Ecosystem Monitoring Project

Annual Report

BPA Project Number: 2003-007-00
Contract Number: 33854
Performance/Budget Period: September 1, 2007 – August 31, 2008

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October 2008

Lower Columbia River Ecosystem Monitoring Project
Annual Report for Year 4 (September 1, 2007 to August 31, 2008)

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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 (LCRE) 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 needs for habitat and toxics monitoring and data management through its Ecosystem Monitoring Project (EMP). Efforts for the EMP include the development of an ecosystem classification system and on-the-ground monitoring of vegetation, habitat, juvenile salmon, and water quality. This monitoring was originally intended to address Reasonable and Prudent Alternatives (RPAs) 161, 163, and 198 of the 2000 Biological Opinion for the Federal Columbia River Power System, and now addresses RPAs 58, 59, 60, and 61 of the 2008 Biological Opinion. The Estuary Partnership executes the EMP in collaboration with the University of Washington (UW), Battelle-Pacific Northwest National Laboratory (PNNL), National Oceanic and Atmospheric Administration Fisheries (NOAA-Fisheries), United States Geological Survey (USGS) Western Fisheries Research Center at the Columbia River Research Laboratory (CRRL), and USGS Oregon Water Science Center. Financial support for the EMP comes from the Bonneville Power Administration (BPA) and Northwest Power and Conservation Council (NPCC).

This report describes accomplishments for the EMP during September 1, 2007 to August 31, 2008, or Year 4 of this on-going project. During this period, the Estuary Partnership and monitoring partners:

- Refined the Columbia River Estuary Ecosystem Classification (Classification), including a revision to the hydrogeomorphic boundary between Reaches F and G, inclusion of hydrologic processes and geomorphic structures in the delineation of complexes, and development of 3 ancillary datasets (dikes/levees, floodplain, and dredge material) to support the Classification (UW).
- Planned and implemented a bathymetry workshop to discuss data gaps and collection (Estuary Partnership, UW, and USGS).
- Prioritized bathymetric data gaps in the LCRE and incorporated this information into a data collection strategy for implementation beginning in 2008-2009 (Estuary Partnership and UW).
- Generated and released a Request for Proposals (RFP) to solicit bids from private contractors to conduct bathymetric survey work (Estuary Partnership and UW).
- Formalized the monitoring program’s goal and objectives, examined other sampling design considerations, and assessed the potential of a probabilistic survey design for the EMP (USGS, Estuary Partnership, NOAA-Fisheries, and PNNL).
- Facilitated 2007-2008 monitoring efforts by providing GIS support for site selection, coordinating discussions and site field trips, acquiring special use permits for site access, assisting sampling crews, creating a geodatabase of monitoring activities, and managing partner subcontracts (Estuary Partnership).
- Collected vegetation and sediment data at 4 sites in Reach H and 2 previously sampled sites in Reach F to characterize vegetation and sediment conditions at all sites and assess year-to-year trends in vegetation at Reach F sites (PNNL and USGS).
- Sampled juvenile salmon and their prey at 4 sites in Reach H and 1 previously sampled site in Reach F to characterize juvenile salmon occurrence, condition, and prey at all sites and year-to-year trends at the Reach F site (NOAA-Fisheries).
- Monitored water depth and basic water chemistry parameters at 1 in Reach H and 1 in Reach F to provide water depth and chemistry data for integration with results from the vegetation and salmon sampling (USGS).
- Characterized habitat conditions and biological communities at 3 forested tidal freshwater wetlands (UW).
- Compiled Classification and monitoring reports contributions from partners into this annual report document (Estuary Partnership).

- Developed scopes of work for the 2008-2009 monitoring efforts (Estuary Partnership, UW, PNNL, USGS, and NOAA-Fisheries).
- Participated in regional monitoring coordination efforts, like Estuary and Oceanic Subgroup (EOS), Pacific Northwest Aquatic Monitoring Partnership (PNAMP) workgroups, 2008 Columbia River Estuary Conference, Northwest Environmental Data-Network (NED) group (Estuary Partnership).

The EMP's 2007-2008 work elements will facilitate 2008-2009 work elements, such as further developments to the Classification, documentation of the Classification's development and applications, bathymetry collection, and continued monitoring of undisturbed emergent wetlands and forested tidal freshwater wetlands. Results from the 2007-2008 sampling of vegetation, sediment, salmon, and water quality will be integrated with results from past sampling efforts and 2008-2009 sampling scheduled to occur in Reach C.

1.0 Project Background

In September 2003, the Bonneville Power Administration (BPA) and the Northwest Power and Conservation Council (NPCC) awarded a three-year contract to the Lower Columbia River Estuary Partnership (Estuary Partnership) for its Ecosystem Monitoring Project (EMP) in the lower Columbia River and estuary (LCRE). Prior to this date, the Estuary Partnership's Science Work Group designed some project elements, including toxic contaminant and habitat monitoring. Once funding was secured, BPA project managers finalized the project with the Science Work Group. Plans were made to monitor conventional and toxic pollutants using a multi-species approach (including salmon, eagles, and osprey), and develop a data management strategy. The Estuary Partnership coordinates monitoring and data analysis, resolves problems, develops projects, provides project oversight, and administers the EMP with technical guidance from the Science Work Group.

Although fieldwork was scheduled for late 2003, BPA notified the Estuary Partnership that the project required further refinement and subsequent review by the Independent Scientific Review Panel (ISRP). Specifically, the pollutant monitoring should focus on salmon and the effects of toxic and conventional pollutants in the LCRE on salmon. Furthermore, BPA requested that monitoring for fecal coliform and mercury and data management be removed from the proposal. While the habitat monitoring portion of the project was in relatively good condition, no work could proceed until the pollutant monitoring portion was revised. After the Estuary Partnership, United States Geological Survey (USGS), and National Oceanic and Atmospheric Administration Fisheries (NOAA-Fisheries) revised and re-submitted the toxic contaminant portion, the full monitoring plan was reviewed by the ISRP in April 2004. The ISRP had a favorable review of the toxic contaminant monitoring portion, and given minor revisions, this 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 address comments by clearly defining the goals and methods of the habitat monitoring program.

Following the ISRP's review of the Columbia River Estuary Habitat Monitoring Plan, the Estuary Partnership, Battelle-Pacific Northwest National Laboratory (PNNL), USGS, and University of Washington (UW) worked in Year 2 (September 1, 2004 to August 31, 2005) of the EMP to develop a sampling plan for the LCRE. The Estuary Partnership and monitoring partners use this sampling plan to monitor the status and trends of habitat types in the LCRE. The sampling plan is informed by the draft Columbia River Estuary Ecosystem Classification (Classification) in development by UW and USGS (Simenstad et al., 2007) for the EMP. This Classification is based on LANDSAT TM imagery and bathymetric datasets and was used to identify specific LCRE reaches for sampling during summer 2005. During these 2005 surveys in Reaches D and F (see Figure 1 in Study Area), PNNL collected data on habitat conditions including salinity, water depth, temperature, dissolved oxygen, and vegetative cover and derived water elevation estimates for the EMP. Results of this sampling were summarized in the Columbia River Estuary Habitat Monitoring Pilot Field Study and Remote Sensing Analysis (Sobocinski et al., 2006a).

Additionally, during 2004-2005 of the EMP, NOAA-Fisheries and USGS implemented toxic contaminant monitoring to assess contaminant accumulation in sensitive habitat areas, trends over time, and impacts on salmon. NOAA-Fisheries convened a workshop with managers of other fish, habitat, and water quality monitoring projects in the LCRE (River miles 0-146) to develop a conceptual model for tracking toxic contaminant sources, pathways, and effects on salmon populations (Dietrich et al. 2005). NOAA-Fisheries used this conceptual model to then develop quantitative models describing contaminant uptake and bioaccumulation by juvenile salmon in the LCRE, and ecological risk models linking contaminant body burdens in salmon to health risks such as impaired immune systems, decreased growth rates, 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. Lastly, in

2004-2005, NOAA-Fisheries sampled fish from April 2005 through September 2005 while USGS conducted fixed station water quality monitoring and installed semipermeable membrane devices (SPMDs) to provide data on conventional and toxics pollutants near the fish sampling sites.

During Year 3 (September 1, 2005 to August 31, 2006) of the EMP, habitat work elements concentrated on vegetation surveys and refinement of the Classification and bathymetric datasets. In July 2006, PNNL surveyed vegetation at 4 tidally influenced wetlands in Reach G (see Figure 1 in Study Area) and re-sampled 2 sites in Reach F, which were sampled in Year 2, to assess interannual variability in vegetation cover and composition (Sobocinski et al., 2006b). UW revised the Classification, developed a new Classification level (Geomorphic Catena), created 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 and estuary meetings. USGS collected bathymetric data and expended funds to identify additional bathymetric datasets for filling critical data gaps in secondary channels and shallows in priority reaches.

Contaminant work elements of the EMP during 2005-2006 involved analyzing contaminants in juvenile salmon samples, revising contaminant models, and assessing contaminants in the water column. NOAA-Fisheries completed analyses 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 2004-2005. NOAA also expanded a population model to incorporate population-specific contaminant effects on salmon stocks within the Lower Columbia River Evolutionary Significant Unit (ESU). Models were updated with fish exposure data, water quality, sediment, and salmonid prey information generated from 2005 sampling by NOAA-Fisheries and USGS. Moreover, NOAA-Fisheries incorporated new information on biological effects of contaminants on salmonids into the ecological risks models and explored options for modeling contaminant uptake by juvenile salmonids in the Columbia (e.g., Trophic Trace steady state uptake models). NOAA-Fisheries developed a non-equilibrium model, which may more effectively capture contaminant uptake in salmonids that move quickly through portions of the Columbia River Estuary. USGS retrieved Semipermeable Membrane Devices (SPMDs) from 1 site in the Willamette River and 3 sites in Columbia River, and analyzed samples 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 the EMP, the Estuary Partnership and monitoring partners compiled and synthesized the results from past toxic contaminant monitoring efforts (described above). Data describing toxic contaminants in the water column, sediments, and juvenile salmonids (collected by USGS and NOAA-Fisheries, 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" (LCREP 2007, available in Pisces and on the Estuary Partnership's website). This report integrates the results of water quality and salmon sampling to document the presence and effects of toxic contaminants on juvenile salmon, including stocks listed under the Endangered Species Act, in the LCRE. NOAA-Fisheries used the information in this report to update the contaminant transport and ecological risk models.

Additionally, in 2006-2007 of the EMP, the Estuary Partnership and monitoring partners created tools and built datasets to support comprehensive status and trends monitoring of habitat types in the LCRE. Habitat monitoring work elements for 2006-2007 included refinements to the Classification, identification of bathymetric data gaps, initial designs of a scientifically-sound sampling design, and development of fundamental vegetation datasets. UW and USGS refined the Classification (Simenstad et al., 2007) using completed LiDAR and available bathymetric datasets. USGS used the Classification to begin developing a sampling design strategy intended for use in Years 5-7 of this Project for selecting sampling locations.

PNNL continued building fundamental datasets describing wetland vegetation patterns along elevation gradients in the LCRE. Their 2007 surveys expanded vegetation and elevation datasets to include 4 sites in Reach E and included re-sampling of 2 sites in Reach F (see Figure 1 in Study Area).

In 2006-2007, NOAA-Fisheries sampled juvenile salmon at 2 tidal freshwater sites (1 in Reach E and 1 in Reach F), and found that wild juvenile salmon, especially Chinook (*Oncorhynchus tshawytscha*), are feeding and rearing at these sites primarily from early May through July. These sites appear to function as nursery habitat for other fish species as well. NOAA-Fisheries also reported on analyses of previously collected samples. They found that salmon collected in 2005 grew at significantly different rates among sites for each of the 3 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 showed uptake of PCBs, DDTs, and PBDEs. Salmon fed on a variety of prey items, including 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.

During 2006-2007, analyses of filtered water, suspended sediment, and extracts from SPMDs detected pesticides, pesticide degradation products, pharmaceuticals, personal care products, and other contaminants at nearly all sampling sites. Although the compounds detected 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. These data also indicate that the Willamette River is an important source of contaminants to the estuary.

In Year 4 (September 1, 2007 to August 31, 2008) of the EMP, UW continued their efforts on the Classification, including a revision to the hydrogeomorphic boundary between Reaches F and G, inclusion of hydrologic processes and geomorphic structures in the delineation of complexes, and development of 3 ancillary datasets (dikes/levees, floodplain, and dredge material). Additionally, the Estuary Partnership and UW prioritized bathymetric data gaps in the LCRE and incorporated this information into a data collection strategy for implementation starting in 2008-2009. The Estuary Partnership, USGS, NOAA-Fisheries, and PNNL formalized the monitoring program’s goal and objectives, examined other sampling design considerations, and assessed the potential of a probabilistic survey design for the EMP at current project funding levels.

For monitoring efforts during 2007-2008, PNNL and USGS collected vegetation and sediment data at 4 sites in Reach H and 2 previously sampled sites in Reach F to characterize vegetation and sediment conditions at all sites and assess year-to-year trends in vegetation at Reach F sites. NOAA-Fisheries sampled juvenile salmon and their prey at 4 sites in Reach H and 1 previously sampled site in Reach F to characterize juvenile salmon occurrence, condition, and prey at all sites and year-to-year trends at the

Reach F site. USGS monitored water depth, temperature, dissolved oxygen, pH, turbidity, and conductivity at 1 in Reach H and 1 in Reach F to provide water depth and basic chemistry data for integration with results from the vegetation and salmon sampling efforts. Lastly, UW characterized habitat conditions and biological communities at 3 forested tidal freshwater wetlands.

2.0 Study Area

The lower Columbia River and estuary (LCRE) is designated an "estuary of national significance" and as such is part of the National Estuary Program, established in Section 320 of the Clean Water Act. The Ecosystem Monitoring Project's (EMP) study area is the study area of the Estuary Partnership and includes all waters that are tidally influenced (area denoted in Figure 1). The LCRE extends from the plume of the Columbia River at river mile (RM) 0 upstream to the Bonneville Dam at RM 146. The Estuary Partnership and monitoring partners collect data for the EMP on habitats supporting juvenile salmonids, including shallow emergent wetlands, undiked tidally influenced sloughs adjacent to the Columbia River, scrub/shrub forested wetlands, and mud/sand flats.

The Estuary Partnership and monitoring partners use a multi-scaled stratification sampling design for the habitat monitoring component of the EMP using the Classification. The LCRE is divided by major hydrogeomorphic transitions, yielding 8 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. Previous habitat monitoring efforts for the EMP have concentrated on Reaches D and F (2004-2005), G and F (2005-2006), and E and F (2006-2007). In 2007-2008, the Estuary Partnership and partners monitored habitats in Reaches H and F.

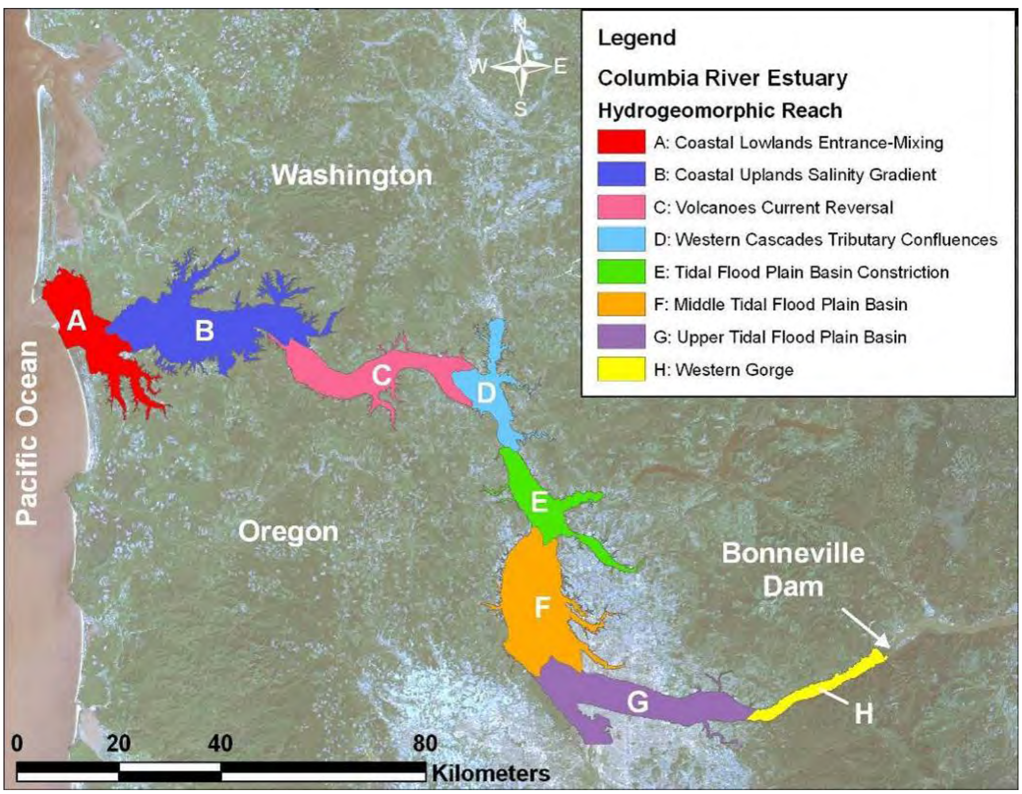


Figure 1: Lower Columbia River and estuary (LCRE) with hydrogeomorphic reaches (A-H) outlined and specified by color.

3.0 2007-2008 Estuary Partnership's Activities for the EMP

Funding for the EMP supports the Estuary Partnership's Monitoring Coordinator. As part of 2007-2008 EMP efforts, the Monitoring Coordinator planned and implemented the bathymetry workshop with UW and USGS, facilitated discussions planning 2007-2008 monitoring efforts, coordinated site field trips, acquired special use permits for accessing monitoring sites, and managed EMP subcontracts with UW, USGS, and NOAA-Fisheries. The Monitoring Coordinator compiled report contributions from ecosystem monitoring subcontractors into this annual report document. Lastly, the Monitoring Coordinator developed new scopes of work with these subcontractors for the 2008-2009 EMP activities.

EMP funds also support the Monitoring Coordinator's work on the Estuary Partnership's action effectiveness program funded by BPA. For this program, the Monitoring Coordinator developed a monitoring plan for implementation in Summer 2008, presented this plan to the Estuary and Oceanic Subgroup (EOS) and Estuary Partnership's Science Work Group, and developed and managed effectiveness monitoring subcontracts with NOAA-Fisheries, Columbia River Estuary Study Taskforce (CREST), Scappoose Bay Watershed Council, Parametrix, and Ash Creek Forest Management for 2007-2008. The Monitoring Coordinator developed new scopes of work with these effectiveness monitoring subcontractors for 2008-2009 monitoring. The Monitoring Coordinator will also compile contributions from these subcontractors for the Restoration Program's 2007-2008 annual report to BPA.

In addition to the work described above for the EMP and effectiveness monitoring program, the Monitoring Coordinator contributed to regional monitoring efforts, such as:

- Development of the "Research, Monitoring and Evaluation Plan for the Federal Columbia River Estuary Program"
- Participation in EOS
- Coordination with Pacific Northwest Aquatic Monitoring Partnership (PNAMP) workgroups related to the estuary and effectiveness monitoring
- Development of an inventory of on-going effectiveness monitoring at restoration sites
- Refinements to standardized protocols for restoration effectiveness monitoring
- Participation in the 2008 Columbia River Estuary Conference and delivered a presentation on the impacts of invasive species on restoration projects
- Revisions to the NOAA Estuary Recovery Module
- Comments on amendments to the NPCC's Fish and Wildlife Plan

Funds from BPA and other sources supported additional activities by the Monitoring Coordinator. These activities included coordination with on-going regional toxic contaminants efforts, such as planning for monitoring and reduction actions with EPA's Toxics Reduction Workgroup and for the institution of an Oregon Drug Take Back Program. The Monitoring Coordinator participated on The Oregon Task Force on the Shipping Transport of Aquatic Invasive Species and helped develop recommendations to reduce the introductions of invasive species associated with shipping transport. With funds from EPA, the Monitoring Coordinator and subcontractors developed an online "Toxics Monitoring Interactive Map" that features contaminant data from over 400 sites, including EMP contaminant work supported by BPA. Data from the Bi-State Water Quality Studies and the EMP were compiled into one accessible map, which allows viewers to examine the 2 datasets side by side and search for data by monitoring program, site, contaminant, and media sampled. The Monitoring Coordinator and subcontractors also developed and incorporated fact sheets on 7 toxic contaminants into the Estuary Partnership's website to provide an overview of contaminants of concern in the lower river, where they are found, and their impacts on the environment and salmon.

Funding for the EMP also provides partial support for the Estuary Partnership's GIS/Data Management Specialist. For the 2007-2008 EMP efforts, the GIS/Data Management Specialist participated in bathymetry, site selection, data sharing, and coordination efforts. The Specialist prioritized bathymetric data gaps in the LCRE for data collection based on participant feedback gathered at the 2007 Bathymetry workshop. The Specialist and UW developed a strategic plan for data collection, and generated a Request For Proposals (RFP) to solicit bids from private contractors to conduct bathymetric survey work. The Specialist analyzed various GIS datasets to support the 2007-2008 site selection process for on-the-ground monitoring in Reach H and has began developing a geodatabase inventory of EMP monitoring efforts. The Specialist also provided field support for NOAA-Fisheries sampling crews during the 2008 field season. The Specialist coordinated data sharing efforts in order to disseminate datasets, including those generated by the EMP, to public and private entities engaged in natural resource protection and restoration activities in the LCRE. The Specialist also participated in PNAMP workgroups relevant to data management and the Northwest Environmental Data-Network (NED) group.

In addition to the work described above for the EMP program, the GIS/Data Management Specialist contributed to the following regional monitoring efforts:

- Processing of the LiDAR dataset to establish an accurate waterline delineation for the LCRE. This process removes inaccurate data from the dataset, and will facilitate the development of a seamless elevation model for the land-water interface. This model will serve to inform the Classification.
- Generation of maps for the NOAA Estuary Recovery Module
- Development of a geodatabase inventory of on-going effectiveness monitoring at restoration sites
- Data formatting for "Toxics Monitoring Interactive Map" funded by EPA and displaying contaminant data collected by the EMP
- Generation of maps for Toxics Summit meeting held in January 2008

4.0 Columbia River Estuary Ecosystem Classification (Classification)

The 2007-2008 project period represents the fifth year developing and refining the Classification. The Classification is a hierarchical framework that will allow delineation of the diverse ecosystems and component habitats across different scales in the LCRE. The primary purpose of this Classification is to enable systematic monitoring of diverse, scale-dependent, and scale-independent ecosystem attributes. The Classification, however, also provides a more utilitarian framework for understanding the underlying ecosystem processes that create the dynamic structure of the LCRE. As such, it aims to provide the broader community of scientists and managers who seek a larger scale of understanding that is required to study, manage, and restore LCRE ecosystems.

4.1 Classification Background

Based on classification schemes developed for other estuarine ecosystems and concepts of ecosystem geography (Bailey, 1996), UW and USGS developed a classification scheme for the LCRE that has 6 hierarchical levels:

1) Ecosystem Province (based on EPA Ecoregion Level II)
2) Ecoregion (based on EPA Ecoregion Level III)
3) Hydrogeomorphic Reach (based on modified EPA Ecoregion Levels III and IV)
4) Ecosystem Complex (based on Primary Cover Class and geomorphic setting within each hydrogeomorphic reach)
5) Geomorphic Catena (based on concepts in Stanford et al., 2005)
6) Primary Cover Class (based on cover data from LANDSAT or other remote sensing datasets)

The Classification is designed to aggregate land and aquatic cover classes according to the ecosystem processes that structure landscape attributes, including biotic habitats, at different spatial scales. The Classification's methodology is entirely GIS-based using automated processes with minimal manual classification to generate an objective and repeatable hydrogeomorphic class system. An explicit goal is to not involve any subjective delineation of classes at any level, but to either utilize scientifically-based classification schemes that already exist for the area or to develop rational rules adaptable to GIS-based analyses. Many data sources are all readily available and inexpensive GIS map layers that, if updated or improved in the future, can be incorporated into the Classification methodology. All GIS data in the Classification methodology are readily available and offered free of charge from state and federal government agencies (Table 1). The Classification relies primarily on contemporary data sources. However, UW and USGS will incorporate historical data sources to cross-validate the methods.

Table 1: Sources and attributes of spatial data used to develop Classification (RKm 75 = RM 46, Rkm 214 = RM 133, RKm 230 = RM 145).

Data Type	Year	Spatial Extent	Resolution	Data Source(s)
Ecoregions	1984 to 2003	RKm 0 to 230	Varies	U.S. Environmental Protection Agency (EPA)
Bathymetry	1999 -2006 survey	RKm 0 to 75	To be determined	U.S. Army Corps of Engineers, USGS
	1938 to 1958	RKm 75 to RKm 230	30 m	NOAA National Ocean Service
Hydrology	varies	RKm 0 to 230	1:24,000	USGS topographic surveys as digital raster graphics (DRG)
	varies	RKm 0 to 230	30 m	Floodplain extent from Earth Design Consultants, Inc.
Land Cover	2000	RKm 0 to 230	30 m	LANDSAT 7 TM imagery from Estuary Partnership and Earth Design Consultants, Inc.
	1974	RKm 0 to 230	1:24,000	National Wetland Inventory (NWI)
Elevation	varies	RKm 0 to 230	10 m	USGS Digital Elevation Models (DEMs)
	2004 (avail. 2005)	RKm 0 to 230	unknown	USGS LIDAR Survey
Aerial Imagery	2001	RKm 0 to 230	1 m	Digital Ortho Quads from Oregon Spatial Data Clearinghouse
Historical Bathymetry (H-sheets) Historical Topography and Land Cover (T-sheets)	1866 to 1901	RKm 0 to 214	1:10,000 to 1:20,000 1:10,000	U.S. Coast and Geodetic Surveys, provided by NOAA Coastal Services Center

For more information on the Classification development, see Leary et al. (2005).

Currently, completion of the Classification is contingent upon collection and incorporation of new bathymetric and land cover datasets. As these data become available, work in 2007-2009 will be devoted to refining criteria and rules for delineating Classification Levels IV (Complex) and V (Catena). Specific developments for 2007-2008 included: (1) minor adjustment to the Level III Hydrogeomorphic Reach boundary between Reaches F and G; (2) major restructuring of the Level IV Complex delineation to improve representation of hydrologic processes and geomorphic structure; and (3) generation of ancillary datasets for the Classification.

4.2 Reach Boundary Adjustments

UW reviewed the Classification and adjusted the boundary between Level III Hydrogeomorphic Reaches F and G, which occurs at the confluence of the Willamette River and Columbia River. The former delineation of this boundary was located in the mid-channel of the Willamette River. UW modified the delineation so that the boundary between Reaches F and G now occurs upstream of the Willamette and Columbia River confluence to accurately reflect the hydrologic differences between the reaches (Figure 2).

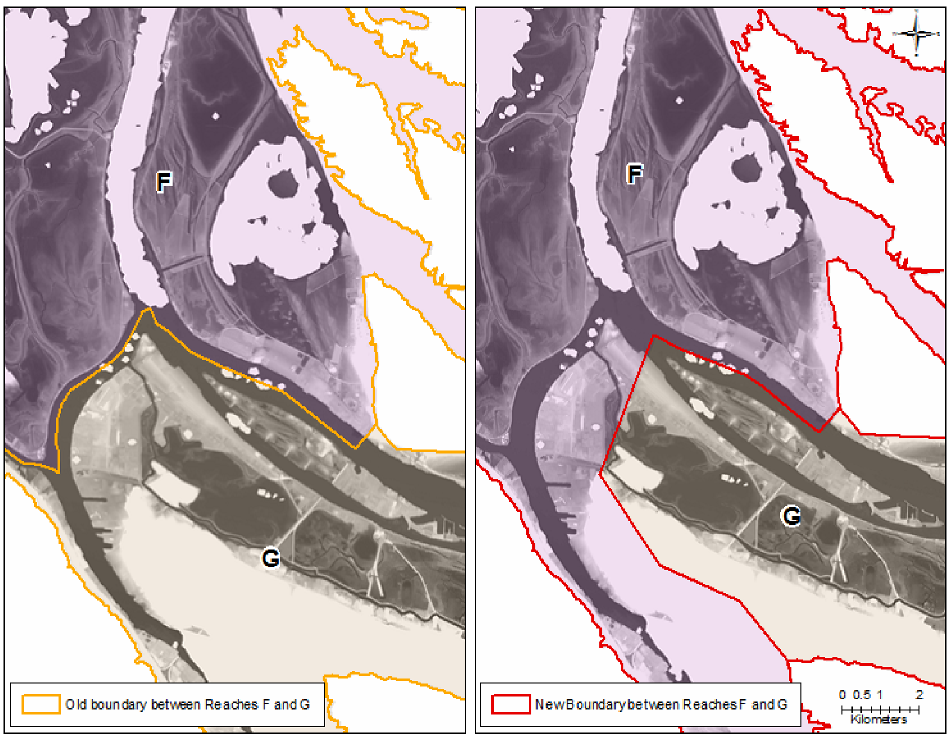


Figure 2: Former (left) and new (right) boundary between Hydrogeomorphic Reaches F and G.

4.3 Complex Delineation

We restructured the complexes to more closely represent the hydrologic processes and geomorphic structure of the estuary. Figure 3 illustrates the hydrologic (vertical axis) and geomorphic (horizontal axis) components of the Level IV Complexes across the estuarine landscape. The structure of the complexes depends upon identifying the thalweg, mean lower low water (MLLW) tidal level or lowest river stage (depending on the Level III Hydrogeomorphic Reach), constraining features of the LiDAR at bankfull flood elevation, vegetation, tidal inundation, and geomorphic location. The primary datasets used for delineating the complexes were the bathymetric DEM generated in 2006-2007 of this project, bare earth LiDAR from the Puget Sound LiDAR Consortium (PSLC), imagery from the National Agricultural Inventory Program (NAIP), and Landsat TM 2001 data from the Estuary Partnership.

Geomorphic setting

Hydrology

	Primary Channel	**Secondary Channel**	**Floodplain Channel**	**Tributary Channel**
Above bankfull	Island; Ocean beach/bar (Reach A only)	Island	Floodplain; Floodplain island	
Below bankfull, vegetation present	Intermittently exposed island	Intermittently exposed island	Floodplain island	
Below bankfull	Intermittently exposed	Intermittently exposed	Floodplain distributary channel; Floodplain lake; Floodplain Slough (blind)	Tributary
Below MLLW or lowest river level	Permanently flooded	Permanently flooded		
Deepest	Thalweg	Thalweg		

Figure 3: Matrix of Level IV complexes.

4.3.1 Bankfull

We used bankfull elevation to discern the hydrologic and geomorphic setting of the complexes. The elevation of terraces adjacent to the Columbia River (and hence, constraining the river's flow prior to floodplain inundation) denotes bankfull river stage. We generated a simplified bankfull delineation in GIS using flood stage elevation values from the 1968 USACE flood profile graph (USACE 1968). To fill gaps between known elevations and create a continuous surface elevation, we interpolated elevation values longitudinally along the river. The resulting interpolated surface was applied to the LiDAR to identify areas located above and below bankfull stage. The dataset was then edited to differentiate between terraces of the primary river channel and adjacent areas. Adjacent areas were further classified as secondary, floodplain, or tributary channels (Figure 3).

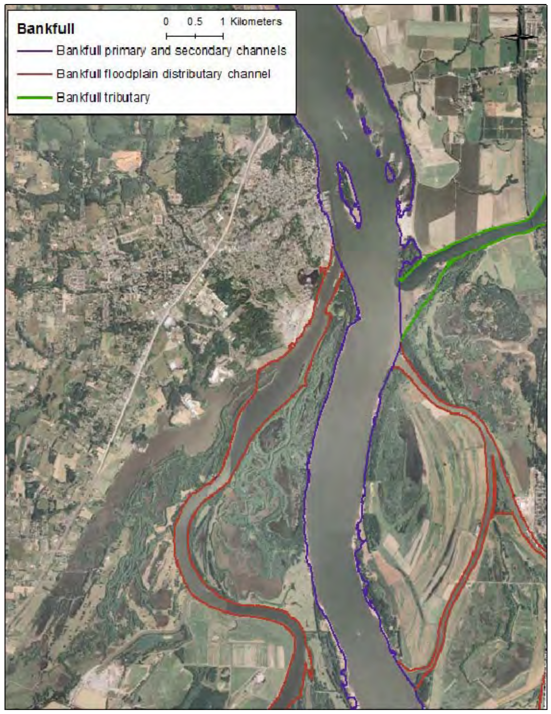


Figure 4: Example of bankfull delineations.

4.3.2 Geomorphic Location

Channels. There are four types of channels: (1) primary; (2) secondary; (3) floodplain; and (4) tributary. The primary channel is the main river channel constrained by terraces at an elevation identified by the bankfull elevation. A secondary channel is separated from the primary channel by a geomorphic feature (e.g., an island), but is still constrained by the main river bankfull terraces. The floodplain proper is the area inundated when the river crests the terraces above the bankfull elevation. A floodplain channel is outside of the bankfull terrace features that constrain the primary channel (Figure 3), but is connected to the river at one or more locations. A tributary channel has a tidally influenced confluence with the primary channel of the Columbia River and bankfull elevation terraces are present.

Islands. Islands are identified within the primary, secondary, and floodplain channels. An island may be greater in elevation than bankfull stage or below bankfull stage but vegetated. In the later case, the island is classified as an intermittently exposed island.

4.3.3 Hydrology

Thalweg. We renamed the "mainstem channel complex" from the previous version of the Classification to "thalweg complex" to more accurately describe the hydrologic feature. Thalweg is a fluvial geomorphic term for the line of lowest points along the length of a channel and generally represents the area of greatest velocity. The thalweg of the Classification includes all bathymetric depths of 10 m or greater in Level III Hydrogeomorphic Reaches A through F, and depths of 4.5 m or greater in Reaches G and H. The thalweg in Reaches A through F is primarily the navigation channel, which is dredged to maintain a consistent depth for cargo shipping, and remnants of the historical thalweg that has since been redirected by navigation channel dredging. Dredging activities cease in Reach G, where Interstate Highway 5 crosses the Columbia River at river kilometer (RKm) 171. Refer to the Columbia River Coalition's website for dredging details (http://www.channeldeepening.com/channel_projoverview.asp).

Permanent Flooded. The Permanently Flooded complex extends from the thalweg to MLLW tidal elevation equivalent on NAVD88 in Reaches A through D. For Reaches E through H, the Permanently Flooded complex extends from the thalweg to the lowest recorded river elevation. Recorded low water elevations are available for three sites in Reaches E through H. Therefore, we interpolated the low water elevations for the Columbia River estuary using recorded values at St. Helen's (RKm 138), Vancouver (RKm 169), and Bonneville Dam (RKm 233).

Intermittently Exposed (Island). The Intermittently Exposed complex extends from permanently flooded complexes to the bankfull elevation. Intermittently Exposed complexes may also be islands that are below bankfull elevation but are vegetated. Intermittently Exposed Islands occur primarily in the lower estuary in Reaches A through C.

Floodplain, Floodplain Slough (Blind), and Floodplain Lake. The floodplain is the area beyond the bankfull elevations defined by terraces adjacent to the primary channel. Features within the floodplain include Floodplain Channel and Floodplain Islands, which both have terrestrial areas above bankfull elevation. Conversely, Floodplain Slough and Floodplain Lake are also within the floodplain, as water features below bankfull elevations that may also be connected to the primary channel.

Modifiers. We will use modifiers in the Classification for the Level IV Complexes to indicate alterations impeding tidal exchange partially or completely with the historical intertidal and floodplain areas. The modifiers will be derived from one or more of the ancillary data products that we developed this year. The ancillary datasets are described in the next section.

4.4 Classification Ancillary Datasets

We developed 3 ancillary datasets (levees, dredge materials, and floodplain; described below) to support the Classification. These datasets will be incorporated into the Classification as modifiers to the Complexes.

4.4.1 Levees

Delineation of levees (or dikes) is 80% complete. The remaining work is dataset validation against existing partial levee/dike datasets and maps provided by the USACE, Columbia River Estuary Study Taskforce (CREST), and Estuary Partnership. Levees were compiled using the PSLC bare earth LiDAR as the base digitizing dataset and with high-resolution imagery from the National Agriculture Inventory Program (NAIP). The final dataset includes lines delineating actual levees and polygons of intertidal and floodplain areas affected by the levees. We delineated partial and full levees and included levees with tide gates. Full documentation of the GIS methods will be included with the metadata. The levees dataset will provide a modifier to the Classification's Level IV Complex; complexes with a partial or full levee will have a modifier of "impeded flow" in the complex attribute table.

4.4.2 Dredge Materials

Dredge materials deposited on land are discernable on the PSLC bare earth LiDAR. We are developing a polygon dataset outlining the visible dredge materials using heads-up digitizing with the PLSC LiDAR. Full documentation of the GIS methods will be included with the metadata. Complexes with dredge fill present will have a modifier of "fill identified" in the complex attribute table.

4.4.3 Floodplain

We generated a dataset delineating the outer extent of the historical Columbia River floodplain based on elevations from the USACE flood profile graph and the highest flood recorded (which occurred in 1867). The flood elevations varied with river mile due to changes in riverbed elevation and fluctuating tide and river levels. We created a single plane of reference, or interpolation of known flood elevations, to generate continuous values for the entire estuary. The plane of reference was cross-referenced with the

LiDAR to identify areas inundated by floodwaters. We are in the process of comparing the inundated areas with the historical topographic data to refine the outer delineation of the floodplain. Full documentation of the GIS methods will be included with the metadata.

4.5 Updates to the Classification's Bathymetric Dataset

USACE conducts annual surveys of the Columbia River estuary and posts the data periodically on their website (https://www.nwp.usace.army.mil/op/nwh/home.asp). Their surveys are limited to discrete areas that vary year to year. We reviewed these data, and will incorporate them into the Classification's bathymetric model at a later date. In 2008-2009, additional bathymetric field data will be collected. Once these new data are available, we will complete a comprehensive update to the bathymetric model including the annual USACE survey data.

5.0 Strategy for Bathymetric Data Collection

In October 2007, the Estuary Partnership, UW, and USGS convened a workshop to discuss bathymetry gaps and applications in the LCRE. At this workshop, resource managers prioritized areas of bathymetric data gaps for collection. The Estuary Partnership and UW, then, developed a strategy for bathymetry collection based on the gap priority rankings from the workshop. This strategy is needed because bathymetry collection in the LCRE has historically been implemented for navigation purposes and shipping channel maintenance, leaving many data gaps distributed throughout the LCRE. A complete and up-to-date bathymetry dataset is needed to support several management tasks. For instance, bathymetry can inform site selection for monitoring and restoration efforts in tidally-influenced emergent wetlands, which have poorly characterized bathymetry in the current dataset. Additionally, bathymetry is critical for delineating Level IV Complexes and Level V Catena and completing the Classification.

At the workshop, participants reviewed identified gaps and ranked them based on the need for data collection. Possible collection methods and associated advantages and disadvantages were discussed, and are briefly outlined in Section 4.3. The Estuary Partnership and UW will conduct additional analysis with data collection subcontractors to identify cost effective methods for addressing data gaps found in different environments in the lower river. Information presented here provides a basis for starting this process and developing an effective strategy for filling these crucial data gaps.

5.1 Gap Characteristics

The following figures and tables display the bathymetric data gaps in relation to the Classification's hydrogeomorphic reaches. Figure 5 displays existing bathymetric data gaps in the LCRE. We define "gaps" as areas where no data have been collected since 1999. While data were collected in many of these gaps during the 1935 – 1950 NOAA surveys, these data are generally inadequate for our management purposes because of the estuary's dynamic physical conditions. In some cases, it may be possible to interpolate between existing LiDAR and bathymetric data for smaller gap areas that are limited to a narrow width of interpolation (Figure 6). This technique may also be useful for generating a continuous coverage of elevations across the land-water interface and between topographic LiDAR data and bathymetric datasets. However, data interpolation is only applicable to smaller gaps and is not applicable for areas where no bathymetric data exists (e.g., the Multnomah Channel, left channel in Figure 6)

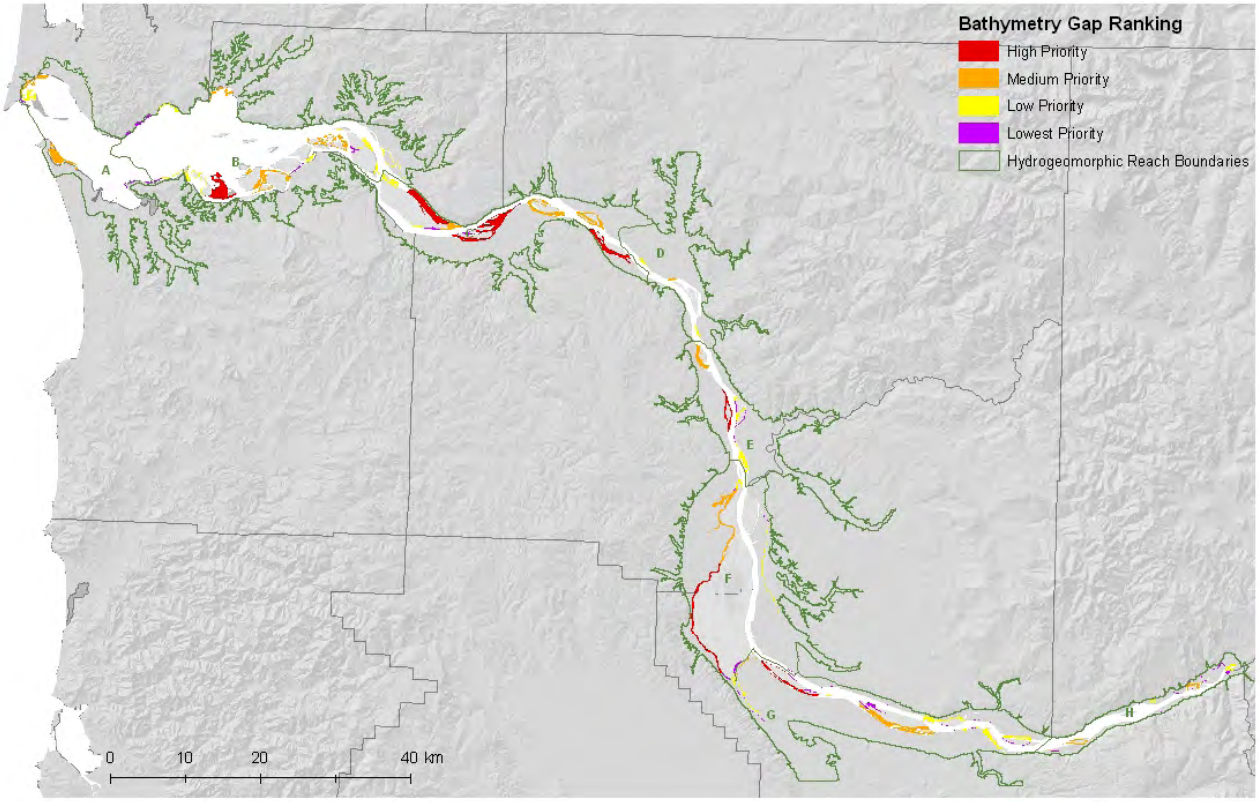


Figure 5: Existing bathymetric gaps ranked by priority for data collection.

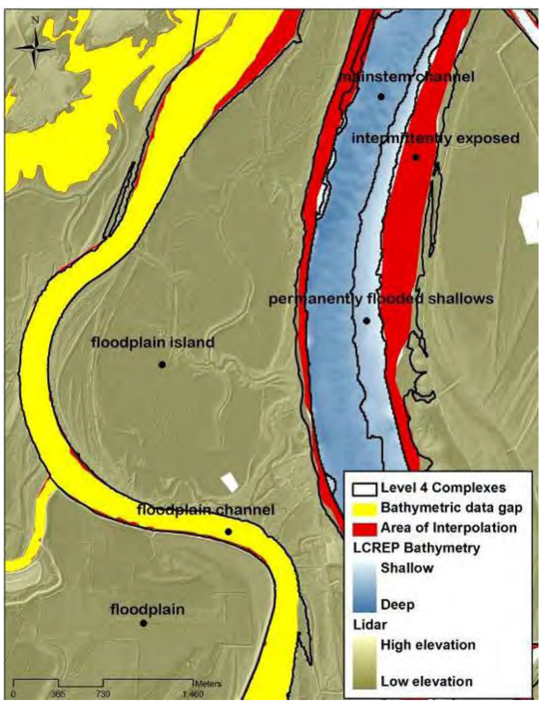


Figure 6: Reach F complexes (black outline), areas where interpolation can fill bathymetric gaps (red), and bathymetric data gaps where interpolation techniques are not applicable (yellow).

While data gaps exist within a variety of geomorphic features, several of the high priority areas are shallow tidally-influenced habitats. These are most prevalent in the lower portion of the estuary (River Mile 50 and below), where Reaches B and C contain the largest areas of high priority gaps (Figure 7, Figure 8). Deep-water areas within the main channel and side channels were also identified as priorities for data collection. Figure 7 shows the total gap area by reach and a more detailed summary by level of importance is displayed in Figure 8. Figure 9 provides a summary of the high and medium priority areas based on a simple geomorphic feature for each hydrogeomorphic reach. Figure 9 outlines the extent of the shallow water gaps, of which approximately 5,500 acres of gaps are in Reaches A, B, and C.

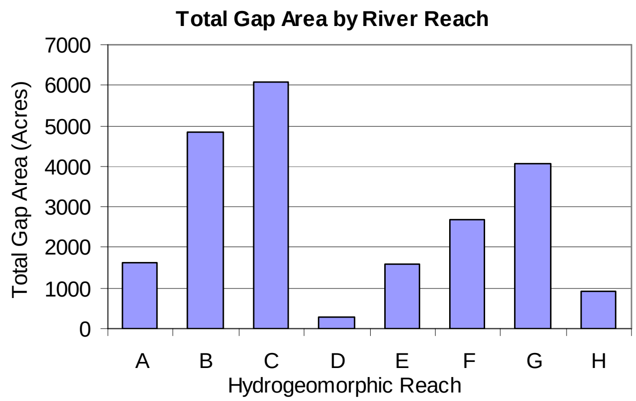


Figure 7: Gap area in acres by reach.

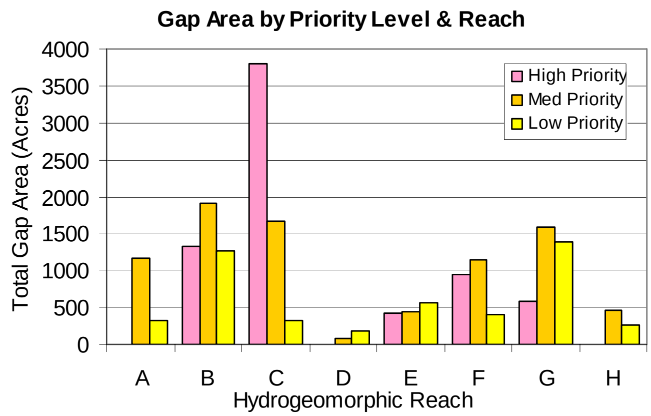


Figure 8: Gap area by reach and priority.

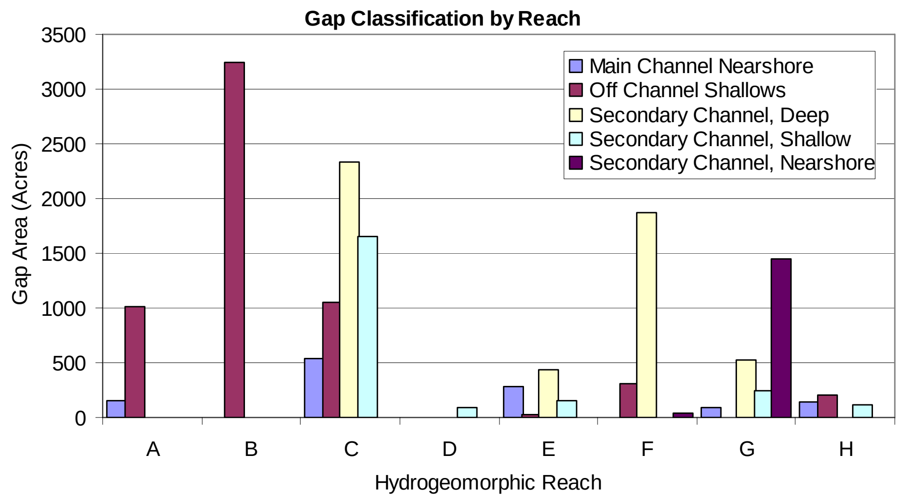


Figure 9: High and medium priority gaps by reach and geomorphic feature.

5.2 Detailed Gap Information

Appendix 1 provides results of the workshop detailing information on 23 high and medium priority gaps, covering approximately 15,000 acres. These priority rankings are based on feedback from bathymetry workshop participants whereby each participant was asked to rank gaps by level of priority; high, medium, and low. Participants then ranked the importance of data collection for gaps in the 8 hydrogeomorphic reaches. After results were compiled, numerical rankings of gap importance were derived using a weighted averaging system and then converted to a four tier ranking system: high, medium, low, and lowest priority, as follows:

High priority:	Numerical score > 7
Medium priority:	Numerical score between 4 and 7
Low priority:	Numerical score between 1 and 4
Lowest priority:	Numerical score of 0 (area received no input from participants)

5.3 Data Collection Methods

At the workshop, participants also discussed suitable data collection methods. The three major techniques discussed were sonar (multi, single-beam, or sidescan), aerial LiDAR, and acoustic Doppler current profiler (ADCP). Each technique has advantages and limitations, which are highly dependent on economic constraints, desired resolution, geomorphic characteristics, and extent of survey coverage area.

Highlights of the different collection methods include:

- Sonar techniques typically operate better in deeper waters, and are the likely technique for collecting bathymetry in the mainstem, side channels, and deeper off-channel habitats that remain permanently inundated.
- Sidescan and single-beam unidirectional sonar techniques are the most applicable for data collection in shallow water.
- Multi-beam sonar is more expensive and challenging to operate than single beam sonar, but offers higher resolution and more continuous data coverage.
- LiDAR instruments offer great promise for collection in shallow areas (e.g., tidal flats or transition zones along riverbanks), where the combination of tidal range and river stage expose the riverbed. In these exposed areas, LiDAR would provide results with high resolution and

accuracy and cover large areas. However, LiDAR data collection is limited by substantial costs and its inability to penetrate water surfaces for depth data collection.

- Bathymetric LiDAR is capable of penetrating water, and could be the most promising technique of all with future improvements. Current limitations include substantial costs and data collection only in water with low turbidity (i.e., the current range of operation is limited to about 1 secchi-depth).
- ADCP offers sounding capabilities, and is potentially a more cost effective method compared to sonar.
- No single data collection technique is apt to be used to fill all data gaps. Instead, a combination of techniques will be needed for data collection.

5.4 Conclusions

We identified approximately 22,000 total acres of bathymetric data gaps in the LCRE. Approximately 15,000 acres were identified as high or medium priority areas for data collection. Characterization of the bathymetry in these areas would greatly benefit the Classification, provide data on the extent and distribution of shallow water habitat in the LCRE, and support ongoing restoration and monitoring needs. Of the 15,000 acres of high and medium priority areas, we identified approximately 1,500 acres, which may be addressed with GIS interpolation techniques. The remaining 13,500 acres require on-the-ground bathymetric data collection.

The Estuary Partnership and UW will discuss data collection plans with potential subcontractors in the coming months so that bathymetry collection can begin in 2008-2009. Upcoming data collection challenges include: 1) the diversity of geomorphic features, which requires different collection techniques; 2) water turbidity, which can limit the available techniques; and 3) large spatial distribution of gaps, which increases the logistical effort required to fill data gaps. Regardless of the methods chosen, comprehensive data collection to fill these gaps is necessary to complete the Classification and support monitoring, restoration, and modeling efforts by the Estuary Partnership, Action Agencies, and LCRE resource managers.

6.0 Strategy for Sampling Design and Resource Allocation

As part of the EMP in 2007-2008, USGS assisted the Estuary Partnership and monitoring partners (NOAA-Fisheries, PNNL, and USGS) with the following work element:

- Strategy for sampling design and resource allocation

For this effort, USGS worked with the Estuary Partnership and monitoring partners to outline the overall monitoring program's goal, clarify 2008 objectives and hypotheses, initiate a survey design process, examine other sampling design considerations, and assess the potential of a probabilistic survey design. This section is a synthesis of discussions with the Estuary Partnership, USGS, and monitoring partners, and summary documents provided by USGS.

Initially, a probabilistic sampling design for the LCRE had been designed to support a large sampling effort at a large number of sites to monitor ecosystem condition. However, available 2007-2008 funding levels did not support this large monitoring effort. Moreover, 2007-2008 monitoring efforts were focused on undisturbed emergent wetlands, which are likely important habitats for juvenile salmon but limited in number due to past land use activities and geographic features of the basin. Thus, the monitoring partners determined that the most appropriate strategy for selecting sites so that 2008 data were comparable with past efforts was to select sites based on specific criteria (in lieu of the probabilistic design). In this section, USGS describes the process resulting in the current sampling plan, progress toward completing a survey design process, and design considerations from relevant monitoring programs. Lastly, USGS provide recommendations for future efforts to develop a sampling design for the EMP.

6.1 Sampling Design Status

When the EMP began in 2004, PNNL and the Estuary Partnership outlined a two-phase process for developing a sampling design for LCRE monitoring efforts (Lower Columbia River Estuary Partnership, LCREP, 2004). Phase I: Inventory would inventory habitats in the LCRE. During Phase I: Inventory, habitat monitoring was to describe estuarine habitat types, provide field verification of remote sensing-based project components like the Columbia River Estuary Ecosystem Classification (Classification; see Simenstad et al., 2007), and measure variability in estuarine habitats so that an appropriate population could be identified for sampling in subsequent efforts. Phase II: Long-Term Monitoring was to combine the habitat inventory with the Classification in order to refine the sampling design. Both phases were to incorporate a stratified rotational sampling design based on the Classification and include fixed and randomly selected monitoring sites.

Originally, the geographic scope of the habitat monitoring plan was the entire estuary as defined by the highest uncontrolled flood elevation. The scope of the sampling design was shallow water aquatic habitats (e.g., marshes), riparian fringe habitats, and adjacent small tidal channels in undiked areas of the estuary between the mouth and Bonneville Dam (LCREP, 2004). The navigable waterway and mainstem channel were excluded from the statistical population under consideration. Using a GIS platform and bathymetry and topography datasets, the LCRE was divided into eight hydrogeomorphic reaches. The 2004 plan then outlined the following sampling strategy for each reach: "… 20 points will be sampled, providing a total population of 160. We [the Estuary Partnership] will initiate a stratified rotational sampling design, which will utilize both fixed and randomly selected sites. Fixed sites will represent those areas closest to a pristine condition in each stratum and are intended to be carried through to Phase II of the project. These sites may already be recognized as having ecological value and should be included in the initial stage to maximize data for the long-term component of the plan" (LCREP, 2004).

The proposal submitted to BPA for the FY2007-2009 funding cycle included a scaled-down version of the 2004 design to implement Phase II monitoring. Work was proposed to: 1) assess the current status of primary and secondary productivity in three or more strata of instream channel habitats (e.g., deep main channel, shallow channel margins, lateral side-channel) of the lower river; 2) implement a status and trends monitoring program that fully describes the key ecological conditions within estuarine shallow and inter-tidal habitats of the LCRE utilizing data from vegetation, water quality, sediment cores, and prey monitoring; and 3) conduct systematic monitoring of the water and sediment quality and vegetation structure of the habitats where juvenile salmonids are present. This proposed monitoring would have focused on more than 1 habitat type within the LCRE and status and trends monitoring. A panel design was proposed, including 8 fixed sites (one in each hydrogeomorphic reach) and randomly distributed probabilistic sites in each reach. Together, the fixed and randomly distributed sites would have yielded information on the spatial and temporal variation of habitat conditions using the statistical design proposed in LCREP (2004).

However, the proposed project was not fully funded, *resulting in the removal of primary and secondary productivity from the work effort and a narrowed monitoring focus on two reaches and one specific habitat type* (emergent wetlands that are undisturbed, or "closest to pristine condition," LCREP 2004). For the 2007-2008 monitoring efforts, monitoring partners selected 4 sites in Reach H based on specific criteria (see below) and retained 2 previously sampled sites in Reach F for examining year-to-year trends. Selecting sampling sites based on specific criteria (e.g., emergent wetlands) rather than using a randomized approach is a deterministic or preferential selection process, and thus limits extrapolation of results to other emergent wetlands within these reaches or similar wetlands in other reaches. While this sampling plan does not constitute a rotational panel design as originally envisioned in LCREP (2004), the current approach is appropriate for an observational study characterizing the condition of selected habitats in Reach H. As a result of the preferential site selection criteria (see below) necessitated by limited 2007-2008 funds, the 2008 sampling effort continues Phase I: Inventory activities rather than implementing Phase II: Long-Term Monitoring activities.

