assist in assessment of fish, algae/aquatic plants and the benthos.

USFWS (1996) - Bald Eagles

- Complete analysis of the bald eagle eggs collected in 1995.

USGS (1995) - Analysis of Current and Historical Water Quality Data

- Develop and validate conceptual water quality models and the interagency design and conduct of a monitoring and evaluation program; and the summarization and integration of all Bi-State water quality data.

This review suggests several necessary areas of research. Those with most immediate application include:

- Identify the synergistic population and biochemical effects of the mix of contaminants actually experienced by the organisms, as distinct from the isolation of single contaminants and their effects. The effects of these contaminants on organisms are not likely to be independent, linear, and orthogonal.
- Evaluate effects of contaminants on photosynthesis;
- Conduct simulation modeling of the biophysical system with prognostic evaluation of the effects of habitat changes and river management on contaminant availability, synergy, and uptake. This is a tractable way of addressing the components of a watershed while coordinating the research in advance of deploying field workers..
- Evaluate use and resource partitioning in the estuary by lower organisms, fish and wildlife; and
- Conduct field and simulation studies in the 30 sub-basins and the evaluate their contaminant contributions to the lower river and estuary.
- Define and map habitat requirements and use by selected species.

ECOSYSTEM MODELS: One of the problems with the current Bi-State effort was the lack of a clear organizing approach to facilitate the integration and interpretation of the data. A number of the participants in the Bi-State process (e.g. Tetra Tech and USGS) have advocated the development of conceptual and simulation models to clarify biophysical relationships, investigate ecosystem process, and test relationships and policies. A greater understanding of contaminant accumulation pathways would aid in developing relevant models to predict future tissue contaminant levels based on projected changes in the amounts of contaminants released to the environment and long-term degradation of previously released persistent chemicals (Tetra Tech 1994b).

We believe that a conceptual and simulation model would be a beneficial activity in the LCR. A conceptual model would ensure consistency in coordinating sampling sites, times, and units of measurement. It would also foster results that could be related in ways fundamental to understanding the ecosystem and effects of contamination. For example, the type of feedback loops, positive "boom/extinction" or negative "homeostatic/buffering, and their strength or dominance, would indicate where remedial actions could likely give the best results. This type of model would also indicate data gaps and specific links would help the analyst. Furthermore, a common and graphical understanding of system elements such as important state variables and rates would be explicit.

Traditionally, mathematical models have been employed by research teams, often independently, to generate black box solutions. It is recommended that a participatory modeling workshop be employed to graphically capture the goals, pattern, and process of the Bi-State program effort. This technique would serve as a forum to capture the knowledge of the many agencies and contributors.

The use of the GIS products should be clarified. The effort was titled habitat mapping - however land, water, and vegetation types were mapped. These are important elements of habitats and a clearly useful initial step in delineating habitats. However, habitat is specific to the species and its requirements for food, space, cover, etc., and includes such variables as vegetation and water body size, shape, and juxtaposition, human disturbance, and distance from edges, among others. The USFWS's Habitat Evaluation Procedure (HEP) would be useful because it attempts to identify the major elements of an animal's habitat in a model.

HEP habitat suitability index models exist for bald eagles (for two seasons) and mink. A GIS analysis, including field checks of unmapped associations of the model, of habitat suitability for eagle and mink should be a priority. However, using the indicator species requirements to assess contaminant impacts and management responses may not elucidate problems within the food web, which an ecosystem approach may reveal. To protect key predator species, we believe that an ecosystem model would be a better approach to determine if the habitat for a predator's prey base is being lost.

PROGRESS ON RECONNAISSANCE REPORT RECOMMENDATIONS: It is useful to compare the work of the past three years with the recommendations in Tetra Tech's (1993b) Reconnaissance Report. Of the 46 activities suggested, three have been partially addressed by field studies reported herein (map habitats, document their loss, and evaluate sensitivity of key fish and wildlife species to water quality). An additional four of the activities species were partially reviewed in this document: the contaminant analysis of salmonids, contamination of *Corophium,* contaminants in important aquatic ecological and food species and high lipid accumulators, and contaminant loading from tributaries. Additionally, the Columbia River Intertribal Fish Commission (1994) conducted a study of human fish consumption patterns.

Two of the remaining 38 recommendations appear partially redundant (characterize and compare contaminant sources with Canada's and develop a data base for their entry/develop a data management system and develop effluent monitoring standards and protocols for all parties who monitor/develop protocols for sampling, handling, and analysis). Although the remaining 36 seem to be reasonable and well conceived, based in part on the information in this review, 11 of the 36 appear to deserve particular attention:

- Model the effects of tidal reversal and predictive water quality;
- Additional sampling to further define/confirm problem depositional sites;
- Sample in other seasons and flow regimes;
- Analyze sediment cores;
- Monitor clean mussels at reference points;
- Define the types and amounts of contaminants produced by each industry and using chemical fingerprinting and source tracking methods;
- Identify contaminants from land uses;
- Characterize non-point pollution;
- Conduct habitat quality assessments;
- Clarify the biology/processes/pathways of bioaccumulation for selected species; and
- Use endemic sediment-dwelling biota as bioassay species.

