DEVELOPMENT AND IMPLEMENTATION OF THE FISH TISSUE SAMPLING PROGRAM AT THE PORTLAND HARBOR SITE

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ABSTRACT: The Willamette River in Portland Harbor was designated as a federal Superfund Site in December 2000. The current study area extends approximately 11 river miles from Downtown Portland to one mile above the confluence of the Willamette River with the Columbia River. The site involves 10 potential responsible parties, six tribal governments, and two federal and one state natural resource trustees. The site is managed jointly by the U.S. Environmental Protection Agency (USEPA) and the State of Oregon Department of Environmental Quality (ODEQ). Under this arrangement, EPA is responsible for managing the in-water portion of the site, while upland source control evaluations are managed by ODEQ.

During the remedial investigation (RI), samples were collected from a range of media including sediments, surface water, stormwater, transition zone water and fish and shellfish tissue to characterize the nature and extent of contamination and assess risks to human health and the environment. Site contaminants include metals, phthalate esters, polycyclic aromatic hydrocarbons (PAHs) and other petroleum related contaminants, polychlorinated biphenyls (PCBs), organochlorine pesticides, and chlorinated dioxins and furans.

Approximately 400 fish and shellfish tissue samples were collected and analyzed for site contaminants. Fish tissue samples were collected over multiple rounds of sampling for the purpose of assessing risks to human health and the environment. Collocated sediment samples were collected to support the bioaccumulation model and the development of risk based cleanup goals for the site. The initial round of sampling represented a broad inventory of fish and shellfish species at site. The tissue sampling effort targeted a wide range of feeding guilds and fish species known to be targeted by local fishers. Both whole body and fillet fish were collected. Subsequent rounds of tissue sampling were used to refine the characterization.

This paper discusses the approach used to characterize fish and shellfish at the Portland Harbor site including the rationale for the initial round of tissue sampling and refinements to the fish tissue collection program. Lessons learned from the fish tissue collection process are discussed and recommendations for the design of sampling programs to support a range of remedial investigation and risk assessment goals are also presented.

BACKGROUND

The Portland Harbor site is located on the Willamette River in Portland, Oregon. The site extends approximately 11 miles from downtown Portland to just above the confluence with the Columbia River. The Willamette River is the 13th largest river in the United States in terms of flow and drains a 12,000 square mile river basin that is home to 70% of Oregon's population. Due to western Oregon's typically wet winters and dry summers, river flow vary seasonally from

10,000 to 100,000 cubic feet per second (cfs) with flows in excess of 400,000 cfs during flood conditions such as occurred in 1948, 1964 and 1996. The Willamette River is tidally influenced through the Portland Harbor site and experiences flow reversals during low flow conditions in late summer and early fall.

The Willamette River supports a wide variety of fish and supports a popular recreational fishery. Two salmon runs listed as threatened under the federal Endangered Species Act use the river as a migratory corridor and as rearing habitat. A 1993 survey indicated 39 resident fish species in the Lower Willamette River. Four species were considered major sports fish: Walleye, black crappie, white crappie and smallmouth bass. Migratory species present in the Lower Willamette River include Chinook salmon, Coho salmon, sockeye salmon, steelhead, American shad, Pacific Lamprey and White Sturgeon. Shellfish known to reside in the LWR include crayfish, Corbicula and freshwater mussels.

A 2002 initial public health assessment, the Agency for Toxic Substances and Disease Registry (ATSDR) identified the consumption of contaminated fish as the major exposure pathway that people could be exposed to Portland Harbor site contaminants. At that time, a lack of data on contaminants in fish tissue limited the ability of ATSDR to conduct a thorough public health risk assessment and a large fish sampling effort was recommended. At that time, the Lower Willamette Group (LWG) was in the initial stages of developing a remedial investigation and feasibility study (RI/FS) work plan. In order to expedite the RI/FS, EPA and the LWG agreed to table the work plan development and move forward the collection and chemical analysis of fish tissue as an initial step in the RI to supplement the existing sediment data set and support development of a comprehensive work plan.

