# Ecosystem Monitoring Project

## Annual Report for Year 5

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**Lower Columbia River Ecosystem Monitoring Project**
**Annual Report for Year 5 (September 1, 2008 to August 31, 2009)**

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## Executive Summary

Our ability to understand the relationships between sensitive organisms, such as salmonids, and the lower Columbia River 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, 1999) to address needs for habitat and toxic contaminant monitoring and data management through its Ecosystem Monitoring Project (EMP). Efforts for the EMP include an ecosystem classification system and on-the-ground monitoring of vegetation, habitat, juvenile salmon, and water quality. This monitoring was 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 addresses RPAs 58, 59, 60, and 61 of the 2008 Biological Opinion. The Estuary Partnership executes the EMP by engaging regional experts at the University of Washington (UW), Battelle-Pacific Northwest National Laboratory (PNNL), National Oceanic and Atmospheric Administration Fisheries (NOAA-Fisheries), and United States Geological Survey (USGS). Financial support for the EMP comes from the Bonneville Power Administration (BPA) and Northwest Power and Conservation Council (NPCC).

This report describes EMP accomplishments during September 1, 2008 to August 31, 2009, or Year 5 of this on-going project. During this period, the Estuary Partnership and monitoring partners:

- Further developed the Columbia River Estuary Ecosystem Classification (Classification), including delineation of draft Classification Levels 4-6 for Reach F and development of ancillary datasets (dikes/levees, floodplain, and dredge material) to support the Classification (UW, USGS).
- Prepared a report describing the Classification's conceptual basis, methods, and applications and submitted report to USGS for peer-review and publication (UW, USGS, and Estuary Partnership).
- Collected bathymetry data, filling 12,600 acres of 14,235 acres identified as high and medium priority data gaps and needed for completing the Classification (Estuary Partnership).
- Convened a landcover workshop to discuss collection strategies for landcover data acquisition (Estuary Partnership, UW).
- Generated and released a Request for Proposals (RFP) to solicit bids from private contractors to acquire landcover data for the LCRE (Estuary Partnership).
- Facilitated 2008-2009 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 datasets (such as vegetation, habitat, prey, and salmonids) at 4 sites in Reach C, 2 previously sampled site in Reach F, and 1 previously sampled site in Reach H to characterize habitat, fish, and prey at all sites and assess year-to-year trends at previously sampled sites (PNNL, NOAA-Fisheries, and USGS).
- Characterized habitat 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 2009-2010 monitoring efforts (Estuary Partnership, UW, PNNL, USGS, and NOAA-Fisheries).
- Participated in regional monitoring coordination efforts, like Pacific Northwest Aquatic Monitoring Partnership (PNAMP) and Estuary Partnership's Science Work Group (Estuary Partnership).
- Supported other Action Agency 2008 BiOp implementation efforts such as the USACE's Cumulative Effects of Restoration Project and LiDAR processing (Estuary Partnership)

The EMP's 2008-2009 work elements will facilitate 2009-2010 work elements, such as delineation of Classification Level 4 for additional reaches, bathymetry and landcover data collection, continued monitoring of undisturbed emergent wetlands, and synthesis of previously collected data at emergent and forested tidal freshwater wetlands. Results from the 2008-2009 sampling of vegetation, sediment, salmon, and water quality will be synthesized and integrated with results from past sampling efforts and 2009-2010 sampling.

## 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) focused on the lower Columbia River 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 (LCREP, 2004) was drafted to address comments by more clearly defining the goals and methods of the habitat monitoring portion of the EMP.

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; Simenstad et al., In review) 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 (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 (Figure 1) 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 (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 three-spine 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.

In Year 5 (September 1, 2008 to August 31, 2009) of the EMP, UW along with USGS continued their efforts on the Classification, including delineation of draft Classification Levels 4-6 for Reach F and development of ancillary datasets (dikes/levees, floodplain, and dredge material). Using Level 4, UW compared historical versus current conditions in Reach F. The Estuary Partnership, UW, and USGS developed a report describing the conceptual basis, methods, and applications of the Classification (Simenstad et al., In review). As of November 2009, this document is being peer-reviewed via the USGS publication process. Upon review and revision, the document will be published and made available via USGS and the Estuary Partnership. Completing the Classification to Level 6 for the entire LCRE requires bathymetry and landcover data. Thus, the Estuary Partnership contracted for bathymetry data collection, filling 12,600 acres of 14,235 acres identified as high and medium priority data gaps in 2009. We also hosted a landcover workshop to discuss data gaps and collection strategies and then released a Request for Proposals to select a contractor for acquiring these data in 2010-2011. Finally, we processed existing LiDAR data to fill data gaps in riparian topography for use by monitoring and restoration partners in the LCRE.

In 2008-2009, PNNL, USGS, and NOAA-Fisheries collected information (e.g., vegetation, habitat, basic water quality, macroinvertebrates, and salmonids; data collected varied by site) at 4 sites in Reach C, 2 previously sampled sites in Reach F, and 1 previously sampled site in Reach F to characterize all sites and assess year-to-year trends at previously sampled sites. UW characterized habitat conditions and biological communities at 3 forested tidal freshwater wetlands.

## 2.0 EMP Efforts by the Estuary Partnership in 2008-2009

Funding for the EMP supports the Estuary Partnership's Monitoring Coordinator. As part of 2008-2009 EMP efforts, the Monitoring Coordinator:

- Planned and implemented the landcover workshop with support from UW, PNNL, and USGS
- Developed a Request for Proposals with GIS/Data Management Specialist to identify a contractor to acquire landcover dataset in 2010-2011
- Coordinated development of the Classification and work timelines
- Contributed material to and reviewed the Classification document (Simenstad et al., In review)
- Facilitated discussions and planning for 2008-2009 monitoring efforts
- Coordinated site field trips
- Acquired special use permits for accessing monitoring sites
- Provided field support for EMP monitoring partners
- Coordinated Science Work Group meetings dedicated to the ecosystem monitoring efforts
- Managed EMP subcontracts with UW, PNNL, USGS, and NOAA-Fisheries
- Compiled report contributions from EMP subcontractors into this annual report to BPA
- Developed new scopes of work with EMP subcontractors for the 2009-2010 EMP activities
- Prepared and presented materials for several meetings with BPA, NOAA Fisheries, PNNL, and other regional monitoring partners to determine scope of EMP activities for 2009-2010

EMP funds also support the Monitoring Coordinator's work on the Estuary Partnership's Action Effectiveness Monitoring (AEM) program funded by BPA. For this program, the Monitoring Coordinator:

- Developed site monitoring plans for 2008-2009 AEM efforts
- Coordinated a Science Work Group meeting dedicated to AEM

- Supported USACE's Cumulative Effects of Restoration project by compiling and analyzing Fort Clatsop AEM data for a preliminary meta-analysis and reviewing and presenting results
- Developed and managed AEM subcontracts with NOAA-Fisheries, Columbia River Estuary Study Taskforce (CREST), Scappoose Bay Watershed Council, Parametrix, and Ash Creek Forest Management for 2008-2009
- Developed new scopes of work with AEM subcontractors for 2009-2010
- Organized and facilitated site trips with subcontractors to discuss AEM methods and challenges and ensure data comparability between sites
- Compiled AEM reports from subcontractors for the Restoration Program's 2008-2009 annual report to BPA

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

- Coordination and communication amongst parties by staying abreast of RME activities in the LCRE and sharing this information and principal contacts
- Coordination with Pacific Northwest Aquatic Monitoring Partnership (PNAMP) workgroups related to the estuary, Action Effectiveness Monitoring, and Integrated Status and Trends Monitoring
- Development of an inventory of on-going effectiveness monitoring at restoration sites
- Refinements to standardized protocols for restoration effectiveness monitoring
- Revisions to the NOAA Estuary Recovery Plan Module including update of on-going estuary RME projects tables and revising water quality sections and Chapter 6 RME

Funding for the EMP also provides partial support for the Estuary Partnership's GIS/Data Management Specialist. For the 2008-2009 EMP efforts, the GIS/Data Management Specialist:

- Developed the survey plan and scope of work for the acquisition of shallow water bathymetry data throughout the LCRE
- Supervised bathymetry data collection in the LCRE by subcontractor David Evans and Associates
- Processed final bathymetry raster grids provided by David Evans and Associates in order to maximize funding available on-the-ground bathymetry data collection
- Planned and implemented the landcover workshop with UW and support from PNNL and USGS
- Developed a Request for Proposals with Monitoring Coordinator to identify a contractor to acquire landcover dataset in 2010-2011
- Analyzed various GIS datasets to support the 2008-2009 site selection process for on-the-ground monitoring in Reach C and further developed a geodatabase inventory of EMP monitoring efforts
- Provided field support for NOAA-Fisheries, PNNL, and UW sampling crews during the 2009 field season
- Delivered updates on the bathymetry and landcover data collection at several SWG meetings
- 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

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 2005 Puget Sound LiDAR consortium LCRE LiDAR dataset to establish 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 and habitat restoration projects.
- Generation of maps for the NOAA Estuary Recovery Plan Module

- Development of a geodatabase inventory of on-going effectiveness monitoring at restoration sites
- Participation in planning and providing guidance to USACE for the development of a digital terrain model for the LCRE to be developed by the USACE in 2009 and collection of new LiDAR data

## 3.0 EMP Coverage of RPAs in the 2008 Biological Opinion

Work implemented under the Ecosystem Monitoring Project addresses Reasonable and Prudent Alternatives (RPAs) 58, 59, 60, and 61 of the 2008 Biological Opinion for the Federal Columbia River Power System (FCRPS). From May – July 2009, the Estuary Partnership presented overviews describing RPA coverage by the EMP to the Bonneville Power Administration, US Army Corps of Engineers, and NOAA-Fisheries. This section summarizes the EMP coverage of RPAs presented to the Action Agencies.

The EMP is the only estuary project covering RPAs 59.1 and 59.2 calling for collecting bathymetry and developing a hierarchical classification system, respectively. See the Bathymetry and Classification sections of this report for more information. The EMP supports RPAs 60.1 and 60.2 as the EMP coordinates with the Reference Site Study (funded by the Estuary Partnership/BPA under the Habitat Restoration contract) to collect data at undistributed sites throughout the LCRE. Coordination between these two projects maximizes efficiency and yields a greater number of reference sites. The EMP supports RPAs 61.1 and 61.3 by collecting data on juvenile salmonid usage of the estuary and Chinook genetic stocks. See Table 1 and Table 2 for coverage summaries of RPAs 58.3 and 59.5, respectively.

**Table 1: EMP Coverage of RPA 58.3.**

| **Estuary Projects Covering RPA** | **Spatial Overlap** | **# of Sites** | **Data Collected** |
|---|---|---|---|
| 7 including EMP | Minimal<br><br>EMP covers tidal FW portion (Reaches C-H) | 16 fish & prey sites ('04-'09)<br>• 8 EMP emergent wetland sites<br>• 2 EMP emergent wetland fixed sites<br>• 6 EMP mainstem sites<br>6 prey sites at EMP forested wetlands ('08-'09) | • Growth rates<br>• Prey samples in juvenile salmonid stomach contents, emergent vegetation, open water, & benthic cores |

**Table 2: EMP Coverage of RPA 59.5.**

| Estuary Projects Covering RPA | Spatial Overlap | # of Sites | Data Collected |
|---|---|---|---|
| 8 including EMP | Minimal | 29 total ('04-'09) vegetation<br>• 20 EMP emergent wetland sites<br>• 3 EMP emergent wetland fixed sites<br>• 6 EMP forested wetland sites | • Vegetation % cover<br>• Community structure<br>• Topography<br>• Channel cross-sections |
| | | 5 total ('04-'09) water quality<br>• 4 EMP emergent wetland sites<br>• 1 EMP emergent wetland fixed site | • Vary by site<br>• Temperature, dissolved oxygen, salinity, turbidity, conductivity |
| | | 0 sites for primary & secondary productivity | • None |

Originally, RPA 59.5 was developed based on the rotational panel design proposed in LCREP (2004). The design called for a synoptic sampling of 160 sites throughout the lower river to inventory the types of habitat and their conditions. Subsequent monitoring would collect data at 8 fixed sites and 12 randomly distributed sites annually rotating around the lower river. This design would allow an understanding of baseline conditions (i.e., status) and changes in those conditions over time (i.e., trends) in a cost effective manner. Table 3 summarizes the proposed data collection design. To date, this design has not been fully implemented in the LCRE. Monitoring is limited spatially to 4-6 sites per year and 1-2 habitat types and limited coverage in the parameters sampled. Monitoring by the EMP largely focuses on undisturbed emergent wetlands with some freshwater wetland sampling, limiting results to these habitat types alone (i.e., data cannot be extrapolated to other habitats). Additionally, water quality and sediment data collection are limited to a few sites and primary and secondary productivity are not monitored. Due to the limited implementation of the rotational panel design, the data collected to date support minimal status and trends analyses.

**Table 3: Summary of rotational panel design proposed for estuary monitoring in LCREP (2004).**

| Phase | # of Sites | Monitoring Parameters | Status |
|---|---|---|---|
| 1<br><br>Inventory | 20 sites per reach<br><br>(160 sites total sampled in 1 year) | • Landscape features, hydrology, sediment, basic WQ, macro-invertebrates, and vegetation at all 160 sites | • Limited implementation<br>• Sample veg. & macroinvertebrates at 3-4 sites per reach each summer<br>• Sample hydrology & WQ at subset<br>• Sample sediment qualitatively<br>• Landscape features not assessed |
| 2<br><br>Long-term Monitoring | 8 fixed sites in 8 reaches; 12 randomly distributed sites in 1-2 reaches<br><br>(20 sites total/year) | • Same as above | • Limited implementation<br>• 1 fixed site in Reach F for veg., macroinvertebrates, & WQ ('07-'09)<br>• 1 fixed site in Reach F for veg. ('05-'09)<br>• 1 fixed site in Reach H for veg. & macroinvertebrates ('08-'09) |

Overall, all tasks within the EMP address multiple RPAs and implement the 2008 FCRPS Biological Opinion. This data collection provides juvenile salmonid stock data in understudied reaches, feeds into development of regional restoration strategies, provides key data on habitat, prey resources, and juvenile salmonid usage of wetland habitats, and yields reference site data for implementation and evaluation of restoration actions.

## 4.0 Study Area

The lower Columbia River 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. 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 emergent wetland 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), E and F (2006-2007), and H and F (2008-2009). In 2008-2009, the Estuary Partnership and partners monitored emergent wetland habitats in Reaches C, F, and H.

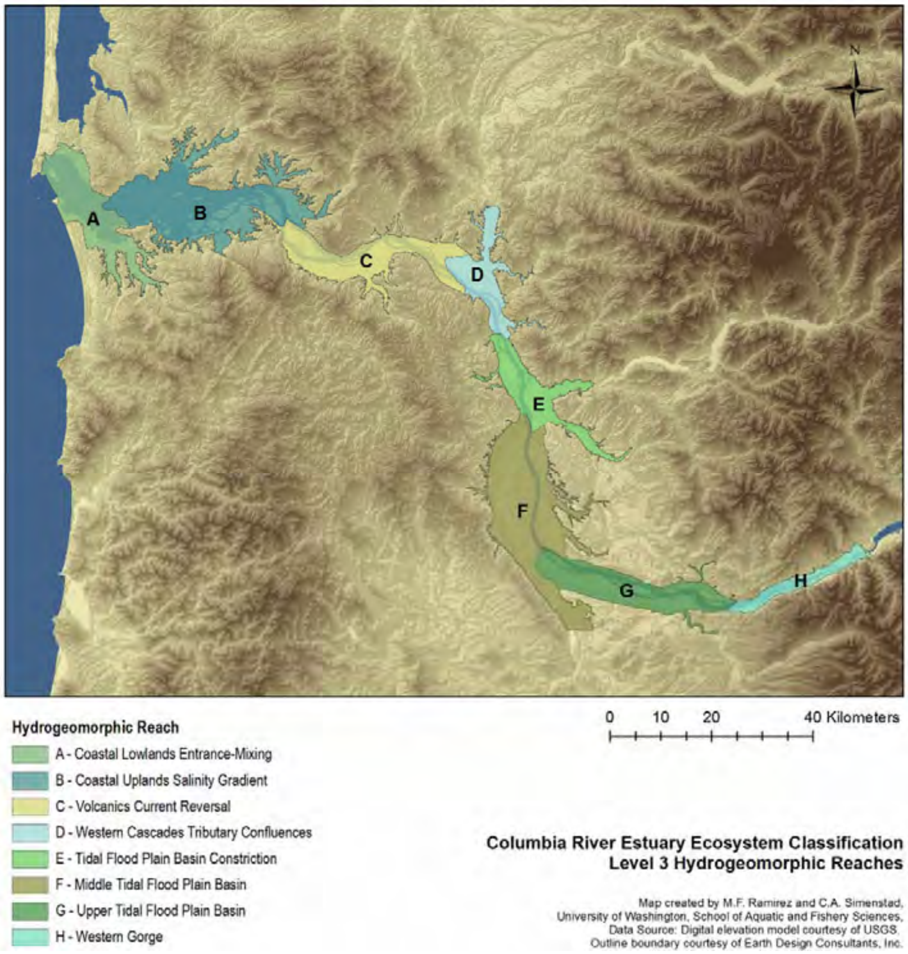



**Figure 1: Lower Columbia River and estuary (LCRE) with hydrogeomorphic reaches (A-H) outlined and specified by color (2009 version of hydrogeomorphic reaches).**

## 5.0 Columbia River Estuary Ecosystem Classification (Classification)

The 2008-2009 project period is the sixth 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. Hence, the Classification should also provide an important framework for habitat restoration and protection strategies.

Comprehensive completion of the Classification is dependent on the acquisition and incorporation of new bathymetric and landcover remote sensing data; however, in 2008-2009, we have completed a draft version of Ecosystem Complexes (Level 4) and Geomorphic Catena (Level 5) for Hydrogeomorphic Reach F, and generated comprehensive levee and dredge disposal datasets to support the Classification. Given the progress in development of the Classification, a draft version of a historic to contemporary comparison of Ecosystem Complexes was completed for Reach F.

## 5.1 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 Stanford et al., 2005)
6) Primary Cover Class (based on cover data from LANDSAT or other remote sensing datasets)

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

## 5.2 Classification Level 4: Ecosystem Complexes

Ecosystem complexes involve biophysical patches that reflect both antecedent processes that establish long-term geomorphic templates in the estuary and its floodplain but also reflect continuous processes and changing landscapes. Thus, they include the overlapping of the massive Holocene disturbances (e.g., landslide and volcanic sediment pulses, large floods and storm surges, and tectonic movement) with shorter-term biophysical processes (e.g., more localized flooding, sediment accretion, vegetation succession, local extinction and recruitment events) as well as the reflections of anthropogenic modifications on the landscape such as diking and filling, channel hardening, and urban and suburban development on the floodplain.

Delineation of Ecosystem Complexes in 2008-2009 focused on Hydrogeomorphic Reach F. Numerous data sources and GIS processes are used to derive the Classification Level 4—Ecosystem Complex. The foundation of the Ecosystem Complex level was the isolation of major hydrologic features of the estuary represented by the bathymetric data. A deep-water channel was defined for depths greater than 8 m and extracted from the map layer to create a separate single map layer in polygon format. Distributary channel bathymetry, defined as depths greater than 1 m, was extracted, and processed in Spatial Analyst to create polygon boundaries for the complexes in a single map layer. Complex boundary map layer was overlaid on land cover data, bathymetric data, aerial imagery, and elevation data. A rules-based approach was used in an automated manner to classify the complexes based on the percentages of the map layer classes that appear within each individual complex.

Figure 2 illustrates 13 classes of complexes that occur in reach F. We delineate some natural features within the reach, such as rocky outcrops in the Holocene flood plain, which are never inundated ("terrestrial"). We do not distinguish anthropomorphic modifications because they are assumed to be nested at finer scale within complex although they may in some cases encompass an entire complex, e.g., where floodplain islands have been surrounded by dikes (levees). Hydrogeomorphic Reach F ecosystem complexes distinguish between the thalweg, permanently flooded, and intermittently exposed (wetlands) areas of both primary (mainstem) and tributary channels. The dominant areal features are floodplain and channel islands (four) and a distinct terrestrial floodplain feature (Floodplain Terrace).

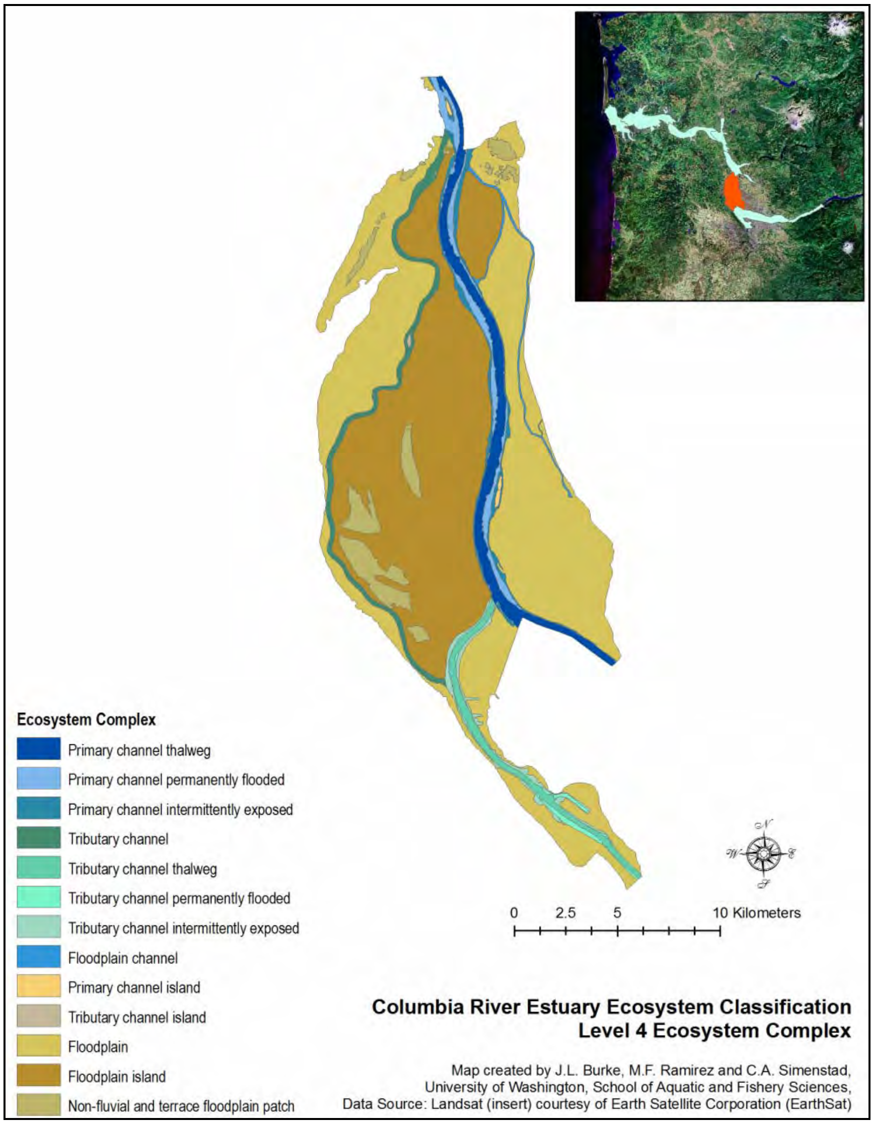



**Figure 2: Classification Level 4 (Ecosystem Complexes) illustrated for Hydrogeomorphic Reach F based on delineating mainstem and distributary channels using current bathymetry data and analyses of floodplain geology and geomorphology.**

## 5.3 Classification Level 5: Geomorphic Catena

Geomorphic catena form the mosaic of features nested within ecosystem complexes. Because they vary and change over space and time as a function of both natural ecosystem processes and intrinsic, moderate or minor disturbances, the catena constitute a 3-dimensional shifting mosaic of ecosystems along the river-ocean continuum (Stanford et al., 2005).

Geomorphic catena work in 2008-2009 focused on Reach F where Ecosystem Complexes were also delineated. Geomorphic catena are classified and delineated in two steps: (1) refinement of complexes by verifying the geo-processing rules-based delineation (based on bathymetry), use multiple mapping criteria and sources to distinguish water body and geologic and geomorphic floodplain and adjoining terrestrial features (units) occurring within each complex; and, (2) apply Level 6—Primary Cover Class data in conjunction with other geospatial data (e.g., LiDAR) to delineate discrete biological associations with the geologic/geomorphic units delineated in step (1). In addition to bathymetry, the primary data sources for the first step included: (1) aerial photography; (2) topography maps; (3) soils maps; (4) geology maps; the primary sources for the second step included the LiDAR bathymetry and LANDSAT land cover data.

Figure 3 illustrates the 29 classes of geomorphic catena identified within Reach F. This includes ten tidal flood plain classes and an additional two relict classes (bedrock, terrace) that occur both within and outside flood plains, and seven artificial classes which are extensively modified by anthropogenic modifications but which are still embedded within the ecosystem complexes. While many of the geomorphic catena are somewhat discrete (e.g., floodplain terrace features), although often composing ‘clusters’ that may serve unique functions in their own right, some catena are extensively interconnected. For instance, floodplain channels typically connect to floodplain lake/pond and floodplain herbaceous low marsh and floodplain forests. Similarly, floodplain bar and scroll features are often associated with floodplain lake/ponds and herbaceous low marshes within the scroll features.

