Ecosystem Monitoring Project

Annual Report

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Lower Columbia River Ecosystem Monitoring Project
Annual Report for Year 3b (September 1, 2006 to August 31, 2007)

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Executive Summary

Our ability to understand the relationships between sensitive organisms, such as salmonids, and the lower Columbia River and estuary ecosystem is greatly hindered by major data gaps and poor access to existing data. The Lower Columbia River Estuary Partnership (Estuary Partnership) implements elements of its Aquatic Ecosystem Monitoring Strategy (LCREP, 1998) to address habitat and toxics monitoring needs and data management through the Ecosystem Monitoring Project. The Ecosystem Monitoring Project has two main components: habitat monitoring (involving field surveys and development of an ecosystem classification system) and water quality monitoring (comprised of water chemistry data collection, juvenile salmonid sampling, and creation of three models describing salmonid uptake, transport, and ecological risk of toxics). This monitoring was originally intended to address Reasonable and Prudent Alternatives 161, 163, and 198 of the 2000 Biological Opinion for the Federal Columbia River Power System. The Estuary Partnership executes this monitoring project by collaborating with National Oceanic and Atmospheric Administration (NOAA) Fisheries; United States Geological Survey (USGS) Columbia River Research Laboratory (CRRL), Biological Resources Discipline (BRD), and Water Resources Discipline (WRD); Battelle-Pacific Northwest National Laboratory (PNNL); and University of Washington (UW). Financial support for the Ecosystem Monitoring Project is provided by Bonneville Power Administration (BPA) and Northwest Power and Conservation Council (NPCC).

This document describes accomplishments and project status during Year 3b (September 1, 2006 to August 31, 2007) of the Ecosystem Monitoring Project. The Project made progress in the collection and analysis of habitat and water quality data, and delivered the "The Lower Columbia River and Estuary Ecosystem Monitoring: Water Quality and Salmon Sampling Report" (uploaded into Pisces and available on the Estuary Partnership's website). This report integrates results of previous water quality and salmon sampling efforts to document the presence and effects of toxic contaminants on juvenile salmon, including stocks listed under the Endangered Species Act, in the lower Columbia River and estuary.

Habitat monitoring in Year 3b focused on creating tools and building datasets necessary for planning and conducting comprehensive monitoring to assess the status and trends of habitat types in the lower Columbia River and estuary. Work elements listed under Habitat Monitoring for Year 3b of this contract were directed at refining the hydrogeomorphic classification for the Columbia River Estuary, developing a scientifically-sound sampling design, and building fundamental datasets. UW and USGS CRRL were subcontracted to improve the Columbia River Estuarine Ecosystem Classification (Classification system, Simenstad et al., 2006). USGS BRD was subcontracted to develop a robust sampling design (based on the Classification system) to support future monitoring efforts. PNNL was subtracted to continue building fundamental datasets describing wetland vegetation along elevation gradients in the Columbia River Estuary.

Water quality monitoring in Year 3b continued to address issues such as the contaminant accumulation in sensitive habitats, trends over time, and impacts on salmonids. Work elements listed under Toxics Monitoring for Year 3b were directed at reporting the results of salmonid and water quality sampling (conducted by NOAA and USGS WRD). NOAA was subcontracted to sample juvenile salmon, prey resources, and sediment and then analyze samples for contaminants (e.g., PAHs, PCBs, DDT, PBDEs). USGS WRD was subcontracted to analyze contaminant data from samples of filtered water, suspended sediment, and extracts from Semipermeable Membrane Devices collected in Years 2 and 3.

Project Background

Bonneville Power Administration (BPA) and the Northwest Power and Conservation Council (NPCC) originally awarded a three year contract in September 2003 to the Lower Columbia River Estuary

Partnership (Estuary Partnership) for its Ecosystem Monitoring Project. Prior to this date, the Estuary Partnership's Science Work Group had been working on designing elements of this project involving toxics monitoring and habitat monitoring. With funding secured, BPA project managers finalized the project with the Science Work Group. Plans were developed to proceed with a toxics monitoring plan that took a multi-species approach (including salmon, eagles, and osprey), monitored conventional and toxic pollutants (including fecal coliform and mercury), and developed a data management strategy.

With plans to begin fieldwork in late 2003, BPA notified the Estuary Partnership that the project required review by the Independent Scientific Review Panel (ISRP) once it was further defined. Specifically, the toxics monitoring program focus should be on salmonids and the effects of toxic and conventional pollutants in the Columbia River Estuary on salmonid species. Further, it was requested that fecal coliform, mercury, and data management be removed from the proposal. It was also indicated that the habitat monitoring portion of the project was in relatively good condition; however, no work could proceed until the toxics monitoring portion of the project was resolved. Once Estuary Partnership staff, USGS, NOAA Fisheries re-submitted the toxics portion of the project, the habitat and toxics monitoring portions were reviewed by the ISRP in April. ISRP yielded a favorable review of the toxics monitoring portion and given minor additions, the water quality monitoring could move forward. The habitat monitoring portion, however, did not receive favorable reviews. Thus, the Columbia River Estuary Habitat Monitoring Plan (Lower Columbia River Estuary Partnership, 2004) was drafted to define clearly the goals and methods of the habitat monitoring program.

Once the Columbia River Estuary Habitat Monitoring Plan was reviewed by the ISRP, Estuary Partnership staff, Pacific Northwest National Laboratory (PNNL), USGS, and the University of Washington (UW) focused on creating a scientifically sound sampling plan for the Columbia River Estuary during Year 2 (September 1, 2004 to August 31, 2005) of the Ecosystem Monitoring Project. The habitat monitoring program is utilizing the sampling plan to measure the status and trends of habitat types in the Columbia River Estuary. The sampling plan was informed by the creation and refinement of the Columbia River Estuarine Ecosystem Classification by University of Washington and USGS CRRL (Simenstad et al., 2006). This classification is being developed from Landsat TM imagery and bathymetry data and was used to identify specific reaches of the Columbia River Estuary to sample during summer 2005. Field surveys were conducted in Reaches D and F (see Figure 1 in Study Area) to collect biological and chemical data on habitat conditions, including salinity, depth, temperature, dissolved oxygen, vegetative cover, and water elevation estimates. Results of this sampling are summarized in the Columbia River Estuary Habitat Monitoring Pilot Field Study and Remote Sensing Analysis (Sobocinski et al., 2006a; available on the Estuary Partnership's web site at: www.lcrep.org/eco_habitat_monitor.htm).

During Year 2, toxics monitoring was also implemented by NOAA Fisheries and USGS WRD to address the accumulation of toxics in sensitive habitat areas, contaminant trends over time, and contaminant impacts on salmonids. NOAA Fisheries organized a workshop to coordinate fish, habitat, and water quality monitoring projects in the lower Columbia River (RM 0-146) as a means of creating a conceptual model to track toxic sources, pathways, and effects on salmonid populations (Dietrich et al. 2005; see also Scholz et al. 2006). This conceptual model was used as a basis for developing quantitative models for the uptake and bioaccumulation of contaminants by juvenile salmon in the Columbia River Estuary. Moreover, NOAA developed ecological risk models to link contaminant body burdens in salmonids to health risks such as impaired immune systems, growth inhibition, and reduced survival rates (Loge et al. 2005, Spromberg and Meador 2005). The ecological risk models also examine the impacts of these health risks on the survival and productivity of federally listed salmonids. Finally for Year 2, NOAA conducted fish sampling from April 2005 through September 2005 and USGS WRD conducted fixed station water quality monitoring and installed semipermeable membrane devices (SPMDs) to provide data on conventional pollutants and toxics near NOAA salmonid sampling sites.

During Year 3 (September 1, 2005 to August 31, 2006), habitat monitoring concentrated on vegetation surveys and refinement of the Classification system and bathymetric datasets. In July 2006, PNNL surveyed vegetation at four tidally influenced wetlands in Reach G (see Figure 1 in Study Area) and re-sampled two sites, which were sampled in Year 2, to assess interannual variability in vegetation cover and composition. A final report was submitted to the Estuary Partnership in August 2006 (Sobocinski et al., 2006b). The University of Washington revised the Classification system, developed a new classification level (Geomorphic Catena), developed essential ancillary datasets to refine the Landsat TM 2000 classified imagery, finalized stage one of the Landsat TM 2000b refinement, and presented the classification at several Columbia River Estuary science and management meetings. USGS CRRL collected bathymetry data and expended funds to identify additional bathymetry datasets for filling in critical data gaps located in secondary channels and shallows in priority reaches. Finally, USGS CRRL continued working with the Estuary Partnership and UW on bathymetry data gaps and data sharing and coordination.

Water quality monitoring in Year 3 involved analyzing contaminants in juvenile salmon samples, revising contaminant models, and assessing contaminants in the water column. NOAA Fisheries completed analysis of juvenile salmonid samples (including whole bodies for chlorinated hydrocarbons, stomach contents for chlorinated and aromatic hydrocarbons, bile for metabolites of aromatic hydrocarbons, fin samples for genetic stock determination, and blood for vitellogenin, an indicator of exposure to environmental estrogens) collected in Year 2. NOAA also expanded a population model to incorporate population-specific contaminant effects on salmon stocks within the Lower Columbia River Evolutionary Significant Unit (ESU) (Spromberg and Johnson 2006). Models were updated with fish exposure data, water quality, sediment, and salmonid prey information generated from NOAA's and USGS's 2005 field sampling. Moreover, NOAA is incorporating new information on biological effects of contaminants on salmonids into the ecological risks models and is exploring existing options for modeling contaminant uptake by juvenile salmonids in the Columbia (e.g., the Trophic Trace steady state uptake models developed by Battelle and Windward). NOAA is developing a non-equilibrium model, which may more effectively capture contaminant uptake in salmonids that move quickly through portions of the Columbia River Estuary. Finally, during Year 3, USGS WRD retrieved Semipermeable Membrane Devices (SPMDs) from one site in the Willamette River and three sites in Columbia River. The SPMDs were analyzed for polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides (OCs), and polybrominated diphenyl ethers (PBDEs).

In Year 3b (September 1, 2006 to August 31, 2007) of this contract, all subcontractors focused on documenting the results of past toxic monitoring (described above). Data describing toxics in the water column, sediments, and juvenile salmonids (collected by USGS WRD and NOAA, respectively in Years 2-3) were analyzed and presented in a final report, "The Lower Columbia River and estuary Ecosystem Monitoring: Water Quality and Salmon Sampling Report" (uploaded into Pisces and available on the Estuary Partnership's website). This report integrates the results of previous water quality and salmon sampling efforts to document the presence and effects of toxic contaminants on juvenile salmon, including stocks listed under the Endangered Species Act, in the lower Columbia River and estuary. Information in this report was used to update the contaminant transport and ecological risk models.

Additionally, in Year 3b, the Ecosystem Monitoring Project focused on creating tools and building datasets necessary for planning and conducting comprehensive habitat monitoring to assess the status and trends of habitat types in the lower Columbia River and estuary. The work elements listed under Habitat Monitoring for Year 3b (September 1, 2006 to August 31, 2007) of this contract were directed at refining the hydrogeomorphic classification for the Columbia River Estuary, identifying bathymetry gaps, developing a scientifically-sound sampling design, and building fundamental vegetation datasets. UW and USGS CRRL refined the Columbia River Estuarine Ecosystem Classification system (Simenstad et al., 2006) using completed Lidar and bathymetric data. USGS BRD used the Classification system to develop a

sampling design strategy that will be utilized in Years 4-7 of this Project to select sampling locations. PNNL were subcontracted to continue building fundamental datasets describing wetland vegetation patterns along elevation gradients in the Columbia River Estuary (CRE). Their 2006 surveys at 4 sites expanded vegetation and elevation datasets to include Reach G (see Figure 1 in Study Area).

In Year 3b, NOAA sampled juvenile salmon and found that wild juvenile salmon, especially Chinook (*Oncorhynchus tshawytscha*), are feeding and rearing at two tidal freshwater sites (representative of other tidal freshwater sites throughout the CRE). Sites are used by salmon primarily from early May through July, and appear to function as nursery habitat for other fish species as well. Salmon grew at significantly different rates among sites for each of the three time periods tested. Fish from Columbia City had the lowest growth rates, possibly due to their chemical contaminant load. Fish from this area had especially high concentrations of PAHs in their prey and also showed uptake of PCBs, DDTs, and PBDEs. Salmon fed on a variety of prey items, including both aquatic and terrestrial invertebrates. Chemical testing of salmon found that fish from several sites had elevated vitellogenin levels, indicating that exposure to environmental estrogens may be more widespread than expected. Additionally, salmon from several sites had higher vitellogenin levels in May than in June, which suggests a possible temporal variation to estrogenic compound exposure.

Although contaminant concentrations in juvenile salmon from some sampling sites were relatively high, sediment contaminant levels were uniformly low. When compared to other urban sites in the Pacific Northwest, contaminant levels in the lower Columbia River sediments were low. This suggests that bed sediments may not be the primary source of exposure for juvenile salmon. Instead, contaminants in the food web, on suspended particles, and in the water column may be important sources of exposure. Comparison of contaminant burdens in juvenile Chinook salmon and Threespine Sticklebacks (*Gasterosteus aculeatus*, a resident fish species), found that overall, concentrations were higher and less variable in sticklebacks. However, concentrations of PCBs were an exception to this trend, indicating that other factors are influencing salmon body burdens, such as accumulation of contaminants upstream of the sampling site.

Analyses of filtered water, suspended sediment, and extracts from SPMDs detected pesticides, pesticide degradation products, pharmaceuticals and personal care products, and other contaminants at nearly all sampling sites. Although the compounds detected during this study were present at levels that are low relative to laboratory reporting limits, their detection in systems as large as the Columbia and Willamette Rivers indicates that they are likely widespread throughout the basin and concentrations may be considerable higher near their sources. Data also indicate that the Willamette River is an important source of contaminants to the estuary.

Study Area

The Ecosystem Monitoring Project's study area is the lower Columbia River and estuary (CRE), which is defined by the Clean Water Act as waters that are tidally influenced (area denoted in Figure 1). The CRE extends from the plume of the Columbia River to the Bonneville Dam [river mile (RM) 0-146]. The Ecosystem Monitoring Project is focused on habitats that support juvenile salmonids, including shallow emergent wetlands, undiked tidally influenced sloughs adjacent to the Columbia River, scrub/shrub forested wetlands, and mud/sand flats.

The habitat monitoring component of the Ecosystem Monitoring Project relies on a multi-scaled stratification of the lower Columbia River and estuary. The CRE is stratified by major hydrogeomorphic transitions, yielding eight distinct reaches, each with unique characteristics and physical processes (Figure 1). Reach boundaries are based on the Environmental Protection Agency's (EPA) Level IV Ecoregions

that were modified to include important parameters such as salinity intrusion, maximum tide level, upstream extent of current reversal, geology, and major tributaries. Habitat monitoring efforts in the CRE have thus far focused on Reaches D (Year 2), F (Year 2), and G (Year 3). Habitat monitoring in Year 3b focused on Reaches E and F.

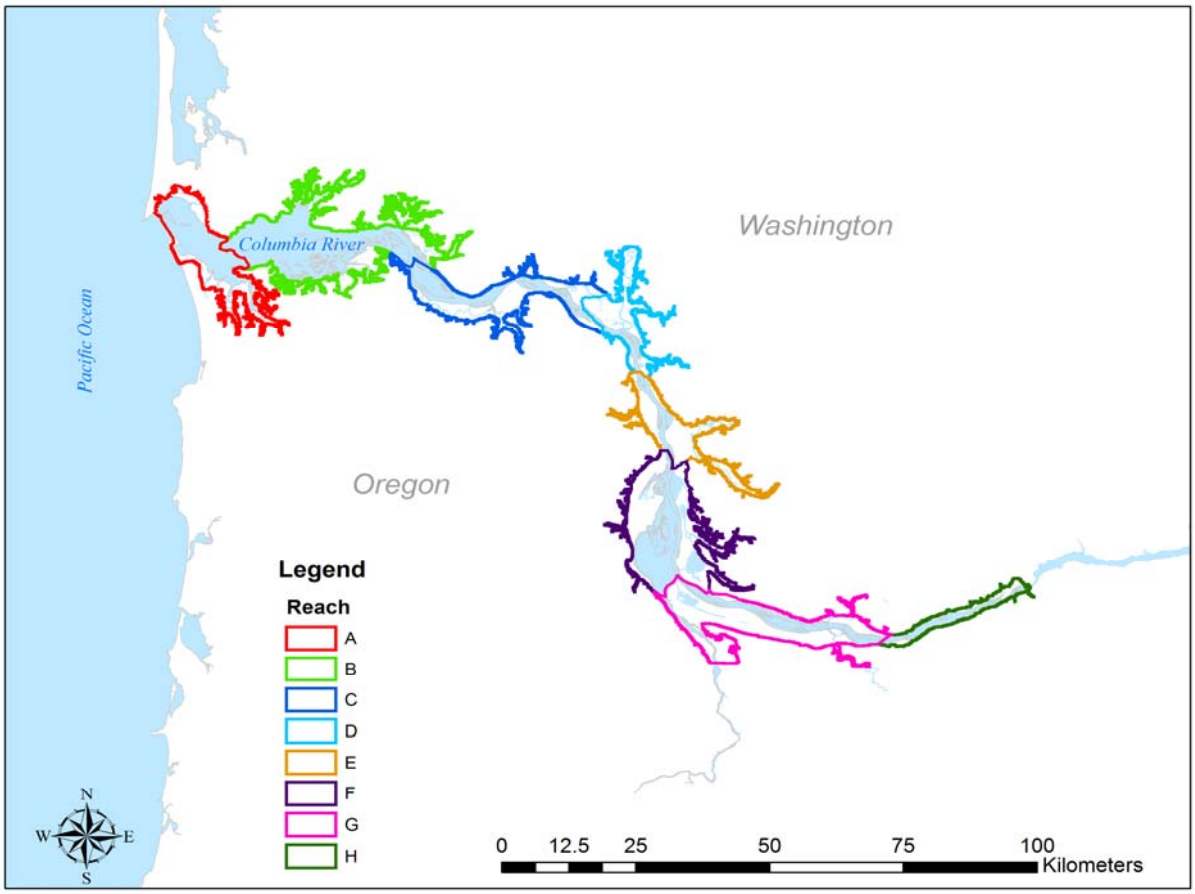


Figure 1: Lower Columbia River and estuary with hydrogeomorphic reaches outlined and specified by color.

Summary of Habitat Monitoring Activities in Year 3b

Three work elements comprised the habitat monitoring efforts in Year 3b:

1) Revision of Lower Columbia River Estuarine Ecosystem Classification System (UW and USGS CRRL);
2) Development of the sampling design and plan for long-term habitat monitoring (USGS BRD); and
3) Surveys and analysis of habitat conditions (PNNL).

These accomplishments will be used to direct rotational panel sampling in Years 4-7.

UW and USGS CRRL Columbia River Estuarine Ecosystem Classification

The Columbia River Estuarine Ecosystem Classification (the Classification) underwent modifications in Year 3b to update bathymetry throughout the estuary, incorporate recent Lidar[1] data for the estuary and floodplain, and finalize Level 4 (Complex) of the Classification. In addition, UW conducted a bathymetric gap assessment to identify areas lacking bathymetry or bare-earth lidar elevations that prohibit geomorphic delineation of complexes and analyses of landscape metrics at all levels.

Updates to the Bathymetry Dataset

In Year 3b, we continued development of the Classification by updating the bathymetric dataset that serves as the base layer for delineating the Complexes. Dates for bathymetry acquisition in the Columbia River estuary range from 1938 through the present. The most current datasets are in the mainstem shipping channel where portions are updated annually by the U.S. Army Corps of Engineers (USACE). The remaining areas in the estuary are a composite of surveys spanning 60 years of data collection. Because the estuary's bathymetric and geomorphic structures are dynamic through time, appropriate application of the Classification depends on the most current data to represent estuarine geomorphic features. Therefore, the bathymetric data was filtered by date using river flow as a criterion such that 2003-present represents a multi-year stable collection of data (Figure 2). It is planned that additional bathymetric data will be added from 2007, 2008, and possibly 2009 surveys if a major flood event does not occur prior to the surveys.

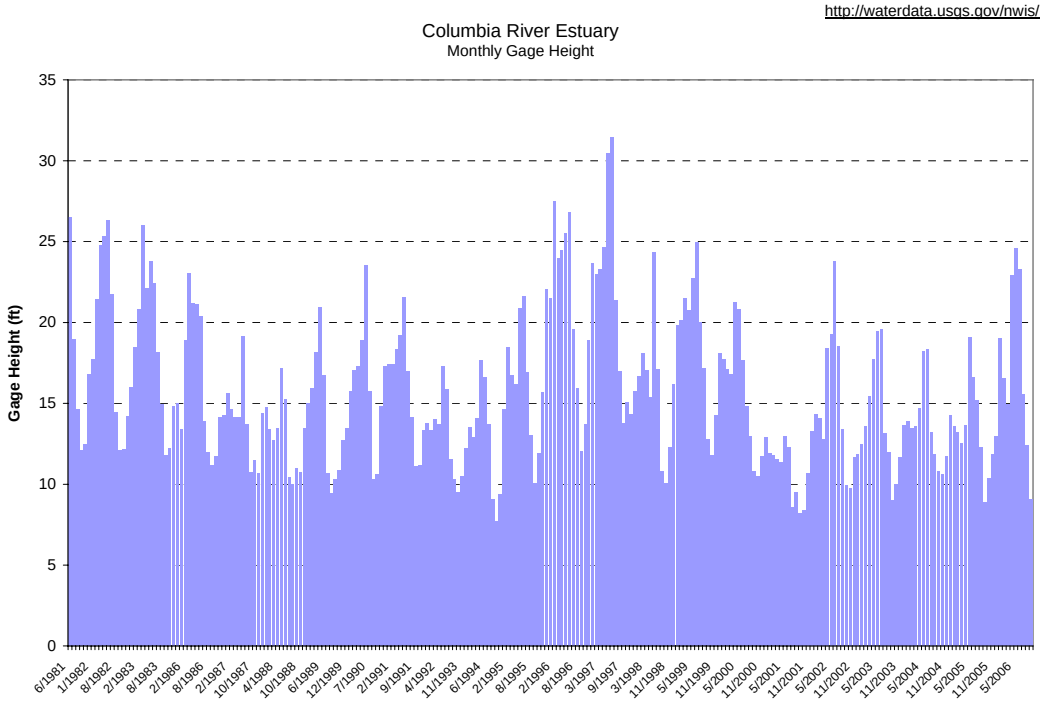


Figure 2: Monthly gage heights for the Columbia River below Bonneville Dam, 1981-2006.

A gap analysis conducted in Years 2 and 3 guided new field sampling for bathymetry and investigation of available data not addressed by the USACE data collection. In Years 3 and 3b, the United States

[1] Lidar, a term derived from LIght Detection And Ranging, is an optical remote sensing technology to obtain bare earth and structural elevation values from aerial flight. We chose to follow the standards of the American Society of Photogrammetry and Remote Sensing, which no longer considers lidar an acronym, similar to the former acronyms laser (light amplification by stimulated emission of radiation) and radar (radio detecting and ranging).

Geological Survey Columbia River Research Laboratory (USGS CRRL) conducted a field collection of new bathymetric data in areas with significant gaps. Filling of these bathymetric gaps reduced uncertainty in the Classification at the Complex and Catena (Level 5) levels in areas of immediate interest and monitoring priority. Furthermore, the field collection effort demonstrated the time, cost, and benefit of reducing bathymetry gaps.

We re-evaluated current bathymetric gaps in Year 3b after incorporating the lidar bare-earth elevation data, which potentially addressed bathymetric gaps in the intertidal areas (Figure 3).

The Classification currently includes five bathymetric datasets compiled by the USGS CRRL (Hatten and Batt 2007) (Table 1). The USACE is the primary source of recent bathymetric data for the Columbia River estuary through the Channels and Harbors Project (https://www.nwp.usace.army.mil/op/nwh/chstatus.asp). Several internet-based WEB sites are available to download these free datasets. Additional datasets include bathymetric data collected by USGS CRRL in 2005 and 2006.

Table 1: Bathymetry source data compiled by USGS CRRL, 2007.

Source	Year(s)
USACE navigation-channel bathymetric survey	1999
USACE bank-to-bank bathymetric survey	2003
USACE navigation-channel bathymetric survey	2003
USACE navigation-channel bathymetric survey	2006
Columbia River Research Laboratory bathymetric survey	2005, 2006

For consistency, all bathymetric (depth) values were reconciled to the NAVD88 vertical datum. We applied a spatial-temporal screening to the surveys to eliminate overlapping datasets and to retrieve the most recent dataset. Our screening methods replicated the methods of Gesch and Wilson (2005). After we assembled a complete and appropriate bathymetric dataset, we interpolated the point data to generate a bathymetric digital elevation model (DEM) at 10-m resolution, with additional processing to prevent interpolation beyond the area of the data points. The interpolation methodology replicated that of Foxgrover *et al.* (2003). The bathymetric 10-m DEM served as the basis to delineate the Level 4 Complexes.

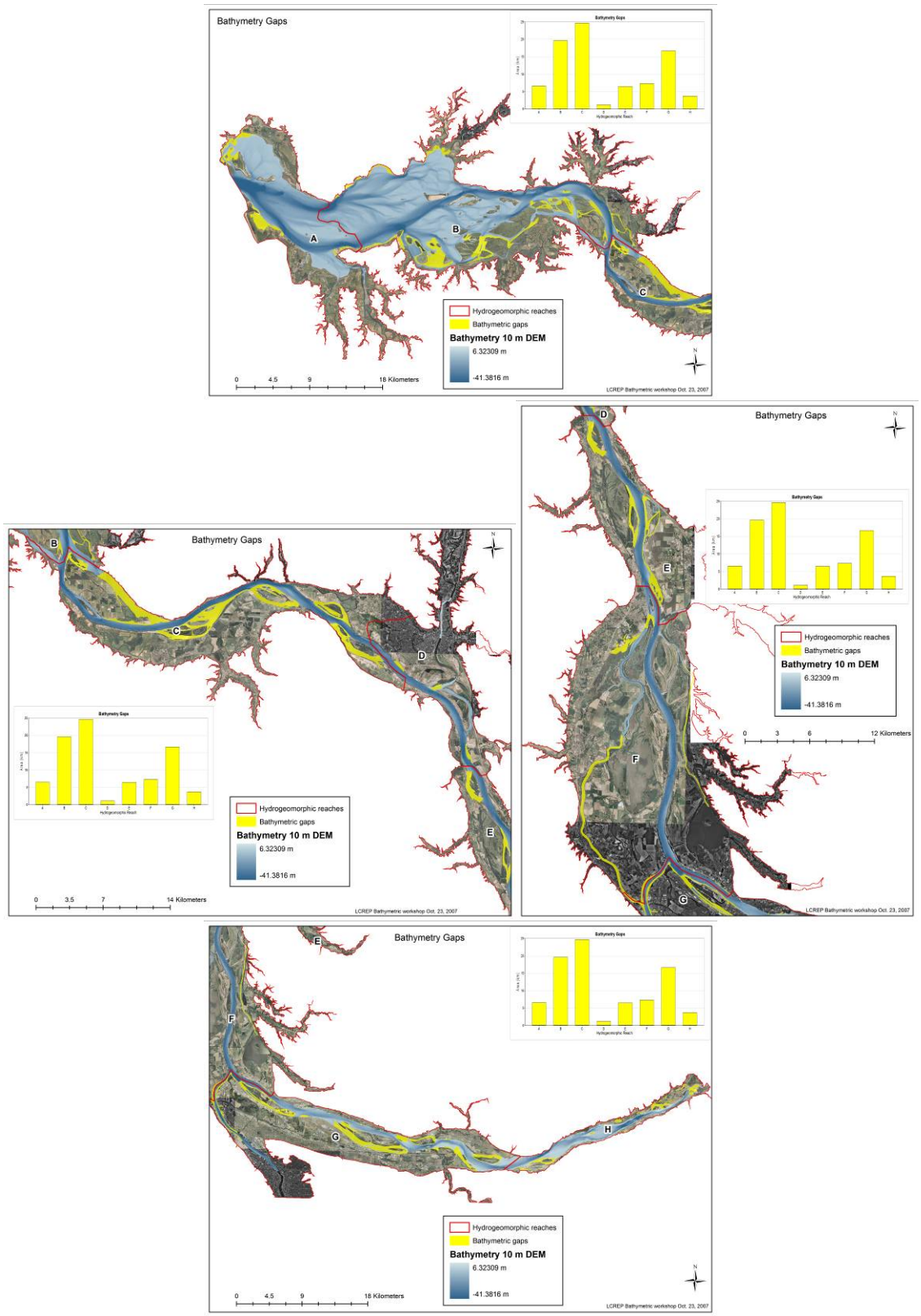


Figure 3: Bathymetry and lidar gaps (denoted by yellow areas) for the Columbia River estuary assessed by Hydrogeomorphic Reach.

Incorporating Lidar Data

Terrestrial elevation values for the Columbia River estuary and floodplain were formerly determined using USGS 10-m DEMs dated from the 1980s. Early analysis of the USGS DEM data for the Classification revealed that the USGS DEM dataset was not consistent with the current structure of the islands and other features in the estuary, creating spatial discrepancies in the landscape. From January 10 to February 20, 2005, the Puget Sound Lidar Consortium contracted a comprehensive collection of lidar full-return and bare-earth elevation values in the Columbia River estuary and floodplain (Lidar Bare Earth DEM, 2005). This effort represented a significant update to the terrestrial elevation dataset and the Classification because terrestrial (elevation) values characterize the geomorphic structure of the estuary and are the source for analytical metrics at both the Complex and Catena levels of the Classification. Therefore, the Classification benefited from the inclusion of 2005 Lidar bare-earth dataset.

The Consortium distributed the 2005 Lidar bare-earth dataset in late fall of 2006 as 1.8-m (6 foot) resolution DEMs. Prior to incorporating the lidar datasets with the Classification, we mosaiced the individual tiles to generate a complete lidar bare-earth DEM for each Hydrogeomorphic Reach. Upon review of these lidar data, UW determined that the dataset contained erroneous water surface elevation values that presented potentially misleading representation of elevation that would be used in calculating the metrics and analysis (Figure 4). USGS and UW initiated an effort in Year 3b to remove the erroneous water elevation values and will continue this process into Year 4; at the end of Year 3b, we had eliminated erroneous water elevation values from Hydrogeomorphic Reaches A, G, and H. The lidar in these reaches is now acceptable for the Classification.