METHODS:

Tissue sampling at the Portland Harbor site took place of four rounds of sampling. Target tissue species were developed jointly by the LWG and EPA through a series of meetings. Field sampling plans (FSPs) and quality assurance project plans (QAPPs) governed all tissue sampling programs. Depending on species, fish were captured using electrofishing, set lines, angling, traps and a benthic sledge. Electrofishing required a National Marine Fisheries Service (NMFS) 4(d) scientific take permit and a Section 10 scientific take permit issued by ODFW due to the presence of species listed as threatened under the Endangered Species Act (ESA). Navigation and station positioning was accomplished using a digital GPS. Crayfish were captured using medium size Promar collapsible minnow traps. Clams were collected using the benthic sledge. For clams, sculpin and crayfish, collocated sediment samples were also collected. During the Round 3 tissue collection effort, the LWG utilized volunteers from the Oregon Bass and Panfisher Club (OBPC). OBPC members captured fish using a variety of baits including commercial crank bait, tube jigs and corn kernels. Carp were collected by chumming the area with corn kernels prior to capture using a rod and reel.

Fish filleting was performed for important recreational fish including black crappie, brown bullhead, carp and smallmouth bass. During Round 1, chemical analysis was performed on separate composite fillet and whole-body samples. During Round 3, the analysis was performed on fillets and the whole-body without the fillet. Whole-body chemical concentrations were determined by algebraically combing the two sample results. Due to the number of fish being processed, a field laboratory was established onsite to process fish for chemical analysis. Upon collection, tissue samples were wrapped in foil and sent to a field laboratory for daily processing. At the field lab, individual whole-body fish were unwrapped, measured, visually

inspected and, depending on the species, filleted. Whole fish and fish fillets were individually wrapped and frozen prior to compositing. Following final agreement with EPA on the species-by-species compositing scheme, individual whole-body fish or fillets were pooled together, according to the compositing plan, in large plastic bags and labeled with the composite identification number. Compositing was performed to ensure that fish were of the same size class; the smallest fish could not be less than 75% of the largest fish. Frozen composite samples were then shipped frozen (on dry ice) to the chemical laboratory for tissue homogenization. Quality control samples included filed replicates and split samples. Split samples were obtained in the laboratory by splitting the composited tissue samples following homogenization.

ROUND 1 SAMPLING:

The Round 1 sampling program took place during the summer and fall of 2002. The objectives of the Round 1 tissue sampling program were to: 1) Collect tissue from nine fish species, one crayfish, and one clam species for chemical analysis; 2) Collect collocated surface sediments at sculpin, crayfish, and benthic infauna stations; 3) Collect benthic infauna at a subset of surface sediment chemistry stations and tissue sampling locations; and 4) Perform a reconnaissance survey for benthic tissue and lamprey ammocoete tissue. Target species for the BERA were smallmouth bass, sculpin, subyearling Chinook salmon, largescale sucker, peamouth, northern pikeminnow, Pacific lamprey ammocoetes, and crayfish. Target species for the BHHRA were carp, black crappie, bullhead, smallmouth bass, and crayfish. In addition to the target species, walleye and largescale sucker were collected as alternative species for bullhead and carp, respectively.

The benthic tissue reconnaissance conducted in September 2002 concluded that the Portland Harbor benthic community was dominated by very small organisms (e.g., midges and oligochaetes). The survey further determined that the non-native bivalve species, *Corbicula fluminea*, was the largest and most widespread benthic invertebrate in the Lower Willamette River and potentially was in sufficient abundance to provide invertebrate tissue samples for tissue body burden analyses. In October and November 2002, clam collection was attempted by repeated casts of a 0.1-m^2 van Veen grab sampler at five target locations. In addition, an unsuccessful attempt was made to rake clams from a shallow subtidal beach at Station 07R030. Clam collection was attempted over multiple sampling days at each proposed FSP location. After considerable effort, only two locations yielded sufficient biomass to conduct tissue analyses for a full suite of target analytes; fifty-three grams were collected at a third station (allowing limited chemical analysis) while the remaining two stations yielded only nominal amounts. Lamprey ammocoetes were eliminated from the Round 1 sampling program after two reconnaissance surveys determined that the apparent low abundance of the larval fish at that time of year would yield insufficient quantities for laboratory tissue analyses (SEA and Windward 2003).

In total, the LWG field teams collected fish throughout the Portland Harbor study area both day and night, over portions of 79 days. A total of 1,870 fish were collected, including 863 sculpin, 419 crayfish, 128 largescale sucker, 90 smallmouth bass, 78 carp, 92 subyearling Chinook salmon, 64 brown bullhead, 35 northern pikeminnow, 48 black crappie, 30 peamouth, 18 yellow bullhead, 3 lamprey ammocoetes, and 2 walleye. A summary of the Round 1 tissue sampling program is presented in Table 1.