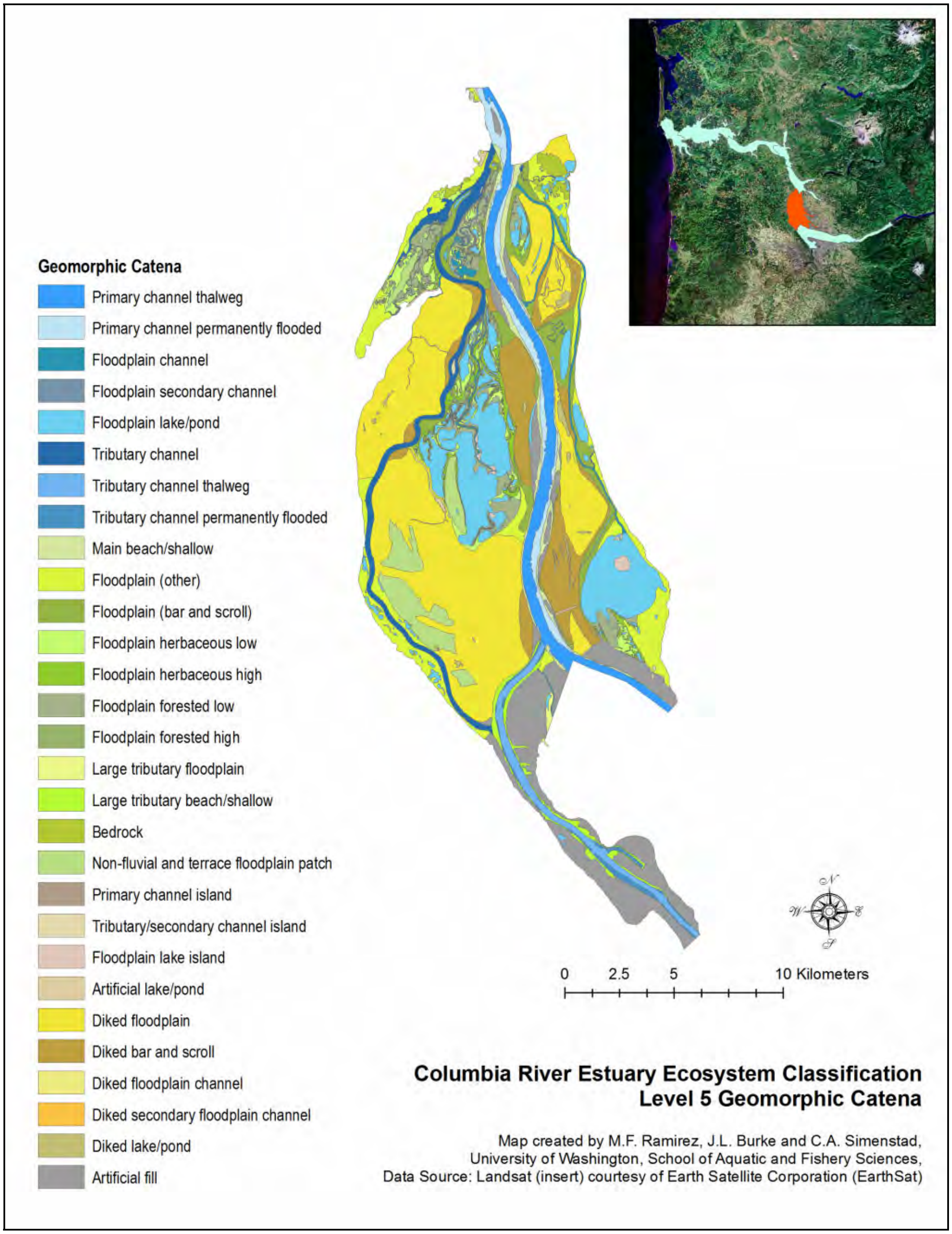



**Figure 3: Classification Level 5 (Geomorphic Catena) illustrated for Hydrogeomorphic Reach F.**

## 5.4 Ancillary Levee and Dredge Datasets

Two estuary-wide datasets (levees and dredge material) were developed in support of the Classification, and are used as modifiers to the Geomorphic Catena classes. The levee dataset includes lines delineating levees (or dikes) that were compiled using the bare earth USGS LiDAR Survey (2004) as the base digitizing dataset and with high-resolution imagery from the National Agriculture Inventory Program

(NAIP). While the LiDAR served as the primary data source, review and validation was conducted using existing levee/dike datasets or documentation provided by the USACE (1989 Drainage District Report and maps), and the Estuary Partnership. We delineated levees that resulted in significant interruption of hydrologic connectivity. Levees were not included if connectivity remained (or had been restored through a levee breach) such that semblance of a channel/wetland system was evident. Examples of such areas include the west end of Svenson Island (Figure 4), north Karlson Island, as well as sections of railroad that pass over a bridge allowing for regular tidal inundation.


**Figure 4: Levee delineation (red line) at Svenson Island. A relic levee around the west end of the island is evident from the Lidar; however, a gap at the NW corner of the island allows for regular tidal inundation of the area.**

Dredge materials deposited on land are discernable on the bare earth USGS LiDAR Survey. A polygon dataset was developed outlining the visible dredge materials using heads-up digitizing with the PLSC LiDAR. While the LiDAR served as the primary data source, review and validation was conducted using an existing dredge material dataset provided by CREST, USGS geologic maps, and historic topographic surveys (T-sheets). Attempts were made to distinguish between two types of fill: dredge disposal and industrial fill, the former often unvegetated and undeveloped, occurring on main stem islands and shorelines; the latter being typical of large heavily developed areas (e.g., Portland, OR at the Willamette confluence, and Longview, WA). An approximate area of 65 km$^2$ is identified as dredge material, 27 km$^2$ of this characterized as dredge disposal and 38 km$^2$ as industrial fill.

## 5.5 Change Analysis for Reach F

In addition to spatial analyses within and between systems, a standardized method for delineating ecosystems provides a framework for temporal analyses of changes in ecosystem structure and function. We have tested application of our geospatial processing procedures for ecosystem complexes to the 1866-1901 United States Coast and Geodetic Survey (USCGS) “t-sheet” topographic surveys for Hydrogeomorphic Reach F for comparison with our current draft of ecosystem complexes in 2000 (Figure 5). Despite the time interval, this comparison indicates that the basic structure of ecosystem complexes has not changed significantly except for the effect of navigational dredging of the mainstem channel through the reach, which produced a much more uniform, connected thalweg throughout.

Further analyses of the landscape attributes of the ecosystem complexes, where metrics are derived for the different complexes as landscape patches, quantify changes in their dimensions and shapes that may be indicators of changes in their function in the estuary. For example, while total area of most ecosystem complexes did not change dramatically between 1866-1901 and 2000, the Primary Channel Permanently Flooded class declined and the Primary Channel Thalweg class increased, as noted above (Figure 6). In addition, the total edge of the Primary Channel Intermittently Exposed increased but decreased for the Primary Channel Permanently Flooded. Metrics describing ecosystem complex patch configuration indicated further manifestations of these changes in the primary and tributary channels. For example, perimeter:area ratio increased for the Tributary Channel Permanently Flooded and Intermittently Exposed complexes, but decreased for the Primary Channel Permanently Flooded and Intermittently Exposed complexes as well as the Floodplain complex.

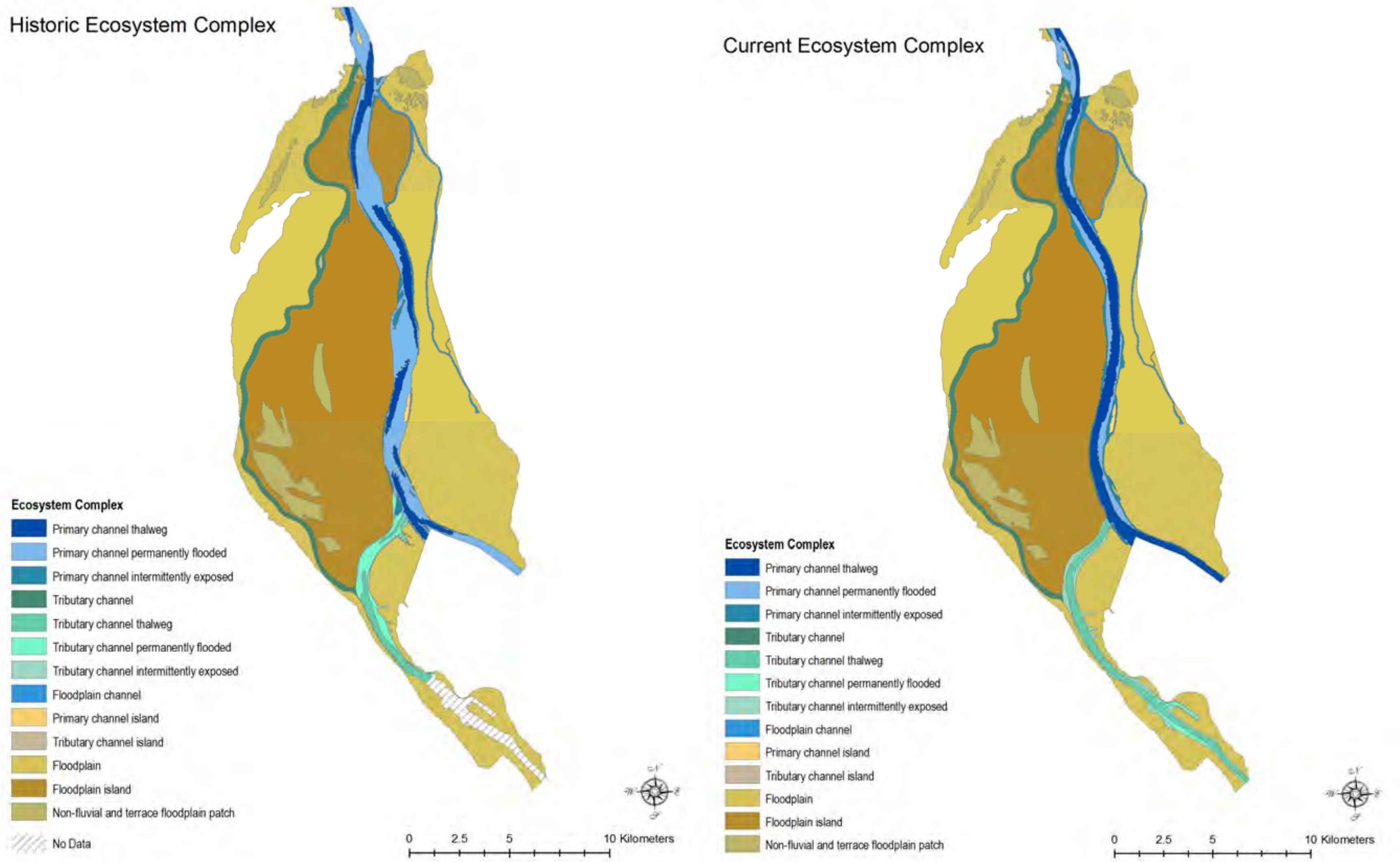



**Figure 5: Delineation of historic (1866-1901) vs. current (2000) Ecosystem Complexes for Hydrogeomorphic Reach F.**

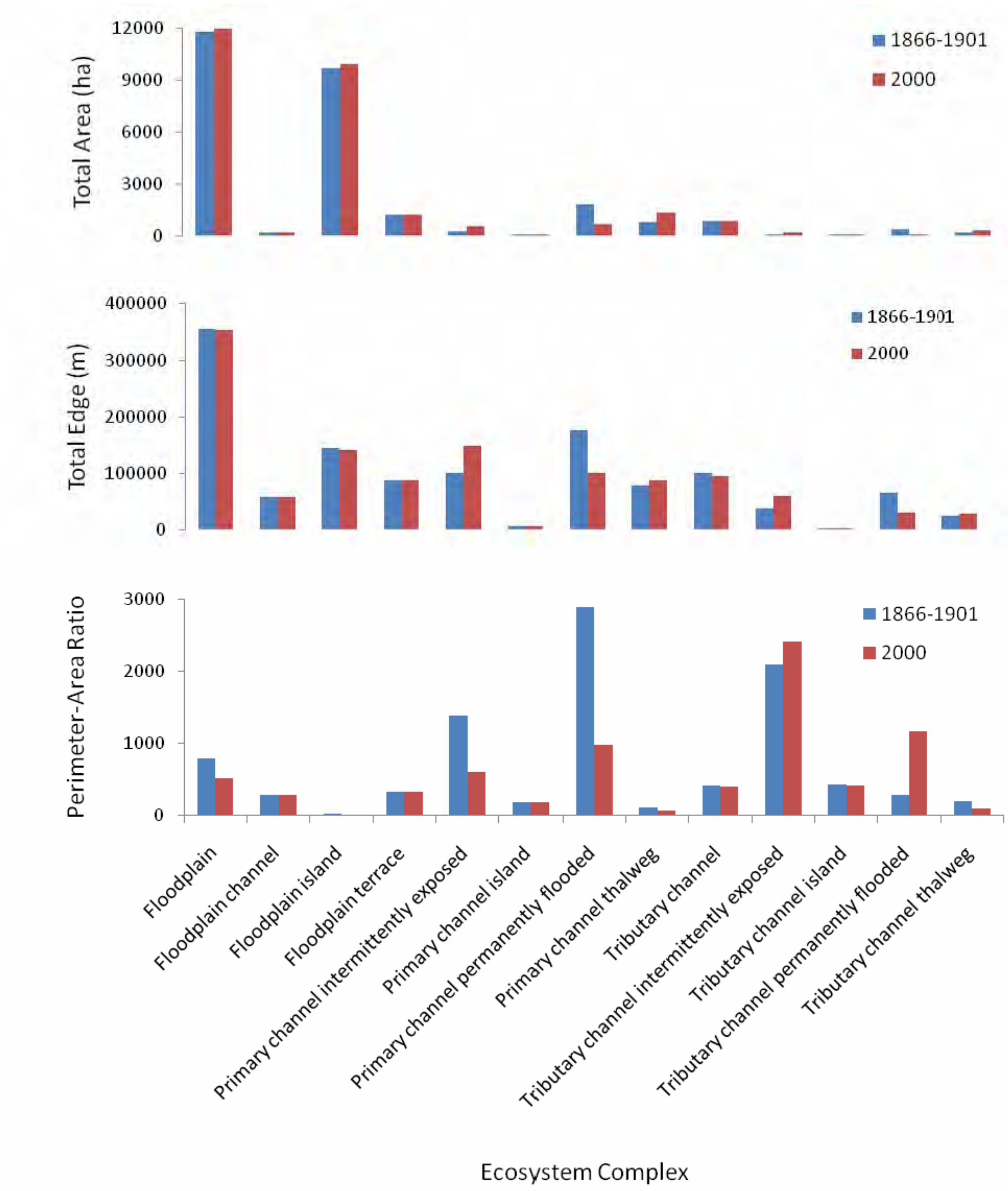



**Figure 6: Landscape metrics quantified for historic (blue bars) vs. current (red bars) Ecosystem Complexes in Hydrogeomorphic Reach F.**

## 5.6 Classification Work Efforts Planned for 2009-2010

Classification activities planned for the project period September 1, 2009 – August 31, 2010 include delineation of Level 4 Complexes for all or most reaches (depending on the availability of bathymetry data), delineation of draft Level 5 Catena for some reaches, and coordination with the landcover data acquisition project (described below). In addition, publication of Classification document is anticipated for 2010 (Simenstad et al., In review).

## 6.0 Datasets Needed to Complete the Classification

Completion of the Classification Levels 1 to 6 for the entire LCRE requires up-to-date bathymetry and landcover data. Bathymetry supports delineation of Levels 4 (Ecosystem Complexes) and 5 (Geomorphic Catena). Landcover supports delineation of Levels 5 (Geomorphic Catena) and 6 (Primary Cover Class). Thus, in 2009 and continuing in 2010-2011, the Estuary Partnership is coordinating efforts to fill these data gaps and provide these datasets to UW and USGS to facilitate Classification completion.

## 6.1 Bathymetry

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 (Figure 7, Figure 8). 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 critical for delineating Level 4 Complexes and Level 5 Catena and completing the Classification. In addition, bathymetry can inform site selection for monitoring and restoration efforts in tidally influenced emergent wetlands, which have poorly characterized bathymetry in the current dataset. See Jones et al. (2008) for additional information on the bathymetry workshop, collection strategy, and data gap characteristics.

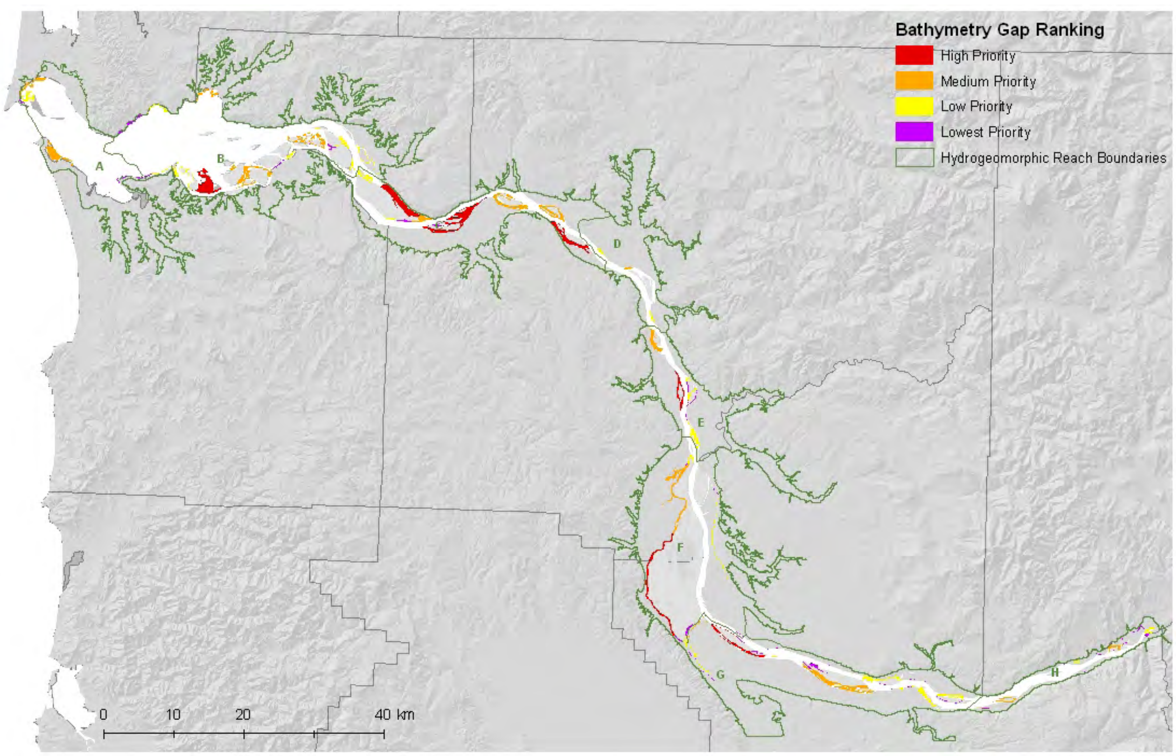



**Figure 7: Existing bathymetric gaps ranked by priority for data collection.**

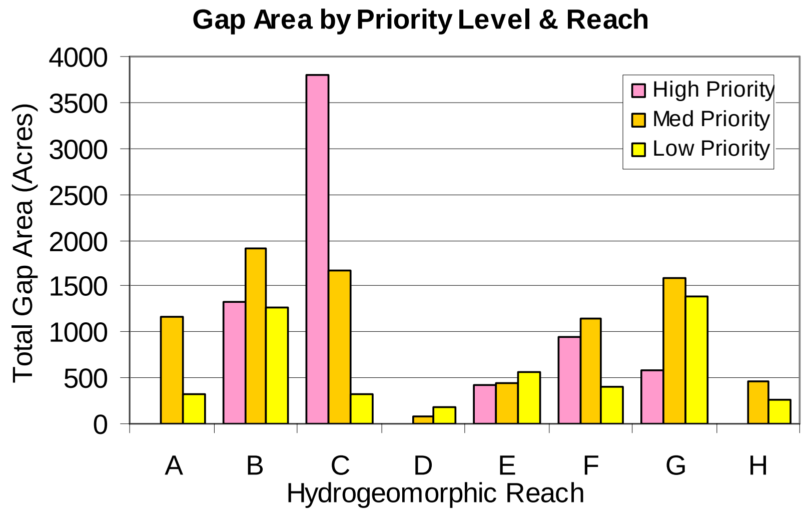



**Figure 8: Bathymetry gap area by reach and priority.**

In February 2009, the Estuary Partnership contracted with David Evans & Associates Marine Services (DEA) to collect the bathymetry data. The Estuary Partnership took on all post processing of final raster grids to maximize the amount of funding available to DEA for data collection. The survey plan divided the LCRE into 9 groups (Figure 9). Collection in 2009 focused on Reaches B – G (or Groups 1-5 and 9) because funding was not sufficient to cover gaps in all reaches and these reaches were the focus of Classification development in 2008-2009. Additionally, data collection was scheduled to occur during highest possible water levels to maximize data collection and eventual integration with LiDAR data into a seamless dataset. Expected 2009 bathymetry products included single beam (and some multi-beam) coverage of all high and most medium priority gaps in Reaches B-F (11,830 acres) where physical conditions and water levels permitted collection and single beam coverage of some adjacent low priority gaps where time permitted. Additionally, DEA would convert the high-resolution (1-m) multi-beam survey data that they collected for NOAA in 2008 to a vertical datum consistent with existing Classification datasets (CRD to NAVD88). This DEA/NOAA bathymetry coverage extends from RM 30 to 110.

DEA collected bathymetry data from April to July 2009 and surveyed 12,589 priority acres, exceeding the collection target of 11,830 acres. Overall, high and medium priority gaps were filled in Group 1(Reach F), Group 2 (Reach E), Group 3 (Reaches D and E), Group 4 (Reaches D and C), Group 5 (Reach C), and Group 9 (Reach G). Remaining gaps for data collection are Group 6 (Reach C) and Group 7/8 (Reaches B and C). DEA utilized jet skis to access extreme shallow water areas. To date, all DEA/NOAA multi-beam data have been converted to NAVD88 and all data have been delivered to the Estuary Partnership for post processing.