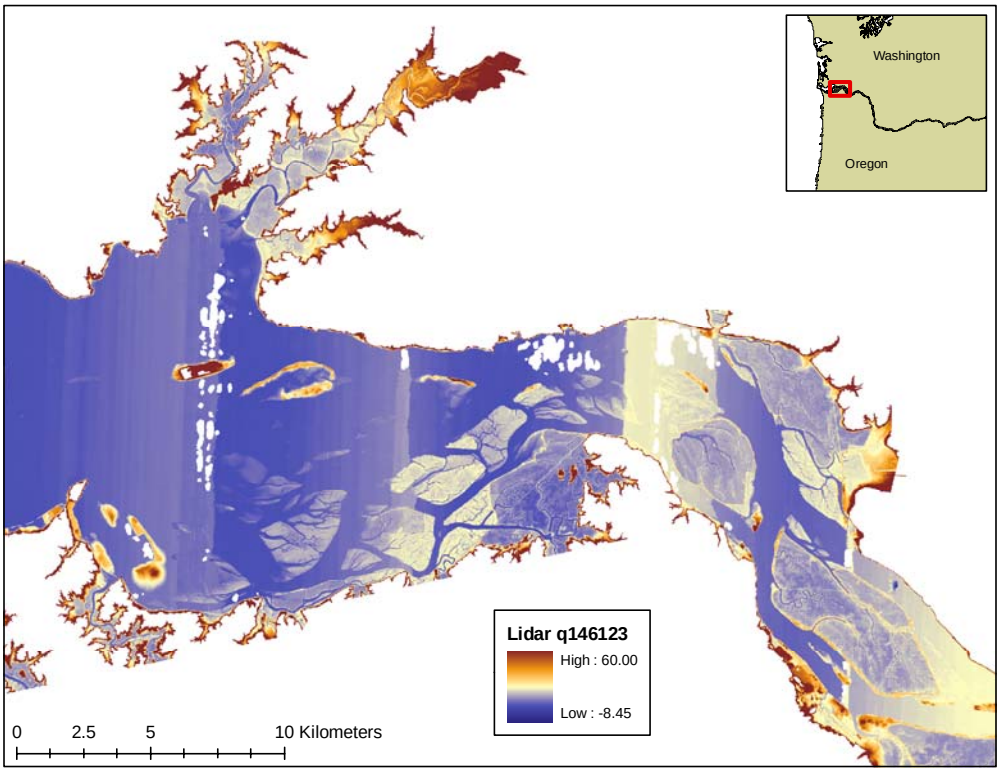


Figure 4; Lidar bare earth elevation DEM, including the water surface elevation values that varied with the tide level during the survey flights.

Benefits of Using the Columbia River Estuary Lidar

The lidar data will also enable delineation of the Complexes by providing the data to model bank-full elevations in the estuary in addition to the delineation of dikes and the historical floodplain for the Classification. Using a spatially-variable elevation threshold generated from the USACE 1968 Flood Profile diagram, our delineation of the bank-full mainstem river generated desirable results Thus, delineating the bank-full elevation provided a elevation value to divide seasonally-inundated Floodplain Complexes from tidally-inundated Complexes. Previously, UW did not have an up-to-date dataset to separate these Complexes.

In addition to the delineation of the Complexes, the lidar dataset addressed intertidal areas lacking bathymetric survey data, addressing gaps for many of these estuarine landscape features.

Level 4 Complexes

Complexes were delineated and finalized using the bathymetry and lidar datasets compiled in Year 3b, high-resolution aerial imagery, and land cover classification. Burke and Sobieszczyk (2007) describe the methods used to delineate the complexes as a rules-based approach in GIS. This approach was coupled with automated delineation of threshold elevation values for the Main Channel complex and the bank-full elevation to divide the Floodplain Complexes from the Shallows. Elevation thresholds used to delineate Complexes varied by Hydrogeomorphic Reach due to the gradual rise in elevation upriver and geomorphologic differences in the bathymetry between the Reaches.

Summary of Upcoming Year 4 Activities

Following the review of the complexes and removal of the erroneous water-surface elevations from the lidar dataset, we will generate a dike, fill, and historical floodplain GIS datasets that will augment the Classification. We will also update the bathymetry data layer and conduct pre-planning activities for field collection of bathymetry in data gaps priority areas. In addition, we will conduct, review, and finalize the Level 5 (Catena) of the Classification and develop the methodology for metrics. All datasets will be delivered to Estuary Partnership as GIS datasets for dissemination to the public.

USGS BRD Sampling Design Based on the Classification System

Introduction

The Columbia River Estuarine Ecosystem Classification is based on hydrogeomorphology and partitions the lower river initially into ecosystem types, then further into hydrogeomorphic reaches, complexes, and cover types (Simenstad et al., 2006). Understanding and describing the physical, chemical, and biological characteristics of these varied ecosystems or specific habitats is critical to our understanding of the role of the estuary in salmon recovery. The Classification system provides us with a valuable tool not only for visualizing the components of the ecosystem but also for designing statistically rigorous sampling strategies for our on-the-ground habitat and water quality monitoring.

In 2006-2007, we developed a probabilistic sampling design for identifying sampling sites. Here, we describe the sampling design strategy and a potential sampling design applicable for assessing the existing status and variability of bottom sediments among different strata of instream channel ecosystems (e.g., deep main channel, tidal channels bordering vegetated wetlands, shallow channel margins, and lateral secondary channels) in a reach of the Lower Columbia River.

Methods

Conceptual Model

The conceptual model underlying the Columbia River Estuarine Ecosystem Classification is that there are distinct measurable differences in physical and ecological conditions among categories or classes within each of the hierarchical levels. For example, we would expect that there are distinct differences among the instream channel catena (i.e., secondary channels, shallow subtidal slopes, and flats and dendritic channels) in sediment grain size (e.g., d50 and d84), mean velocity, depth, FPOM/CPOM, and other physical features. Also, we would expect that the variation within a complex or catena is smaller than the variation among these classes.

Using this conceptual model, we can formulate hypotheses regarding the distributional properties of sediments in the lower Columbia River. For instance, we could hypothesize that spatial variability patterns among instream ecosystem strata are related to small scale features such as hydrogeomorphology (depth, velocity, substrate, and residence time) as well as important large scale features such as the amount of near shore wetlands and tidal flats versus diked floodplain, amount of urban and agricultural land use, and unique tributary inputs. We propose to test this working hypothesis with a stratified random sampling design that would facilitate the evaluation of multiple hypotheses.

Master Grid for the Stratified Randomized Sampling Design

Anthony Olsen (EPA-Corvallis) created the 30 x 30-m master randomized grid of sampling points for the Lower Columbia River and floodplain using the LCRE floodplain boundary developed by UW and USGS. This master grid includes over one million sampling points, yielding a very high density of potential sampling points for each reach and habitat complex (Figure 5). Depending on sampling objectives, however, sampling points can be aggregated to larger and larger cells in multiples of three (e.g., 180 x 180 m or 300 x 300 m). This randomized sampling grid will not have to be created again and can serve as the master template for all randomized statistical sampling designs. We continue to work with EPA researchers to provide an overall technical review of sampling designs and to ensure that sample designs are integrated (where applicable) with other ongoing survey sampling designs in the region.

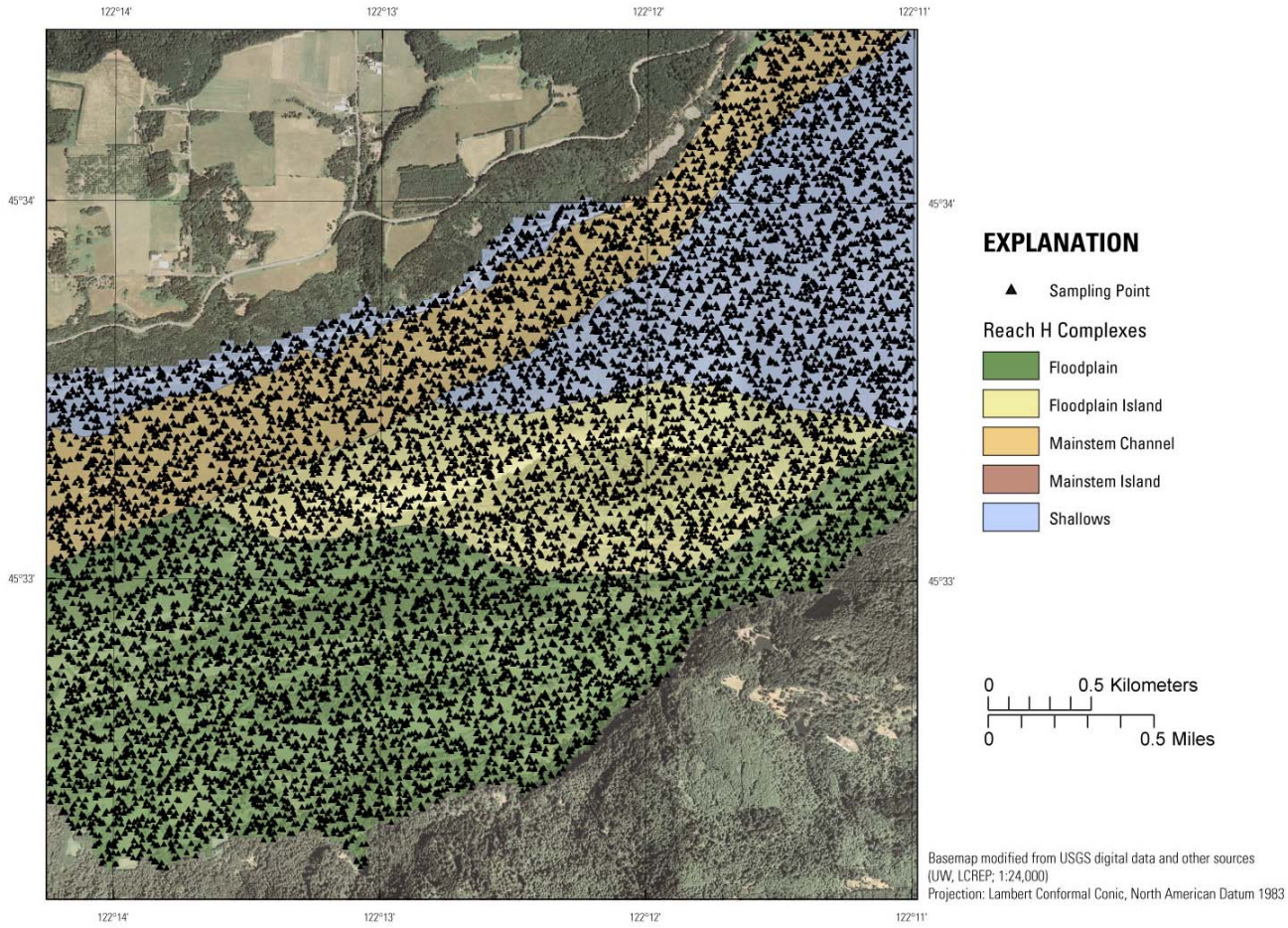


Figure 5: Portion of Reach H complexes and overlay of master point grid (denoted by black triangles), illustrating the high density of potential sampling sites in a reach and across complexes.

Proposed Pilot Sampling Site Selection and Field Study

The probabilistic sampling design will be drafted for one to two reaches using the master 30 x 30-m point grid (Figure 5). The Classification system will be layered over the point grid so that we can select random sampling locations within two channel strata of the Classification system (e.g., habitat complexes and the catena within the complexes). Each reach will have a unique list of habitat complexes, catena types, and their respective frequencies of occurrence. For example, Reach H may only contain 5 habitat complexes with a frequency of individual patches of complexes ranging from 1 to 5 (Figure 6). On the other hand, Reach B may contain 8 habitat complexes with a range of patches from 4 to 30. Likewise, the catena will likely have a similar pattern in the diversity and abundance within and among reaches. A minimum of three random sampling points should be selected from each of the catena within the two in-channel habitat complexes (main channel vs. shallows). Without prior knowledge of the variability associated with the metrics measured, a minimum of three points will likely provide a starting point to understand how many samples will be necessary to address the hypotheses (Figure 7). Our upcoming Years 4-7 will allow us to better understand the variability in the metrics that characterize substrate habitats and their variability within and among the different distinct habitat types (e.g., shallow secondary channels, shallow flats, and shallow high order dendritic tidal channels).

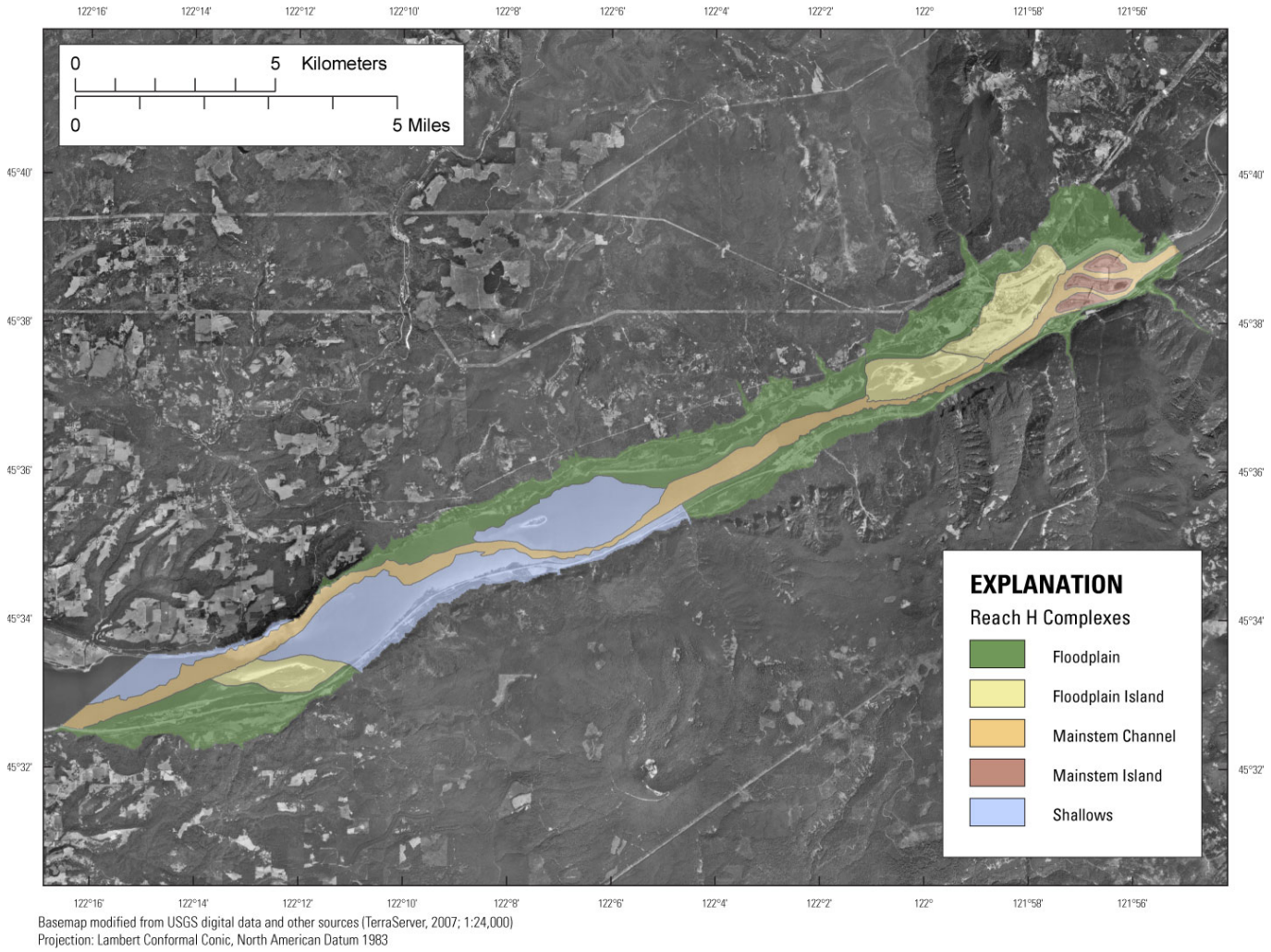


Figure 6: Reach H complexes.

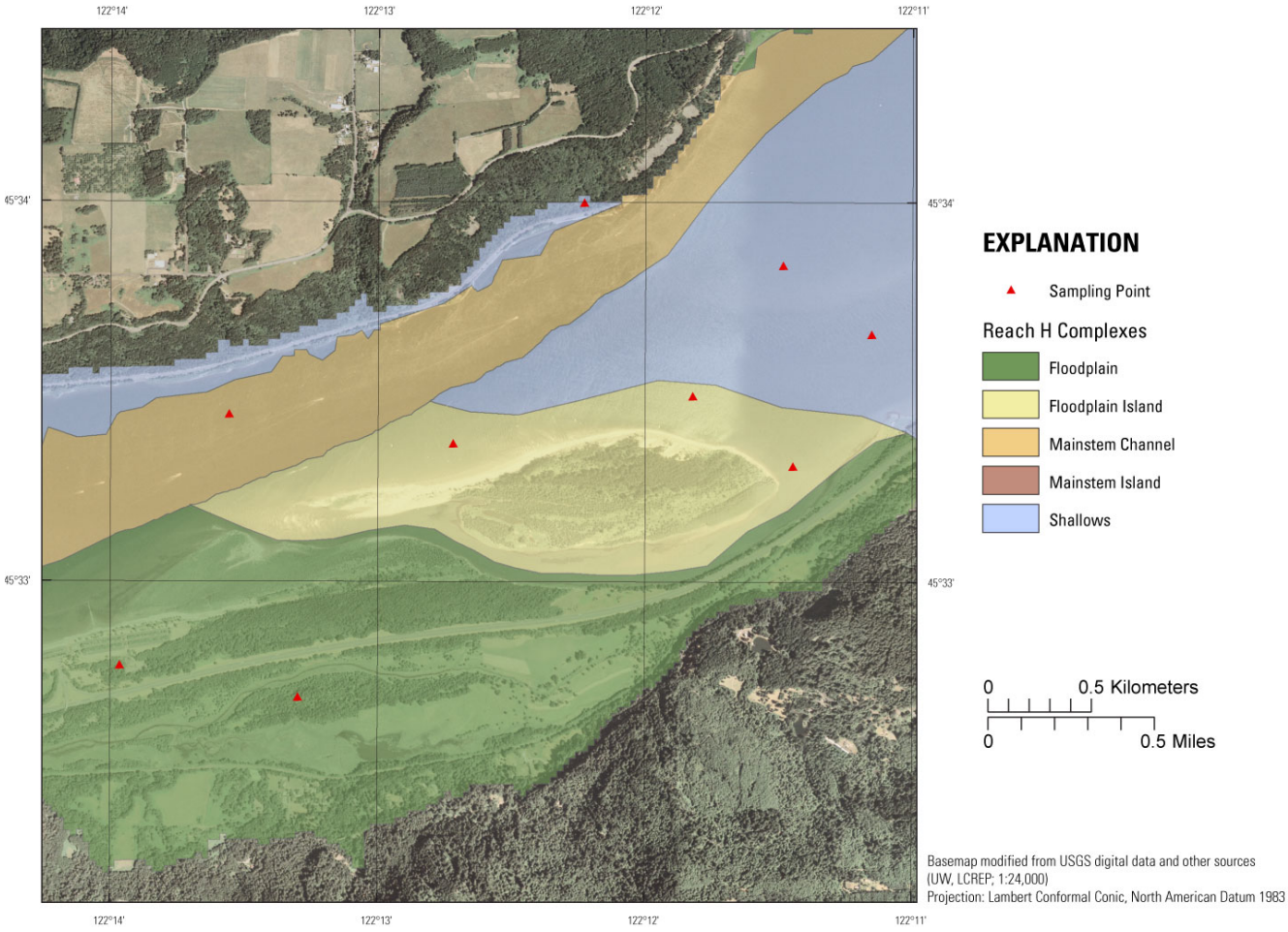


Figure 7: Reach H complexes with randomly selected sampling locations (denoted by red triangles).

Field sampling will also provide a test of one of many possible probabilistic sampling designs that can be derived from the Classification system and the applicability and definition of different ecosystem strata selected. While this probabilistic design assumes that all strata can be easily located and properly sampled in the field, this assumption has not been tested. Field sampling would allow us to determine proper field protocols and decision criteria to ensure that a sample is within the appropriate strata (e.g., complex or catena) and appropriate sampling unit. Results from the sediment characterization will allow us to test our theories that the different strata have distinguishable characteristics and, thus, provide information for refinement of the Classification system. This information on the different sediment composition is important to define instream ecosystems, particularly with the large variety of shallow-water areas or habitats in the LCR that are known to be important for salmonids. In addition, methods for collecting quantitative data from a rigorous statistical design, as described here, will also assist other researchers addressing issues such as habitat use by salmon prey, colonization or spread of invasive species, and potential food-web contaminants.

Future Design Plans

We are using the Classification system to develop a sampling design useful for the characterizing and assessing the utilization of shallow tidal-wetland ecosystems by juvenile salmonids. We will determine the number and extent of tidal wetland areas and instream channel catena that border these ecosystems

and select sites randomly or proportionally depending on the variety and number of combinations of these paired classes within the reach.

Battelle-Pacific Northwest National Laboratory (PNNL) Vegetation Surveys

Introduction

The goals for PNNL's habitat monitoring efforts in summer 2007 were to select four study sites in the focal reach, Reach E, and to conduct field measurements at the selected sites in Reach E, as well as at two sites in Reach F, which were previously surveyed in 2005 and 2006 (Figure 1, Figure 8).

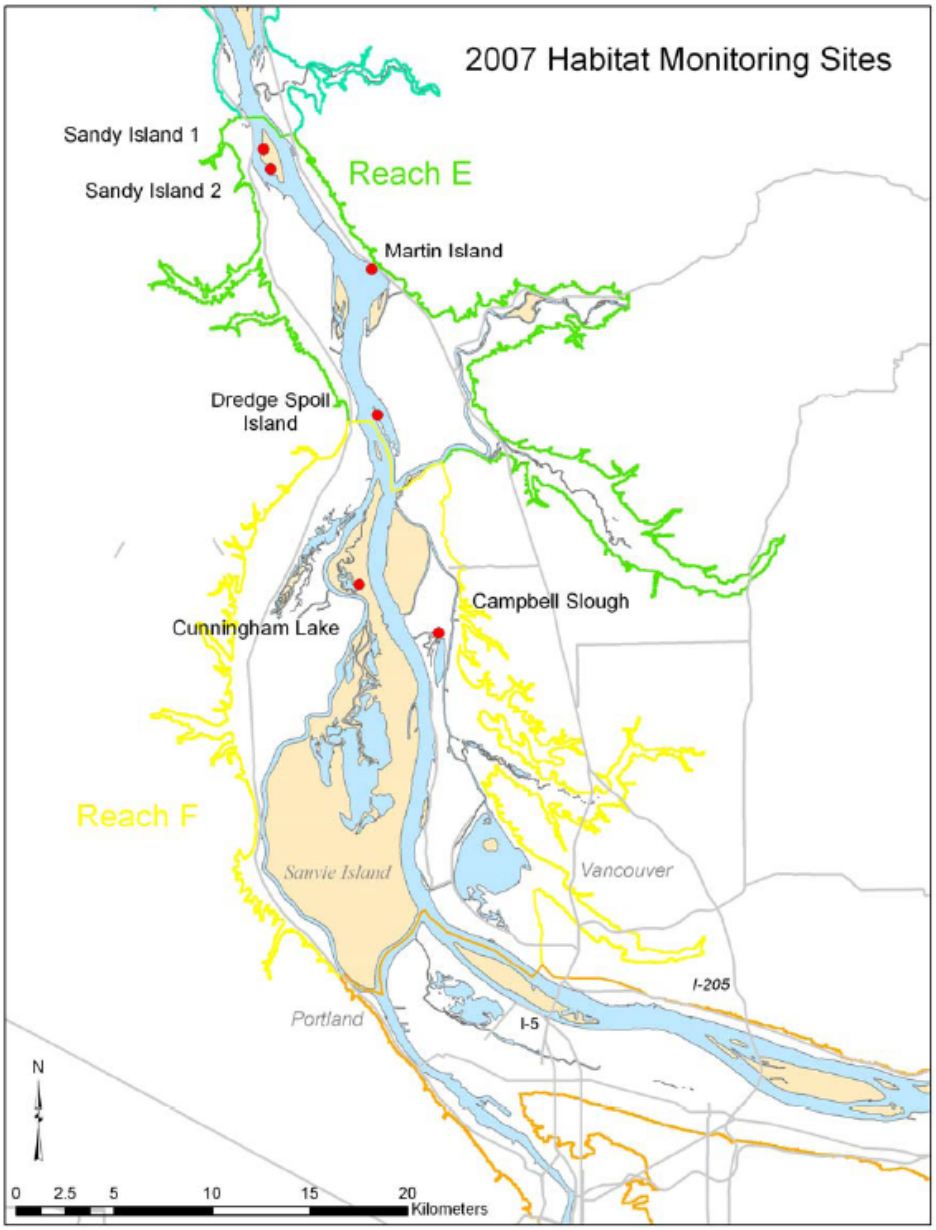


Figure 8: Map of Reaches E and F, showing 2007 sites for PNNL vegetation surveys.

Reach E was selected as the focal reach because of its interest to our collaborators, particularly NOAA Fisheries, who collected fish samples in this reach during spring 2007. Three of our sampling sites were common sites for these efforts. Reach E extends upstream from Goble, OR/Kalama, WA (upstream of the mouth of the Kalama River) to just downstream of St. Helens, OR at the confluence of the Lewis River.

In April, a site selection field trip was made with NOAA Fisheries and Estuary Partnership staff to evaluate potential sites. In selecting sites, the research team sought consistency in type to those surveyed in Reaches D, F, and G in previous years, specifically shallow water wetlands, mainstem fringing or off-channel, with characteristic emergent marsh vegetation and typically fine sediments. In addition, a sub-set of the sites had to be fishable by beach seine or similar gear-type for the NOAA Fisheries effort. As in past years, high water during the site selection field trip (Figure 9) precluded forming a definitive site list. A list of candidate sites was compiled, with final site selection made by the research team at the time of the survey in July.

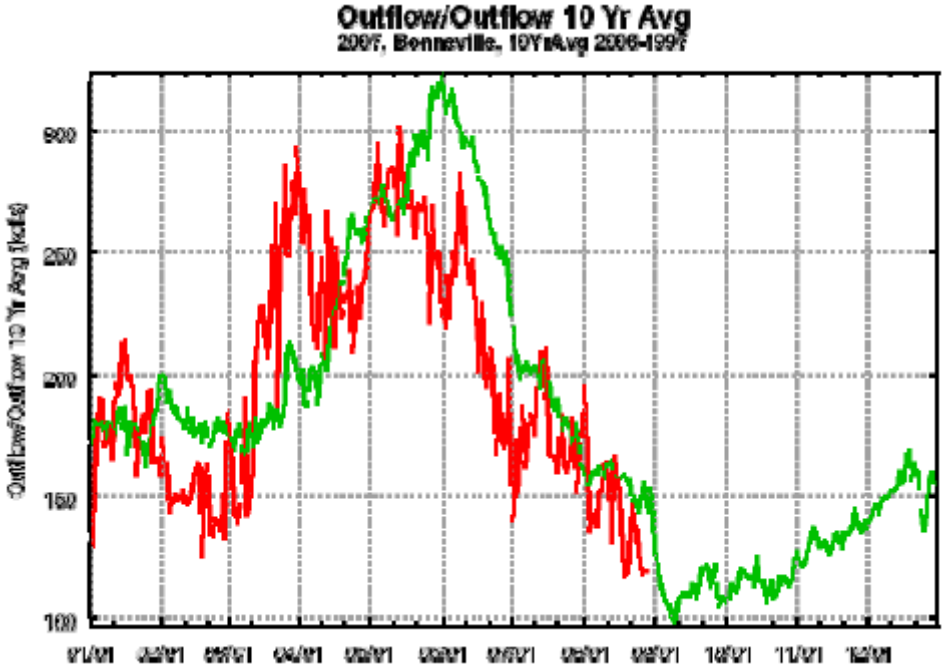


Figure 9: Outflow at Bonneville Dam, comparing outflow in 2007 (denoted by red line) to 10-year average (denoted by green line) (Columbia River DART, 2007).

Sites

On-the-ground habitat monitoring field surveys were undertaken from July 17-26, 2007. A total of six sites were visited, four in Reach E and two in Reach F (Figure 1, Figure 8). In Reach E, the four sites were: Sandy Island #1 (across from Goble, OR), Sandy Island #2 (upstream from Goble, OR), Dredge Spoil Island (DSI, part of an unnamed island complex just downstream of the confluence of the Lewis River), and Martin Island (a site on the Washington side of Martin Island). In Reach F, the sites were: Campbell Slough (approximately 1.4 km from the mainstem of the Columbia) and Cunningham Lake (at the end of Cunningham Slough approximately 6.4 km from the mainstem of the Columbia), which were both originally surveyed in summer 2005 and resurveyed in 2006. We included these sites in our 2007 survey to assess inter-annual variability at these shallow water wetlands. As part of another BPA project, we also conducted surveys of vegetation and elevation at two sites previously surveyed in Reach G (Chatham Island and Sandy River Delta). The results from that effort will be shared and included in the data-roll up to be completed during Year 4 (September 1, 2007 – August 31, 2008).

Both the Martin Island and DSI sites are fringing wetlands on mainstem islands. Martin Island (Figure 10a) has finer sediments (silt/mud), a shallow transition to the upland, and has been recently grazed by cattle. The DSI site (Figure 10b) has coarser (sand/silt) sediments and a more steeply rising bank to the upland. The Sandy Island #1 site (Figure 10c) is an expansive wetland with a channel network that extends almost 1 km from the mouth of the slough. It has fine (mud/silt) sediments and large areas of shallow-water wetland with fringing bank gradually sloping to upland. Sandy Island #2 (Figure 10d) also has a small channel extending away from the mouth of the slough, with the majority of the surveyed site sitting at the head of a wide inlet/slough on Sandy Island. Sediments here are similar to those at Martin Island and coarser than those at the Sandy Island #1 site. A large area of accumulated sand (possibly dredged material) is located directly south of the site.

The two sites in Reach F, Campbell Slough (Figure 10e) and Cunningham Lake (Figure 10f), were surveyed in 2005 and 2006. At Campbell Slough, noticeable signs of grazing were evident during the 2007 survey although no cows were observed during the site visit. These two sites have been included in each survey to better understand inter-annual variability in the absence of a true rotational-panel sampling design.