We began this paper with an explanation of the rationale for the initial surveys and the focus on selected species. As the analysis and recommendations suggest, the work to date indicates the incorporation of an additional and complementary approach at this stage would be revealing: enough is probably known by now to develop a conceptual model to identify the important variables, links, and types of feedback; and the use of ecological important species as well as known accumulators. Although the recommendations for expansion and monitoring of work which has been initiated in the first five years is well-taken, the integrative approach will add much, permit some parsimony and economy of effort, permit a real integration of data, and, ultimately, policy testing through simulation.

Immediate action need not await further results from the suggested research. The identification of significant point sources of specific contaminants in the river has already occurred, a monitoring program for these sources, and a short term program of remediation, realignment, or decommissioning, and enforcement can begin now.

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GLOSSARY

- ACs - Aromatic Compounds
    - FACs - fluorescent aromatic compounds
    - PAHs - polynuclear aromatic hydrocarbons
- AHH - aryl hydrocarbon hydroxylase
- GIS - geographic information system
- HAI - Health Assessment Indexes (Adams *et al.* 1993)
- IBI - Index of Biological Integrity (Karr *et al.* 1986).
- LOAEL - "lowest observable adverse effect level"
- NOAEL - "no observable adverse effect level"
- PAHs - polynuclear aromatic hydrocarbons
- PCH - polychlorinated hydrocarbon
- TEF - toxic equivalency factor
    - I-TEF - international toxic equivalency factor
    - C-TEF - chicken toxic equivalency factor
- TEQ - toxic equivalent, estimated threshold dose
    - C-TEQ - chicken toxic equivalent
    - I-TEQ - international toxic equivalent

RESPONSE TO PEER REVIEW COMMENTS

Since this report was turned in on November 17, 1995, it has been rewritten extensively, twice. The first two drafts were completed by Stephen Berwick (WILDSystems). Subsequently, most of the large volume of comments have been addressed in this third version. Comments from other Washington Department of Ecology and Oregon Department of Environmental Qualtiy staff not detailed hered are noted.

Comments from Charles Simenstad, University of Washington, School of Fisheries:

Comment 1. There is no explicit statement of goals and objectives.

Response 1. Goals and objectives of the program and objectives of the report are stated in the first paragraph.

Comment 2. "The Introduction calls the report a *literature review*" and describes how the report is inadequate and what a satisfactory report should contain.

Response 2. Comment noted.

Comment 3. "The writing is atrocious."

Response 3. We believe that this quality of the product has benefitted from a few extra weeks to work on the report.

Comment 4. "The report should be completely reorganized."
Response 4. The has been extensively rewritten.

Comment 5. "The contents of the report appears to go far beyond the scope of the topic and the data . . . "

Response 5. We believe that this version is more focused on the Bi-State fish and wildlife studies.

Comment 6. Literature citations are old or missing.

Response 6. Comment noted.

Comment 7. Figure 1, *Flow of Energy . . ,* has many problems
Response 7. Comment noted.

Comment 8. "Information appears completely out of place or critical information is absent."
Response 8. Comment noted.

Comment 9. There is no data describing how and to what degree *Asterionella, Eurytemora affinis, Corophium salmonis,* and *Oncorhynchus tshawytcha* constitute major food web pathways.

Response 9. To the extent possible it was described why these chosen species were chosen and how they into the food web. Major diet items for each organism are provided. From the literature available it was really only feasible to suggest bioaccumulation and pathways between many of these organisms. The pathway and bioaccumulation is fairly obvious for some organisms. For example largescale suckers are long-lived benthic feeders that accumulate residues from the contaminated sediment. They are eaten by bald eagles, mink and river otter.

Comment 10. "The information about the four "representative aquatic species" is often out of date and sometimes erroneous."

Response 10. Comment noted. The draft Literature Review and Contamination Ecology Report utilized the extent of available literature up to about October 1994. In this report we were only able to summarize important information, which may be pertinent to our stated objective, from those earlier works. The relationship between the four representative species and the "target" species, or the ecology of the lower Columbia River, was not a clear as we had hoped. We suggested areas where additional research may be useful.

Comment 11. "Many broad generalizations are unsubstantiated, inappropriate, unreferenced or entirely wrong, . . "

Response 11. Comment noted.

Comment 12. It is difficult to see how synthesis has occurred in the section on "Human Health Risks from Contaminated Fish".

Response 12. The human health section was deleted because it is outside the scope of the fish and wildlife project and will be addressed elsewhere in the Bi-State program.

Comment 13. The Synthesis and Conclusion section (VIII) is unconvincing and largely unsubstantiated.

Response 13. Comment noted.

Comments from Bruce McCain, National Marine Fisheries Service, Newport, Oregon:

Comment 1. The lower Columbia River and estuary are not as highly contaminated as the Executive Summary states.

Response 1. Comment noted. No such strong statements are included in this report.

Comment 2. DDT and PCB levels have decreased in the U.S. and the lower Columbia River.

Response 2. Comment noted.