Chemical analysis results of the Round 1 tissue sampling program were presented in the Round 1 Site Characterization Summary Report (Integral, 2004). Data for polychlorinated biphenyls, a key bioaccumulative chemical at the site, are presented in Table 1 for comparison

purposes. As shown in Table 1, the highest concentration of PCBs was detected in whole body smallmouth bass and carp samples. For smallmouth bass the ration of fillet to whole body was less than 10%. However, the fillet to whole-body ration for carp was approximately 50%. This is likely due to the higher lipid content of carp.

Table 1 – Round 1 Fish Sampling Summary

Species	Basis	Sample Type	Number Collected	Mean PCB Concentration (ug/kg)
Black crappie	Significant recreational fish species, potential for bioaccumulation, limited home range, predator target species, abundant species.	Whole-body	4	134
		Fillet	4	24.1
Brown bullhead	Consumed by recreational fishers, limited home range, bottom feeder, abundant species.	Whole-body	6	404
		Fillet	6	354
Carp	Preferentially consumed by some non-tribal populations, large home range, bottom feeder, abundant species.	Whole-body	6	1640
		Fillet	6	812
Smallmouth bass	Significant recreational fish species, potential for bioaccumulation, limited home range, predator target species, abundant species.	Whole-body	14	1110
		Fillet	5	62
Crayfish	Consumed by recreational fishers, representative of epibenthic feeding guild.	Whole-body	27	63.6
Subyearling Chinook	Listed as threatened under endangered species act. Subyearling Chinook may overwinter in Portland Harbor.	Whole-body	6	55.8
Largescale sucker	Potentially consumed species, bottom feeder similar to carp. Similar bioaccumulation potential as carp.	Whole-body	6	819
Northern pikeminnow	Potentially consumed species, large home range fish.	Whole-body	6	833
Peamouth	Not a consumed species. Selected to represent water column feeding guild.	Whole-body	4	187
Sculpin	Small home range. Prey item for ecological receptors.	Whole-body	27	562
Freshwater Asian clam (Corbicula)	Benthic species. Some evidence of human consumption	Whole-body	3	86.3

ROUND 2 TISSUE SAMPLING

The Round 2 tissue sampling program was designed to address species that were not collected in sufficient numbers during Round 1 and migratory species where additional information was necessary to address public health concerns. Round 2 tissue sampling was performed in 2004 and 2005. A summary of these sampling efforts is described below.

Adult Chinook Salmon, White Sturgeon and Adult Pacific Lamprey: Due to the large home range of these species it was unclear whether chemical analysis of these species could be used to support remedial action decisions at the Portland Harbor Site. For example, salmon and lamprey spend a significant portion of their adult lives at sea and some white sturgeon may travel over a hundred miles. As a result, an interagency investigation was performed to examine the level of contaminants in adult Chinook, white sturgeon and adult Pacific lamprey to provide information to the general public regarding contaminant levels in these fish species. Agencies involved in implementing and funding this tissue collection effort included Oregon Department of Human Services (ODHS), ATSDR, EPA Region 10, Oregon Department of Fish and Wildlife ODFW) and the City of Portland. Some species such as Pacific lamprey were collected outside the Portland Harbor study area.

Subyearling Chinook: Subyearling Chinook were collected to determine the extent to which Subyearling Chinook are accumulating site contaminants and estimate exposure through

analysis of stomach contents. Two site reconnaissance surveys were performed in April and May 2005. Subyearling Chinook tissue samples were collected at four target locations – 3 within the study area and one upstream. Tissue data was used to support the Portland Harbor baseline ecological risk assessment (BERA) while the stomach contents data was used to support the natural resource damage assessment (NRDA) at the Portland Harbor site.

Benthic Invertebrates: During Round 1, only a limited number of clam samples were collected for tissue chemistry analyses. For the BERA, clam tissue was collected to support the dietary exposure pathway for fish and wildlife and to support the evaluation of risks to the benthic community through the tissue-residue line of evidence. In addition, clam tissue data were used to support the foodweb model calibration and estimate site specific BSAFs and support the evaluation of risk to human health. Multi-plate samplers were deployed in 2005 but proved ineffective; did not obtain sufficient tissue mass. A benthic sledge was used to collect the clam tissue. The benthic sledge was dragged through the sediments to collect the clams. Although multiple drags were required to collect sufficient tissue mass for chemical analysis, this approach was far more successful than use of the van Veen sampler with 33 locations throughout the Portland Harbor study area successfully sampled. In addition to the collection of clams from the study area, laboratory bioaccumulation testing was also performed to estimate uptake from site sediments.