6.2 Program Goals and Objectives

In 2008, the Estuary Partnership and monitoring partners outlined the goals and objectives of the overarching program and the 2008 monitoring efforts as:

- Overarching Monitoring Goal
  Assess tidally influenced wetlands in the tidal freshwater portion of the lower Columbia River estuary as juvenile salmonid habitat.

- 2008 Monitoring Goal
  Assess tidally influenced emergent wetlands in Reaches F and H as juvenile salmonid habitat.

- 2008 Monitoring Objectives
  1. To assess the year-to-year variability in vegetation, water quality, and availability of juvenile salmonid prey species in emergent tidal wetlands and the occurrence of juvenile salmon adjacent to these tidal wetlands at 2 previously sampled sites in Reach F.

  2. To characterize the variability in vegetation, water quality, and availability of juvenile salmonid prey species in emergent tidal wetlands and the occurrence of juvenile salmon adjacent to these tidal wetlands in Reach H.

6.3 Site Selection Criteria, 2008

The Estuary Partnership used the National Wetland Inventory (NWI, available at http://www.fws.gov/nwi/) in Reach H to generate a list of potential sampling sites. This initial list was filtered using the following criteria applied in previous years to select the vegetation monitoring sites:

1. The site's wetland vegetation is classified as "emergent" in the NWI layer.
2. The site has tidal connectivity with the mainstem Columbia River.
3. The site's wetland is minimally disturbed (e.g., no diking, active grazing, tide-gate modifying flow regime present at the site).
4. The area of wetland is greater than 5 acres.

During this process, Ecosystem Monitoring Project's partners determined that a randomization sampling design was not appropriate for current monitoring efforts because:

1) Monitoring was focused on a specific habitat type (undisturbed emergent wetland) and reach.
2) A limited number of emergent wetlands occur on the landscape due to past land use activities.
3) Sampling was only possible at a limited number of sites due to reduced funding.
4) Data collected in 2008 should be consistent and comparable with data collected in 2006 and 2007.

On February 8, 2008, the Estuary Partnership, NOAA-Fisheries, PNNL, and USGS met to refine the site selection criteria and further filter the list of potential sites. Field observations during reconnaissance trips held beforehand led to additional criteria refinement.

In the end, the final habitat criteria used to select the 2008 monitoring sites were:

1. The site's wetland vegetation is classified as "emergent" in the NWI layer.
2. The site has tidal connectivity with the mainstem Columbia River.

3. The site's wetland is minimally disturbed (e.g., no diking, active grazing, tide-gate modifying flow regime present at the site).
4. The area of wetland is greater than 5 acres.
5. Wetlands at the site are shallow-water.
6. The site is mainstem fringing or off-channel habitat.
7. The site is not located near immediate stressors or disturbance like industry, grazers, or recreational use.
8. Site sediments are generally smaller particle sizes, which are characteristic of lower-energy systems and more likely to support emergent marsh habitats than habitats with larger particle sizes.

Additional logistical criteria included:
1. Stream channels are present at the site to facilitate the collection of cross-section and fish data.
2. The site is fishable by beach seine or similar gear-type.
3. The site is accessible for sampling purposes and with landowner permission.

The final criteria for 2008 site selection were selected based on funding levels, the desire for data comparability with previously collected data, and other reasons outlined above. This site selection strategy focused the monitoring effort and facilitated the collection of data comparable with previous efforts. This strategy, however, does, not meet the original goal of the monitoring submitted for the FY 2007-2009, because current monitoring can only focus on 1 habitat type (undisturbed emergent wetlands) and not multiple habitat strata with current funding levels. At this time, data collected by the EMP will not support an assessment of ecosystem condition nor overall wetland condition within individual reaches due to its limited scope. The strategy does not support the collection of data that represents variation within and between different wetland types across the entire reach(es) being sampled or at an estuary-wide scale. At this time, it is not feasible to collect data facilitating the extrapolation of sampling results to the reach scale and considerations of statistical issues like the optimal size of the sampling unit, sources of error, and measures of variation. Instead, data collected in 2008 characterize a subpopulation of Reach H's wetlands (undisturbed emergent wetland), which are likely important habitat for juvenile salmon. The remaining wetland types in Reach H may have less salmon and lower abundances of marsh vegetation and wider ranges in sediment particle size and other physical attributes. While the 2008 effort provides initial information useful for understanding habitat conditions and salmonid use of undisturbed emergent wetlands in Reach H, sampling at a larger number of sites and habitat types throughout the 8 reaches is necessary to extend results to the estuary at large, assess system-wide ecosystem "health," and obtain the adequate statistical power needed for such analyses.

6.4 Survey Design Process

This year, the EMP initiated a survey design process to document monitoring metrics, methods, and sampling method variability. Further work on completing the survey design process is apt to require a specific work element in future contracts. Additionally, assessing sampling method variability will require additional data and work element support to complete the analyses.

PNNL Vegetation Metrics

Metrics monitored in 2008

- Vegetation
    - Percent cover using transect/quadrat surveys
    - Proximate areas mapped using hand-held Trimble GPS
- Elevation
    - Measured with RTK GPS
- Channel Cross-Sections (if sites have channels)
- Water surface elevation and temperature probes

Potential metrics for future monitoring:

- Shallow water bathymetry
  - Using a surveyor with RTK Rover to collect an array of points below vegetated habitats to wadeable depth.

USGS Water Quality Metrics

USGS deploys YSI 6600EDS sondes to collect the following water depth and quality data (Table 2).

Table 2: Range, resolution, and accuracy for USGS water depth and quality metrics.

Monitoring Metric	Range	Resolution	Accuracy
Water depth	0-30 ft, 0-9 m	0.001 ft, 0.0003 m	±0.06 ft, ±0.02 m
Temperature	-5 to 70 °C	0.01 °C	±0.15 °C
Specific conductance	0-100 µS/cm	0.001-0.1 µS/cm	± µS/cm
ROX optical dissolved oxygen	0-50 mg/L	0.01 mg/L	±0-20 mg/L
pH	0-14 units	0.01 units	±0.2 units
Turbidity	0-1000 NTU	0.1 NTU	±0.3 NTU

NOAA-Fisheries Fish and Prey Sampling Metrics

With funds from BPA for the EMP, NOAA-Fisheries examines the following metrics:

- Catch per unit effort (CPUE) by site and over sampling season at each site
  - Fish collected by beach seine
- Proportions of fish species (resident fish vs. salmonids) collected in beach seines by site and over sampling season at each site
- CPUE for all fish species/species of interest
- Proportions of genetic stocks present at sites per sampling event and over sampling season at each site
  - Genetic identification will be conducted on individual juvenile Chinook salmon
- Proportions of marked (hatchery) and unmarked (presumably wild) fish present at sites and over sampling season at each site
- Fish length (fork length in mm)
- Fish weight (nearest 0.1 g)
- Condition index calculated from length and weight
- Whole body lipid content
  - Likely measured on composite samples or 3-5 fish each, matched by site, sampling time, and stock
- Proportions of various lipid classes
  - Likely measured on composite samples or 3-5 fish each, matched by site, sampling time, and stock
- Average daily growth rate (e.g., over the last 14 day period)
  - Determined from otolith analysis on individual fish
- Water temperature, dissolved oxygen, and salinity
  - Collected only while sampling sites for fish
- Biomass/proportions of prey species in different taxonomic groupings in aquatic and terrestrial environments at the sites

    - Likely be a semi-quantitative estimate at best, sweep netting/net towing measured areas for a set amount of time
- Biomass/proportions of prey species in different taxonomic groups and of aquatic and terrestrial origin in stomach contents of juvenile salmon

With non-BPA funds (e.g., from NOAA-Fisheries, Portland Harbor Trustees), NOAA-Fisheries may conduct additional analyses, yielding data on:

- Juvenile salmon whole body concentrations of PCBs, DDTs, and PBDEs
    - Likely measured on composite samples or 3-5 fish each, matched by site, sampling time, and stock
- Concentrations of PCBs, DDTs, PBDEs and PAHs in juvenile salmon stomach contents
    - Measured on composite samples of 5-10 fish
- Concentrations of PAH metabolites in juvenile salmon bile
    - Measured on composite samples of 5-10 fish
- Plasma vitellogenin levels in individual fish as an indicator of exposure to estrogenic compounds

Additionally, during the survey design process, USGS compiled background information on probabilistic sampling design theory and associated issues that may be useful for future sampling design efforts in the LCRE. This information can be found in Appendix 2.

6.5 Examples of Sampling Design Considerations from Other Monitoring Programs

Monitoring programs throughout the country use designs spanning the spectrum of survey design types to address diverse management and regulatory issues. The geographic coverage of surveys range from nationwide, regional, and localized areas and can be further constrained to address a specific attribute of a localized area. Here, USGS provides examples of monitoring programs that assess conditions of a region (coastal component of EPA's Western Environmental Monitoring and Assessment Program, EMAP), localized area (San Francisco Bay), and a particular component of a localized area (eelgrass habitat in Puget Sound, WA). An excellent resource is Dr. John Skalski's thorough discussion of recommended designs for status and trends and action effectiveness monitoring programs in the LCRE (Appendix B, Johnson et al., 2008).

In the examples below, the process used to formulate a sampling design is adaptable to the EMP. Generally, planning and executing a sample survey involves: (1) completing a Survey Design Process, which includes establishing objectives and design requirements (e.g., precision goal/confidence limits needed for results, types of questions or hypotheses addressed), establishing the target population and sampling frame, selection of the survey design and selection of a random sample of units, (2) specification of a response design to be followed for collecting data from the selected units, (3) summarizing the data with statistical analysis procedures appropriate for the survey design, and (4) communicating results.

6.5.1 EPA's Western EMAP Coastal Program

The Western EMAP Coastal Program is highlighted here to illustrate the design of a regional study and how monitoring in the LCRE might be structured to inform assessments of the status and trends of west coast estuaries. The intent of this program is to apply EMAP's monitoring and assessment methodologies and create an integrated and comprehensive coastal monitoring program along the west coast. Survey objectives are to: 1) describe current ecological conditions of estuaries in Washington and Oregon using environmental quality indicators and a statistically-based survey design; 2) establish a baseline for evaluating change in estuarine resources over time; 3) develop and validate methods for future coastal monitoring and assessments; 4) transfer technical approaches and methods for designing, conducting and analyzing data from EPA to the states and others; and 5) build a water monitoring program with the states and others for improved management and protection of western estuaries.

EMAP Design Method

Two features of EMAP are the probability-based selection of sample sites and the use of ecological indicators. The development of an EMAP-type probabilistic survey design begins with creating a list of all units, or sampling locations, of the target population from which to select the sample. Sampling locations are then selected randomly from this list. The list or map that identifies every unit within the population of interest is termed the sampling frame. This type of survey design allows for estimates of the entire resource of interest, in this case the estuaries of Oregon and Washington. The sampling frame for the EMAP Western Coastal Program was developed in GIS from USGS 1:100,000 scale digital line graphs and included the estuarine area of Oregon and Washington, covering 8,670 square kilometers (or 3,348 square miles). Sample locations were then selected from the sampling frame using methods described in Diaz-Ramos et al. (1996), Stevens (1997), and Stevens and Olsen (1999).

Monitoring Overview

During summer 1999, EPA began assessing the ecological condition of small estuaries in Oregon and Washington (Hayslip et al. 2006). In 2000, sampling expanded to the Puget Sound and the Columbia River estuary. The overall assessment required the integrated analysis of data collected from small estuarine systems in 1999 with data collected from larger estuarine systems in 2000. A total of 50 sampling locations were selected for sampling during 1999 campaign in smaller estuaries using the method described above.

The 2000 sampling in Washington State included only Puget Sound and its tributaries. For this component, EPA slightly modified the sites selection process to coordinate with a survey previously conducted by NOAA’s National Status and Trends Program and to facilitate the combination of the existing NOAA data with EMAP data. In this case, the EMAP sampling frame was extended to include Canadian waters at the north end of Puget Sound, and overlain on existing NOAA monitoring sites. EMAP selected 41 stations previously sampled by NOAA and 30 new EMAP stations.

In Oregon for the 2000 effort in the Columbia River main channel, the sampling design split the area into two subpopulations, the lower saline portion vs. upper, more freshwater portion, where 20 and 30 sites were sampled, respectively. Additionally, Tillamook Bay was allocated 30 of the total 50 sampling sites. For analyses and reporting, all sites from both states and for both years were combined to represent the condition of the entire 8,670 square kilometers of estuaries in Oregon (710 square kilometers) and Washington (7,960 square kilometers).

Monitoring to Inform Management or Regulatory Issues

Most monitoring programs are structured to address management or regulatory issues by monitoring important attributes of the system. For example, the EPA’s process for identifying indicators is applicable to the development of other monitoring programs (Figure 10; EPA, 2008). This process entails identifying important ecosystem attributes based on both scientific information and regulatory and environmental policy goals, and then using this information to develop assessment questions. The assessment questions link regulations and policy goals to specific indicators representing important ecosystem attributes. The indicators, in turn, inform assessment questions. The overall program would provide a measure of overall system condition and allow an assessment of each indicator (specific attribute) and/or metric.

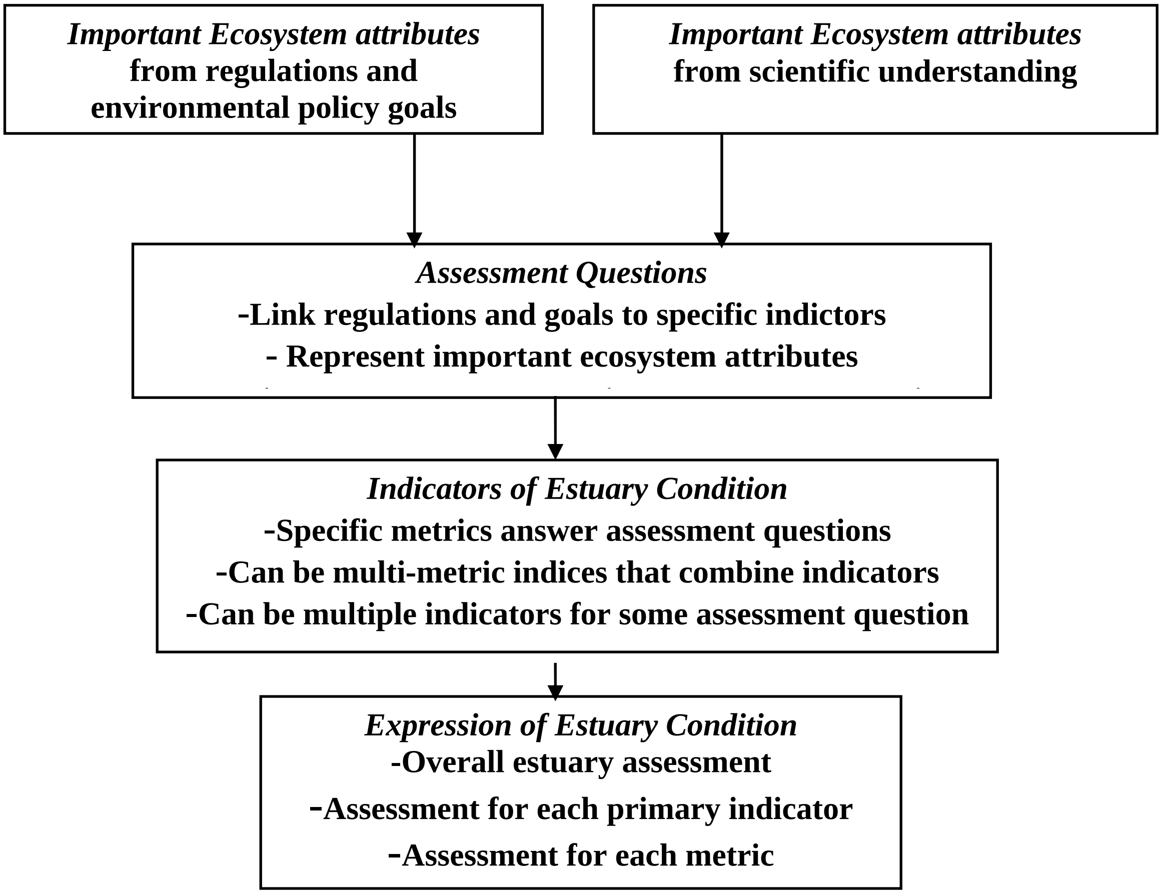


Figure 10: Process for formulating monitoring indicators of system condition (EPA, 2008).

EPA conducted the Western EMAP Coastal Program study within the context of the Clean Water Act (CWA). Since the CWA aims to restore and maintain the chemical, physical, and biological integrity of the Nation's waters, EPA measured chemical (e.g., sediment chemistry and fish-tissue contaminants), physical (e.g., water clarity and silt-clay content), and biological (fish and invertebrate communities and toxicity testing) conditions. Coastal EMAP uses ecological indicators, or measurable characteristics of the environment, to quantify these conditions. Hayslip et al. (2006) describe the significance of each indicator within the CWA context. Jackson et al. (2006) describes EPA's methods for the development of ecological indicators. EPA also convened workshops to help develop and define important indicators and metrics for assessing ecosystem health (see http://www.epa.gov/emap/greatriver/grewkshp.html).

6.5.2 San Francisco Estuary

The San Francisco Estuary (SFE) monitoring program is highlighted here (San Francisco Estuary 2008), to illustrate some sampling-design considerations associated with status and trends monitoring for water quality (including toxic contaminants) and sediment in a localized monitoring program.

Jassby et al. (1997) describes the sampling-design considerations along the SFE's longitudinal gradient that are related to salinity, suspended particulate matter, and chlorophyll *a*. These three water-quality parameters are commonly monitored in estuaries. In this paper, they address a common monitoring issue of how samples should be collected to facilitate comparison of regional attributes (like mean concentration or mean species abundance) among various subregions, patches, or strata. Answering this question requires understanding the spatial and temporal variability in and among regional attributes of interest for monitoring. The objective of the SFE program is to determine the best sampling design for capturing longitudinal spatial variability so that comparisons can be made among longitudinal sub-regions of the estuary. If the program desired to capture vertical (e.g., water column) or horizontal spatial components, then different sampling-design considerations would be required. Similar incorporation of spatial variability into sampling designs may be needed for LCRE monitoring programs assessing environmental and biological differences among horizontal habitat strata (e.g., salmonid usage of shallow tidal wetland areas, potential for contaminants or invasive species to occur among and between shallow-water strata).

Jassby et al. (1997) compare precision estimates for the three water-quality parameters along a longitudinal profile and among three broad sample-design categories (simple random, systematic, and stratified sampling). The authors consider how many samples are required for each design category given a desired level of precision (e.g., $p \leq 0.05$), and compare the performance of the designs. Deciding on a station array requires consideration of three linked issues, addressed here in sequence. First, what kind of sampling design should be adopted (e.g., random, systematic or stratified)? Second, how can the precision (variance) of the transect mean be estimated? Third, for a prescribed level of precision, how many samples (stations along a transect) are required?

The longitudinal transect data for the three parameters were grouped into strata or reaches based on a regression-tree building method optimized to minimize the variability within strata and to maximize the variability between strata. The number of strata was found to change among the three parameters within a sampling season and within a parameter among seasons. For example, in April chlorophyll *a* exhibited near homogeneity, allowing one stratum to be representative of concentrations, over a relatively long region covering almost 100 km. For the same region, however, suspended particulate matter required four strata. On the other hand, looking at just chlorophyll a among seasons showed greater variability over the entire sampling length—8 strata in September and 5 strata in April.

Overall, stratified random sampling performed better than simple random sampling for all parameters. However, systematic sampling performed better if there were at least 10 sampling locations. If within stratum variability was known, optimal allocation (stratified sampling with unequal probability) was able to increase precision another 23-45% for the three parameters. If however, the number of samples was increased to 20 locations, systematic sampling exceeded even stratified random with optimal allocation. Whether one stratified the systematic sampling or used just simple systematic sampling, the performance varied among the three measured parameters: stratified was slightly better for salinity, worse for suspended particulate matter (regardless of sample size), and sometimes better/sometimes worse for chlorophyll a (Jassby et al. 1997). Therefore, if enough sample locations can be collected simple systematic sampling was the best without the need to stratify the samples.

The “Regional Monitoring Program for Water Quality in the San Francisco Estuary: 2008 Program Plan” (SFE-RMP) provides a good example of how management, fiscal and statistical sampling-design considerations are combined in developing a research monitoring plan. The following excerpts from the SFE-RMP serve to highlight these considerations.

> The Status and Trends (S&T) monitoring program for water and sediment was last revised in 2002 to include a randomized design suited to addressing questions related to a representative characterization of contaminant concentrations in water and sediment. Water sampling for the S&T monitoring program occurs once a year in the summer. Summer has been selected for sampling because inter-annual variation due to natural variables, primarily freshwater inflow, is minimized during this period. In 2007 as part of the redesign process, a recommendation was made to alternate seasons in which sediment is sampled. A primary goal of the sediment sampling is to understand what is causing sediments to be toxic, and there appears to be a seasonal aspect, with winter sampling exhibiting higher toxicity. In 2008, sediment will be

collected in summer as in prior years; however, starting in 2009, sediment samples will be collected in alternate seasons starting with a wet season (winter) collection event. The Exposure and Effects workgroup also recommended that sediment be analyzed for benthos in addition to sediment chemistry and toxicity. With all three lines of evidence (i.e., benthos, sediment chemistry and sediment toxicity), conducting sediment assessments in accordance with the Sediment Quality Objectives, which are scheduled to be promulgated in 2008, will be possible.

The number of S&T monitoring stations varies by segment for water and sediment measurements based on current Regional Board management priorities, statistical power achieved for key contaminants, and fiscal considerations. In addition, five historical water stations and seven historical sediment stations are sampled to maintain time series for long-term trend analyses. In 2007, as part of the program redesign, statistical power analyses were conducted to determine the optimal number of stations to detect trends and exceedances of water quality objectives.

The preceding regional example from SFE provides insight into some of the considerations that are important regarding a strong sample design, while also illustrating the complexity of sampling-design considerations in a large heterogeneous geographic region. These examples also serve to point out the importance of having data that quantifies the variability among and within various spatial and temporal components that match the specific sampling parameters, expected statistical-summary reporting attributes (e.g., mean, total, standard deviation, maximum and minimum) and objectives of the project. While a simple randomized sample design may suffice if there is no *a priori* knowledge of the overall system being studied, the more that is known about the spatial and/or temporal variability of the attributes being monitored, the more the sampling design can be structured to maximize the potential to address complex and specific research questions with greater precision.

6.5.3 Eelgrass Survey in Puget Sound, WA

Another example describes a localized study from Puget Sound that assessed the status and trends of eelgrass habitat (*Zostera marina L.*; Berry et al., 2003). This study's results and methods are good examples of analytical frameworks that include on-going design evaluations. The specific work discussed here is part of the larger Submerged Vegetation Monitoring Project, which monitors status and trends of several submerged aquatic vegetation species in Puget Sound. The Submerged Vegetation Monitoring Project was, in turn, nested in the larger Puget Sound Ambient Monitoring Program, which is a multi-agency research effort tracking ecosystem health indicators. Information is available at: http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_monitoring.aspx.

Site Selection

To address the goals of the project, the investigators developed a sampling design that would allow valid inferences about the population of *Z. marina* throughout Puget Sound on an annual basis (status) and over time (trends). The protocol uses sampling with partial replacement (SPR), a type of rotational design that optimizes the joint goals of accurately estimating population status and accurately and precisely estimating changes over time (Skalski, 1990; Berry et al., 2003). A fixed fraction of the sampling sites (20 percent for this study) is replaced annually with a new random selection. The precision of *Z. marina* abundance estimates is improved over time as subsequent years of data are used to update site-specific estimates. For each sampling year, there is an initial estimate of *Z. marina* area based on sampling during that year and then an adjusted estimate is made when data from the following year become available. Sites replaced after initial sampling were not available for sampling again for five years.

To randomly select sampling sites, the investigators developed a sampling frame that delineated all potential *Z. marina* habitats and defined sites using GIS. The boundaries of these habitats were defined using digital data that approximated the minimum and maximum depth of *Z. marina* occurrence. The minimum depth boundary was defined using an approximate Mean High Tide line, which was digitized from 1:12,000 orthophotos. The maximum depth boundary was defined using a –20 foot depth contour, which was interpolated from NOAA soundings. The adequateness of the depth boundaries for *Z. marina* habitat is limited by the age and resolution of the data used to develop them. However, the boundaries narrowed the survey area to include only shallow littoral areas where *Z. marina* might occur. All potential *Z. marina* habitats were stratified based on the geomorphological characteristics of Puget Sound.

The investigators state that the primary purpose of the stratification was to produce the most precise extrapolation of *Z. marina* from the sampled sites over the study area. The secondary purpose of the stratification was to compare different bed types. Two broad strata were defined: 1) Flats Areas, with extensive broad shallows, such as river deltas, and pocket beaches and 2) Fringe Areas, with relatively linear shorelines where potential *Z. marina* habitat is limited to a narrow band by bathymetry. Fringe sites were defined to include a 1000 m segment of a –20 ft depth contour. The length of 1000 m was chosen simply because it could be easily sampled in half of a day and the investigators believed that it was a large enough stretch of shoreline to represent bed characteristics in most areas. The authors further delineated the fringe area into narrow and wide categories. A threshold width of 305 m (1000 ft) was used to differentiate narrow and wide sites. The investigators found that wide fringe sites have a much larger range in the amount of *Z. marina* than narrow fringe sites. Partitioning the fringe strata into narrow and wide fringes greatly improved the precision of the overall estimate.

In addition to the random sampling sites selected for the 5-year sampling rotations, 6 fixed sites were chosen for long-term sampling. The fixed sites are intended to provide continuous monitoring data to compare with shorter time series (5 years) at the randomly selected sites. The fixed sites were selected after informal consultation with a group of Puget Sound scientists familiar with *Z. marina* distribution throughout the state. The sites were selected to represent a range of geographical locations, management concerns, research interests, and habitat types.

In the first year of sampling, 9 “flats” sites, 45 “narrow fringe” sites, and 6 “wide fringe sites” were randomly selected for sampling. A decision was made, based on the assumption that within-site variation is larger among flats sites, to allocate a larger relative proportion of sites to the flats stratum. Following the first year of sampling, the authors estimated the optimal sampling allocation among strata by considering variance associated with each stratum, desired coefficient of variation and sampling time required for each stratum (Cochran, 1977). They found that a 3:1 ratio of narrow to wide fringes was optimal. Thus, 15 wide fringe sites were selected to sample in 2001. In 2002, the rotation of sites was implemented by selecting 20% of the sites for replacement with newly selected random sites in each stratum.

The investigators also created regions that allow for *post hoc* analysis of the data over smaller geographic areas. They defined five regions based on oceanographic basins and habitat characteristics with the boundaries along oceanographic sills as delineated by Ebbesmeyer et al. (1984). The regions were developed to account for two competing goals: (1) to define sufficiently discrete geographic areas to capture smaller scale trends and (2) to maintain enough sites per region to attain acceptable statistical power (Berry et al. 2003). Random site selection was completed with one criterion, that at least three fringe sites would be represented in each region. If the random draw contained less than three fringe sites per region a new random draw was selected.

Samples were collected between June and October during the period of maximum vegetative biomass (Phillips 1984). This broad sampling window allowed field crews to visit many sites over a large geographic area with a single vessel. To increase the comparability of individual sites over multiple years, the sites were sampled at approximately the same date among years. Over the course of the study, the protocols were amended and updated as necessary based on information that was gathered in initial efforts.

Similarly, the adequacy of the sampling design for the Submerged Vegetation Monitoring Project was evaluated after several years of data collection. The statistical framework for this study was described in appendix L of Berry et al. (2003) by Dr. John Skalski. This framework describes the statistical methods used to estimate *Z. marina* area within sites and across Puget Sound based on survey sampling data and the calculation of variance estimates for within-site sampling error as well as Puget Sound-wide sampling error. The report also describes the framework for the rotational sampling designs that were used to estimate eelgrass area and updated annual estimates in year i using data collected in year i +1. Annual changes in eelgrass area were calculated and the methods for determining a five-year trend described. After the first four years of data collection, an assessment of whether the statistical framework was performing as intended and whether specific refinements to the sampling and analysis procedures were necessary was conducted (Dowty, 2005). Dowty (2005) provided an assessment of whether the project was meeting the key monitoring objective to reliably detect a 20% loss of *Z. marina* in Puget Sound over 10 years, recommendations for improvements to the study design that increased the ability to meet monitoring and management needs within current resource constraints and provided a validation that assumptions made in the initial sampling design before data were available were appropriate.

6.5.4 Synthesis of Sampling Designs Considerations from Other Programs

In summary, these examples illustrate design considerations and methods applicable to the development of a sampling design for the EMP. In some examples, programs with the goal of long-term monitoring started with a subset of fixed sites and observational studies. Sampling designs that revisit the same set of sites have been implemented elsewhere with the intent of assessing trends (Urquhart et al. 1998) and there is precedence for the selection of sites based on their perceived importance. For instance, Berry et al. (2003) selected what they described as "fixed sites" with the intent of providing continuous monitoring data to compare with shorter time series at randomly selected sites. These fixed sites were selected after informal consultation with a group of Puget Sound scientists familiar with *Z. marina* distribution throughout the state and were selected to represent a range of geographical locations, management concerns, research interests, and habitat types. These strategies are somewhat similar to the site selection process used in 2008 and may be appropriate for Phase I: Inventory. Our discussion of these examples indicate that the Estuary Partnership and monitoring partners should consider expanding the EMP to include a probability-based sampling strategy in order to provide data for scientific inferences about the estuary system as a whole as funding becomes available.

6.6 Recommendations

In future sampling design efforts, USGS recommends that the Estuary Partnership and monitoring partners refine the EMP monitoring by: (1) continuing the Survey Design Process, which includes establishing objectives and design requirements (i.e., desired precision goals and confidence limits, types of questions or hypotheses addressed), target population, sampling units, sampling frame, design selection, and a random selection of sample units; (2) specifying a response design to be followed for collecting data from the selected units; and (3) summarizing the data with statistical analysis procedures appropriate for the new survey design. If needed, the EPA's website provides more discussion of the above terms (http://www.epa.gov/nheerl/arm/designpages/monitdesign/survey_overview.htm).

To facilitate the completion of these above steps, the following recommendations should be considered (as funding allows):

1. The Estuary Partnership and monitoring partners convene a workgroup or a workshop to discuss proposed goals and objectives and associated metrics, methods, and survey design. This review may consider the current and future monitoring efforts.

2. The EMP revisit the original recommendations for a probability-based sampling design set forth in LCREP (2004) and adapt this plan to address the current programs goal and objectives.

3. The program incorporate Dr. John Skalski's recommendations for a status and trends and action effectiveness monitoring program (Johnson et al., 2008) to the extent possible given current goals and objectives and fiscal constraints.

4. The EMP assess the variability in measured metrics by examining data collected in 2008 and previous years (or when enough data are available to support a variability analysis). This assessment is needed to determine the level of effort required to accurately represent monitoring metrics, performance of the statistical framework, and refinements (if necessary) to the sampling and analysis procedures.

6.7 Conclusions

At existing funding levels, the Estuary Partnership and monitoring partners can only sample a specific habitat attribute (undisturbed emergent wetlands) of the LCRE and at a small number of sites in the EMP. This project is not capable of assessing all types of tidally influenced wetlands in the tidal freshwater portion of the lower Columbia River and estuary as juvenile salmon habitat. Recognizing this limitation, the goals and objectives of the project should be refined to reflect this focus on undisturbed emergent wetlands and their role as salmonid habitat. Additionally, since this monitoring effort concentrates on a specific habitat type and is not based on a probabilistic design, results cannot be applied to all tidally influenced wetlands within a reach or at the estuary scale. Although there are no randomly selected sites in this program, selected sites can be re-sampled over time to provide information on trends in undisturbed emergent wetlands. If this project was capable of assessing more wetland habitat types and more sites in the LCRE, then a different approach would likely be required for selecting sampling sites.

In this section, USGS discussed three monitoring programs and their approaches to sampling designs and conducting research within the context of management and regulatory issues. As the EMP matures, these examples may provide guidance for restructuring program goals and objectives, defining new indicators and metrics, and developing a rigorous, defensible sampling design accounting for spatial and temporal variability at a large number of sites. Such development will facilitate the Estuary Partnership and monitoring partners moving the EMP from Phase I: Inventory to Phase II: Long-Term Monitoring (LCREP, 2004). As resources become available for developing the EMP, the Estuary Partnership and monitoring partners can draw on the substantial regional and national expertise and its coordination with other groups like the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) to formulate monitoring designs.

7.0 2008 Sampling Sites for Vegetation, Sediment, Water Chemistry, and Salmon

In 2007-2008, the EMP partners selected 4 sites in Reach H for monitoring. Reach H sites were: (1) Hardy Creek, near North Bonneville, WA; (2) Pierce Island, across from Hardy Creek; (3) Franz Lake, near Skamania, WA; and (4) Sand Island, near Rooster Rock State Park, OR (Figure 11).

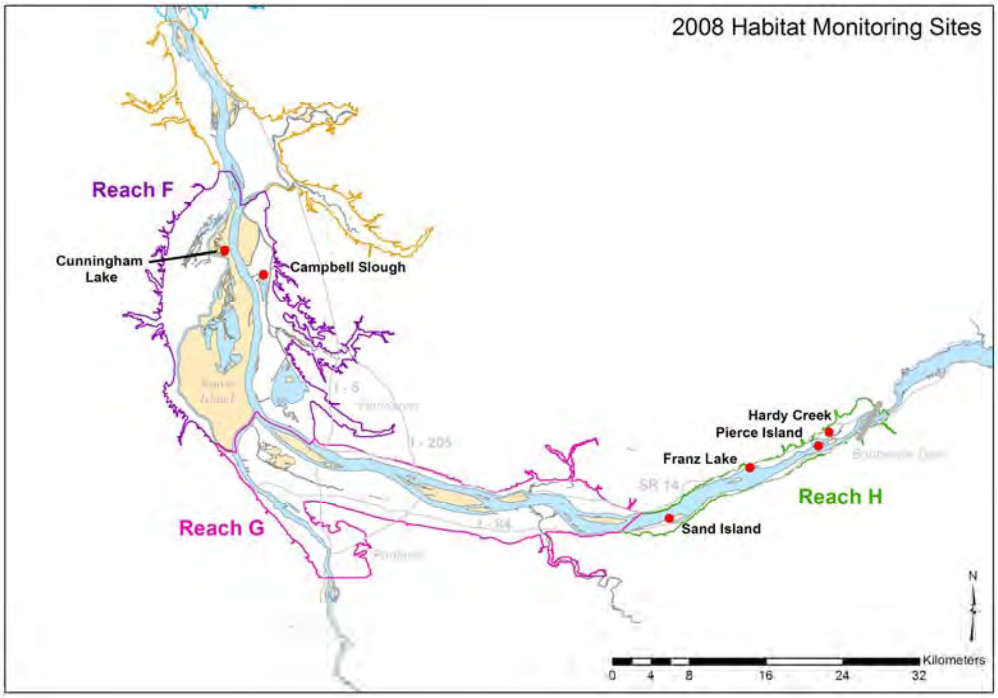
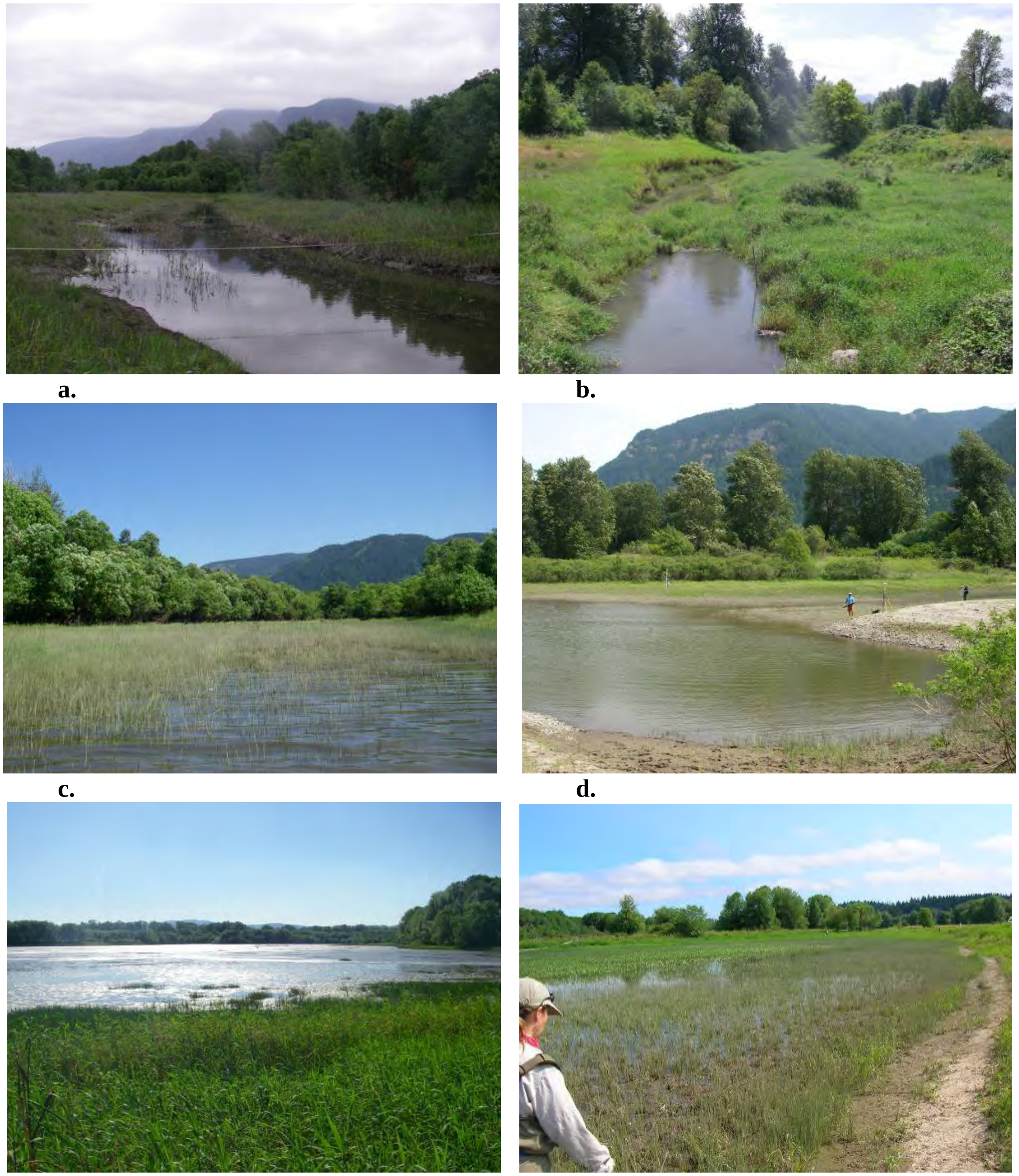


Figure 11: Map of 2008 sites in Reaches H and F.

Franz Lake and Hardy Creek sites are part of the Pierce National Wildlife Refuge. The Franz Lake site (Figure 12a) is an expansive wetland with a channel extending 2 km from the mouth of the slough to a large ponded area, with the monitoring area approximately 350 m from the mouth. Several beaver dams have created a series of ponds along the length of the channel. The channel is further characterized by fine (mud/silt) sediments and large areas of shallow-water wetland with fringing bank gradually sloping to upland. Analogous to the Franz Lake area, the Hardy Creek site includes a long channel leading to a system of ponds (Figure 12b); however, the ponds are regulated by water management devices aimed at perpetually maintaining standing water for wildlife within the Refuge. Hardy Creek is a perennial stream, with a narrow band of high emergent marsh along the channel margins. The monitoring area was approximately 1.7 km from the mouth of the channel.

Pierce Island is owned by the Nature Conservancy and Sand Island is part of Rooster Rock State Park. Both mainstem island sites are broadly characterized by emergent wetlands leading to ponded areas. As a dredge disposal site, the Sand Island (Figure 12c) study area includes sandy sediments and a high, steep banked bluff to the north side of the site. The Pierce Island site (Figure 12d) has coarser (sand/cobble) sediments and a lower steeply rising bank to the upland reaches of the island.

Downstream of Reach H, the remaining 2 sites for 2007-2008 monitoring are in Reach F (Cunningham Lake and Campbell Slough; Figure 11). These sites have been surveyed annually since the original 2005 monitoring. Cunningham Lake is located at the end of Cunningham Slough approximately 6.4 km from the mainstem of the Columbia River (Figure 12e). The second site, Campbell Slough, is located approximately 1.4 km from the mainstem of the Columbia River (Figure 12f). At Campbell Slough, there was noticeable evidence of grazing during the 2008 survey, though no cows were observed during the site visit. In the absence of a true rotational-panel sampling design, these two sites have been included within each annual survey to better understand inter-annual variability in vegetation and fish use patterns.



a. b. c. d. e. f.

Figure 12: Reach H sites: a) Franz Lake, b) Hardy Creek, c) Sand Island, d) Pierce Island; Reach F sites: e) Cunningham Lake, f) Campbell Slough.

In 2008, PNNL monitored vegetation conditions at all Reach H sites and additionally at 2 Reach F sites, where they surveyed vegetation in 2005, 2006, and 2007. NOAA-Fisheries collected fish samples during spring and summer at all Reach H sites and Campbell Slough in Reach F, where they monitored fishes in 2007. USGS collected sediment samples at all Reach H and F sites, and deployed water quality monitors at Campbell Slough and Sand Island.

8.0 Vegetation Monitoring

PNNL monitored vegetation from July 21-25, 2008 at the 4 Reach H and 2 Reach F sites (Figure 11). They surveyed wetland topography and characterized vegetation cover and plant community structure at these sites.

8.1 Methods

8.1.1 Channel Metrics

Channel cross-sections were surveyed at sites containing channel networks. This metric lends itself to understanding the relationships between cross-section dimensions, marsh size, and opportunity for fish access, which are currently being developed for wetlands elsewhere in the Columbia River estuary. This effort will aid in understanding the channel dimensions necessary to maintain a marsh ecosystem during restoration efforts. The primary objective of this sampling is to determine if sites in Reach H have cross-sections comparable with other locations in the LCRE. When possible, we collected 5 channel cross-sections from the mouth of the main marsh distributary channel to the headwaters of this channel. Intermediate cross-section surveys were done at the confluence of major secondary channels or equidistant along the channel, as appropriate.

8.1.2 Transect Surveys

As in previous years, we surveyed sites for elevation, determined percent cover of vegetation along transects, and mapped prominent vegetation types. Upon arrival at a site, the optimum location of transects was established so that all major plant communities from the water's edge to the upland area would be included in the survey. Typically, 3 transects were established at a site and radiated from a hub. A station was also designated for each site from which photographs were taken to document the 360-degree view.

Above the influence of tidal fluctuation, rebar was installed to serve as a benchmark for making all local elevation measurements. This benchmark was surveyed using a Trimble real time kinematic (RTK) global positioning system (GPS) with survey-grade accuracy. All vertical survey data were referenced to NAVD88 while horizontal data were referenced to 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, or estimate of error, for each set of static data collected by the base receiver. Elevations were surveyed either directly with the RTK or with an auto level referenced to the established benchmark.

Trimble Geomatics Office (TGO) was used to process the data. Each survey was imported and overviewed. Benchmark information was entered into TGO and rover antenna heights were corrected for disc sink (measured at each survey point to the nearest half inch) at each point. The survey was then recomputed within TGO and exported in a GIS shapefile format. Surveys were visually checked within TGO and GIS software for validity.

Along each transect, vegetative percent cover was evaluated at 2-m intervals. If the transect length exceeded 100 m and/or the vegetation was deemed homogeneous, evaluations were conduced at 3-m intervals. At each interval on the transect tape, a 1-m^2 quadrat was placed on the substrate and percent cover was estimated by 2 observers. An average of the 2 observations was entered for each station to minimize observer bias. In addition to vegetative cover, features such as bare ground, open water, wood, and wrack were evaluated. When plant identification could not be determined in the field, a specimen was collected for identification using keys or manuals in the laboratory. If an accurate identification was not resolved, the plant remained "unidentified" within the database. Where visibility through the water column confounded assessments, the degree of submerged aquatic vegetation coverage was estimated to the extent possible by the observers. Sediment character was qualitatively noted within the transects (e.g., fines, mixed coarse, sand).

All initial data assessments were recorded on data sheets during site visits, and subsequently transferred into Microsoft Excel at the laboratory. Quality assurance checks were performed on 100% of the data entered. 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 kept.

8.1.3 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 loaded into a GIS where site maps showing major vegetation communities and features were created.

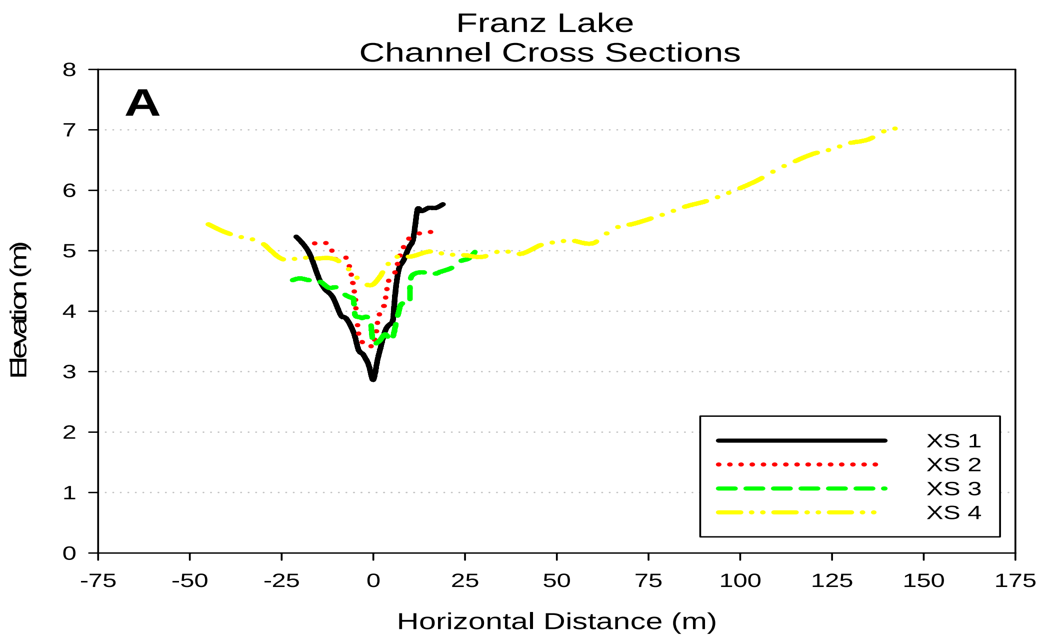
8.1.4 Hydrology

Water level loggers (Onset Computer, HOBO Water Level Logger) were placed at 5 of the 6 sites this year (Cunningham Lake was the exception due to the lack of prominent channel for placement). These data loggers record water level and temperature and were set to record at 1-hour intervals. They will be retrieved and downloaded for analysis in 2009.

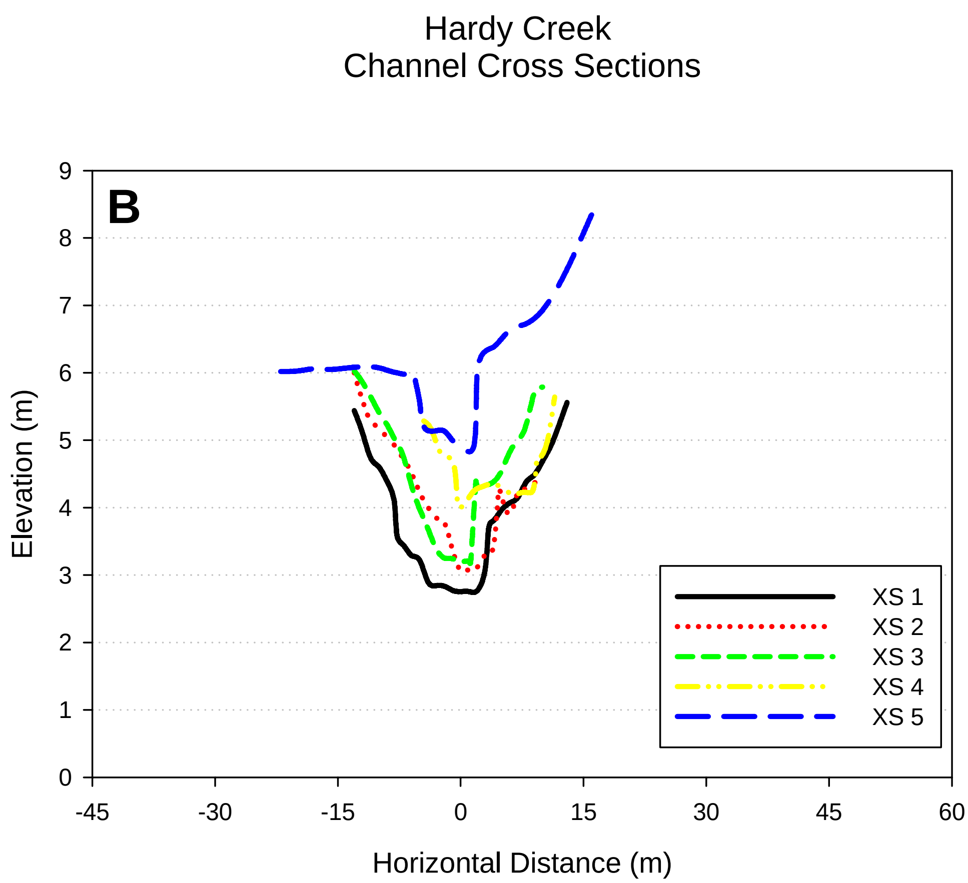
8.2 Results

8.2.1 Channel Cross-sections

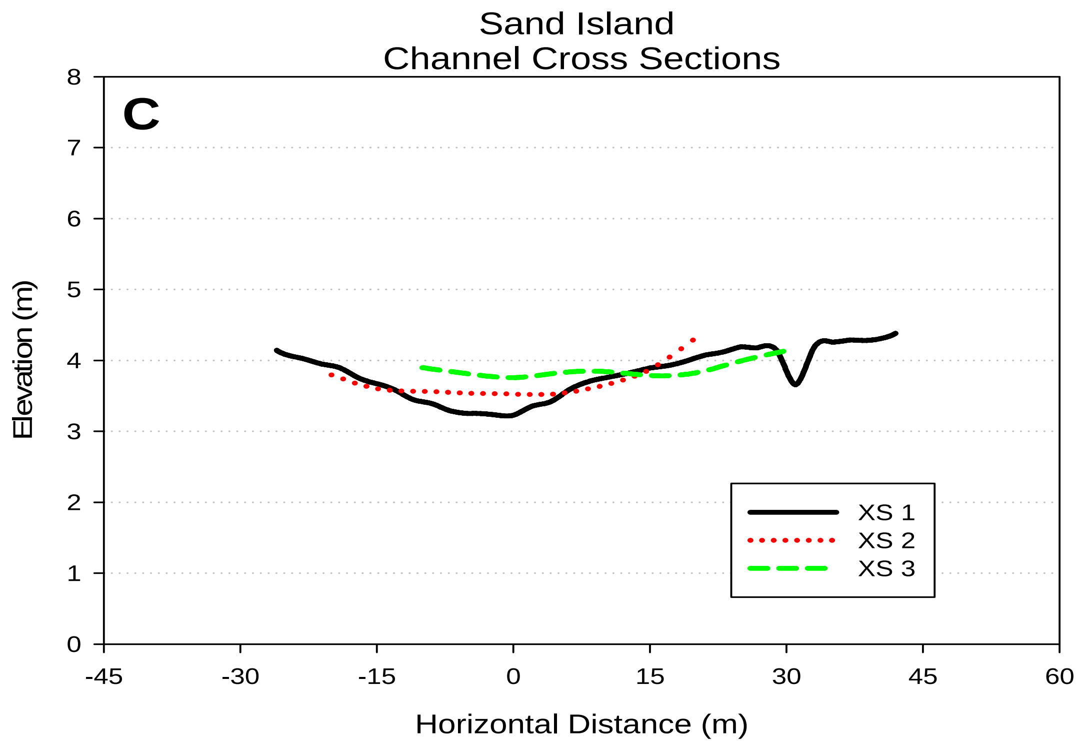
Elevations of the channel cross-sections are shown in Figure 13. For all sites, we collected the first cross-section at the mouth of the channel and then collected subsequent cross-sections progressing toward the upper portion of the study area. Vegetation surveys coincided with the channel cross-section surveys at the following locations shown in Table 3. Cross-sections were not conducted at Cunningham Lake since it lacked a prominent channel. The slough at the Campbell Slough site may be measured in future years if time permits. Further analysis of cross-channel data will coincide with the Estuary Partnership’s Reference Site Study and is scheduled for Fall 2008.

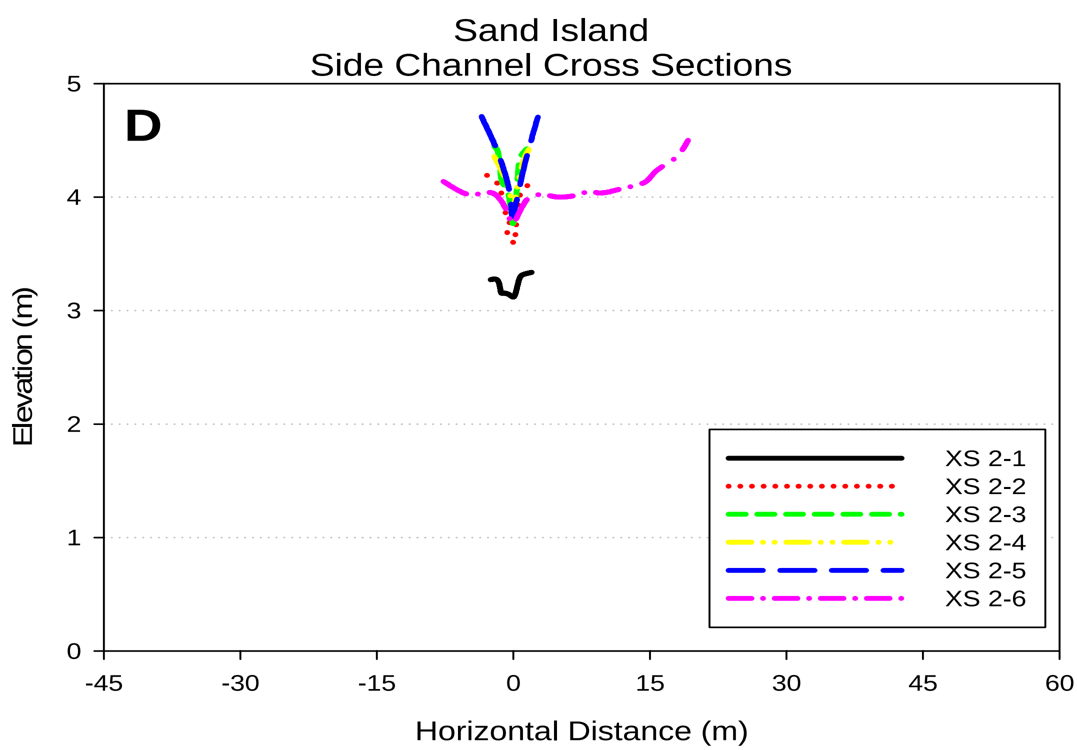


Franz Lake
Channel Cross Sections
A
Elevation (m)
Horizontal Distance (m)
0
1
2
3
4
5
6
7
8
-75
-50
-25
0
25
50
75
100
125
150
175
XS 1
XS 2
XS 3
XS 4



Hardy Creek
Channel Cross Sections
B
Elevation (m)
Horizontal Distance (m)
0
1
2
3
4
5
6
7
8
9
-45
-30
-15
0
15
30
45
60
XS 1
XS 2
XS 3
XS 4
XS 5


Sand Island
Channel Cross Sections
C
Elevation (m)
Horizontal Distance (m)
XS 1
XS 2
XS 3
0
1
2
3
4
5
6
7
8
-45
-30
-15
0
15
30
45
60


Sand Island
Side Channel Cross Sections
D
Elevation (m)
Horizontal Distance (m)
XS 2-1
XS 2-2
XS 2-3
XS 2-4
XS 2-5
XS 2-6
0
1
2
3
4
5
-45
-30
-15
0
15
30
45
60

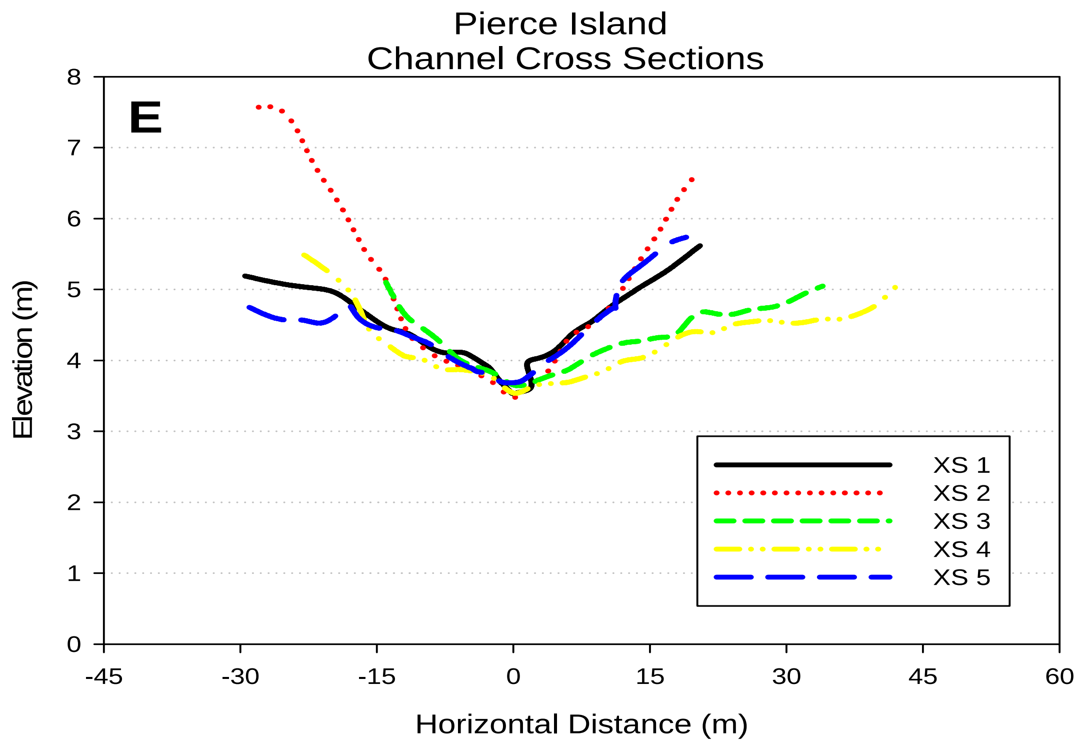


Figure 13: Elevations of 5 channel cross-sections at: A) Franz Lake; B) Hardy Creek; C) Sand Island; D) Sand Island side channel; and E) Pierce Island.