Methods

Transect Surveys

Similar to habitat monitoring methods used in 2005 and 2006, we surveyed for site elevation and mapped percent vegetation cover along transects and prominent vegetation types. Upon arrival at the site, we determined the optimum location of transects such that all major plant communities from water's edge to upland area would be included in the survey. Typically, three transects were established at each site, radiating from a single hub. A station was also designated for each site from which photographs were taken to document a 360-degree view.

In an area above tidal influence, we installed a length of rebar as a benchmark from which all local elevation measurements were made. This benchmark was surveyed using a Trimble real time kinematic (RTK) global positioning system (GPS), with survey-grade accuracy. All surveying was referenced to the North American Vertical Datum (NAVD-88); horizontal position was referenced to North American Datum (NAD83). Data collected from the base receiver were processed using the automated Online Positioning User Service (OPUS) provided by the National Geodetic Survey. OPUS provides a Root Mean Squared (RMS) value for each set of static data collected by the base receiver, which is an estimate of error.

Trimble Geomatics Office (TGO) was used to process data. Benchmark information was entered into TGO and rover antenna heights were corrected for disc sink (to the nearest half inch) at each point. Surveys were visually checked with both TGO and GIS software for validity.

Along each transect, percent cover was estimated every 2 m (or every 5 m if the transect was over 100 m long and/or the vegetation was considered relatively homogeneous). Percent cover within a 1 m^2 quadrat placed on the substrate was estimated by two observers. An average of both observations was recorded to minimize observer bias. In addition to vegetative cover, features such as bare ground, open water, and wrack were also recorded. When plants could not be identified in the field, a sample was collected for later identification using keys or manuals. If identification was not possible, it was considered as "unidentified." Where visibility through the water column was possible, cover estimates were also estimated for submerged aquatic vegetation. Plant species were each assigned a list code. Sediment character was qualitatively noted (fines, mixed coarse, sand, etc.).

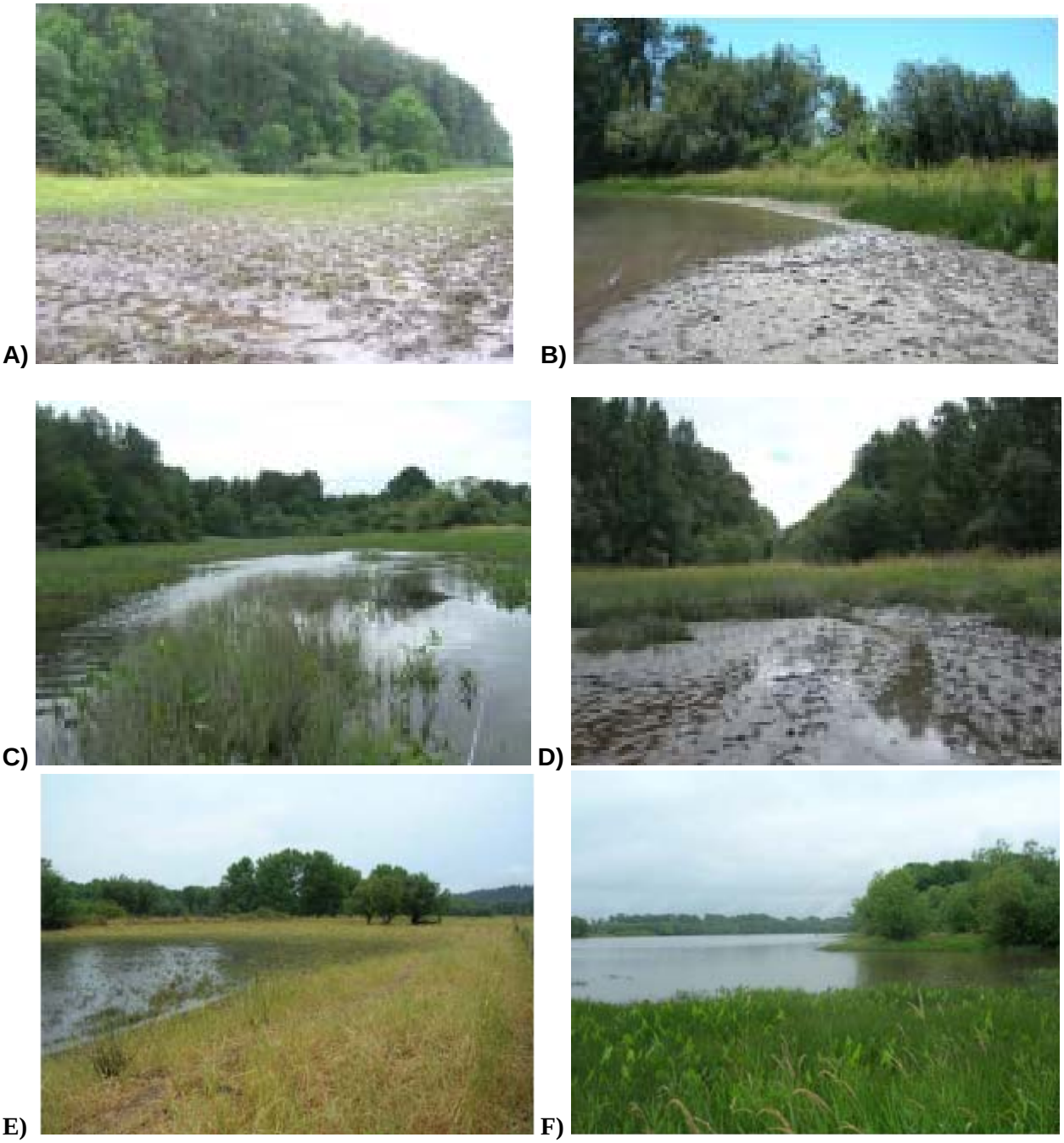


Figure 10: 2007 PNNL sites. Reach E sites: a) Martin Island; b) Dredge Spoil Island (Lewis River mouth); c) Sandy Island #1; and d) Sandy Island #2. Reach F sites: e) Campbell Slough; and f) Cunningham Lake.

In the field, all data were recorded on paper, and subsequently entered into Microsoft Excel at the lab. Quality assurance checks were performed on 100% of the data collected. Elevations from the RTK survey were entered into the Excel spreadsheet to correspond to the appropriate transect and quadrat location. Additionally, a field notebook with written observations was also kept.

Mapping

Using a Trimble GeoXT handheld GPS unit, the extent of the site (using reasonable natural boundaries) was mapped and major vegetation bands and patches were delineated within the site. Additionally, features of importance to the field survey (including benchmarks, transect start/end points, and photopoints) were also identified and cataloged. All data were put into a GIS and maps of each site showing major communities and features were created.

Channel Metrics

At sites with channel networks, channel cross-sections were surveyed to further understand the relationship between cross-section dimensions and marsh size. Since these relationships are being developed for wetlands elsewhere in the estuary, an objective of this study was to examine if sites in Reaches E and F had similar relationships. This effort will aid in understanding the necessary channel dimensions for maintaining a marsh when restoring these habitats. When possible, five cross-sections were collected, from the mouth of the main marsh distributary channel to the channel headwaters. Intermediate cross-section surveys were conducted at the confluence of major secondary channels or equidistant along the channel, as appropriate. Elevations along cross sections are shown in Figure 11. Further analysis of cross-channel data will coincide with another project that is scheduled for completion in fall 2007.

Transect Surveys and Mapping Results

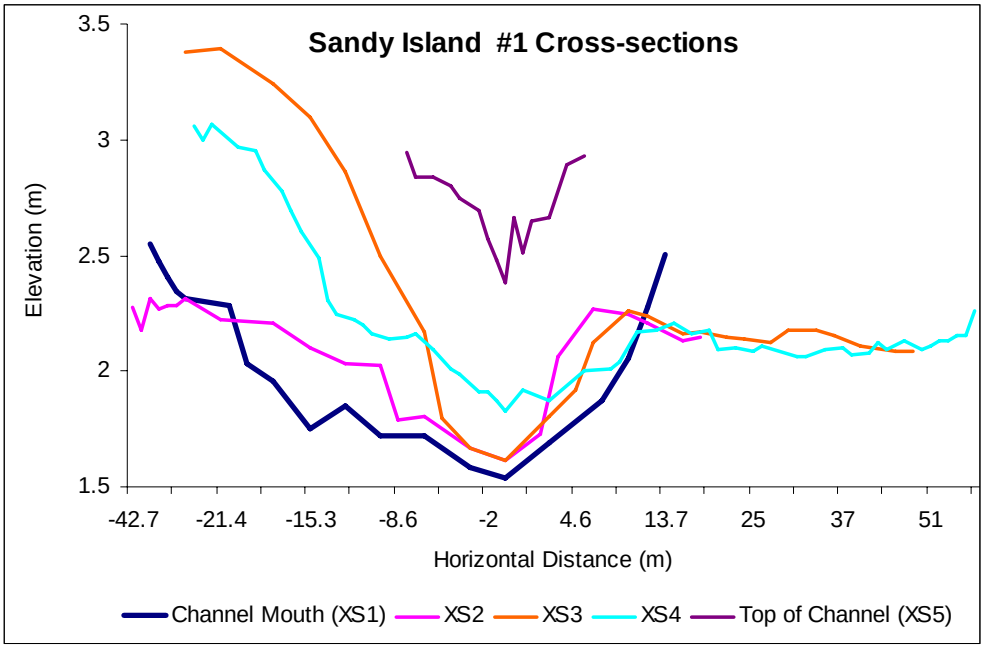
Vegetation patterns in Reach E were similar to those in previously surveyed reaches (D, F, and G). Common spikerush (*Eleocharis palustris)* and wapato *(Sagittaria latifolia)* dominated lower elevations, reed canary grass (*Phalaris arundinacea*) at mid-elevations, and willows (*Salix* spp.) mostly made up the upland border. Elevations of the species sampled in 2007 are shown in Figure 12. Maps of vegetation distributions at each site (Figure 13 - Figure 18) illustrate vegetation patterns and the geographic locations of each major species group related to tidal channels.

During the early part of the sampling period (particularly at Cunningham Lake and Campbell Slough), we noted that many of the plant species were flowering or had gone to seed even though the plants were submerged at the time of sampling. This indicated that the water level in the river had dropped and risen again. This hypothesis was confirmed by the Oregon Department of Fish and Wildlife, Sauvie Island field office. Furthermore, the outflow plot from Bonneville Dam (Figure 9) depicts a drop in water level in early July followed by a rise during the sampling period. The long-term implications of this type of water regime are unknown.

Reed-canary grass and common spikerush were the most commonly occurring species. Species lists for each site are at displayed in Table 2 and Table 3. Martin Island had the most diverse plant community, possibly because it is highly disturbed and includes upland weedy species. Species at Campbell Slough and Cunningham Lake were similar those found previous years (Table 3).

While we did not quantify sediment grain size, we did note that sites in Reach E were similar to those in Reach D—more mainstem sites had coarser sediments, while sites in sloughs or backwater areas had finer sediments.

a)



b)

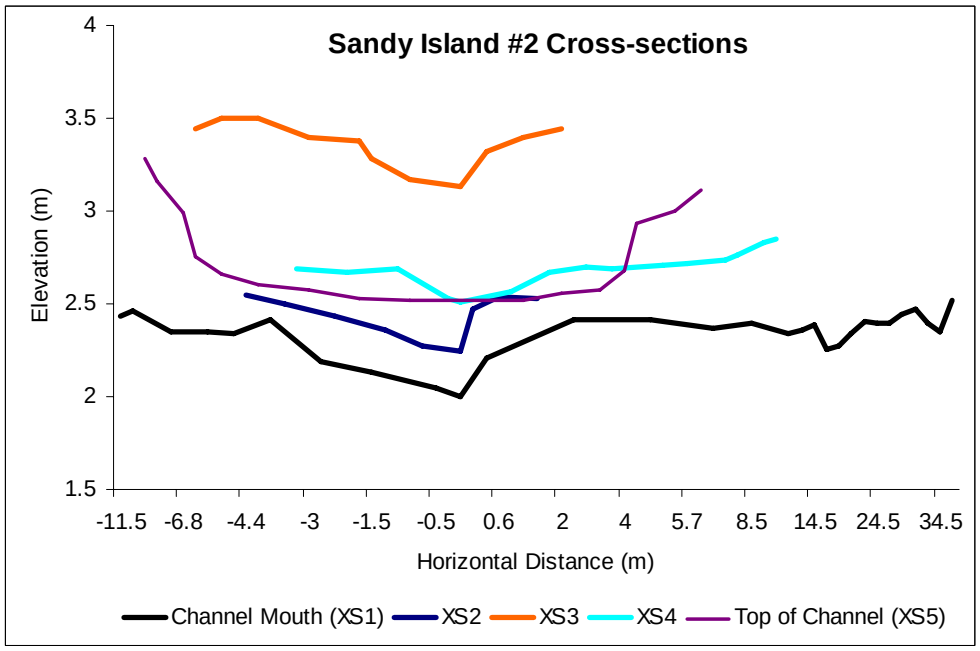


Figure 11: Channel cross-sections at: a) Sandy Island #1; and b) Sandy Island #2, 2007.

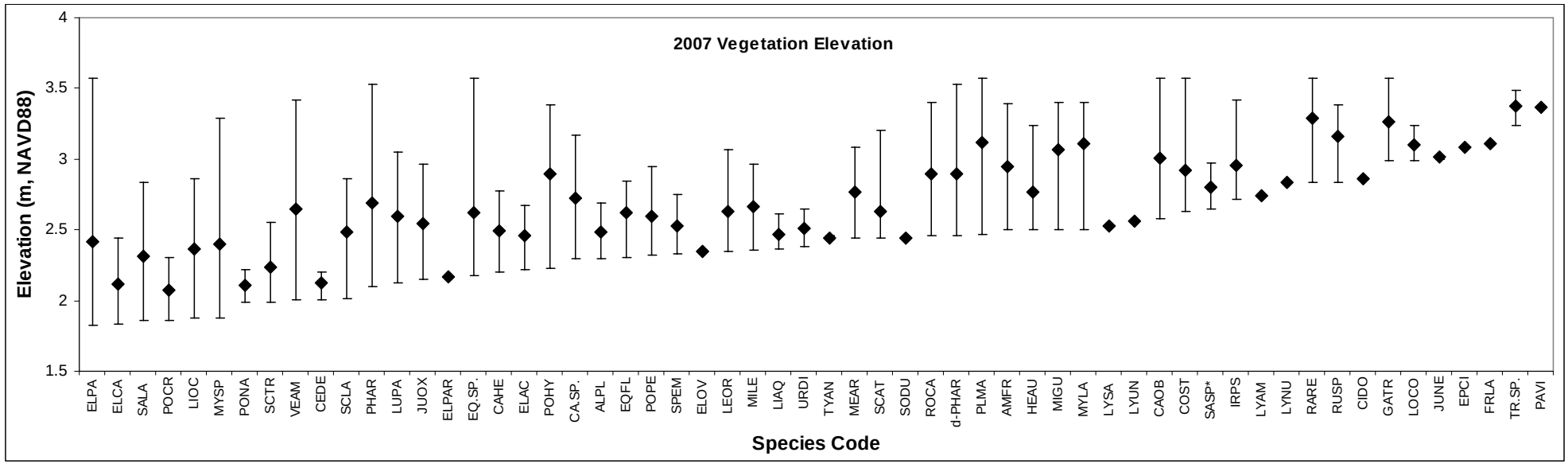


Figure 12: Vegetation by elevation for 2007 sampling sites. See Table 2 and Table 3 for species codes.

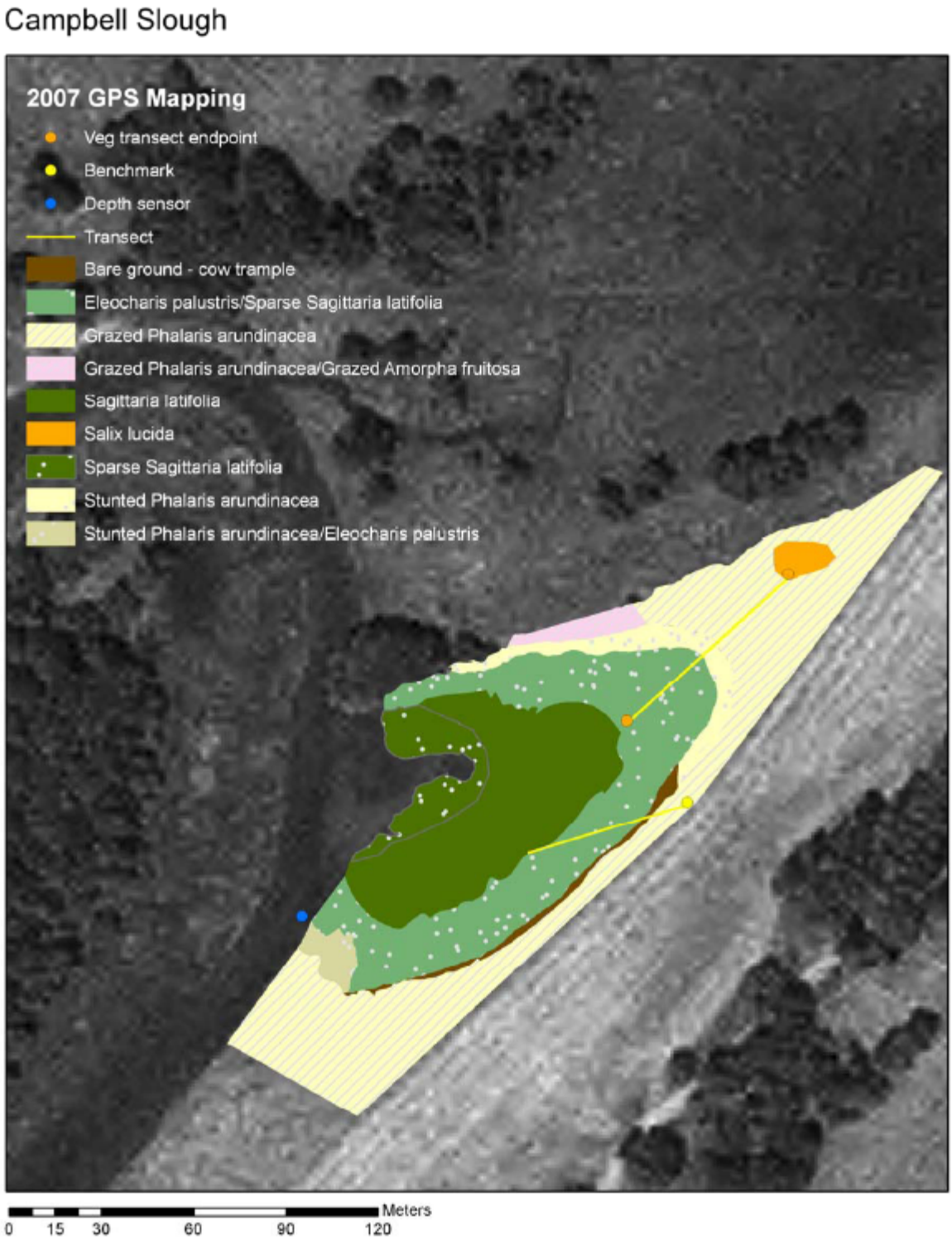


Figure 13: Vegetation distributions at Campbell Slough, 2007.

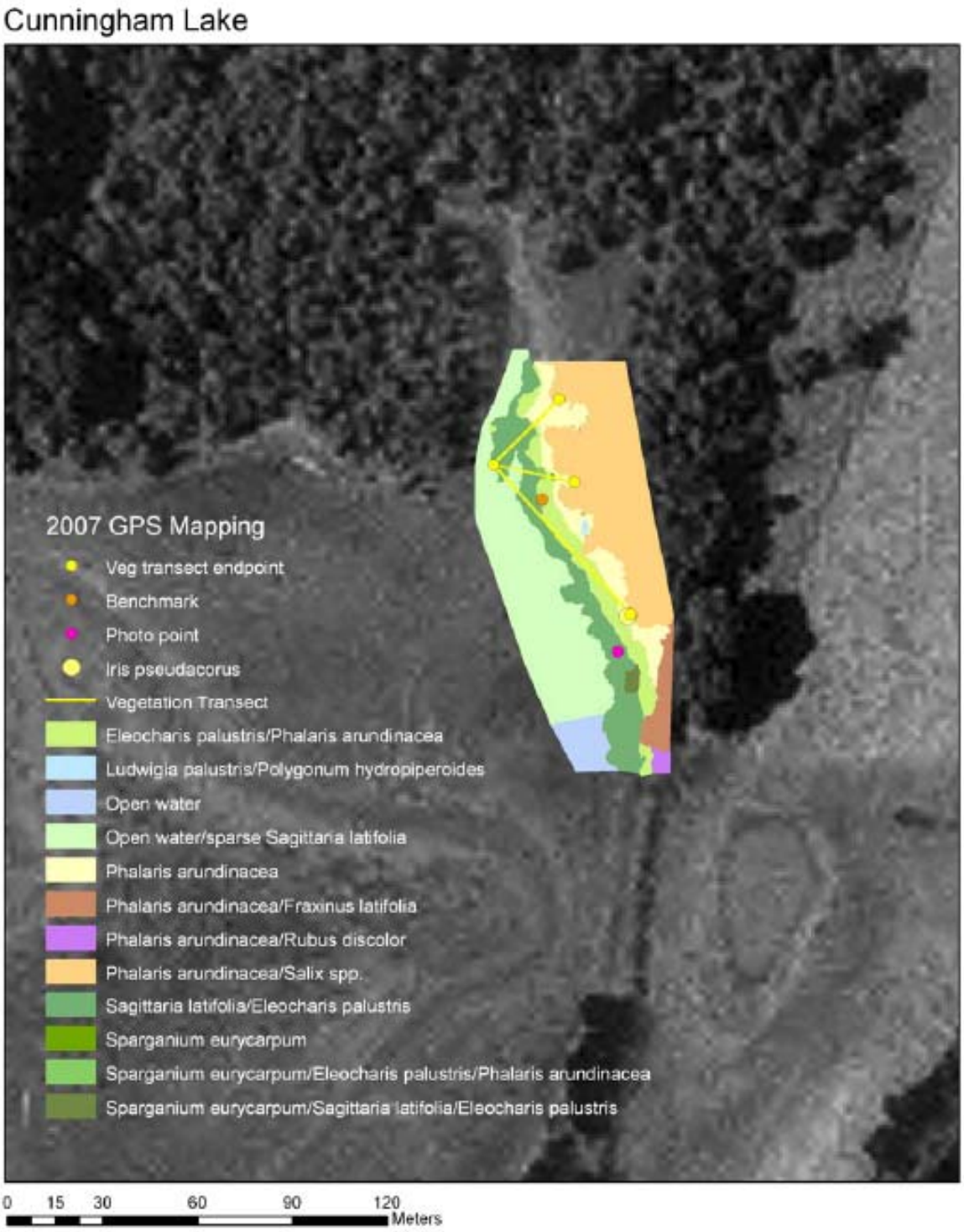


Figure 14: Vegetation distributions at Cunningham Lake, 2007.

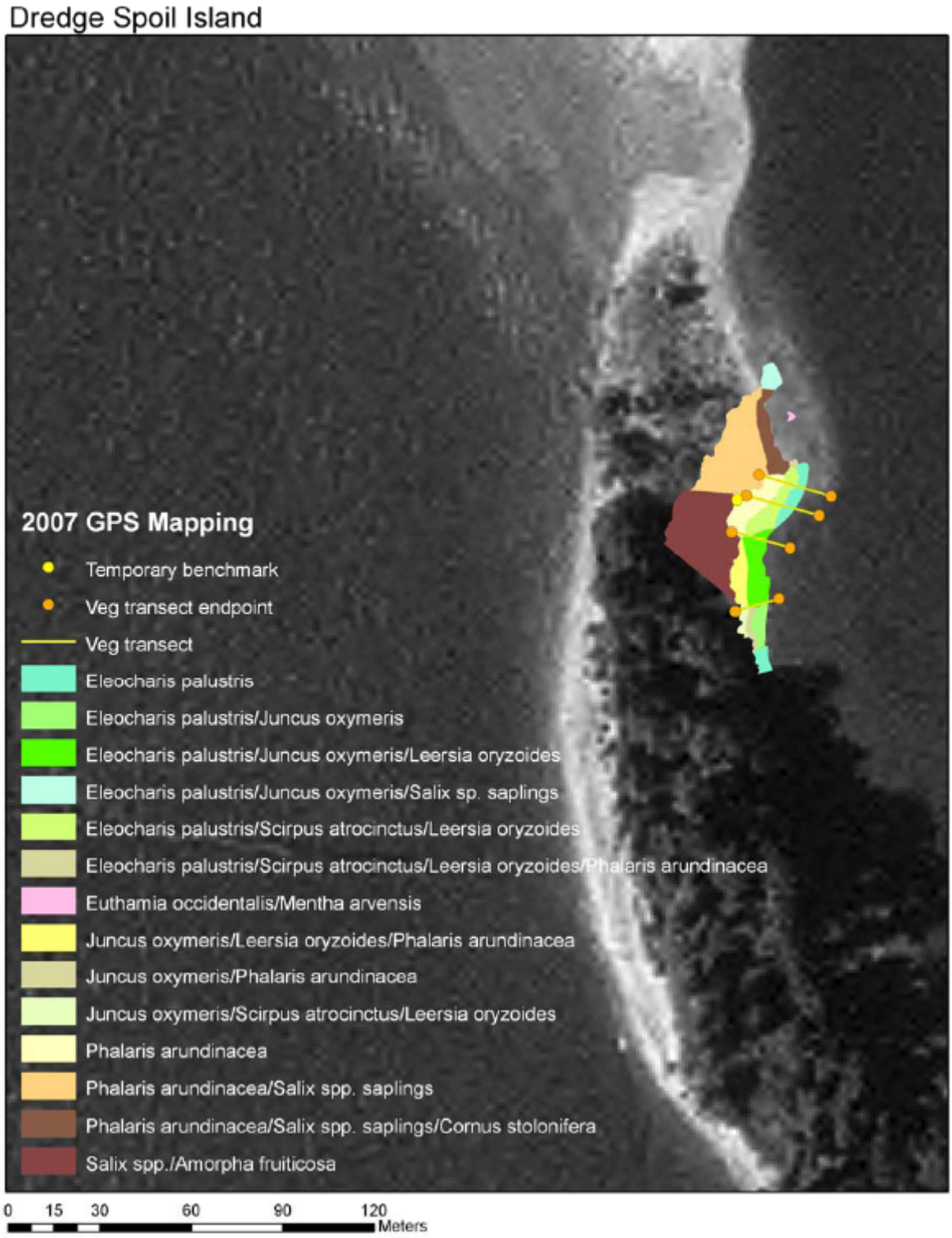


Figure 15: Vegetation distributions at Dredge Spoil Island (Lewis River Mouth), 2007.

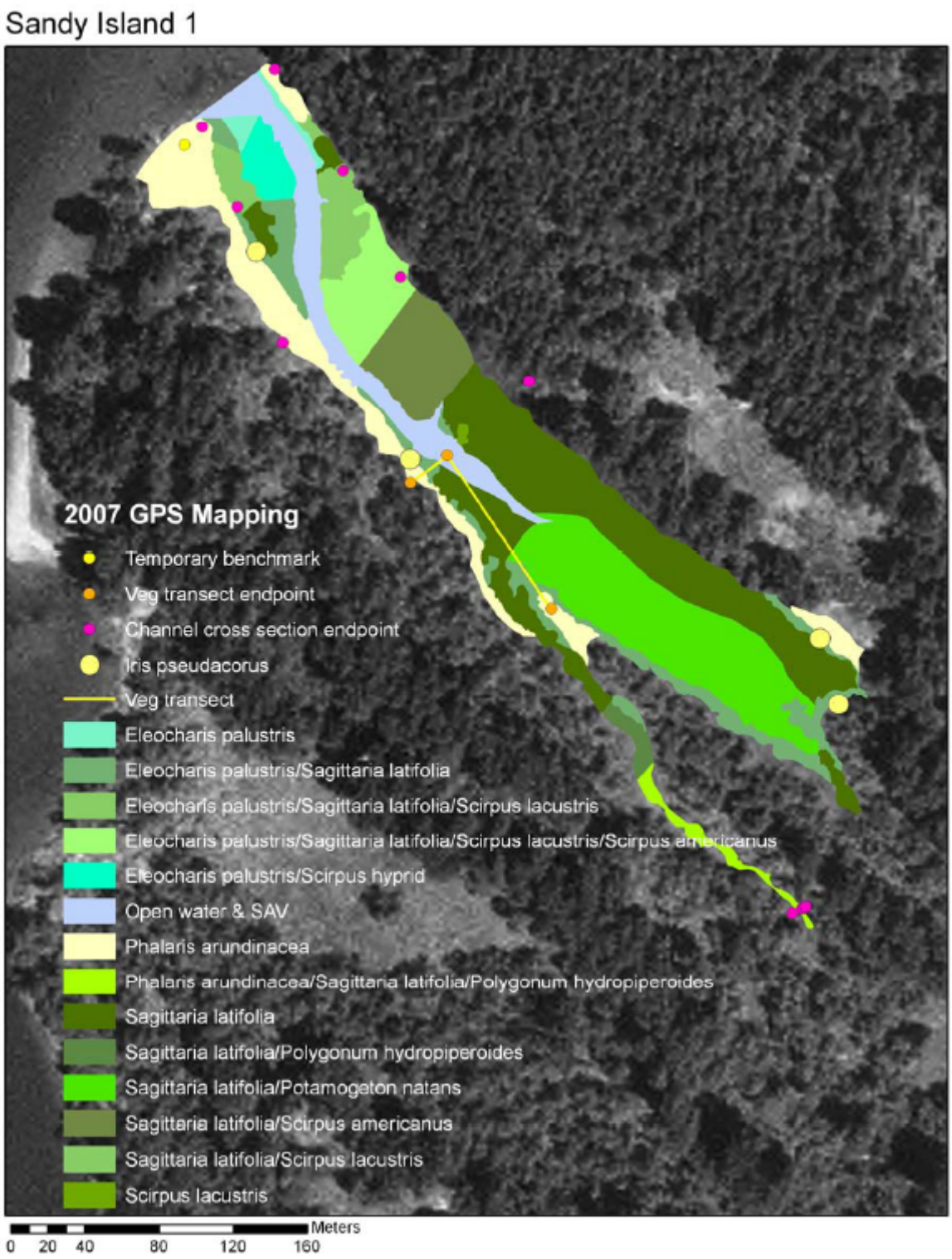


Figure 16: Vegetation distributions at Sandy Island #1, 2007.