Comment 3. Human Health study is a draft report and conclusions need to be toned down.

Response 3. Comment noted. See *Response 12* above.

Comment 4. Section D.5. Contaminants, page 18, contains some inaccuracies and does not include some very important references.

Response 4. This draft now has no reference on the effects of contaminants on adult salmon. Unfortunately we were unable to review Arkoosh et al. (1991) etc. which are listed. We have put greater emphasis on reporting the work on the target species.

Comment 5. Section G.2. Fish Health, page 22, is difficult and seems to be quite speculative.

Response 5. Comment noted.

Comment 6. Data in table 13, page 43, needs to be verified.

Response 6. This table is not in the current report.

Comments from Avis Newell, Oregon Department of Environmental Quality:

Comment 1. "The references used to describe general toxicity and biogeochemical processes and occurrence are outdated."

Response 1. Comment noted.

Comment 2. "This report should be more specific, linking the contaminant levels found in the LCR to known effects, clearly identifying problematic upstream sources that may eventually cause problems downstream, but are as yet undocumented."

Response 2. Upstream reports of contaminants are not discussed in the current report.

Comment 3. There is no linkage between known effects on these organisms and the contaminant levels found in the LCR.

Response 3. Comment noted.

Comment 4. It is not clear why *A. formosa* was chosen.

Response 4. We believe that the current report explains why *A. formosa* was chosen.

Comment 5. The skeletal deformities research is not well explained.

Response 5. Comment noted.

<u>Comments from Lawrence Curtis, East Tennessee State University</u>:

Comment 1. Some of the statements are unsupported, such as "the LCR is highly contaminated" and "LCR contaminants present a dramatic threat to human health"..

Response 1. Comment noted.

Comment 2. In the introduction the literature cited is too old and there are many inaccuracies or typographical errors..

Response 2. Comment noted.

Comment 3. A more complete review of recent literature is needed.

Response 3. Comment noted.

Comment 4. A comprehensive survey of the peer-reviewed literature to put LCR research into a national and international perspective is not provided.

Response 4. The reports <u>Lower Columbia River Basin Bi-State Water Quality Program Fish and Wildlife Literature Review</u> (July 29, 1994) and <u>Contamination Ecology of Selected Fish and Wildlife of the Lower Columbia River</u> (draft - October 14, 1994) may serve a response to this comment.

Comment 5. Minimum doses for DDT, DDE, dieldrin and aldrin which produce various biological responses are available.

Response 5. We regret that we did not have time to look these up, but agree that they would be useful information to include in the report.

Comment 6. Section III is generally adequate, but there are issues of concern.

Response 6. The comment needs to be more specific for us to address.

Comment 7. The work on male river reproductive organs needs to be reported more accurately.

Response 7. Comment noted

Comment 8. Tables are poorly produced.

Response 8. Comment noted. Table 13 is not used in this draft.

Comment 9. Conclusions are subjective.

Response 9. The final report has been considerably rewritten.

Comment 10. The characterization of life history and contaminant sensitivity for species chosen for emphasis are well organized. With the exceptions noted above, information form individual reports are adequately summarized.

Response 10. Comment noted. We hope the final is a better product.

Comments from Richard Olsen, Argonne National Laboratory:

Comment 1. It is not clear how this report fits into the overall program objectives and how final conclusions and recommendations will be integrated and synthesized.

Response 1. We believe that this recent draft more clearly addresses your concern.

Comment 2. The combined report lacks effective integration among the various technical presentations and perhaps more importantly with other components of the overall program.

Response 2. Same as response 1.

Comment 3. The current report draft is largely a conglomeration of a number of separate interim reports which percent the perception of having been carried out independently.

Response 4. We believe that they were carried out independently. We have tried to integrate the disparate results.

Comment 5. The report does not to any significant degree relate contaminant levels in biota and the resulting ecological risk to the temporal and spatial data apparently compiled for contaminants of concern.

Response 5. Comment noted. We hope the final is a better product.

Comment 6. The spatial relationship of contaminants to biological effects is only weakly developed.

Response 6. Comment noted.

Comment 7. The GIS work is not fully utilized. Perhaps the low level of integration is largely a result of timing for completion of various program components.

Response 7. Timing for completion of products had a major negative impact on the quality of the draft. In this product time did not allow us to produce a more integrated report. There was inadequate time to confer with other authors of Bi-State products after their drafts were completed in late 1995. This product at least benefitted from having the final reports, which were out in January 1996.

Comment 8. The report needs a conclusion section.

Response 8. Comment noted.

Comment 9. It would help to focus the analyses and minimize the perception in the current presentation of a program consisting of a number of uncoordinated research products.

Response 9. Comment noted.

Comment 10. Why were the particular target species chosen.

Response 10. We believe that this was addressed in the current report.

Comment 11. "Indicator species" and "target species" was used interchangeably.

Response 11. Comment noted.

Comment 12. Reviewer recommends that an EPA Ecological Risk Assessment be used in the Bi-State program.

Response 12. This comment beyond the scope of this report.

All specific comments by this reviewer are noted.

Comments from Jean Cameron, USFWS:

All commments noted above.