Table 3: Cross-sections where vegetation surveys were collected.

Site	Cross-section
Franz Lake	3,4
Hardy Creek	5
Sand Island	1
Pierce Island	2,3

8.2.2 Mapping and Transect Surveys

Vegetation patterns observed at Reach H sites were similar to those observed in other surveyed reaches. Common spikerush (Eleocharis palustris) and wapato (Sagittaria latifolia) dominated lower elevations, reed canary grass (Phalaris arundinacea) at mid-elevations, and willows (Salix spp.), cottonwood (Populus balsimifera), and ash (Fraxinus latifolia) at the upland border. Site maps showing vegetation distributions (Figure 14-Figure 19) illustrate vegetation patterns and locations of major species groups related to tidal channels.

Elevations of species observed during 2008 sampling are shown in Figure 20. Species were generally found at higher elevations in Reach H relative to Reach F because of the higher elevation of the riverbed in Reach H. Correcting the elevations from the North American Vertical Datum of 1988 (NAVD88) to the Columbia River Datum can alleviate the differences due to the increasing elevation of the riverbed. However, at this time, elevation corrections to the Reach H data have not been conducted.

In general, elevations of the dominant vegetation communities fall within a narrow range of 1 to 2 m. Exceptions are some tree species where the cover may have been due to overhanging vegetation, with the plants rooted at different elevations. Also, reed-canary grass (PHAR), horsetail (EQSP), and plantago (PLLA) have broad elevation ranges due to adaptations with and between species. Elevations where some species occur, particularly wapato (SALA) and spikerush (ELPA), are more likely resulting from water inundation timing rather than simply elevation. For example, wapato was found at the upper and lower transects of Franz Lake (channel cross-sections 3 and 4), which varied approximately 1 m in elevation and inundation at the upper transect was modified by extensive beaver dams. Data from water level sensors will be evaluated after retrieval in 2009 to determine the importance of inundation periods for these wetland communities.

Species observed in 2008 at Campbell Slough and Cunningham Lake were similar to those observed in previous years (Table 4). For all the 2008 sampling sites, reed-canary grass and common spikerush were the most commonly occurring species, except at Franz Lake and Hardy Creek (Table 5). At Franz Lake, water smartweed (Polygonum amphibium) was the most common species whereas grasses with bare ground were the dominant cover types at Hardy Creek. Bare ground was also a prominent feature at the Pierce and Sand Island sites. Percent cover of species is provided in Table 6.

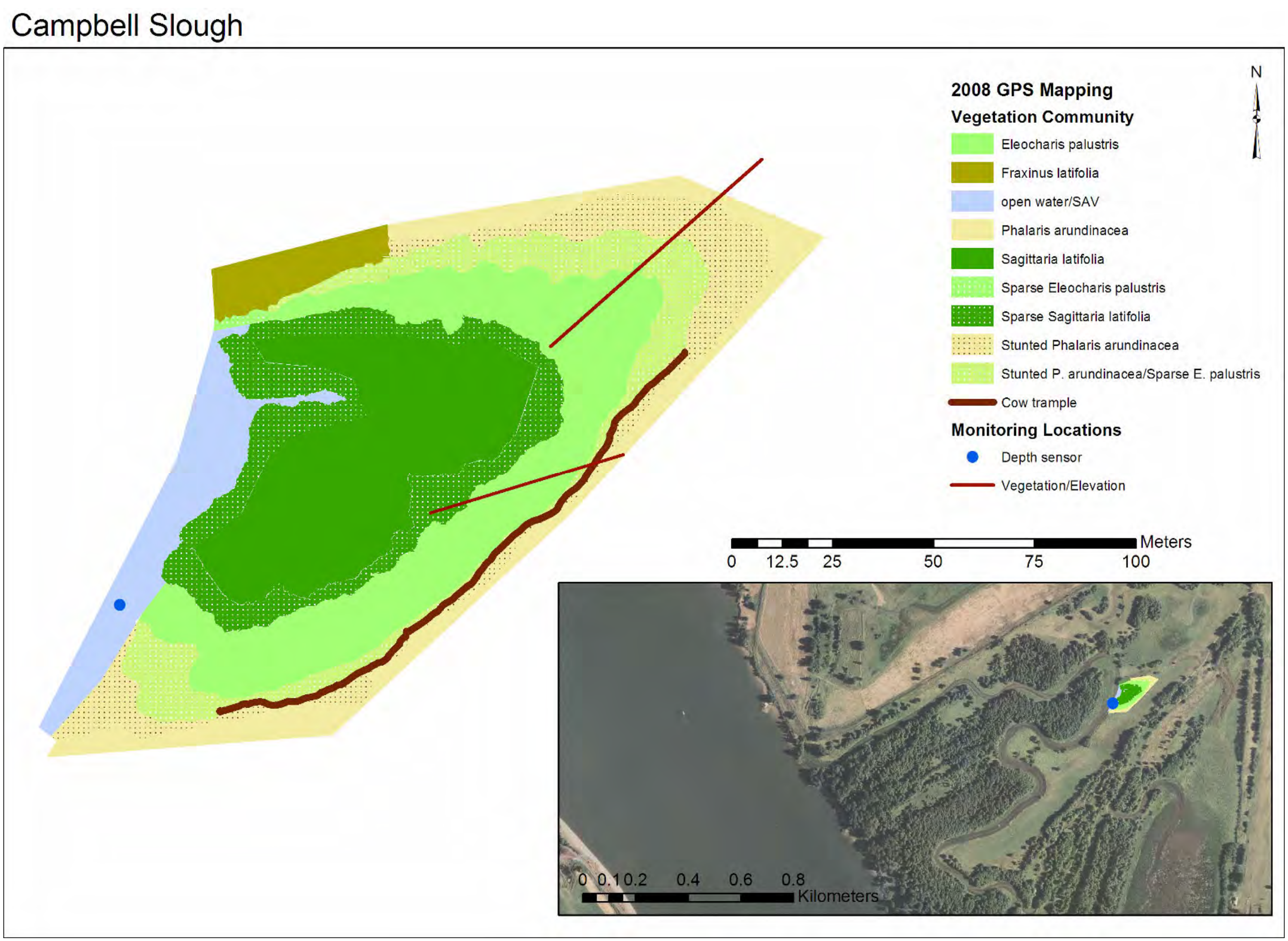


Figure 14: Vegetation distributions at Campbell Slough, 2008.

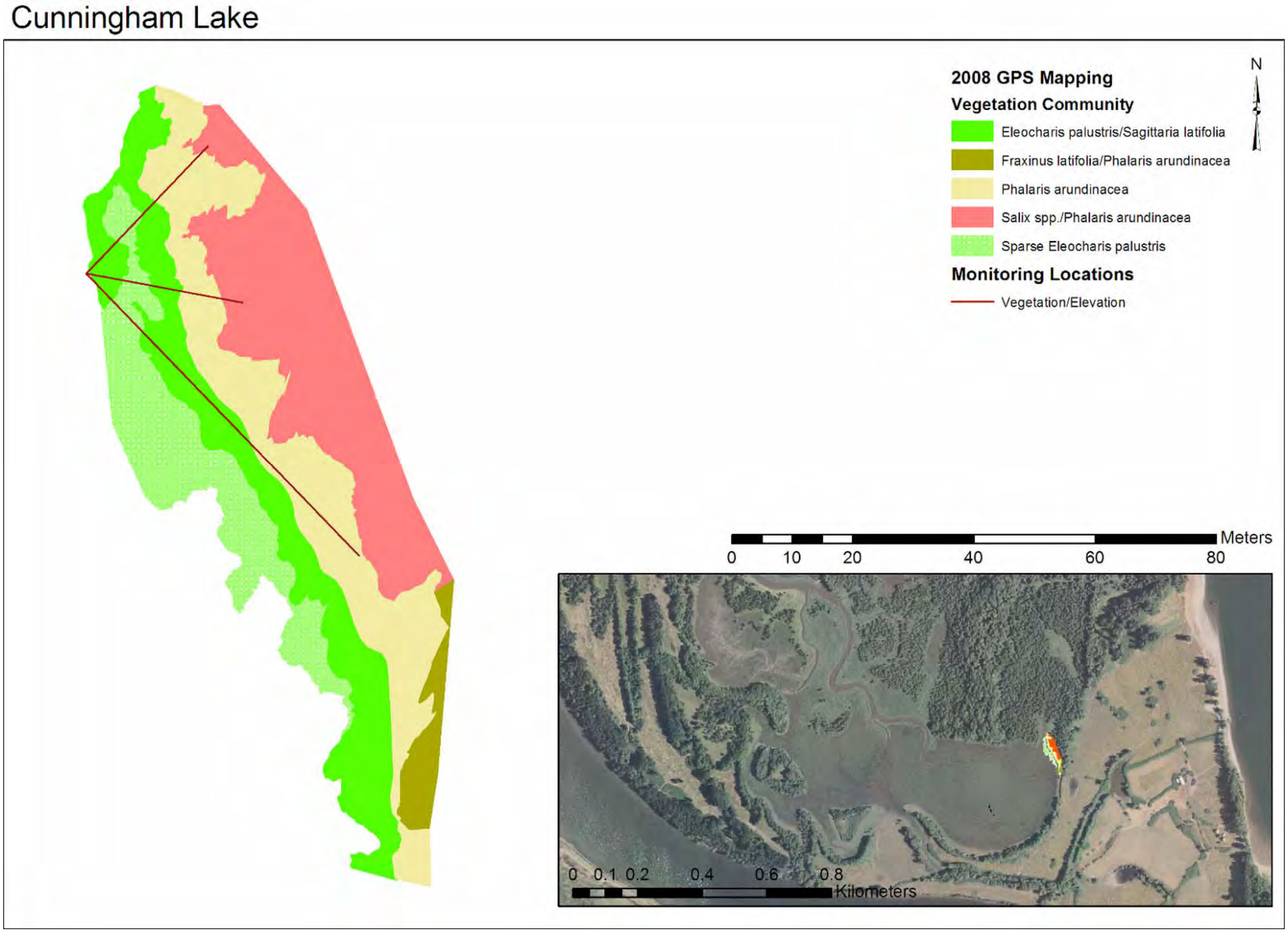


Figure 15: Vegetation distributions at Cunningham Lake, 2008.

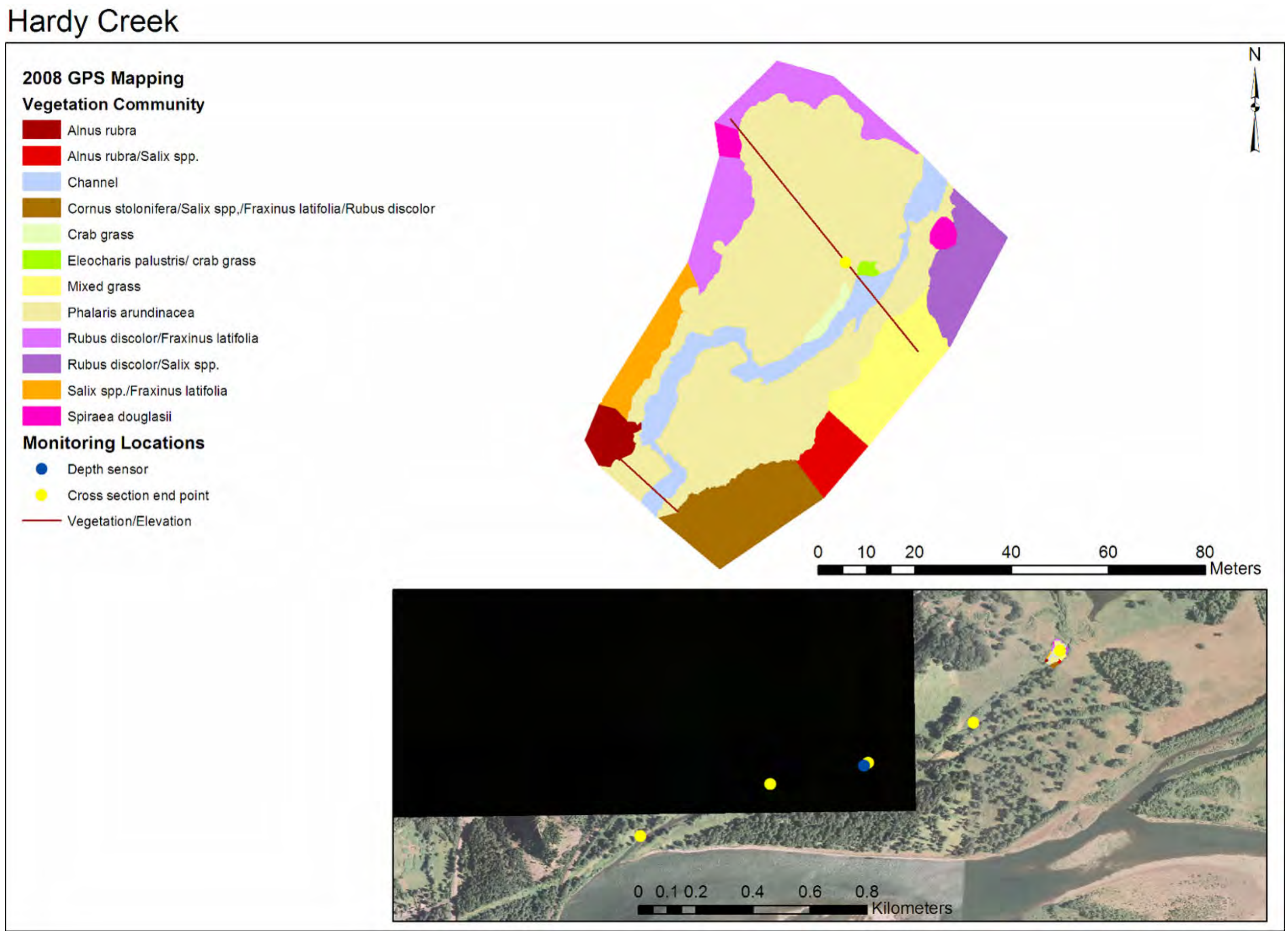


Figure 16: Vegetation distributions at Hardy Creek, 2008.

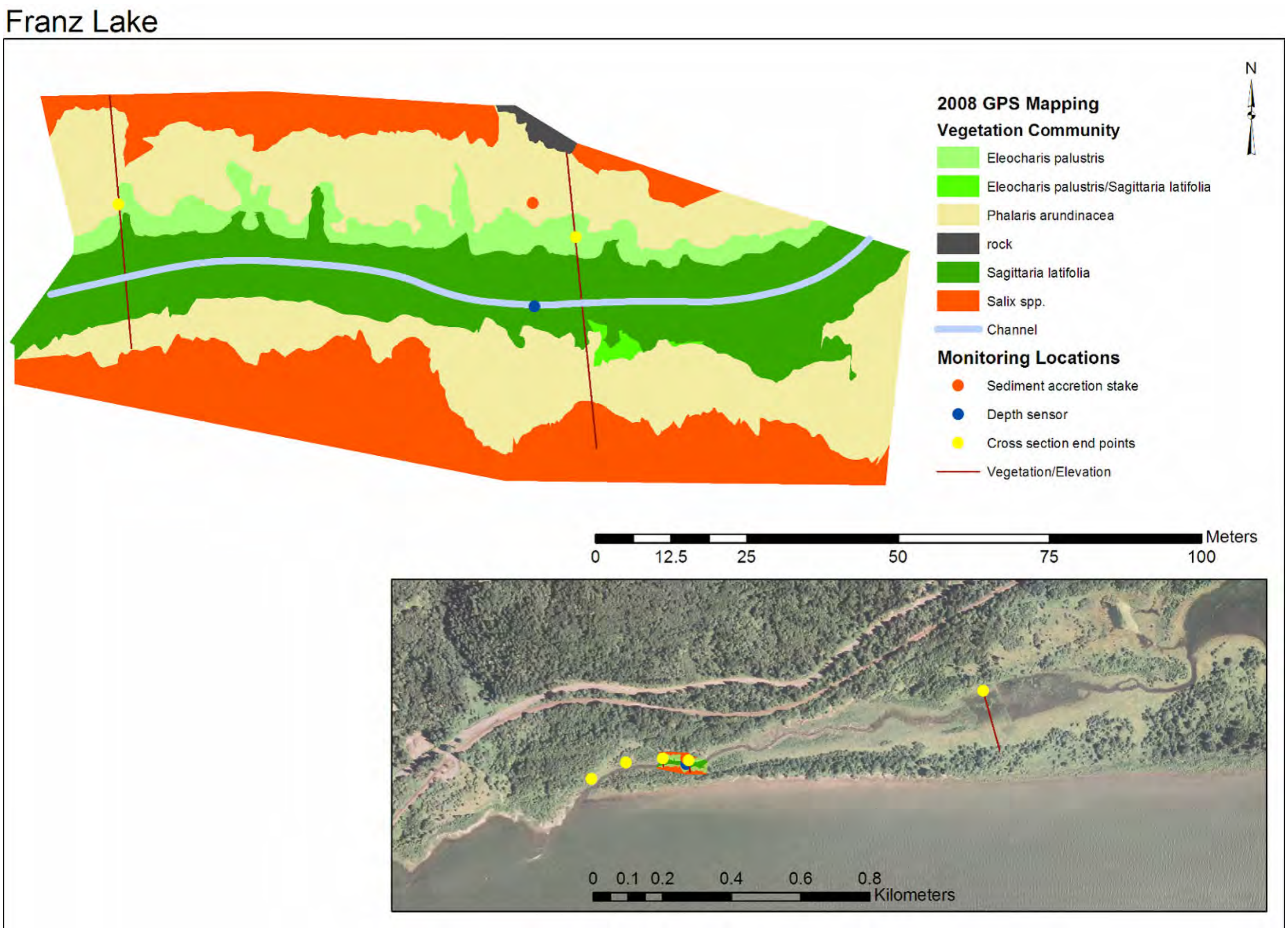


Figure 17: Vegetation distributions at Franz Lake, 2008.

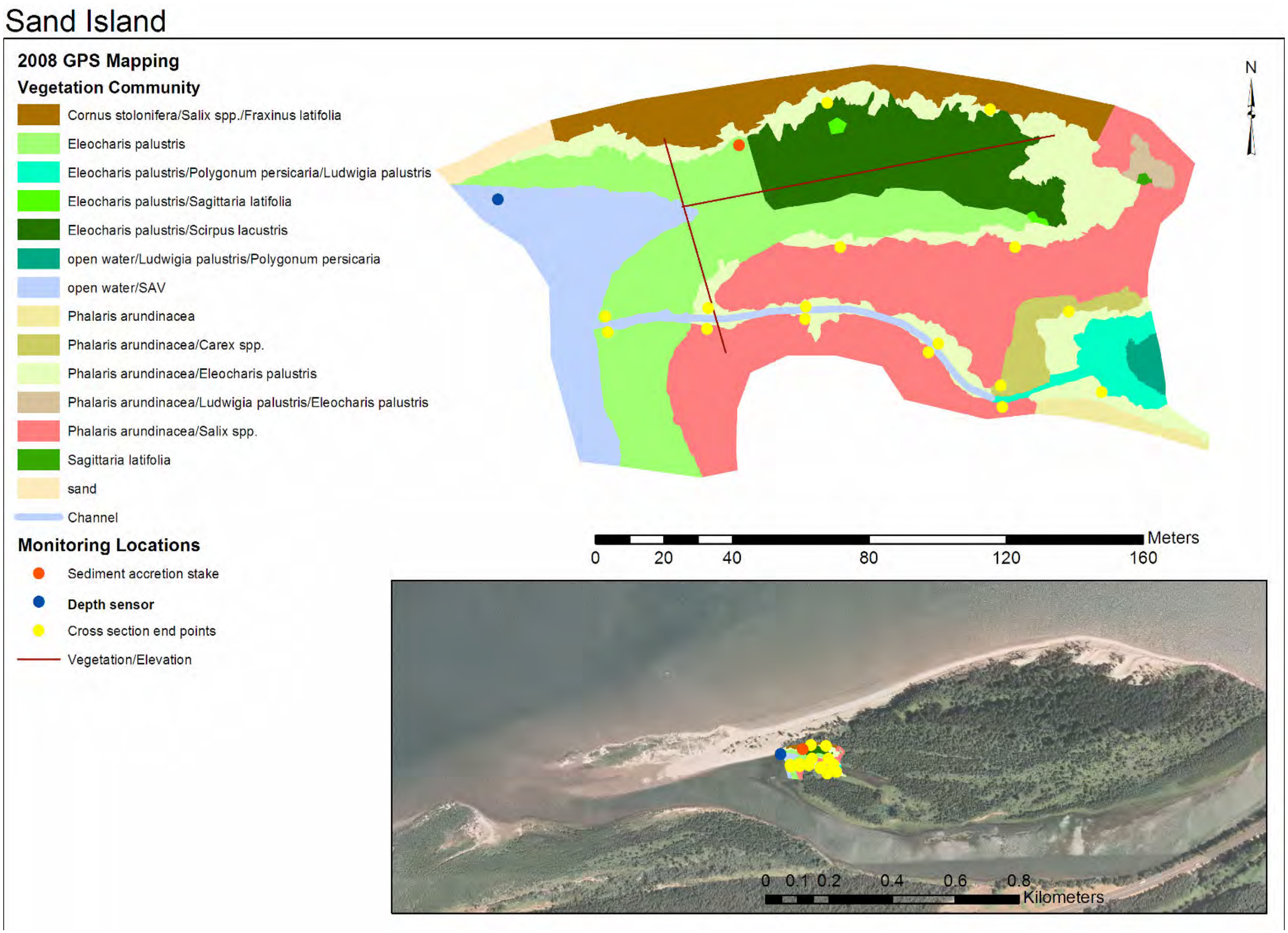


Figure 18: Vegetation distributions at Sand Island, 2008.

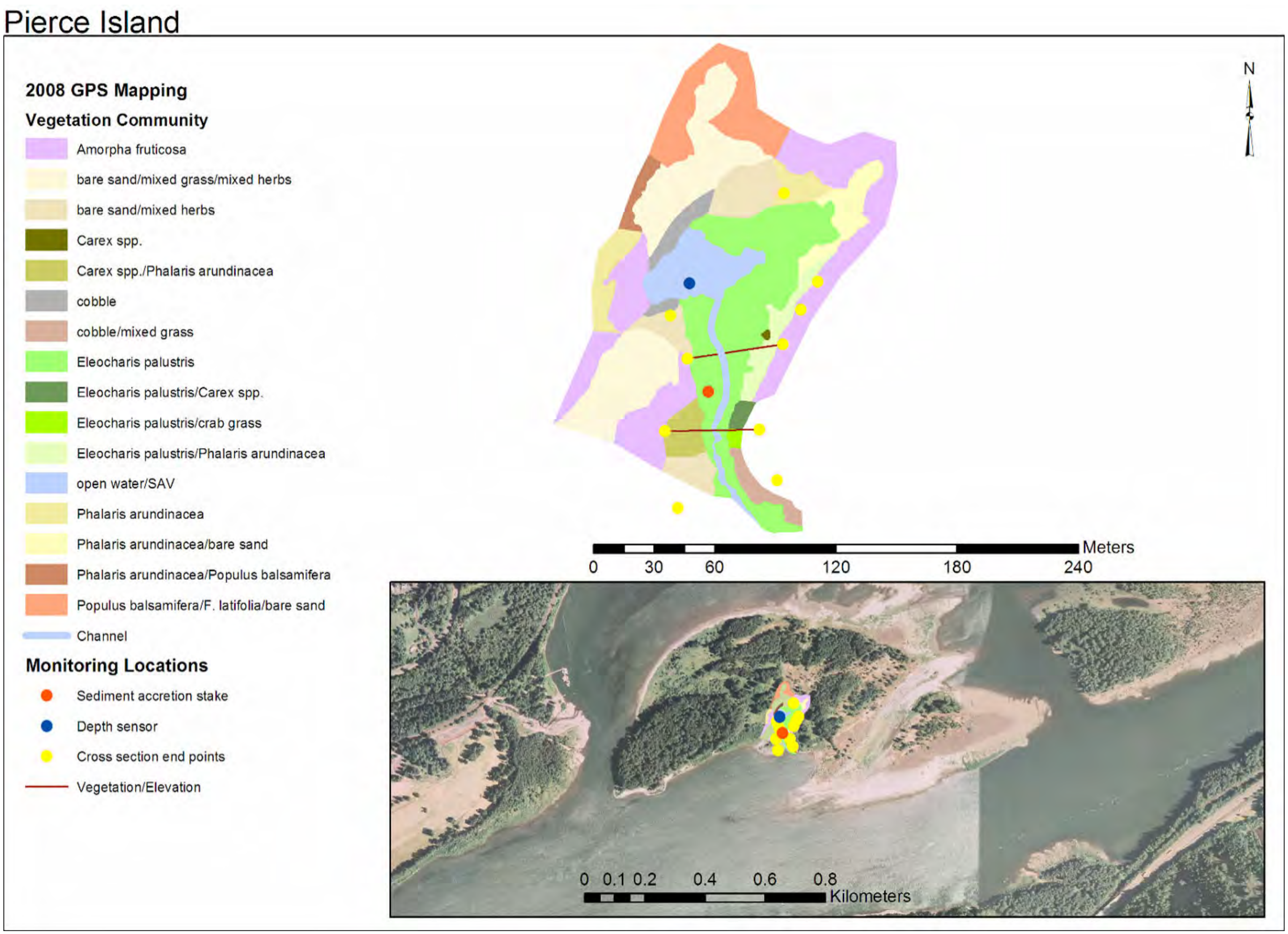


Figure 19: Vegetation distributions at Pierce Island, 2008.

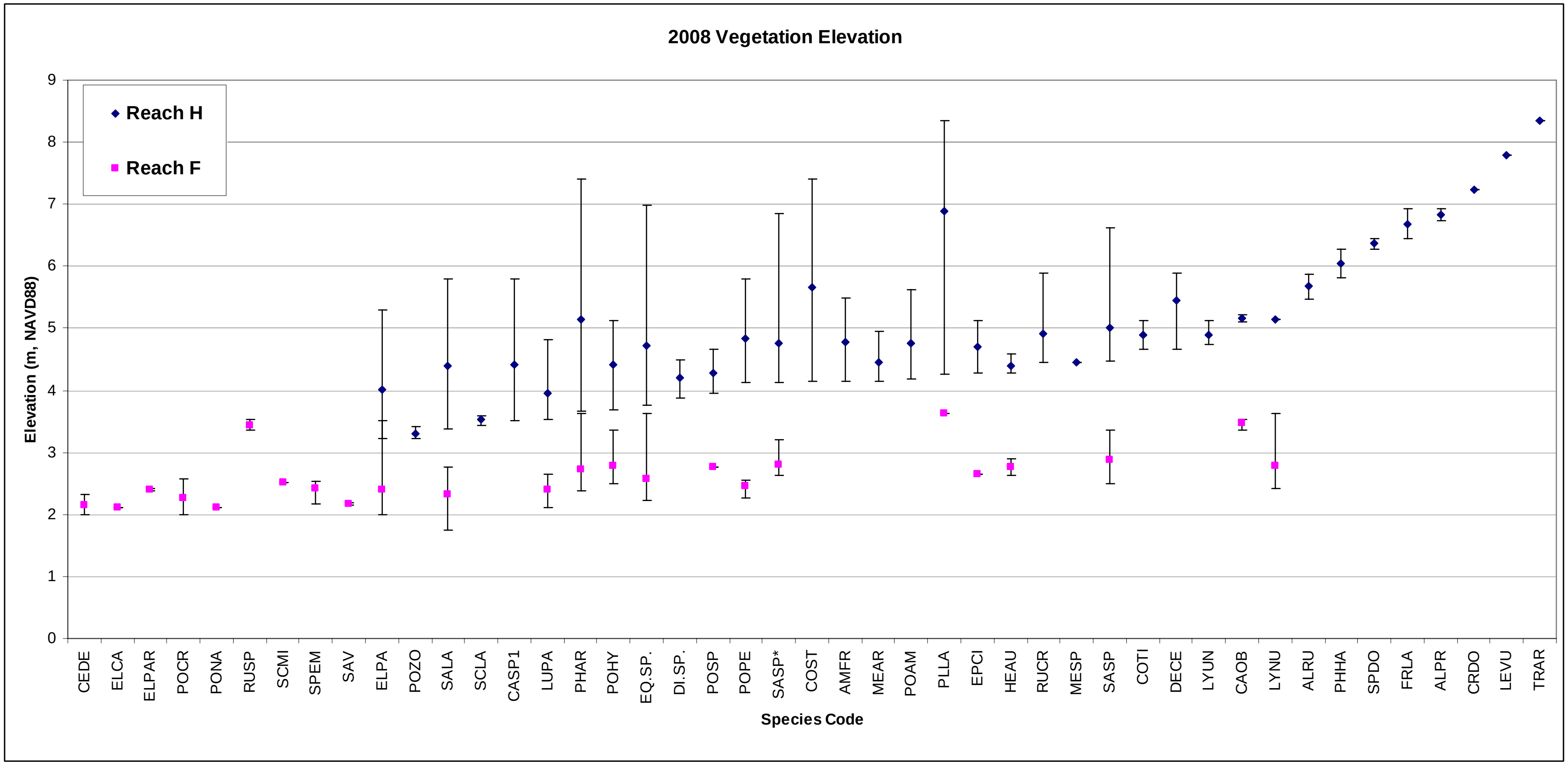


Figure 20: Vegetation by elevation for 2008 sites. Error bars represent the minimum and maximum elevations where species occurred in the transects (See Table 5 for species codes).

Table 4: Plant species lists for Campbell Slough and Cunningham Lake, 2005-2008. Introduced species are highlighted in yellow.

Species (Scientific Name)	Species (Common Name)	Code	Campbell Slough 2005	Campbell Slough 2006	Campbell Slough 2007	Campbell Slough 2008	Cunningham Island 2005	Cunningham Island 2006	Cunningham Island 2007	Cunningham Island 2008
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	
Carex obnupta	slough sedge	CAOB				X				
Elodea canadensis	common waterweed	ELCA		X		X				
Eleocharis palustris	creeping spikerush	ELPA	X	X	X	X	X	X	X	X
Eleocharis parvula	small spikerush	ELPAR					X			X
Epilobium ciliatum	hairy willowherb	EPCI								X
Equisetum fluviatile	water horsetail	EQFL	X	X			X	X	X	
Equisetum sp.	horsetail	EQSP			X	X				X
Fraxinus latifolia	Oregon ash	FRLA		X						
Helenium autumnale	mountain sneezeweed	HEAU				X				
Impatiens noli-tangere	yellow touch-me-not	IMNO								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			X	X
Lysimachia nummularia	Creeping jenny	LYNU	X	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	X	X
Plantago lanceolata	narrowleaf plantain	PLLA				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	X				
Polygonum hydropiperoides	mild waterpepper	POHY				X	X	X	X	
Potamogeton natans	floating-leaved pond weed	PONA	X				X	X		X
Polygonum persicaria	ladysthumb	POPE			X	X			X	X
Ranunculus repens	creeping buttercup	RARE			X					
Rumex crispus	curly dock	RUCR				X				
Rumex spp.	dock	RUSP			X	X				
Sagittaria latifolia	wapato	SALA	X	X	X	X	X	X	X	X
Salix lucida var. lasiandra	Pacific willow	SALU	X				X			
Salix spp.	willow	SASP		X	X	X		X	X	X
Scirpus lacustris	tule	SCLA					X		X	
Scirpus microcarpus	small-fruit bulrush	SCMI								X
Sparganium emersum	narrowleaf burreed	SPEM				X	X	X	X	X
Veronica americana	American brooklime	VEAM	X		X		X	X		

Table 5: Plant species list by site with species code, 2008. Introduced species are highlighted in yellow.

Species (Scientific Name)	Species (Common Name)	Code	Hardy Creek	Pierce Island	Franz Lake	Sand Island	Campbell Slough	Cunningham Lake
Alopecurus pratensis	meadow foxtail	ALPR	X					
Alnus rubra	red alder	ALRU	X					
Amorpha fruticosa	indigo bush	AMFR		X				
Carex obnupta	slough sedge	CAOB			X		X	
Caerx sp.	sedge	CASP		X	X	X		
Cornus stolonifera	red-osier dogwood	COST	X	X		X		
Crataegus douglasii	black hawthorn	CRDO			X			
Deschampsia cespitosa	tufted hair grass	DECE		X				
Digitaria spp.	crab grass	DISP		X				
Elodea canadensis	common waterweed	ELCA					X	
Eleocharis palustris	creeping spikerush	ELPA		X	X	X	X	X
Eleocharis parvula	small spikerush	ELPAR						X
Epilobium ciliatum	hairy willowherb	EPCI						X
Equisetum sp.	horsetail	EQSP	X	X	X	X	X	X
Fraxinus latifolia	Oregon ash	FRLA	X		X			
Helenium autumnale	mounatin sneezeweed	HEAU		X	X		X	
Impatiens noli-tangere	yellow touch-me-not	IMNO						X
Leucanthemum vulgare	oxeye daisy	LEVU	X					
Ludwigia palustris	water-purslane	LUPA				X	X	X
Lysimachia nummularia	Creeping jenny	LYNU		X			X	
Mentha arvensis	field mint	MEAR		X				
Mentha spp.	mint spp.	MESP			X			
	mixed grass	MG	X					
Phalaris arundinacea	reed canary grass	PHAR	X	X	X	X	X	X
Phacelia hastata	silver-leaf phacelia	PHHA		X				
Plantago lanceolata	narrowleaf plantain	PLLA	X	X			X	
Polygonum amphibium	water smartweed	POAM			X			
Potamogeton crispus	curly leaf pondweed	POCR					X	
Polygonum hydropiperoides	mild waterpepper	POHY			X	X	X	
Potamogeton natans	floating-leaved pond weed	PONA						X
Polygonum persicaria	ladysthumb	POPE			X	X	X	X
Polygonium spp.		POSP				X		
Potamogetan zosterformis	flatstem pondweed	POZO				X		
Rumex crispus	curly dock	RUCR		X			X	
Rumex spp.	dock	RUSP					X	
Sagittaria latifolia	wapato	SALA			X	X	X	X
Salix spp.	willow	SASP		X	X	X	X	X
Scirpus lacustris	tule	SCLA				X		
Scirpus microcarpus	small-fruit bulrush	SCMI						X
Spirea douglasii	spirea	SPDO	X					
Sparganium emersum	narrowleaf burreed	SPEM					X	X
Trifolium arvense	rabbit-foot clover	TRAR	X					

Table 6: Site elevation and vegetation species percent cover where the 3 dominant cover classes per site are highlighted in red.

	Campbell Slough		Cunningham Lake		Franz Lake	
Elevation (m, NAVD88)						
Avg	2.47		2.47		4.85	
Min	1.74		2.04		3.47	
Max	3.53		2.80		7.02	
	% Cover		**% Cover**		**% Cover**	
Species	Average	80% CI	Average	80% CI	Average	80% CI
BG	0.0	0.0	0.0	0.0	4.3	2.3
OW	0.0	0.0	0.0	0.0	7.0	2.6
ALPR	0.0	0.0	0.0	0.0	0.0	0.0
ALRU	0.0	0.0	0.0	0.0	0.0	0.0
AMFR	0.0	0.0	0.0	0.0	0.0	0.0
CAOB	0.5	0.5	0.0	0.0	1.6	1.5
CASP1	0.0	0.0	0.0	0.0	3.1	1.4
CEDE	0.2	0.2	0.0	0.0	0.0	0.0
COST	0.0	0.0	0.0	0.0	0.0	0.0
COTI	0.0	0.0	0.0	0.0	0.0	0.0
CRDO	0.0	0.0	0.0	0.0	0.9	1.1
DECE	0.0	0.0	0.0	0.0	0.0	0.0
DISP	0.0	0.0	0.0	0.0	0.0	0.0
ELCA	0.1	0.1	0.0	0.0	0.0	0.0
ELPA	**14.4**	3.2	**15.7**	3.0	3.1	0.8
ELPAR	0.0	0.0	0.6	0.5	0.0	0.0
EPCI	0.0	0.0	0.1	0.1	0.0	0.0
EQSP	0.5	0.4	2.1	0.6	2.1	0.5
FRLA	0.0	0.0	0.0	0.0	0.1	0.1
HEAU	0.2	0.1	0.0	0.0	0.7	0.4
LEVU	0.0	0.0	0.0	0.0	0.0	0.0
LUPA	2.5	0.8	2.3	0.6	0.0	0.0
LYNU	0.6	0.4	0.0	0.0	0.0	0.0
LYUN	0.0	0.0	0.0	0.0	0.0	0.0
MEAR	0.0	0.0	0.0	0.0	0.0	0.0
MESP	0.0	0.0	0.0	0.0	0.1	0.1
MG	0.0	0.0	0.0	0.0	0.0	0.0
PHAR	**28.5**	6.1	**31.8**	6.1	**34.2**	5.2
PHHA	0.0	0.0	0.0	0.0	0.0	0.0
PLLA	0.1	0.1	0.0	0.0	0.0	0.0
POAM	0.0	0.0	0.0	0.0	**8.2**	2.5
POCR	0.9	0.5	0.0	0.0	0.0	0.0
POHY	0.2	0.1	0.0	0.0	0.1	0.1
PONA	0.0	0.0	trace	0.0	0.0	0.0
POPE	0.1	0.1	1.1	0.4	0.7	0.4
POSP	0.0	0.0	0.0	0.0	0.0	0.0
POZO	0.0	0.0	0.0	0.0	0.0	0.0
RUCR	0.0	0.0	0.0	0.0	0.0	0.0
RUSP	0.2	0.1	0.0	0.0	0.0	0.0
SALA	**4.4**	0.8	**6.0**	1.0	**7.8**	1.9
SASP	2.3	1.8	4.3	2.5	4.9	2.2
SAV	0.2	0.1	0.0	0.0	0.0	0.0
SCLA	0.0	0.0	0.0	0.0	0.0	0.0
SCMI	0.0	0.0	0.2	0.2	0.0	0.0
SPDO	0.0	0.0	0.0	0.0	0.0	0.0
SPEM	trace	0.0	1.0	0.4	0.0	0.0
TRAR	0.0	0.0	0.0	0.0	0.0	0.0

Table 6 (continued)

	Hardy Creek		Sand Island		Pierce Island	
Elevation (m, NAVD88)						
Avg	6.15		3.69		4.77	
Min	4.51		3.23		3.47	
Max	8.34		4.38		7.57	
	% Cover		% Cover		% Cover	
Species	Average	80% CI	Average	80% CI	Average	80% CI
BG	**13.0**	2.2	**30.6**	3.9	**36.6**	5.6
OW	11.1	5.8	25.2	5.7	15.2	6.0
ALPR	1.6	1.6	0.0	0.0	0.0	0.0
ALRU	3.8	3.1	0.0	0.0	0.0	0.0
AMFR	0.0	0.0	0.0	0.0	4.5	2.9
CAOB	0.0	0.0	0.0	0.0	0.0	0.0
CASP1	0.0	0.0	2.4	1.1	4.0	1.8
CEDE	0.0	0.0	0.0	0.0	0.0	0.0
COST	0.7	0.7	0.1	0.2	0.1	0.1
COTI	0.0	0.0	0.0	0.0	0.4	0.4
CRDO	0.0	0.0	0.0	0.0	0.0	0.0
DECE	0.0	0.0	0.0	0.0	0.9	0.6
DISP	0.0	0.0	0.0	0.0	0.6	0.3
ELCA	0.0	0.0	0.0	0.0	0.0	0.0
ELPA	0.0	0.0	**29.1**	3.6	**11.4**	2.5
ELPAR	0.0	0.0	0.0	0.0	0.0	0.0
EPCI	0.0	0.0	0.0	0.0	0.1	0.1
EQSP	0.7	0.5	0.1	0.1	2.5	0.6
FRLA	2.3	2.5	0.0	0.0	0.0	0.0
HEAU	0.0	0.0	0.0	0.0	0.2	0.3
LEVU	0.2	0.3	0.0	0.0	0.0	0.0
LUPA	0.0	0.0	1.2	0.7	0.0	0.0
LYNU	0.0	0.0	0.0	0.0	0.1	0.1
LYUN	0.0	0.0	0.0	0.0	0.2	0.2
MEAR	0.0	0.0	0.0	0.0	0.9	0.5
MESP	0.0	0.0	0.0	0.0	0.0	0.0
MG	**5.0**	2.9	0.0	0.0	0.4	0.4
PHAR	**61.7**	7.1	**8.0**	2.7	**9.3**	3.4
PHHA	0.0	0.0	0.0	0.0	0.1	0.1
PLLA	2.3	1.3	0.0	0.0	trace	0.0
POAM	0.0	0.0	0.0	0.0	0.0	0.0
POCR	0.0	0.0	0.0	0.0	0.0	0.0
POHY	0.0	0.0	trace	0.0	0.0	0.0
PONA	0.0	0.0	0.0	0.0	0.0	0.0
POPE	0.0	0.0	0.2	0.1	0.0	0.0
POSP	0.0	0.0	0.1	0.1	0.1	0.1
POZO	0.0	0.0	0.9	0.5	0.0	0.0
RUCR	0.0	0.0	0.0	0.0	0.5	0.3
RUSP	0.0	0.0	0.0	0.0	0.0	0.0
SALA	0.0	0.0	0.5	0.4	0.0	0.0
SASP	0.0	0.0	2.9	2.0	0.0	0.0
SAV	0.0	0.0	0.0	0.0	0.0	0.0
SCLA	0.0	0.0	1.9	0.8	0.0	0.0
SCMI	0.0	0.0	0.0	0.0	0.0	0.0
SPDO	1.6	1.2	0.0	0.0	0.0	0.0
SPEM	0.0	0.0	0.0	0.0	0.0	0.0
TRAR	0.2	0.3	0.0	0.0	0.0	0.0

Of the 6 vegetation monitoring sites, Pierce Island had the most diverse plant community (Figure 21), likely resulting from the site being somewhat exposed and therefore dynamic with the river's hydrologic fluctuations with outflows from the Bonneville Dam (Figure 22). The exposure of the site coupled with the high elevation (> 6 m) of the surveyed areas resulted in the inclusion of more upland species. Many species at the upper extents of transects at Pierce Island were not easily identifiable because they were very small and had not yet flowered, likely due to recent high water levels.

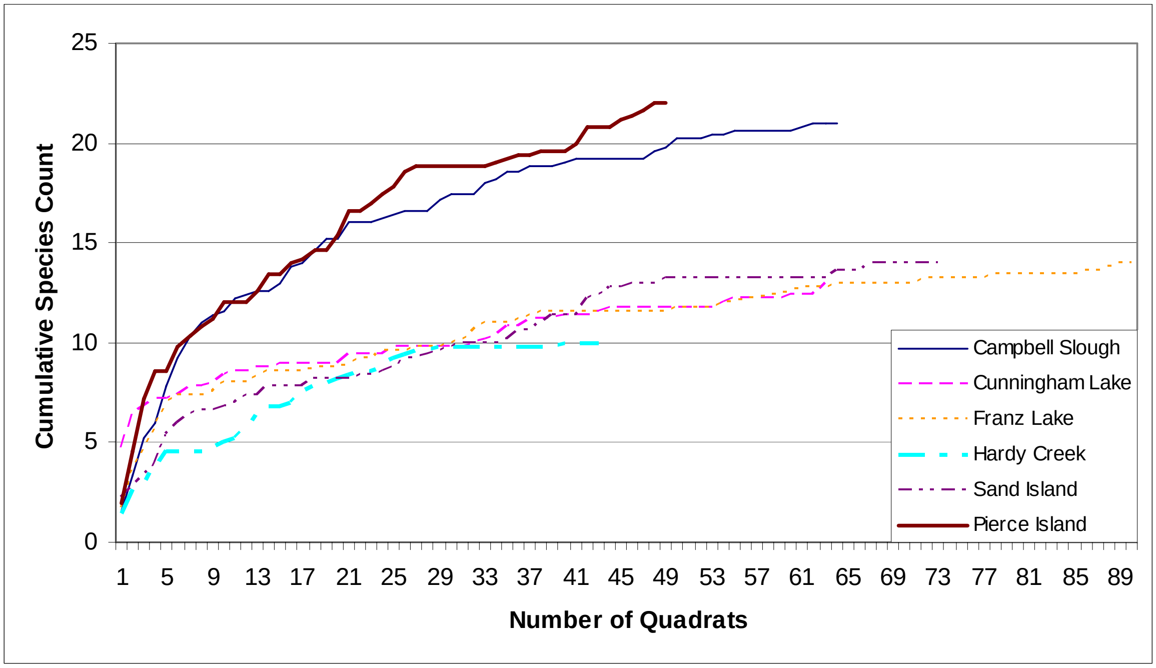


Figure 21: Species-area curves for 2008 sites.

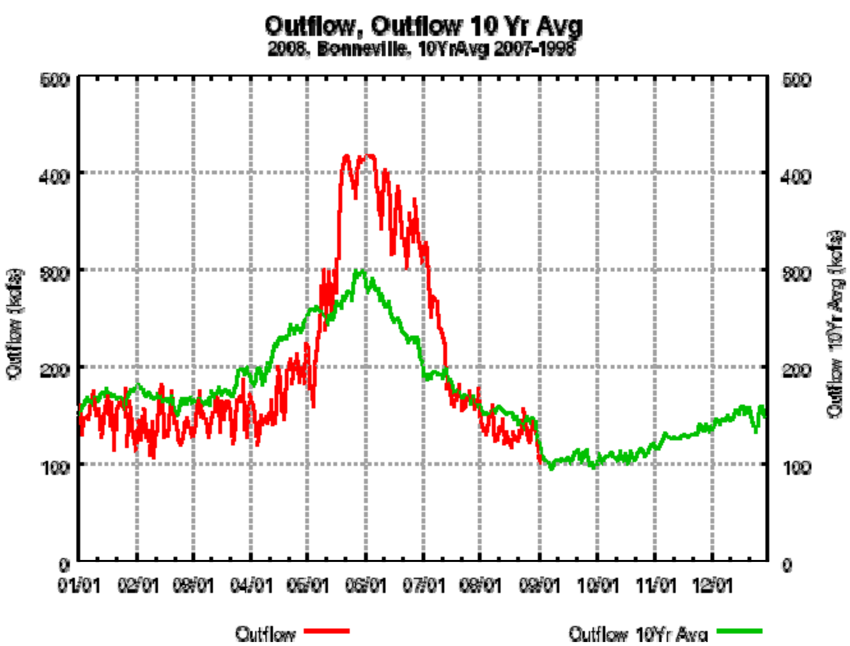


Figure 22: Outflow at Bonneville Dam, comparing outflow in 2008 (red) to the 10-year average (green). Data from Columbia River DART website.

Vegetation at all sites exhibited stunted growth likely due to the recent above-average water levels, which were over 2 m higher then the 20-yr median values during the period from mid-May to mid July (Figure 23). The dominance of *P. amphibium* at Franz Lake was likely because of recent high water levels; the plant occurs in shallow-water margins but often forms mats in deeper water.

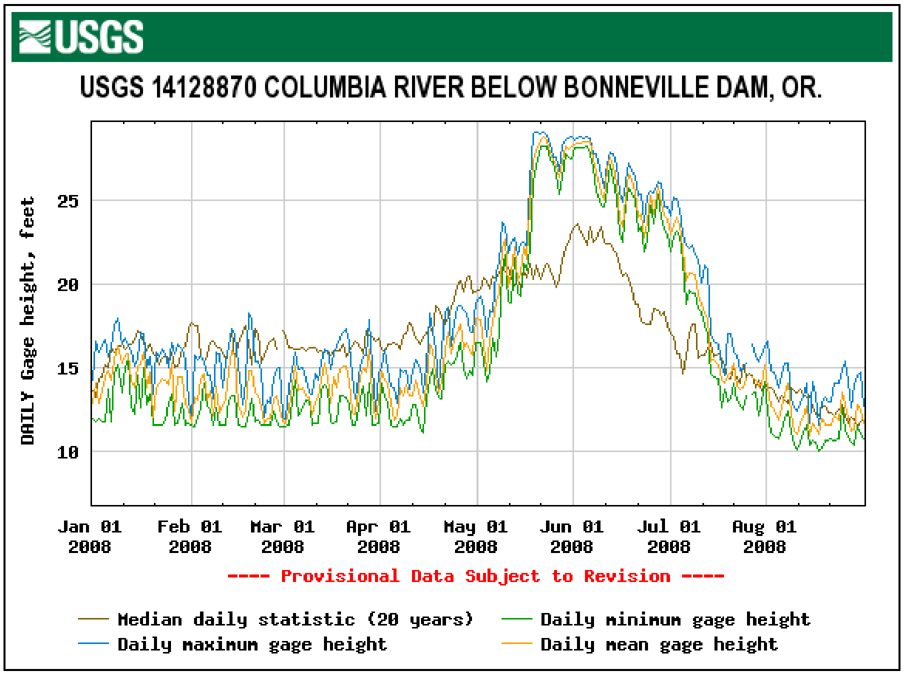


Figure 23: 2008 waters levels below Bonneville Dam compared to 20-year median level Data from USGS website.

Sediment grain-size was not quantitatively assessed as part of our research, and was instead conducted by USGS. However, we noted that the sediment characteristics of sites in Reach H were similar to sediments notes at sites in previously monitored reaches. Generally, we find that coarser sediments dominate mainstem sites whereas finer sediments dominate sites in sloughs or backwater areas.

9.0 Sediment and Water Chemistry and Depth Monitoring

To support characterizations of salmon habitat by PNNL and NOAA-Fisheries, USGS performed the following 2 monitoring work elements in 2007-2008:

1) Collect sediment grain-size data
2) Seasonal water-quality monitoring

9.1 Sediment Grain-size

In coordination with PNNL's vegetation monitoring and NOAA-Fisheries' salmon sampling during the week of July 21, 2008, USGS collected sediment samples at 2 sites in Reach F and 4 sites in Reach H (Figure 11). In the field, USGS consulted with PNNL to determine site elevation gradients based on the primary vegetation types present. Sites were then divided into sampling "zones," representing the different vegetation and elevation types. Samples were collected from each zone to characterize the range of elevation and vegetation characteristics at a given site (Table 7). Samples were typically collected in upland areas dominated by plants like reed canary grass, lower elevation areas with various plants (e.g., creeping spikerush, and wapato), channel edges, and the thalweg. Note, not all sites had the same number of vegetation-elevation zones, limiting consistent sampling between sites. Figure 24 illustrates some of the differences in samples collected at Hardy Creek, Sand Island, and Pierce Island. USGS also collected replicate samples to assess the variability associated with this compositing technique and the natural variation within the composited areas. Samples were sent to the USGS Cascades Volcano Observatory Sediment Lab for analyses of full grain-size and organic-carbon content. Once these results are available, the data will be summarized and made available for integration with the data from NOAA-Fisheries and PNNL to further characterize salmonid habitat at these sites.

Table 7: Elevation and vegetation characteristics of sediment samples from 2008 EMP sites.

Sample number	Elevation and Vegetation Characteristics
Campbell Slough 07/21/08	
R1	*Phalaris arundinacea*, Reed canary grass (PHAR)
R2	*Eleocharis palustris*, Creeping spikerush (ELPA)
R3	*Sagittaria latifolia*, Wapato (SALA)
R4	Intermediate edge of channel, little or no vegetation
R5	Channel thalweg, little or no vegetation
R6	Replicate of R4 area
Cunningham Lake 07/21/08	
C1	*Phalaris arundinacea*, Reed canary grass (PHAR)
C2	Mix of *Sagittaria latifolia*, Wapato (SALA) and *Eleocharis palustris*, Creeping spikerush (ELPA)
C3	Lower elevation area of ELPA
C4	Edge of channel, little or no vegetation
C5	Channel thalweg, no vegetation
C6	Replicate of C2 area
Franz Lake 07/22/08	
F1	*Polygonum amphibium*, Watersmart weed (POAM)
F2	*Phalaris arundinacea*, Reed canary grass (PHAR)
F3	*Eleocharis palustris*, Creeping spikerush (ELPA)
F4	Higher elevation area of *Sagittaria latifolia*, Wapato (SALA)
F5	Lower elevation area of SALA
F6	Channel thalweg, little or no vegetation
Hardy Creek 07/23/08	
H1	*Phalaris arundinacea*, Reed canary grass (PHAR)
H2	Edge of channel, less dense area of PHAR and *Digitaria spp*., Crabgrass (DISP)
H3	Edge of water, some *Eleocharis palustris*, Creeping spikerush (ELPA) and DISP
H4	Channel thalweg, no vegetation, cobbly bottom
H5	Replicate of H3 area
Sand Island 07/24/08	
S1	Sand and mixed vegetation—trees and taller *Phalaris arundinacea*, Reed canary grass (PHAR)
S2	Sand/mud mix and mixed vegetation—shorter PHAR, *Carex spp*., Sedge (CASP)
S3	Higher elevation area of *Eleocharis palustris*, Creeping spikerush (ELPA)
S4	Lower elevation area of ELPA
S5	Open water, no vegetation
S6	Far side of the slough, PHAR
S7	Replicate of S4 area
Pierce Island 07/25/08	
P1	*Phalaris arundinacea*, Reed canary grass (PHAR)
P2	Shorter green grass, perhaps *Carex spp*., Sedge (CASP)
P3	Higher elevation area of *Eleocharis palustris*, Creeping spikerush (ELPA)
P4	Edge of water, lower elevation area of ELPA
P5	Open water, little or no vegetation
P6	Replicate of P4 area

Hardy Creek H2

Hardy Creek H4

Sand Island S1

Sand Island S3

Sand Island S6

Pierce Island P5

Figure 24: Examples of composite samples collected from 2008 EMP sites for sediment grain-size analysis.

9.2 Water Chemistry and Depth

USGS deployed water-quality monitors at 2 sites where NOAA-Fisheries and PNNL conducted salmon and vegetation sampling, respectively. Even though 5 sites were chosen for salmon sampling, funding was only available to perform water-quality monitoring at 2 sites. The 2 sites were: 1) Campbell Slough located in the Roth Unit of the Ridgefield National Wildlife Refuge and where NOAA-Fisheries sampled fish in 2007 and 2008 and PNNL monitored vegetation from 2005-2008; and 2) Sand Island near Rooster Rock State Park where the logger was deployed in a slough on the downstream end of the island (Figure 11; Table 8).

Table 8: Site and deployment information for water-quality monitors.

Site	Reach	Latitude	Longitude	Monitor Deployment Date	Monitor Retrieval Date
Campbell Slough	F	45° 47’ 05”	122° 45’ 14.5”	June 27, 2008	July 23, 2008
Sand Island	H	45° 33’ 10”	122° 12’ 47”	May 30, 2008	August 15, 2008

At these sites, USGS deployed 2 sondes (Yellow Springs Instruments, YSI, model 6600EDS) equipped with water temperature, specific conductance, pH, dissolved oxygen, turbidity, and depth probes. See Table 2 for accuracy and effective ranges for each probe. Monitors were deployed to characterize water-quality and depth conditions during the periods when juvenile salmon were likely present at these sites, migrating away from the sites, and shortly thereafter. The general time period was designed to be mid-May through mid-August, with visits roughly every 3 weeks to exchange the batteries, check the calibration of the variables, and make any adjustments needed.