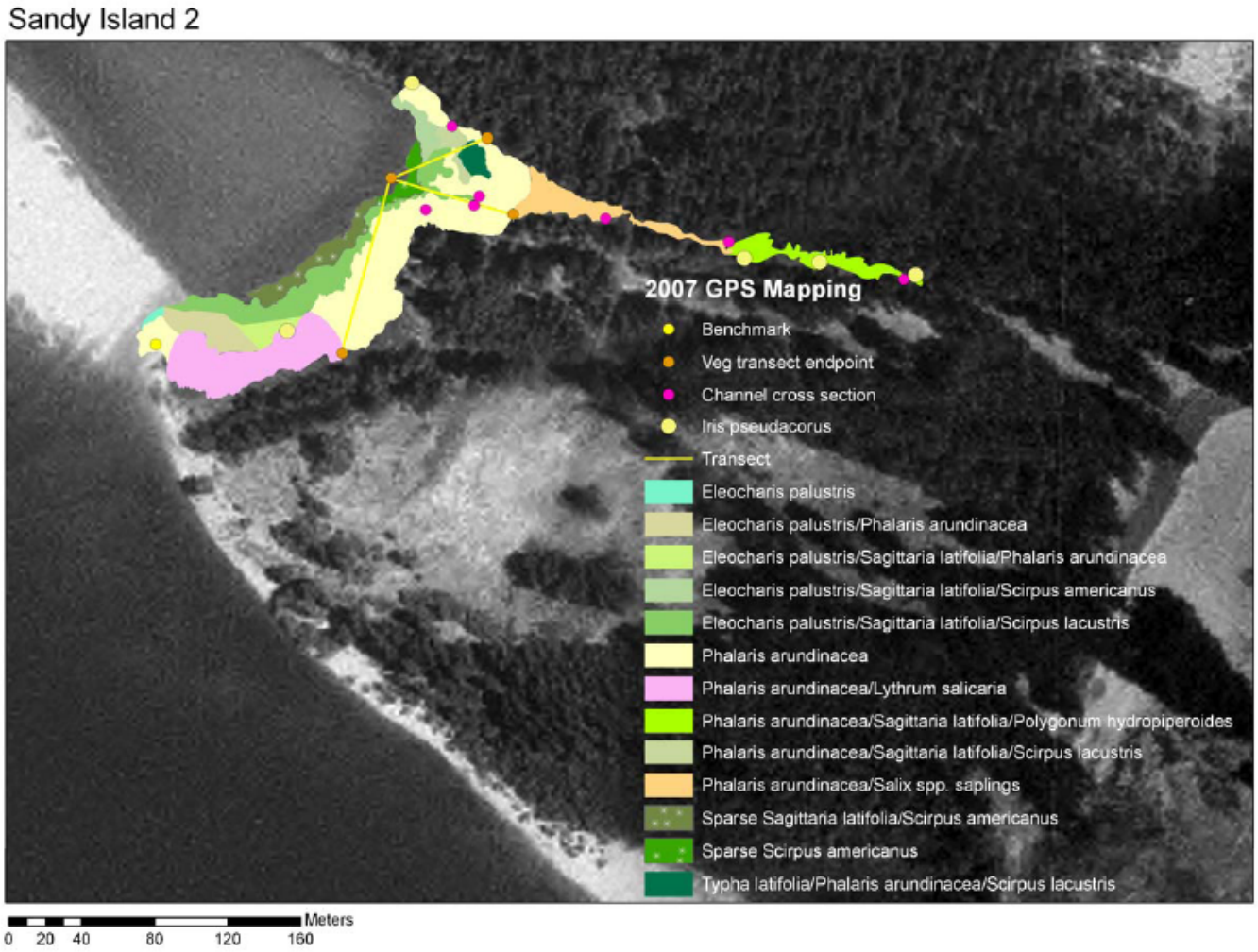


Figure 17: Vegetation distributions at Sandy Island #2, 2007.

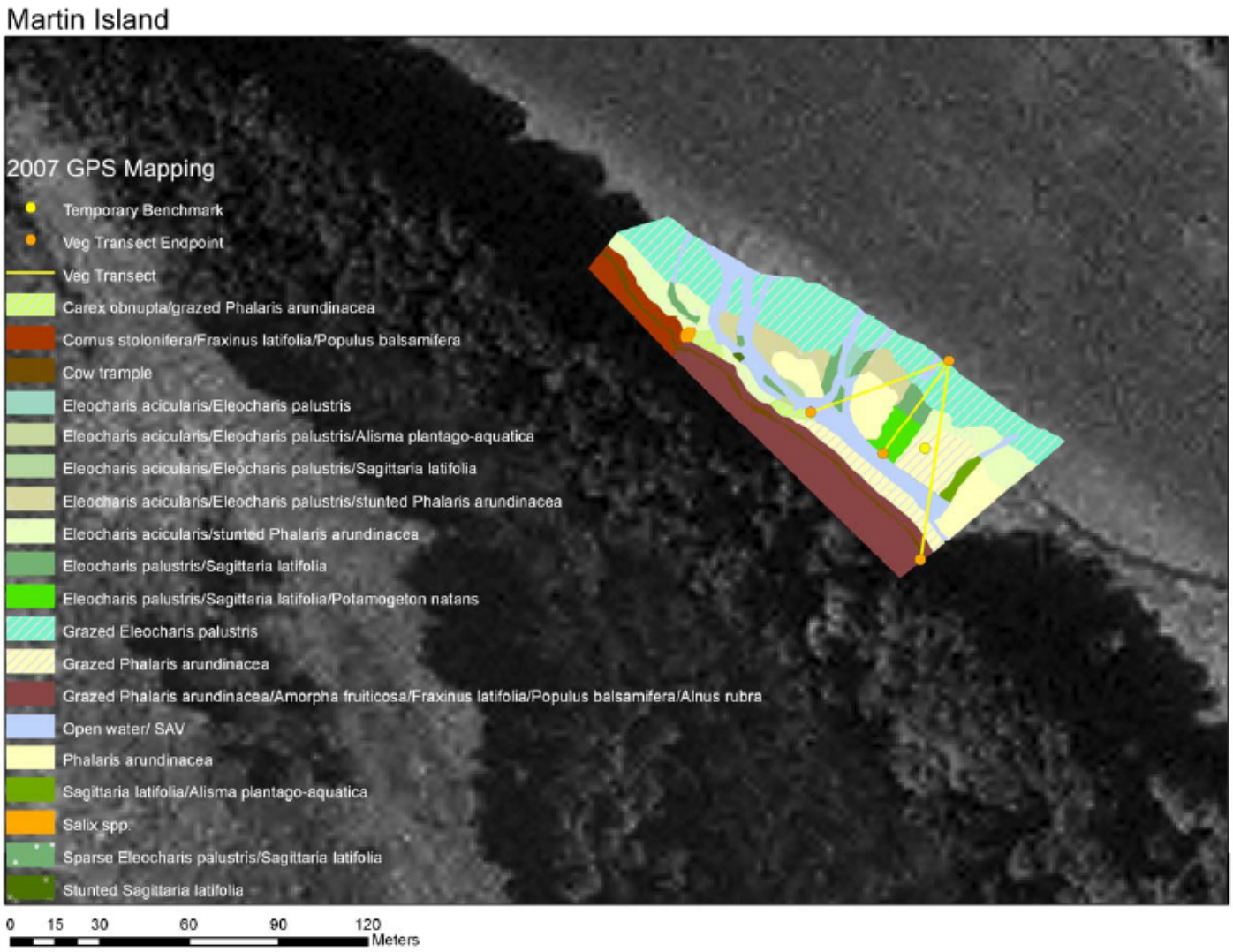


Figure 18: Vegetation distributions at Martin Island, 2007.

Table 2: Plant species list by site with species code, 2007. Invasive species are highlighted.

Species (Scientific Name)	Species (Common Name)	Code	Dredge Spoil Island	Martin Island	Sandy Island #1	Sandy Island #2	Campbell Slough	Cunningham Island
Alisma plantago-aquatica	broadleaf water plantain	ALPL		X	X			X
Amorpha fruticosa	indigo bush	AMFR		X				
Callitriche heterophylla	water starwart	CAHE			X		X	X
Carex obnupta	slough sedge	CAOB	X	X				
Caerx sp.	sedge	CASP	X					
Ceratophyllum demersum	coontail	CEDE		X				
Cornus stolonifera	red-osier dogwood	COST	X	X		X		
Elecocharis acicularis	needle spikerush	ELAC		X				
Elodea canadensis	common waterweed	ELCA		X	X			
Eleocharis palustris	creeping spikerush	ELPA	X	X	X	X	X	X
Epilobium ciliatum	hairy willowherb	EPCI	X					
Equisetum fluviatile	water horsetail	EQFL			X			X
Equisetum sp.	horsetail	EQSP	X	X			X	
Fraxinus latifolia	Oregon ash	FRLA		X				
Galium trifidum	snall bedstraw	GATR		X				
Helenium autumnale	mounatin sneezeweed	HEAU	X	X				
Iris pseudacorus	yellow iris	IRPS		X			X	
Juncus nevadensis	Sierra rush	JUNE		X				
Juncus oxymeris	pointed rush	JUOX	X	X				
Leersia oryzoides	rice cut-grass	LEOR	X		X	X		
Limosella aquatica	water mudwart	LIAQ		X			X	
Lilaeopsis occidentalis	lilaeopsis	LIOC		X				
Lotus corniculatus	birdsfoot trefoil	LOCO	X				X	
Ludwigia palustris	water-purslane	LUPA	X	X	X		X	X
Lycopus americanus	American bugleweed	LYAM		X				
Lysimachia nummularia	Creeping jenny	LYNU					X	
Lythrum salicaria	purple loosestrife	LYSA				X		
Lycopus uniflorus	northern bugleweed	LYUN				X		
Mentha arvensis	field mint	MEAR	X	X				
Mimulus guttatus	common monkeyflower	MIGU		X				
Mimulus lewisii	purple monkeyflower	MILE		X				
Myosotis laxa	small water forget-me-not	MYLA	X	X				
Myriophyllum spicatum	Eurasian water milfoil	MYSP	X	X	X			
Parentucellia viscosa	yellow parentucellia	PAVI		X				
Phalaris arundinacea	reed canary grass	PHAR	X	X	X	X	X	X
Plantago major	common plantain	PLMA		X			X	
Populus balsamifera	black cottonwood	POBA				X		
Potamogeton crispus	curly leaf pondweed	POCR		X	X		X	
Polygonum hydropiperoides	mild waterpepper	POHY	X	X	X			X
Potamogeton natans	floating-leaved pond weed	PONA		X	X			
Polygonum persicaria	ladysthumb	POPE					X	X
Ranunculus repens	creeping buttercup	RARE		X			X	
Rorripa calycina	persistent-sepal yellow cress	ROCA		X				
Rubus discolor	Himalyan blackberry	RUDI		X				
Rumex spp.	dock	RUSP		X			X	
Rubus ursinus	trailing blackberry	RUUR		X				
Sagittaria latifolia	wapato	SALA		X	X	X	X	X
Salix spp.	willow	SASP	X		X	X	X	X
Scirpus americanus	three-square bulrush	SCAM				X		
Scirpus atrocinctus	wooly sedge	SCAT	X					
Scirpus lacustris	tule	SCLA	X		X	X		X
Scirpus triqueter	threesquare tule	SCTR			X	X		
Solanum dulcamara	bittersweet nightshade	SODU				X		
Sparganium emersum	narrowleaf burreed	SPEM			X			X
Trifolium sp.	clover	TRSP		X				
Typha anugustifolia	narrowleaf cattail	TYAN				X		
Veronica americana	American brooklime	VEAM	X	X	X		X	

Table 3: Plant species lists for Campbell Slough and Cunningham Lake over three sampling years, 2005-2007. Invasive species are highlighted.

Species (Scientific Name)	Species (Common Name)	Code	Campell Slough			Cunningham Island		
			2005	2006	2007	2005	2006	2007
Alisma plantago-aquatica	broadleaf water plantain	ALPL				X		X
Amorpha fruticosa	indigo bush	AMFR		X				
Callitriche heterophylla	water starwart	CAHE		X	X	X	X	X
Elodea canadensis	common waterweed	ELCA		X				
Eleocharis palustris	creeping spikerush	ELPA	X	X	X	X	X	X
Eleocharis parvula	small spikerush	ELPAR				X		
Equisetum fluviatile	water horsetail	EQFL	X	X		X	X	X
Equisetum sp.	horsetail	EQSP			X			
Fraxinus latifolia	Oregon ash	FRLA		X				
Iris pseudacorus	yellow iris	IRPS			X		X	
Juncus acuminatus	tapertip rush	JUAC	X			X		
Limosella aquatica	water mudwart	LIAQ			X			
Lotus corniculatus	birdsfoot trefoil	LOCO			X			
Ludwigia palustris	water-purslane	LUPA			X			X
Lysimachia nummularia	Creeping jenny	LYNU	X	X	X			
Mentha arvensis	field mint	MEAR		X				
Myriophyllum spicatum	Eurasian water milfoil	MYSP		X				
Phalaris arundinacea	reed canary grass	PHAR	X	X	X	X	X	X
Plantago major	common plantain	PLMA			X			
Potamogeton amphibium	water ladysthumb	POAM		X		X		
Populus balsamifera	black cottonwood	POBA		X				
Potamogeton crispus	curly leaf pondweed	POCR			X			
Polygonum hydropiperoides	mild waterpepper	POHY				X	X	X
Potamogeton natans	floating-leaved pond weed	PONA	X			X	X	
Polygonum persicaria	ladysthumb	POPE			X			X
Ranunculus repens	creeping buttercup	RARE			X			
Rumex spp.	dock	RUSP			X			
Sagittaria latifolia	wapato	SALA	X	X	X	X	X	X
Salix lucida var. lasiandra	Pacific willow	SALU	X			X		
Salix spp.	willow	SASP		X	X		X	X
Scirpus lacustris	tule	SCLA				X		X
Sparganium emersum	narrowleaf burreed	SPEM				X	X	X
Veronica americana	American brooklime	VEAM	X		X	X	X	

Findings of PNNL Habitat Surveys and Analysis

Results from vegetation surveys show that general patterns of wetland vegetation are consistent with downstream sites previously sampled during summer 2005 and 2006. By developing an understanding of inter-annual variability at each site, an effective long-term monitoring program can be established. The variability in vegetation boundaries observed from one year to the next, despite the slight difference in sampling timing between the two years, suggests that increasing the number of sampling periods may be necessary to fully capture the vegetation communities at these sites. Ephemeral plants are likely over- or under-represented, depending upon the survey season. Thus, a better understanding of seasonal differences should be a goal of future habitat monitoring efforts. Such efforts will also be critical for drawing linkages between vegetation and habitat structure as they relate to salmonid use of wetland habitats.

Summary of Water Quality Monitoring Activities in Year 3b

Toxics monitoring in Year 3b centered on report writing and continued research of salmonid contaminant uptake and prey sources and water quality, involving the following nine elements:

1) Examination of patterns of habitat use by juvenile salmonids and prey availability;
2) Assessment of salmon stomach contents to identify type and origin of prey (terrestrial or aquatic) and determine whether diet is a source of contaminant exposure;
3) Analysis of salmon otoliths to determine effects of contaminants on growth;
4) Biochemical analysis of salmon samples for lipids, enzymes, and hormones to determine impacts of contaminants on juvenile salmon growth and metabolism;
5) Chemical analysis of river sediments, whole body Chinook salmon, and whole body threespine sticklebacks (*Gasterosteus aculeatus*) for contaminants;
6) Test of new liquid chromatography and mass spectroscopy methods to measure wastewater and estrogenic compounds in juvenile salmon bile and plasma samples;
7) Yearling Chinook salmon (*Onchorhynchus tshawytscha*) sampling in Lower Columbia Estuary;
8) Compilation of water quality and salmonid monitoring report (Estuary Partnership, NOAA, USGS WRD);
9) Compilation of all data and production of USGS Scientific Investigations Report (USGS WRD).

Work on all elements was completed by NOAA, expect for element 8, which was completed by the Estuary Partnership, NOAA, and USGS WRD, and element 9, which was completed by USGS WRD.

NOAA Salmon Sampling and Analyses

The following section describes accomplishments in work elements 1-7 listed above. The overall objectives of these work elements are to:

- Examine temporal and spatial trends of persistent organic pollutants in out-migrant juvenile Chinook salmon in the lower Columbia River
- Evaluate potential adverse effects of contaminants on salmon and estuarine food webs
- Explore potential sources of contamination (hatchery feed, sediments, water column, and prey) for juvenile salmon
- Assess the influence of stock origins on contaminant accumulation and exposure risk

Reconnaissance of Habitat Use and Prey Availability

In spring and summer of 2007, we conducted a reconnaissance survey to monitor habitat use by juvenile Chinook salmon and prey availability at two tidal freshwater sites (Campbell Slough near Ridgefield National Wildlife Refuge in Reach F and Sandy Island in Reach E) (Figure 19, Table 4). Our objectives were to test sampling techniques and collect preliminary information on fish habitat use in relation to physical habitat characteristics, availability of prey organisms, and levels of toxic contaminants. Battelle PNNL conducted vegetation characterization surveys at these same sites.

From May to July 2007, we did biweekly sampling of stream-type Chinook salmon using a beach seine. Fishing was conducted at two sites on Sandy Island. Sandy Island #1 was the routine sampling site while Sandy Island #2 was sampled as an alternative fishing site when Sandy Island #1 was at low tide.

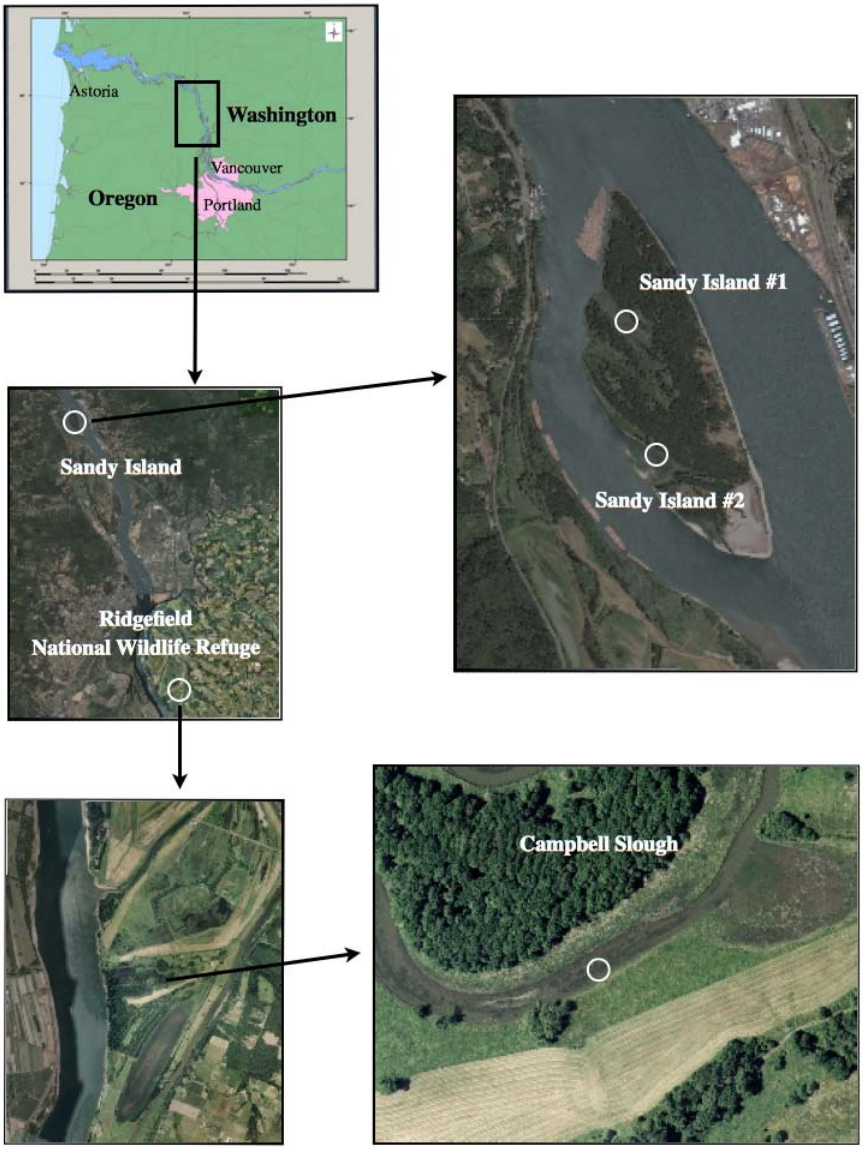


Figure 19: Locations of 2007 salmon sampling sites in Lower Columbia River and estuary.

Table 4: Coordinates for salmon sampling sites, 2007.

Site Description	Latitude	Longitude
Ridge Field NWR (Campbell Slough)	45°47.058’	122°45.259’
Sandy Island #1	46°0.544’	122°52.065’
Sandy Island #2	46°0.030’	122°51.517’

At each sampling point, we recorded species richness, abundance, catch-per-unit-effort (CPUE) for all species, water temperature, and tide condition. We also examined salmonids for fin clips and coded wire tags (CWTs) in order to determine proportions of marked (known hatchery origin) vs. unmarked (potentially wild) salmon. We measured and weighed subsets of juvenile Chinook salmon and collected: bile for measurement of metabolites of aromatic hydrocarbons; stomach contents for measurement of aromatic hydrocarbons and other persistent organic pollutants (POPs), including DDTs, PCBs, various organochlorine pesticides, and PBDEs; blood for measurement

of vitellogenin, an indicator of exposure to environmental estrogens; whole bodies for measurement of bioaccumulative POPs; fin clips for genetic stock identification; and otoliths for aging and growth rate determination. Numbers of samples collected from each site are shown in Table 5. Whole body samples were wrapped individually in aluminum foil and stored at -80ºC.

Table 5: Numbers of samples by type collected from juvenile salmon in the Lower Columbia Estuary, 2007.

Site	# of fish	Blood	Otolith	Bile (Comp)	Stomach Chemistry (Comp)	Stomach Taxonomy (Comp)	Whole body Chemistry	Genetics
Ridgefield NWR (Campbell Slough)	92	51	78	4	3	2	88	79
Sandy Island #1	102	15	60	2	3	1	89	60
Sandy Island #2	22						22	

Habitat Use of Juvenile Chinook Salmon and Other Species

2007 sampling results showed that juvenile salmon and other juvenile fish species were feeding and rearing at Campbell Slough and Sandy Island (Table 6). Juvenile Chinook were captured at all three sites, with the percentage of catch ranging from 4% at Campbell Slough to 12.5% at the Sandy Island #2 site. The most abundant non-salmonid species were threespine stickleback (*Gasterosteus aculeatus*), yellow perch (*Perca flavescens)*, and goldfish (*Carassius auratus)*. Stickleback and goldfish were the predominant species at the Campbell Slough site. While sticklebacks were abundant during all sampling periods, juvenile goldfish were at found only in June. Threespine sticklebacks also comprised a large percentage of the fish capture at the Sandy Island #1 site. At the Sandy Island #2 site, however, yellow perch was the predominant species. Other species of significance were banded killifish (*Fundulus diaphanous*) and yellow perch (*Perca flavescens*) at Campbell Slough, banded killifish and largescale sucker (*Catostomus snyderi)* at Sandy Island #1, and banded killifish at Sandy Island #2. Overall, Campbell Slough had the greatest total number of species captured (19), with 16 species captured at Sandy Island #1, and 8 species at Sandy Island #2.

Table 6: Fish species captured and percent of each species at sampling sites, 2007.

	Percent of Catch		
Species	**Campbell Slough**	**Sandy Island #1**	**Sandy Island #2**
Chinook	4.07	8.78	12.5
chum salmon	0.00	0.42	0
coho	0.03	0	0
threespine stickleback	36.23	66.10	0
yellow perch	4.49	1.08	76.3
Crappie, sp.	0.66	0.25	1.88
banded killifish	5.90	12.46	4.38
largescale sucker	0.10	3.26	0.63
peamouth	0.41	5.66	0.63
Northern pikeminnow	1.38	0.42	0
sculpin, sp.	0.59	0.40	2.5
common carp	0.24	0.28	0
starry flounder	0.00	0.31	1.25
smallmouth bass	1.52	0.03	0
goldfish, sp.	42.24	0.03	0
American shad	0.59	0.17	0
pumpkinseed	0.66	0	0
largemouth bass	0.31	0	0
bullhead, yellow	0.10	0	0
bluegill	0.31	0	0
chiselmouth	0.17	0.34	0
Total species caught	19	16	8

The majority (96.55%) of juvenile salmonids captured at all sites were Chinooks (99.16%, 95.1% and 100% at Campbell Slough, Sandy Island #1 and Sandy Island #2, respectively) (Figure 20). Chum salmon (*O. keta*) were found only at Sandy Island #1, and represented 3.23% of the salmon captured at all sites combined. Only one coho salmon (*O. kisutch*) was captured (at Campbell Slough) during the May – July sampling time, and represented only 0.22% of all salmon captured. The CPUE of Chinook salmon was generally greater at the Sandy Island sites than at Campbell Slough (Ridgefield).

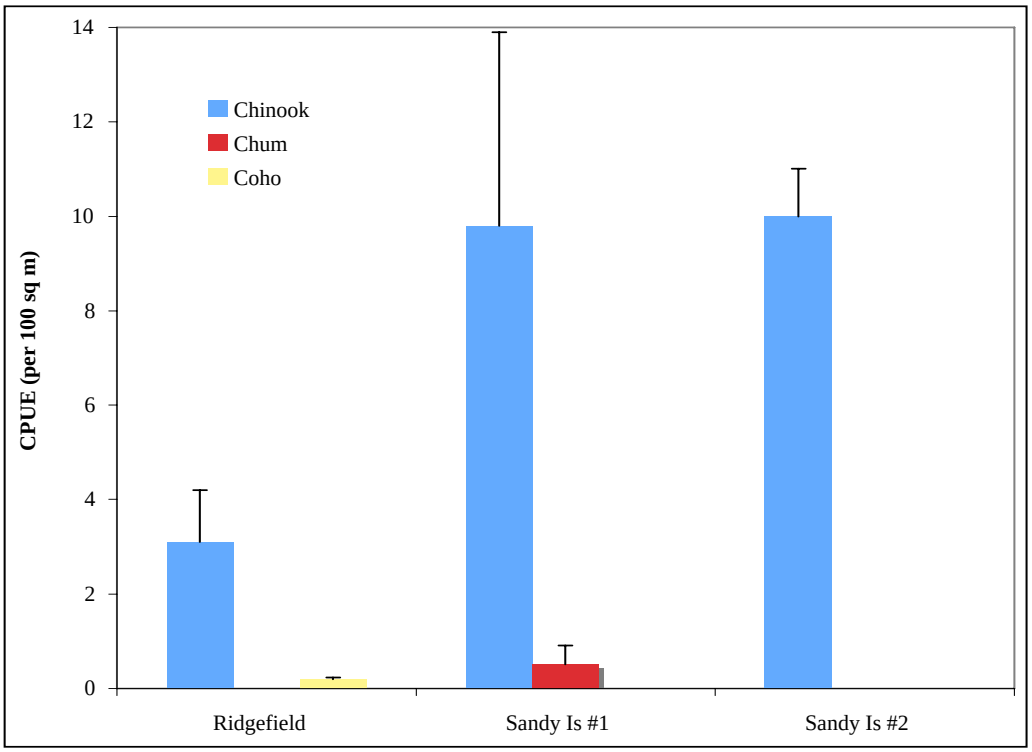


Figure 20: Total catch per unit effort (CPUE) of all salmonids (error bars show ± standard error), 2007.

Presumably wild (unmarked) and hatchery (marked) fish were found at both sites (Table 7). Marked hatchery fish made up ~52% of the catch at Campbell Slough and ~37% at Sandy Island #1. No marked fish were found at the Sandy Island #2 site. Hatchery fish were generally larger than the wild fish (Table 7). Their mean length ranged from 83.5 to 87 mm and weight from 6.8 to 7.6 g. In comparison, the mean length of unmarked fish ranged from 58.3 to 75.5 mm and weight from 2.5 to 5.1 g. The unmarked fish tended to be larger at Campbell Slough than at the Sandy Island sites.

Table 7: Mean length and weight (± standard deviation) of unmarked (presumably wild) vs. marked (hatchery) subyearling juvenile Chinook salmon collected in the Lower Columbia River and estuary, 2007.

Site	Mark	Proportion of catch	Length (mm)	Weight (g)
Campbell Slough	unmarked	48.2%	75.7±8.3 (n = 54)	5.1±1.8 (n = 54)
	marked	51.8%	83.5±9.1 (n = 58)	6.8±2.1 (n = 58)
Sandy Island #1	unmarked	62.5%	59.3±9.2 (n = 45)	2.5±1.3 (n = 58)
	marked	37.5%	87.0±7.0 (n = 27)	7.6±1.4 (n = 44)
Sandy Island #2	unmarked	100%	58.3±9.7 (n = 22)	2.7±1.3 (n = 22)

The average length of juvenile Chinook was greatest in the early May sampling at both Campbell Slough and Sandy Island (Table 8), probably because of a high proportion of hatchery fish captured during this sampling period. This finding reflects the general trend for larger hatchery fish to predominate early in the season after hatchery release, and then quickly migrate towards salt water, leaving smaller wild fish that spend a longer time rearing in the estuary (Fresh et al., 2005; Bottom et al., 2005). Over the remaining sampling season, salmon size remained fairly stable at Campbell Slough and increased slightly at Sandy Island, though no significant differences in mean length and weight were observed. Relative proportions of marked (hatchery) or non-marked fish (wild) at each sampling may have influenced fish size, with newly released hatchery fish masking seasonal growth by wild fish. Alternatively, fish may migrate out of these tidal freshwater sites once they reach a certain size, so size increases would not be apparent.

Table 8: Length and weight (± standard deviation) and number of juvenile salmon by site and date, 2007.