Overall, the Round 2 testing program was useful for providing information to the ODHS regarding the level of contamination in key species consumed by recreational and Tribal fish consumers. In addition, the successful application of the benthic sledge and subsequent chemical analysis of clam tissue demonstrated that clam tissue is important species for evaluating risks to human health and the environment and long-term monitoring.

ROUND 3A TISSUE SAMPLING

Round 3 Tissue Sampling was designed to address additional data gaps. Round 3A data gaps were data gaps that were readily identifiable without a detailed evaluation. Round 3B data gaps were identified based on information presented in the Round 2 Comprehensive Site Summary and Data Gaps report. Round 3A data gaps included lamprey ammocoetes and whole body white sturgeon. Round 3B data gaps included smallmouth bass, carp, sculpin, clam and crayfish tissue. The Round 3A tissue sampling program is described below.

Lamprey Ammocoetes: Due to the failure to collect sufficient lamprey ammocoetes during the Round 1 sampling effort, a modified electrofisher that had been used successfully in the Great Lakes (Bergstedt and Genovese 1994) was deployed in the fall of 2006. The electrofishing approach was successful in collecting limited tissue mass within the Portland Harbor sites. In order to have sufficient tissue mass, samples were composited into three composites from the Portland Harbor Study Area and three composites from upstream of the site. Due the limited tissue mass, full chemical analysis was not possible for all lamprey samples; a prioritization scheme was developed to identify analytes for each composite sample. In addition to tissue sampling, a toxicity testing program was implemented to test the relative sensitivity of lamprey based on exposure to water. Lamprey were exposed to six chemicals (copper, pentachlorophenol, lindane, naphthalene, diazinon and aniline) selected to specifically to evaluate the response of lamprey to chemicals with six different mechanisms of toxic action. A comparison of the measured ammocoete LC50s to toxicity data for other aquatic species exposed to the same six chemicals suggest that lamprey are in middle to tolerant end of the species sensitivity distribution for aquatic species for all six tested chemicals.

White Sturgeon: 15 pre-breeding White Sturgeon were collected for whole-body tissue analysis to support the ecological risk assessment. Three sturgeon each were collected from five separate river reaches. Due to the large size of the sturgeon, a specially constructed blender large enough to hold a 42 sturgeon was utilized for sample homogenization. As part of the sturgeon sampling program, a detailed health assessment was performed and the livers were transmitted to the natural resource trustees to support the NRDA.

The testing of white sturgeon and lamprey ammocoetes were generally lower than resident species collected at the Portland Harbor site. However, the data were useful to support the ecological risk assessment and understand the degree to which these species are being impacted by Portland Harbor contaminants.

ROUND 3B TISSUE SAMPLING:

Round 3B tissue sampling focused on sculpin, crayfish, smallmouth bass, carp and Asian Clam. The stated goals of the sampling effort were to refine uncertainties in COI concentrations, ensure that representative data was collected to identify sources of contamination and characterize ranges in risk, and confirm the utility, ability and accuracy of the foodweb model. During Round 1, the sampling effort focused on river miles (RM) 3 – 9. The round 3B sampling effort expanded the range of the characterization to between RM 1 and 12.2. In addition, because of questions about the degree to which smallmouth bass cross from one side of the river to the other, the smallmouth bass tissue collection was designed to ensure that each side of the river was characterized in one-mile increments. Finally, at locations where sufficient tissue mass was available, both depurated and non-depurated clam tissue was collected.

The Round 3B sampling program, summarized in Table 2, confirmed the Round 1 tissue sampling program. It is clear that from the results of the testing, carp, smallmouth bass, sculpin and freshwater clams are the key species in support of the BHHRA and BERA and for ongoing monitoring. Although crayfish are a significant fishery in Portland Harbor, the up-trophic (scavenging) and intertrophic (cannibalism) consumption behavior of crayfish make them a less useful species for either the risk assessment or long-term monitoring.