This year, the melting of the large snow pack in the basin caused extremely high water levels in mid-May and into June (Figure 23). This led to delays in monitor deployment because site access was hindered, particularly at Campbell Slough, and deployment designs had to be modified to accommodate these high water levels (Figure 25). The modified deployment apparatus at Campbell Slough presented issues once the water levels dropped as well, causing the monitor to be left “high and dry.” During the July salmon sampling, NOAA-Fisheries did not collect any salmon, and concluded their sampling at the site for the year. Therefore, the monitor was removed from the site rather than adjusting the deployment design to accommodate the lower water levels. This resulted in a deployment duration of roughly one month for the Campbell Slough monitor. The Sand Island monitor was also left “high and dry” when the water levels drop dramatically in a short time period at the end of July. Since NOAA-Fisheries were still collecting salmon at the site, the deployment design was adjusted to accommodate the lower water levels and the monitor was left in place into August. Therefore, the Sand Island monitor was in place for roughly 2.5 months. Data from these deployments are being checked and reviewed based on calibration data. They will be available on the internet this fall and presented in next year’s annual report.

Pipe containing water-quality monitor at Campbell Slough, July 21, 2008

Location of water-quality monitor at Sand Island and buoy/pipe apparatus.

Figure 25: Water-quality monitors at Campbell Slough and Sand Island.

10.0 Juvenile Salmon Monitoring

From 2007 to 2010, the EMP's objectives are to characterize undisturbed emergent wetlands, and monitor salmon occurrence and health in those habitats in 3 different reaches of the LCRE. In 2008, NOAA-Fisheries, USGS, PNNL, and the Estuary Partnership monitored salmon and habitats in Reaches H and F of the LCRE. As part of this monitoring effort, NOAA-Fisheries focused on the following 6 work elements:

1) A survey of prey availability and habitat use by salmon and other fishes at 4 sites in Reach H and 1 site in Reach F and data collection on fish habitat use in relation to physical habitat characteristics (monitored by PNNL and USGS). This effort included re-sampling of the 2007 Campbell Slough site in the Ridgefield National Wildlife Refuge (NWR) in Reach F to examine year-to-year trends in fish use of the site.
2) Taxonomic analyses of prey in salmon stomach contents to identify prey types at different sites and times and determine the proportion of salmon prey from aquatic vs. terrestrial sources. NOAA-Fisheries will use these data to assess sources of contaminants in salmon prey and potential relationships between prey type and contaminant uptake by salmon.
3) Analyses of otoliths collected from juvenile Chinook salmon at 2007 and 2008 sites for determination of growth rates.
4) Analyses of biochemical measures of growth and condition for juvenile Chinook salmon collected at 2007 and 2008 sites.
5) Identification of genetic stock for juvenile Chinook salmon collected at 2007 and 2008 sites.
6) Compilation of data and annual report preparation.

In addition to the above work elements, NOAA-Fisheries conducted additional research and monitoring activities to build upon their EMP-related work conducted from 2005-2007. These activities included:

- Chemical analyses and genetic stock identification of yearling Chinook samples collected in 2007 from sites near the estuary's mouth. These analyses will provide important information on contaminant exposure in yearling Chinook salmon with stream-type life histories. Chemical analyses were conducted with NOAA-Fisheries funds.

- Chemical analyses of stomach contents from juvenile Chinook salmon collected in 2007 from the Campbell Slough and Sandy Island sites. Chemical analyses were conducted with NOAA-Fisheries funds.
- Completion of reports and manuscripts describing data collected earlier in the Ecosystem Monitoring Project. Manuscripts are intended for publication in peer-reviewed literature using NOAA-Fisheries funds.

10.1 Survey of Prey Availability and Fish Habitat Use

In spring and summer 2008, NOAA-Fisheries monitored prey availability and habitat use by juvenile Chinook salmon and other fishes at 4 tidal freshwater sites in Reach H. Sampling sites were Sandy Island near Rooster Rock State Park, Beacon Rock Slough near Beacon Rock State Park, Franz Lake, and Pierce Island (Figure 11). Additionally, they re-sampled fish at the 2007 Ridgefield Wildlife Refuge site (Campbell Slough) in Reach F to examine year-to-year trends in fish use of the site (Figure 11). Campbell Slough is 1 of 2 fixed stations for long-term monitoring by the EMP. Our objectives were to collect preliminary information on fish habitat use that may be related to physical habitat characteristics and availability of prey organisms. Samples were also collected and archived for measurement of toxic contaminants, although this was not a specific project objective at this time. At these fish sampling sites, PNNL conducted vegetation and habitat characterization surveys and USGS collected sediment samples.

10.1.1 Fish Collection and Sample Methods

Monitoring for fish and prey was initiated in April 2008, and continued on a monthly basis through August 2008. Fish were collected routinely by beach seine from the 4 sites in Reach H (Figure 11, Table 9) and at Campbell Slough in Reach F (Figure 11, Table 9). At each sampling event, we recorded species richness, abundance, and catch-per-unit-effort (CPUE) for all species as well as water temperature and tide condition. Salmonids were examined for fin clips and coded wire tags (CWTs) to determine the proportions of marked (known hatchery origin) and unmarked (potentially wild) fish. Subsets of juvenile Chinook (*Onchorhynchus tshawytscha*), coho (*O. kisutch*), and chum (*O. keta*) salmon were measured and weighed. Additionally, from Chinook salmon, we collected stomach contents for prey taxonomy; whole bodies for lipid content; otoliths for estimation of age and growth rates; fin clips for genetic stock identification; and otoliths for aging and growth rate determination. As time and fish availability permitted, we also 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, organochlorine pesticides, and polybrominated diphenyl ethers (PBDEs); blood for measurement of vitellogenin as a screen for exposure to environmental estrogens and potentially for plasma chemistry and hormones related to growth; and whole bodies for measurement of bioaccumulative POPs. Table 10 lists the numbers of samples collected from each site at each sampling event.

Table 9: Site coordinates for 2008 EMP salmon sampling sites.

Site Name	Reach	Latitude	Longitude
Beacon Slough	H	45.628217°	-122.012150°
Pierce Island	H	45.620967°	-122.010800°
Franz Lake	H	45.600583°	-122.103067°
Sand Island	H	45.553350°	-122.211117°
Campbell Slough	F	45.783867°	-122.754850°

Table 10: 2008 samples collected from juvenile salmon in the LCRE. All samples were analyzed as an individual samples, except for the bile and stomach chemistry samples, which were analyzed as composite samples.

Collection Date	Site	# of Juvenile Chinook Collected	Genetics	Otoliths	Bile	Blood	Stomach Taxonomy	Stomach Chemistry	Body Chemistry
4/16/08	Franz Lake	33	33	3	1	0	15	1	33
4/16/08	Pierce Island	9	9	9	1	0	9	0	9
4/16/08	Sand Island	14	14	13	1	0	14	0	13
4/17/08	Campbell Slough	6	6	6	1	0	6	0	6
5/12/08	Campbell Slough	4	4	0	1	0	4	0	4
5/14/08	Franz Lake	7	7	7	1	0	7	0	7
5/16/08	Campbell Slough	33	33	33	1	18	15	1	33
6/9/08	Beacon Slough	13	13	13	0	0	13	0	13
7/21/08	Sand Island	1	1	1	0	0	0	0	1

10.1.2 Results for Patterns of Habitat Use by Fishes at 2008 Sites

In 2008, we encountered considerable variation in water level at all of our sampling sites in Reach H and at Campbell Slough (Figure 23). The high and variable water levels were due in part to unusual weather conditions and Bonneville dam releases (particularly in Reach H). Extreme high water levels made some sites inaccessible for sampling. Thus, fish sampling could not occur every month at some sites (Table 11). At all sites, water temperature varied throughout the season, ranging from 5.9 – 9.9°C in April to 13.9 – 26.9°C in August (Table 11). Observed temperatures were consistent between Franz Lake, Pierce Island, Sand Island, and Campbell Slough whereas temperatures at Beacon Slough tended to be lower than the temperatures at other sites. For instance, April temperatures for Beacon Rock were only 5.9°C vs. 9.2-9.7°C for other sites and August temperatures were only 13.9°C for Beacon Rock vs. temperatures exceeding 23°C at all sites, except Pierce Island which was not sampled in August.

Table 11: Average water temperature (°C) and fishing attempts made at 2008 EMP fishing sites and Campbell Slough in 2007.

Site	Month	Temperature (°C)	Fishing Attempts
Beacon Slough	April	5.9	3
	May	7.6	3
	June	12.6	2
	July	12.8	3
	August	13.9	3
Franz Lake	April	9.2	3
	May	13.4	3
	June	NA	0[b]
	July	17.5	3
	August	26.0	3[a]
Pierce Island	April	9.9	2
	May	13.8	2
	June	13.1	1
	July	17.5	1
	August	NA	0[c]
Sand Island	April	9.7	3
	May	14.3	3
	June	NA	0[b]
	July	24.4	3
	August	26.9	2[a]
Campbell Slough 2008	April	9.5	3
	May	15.8	3
	June	NA	0[b]
	July	21.2	3
	August	23.3	3[a]
Campbell Slough 2007	May 4	11.5	3
	May 18	14.3	3
	June 1	16.5	3
	June 13	16.8	3
	June 28	18.0	2
	July 19	21.0	3

Puget Sound Beach Seine was used to fish all of the sites except: [a] where baby beach seine (10 x 1.5 m) was used; [b] where sites were not fishable due to extremely high water; and [c] where sites were not fishable due to low water levels.

In spite of occasional sampling difficulties, our monitoring efforts in 2008 showed that juvenile salmon and other juvenile fish species were feeding and rearing at all Reach H sites and Campbell Slough in Reach F (Table 12). Juvenile Chinook were captured at all 5 sites, with the percentage of total catch ranging from 0.55% at lowest site to 32.52% at highest site (Table 12). Coho salmon were captured at 4 of the 5 sites, ranging from 2.50 to 9.38% of the total catch whereas chum salmon were captured at all 5 sites, ranging from 0.06 to 3.87% of the total catch. Of the non-salmonid species, three-spine stickleback, carp, and chiselmouth were the most abundant. Three-spine stickleback were the dominant species at Beacon Slough; carp and chiselmouth were the most abundant species at Franz Lake; chiselmouth and three-spine stickleback were the dominant species at Sand Island, and carp and three-spine stickleback were the predominant species at Ridgefield. Overall, Sand Island had the greatest total number of species captured (18) while 11-16 species were collected at the other sites.

Table 12: Fish species captured and percent of each species at 2008 EMP fishing sites and Campbell Slough in 2007.

Species	Beacon Slough	Franz Lake	Pierce Island	Sand Island	Campbell Slough, 2008	Campbell Slough, 2007
salmon, Chinook	0.71	5.32	32.52	0.55	2.91	4.07
salmon, coho	2.50	3.01	9.38	2.73	0	0.03
salmon, chum	0.12	0.53	3.87	0.14	0.06	0
bass, smallmouth	0	1.95	0	0.38	0.23	1.52
bass, largemouth	0	0	0	0	0	0.31
bluegill	0	0	0.10	0.24	0	0.31
bullhead, brown	0	0	0	0.10	0.06	0
bullhead, yellow	0	7.00	7.34	0.03	0.04	0.10
carp, sp	0.06	31.29	0	0.79	32.59	0.24
catfish, blue	0	0	0	0.03	0	0
catfish, channel	0	0.09	0	0	0	0
chiselmouth	1.14	29.08	4.99	41.23	0.34	0.17
crappie, sp	0	0	0	0	0	0.66
killifish, banded	0.06	7.54	6.63	1.62	4.22	5.90
northern pikeminnow	0	0.27	0.20	1.04	2.85	1.38
peamouth	0.03	0.27	0	5.70	0.17	0.41
perch, yellow	0	0	0	0	2.68	4.49
pike, walleye	0	0.09	0	0	0	0
pumpkinseed	0.99	5.67	1.43	4.90	1.42	0.66
sculpin (*Cottidae*) sp.	0.34	0.35	0.61	0.28	0.63	0.59
sculpin, mottled	0.03	0	0	0	0	0
shad, American	0	0	0	0	5.24	0.59
stickleback, threespine	94.01	7.45	32.82	39.78	45.98	36.23
sturgeon, white	0	0	0	0.21	0	0
sucker, largescale	0	0.09	0	0.24	0.63	0.10
Total species captured	11	16	11	18	16	19
Total fish captured	3237	1128	981	2896	1755	2898

Overall, Chinook salmon were the most abundant juvenile salmon species, representing 63% of all salmon captured. However, the proportion of Chinook salmon caught from site to site (22%, 60%, 77%, 98%, and 20% at Beacon Slough, Franz Lake, Pierce Island, Campbell Slough, and Sand Island, respectively), and they were not the most abundant species at all sampling sites (Figure 26; Table 13). Coho salmon were also relatively abundant at Reach H sites (Figure 26; Table 14), making up 35% of all salmon captured, but were absent from Campbell Slough in Reach F. Coho were the most abundant salmon species at Beacon Slough and Sand Island where they made up 74% and 79%, respectively, of the total salmon catch. Coho made up 34% of the catch at Franz Lake while they made up 23% of the catch at Pierce Island. Chum salmon found were at all sites except Pierce Island, but represented only 1.6% of the salmon captured at all sites combined. Chum salmon were most abundant at Beacon Slough and Franz Lake, where they made up 3.7% and 5.9% of the total salmonid catch; at the other sites, they represented 0 – 1.9% of the catch (Figure 26; Table 15). Generally, we collected chum salmon only in April, Chinook from April to July, and coho from April to August (though not at all sampling sites).

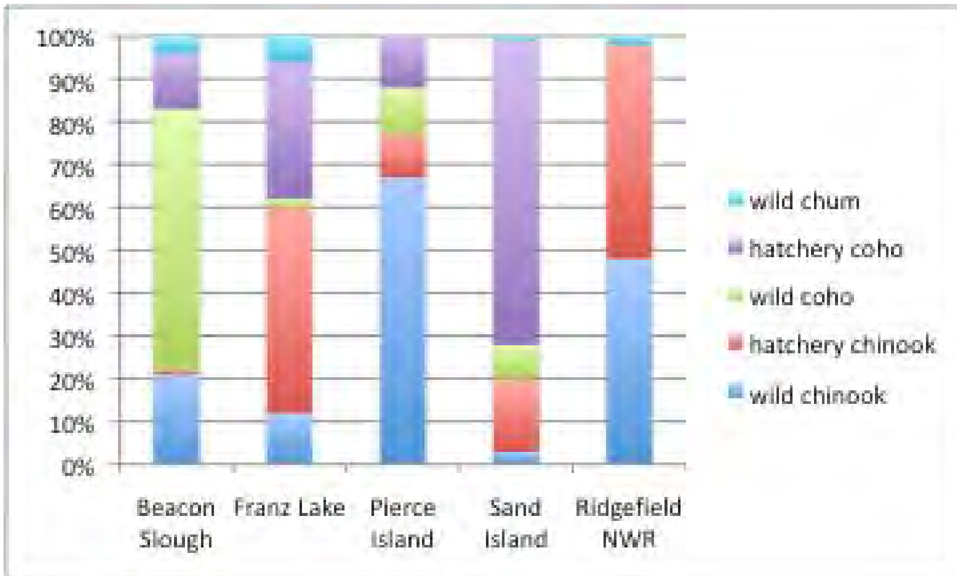


Figure 26: Proportions of wild vs. hatchery salmon species collected at 2008 EMP fishing sites.

Table 13: Total catch, percent unmarked salmon, and length and weight (± standard deviation) for unmarked (presumably wild) vs. marked (hatchery) by month for subyearling Chinook salmon collected at the 2008 EMP fishing sites and Campbell Slough in 2007.

				Unmarked		Marked	
Site	**Month**	**Total Caught (n)**	**% Unmarked of Total Catch**	**length (mm)**	**weight (g)**	**length (mm)**	**weight (g)**
Beacon Slough	April	5	100	43.6±1.5 n=5	1.00±0.00 n=5		
	May	4	100			132.0±11.0 n=4	23.6±6.3 n=4
	June	14	92.3	69.6±7.9 n=13	3.8±1.1 n=13	84.0 n=1	6.2 n=1
	July	1	100	68.0 n=1	3.3 n=1		
	Aug	0	NA				
Franz Lake	April	47	4.3	82.0±0.0 n=1	5.9±0.0 n=1	79.6±6.3 n=33	5.2±1.5 n=33
	May	14	69.2	51.1±9.8 n=10	1.6±1.1 n=10	78.5±1.9 n=4	5.0±0.4 n=4
	June	0	NA				
	July	0	NA				
	Aug	0	NA				
Pierce Island	April	134	99.3	41.9±6.3 n=25	1.0±0.3 n=25		
	May	137	73.7	50.45±5.6 n=20	1.46±0.6 n=20	142.2±8.4 n=9	28.5±6.3 n=9
	June	29	100	57.7±5.8 n=29	2.1±0.7 n=29		
	July	20	70	78.0±9.5 n=14	6.0±2.1 n=14	85.3±3.6 n=6	7.4±1.2 n=6
	Aug	0	NA				
Sand Island	April	14	14.3	44.0±1.4 n=2	1.00±0.0 n=2	76.1±3.6 n=12	NA N=12
	May	0	NA				
	June	0	NA				
	July	0	NA				
	Aug	0	NA				
Campbell Slough, 2008	April	15	86.7	49.2±6.0 n=13	1.2±0.4 n=13	87.5±5.0 n=2	6.9±3.7 n=2
	May	36	27.8	70.4±6.9 n=10	3.6±1.5 n=10	87.85±7.35 n=26	7.2±1.9 n=26
	June	NA	NA				
	July	0	NA				
	Aug	0	NA				
Campbell Slough, 2007	May	31	22.6	75.3±6.6 n=7	4.7±0.9 n=7	87.5±4.1 n=24	7.6±1.2 n=24
	June	39	71.8	76.0±6.6 n=28	5.2±1.8 n=28	75.3±4.1 n=11	5.3±2.9 n=11
	July	0	NA				

Table 14: Total catch, percent unmarked salmon, and length and weight (± standard deviation) for unmarked (presumably wild) vs. marked (hatchery) by month for juvenile coho salmon collected at the 2008 EMP fishing sites. No coho salmon were captured at Franz Lake or Sand Island after May.

Site	Month	Total Caught (n)	% Unmarked of Total Catch	Unmarked		Marked	
				length (mm)	weight (g)	length (mm)	weight (g)
Beacon Slough	April	1	100	42.0±0.0 n=1	1.0±0.0 n=1		
	May	8	12. 5	118.0±13.3 n=7	13.0±5.3 n=7	128.0±0..0 n=1	18.2±0.0 n=1
	June	13	46.2	69.8±21.2 n=5	4.9±10.5 n=5	135.9±5.5 n=7	24.0±1.8 n=7
	July	1	100	85.0±0.0 n=1	NA		
	August	58	100	87.1±8.3 n=25	8.1±2.1 n=25		
Franz Lake	May	34	5.9	102.7±56.9 n=3	14.3±12.2 n=3	139.0±11.6 n=29	26.9±6.0 n=29
Pierce Island	April	41	100	43.0±0.0 n=1	1.0±0.0 n=1		
Pierce Island	May	52	7.7	66.0±8.5 n=2	2.8±0.5 n=2	144.7±6.4 n=3	26.0±2.0 n=3
Sand Island	May	56	1.8	132.0±0.0 n=1	19.0±0.0 n=1	135.8±10.7 n=25	24.9±6.1 n=25

Table 15: Total catch, percent unmarked salmon, and length and weight (± standard deviation) for unmarked (presumably wild) by month for juvenile chum salmon collected at the 2008 EMP fishing sites. All chum salmon were unmarked.

Site	Month	Total Caught (n)	% Unmarked of Total Catch	Length (mm)	Weight (g)
Beacon Slough	April	4	100	42.8±3.3 n=4	1.00±0.0 n=4
Franz Lake	April	6	100	43.3±4.1 n=6	1.0±0.2 n=6
Campbell Slough	April	1	100	50.0±0.0 n=1	0.8±0.0 n=1
Sand Island	April	1	100	43.0±0.0 n=1	1.0±0.0 n=1

All collected chum salmon were unmarked (presumably wild fish), but marked (hatchery) and unmarked (presumably wild) coho and Chinook salmon were found at all sites where collected (Figure 26; Table 13-Table 15). Overall, 28% of Chinook and 56% of coho captured were marked, hatchery fish. The proportions of marked, hatchery fish varied from site to site. At Beacon Slough, 4% of Chinook and 17% of coho were hatchery fish; at Franz Lake, 80% of Chinook and 94% of coho were hatchery fish; at Pierce Island, 13% of Chinook and 52% of coho were hatchery fish; and at Sand Island, 86% of Chinook and

98% of coho were hatchery fish. At Campbell Slough, 51% of Chinook collected were of hatchery origin; no coho were collected from this site.

The collected hatchery fish were generally larger than wild fish (Figure 27- Figure 30; all remaining figures found at the end of this section; Table 13-Table 14). For Chinook, the mean length of unmarked fish ranged from 41.9 to 82 mm and weight from 1.0 to 6.0 g. In comparison, the mean length of marked Chinook ranged from 76.1 to 132 mm and weight from 5.0 to 23.6 g. For coho, the mean length of unmarked fish ranged from 42.0 to 132 mm and weight from 1.0 to 6.0 g, while the mean length of marked fish ranged from 128.0 to 144.7 mm and weight from 18.2 to 26.9 g (Figure 29-Figure 30). The unmarked Chinook tended to be larger at Campbell Slough than at the Reach H sites in April and May when fish were collected at the most sites.

Over the sampling season, the average length of unmarked juvenile Chinook tended to increase, and peaked in July at Pierce Island (Figure 27; Table 13). In contrast, the marked, hatchery fish showed little temporal trends in size. Overall, some larger fish (132-142 mm), probably yearling Chinook, were collected in May at Beacon Slough and Pierce Island, but fish were in the 75-85 mm range at all other sites and sampling events (Figure 28). Unmarked coho also tended to increase in size with time at the two 2 where the were capture in multiple months (Beacon Slough and Pierce Island; Figure 29). The exception was the large unmarked coho captured at Beacon Slough in May; its size was comparable to that of marked coho, probably yearling fish, caught at that site at that time, and it could have been an unmarked hatchery fish. Marked coho also increased in size with time at Beacon Slough, where they were caught in both May and June, but were caught only in May precluding data comparison (Figure 30).

The number of fish of all species and number of species captured-per-unit-effort (CPUE) increased over the sampling season and peaked in August (Figure 31-Figure 32). Juvenile salmon showed a different trend; they were generally most abundant in May and June and declined in July and August, except for a large number of coho salmon caught in August at Beacon Slough (Figure 33). However, patterns were variable from site to site. Salmon were caught only in April and May at Campbell Slough and Franz Lake. Fish may have been utilizing these sites in June, but site access hindered sampling. Chinook salmon were present at the sites most often in April through June, and were absent from all sites in August (Figure 34). For sites that could be sampled throughout the season (Beacon Slough and Pierce Island), CPUE tended to increase through June and decline in July and August. Of all the sampling sites, Pierce Island had the highest CPUE for Chinook salmon, and generally the highest CPUE for all salmonids, with the exception of larger catches in May at Franz Island and in August at Beacon Slough. The decrease in CPUE for salmonids in July and August may have been influenced by the increased water temperature, which exceeded 23°C at all sites sampled in August. However, water temperature did not appear to affect the non-salmonid fishes.

In summary, our sampling showed that wild juvenile Chinook, coho, and chum salmon are feeding and rearing in representative tidal freshwater sites in Reach H of the LCRE. Chum salmon were present in April only, but Chinook were using the sites from April through July, and coho were using the sites from April through August. The sites also appear to function as nursery areas for other fish species. Extreme fluctuations in water level, due in part to dam operations, made consistent sampling of the sites difficult and may have compromised our ability to document habitat occurrence patterns for juvenile salmon in this reach. High water temperatures may have limited fish use of some sites in July and August, although Chinook salmon were absent from all sites in Reach H by August despite moderate temperatures. In comparison with Campbell Slough in Reach F, sites in Reach H had higher proportions of coho salmon and a somewhat smaller range in size for wild Chinook salmon.

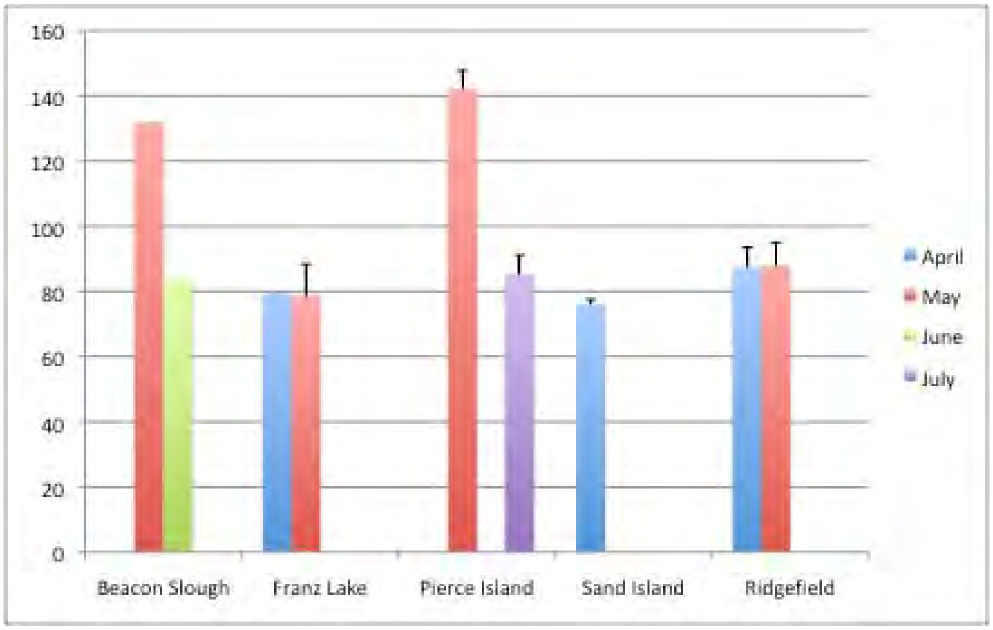


Figure 27: Mean length (± standard deviation) of unmarked (presumably wild) subyearling Chinook salmon over the sampling season at the 2008 EMP fishing sites.

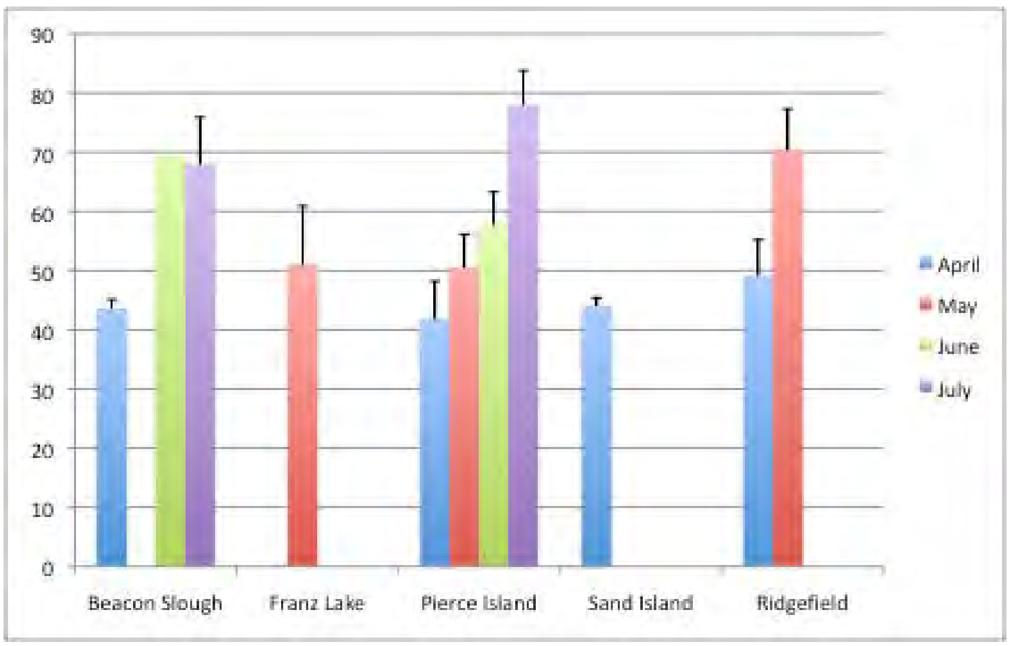


Figure 28: Mean length (± standard deviation) of marked (presumably hatchery) Chinook salmon over the sampling season at the 2008 EMP fishing sites.

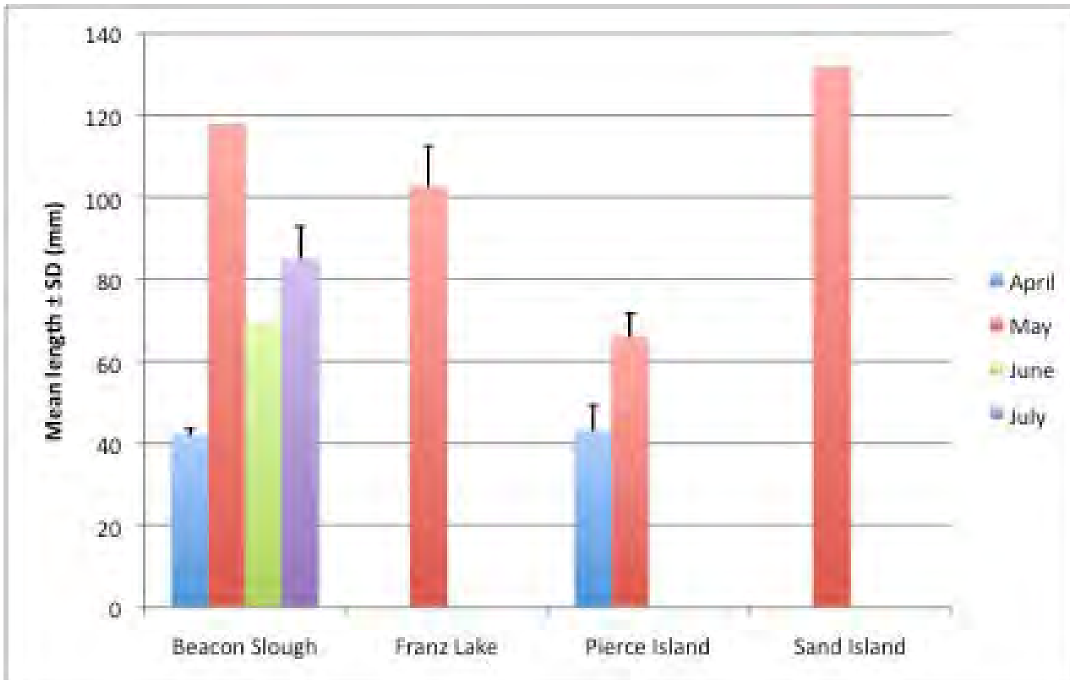


Figure 29: Mean length (± standard deviation) of unmarked (presumably wild) coho salmon over the sampling season at the 2008 EMP fishing sites.

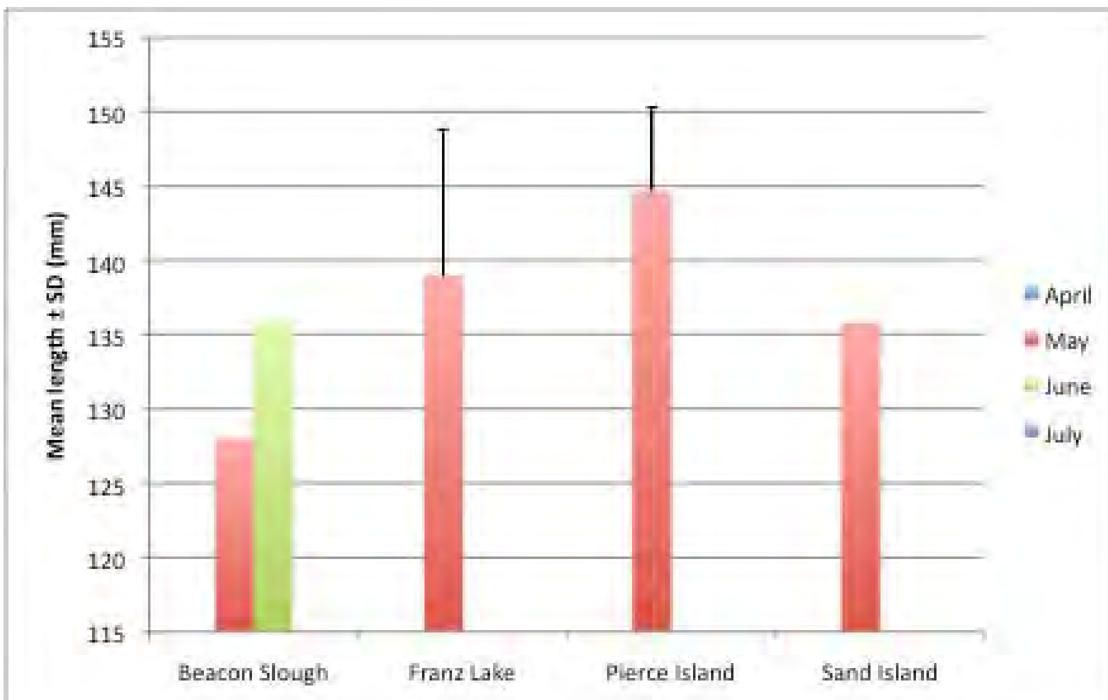


Figure 30: Mean length (± standard deviation) of marked (presumably hatchery) coho salmon over the sampling season at the 2008 EMP fishing sites.

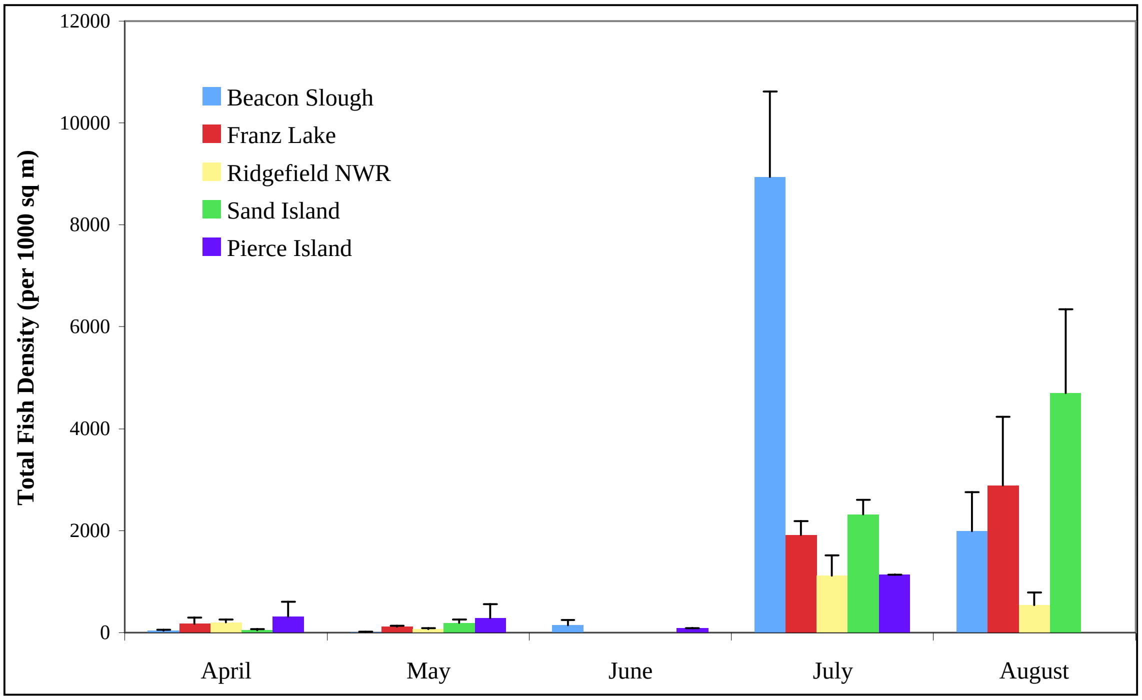


Figure 31: Number of fish of all species captured per unit effort (± standard error) by site and month at the 2008 EMP fishing sites.

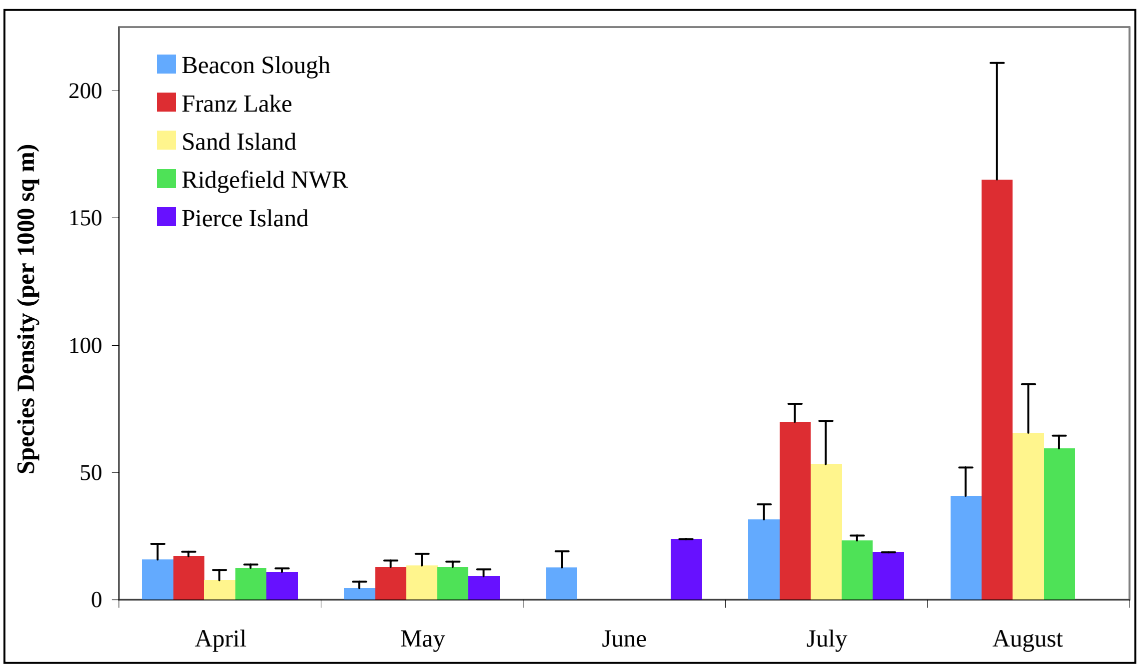


Figure 32: Number of species captured per unit effort (± standard error) by site and date at the 2008 EMP fishing sites.

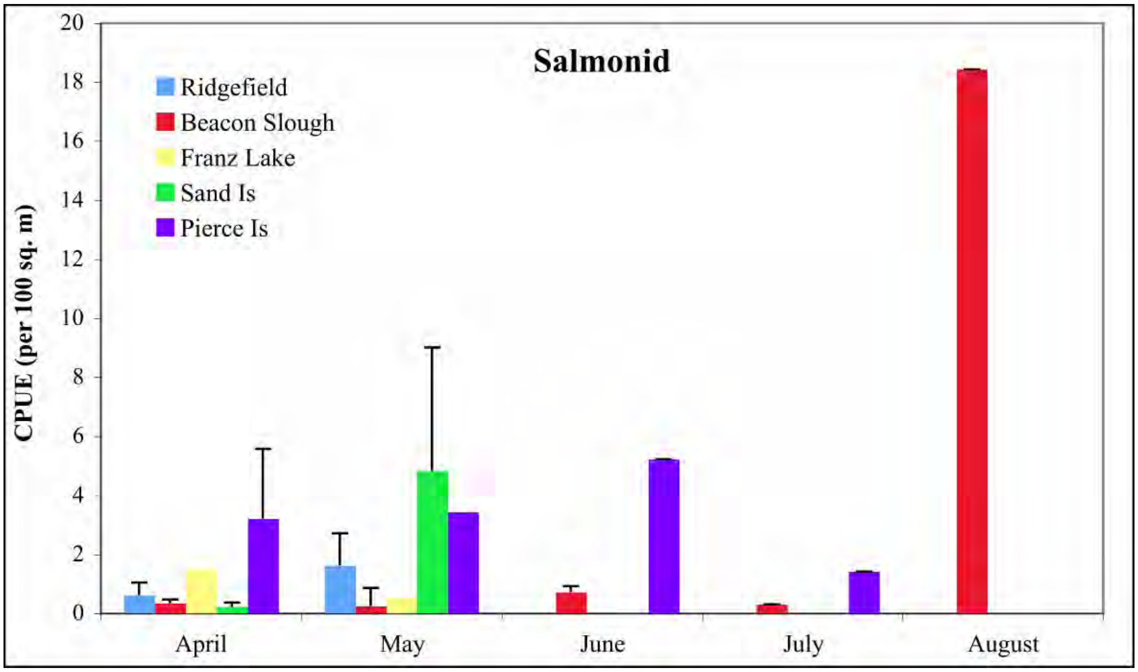


Figure 33: Total catch per unit effort (CPUE; ± standard error) of all salmonids collected by month.

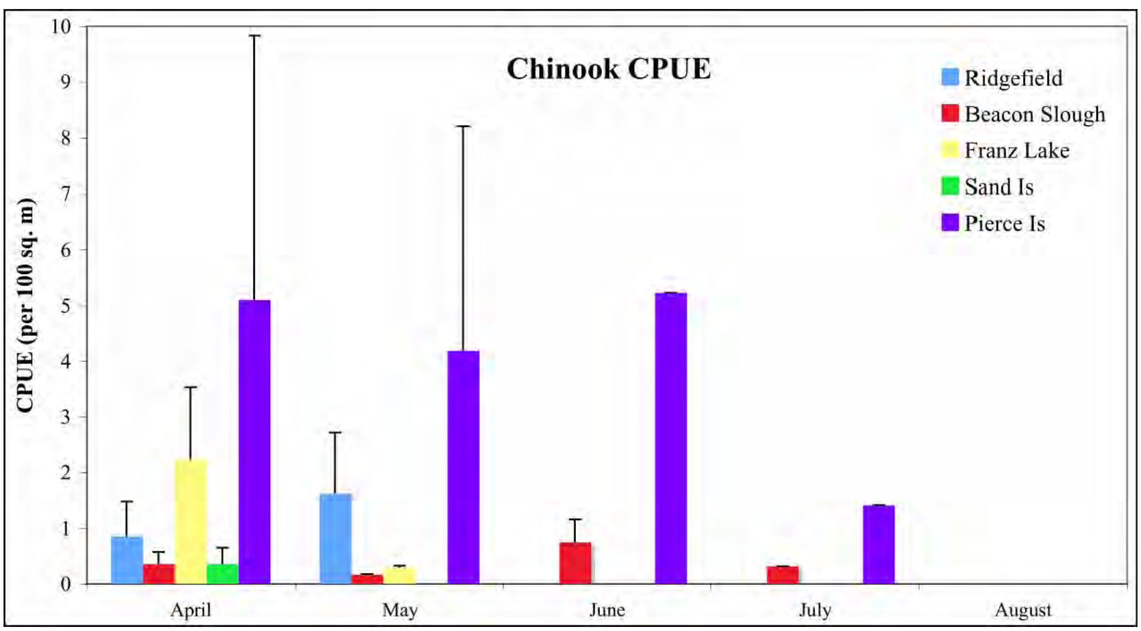


Figure 34: Number of Chinook captured per unit effort (CPUE; ± standard error) by date and EMP site.

10.1.3 Results for Year-to-Year Trends in Fish Use at Campbell Slough

The Campbell Slough site in the Ridgefield NWR was selected for monitoring long-term trends in fish habitat occurrence in the estuary. This site was sampled for fish in both 2007 and 2008 and wetland vegetation patterns in 2005, 2006, 2007, and 2008. Our 2007 fish sampling was conducted from early May through July whereas 2008 sampling was conducted from April through August. Due to higher and more variable water levels in 2008 relative to 2007, we could not sample the site in June 2008 and hence do not have fish data available for this month for comparison.

In spite of difficulties with site access, our sampling overall showed that juvenile salmon and juveniles of other fish species were feeding and rearing at the Ridgefield site in both 2007 and 2008 (Table 11). Juvenile Chinook were captured in both years; the percentage of total catch was 4% in 2007 and 2.9% in 2008 (Table 12). Of the non-salmonid species, three-spine stickleback, juvenile yellow perch, and juvenile carp were the most abundant in 2007; similarly, in 2008 the most abundant species were stickleback and carp.

In 2007 and 2008, Chinook salmon made up 97% and 98%, respectively, of the juvenile salmonid catch. In 2007, we collected no chum salmon and only one coho salmon; in 2008, the opposite occurred as we collected only one chum salmon and no coho salmon. In 2007, juvenile Chinook were present from the start of sampling in May through June. In 2008, juvenile Chinook were present from the start of sampling in April through May; fish may have also been utilizing this site in June 2008, but no data are available due to the high water levels. In both sampling years, we did not collect salmon in July and August, possibly because of water temperatures exceeding 20°C in both years (Table 11). The total number of fish of all species, species richness, and the number of Chinook captured-per-unit-effort (CPUE) was less in 2008 than in 2007. Likely factors include high water levels, difficulty fishing the site, and interannual variation in populations.

In 2007 and 2008, both hatchery (marked) and presumably wild (unmarked) Chinook salmon were found at the site and in similar proportions. Hatchery fish accounted for 52% of the catch in 2007 and 51% in 2008 (Table 16). Fish of hatchery origin were nearly the same size and weight in both years. In 2008, the mean length of marked Chinook ranged from 87.5 to 87.9 mm and weight from 6.9 to 7.2 g, while in 2007 the mean length of hatchery fish ranged from 83.5 to 87 mm and weight from 6.8 to 7.6 g. Unmarked fish were slightly smaller in 2008 than in 2007; in 2008, the mean length of unmarked fish ranged from 49.2 to 70.4 mm and weight from 1.2 to 3.6 g. In comparison, the mean length of unmarked fish in 2007 ranged from 58.3 to 75.5 mm and weight from 2.5 to 5.1 g. This difference is likely due to the different sampling periods between the 2 years. The majority of salmon were collected in April and May in 2008 vs. May and June in 2007.

Table 16: Mean length and weight (± standard deviation) of marked (hatchery) and unmarked (presumably wild) subyearling juvenile Chinook salmon collected at Campbell Slough (in the Ridgefield NWR) in 2007 vs. 2008.

Site and Year	Fish Type	Proportions of Catch	Length Range (mm)	Weight Range (g)
Campbell Slough, 2007	non-marked	48%	58.3-75.5 mm n=54	2.5-5.1 g n=54
	marked	52%	83.5-87 mm n=58	6.8-7.6 g n=58
Campbell Slough, 2008	non-marked	49%	49.2-70.4 mm n=25	1.2-3.6 g n=25
	marked	51%	87.5-87.9 mm n=26	6.9-7.2 g n=26

In summary, our sampling showed that the number of fish captured was generally lower at Campbell Slough in 2008 than in 2007. However, patterns of salmonid occurrence were similar in both years, with the exception of June 2008, when very high water levels prevented fish sampling and data collection for year-to-year comparisons for the month of June.

10.2 Prey Availability Surveys and Diet Analyses for Juvenile Chinook Salmon

NOAA-Fisheries is analyzing diets of juvenile Chinook salmon and identifying prey species in salmon habitats to understand prey sources for juvenile salmonids and the potential influence of prey availability on juvenile salmonid occurrence in various habitat types. A related objective (not funded by this project) is to use these data to identify potential sources of contaminants affecting salmon in the LCRE. We are in various stages of processing samples collected in 2005, 2007, and 2008. The collection methods and status of sample processing and analyses for each year of sample collection are outline below.

10.2.1 Invertebrate Collection Methods

For the invertebrate prey sampling, the objective was to collect aquatic and terrestrial invertebrate samples and identify the taxonomic composition and abundance of salmonid prey available at sites when juvenile salmonids were collected. These data will be compared with the taxonomic composition of prey found in stomach contents of fish collected concurrently.

In 2008, we did 3 types of invertebrate collections:

1) Open water column Neuston tows (3 tows at each site at each sampling time). These tows collect prey available to fish in the water column and on the surface of open water habitats. For each tow, the net was towed for a measured distance of at least 10 m. Invertebrates, detritus, and other material collected in the net were sieved, and invertebrates were removed and transferred to a labeled glass jar or Ziploc bag. The jar or bag was then filled with 95% ethanol so that the entire sample was covered.
2) Emergent vegetation Neuston tows (3 tows at each site at each sampling time). These vegetation tows collect prey associated with emergent vegetation and available to fish in shallow areas. For each tow, the net was dragged through water and vegetation at the river margin where emergent vegetation was present and where the water depth was < 0.5 m deep for a recorded distance of at least 5 m. The samples were then processed and preserved in the same manner as the open water tows.
3) Terrestrial sweep netting (3 collections at each site at each sampling time). Sweep netting collects terrestrial invertebrates that are associated with riparian vegetation and may be prey for fish in these habitats. For these samples, insects were collected using a sweep net along a transect of a recorded distance of at least 5 m along the river margin where vegetation was present. Transects were parallel to the bank and approximately 3 m from the water's edge. The net was swept through the vegetation for the length of the transect and for ~0.5 m on either side once thoroughly. Insects were transferred from the net into labeled plastic bags or jars containing some ethanol to both kill the inverts and trap them in the bag or jar. Additional ethanol was when added to preserve the samples.

Table 17 lists the numbers of prey samples collected from each site at each sampling event. The results to date of the prey availability and Chinook diet analyses are presented below.

Table 17: Terrestrial and aquatic prey samples collected at the 2008 EMP sites.

	Open Water						Emergent Vegetation						Sweep Nets						Total
Site	April	May	June	July	Aug	Total	April	May	June	July	Aug	Total	April	May	June	July	Aug	Total	
Beacon Slough	1	3	2	3	3	12	3	3	2	3	3	14	3	3		7	3	16	42
Franz Lake	3	3		3	3	12	3	3				6	3			4	3	10	28
Sand Island	3	3			2	8	3	3			2	8	3				2	5	21
Campbell Slough	3	3		3	3	12		3				3	3	3		3	3	12	27
Total	10	12	2	9	11	44	9	12	2	3	5	31	12	6	0	14	11	43	118

10.2.2 2005 Chinook Diet Analyses

A total of 14 composite diet samples were collected in May and June 2005 from 8 EMP sites (Table 18). We have completed the identification, enumeration, and measurement of prey items collected from Chinook stomachs, and partially completed data analyses. Here, we present data on the counts of prey items. We are currently calculating estimates of prey biomass and will provided these data in forthcoming reports. Because each sample is a composite of stomach contents from ~10-15 fish per site, analyses reflect general feeding behavior at that site and time; analyses do not reflect individual fish feeding behavior.

Juvenile Chinook fed on a diverse assemblage of invertebrates, with aquatic invertebrates making up the majority of prey items in 10 of the 14 samples (Figure 35; Table 18-Table 19). Cladoceran spp. were overwhelmingly the most abundant taxa in a few of the May samples (Figure 35; Table 10) while Chironomidae spp. (Diptera) were present and often abundant in all samples. The majority of the prey items were likely selected from the middle to upper water column (as opposed to the benthos). For example, Cladocerans were found in the water column and 66% of the 2,012 Chironomidae counted were pupae or emerging adults. Terrestrial insects generally made up less than 30% of the prey items (Table 19), although prey in fish collected at Morrison Street Bridge were ~50% terrestrial on both sampling dates. Terrestrial insects were diverse with Psocoptera, Hemiptera and Hymenoptera being most common and Lepidoptera, Thysanoptera and Isoptera being least common. Although we have not completed the biomass estimates, we predict that amphipods and isopods will contribute significantly to the biomass of salmon diets.

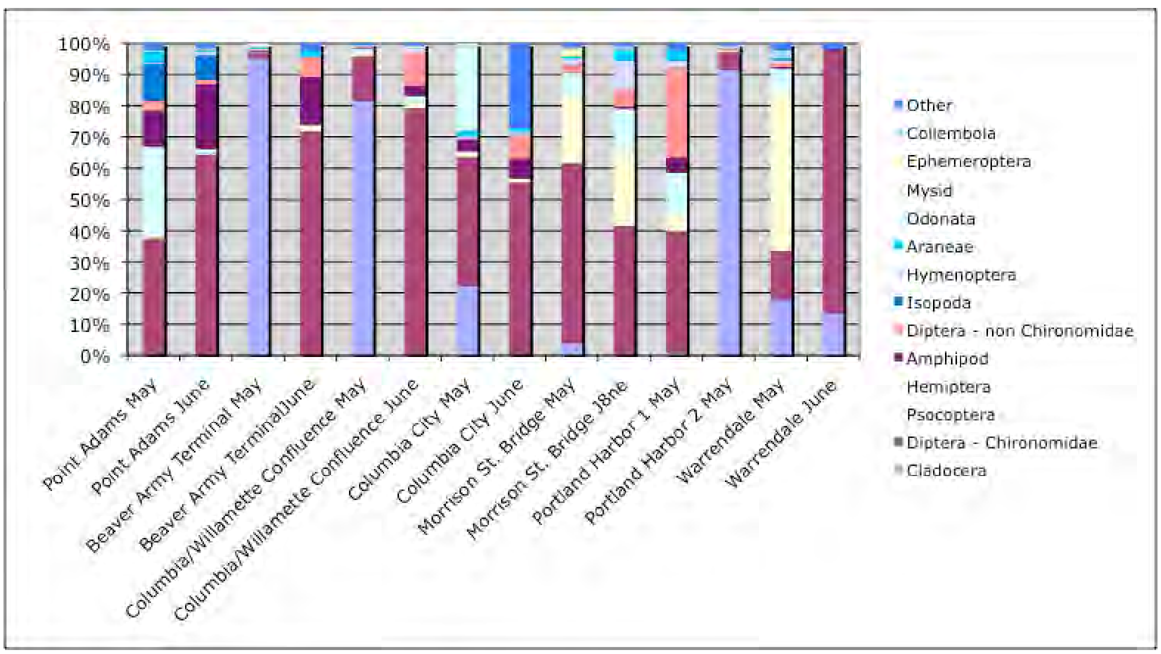


Figure 35: Proportions of invertebrate taxa in the stomachs of juvenile Chinook collected at 8 EMP sites in 2005.

Table 18: Quantitative summary of taxa in juvenile Chinook stomachs collected at EMP sites in 2005. Each sample is a composite of stomach contents from ~10-15 fish per site. Thus, analyses reflect general feeding behavior at that site and time, not individual fish feeding behavior.

Site	Date	Cladocera	Diptera - Chironomidae	Psocoptera	Hemiptera	Amphipod	Diptera - non Chironomidae	Isopoda	Hymenoptera	Araneae	Odonata	Mysid	Ephemeroptera	Collembola	fish	Insect eggs	snail	unknown	Coleoptera	Nematoda	Trichoptera	mite	Thysanoptera	Lepidoptera	bone	Bivalvia	Maxillopoda	Diplopoda	Isoptera	Oligochaete	Pseudoscorpionida	Grand Total
Beaver Army Terminal	16-May-05	1294	26		4	8	1		4	5		17																				1359
Beaver Army Terminal	21-Jun-05		33	1		7	3			1										1												46
Columbia Willamette Confluence	15-May-05	1265	223	21	17	3	5		8	6								1	2				1									1552
Columbia Willamette Confluence	22-Jun-05		99	2	3	4	13		2		1										1											125
Columbia City	17-May-05	24	44	2		4			1	2	28	2																				107
Columbia City	21-Jun-05		45	1		5	6		1	1						15		2	2	1						2						81
Morrison St. Bridge	13-May-05	21	321	121	41		13		11	4			12	5				2			2	1						1				555
Morrison St. Bridge	22-Jun-05		127	76	39	2	16		29	10				4								3										306
Point Adams	16-May-05		155	5	117	47	14	50	1	15		1						4			2			1	1						1	414
Point Adams	22-Jun-05		210	1	5	67	5	25	5	1		2								1	1	1		1	1							326
Portland Harbor 1	14-May-05	1	50	7	17	6	37		3	4										2										1		128
Portland Harbor 2	14-May-05	2026	125	14	14	1	2		6				8	1	15				1	1							2		1			2217
Warrendale	12-May-05	33	29	96	12	1	2		2	1				5					1	1		1	1									185
Warrendale	23-Jun-05	85	531			1											10		2		1											630
Grand Total		4749	2018	347	269	156	117	75	73	50	29	22	20	15	15	15	10	9	8	7	7	6	2	2	2	2	2	1	1	1	1	8031

Table 19: Percentage of prey items identified as aquatic vs. terrestrial in origin. Insects that were pupae and emerging from the aquatic habitat (e.g., Chironomidae pupae) are included in the aquatic column. Because origin could not be determined for all items, some percentages do not sum to 100%.