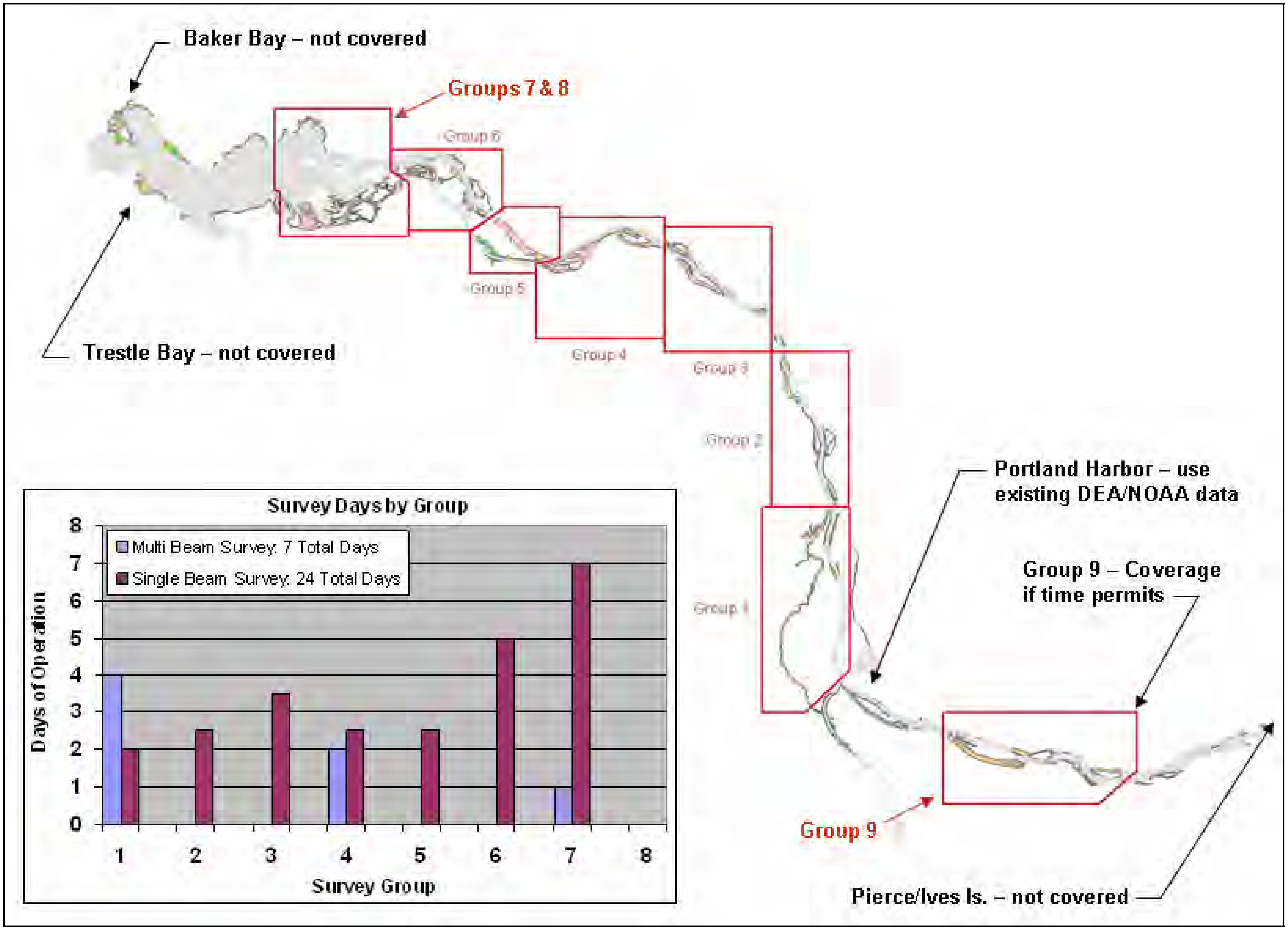



**Figure 9: Bathymetry survey plan showing LCRE divided into 9 collection groups. Inset table shows days of survey by group. In 2009, high and medium gaps were filled in Groups 1-5 and 9. In 2010, gaps in Groups 2, 6, 7/8, and 9 will be targeted for collection.**

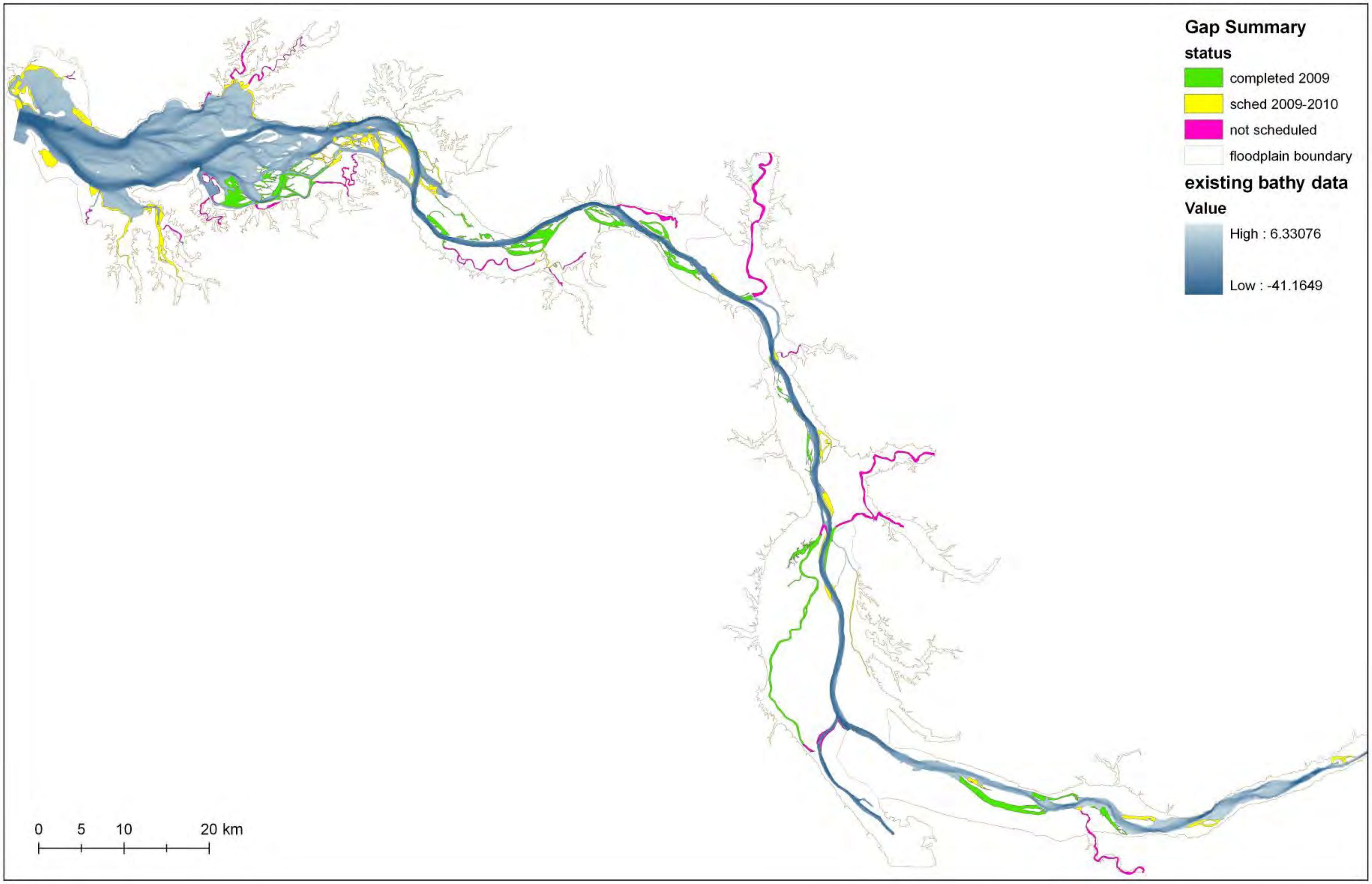



**Figure 10: Map of LCRE showing bathymetry data collected in 2009 (green), bathymetry scheduled for collection in 2009-2010 (yellow), and remaining bathymetry gaps not scheduled for collection (pink).**

Comparison of the new 1-m bathymetry data with the older 10-m resolution data reveals substantial improvements in bathymetry data for the LCRE (Figure 11). Topography variation in the riverbed (e.g., around pile structures shown as black lines) is now apparent in the data, increasing their applicability to other monitoring and restoration projects in the LCRE.

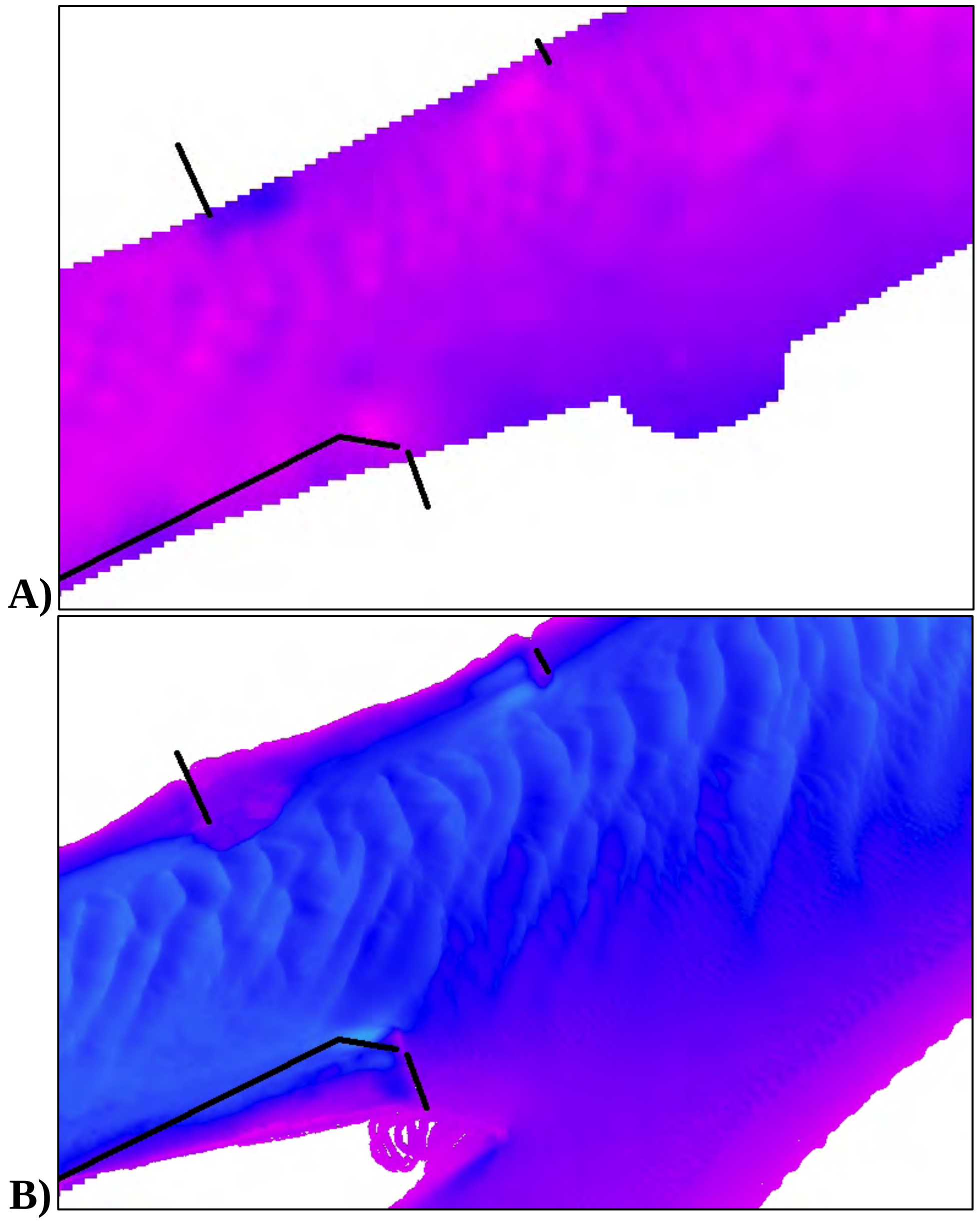



**Figure 11: Comparison of bathymetry datasets at: A) 10-m resolution; and B) 1-m resolution.**

In 2010, the Estuary Partnership will renew their contract with DEA to survey remaining priority gaps in Reaches H, C, and A (Figure 10). This will include a possible extension of bathymetry coverage to major tributaries and sloughs to support restoration efforts. The Estuary Partnership will finish post processing of single beam data and newly collected data (as they become available) and deliver all processed data to UW for work on the Classification.

## 6.2 Landcover

Like bathymetry, an up-to-date landcover dataset is needed to complete the Classification. Specifically, landcover assists in the delineation of Levels 5 (Geomorphic Catena) and 6 (Primary Cover Class). The existing 2000 LANDSAT classification is nearly 10 years old and is functionally limited with regard to the Classification. For instance, the 2000-landcover data does not differentiate well between tidal and non-tidal wetlands, uplands and wetlands, and forest classes like mixed, coniferous, and deciduous forests.

To address this data gap, the Estuary Partnership convened a Landcover Workshop in May 2009 to investigate options for acquiring a more-recent landcover dataset. We engaged experts at UW, PNNL, and other regional groups with landcover and remote sensing expertise to assist in developing the workshop materials and round-table discussion materials. Over 45 people from consulting, non-profit, and academic organizations participated in the workshop. Regional experts identified limited acquisitions options due to the numerous complications such as the large spatial extent of the LCRE, restricted atmospheric window for cloud-free images, limited tidal window, and a final product with high spatial resolution (30-m or better).

Of the options identified at the workshop, LANDSAT, or a sensor operating at a similar spatial scale, was identified as the most reasonable choice given the limiting factors. The Estuary Partnership presented BPA, NOAA-Fisheries, USACE, and UW with 3 possible classification options utilizing LANDSAT imagery:

1. Update/improve existing 2000 classification (lowest cost, lowest probability of quality output)
2. Utilize archived imagery and pre-existing training/ground truth data
3. Utilize archived imagery and an intensive field effort to collect new training/ground truth data (highest cost, highest probability of high quality output).

BPA and others recommended Option 3. Thus, the Estuary Partnership developed and released a Request for Proposals (RFP) in August 2009 to identify a contractor to coordinate and collect the training/ground truth data and classify the imagery into a new landcover dataset.

As of November 2009, the Estuary Partnership completed the RFP process. Once the Estuary Partnership's master contract for 2009-2010 is executed, the Estuary Partnership will execute a subcontract with the identified vendor for the landcover effort. Table 4 outlines the anticipated schedule for the landcover effort, assuming a start date of January 1, 2009. This schedule may change based on contracting with the identified vendor. Earlier versions of this table submitted in BPA Pisces were based on a November 1, 2009 start date.

**Table 4: Outline of landcover effort based on a January 1, 2010 start date. Schedule may change based on contracting with identified vendor and execution of LCREP-BPA contract.**

| Approx. Due Date | Description |
|---|---|
| **Phase 1 – Sampling methodology and collection of training and ground truth data** | |
| Jan 1, 2010 | Start Phase I |
| Jan 15, 2009 | Complete review of existing classification and available training data sources |
| Feb 20, 2009 | Complete sampling designs for newly acquired training and ground truth data |
| Mar 1, 2010 | Complete database schema for training and ground truth data |
| Mar-Apr 2010 | Complete 1st round of on the ground data collection (leaf-off) |
| Apr 1, 2010 | Complete review of supporting datasets for classification |
| Jun-Aug 2010 | Complete 2nd round of on the ground data collection (leaf-on) |

| Approx. Due Date | Description |
| --- | --- |
| Aug 31, 2010 | Deliver report and database of QA/QC field data |
| **Phase 2 – Classification of RS imagery based on training data** | |
| Sep 1, 2010 | Start Phase 2 |
| Oct 1, 2010 | Complete selection of imagery for landcover classification |
| Jan 10, 2011 | Complete classification and accuracy assessment for cover classes |
| Jan 31, 2011 | Deliver final report |
| Aug 31, 2011 | Deliver draft of peer reviewed publication on work effort and analysis |

## 7.0 Characterization of Emergent Wetlands in the LCRE

The on-going objective of the Ecosystem Monitoring Project is to characterize tidal freshwater habitats and monitor salmon occurrence and health in those habitats in the LCRE. Based on funding levels, the EMP has largely concentrated on characterizing relatively undisturbed emergent wetlands and tidal forested wetlands that provide important rearing habitat for juvenile salmonids. Since 2007, we have co-located vegetation, fish, fish prey, and additional habitat monitoring sites as much as possible in emergent wetlands in order to have the same datasets for multiple sites throughout the LCRE. Figure 12 shows the locations of EMP sampling sites. Data collected at these sites support multiple RPAs in the 2008 Biological Opinion, provide reference site and salmonid genetic stock information for regional restoration programs, and contribute to our understanding of salmonid occurrence and habitat usage in the LCRE.

As of November 2009, the EMP has collected:

- One-time vegetation and habitat data at 20 emergent wetlands between 2005 and 2009 ("status sites;" sites denoted by yellow, red, green, and blue squares)
- Multiple summers of vegetation and habitat data at 3 additional emergent wetlands between 2005 and 2009 ("year-to-year trend sites;" sites denoted by purple and black squares)
- Salmon and prey data over one sampling season (approximately March/April – August) at 8 emergent wetlands between 2007 and 2009 ("status sites;" sites denoted by yellow, red, and green fish)
- Multiple sampling seasons of salmon and prey data at 2 additional emergent wetlands between 2007 and 2009 ("year-to-year trend sites;" sites denoted by purple and black fish)
- Basic water quality and depth over one sampling season (varies by year) at 4 emergent wetlands between 2006 and 2009 ("status sites;" sites denoted by orange, red, and blue triangles)
- Basic water quality and depth over multiple sampling seasons at 1 additional emergent wetland in 2006, 2008-2009 ("year-to-year trend site;" site denoted by purple triangle)
- Community data at 6 forested wetlands from 2008-2009 (sites denoted by "trees")

Co-located datasets collected by the EMP include:

- Vegetation, habitat, salmon, and prey at 8 emergent wetlands between 2007 and 2009
- Vegetation, habitat, salmon, prey, and basic water quality parameters relevant to salmonids at a subset of 3 emergent wetlands between 2008 and 2009

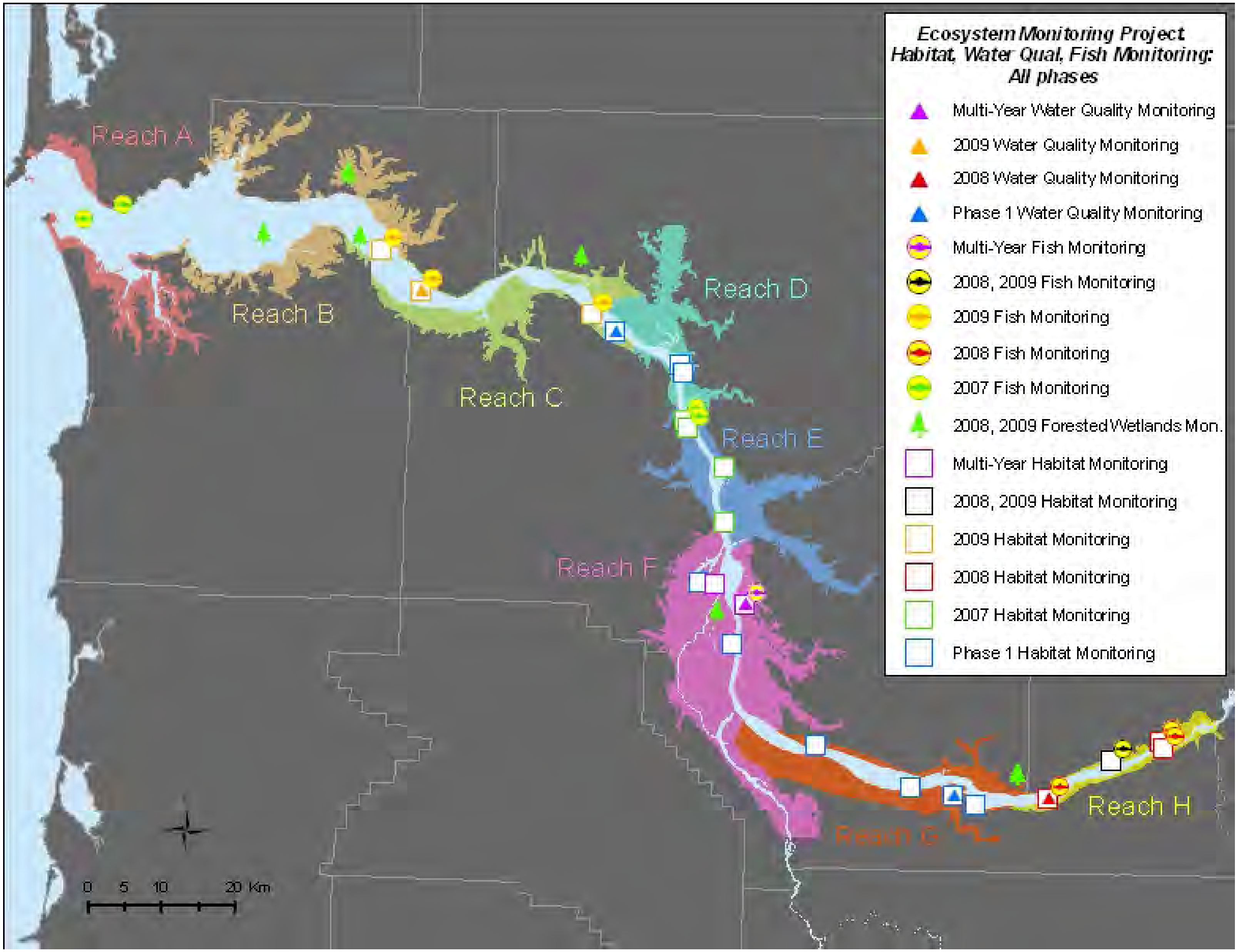



**Figure 12: Map of EMP sites throughout the LCRE by year and monitoring type.**

## 7.1 Sites

### 7.1.1 Selection

For the 2009 data collection efforts, the Estuary Partnership used the National Wetland Inventory (NWI, available at http://www.fws.gov/nwi/) for Reach C (Figure 1) 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 2009 should be consistent and comparable with data collected from 2006 to 2008.

In spring 2009, the Estuary Partnership, NOAA-Fisheries, PNNL, and USGS visited the potential sampling sites during a reconnaissance trip. In the end, the final habitat criteria used to select the 2009 monitoring sites were:

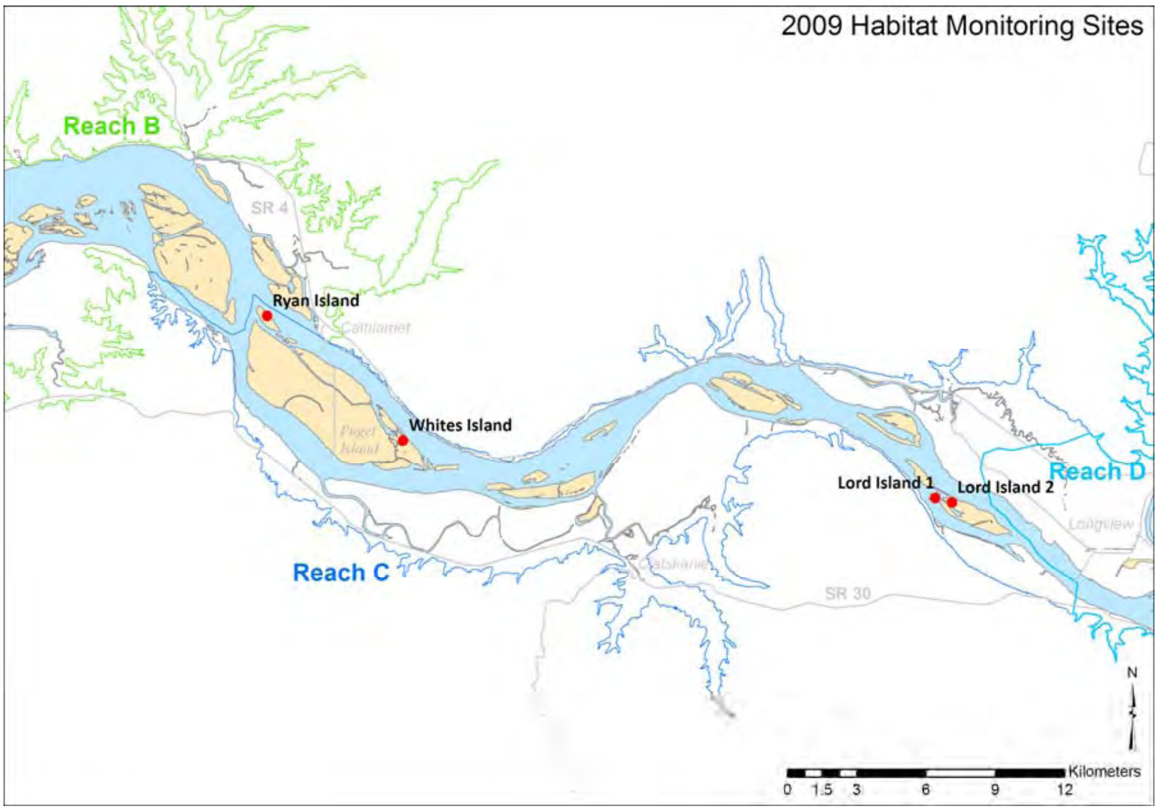
1. The site's wetland vegetation is classified as "emergent" in the NWI layer.
2. The site has tidal connectivity with the mainstem Columbia River.
3. The site's wetland is minimally disturbed (e.g., no diking, active grazing, tide-gate modifying flow regime present at the site).
4. The area of wetland 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 2009-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 2009 characterize a subpopulation of Reach C's wetlands (undisturbed emergent wetland), which are likely important habitat for juvenile salmon. The remaining wetland types in Reach C may have less salmon and lower abundances of marsh vegetation and wider ranges in sediment particle size and other physical attributes. While the 2009 effort provides initial information useful for understanding habitat conditions and salmonid use of undisturbed emergent wetlands in Reach C, 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.

In 2009, the EMP partners selected 4 sites in Reach C for monitoring. Reach C sites were Ryan Island, White Island, Lord-Walker (or Lord) Island 1, and Lord-Walker (or Lord) Island 2 (Table 5; Figure 13A). Partners re-sampled 3 sites (Campbell Slough and Cunningham Lake in Reach F and Franz Lake in Reach H) where data were previously collected (Table 5; Figure 13B).




