POLYCHLORINATED DIOXINS AND - FURANS IN COLUMBIA RIVER SPORTFISH: CHIEF JOSEPH DAM TO MCNARY DAM

by
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EXECUTIVE SUMMARY

The Washington State Department of Ecology (Ecology) has conducted a survey of polychlorinated dibenzodioxins (PCDDs) and -furans (PCDFs) in muscle tissue of sportfish from the middle reaches of the Columbia River. Concentrations in ten species of sportfish collected between Chief Joseph Dam and McNary Dam from May - November 1990 are reported here.

Concerns over PCDD/PCDF contamination of Columbia River sportfish originally stemmed from EPA data on fish collected in the lower Columbia during 1987 and 1989. These data showed elevated concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF), particularly in Lake Wallula below the Boise Cascade bleached kraft pulp mill in Wallula, Washington. Partly in response to EPA's findings, the Northwest Pulp and Paper Association (NWPPA) in 1989 commissioned an independent assessment of human health risks due to TCDD in edible tissues of fish from the lower reaches of the Columbia. They concluded that eating Columbia River fish does not pose a significant human health risk based on present consumption patterns.

In the upper reaches of the Columbia, investigations of PCDDs and PCDFs in fish have centered around the Celgar Pulp Company bleached kraft mill in Castlegar, British Columbia, about 30 river miles above the U.S./Canada border. In 1988, Environment Canada reported high TCDD and TCDF concentrations in lake whitefish below Celgar. The B.C. Ministry of Environment and Celgar Pulp Co. conducted subsequent studies which yielded similar findings. Ecology also performed an extensive survey of PCDDs/PCDFs in Lake Roosevelt, the pool immediately downstream of Celgar formed by Grand Coulee Dam, and found significant concentrations in several fish species and other media.

The objective of the present investigation was to obtain an accurate estimate of mean TCDD and TCDF concentrations in muscle tissue of major sportfish species from Chief Joseph Dam to McNary Dam. Prior to this survey, few data existed on TCDD and TCDF concentrations in fish or other media in this 250-mile portion of the Columbia River. The results of this investigation have been provided to the Washington State Department of Health (Health) for an assessment of human health implications. Health's assessment was near completion at the time of this printing.

PCDDs and PCDFs are principally formed as by-products of industrial chemical processes and during combustion of chlorinated organic compounds, municipal waste incineration, and chlorine bleaching of wood pulp. Of the 210 congeners (forms) of PCDDs/PCDFs, only the 17 congeners with the 2,3,7,8-substitution pattern are considered highly toxic. TCDD is the most toxic of these, while TCDF is considered 1/10 as toxic as TCDD. Toxicity of mixtures of PCDDs/PCDFs is assessed using a set of toxicity equivalence factors (TEFs) to convert the toxicity of each congener to that of TCDD, the result being called toxicity equivalents, or TEQs. Calculation of TEQ for a hypothetical fish sample containing 5 parts per trillion (ppt) TCDD and 23 ppt TCDF is as follows: $[5 + (0.1 \times 23)] = 7.3$ ppt TEQ.

In the past, disagreement on the levels of PCDDs and PCDFs in fish that warrant advisories for human health has resulted in varying consumption limits recommended by government agencies. Canadian health advisories regarding consumption of lake and mountain whitefish downstream of the Celgar mill have been based on Health and Welfare Canada's legal limit of 20 ppt TCDD (here applied to TEQs) and the B.C. Ministry of Environment's preliminary health advisory for the Columbia River of 11.4 ppt TEQ. The U.S. Food and Drug Administration has advised that TCDD concentrations less than 25 ppt are little cause for human health concern.

Ecology uses a criterion of 0.07 ppt TCDD in fish tissue to assess violations of state surface water quality standards. This value is for an increased lifetime cancer risk of 1 in 1,000,000 and is derived from the EPA health criterion for TCDD of 0.013 parts per quadrillion in water and a bioconcentration factor of 5,000. In their health assessment for TCDD and TCDF in Lake Roosevelt, Health concluded that TEQs in sportfish do not constitute levels for restricting human consumption. In order to reduce exposure to TCDD and TCDF, Health recommends that people eating Lake Roosevelt sportfish: remove the skin and fat before cooking, allow fat to drip off during cooking, eat smaller and younger fish, reduce the size of portions, and consume less fish.

For the present survey, Ecology analyzed TCDD and TCDF concentrations in muscle tissue of walleye, lake whitefish, rainbow trout, smallmouth bass, largemouth bass, carp, channel catfish, white sturgeon, and chinook salmon. Resident species were collected from four of the eight impoundments on the middle Columbia mainstem. These were Rufus Woods Lake, Rock Island Reservoir, Priest Rapids Reservoir, and Lake Wallula. Returning chinook were sampled from hatcheries at Priest Rapids and Leavenworth. In addition, mountain whitefish and rainbow trout from Lake Wenatchee and chinook salmon from the Columbia mouth were used to determine background TCDD/TCDF concentrations. In all, 46 composite samples representing 187 individual fish were analyzed for this survey.

Except for walleye, TCDD was detected in all resident mainstem fish samples. Mean TCDD concentrations range from less than 0.1 ppt in Rock Island walleye, to 4.3 ppt in channel catfish from Lake Wallula. TCDF was detected in all mainstem samples with mean concentrations ranging from 1.4 ppt in Lake Wallula channel catfish to 142 ppt in lake whitefish from Rufus Woods Lake.

The TCDF concentrations observed in whitefish are much higher than other samples and are probably a reflection of upstream contamination in Lake Roosevelt due to discharges by the Celgar mill. Rufus Woods whitefish specimens may have originated from Lake Roosevelt and been flushed downstream during drawdown of the reservoir. Walleye and rainbow trout from Rufus Woods Lake had low to non-detectable TCDD/TCDF concentrations. The weight of evidence from presently available data suggests Rufus Woods Lake is not substantially contaminated.

Mean TEQ concentrations in resident fish samples from the Columbia mainstem were moderately to substantially elevated above background. Aside from whitefish, fish from Rufus Woods Lake, Rock Island and Priest Rapids reservoirs, as well as bass from Lake Wallula, had TEQs 2 to 15 times higher than background. TEQs in whitefish and the remaining species from Lake Wallula had TEQs 45 to 160 times higher than background samples.

Both EPA and NWPPA had previously conducted surveys of TCDD/TCDF in fish from Lake Wallula. Although species, site, and temporal differences make direct comparisons of survey results difficult, Ecology's data generally agree better with results of the NWPPA investigation and suggest that Lake Wallula is presently not as contaminated as EPA data originally indicated.

Selected catfish, carp, sturgeon, and lake whitefish samples were analyzed for all other 2,3,7,8-substituted PCDDs and PCDFs. Detection of these additional congeners was essentially restricted to Lake Wallula samples, with 2,3,4,7,8-PeCDF being the most frequently detected congener. The majority of these compounds were present at concentrations of 1 ppt or less, and overall contribution to TEQs averaged about nine percent.

Results of TCDD/TCDF analyses in muscle tissue from two races of returning Columbia River chinook salmon show this species is not accumulating significant amounts of TCDD or TCDF. TCDD and TCDF concentrations were low to non-detectable for all samples analyzed. TEQs were one and a half times higher than background in spring chinook from Leavenworth and three times higher than background in fall chinook from Priest Rapids. Differences in exposure time to Columbia River water may account for the slight contrast in TEQs between spring and fall chinook. Similar findings for chinook were also reported in the NWPPA survey.

With the completion of this investigation, TCDD/TCDF data are now available from seven surveys covering approximately 800 miles of the Columbia River, from above Castlegar, B.C. to the river's mouth. In terms of TEQs in fish muscle, the highest concentrations are found below the Celgar pulp mill in both the Canadian reaches and Lake Roosevelt. Travelling downstream, there appears to be a trend towards declining TEQs from Celgar to Priest Rapids. Concentrations are again elevated at Lake Wallula, followed by a downstream region of reduced concentrations, and finally, levels near background at the mouth.

Based on the results reported here, it is recommended that:

1. TCDD/TCDF in media such as sediment and fish tissue be monitored to assess the effectiveness of source control at Boise Cascade Wallula.

2. Studies be conducted to determine the ecological implications of PCDDs/PCDFs in the Columbia River.

3. The occurrence of PCDDs/PCDFs in the Snake River be evaluated to determine potential loading to the Columbia River. Data on the extent of PCDD/PCDF contamination in the Snake River, a tributary with a potentially significant PCDD/PCDF source, the Potlatch Lewiston bleached kraft pulp mill, are essentially non-existent.

INTRODUCTION

Recently, concerns have been raised over polychlorinated dibenzodioxin (PCDD) and polychlorinated dibenzofuran (PCDF) contamination of Columbia River fish. These concerns originally stemmed from EPA data on fish collected in the lower Columbia during 1987 and 1989 that showed elevated concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF), particularly in Lake Wallula below the Boise Cascade bleached kraft pulp mill in Wallula, Washington (Tetra Tech, Inc., 1990-draft). Partly in response to EPA's findings, in 1989 the Northwest Pulp and Paper Association commissioned an independent assessment of human health risks due to TCDD in muscle tissue of fish from the lower reaches of the Columbia (Beak Consultants Inc., 1989a,b; Keenan *et al.*, 1990). They concluded that eating Columbia River fish does not pose a significant human health risk based on present consumption patterns.

In the Spring of 1988, Environment Canada conducted a survey of PCDDs/PCDFs in fish from the vicinity of ten inland British Columbia pulp mills, including the Celgar Pulp Company bleached kraft mill located on the Columbia River about 30 river miles above the international border (Mah *et al.*, 1989). They reported high TCDD and TCDF concentrations in lake whitefish (*Coregonus clupeaformis*) below Celgar. The British Columbia Ministry of Environment and Celgar Pulp Co. conducted subsequent studies which yielded similar findings in a second species, mountain whitefish (*Prosopium williamsoni*) (B.C. Ministry of Environment, 1990-draft; E.V.S. Consultants, Ltd., 1990). As a result, health advisories were issued to limit consumption of lake whitefish caught below Celgar to a maximum of 40 grams per week, (Kirkpatrick, 1989) and mountain whitefish to a maximum of 205 grams per week (B.C. Ministry of Environment, 1990-draft).

Results of the survey by Environment Canada elicited concerns that contamination stemming from the Celgar mill may extend down into Lake Roosevelt, the Columbia River reservoir formed by Grand Coulee Dam. Therefore, the Washington State Department of Ecology (Ecology) conducted an extensive survey of PCDDs/PCDFs in Lake Roosevelt. Ecology found significant concentrations in several fish species and other media (Johnson *et al.*, 1991 a,b,c)

While the upper and lower reaches of the Columbia have been well studied for TCDD/TCDF contamination in fish, a void in data existed for the middle reaches. Ecology responded by undertaking a survey of TCDD/TCDF in sportfish from just above Chief Joseph Dam (Rufus Woods Lake) to McNary Dam (Lake Wallula) during May to November 1990, which is the subject of this report. Figure 1 shows the portion of Columbia River examined during this investigation.

The objective of this survey was to obtain an accurate estimate of mean TCDD and TCDF concentrations in muscle tissue of major sportfish species from popular harvest areas. During the course of this investigation, 187 individual fish were collected resulting in a total of

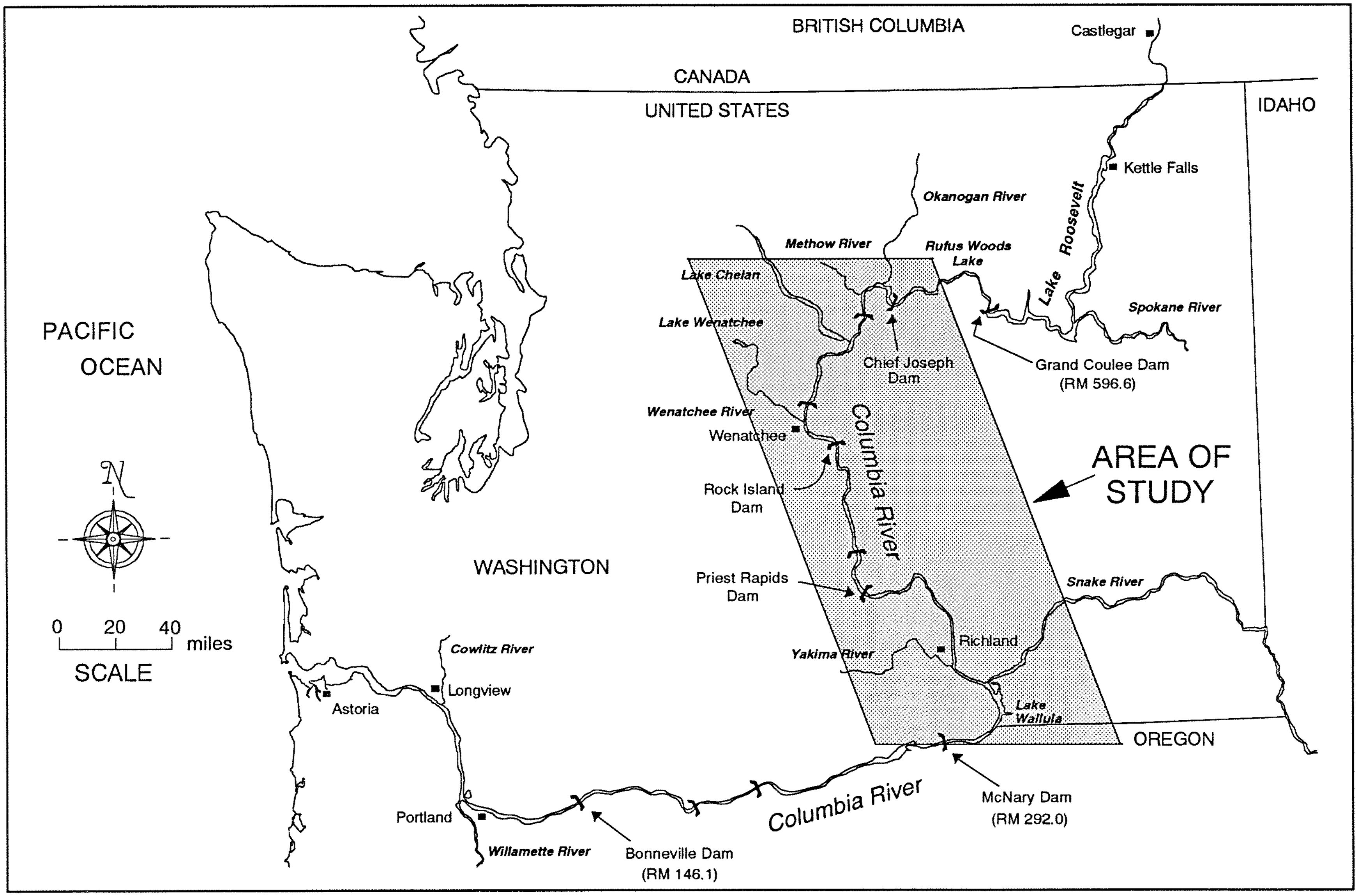

Figure 1. Area of Study for Ecology 1990 Survey of PCDDs and PCDFs in Sportfish from Chief Joseph Dam to McNary Dam

46 composite tissue samples analyzed for TCDD and TCDF. A subset of samples was also analyzed for all other potentially toxic PCDDs and PCDFs to determine extent of contamination from these compounds. The data contained in this report have been provided to the Washington State Department of Health (Health) for an assessment of human health implications. Health's assessment was near completion at the time of this printing.