Site	Date	% Aquatic	% Terrestrial
Beaver Army Terminal	5/16/2005	99	1
Beaver Army Terminal	6/21/2005	91	9
Columbia/Willamette Confluence	5/15/2005	96	4
Columbia/Willamette Confluence	6/22/2005	86	14
Columbia City	5/17/2005	92	7
Columbia City	6/21/2005	85	15
Morrison St. Bridge	5/13/2005	57	43
Morrison St. Bridge	6/22/2005	43	55
Point Adams	5/16/2005	63	37
Point Adams	6/20/2005	94	6
Portland Harbor 1	5/14/2005	66	29
Portland Harbor 2	5/14/2005	98	2
Warrendale	5/12/2005	36	61
Warrendale	6/23/2005	100	0

10.2.3 2007 Salmon Prey Availability Surveys and Chinook Diet Analyses
Invertebrate samples were collected from the Campbell Slough site at the Ridgefield NWR primarily for future chemistry analyses. We were opportunistic in our sampling efforts, trying to collect sufficient biomass (0.5 g wet weight) of representative invertebrate prey taxa. Diet samples were collected from fish when available, with a total of 2 samples obtained for stomach contents taxonomy and 3 samples for stomach contents chemistry. The stomach contents chemistry samples have been processed and results are presented below. Invertebrate samples collected by Neuston tow and sweep net for taxonomic and chemical analyses and stomach contents samples collected for taxonomic analyses are currently being processed.

10.2.4 2008 Salmon Prey Availability Surveys and Chinook Diet Analyses
As of August 2008, 118 invertebrate samples have been collected from the 2008 EMP sites, as well as stomach contents samples from 83 individuals Chinook salmon for taxonomic analyses. Aquatic and terrestrial prey samples include 50-m Neuston tows from open water sites where fish are collected, 10-m Neuston tows through emergent vegetation, and 10-m terrestrial sweep collections from riparian areas adjacent to emergent vegetation. Preliminary observations indicate Chironomidae larvae and pupae and Cladocerans will dominate open water collections while Odonata larvae and Trichoptera larvae will dominate emergent vegetation collections. Chironomidae adults and other Diptera adults dominate the terrestrial sweep collections. Sample processing is on-going and will be documented in forthcoming reports.

10.3 Otolith Analyses for Growth Rate Determination
For EMP sampling in 2007 and 2008, otoliths were collected from juvenile fall Chinook salmon from Campbell Slough (2007 and 2008), Sandy Island near Goble, OR (2007), Beacon Slough (2008), Franz Lake (2008), Pierce Island (2008), and Sand Island near Rooster Rock State Park, OR (2008). Otoliths from fall Chinook were also collected for the Estuary Partnership's Effectiveness Monitoring Project at 2 Mirror Lake sites (Mirror Lake #1 and Mirror Lake #4), and for supplementary sampling conducted in cooperation with NOAA's National Ocean Service from 2 sites near the Willamette/Columbia Confluence (Confluence Oregon and Confluence Washington). We present growth rate analyses of fish from the

EMP, Mirror Lake, and Confluence sites to compare estimated growth rates from the widest possible range of sites.

10.3.1 Methods for Otolith Analyses

Otoliths from fish ranging in size from 52-95 mm (fork length) were extracted and processed for microstructural analysis of recent growth (Table 20). Specifically, sagittal otoliths were embedded in Crystal Bond© and polished in a transverse plane using 30-3μm lapping film. Using Image Pro Plus© (version 5.1), with a mediacybernetics (evolutionMP color) digital camera operating at a magnification of 20 x, NOAA-Fisheries determined the average fish daily growth rate (i.e., mm of fish length/day) 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 (total otoliths analyzed = 131; left sagittal otolith were used). Average daily growth (DG, mm/day) was determined using the Fraser-Lee equation:

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

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

where La and Oa represents fish length and otolith radius at time a (i.e., last 7, 14, or 21 days), respectively, d is the intercept (13.563) of the regression between fish length and otolith radius, Lc and Oc are the fish length and otolith radius at capture, respectively.

An ANOVA was used to determine whether average daily growth rates differed among sites. Data were normally distributed according to the Shapiro-Wilks test.

Table 20: Otolith sample sizes per site.

Site	# of Otoliths
Campbell Slough (Ridgefield), 2007	14
Campbell Slough (Ridgefield), 2008	10
Beacon Slough	9
Franz Lake	12
Pierce Island	5
Sand Island	8
Mirror Lake #1	9
Mirror Lake #4	11
Confluence Oregon	13
Confluence Washington	15

10.3.2 Results of Otolith Analyses

Based on our ANOVA's, Chinook growth rates varied significantly for each of the time intervals (7, 14, and 21 days) (Figure 36; Table 21). Based on a Bonferroni test (within each time interval), we determined that Chinook from Ridgefield (2007) had significantly greater daily growth rates than fish from Confluence Washington (i.e., recent growth for the last 7, 14, or 21 days). Fish from Mirror Lake #4 also had significantly lower growth rates than that of Ridgefield (2007), but this was limited to our assessment of the last 7 days of growth (Figure 36; Table 21). Finally, fish from Sand Island had significantly lower growth rates than that of Ridgefield (2007), but this was limited to our assessment of the last 14 days of growth (Figure 36; Table 21).

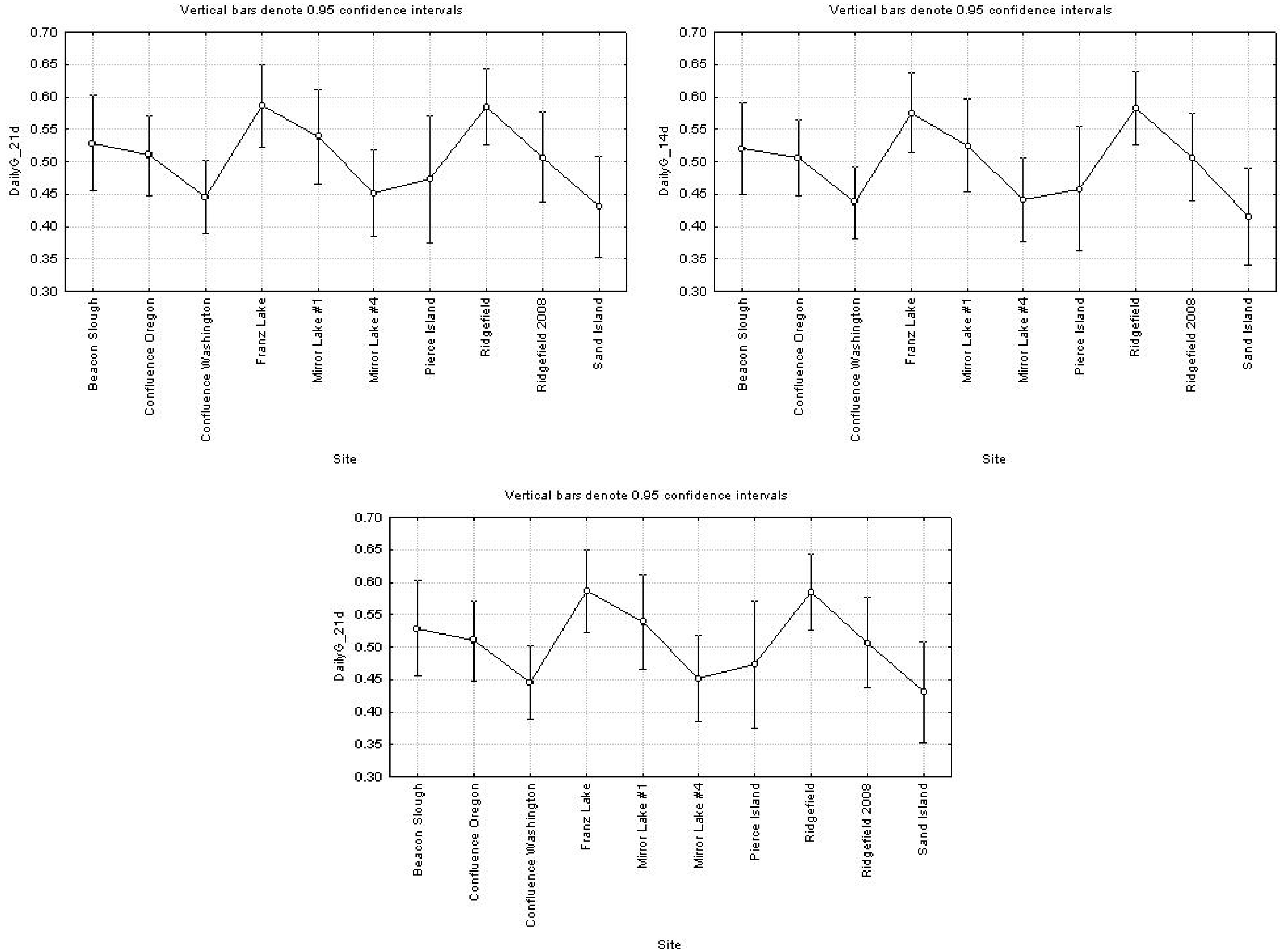


Figure 36: Box plots of the average daily growth rates for three intervals of recent growth (7 days, 14 days, and 21 days) for juvenile Chinook salmon collected in the LCRE.

Table 21: ANOVA results comparing Chinook recent (last 7, 14, and 21 days) daily growth rates among 7 sites in the LCRE.

Source	df	Mean-Square	F-ratio	P
Last 7 days	9	0.038	3.46	0.0009
Error	96	0.010		
Last 14 days	9	0.037	3.26	0.001
Error	96	0.011		
Last 21 days	9	0.035	2.86	0.004
Error	96	0.01		

10.4 Biochemical Measures of Salmon Growth and Condition

To measure biochemical indicators of salmon growth and condition, NOAA-Fisheries collected salmon whole bodies for analysis of lipid content and classes and plasma for blood chemistry analysis and possible analysis of hormones associated with growth (e.g., insulin-like growth factors, thyroid hormones). The plasma samples could also be used for vitellogenin analyses as a way of screening for exposure to estrogenic compounds.

Because of the small size of the fish collected and staffing and funding limitations, we were unable to collect blood samples from salmon at all sampling sites. Instead, blood samples were collected from 58 fish; of these, 19 samples were from Confluence Washington, 21 samples from Confluence Oregon, and 18 samples from Campbell Slough. We are now determining the best use of these samples based on the sample size and results of other tests for differences in growth.

Lipid content analyses have been completed for the yearling Chinook salmon collected in 2007 (See Section 10.7). These fish were collected by purse seine from 2 sites near the estuary's mouth. The lipid content of these fish ranged from 0.33 – 1.3%, but for most of the fish, lipid levels were below 1% (Figure 37). The lipid content of the yearling fish was low relative to levels in the salmon collected from tidal freshwater sites and more similar to lipid data for older subyearling collected from the estuary's mouth by purse seine (Figure 38; Johnson et al. 2007). Loss of lipids is expected as salmon enter the saltwater portion of the estuary and undergo smoltification (Brett, 1995). However, the low lipid levels observed in these yearling fish generally fall below 1%, or the lipid level associated with poor salmonid survival (Finstad et al. 2004; Biro et al., 2004).

Analyses of whole bodies for lipid content and classes are now in progress for the subyearling juvenile Chinook salmon collected in 2007. Analyses of the 2008 samples will then follow.

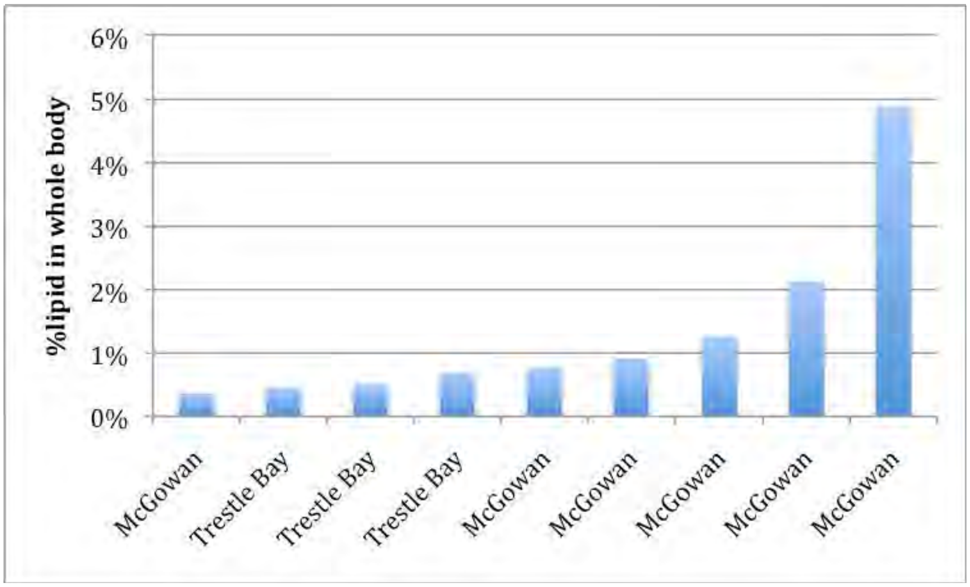


Figure 37: Lipid contents for yearling Chinook salmon collected from the Columbia River mouth. Lipid values less than 1% are associated with low survival rates for salmonids.

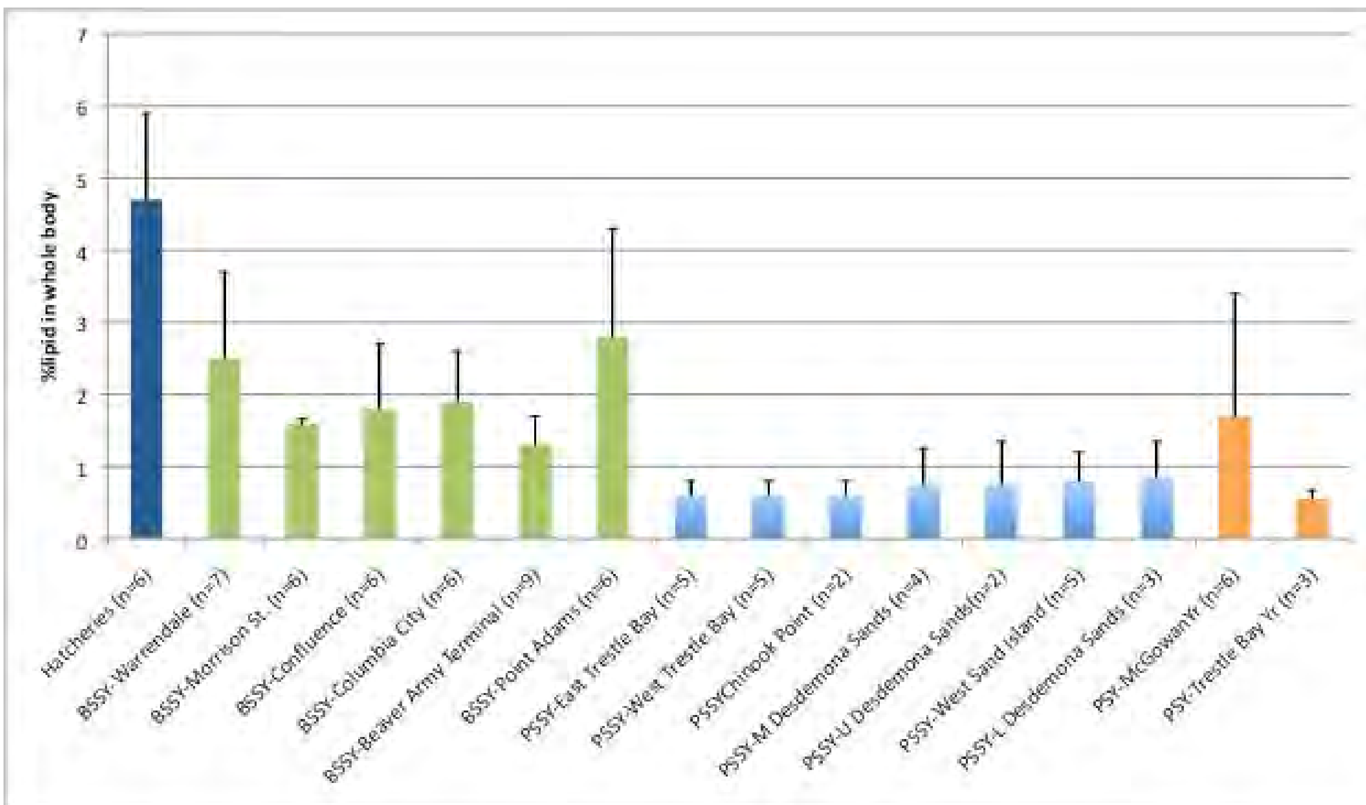


Figure 38: Lipid content of yearling Chinook salmon collected by purse seine from the mouth of the Columbia River estuary (PSY) vs. lipid contents for: 1) subyearlings from Columbia Basin hatcheries; 2) subyearlings collected by beach seine at shallow water tidal freshwater sites (BSSY); and 3) subyearlings collected by purse seine at deeper water estuarine sites (PSSY). Lipid values less than 1% are associated with low survival rates for salmonids.

10.5 Genetic Stock Identification of Juvenile Salmon Collected in 2007 and 2008

Genetic analyses showed that fish from several different Columbia River stocks were collected in our 2007 sampling at Ridgefield (Campbell Slough) and Sandy Island (Figure 39). Fish from Campbell Slough came primarily from the Spring Creek Fall (47%) and Upper Columbia River Fall (34%) reporting groups. West Cascades Fall (13%) and Willamette River spring (5%) stocks made up smaller proportions of captured fish. No fish from the West Cascades Spring, Middle Columbia Spring, or Snake River/Deschutes Fall stocks were collected. At Sandy Island, fish were primarily from the Spring Creek Fall (53%) and West Cascades Fall (40%) stocks. Small proportions of fish (~2-4%) were from the Snake River/Deschutes Fall, Willamette Spring, and Upper Columbia River Fall stocks. No fish from the Middle Columbia Spring group were collected. The stocks present at Campbell Slough and Sandy Island were fairly similar to those identified at nearby sites (e.g., Confluence, Columbia City, and Beaver Army Terminal) in 2005. However, the proportion of fish belonging to the Spring Creek Fall group tended to be high at both Sandy Island and Campbell Slough, and Campbell Slough had a higher percentage of fish from the Upper Columbia River Fall group.

The proportions of fish in various genetic groups at Sandy Island and Campbell Slough also varied by time (Figure 40). In early May, almost all of the fish captured at both Campbell Slough and Sandy Island were from the Spring Creek Fall group. These fish were almost entirely marked, hatchery fish; 80% of fish from Campbell Slough and 100% of fish from Sandy Island had fin clips. The small proportion of Campbell Slough fish assigned to the Willamette Spring group did not have fin clips. In late May and June, a greater diversity of stocks was observed at both sites, and the stocks present were quite different. At Sandy Island, the majority of fish (84%) were from the West Cascade group, while at Campbell Slough, fish from the Upper Columbia River Fall group predominated, making up 62-66% of sampled fish. The majority of these fish were did not have fin clips and so were presumably wild.

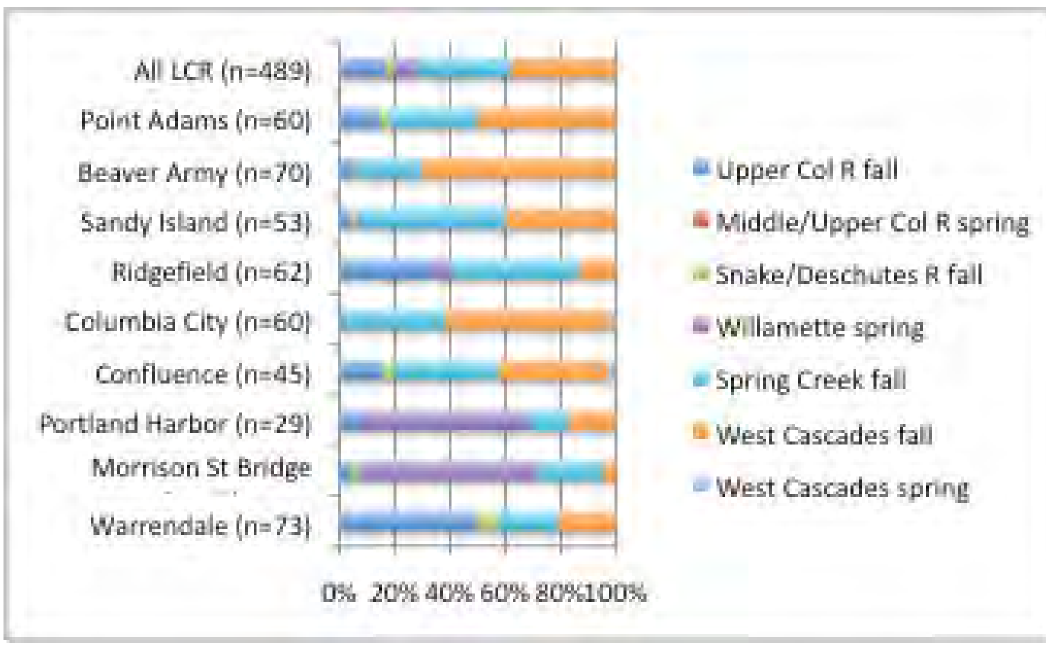


Figure 39: Genetic stock identification of juvenile Chinook salmon from Ridgefield (Campbell Slough) and Sandy Island in 2007. Genetic stock data for juvenile Chinook salmon collected in 2005 by the EMP are included for comparison.

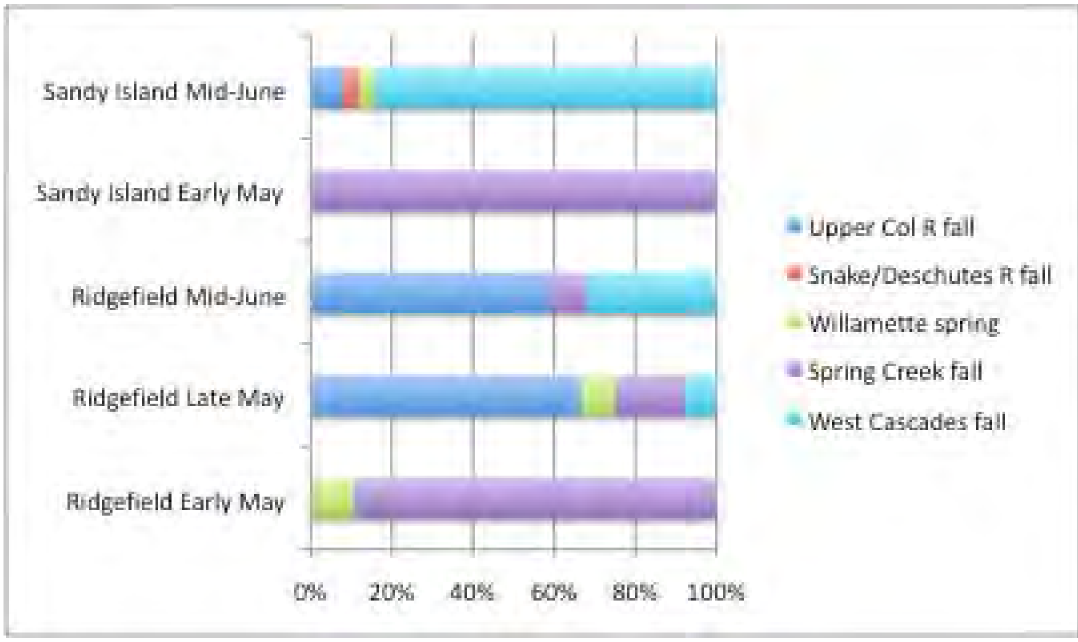


Figure 40: Temporal changes in juvenile salmon stocks collected at Ridgefield (Campbell Slough) and Sandy Island in 2007.

Genetic stock information is available for juvenile Chinook salmon sampled at the 2008 EMP sites from April through June; samples collected in July and August are currently being analyzed and will be included in a later report from NOAA-Fisheries. The preliminary data show that, at all sites except Beacon Slough, the majority of fish (56-93%) came from the Spring Creek Fall reporting group (Figure 41). At Pierce Island and Franz Lake, smaller proportions of fish were also present from the Snake/Deschutes River and/or Upper Columbia River Fall reporting group. At Ridgefield and Franz Lake, small proportions of fish were present from the Snake/River Deschutes Fall, Upper Columbia Fall, and West Cascades Fall reporting groups, as well as a few West Cascades Spring and Willamette Spring Chinook. The 2008 genetic profile for Campbell Slough was similar to that observed at the site in early May 2007. Unlike most of the EMP 2008 sites, no Spring Creek fish were collected at Beacon Slough; instead, 46% of fish were from the Snake/Deschutes River reporting group and 54% of fish were from the Upper Columbia River Fall reporting group.

The marked hatchery fish collected at the 2008 EMP sites came primarily from the Spring Creek Fall group (Figure 42). The few salmon identified as Willamette and West Cascde Spring Chinook were of hatchery origin. A number of the wild Chinook also came from the Spring Creek Fall group, but the Snake/Deschutes River Fall and Upper Columbia River Fall stocks were most common.

As at Campbell Slough and Sandy Island in 2007, the proportions of fish in various genetic groups at the 2008 EMP sites changes with time (Figure 43). Approximately 80% of all fish sampled in April and May were from the Spring Creek Fall group, perhaps reflecting the higher proportion of hatchery fish collected during that period. In June, the range of stocks was more diverse. The highest proportion of fish were from the Upper Columbia Fall reporting group, but substantial proportions of fish from the Snake River/Deschutes Fall and West Cascades Fall stocks were also observed, as well as a few Spring Chinook.

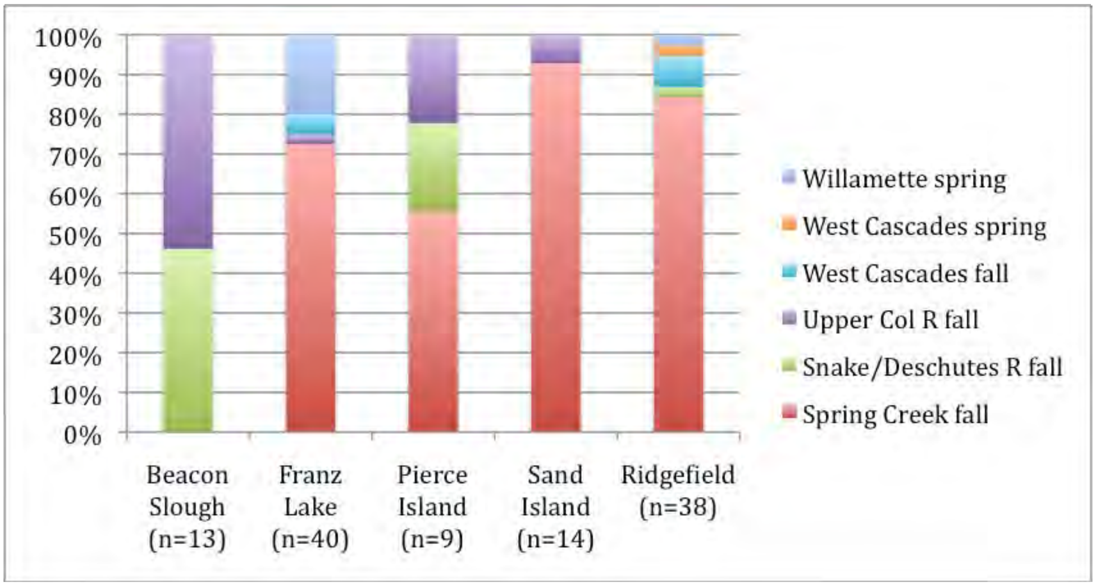


Figure 41: Genetic stock identification of juvenile Chinook salmon from 2008 EMP sites. Only fish collected from April through June are included.

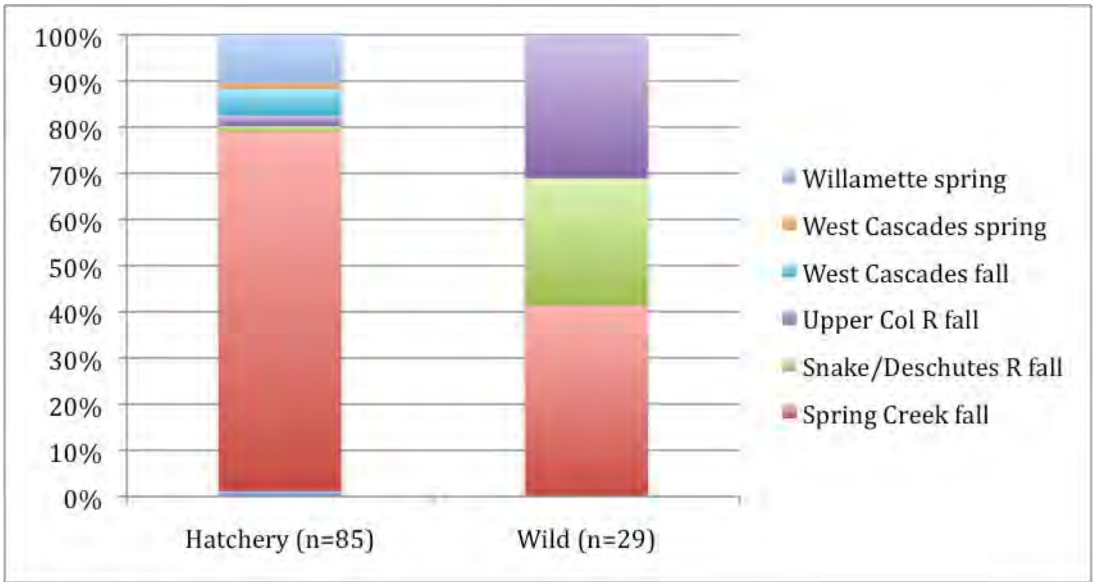


Figure 42: Genetic stock identification of hatchery vs. wild juvenile Chinook salmon from the 2008 EMP sites. Only fish collected from April through June are included.

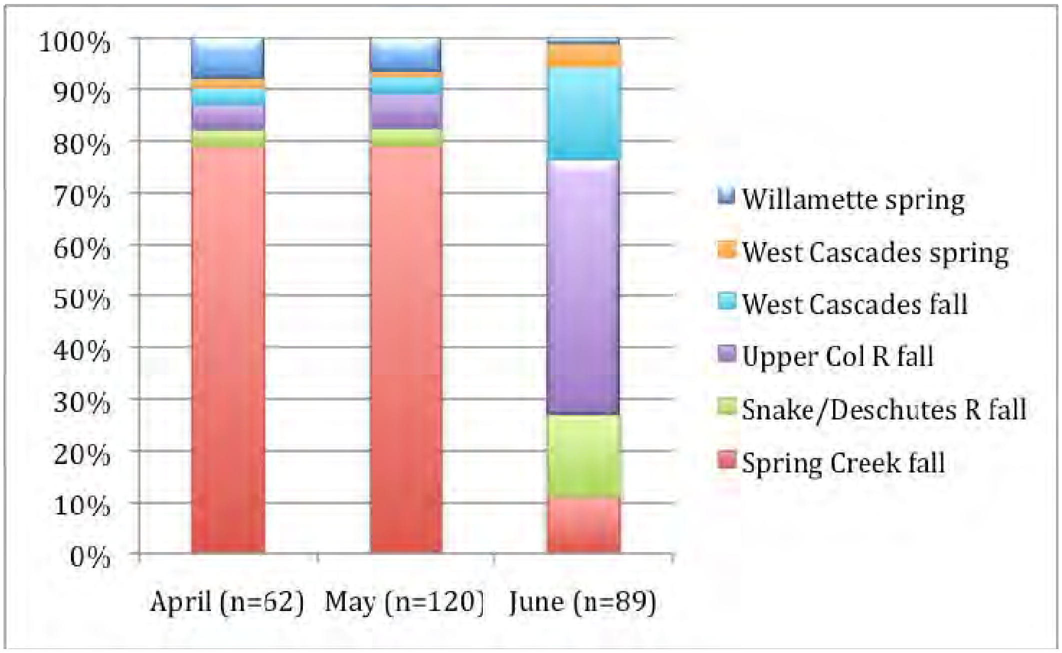


Figure 43: Temporal changes in juvenile salmon stocks collected at Ridgefield (Campbell Slough) in 2008.

10.6 Contaminant Concentrations in Stomach Contents of Juvenile Salmon

In 2007, NOAA-Fisheries collected stomach content samples for juvenile Chinook salmon at Campbell Slough and Sandy Island. Samples were processed in 2007-2008. NOAA-Fisheries found that DDTs, PCBs, PBDEs and PAHs were found at measurable concentrations in stomach contents of fish from both Campbell Slough and Sandy Island (Figure 44; Figure 45). However, the concentration of total PAHs was only 42 ng/g wet wt at Campbell Slough vs. 460 ng/g wet wt at Sandy Island. The total PAHs concentration at Sandy Island is similar to concentrations measured in stomach contents from fish collected from Warrendale in 2005 (Figure 44).

Of the high molecular weight PAHs (HAHs), fluoranthene and pyrene accounted for 61% of ∑HAHs at Campbell Slough and 49% of ∑HAHs at Sandy Island. Different low molecular weight PAHs (LAHs) dominated samples at the 2 sites. At Sandy Island, phenanthrene comprised 33% of ∑LAHs in stomach contents. At Campbell Slough, naphthalenes (naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, dimethyl naphthalene, and trimethylnaphelalene) made up 60% of ∑LAHs. Retene, which is a derivative of wood products, made up ~8% of ∑LAHs in salmon stomach contents from Campbell Slough and 11% of ∑LAHs in salmon stomach contents from Sandy Island. These percentages are somewhat higher than the 5% retene or less measured in 2005 samples at Warrendale. Overall, LAHs made up about 76% of total PAHs in Campbell Slough samples vs. 43% in Sandy Island samples (Figure 44).

Concentrations of DDTs and PCBs in salmon stomach contents from both sites were very similar to levels found in 2005 at the nearby Columbia City site (Figure 45). The average PCB concentration was 37 ng/g wet wt at Campbell Slough vs. 36 ng/g wet wt at Sandy Island, as compared to 28 ng/g wet wt at Columbia City. Concentrations of DDTs in stomach contents samples were 21 ng/g wet wt at Campbell Slough and 36 ng/g wet wt at Sandy Island, very similar to the DDT concentrations in 2005 stomach contents samples. Of the six DDT isomers measured, p,p’-DDE and p,p’-DDD predominated samples from Campbell Slough and Sandy Island, accounting for 81% and 19% of total DDTs, respectively, at Campbell Slough, and 72% and 24% of total DDTs at Sandy Island. At Sandy Island, o,p’-DDD, o,p’-DDT, p,p’-DDT were also detected, while at Campbell Slough, only additional isomer detected was o,p’-

DDD. Average concentrations of all these isomers were quite low (<2 ng/g wet wt) in samples from both sites. o,p'-DDE was below detection limits in all samples.

Sandy Island and Campbell Slough did differ in concentrations of PBDEs (Figure 45). At Campbell Slough, PBDEs were barely detectable in stomach contents, at an average concentration of only 2.5 ng/g wet wt. At Sandy Island, however, the average concentration was 21 ng/g wet wt, lower than concentrations observed in salmon from Morrison Street Bridge and Columbia City in 2005, but higher than values measured in 2005 samples.

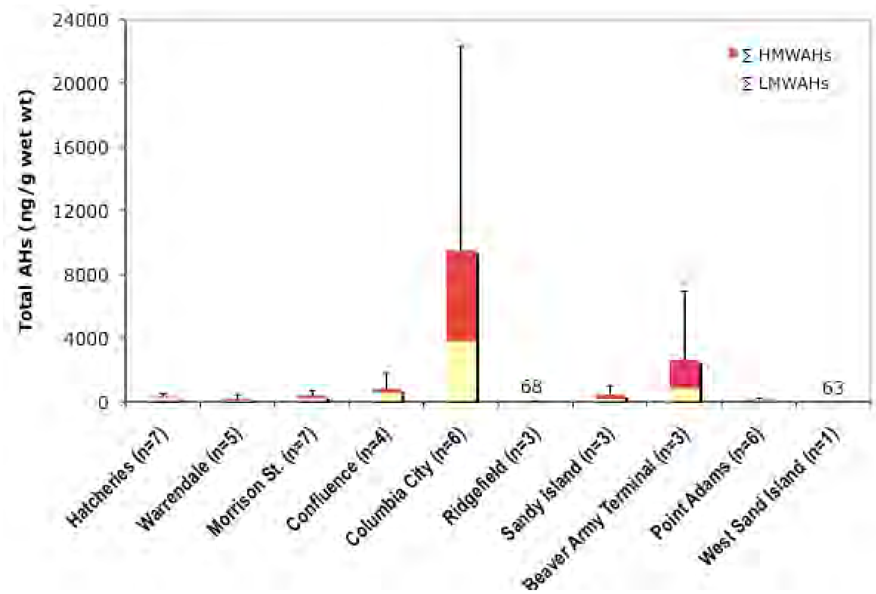


Figure 44: Concentrations (ng/g wet wt) of total aromatic hydrocarbons (AHs) in stomach contents of subyearling fall Chinook salmon collected in 2007 from Ridgefield (Campbell Slough) and Sandy Island. Data from 2005 EMP samples are included for comparison. Error bars show mean + 1 standard deviation.

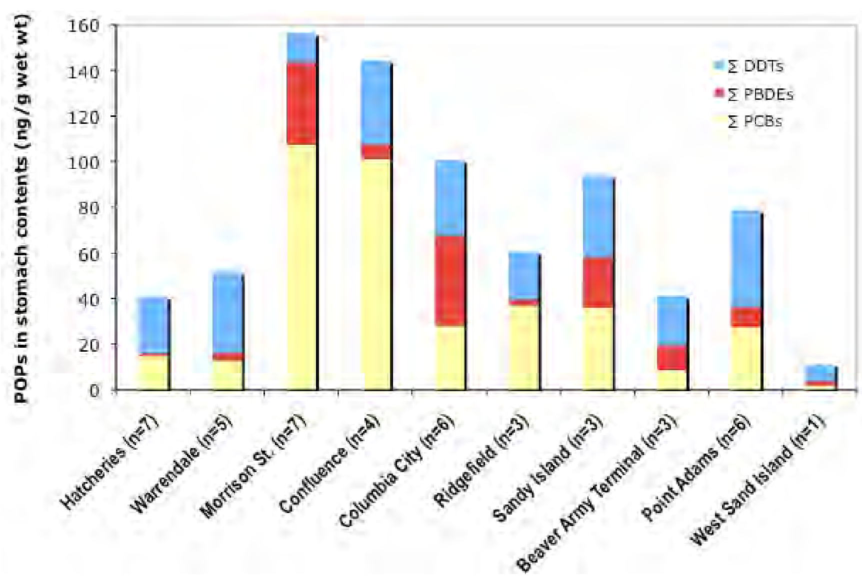


Figure 45: Concentrations (ng/g wet wt) of persistent organic pollutants (POPs; DDTs, PBDEs, and PCBs) in stomach contents of subyearling fall Chinook salmon collected from Ridgefield (Campbell Slough) and Sandy Island in 2007. Data from 2005 EMP samples are included for comparison.

10.7 Contaminants in Yearling Chinook in the LCRE

In May 2007, we collaborated with the Fish Ecology Division of NOAA's Northwest Fisheries Science Center to collect whole bodies of ten yearling Chinook salmon by purse seine from two sites, North Channel (Latitude 46.2361, Longitude -123.8956) and Trestle Bay (Latitude 46.21695, Longitude -123.9665) in the saltwater portion of the LCRE (Reach A shown in Figure 1). These samples were collected to provide information on contaminant exposure in yearling Chinook salmon with stream-type life histories. Chemical analyses were conducted with NOAA-Fisheries funds in summer 2008.

The results showed that concentrations of PCBs and PBDEs in whole bodies of these fish were relatively low compared to concentrations observed in subyearling Chinook salmon collected from estuarine and tidal freshwater sites (Figure 46). Concentrations of DDTs (17-36 ng/g wet wt) were more comparable to those measured in subyearling Chinook (Figure 46). However, as noted above (See Section 10.4), the lipid content of these fish was often very low, especially in fish from Trestle Bay. Of the 9 fish analyzed so far, 6 had lipid content below 1%, a level that is associated with an increased likelihood of mortality (Biro et al. 1994). Lipid content in some fish was as low as 0.3-0.4%

Because of their low lipid content, lipid-adjusted concentrations of PCBs and PBDEs were more comparable than wet wt concentrations to levels observed in subyearling Chinook. In fact, a few yearling fish had concentrations of PCBs and DDTs, on a lipid weight basis, that approached or exceeded estimated threshold effects levels of 2,400 ng/g lipid for PCBs (Meador et al. 2002) and 5,000-6,000 ng/g lipid for DDTs (Beckvar et al. 2005; LCREP 2007). For instance, a fish from McGowan had a DDT level of 6,500 ng/g lipid, a fish from Trestle Bay had a DDT level of 5,000 ng/g lipid, and another fish from Testle Bay had a PCB level of 2,400 ng/g lipid.

Overall, these data are consistent with other information on contaminants in yearling Chinook (Dietrich et al. 2008). In both this study and Deitrich et al. (2008), concentrations of PCBs and PBDEs (contaminants found predominantly in the urbanized portions of the LCRE like Portland and Vancouver) were relatively low, while concentrations of DDTs were higher. This suggests that the yearlings absorbed DDTs during residence at freshwater sites, but their accumulation of PCBs and PBDEs as they moved through the lower river was minimal, probably because they spent little time feeding and rearing urbanized portions of the river (Fresh et al. 2005).

Genetic analyses of the yearling fish are currently in progress so that we can identify their stock of origin. These data are expected by the end of September 2008 and will be included in forthcoming reports.

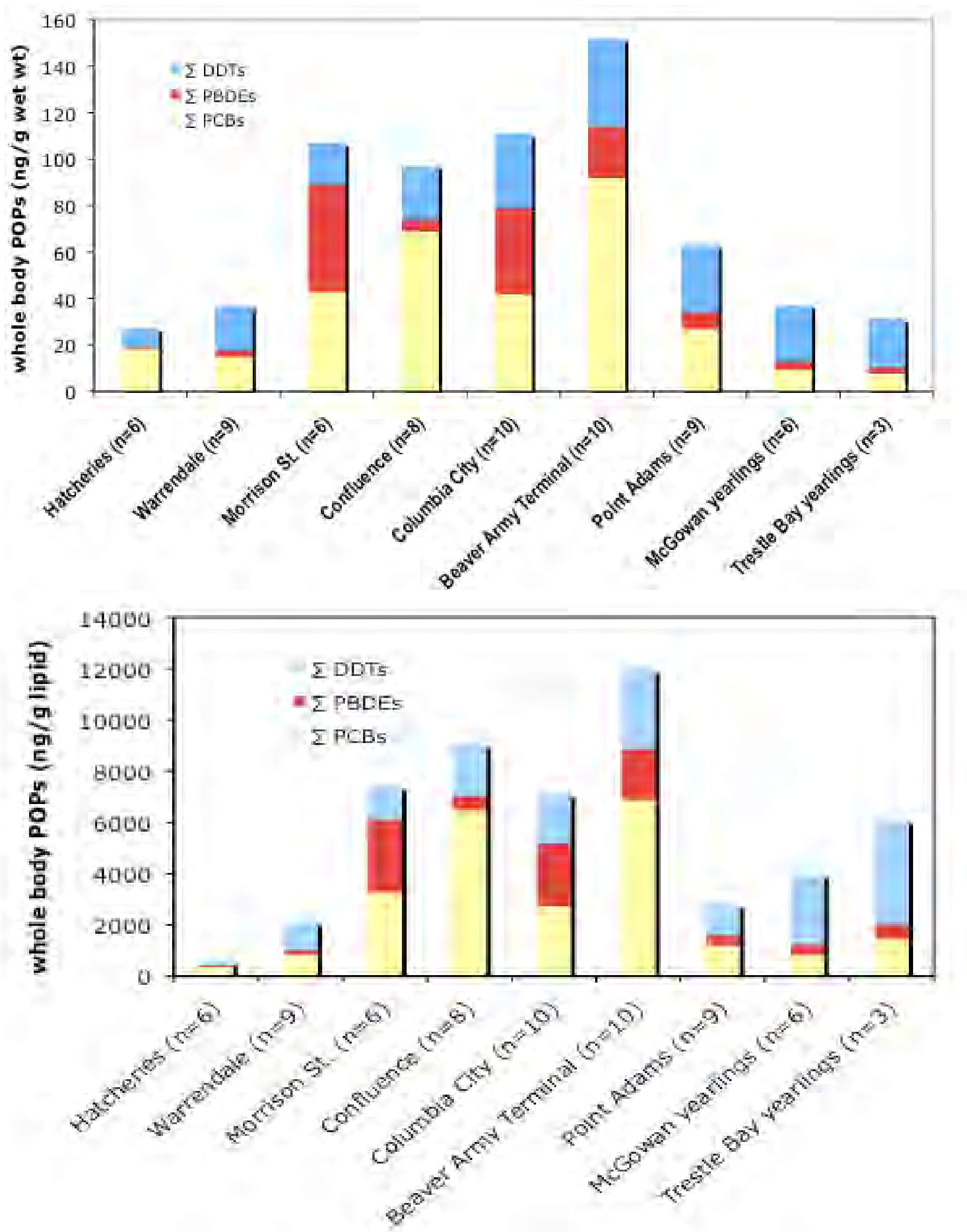


Figure 46: Concentrations (in ng/g wet wt and ng/g lipid) of POPs (DDTs, PCBs, and PBDEs) in whole bodies of yearling Chinook salmon collected from the estuary's mouth in 2007. Data for subyearling Chinook salmon collected from hatcheries and near-shore shallow water sites in 2005 are included for comparison.

10.8 NOAA-Fisheries Publications Based on EMP Work

The following 8 publications described results of previous NOAA-Fisheries work conducted for the EMP and related data. These publications have been published over the past year, submitted to journals, or are in preparation.

Arkoosh, M. R, D. A. Boylen, J. P. Dietrich, G. M. Ylitalo, B. F. Anulacion, C. F. Bravo, L. L Johnson, T. K. Collier, and F. J. Loge. Disease susceptibility of subyearling Chinook salmon (Oncorhynchus tshawytscha) after exposure to environmentally relevant concentrations of polybrominated diphenyl ethers (PBDEs). Environmental Science and Technology (Submitted).

Dietrich J. D., M. R. Arkoosh, L. L. Johnson et al. Conceptual model of the contaminant and endangered salmonid species interactions within the lower Columbia River and estuary (In prep).

Dietrich J. D., M .R. Arkoosh, L. L. Johnson et al. Modeling the dynamic uptake and elimination of PBDEs in juvenile Chinook salmon migrating through the lower Columbia River and estuary (In prep).

Johnson, L. L., M. L. Willis, O. P. Olson, R. W. Peace, C. A. Sloan, and G. M. Ylitalo. 2008. Contaminant Exposure in Juvenile Salmon from Columbia River Hatcheries (in NOAA internal review; to be submitted to the North American Journal of Aquaculture).

Yanagida, G., B. F. Anulacion, J. Bolton, D. Boyd, O. P. Olson, R. Pearce, S. Y. Sol, G. Ylitalo, and L. L. Johnson. PAHs and Endangered Salmon in the Lower Columbia River and Estuary (In prep).

Johnson, L. L., B. F. Anulacion, J. Bolton, D. Boyd, D. P. Lomax, P. Moran, O. P. Olson, C. Sloan, S. Y. Sol, G. Ylitalo, et al. Bioaccumulative Contaminants in Outmigrant Juvenile Chinook Salmon Stocks from Columbia River (In prep).

Johnson, L. L., B. F. Anulacion, M. R. Arkoosh, J. Bolton, D. Boyd, J. Dietrich, F. Loge, D. P. Lomax, P. Moran, O. P. Olson, C. Sloan, S. Y. Sol, J. Spromberg, M. Willis, G. Yanagida, G. Ylitalo, T. K. Collier et al. 2008. Chemical Contaminants and Endangered Salmon in the Lower Columbia River and Estuary: Results of the Fish Monitoring Component of the Lower Columbia River Water Quality Monitoring Project 2003-2006. NOAA Tech. Memo (In prep).

Sloan, C. A., B. F. Anulacion, J. L. Bolton, D. Boyd, G. M. Ylitalo, S. Y. Sol, O. P. Olson, and L. L. Johnson. 2008. Polybrominated diphenyl ethers in out-migrating juvenile Chinook salmon from the Lower Columbia River and Estuary and from Puget Sound, WA (In prep).

11.0 Characterization of Forested Tidal Freshwater Wetlands in the LCRE

Tidal freshwater wetlands exist only where the influence of tides extend beyond the reach of saline water. The forested tidal freshwater wetlands of the LCRE make up a significant portion of the estuary and provide habitat for juvenile salmonids (Oncorhynchus spp.), many of which are listed as threatened or endangered under the US Endangered Species Act (Bottom et al., 2005). While studies are being conducted on emergent marsh ecosystems and physical processes in the LCRE, only preliminary work has explored forested tidal freshwater and scrub-shrub wetlands of the LCRE, and seldom from a comprehensive community structure perspective (Christy and Putera, 1993; LCREP, 1999; Diefenderfer, 2007). Comprehensive ecological characterizations are necessary to build baseline datasets and conceptual models of ecosystem components and structure. Such information can be used to assess future changes due to anthropogenic or climatic alterations in the Columbia River watershed.

The goal of this work element is to quantitatively characterize 5 to 6 tidal forested wetlands along the tidal freshwater portion of the LCRE. A community profile will be constructed from the quantitative assessment, and focus on associations among particular species and environmental factors that determine these associations. Sites will be selected to capture spatial variation among the 8 hydrogeomorphic reaches of the estuary, as delineated by the Classification (Simenstad et al., 2007). Remotely sensed imagery will be used to discern how tree canopy topography and shoreline geomorphology relate to riverine physical factors (e.g., landscape setting, extent of tidal inundation, and seasonal flooding). Such relationships are potentially useful for extrapolating site-specific characterizations to broader areas of forested tidal wetlands in the estuary. The field studies will gather data on both biotic and abiotic components, including plant and animal species present and soil texture and grain size measurements. Hydrologic data from nearby water level gauges will provide the broader context to the physical profile of the sites' characteristics. Other factors influencing tidal forested wetland biotic communities, such as invasive and non-native plant and animal species, will also be incorporated into the study.

11.1 Study Sites

Candidate sites for field studies were selected by examining current satellite imagery of the LCRE available on Google Earth® and maps of forested wetland locations present in the late 1970s (U.S. Army Corps of Engineers 1976). Individual sites were then researched using the internet, personal communications with Si Simenstad, Jennifer Burke, Kathryn Sobocinski, and the Estuary Partnership, and field visits. Sites were selected based upon the presence of relatively unimpacted forested wetlands, representation of different variants of forested wetlands present in the estuary, site accessibility, and the availability of historic vegetation records for comparison purposes. Three sites, Big Creek, Willow Bar, and Mirror Lake, were selected for the 2008 field season (Figure 47). For the 2009 field season, 2-3 new sites will be selected for data collection.

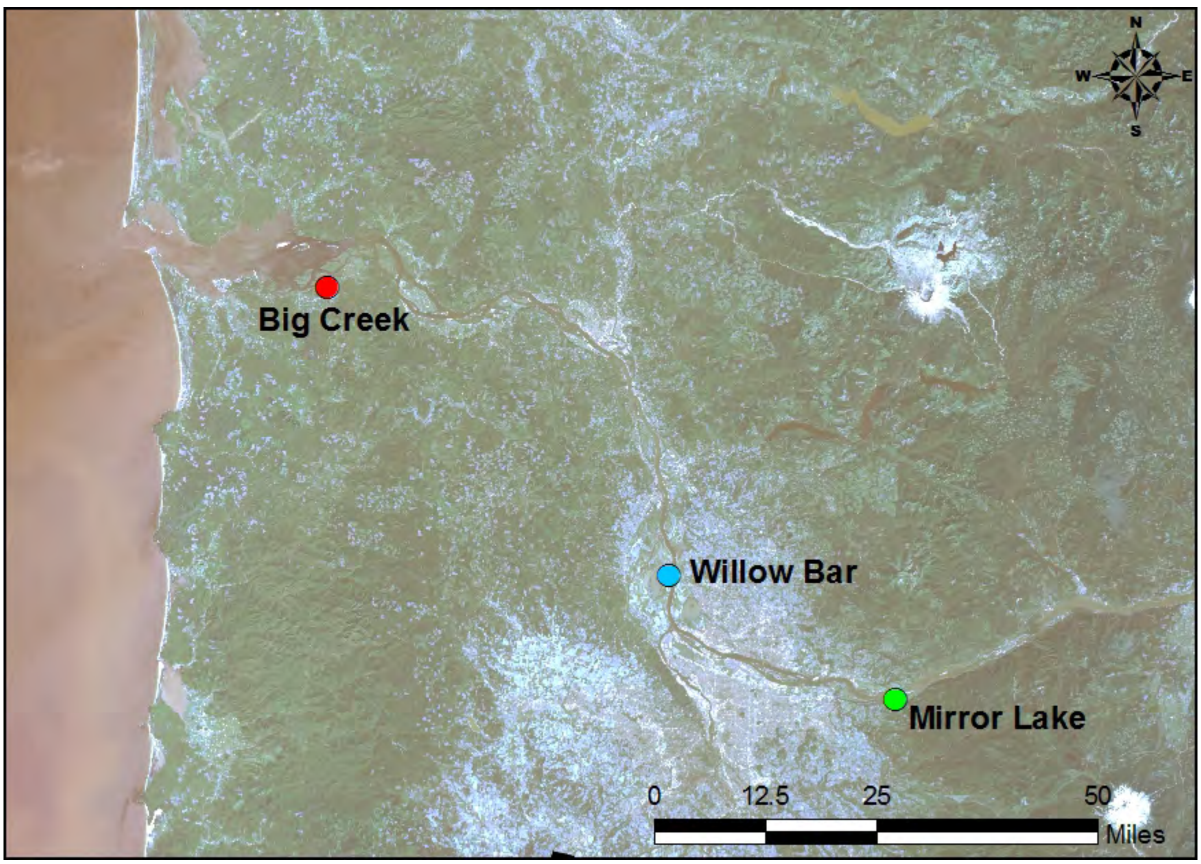


Figure 47: Sites for community characterization of forested tidal wetlands in the LCRE, 2008.

The study site closest to the mouth of the Columbia River is located on Big Creek (near Knappa, OR), near the confluence of the creek and Knappa Slough at approximately River Kilometer (RKm) 42 of the mainstem Columbia River (Figure 47). The forested wetlands at Big Creek represent Sitka spruce tidal swamps that were once common in the Columbia River estuary. Additionally, a salmon hatchery is located approximately 4.8 km upstream of the confluence, suggesting that the wetlands important salmon habitat. Railroad tracks run along the shore of the Columbia River, crossing Big Creek, and are used to access the study site. Tidal fluctuation in Big Creek is approximately 2.0-2.6 m. The wetlands at Big Creek are dense with shrub species such as willows (Salix spp.), dogwood (Cornus spp.), and blackberry (Rubus spp.), and large trees such as Sitka spruce (Picea sitchensis) and western red cedar (Thuja plicata) provide canopy cover (Figure 48). The forested wetlands at Big Creek are owned and monitored by The Nature Conservancy (TNC), who encourages the public to enjoy birding, canoeing, and kayaking in the preserve; our access to the site is authorized under TNC permits.

Figure 48: Forested tidal wetlands at Big Creek.

Upstream of Big Creek, Willow Bar is located at approximately RKm 153 along the mainstem Columbia River and is connected to Sauvie Island, Oregon, via a land bridge (Figure 47). Between Willow Bar and Sauvie Island is an inlet that contains tidal forested wetlands comprised mainly of willow, black cottonwood, (Populus balsamifera spp. trichocarpa) and Oregon ash (Fraxinus latifoilia) trees (Figure 49). Willow Bar appears to function as a riparian floodplain as well as a wetland area, because at peak river flows in June 2008 the study site was inaccessible due to high water. During times of lower flow, shallow water (less than 0.6 m deep at low tide) is present in the inlet, and tidal fluctuation is approximately 1 foot. Willow Bar is part of the Sauvie Island Wildlife Area and is managed by the Oregon Department of Fish and Wildlife. Hunting is permitted on Willow Bar between October and January each year.

Figure 49: Forested tidal wetlands at Willow Bar.

The furthermost upstream site is Mirror Lake, located at approximately RKm 208. This site is a wetland area about 32 km downstream of Bonneville Dam, and is connected to the Columbia River by two large culverts underneath Interstate 84 (Figure 47). The vegetation present is very similar to that of Willow Bar (Figure 50). Also like Willow Bar, the wetland area functions as a riparian floodplain, and was partly inaccessible during peak river flows in June 2008. During lower flow periods, shallow water is present in the wetland, and tidal fluctuations are minimal. Mirror Lake is part of Rooster Rock State Park, and is managed by the Oregon State Parks department. The wetlands at Mirror Lake receive little public use.