A)

B)

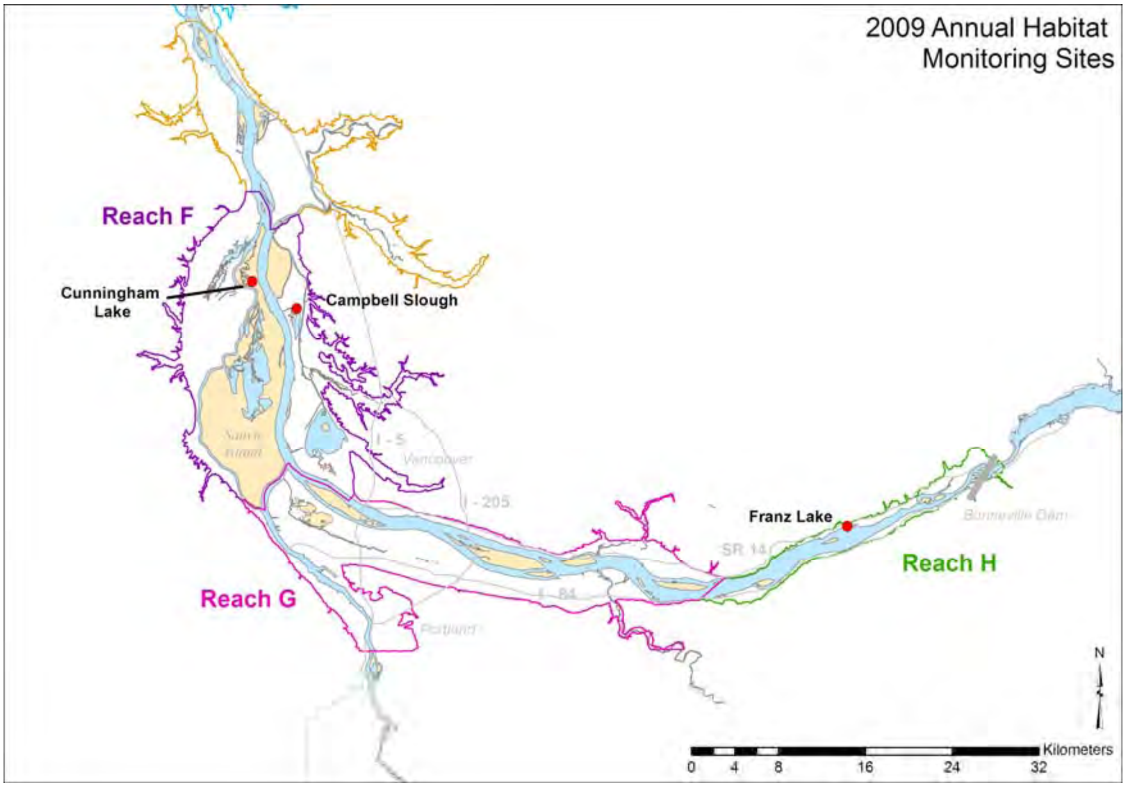



**Figure 13: Maps showing 2009 sampling sites in: A) Reach C; and B) Reaches F to H.**

**Table 5: Summary of sampling effort by site and year(s) for sites where data were collected in 2009. Note: Lord-Walker Island 2 was sampled by the EMP in conjunction with the Reference Site Study; thus, only vegetation and habitat data were collected at Lord-Walker 2.**

| Reach | Site | Vegetation & Habitat | Fish & Prey | Water Quality & Depth |
|---|---|---|---|---|
| C | Ryan Island | 2009 | 2009 | |
| | Lord-Walker Island 1 | 2009 | 2009 | |
| | Lord-Walker Island 2** | 2009 | | |
| | White Island | 2009 | 2009 | 2009 |
| F | Cunningham Lake | 2005-2009 | 2007-2009 | |
| | Campbell Slough | 2005-2009 | 2007-2009 | 2008-2009 |
| H | Franz Lake | 2008-2009 | 2008-2009 | |

### 7.1.2 Descriptions

Ryan Island is located at the northern (downstream) corner of Puget Island near Cathlamet, Washington on the mainland. Ownership of the island is unknown at this time; however, a conservation easement may exist on the island. The site is an extensive undisturbed wetland with well developed tidal channels. The site is near the mouth of one of the tidal channels where it empties into Cathlamet channel the other side of the tidal channel grades up to the forested portion of the island. The site appears to be affected by the strong energies of the main channel as evidenced by bank erosion in the sample area (Figure 14A).

White Island is located on the southern (upstream) end of Puget Island, also near Cathlamet, Washington. A portion of the island is owned by Washington Department of Fish and Wildlife (WDFW) and is maintained as Columbia white-tailed deer habitat. The monitoring site, located at the confluence of a large tidal channel and an extensive slough system (Figure 14B), is approximately 0.5 km from the Cathlamet Channel. The site is characterized by primarily high marsh and a few willows, with numerous small tidal channels.

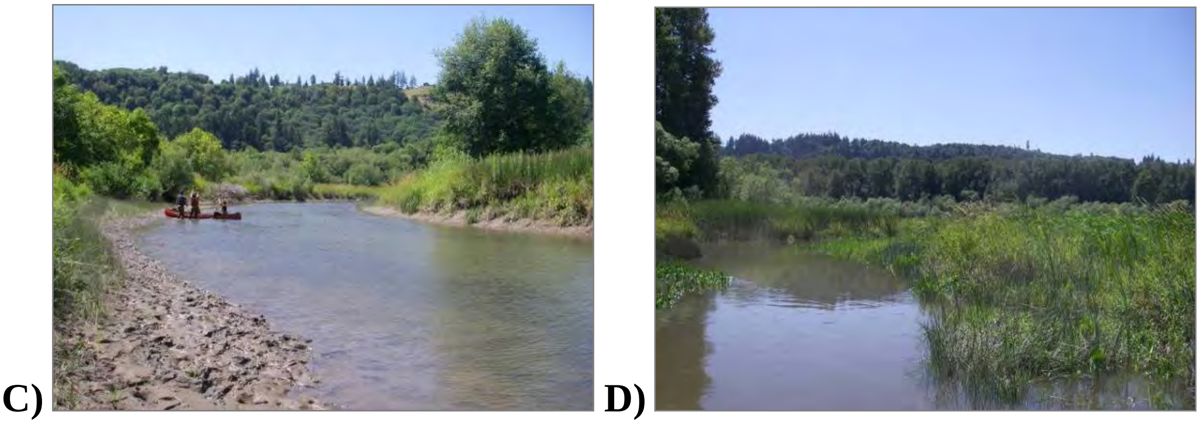
Lord Island is at the upstream end of Reach C near Longview, Washington and is owned by Columbia Land Trust. The island was not present on the historic maps (from the 1880s) and has a history of dredge material placement. The interior of the island has an extensive area of mudflats, shallow water and emergent wetlands. Two sites were monitored on Lord Island. The first (Lord Island 1) is located at the downstream end of the island in an area of a steep sided flow-through shallow channel (Figure 14C). This area has fringing emergent wetlands on the banks of the wide channel and was the area sampled for fish. The second site (Lord Island 2) is located on the interior of the island and is connected to the River through a series of very shallow channels and flats (Figure 14D). This site was too shallow and muddy for fish sampling, but deemed worthy of monitoring other metrics to characterize the habitat. This site was sampled in conjunction with the Estuary Partnership's Reference Site Study.

Upstream of Reach C, the remaining two sites (Cunningham Lake and Campbell Slough) are in Reach F (Figure 13B). 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 15A). The second site, Campbell Slough, is located approximately 1.4 km from the mainstem of the Columbia River (Figure 15B). At Campbell Slough, there was no noticeable evidence of grazing during the 2009 survey, unlike previous years. 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 patterns.

The remaining site is located further upstream in Reach H, near Skamania, WA. The Franz Lake site (Figure 15C),part of the Pierce National Wildlife Refuge, 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. This site was added to the sampling plan in 2009 to increase the inter-annual variability dataset.

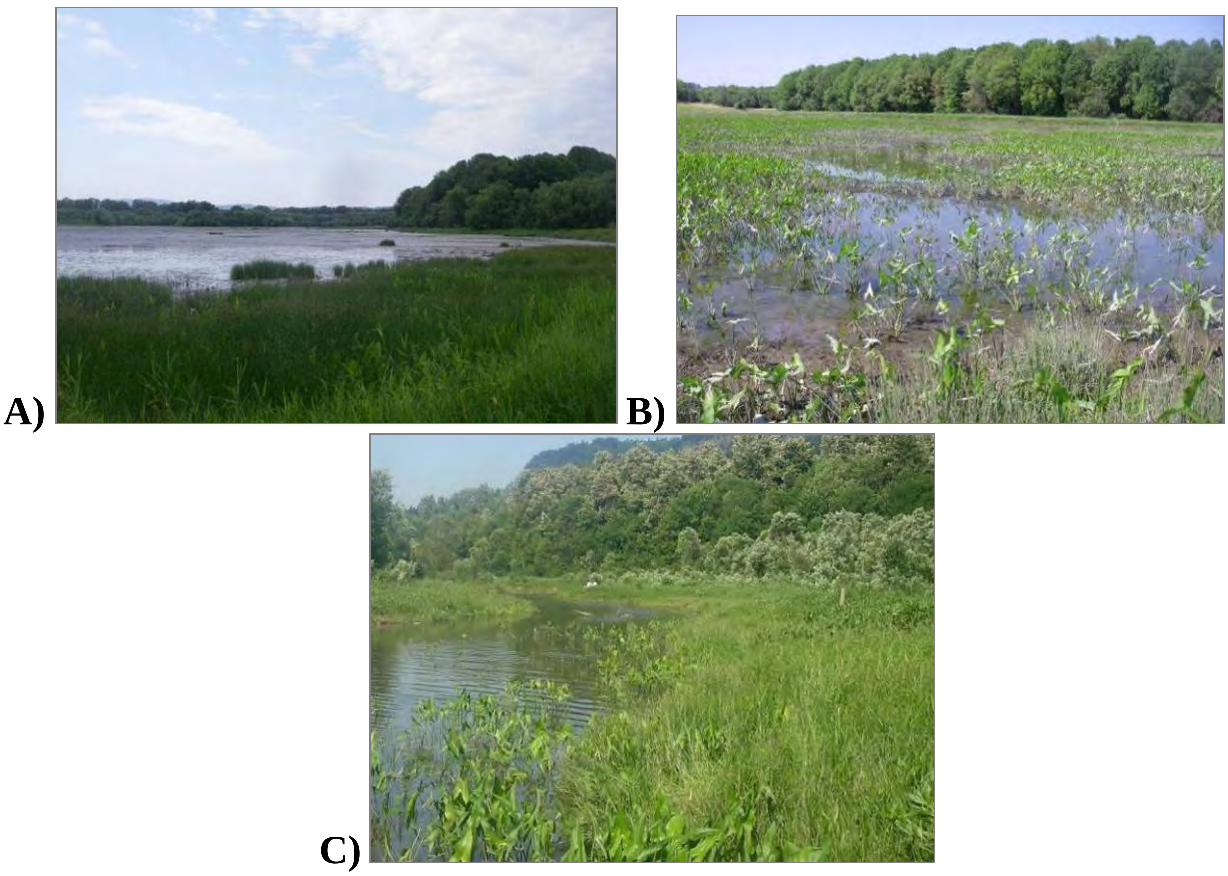
**A)**

**B)**



C) D)

**Figure 14: Photos of Reach C sites: (a) Ryan Island, (b) Whites Island, (c) Lord Island 1, and (d) Lord Island 2.**



A) B) C)

**Figure 15: Photos of Reach F sites: a) Cunningham Lake; b) Campbell Slough and Reach H site: c) Franz Lake.**

## 7.2 Water Year

The water level fluctuations throughout the year, due to the variability in flows of the Columbia River, can affect the vegetation communities and fish sampling at the monitoring sites. A means of characterizing the variability is to evaluate the outflow at Bonneville Dam relative to the 10-year mean (Figure 16). This information, provided by USGS, allows a comparison between years and an evaluation of the timing of the spring freshet. In 2009, outflow was generally below the average except for the period of the spring freshet, in late April and late May (three weeks total). During this time outflow was above average by approximately 50 thousand cubic feet per second (kcfs). In comparison, in 2008 outflow was also generally below average except for the period of the spring freshet, during which time flows were considerably above average by approximately 100 cfs for eight weeks from mid May to Mid July.

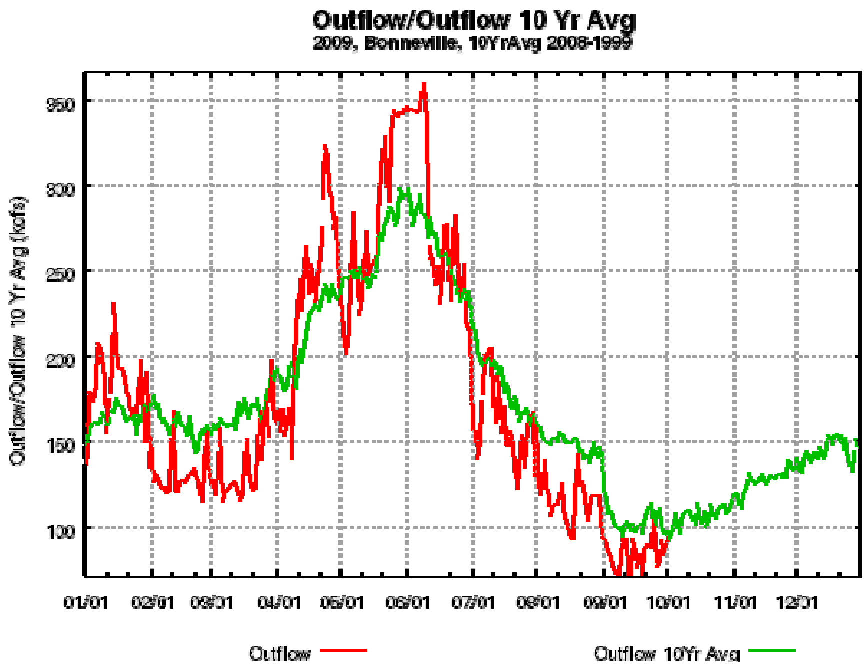



**Figure 16: Outflow at Bonneville Dam, comparing outflow in 2009 (red) to 10-year average (green). Data from Columbia River DART website: [http://www.cbr.washington.edu/dart/river.html](http://www.cbr.washington.edu/dart/river.html)**

## 7.3 Vegetation and Habitat Monitoring

The goal of the monitoring component is to assess emergent wetlands with the objective of characterizing salmonid habitats in the Columbia River from previously understudied portions of the estuary from Reach C to Reach H (Bonneville Dam). PNNL's role in this multi-year study is to monitor the habitat structures (e.g., vegetation, sediment, and channel morphology) as well as hydrologic patterns.

In 2008-2009, PNNL collected field data on vegetation and habitat conditions at 4 study sites in Reach C, 2 in Reach F, and 1 site in Reach H (Figure 1; Figure 13). The four sites in Reach C are new sample sites added this year and the other three are previously monitored sites, which are monitored to evaluate interannual trends. The sites in Reach F have been monitored previously in 2005-2008 and the Reach H sire was monitored in 2008. To date, 22 emergent wetland sites have been sampled in this program. In future years, we anticipate sampling an additional 3 sites per year plus re-sampling of 2-3 sites in a rotational pattern.

Vegetation monitoring occurred from July 21-28, 2008. A total of 7 sites were sampled, 4 in Reach C, 2 in Reach F, and 1 in Reach H (Figure 13). The sites within Reach C included (1) Ryan Island, (2) White Island, and (3) Lord Island 1, and (4) Lord Island 2. Two sites were evaluated for vegetation at Lord Island; however, due to sampling constraints, fish sampling was conducted only at Lord Island 1 and a depth/temperature sensor was deployed by PNNL in 2008 only at Lord Island 2. The sampling at Lord Island 2 was in conjunction with the Estuary Partnership's on-going Reference Site Study.

### 7.3.1 Methods

As in previous years (i.e., 2005-2008), we surveyed sites for elevation, determined percent cover of vegetation along transects (see Appendix A for species code information), and mapped prominent vegetation communities within the marsh. This year, we also measured channel cross sections, installed sediment accretion stakes at all the sites, and collected sediment samples at the new sites in Reach C. Methods generally follow the restoration monitoring protocols developed by Roegner et al. (2009) for the Lower Columbia River and Estuary.

**Transect Surveys**

Upon arrival at a given site, the optimum location of transects was established such that all major plant communities from the water's edge to the upland area would be included in the survey. Two to five transects were established at a site, depending on the diversity of vegetation. At all sites, transects were located to encompass the elevation gradient at the site from the unvegetated channel up to high marsh or trees. A station was also designated for each site from which photographs were taken to document the 360-degree view.

Elevation at all sites was surveyed using a Trimble real time kinematic (RTK) global positioning system (GPS) with survey-grade accuracy. All surveying was referenced to the NAVD88 vertical datum; horizontal position was 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 for each set of static data collected by the base receiver, which is an estimate of error. A local surveyed benchmark was located whenever possible and measured with the RTK to provide a comparison between the local benchmark and OPUS derived elevations. 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 two-meter intervals. If the transect length exceeded 100-m and/or the vegetation was deemed homogeneous, evaluations were conduced at three meter intervals. At each interval on the transect tape, a 1-$m^2$ quadrat was placed on the substrate and percent cover was estimated by two observers. An average of the two 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 also evaluated. When plant identification could not be determined in the field, a specimen was collected for identification using keys or manuals at 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.

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 also kept.

**Mapping**

Using a Trimble GeoXT handheld GPS unit, a representative portion of each site (using reasonable natural boundaries) was mapped and major vegetation communities were delineated within the site. Additionally, features of importance to the field survey (e.g., transect start/end points, depth sensor location, and photo-point) were also mapped. All data were input to a GIS and maps of each site showing major communities and features were created.

**Channel Metrics**

In addition to the elevation surveys conducted along the vegetative transects, channel cross-sections were surveyed at sites containing channel networks. This metric lends itself to further understanding the relationship between cross-section dimensions, marsh size, and opportunity for fish access and is currently being developed for wetlands elsewhere in the Columbia River estuary. This effort will aid in understanding the channel dimensions necessary to maintaining a marsh ecosystem via restoration efforts within these habitats. The primary objective associated with this data collection effort is to determine how unmodified channels may differ between reaches, as well as to document similarities within the region with regard to fish access. When possible, we collected five 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.

**Sediment**

Sediment samples were collected within each major vegetation community strata at Ryan Island, Whites Island, and Lord Island 1 (at Lord Island 2 sediment samples from the channel and the marsh plane were taken as part of another study). Sediment samples were collected in 2008 at Campbell Slough, Cunningham Lake, and Franz Lake and were therefore not recollected this year. Four 10 cm cores were collected within each strata and homogenized in a large metal bowl, placed in a clean plastic bag, and kept in a cooler until shipment to the analyzing lab. Samples were analyzed by Columbia Analytical Services in Kelso, Washington for total organic carbon (TOC) following the ASTM D4129-82M method and grain size following PSEP (1986) methods. Samples were analyzed within 28 days from the time of collection.

**Hydrology**

In 2008, water level loggers (Onset Computer, HOBO Water Level Logger) were placed at five of the six 2008 monitoring sites (Cunningham Lake was the exception due to the lack of prominent channel for placement). In addition, in 2008 a sensor was placed at Lord Island 2 in anticipation of the 2009 sampling. These data loggers record water level and temperature and were set to log at 1-hour intervals. The sensors were retrieved and downloaded for analysis in 2009.

In 2009, water level loggers were placed at two of the 2008 Reach C sites (Whites Island and Ryan Island) and three potential 2009 Reach C sites (Bradwood Slough, Jackson Island, and Wallace Island). In addition, a sensor was placed at Cunningham Lake in 2009 to get an indication of water levels at the site even if the sensor is exposed a portion of the time. The sensor at Campbell Slough was downloaded in 2009 and re-deployed for another year. These sensors will be downloaded in 2010.

The data from the loggers was used to calculate inundation metrics from the marsh and channel elevations collected at those sites. The elevation data for Sand Island, Hardy Creek and Pierce Island were collected in 2008. The data for the other sites were collected in 2009. The growing season was based on the number of frost-free days for the region as determined by the Natural Resource Conservation Service (NRCS) in the wetland determination (WETS) table for Astoria, OR (NRCS, 2002). The start of the growing season was determined to be April 7 and the end was November 9. The frequency of inundation during the growing season was also limited to daylight hours (between 0900 and 1700).

### 7.3.2 Results

**Mapping and Transect Surveys**

Vegetation patterns in Reach C were somewhat similar to those in other surveyed reaches. Common spikerush (*Eleocharis palustris)* and wapato *(Sagittaria latifolia)* dominated lower elevations and the upland border was comprised of willows (*Salix* spp.), cottonwood (*Populus balsimifera)*, and ash (*Fraxinus latifolia*). However, the mid-elevations at the Reach C sites were comprised of a higher number and more diverse mix of wetland species then previously observed in the higher reaches (Table 6). Maps of vegetation distributions at each site (Appendix B) illustrate vegetation patterns and the spatial distribution of each major species communities relative to tidal channels at each site.

Species at Campbell Slough, Cunningham Lake and Franz Lake were similar to those in previous years (Table 7). However, there was a greater number of species at all three sites in 2009 compared to previous years. This could be explained by a variety of factors including the previous high water year, which not only caused a disturbance of sorts, but also could have brought in additional seed sources. The vegetation at the sites in 2008 was stunted and likely had lower species diversity during the July sample period due to the recent high water levels in that year. Additionally, Campbell Slough could be recovering from the disturbance of cattle grazing in previous years.

**Table 6: Species lists by code for 2009 Reach C sites, number of species is provided at the bottom of the table (see Appendix A for species names). Non-native species are shaded in yellow. Native species that are considered "weedy/invasive" are denoted by "**."**

| Species Common Name | Code | Ryan Island | White Island | Lord Island 1 | Lord Island 2 |
|---|---|---|---|---|---|
| spike bentgrass | AGEX | X | X | | |
| broadleaf water plantain | ALPL | X | X | | |
| red alder | ALRU | | | X | |
| nodding beggars-ticks | BICE** | | X | | |
| water starwart | CAHE | X | X | X | |
| Lyngby sedge | CALY | X | X | | |
| yellow marsh marigold | CAPA | X | | | |
| sedge | CASP | | | X | X |
| coontail | CEDE | | | X | |
| Canada thistle | CIAR | | | X | |
| tufted hair grass | DECE | X | | | |
| tufted hairgrass | DISA | X | | X | X |
| needle spikerush | ELAC | | X | | |
| common waterweed | ELCA | X | X | X | |
| creeping spikerush | ELPA | X | X | X | X |
| hairy willowherb | EPCI | X | X | X | X |
| scouringrush horsetail | EQHY | | | X | |
| water horsetail | EQFL | X | X | | |
| horsetail | EQSP | | | X | X |
| Cleavers bedstraw | GAAP** | X | | | |
| Pacific bedstraw; cleavers; small bedstraw | GASP | X | | | |
| fragrant bedstraw | GATR2 | X | X | | |
| American mannagrass | GLGR | | X | | |
| fowl mannagrass | GLST | | X | | |
| Western St. Johns wort | HYSC | X | | | |
| Western St. Johns wort | HYSC | | | X | |
| spotted or common touch-me-not | IMSP | X | X | X | |
| yellow iris | IRPS | X | X | | |
| soft rush | JUEF | | X | X | |
| pointed rush | JUOX | X | X | | |

| Species Common Name | Code | Ryan Island | White Island | Lord Island 1 | Lord Island 2 |
|---|---|---|---|---|---|
| rush | JUSP | X | | | |
| rice cut-grass | LEOR | X | | | X |
| lilaeopsis | LIOC | | X | X | |
| birdsfoot trefoil | LOCO | X | X | X | |
| water-purslane | LUPA | X | X | X | X |
| American bugleweed | LYAM | X | | | |
| purple loosestrife | LYSA | X | | X | |
| field mint | MEAR | X | | | |
| common monkeyflower | MIGU | X | X | | |
| moss | MOSS | | X | X | |
| small or common forget-me-not | MYSP | X | X | X | X |
| milfoil | MYSP2 | X | X | X | |
| water parsley | OESA | X | X | | |
| reed canary grass | PHAR | X | X | X | X |
| white bog orchid | PLDI | X | | | |
| Pacific silverweed | POAN | | X | | |
| annual bluegrass | POAN2 | | | X | |
| curly leaf pondweed | POCR | X | | X | |
| mild waterpepper | POHY | X | X | | X |
| sword fern | POMU | | | X | |
| spotted ladysthumb | POPE | | X | | X |
| knotweed, smartweed | POSP | X | | | |
| flatstem pondweed | POZO | | X | X | |
| curly dock | RUCR | X | | | |
| wapato | SALA | X | X | X | X |
| Sitka willow | SASI | | | X | |
| willow | SASP | | | X | X |
| three-square bulrush | SCAM | X | | X | X |
| small-fruit bulrush | SCMI | | | X | |
| softstem bulrush, tule | SCTA | | | | X |
| hemlock waterparsnip | SISU | X | X | | |
| Canada goldenrod | SOCA | | | X | |
| bittersweet nightshade | SODU | X | | | |
| narrowleaf burreed | SPEM | X | | | |
| narrowleaf cattail | TYAN | X | X | | |
| common cattail | TYLA | | | | X |
| American brooklime | VEAM | | X | X | X |
| | **Total** | 41 | 34 | 34 | 17 |

**Table 7: Species lists by code for Campbell Slough and Cunningham Lake over four sampling years and Franz Lake for two sampling years (see Appendix A for species names). Non-native species are shaded in yellow. Native species that are considered "weedy/invasive" are denoted by "**."**

| | | **Campbell Slough** | | | | | **Cunningham Island** | | | | | **Franz Lake** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Common Name** | **Code** | **05** | **06** | **07** | **08** | **09** | **05** | **06** | **07** | **08** | **09** | **08** | **09** |
| broadleaf water plantain | ALPL | | | | | | X | | X | | | | |
| indigo bush | AMFR | | X | | | | | | | | | | |

| Species Common Name | Code | Campbell Slough | | | | | Cunningham Island | | | | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 05 | 06 | 07 | 08 | 09 | 05 | 06 | 07 | 08 | 09 | 08 | 09 |
| | BESY | | | | | | | | | | | | X |
| bearded sedge | CACO | | | | | | | | | | X | | X |
| water starwart | CAHE | | X | X | | | X | X | X | | | | |
| slough sedge | CAOB | | | | X | | | | | | | X | X |
| sedge | CASP | | | | | X | | | | | | X | |
| black hawthorn | CRDO | | | | | | | | | | | X | |
| needle spikerush | ELAC | | | | | | | | | | X | | X |
| common waterweed | ELCA | | X | | X | X | | | | | | | |
| ovoid spikerush | ELOV | | | | | | | | | | | | X |
| creeping spikerush | ELPA | X | X | X | X | X | X | X | X | X | X | X | X |
| small spikerush | ELPAR | | | | | | X | | | X | | | |
| hairy willowherb | EPCI | | | | | | | | | X | | | X |
| water horsetail | EQFL | X | X | | | | X | X | X | | | | |
| horsetail | EQSP | | | X | X | X | | | | X | X | X | X |
| Oregon ash | FRLA | | X | | | | | | | | | X | X |
| mountain sneezeweed | HEAU | | | | X | X | | | | | | X | X |
| yellow touch-me-not | IMNO | | | | | | | | | X | | | |
| spotted or common touch-me-not | IMSP | | | | | | | | | | X | | |
| yellow iris | IRPS | | | X | | | | X | | | X | | |
| tapertip rush | JUAC | X | | | | | X | | | | | | |
| pointed rush | JUOX | | | | | X | | | | | | | |
| rice cut-grass | LEOR | | | | | X | | | | | X | | X |
| water mudwart | LIAQ | | | X | | | | | | | | | X |
| lilaeopsis | LIOC | | | | | X | | | | | | | |
| birdsfoot trefoil | LOCO | | | X | | X | | | | | | | |
| water-purslane | LUPA | | | X | X | X | | | X | X | X | | X |
| creeping jenny | LYNU | X | X | X | X | X | | | | | X | | |
| Pacific crab apple | MAFU | | | | | | | | | | | | X |
| field mint | MEAR | | X | | | X | | | | | | | X |
| mint spp. | MESP | | | | | | | | | | X | X | |
| moss | MOSS | | | | | X | | | | | | | |
| Eurasian water milfoil | MYSP2 | | X | | | | | | | | | | |
| reed canary grass | PHAR | X | X | X | X | X | X | X | X | X | X | X | X |
| narrowleaf plantain | PLLA | | | | X | | | | | | | | |
| common plantain | PLMA | | | X | | X | | | | | | | |
| water ladysthumb | POAM | | X | | | | X | | | | | X | X |
| Pacific silverweed | POAN | | | | | | | | | | | | X |
| black cottonwood | POBA | | X | | | | | | | | | | |
| curly leaf pondweed | POCR | | | X | X | X | | | | | | | |
| mild waterpepper | POHY | | | | X | | X | X | X | | X | X | |
| floating-leaved pond weed | PONA | X | | | | | X | X | | X | X | | |
| ladysthumb | POPE | | | X | X | X | | | X | X | X | X | X |
| knotweed, smartweed | POSP | | | | | X | | | | | | | |
| creeping buttercup | RARE | | | X | | X | | | | | | | |
| curly dock | RUCR | | | | X | X | | | | | | | |
| Himalayan blackberry | RUDI | | | | | | | | | | X | | |
| dock | RUSP | | | X | X | | | | | | | | |

| Species Common Name | Code | Campbell Slough | | | | | Cunningham Island | | | | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 05 | 06 | 07 | 08 | 09 | 05 | 06 | 07 | 08 | 09 | 08 | 09 |
| wapato | SALA | X | X | X | X | X | X | X | X | X | X | X | X |
| Pacific willow | SALU | X | | | | | X | | | | | | |
| willow | SASP | | X | X | X | X | | X | X | X | X | X | X |
| three-square bulrush | SCAM | | | | | X | | | | | | | |
| woolly sedge | SCCY | | | | | | | | | | | | X |
| tule | SCLA | | | | | | X | | X | | | | |
| small-fruit bulrush | SCMI | | | | | | | | | X | | | |
| softstem bulrush, tule | SCTA | | | | | | | | | | X | | X |
| narrowleaf burreed | SPEM | | | | X | | X | X | X | X | X | | |
| stinging nettle | URDI | | | | | | | | | | | | X |
| American brooklime | VEAM | X | | X | | | X | X | | | | | X |
| | **Total** | **9** | **14** | **17** | **17** | **23** | **15** | **11** | **12** | **13** | **19** | **14** | **25** |

Elevations of species observed during 2009 sampling are shown in Figure 17. Species were generally found at higher elevations in Reaches F and H because of the higher elevation of the riverbed in these reaches. Correcting the elevations from the North American Vertical Datum of 1988 (NAVD88) to the Columbia River Datum (CRD) can alleviate the elevation differences due to the increasing elevation of the riverbed. However, at this time, corrections to Reach H have not been determined.