Background on PCDDs and PCDFs

PCDDs and PCDFs are principally formed as by-products of industrial chemical processes and during combustion of chlorinated organic compounds, incineration of municipal waste, and chlorine bleaching of wood pulp (EPA, 1987; Environment Canada/Health and Welfare Canada, 1990). They have no commercial or domestic applications and are not produced intentionally, except for the small quantities used for research purposes (Palmer *et al.*, 1988).

Figure 2 shows the structure and numbering system of PCDDs and PCDFs. There are 75 different PCDD congeners, or forms, of which 2,3,7,8-TCDD (commonly referred to as dioxin) is the most toxic and widely studied. PCDFs are chemically similar to PCDDs and occur in 135 forms. Most significant of the PCDFs detected in Columbia River fish is 2,3,7,8-TCDF because of its pervasiveness in fish from the vicinity of bleached kraft pulp mills (Mah *et al.*, 1989; B.C. Ministry of Environment, 1990-draft; Tetra Tech, Inc., 1990 - draft; Johnson *et al.*, 1991a).

PCDDs and PCDFs with chlorine atoms located at the 2,3,7, and 8 positions are considered to be the most toxic. There are 7 PCDDs and 10 PCDFs with this substitution pattern. To assess the toxicity of PCDD/PCDF mixtures in fish, a set of toxicity equivalence factors (TEFs) are used to convert toxicity of each congener to that of TCDD, called toxicity equivalents, or TEQs (Barnes *et al.*, 1989). Calculation of TEQ for a hypothetical fish sample containing 5 parts per trillion (ppt) TCDD and 23 ppt TCDF (considered to be 1/10 as toxic as TCDD, giving it a TEF of 0.1) is as follows: $[5 + (0.1 \times 23)] = 7.3$ ppt TEQ.

In the past, disagreement on the levels of PCDDs and PCDFs in fish that warrant advisories for human health has resulted in varying consumption limits recommended by government agencies. Canadian health advisories regarding consumption of lake and mountain whitefish downstream of the Celgar mill, have been based on Health and Welfare Canada's legal limit of 20 ppt TCDD (here applied to TEQs) and the B.C. Ministry of Environment's preliminary health advisory for the Columbia River of 11.4 ppt TEQ. The U.S. Food and Drug Administration (Hall, 1981) has advised that TCDD concentrations less than 25 ppt are little cause for human health concern.

Ecology, on the other hand, uses a criterion of 0.07 ppt TCDD in fish tissue to assess violations of state surface water quality standards. This value is based on an increased lifetime cancer risk of 1 in 1,000,000 and is derived from the EPA health criterion for TCDD of 0.013 parts per quadrillion in water and a bioconcentration factor of 5,000 (EPA, 1986a). EPA is presently re-evaluating their risk assessment methodology for TCDD, largely based on new evidence of how

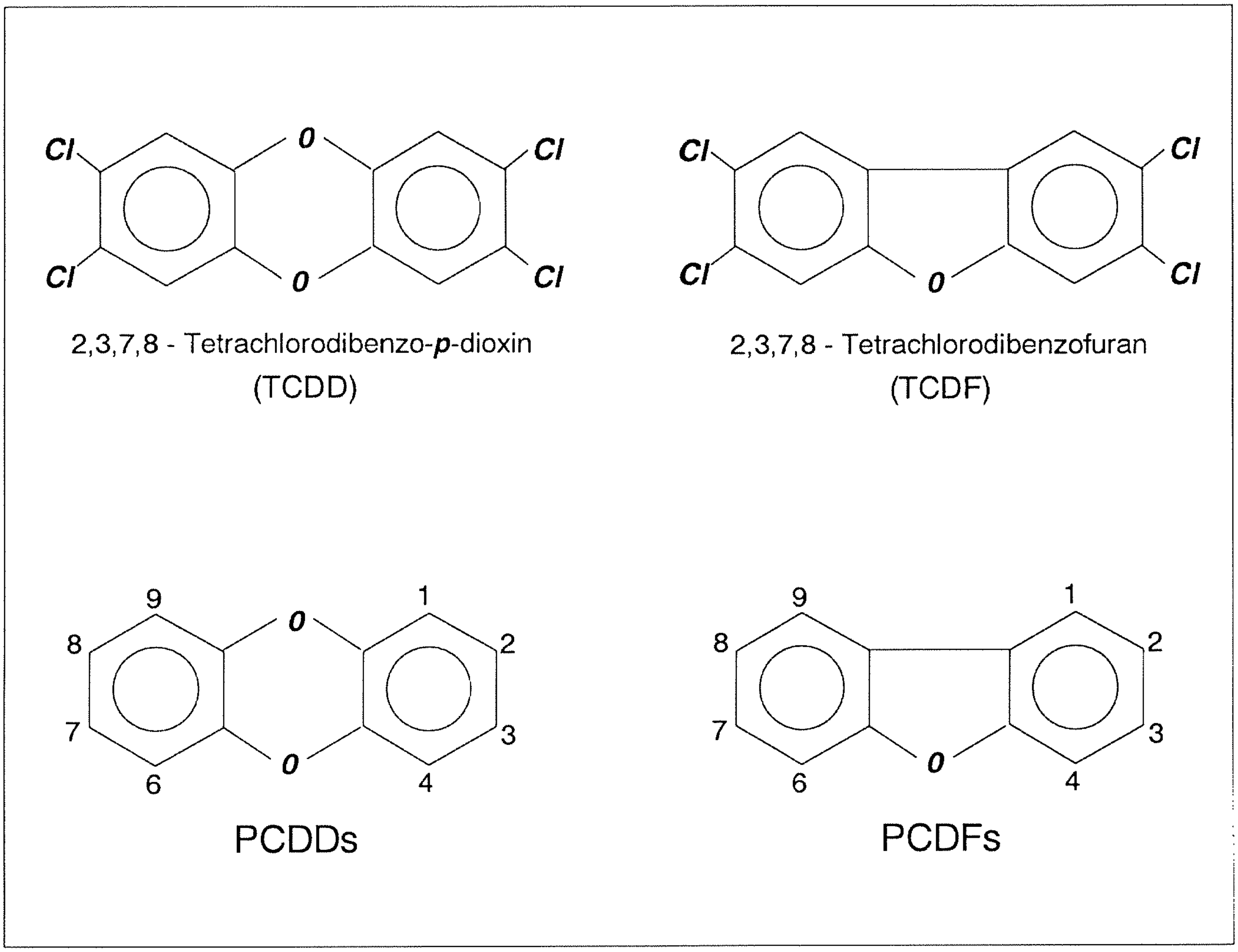

Figure 2. Chemical Structure of TCDD and TCDF and Numbering System for PCDDs and PCDFs

TCDD works at the molecular level (Roberts, 1991). The mechanistic approach, agreed upon by participants of the Banbury Center meeting in 1990, is likely to replace results of epidemiological studies and dose-response studies in laboratory animals as the basis for TCDD risk assessment.

Health relied heavily on the mechanistic approach in their report on health implications of TCDD and TCDF in Lake Roosevelt sportfish. They concluded that average muscle TEQ concentrations, which ranged from 0.3 to 17 ppt, do not constitute levels for restricting human consumption (Mariën *et al.*, 1991). In order to reduce exposure to TCDD and TCDF, Health recommends that people eating Lake Roosevelt sportfish: remove skin and fat before cooking, allow fat to drip off during cooking, eat smaller and younger fish, reduce the size of portions, and consume less fish.

PCDDs and PCDFs are relatively insoluble - less than one part per billion in water - and have a high octanol/water partition coefficient ($K_{o/w}$), defined as the ratio of a compound's concentration in n-octanol to water in an equal mixture of the two solvents (Crummett and Stehl, 1973; Smith *et al.*, 1988). These characteristics cause it to be sequestered in the fatty tissues of organisms and adsorbed to carbon-containing sediment in the aquatic environment (Maybe *et al.*, 1982; EPA, 1984; Opperhuizen and Sijm, 1990)

Decomposition of PCDDs and PCDFs in the aquatic environment may be a very slow process. Half-lives of these compounds in sediments are probably greater than one year, and may be ten years or more for TCDD (Eisler, 1986; Environment Canada/Health and Welfare Canada, 1990).

Sources of PCDDs and PCDFs to the Study Area

Pulp mills, wood-treating operations, and to a lesser extent, municipal sewage treatment plants and the agriculture industry, have all been identified as potential point sources of PCDDs and PCDFs to the Columbia River (BCI, 1991-draft). Pulp mills using chlorine bleaching processes, however, appear to be the primary source of TCDD and TCDF.

Three bleached kraft pulp mills discharge directly or indirectly to the study area. Effluent from the Celgar pulp mill in Castlegar, B.C. is discharged to the Columbia approximately 30 river miles above the international border. The Potlatch Corporation mill in Lewiston, Idaho discharges to the Snake River near the Washington/Idaho border, approximately 140 river miles from the Columbia River confluence below the Tri-Cities. The Boise Cascade Wallula mill's outfall is located in Lake Wallula at about river mile 314, just above the mouth of the Walla Walla River. While wastewater from Washington and Idaho mills receive secondary treatment, effluent from the Celgar mill is not treated before being discharged.

Relatively little is known about quantities of TCDD and TCDF discharged to the Columbia River. One evaluation of TCDD point sources concluded that effluent from the Boise Cascade

Wallula mill accounted for approximately half of the documented 45 mg TCDD discharged to the Columbia River Basin from pulp mills each day in 1987 (BCI, 1991-draft). However, in 1989 the plant changed defoamers which contained TCDD precursors, reducing TCDD concentrations in the effluent by approximately 40 to 70% (Houck, personal communication; Ross, personal communication). In addition, the mill recently installed a new chlorine dioxide generator and plans to increase its chlorine dioxide substitution for chlorine by as much as 70%. This is also projected to significantly reduce the amount of TCDD and TCDF discharged by the mill.

Daily TCDD emissions for the Celgar and Potlatch pulp mills were estimated to be 1.4 mg and 10.6 mg, respectively, in 1987 (BCI, 1991-draft). Like the Boise Cascade Wallula mill, the Potlatch mill in Lewiston has taken measures to reduce its TCDD emissions, in part because of the recent EPA Columbia River total maximum daily load (TMDL) requirements for TCDD which are designed to protect the water quality standard of 0.013 parts per quadrillion. EPA plans to achieve the TMDL for TCDD by allocating maximum loads to point and non-point sources in the Columbia River Basin. Waste load allocations for Boise Cascade Wallula and Potlatch Lewiston are 0.25 and 0.39 mg TCDD/day, respectively (EPA, 1991). Although EPA does not have the authority to regulate TCDD emissions from Celgar, it is believed that this mill will reduce its TCDD loading to approximately 0.05 mg/day by 1994, following plant expansion and modernization.

METHODS

Study Area and Sampling Sites

Figure 3 shows where fish samples were collected. Resident sportfish were collected at four of the eight impoundments on the middle Columbia mainstem. These were Rufus Woods Lake[1], Rock Island Reservoir, Priest Rapids Reservoir, and Lake Wallula. Fish collection sites were at the downstream end of each reservoir; sites were between 60 and 100 miles apart. Fish samples from Lake Wallula were collected approximately 17 miles below the Boise Cascade mill outfall, except for sturgeon which were obtained approximately 2 miles below the outfall. Collection points are specified in Appendix A.

Samples were collected from two separate runs of a migratory species, chinook salmon. Spring chinook were obtained at the U.S Fish and Wildlife Service Leavenworth National Fish Hatchery on the Wenatchee River. Fall chinook samples came from the Washington Department of Fisheries Priest Rapids Spawning Channel at Priest Rapids Dam.

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[1] The Rufus Woods Lake data were previously reported in Johnson *et al.*, (1991a). They are reported again here for comparison with downstream results.