Table 2 – Round 3B Fish Sampling Summary

Species	Basis	Sample Type	Number Collected	Mean PCB Concentration (ug/kg)
Carp	Expand river mile coverage and support foodweb model. Preferentially consumed by some non-tribal populations, large home range, bottom feeder, abundant species.	Body w/o Fillet	6	3610
		Fillet	6	2520
Smallmouth bass	Expand river mile coverage and gather data from each side of the river. Significant recreational fish species, potential for bioaccumulation, limited home range, predator target species, abundant species.	Body w/o Fillet	18	1300
		Fillet	18	166
Sculpin	Expand river mile coverage and support foodweb model.	Whole-body	16	705
Crayfish	Expand river mile coverage. Consumed by recreational fishers, representative of epibenthic feeding guild.	Whole-body	9	152
Freshwater Asian clam (Corbicula)	Expand river mile coverage. Gather data on depurated and non-depurated samples. Benthic species. Some evidence of human consumption.	Whole-body (nondepurated)	10	169
		Whole-body (depurated)	4	183

CONCLUSIONS AND RECOMMENDATIONS:

The Portland Harbor RI collected and analyzed a range of tissue species. The initial sampling program targeted the largest range of species, each one selected to represent a specific feeding guild or target species known to collected at the site by recreational, subsistence and/or tribal fishers. Consistent with an iterative RI approach, the tissue sampling program was refined throughout the RI. In many cases, alternative collection methods were developed to collect target species. For example, the benthic sledge was used successfully to collect clam samples and a modified electrofishing device was used to collect lamprey ammocoetes. Another key consideration in the development of the sampling program was whether to sample anadromous or wide-ranging fish species such as Chinook salmon, Pacific lamprey and white sturgeon. It was determined that for returning anadromous species such as salmon and lamprey, the information could not necessarily be used to support a remedial action decision. However, the information was deemed important from a public health perspective since these species are consumed by Tribal and sport fishers. As a result, a collaborative partnership was established to collect these species to inform the community about fish consumption risks. Regarding white sturgeon, there was enough uncertainty about their migratory habits, that whole body fish were collected from the Portland Harbor site to support the ecological risk assessment. In designing a fish tissue sampling program, the following recommendations are offered:

1) Implement a wide ranging fish sampling program as an initial step. The initial sampling effort should be a broad survey designed to identify the species that have the greatest potential to bioaccumulate site contaminants, target specific feeding guilds to support the ecological risk assessment and food web model, determine relative abundance of the various species, and identify any alterations to the collection methods.
2) Focus on small home range fish species. The interpretation of large home range fish tissue results is difficult, especially of the home range is larger than the size of the site. Even for resident species with larger home ranges, it is difficult to establish a link between sediment and tissue concentrations. Large home range fish should be included if consumed in significant numbers to support the human health risk assessment and/or to public health outreach efforts.
3) Chemical analysis should include collocated tissue and sediment for small home range species. In addition surface water samples should also be collected to support the food web model and understand the relationship between contamination present in sediment, fish tissue and surface water. For chemicals such as PCBs, specific congeners should be analyzed. High volume water samples or passive sampling devices should be used to ensure that detection limits are adequate. Emerging chemicals such as PBDEs should also be included in the data set.
4) Consider the use of local fishermen to collect needed fish species. Local fisherman and guides are your best source of information about fish habits and may be used to capture fish for testing more efficiently than electroshocking techniques. Do not underestimate local knowledge.
5) Refine the sampling program to focus on a limited set of target fish species. The number of target fish species is a site specific consideration. Enough fish species will need to be collected to support all relevant exposure pathways and the development of bioaccumulation models. For the Portland Harbor risk assessment, it was determined that the following fish species were most important:

- Common Carp – large home range fish. High lipid content. Consumed by subsistence fishers.
- Smallmouth bass – small home range, high trophic level predator. Consumed by recreational fishers.
- Sculpin – small home range. Dietary component for wildlife ecological receptors such as mink and osprey
- Clams – benthic species. Do not metabolize PAHs. Can be used to support both human health shellfish consumption exposure scenarios and fish and wildlife dietary evaluations.
- Juvenile Chinook salmon and Pacific Lamprey Ammocoetes: Because of the cultural significance if these two species for Native American populations, out-migrating anadromous fish species should be targeted. It should be noted that Chinook salmon are listed as threatened on the endangered species act and that Pacific lamprey are listed by ODFW as a species of concern.

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