Site	Date	Length (mm)	Weight (g)	Number
Campbell Slough	5/4/07	84.4±6.9	6.9±1.6	34
	6/1/07	75.1±12.8	5.3±2.8	20
	6/13/07	75.7±7.0	5.1±1.5	38
	Total	78.8±9.5	5.8±2.1	92
Sandy Island #1	5/3/07	87.2±7.0	7.7±1.4	45 vs. 22
	5/31/07	53.3±7.9	1.8±1.0	27
	6/14/07	63.6±4.4	2.87±0.6	30
	Total	71.3±16.1	4.7±2.9	102
Sandy Island #2	5/31/07	58.3±9.7	2.7±1.3	22

The number of fish species and number of all fish caught per unit effort (CPUE) increased from May to June, but then declined in July (Figure 21, Figure 22). Juvenile salmon showed a similar trend, being most abundant in May and June and then virtually absent by July (Figure 23). An especially high number of juvenile salmon were caught at the Sandy Island #1 site in early May, which is perhaps correlated with a release of hatchery fish. The decrease in CPUE for both salmonid and non-salmonid fishes in July may have been influenced by water temperature, which approached 20^{o}C at both sites that month (Figure 24).

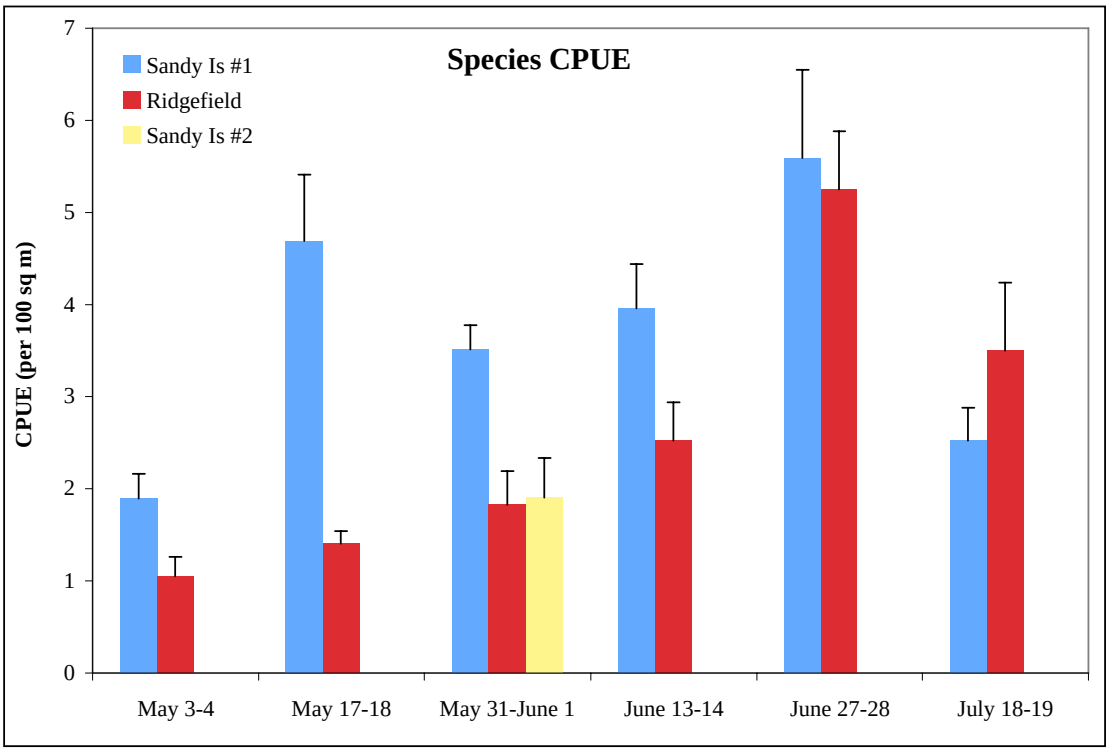


Figure 21: The number of species captured per unit effort (CPUE), by site and date (errors bars show ± standard error), 2007.

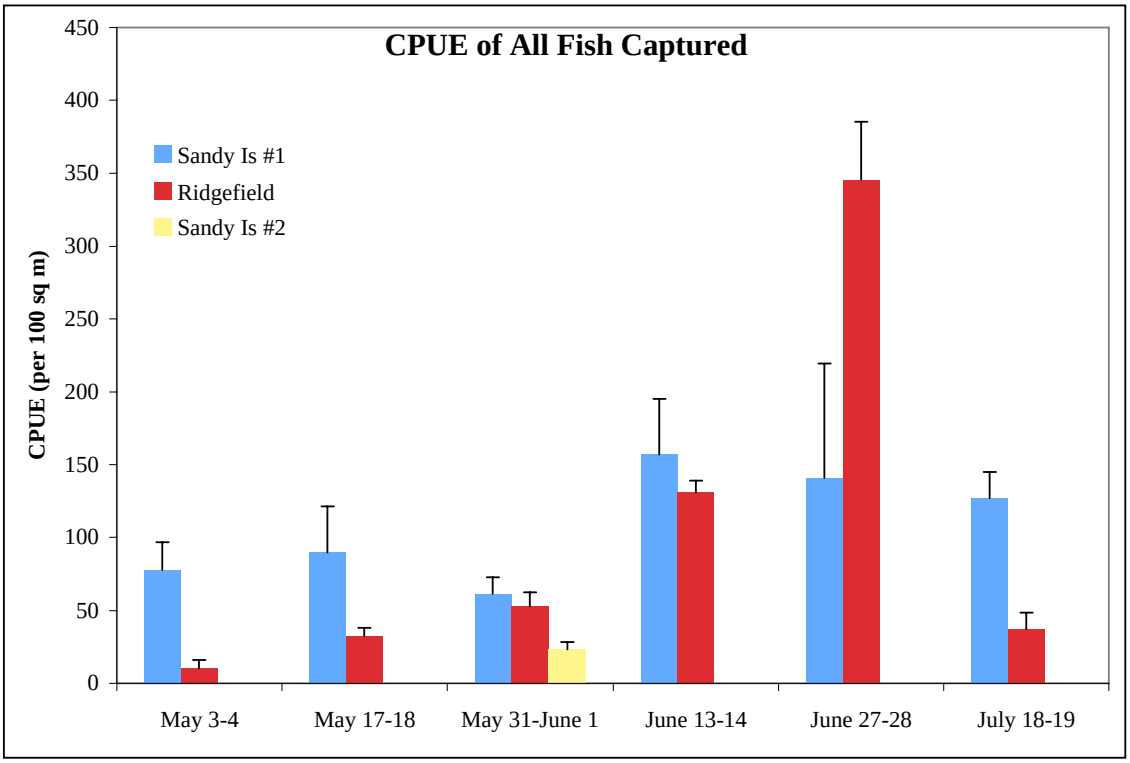


Figure 22: The number of fish of all species captured per unit effort (CPUE), by site and date (error bars show ± standard error), 2007.

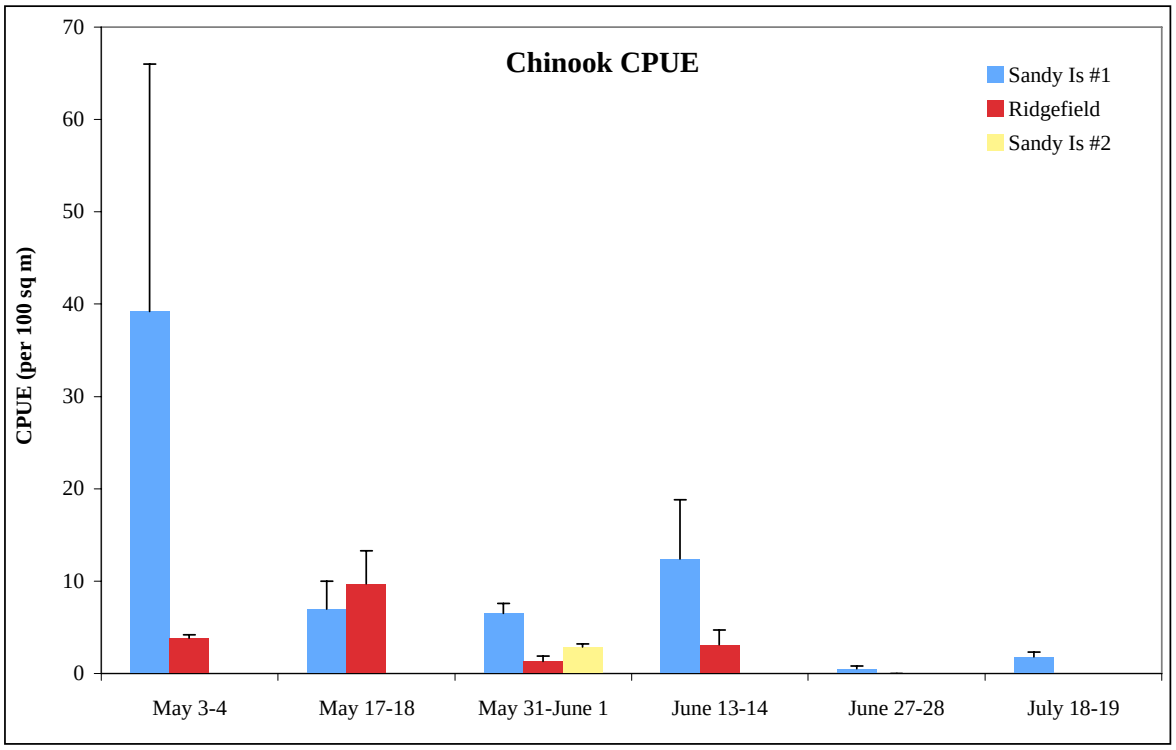


Figure 23: Number of Chinook salmon captured per unit effort (CPUE) by site and date (error bars show ± standard error), 2007.

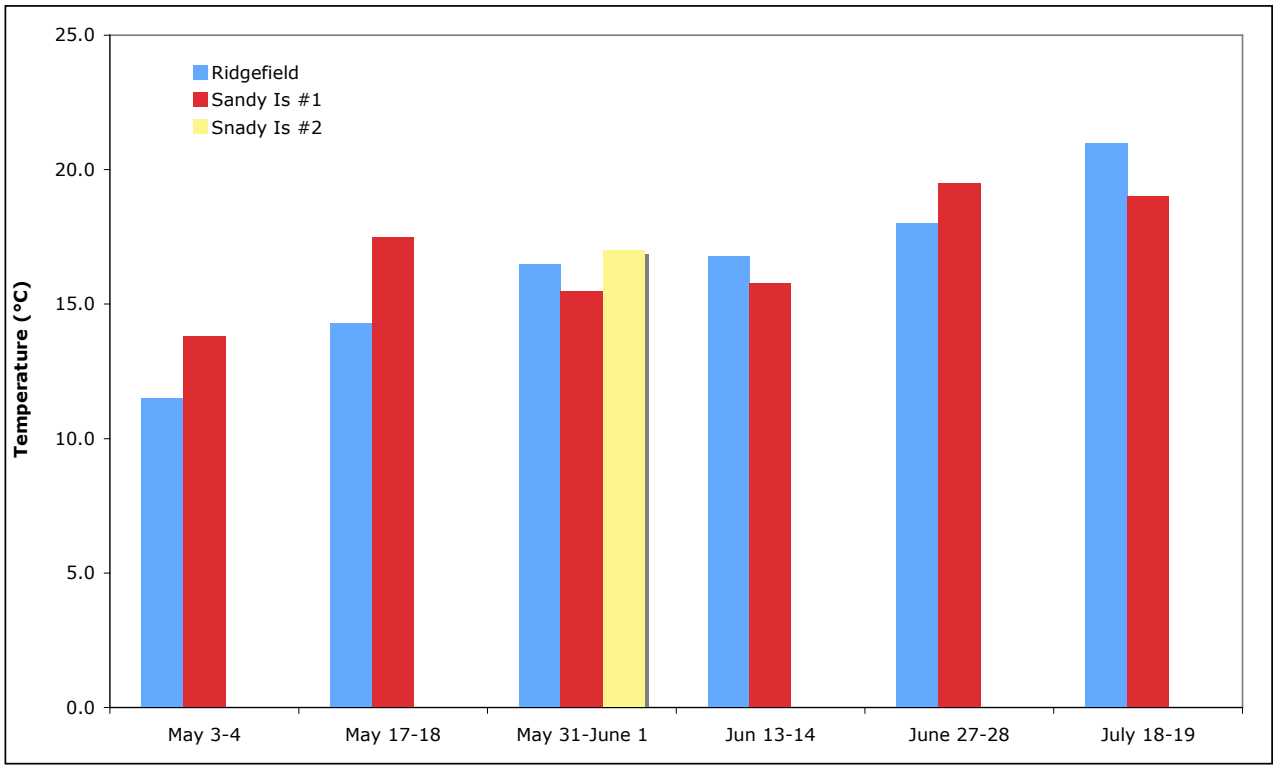


Figure 24: Bi-monthly water temperatures measured at salmon sampling sites, 2007.

In summary, this pilot study showed that wild juvenile salmon, especially juvenile Chinook, are feeding and rearing at two representative tidal freshwater sites in the lower Columbia River from early May through July. The sites also appear to function as nursery areas for other fish species. Warm water temperature may be limiting use of these sites later in the season, although there may be other contributing factors.

Prey Availability

In addition to fish sampling at Campbell Slough and Sandy Island, we also surveyed aquatic and terrestrial habitats to identify the major prey species available to juvenile salmon during their rearing and migration. We used insect sweep nets to collect invertebrates in riparian vegetation adjacent to reaches where fish were collected, and, towed Neuston nets by boat or by hand to collect aquatic invertebrates in the water column. Invertebrates were collected between 3 May and 13 June 2007 at Campbell Slough (3 sampling dates) and Sandy Island (2 sampling dates). Prey samples were sorted and composited by taxon for chemical analysis to determine levels and types of contaminants in different food sources. Stomach contents of juvenile Chinook salmon were also collected for taxonomic analysis to determine which invertebrate species are actually consumed (described below).

Very low numbers of both terrestrial and aquatic prey were collected at Sandy Island, with the exception of an abundance of aquatic beetles (Coleoptera) on May 31 (Table 9). Prey abundance and diversity were greater at Campbell Slough, where caddisfly larvae (Trichoptera), hoppers (Homoptera), damselfly larvae and adults (Odonata), and terrestrial flies (Diptera) were abundant. Contaminant analysis of samples is scheduled for 2007-2008 with NOAA funding.

Table 9: Prey taxa collected at Campbell Slough and Sandy Island, 2007.

Sampling site	Major Prey Taxa Collected
Campbell Slough	Caddisfly (Trichoptera); Hoppers (Homoptera); Damselfly (Odonata); Terrestrial Diptera
Sandy Island	Aquatic beetles (Coleoptera)

Assessment of Salmon Prey and Associated Contaminants

In 2005 (Year 2 of this project), we collected juvenile Chinook stomach samples from sites at Warrendale, Columbia City, Morrison Street Bridge, Willamette/Columbia confluence, Beaver Army Terminal, Point Adams, and West Sand Island (Figure 25). In Year 3b, we assessed the taxonomy of prey in these stomach samples to identify prey types. We also analyzed samples for contaminants. This information will be used to investigate if contaminants are derived from terrestrial vs. aquatic sources and the relationship between contaminant uptake and prey type.

Figure 25: Locations of juvenile Chinook salmon sampling sites for contaminants study, 2005.

Taxonomy of Stomach Contents

Diets of juvenile Chinook salmon are being analyzed to better understand potential sources of contaminants affecting fish in the Lower Columbia River and estuary. We expect that differences in sources and composition of prey consumed by juvenile Chinook salmon may help explain variation in contaminant concentrations found in fish tissue and bile. Thus, we identified major prey species in stomach contents of juvenile salmon (collected in 2005). Dominant prey items in Chinook stomachs were identified and counted, and are currently being calculated by number and weight using statistics describing the prey's origins (terrestrial or aquatic) and life histories (e.g. short generation time, larval stage associated with fine sediments or the water column).

Preliminary analyses indicate that juveniles feed on a variety of prey, including aquatic and terrestrial insects and other invertebrates. Aquatic diptera, primarily midges of the family Chironomidae, were abundant in many samples. Due to their small size, however, their contribution to prey biomass was often relatively low compared to terrestrial insects and other aquatic invertebrates. Variation in prey items between months at the same sites indicates there may be as much temporal variation as there is spatial variation in resources. These taxonomic and life history data compliment analyses of contaminants in fish (stomachs, tissue and bile) and in the environment (water and sediment) collected concurrently. Linking specific contaminants or concentrations of contaminants to prey resources may be difficult because of variation in diets observed thus far and opportunistic feeding behavior of salmon. Future studies should collect a diverse range of potential prey items as well as site- and time- specific stomach content samples to identify potential sources of contaminants in specific prey types.

Table 10

Table 10 lists taxa in order of biomass. The first listed taxon makes up the majority of biomass of the sample; the next listed taxa are contribute(s) significantly to biomass of the sample. Since each sample is a composite of

stomach contents from ~10-15 fish per site, analyses reflect general feeding behavior at that site and time but do not reflect individual fish feeding behavior.

Preliminary analyses indicate that juveniles feed on a variety of prey, including aquatic and terrestrial insects and other invertebrates. Aquatic diptera, primarily midges of the family Chironomidae, were abundant in many samples. Due to their small size, however, their contribution to prey biomass was often relatively low compared to terrestrial insects and other aquatic invertebrates. Variation in prey items between months at the same sites indicates there may be as much temporal variation as there is spatial variation in resources. These taxonomic and life history data compliment analyses of contaminants in fish (stomachs, tissue and bile) and in the environment (water and sediment) collected concurrently. Linking specific contaminants or concentrations of contaminants to prey resources may be difficult because of variation in diets observed thus far and opportunistic feeding behavior of salmon. Future studies should collect a diverse range of potential prey items as well as site- and time- specific stomach content samples to identify potential sources of contaminants in specific prey types.

Table 10: Qualitative summary of taxa in Chinook salmon stomachs, 2005.

Sampling site	May	June
Warrendale	Psocoptera; Aquatic Diptera (Chironomidae)	Aquatic Diptera (Chironomidae)
Portland Harbor 1	Aquatic Diptera (Chironomidae); Homoptera	
Portland Harbor 2	Cladocera (Daphnia); Homoptera & Aquatic Diptera	
Morrison St. Bridge	Aquatic Diptera (Chironomidae); Psocoptera	Hymenoptera (ants)
Confluence	Cladocera (Daphnia); Homoptera & Aquatic Diptera	Aquatic Diptera (Chironomidae); Odonata
Columbia City	Odonata (damselflies); Isopoda	Aquatic Diptera (Chironomidae); Isopoda
Beaver Army Terminal	Cladocera (Daphnia); Homoptera & Aquatic Diptera	Aquatic Diptera (Chironomidae); Isopoda
Point Adams	Amphipoda & Isopoda	Mysidacea; Amphipoda & Aquatic Diptera

Chemistry of Stomach Contents

Stomach contents of juvenile Chinook salmon collected in 2005 (Year 2 of this project) were tested for concentrations of toxic contaminants to determine whether diet is a source of exposure. Most of these analyses were completed in Year 3 of this project, and are presented in Leary et al. (2006). Additional samples were analyzed in Year 3b, and are presented in the "Water Quality and Salmon Sampling Report" (LCREP, 2007).

PCBs, PAHs, DDTs, and PBDEs were detected in stomach content samples from all sites, indicating that prey are a source of contaminant exposure in the lower Columbia River (Figure 26, Figure 27). Levels of PCBs and PAHs were especially high in stomach contents from the lower Willamette River and Willamette-Columbia River Confluence, which are surrounded by urban and industrial activities (Figure 26). Levels of PBDEs were highest at Columbia City and lower Willamette River. DDT concentrations in stomach contents averaged from 13 to 42 ng/g wet weight, with the lowest averages at the Lower Willamette site and the highest at Point Adams. These averages are relatively high compared to measurements in salmon from other Northwest estuaries (Johnson et al., 2007). Concentrations of DDT in stomach contents were highest in fish from the Lower Willamette and Columbia City sites. Both low and high molecular weight PAHs were detected (Figure 27). The highest levels were measured at the lower Willamette, Willamette-Columbia River Confluence, Columbia City, and Beaver Army Terminal sites, with especially high concentrations of total PAHs (>10,000 nanograms per gram [ng/g] wet weight) at Columbia City.

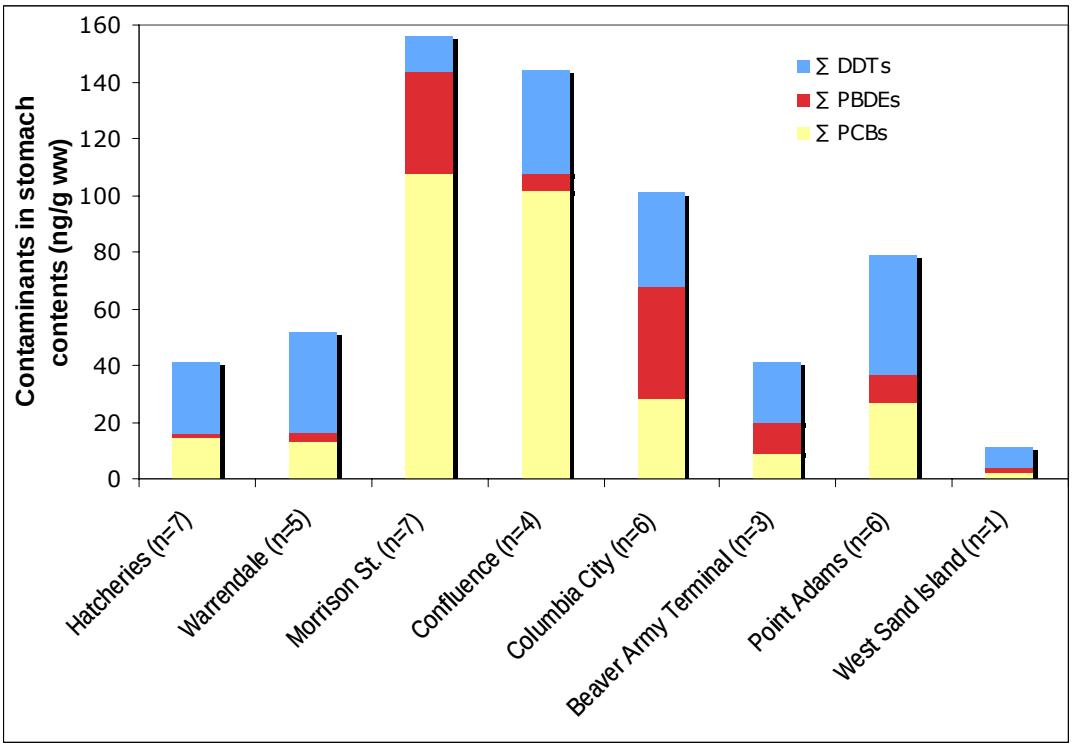


Figure 26: PAH contaminants in stomach contents of juvenile Chinook salmon, 2005. HMW PAHs = high molecular weight PAHs; LMW PAHs = low molecular weight PAHs.

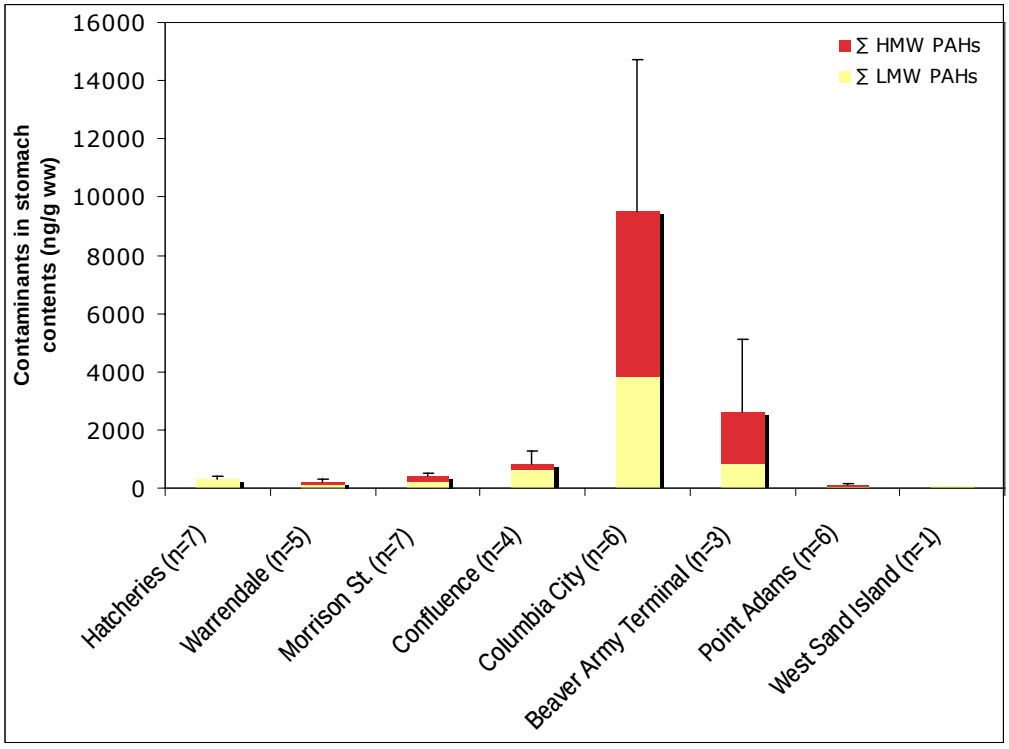


Figure 27: DDT, PBDEs, and PCBs contaminants in stomach contents of juvenile Chinook salmon (error bars show mean + 1 standard deviation), 2005.

PAH levels in samples from Columbia City and Beaver Army Terminal were over 7,000 ng/g wet weight, possibly high enough to be of concern. Similar concentrations have been associated with impaired growth and immune system function in juvenile salmon from contaminated sites in Puget Sound (Arkoosh et al., 1991, Casillas et al., 1995, Arkoosh, 1998; Casillas et al. 1998). In laboratory experiments, juvenile salmon with dietary PAH concentrations comparable to those observed in the lower river showed changes in metabolism, growth, blood chemistry, and fatty acid profiles, which were similar to changes in starving animals (Meador et al., 2006). Although it is not certain that toxic contaminants caused these effects, lipid profiles in salmon from Beaver Army Terminal were akin to those in PAH-exposed laboratory fish.

Contaminant Loads by Chinook Salmon Ecological Significant Units

In Year 3, we began analyses of whole body salmon samples (collected in 2005), focusing on samples assigned to the lower Columbia River Chinook Ecological Significant Unit (ESU). In Year 3b, we expanded analyses to include samples from other stocks. Much of the related data and analyses are presented in the "The Lower Columbia River and estuary Ecosystem Monitoring: Water Quality and Salmon Sampling Report" (henceforth referred to as the "Water Quality and Salmon Sampling Report," LCREP, 2007). After our completion of the 2007 report, the NOAA genetics group revised their ESU Classification system, splitting the lower Columbia River Chinook ESU into the West Cascades and Spring Creek ESUs. Here, we presented updated contaminant results for the revised ESU Classification system.

We mainly collected juvenile salmon from the 2 lower Columbia River stocks, though other salmon stocks were also represented (Figure 28). At the Lower Willamette and Confluence sites, we mainly caught fish from Willamette River stocks. At the Warrendale site, juveniles were predominantly from Middle Columbia, Upper Columbia, and Snake River stocks. Juveniles from upriver stocks (Middle Columbia, Upper Columbia, and Snake River) were collected at nearly every sampling site, demonstrating that these upriver stocks are feeding and rearing in urban, industrialized sites in the tidal freshwater portion of the lower river.

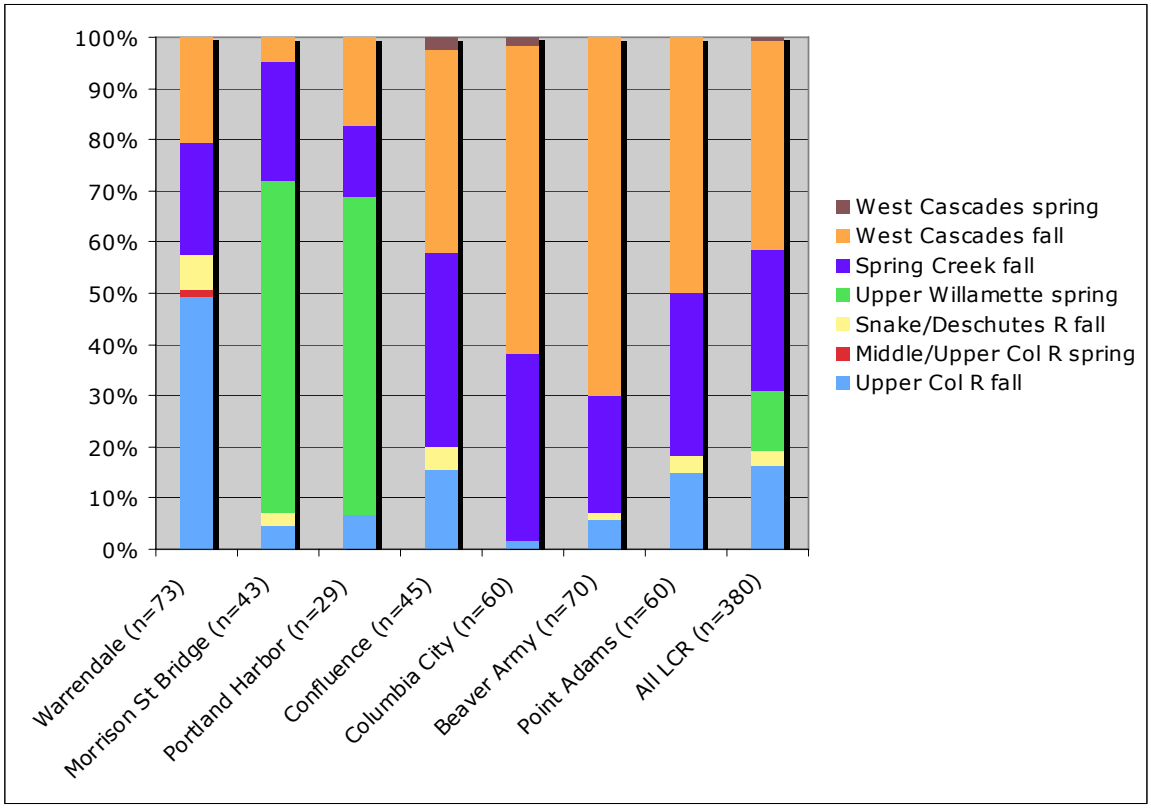


Figure 28: Genetic origin of juvenile Chinook salmon collected in the Lower Columbia River and estuary, 2005.