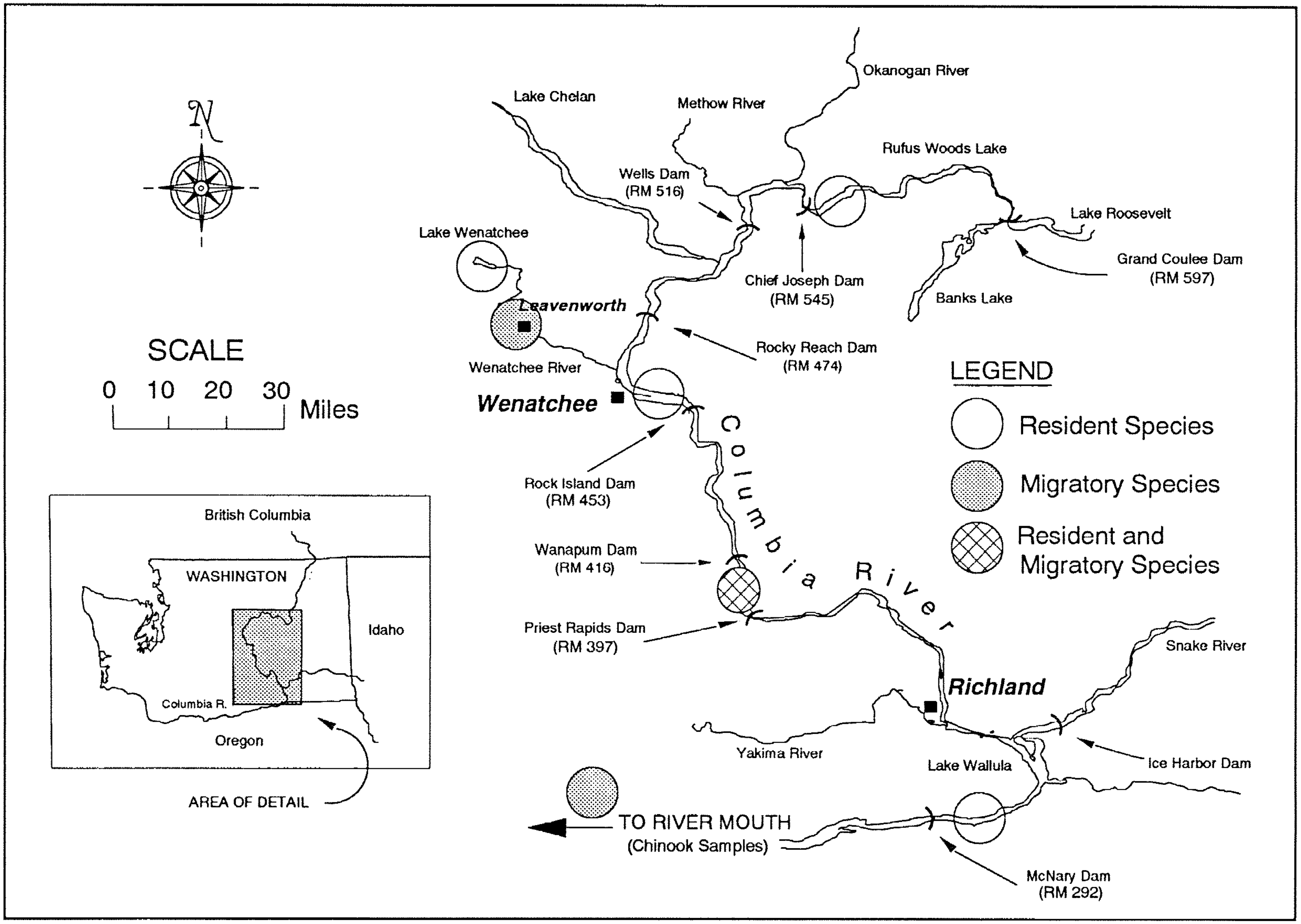

Figure 3. Location of Fish Collection Sites for Ecology 1990 Survey of PCDDs and PCDFs from Chief Joseph Dam to McNary Dam

Fish samples were collected from two additional sites to obtain data on background concentrations of TCDD and TCDF. Resident species were collected from Lake Wenatchee, an undeveloped Cascade Mountain lake high in the Columbia River drainage. A previous Ecology survey showed very low to non-detectable concentrations of environmental contaminants in Lake Wenatchee fish and sediments (Johnson and Norton, 1990). Background concentrations for chinook salmon were determined in samples of fall chinook collected at the mouth of the Columbia River.

Fish Species and Sample Size

Table 1 lists the fish species and number of samples collected at each site. The following species were analyzed:

- Walleye (*Stizostedion vitreum*)
- Lake Whitefish (*Coregonus clupeaformis*)
- Rainbow Trout (*Oncorhynchus mykiss*, formerly *Salmo gairdneri*)
- Smallmouth Bass (*Micropterus dolomieui*)
- Carp (*Cyprinus carpio*)
- Channel Catfish (*Ictalurus punctatus*)
- Largemouth Bass (*Micropterus salmoides*)
- White Sturgeon (*Acipenser transmontanus*)
- Mountain Whitefish (*Prosopium williamsoni*)
- Chinook Salmon (*Oncorhynchus tshawytscha*)

Species were chosen based on popularity as sportfish and availability. Samples of at least two resident species were desired at each of the mainstem sites. Information on fish harvest patterns was furnished through interviews with Larry LaVoy (Wash. Dept. of Fisheries), Ken Williams (Wash. Dept. of Wildlife), Joe Foster (Wash. Dept. of Wildlife), Olaf Langness (Colville Tribe), and Kirk Truscott (Colville Tribe).

Because of differences in habitat, water temperature, food availability, and other factors, species composition and abundance of fish changed dramatically from the upper to lower reaches of the study area. Samples obtained in the upper reaches consisted of walleye, lake whitefish, and rainbow trout. At downstream sites these cold-water species were replaced by bass, carp, and catfish.

Although carp are not a desirable sportfish in many parts of Washington, smoked carp is deemed excellent eating by some (Wydoski and Whitney, 1979). Health has expressed some concern that Southeast Asian-Americans living in the Tri-Cities area may consume a substantial amount of carp (Amman, personal communication; Lorenzana, personal communication). EPA found high concentrations of TCDD and TCDF (TEQ=88 ppt) in whole carp from Lake Wallula (Tetra Tech, Inc., 1990-draft).

Table 1. Sportfish Species Collected in the Study Area

	Rufus Woods Lake	Rock Island Reservoir	Priest Rapids Reservoir	Lake Wallula	Wenatchee River	Background Sites	
						Lake Wenatchee	Columbia River Mouth
Resident							
Walleye	10(2)	9(2)					
Lake Whitefish	10(2)	2(1)					
Rainbow Trout	15(3)					4(1)	
Smallmouth Bass			2(1)				
Carp			15(3)	15(3)			
Channel Catfish				15(3)			
Largemouth Bass				10(2)			
White Sturgeon				5(1)			
Mountain Whitefish						15(3)	
Migratory							
Spring Chinook					20(5)		
Fall Chinook			20(5)				20(5)

Note: values represent numbers of fish collected; number of composite samples analyzed in parentheses

Chinook salmon were chosen among the six migrating salmonid species in the Columbia River drainage because of their importance throughout the lower and middle Columbia. The Northwest Pulp and Paper Association (NWPPA) reported that the general population eating fish caught in the lower Columbia consumed more chinook than any other species (Beak Consultants Inc., 1989b). NWPPA also concluded that in 1988, populations of four native tribes in the lower Columbia Basin consumed four times more chinook than any other species caught by Columbia River treaty fishermen.

Five composite samples of chinook were analyzed from each site. Each of the chinook composites consisted of muscle tissue from four individual fish. For each of the resident species, an effort was made to collect enough fish for three composite samples (five fish per composite) at each site. However, desired numbers of samples were obtained for only one of three species at Rufus Woods Lake, no species at Rock Island, one of two species at Priest Rapids, and two of three species at Lake Wallula. Target species were most abundant at Rufus Woods Lake and Lake Wallula and least abundant at Rock Island where only 11 fish (two whitefish and nine walleye) were collected during three separate sampling efforts.

Fish Collection and Sample Preparation

Resident species were obtained by electroshocking, gill net, or hook-and-line. An effort was made to keep only legal fish for those species with size limits (rainbow trout, sturgeon, and chinook). In the case of rainbow trout, however, some sub-legal sized fish were taken to achieve larger sample size. For species with no minimum size limit (walleye, lake whitefish, bass, carp, and channel catfish), only those large enough to reasonably be consumed were used for analysis.

Lake Wallula sturgeon muscle tissue was furnished by Battelle Pacific Northwest Laboratories. Chinook salmon from the Columbia River mouth were purchased from Chinook Packing Company in Chinook, Washington, within 48 hours of being gillnetted at the Columbia River mouth. All other samples were collected by Ecology. Biological data including length, weight, and age of each fish can be found in Appendix A.

In the field, fish selected for analysis were subdued by a sharp blow to the head and placed in a clean polyethylene bucket. The location, species, length, weight, and other observations were recorded in a notebook and on a sample tag. The specimen, along with its corresponding sample tag, was then double-wrapped in aluminum foil (dull side against fish) and placed in a Ziploc® bag. Samples were kept on ice while in the field and subsequently frozen for later dissection.

Except for sturgeon, which were analyzed individually, each sample was a composite of approximately 40 grams of anterior, epaxial muscle from each of two to five individual fish. The fish were sorted into groups of similar average size for each composite of that species. Tissue was obtained by removing a rectangular-shaped section of muscle above the lateral line and forward of the dorsal fin. Skin was discarded.

Only stainless steel instruments, washed with Liquinox® detergent followed by sequential rinses with deionized water, pesticide-grade acetone, and pesticide-grade hexane, came in contact with the muscle tissue. All dissection instruments underwent this cleaning procedure for each species and site, and new scalpel blades were used for each composite. Samples were placed in Series 300 amber glass bottles with teflon lid-liners specially cleaned for trace organics analysis (I-Chem, Hayward, California; series 300).

Analytical Methods and Quality Assurance

Tissue homogenization and chemical analyses were done by Triangle Laboratories, Inc. (Research Triangle Park, North Carolina) or Alta Analytical, Inc. (El Dorado Hills, California). Each sample was analyzed for TCDD, TCDF, and percent lipids, with selected samples re-analyzed for all 2,3,7,8-substituted PCDDs/PCDFs.

TCDD and TCDF were measured using isotope dilution, high resolution GC/MS (EPA Method 8290 - EPA, 1986b). A schematic illustration of the procedure is shown in Figure 4. The 5 mL extract used for lipid analysis was evaporated to 1 mL, transferred to a pre-weighed aluminum drying dish by rinsing with petroleum ether, dried in a fume hood overnight, and re-weighed for determination of percent lipid.

Triangle Laboratory data were reviewed for qualitative and quantitative accuracy by Dr. William Luksemburg, an independent expert under contract to Ecology. Stuart Magoon of the Ecology/EPA Laboratory in Manchester, Washington, reviewed data from Alta Analytical.

Reviewers evaluated ion chromatograms, initial and daily continuing calibrations, column performance check mixes, calculations of positive values and detection limits, isotopic abundance ratios for internal/surrogate/recovery standards and positive natives, matrix spikes and spike duplicates, and percent lipid calculations. All data reported here have been deemed acceptable for use according to the quality assurance requirements of Method 8290.

Analysis of duplicate split samples provides an estimate of analytical precision. Table 2 shows results of duplicate TCDD/TCDF analyses of six fish tissue samples. In most instances, duplicate analyses agreed within 20% or better. For TCDD, the relative percent difference (RPD; a measure of variability about the mean) ranged from 0 to 23% with a mean of 12%. TCDF analyses had a mean RPD of 11% with a range of 0 to 40%.

A combined smelt/carp sample from Petenwell Reservoir in Wisconsin was obtained from the EPA Environmental Research Laboratory (ERL) in Duluth, Minnesota, to assess analytical accuracy. Petenwell Reservoir, a pool of the Wisconsin River, also receives pulp and paper mill effluent. Results of TCDD analyses showed good agreement between ERL and Triangle, but poor agreement between Alta and these two labs. EPA reported TCDD concentrations of 19.6 ± 2.0 ppt (n=12); Triangle reported 24.2 ± 1.3 ppt (n=2); Alta reported 11 ppt (n=1). The reason for this low result by Alta could not be determined. Better agreement between Alta and Triangle was achieved in TCDD and TCDF analysis of a Lake Wallula sturgeon sample. Results reported by Triangle and Alta were 4.2 and 5.6 ppt, respectively, for TCDD (RPD = 29%) and 85 and 91 ppt, respectively, for TCDF (RPD = 7%).

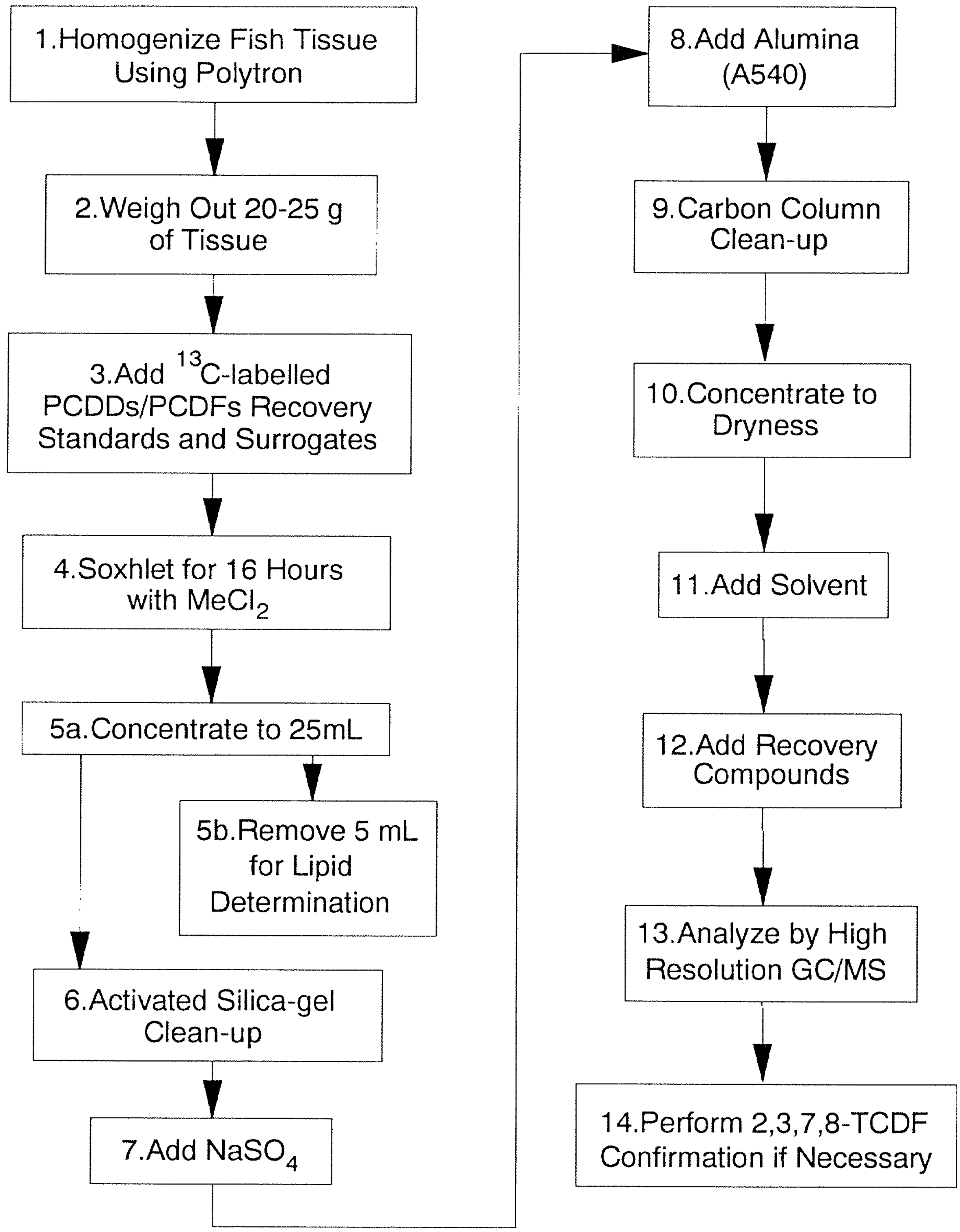

Figure 4. Schematic of Analytical Procedures for PCDDs and PCDFs

Table 2. Precision of Duplicate TCDD/TCDF Analyses (parts per trillion).