In general, the elevations of the dominant vegetation communities within each Reach fall within a narrow range of 1-2 m. Exceptions to this are some tree species (SASI, ALRU) where the cover may have been due to overhanging vegetation, with the plants rooted at different elevations. Many of the higher elevation species in Reach C are from the upper portions of the Lord Island 1 site, which was greater then 4 m and approximately 1.5 m higher than any other Reach C sites (see site elevation ranges in Appendix A). Also, reed-canary grass (PHAR) and horsetail (EQSP) have broad elevation ranges due to adaptations within and between species.

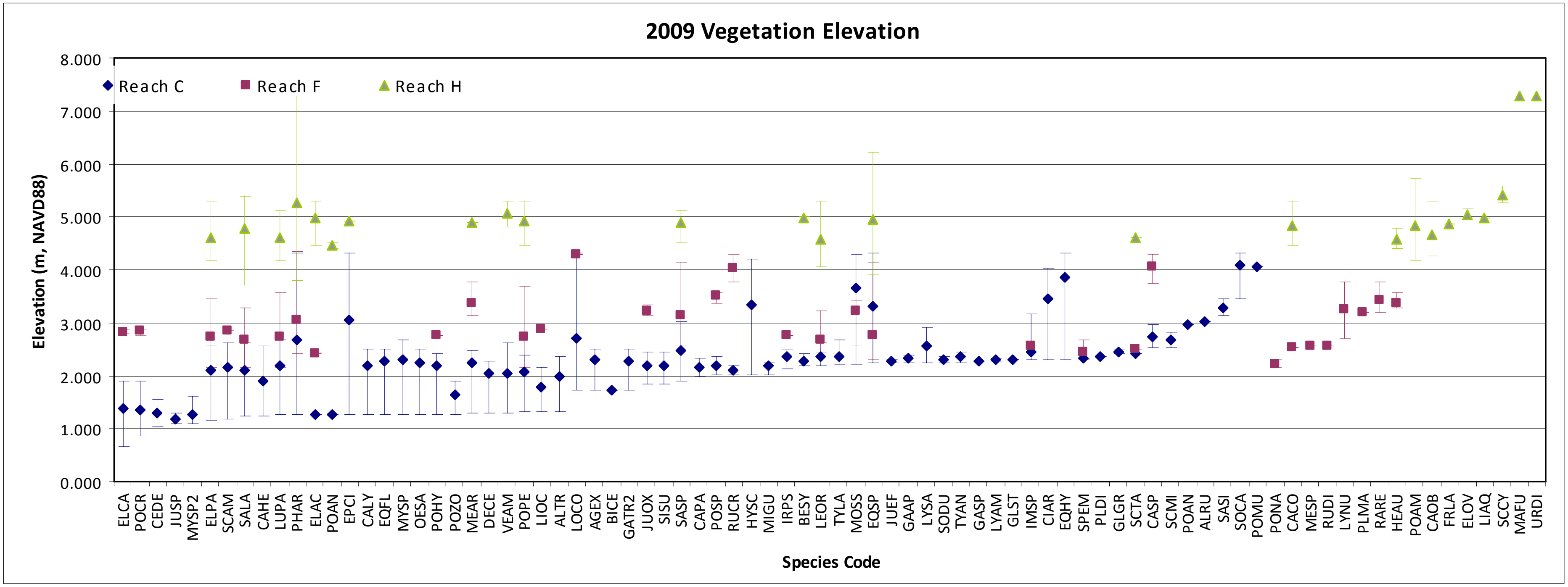



**Figure 17: Vegetation elevations by reach for sites sampled in 2009. Error bars represent the minimum and maximum elevations at which the vegetative species occurred within transects (See Appendix A for species names).**

The elevation at which many of the species are found, particularly wapato (SALA) and spikerush (ELPA), is more likely due to the frequency and duration of inundation rather than just elevation. At some sites for example, Franz Lake wapato was found at the upper and lower transects of Franz Lake (channel cross sections 2 and 3 on Figure 20G), which differed approximately 1 m in elevation, however the upper transect was modified by extensive beaver dams which likely increased the inundation period.

In Table 8, we calculated the percent of time inundated for the deployment period (July 2008 to July 2009) and for the growing season (April to November) that specific elevations of the marsh were inundated. We did not evaluate spatial differences at the sites, but rather looked the frequency the water level was greater than the average elevation of the marsh 0.15 m and 1.0 m. For these calculations, the channel portions of the study site were not included in the averages (channel inundation is discussed in the Channel Section below). The percent of time the average marsh elevation is inundated during the growing season varied between 33 and 43 percent, with the exception of Lord Island 1 and Hardy Creek. Both of these sites are characterized by steep sided high banks, explaining the lower inundation time. The difference between the Reach C and Reach H sites is evident by the difference in the amount of time the marsh has greater then 1 m of water over the average elevation. The Reach H sites range from 12 to 32 percent of time with greater then 1 m water level (except Hardy Creek),whereas the Lord Island 2 site was only inundated to this level less then 1 percent of the time.

Table 9 documents the most common species found at the 2009 monitoring sites. At the Reach C sites, the cover was dominated by reed-canary grass (*Phalaris arundinacea*) except at Lord Island 2, a generally lower elevation marsh. In general, the Ryan Island and Whites Island sites were characterized by a diverse mix of high marsh species, while the Lord Island 2 species were more indicative of a less diverse, low elevation marsh. Reed-canary grass, common spikerush (*Eleocharis palustris*) and wapato (*Sagittaria latifolia*) were the most commonly occurring species at Campbell Slough and Cunningham Lake. At Franz Lake, water smartweed (*Polygonum amphibium*) was also a common species. Percent cover of all species is provided in Appendix A.

**Table 8: Inundation time at the average marsh elevation (in meters, relative to the vertical datum NAVD88) and 0.15 m and 1.0 m water levels from sites where water level data was collected from 2008-2009.**

| | | | **Total Deployment Period** | | **Growing Season** | |
|---|---|---|---|---|---|---|
| | | Elevation (m, NAVD88) | Time (hours) | % Time Deployed | Time (hours) | % Time Deployed |
| **Lord Island 1** | Sensor | 1.611 | 7438 | 91.7 | 1414 | 93.0 |
| | Marsh Average | 3.081 | 718 | 8.9 | 54 | 3.6 |
| | Average + 15 cm | 3.231 | 431 | 5.3 | 19 | 1.3 |
| | Average + 1 m | 4.081 | 10 | 0.1 | 0 | 0.0 |
| **Lord Island 2** | Sensor | 1.611 | 7438 | 91.7 | 1414 | 93.0 |
| | Marsh Average | 2.280 | 3978 | 49.0 | 651 | 42.8 |
| | Average + 15 cm | 2.430 | 3248 | 40.0 | 503 | 33.1 |
| | Average + 1m | 3.280 | 370 | 4.6 | 9 | 0.6 |
| **Campbell Slough** | Sensor | 2.688 | 8522 | 95.7 | 1625 | 91.1 |
| | Marsh Average | 3.364 | 2521 | 28.3 | 583 | 32.7 |
| | Average + 15 cm | 3.514 | 2108 | 23.7 | 508 | 28.5 |
| | Average + 1m | 4.364 | 686 | 7.7 | 156 | 8.7 |
| **Sand Island** | Sensor | 3.298 | 7750 | 83.6 | 1545 | 80.9 |
| | Average | 3.789 | 3973 | 42.9 | 835 | 43.7 |

| | | Elevation (m, NAVD88) | Total Deployment Period | | Growing Season | |
|---|---|---|---|---|---|---|
| | | | Time (hours) | % Time Deployed | Time (hours) | % Time Deployed |
| | Average + 15 cm | 3.939 | 3518 | 38.0 | 773 | 40.5 |
| | Average + 1m | 4.789 | 2177 | 23.5 | 609 | 31.9 |
| **Franz Lake** | Sensor | 3.742 | 9195 | 99.8 | 1879 | 99.5 |
| | Marsh Average | 5.047 | 2190 | 23.8 | 624 | 33.1 |
| | Average + 15 cm | 5.197 | 2020 | 21.9 | 578 | 30.6 |
| | Average + 1m | 6.047 | 773 | 8.4 | 236 | 12.5 |
| **Hardy Creek** | Sensor | 3.344 | 9201 | 99.0 | 1884 | 98.3 |
| | Marsh Average | 6.308 | 770 | 8.3 | 239 | 12.5 |
| | Average + 15 cm | 6.458 | 684 | 7.4 | 218 | 11.4 |
| | Average + 1m | 7.308 | 324 | 3.5 | 115 | 6.0 |
| **Pierce Island** | Sensor | 3.166 | 8638 | 93.2 | 1711 | 89.7 |
| | Marsh Average | 5.006 | 2248 | 24.3 | 637 | 33.4 |
| | Average + 15 cm | 5.156 | 2101 | 22.7 | 613 | 32.1 |
| | Average + 1m | 6.006 | 904 | 9.8 | 288 | 15.1 |

**Table 9: Percent cover of dominant vegetation species at 2009 monitoring locations.**

| | Reach C | | | | Reach F | | Reach H |
|---|---|---|---|---|---|---|---|
| | **Ryan Island** | **White Island** | **Lord Island 1** | **Lord Island 2** | **Campbell Slough** | **Cunningham Lake** | **Franz Lake** |
| *Carex lyngbyei* | 17.4 | 8.3 | | | | | |
| *Eleocharis palustris* | | | | | 40.0 | 35.3 | |
| *Elodea canadensis* | | | 16.8 | | | | |
| *Impatiens spp.* | 7.5 | | | | | | |
| *Myosotis spp.* | | 9.2 | | | | | |
| *Phalaris arundinacea* | 34.6 | 43.0 | 22.4 | 9.4 | 37.9 | 38.5 | 36.3 |
| *Polygonum amphibium* | | | | | | | 13.1 |
| *Polygonum hydropiperoides* | | | | 11.3 | | | |
| *Sagittaria latifolia* | | | | 23.7 | 14.3 | 8.7 | 8.1 |
| *Typha latifolia* | | | | 14.3 | | | |
| Bare ground | | | 25.8 | | 15.1 | 16.6 | 19.4 |
| Total percent cover of dominant species | 59.5 | 60.5 | 65 | 58.7 | 107.3 | 99.1 | 76.9 |

**Sediment**

The percent total organic carbon (TOC) in the sediment samples is indicative of mineral soil, with organic soils generally having TOC greater then 12 percent (Mitsch and Gosslink, 1993). Peat is not common in the soils at these sites, which makes them unusual in comparison with many wetland sites. We are curious why this is the case in the LCRE, and will delve into an explanation when we compare these sites with others in the system.

Most of the samples are similar in TOC and grain size content, with a dominant portion of silt and some smaller sand particles, with a few exceptions (Table 10; Figure 18; Figure 19). Ryan Island is distinct in having the widest range of TOC among the sample locations. The high marsh TOC sample at Ryan (RI-4) is twice that of any other sample except the high marsh sample at Whites Island (WI-5). This sample also contains a greater percentage of the larger grain sizes than any other sample and the greatest portion of clay. Conversely, Ryan Island also has the sample with the lowest TOC (RI-3). Sample RI-3 also contains the highest amount of medium/fine sand and lowest amount of silt/clay, which may decrease retention of organics in the sediment. This sample was taken near the mouth of the tidal channel, which may experience greater flows, limiting the settling of fine particles. Whites Island samples are similar across all of the vegetation strata, with more silt present than the other sites. In comparison, Lord Island has less silt and more sand in its samples, which may be due to the history of dredge material deposition. The exception to this is sample LI2-2 which is more similar to the Whites Island samples. There exists a considerable difference in elevation and vegetation between the Lord Island sites, with the LI2 site lower overall (See elevation ranges for entire site in Appendix A) and more protected and therefore more likely to accrete finer sediments.

**Table 10: Vegetation strata associated with sediment samples at 2009 monitoring sites in Reach C.**

| Site | Sample | Vegetation Strata |
|---|---|---|
| Ryan Island | RI-1 | Channel/SAV |
| | RI-2 | *Eleocharis palustris* (ELPA) |
| | RI-3 | *Carex obnupta/C. lyngbyei* (CAOB/CALY) |
| | RI-4 | *Phalaris arundinacea, Iris pseudacorus, C. lyngbyei* (PHAR/IRPS/CALY) |
| White Island | WI-1 | Channel/SAV |
| | WI-2 | *Sagittaria latifolia* (SALA) |
| | WI-3 | *Eleocharis palustris* (ELPA) |
| | WI-4 | *Carex obnupta* (CAOB) |
| | WI-5 | *Phalaris arundinacea* (PHAR) |
| Lord Island 1 | LI1-1 | *Phalaris arundinacea* (PHAR) |
| | LI1-2 | *Eleocharis palustris* (ELPA) |
| | LI1-3 | Channel/Bare mud |
| | LI1-4 | Channel/SAV |
| Lord Island 2 | LI2-1 | Channel/Bare mud |
| | LI2-2 | *Sagittaria latifolia* (SALA) |

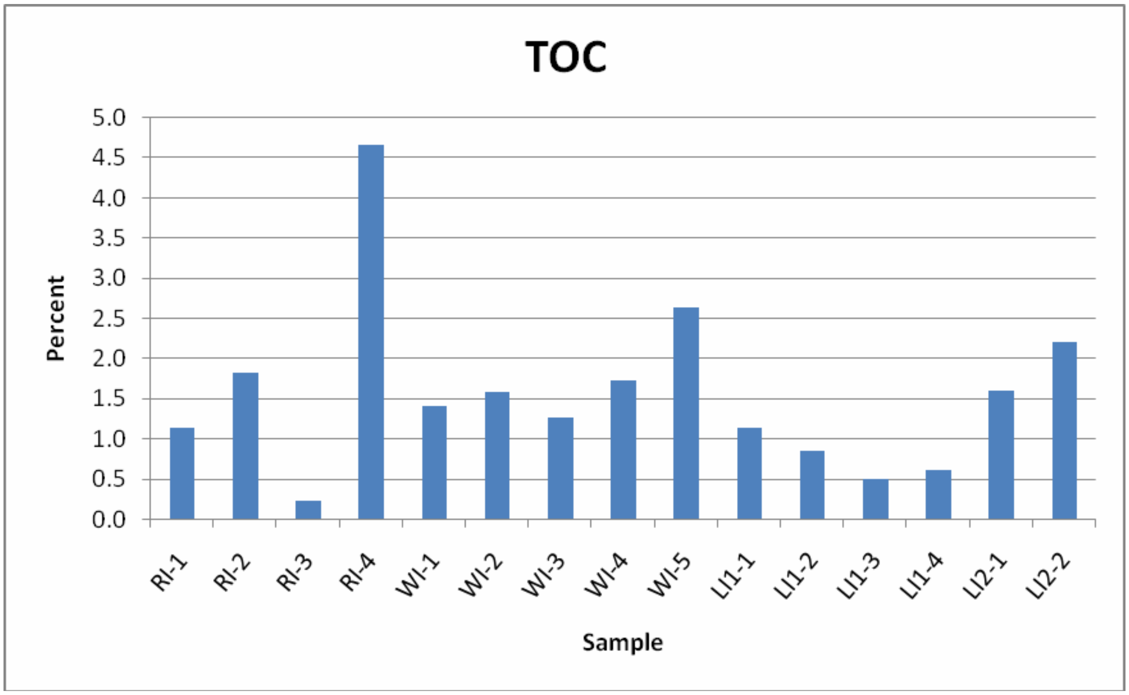



**Figure 18: Total organic carbon (TOC) in sediment samples from 2009 monitoring sites in Reach C.**

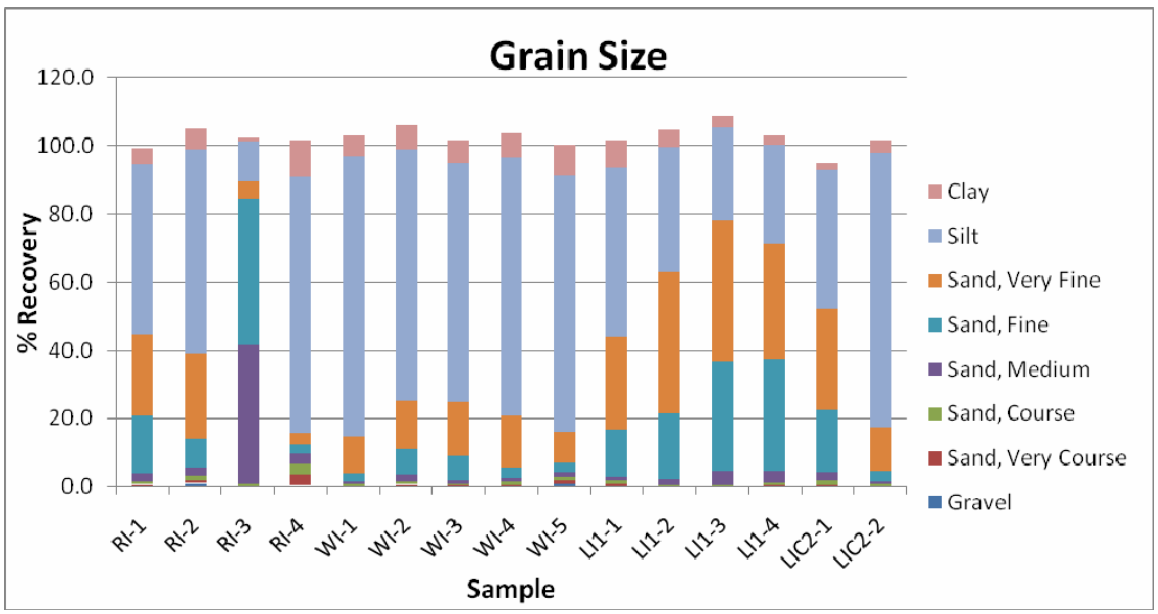



**Figure 19: Grain size distribution in the sediment samples from 2009 monitoring sites in Reach C.**

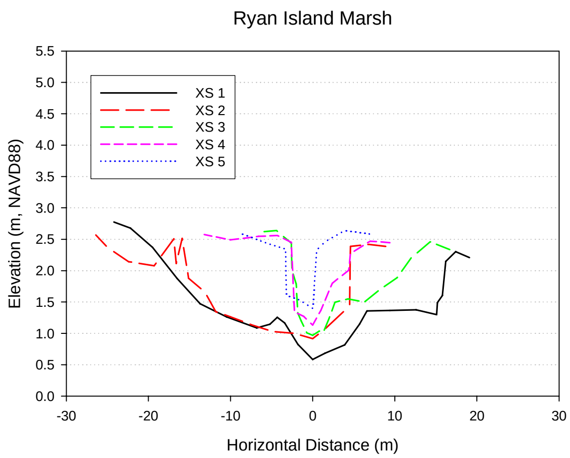
**Channels**

The elevations of the cross-sections are shown in Figure 20. 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:

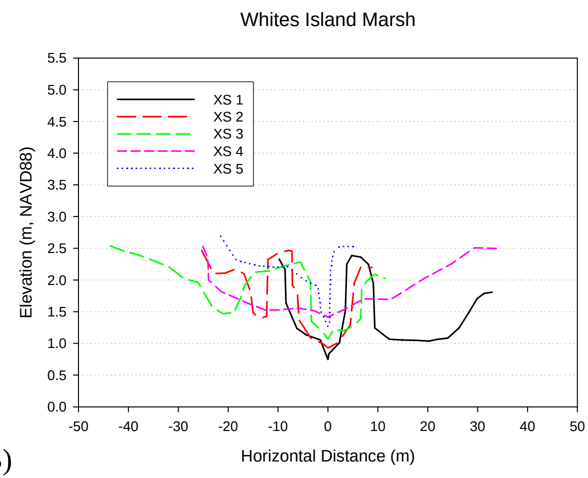
<u>Site                                        Cross Section(s)</u>

| | |
|---|---|
| Lord Island 1 | 1,2 |
| Lord Island 2 | 2 |
| Cunningham Lake | 1 |
| Franz Lake | 2,3 |

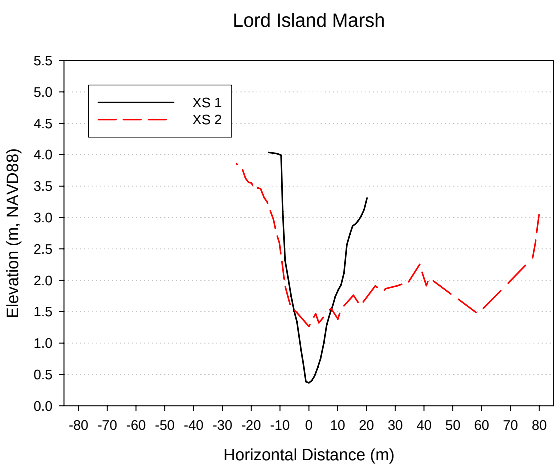
Cross sections were conducted at Cunningham Lake for the first time since the inception of monitoring there under this program. Previously the lack of a prominent channel deemed it unnecessary, however, in an effort to better characterize the site we decided to include the elevation and morphology of the channel as well as the annual water levels. The slough at the Campbell Slough site was also measured in 2009 to provide additional data on fish access to the site. If time permits in future years, we will try to measure the mouth of the slough as well. Further analysis of cross-channel data will coincide with the Estuary Partnership's Reference Site Study and will be included in the multi-year analysis for the annual monitoring sites as part of the current study.