Among the different salmon stocks, concentrations of PCBs were highest in salmon from the Lower Columbia and Snake River stocks (Figure 29). Snake River salmon do not appear to be bringing these high PCB loads with them from upriver because concentrations in juveniles from Warrendale— where upriver stocks enter the lower Columbia River—were low. This suggests that Snake River stocks are absorbing significant amounts of PCBs as they rear in the tidal freshwater portions of the lower river.

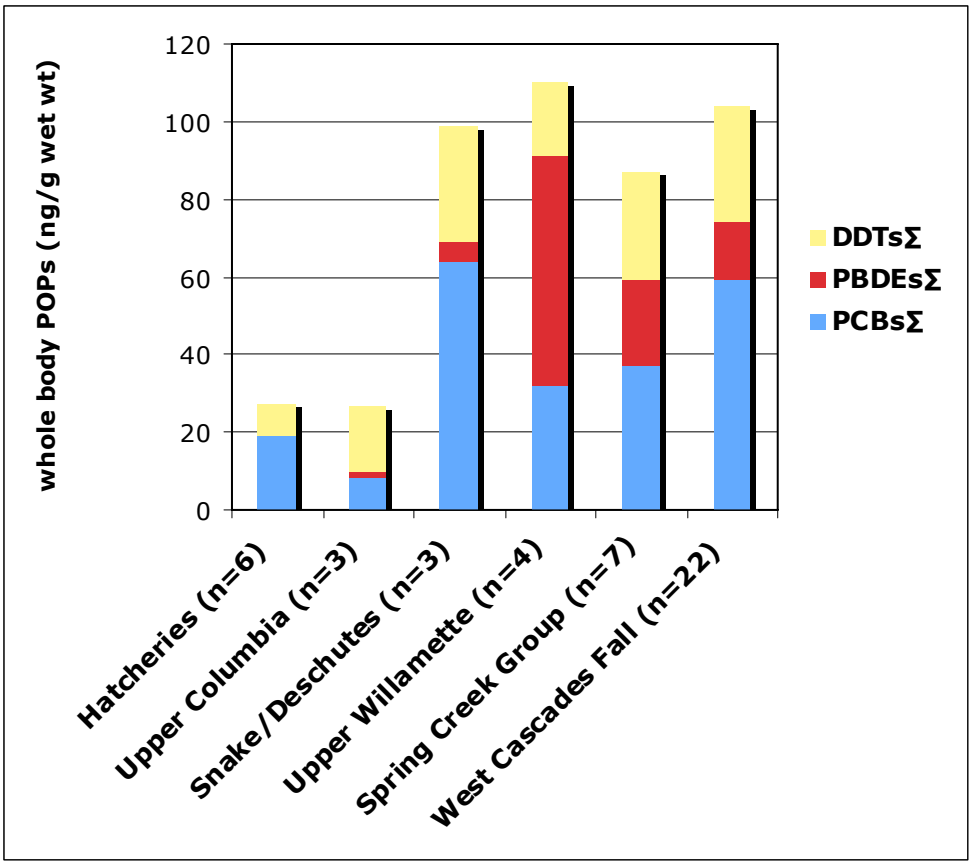


Figure 29: Whole body contaminant burdens (DDT, PBDEs, and PCBs) in juvenile Chinook stocks by ESU genetic grouping, 2005.

The highest PBDE concentrations were observed in Willamette River stocks, indicating the influence of rearing in the urban Portland environment. PBDEs were also high in the Lower Columbia and Middle Columbia stocks. However, PBDE concentrations were relatively low in juveniles at the Warrendale site. These results suggest that Middle Columbia stocks are absorbing much of their PBDE load while rearing in the tidal freshwater areas of the lower river.

Further data on whole body contaminant burdens were described in Year 3's Annual Report (Leary et al., 2006) and the "Water Quality and Salmon Sampling Report" (LCREP, 2007).

Pilot Studies of Indicators of Juvenile Salmon Health

In this section, we describe results of three pilot studies investigating field indicators of juvenile salmon health. These studies examined:

1) Salmon otoliths for growth rate determination;
2) Growth patterns and fish condition (e.g., lipids); and
3) Indicators of salmonid exposure to endocrine-disrupting contaminants

For all three studies, we used juvenile fall Chinook salmon collected in 2005 from sites in the Lower Columbia River and estuary (Warrendale, Columbia City, Morrison Street Bridge, Willamette/Columbia confluence, Beaver Army Terminal, Point Adams, and West Sand Island; Figure 25).

Analysis of Salmon Otoliths and Growth Rates

In 2007, we evaluated otoliths of juvenile fall Chinook salmon to estimate growth rates. These data will help determine if contaminants are affecting the growth of juvenile salmon in the CRE. The average daily fish growth rate (i.e., mm of fish length/day) was determined for three time periods: a) the last 7 days of their life, b) the last 14 days of their life, and c) the last 21 days of their life. Average daily growth (DG, mm/day) was determined using the following Fraser-Lee equation:

$$La = d + \frac{Lc - d}{Oc} Oa$$

$$DG = \frac{Lc - La}{a}$$

where La and Oa represent fish length and otolith radius at a time period (i.e., last 7, 14, or 21 days). Respectively, d is the intercept (30.078) of the regression between fish length and otolith radius while Lc and Oc are the fish length and otolith radius at capture.

Results show that the salmon grew at significantly different rates among certain sites for each of the three time periods (ANOVA, $p < 0.05$). Since results are similar for the three time periods, representative results for the 14 day time period are shown in Figure 30. Growth rates were highest in salmon from the Warrendale and Lower Willamette sites. Of the last 14 and 21 days, fish from Columbia City had significantly lower growth rates than fish from the Lower Willamette site.

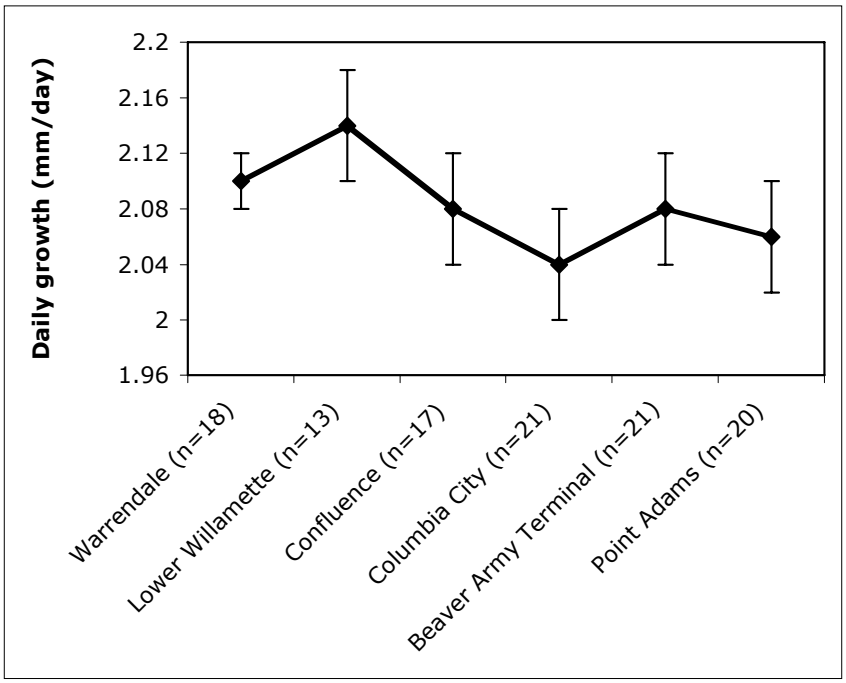


Figure 30: Average daily growth rates of juvenile fall Chinook salmon during the last 14 days prior to collection (error bars show ± standard error). Salmon were collected from seven sites in the Lower Columbia River and estuary, 2005.

Chemical contaminants may contribute to the lower growth rates of the Columbia City fish, as salmon from the Columbia City site have especially high concentrations of PAHs in their prey (LCREP, 2007), and show uptake of contaminants such as PCBs, DDTs, and PBDEs (e.g., Figure 29). Since exposure was also elevated in salmon from other sites (including the Lower Willamette River), other factors are clearly involved, such as prey availability, physical habitat quality, and genetic origin. This preliminary study establishes that otolith analysis can be a valuable tool for assessing salmon growth and health in the river and estuary.

Growth Patterns and Body Fat of Juvenile Salmon

Juvenile Chinook salmon (collected in 2005) were assayed for lipids (body fat) to determine impacts of contaminants on the growth and metabolism of juvenile Chinook salmon.

The largest juvenile salmon were generally found at Point Adams (near the mouth of the Columbia River) (Figure 31, Figure 32). Otherwise, fish length and weight did not differ considerably between sites. However, a clear seasonal pattern in salmon size was observed as fish length and weight tended to increase from April to September (Figure 33, Figure 34). This trend was most marked among juveniles collected at the Beaver Army Terminal site.

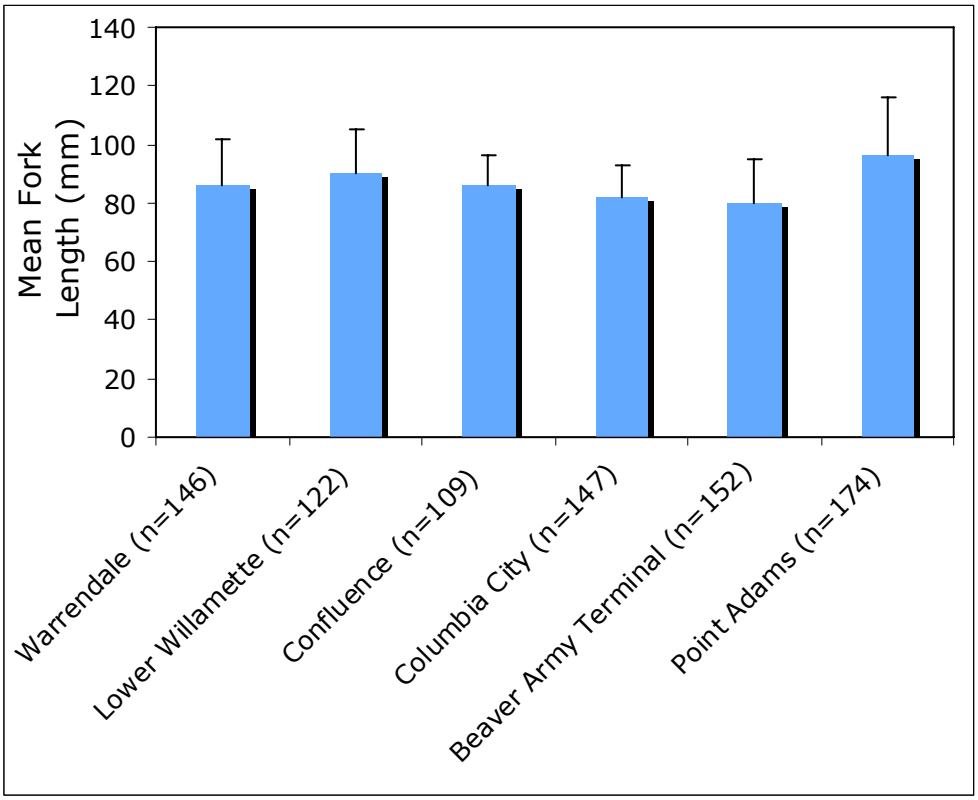


Figure 31: Mean fork length (mm) of juvenile Chinook salmon collected in 2005 (error bars show mean + 1 standard deviation; n = number of individual salmon sampled).

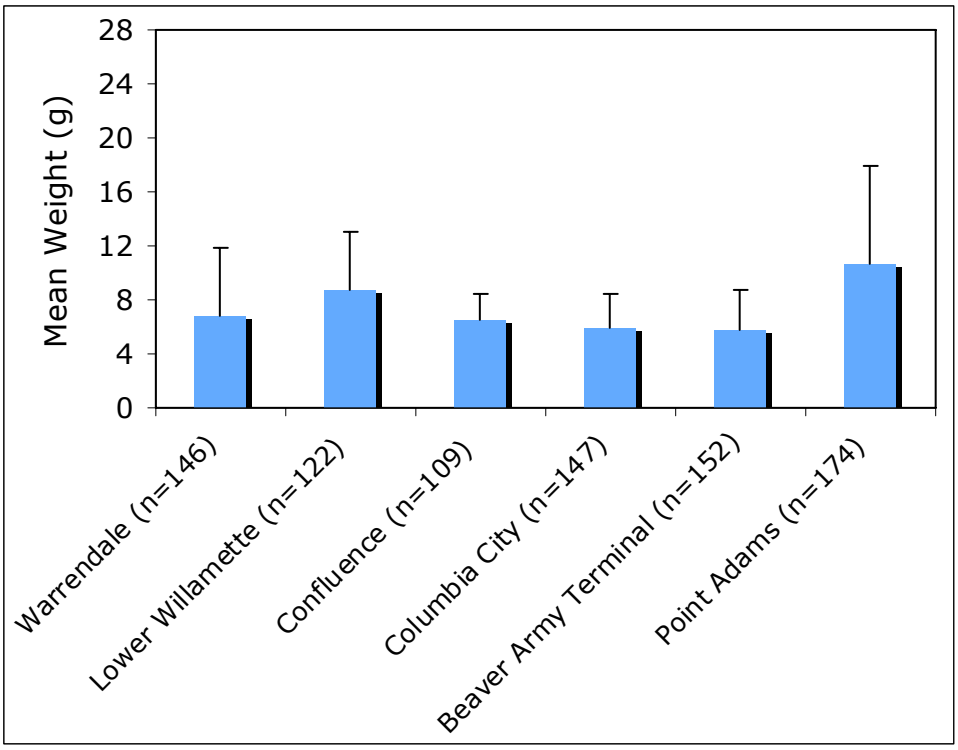


Figure 32: Mean weight length (g) of juvenile Chinook salmon collected in 2005 (error bars show mean + 1 standard deviation; n = number of individual salmon sampled).

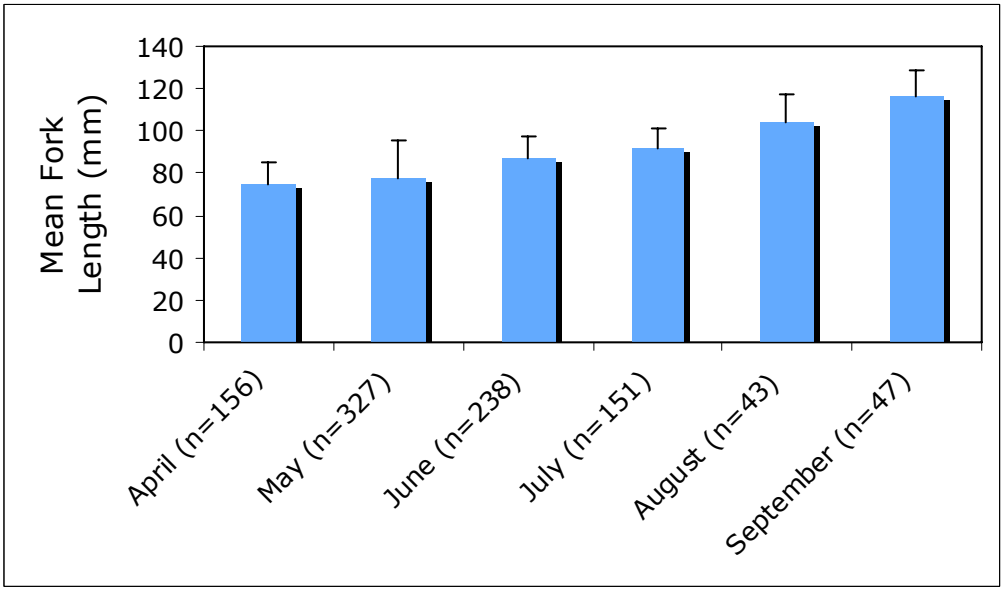


Figure 33: Mean fork length (mm) of juvenile Chinook salmon collected in 2005 by month (error bars show mean + 1 standard deviation; n = number of individual salmon sampled).

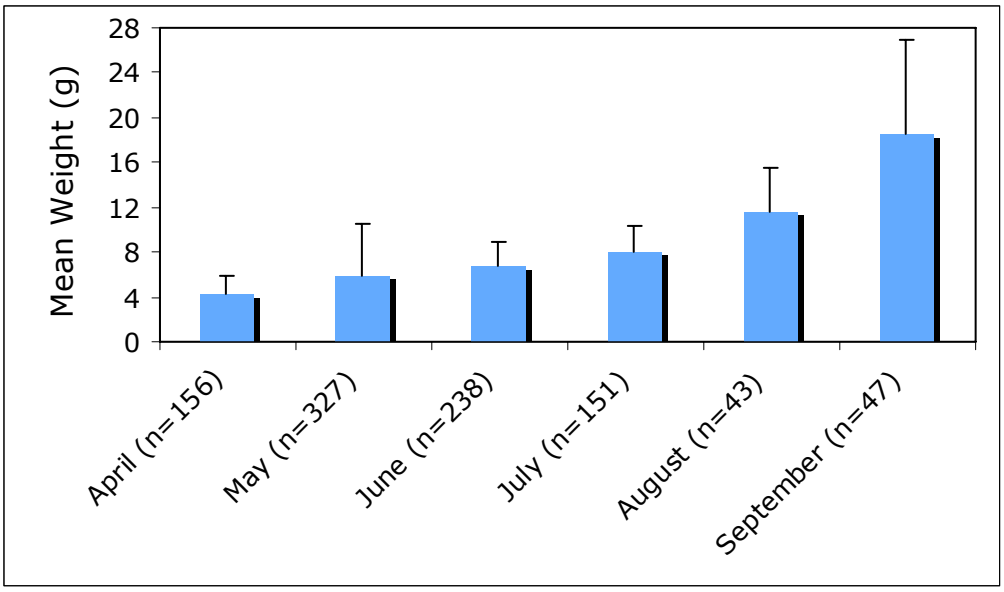


Figure 34: Mean weight (g) of juvenile Chinook salmon collected in 2005 by month (error bars show mean + 1 standard deviation; n = number of individual salmon sampled).

Lipid content in field-collected juveniles varied from 0.6 - 5.4 %, with the highest mean levels in fish from Point Adams and the lowest in fish from Beaver Army Terminal (Figure 35). Again, there was a seasonal pattern: average percentages were lowest (1.3 - 1.7 %) in April and May and highest (2.3 - 2.8%) in June, July, and August (Figure 36). Most of the lipids in field-collected salmon bodies consisted of triglycerides and cholesterol, which accounted for 65% and 20%, respectively, of total lipids (Figure 35). Normally, the ratio of triglycerides to cholesterol increases as the season progresses and fish put on weight. In the later part of the season, this ratio varied within the lower river. We observed that triglycerides were highest and cholesterol lowest among the Point Adams fish and the opposite relationship in the Beaver Army Terminal fish, whose lipid profiles resembled those of malnourished fish.

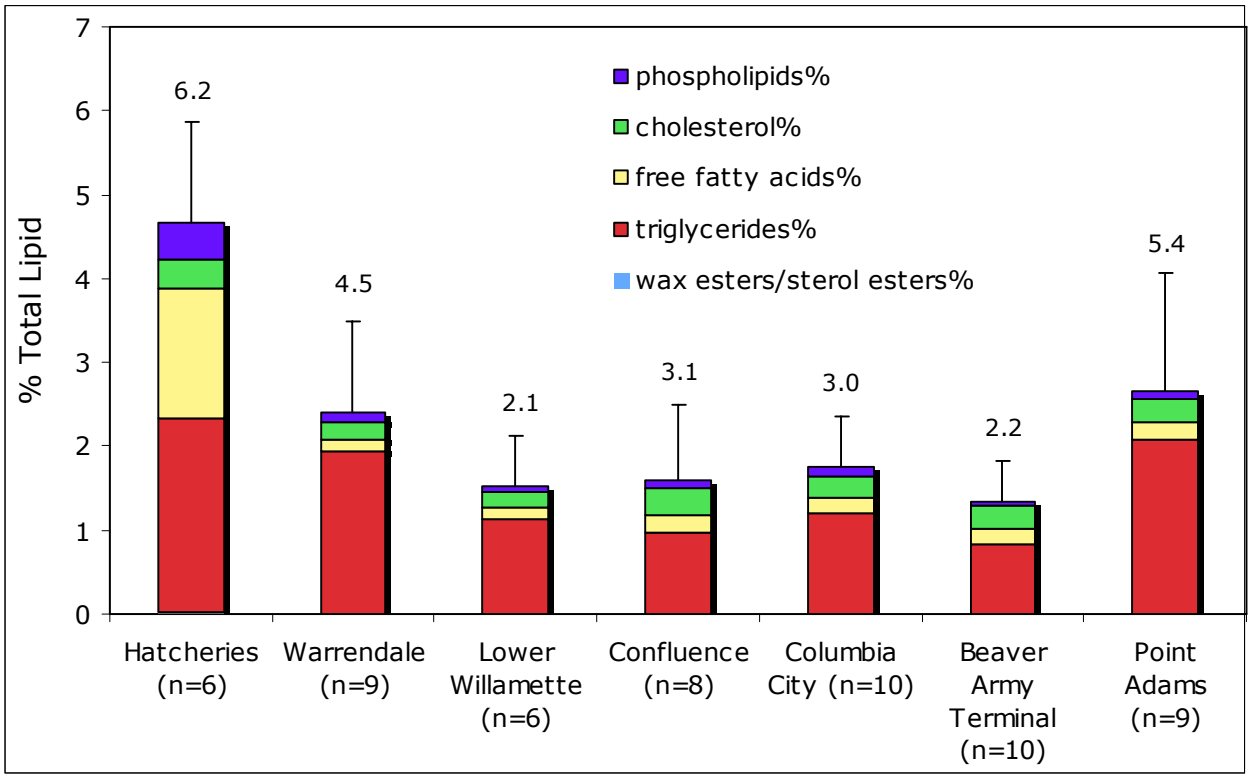


Figure 35: Breakdown of total lipids in juvenile Chinook salmon collected in 2005 by site (errors bars are mean +1 standard deviation; n = number of composite salmon samples). Composite samples used 5-10 juvenile salmon. The maximum number for the site is shown above each bar.

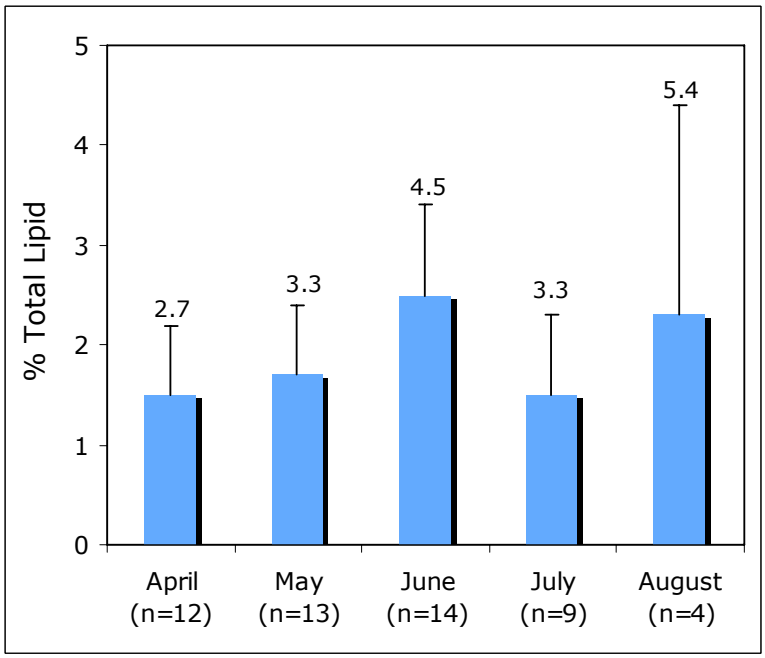


Figure 36: Percent total lipids in juvenile Chinook salmon collected in 2005 by month (errors bars are mean +1 standard deviation; n = number of individual salmon sampled).

Lipid amounts generally were higher in hatchery-collected fish (2.6 - 6.2%) than in field-collected fish (0.6 - 5.4%) (Figure 35). This higher lipid content in hatchery fish provides energy reserves, but also facilitates the uptake of bioaccumulative toxics, which are stored in body fat. As long as fat stores remain high, the risk to the fish is low. Yet, when hatchery juveniles enter the river and mobilize their fat for energy, these bioaccumulative toxics are released in the body, potentially increasing the risk of health effects. Exposure levels in the hatchery fish sampled were generally low, but the lipid-contaminant interaction is worth consideration when evaluating hatchery practices.

Indicators of Salmonid Exposure to Endocrine Disrupting Contaminants: Vitellogenin Analysis of Juvenile Chinook Plasma

Vitellogenin, an egg yolk precursor protein that is normally present in the blood of adult female salmon, is a bioindicator of exposure to endocrine disrupting contaminants (that mimic estrogen) in adult males or juveniles. To roughly estimate plasma vitellogenin levels in juvenile Chinook salmon (collected in the CRE in 2005), we performed vitellogenin analyses using the Best Checker Vitellogenin Detection Kit. All sample results were either negative (below 3,000 ng/ml) or weakly positive. Weak positives had vitellogenin levels of 3,000 ng/ml (or slightly above) (Table 11), indicating xenoestrogen exposure in salmon at sites around the Portland area.

Table 11: Results of vitellogenin analysis with Best-Checker Vitellogenin Detection Kit, 2005.

Site Name	Sample Size	# Weak Positives	% Positive
Columbia City	17	0	0
Point Adams	11	0	0
Confluence	24	2	8
Morrison St. Bridge/Portland Harbor	30	4	13
Beaver Army Terminal	9	0	0
Warrendale	17	0	0

Remaining plasma was quantified by enzyme-linked immunosorbent assay (ELISA), a more sensitive testing method, with detection limits as low as 30 ng/ml vitellogenin in plasma (depending on volume). The ELISA assay detects vitellogenin in samples by binding it to an antibody-coated surface, and then linking it with an indicator- or enzyme- permitting quantification of the bound material. The enzyme activity is measured colorimetrically, and is inversely proportional to the amount of free vitellogenin in the plasma sample. Assay calibration was done using purified salmonid vitellogenin at varying concentrations on a standard curve.

Vitellogenin was also measured in plasma reference samples from unexposed control Chinook salmon. Control fish were hatched and reared at the NMFS facility in Mukilteo, WA, from eggs that were obtained from the UW Hatchery in December 2005. Juveniles smolted and were transferred to seawater 5 – 6 weeks prior to plasma collection in July 2006 (Jim Meador, NMFS, pers. comm.).

Like the vitellogenin screening Detection Kit, the ELISA results showed vitellogenin production in samples from the Confluence and Morrison Street Bridge/Portland Harbor sites (Figure 37). In addition, ELISA was able to detect vitellogenin at several other sites (Columbia City, Point Adams, and Warrendale) where mean plasma vitellogenin concentrations were 2.5 – 4 fold higher than the control mean. These results suggest that exposure to environmental estrogens may be more widespread than indicated by original screening analysis. Furthermore, samples from some sites had higher vitellogenin levels in May than June, suggesting possible temporal variation in estrogenic exposure.

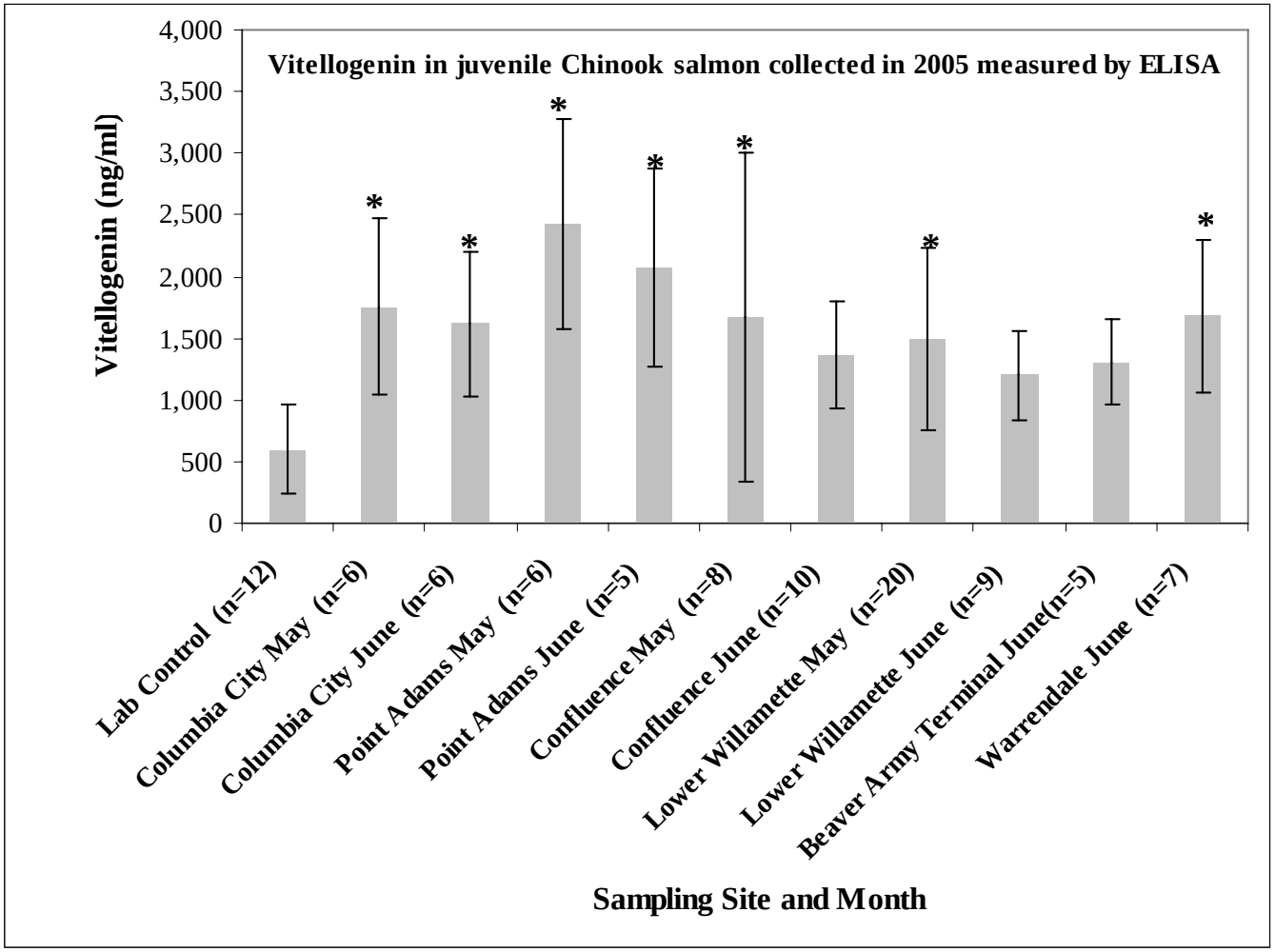


Figure 37: Results of ELISA analysis for vitellogenin in juvenile Chinook salmon plasma (error bars show mean ± 1 standard deviation), 2005.