Sample No.	Laboratory	Analysis #1	Analysis #2	Relative Percent Difference *
		2,3,7,8-TCDD		
038161	Alta	2.5	2.8	11%
038164	Alta	4.4	4.4	0%
508132	Alta	0.8	1.0	22%
218009	Triangle	0.2	0.2	0%
458165	Triangle	3.2	2.8	13%
368108	Triangle	1.9	2.4	23%
				Mean = 12%
		2,3,7,8-TCDF		
038161	Alta	0.9	0.6	40%
038164	Alta	14	14	0%
508132	Alta	54	46	16%
218009	Triangle	1.1	1.1	0%
458165	Triangle	87	88	1%
368108	Triangle	154	172	11%
				Mean = 11%

* Range as a percent of duplicate mean

RESULTS AND DISCUSSION

TCDD and TCDF Concentrations in Resident Species

A summary of TCDD/TCDF concentrations measured in resident sportfish is shown in Table 3. Analytical results of all 46 samples can be found in Appendix B. Except for walleye, TCDD was detected in all mainstem fish samples. Mean TCDD concentrations ranged from less than 0.1 ppt in Rock Island walleye to 4.3 ppt in channel catfish from Lake Wallula. TCDF was detected in all mainstem samples with mean concentrations ranging from 1.4 ppt in Lake Wallula channel catfish to 142 ppt in lake whitefish from Rufus Woods Lake. Mean TEQs ranged from 0.2 ppt in Rock Island walleye to 16 ppt in lake whitefish from Rufus Woods Lake.

Aside from the elevated TCDD and TCDF concentrations in the whitefish from Rufus Woods Lake and Rock Island, Lake Wallula fish appeared to be the most contaminated. Fish in the other three reservoirs, except whitefish, had comparatively low concentrations. Three of the four species sampled from Lake Wallula and lake whitefish from Rufus Woods Lake had mean TCDD concentrations an order of magnitude greater than all other samples. Channel catfish showed the highest mean concentrations (4.3 ppt) followed, in decreasing order, by carp (4.2 ppt), sturgeon (3.4 ppt), and whitefish (2.2 ppt). Mean TCDD concentrations in other samples were generally less than 0.6 ppt and TCDD was not detected in any of the walleye samples at detection limits ranging from 0.1 to 1.8 ppt.

TCDF concentrations in whitefish from Rufus Woods Lake are comparable to those found in the same species in Lake Roosevelt (Johnson *et al.*, 1991a). At a mean of 142 ppt, they are two and a half to three times greater than concentrations found in Lake Wallula sturgeon (mean = 58 ppt) and Rock Island whitefish (50 ppt), and one to two orders of magnitude higher than mean TCDF concentrations in all other samples (range = 1.4 - 16 ppt).

The TCDF concentrations observed in whitefish are probably a reflection of upstream contamination in Lake Roosevelt due to discharges by the Celgar mill. As discussed in Johnson *et al.* (1991a), the Rufus Woods whitefish specimens may have originated from Lake Roosevelt. Tagging studies have shown most Lake Roosevelt sportfish species are flushed downstream to some extent during spring drawdown of the reservoir (Scholz, personal communication). Limited Ecology data on sediments and bottom fish (whole largescale suckers) from the upper Columbia show a 60 - 80% reduction in the level of TCDF contamination between lower Lake Roosevelt and the site in Rufus Woods Lake where the whitefish samples were obtained (Johnson *et al.*, 1991c). There are no similar data to assess the extent of TCDD/TCDF attenuation below Rufus Woods Lake.

The mean TCDD/TCDF concentrations measured in fish from Lake Wenatchee, the background area for the present study, are shown at the bottom portion of Table 3. TCDD was not detected

Table 3. TCDD and TCDF Concentrations in Muscle Tissue of Resident Columbia River Sportfish Collected August – November 1990 (mean +/– 1 standard deviation in parts per trillion, wet weight basis).

Sample Location	Species	No. Samples Analyzed	Percent Lipid	2,3,7,8–TCDD	2,3,7,8–TCDF	TEQ
RUFUS WOODS LAKE	Walleye	2	0.7+/–0.3	ND (0.4–1.8)	2.6+/–1.3	0.8+/–0.9
	Rainbow Trout	3	1.6+/–0.2	0.2+/–0 EMPC	4.3+/–0.7	0.6+/–0.1
	Lake Whitefish	2	9.4+/–2.0	2.2+/–0.1	142+/–29	16+/–2.8
ROCK ISLAND RESERVOIR	Walleye	2	1.8+/–0.8	ND (0.1–0.2)	1.6+/–0.2	0.2+/–0.1
	Lake Whitefish	1	4.8	0.9	50	5.9
PRIEST RAPIDS RESERVOIR	Smallmouth Bass	1	2.0	0.2	3.0	0.5
	Carp	3	8.9+/–5.1	0.4+/–0.1	12+/–2.3	1.5+/–0.3
LAKE WALLULA	Largemouth Bass	2	3.6+/–0.6	0.6+/–0.2	2.2+/–0.1	0.8+/–0.2
	Channel Catfish	3	1.3+/–1.2	4.3+/–1.5	1.4+/–0.6	4.5+/–1.6
	Carp	3	8.7+/–7.0	4.2+/–0.8	16+/–2.5	5.8+/–0.9
	White Sturgeon	5	6.0+/–1.9	3.4+/–1.2	58+/–27	9.3+/–3.0
LAKE WENATCHEE (background area)	Rainbow Trout	1	2.5	ND (0.2)	0.2	0.1
	Mountain Whitef	3	4.0+/–1.4	ND (0.1–0.3)	0.3+/–0.1	0.1+/–0.06

TEQ = 2,3,7,8–TCDD Toxic Equivalents [TCDD + (0.1)TCDF]

ND = Not Detected; detection limits shown in parentheses

EMPC = Estimated Maximum Possible Concentration

Note: 1/2 detection limit used to calculate TEQs for non–detected values in either mountain whitefish or rainbow trout samples from Lake Wenatchee (detection limits = 0.1 - 0.3 ppt). TCDF was detected in both species at concentrations ranging from 0.2 - 0.4 ppt. TEQ concentrations averaged 0.1 ppt. Similar TEQs have been reported by EPA in fish analyzed from 34 background sites nationwide during the National Bioaccumulation Study (Tetra Tech, Inc., 1990-draft).

Although background samples collected for this survey do not provide a same-species comparison with mainstem samples, they do provide an estimate of background concentrations in a lake of the Columbia River basin whose only known source of TCDD/TCDF is atmospheric deposition (Czuczwa *et al.*, 1984). When compared to background, mean TEQ concentrations in resident fish samples from the Columbia mainstem are moderately to substantially elevated. Aside from whitefish, fish from Rufus Woods Lake, Rock Island Reservoir, Priest Rapids Reservoir, as well as bass from Lake Wallula, had TEQs from 2 to 15 times higher than background. TEQs in whitefish and the remaining species from Lake Wallula had TEQs from 45 to 160 times higher than background samples.

TCDD and TCDF Concentrations in Migratory Species

Results of TCDD/TCDF analyses on muscle tissue from two races of returning Columbia River chinook salmon showed this species is not accumulating significant amounts of TCDD or TCDF (Table 4). TCDD and TCDF concentrations were low to non-detectable for all samples analyzed.

Mean TEQs for Leavenworth spring chinook and Priest Rapids fall chinook were 0.3 ppt and 0.6 ppt, respectively. Fall chinook from the mouth of the Columbia River, analyzed to give background concentrations, had a mean TEQ of 0.2 ppt.

TEQs were one and a half times background in spring chinook from Leavenworth and three times background in fall chinook from Priest Rapids. Lipid-normalization of mean TEQs in these two groups set them further apart - 5.2 pg/g lipid for Leavenworth chinook and 16 pg/g lipid for Priest Rapids chinook - suggesting that lipid content is not the sole determinant of TCDD and TCDF accumulation.

Differences in exposure time to Columbia River water may account for the slight contrast in TEQs. As adults, the Leavenworth fish spent probably no more than a few weeks in the Columbia River, migrating quickly from the mouth to the hatchery located on the Wenatchee River (LaVoy, personal communication; Wydoski and Whitney, 1979). Fish collected at the Priest Rapids hatchery probably spent one to two months in the Columbia before arriving at the hatchery in early November (Petersen, personal communication; Sneva, personal communication).

Table 4. TCDD and TCDF Concentrations in Muscle Tissue of Returning Columbia River Chinook Salmon Collected May – November 1990 (mean +/– 1 standard deviation in parts per trillion, wet weight basis).

Sample Location	Species	No. Samples Analyzed	Percent Lipid	2,3,7,8–TCDD	2,3,7,8–TCDF	TEQ
LEAVENWORTH	Spring Chinook	5	5.8+/–3.2	0.2 EMPC*	1.5+/–0.5	0.3+/–0.1
PRIEST RAPIDS	Fall Chinook	5	3.7+/–1.2	0.2 EMPC**	4.6+/–2.1	0.6+/–0.3
COLUMBIA RIVER MOUTH (background area)	Fall Chinook	5	6.6+/–2.4	ND (0.1–0.5)	0.7+/–0.4	0.2+/–0.1

TEQ = 2,3,7,8–TCDD Toxic Equivalents [TCDD + (0.1)TCDF]
EMPC = Estimated Maximum Possible Concentration
* – detected in 3 of 5 samples only
** – detected in 2 of 5 samples only
ND = Not Detected; detection limits shown in parentheses
Note: 1/2 detection limit used to calculate TEQs for non–detected values

Findings reported by NWPPA also suggest that differences in time of exposure to Columbia River water may account for differences in TCDD and TCDF concentrations in two races (upriver and tule, or downriver, races) of fall chinook (Beak Consultants Inc., 1989a). Tule chinook generally spend more time in the lower river than upriver chinook, which pass quickly through the lower river on their way upstream. NWPPA collected samples of each race, both at the Columbia River mouth and below Bonneville Dam. Of ten samples collected at the mouth, TCDD was detected in five tule chinook (mean = 0.32 ppt) but not detected in five upriver chinook (detection limits = 0.11 - 0.22 ppt). The mean TCDF concentration was also higher in the tule chinook compared to upriver specimens (7.0 and 1.7 ppt, respectively). For those chinook collected below Bonneville Dam, only slight differences in TCDD and TCDF were reported (for tule chinook, TCDD was detected in 2 of 5 samples at a mean of 0.3 ppt, and mean TCDF was 4.5 ppt; for upriver chinook, TCDD was detected in 1 of 5 samples at a concentration of 0.2 ppt, and mean TCDF was 3.9 ppt). Percent lipids in muscle tissue of upriver chinook samples was substantially higher than those in tule race fish (9.1 vs. 2.5%, respectively).

Relative Importance of Other PCDD/PCDF Congeners

One sample each of channel catfish, carp, and sturgeon from Lake Wallula and one lake whitefish sample from Rufus Woods Lake were re-analyzed for all 2,3,7,8-substituted PCDDs and PCDFs, following initial TCDD/TCDF analysis. The sample with the highest TEQ for that species was selected for analysis. Table 5 shows these results and lists the toxicity equivalence factor (TEF) of each analyte.

Detection of other PCDDs/PCDFs was essentially restricted to Lake Wallula samples. Present in three samples, 2,3,4,7,8-PeCDF was the most frequently detected congener. Two compounds (1,2,3,7,8-PeCDF and OCDD) were found in two samples each, while HxCDD, HpCDD, and OCDF were each detected in one sample only. OCDF was the only congener detected in the sample from Rufus Woods Lake. Aside from the octa-congeners, which are the least toxic, these compounds were present at concentrations of 1 ppt or less.

Figure 5 depicts the relative contribution to the TEQ by TCDD, TCDF, and other congeners combined. As a result of their low concentration and low toxicity relative to TCDD, overall contribution of the other congeners to TEQ averaged only 9%.

Similar findings were reported by Ecology in samples collected from Lake Roosevelt (Johnson *et al.*, 1991a). In four muscle samples analyzed for PCDDs/PCDFs, 2,3,4,7,8-PeCDF and OCDD were the most frequently detected compounds. Average contribution to TEQ by these and other congeners was approximately 4%.

EPA also attained comparable results in lower Columbia River fish muscle analyzed for the National Bioaccumulation Study (Tetra Tech, Inc., 1990-draft). Detection frequency for other PCDDs/PCDFs in EPA samples was approximately three per sample, with average contribution of other congeners to the TEQ of 11%. OCDD and OCDF were not analyzed by EPA.

Table 5. Analysis of Selected Samples for All 2,3,7,8-substituted PCDDs and PCDFs (parts per trillion, wet weight basis).