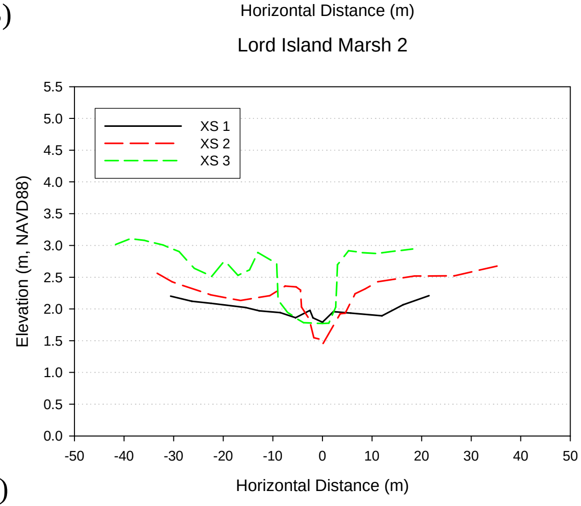

A)



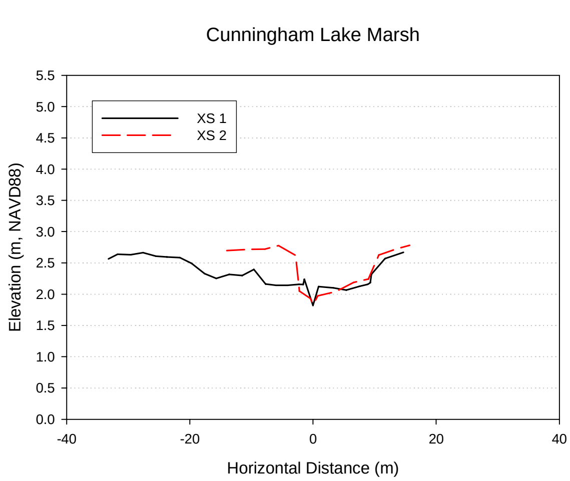

B)



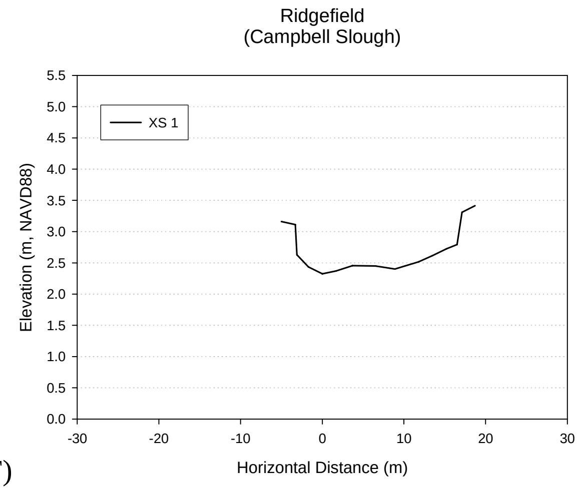

C)



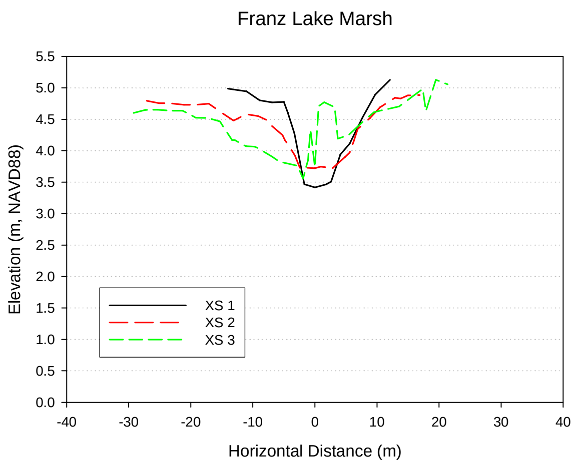

D)




E)




F)




G)

**Figure 20: Elevations of channel cross-sections at: A) Ryan Island; B) Whites Island; C) Lord Island 1; D) Lord Island 2; E) Cunningham Lake; F) Campbell Slough; and G) Franz Lake.**

Channel inundation varied between sites depending on the morphology and elevation of the channels (Table 11). Channels with a low elevation gradient and a depth greater then 0.7 m were generally inundated to a depth greater then 15 cm 100 percent of the time (e.g., Lord Island 1, Campbell Slough, Franz Lake, and Hardy Creek). These sites gradually become less inundated as the channel elevation increases. Two sites had shallow channel depths at the mouth: Lord Island 2 and Sand Island cross section 2. Lord Island 2 had a higher channel elevation at the mouth, which may limit inundation during some water levels, however without a greater understanding of the overall water movement at the site this can not be determined. The Sand Island site was a shallow channel, but also was located at a lower elevation then the rest of the channel and was inundated 99 percent of the time, thereby not limiting inundation in the rest of the channel.

Bank elevations and therefore channel morphology also varied among sites. Three sites were characterized by high bank elevations: Lord Island 1, Hardy Creek, and Pierce Island. At these sites, the top of the bank was difficult to determine and in all cases a portion of the bank included a fringe of emergent marsh vegetation, however the extent was limited by the slope of the bank.

At several sites, the top of the bank elevation is lower then the average marsh elevation. This occurs in areas where the vegetation and elevation transects include a portion of the high marsh as well as the low marsh. The Campbell Slough cross section was located on the edge of the emergent marsh vegetation in an area of wapato and spikerush on the low bank. Therefore, the top of the bank elevation is actually lower then the average marsh surface, which did not include much of the low wapato area due to sampling difficulty (Appendix B).

**Table 11: Channel depth and inundation at the cross-sections for sites where water level data were collected in 2008-2009.**

| Site | Cross Section Location | Bank Elevation (m, NAVD88) | Thalweg Elevation (m, NAVD88) | Channel Depth (m) | % Time WL >15 cm in channel | % Time WL >top channel bank |
|---|---|---|---|---|---|---|
| **Lord Island 1** | 1 (mouth) | 3.312 | 0.369 | 2.943 | 100 | 4 |
| | 2 | 3.043 | 1.265 | 1.778 | 100 | 10 |
| **Lord Island 2** | 1 (mouth) | 2.087 | 1.793 | 0.294 | 69 | 60 |
| | 2 | 2.296 | 1.432 | 0.864 | 100 | 48 |
| | 3 | 2.889 | 1.770 | 1.119 | 71 | 16 |
| **Campbell Slough** | 1 | 3.113 | 2.324 | 0.789 | 100 | 40 |
| **Sand Island** | 1-1 (mouth) | 4.192 | 3.227 | 0.965 | 69 | 31 |
| | 1-2 | 3.795 | 3.530 | 0.265 | 47 | 43 |
| | 1-3 | 3.895 | 3.756 | 0.139 | 39 | 39 |
| | 2-1 (mouth) | 3.263 | 3.119 | 0.144 | 99 | 96 |
| | 2-2 | 4.120 | 3.599 | 0.521 | 45 | 32 |
| | 2-3 | 4.425 | 3.771 | 0.654 | 38 | 27 |
| | 2-4 | 4.356 | 3.878 | 0.478 | 35 | 28 |
| | 2-5 | 4.710 | 3.842 | 0.868 | 36 | 24 |
| | 2-6 | 4.401 | 3.771 | 0.630 | 38 | 27 |
| **Franz Lake** | 1 (mouth) | 4.669 | 2.864 | 1.805 | 100 | 27 |
| | 2 | 4.449 | 3.424 | 1.025 | 100 | 32 |
| | 3 | 4.173 | 3.474 | 0.699 | 100 | 74 |
| **Hardy Creek** | 1 (mouth) | 3.806 | 2.752 | 1.054 | 100 | 56 |
| | 2 | 3.779 | 3.066 | 0.713 | 100 | 59 |
| | 3 | 4.279 | 3.192 | 1.087 | 100 | 37 |
| | 4 | 4.707 | 4.013 | 0.694 | 40 | 28 |
| | 5 | 5.973 | 4.920 | 1.053 | 25 | 12 |
| **Pierce Island** | 1 (mouth) | 4.953 | 3.530 | 1.423 | 58 | 25 |
| | 2 | 7.554 | 3.474 | 4.080 | 62 | 0 |
| | 3 | 4.663 | 3.653 | 1.010 | 51 | 28 |
| | 4 | 4.543 | 3.538 | 1.005 | 58 | 29 |
| | 5 | 4.739 | 3.687 | 1.052 | 48 | 26 |

### 7.3.3 Summary

Monitoring in Reach C resulted in the characterization of more species rich sites, with greater tidal influence, and more complex tidal channels. The evaluation of the marsh and channel elevations with hydrology data is increasing our ability to better characterize the drivers for the vegetation communities at the ecosystem monitoring sites. In 2010, we will continue to analyze data from this year, as well as the three previous sampling seasons, to further understand plant communities, elevation, and hydrology in the different reaches of the estuary. Additionally, we look forward to working with NOAA-Fisheries and USGS to coordinate efforts on fish and invertebrate sampling as well as water and sediment quality with our habitat characterizations.

## 7.4 Water Chemistry and Depth Monitoring

To support characterizations of salmon habitat by PNNL and NOAA-Fisheries, USGS conducted seasonal water-quality monitoring to characterize basic water quality conditions (e.g., temperature and dissolved oxygen) relevant to salmonids. They deployed water-quality monitors at two of the sites where the other monitoring partners (NOAA-Fisheries and PNNL) were conducting salmonid and vegetation sampling. Although 5 sites were chosen for salmonid sampling, funding was only available to perform water-quality monitoring at 2 sites (Table 12). The two sites chosen were Campbell Slough located in the Roth Unit of the Ridgefield National Wildlife Refuge where PNNL and NOAA-Fisheries have conducted vegetation and fish data, respectively, over multiple years (Table 5; Figure 21) and Birnie Slough on the northern side of White's Island. Birnie Slough (referred to as the "White Island" site) is a main-stem island in Reach C sampled for the first time this year by all agencies (Table 5; Figure 22).

**Table 12: Site information for locations of water-quality monitors.**

| Site | Reach | Latitude | Longitude | Deployment Date | Retrieval Date |
|---|---|---|---|---|---|
| Campbell Slough | F | 45° 47' 05" | 122° 45' 14.5" | May 7, 2009 | August 21, 2009 |
| White Island | C | 46° 09' 39" | 123° 20' 16" | May 27, 2009 | August 13, 2009 |

**Figure 21: Campbell Slough, Roth Unit, Ridgefield Wildlife Refuge. Left: Ponded area, yellow arrow shows direction to water-quality monitor. Right: Pipe housing used to deploy water-quality monitor (This picture is from 2008. In 2009, an extra piece of pipe was added so that the monitor was not left out of the water as happened in 2008.)**


**Figure 22: Birnie Slough (White Island) on Columbia River near Cathlamet, WA. Left: Looking upstream from mouth of slough at location of water-quality monitor (in yellow circle). Right: Pipe housing used to deploy water-quality monitor, looking downstream towards mouth of slough.**

### 7.4.1 Methods

The monitors deployed at these two sites were Yellow Springs Instruments (YSI) model 6600EDS equipped with water temperature, specific conductance, pH, dissolved oxygen, depth, and turbidity probes. See Table 13 for the specifics on the accuracy and effective ranges for each of these probes. The deployment period for these monitors was designed to characterize water-quality conditions while juvenile salmonids were present, during the period of time when they migrated 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.

**Table 13: Range, resolution, and accuracy for water-quality monitors deployed by USGS**

| 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 |

### 7.4.2 Results

Table 14 and Table 15 show the minimum, mean, median, and maximum values measured for each parameter during deployment at each site. The similarity of these datasets between sites is somewhat surprising. White Island is further down in the estuary, so higher water temperatures and specific conductance values may be expected due to the influence of more inputs to the system. The sampling location on Campbell Slough, however, is much further off the mainstem, therefore, higher water temperatures may be expected because of the slower-moving slough-like nature of the site, and the specific conductance could be influenced more by the upstream inputs than the Columbia River itself.

These competing factors appear to cancel each other out and the general characteristics at each site appear similar.

**Table 14: Minimum, mean, median, and maximum concentrations for parameters measured at Campbell Slough.**

| Values | Water Temperature | Specific Conductance | Dissolved Oxygen | pH | Turbidity |
|---|---|---|---|---|---|
| Minimum | 10.5 | 95 | 2.9 | 6.9 | 0.9 |
| Mean | 20.3 | 143 | 9.8 | 8.2 | 17.9 |
| Median | 20.2 | 144 | 9.9 | 8.1 | 14.0 |
| Maximum | 34.4 | 187 | 16.6 | 10.0 | 75.0 |

**Table 15: Minimum, mean, median, and maximum concentrations for parameters at measured at White Island.**

| Values | Water Temperature | Specific Conductance | Dissolved Oxygen | pH | Turbidity |
|---|---|---|---|---|---|
| Minimum | 14.2 | 101 | 3.7 | 7.0 | 0.8 |
| Mean | 18.7 | 123 | 9.4 | 7.9 | 4.3 |
| Median | 18.5 | 124 | 9.9 | 7.9 | 3.9 |
| Maximum | 25.3 | 156 | 13.0 | 9.2 | 19.0 |

The daily and seasonal patterns at the two sites, however, show much larger differences (Figure 23 and Figure 24). White Island, which is further down in the estuary, shows a much stronger tidal influence in the daily fluctuations of these parameters. It is also more closely linked to the influence of the mainstem because of its location on a mainstem island and the sampling location is just upstream of from the mouth of the slough. The sampling location at Campbell Slough is much further away from the mouth and, therefore, the influences of the Columbia River are dampened. The tidal variations are, however, still noticeable, particularly later in the season when water levels are lower and the factors of snowmelt and dam releases are not as strong. Fluctuations in the specific-conductance values, particularly earlier in the season, indicate that upstream factors may be affecting this site. This observation needs to be explored further.

One of the key reasons for studying these sites is to learn more about their function as off-channel habitat for salmon. Both sites experience periods of “poor” water quality with respect to conditions for salmon health. Warm water (water temperatures greater than 20 degrees Celsius), low dissolved oxygen (less than 8 milligrams per liter [mg/L]), and high pH (higher than 9) create stressful conditions for salmon. At White Island, dissolved-oxygen levels fell below 8 mg/L during some part of the day for most of the deployment period with the amount of time below 8 mg/L and the distance below 8 mg/L increasing throughout the season. The wide diurnal swings in pH (up to 1.5 units) and dissolved oxygen (as much as 9 mg/L) may be indicative of high productivity, which may be beneficial in providing a food source for the salmon. Water temperatures at the site were not over 20 degrees Celsius until late July when many juvenile salmonids had already made their way through the system.

The influence of algal growth and productivity affected conditions at Campbell Slough, also. Once water temperatures reached 20 degrees Celsius in late June, pH increased, indicating a period of algal growth. These high pH values (often above 8.5) along with the warm water temperatures can create stressful conditions for salmon. NOAA-Fisheries data indicate that few salmon were observed at this site in July, perhaps because of these stressors. In early August, the pH fell and the dissolved oxygen decreased indicating algal die-off and decomposition. Again, these conditions can be harmful to salmon, but the out-migrating juveniles seem to be on their way to the ocean by August and are no longer using this site.

In summary, the water-quality conditions at these two very different sites show many similarities in terms of general water-quality conditions but also indicate some differences perhaps due to the influence of inputs to each site. This needs to be further investigated. Both sites offered periods of suitable water quality to support salmon health, particularly earlier in the season, but both sites also experienced periods of “poor” water quality that may be stressful for salmon health.

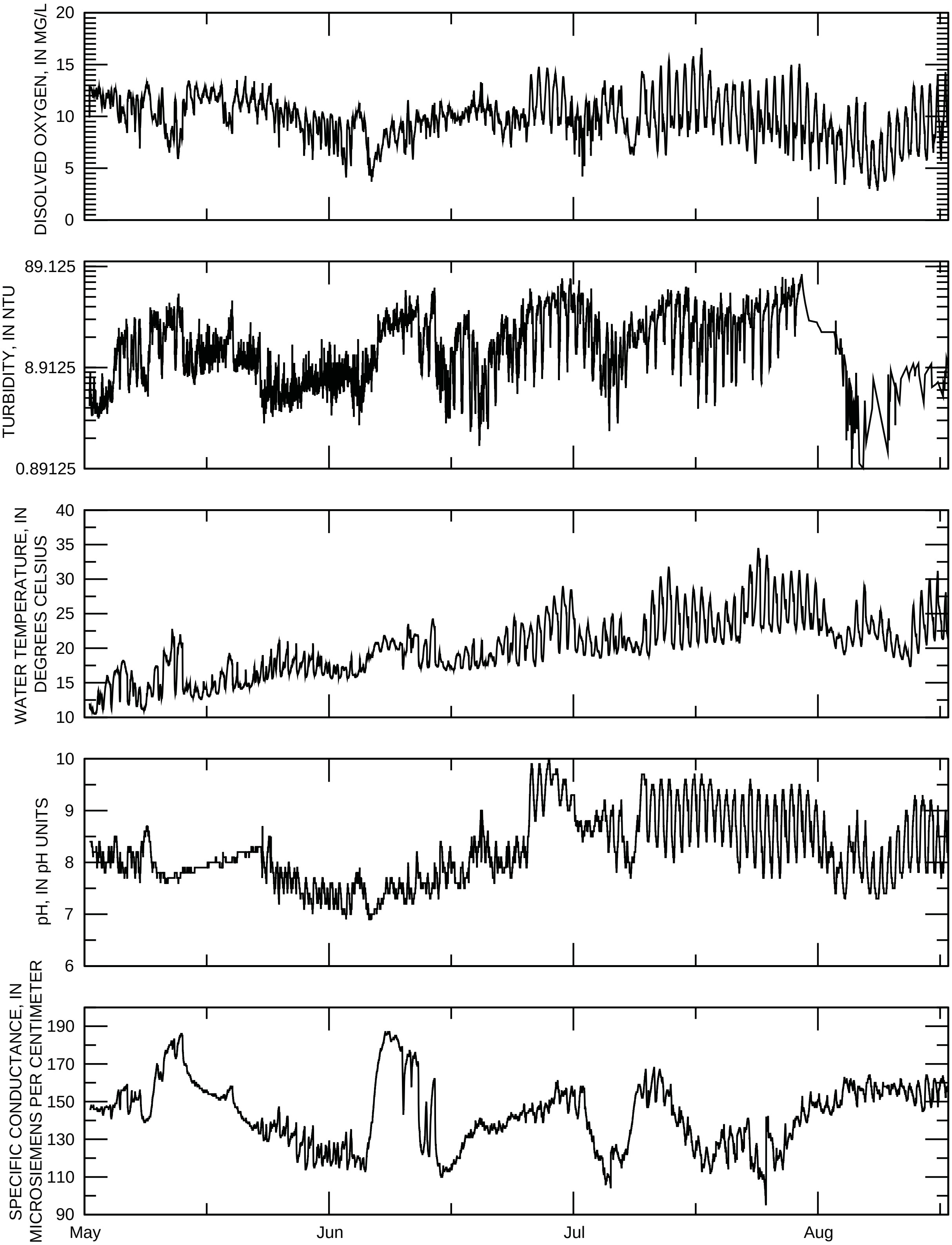



**Figure 23: Continuous measurements of selected water-quality parameters from May 7 to August 21, 2009, at Campbell Slough.**

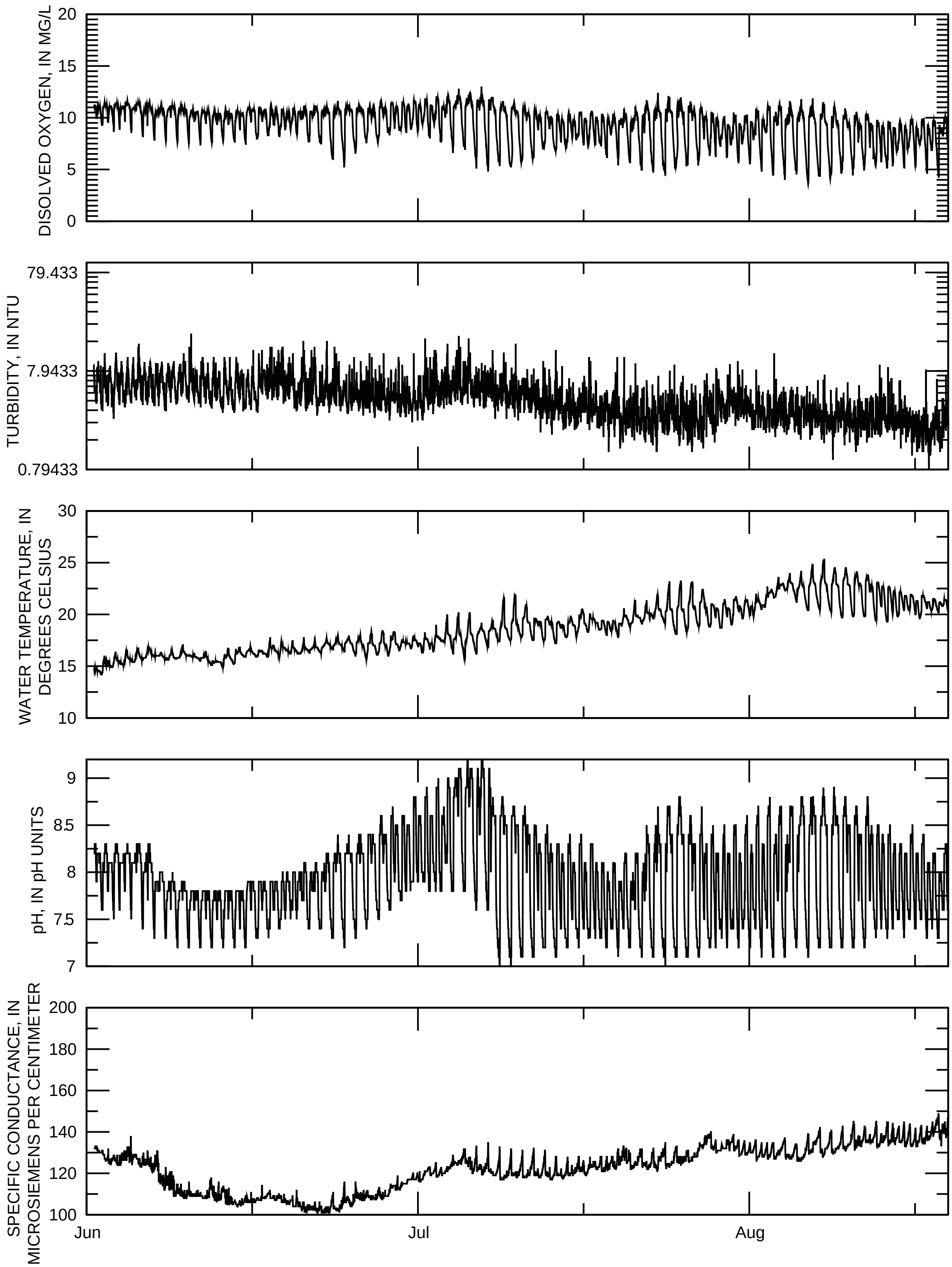



**Figure 24: Continuous measurements of selected water-quality parameters from May 27 to August 13, 2009, at White Island.**

## 7.5 Juvenile Salmon and Prey Monitoring

In 2008-2009, NOAA Fisheries focused on the following six work elements:

1. A survey of prey availability and habitat use by salmon and other fishes at three sites in Reach C of the LCRE and data collection on fish habitat use in relation to physical habitat characteristics (monitored by PNNL and USGS). This effort also included re-sampling of the 2007 Campbell Slough site in the Ridgefield National Wildlife Refuge (NWR) in Reach F and the 2008 Franz Lake site in Reach H in order to examine year-to-year trends in fish use of these sites.
2. Taxonomic analyses of prey in salmon stomach contents in order 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 2009 sites for determination of growth rates.
4. Analyses of biochemical measures of growth and condition for juvenile Chinook salmon collected at 2008 and 2009 sites.
5. Identification of genetic stock for juvenile Chinook salmon collected at 2009 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 information collected between 2005 and 2007. These activities included:

- Chemical analyses of stomach contents, bodies, and bile from juvenile Chinook salmon collected in 2008 from the Reach H sites. Chemical analyses were conducted with NOAA Fisheries funds. Analyses were also done on additional fish collected from sites near the Lower Willamette and Lower Columbia Confluence.
- 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.

In spring and summer 2009, we monitored prey availability and habitat use by juvenile Chinook salmon and other fishes at 4 tidal freshwater sites in Reach C. Sampling sites were Lord-Walker Island, Ryan Island, and White Island (Figure 13A). Additionally, we re-sampled fish at the 2007-2008 Ridgefield Wildlife Refuge site (Campbell Slough) in Reach F and the 2008 Franz Lake site in Reach H in order to examine year-to-year trends in fish use of the site (Figure 13B; Table 5). 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 objective of the project.

### 7.5.1 Methods

**Fish Monitoring**

Monitoring for fish and prey was initiated in April 2009, and continued on a monthly basis through August 2009. Fish were collected routinely by beach seine from the three sites in Reach C, at Campbell Slough in Reach F, and at Franz Lake in Reach H. See Figure 13 for a map of the sampling sites, Table 5 for a summary of the sampling effort, and Table 16 for salmon sampling site coordinates. 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) in order to determine the proportions of marked (known hatchery origin) and unmarked (potentially wild) fish. Subsets of juvenile Chinook (*Onchorhynchus tshawytscha*), coho (*Onchorhynchus kisutch*), and chum (*Onchorhynchus 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, various organochlorine pesticides, and poly-brominated diphenyl ethers (PBDEs); and whole bodies for measurement of bioaccumulative POPs. Table 17 lists the numbers of samples collected from each site at each sampling event.