Figure 50: Forested tidal wetlands at Mirror Lake.

Two to three additional sites will be selected between October 2008 and March 2009 for the 2008-2009 field season. Sites will be chosen using the same methodology as for the 2008 study sites.

11.2 Methods

11.2.1 Transect and Zone Sampling Design

At each site, we established three transects aligned perpendicular to the water portion of the wetland area. The goal of the transect method was twofold: 1) to capture the full range of variation in species present and physical conditions at a given site; and (2) to document changes in species and conditions over the gradient from the wetland area to the forested/uplands area. Transects were positioned at least 100 meters apart, which was necessitated by the methods for the bird surveys. Bird survey literature agrees that the audio portion of point count surveys covers a 50-m radius, so point count locations should be a minimum of 100 m from one another (Ralph et al., 1995). Along each transect, vegetation zones were identified, including aquatic, emergent, scrub/shrub, and forested zones. The zones were usually easily differentiated from one another by noticeable transitions in vegetation composition. In the case that a zone did not exist, we did not collect samples for that location. For example, Big Creek tended to transition immediately to scrub/shrub or forest zones at the creek bank, resulting in no data for the aquatic and emergent zones at the site.

11.2.2 Sediment Analyses

Along each transect and zone, we collected sediment cores, which will be analyzed for percent organic content following using standard laboratory procedures to burn and weigh sediments. We will also analyze the sediment cores for grain size using standard laboratory sieving procedures. The sediment organic content and grain size data will contribute to the physical profile of the sites, and used to test for similarity between forested wetland sites.

11.2.3 Vegetation

We used a combination of 2-meter wide belt transects and 10-m x 10-m plots to document the vegetation present at the sites. A 2-meter wide belt transect was established at each sampling transect from well within the aquatic vegetation zone to the edge of the forested vegetation zone. We recorded all vegetation species present within each 1-m interval along the length of the transect. In order to adequately capture the full range of tree species present at the sites, we established a 10-m x 10-m plot at the edge of the forested zone (marked by the first tree of stem diameter of 2 centimeters or more). Within the forested plot, all species present were recorded, the diameter at breast height (DBH) was measured and recorded, and the percentage of canopy cover provided by each species of tree within the plot was estimated. If no forested zone was present for a given transect (this was the case with two transects), we confined the vegetation survey to only a 2-m belt transect that extended well into the scrub/shrub zone. If the vegetation transitioned immediately from the water to the forested zone for a given transect (this was the case with one transect), we confined the vegetation survey to only a 10x10 meter plot.

11.2.4 Invertebrates

To monitor benthic macroinvertebrates, we used one 5-cm diameter (19.6 cm^2) benthic core to collect sediments 10-cm in depth in each zone and along each transect. Samples were sieved and washed over 500-µm sieves. Samples were fixed using a 10% buffered formalin solution, and were later analyzed in the laboratory to identify and enumerate the benthic macroinvertebrate taxa present. To date, approximately half of the samples collected in the field have been analyzed in the laboratory.

To monitor terrestrial invertebrates, we placed one insect fall-out trap in each transect and zone for a 24-hour period. Insect fall-out traps consist of an approximately 28-L plastic tub supported on the bottom by a PVC platform and held in place on the sides by PVC pipes or bamboo poles. The tub is partially filled with water and biodegradable dish soap. At the end of the 24-hour period, the trap is sieved into a 106-µm sieve, washed, and fixed using a 70% isopropanol solution. The taxa present are later identified in the laboratory. To date, approximately half of the samples collected in the field have been analyzed in the laboratory.

11.2.5 Amphibians

Systematic visual search methods were employed for amphibian identification (Bury and Corn, 1991). In general, amphibian surveys during summer 2008 was most successful when walking between transects or zones for other sampling purposes, rather than during specific searches.

11.2.6 Birds

We conducted systematic bird surveys at each site once per season approximately during the period of maximum spring migration, and will repeat again during the fall migration period. Birds present at the sites were surveyed using 10-minute point count methods and both visual and audio identification (Ralph et al. 1995). The surveyor stood at a point within each transect where they felt they had a good view of all portions of the wetland, which varied among sites due to topography and vegetation. Binoculars and field identification guides were used to visually identify species during the 10 minutes of the field observation. Audio identifications were also permitted, and a small recording device was used to record bird calls and songs during the length of the observation. The recording was later analyzed for any bird species not already identified visually or audibly in the field. We repeated the 10-minute survey at each transect for a total of three times at a site, giving a total of 90 minutes of bird surveys during each visit. The fall and winter bird surveys at Big Creek, Willow Bar, and Mirror Lake will be conducted between October 2008 and February 2009. The bird survey at Willow Bar is impacted by hunting season, which runs October 11, 2008 through January 31, 2009, and prohibits safe site access for bird surveying. The fall survey at Willow Bar will be conducted prior to October 11, and the winter survey cannot be conducted until February 2009.

11.2.7 Small Mammals

We surveyed small mammals present at the sites using visual sightings and tracking and scat identification. Small mammal searches were not limited to transects and zones, since animal ranges may cover the entire site, although it was noted where within the site small mammals were seen (i.e., near Transect 1, or between Transects 1 and 2).

11.3 Results

At this time, this monitoring effort is in the data-gathering phase. Hence, statistically supported results are unavailable. Results from the 3 sites studied in 2007-2008 will be available in spring 2009 following completion of the winter bird surveys at the three sites. Data analysis will be accomplished using multivariate statistics methods such as ordination and cluster analysis. The analyses will test site similarity and the relationships between vegetative and faunal assemblages and physiochemical factors such as soil texture and amount of tidal inundation. Results from all sites will be available in late winter or early spring 2010. Due to the incomplete nature of the laboratory analysis for sediment grain size, percent organic content, benthic macroinvertebrates, and insects, preliminary results or impressions are not yet available for these categories.

Here are some of our initial impressions formed during the field sampling. Overall, Willow Bar and Mirror Lake appear to be similar in terms of their function as a riparian floodplain and presence of wetland vegetation and animal species. Both sites are dominated by black cottonwood, Pacific willow, and Oregon Ash in their forested zones, and have similar scrub/shrub, emergent, and aquatic zone vegetation species. The birds and small mammals observed at the 2 sites seem more similar than to those observed at the Sitka spruce-western cedar tidal swamp at Big Creek, and the scrub/shrub species present are also somewhat different from those at the other 2 sites. One of the most noticeable differences between the sites is the presence of an extended aquatic and emergent zone at both Willow Bar and Mirror Lake, and the absence of these zones at Big Creek. In conclusion, we view the tidal forested wetlands at the 3 sites falling into 2 basic categories: (1) Big Creek can be classified as a Sitka spruce tidal swamp, while Willow Bar and Mirror Lake can be categorized as deciduous tidal riparian floodplain and wetland.

11.4 Work Products

The final product of this project will be a community profile report, comparable to the U.S. Fish and Wildlife Service's Community Profile Series, commensurate with a graduate student (University of Washington) M.S. thesis and associated scientific peer-review journal manuscript, that describes the major taxa and physical characteristics of other ecosystems (Wharton et al., 1982). The community profile will be constructed from a quantitative assessment of both biotic and abiotic site characteristics, and will focus on associations among particular species within the ecosystem and the environmental factors that influence these associations. The type and extent of invasive species at these sites will also be included in the report to provide a current estimate of their incidence and potential effect on native vegetation. The community profile will be the first document of its type for this region, and will provide a baseline for any future ecological studies in the area. The study will be integrated with the larger Classification effort currently in progress (Simenstad et al., 2007) and helpful for ground-truthing the ecological component of the Classification.

Data from this study are entered in an Access database that will be tested for appropriate Quality Assurance/Quality Control measures and delivered to Estuary Partnership at the study's completion. Preliminary presentations on the emerging results will be presented to Estuary Partnership and interested parties in autumn 2008 and 2009, following the completion of each field season, and in spring 2010, at completion of the study and the UW graduate student degree program.

12.0 Summary of Ecosystem Monitoring Project for 2007-2008

In Year 4 (2007-2008), the Ecosystem Monitoring Project made progress on the Classification and monitoring efforts. UW refined the Classification, including a revision to the hydrogeomorphic boundary between Reaches F and G, improvements to delineation methods for complexes, and development of ancillary datasets. The Estuary Partnership and UW prioritized bathymetry data gaps in the LCRE and developed a data collection strategy that will begin implementation in 2008-2009. All monitoring partners worked on formalizing the monitoring program's goal and objectives and USGS provided examples of other sampling design considerations and assessed the potential of a probabilistic survey design for the EMP. PNNL and USGS collected vegetation and sediment data at 4 sites in Reach H and 2 previously sampled sites in Reach F to characterize vegetation and sediment conditions at all sites and assess year-to-year trends in vegetation at Reach F sites. NOAA-Fisheries sampled juvenile salmon and their prey at 4 sites in Reach H and 1 previously sampled site in Reach F to characterize juvenile salmon occurrence, condition, and prey at all sites and year-to-year trends at the Reach F site (NOAA-Fisheries). USGS monitored water depth, temperature, dissolved oxygen, and conductivity at 1 in Reach H and 1 in Reach F to provide water depth and basic chemistry data for integration with results from the vegetation and salmon sampling efforts (USGS). Lastly, UW characterized habitat conditions and biological communities at 3 forested tidal freshwater wetlands (UW).

13.0 Planned Ecosystem Monitoring Project Activities for 2008-2009

In 2008-2009, the EMP will continue work on the Classification and developing spatial datasets. UW and USGS will collaborate to incorporate information on the long-term geomorphic and hydrologic processes shaping landscape features into the Classification. This work will expand the Classification's framework to include processes such as flow, sediment transport, and episodic geologic events (e.g., volcanism, earthquakes, and landslides). With this expansion, we will add Classification modifiers for categorizing ecosystems at the Complex and Catena (IV and V, respectively) levels according to formative and maintaining processes and associated timescales. We will continue work on developing methods for delineating catena that are consistent with refinements to the complex methodology. Additionally, UW, USGS, and the Estuary Partnership will develop a document describing the Classification's underlying concepts, methods, and applications. USGS has proposed to publish this document upon its completion. The Estuary Partnership and UW will implement the bathymetric data collection strategy to fill data gaps in the LCRE, and plan a landcover workshop.

Monitoring efforts for 2008-2009 will include vegetation, water chemistry, and salmon monitoring in Reach C of the LCRE. On-the-ground monitoring partners will continue to work closely to ensure efforts are not duplicated and resources can be shared to maximize the efficiency of the EMP. Monitoring partners will work on integrating datasets to characterize undisturbed emergent wetlands as juvenile salmon habitat in the LCRE. UW will sample 2-3 forested tidal freshwater wetlands and compile the data into a profile of the biological community and habitat conditions.

All Classification, spatial datasets, and monitoring related work efforts will be compiled into an annual report to BPA.

14.0 EMP Budgets

Table 22: Budget for Estuary Partnership's EMP contract.

BPA Project Number: 2003-007-00
Contract Number: 33854
Performance/Budget Period: September 1, 2007 – August 31, 2008
Funds Received to date include expenses through 7/31/2008, which have been billed and payment received from BPA. Does not include expenses incurred after 7/31/2008.

Budget Items	**Original Contract**	**Amendment #1**	**Amendment #2**	**Funds Received To Date**	**Contract Balance**
I. Direct Costs					
Personnel	$ 83,526.00	$ 83,526.00		$64,435.72	$ 19,090.28
Travel	$1,597.00	$1,597.00		$1,687.84	$ (90.84)
Office Supplies	$2,400.00	$2,400.00		$2,399.99	$ 0.01
Vehicles	$1,200.00	$1,200.00		$450.82	$ 749.18
Project Supplies or Equipment	$ 19,796.00	$ 19,986.00		$36,260.85	$ (16,274.85)
Rent Utilities	$ 6,150.00	$ 6,150.00		$6,150.00	$ -
Sub Total	*$ 114,669.00*	*$ 114,859.00*		*$111,385.22*	*$ 3,473.78*
Overhead *(20% on above)*	$22,934.00	$ 22,972.00		$22,343.04	$ 628.96
Sub Total Direct Costs	*$ 137,603.00*	*$ 137,831.00*		*$133,728.26*	*$ 4,102.74*
II. Sub Contracts					
Pt 1: Ecosystem/Habitat Mon					
Battelle	$91,000.00	$ 91,000.00		$79,871.29	$ 11,128.71
Univ of Washington	$172,267.00	$ 172,267.00		$171,315.32	$ 951.68
Pt. 2: Water Qual/Toxics Mon.					$ -
NOAA	$84,000.00	$ 84,000.00		$83,349.44	$ 650.56
Technical Consultants	$ 500.00	$ 500.00		$2,047.50	$ (1,547.50)
Sub Contracts Sub Total	*$347,767.00*	*$347,767.00*		*$336,583.55*	*$11,183.45*
Project Management	$44,309.00	$ 46,352.00		$50,327.98	$ (3,975.98)
Totals	**$ 529,679.00**	**$ 531,950.00**		**$520,639.79**	**$ 11,310.21**

Table 23: Budget for USGS' EMP contracts.

BPA Project Number: 2003-007-00
Contract Numbers: 33959 and 33960
Performance/Budget Period: September 1, 2007 – August 31, 2008
Funds Received to date include expenses through 9/23/2008 for contract #33959 and 8/19/2008 for contract #33960, which have been billed and payment received from BPA. Does not include expenses incurred after 9/23/2008 and 8/19/2008, respectively, for the 2 contracts.

Budget Items	**Original Contract**	**Amendment #1**	**Amendment #2**	**Funds Received To Date**	**Contract Balance**
USGS contract #33959	$ 39,321.00	$ 39,321.00		$ 18,876.00	$ 20,445.00
USGS contract #33960	$ 56,005.00	$ 76,441.00		$ 23,330.54	$ 53,110.46
Total	$ 95,326.00	$ 115,762.00		$ 42,206.54	$ 73,555.46

15.0 References

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Appendix 1: Detailed Information on Bathymetric Data Gaps

Table 1: Detailed Information for Bathymetric Gap Areas

Site_ No	Reach	Final Rank	Priority	Area (Acres)	Lat	Lon	Approx Locat	Class	Interpolate?	NOAA_NOS_INFO	Comments
1	C	10.1	HIGH	1628	46.15182	-123.2386	Wallace Island	Mixture of moderate depth channels and flats.	No	Digital data available: HO7862 (1951), HO6242 (1937). Covers most side channels in this area. HO1336 available in image format. Date unknown	Most of the flats are not well covered by the old bathymetry. Should be straightforward data collection in channel. More difficult in flats.
2	F	9.0	HIGH	937	45.69487	-122.8492	Multnomah Channel, South	Generally deep channel, steep banks	No	Digital Data available: HO6333 (1938), HO6332 (1938), HO6334 (1938)	Should be straightforward collection w/ soundings/sonar
3	C	8.0	HIGH	1287	46.17226	-123.3448	Cathlamet Channel	Deep channel with steep banks, and some tidal flats. Also Bernie Slough, a narrow, shallow channel, between PI and LI	No	Digital data available: HO6242 (1937), HO7720 (1949). HO1335 available in image. Date unknown.	Most of the channel should be straightforward collection. Could be difficult in flats, and Bernie Slough.
4	E	7.5	HIGH	418	45.93984	-122.8176	Deer Island	Unknown depths in main stem channel and main side channel. Also shallow side channels	No	Digital data available: HO7893 (1951). No coverage in most of slough.	Important area due to ongoing restoration activities
5	G	7.4	HIGH	584	45.61932	-122.703	North Portland Harbor	Mostly deep channels	No	Digital data available: HO7129 (1948), HO6333 (1939)	Should be straightforward, but could be complicated by overwater structures - docks, marinas, etc.
6	B	7.4	HIGH	1330	46.18516	-123.703	Cathlamet Bay, Lois Island	Mostly shallow flats and small tidal channels. Some moderate channels.	No	Digital data available: HO7179 (1947), HO7180 (1947)	Probably a difficult area to survey due to numerous shallows, flats, and small tidal channels.
7	C	7.0	HIGH	884	46.13244	-123.0304	Lord and Walker Islands	Mostly deep channels	No	Digital data available: HO6244 (1937), HO7746 (1949), HO7747 (1949)	Should be straightforward collection w/ soundings/sonar
8	A	7.0	MED	383	46.30626	-124.0276	Baker Bay/Ilwaco	Shallows along Baker Bay Shoreline	No	Nothing in digital format. TIFF images of soundings are available	Area covers most of Baker Bay shoreline. Looks like a combination of flats and moderately shallow areas. Additional areas exist east of gap polygons
9	E	6.2	MED	452	46.00264	-122.8669	Sandy Island	Mostly Deep channel on W side of Sandy Is. Also some shallows and 1 shallow channel extending into Sandy Isl	No	Digital data available: HO7742 (1949)	Should be straightforward. Small area. More difficult shallow areas.
10	B	6.2	MED	971	46.19882	-123.6262	Cathlamet Bay, Karlson Island	Short section of moderately deep channel. Several smaller channels/tidal channels	No	Digital data available: HO6181 (1937), HO5928 (1935), HO7817 (1950)	Numerous channels could be complicated, but since older coverage is good it may be ok. No large flats, but tide could be critical for the small channels.

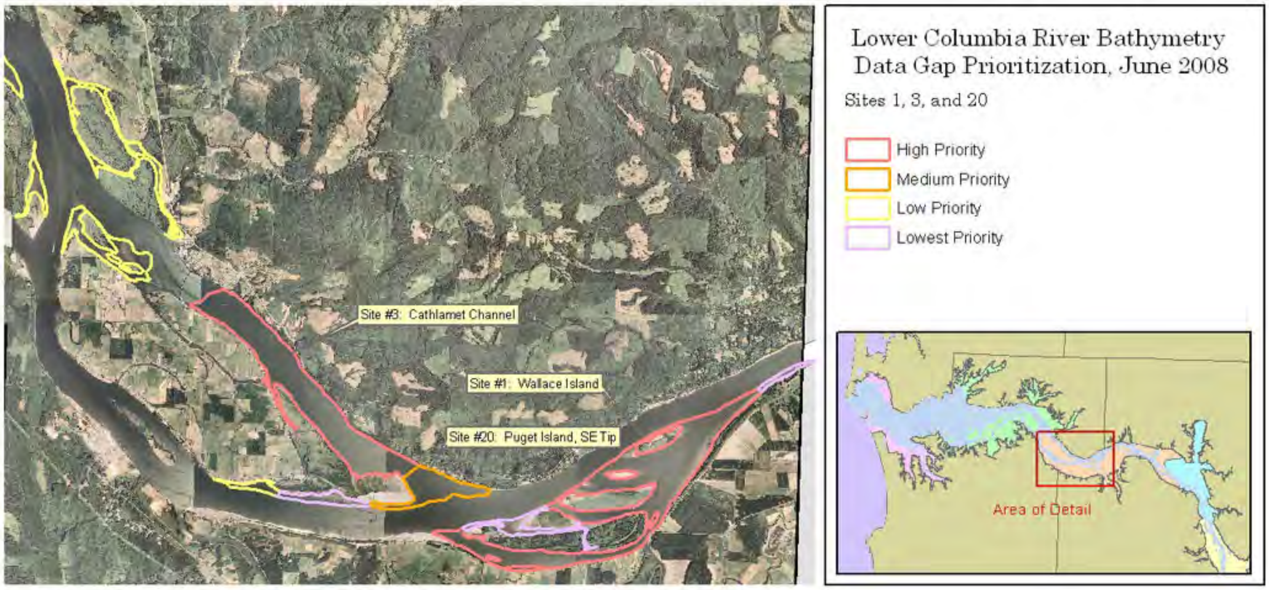
Site_ No	Reach	Final Rank	Priority	Area (Acres)	Lat	Lon	Approx Locat	Class	Interpolate?	NOAA_NOS_INFO	Comments
11	G	5.7	MED	145	45.636 99	-122.7765	Mouth of Willamette and Confluence	Deep channel with steep banks, and some overwater structures (piers, docks, unloading, etc).	No	Digital data available: HO6334 (1938)	Area is mostly along immediate shoreline, but banks should be relatively steep. Problems in areas of OW structures.
12	G	5.7	MED	1443	45.570 85	-122.5129	Government Island, S Channel	Shallow channel.	No	Digital data available: HO7130 (1946), HO 7129 (1948)	Should be straightforward with shallow draft vessel.
13	A	5.2	MED	785	46.215 54	-123.9828	Point Adams	Shallow lagoon adjacent to river mouth	No	Nothing in digital format. TIFF images of soundings may be available	Unsure about this area.
14	B	5.0	MED	654	46.247 52	-123.5141	Quinns/Welc h Islands	Shallow channels and flats around islands	Possible, wi/ medium confidence	Digital data available: HO7816 (1950), HO6181 (1937)	Could be difficult access. Tide could be critical for smaller channels and flats.
15	F	5.0	MED	833	45.804 01	-122.8138	Multnomah Channel, North	Generally deep channel, steep banks	No	Digital data available: HO6332 (1938), HO6247 (1937)	Should be straightforward collection w/ soundings/sonar
16	F	5.0	MED	313	45.832 47	-122.8234	Scappoose Bay	Unknown depths in main channel. Many shallow tributaries	No	None available.	More complex due to numerous shallow channels.
17	C	4.8	MED	785	46.175 89	-123.1428	Crims Island	Mostly moderate depth and deep channels, some smaller channels extending into island	No	Digital data available: HO7748 (1949), HO6243 (1937), HO7862 (1950)	Should be straightforward coverage in most of the area. Mostly deep.
18	B	4.8	MED	292	46.301 81	-123.7057	Grays Bay	Mostly shallow flats at entrance to Bay.	No	Digital data available: HO8419 (1958)	Area is shallow and will require shallow draft vessel.
19	D	4.6	MED	86	46.096 03	-122.9179	Mouth of Cowlitz River	Mostly shallows and sand at entrance to Cowlitz	No	Digital data available: HO7744 (1949)	Area is shallow, and there appear to be many sand flats.
20	C	4.6	MED	305	46.150 66	-123.3012	Puget Island, SE Tip	Appears to be mostly deep channel at tip of island.	No	Digital data available: HO7720 (1949)	Should be straightforward. Small area. Could combine with Cathlamet Channel gap.
21	H	4.3	MED	204	45.624 35	-122.0074	Pierce and Ives Island	moderate depth channels between islands and mainland	No	None available.	Should be straighforward in moderate depth channels with high/mod. water levels.
22	C	4.1	MED	583	46.164 65	-123.0605	Hump and Fisher Islands	Moderate depth channel and embayment. Deep main channel with steep embankment.	No	Digital data available: HO6244 (1937), HO7748 (1949), HO7747 (1949)	Should be straightforward.
23	H	4.1	MED	258	45.553 51	-122.2069	Sand Island	Shallows along Main Stem, and side channels with some shallows.	Possible at N end of island, w/ medium confidence	None Available.	May require shallow draft vessel during low water periods.

Gap Detail Maps

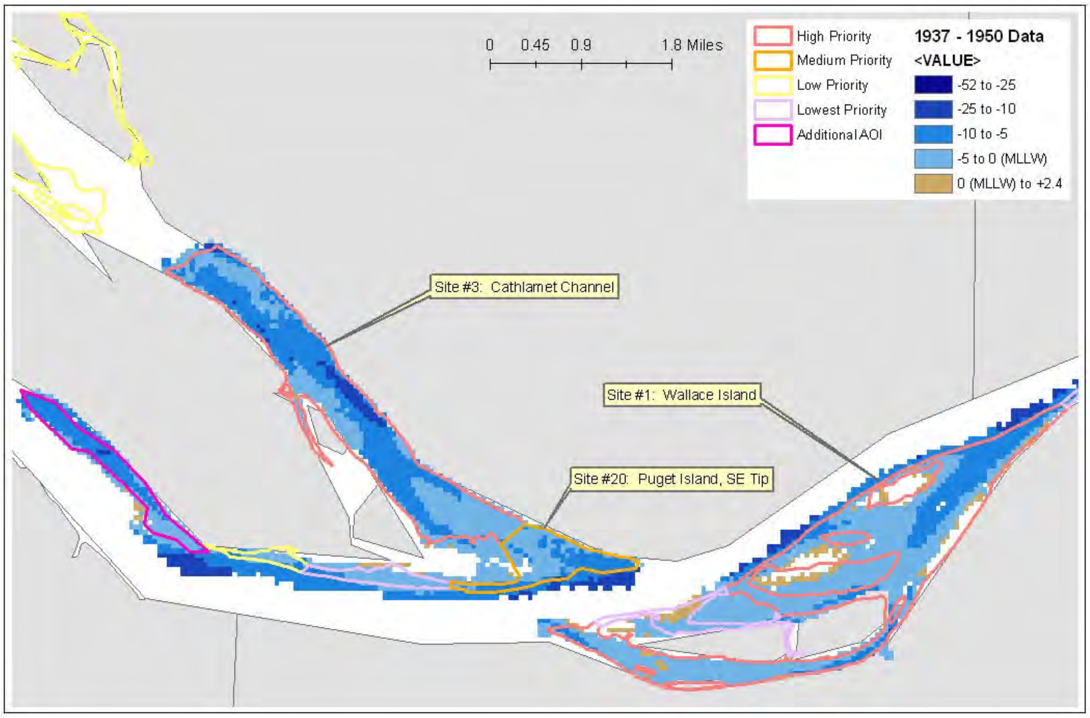
Notes:

Bathymetry shown here in raster and NOS chart format represent approximate detail from NOS survey data prior to 1997. These are for reference purposes only, to provide an idea of the approximate bathymetry for the priority areas.

Some of the raster and NOS chart maps shown here include additional polygons labeled ‘Additional AOI”. These areas should be considered as low priority areas.



Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE ?	NOAA_NOS_INFO	Comments
1	C	10.1	HIGH	1628	46.1518224	-123.23865	Wallace Island	Mixture of moderate depth channels and flats.	No	Digital data available: HO7862 (1951), HO6242 (1937). Covers most side channels in this area. HO1336 available in image format. Date unknown	Most of the flats are not well covered by the old bathymetry. Should be straightforward data collection in channel. More difficult in flats.
3	C	8.0	HIGH	1287	46.1722585	-123.344794	Cathlamet Channel	Deep channel with steep banks, and some tidal flats. Also Bernie Slough, a narrow, shallow channel, between PI and LI	No	Digital data available: HO6242 (1937), HO7720 (1949). HO1335 available in image. Date unknown.	Most of the channel should be straightforward collection. Could be difficult in flats, and Bernie Slough.
20	C	4.6	MEDIUM	305	46.1506575	-123.301156	Puget Island, SE Tip	Appears to be mostly deep channel at tip of island.	No	Digital data available: HO7720 (1949)	Should be straightforward. Small area. Could combine with Cathlamet Channel gap.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1937 - 1950 Data
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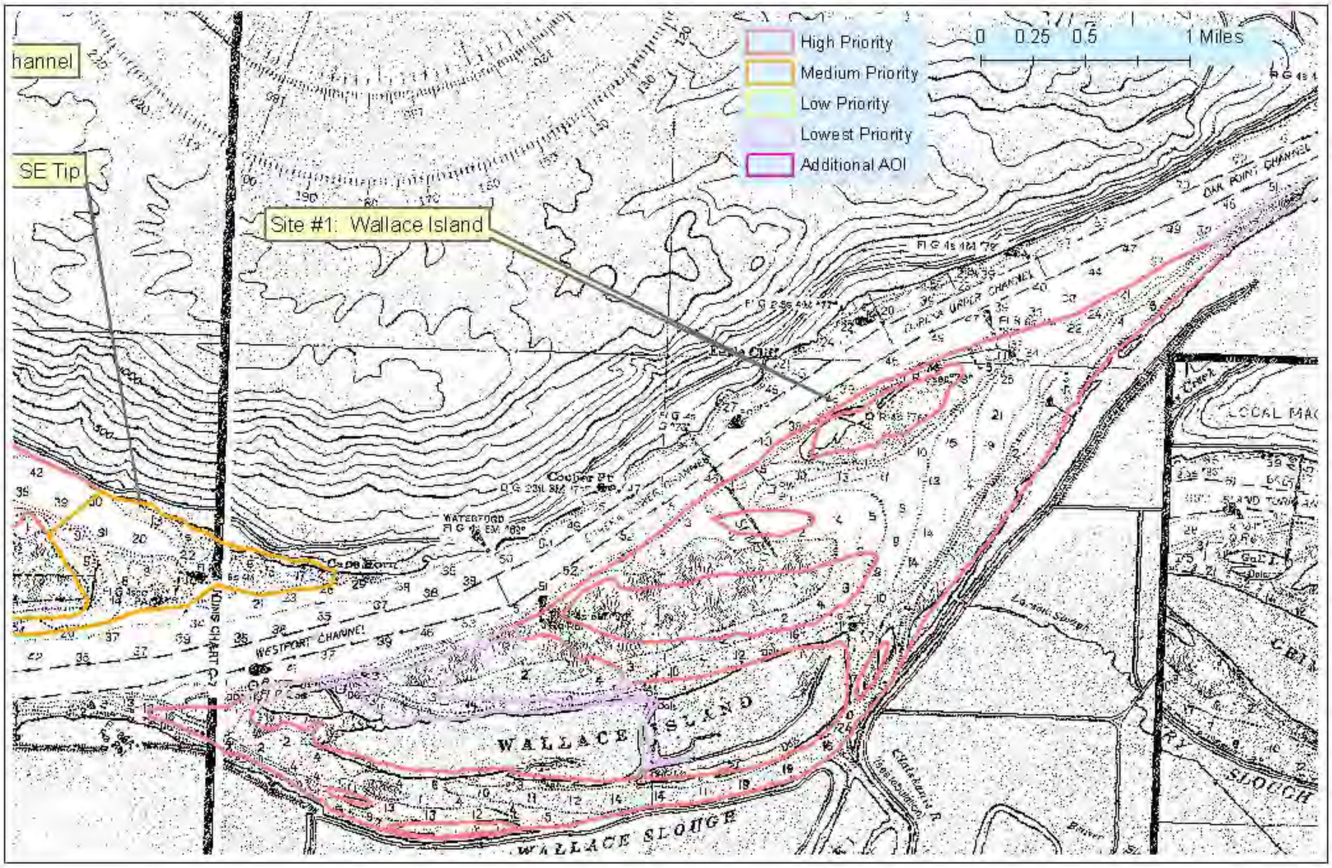
Site #3: Cathlamet Channel
Site #1: Wallace Island
Site #20: Puget Island, SE Tip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Medium Priority
Low Priority
Lowest Priority
Additional AOI
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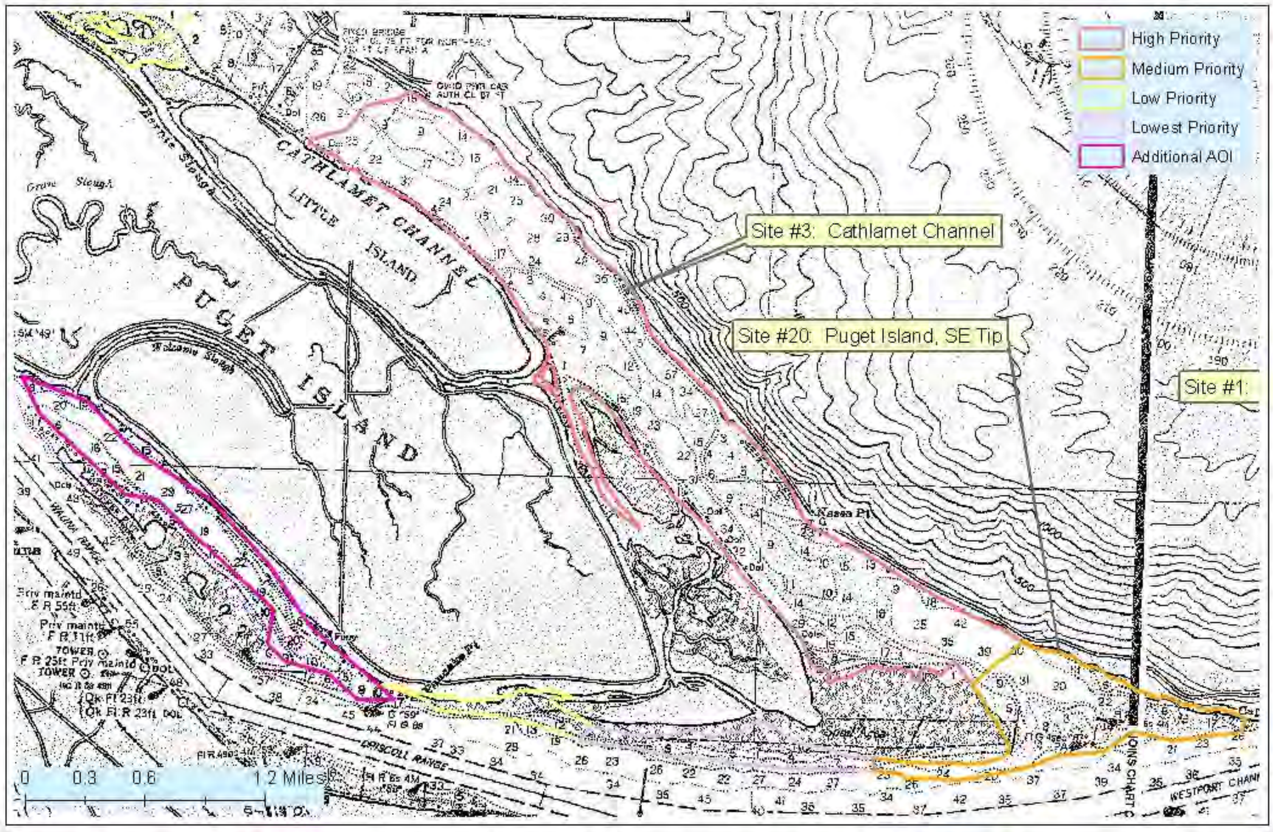
hannel
SE Tip
Site #1: Wallace Island
WALLACE ISLAND
WALLACE SLOUGH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Lowest Priority
Additional AOI
Site #3: Cathlamet Channel
Site #20: Puget Island, SE Tip
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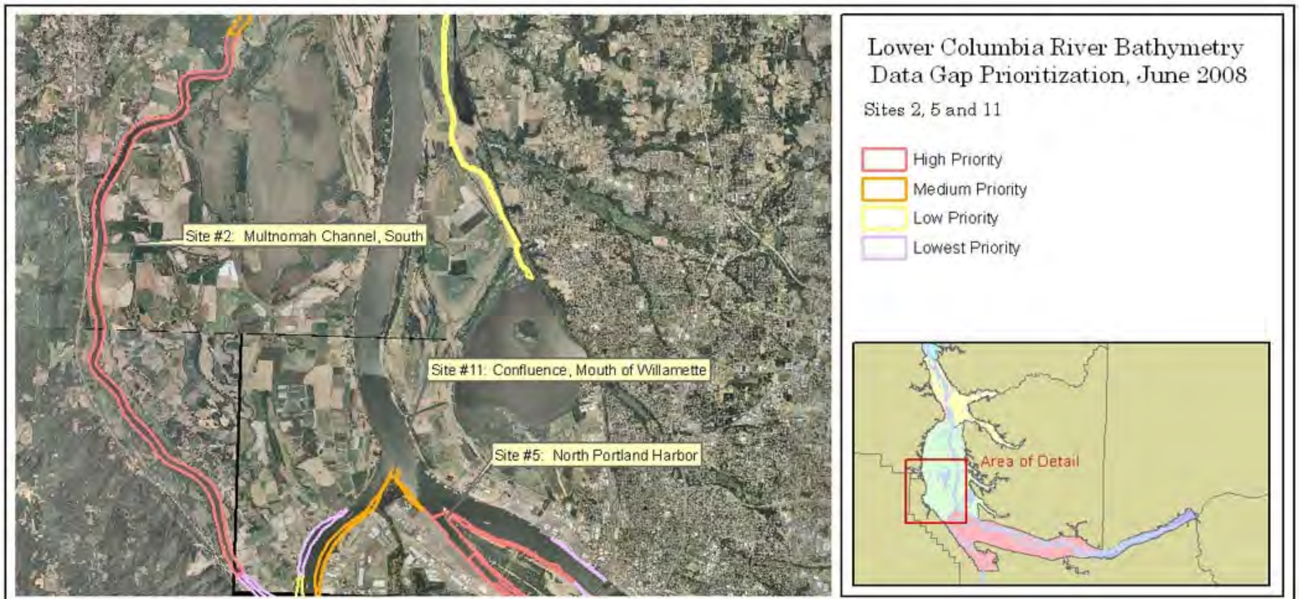
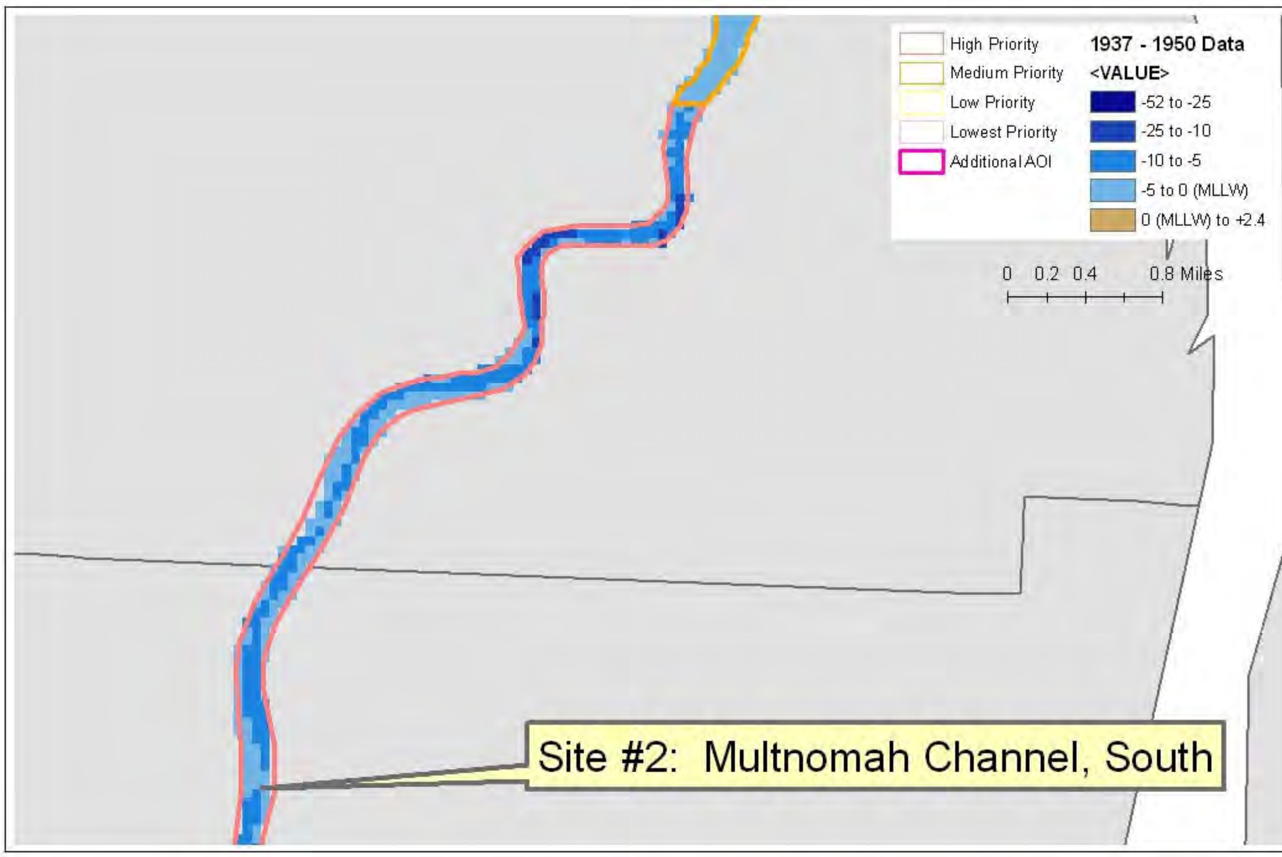
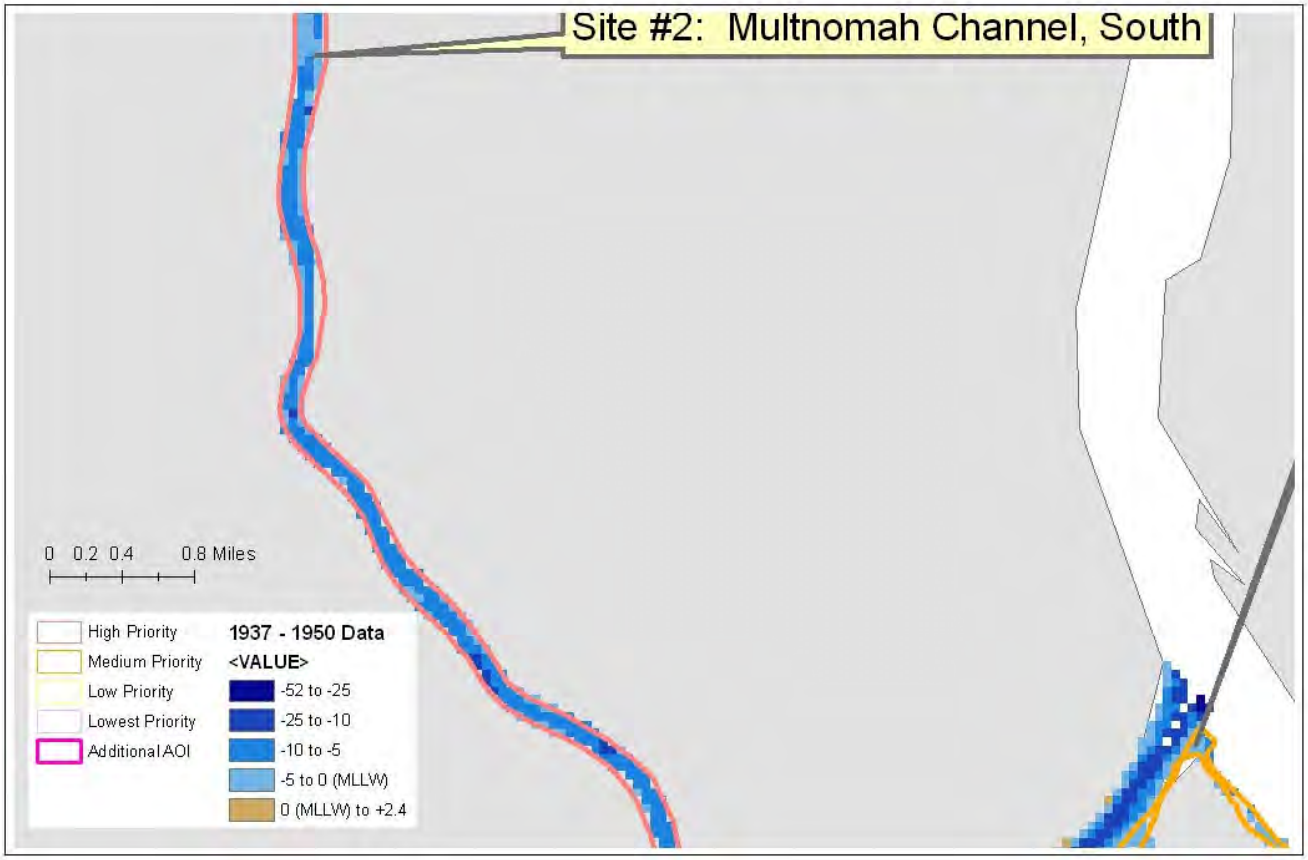
CATHLAMET CHANNEL
LITTLE ISLAND
0 0.3 0.6 1.2 Miles



Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
2	F	9.0	HIGH	937	45.6948689	-122.849177	Multnomah Channel, South	Generally deep channel, steep banks	No	Digital Data available: HO6333 (1938), HO6332 (1938), HO6334 (1938)	Should be straightforward collection w/ soundings/sonar
5	G	7.4	HIGH	584	45.6193246	-122.703011	North Portland Harbor	Mostly deep channels	No	Digital data available: HO7129 (1948), HO6333 (1939)	Should be straightforward, but could be complicated by overwater structures - docks, marinas, etc.
11	G	5.7	MEDIUM	145	45.6369873	-122.776547	Mouth of Willamette and Confluence	deep channel with steep banks, and some overwater structures (piers, docks, unloading, etc).	No	Digital data available: HO6334 (1938)	Area is mostly along immediate shoreline, but banks should be relatively steep. Problems in areas of OW structures.

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Low Priority
Lowest Priority
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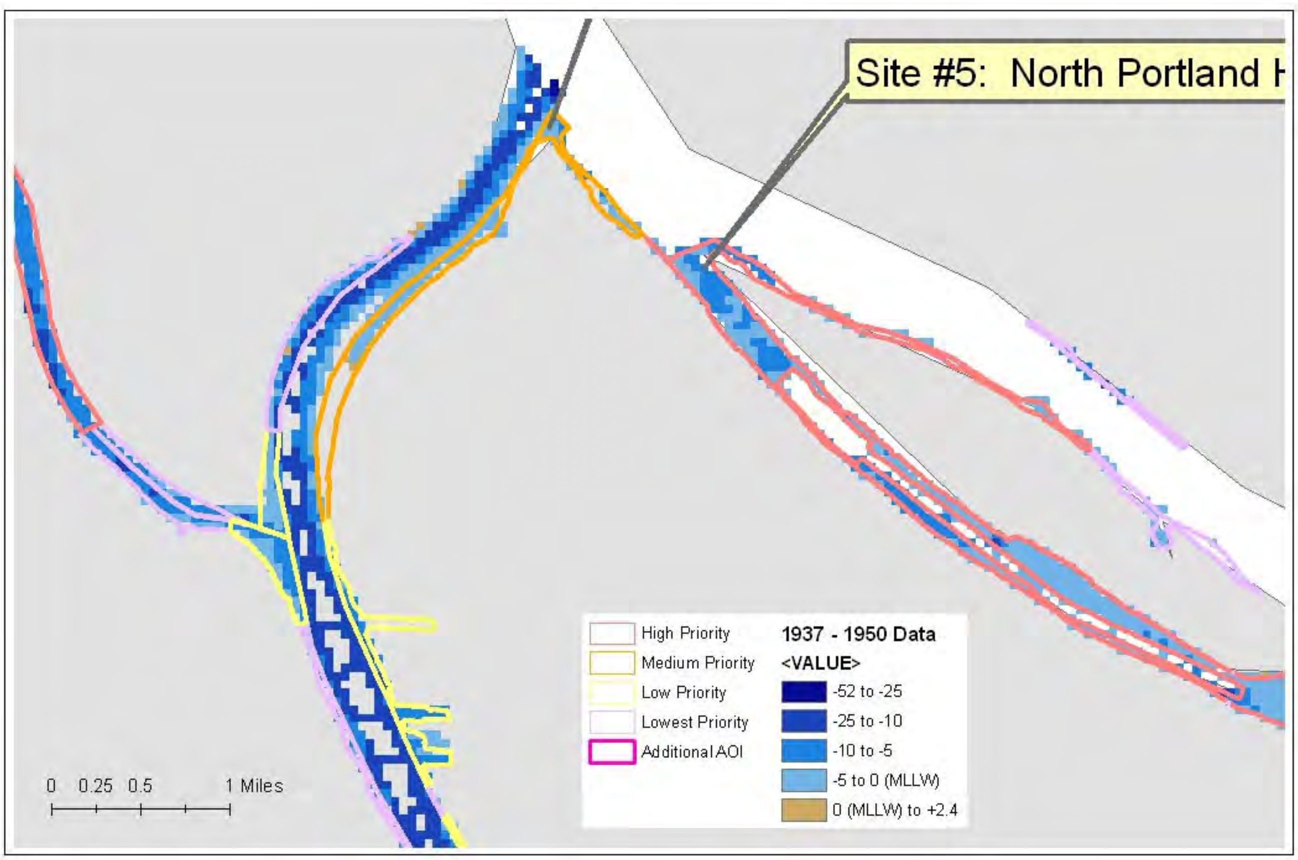
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Medium Priority
Low Priority
Lowest Priority
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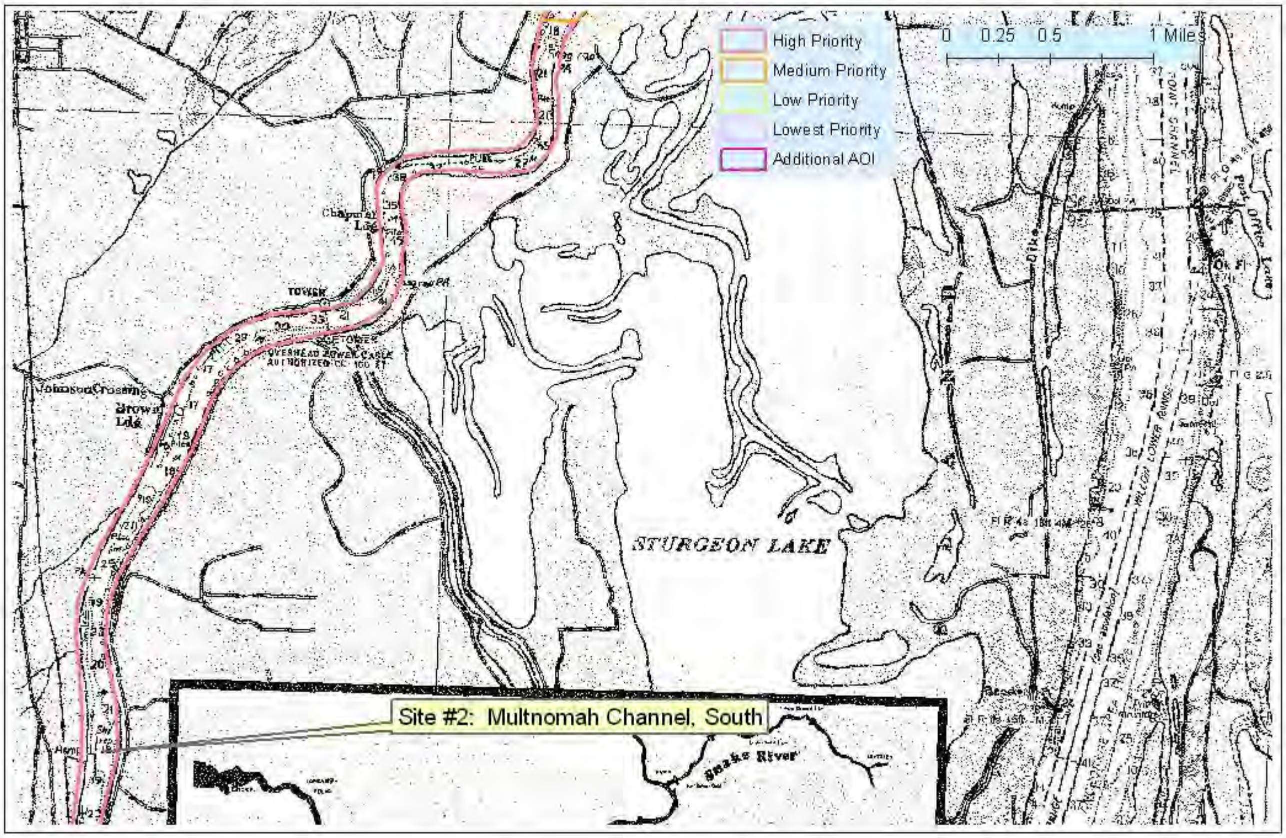
0 (MLLW) to +2.4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Low Priority
Lowest Priority
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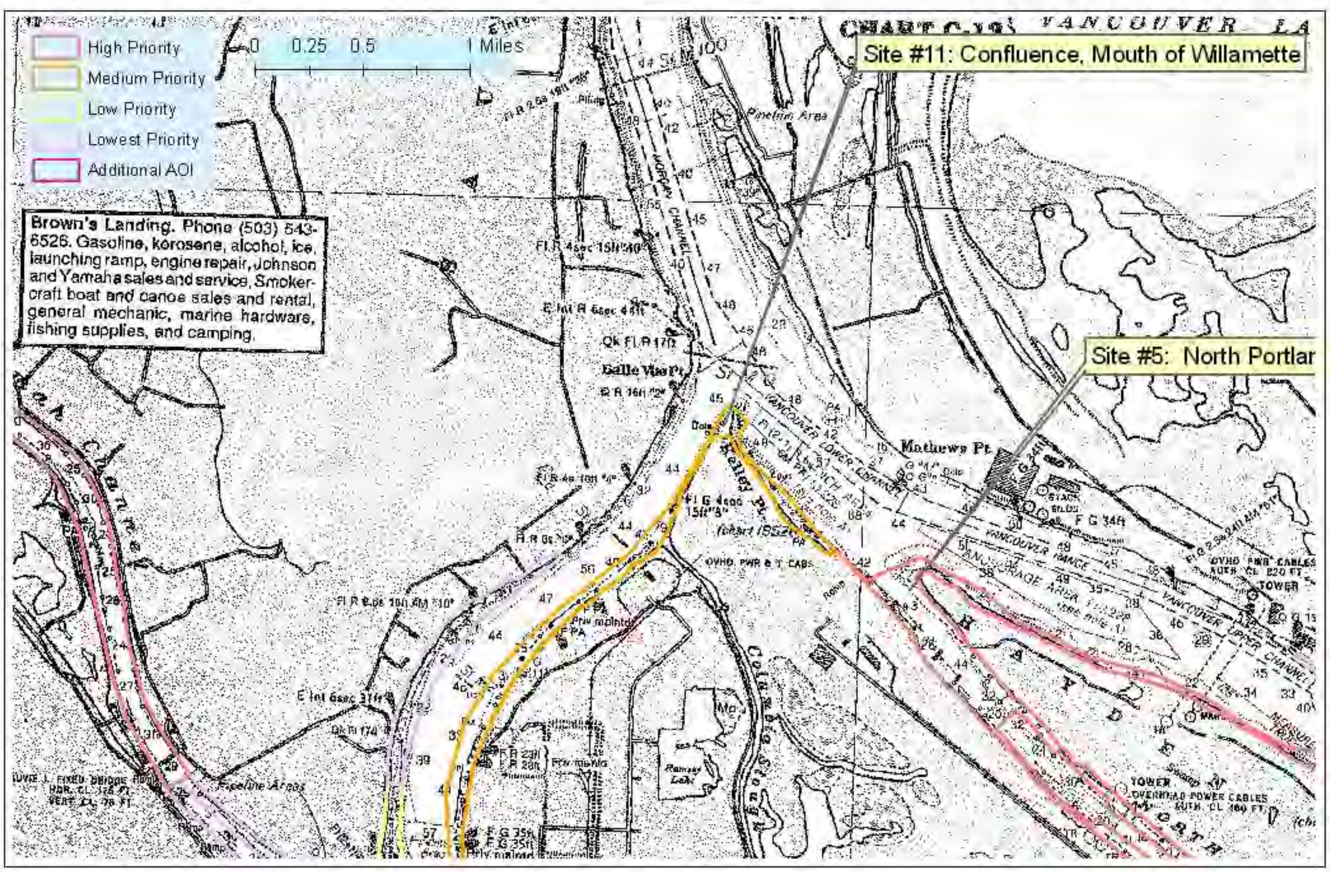
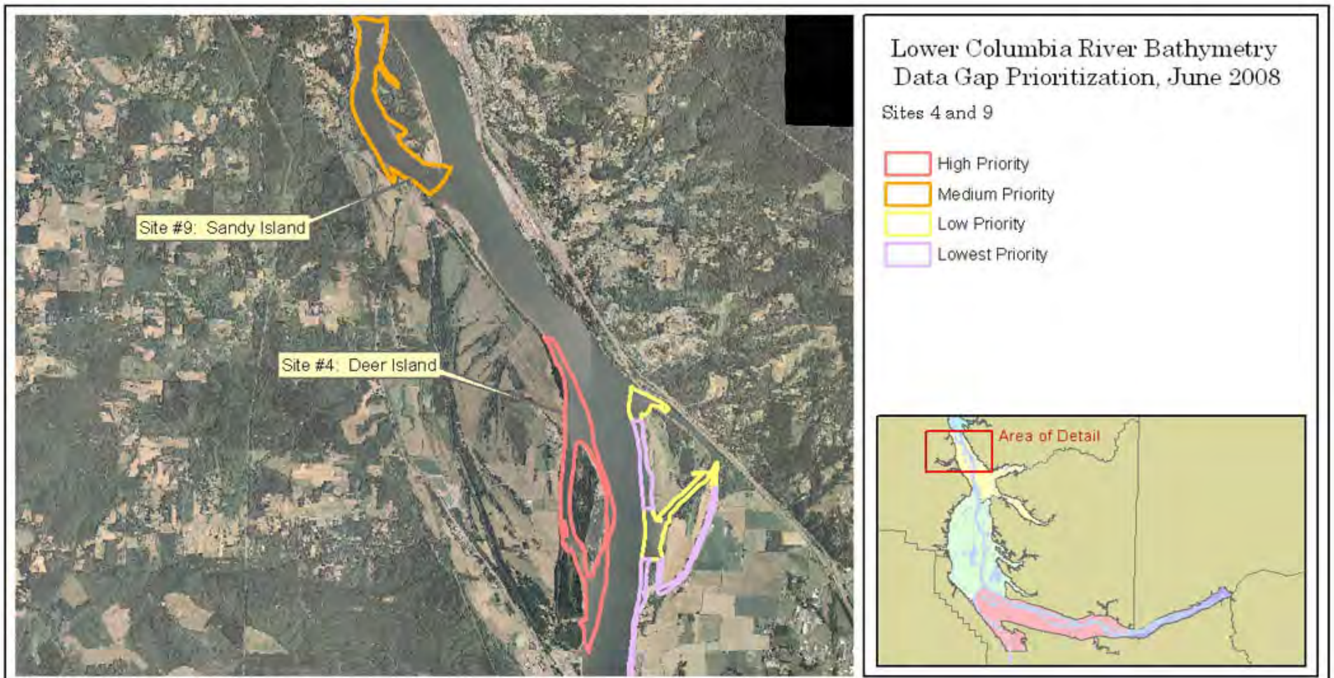
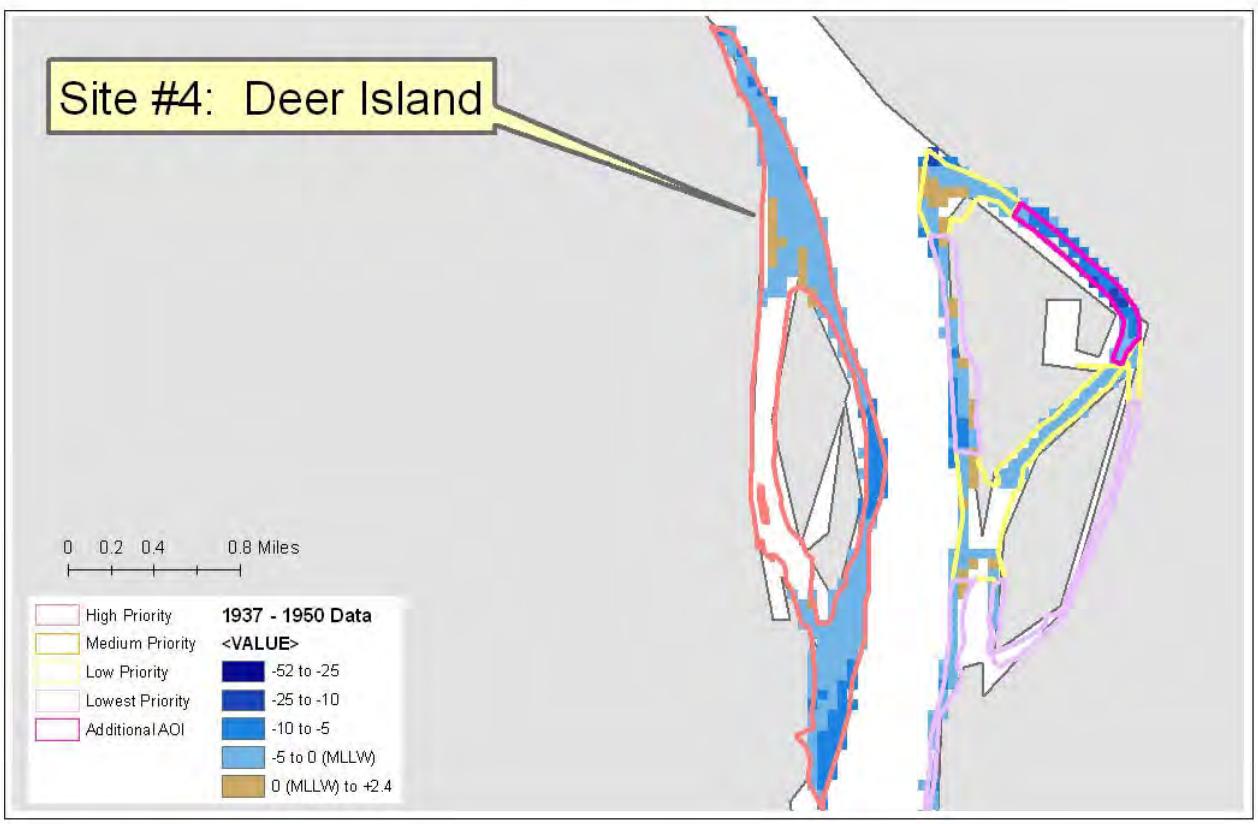
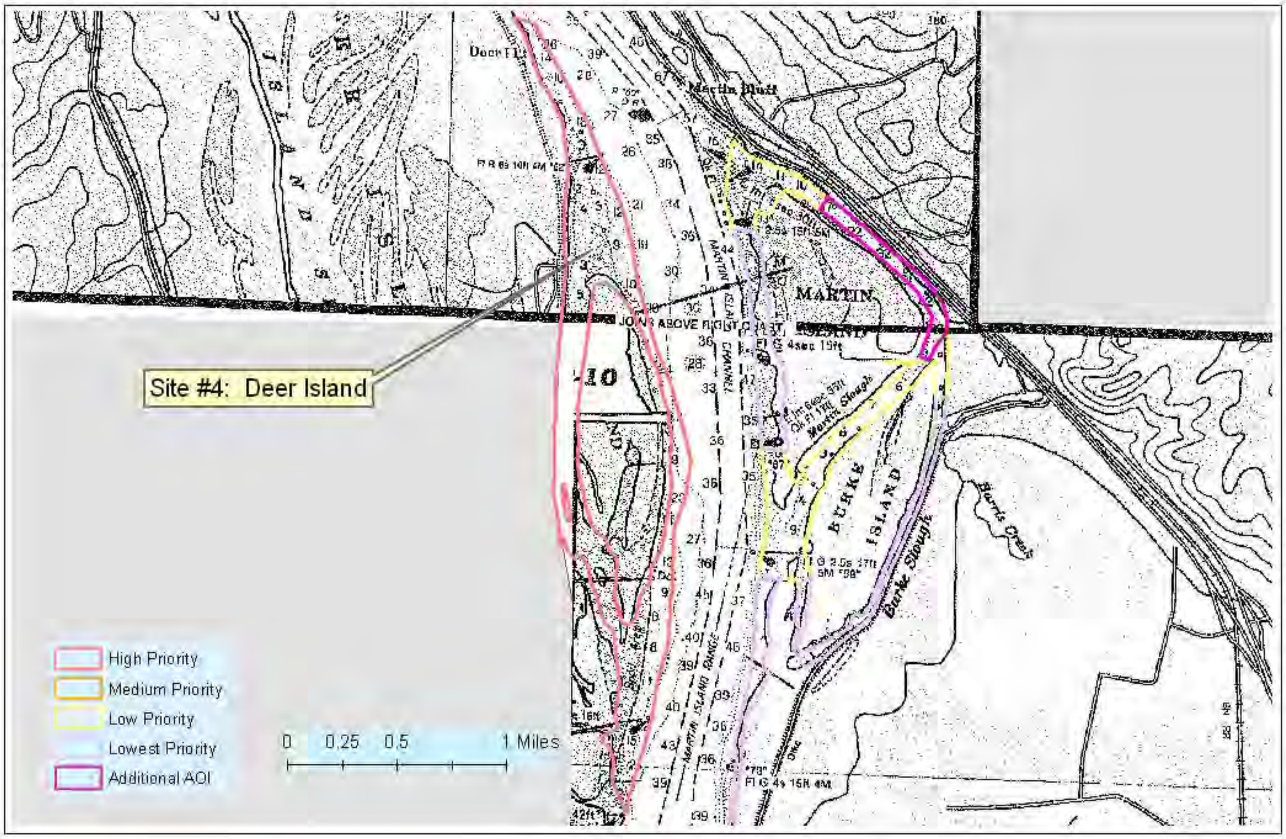
STURGEON LAKE
Site #2: Multnomah Channel, South