Species:		Channel Catfish	Carp	Sturgeon	Lake Whitefish
Location:		Lake Wallula	Lake Wallula	Lake Wallula	Rufus Woods Lake
Sample Number:		038162	038165	458164	368108
PCDDs	TEF				
2,3,7,8-TCDD	1	5.0	4.9	5.6	1.7 EMPC
1,2,3,7,8-PeCDD	0.5	ND (0.6)	ND (0.5)	ND (0.7)	ND (1.6)
1,2,3,4,7,8-HxCDD	0.1	ND (0.5)	ND (0.2)	ND (0.4)	ND (1.0)
1,2,3,6,7,8-HxCDD	0.1	ND (0.4)	0.8	ND (0.4)	ND (1.0)
1,2,3,7,8,9-HxCDD	0.1	ND (0.5)	ND (0.4)	ND (0.5)	ND (1.1)
1,2,3,4,6,7,8-HpCDD	0.01	ND (0.6)	1.0	ND (0.5)	ND (1.5)
OCDD	0.001	ND (1.5)	2.1	8.1	ND (4.2)
PCDFs	TEF				
2,3,7,8-TCDF	0.1	1.8	19	91	176
1,2,3,7,8-PeCDF	0.05	ND (0.3)	0.4	0.8	ND (1.0)
2,3,4,7,8-PeCDF	0.5	0.9	1.0	0.9	ND (1.1)
1,2,3,4,7,8-HxCDF	0.1	ND (0.8)	ND (0.2)	ND (0.7)	ND (0.5)
1,2,3,6,7,8-HxCDF	0.1	ND (0.6)	ND (0.2)	ND (0.5)	ND (0.5)
2,3,4,6,7,8-HxCDF	0.1	ND (0.2)	ND (0.2)	ND (0.6)	ND (0.6)
1,2,3,7,8,9-HxCDF	0.1	ND (0.2)	ND (0.2)	ND (0.9)	ND (0.8)
1,2,3,4,6,7,8-HpCDF	0.01	ND (0.3)	ND (1.1)	ND (0.4)	ND (0.6)
1,2,3,4,7,8,9-HpCDF	0.01	ND (0.1)	ND (1.8)	ND (0.5)	ND (1.0)
OCDF	0.001	ND (0.6)	ND (0.2)	ND (3.6)	3.6
	TEQ =	5.7	7.6	15.6	20.9
	% TCDD	84 %	64 %	36 %	8 %
	% TCDF	3 %	25 %	58 %	87 %
	% Other Congeners	13 %	11 %	6 %	5 %

TEF = Toxicity Equivalence Factor

ND = Not Detected; detection limits shown in parentheses

EMPC = Estimated Maximum Possible Concentration

Note: 1/2 detection limit used to calculate TEQs for non-detected values

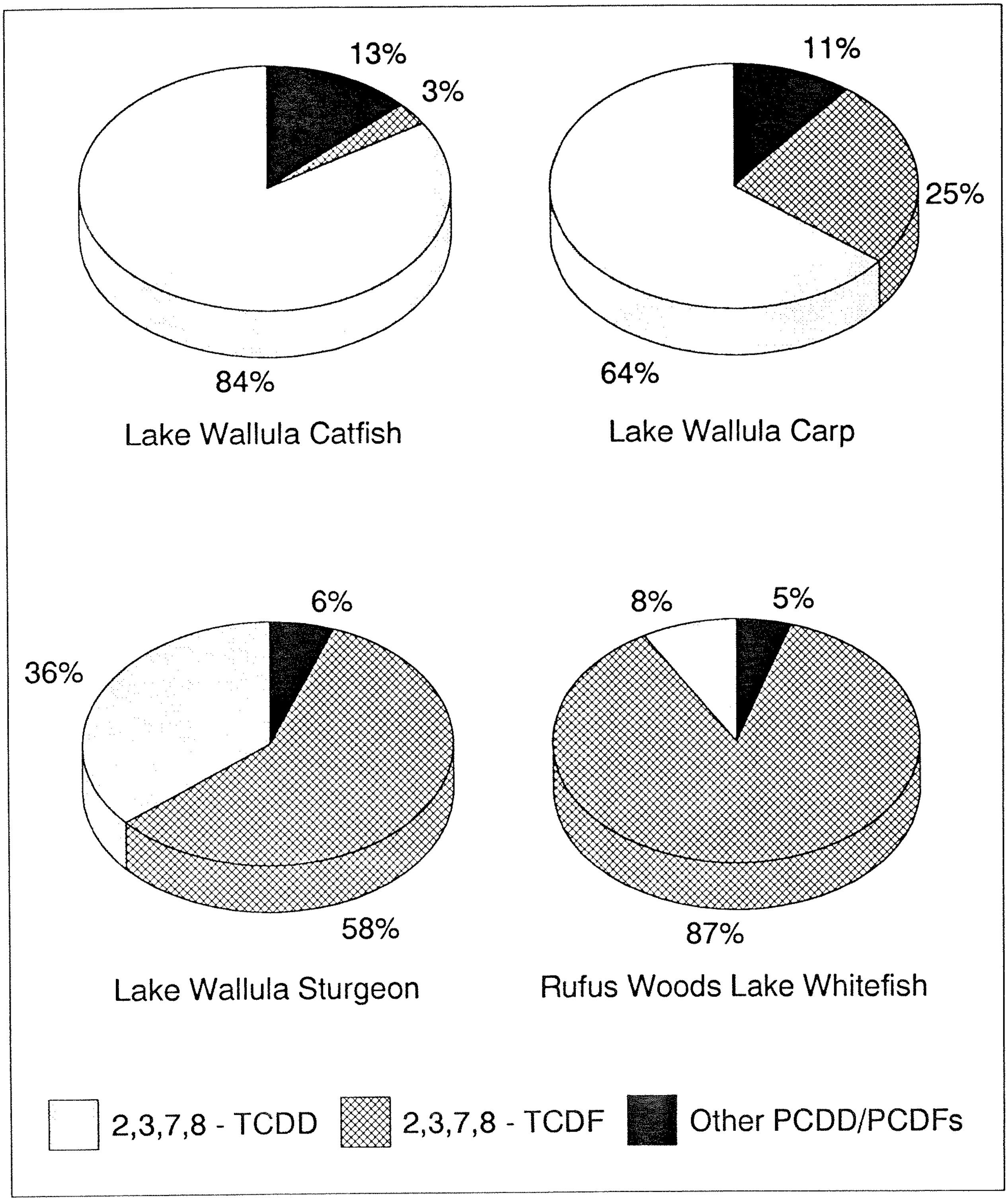

Figure 5. Percent Contribution of TCDD, TCDF, and Other 2,3,7,8 - Substituted PCDD/PCDF Congeners To TEQ

Comparison of Lake Wallula Findings with Previous Surveys

Because it receives effluent from a pulp mill, Lake Wallula was targeted for fish analyses to be included in the EPA National Bioaccumulation Study. Fish analyzed for PCDDs and PCDFs in 1987 and 1989 showed this area to be one of the most potentially contaminated in the Columbia River, largely based on elevated TCDD/TCDF concentrations in a single whole carp sample collected below the Boise Cascade outfall. Table 6 compares results of EPA's analyses of Lake Wallula fish with the recent NWPPA and Ecology surveys. Figure 6 shows where samples were obtained.

While the highly elevated concentrations of TCDD and TCDF in the EPA carp sample are noteworthy, this whole body data cannot be directly compared to carp muscle samples analyzed by NWPPA and Ecology. Percent lipid in the whole carp was 25%, five times higher than NWPPA samples and three times higher than Ecology samples. Whereas there is some controversy over the appropriateness of normalizing concentrations of organochlorine chemicals to lipid (Schmitt *et al.*, 1990), Johnson *et al.* (1991a) found a strong correlation between both TCDD and TCDF and percent lipid in muscle tissue of Lake Roosevelt sportfish. Additionally, tissues other than muscle are likely to concentrate TCDD and TCDF to a greater degree due, in part, to higher lipid content. Liver and eggs from Lake Roosevelt sportfish, which had higher percent lipid than muscle, were also found to have much higher TCDD and TCDF concentrations.

The extensive NWPPA survey of TCDD and TCDF in muscle tissue of fish from the lower reaches of the Columbia River was conducted partly in response to the EPA findings and concerns about impending EPA guidelines for effluent and receiving water concentrations of TCDD (Beak Consultants Inc., 1989a). Of the six areas sampled between RM 332 and the mouth, fish collected in Lake Wallula near the Tri-Cities (RM 326 to RM 332) had the highest TCDD and TCDF concentrations. Mean TEQs were one to two orders of magnitude lower than the EPA carp sample, and up to an order of magnitude lower than the other EPA samples. However, the NWPPA samples were collected several miles above the Boise Cascade outfall while the EPA samples were collected below the outfall.

Ecology's decision to sample fish from Lake Wallula was largely an attempt to resolve the apparent discrepancy between EPA's and NWPPA's findings. In general, the data reported here agree better with NWPPA than EPA. Muscle tissues of sturgeon collected below the Boise Cascade mill by Ecology had similar mean TCDD and TCDF concentrations compared to those collected above the mill by NWPPA. Carp muscle samples collected separately by Ecology and NWPPA showed similar agreement.

One possible explanation for the comparable TCDD/TCDF concentrations in fish above and below the Boise Cascade mill is movement of fish through the reservoir. Tagging studies have shown substantial movement of sturgeon within Lake Wallula and other Columbia River reservoirs, sometimes travelling over 50 miles in a period of four to six weeks (Haynes *et al.*,

Table 6. Summary of Available Data on TCDD and TCDF Concentrations in Fish from Lake Wallula (means in parts per trillion, wet weight basis)

Investigator	Species	Tissue	No. Samples Analyzed	Date Collected	% Lipid	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ
EPA*	Channel Catfish	Muscle fillet	1	Aug87	3.6	7.9	5.0	8.4
	Largescale Sucker	Whole fish	1	Aug87	17	5.1	42	9.3
	Carp	Whole fish	1	Mar89	25	56	321	88
NWPPA**	Largescale Sucker	Muscle fillet	5	Aug-Nov89	1.7	ND (0.45)	3.4	0.6
	Carp	Muscle fillet	5	Aug-Nov89	5.0	2.6	18	4.4
	White Sturgeon	Muscle fillet	5	Aug-Nov89	5.4	1.7	62	7.9
ECOLOGY	Largemouth Bass	Muscle fillet	2	Sep90	3.6	0.6	2.2	0.8
	Channel Catfish	Muscle fillet	3	Sep90	1.3	4.3	1.4	4.5
	Carp	Muscle fillet	3	Sep90	8.7	4.2	16	5.8
	White Sturgeon	Muscle fillet	5	Oct90	6.0	3.4	58	9.3

* = Source: Tetra Tech, 1990-draft
** = Source: Beak Consultants Inc., 1989
ND = Not Detected; detection limits shown in parenthesis

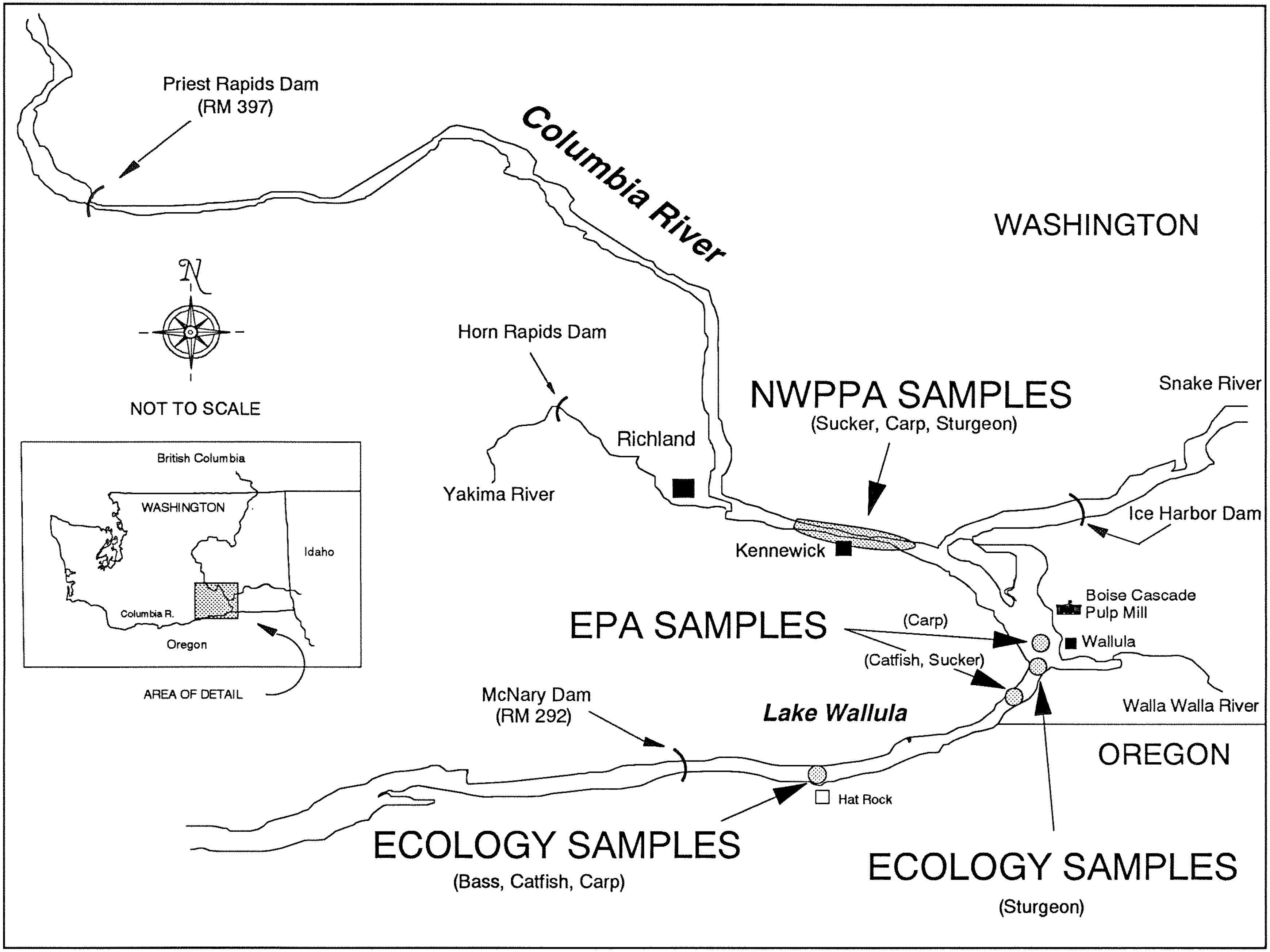

Figure 6. Sites in Lake Wallula where Data are Available on TCDD and TCDF Concentrations in Fish (as of July, 1991)

1978); Beamesderfer, personal communication). There are no available data on carp to determine the extent of their movement in Lake Wallula.

Review of Available Data for Columbia River Resident Species

With the completion of this investigation, TCDD/TCDF data are now available from seven surveys covering approximately 800 miles of the Columbia River, from above Castlegar, B.C., to the river's mouth[2]. Figure 7 shows locations in the mainstem Columbia where resident fish samples have been collected. Figure 8 summarizes results of 178 samples collected and analyzed during these investigations. This summary only includes results of muscle (fillet) analysis; whole body data were not used. Mean TEQ concentrations are shown, illustrating relative contribution by TCDD and TCDF, species, sample size, investigator, and sample location. Lake Wallula was divided into upper and lower portions in this graph to delineate observations made above and below the pulp mill.

The highest TEQ concentrations are found below the Celgar pulp mill. Environment Canada reported mean TEQ concentrations of 86 ppt in lake whitefish (Mah *et al.*, 1989) and Celgar Pulp Company reported 54 ppt in mountain whitefish (E.V.S. Consultants Ltd., 1990) in the vicinity of Celgar. Ecology reported mean TEQs of 17 ppt in sturgeon and 16 ppt in lake whitefish from Lake Roosevelt (Johnson *et al.*, 1991a). TEQs generally diminish downstream from Celgar to a low at Priest Rapids (mean carp TEQ = 1.5 ppt; smallmouth bass = 0.5 ppt), although this apparent trend may be partially due to species differences. Concentrations are again elevated at Lake Wallula followed by a downstream region of reduced concentrations; levels are near background at the river mouth.