**Table 16: Coordinates (in decimal degrees) for 2009 salmon sampling sites.**

| Site | Reach | Latitude | Longitude |
|---|---|---|---|
| Lord-Walker Island | C | 46.137216° | -123.040278° |
| Ryan Island | C | 46.206600° | -123.414817° |
| White Island | C | 46.159350° | -123.340133° |
| Campbell Slough (Ridgefield NWR) | F | 45.783867° | -122.754850° |
| Franz Lake | H | 45.600583° | -122.103067° |

**Table 17: Samples collected from juvenile Chinook in 2009 as part of the EMP. No blood samples were collected in 2009.**

| Site | Collection Date | # Collected | # Fin Clipped (Marked) | Otolith | Bile | Stomach Taxonomy | Stomach Chemistry | Body Chemistry | Genetics |
|---|---|---|---|---|---|---|---|---|---|
| Franz Lake | 5/4/09 | 8 | 7 | 8 | 0 | 8 | 0 | 8 | 8 |
| Lord-Walker Island | 5/3/09 | 6 | 4 | 6 | 0 | 6 | 0 | 6 | 6 |
| | 5/31/09 | 11 | 0 | 0 | 0 | 0 | 0 | 5 | 11 |
| Ridgefield | 5/4/09 | 31 | 31 | 31 | 1 | 10 | 21 | 31 | 31 |
| | 6/1/09 | 25 | 22 | 25 | 1 | 9 | 15 | 25 | 25 |
| | 6/28/09 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 3 |
| Ryan Island | 5/3/09 | 10 | 0 | 10 | 0 | 9 | 0 | 10 | 10 |
| | 5/31/09 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| | 6/29/09 | 10 | 4 | 10 | 0 | 10 | 0 | 10 | 10 |
| White Island | 4/5/09 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| | 5/3/09 | 10 | 1 | 10 | 0 | 10 | 0 | 10 | 10 |
| | 5/31/09 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 9 |
| | 6/29/09 | 2 | 2 | 2 | 0 | 2 | 0 | 2 | 2 |
| | 7/29/09 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Total** | | 133 | 75 | 102 | 2 | 64 | 36 | 107 | 133 |

**Invertebrate Prey Sampling Methods**
Our objective was to collect aquatic and terrestrial invertebrate samples that will help us identify the taxonomic composition and abundance of salmonid prey available at the time juvenile salmonids are collected. These data will be compared with the taxonomic composition of prey found in stomach contents of fish collected concurrently. We did three types of collections:

1. Open water column Neuston tows where n = 2 collections at each site at each sampling time. With this type of sampling, prey that are available to fish in the water column and on the surface of open water habitat were sampled. 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 was 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 the entire sample was covered.
2. Emergent vegetation Neuston tows where n = 2 collections at each site at each sampling time. With this type of sampling, prey associated with emergent vegetation and available to fish in shallow areas were collected. For each tow, the net was dragged through water and vegetation at the river margin where emergent vegetation was present and where the depth of water 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 where n = 2 collections at each site at each sampling time. With this type of sampling, terrestrial invertebrates that are associated with riparian vegetation and may be prey for fish in these habitats were sampled. 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 18 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 18: Invertebrate samples collected in 2009 as part of the EMP. The number reflects the total number of samples collected, including open water tows and emergent vegetation tows. An "*" indicates that juvenile salmonid stomachs were also collected at the site on the same date.**

| Site | Early April | Early May | Early June | Late June | Late July | Late August | Total |
|---|---|---|---|---|---|---|---|
| Campbell Slough | | 4* | 4* | 4 | 6 | 4 | 22 |
| Franz Lake | 6 | 4* | | 4 | 5 | | 19 |
| Ryan Island | 6 | 4* | 4 | 4* | 4 | 4 | 26 |
| White Island | 6 | 4* | 4 | 4 | 4 | 2 | 24 |
| Lord-Walker Island | 5 | 4* | 4* | 2 | 4 | 4 | 23 |
| **Total** | 23 | 20 | 16 | 18 | 23 | 14 | 114 |

### 7.5.2 Results
In 2009, we encountered considerable variation in water level at all of our sampling sites in Reach C and at Campbell Slough and Franz Lake (Figure 25). The high and variable water levels at the Franz Lake site in Reach H were due in part to Bonneville dam releases. Extreme high water levels made some sites inaccessible for sampling. The variation in water level in Reach C was partly due to tidal conditions. We tried to time our sampling to coincide with high tide, but this was not always possible. Thus, fish sampling could not occur every month at some sites (Figure 31; Figure 32; Table 19). At all sites, water temperature varied throughout the season, ranging from 7.8 – 10.7°C in April to 24.5 – 28.6°C in August

(Figure 26; Figure 31; Figure 32). Observed temperatures were similar throughout the season at Ryan Island, White Island, Lord Walker Island, and Franz Lake, whereas temperatures at Campbell Slough tended to be higher than the other sites. For instance, July temperatures for Campbell Slough were 24.2°C vs. 17.3-20°C for other sites.

**Fishing**

In spite of occasional sampling difficulties, our monitoring efforts in 2009 showed that juvenile salmon and other juvenile fish species were feeding and rearing at all Reach C sites as well as at and at Campbell Slough in Reach F and Franz Lake in Reach H (Table 20). Juvenile Chinook were captured at all five sites, with the percentage of total catch for the entire sampling period ranging from 0.5% at lowest site and sampling event to 3.8% at highest site (Table 20). Coho salmon were captured at two of the five sites (Franz Lake and Lord/Walker Island), at percentages ranging from 1 to 1.9% of total catch, and chum salmon were captured at four of the five sites, with the percentage of total catch ranging from 1 to 0.48%. Of the non-salmonid species, three-spine stickleback, carp, yellow perch and chiselmouth were the most abundant. Three-spine stickleback were the dominant species at all of the Reach C site (Lord Walk Island, Ryan Island, and White Island). Chiselmouth was the most abundant species at Franz Lake; and carp and yellow perch were the predominant species at Campbell Slough. Overall, Franz Lake and Campbell Slough had the greatest total number of species captured (19), with number of species captured at other sites ranging from 7 to 12.

Fish assemblages were analyzed for fish species diversity using the Shannon–Wiener diversity index (Margalev, 1958) after adjusting for fishing effort (CPUE, expressed as number per 1000 $m^2$). Campbell Slough and Franz Lake had the highest species diversity (Figure 27) while White Island had the lowest. Reach C sites had lower species diversity than either Campbell Slough or Franz Lake. This is reflected in the more equal percentage of different species captured at Campbell Slough and Franz Lake than other sites (Figure 27). While more total species were captured at Campbell Slough than at Franz Lake, when adjusted for fishing effort, species richness at Franz Lake was higher (Figure 27). This is reflected in the more equal percentage of different species captured at Campbell Slough and Franz Lake than other sites (Table 20).

Overall, Chinook salmon were the most abundant juvenile salmon species, representing 80% of all salmon captured. However, the proportion of salmonid catch that Chinook salmon represented varied from site to site (91%, 71%, 98%, 100%, and 35% at Lord/Walker Island, Ryan Island, White Island, Campbell Slough, and Franz Lake, respectively), and they were not the most abundant species at all sampling sites (Figure 28). Overall, coho salmon made up 7.6% of the total salmonid catch. Coho were the most abundant salmon species at Franz Lake where they made up 59% of the total salmon catch, but were absent from Campbell Slough in Reach F and Ryan Island and White Island in Reach C, and only made up 0.7% of the salmonid catch at Lord Walker Island in Reach C. Chum salmon accounted for 12% of the salmonid catch. They were most abundant at Ryan Island, where they made up 28.6% of the total salmonid catch; at the other sites, they represented 0 – 8.3% of the catch (Figure 28). In addition to salmon species, cutthroat trout and steelhead trout were caught at Lord/Walker Island, where they made up 1.7% and 3.4% of the total catch, respectively. Trout species were not found at any of the other sampling sites, and accounted for less than 1% of the salmonid catch overall. We collected chum salmon mainly in April, Chinook from April to July, and coho in May. The trout species were found in April only.

All collected chum salmon were unmarked (presumably wild fish), but both marked (hatchery) and unmarked (presumably wild) coho and Chinook salmon were generally found at the sites where these species were collected (Figure 28). Overall, 24% of Chinook and 77% of coho captured were marked hatchery fish. The proportions of marked, hatchery fish varied from site to site. At Lord/Walker Island, 2.3% of Chinook and 0% of coho were hatchery fish; at Ryan Island, 4.8% of Chinook were hatchery fish (no coho were observed); at White Island, 15% of Chinook were hatchery fish (no coho were observed); at Franz Lake, 35% of Chinook and 79% of coho were hatchery fish; and Campbell Slough, 96% of Chinook collected were of hatchery origin; no coho were collected from this site.

When adjusted for fishing effort, Chinook abundance increased from April until reaching a peak in May to early June, then declined rapidly (Figure 29) at most sites. At Franz Lake, abundance was similar in both April and May and then dropped to zero after May. Lord Walker Island had the highest peak abundance (May and early June), followed by White Island (May) and Campbell Slough (early June).

The mean length of all Chinook captured was significantly (p = 0.0001) higher at Campbell Slough than all other sites, and significantly (p =  0.0072) lower at Lord/Walker Island than all sites except Franz Lake (Figure 30). The collected hatchery fish were generally larger than wild fish (Table 21; Table 22;Figure 31; Figure 32). For Chinook, the mean length of unmarked fish ranged from 41 to 73 mm and weight from 0.5 to 5.7 g. In comparison, the mean length of marked Chinook ranged from 74 to 150 mm and weight from 0.5 to 31 g. For coho, the mean fork length of unmarked fish ranged from 40 to 132 mm and weight from 0.5 to 23 g, while the mean length of marked fish was 145 mm and weight was 32 g (Table 22). The unmarked Chinook were largest at Campbell Slough, with a mean length of 71 mm, and smallest at Franz Lake and Lord Walker Island were mean lengths ranged from 45-50 mm. White Island and Ryan Island were intermediate (mean length 55-58 mm).

Over the sampling season, the average length of unmarked juvenile Chinook tended to increase, and peaked in late June (Table 21; Figure 31). In contrast, the marked hatchery fish showed no clear temporal trends (Figure 32). One larger fish (150 mm), probably yearling Chinook, was collected in April at White Island, but fish were in the 75-85 mm range at all other sites and sampling events. Average length was highest in early June, 86 mm as compared to 79-80 mm in May and late June. Unmarked chum also tended to increase in size with time, with their average length increasing from 44 mm in April to 54 mm in May (Table 23). Changes in the size of coho salmon could not be evaluated because this species was captured in May only.

Condition factor was significantly lower in Chinook from Franz Lake (p = 0.0066) than all other sites (Figure 33). Overall, condition factor also increased from April to until it peaked in June. It should be noted that only one Chinook was captured in July, making it difficult to make interpretations of condition factor in Chinook after June. Condition factor between marked and unmarked Chinook was similar at most sites with no discernable pattern (Fig 16). Only at Franz Lake did unmarked Chinook have a significantly lower (p = 0.0015) condition factor than marked fish, while condition factor was significantly lower (p = 0.0480) in marked Chinook at Campbell Slough (Figure 34).

In summary, our sampling showed that wild juvenile Chinook, coho, and chum salmon are feeding and rearing in representative tidal freshwater sites in Reach C of the LCRE. Chum salmon were present in April and May only, but Chinook were using the sites from April through July, and coho were using the sites from April through the end of August. The sites also appear to function as nursery areas for other fish species. High water temperatures may have limited fish use of some sites in July and August. When reaches were compared, Reach C had higher proportions of chum salmon than either the Campbell Slough site in Reach F or the Franz Lake site in Reach H, whereas the Franz Lake site in Reach H had higher proportions of coho salmon than the sites in Reaches C and F. In comparison with Campbell Slough in Reach F, the sites in both Reaches C and H tended to have higher proportions wild Chinook salmon in small size classes.

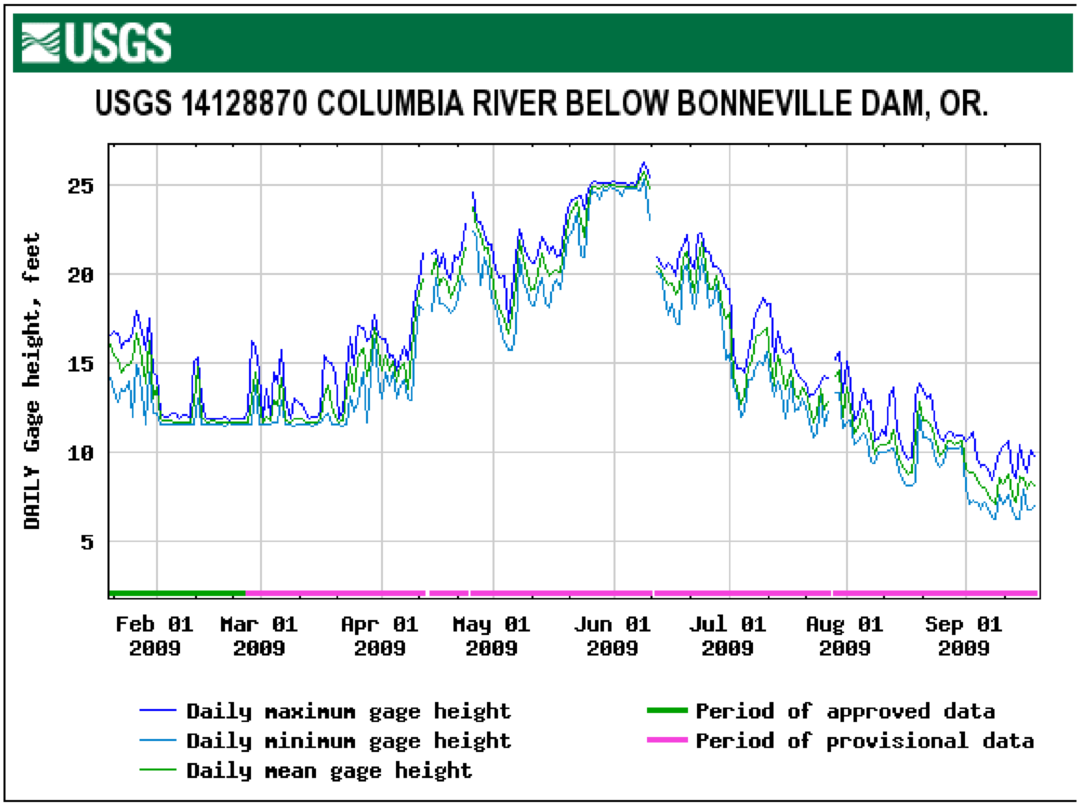



**Figure 25: Water depth (ft) below Bonneville Dam (Lat 45° 38'00", long 121° 57'33") over the salmon sampling period. Data provided by USGS.**

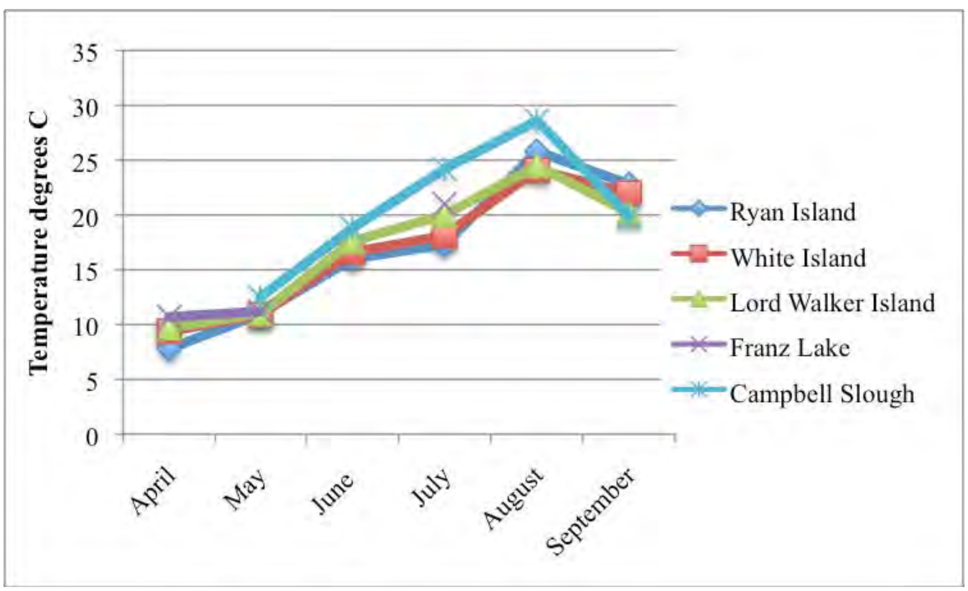



**Figure 26: Mean water temperature in degrees centigrade by month at each site.**

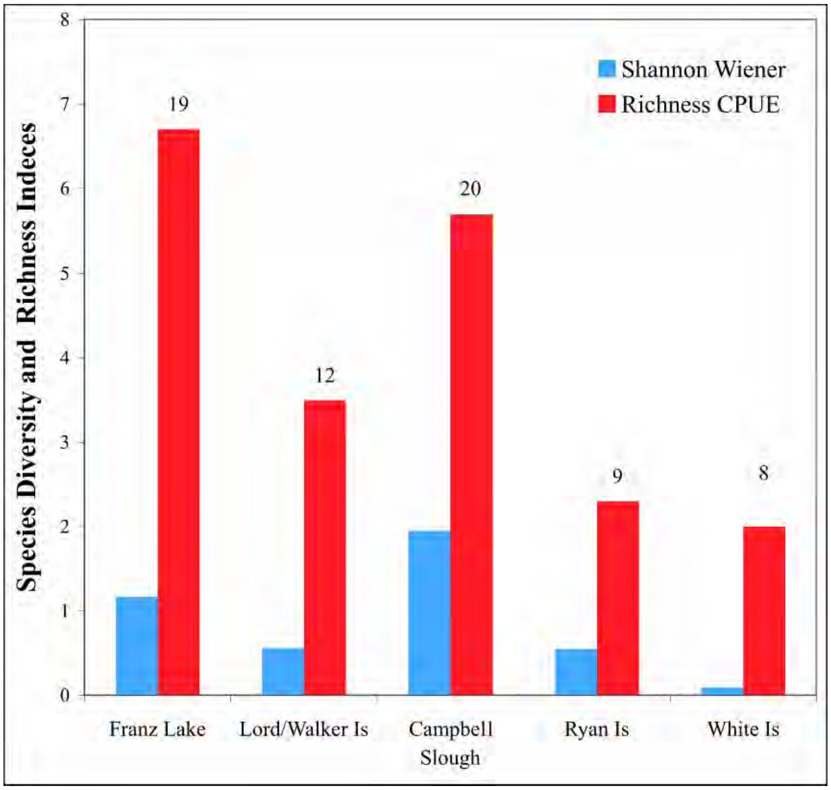



**Figure 27: Fish species diversity and species richness adjusted for fishing effort (expressed as number of species per 1000 m$^2$) at LCREP 2009 sites (number above bars = total number of species captures).**

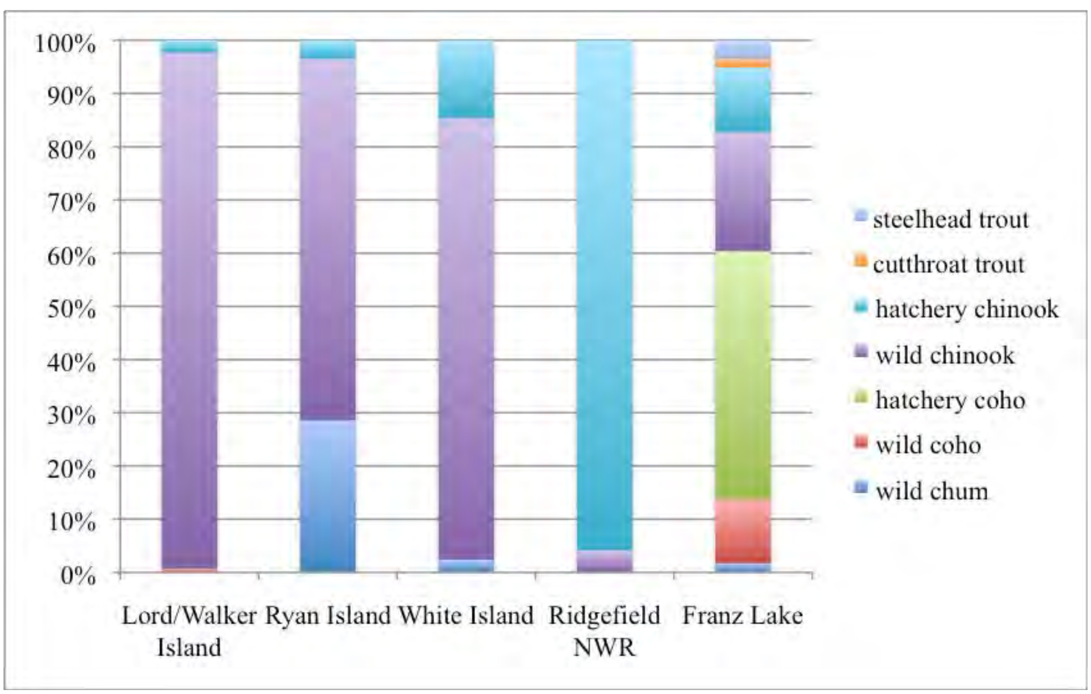



**Figure 28: Proportions of wild vs. hatchery salmon species collected at the 2009 EMP sites.**

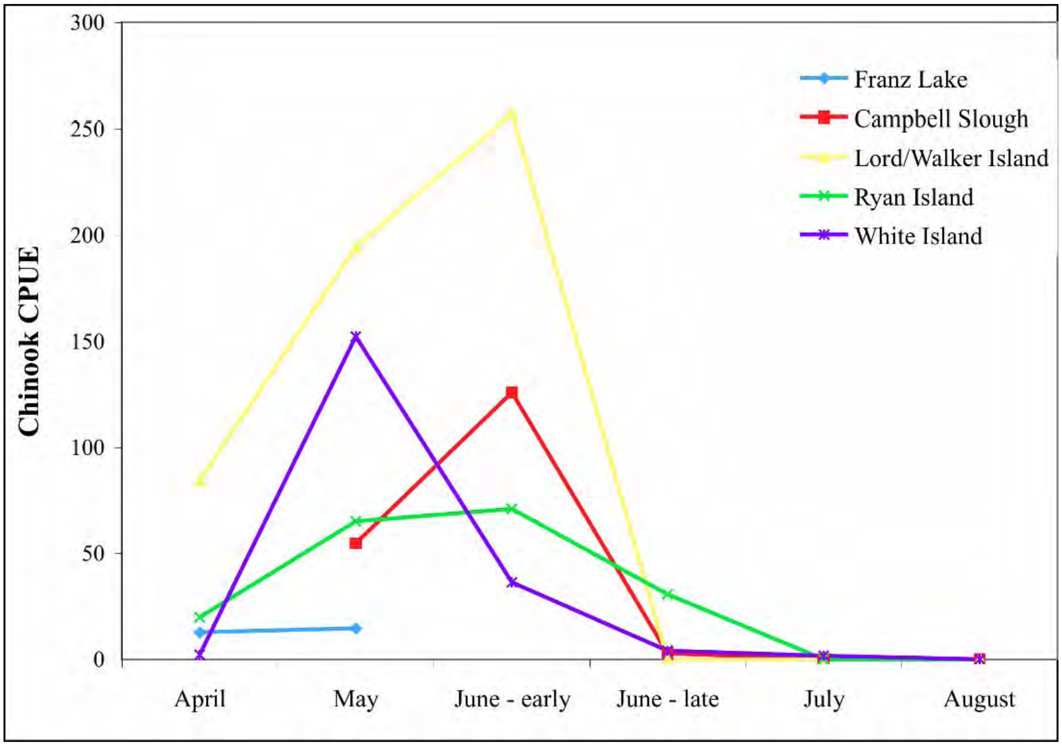



**Figure 29: Juvenile Chinook captured during 2009 when adjusted for fishing effort (number of fish per 1000 m$^2$).**

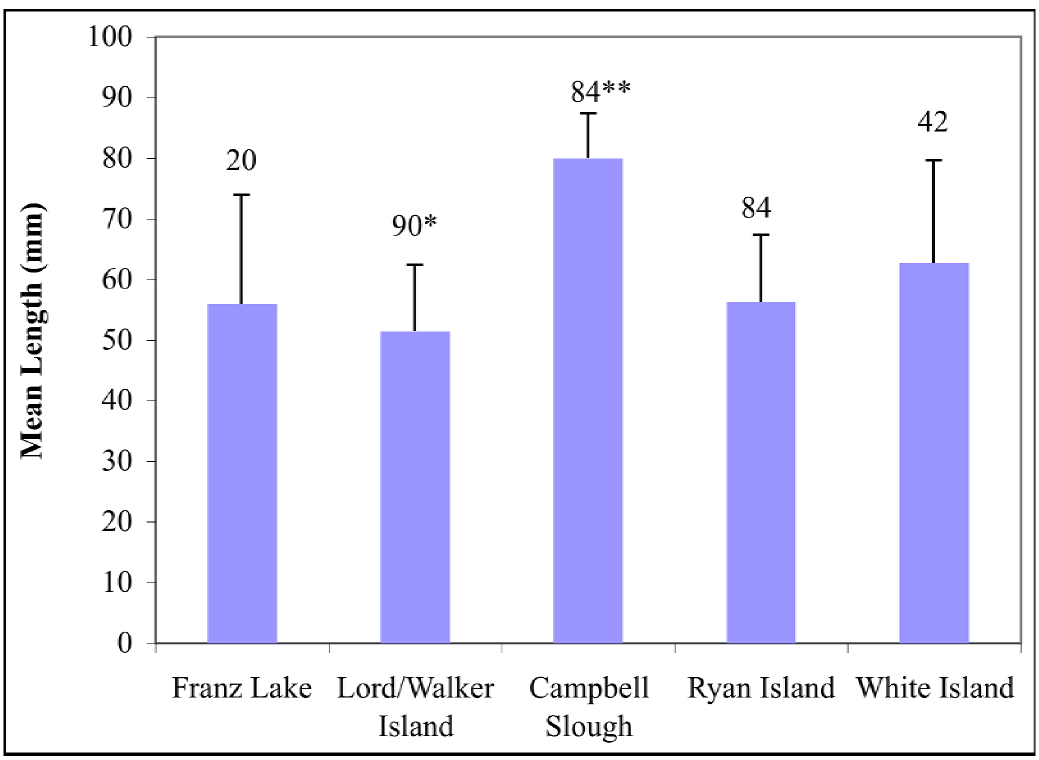



**Figure 30: Mean length of juvenile Chinook by site (** = significantly larger than all other sites, number above bars = number of fish measured).**