Samples with vitellogenin levels below the detection limit were assigned a value of half detection limit (three samples from the control group and one sample from MSB/PH 5/17). Asterisks (*) in Figure 37 indicate samples that were significantly different from the control mean, as determined by Analysis of Variance and Dunnett's Comparison to Control Method for testing for significant differences among means ($p < 0.05$).

Investigation of Contaminant Sources and Resident Fish Uptake

Fish and river sediments were analyzed for PCBs, PAHs, PBDEs, and organochlorine pesticides to provide data on contaminant uptake in fish and on potential sources or reservoirs of toxics. Sticklebacks were chosen to provide data on a species more resident than juvenile salmon. We collected fish (in June 2005) and sediments (in April and September 2005) at Chinook salmon sampling sites (Warrendale, Columbia City, Morrison Street Bridge, Willamette/Columbia confluence, Beaver Army Terminal, Point Adams, and West Sand Island sites shown in Figure 25). We completed analyses of these samples in 2007.

Sediment Chemistry

Results show that sediment contaminant levels were uniformly low (Figure 38), even though contaminant concentrations in juvenile salmon were relatively high at some sites (Leary et al., 2006). At all sites (except the

Lower Willamette), sediments had mean concentrations of DDTs less than 1 ng/g dry wt and mean concentrations of PBDEs below limits of quantification. At the Willamette sites, these chemicals were present at concentrations of 3.3 and 3.5 ng/g dry wt, respectively, in sediments. Sediment concentrations of PCBs were 25-30 ng/g dry wt at the Lower Willamette and Confluence sites and less than 3 ng/g dry wt at all other sites.

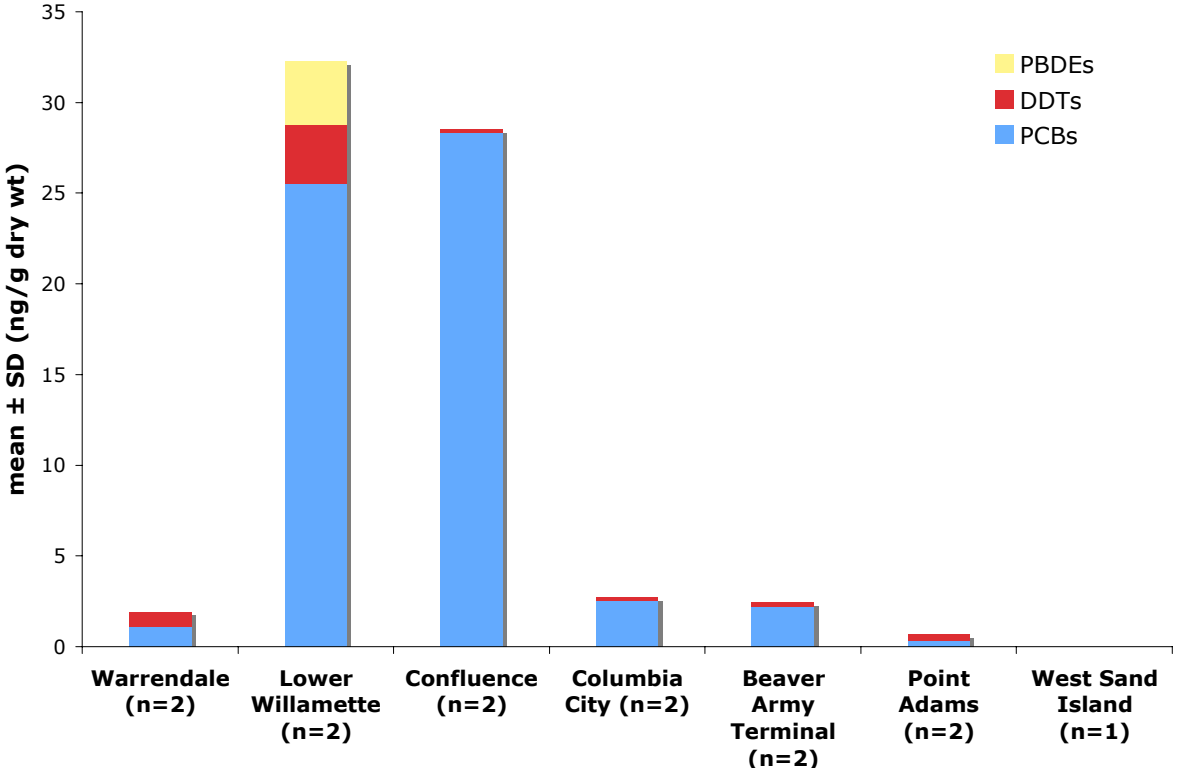


Figure 38: Concentrations of PCBs, DDTs, and PBDEs (ng/g dry wt) in Lower Columbia Estuary sediments, 2005.

Concentrations of PAHs in sediments were somewhat higher, with total PAH levels ranging from 2.9 ng/g dry wt at West Sand Island to 725 ng/g dry wt at the Lower Willamette site (Figure 39). PAH concentrations were variable at the Warrendale, Confluence, and Point Adams sites, perhaps reflecting the patchy distribution of contaminants in sediments at these sites and the Lower Columbia River (e.g., USACE 1999; LWG 2007).

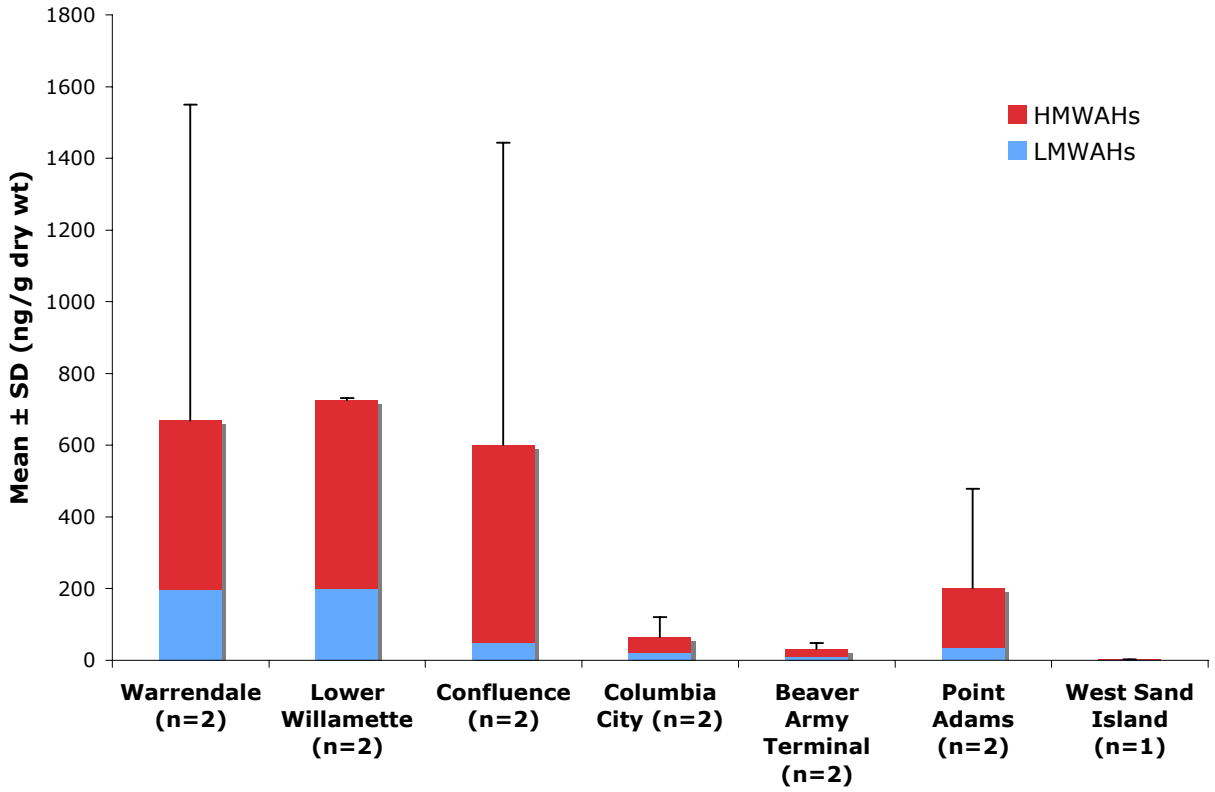


Figure 39: Concentrations of polycyclic aromatic hydrocarbons (PAHs) (ng/g dry wt) in Lower Columbia Estuary sediments (error bars show mean + 1 standard deviation), 2005. HMWAHs = high molecular weight PAHs; LMWAHs = low molecular weight PAHs.

Contaminant levels in Lower Columbia sediments were low relative to contaminant levels observed in sediments at other urban sites in the Pacific Northwest. In urban estuaries in Puget Sound, total PAH concentrations were in the 5,000-10,000 ng/g dry wt range, PCB concentrations in the 200-500 ng/g dry wt range, and DDT concentrations above 10 g/g dry wt are not uncommon (EVS 2003). At Superfund sites in Portland Harbor, concentrations of PAHs were greater than 30,000 ng/g dry wt at some locations, PCBs were in the 1,000-10,000 ng/g dry wt range, and DDTs in the 100-10,000 ng/g dry wt range (LWG 2007). These levels are much greater than the highest concentrations found in sediments that we sampled in the Lower Columbia.

These data suggest that bed sediments may not be the primary source of exposure for salmon at these sampling sites. Although hot spots of contaminated sediment may exist and contribute to salmonid uptake of contaminants, other likely sources of exposure include contaminants in the food web, on suspended particulates, and in the water column.

Stickleback Whole Body Chemistry

Sticklebacks (threespine sticklebacks, *Gasterosteus aculeatus*) were collected in 2005 from three juvenile salmon sampling sites (Columbia City, Beaver Army Terminal, and Point Adams). Sticklebacks were not found at the other sites. Sticklebacks have a diet similar to juvenile salmonids but are a resident species. Thus, we used sticklebacks to compare bioaccumulation in resident fish vs. migratory salmon. Analyses of samples were completed in 2007.

Results show that overall lipid levels in sticklebacks (1 – 3.4%) were similar to those in salmon (Figure 40). However, for the three sites where both species were present, patterns of lipid levels varied by species. Chinook salmon had the highest lipid content at Point Adams (near the mouth of the estuary) and the lowest lipid content at Beaver Army Terminal while sticklebacks were exact opposite (with lowest lipid and triglyceride levels at Point Adams and highest levels at Beaver Army Terminal). Low lipid and triglyceride levels generally reflect poor nutritional condition, and may be an indicator of the habitat quality and suitability for these species.

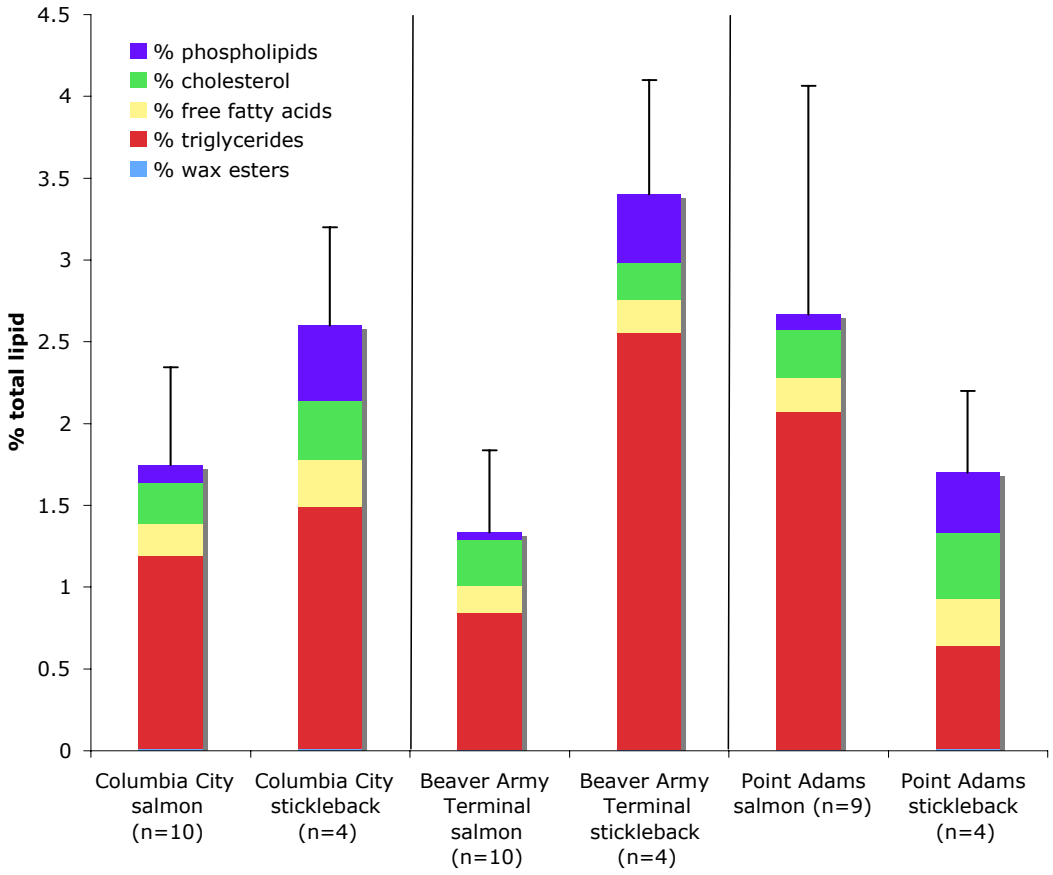


Figure 40: Percentage of whole body lipid content (error bars show mean + 1 standard deviation) and lipid classes in whole bodies of juvenile Chinook salmon and threespine sticklebacks from the Lower Columbia Estuary, 2005.

Concentration of bioaccumulative contaminants in salmon and sticklebacks were similar, typically between 20-50 ng/g ww (Figure 41) and 1000-3000 ng/g lipid (data not shown). As might be expected in a comparison of resident vs. migratory species, overall contaminant concentrations tended to be higher and less variable in sticklebacks than in salmon. Concentrations of PCBs in fish from the Beaver Army Terminal site were an exception to this trend; levels of these compounds were higher in juvenile salmon than in sticklebacks. This unusual relationship suggests that salmon body burdens (e.g., accumulation of contaminants upstream of the sampling site) are influencing factors that are not affecting sticklebacks.

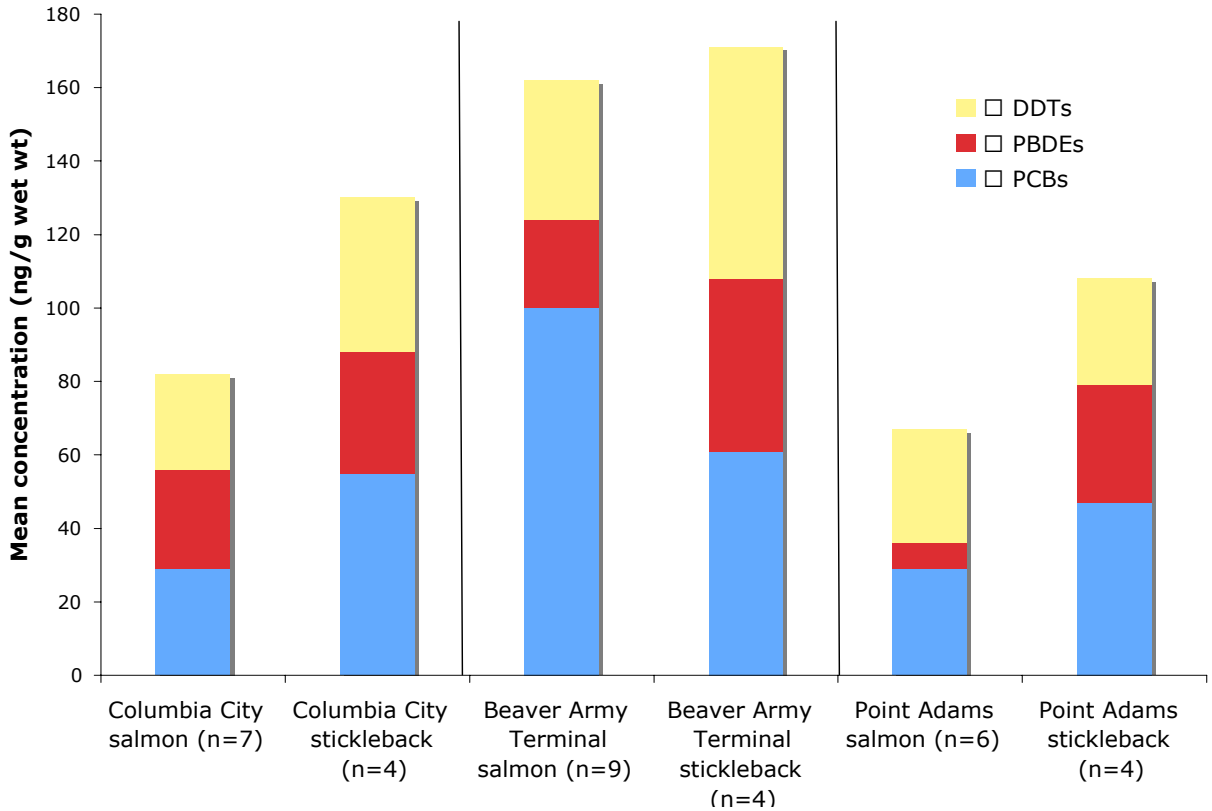


Figure 41: Concentrations of PCBs, DDTs, and PBDEs in ng/g wet weight in whole bodies of juvenile Chinook salmon and threespine sticklebacks from the Lower Columbia Estuary, 2005. Numbers in parentheses represent the number of composite samples (3-5 fish each) analyzed for each site.

New Liquid Chromatography and Mass Spectroscopy Methods

In Year 2 of this project, contaminant and salmon testing found evidence of exposure to estrogenic compounds in juvenile Chinook salmon from Portland Harbor sites. USGS identified various wastewater compounds in water samples from the area, but existing methodologies were not sufficiently robust to measure compounds in fish. We will test new liquid chromatography and mass spectroscopy methods to measure wastewater and estrogenic compounds in juvenile salmon bile and plasma samples. Although proposed as a work element for Year 3b, these efforts have been postponed until Year 4 due to insufficient staffing. To date, we have developed a strategic work plan, and collected and exposed fish to natural and synthetic estrogens and plasticizers in preparation for testing in fall 2007. If successful, these methods will be applied to future studies linking salmon with wastewater and emerging contaminants. Funds allocated for method testing in Year 3b were used for more extensive field sampling.

Collection of Yearling Chinook in the Lower Columbia Estuary

In May 2007, we collaborated with the Northwest Fisheries Science Center (NWFSC) Fish Ecology Division to collect whole bodies of ten yearling Chinook salmon by purse seine from two sites (North Channel and Trestle Bay) in the saltwater portion of the Lower Columbia Estuary (Table 12). The Montlake laboratory will conduct chemical and genetic analyses of these samples in fall 2007. Genetic analysis will be done so we can identify their stock of origin.

Table 12: Purse-seine collection sites for yearling Chinook salmon, 2007.

Sample Date	Station	Lat (dd)	Long (dd)	Fish Length (mm)
5/17/07	North Channel	46.2361	-123.8956	134
				147
				151
				146
				142
				162
5/17/07	Trestle Bay	46.21695	-123.9665	140
				144
				152
				149

Report by the Estuary Partnership, NOAA, and USGS WRD on Water Quality and Salmonid Contaminant Data

In 2007, the Estuary Partnership, NOAA, and USGS developed the "Lower Columbia River and estuary Ecosystem Monitoring: Water Quality and Salmon Sampling Report" to detail results of the juvenile salmon and water quality monitoring efforts during 2004-2005 (LCREP, 2007). This report is uploaded into Pisces and available on the Estuary Partnership's website. This report provides background information on the toxic contaminants monitored by the Ecosystem Monitoring Project and information on the sampling design. The water quality and salmon sampling data were compared to understand which toxic contaminants are contributing to declines in salmon populations and how exposure of juvenile salmon to identified toxics can be reduced. By considering the results of the water quality and salmon sampling together, a more comprehensive picture emerges of how toxics, particularly bioaccumulative ones, are moving through the Lower Columbia River and food chain and affecting juvenile salmon.

Key Report Findings

- PCBs, PAHs, and PBDEs are widespread in the lower river, both geographically and in the food chain.
- Urban and industrial portions along the lower river contribute significantly to toxic loads in juvenile Chinook salmon.
- Juvenile Chinook salmon from upriver salmon stocks are absorbing toxic contaminants during their time in the lower Columbia River and estuary.
- Juvenile Chinook salmon in the lower river are accumulating DDT in their tissue.
- Juvenile Chinook salmon are exposed to estrogen-like compounds in the lower river.
- Copper concentrations were present at levels that could interfere with salmon imprinting, homing, schooling, shoaling, predator detection, predator avoidance, and spawning behavior
- The most frequently detected pesticides were atrazine, simazine, and metolachlor, which are suspected hormone disruptors.

USGS WRD Analysis of Water Quality Data

In 2007, we interpreted and summarized toxics data from previous water-quality monitoring (water-column, suspended-sediment, and SPMDs). Samples were collected from 2004 and 2005 at four sites on the Columbia River main stem and one site in the lower Willamette River. Detailed information on all water-quality data collected during this study (e.g., sample-collection, laboratory, quality-assurance methods, full listing of analytes, and results) were reported previously (Morace, 2006; http://pubs.water.usgs.gov/ds213). We plan to make all data available in easily downloadable formats to allow for more timely retrieval.

Data presented here include results from our analyses of filtered water, suspended sediment, and extracts from SPMDs (Table 13). Although levels of detected compounds were low relative to laboratory reporting limits, the detection of these compounds in streams as large as the Columbia and Willamette Rivers indicates that they are likely widespread throughout the basin and possibly occur at considerably higher concentrations near their sources. The data also indicate that the Willamette River is an important source of contaminants to the estuary.

Table 13: Summary of selected water-quality sampling activities, Columbia River Estuary, 2004-2005

	Filtered Water			SPMD Extracts and Suspended Sediment			
	Nonpharmaceutical Wastewater Compounds	Pharmaceuticals	Pesticides and Degradation Products	Polycyclic Aromatic Hydrocarbons (PAHs)	Organochlorine Pesticides (OCPs)	Polybrominated Diphenyl Ethers (PBDEs)	Polychlorinated Biphenyls (PCBs)
Monthly							
Warrendale			X				
Willamette			X				
Beaver			X				
August 2004 (low flow)							
Warrendale	X	X					
Willamette	X	X					
Columbia City	X	X					
Beaver	X	X					
Point Adams			X				
April 2005 (high flow)							
Warrendale	X	X		X	X	X	X
Willamette	X	X		X	X	X	X
Beaver	X	X		X	X	X	X
Point Adams	X	X	X	X	X	X	X
August 2005 (low flow)							
Warrendale				X	X	X	X
Willamette				X	X	X	X
Beaver				X	X	X	X
Point Adams				X	X	X	X

Water Column Samples

Pesticides and Associated Degradation Products

Pesticides and pesticide degradation products were detected at all sites except Columbia City, which was sampled once for these compounds (Appendix 1). The pesticides detected most frequently were the triazine, herbicides atrazine and simazine, and chloroacetanalide herbicide metolachlor. All three compounds are suspected endocrine disruptors. Diuron was at levels similar to or higher than atrazine, though it was detected less frequently.

Overall, the pesticides and degradation products measured were found most often and at the greatest concentrations in the Willamette River. Johnson et al. (2007) also found concentrations of organochlorine pesticides in fish to be highest near the mouth of the Willamette River, suggesting that the Willamette subbasin is an important source of these compounds to the estuary.

Pesticides and degradation products were more frequently detected during late fall, winter, and spring (November through June) than during the summer and early fall (July through October), suggesting that precipitation may play an important role in mobilizing these compounds. This seasonal pattern was especially evident in the Willamette River because of the large number of detections there. Similar seasonal patterns have been noted by previous investigators in the basin (Fuhrer et al., 1996; Rinella and Janet, 1998).

Wastewater Compounds and Pharmaceuticals

Pharmaceuticals and nonpharmaceutical wastewater compounds were detected at all sites (Table 14, Table 15). While most detections of pharmaceutical compounds occurred during the late summer and low-flow sampling, detections of other wastewater compounds were more evenly distributed between the late summer and spring sampling periods. Concentrations, though generally too low to be quantified, were consistent with ranges reported by Kolpin et al. (2002) in the first nationwide reconnaissance of the occurrence of these compounds in U.S. streams.

Caffeine was detected at least once at each site. Caffeine was the wastewater compound detected most often, and the only one measured at a quantifiable concentration. Other wastewater compounds detected more than once included bisphenol A (a known endocrine disruptor), HHCB (a widely used fragrance compound), and naphthalene (a component of gasoline and product of wood combustion). The suspected endocrine disruptor, tri(2-chloroethyl)phosphate, was detected once in the Willamette River.

Trimethoprim (an antibiotic used in human health care and aquaculture) and anhydro-erythromycin (a degradation product of the human and veterinary antibiotic erythromycin) were the most frequently detected pharmaceutical compounds.

Table 14: Nonpharmaceutical wastewater compounds detected in filtered water, Columbia River Estuary, 2004-2005.

[Concentrations reported in micrograms per liter; detections are shown in bold type and shaded; DEET, N,N-diethyl-meta-toluamide; HHCB, Hexahydrohexamethylcyclopentabenzopyran; --, no data; ND, not detected; < RL, detected but not quantified.]

Sampling location	Date	Anthraquinone	Bisphenol A	Caffeine	DEET	HHCB	Naphthalene Compounds			Tris(2-chloroethyl)phosphate
							Naphthalene	1-Methylnaphthalene	2-Methylnaphthalene	
Warrendale	8/19/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	11/17/2004	--	--	ND	--	--	--	--	--	--
Warrendale	2/15/2005	--	--	**<RL**	--	--	--	--	--	--
Warrendale	4/20/2005	ND	ND	**<RL**	ND	ND	**<RL**	ND	ND	ND
Willamette	8/16/2004	ND	**<RL**	ND	**<RL**	**<RL**	ND	ND	ND	**<RL**
Willamette	11/19/2004	--	--	**<RL**	--	--	--	--	--	--
Willamette	2/17/2005	--	--	**0.046**	--	--	--	--	--	--
Willamette	4/14/2005	ND	ND	**<RL**	ND	ND	ND	ND	ND	ND
Columbia City	8/24/2004	**<RL**	ND	**0.032**	ND	ND	ND	ND	ND	ND
Beaver	8/17/2004	ND	**<RL**	ND	ND	ND	ND	ND	ND	ND
Beaver	11/22/2004	--	--	ND	--	--	--	--	--	--
Beaver	2/16/2005	--	--	ND	--	--	--	--	--	--
Beaver	4/21/2005	ND	ND	**<RL**	ND	**<RL**	**<RL**	**<RL**	**<RL**	ND
Point Adams	8/18/2004	--	--	ND	--	--	--	--	--	--
Point Adams	4/18/2005	ND	ND	**<RL**	ND	ND	ND	ND	ND	ND

Table 15: Pharmaceuticals detected in filtered water, Columbia River Estuary, 2004-2005.

[Concentrations reported in micrograms per liter; detections are shown in bold type and shaded; *, degradation product; --, no data; ND, not detected; < RL, detected but not quantified.]

Sampling location	Date	Acetaminophen	Diphenhydramine*	*Anhydro-erythromycin	Trimethoprim	Tylosin
Warrendale	8/19/2004	ND	ND	**0.057**	**<RL**	ND
Warrendale	4/20/2005	ND	ND	**ND**	ND	ND
Willamette	8/16/2004	ND	ND	**0.091**	**0.006**	ND
Willamette	4/14/2005	ND	ND	**ND**	ND	ND
Columbia City	8/24/2004	ND	ND	**0.047**	ND	ND
Beaver	8/17/2004	**0.172**	ND	**0.065**	**0.005**	ND
Beaver	4/21/2005	ND	ND	**ND**	**ND**	**<RL**
Point Adams	4/18/2005	ND	**<RL**	**ND**	ND	ND

Suspended Sediment

Concentrations of suspended sediment were low during both sampling periods at all four sites, and target analytes were generally detected only at trace levels (Table 16). Polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs) were not detected at all during either sampling period. In contrast, polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) were detected on suspended sediment from all sites during both sampling periods, though generally not at levels that could be quantified.

Table 16: Summary of compounds detected on suspended sediment, Columbia River Estuary, 2005.

[sum, sum of mass of analytes detected at concentrations greater than or equal to the reporting limit (reported in micrograms per kilogram); detections, total number of analytes detected in class; detections are shown in bold type and shaded.]

		Suspended Sediment in Water	Polycyclic Aromtic Hydrocarbons (PAHs)		Organochlorine Pesticides (OCPs)		Polybrominated Diphenyl Ethers (PBDEs)		Polychlorinated Biphenyls (PCBs)	
Analytes in Class:			16		21		11		167	
		(mg/L)	sum	detections	sum	detections	sum	detections	sum	detections
Warrendale	April 2005	**5**	0	0	0	0	0	**10**	0	**29**
Willamette		**10**	0	0	0	0	0	**10**	0	**53**
Beaver		**9**	0	0	0	0	0	**11**	0	**35**
Point Adams		**6**	0	0	0	0	**84**	**11**	0	**39**
Warrendale	August 2005	**4**	0	0	0	0	0	**7**	0	**19**
Willamette		**8**	0	0	0	0	0	**8**	**1.8**	**39**
Beaver		**11**	0	0	0	0	0	**9**	**0.4**	**26**
Point Adams		**9**	0	0	0	0	0	**10**	**1.4**	**41**

Eleven of the 209 PBDE congeners were targeted for analysis during this study (tribrominated PBDE 28, tetrabrominated PBDEs 47 and 66, pentabrominated PBDEs 85, 99, and 100; hexabrominated PBDEs 138, 153, and 154; heptabrominated PBDE 183; and decabrominated PBDE 209). During the April sampling, most of these congeners were detected at trace levels at the Warrendale, Willamette, and Beaver sites, and seven congeners were detected at quantifiable levels at the Point Adams site. Nearly as many detections occurred during the August sampling, but no quantifiable concentrations were measured at that time.