Differences are evident in TCDD/TCDF ratios in fish collected from the upper Columbia and Lake Wallula. Figure 9 illustrates the contribution of TCDD to TEQ in muscle of resident fish collected from these reaches. TCDD contributed an average of 19% to the total TEQ in 75 samples collected from the upper Columbia (Celgar pulp mill to Lake Roosevelt). In contrast, an average of 49% of the TEQ in 29 samples collected from Lake Wallula was due to TCDD.

The TCDD/TCDF ratios seen in the Columbia River fish may be somewhat reflective of concentrations in mill effluent. Limited data on TCDD/TCDF ratios in Celgar effluent are consistent with those seen in fish below the mill (Johnson *et al.*, 1991b). Sediments below

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[2]Several other investigators of PCDDs and PCDFs in Columbia River sportfish are currently ongoing of planned. Oregon Department of Environmental Quality has collected sportfish, bottom fish, and sediment samples from several sites in the lower Columbia, including Lake Wallula. These samples are currently undergoing PCDD/PCDF analysis. In addition, as part of the Bi-State Lower Columbia River Water Quality Program, a collaborative effort is being mounted to assess PCDDs, PCDFs, and other contaminants in fish and sediments from several sites between Bonneville Dam and the mouth.

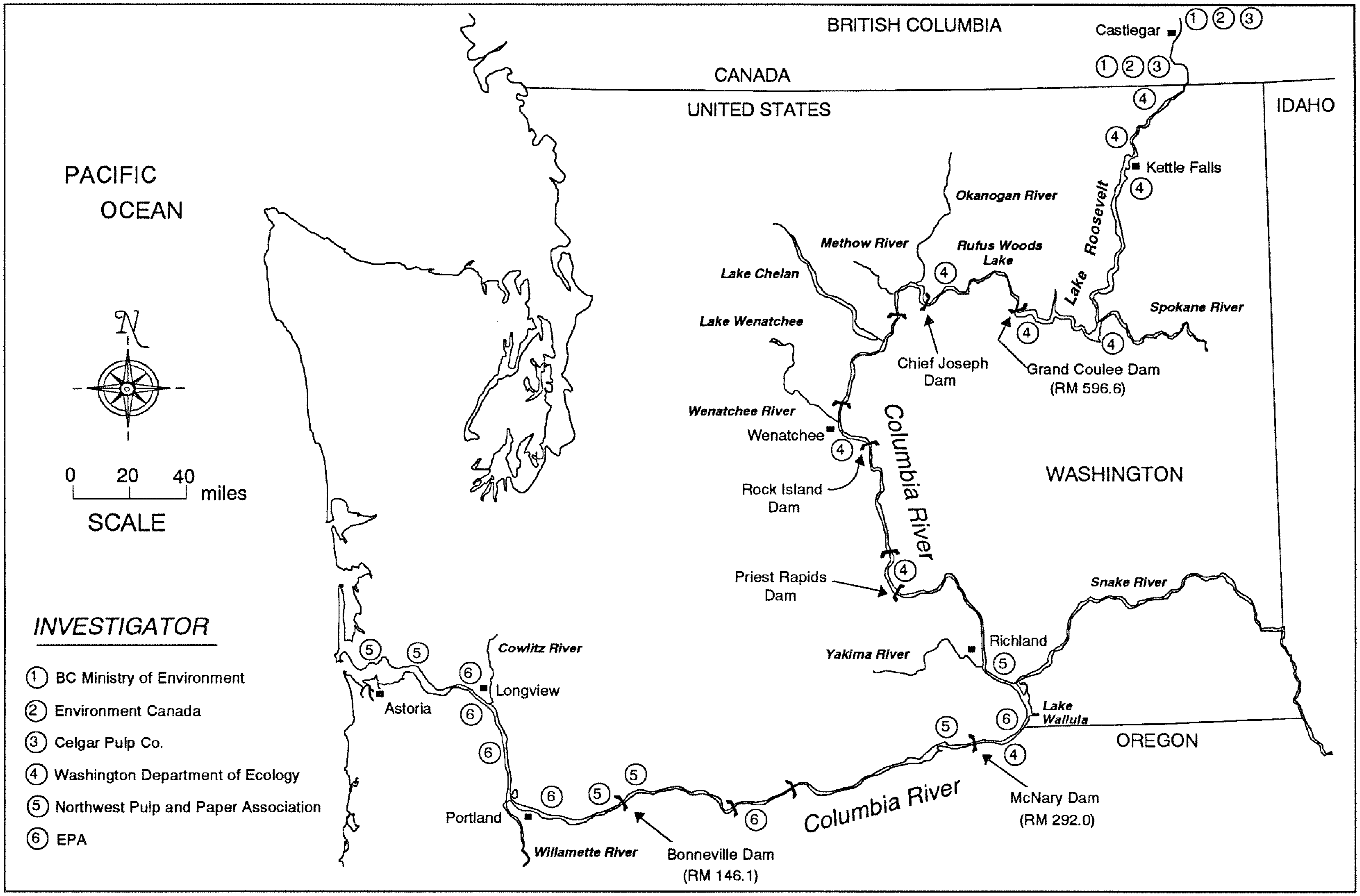

Figure 7. Sites in Mainstem Columbia River where Data are Available on TCDD and TCDF in Muscle Tissue of Resident Fish Species (as of July, 1991)

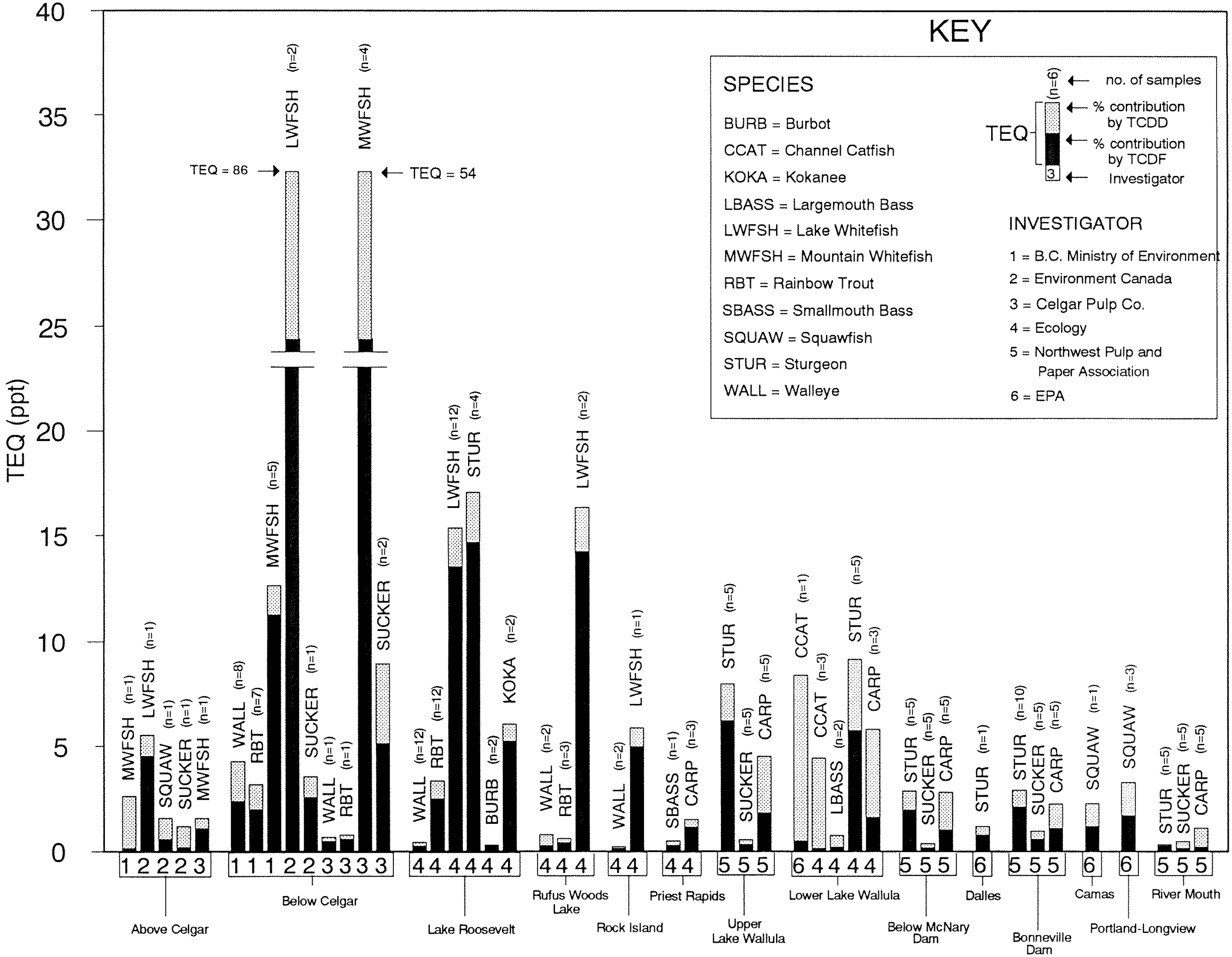

Figure 8. TEQs in Muscle Tissue of Resident Columbia River Fish (See Figure 7 for Sample Locations)

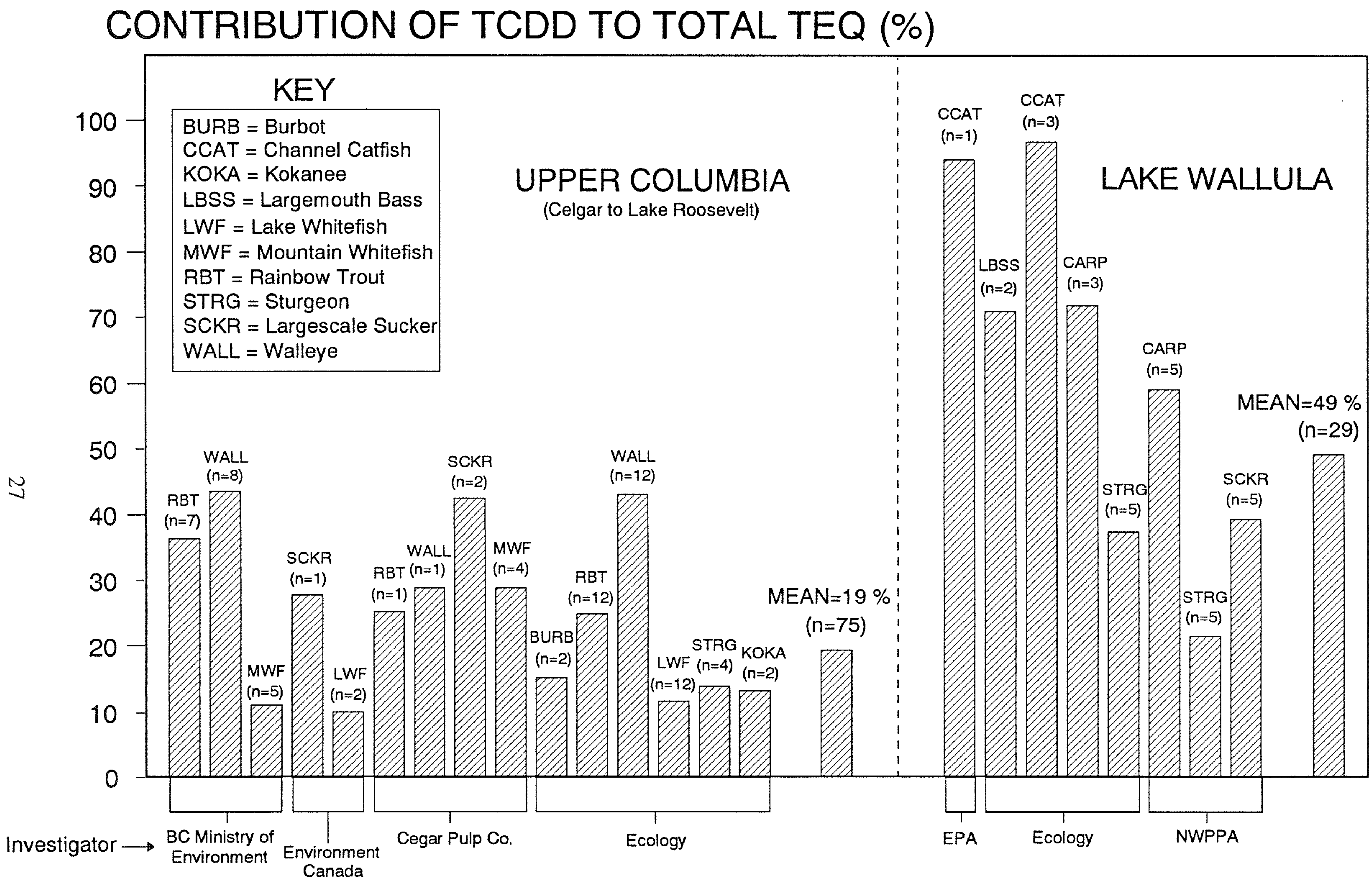

Figure 9. Contribution of TCDD to TEQs in Muscle Tissue of Resident Fish Species from the Upper Columbia River (Celgar to Lake Roosevelt) and Lake Wallula

elgar also have low TCDD/TCDF ratios (Johnson *et al.*, 1991c). At present there are no similar data on discharges from the Boise Cascade Wallula mill or TCDD/TCDF concentrations in Lake Wallula sediments. Although ratios of TCDD/TCDF in mill discharges potentially result in similar ratios in fish, other variables such as species, physicochemical properties, bioconcentration rates, and bioavailability of TCDD and TCDF probably play an important role in accumulation of these compounds (Mehrle, 1988; Opperhuizen and Sijm, 1990).

SUMMARY AND CONCLUSIONS

Sportfish sampled from Rufus Woods Lake, Rock Island Reservoir, and Priest Rapids Reservoir generally have low to non-detectable muscle concentrations of TCDD and TCDF. Lake whitefish from Rufus Woods Lake have elevated muscle TCDD/TCDF, although there is evidence to suggest that these fish may have originated from Lake Roosevelt. Support for this explanation comes from a previous Ecology study in which low to non-detectable TCDD/TCDF concentrations were found in sediment and bottom fish from Rufus Woods Lake.