High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
0 0.25 0.5 1 Miles
Site #11: Confluence, Mouth of Willamette
Brown's Landing. Phone (503) 543-6526. Gasoline, kerosene, alcohol, ice, launching ramp, engine repair, Johnson and Yamaha sales and service, Smoker-craft boat and canoe sales and rental, general mechanic, marine hardware, fishing supplies, and camping.
Site #5: North Portlar
Mathews Pt



Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
4	E	7.5	HIGH	418	45.9398408	-122.817575	Deer Island	Unknown depths in main stem channel and main side channel. Also shallow side channels	No	Digital data available: HO7893 (1951). No coverage in most of slough.	Important area due to ongoing restoration activities
9	E	6.2	MEDIUM	452	46.0026369	-122.866936	Sandy Island	Mostly Deep channel on W side of Sandy Is. Also some shallows and 1 shallow channel extending into Sandy Isl	No	Digital data available: HO7742 (1949)	Should be straightforward. Small area. More difficult shallow areas.




Site #4: Deer Island
High Priority
Medium Priority
Low Priority
Lowest Priority
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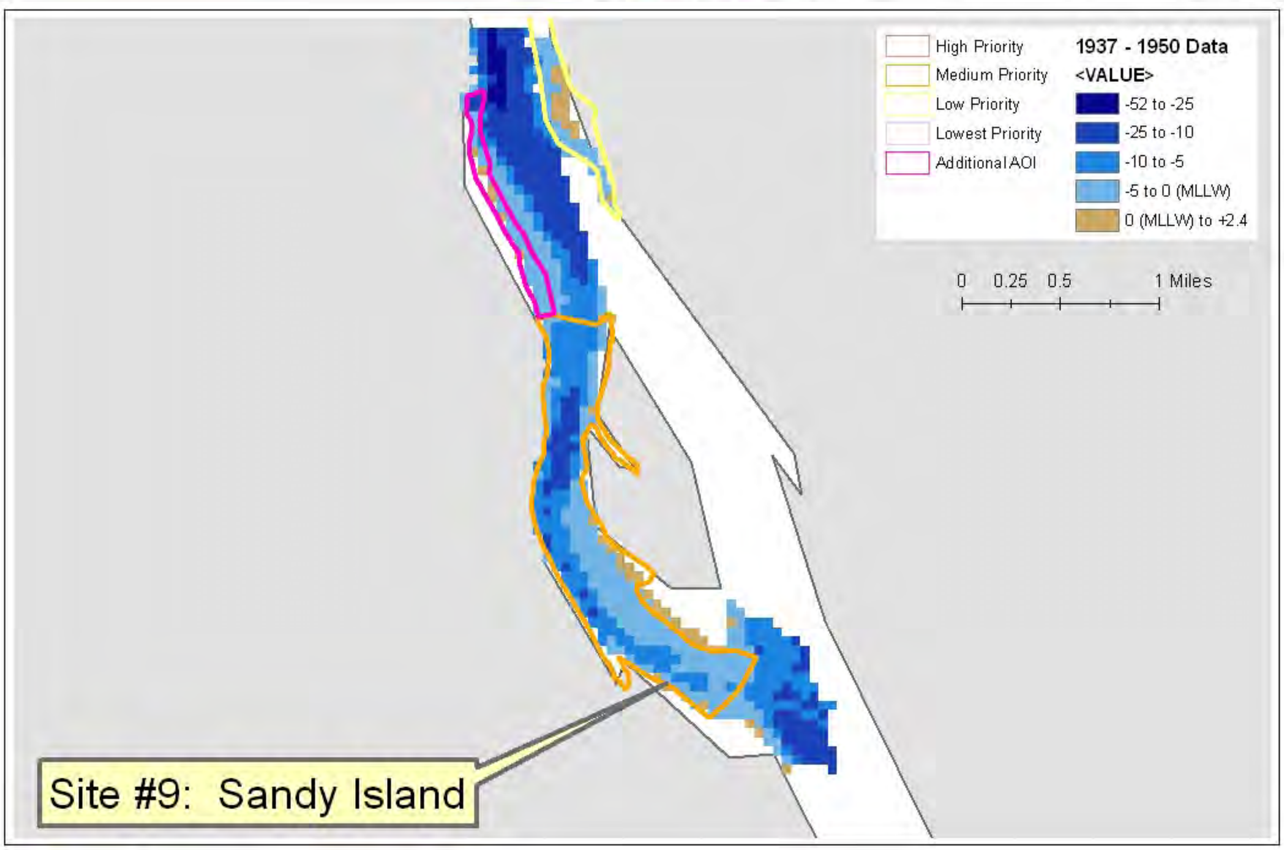
MARTIN
BURKE ISLAND
Burke Slough
Martin Slough
Martin Bluff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Medium Priority
Low Priority
Lowest Priority
Additional AOI
1937 - 1950 Data
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-10 to -5
-5 to 0 (MLLW)
0 (MLLW) to +2.4
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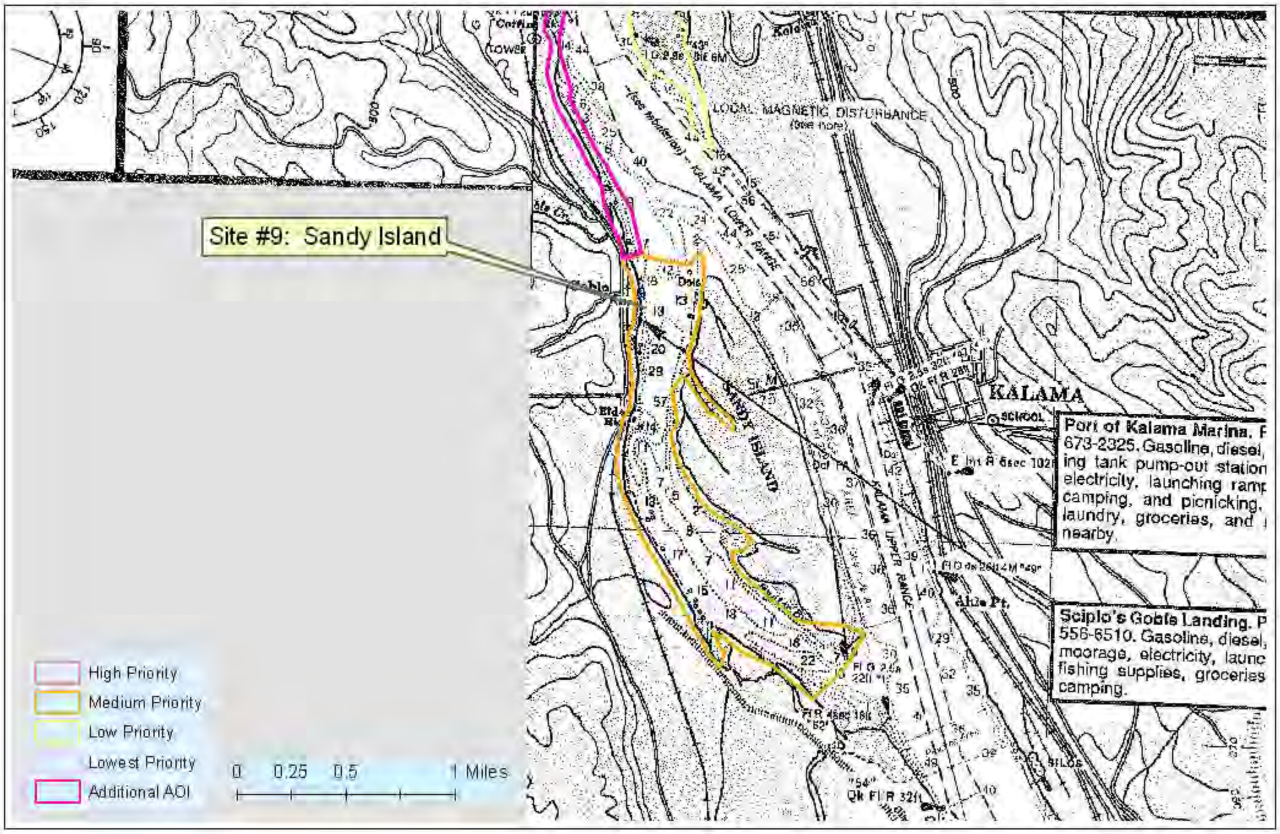
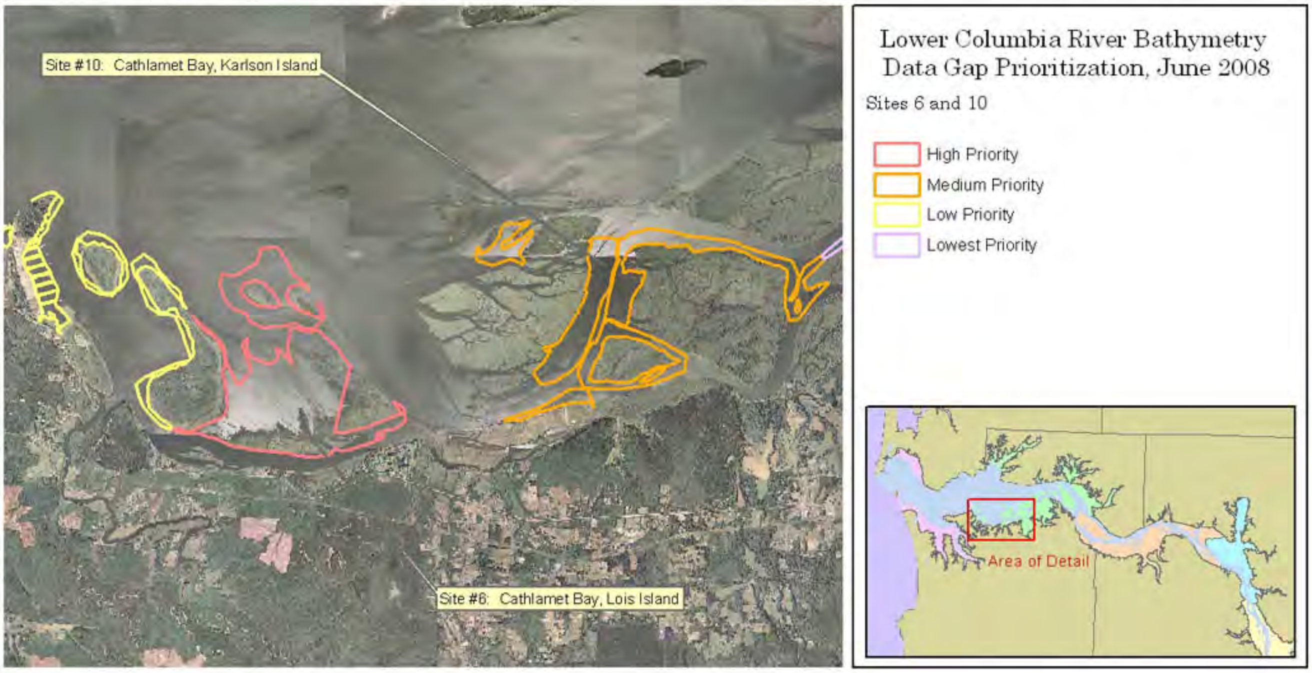
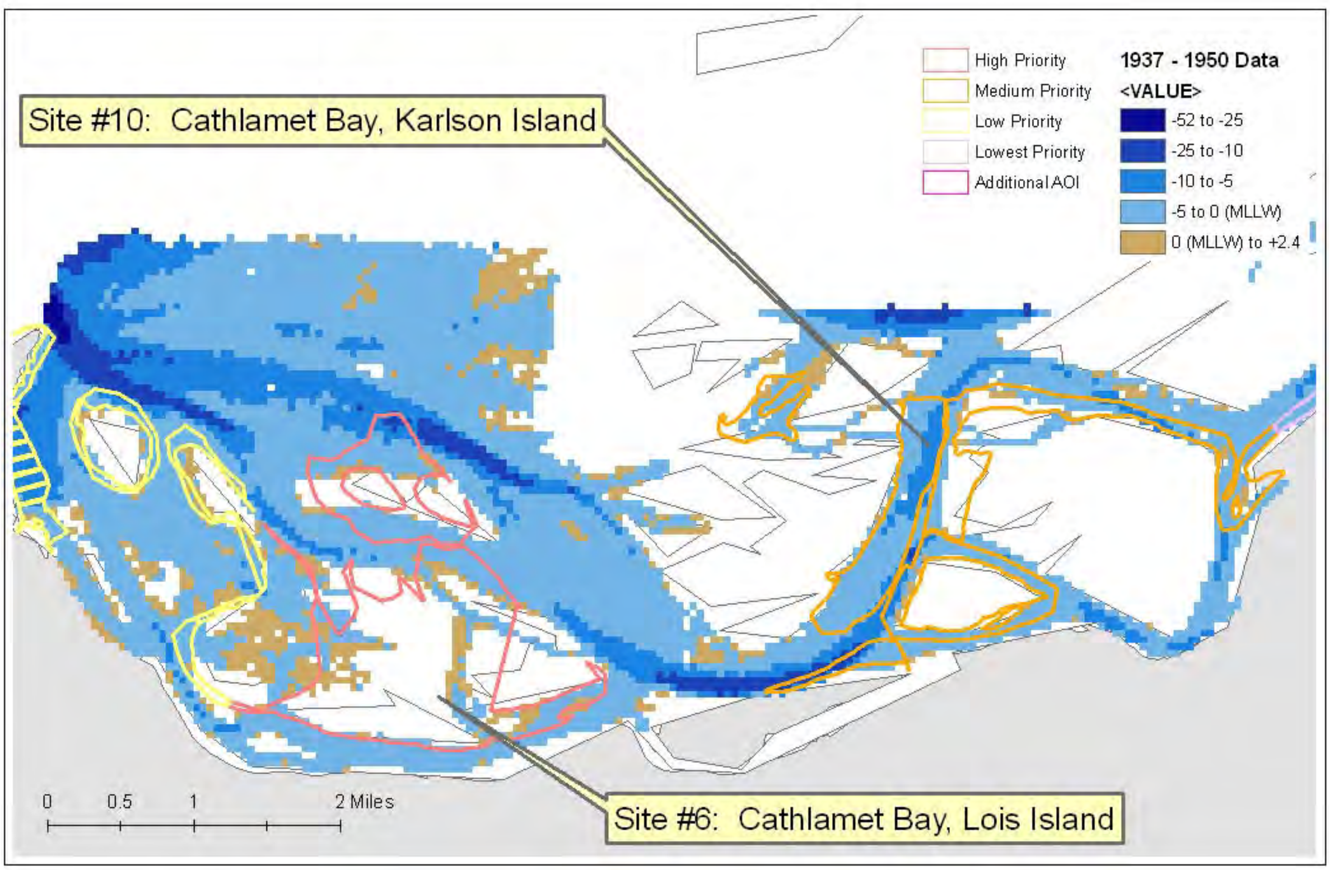
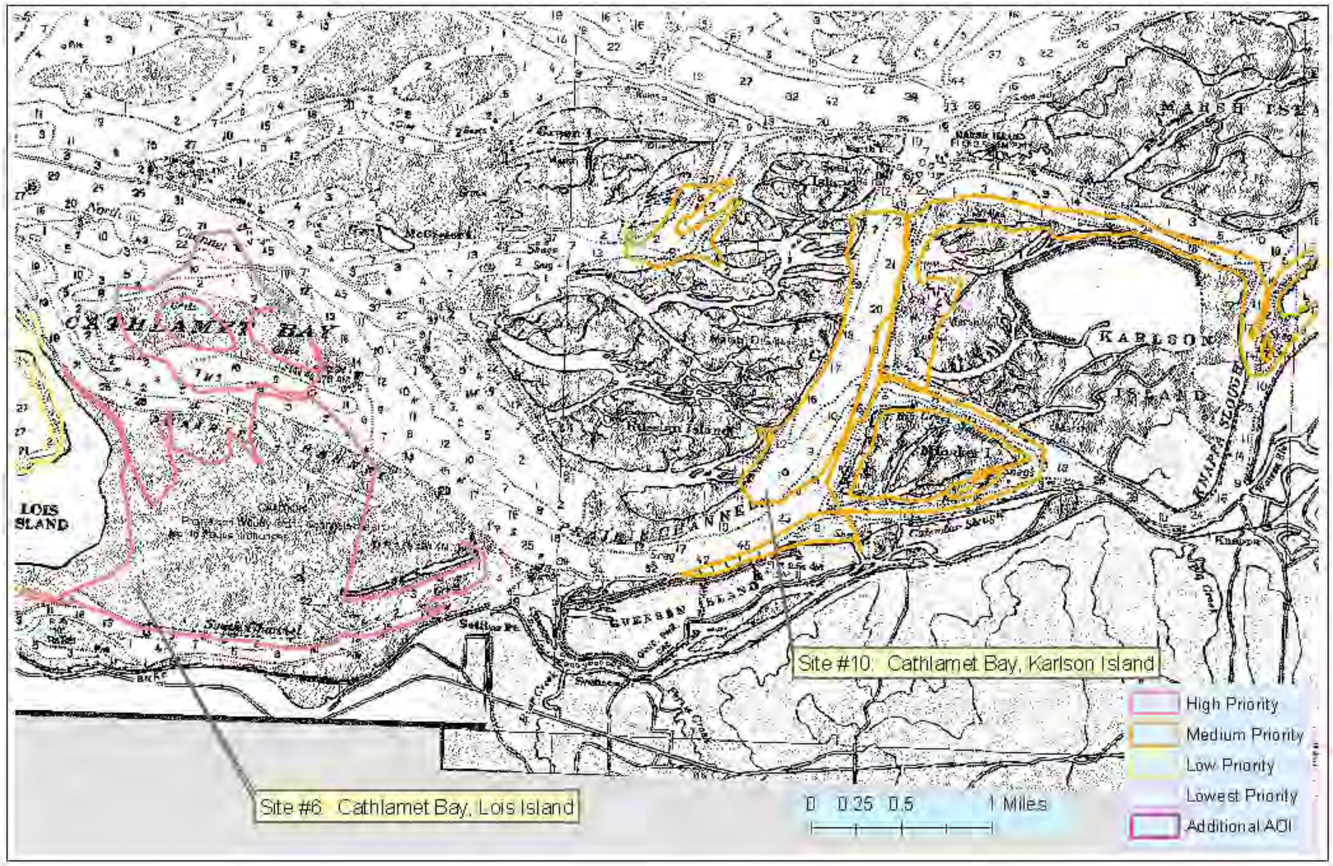
Site #9: Sandy Island


Site #9: Sandy Island
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
0 0.25 0.5 1 Miles
LOCAL MAGNETIC DISTURBANCE
SANDY ISLAND
KALAMA
Port of Kalama Marina.
673-2325. Gasoline, diesel,
ing tank pump-out station
electricity, launching ramp
camping, and picnicking,
laundry, groceries, and
nearby.
Scipio's Goble Landing.
556-6510. Gasoline, diesel,
moorage, electricity, launc
fishing supplies, groceries
camping.

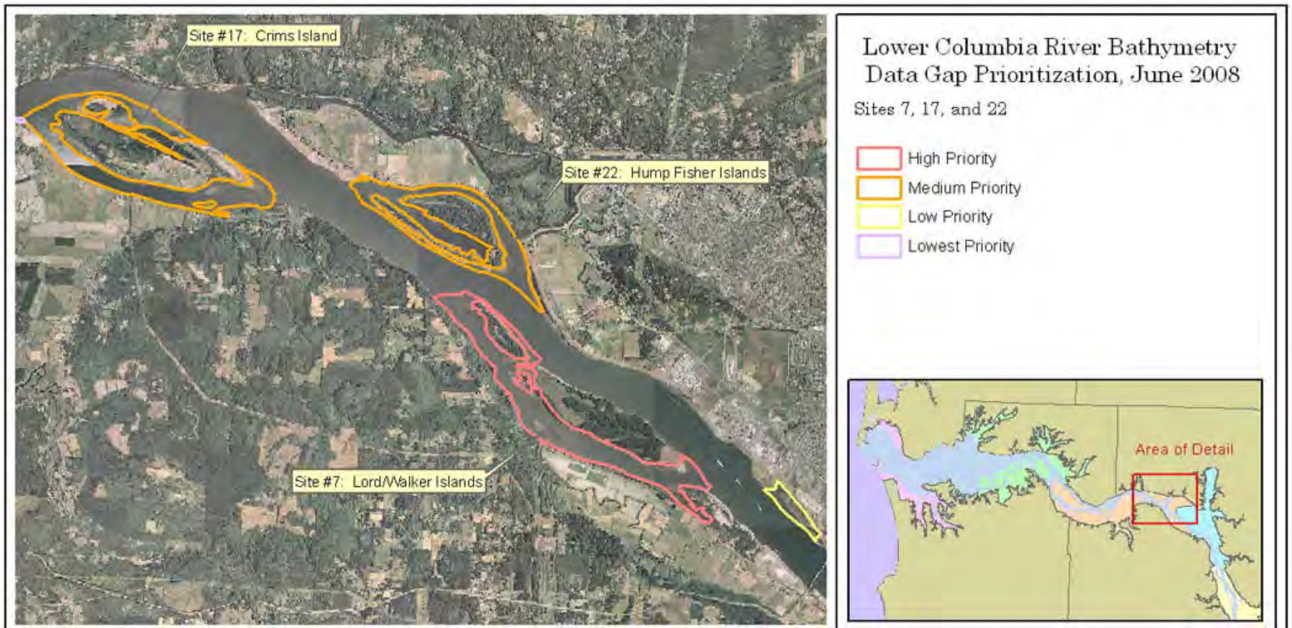


Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
6	B	7.4	HIGH	1330	46.1851557	-123.702965	Cathlamet Bay, Lois Island	Mostly shallow flats and small tidal channels. Some moderate channels.	No	Digital data available: HO7179 (1947), HO7180 (1947)	Porbably a difficult area to survey due to numerous shallows, flats, and small tidal channels.
10	B	6.2	MEDIUM	971	46.1988208	-123.62622	Cathlamet Bay, Karlson Island	Short section of moderately deep channel. Several smaller channels/tidal channels	No	Digital data available: HO6181 (1937), HO5928 (1935), HO7817 (1950)	Numerous channels could be complicated, but since older coverage is good it may be ok. No large flats, but tide could be critical for the small channels.

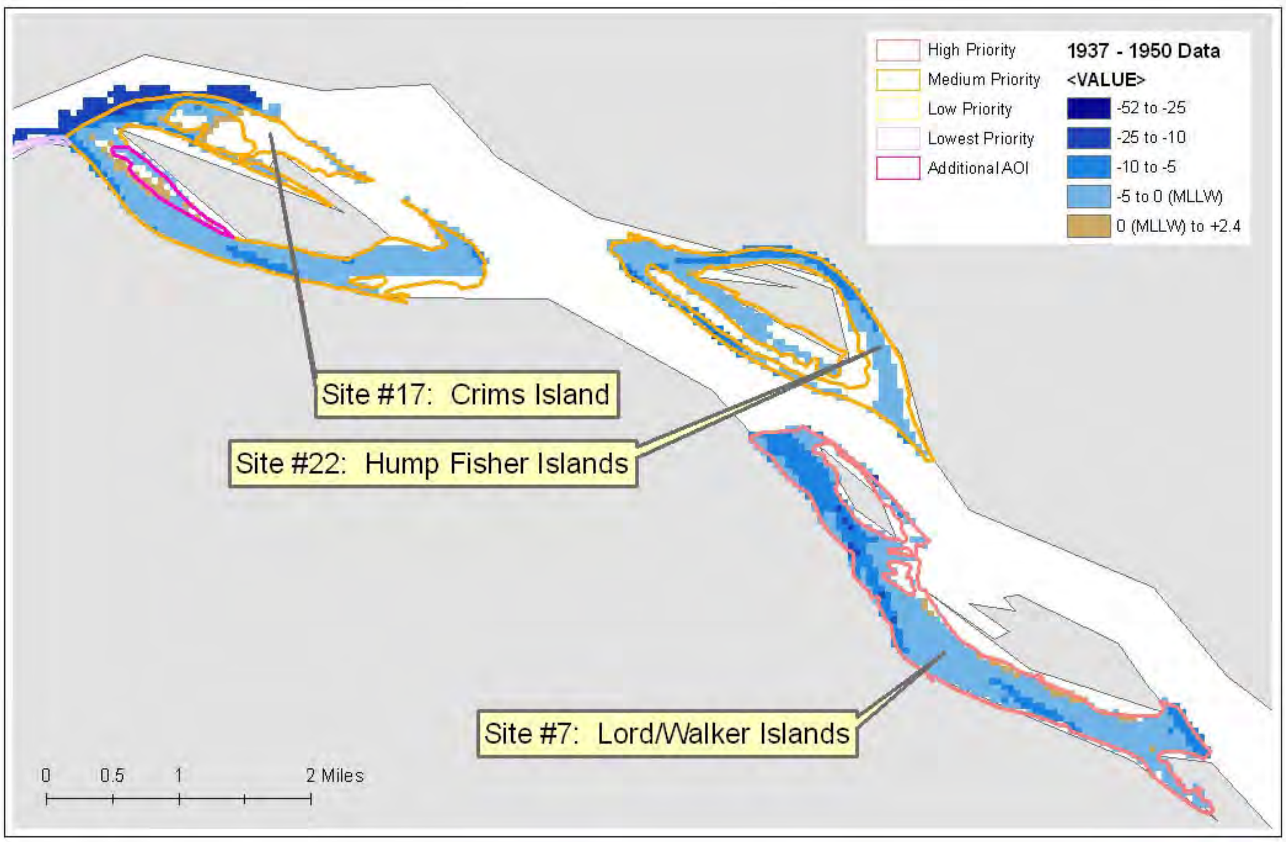


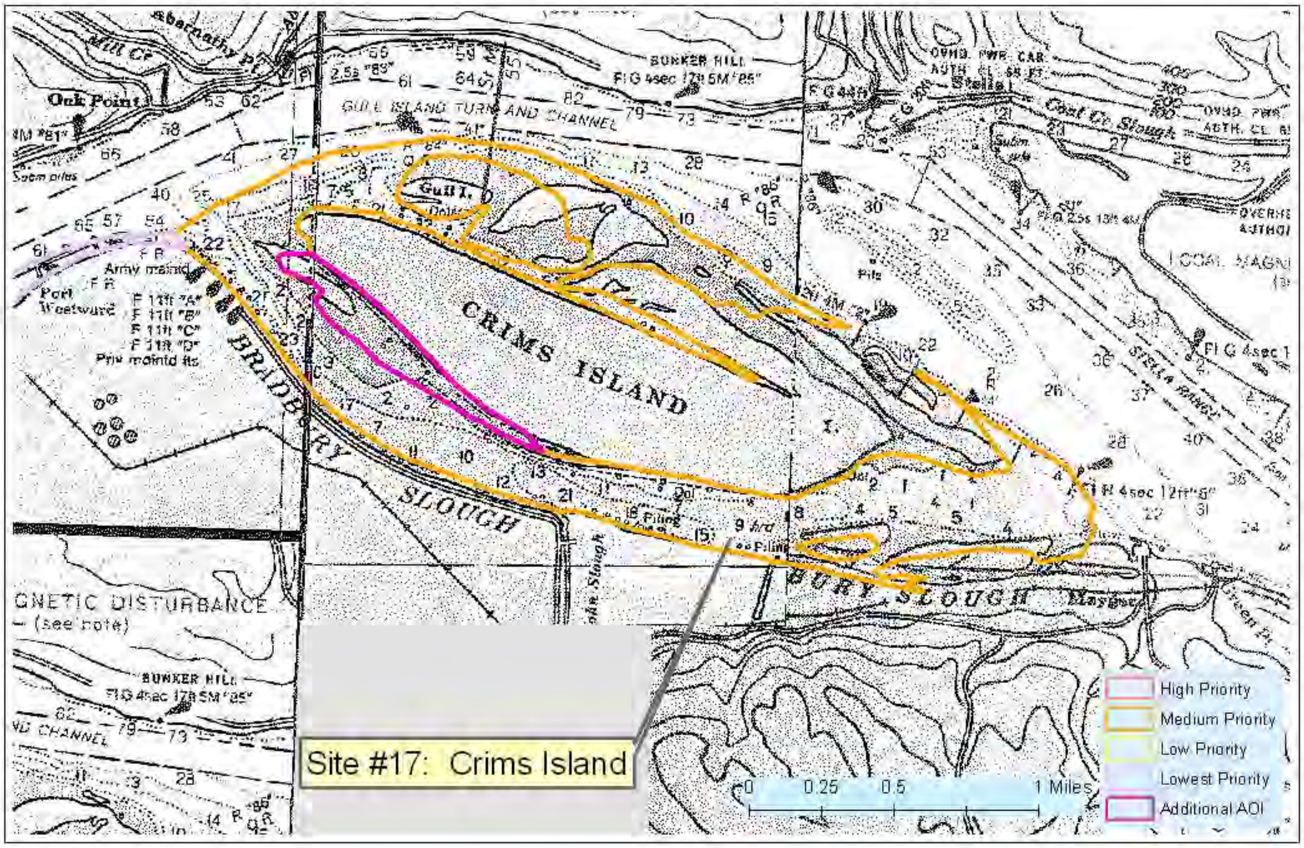


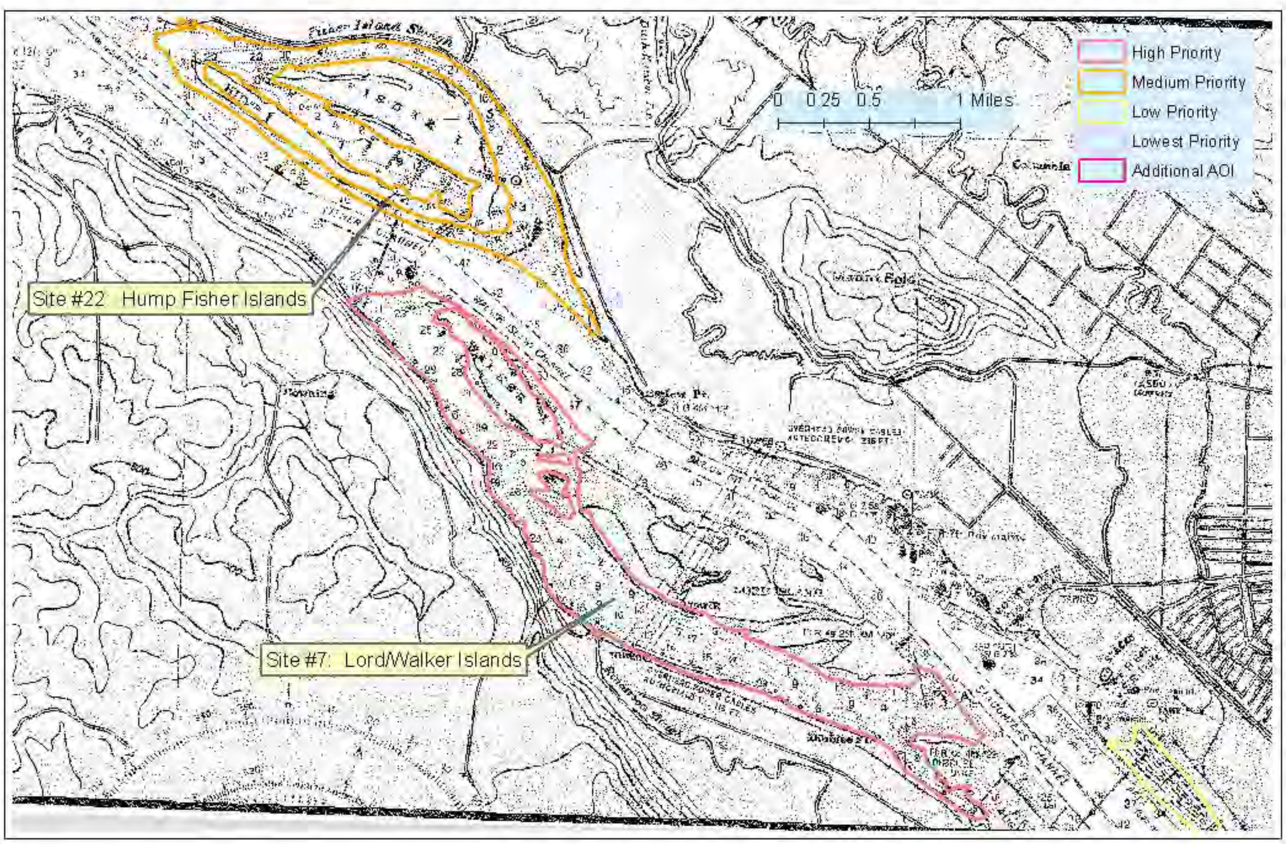
Site #10: Cathlamet Bay, Karlson Island
Site #6: Cathlamet Bay, Lois Island
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
0 0.25 0.5 1 Miles
CATHLAMET BAY
LOIS ISLAND
KARLSON
ISLAND

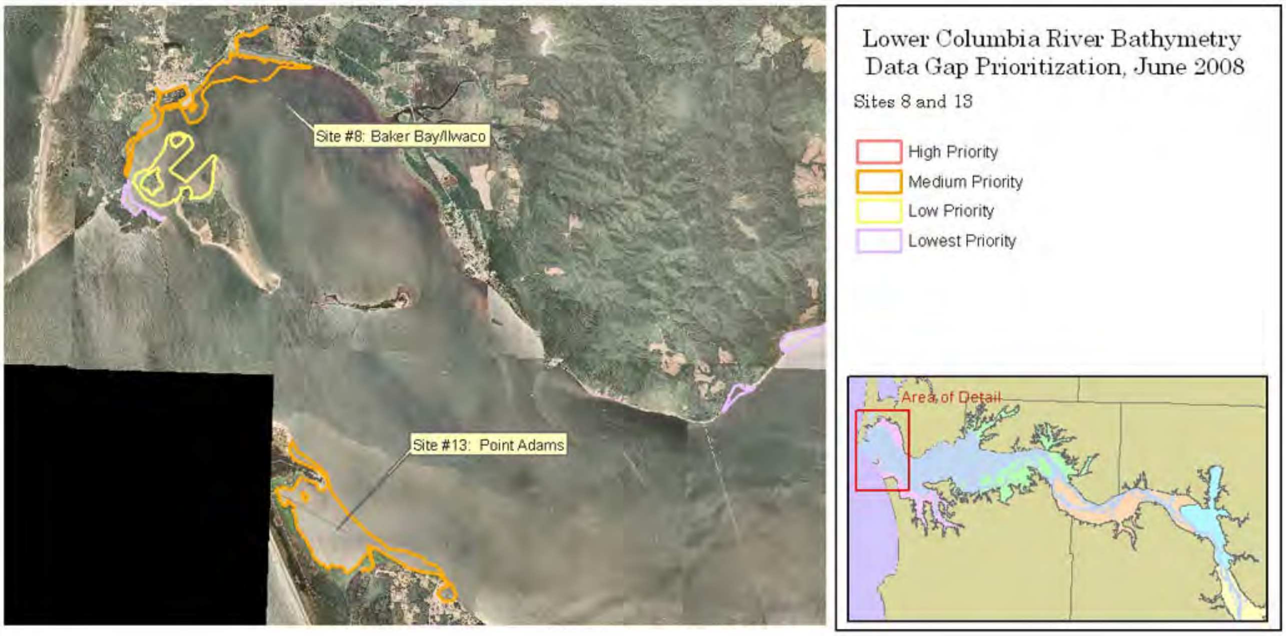


Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER-POLATABLE?	NOAA_NOS_INFO	Comments
7	C	7.0	HIGH	884	46.13244	-123.030447	Lord and Walker Islands	Mostly deep channels	No	Digital data available: HO6244 (1937), HO7746 (1949), HO7747 (1949)	Should be straightforward collection w/ soundings/sonar
17	C	4.8	MEDIUM	785	46.1758925	-123.1428	Crims Island	Mostly moderate depth and deep channels, some smaller channels extending into island	No	Digital data available: HO7748 (1949), HO6243 (1937), HO7862 (1950)	Should be straightforward coverage in most of the area. Mostly deep.
22	C	4.1	MEDIUM	583	46.1646544	-123.060469	Hump and Fisher Islands	Moderate depth channel and embayment. Deep main channel with steep embankment.	No	Digital data available: HO6244 (1937), HO7748 (1949), HO7747 (1949)	Should be straightforward.

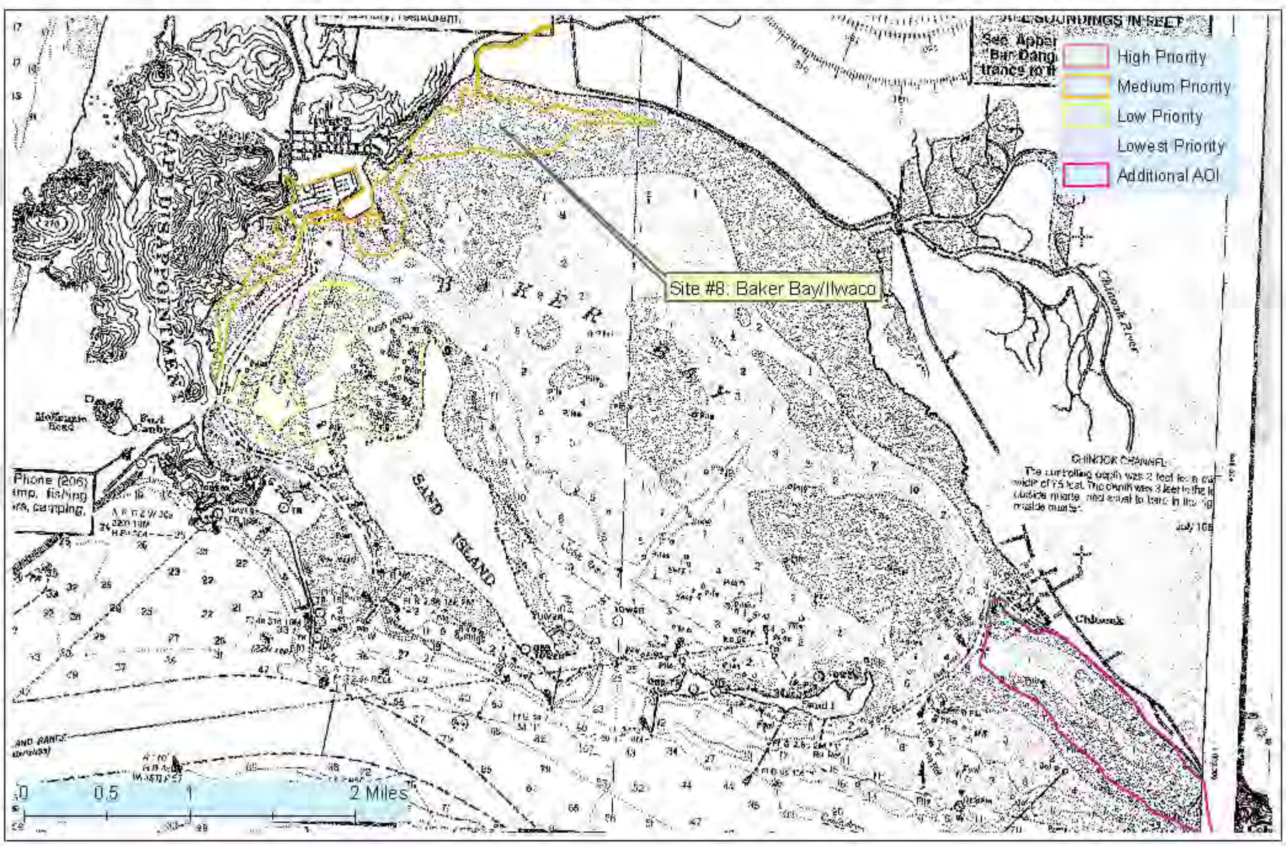


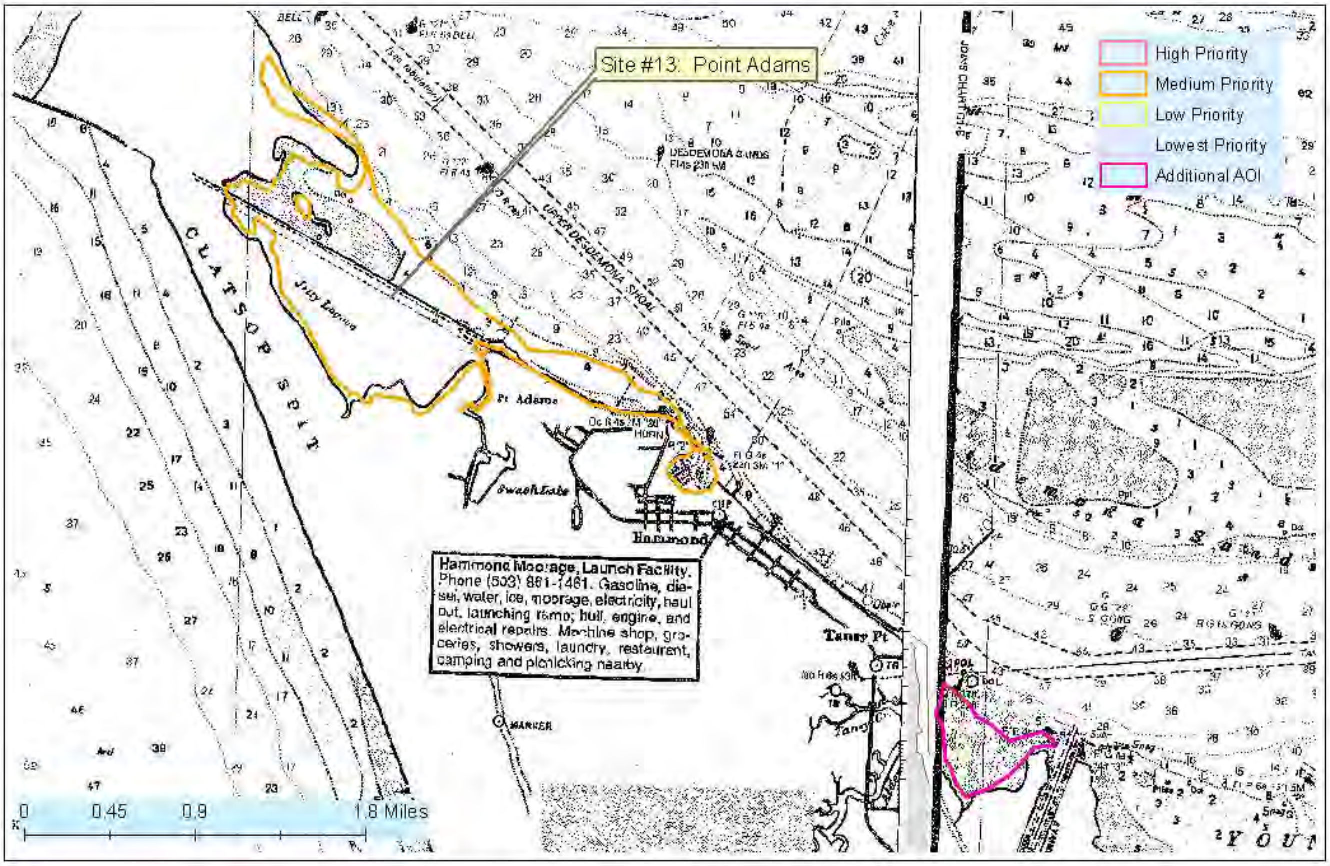

Site #17: Crims Island
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
0 0.25 0.5 1 Miles
CRIMS ISLAND
BRADBURY SLOUGH


Site #22: Hump Fisher Islands
Site #7: Lord/Walker Islands
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
0 0.25 0.5 1 Miles

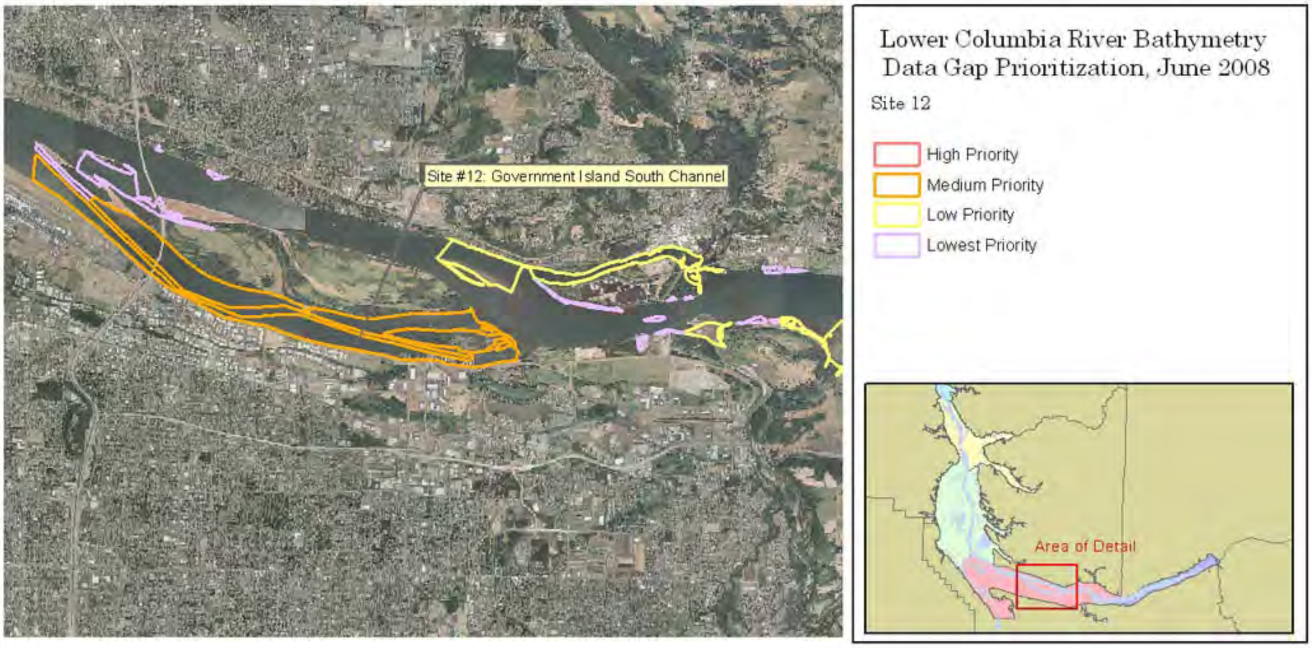


Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
8	A	7.0	MEDIUM	383	46.3082643	-124.027569	Baker Bay/Ilwaco	Shallows along Baker Bay Shoreline	No	Nothing in digitial format. TIFF images of soundings are available	Area covers most of Baker Bay shoreline. Looks like a combination of flats and moderately shallowareas. Additional areas exist east of gap polygons
13	A	5.2	MEDIUM	785	46.2155433	-123.982845	Point Adams	Shallowlagoon adjacent to river mouth	No	Nothing in digitial format. TIFF images of soundings may be available	Unsure about this area.