PCBs were also detected on suspended sediment from all four sites in both April and August. Of the 209 individual PCB congeners, twelve are currently considered to be particularly toxic to fish and birds (tetrachlorinated PCBs 77 and 81, pentachlorinated PCBs 105, 114, 118, 123, and 126; hexachlorinated PCBs 156, 157, 167, 169, and heptachlorinated PCB 189). Congeners 105 and 118 could not be identified individually, but of the remainder of these twelve congeners, only a single detection was measured on suspended sediment during the current study (a trace amount of PCB 77 was detected on sediment from the Point Adams site in August). During both sampling periods, the fewest PCB congeners were detected at Warrendale, suggesting that the lower basin, including the Willamette subbasin, may be the most important source of these compounds to the estuary. This is consistent with the findings of Johnson et al. (2007), who found PCBs in salmon throughout their study area, which covered the Columbia River from the mouth of the Willamette River downstream through the estuary. These data suggest that PBDEs and PCBs are widespread throughout the lower Columbia River Basin.

Semipermeable Membrane Devices (SPMDs)

PAHs were detected at trace levels in SPMDs deployed at the Willamette River and Point Adams sites during April 2005 (Table 17). During August 2005, PAHs were quantified at all sites except Warrendale. Concentrations of PAHs in SPMDs from the August 2005 deployment were similar in magnitude to those measured during the winter of 1998 (McCarthy and Gale, 1999). OCPs were not measured at quantifiable levels at any of the sites during either deployment. However, one or two compounds were detected at trace levels at each site in April 2005. In August, two compounds were detected at trace levels at Point Adams, but no detections occurred at the other sites.

Table 17: Summary of compounds detected in semipermeable membrane devices, Columbia River Estuary, 2005.

[sum, sum of mass of analytes detected at concentrations greater than or equal to the reporting limit (nanograms per SPMD); est., concentrations are estimated; detections, total number of analytes detected in class; detections are shown in bold type and shaded.]

		Low-Molecular-Weight Polycyclic Aromtic Hydrocarbons (PAHs)		High-Molecular-Weight Polycyclic Aromtic Hydrocarbons (PAHs)		Organochlorine Pesticides (OCPs)		Polybrominated Diphenyl Ethers (PBDEs)		Polychlorinated Biphenyls (PCBs)	
Analytes in Class:		16		16		21		11		167	
		sum (est.)	detections	sum (est.)	detections	sum	detections	sum	detections	sum	detections
Warrendale	April 2005	0	0	0	0	0	**1**	**0.2**	**9**	**11**	**14**
Warrendale		0	0	0	0	0	**2**	**0.3**	**9**	**14**	**18**
Willamette		0	**1**	0	0	0	0	**10**	**9**	**5**	**15**
Willamette		0	0	0	0	0	**1**	**34**	**9**	**27**	**34**
Willamette		0	0	0	**1**	0	**1**	**18**	**9**	**12**	**24**
Beaver		0	0	0	0	0	0	**0.4**	**9**	**29**	**34**
Beaver		0	0	0	0	0	**1**	**0.4**	**9**	**27**	**30**
Point Adams		0	**4**	0	**2**	0	**2**	**12**	**9**	**47**	**41**
Warrendale	August 2005	0	**1**	0	**1**	0	0	0	**3**	**4**	**26**
Willamette		**90**	**1**	**1000**	**3**	0	0	**40**	**10**	**47**	**88**
Willamette		**100**	**1**	**1000**	**3**	0	0	**43**	**11**	**54**	**93**
Beaver		**80**	**1**	**800**	**3**	0	0	**16**	**10**	**46**	**87**
Point Adams		**100**	**1**	**700**	**3**	0	0	**6**	**10**	**33**	**82**
Point Adams		**100**	**1**	**600**	**3**	0	**2**	**5**	**10**	**28**	**79**

The eleven PBDE congeners measured on suspended sediment were also measured in SPMD extracts. During both deployment periods, most of these congeners were detected at all four sites, at least at trace levels, and congeners 47 and 99 were measured at the highest concentrations. During the April deployment, SPMDs from the Willamette and Point Adams sites had considerably higher PBDE concentrations than those from either Warrendale or Beaver. In both April and August, the highest concentrations were measured at the Willamette River site and the lowest concentrations occurred at the Warrendale site.

PCBs were detected at all sites. Compared to PBDEs, PCBs occurred more uniformly throughout the study area, except for Warrendale where both concentration and number of congeners detected were relatively low during both deployment periods.

The majority of the quantified PCB mass was from tetra- and pentachlorinated congener groups (Table 18). However, the trichlorinated congener PCB 11 (3,3' dichlorobiphenyl) was the individual congener detected at the highest concentration in all SPMDs except for the April Willamette River deployment. PCB 11 was also measured as a dominant congener in Corbicula clam tissue collected from the same reaches of the Columbia and Willamette Rivers in August and September, 2005 (unpublished data, U.S. Army Corp of Engineers, 2005), and in SPMDs deployed in the Willamette River and between Bonneville Dam and Longview in the Columbia River during May-June 2004 (Johnson and Norton, 2005). Investigations in estuaries in the New York and New Jersey area also found PCB 11 to be a dominant congener in these water bodies, accounting for up to 20% of the total PCB load (Panero, 2006; Mick DeGraeve, Great Lakes Environmental Center, personal communication, 2007). In those cases, the peaks were attributed to inadvertent production of PCB 11 during pigment manufacturing. The source of PCB 11 in the Columbia and Willamette Rivers is unknown.

Table 18: Summary of PCB congener classes detected in semipermeable membrane devices, Columbia River Estuary, 2005.

[Values reported are the sums of the masses of congeners at each chlorination level that were detected at concentrations greater than or equal to the reporting limit (nanograms per SPMD); PCB11 is shown separately because of its preponderance throughout the study area.]

		Chlorination Level						
		PCB11*	Mono-Di Other Mono & Dichlorinated Biphenyls	Tri	Tetra	Penta	Hexa	Hepta, Octa, Nona, Deca
Warrendale	April 2005	**8.2**	0	**0.4**	**0.9**	**1.4**	0	0
Warrendale		**8.8**	0	**0.4**	**2.3**	**1.8**	**0.4**	**0.1**
Willamette		**0.4**	0	0	**3.2**	**1.8**	0	0
Willamette		**1.3**	0	**6.0**	**11.9**	**6.3**	**1.6**	**0.1**
Willamette		**0.6**	0	**0.9**	**6.5**	**3.4**	**0.8**	**0.1**
Beaver		**8.4**	0	**7.0**	**8.6**	**3.6**	**1.2**	**0.1**
Beaver		**8.4**	0	**7.1**	**7.8**	**2.6**	**0.8**	**0.1**
Point Adams		**12.4**	**0.3**	**8.0**	**15.0**	**8.8**	**2.3**	**0.3**
Warrendale	August 2005	**4.0**	0	0	0	0	0	0
Willamette		**6.2**	**0.4**	**6.7**	**13.2**	**13.6**	**5.8**	**0.8**
Willamette		**6.4**	**1.2**	**8.0**	**17.5**	**14.0**	**5.9**	**0.8**
Beaver		**7.8**	**0.4**	**6.7**	**17.1**	**9.9**	**3.6**	**0.3**
Point Adams		**6.8**	0	**4.5**	**11.0**	**7.9**	**2.7**	**0.3**
Point Adams		**5.8**	0	**3.3**	**9.5**	**6.8**	**2.2**	**0.3**

Ecosystem Monitoring Project Summary

In Year 3b (September 1, 2006 – August 31, 2007), the Ecosystem Monitoring Project made many accomplishments and progress in its habitat and toxics monitoring efforts. Refinement of the Lower Columbia River Estuarine Ecosystem Classification (by UW and USGS) and development of sampling design methods (by USGS) will facilitate selection of sampling locations and rigorous monitoring in the Lower Columbia. Vegetation surveys along elevation gradients (by PNNL) add to our understanding of vegetation communities in tidal freshwater wetlands and will be important datasets for examining salmonid use of these habitats. Results of toxic monitoring in juvenile Chinook salmonids, sediments, and water (by NOAA and USGS) confirm that toxics (e.g., PCBs, PAHs, DDT, and PBDEs) are widespread in the Lower Columbia. Our detailed report of salmonid and water quality monitoring results (LCREP, 2007) highlights many of these findings and is now available online. Results from pilot studies illustrate the feasibility of using otoliths to determine salmonid growth rates, differences in salmonid body fat conditions, and the presence of endocrine disrupting contaminants in juvenile salmonids.

In Year 4 (September 1, 2007 – August 31, 2008), we will continue enhancing the Lower Columbia River Estuarine Ecosystem Classification and focus on filling bathymetry data gaps. We will use the Classification system and sampling design methods to select sampling sites in a reach of interest and tidally influenced wetlands. At these sites, we aim to do both habitat and water quality monitoring, including sampling of habitat, vegetation, water quality, and salmonids. We will analyze these data to link vegetation, water quality, and salmonids. Both the habitat and water quality monitoring teams will continue to work closely to ensure efforts are not duplicated and resources can be shared to maximize the efficiency of the Ecosystem Monitoring Project. Additionally, at the end of Year 4, we will develop an annual report detailing the year's progress.

Budget

Bonneville Power Administration
2003-007-00 LCREP Ecosystem Monitoring
Contract #28838/ Cost Reimbursement contract
Performance Period: Sept. 1, 2006 - August 31, 2007

BUDGET TRACKING

Budget Items	Original Contract	Amendment #1	Amendment #2	Funds Received To Date	Contract Balance
I. Direct Costs					
Personnel	$77,272.00			$71,611.72	$5,660.28
Travel	$4,120.00			$3,092.92	$1,027.08
Vehicles	$4,400.00			$503.51	$3,896.49
Supplies / Equipment	$7,800.00			$7,251.25	$548.75
Rent Utilities	$7,800.00			$7,150.00	$650.00
Sub Total	*$101,392.00*			*$89,609.40*	*$11,782.60*
Overhead *(20% on above)*	$20,278.00			$18,059.99	$2,218.41
Capital Equipment	$4,000.00			$690.56	$3,309.44
Sub Total Direct Costs	*$125,670.00*			*$108,359.95*	*$17,310.45*
II. Sub Contracts					
Pt 1: Ecosystem/Habitat Mon					
Battelle	$90,640.00			$12,168.39	$78,471.61
Univ of Washington	$66,000.00			$18,322.09	$47,677.91
Pt. 2: Water Qual/Toxics Mon.					
NOAA	$80,000.00			$48,472.63	$31,527.37
USGS	$215,985.00			$0.00	$215,984.98
Technical Consultants	$40,915.00			$22,168.75	$18,746.25
Sub Contracts Sub Total	*$493,540.00*			*$101,141.88*	*$392,398.12*
Project Management	$49,873.00			$45,716.88	$4,156.12
Totals	**$669,083.00**			**$255,218.71**	**$413,864.69**

Funds Received to date include expenses through 7/31/07 which have been billed and payment received from BPA. Does not include expenses incurred after 7/31/07.

References

Arkoosh, M. R., E. Casillas, E. Clemons, B. McCain, and U. Varanasi. 1991. Suppression of immunological memory in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from an urban estuary. Fish and Shellfish Immunology 1: 261-277.

Arkoosh, M. R. E. Casillas, P. Huffman, E. Clemons, J. Evered, J. E. Stein, and U. Varanasi. 1998. Increased susceptibility of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from a contaminated estuary to the pathogen *Vibrio anguillarum*. Transactions of the American Fisheries Society 127: 360-374.

Bottom, D. L., C. A. Simenstad, J. Burke, A. M. Baptista, D. A. Jay, K. K. Jones, E. Casillas, and M. H. Schiewe. 2005. Salmon at river's end: the role of the estuary in the decline and recovery of Columbia River salmon. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-68, 246 p.

Burke, J.L., and S. Sobieszczyk. 2007. Methodology for Level 4 Complex delineation for the Columbia River Estuarine Ecosystem Classification. Unpublished report. U.S. Geologic Survey, U.S. Department of the Interior. Portland, Or.

Casillas, E., M.R. Arkoosh, E.R. Clemons, T. Hom, D. Misitano, T.K. Collier, J.E. Stein, U. Varansi. 1995. Chemical contamination exposure and physiological effects in outmigrant juvenile Chinook salmon from urban estuaries of Puget Sound, Washington. Pages 657-665 in Proceedings Puget Sound Research '95. Puget Sound Action Team, Olympia, WA.

Casillas, E., B-T L. Eberhart, F.C. Sommers, T.K. Collier, M.M. Krahn, and J.E. Stein. 1998. Effects of chemical contaminants from the Hylebos Waterway on growth of juvenile Chinook salmon. Interpretative report prepared for NOAA Damage Assessment Center.

Columbia River DART. 2007. Columbia River flow data, accessed 8/2007. http://www.cbr.washington.edu/dart/river.html

Dietrich, J., F. Loge, B. Anulacion, J. Spromberg, M. Arkoosh, and L. Johnson. 2005. Conceptual model of the contaminant and endangered salmonid species interactions within the lower Columbia River and estuary. Report to the Lower Columbia Estuary Partnership, September 2005.

EVS. 2003. Status, Trends, and Effects of Toxic Contaminants in the Puget Sound Environment. October 2003.
Prepared for the Puget Sound Action Team by EVS Environment Consultants, Vancouver, BC. EVS Project no. 02-1090-01.

Foxgrover, A., Smith, R. E., and Jaffe, B. E. 2003. Suisun Bay and Delta Bathymetry. CALFED Science Conference 2003. United States Geological Survey. http://sfbay.wr.usgs.gov/sediment/delta/

Fresh, K.L., E. Casillas, L.L. Johnson, and D L. Bottom. 2005. Role of the estuary in the recovery of Columbia River basin salmon and steelhead: an evaluation of the effects of selected factors on salmonid population viability. U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-69, 105 p.

Fuhrer, G.J., D.Q. Tanner, J.L. Morace, S.W. McKenzie, and K.A. Skach. 1996. Water quality of the lower Columbia River basin – analysis of current and historical water quality data through 1994. U.S. Geological Survey Water Resources Investigations Report 95-4294, 157 pp.

Gesch, D. and R. Wilson. 2005. Tampa Bay Bathy/Topo/Shoreline Demonstration Project, Bathymetric / Topographic Merged DEM. NOAA, Office of Coast Survey. http://chartmaker.ncd.noaa.gov/bathytopo/DEM_development.html

Hatten, J.R. and T.R. Batt. 2007. Constructing a digital elevation dataset of the Lower Columbia River and floodplain. Unpublished report. U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory, Cook, WA. 98605.

Johnson, A. and D. Norton. 2005. Concentrations of 303(d) listed pesticides, PCBs and PAHs measured with passive samplers deployed in the lower Columbia River. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA. Publication No. 05-03-06. March 2005.

Johnson, L. L., G. M. Ylitalo, C.A. Sloan, B. F. Anulacion, A. N. Kagley, M.R. Arkoosh, T. Lundrigan, K. Larson, M. Siipola, and T.K. Collier. 2007. Persistent organic pollutants in outmigrant juvenile Chinook salmon from the lower Columbia Estuary, USA. Science of the Total Environment 374 (2-3): 342-366.

Kolpin, D.W., E.T. Furlong, M.T. Meyer, E.M. Thurman, S D. Zaugg, L.B. Barber, and H.T. Buxton. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance. Environmental Science and Technology 36: 1202-1211.

Leary, J.C., J. L. Morace, C. A. Simenstad, J. L. Burke, T. D. Counihan, J. R. HAtten, I. R. Waite, K. L. Sobocinski, J. Dietrich, J. Spromberg, L. Johnson, and G. Ylitalo. 2006. Lower Columbia River ecosystem monitoring project annual report for year 3 (September 2005 to August 2006). Bonneville Power Administration, Project number 2003-007-00, 73 p.

Lidar Bare Earth DEM [computer file]. 2005. Lewis, Yakima, Lower Columbia River Project: Terrapoint. Available: Puget Sound Lidar Consortium, Seattle, WA http://pugetsoundlidar.ess.washington.edu/index.htm [April 3th, 2007].

Loge, F., M. R. Arkoosh, T. R. Ginn, L. L. Johnson, and T. K. Collier. 2005. Impact of environmental stressors on the dynamics of disease transmission. Environmental Science & Technology 39:7329-7336.

Lower Columbia River Estuary Partnership. 2007. Lower Columbia River and estuary ecosystem monitoring: water quality and salmon sampling report. Lower Columbia River Estuary Partnership: Portland, Oregon. Link: http://www.lcrep.org/pdfs/WaterSalmonReport.pdf.

Lower Columbia River Estuary Partnership. 1998. Lower Columbia River estuary plan Volume 2: aquatic ecosystem monitoring strategy for the Lower Columbia River. Lower Columbia River Estuary Partnership: Portland, Oregon.

LWG (Lower Willamette Group). 2007. Portland Harbor RI/FS Comprehensive Round 2 Site Characterization
Summary and Data Gaps Analysis Report. February 2007. Prepared for the Lower Willamette Group by Integral Consulting, Inc., Windward Environmental LLC, Kennedy/Jenks Consultants, and Anchor Environmental LLC. Report Number IC07-0004.

McCarthy, K. and R. Gale. 1999. Investigation of the distribution of organochlorine and polycyclic aromatic hydrocarbon compounds in the lower Columbia River using semipermeable membrane devices. US Geological Survey Water-Resources Investigations Report 99-4051.

Meador, J.P., F.C. Sommers, G.M. Ylitalo, and D.W. Brown. 2006. Altered growth and physiological responses in juvenile Chinook salmon (*Oncorhynchus tshawytshca*) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). Canadian Journal of Fisheries and Aquatic Science 63(10): 2364-2376.

Morace, J.L. 2006. Water-quality data, Columbia River Estuary, 2004-05. U.S. Geological Survey Data Series 213, Portland, Oregon, 18 p.

Panero, Marta A. 2006. Industrial ecology applications: contaminant sources and fate in the NY-NJ Harbor watershed. Presented at Earth Institute Seminars on Sustainable Development, Columbia University, 12 October 2006 (accessed online, 3/12/2007, at http://www.seas.columbia.edu/earth/Panero_IE_pres.pdf).

Rinella, F.A. and M. L. Janet. 1998. Seasonal and spatial variability of nutrients and pesticides in streams of the Willamette Basin, Oregon, 1993-95. U.S. Geological Survey Water Resources Investigation Report 97-4082-C.

Scholz, N.L., S.A. Hecht, C.A. Laetz, C. Jordon, and T.K. Collier. In press. Pesticides, Pacific salmon, and the conceptual basis for endangered species risk assessment.

Simenstad, C.A., J.L. Burke, I.R. Waite, T.D. Counihan and J.R. Hatten. 2006. Lower Columbia River Estuarine Ecosystem Classification phase II. Report to the Lower Columbia River Estuary Partnership, Portland, OR.

Sobocinski, K. L., A. B. Borde, L. M. Miller, R. M. Thom, and L. Tear. 2006a. Columbia River Estuary habitat monitoring pilot field study and remote sensing analysis. PNWD-3475-C, Battelle-Pacific Northwest Division, Richland, WA.

Sobocinski, K., A. Borde, S. Zimmerman, R. Thom. 2006b. Summary of 2006 activities related to ecosystem monitoring. Report to the Lower Columbia River Estuary Partnership Portland, OR.

Spromberg, J. A. and J. P. Meador. 2005. Relating results of chronic toxicity responses to population-level effects: modeling effects on wild Chinook salmon populations. Integrated Environmental Assessment and Management 1(1):9-21.

US Army Corps of Engineers (USACE). 1999. Integrated Feasibility Report for Channel Improvements and Environmental Impact Statement. Columbia & Lower Willamette River Federal Navigation Channel. Prepared by the US Army Corps of Engineers, Portland District; 1999. https://www.nwp.usace.army.mil/ec/h/hr/sqer.htm.

Appendix 1: Pesticides and degradation products detected in filtered water, Columbia River Estuary, 2004–2005.

[Concentrations reported in micrograms per liter; detections are shown in bold type and shaded; *, degradation product; CIAT, 2-chloro-4-isopropylamino-6-amino-s-triazine; EPTC, S-ethyl dipropyl thiocarbamate; MCPA, (4-chloro-2-methylphenoxy) acetic acid; OIET, 2-hydroxy-4-isopropylamino-6-ethylamino-s-triazine; --, not analyzed; ND, not detected; < RL, detected but not quantified.]

Sampling location	Date	Atrazine	Bentazon	Bromacil	Bromoxynil	Carbaryl	Chlorpyrifos	CIAT*	2,4-D	DCPA	Dicamba
Warrendale	6/1/2004	**< RL**	--	--	--	**< RL**	ND	**< RL**	--	**< RL**	--
Warrendale	6/21/2004	**< RL**	--	--	--	ND	ND	ND	--	**< RL**	--
Warrendale	7/19/2004	**< RL**	--	--	--	ND	ND	ND	--	**< RL**	--
Warrendale	8/19/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	9/15/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Warrendale	10/20/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Warrendale	11/17/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	12/14/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Warrendale	1/20/2005	ND	--	--	--	ND	ND	ND	--	ND	--
Warrendale	2/15/2005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	3/15/2005	ND	--	--	--	ND	ND	ND	--	ND	--
Warrendale	4/20/2005	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Willamette	5/25/2004	**0.010**	--	--	--	ND	ND	ND	--	ND	--
Willamette	6/24/2004	**0.007**	--	--	--	ND	ND	ND	--	ND	--
Willamette	7/27/2004	**0.009**	--	--	--	ND	ND	ND	--	ND	--
Willamette	8/16/2004	**0.010**	ND	ND	ND	ND	ND	**< RL**	ND	ND	ND
Willamette	9/14/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Willamette	10/19/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Willamette	10/29/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Willamette	11/19/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Willamette	12/8/2004	**0.008**	--	--	--	ND	ND	ND	--	ND	--
Willamette	12/16/2004	**0.022**	--	--	--	ND	ND	ND	--	ND	--
Willamette	1/18/2005	**0.016**	--	--	--	ND	ND	**< RL**	--	ND	--
Willamette	2/3/2005	**0.045**	--	--	--	ND	**0.010**	ND	--	ND	--
Willamette	2/17/2005	**0.010**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Willamette	3/17/2005	**< RL**	--	--	--	ND	ND	**< RL**	--	ND	--
Willamette	4/14/2005	**0.096**	**< RL**	**< RL**	**< RL**	**< RL**	ND	**E 0.006**	**E 0.09**	ND	**E 0.10**
Columbia City	8/24/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	6/3/2004	**< RL**	--	--	--	ND	ND	**< RL**	--	**E 0.003**	--
Beaver	6/22/2004	ND	--	--	--	ND	ND	ND	--	**< RL**	--
Beaver	7/26/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Beaver	8/17/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	9/13/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Beaver	10/18/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Beaver	11/22/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	12/15/2004	ND	--	--	--	ND	ND	ND	--	ND	--
Beaver	1/19/2005	ND	--	--	--	ND	ND	ND	--	ND	--
Beaver	2/16/2005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	3/16/2005	ND	--	--	--	ND	ND	ND	--	ND	--
Beaver	4/21/2005	**0.011**	ND	ND	ND	ND	ND	ND	ND	ND	--
Point Adams	8/18/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Point Adams	4/18/2005	**< RL**	ND	ND	ND	ND	ND	ND	**< RL**	ND	ND

Sampling location	Date	3,4-Dichloro-aniline*	Diuron	EPTC	Ethoprop	Hexazinone	Malathion	MCPA	Metolachlor	Metribuzin	Metsulfuron-methyl
Warrendale	6/1/2004	--	--	**0.005**	ND	--	ND	--	ND	ND	--
Warrendale	6/21/2004	--	--	ND	ND	--	ND	--	**< RL**	ND	--
Warrendale	7/19/2004	--	--	**< RL**	ND	--	ND	--	**< RL**	ND	--
Warrendale	8/19/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	9/15/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Warrendale	10/20/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Warrendale	11/17/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	12/14/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Warrendale	1/20/2005	--	--	ND	ND	--	ND	--	ND	ND	--
Warrendale	2/15/2005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	3/15/2005	--	--	ND	ND	--	ND	--	ND	ND	--
Warrendale	4/20/2005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Willamette	5/25/2004	--	--	**0.006**	ND	--	ND	--	**< RL**	ND	--
Willamette	6/24/2004	--	--	**E 0.004**	**0.009**	--	ND	--	ND	ND	--
Willamette	7/27/2004	--	--	**E 0.004**	ND	--	ND	--	**< RL**	ND	--
Willamette	8/16/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	**E 0.04**
Willamette	9/14/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Willamette	10/19/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Willamette	10/29/2004	ND	--	--	--	ND	ND	--	ND	ND	--
Willamette	11/19/2004	ND	**0.02**	ND	ND	ND	ND	ND	ND	ND	ND
Willamette	12/8/2004	ND	--	--	--	ND	ND	--	ND	ND	--
Willamette	12/16/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Willamette	1/18/2005	--	--	ND	ND	--	ND	--	**< RL**	**0.019**	--
Willamette	2/3/2005	**0.008**	--	--	--	ND	ND	--	**0.009**	**0.018**	--
Willamette	2/17/2005	**0.007**	**0.05**	ND	ND	**< RL**	ND	ND	ND	ND	ND
Willamette	3/17/2005	--	--	ND	ND	--	ND	--	ND	ND	--
Willamette	4/14/2005	**E 0.012**	**E 0.27**	ND	ND	**E 0.021**	ND	**E 0.10**	**E 0.006**	ND	ND
Columbia City	8/24/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	6/3/2004	--	--	**E 0.004**	ND	--	ND	--	ND	ND	--
Beaver	6/22/2004	--	--	ND	ND	--	**< RL**	--	**< RL**	ND	--
Beaver	7/26/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Beaver	8/17/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	9/13/2004	--	--	ND	ND	--	ND	--	**< RL**	ND	--
Beaver	10/18/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Beaver	11/22/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	12/15/2004	--	--	ND	ND	--	ND	--	ND	ND	--
Beaver	1/19/2005	--	--	ND	ND	--	ND	--	ND	ND	--
Beaver	2/16/2005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	3/16/2005	--	--	ND	ND	--	ND	--	ND	ND	--
Beaver	4/21/2005	ND	**0.04**	ND	ND	ND	ND	ND	ND	ND	ND
Point Adams	8/18/2004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Point Adams	4/18/2005	ND	**0.03**	ND	ND	ND	ND	**< RL**	ND	ND	ND

Sampling location	Date	1-Naphthol*	OIET*	Prometon	Pronamide	Simazine	Sulfometuron-methyl	Triclopyr	Trifluralin
Warrendale	6/1/2004	--	--	ND	ND	ND	--	--	ND
Warrendale	6/21/2004	--	--	ND	ND	ND	--	--	**< RL**
Warrendale	7/19/2004	--	--	ND	ND	ND	--	--	ND
Warrendale	8/19/2004	**< RL**	ND	ND	ND	ND	ND	ND	ND
Warrendale	9/15/2004	--	--	ND	ND	ND	--	--	ND
Warrendale	10/20/2004	--	--	ND	ND	ND	--	--	ND
Warrendale	11/17/2004	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	12/14/2004	--	--	ND	ND	ND	--	--	ND
Warrendale	1/20/2005	--	--	ND	ND	ND	--	--	ND
Warrendale	2/15/2005	ND	ND	ND	ND	ND	ND	ND	ND
Warrendale	3/15/2005	--	--	ND	ND	ND	--	--	ND
Warrendale	4/20/2005	ND	ND	ND	ND	ND	ND	ND	ND
Willamette	5/25/2004	--	--	ND	ND	**0.010**	--	--	ND
Willamette	6/24/2004	--	--	ND	ND	**0.007**	--	--	ND
Willamette	7/27/2004	--	--	ND	ND	ND	--	--	ND
Willamette	8/16/2004	--	ND	ND	ND	**0.008**	ND	ND	ND
Willamette	9/14/2004	--	--	ND	ND	ND	--	--	ND
Willamette	10/19/2004	--	--	ND	ND	ND	--	--	ND
Willamette	10/29/2004	**< RL**	--	ND	ND	**0.006**	--	--	ND
Willamette	11/19/2004	--	ND	ND	ND	ND	ND	ND	ND
Willamette	12/8/2004	ND	--	ND	ND	ND	--	--	ND
Willamette	12/16/2004	--	--	ND	ND	**0.012**	--	--	ND
Willamette	1/18/2005	--	--	ND	ND	**0.011**	--	--	ND
Willamette	2/3/2005	ND	--	ND	**0.010**	**0.011**	--	--	ND
Willamette	2/17/2005	--	ND	ND	ND	**0.005**	**< RL**	ND	ND
Willamette	3/17/2005	--	--	ND	ND	**0.006**	--	--	ND
Willamette	4/14/2005	ND	**< RL**	ND	ND	**0.042**	**< RL**	**< RL**	ND
Columbia City	8/24/2004	ND	ND	ND	ND	ND	ND	ND	ND
Beaver	6/3/2004	--	--	**0.008**	ND	ND	--	--	**< RL**
Beaver	6/22/2004	--	--	**< RL**	ND	ND	--	--	**< RL**
Beaver	7/26/2004	--	--	ND	ND	ND	--	--	ND
Beaver	8/17/2004	ND	<0.008	ND	ND	ND	ND	ND	ND
Beaver	9/13/2004	--	--	ND	ND	ND	--	--	ND
Beaver	10/18/2004	--	--	ND	ND	ND	--	--	ND
Beaver	11/22/2004	--	<0.032	ND	ND	ND	ND	ND	ND
Beaver	12/15/2004	--	--	ND	ND	ND	--	--	ND
Beaver	1/19/2005	--	--	ND	ND	ND	--	--	ND
Beaver	2/16/2005	--	<0.032	ND	ND	ND	ND	ND	ND
Beaver	3/16/2005	--	--	ND	ND	ND	--	--	ND
Beaver	4/21/2005	**< RL**	<0.032	ND	ND	ND	ND	ND	ND
Point Adams	8/18/2004	ND	ND	ND	ND	ND	ND	ND	ND
Point Adams	4/18/2005	ND	ND	ND	ND	ND	ND	ND	ND