Muscle tissue in three of four species collected from Lake Wallula have elevated concentrations of TCDD and, except for catfish, TCDF. Mean TEQ concentrations in channel catfish, carp, and white sturgeon range from 45 to 93 times higher than background. Lake Wallula bass have lower muscle TEQs; about eight times above background. These findings on Lake Wallula fish agree well with results of a 1989 survey conducted by the Northwest Pulp and Paper Association.

Analysis of all 2,3,7,8-substituted PCDDs and PCDFs in selected muscle tissue samples of resident species shows that TCDD and/or TCDF are the most frequently detected, and have the highest concentrations, of any congener. Other congeners do not contribute significantly to total toxicity.

Returning Columbia River salmonids do not appear to be accumulating significant quantities of TCDD or TCDF in their muscle tissue. Anecdotal evidence suggests that length of exposure to Columbia River water may account for slight differences in TCDD/TCDF concentrations between spring and fall chinook.

Data on TCDD/TCDF concentrations in Columbia River fish are now available for 800 miles of the river, from above Castlegar, B.C., to the mouth. In terms of TEQs, the highest concentrations are found in reaches below the Celgar pulp mill, including Lake Roosevelt. A decreasing trend is apparent from Celgar to Priest Rapids Reservoir. The second highest TEQ concentrations are found in Lake Wallula. Reaches downstream of Lake Wallula have decreasing TEQ concentrations, with levels near background at the mouth.

RECOMMENDATIONS

1. Monitor TCDD/TCDF in media, such as sediment and fish tissue, to assess the effectiveness of source control at Boise Cascade Wallula.

2. Conduct a study to determine the ecological implications of PCDDs/PCDFs in the Columbia River. Investigations to date have only considered potential impacts to human health.

3. Assess the occurrence of PCDDs/PCDFs in the Snake River to determine potential loading to the Columbia. Data on the extent of PCDD/PCDF contamination in the Snake River, a tributary with a potentially significant PCDD/PCDF source, the Potlatch Lewiston bleached kraft pulp mill, are essentially non-existent.

REFERENCES

Amman, H., 1990. Personal Communication. Washington State Department of Health, Office of Toxic Substances, Olympia, WA.

Barnes, D.G., F.W. Kutz, and D.P. Bottimore, 1989. Update of Toxicity Equivalency Factors (TEFs) for Estimating Risks Associated with Exposures to Mixtures of Chlorinated Dibenzo-*p*-dioxins and Dibenzofurans (CDDs/CDFs). EPA Risk Assessment Forum.

BCI, 1991 (Draft). Ambient Monitoring Plan for Characterization of Point Source Emissions of Selected Contaminants to Surface Waters of the Columbia River Basin. Prep. *for* EPA, Water Monitoring and Analysis Section - Region 10, Seattle.

B.C. Ministry of Environment, 1990 (Draft No. 3.0). Analysis of Preliminary Results of Dioxin/Furan Survey of Columbia River Fishes. Toxicology Unit, Environmental Protection Division.

Beak Consultants Inc., 1989a. Columbia River Fish Study: Fish Collection, Fish Tissue Sampling, and Age of Fish Sampled. Prep. *for* Northwest Pulp and Paper Assoc., Bellevue, WA.

------, 1989b. Human Consumption Rates of Fish from the Columbia River. Prep. *for* Northwest Pulp and Paper and Association, Bellevue, WA.

Beamesderfer, R., 1991. Personal Communication. Oregon Department of Fish and Wildlife, Clackamas, OR.

Crummett, W.B. and R.H. Stehl, 1973. Determination of Dibenzodioxins and Furans in Various Materials. Environ. Health Perspect. 15:230.

Czuczwa, J.M., B.D. McVeety, and R.A. Hites, 1984. Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans in Sediments from Siskiwit Lake, Isle Royale. Science 226: 568-569.

Eisler, 1986. Dioxin Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service, Contaminant Hazard Review, Report No. 8.

Environment Canada/Health and Welfare Canada, 1990. Priority Substances List Assessment Report No. 1: Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans. Ottawa, Ontario.

EPA, 1984. Ambient Water Quality Criteria for 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin. EPA-440/5-84-007.

-----, 1986a. Quality Criteria for Water, 1986. EPA 440/5-86-001.

-----, 1986b. Test Methods for Evaluating Solid Waste. SW-846.

-----, 1987. National Dioxin Study. EPA/530-SW-87-025.

-----, 1991. Total Maximum Daily Load (TMDL) for 2,3,7,8-TCDD in the Columbia River Basin.

EVS Consultants, Ltd., 1990. Dioxins and Furans, Chlorinated Phenolics, Resin Acids, and Fatty Acids in the Water, Sediments, and Fish from the Columbia River from Hugh Keenlyside Dam to the United States Border. Prep. *for* Celgar Pulp Co., Castlegar, B.C.

Hall, A.H., 1981. August 26 Letter from FDA Commissioner to W.G. Millikan, Governor of Michigan.

Haynes, J.M, R.H. Gray, and J.C. Montgomery, 1978. Seasonal Movements of White Sturgeon (*Acipenser transmontanus*) in the Mid-Columbia River. Trans. Am. Fish. Soc., 107(2):275-280.

Houck, G., 1990. Personal Communication. Washington State Department of Ecology, Industrial Section, Olympia, WA.

Johnson, A., D. Serdar, and S. Magoon, 1991a. Polychlorinated Dioxins and -Furans in Lake Roosevelt (Columbia River) Sportfish. Pub. No. 91-4. Washington State Department of Ecology, Olympia, WA.

------, D. Serdar, and K. Seiders, 1991b. PCDDs/PCDFs in Columbia River Suspended Particulate Matter. Memo. to Carl Nuechterlein, Washington State Department of Ecology, Olympia, WA.

------, D. Serdar, and D. Norton, 1991c. Spatial Trends in TCDD/TCDF Concentrations in Sediment and Bottom Fish Collected in Lake Roosevelt (Columbia River). Pub. No. 91-29. Washington State Department of Ecology, Olympia, WA.

------ and D. Norton, 1990. 1989 Lakes and Reservoir Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Olympia, WA.

Keenan, R.E., A. H. Parsons, E.S. Ebert, P.D. Boardman, S.L. Huntley, and M.M. Sauer, 1990. Assessment of the Human Health Risks Related to the Presence of Dioxins in Columbia River Fish. Prep. *for* Northwest Pulp and Paper Association, Bellevue, WA.

Kirkpatrick, D.C., 1989. Backgrounder to Health Hazard Assessment of Dioxins and Furans in Fish Sampled in Various Locations in British Columbia. Health Protection Branch, Health and Welfare Canada, Ottawa.

LaVoy, L., 1991. Personal Communication. Washington State Department of Fisheries, Wenatchee, WA.

Lorenzana, R., 1990. Personal Communication. Washington State Department of Health, Office of Toxic Substances, Olympia, WA.

Mah, F.T.S., D.D. Mac Donald, S.W. Sheehan, T.M. Touminen, and D. Valiela, 1989. Dioxins and Furans in Sediment and Fish from the Vicinity of Ten Inland Pulp Mills in British Columbia. Environment Canada, Vancouver, British Columbia.

Mariën, K., G. Patrick, and H. Ammann, 1991. Health Implications of PCDD and PCDF Concentrations Reported from Lake Roosevelt Sportfish. Office of Toxic Substances, Washington State Department of Health, Olympia, WA.

Maybe, W.R., J.H. Smith, R.T. Podoll, H.L. Johnson, T.Mill, T.W. Chou, J.Gates, I. Waight Partiridge, and D. Vandenberg, 1982. Aquatic Fate Process Data for Organic Priority Pollutants. EPA-440/4-81-014.

Mehrle, P.M., D.R. Buckler, E.E. Little, L.M. Smith, J.D. Petty, P.H. Peterman, and D.L. Stalling, 1988. Toxicity and Bioconcentration of 2,3,7,8-tetrachlorodibenzodioxin and 2,3,7,8-tetrachlorodibenzofuran in Rainbow Trout. Environ. Toxicol. Chem. 7:47-62.

Opperhuizen, A. and D.T.H.M. Sijm, 1990. Bioaccumulation and Biotransformation of Polychlorinated Dibenzo-*p*-dioxins and Dibenzofurans in Fish. Chemosphere 9:175-186.

Palmer, F.H., R.A. Sapudar, J.A. Heath, N.J. Richard, and G.W. Bowes, 1988. Chlorinated Dibenzo-*p*-dioxin and Dibenzofuran Contamination in California from Chlorophenol Wood Preservative Use. State of California Water Resources Control Board, Division of Water Quality. Report No. 88-5WQ.

Petersen, P., 1990. Personal Communication. Washington State Department of Fisheries, Mattawa, WA.

Roberts, L., 1991. Dioxin Risks Revisited. Science 251:624-626.

Ross, D., 1991. Personal Communication. Boise Cascade White Paper Division, Wallula, WA.

Schmitt, C., J.L. Zajicek, and P.H. Herman, 1990. National Contaminant Biomonitoring Program: Residues of Organochlorine Chemicals in U.S. Freshwater Fish, 1976-1984. Arch. Environ. Contam. Toxicol. (5): 748-782.

Sholz, A., 1991. Personal Communication. Eastern Washington University, Cheney, WA.

Smith, J.A., P.J. Witkowski, and T.V. Fusillo, 1988. Manmade Organic Compounds in the Surface Waters of the United States. U.S. Geological Survey Circular 1007.

Sneva, J., 1991. Personal Communication. Washington State Department of Fisheries, Tumwater, WA.

Tetra Tech, Inc., 1990 (Draft). Bioaccumulation of Selected Pollutants in Fish, a National Study. Prep. *for* EPA Office of Water Regulations and Standards, Washington, D.C.

Wydoski, R.S. and R.R. Whitney. 1979. Inland Fishes of Washington. University of Washington Press.

APPENDICES

APPENDIX A - Biological Data on Fish Samples

RUFUS WOODS LAKE

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Walleye	Bridgeport St.Pk.	8/22/90	655	2763	7
	Walleye	Bridgeport St.Pk.	8/22/90	414	611	3
368110	Walleye	Bridgeport St.Pk.	8/22/90	417	672	4
	Walleye	Bridgeport St.Pk.	8/22/90	456	1043	4
	Walleye	Bridgeport St.Pk.	8/22/90	429	754	4
			mean =	474	1169	4
	Walleye	Bridgeport St.Pk.	8/22/90	432	723	3
	Walleye	Bridgeport St.Pk.	8/22/90	401	615	3
368111	Walleye	Bridgeport St.Pk.	8/22/90	466	977	3
	Walleye	Bridgeport St.Pk.	8/22/90	434	909	3
	Walleye	Bridgeport St.Pk.	8/22/90	491	1268	3
			mean =	445	898	3
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	309	365	1
	Rainbow Trout	Bridgeport St.Pk.	8/22/90	406	779	3
368105	Rainbow Trout	Bridgeport St.Pk.	8/21/90	292	304	<1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	303	317	1
	Rainbow Trout	Bridgeport St.Pk.	8/22/90	334	369	<1
			mean =	329	427	1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	328	352	<1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	295	271	1
368106	Rainbow Trout	Bridgeport St.Pk.	8/21/90	310	370	1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	303	325	<1
	Rainbow Trout	Bridgeport St.Pk.	8/22/90	350	460	<1
			mean =	317	356	1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	320	365	1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	305	315	1
368107	Rainbow Trout	Bridgeport St.Pk.	8/21/90	334	382	1
	Rainbow Trout	Bridgeport St.Pk.	8/21/90	296	322	<1
	Rainbow Trout	Bridgeport St.Pk.	8/22/90	321	381	3
			mean =	315	353	1
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	525	1724	5
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	494	1448	5
368108	Lake Whitefish	Bridgeport St.Pk.	8/22/90	509	1362	5
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	511	1944	8
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	461	1413	6
			mean =	500	1578	6
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	551	1658	4
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	531	1794	6
368109	Lake Whitefish	Bridgeport St.Pk.	8/22/90	520	1613	6
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	496	1436	4
	Lake Whitefish	Bridgeport St.Pk.	8/22/90	501	1409	5
			mean =	520	1582	5

APPENDIX A (Continued)

ROCK ISLAND RESERVOIR

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Walleye	Approx. RM 460	11/7/90	685	4366	7
	Walleye	Approx. RM 460	11/7/90	565	2211	5
508130	Walleye	Approx. RM 460	8/22/90	397	485	N/A
	Walleye	Approx. RM 460	10/17/90	610	2558	6
			mean =	564	2405	6
	Walleye	Approx. RM 460	10/17/90	510	1441	3
	Walleye	Approx. RM 460	10/17/90	523	1603	5
508131	Walleye	Approx. RM 460	10/17/90	510	1374	3
	Walleye	Approx. RM 460	10/17/90	585	2408	7
	Walleye	Approx. RM 460	11/7/90	665	3118	6
			mean =	559	1989	5
508132	Lk. Whitefish	Approx. RM 460	10/17/90	491	1493	3
	Lk. Whitefish	Approx. RM 460	10/17/90	488	1612	3
			mean =	490	1552	3

PRIEST RAPIDS RESERVOIR

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
508133	Smallmouth Bass	Off Cow Canyon	10/18/90	397	1022	4
	Smallmouth Bass	Off Cow Canyon	10/18/90	402	1064	5
			mean =	400	1043	4
	Carp	Off Cow Canyon	10/17/90	625	4392	9
	Carp	Off Cow Canyon	10/17/90	334	660	2
038158	Carp	Off Cow Canyon	10/17/90	630	4111	N/A
	Carp	Off Cow Canyon	10/17/90	526	2093	5
	Carp	Off Cow Canyon	10/17/90	594	3306	N/A
			mean =	542	2912	-
	Carp	Off Cow Canyon	10/17/90	630	4387	9
	Carp	Off Cow Canyon	10/17/90	483	1562	5
038159	Carp	Off Cow Canyon	10/17/90	523	2122	5
	Carp	Off Cow Canyon	10/17/90	660	3750	6
	Carp	Off Cow Canyon	10/17/90	580	3219	N/A
			mean =	575	3008	6
	Carp	Off Cow Canyon	10/17/90	635	4333	9
	Carp	Off Cow Canyon	10/17/90	540	2058	N/A
038160	Carp	Off Cow Canyon	10/17/90	560	2599	5
	Carp	Off Cow Canyon	10/17/90	600	3658	N/A
	Carp	Off Cow Canyon	10/17/90	565	2821	7
			mean =	580	3094	-