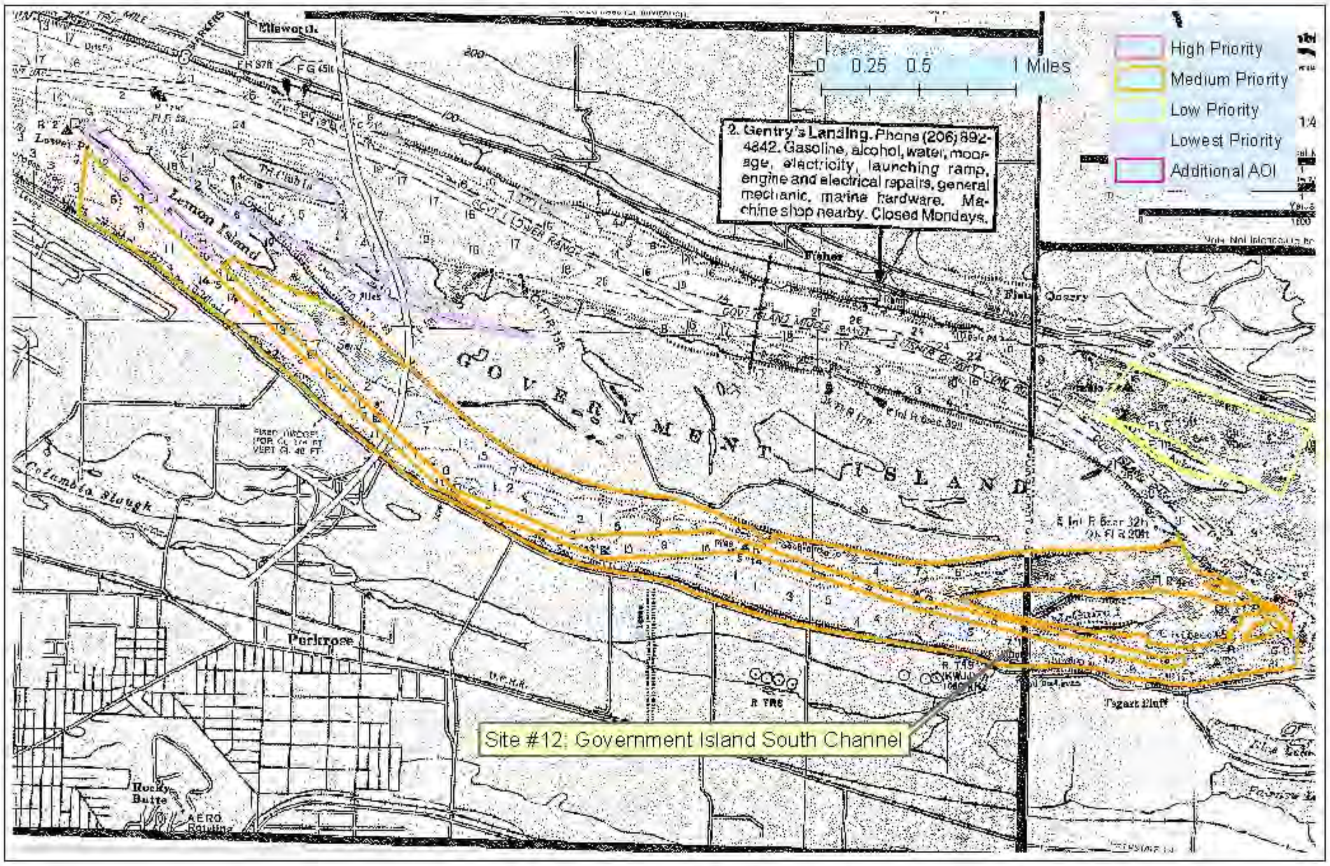


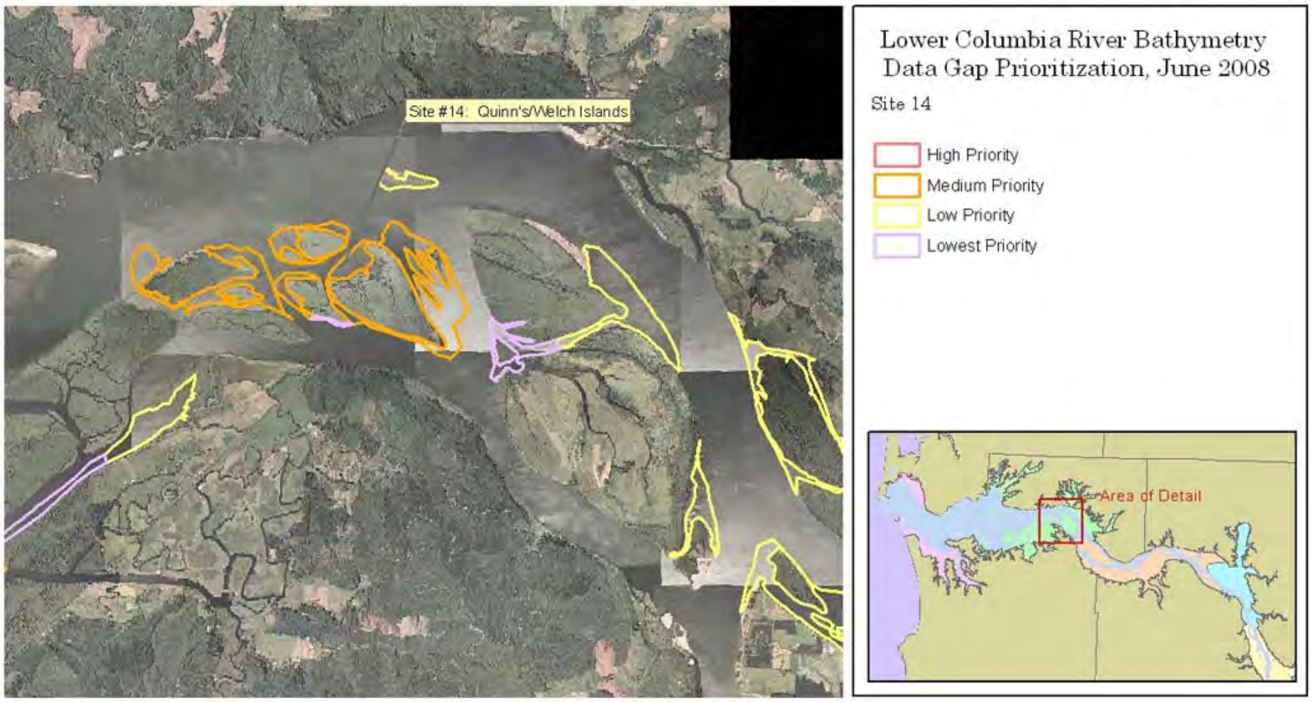


Site #13: Point Adams
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
UPPER DESDEMONA SHOAL
DESDEMONA SANDS
CLATSOP SPIT
Pt Adams
Swash Lake
Hammond
Hammond Moorage, Launch Facility. Phone (503) 861-1461. Gasoline, diesel, water, ice, moorage, electricity, haul out, launching ramp; hull, engine, and electrical repairs. Machine shop, groceries, showers, laundry, restaurant, camping and picnicking nearby.
Tansy Pt
MARKER
0 0.45 0.9 1.8 Miles

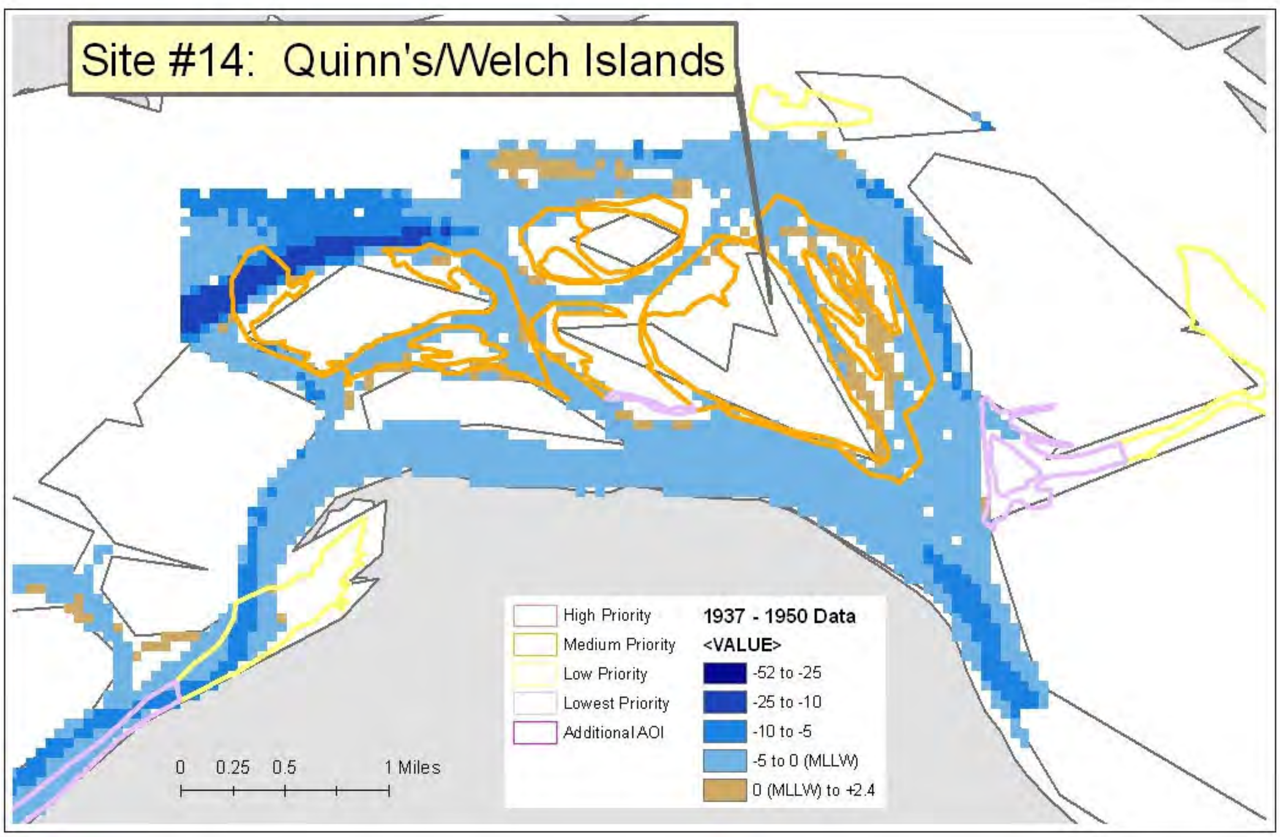


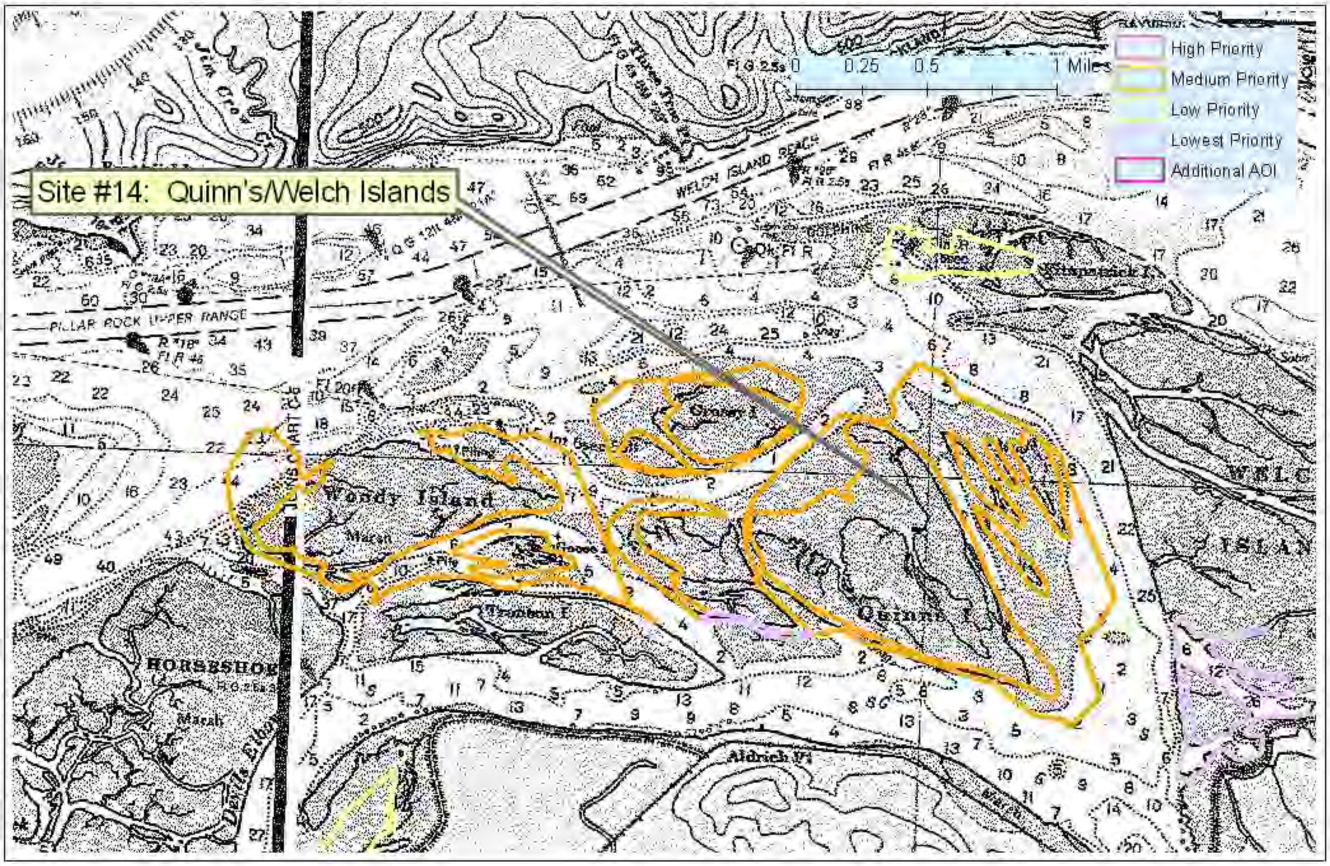
Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
12	G	5.7	MEDIUM	1443	45.5708502	-122.512859	Government Island, S Channel	Shallow channel.	No	Digital data available: HO7130 (1946), HO 7129 (1948)	Should be straightforward with shallow draft vessel.


0 0.25 0.5 1 Miles
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
2. Gentry's Landing. Phone (206) 892-4842. Gasoline, alcohol, water, moorage, electricity, launching ramp, engine and electrical repairs, general mechanic, marine hardware. Machine shop nearby. Closed Mondays.
Lemon Island
GOVERNMENT ISLAND
Columbia Slough
Parkrose
Site #12: Government Island South Channel

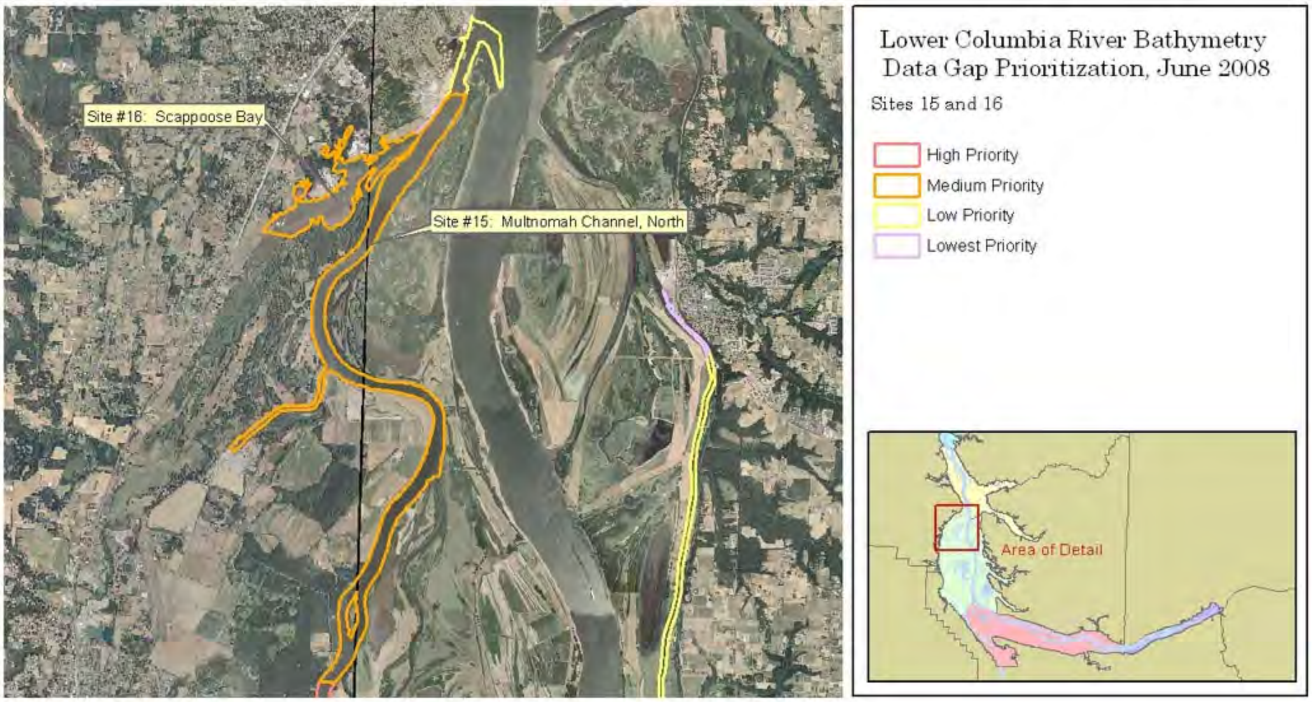


Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER-POLATABLE ?	NOAA_NOS_INFO	Comments
14	B	5.0	MEDIUM	654	46.2475222	-123.514136	Quinns/Welch Islands	Shallow channels and flats around islands	Possible, with medium confidence	Digital data available: HO7816 (1950), HO6181 (1937)	Could be difficult access. Tide could be critical for smaller channels and flats.

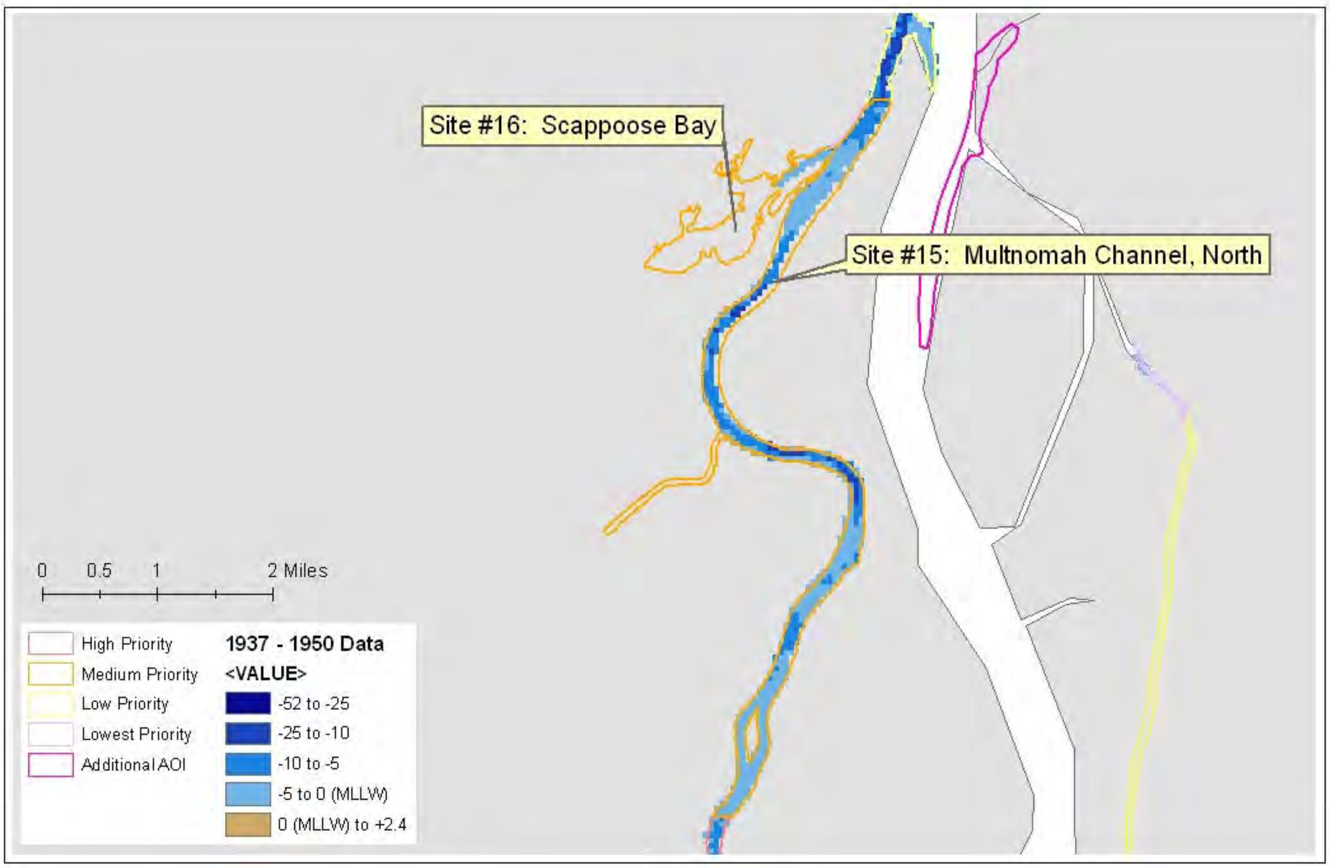


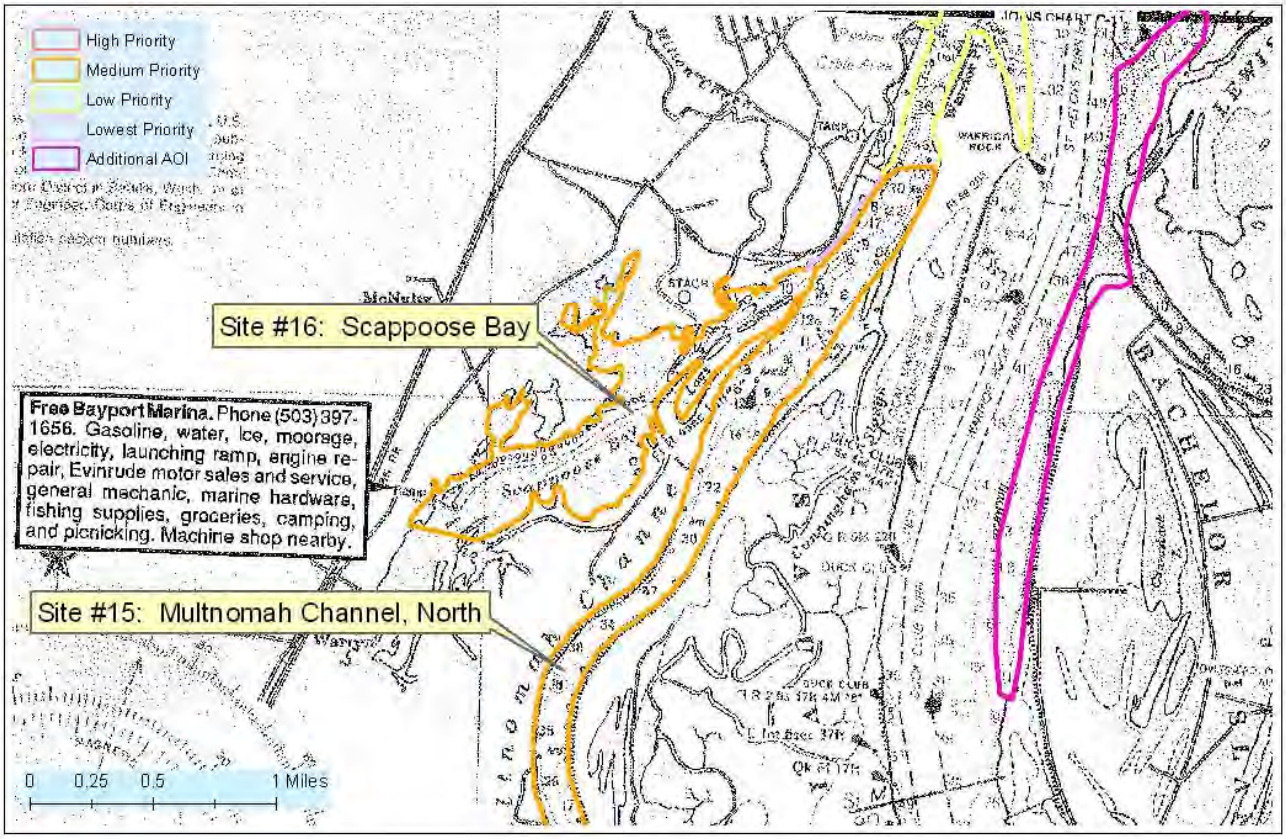


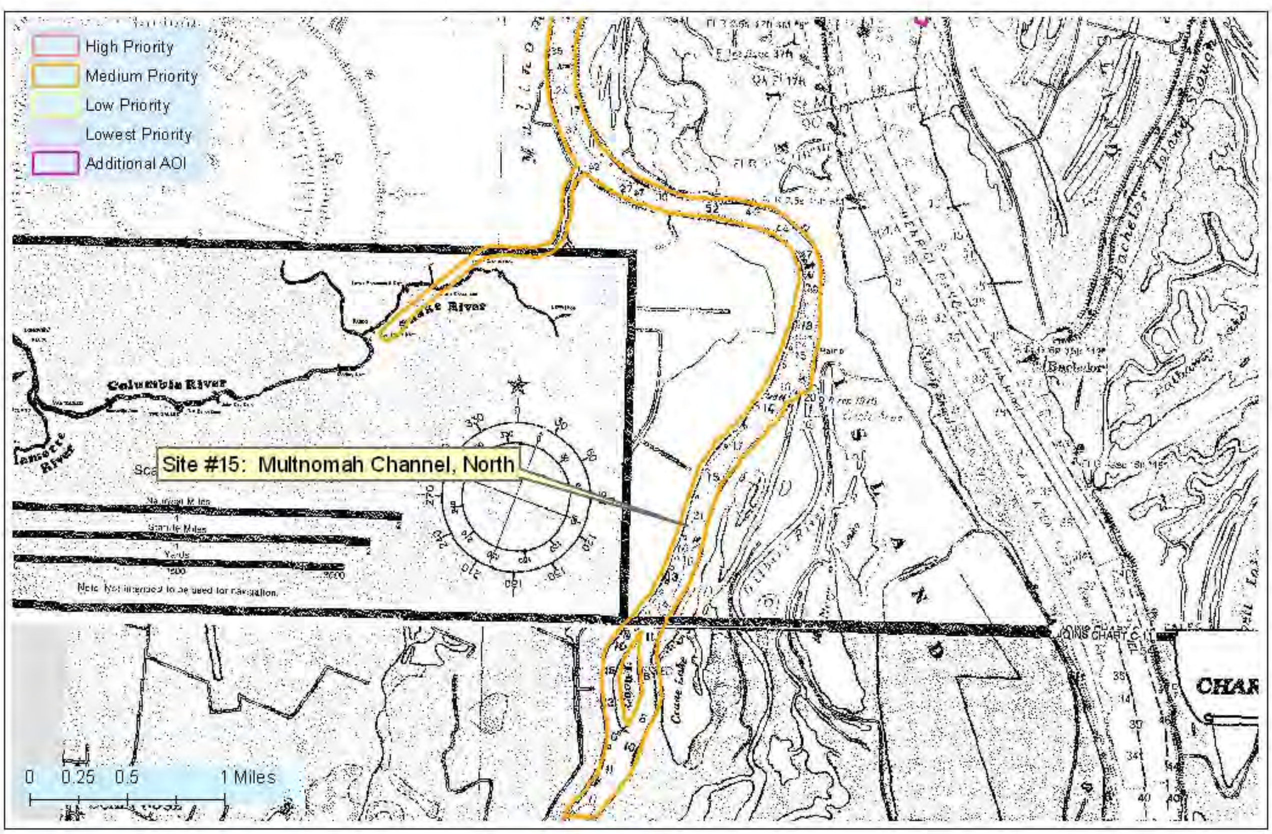
Site #14: Quinn's/Welch Islands
0 0.25 0.5 1 Miles
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI

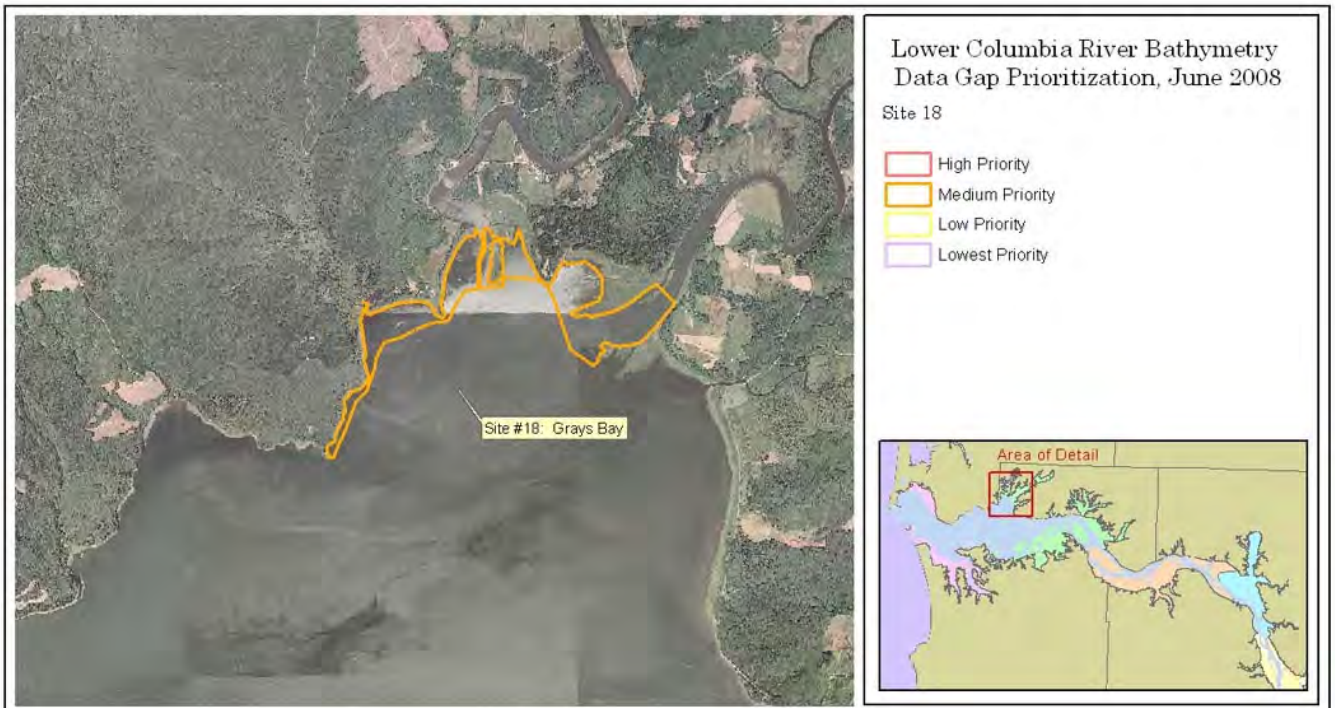


Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER-POLATABLE ?	NOAA_NOS_INFO	Comments
15	F	5.0	MEDIUM	833	45.8040086	-122.813758	Multnomah Channel, North	Generally deep channel, steep banks	No	Digital data available: HO6332 (1938), HO6247 (1937)	Should be straightforward collection w/ soundings/sonar
16	F	5.0	MEDIUM	313	45.8324721	-122.823429	Scappoose Bay	Unknown depths in main channel. Many shallow tributaries	No	None available.	More complex due to numerous shallow channels.

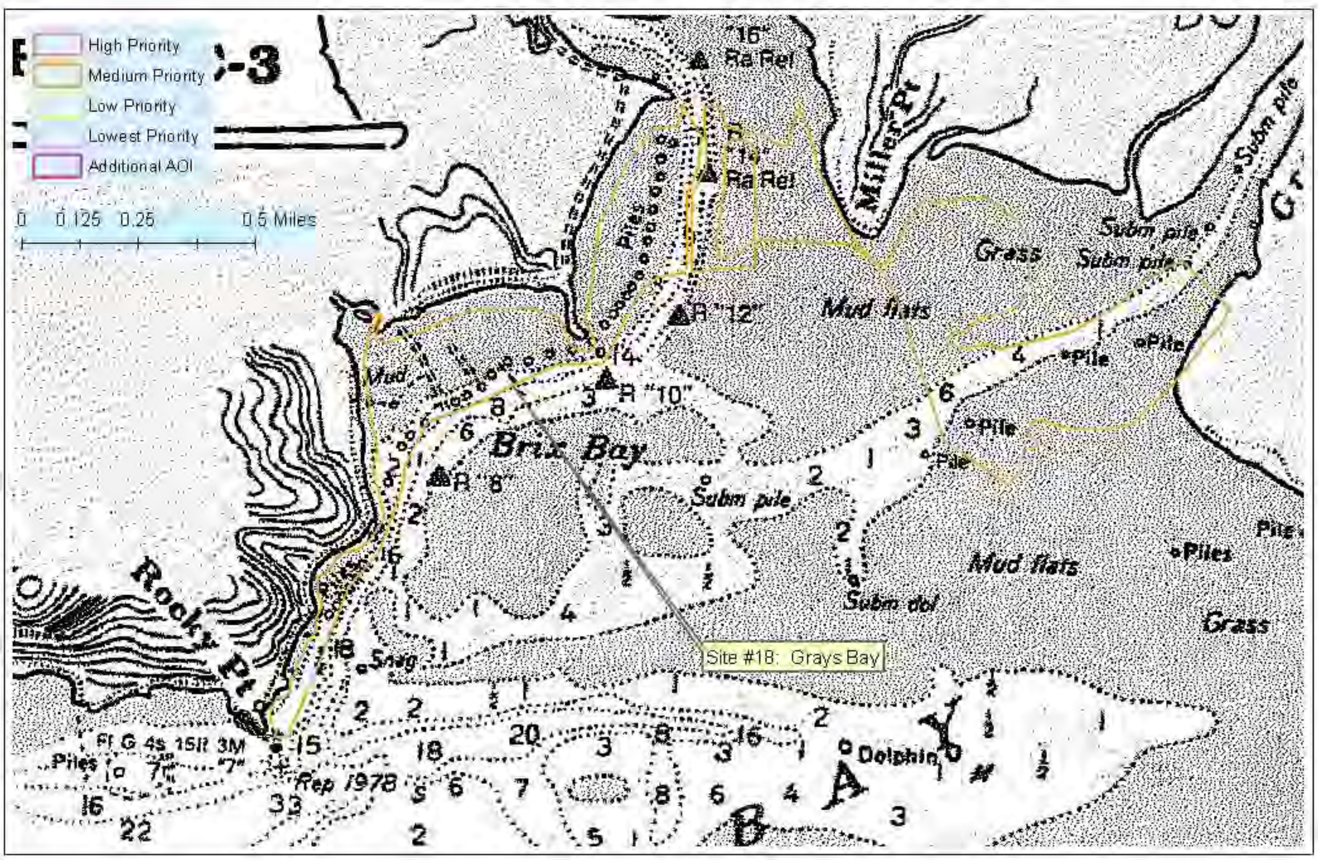


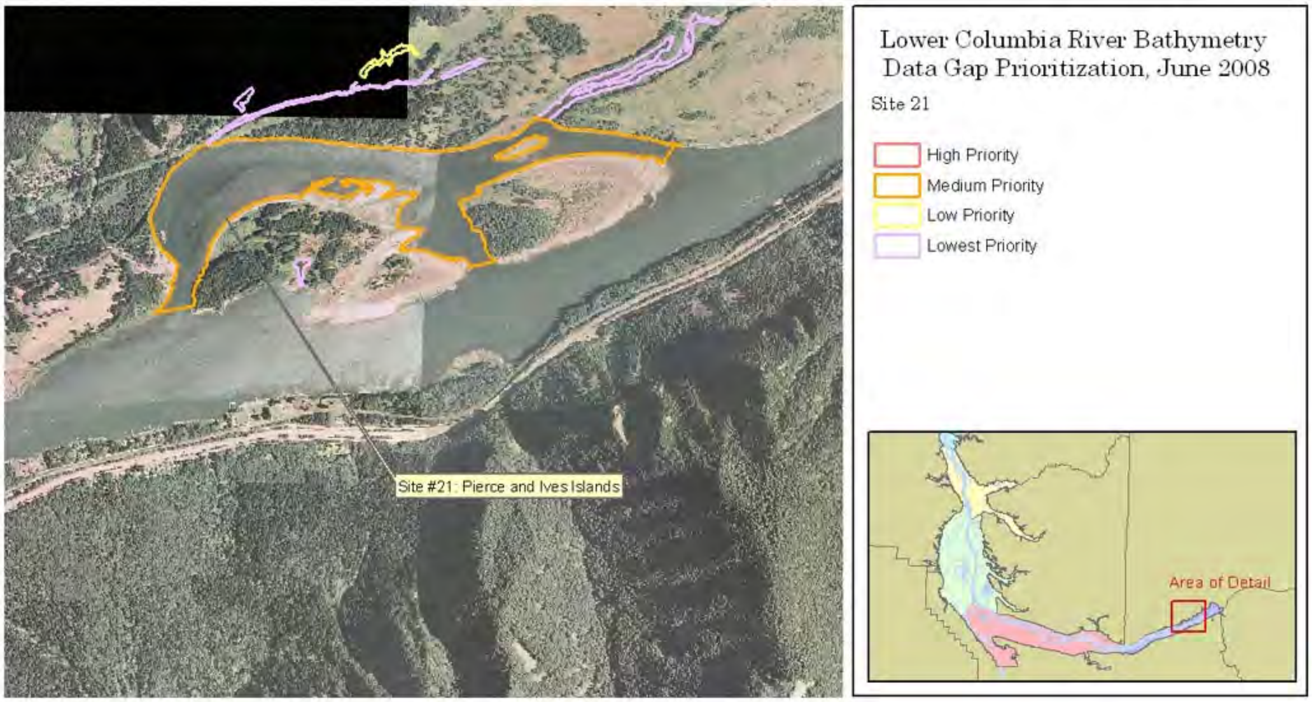

High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
Site #16: Scappoose Bay
Free Bayport Marina. Phone (503) 397-1656. Gasoline, water, ice, moorage, electricity, launching ramp, engine repair, Evinrude motor sales and service, general mechanic, marine hardware, fishing supplies, groceries, camping, and picnicking. Machine shop nearby.
Site #15: Multnomah Channel, North
0 0.25 0.5 1 Miles


High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI
Columbia River
Site #15: Multnomah Channel, North
0 0.25 0.5 1 Miles

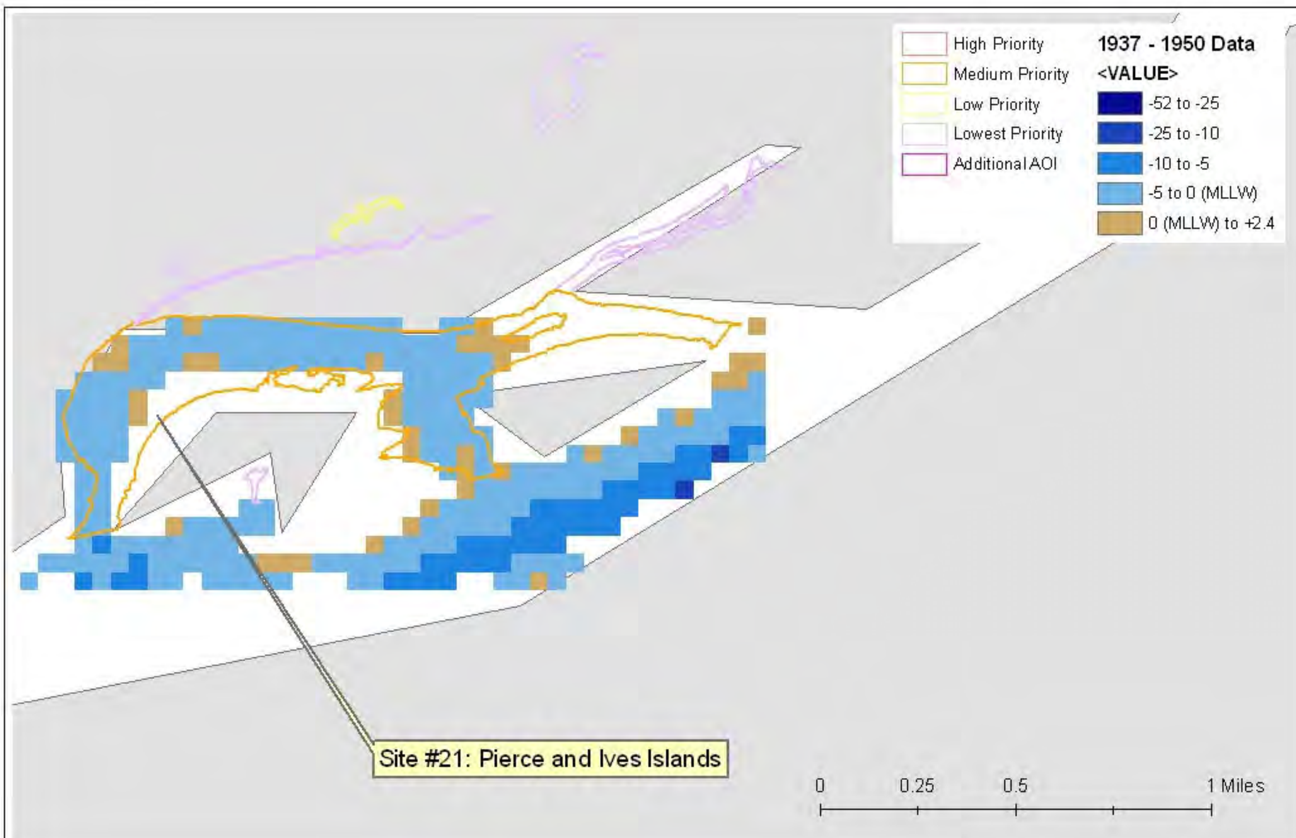


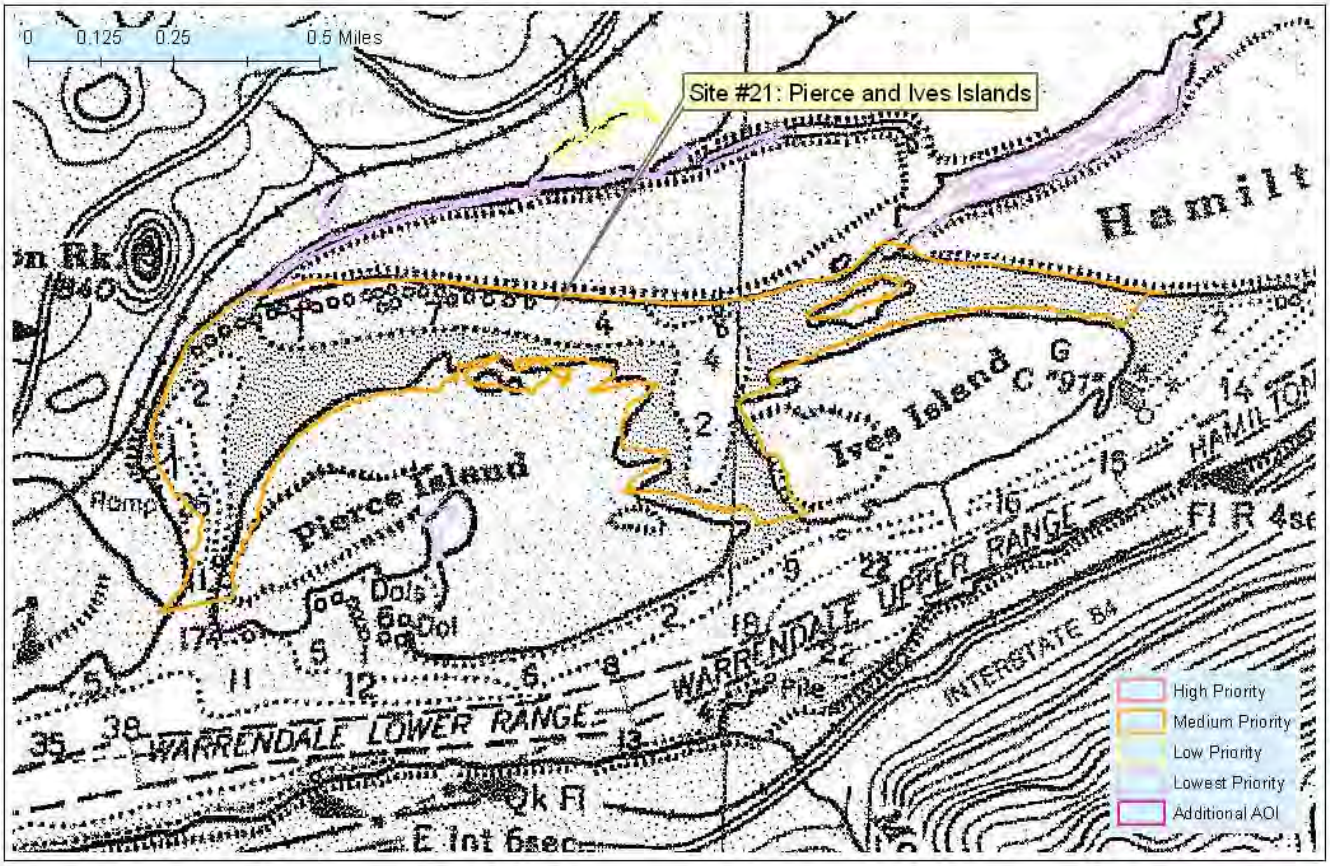
Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
18	B	4.8	MEDIUM	292	46.3018101	-123.705719	Grays Bay	Mostly shallow flats at entrance to Bay.	No	Digital data available: H08419 (1958)	Area is shallow and will require shallow draft vessel.

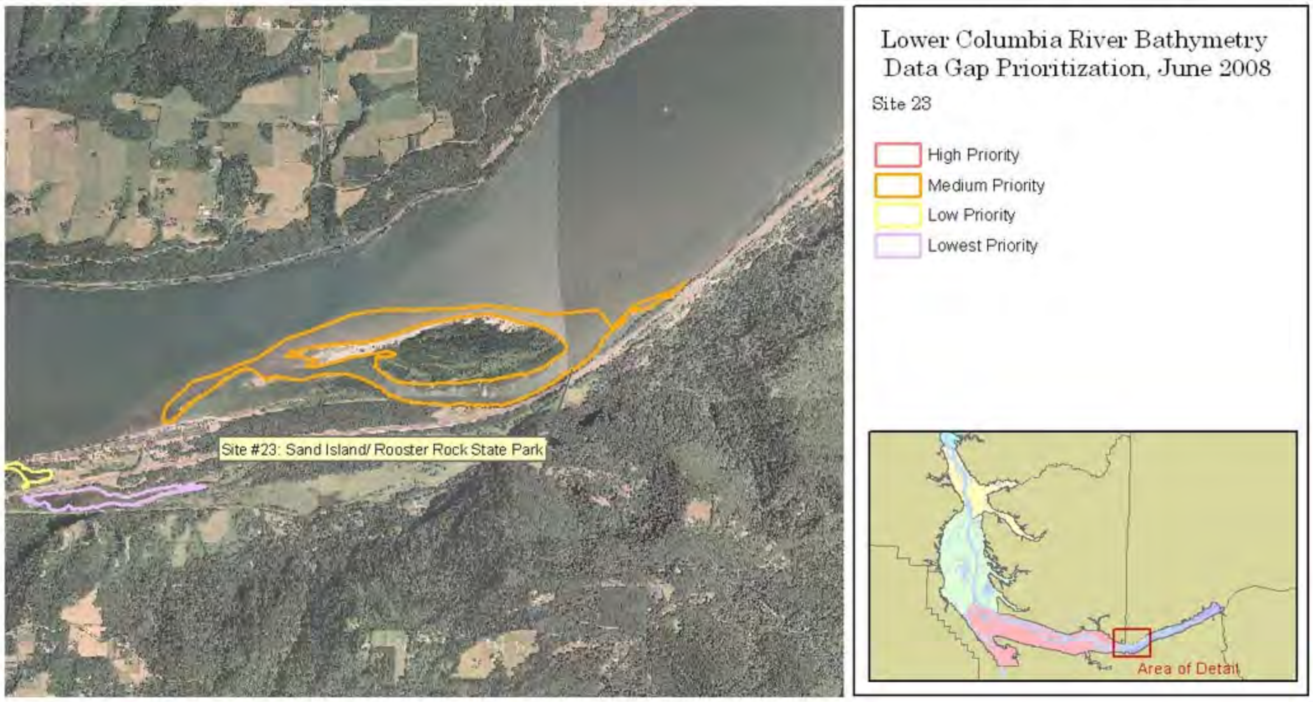




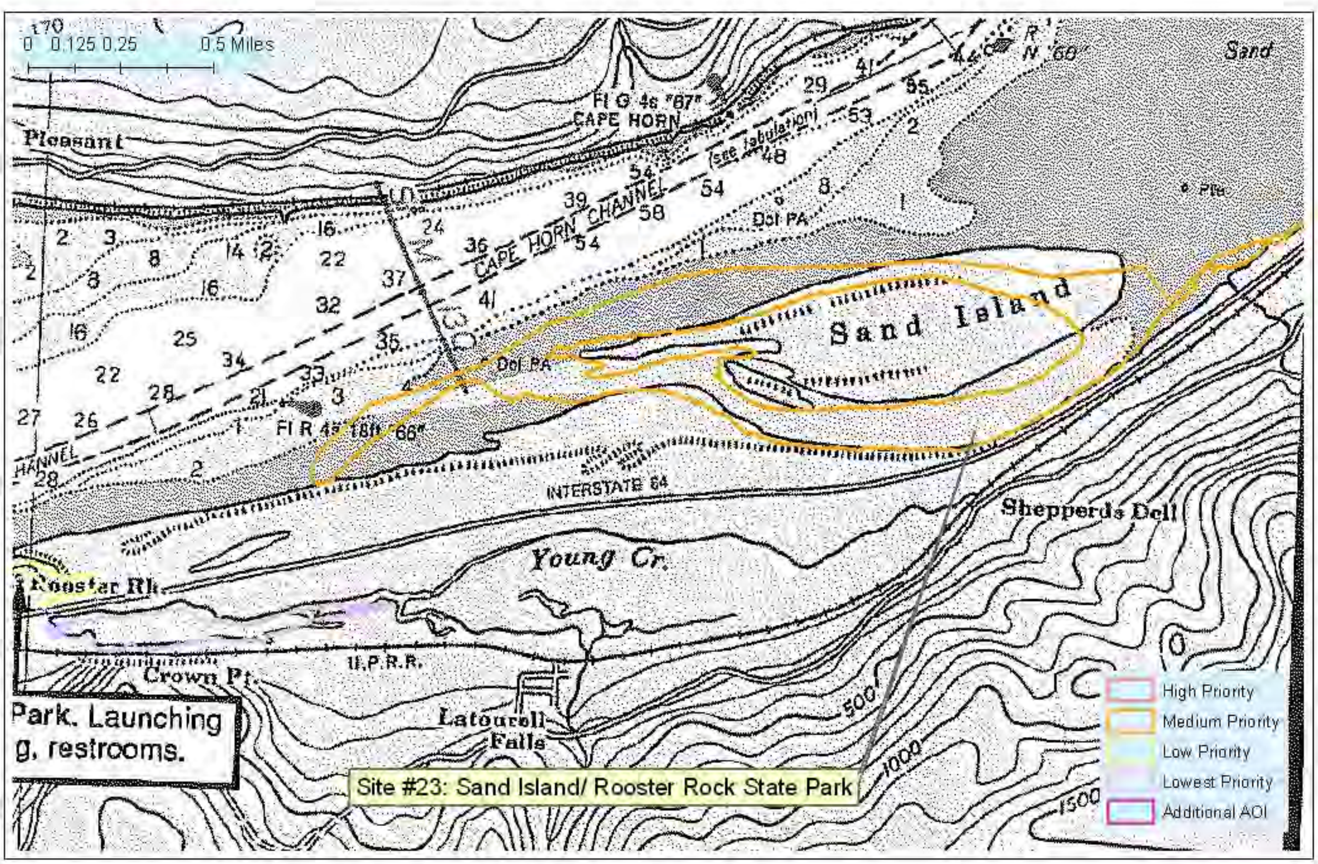
Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER-POLATABLE ?	NOAA_NOS_INFO	Comments
21	H	4.3	MEDIUM	204	45.6243517	-122.007363	Pierce and Ives Island	moderate depth channels between islands and mainland	No	None available.	Should be straightforward in moderate depth channels with high/moderate water levels.




0
0.125
0.25
0.5 Miles
Site #21: Pierce and Ives Islands
Pierce Island
Ives Island
WARRENDALE LOWER RANGE
WARRENDALE UPPER RANGE
INTERSTATE 84
High Priority
Medium Priority
Low Priority
Lowest Priority
Additional AOI



Site No	Reach	Final Rank	PRIORITY	Area (Acres)	LAT	LON	APPROX LOCAT	CLASS	INTER- POLATABLE?	NOAA_NOS_INFO	Comments
23	H	4.1	MEDIUM	258	45.5535059	-122.206853	Sand Island	Shallows along Main Stem, and side shannels with some shallows.	Possible at the north end of island, with medium confidence	None Available.	May require shallowdraft vessel during low water periods.



Appendix 2: Background Information on Probabilistic Sampling Design Theory

To inform future efforts with the survey design process, USGS compiled background information on probabilistic sampling design theory and associated terms that may be useful for future sampling design efforts in the LCRE.

Probabilistic design

The term "probabilistic design," as it pertains to ecological monitoring programs, is commonly associated with the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP). This program is developing tools for monitoring and assessing the status and trends of national ecological resources. EMAP's goal is to use environmental monitoring data from multiple spatial and temporal scales to assess current ecological conditions and forecast future risks to our natural resources. Sampling designs based on EMAP have been widely recommended for monitoring in the Pacific Northwest and the Columbia River Basin (Pacific Northwest Aquatic Monitoring Partnership, 2004; Independent Scientific Review Panel, 2005). The EMAP strategy entails using a probability-based sampling design to spatially sample geographic areas. The EMAP design is commonly used to assess the status of environmental conditions and accommodates stratification to help reduce the overall variance of measured responses across the landscape. Rotational panel designs are one design used by the EMAP program (see http://www.epa.gov/NHEERL/arm/designpages/panelstructures.htm). Yet, one sampling design can rarely successfully accommodate multiple sampling objectives (Johnson and others, 2008) and many design approaches can be used to assess the characteristics of a population (Skalski, 1990).

Census vs. random sample designs

An extreme sampling design would be a census examining every unit in the population of interest. Such an approach, like measuring plant species composition in all LCRE wetlands, is generally impractical and cost prohibitive. A more cost-effective and still statistically valid approach would be to examine a subset of this population through random (or probability) sampling. Studies based on statistical samples rather than complete census are referred to as sample surveys. Sample surveys can be cost effective, and have well developed and documented statistical principles (Cochran, 1977). These principles provide the basis for selecting a subset of sampling units for data collection and methods for statistical analyses.

Selecting a random sample

Since survey sampling is intended to characterize the entire population of interest, the probability of all members of the target population being included in the sample should be known. Simple random selection helps ensure that the sample is representative because all members of the population have an equal chance of being selected. Simple random sampling ensures that no particular portion of the sampling frame (e.g., kinds of river reaches, habitat types) is favored. For example, within an estuary, the chance of selecting a sampling unit that has degraded ecological conditions would be directly proportional to the number of sampling units within the target population that have degraded conditions. That is, if 30% of the target population has degraded conditions, then on average 30% of the randomly selected units in the sample will exhibit degraded conditions. This property of random sampling allows estimates (based only on the sample) to be used to draw conclusions about the target population as a whole. The way samples are selected determines the ability to obtain accurate estimates of population parameters. For example, we clearly would not get a good picture of overall estuary conditions if preferential selection of samples included only sites downstream of sewage outfalls or toxic sites where impacts affect only a small percentage of total estuary area. This kind of sampling program may provide useful information about conditions downstream of sewage outfalls and toxic sites, but would not accurately represent overall conditions in the estuary.

Probability-based sample

A probability-based sample is a sample where every element of the target population has a known, non-zero probability of being selected. That is, every element of the target population has the possibility to be in the sample. The probability selection mechanism guards against site selection bias and provides the basis for valid scientific inference to characteristics of the entire target population. There are many approaches for selecting a probability sample. The approach selected depends on the objectives of the survey, the availability of auxiliary information (e.g., habitat characteristics), logistical or operational constraints in conducting the sampling (e.g., limited funding), the characteristics of the sample frame, and the complexity of the statistical analysis. A few alternative designs are described below.

Simple random sample is the simplest example of a probability-based sample where every sample has the same probability of being selected. This is also known as simple random sampling without replacement. Its major advantage is its simplicity, not only in design but also in statistical analysis of survey results.

Stratified random sample may be the most common probability-based survey design used. When auxiliary information is available for the target population or the survey has multiple objectives, such information can be used to define strata.

Unequal probability sample is an alternative to a stratified random sample. An unequal probability sample is achieved by assigning a probability of selection to each element of the target population, usually depending on auxiliary information. For example, we could assign a probability of selection to each habitat complex within the estuary based on either management priority or complex variability, where a shallow tidal flat would be twice as likely to be selected as a deep mainstem habitat complex, an emergent tidal wetland bordering a secondary channel four times as likely as the other complexes. This type of design provides enormous flexibility to meet objectives as well as a mechanism to increase precision. The statistical analysis is more complex and requires that all analyses use weights derived from the unequal probability of selection.

Reasons for stratifying samples

Some reasons to stratify samples include: 1) administrative or operational convenience, 2) different survey designs are required for particular portions of the target population, or 3) precision can be increased by constructing strata that are homogeneous. Designs for such strata tend to create more independence among strata and often contain subpopulations within strata. Impacts on the sample size needed to achieve acceptable precision are the same under both approaches, meaning increases in the number of desired estimates also increases the number of samples needed. Creation of subpopulations is usually undertaken to support unequal weighting, which provides a method for allocating samples to the subpopulations. It also can improve the precision of the resulting estimates. Creating subpopulations requires auxiliary information for each member of the target population during the design process.

Stratification considerations

For any design including stratification, samples must be allocated among the various strata. The simplest method for this allocation is proportional allocation based on strata size with various size-measurement options possible (e.g., area, frequency of strata, and volume). Another strategy is to account for strata variability and/or sampling costs to provide a more optimal allocation (described previously as unequal probability).

Status and trends monitoring

Establishing whether a monitoring program aims to address status, change, or trends is useful because of the influence of these approaches on survey approaches and designs. Status is typically viewed as a "snapshot" of resource conditions at a certain time (e.g., the number of wetland patches greater than five acres in Reach H during 2008). Providing information on change requires the ability to compare the resource status between multiple time intervals (e.g., the estimated number of patches greater than five acres in Reach H during 2008 compared to 2000 and 2004). Trend questions require several estimates of resource status, often over longer time periods (e.g., the trend in the estimated number of patches greater than five acres in Reach H between 2008 and 2058). Generally, different survey designs and strategies have strengths and weaknesses in their ability to provide estimates for status, change, or trend, often requiring trade-offs among competing objectives within studies seeking to address all three.

The EPA offers definitions and attributes of several different statistical design types online at: http://epa.gov/nheerl/arm/designpages/monitdesign/statdesigntypes.htm.