APPENDIX A (Continued)

LAKE WALLULA

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	415	1187	7
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	226	132	2
038156	Largemouth Bass	Hat Rock St.Pk.	9/28/90	259	229	3
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	254	218	3
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	235	176	3
			mean =	278	388	4
	Largemouth Bass	Hat Rock St.Pk.	9/29/90	319	470	4
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	219	136	2
038157	Largemouth Bass	Hat Rock St.Pk.	9/28/90	286	306	N/A
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	246	204	3
	Largemouth Bass	Hat Rock St.Pk.	9/28/90	298	344	3
			mean =	274	292	3
	Channel Catfish	Hat Rock St.Pk.	9/29/90	552	1887	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	388	574	N/A
038161	Channel Catfish	Hat Rock St.Pk.	9/29/90	498	1356	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	410	625	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	465	1080	N/A
			mean =	463	1104	-
	Channel Catfish	Hat Rock St.Pk.	9/28/90	543	1565	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	391	596	N/A
038162	Channel Catfish	Hat Rock St.Pk.	9/29/90	455	685	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	479	1216	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	507	1103	N/A
			mean =	475	1033	-
	Channel Catfish	Hat Rock St.Pk.	9/29/90	499	1429	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	415	607	N/A
038163	Channel Catfish	Hat Rock St.Pk.	9/28/90	472	933	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	495	1144	N/A
	Channel Catfish	Hat Rock St.Pk.	9/29/90	460	1101	N/A
			mean =	468	1043	-
	Carp	Hat Rock St.Pk.	9/28/90	610	4169	9
	Carp	Hat Rock St.Pk.	9/28/90	519	1744	N/A
038164	Carp	Hat Rock St.Pk.	9/28/90	603	3451	10
	Carp	Hat Rock St.Pk.	9/28/90	528	2269	5
	Carp	Hat Rock St.Pk.	9/28/90	553	2966	6
			mean =	563	2920	8
	Carp	Hat Rock St.Pk.	9/28/90	615	4130	N/A
	Carp	Hat Rock St.Pk.	9/28/90	543	2194	7
038165	Carp	Hat Rock St.Pk.	9/28/90	552	2539	N/A
	Carp	Hat Rock St.Pk.	9/28/90	600	3435	8
	Carp	Hat Rock St.Pk.	9/28/90	588	2831	8
			mean =	580	3026	-

APPENDIX A (Continued)

LAKE WALLULA

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Carp	Hat Rock St.Pk.	9/28/90	560	2218	6
038166	Carp	Hat Rock St.Pk.	9/28/90	590	2812	7
	Carp	Hat Rock St.Pk.	9/28/90	597	3205	9
	Carp	Hat Rock St.Pk.	9/28/90	599	2899	6
			mean =	588	2960	7
458163	Sturgeon	Wallula Junction	10/11/90	1118	6804	6
458164	Sturgeon	Wallula Junction	10/11/90	1219	8618	10
458165	Sturgeon	Wallula Junction	10/18/90	1245	10433	8
458166	Sturgeon	Wallula Junction	10/11/90	1219	9525	10
458167	Sturgeon	Wallula Junction	10/11/90	1118	6350	8
			mean =	1184	8346	8

LAKE WENATCHEE (BACKGROUND AREA)

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Mt. Whitefish	Little Wen. R.	9/12/90	413	905	7
	Mt. Whitefish	Little Wen. R.	9/12/90	361	508	6
398185	Mt. Whitefish	Near Inlet	9/12/90	287	225	3
	Mt. Whitefish	Near Inlet	9/12/90	273	182	3
	Mt. Whitefish	Near Inlet	9/12/90	261	140	2
			mean =	319	392	4
	Mt. Whitefish	Little Wen. R.	9/12/90	371	548	4
	Mt. Whitefish	Near Inlet	9/12/90	273	236	3
398186	Mt. Whitefish	Near Inlet	9/12/90	305	314	6
	Mt. Whitefish	Near Inlet	9/12/90	273	194	3
	Mt. Whitefish	Near Inlet	9/12/90	261	145	3
			mean =	297	287	4
	Mt. Whitefish	Little Wen. R.	9/12/90	371	530	10
	Mt. Whitefish	Little Wen. R.	9/12/90	300	245	5
398187	Mt. Whitefish	Little Wen. R.	9/12/90	276	179	3
	Mt. Whitefish	Near Inlet	9/12/90	304	270	4
	Mt. Whitefish	Near Inlet	9/12/90	275	197	3
			mean =	305	284	5
	Rainbow Trout	Near Outlet	8/20/90	222	122	N/A
038155	Rainbow Trout	Near Outlet	8/20/90	261	193	N/A
	Rainbow Trout	Near Inlet	9/12/90	225	128	N/A
	Rainbow Trout	Near Inlet	9/12/90	244	145	N/A
			mean =	238	147	-

APPENDIX A (Continued)

LEAVENWORTH HATCHERY

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Spring Chinook	USFWS Hatchery	5/23/90	806	5868	4
218005	Spring Chinook	USFWS Hatchery	5/23/90	959	8250	5
	Spring Chinook	USFWS Hatchery	5/23/90	787	4678	4
	Spring Chinook	USFWS Hatchery	5/23/90	784	5188	4
			mean =	834	5996	4
	Spring Chinook	USFWS Hatchery	5/23/90	749	4423	4
218006	Spring Chinook	USFWS Hatchery	5/23/90	816	5471	4
	Spring Chinook	USFWS Hatchery	5/23/90	962	8958	5
	Spring Chinook	USFWS Hatchery	5/23/90	838	5840	4
			mean =	841	6173	4
	Spring Chinook	USFWS Hatchery	5/23/90	819	5783	4
218007	Spring Chinook	USFWS Hatchery	5/23/90	803	5557	4
	Spring Chinook	USFWS Hatchery	5/23/90	1092	12049	5
	Spring Chinook	USFWS Hatchery	5/23/90	749	3941	4
			mean =	866	6832	4
	Spring Chinook	USFWS Hatchery	5/23/90	933	6804	5
218008	Spring Chinook	USFWS Hatchery	5/23/90	810	5103	4
	Spring Chinook	USFWS Hatchery	5/23/90	914	7201	5
	Spring Chinook	USFWS Hatchery	5/23/90	789	4876	4
			mean =	862	5996	4
	Spring Chinook	USFWS Hatchery	5/23/90	927	6974	5
218009	Spring Chinook	USFWS Hatchery	5/23/90	787	4961	4
	Spring Chinook	USFWS Hatchery	5/23/90	905	7144	5
	Spring Chinook	USFWS Hatchery	5/23/90	813	4904	4
			mean =	858	5996	4

PRIEST RAPIDS HATCHERY

	Fall Chinook	Spawning Channel	11/5/90	806	N/A	3-5
448090	Fall Chinook	Spawning Channel	11/5/90	1022	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	800	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	1022	N/A	3-5
			mean =	912	-	-
	Fall Chinook	Spawning Channel	11/5/90	806	N/A	3-5
448091	Fall Chinook	Spawning Channel	11/5/90	857	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	806	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	762	N/A	3-5
			mean =	808	-	-

APPENDIX A (Continued)

PRIEST RAPIDS HATCHERY

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Fall Chinook	Spawning Channel	11/5/90	946	N/A	3-5
448092	Fall Chinook	Spawning Channel	11/5/90	832	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	857	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	984	N/A	3-5
			mean =	905	-	-
	Fall Chinook	Spawning Channel	11/5/90	787	N/A	3-5
448093	Fall Chinook	Spawning Channel	11/5/90	679	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	1060	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	927	N/A	3-5
			mean =	863	-	-
	Fall Chinook	Spawning Channel	11/5/90	1035	N/A	3-5
448094	Fall Chinook	Spawning Channel	11/5/90	991	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	921	N/A	3-5
	Fall Chinook	Spawning Channel	11/5/90	1054	N/A	3-5
			mean =	1000	-	-

COLUMBIA RIVER MOUTH (BACKGROUND AREA)

ECOLOGY SAMPLE NO.	SPECIES	LOCATION	DATE	TOTAL LENGTH (mm)	WEIGHT (g)	EST. AGE (yrs)
	Fall Chinook	Columbia Mouth	9/24/90	924	9412	6
398180	Fall Chinook	Columbia Mouth	9/24/90	881	9270	5
	Fall Chinook	Columbia Mouth	9/24/90	991	13041	6
	Fall Chinook	Columbia Mouth	9/24/90	969	12956	6
			mean =	941	11170	6
	Fall Chinook	Columbia Mouth	9/24/90	914	10149	5
398181	Fall Chinook	Columbia Mouth	9/24/90	914	9582	5
	Fall Chinook	Columbia Mouth	9/24/90	1064	13920	6
	Fall Chinook	Columbia Mouth	9/24/90	994	11397	6
			mean =	972	11262	6
	Fall Chinook	Columbia Mouth	9/24/90	911	9894	5
398182	Fall Chinook	Columbia Mouth	9/24/90	796	5868	5
	Fall Chinook	Columbia Mouth	9/24/90	920	10461	6
	Fall Chinook	Columbia Mouth	9/24/90	902	10433	5
			mean =	882	9164	5
	Fall Chinook	Columbia Mouth	9/24/90	878	9242	4
398183	Fall Chinook	Columbia Mouth	9/24/90	875	8618	4
	Fall Chinook	Columbia Mouth	9/24/90	853	8675	4
	Fall Chinook	Columbia Mouth	9/24/90	1027	13835	5
			mean =	908	10092	4
	Fall Chinook	Columbia Mouth	9/24/90	780	6407	4
398184	Fall Chinook	Columbia Mouth	9/24/90	884	10773	5
	Fall Chinook	Columbia Mouth	9/24/90	911	10263	6
	Fall Chinook	Columbia Mouth	9/24/90	872	9185	4
			mean =	862	9157	5

N/A = Not Available

APPENDIX B - TCDD and TCDF Concentrations in Muscle Tissue of Sportfish from the Study Area, Collected May - November, 1990 [concentrations in parts per trillion (pg/g), wet weight basis]

RESIDENT SPECIES

Sample No.	Species	No. Fish per Composite	Percent Lipid	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ
			RUFUS WOODS LAKE			
368110	Walleye	5	0.5	ND (0.4)	1.7	0.4
368111	Walleye	5	0.9	ND (1.8)	3.6	1.3
368105	Rainbow Trout	5	1.8	0.2 EMPC	4.5	0.6
368106	Rainbow Trout	5	1.4	0.2 EMPC	3.6	0.6
368107	Rainbow Trout	5	1.6	0.2 EMPC	4.9	0.7
368108	Lake Whitefish	5	10.8 *	2.2 *	163 *	18
368109	Lake Whitefish	5	8.0	2.1	122	14
			ROCK ISLAND RESERVOIR			
508130	Walleye	4	2.4	ND (0.12)	1.4	0.2
508131	Walleye	5	1.2	ND (0.23)	1.7	0.3
508132	Lake Whitefish	2	4.8*	0.9 *	50 *	5.9
			PRIEST RAPIDS RESERVOIR			
508133	Smallmouth Bass	2	2.0	0.2	3.0	0.5
038158	Carp	5	6.4	0.5	13	1.8
038159	Carp	5	5.6	0.3	13	1.6
038160	Carp	5	14.8	0.3	9.1	1.2
			LAKE WALLULA			
038156	Largemouth Bass	5	4.0	0.7	2.2	0.9
038157	Largemouth Bass	5	3.2	0.4	2.3	0.6
038161	Channel Catfish	5	1.6*	2.6 *	0.8 *	2.7
038162	Channel Catfish	5	0.4	5.0	1.8	5.2
038163	Channel Catfish	5	2.0	5.4	1.7	5.6
038164	Carp	5	1.6	4.4	14	5.8
038165	Carp	5	8.8*	4.8 *	19 *	6.7
038166	Carp	5	15.6	3.3	16	4.9
458163	Sturgeon	1	4.0	5.2	30	8.2
458164	Sturgeon	1	7.0	4.2	85	13
458165	Sturgeon	1	8.5 *	3.0 *	87 *	12
458166	Sturgeon	1	4.2	2.7	39	6.6
458167	Sturgeon	1	6.1	2.1	47	6.8
			LAKE WENATCHEE (BACKGROUND AREA)			
038155	Rainbow Trout	4	2.5	ND (0.2)	0.2	0.1
398185	Mt. Whitefish	5	5.5	ND (0.3)	0.4 EMPC	0.2
398186	Mt. Whitefish	5	4.0	ND (0.2)	0.2	0.1
398187	Mt. Whitefish	5	2.6	ND (0.1)	0.3	0.1

APPENDIX B (Continued)

MIGRATORY SPECIES

Sample No.	Species	No. Fish per Composite	Percent Lipid	2,3,7,8-TCDD	2,3,7,8-TCDF	TEQ
			LEAVENWORTH HATCHERY			
218005	Spring Chinook	4	5.0	ND (0.6)	2.3	0.5
218006	Spring Chinook	4	1.7	0.2 EMPC	1.1	0.3
218007	Spring Chinook	4	9.3	0.2 EMPC	1.8	0.4
218008	Spring Chinook	4	8.6	ND (0.1)	1.3	0.2
218009	Spring Chinook	4	4.2 *	0.2 EMPC*	1.1 *	0.3
			PRIEST RAPIDS SPAWNING CHANNEL			
448090	Fall Chinook	4	3.7	ND (0.1)	3.8	0.4
448091	Fall Chinook	4	1.9	ND (0.1)	2.7	0.3
448092	Fall Chinook	4	4.0	ND (0.1)	3.2	0.4
448093	Fall Chinook	4	3.6	0.2 EMPC	5.3	0.7
448094	Fall Chinook	4	5.4	0.2 EMPC	7.8	1.0
			COLUMBIA RIVER MOUTH (BACKGROUND AREA)			
398180	Fall Chinook	4	9.6	ND (0.5)	1.3	0.4
398181	Fall Chinook	4	8.5	ND (0.2)	0.6	0.2
398182	Fall Chinook	4	4.0	ND (0.2)	0.3 EMPC	0.1
398183	Fall Chinook	4	4.8	ND (0.3)	0.8	0.2
398184	Fall Chinook	4	6.0	ND (0.1)	0.7	0.1

* = Value is mean of duplicate analyses
EMPC = Estimated Maximum Possible Concentration
ND = Not Detected; detection limits shown in parenthesis
TEQ = 2,3,7,8-TCDD Toxic Equivalents [TCDD + (0.1)TCDF]
Note: 1/2 detection limit used to calculate TEQs for non-detected values