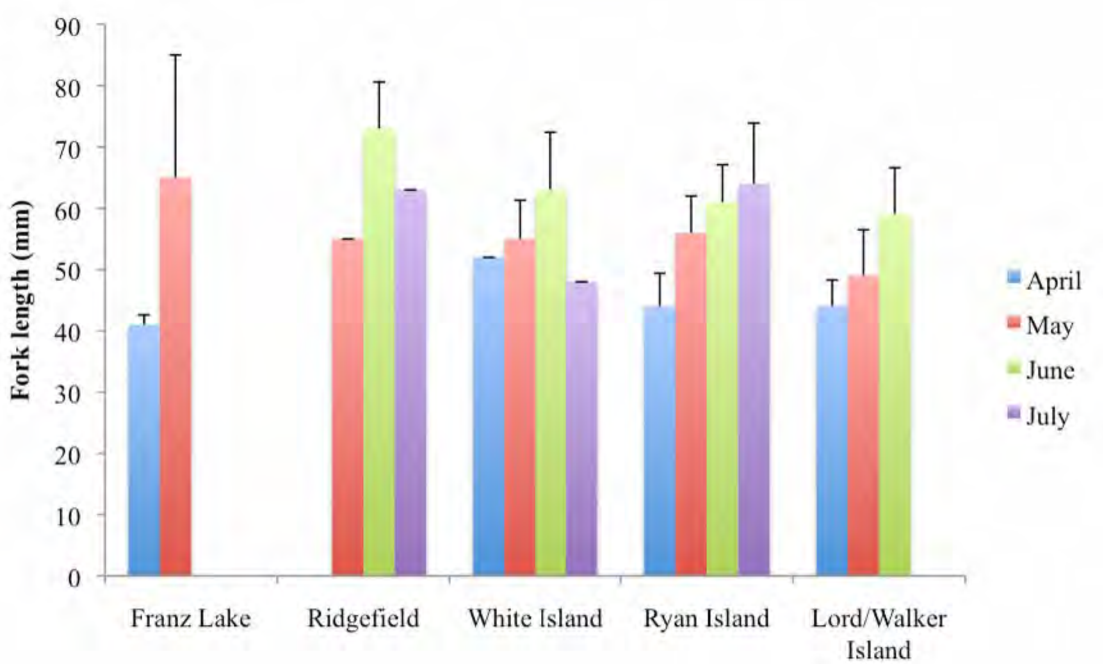



**Figure 31: Mean length (± SD) of unmarked (presumably wild) sub-yearling Chinook salmon over the sampling season at the 2009 EMP sites.**

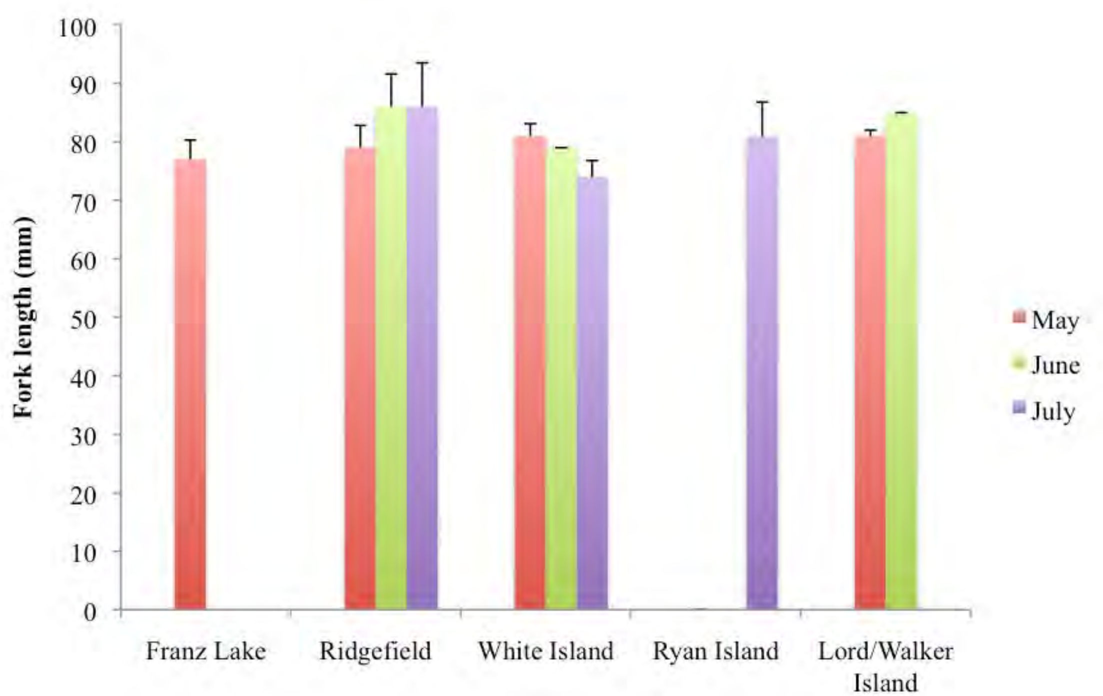



**Figure 32: Mean length (± SD) of marked, hatchery Chinook salmon over the sampling season at the 2009 EMP sites.**

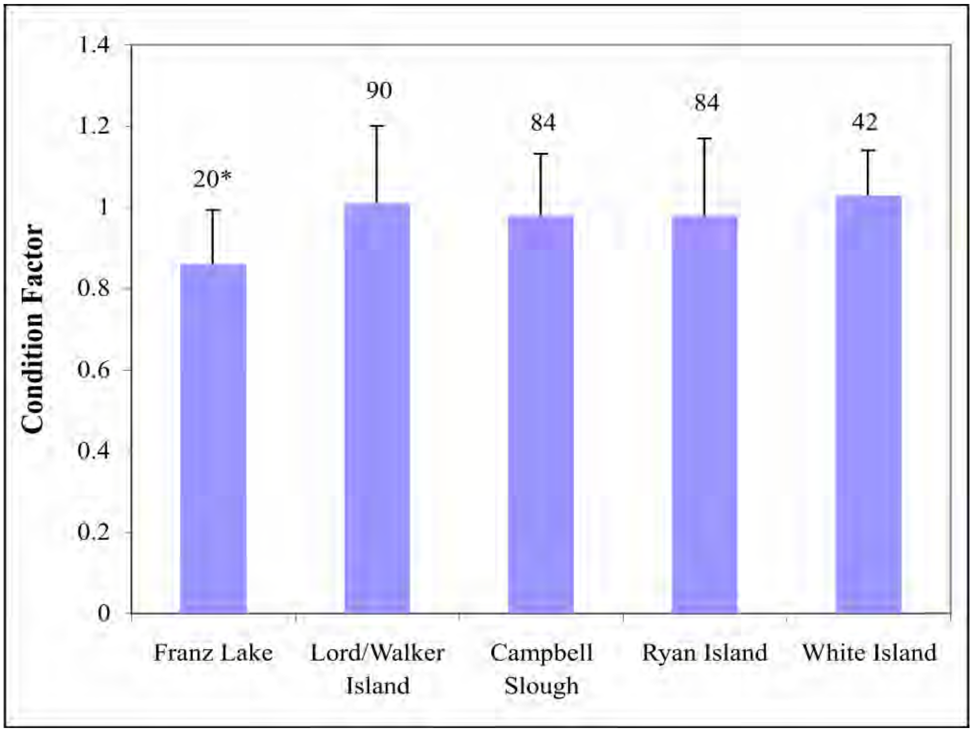



**Figure 33: Chinook condition factor at all sites in 2009 (* = significantly lower than all other sites, number above bars = number of Chinook measured).**

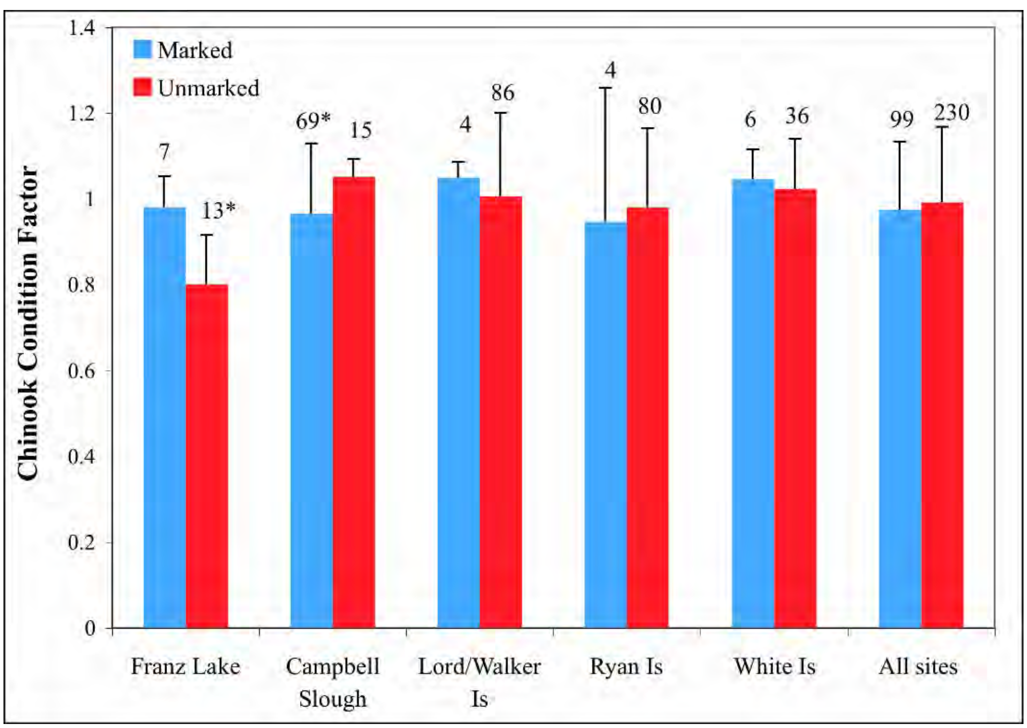



**Figure 34: Chinook condition factor at LCREP 2009 sites (number above bars = number of fish measured, * = significantly lower at same site).**

**Table 19: Average water temperature and fishing attempts at 2009 EMP fishing sites.**

| Site | Date | Temperature (°C) | Fishing Attempts |
|---|---|---|---|
| Ryan Island | 4/6/09 | 7.8 | 3 |
| | 5/4/09 | 11.0 | 2 |
| | 6/1/09 | 16.0 | 2 |
| | 6/29/09 | 17.3 | 2 |
| | 7/29/09 | 25.8 | 3 |
| | 8/25/09 | 22.8 | 1 |
| | 8/26/09 | 22.9 | 3 |
| White Island | 4/6/09 | 9.4 | 3 |
| | 5/4/09 | 10.9 | 2 |
| | 6/1/09 | 16.6 | 2 |
| | 6/29/09 | 18.3 | 3 |
| | 7/29/09 | 24.1 | 3 |
| | 8/26/09 | 22.0 | 3 |
| Lord-Walker Island | 4/7/09 | 9.7 | 2 |
| | 5/4/09 | 11.0 | 1 |
| | 6/1/09 | 17.6 | 1 |
| | 6/29/09 | 2 | 1 |
| | 7/29/09 | 24.5 | 3 |
| | 8/26/09 | 20.2 | |
| Franz Lake | 4/9/09 | 10.7 | 3[a] |
| | 5/5/09 | 11.2 | 2 |
| | Not sampled | NA | 0[b] |
| | 7/1/09 | 21.0 | 3 |
| | 7/28/09 | 28.2 | 3[a] |
| | Not sampled | NA | 0[c] |
| Campbell Slough | Not sampled | NA | 0[b] |
| | 5/5/09 | 12.5 | 2 |
| | 6/2/09 | 18.8 | 1 |
| | 6/28/09 | 24.2 | 3 |
| | 7/27/09 | 28.6 | 3 |
| | 8/25/09 | 19.9 | 3 |

Puget Sound Beach Seine was used to fish all of the sites except [a] where modified block net was used. [b] site not fishable due to extremely high water. [c] site not fishable due to low water level.

**Table 20: Total number of each species captured as a percentage of the total number of all individual fish captured.**

| Site | Date | # of Species | Largemouth bass | Smallmouth bass | Bluegill | Carp | Chisel-mouth | Chub | Crappie | Starry flounder | Goby | Banded killifish | Peamouth | Yellow perch | Northern pikeminnow | Pumpkinseed | Chum salmon | Chinook salmon | Coho salmon | Sculpin | Shad | Cutt-throat rout | Steelhead trout | Three-spine stickleback | Sucker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Franz Lake | 4/9 | 9 | | | | | | | | | | | 3.33 | | | 3.33 | 3.33 | 36.67 | 3.33 | 6.67 | | 3.33 | 6.67 | 33.33 | |
| | 5/5 | 6 | | | | | 91.65 | | | | | | | | 2.73 | | | 0.68 | 2.50 | 0.23 | | | | 2.20 | |
| | 7/1 | 10 | | 1.95 | | | 7.24 | 0.28 | | | | | 5.01 | 1.67 | 38.44 | | | | | 1.95 | 3.62 | | | 38.44 | 1.39 |
| | 7/28 | 8 | | 6.76 | | 29.73 | | | | | | 6.76 | 6.76 | | 10.81 | 10.81 | | | | | | | | 25.68 | 1.35 |
| | Total | 18 | | 0.67 | | 1.24 | 69.29 | 0.06 | | | | 0.28 | 1.35 | 0.34 | 10.22 | 0.51 | 0.06 | 1.12 | 1.91 | 0.67 | 0.73 | 0.06 | 0.11 | 11.01 | 0.34 |
| Lord-Walker Island | 4/7 | 6 | | | | | 0.23 | | | 2.32 | | 3.02 | | | | | 2.78 | 15.78 | | | | | | 75.87 | |
| | 5/4 | 3 | | | | | | | | | | | | | | | | 5.81 | | | | | | 89.87 | 4.32 |
| | 6/1 | 5 | | | | | 0.57 | | | 1.14 | | | | | | | | 7.98 | | | | | | 89.46 | 0.85 |
| | 6/29 | 2 | | | | | | | | | | | | | | | | | | 1.41 | | | | 98.59 | |
| | 7/29 | 4 | | | | | | | | | | 1.36 | 2.48 | | | | | | | 1.00 | | | | 95.15 | |
| | 8/26 | 8 | | | 0.07 | 0.04 | 0.15 | | | | | 15.38 | 1.16 | | | | | | 0.04 | 0.58 | | | | 82.58 | |
| | Total | 12 | | | 0.03 | 0.01 | 0.10 | | | 0.21 | | 7.02 | 1.40 | | | | 0.18 | 1.95 | 0.01 | 0.63 | | | | 88.01 | 0.43 |
| Campbell Slough | 5/5 | 3 | | | | | | | | | | | | | | | | 43.75 | | 2.08 | | | | 53.13 | |
| | 6/2 | 4 | | | | | | | | | | | | 1.52 | | | | 40.91 | | 1.52 | | | | 56.06 | |
| | 6/28 | 13 | | 0.34 | | 6.85 | 0.68 | | 0.34 | | | 1.03 | 0.68 | 40.41 | 3.77 | | | 1.03 | | 10.96 | 0.68 | | | 27.40 | 5.82 |
| | 7/27 | 11 | | 0.80 | | 46.61 | | 0.27 | 3.05 | | | 3.85 | 3.05 | 26.56 | 1.73 | 1.33 | | | | | | | | 7.57 | 0.27 |
| | 8/25 | 16 | 1.18 | 0.51 | 0.17 | 28.93 | 1.02 | 13.54 | 0.85 | | 0.85 | 3.89 | 0.34 | 36.55 | 0.17 | 2.37 | | | | | 7.28 | | | 0.68 | 1.35 |
| | Total | 18 | 0.39 | 0.56 | 0.06 | 30.14 | 0.44 | 4.56 | 1.61 | | 0.28 | 3.06 | 1.50 | 29.76 | 1.39 | 1.33 | | 4.00 | | 1.95 | 2.50 | | | 12.74 | 1.50 |
| Ryan Island | 4/6 | 3 | | | | | | | | | | | | | | | 5.36 | 4.94 | | | | | | 89.70 | |
| | 5/4 | 3 | | | | | | | | | | | | | | | 2.74 | 8.22 | | | | | | 89.04 | |
| | 6/1 | 7 | | | | 1.01 | 3.03 | | | 5.05 | | | | | | | 1.01 | 17.17 | | | | | | 70.71 | 2.02 |
| | 6/29 | 4 | | | | | 0.40 | | | 0.35 | | | | | | | | 0.75 | | | | | | 98.50 | |
| | 7/29 | 4 | | | | 0.11 | | | | | | 1.26 | 30.11 | | | | | | | | | | | 68.53 | |
| | 8/25 | 4 | | | | | 12.30 | | | | | 0.82 | 1.81 | | | | | | | | | | | 85.07 | |
| | Total | 9 | | | | 0.02 | 6.21 | | | 0.15 | | 0.55 | 4.21 | | | | 0.49 | 1.22 | | | | | | 87.14 | 0.02 |
| White Island | 4/6 | 3 | | | | | | | | 1.02 | | | | | | | | 1.02 | | | | | | 97.97 | |
| | 5/04 | 3 | | | | | | | | | | | | | | | 0.79 | 15.87 | | | | | | 83.33 | |
| | 6/1 | 4 | | | | | 3.61 | | | | | | | | | | | 16.87 | | | | | | 78.31 | 1.20 |
| | 06/29 | 6 | | | | | 0.16 | | | 0.04 | | 0.48 | | | | | | 0.12 | | 0.04 | | | | 99.17 | |
| | 07/29 | 3 | | | | | | | | | | | 0.37 | | | | | 0.05 | | | | | | 99.57 | |
| | 08/26 | 2 | | | | | 1.51 | | | | | | | | | | | | | | | | | 98.49 | |
| | Total | 9 | | | | | 0.71 | | | 0.04 | | 0.15 | 0.09 | | | | 0.01 | 0.49 | | 0.01 | | | | 98.50 | 0.01 |

**Table 21: Mean fork length in mm and weight in grams (± SD) of marked (hatchery) and unmarked (presumably wild) sub-yearling Chinook salmon by month at the 2009 EMP sites.**

| | | Unmarked Chinook | | | Marked Chinook | | |
|---|---|---|---|---|---|---|---|
| Site | Date | n | Fork length (mm) | Weight (g) | n | Fork length (mm) | Weight (g) |
| Franz Lake | 4/9/09 | 11 | 41.0 ± 1.6 | 0.5 ± 0.1 | | | |
| | 5/5/09 | 2 | 65.0 ± 19.8 | 3.1 ± 2.4 | 7 | 77.0 ± 3.3 | 4.5 ± 0.6 |
| Lord-Walker Island | 4/7/09 | 37 | 44.2 ± 4.3 | 0.8 ± 0.3 | 0 | - | - |
| | 5/4/09 | 22 | 49.1 ± 7.5 | 1.4 ± 0.7 | 3 | 81.0 ± 1.0 | 5.7 ± 0.2 |
| | 6/1/09 | 27 | 58.9 ± 7.6 | 2.1 ± 0.9 | 1 | 85.0 ± | 6.2 ± |
| | 8/26/09 | 0 | - | - | 0 | - | - |
| Campbell Slough | 5/5/09 | 1 | 55.0 ± | 1.8 ± | 41 | 79.2 ± 3.8 | 4.7 ± 0.8 |
| | 6/2/09 | 13 | 73.2 ± 7.6 | 4.2 ± 1.3 | 26 | 85.8 ± 5.6 | 6.7 ± 1.4 |
| | 6/28/09 | 1 | 63.0 ± | 5.7 ± | 2 | 85.5 ± 0.7 | 7.5 ± |
| Ryan Island | 4/6/09 | 21 | 43.5 ± 5.4 | 0.7 ± 0.3 | 0 | - | - |
| | 5/4/09 | 28 | 55.9 ± 6.0 | 1.7 ± 0.6 | 0 | - | - |
| | 6/1/09 | 18 | 60.9 ± 6.1 | 2.7 ± 1.0 | 0 | - | - |
| | 6/29/09 | 13 | 63.5 ± 9.9 | 2.9 ± 1.2 | 4 | 80.5 ± 5.8 | 5.0 ± 1.9 |
| White Island | 4/6/09 | 1 | 52.0 ± | 1.4 ± 1.4 | 1 | 15 ± | 31 ± |
| | 5/4/09 | 18 | 54.9 ± 6.3 | 1.7 ± 0.6 | 2 | 80.5 ± 2.1 | 5.6 ± 0.6 |
| | 6/1/09 | 13 | 62.5 ± 9.4 | 2.9 ± 1.2 | 1 | 79.0 ± | 5.1 ± |
| | 6/29/09 | 1 | 48.0 ± | 0.9 ± | 2 | 74.0 ± 2.8 | 4.5 ± 0.6 |

**Table 22: Mean length and weight (± SD) of juvenile Coho salmon at the 2009 EMP sites by month of capture. Coho salmon were captured only at the Franz Lake and Lord/Walker Island sites. No coho salmon were captured at Franz Lake after May.**

| | | Coho unmarked | | | Coho marked | | |
|---|---|---|---|---|---|---|---|
| Site | Date | n | Fork Length (mm) | Weight (g) | n | Fork Length (mm) | Weight (g) |
| Franz Lake | 4/9/09 | 1 | 4 ± | 0.5 ± | 0 | - | - |
| Franz Lake | 5/5/09 | 7 | 131.6 ± 12.1 | 22.6 ± 5.4 | 26 | 145.2 ± 6.8 | 31.9 ±4.0 |
| Lord-Walker Island | 8/26/09 | 1 | 57.0 ± | 1.8 ± | 0 | - | - |

**Table 23: Mean length and weight (± SD) of juvenile Chum salmon at the 2009 EMP sites by month of capture.**

| Site | Date | Marked | n | Fork Length (mm) | Weight (g) |
|---|---|---|---|---|---|
| Franz Lake | 4/9/09 | N | 1 | 41.0 ± | 0.4 ± |
| Lord-Walker Island | 4/7/09 | N | 13 | 41.6 ± 3.0 | 0.5 ± 0.1 |
| Ryan Island | 4/6/09 | N | 27 | 45.9 ± 4.2 | 0.8 ± 0.2 |
| Ryan Island | 5/4/09 | N | 16 | 54.7 ± 6.3 | 1.1 ± 0.5 |
| White Island | 5/4/09 | N | 1 | 56.0 ± | 1.6 ± |

**Table 24: Mean length (± SD) of trout species captured at the 2009 EMP sites by month of capture.**

| Site | Date | Species | Marked | n | Fork Length (mm) |
|---|---|---|---|---|---|
| Franz Lake | 04/09/09 | Cutthroat trout | Y | 1 | 236.0 ± |
| Franz Lake | 04/09/09 | Steelhead trout | Y | 2 | 216.5 ± 26.2 |

**Salmonid Prey Availability Surveys and Chinook Diet Analyses**

We are 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 is to use these data to identify potential sources of contaminants affecting fish in the LCRE.

In 2009, we sampled invertebrates at five Columbia River sites in an effort to assess the diversity and relative abundance of prey available to juvenile salmonids. These collections coincided with collections of juvenile salmonids, so that when sufficient numbers of fish were collected the taxonomic composition and abundance of consumed prey can be compared with available prey. We collected 114 samples over 6 sampling periods (Table 18), and corresponding diets were collected from all sites in early May and rarely after that (Table 17; Table 18). We used Neuston nets, towed by boat for open water collections or by hand through emergent vegetation, to collect invertebrates in the water column that would be available to foraging fish. Samples are currently being processed by the Northwest Fisheries Science Center and by Rhithron Associates.

**Otolith Analyses for Growth Rate Determination**

As part of the Ecosystem Monitoring salmon sampling in 2009, otoliths were collected from juvenile fall Chinook salmon from Reach C sites, Campbell Slough, and Franz Lake. The otoliths are now being processed, and reported on in 2010 annual report to BPA.

**Biochemical Measures of Salmon Growth and Condition**

To measure biochemical indicators of salmon growth and condition, we collected salmon whole bodies for analysis of lipid content and classes. Analyses of whole bodies for lipid content and classes are now in progress for the sub-yearling juvenile Chinook salmon collected in 2008, with analyses of the 2009 samples to follow. At this point, we have data for two composite 2008 samples, one from Franz Lake and one from Campbell Slough. The lipid content of juvenile Chinook at these two sites was very similar, about 1.3% at both sites (Figure 35). These levels are similar to those observed at the Salmon and Water Quality sites between Portland Harbor and Beaver Army Terminal, and lower than lipid levels found in salmon from Warrendale and Point Adams (Figure 36). Interestingly, although their lipid content was similar, the distribution of lipid classes differed between the Franz Lake and Campbell Slough, with the fish from the Franz Lake site having a higher proportion of triglycerides than those from Ridgefield (Figure 37).

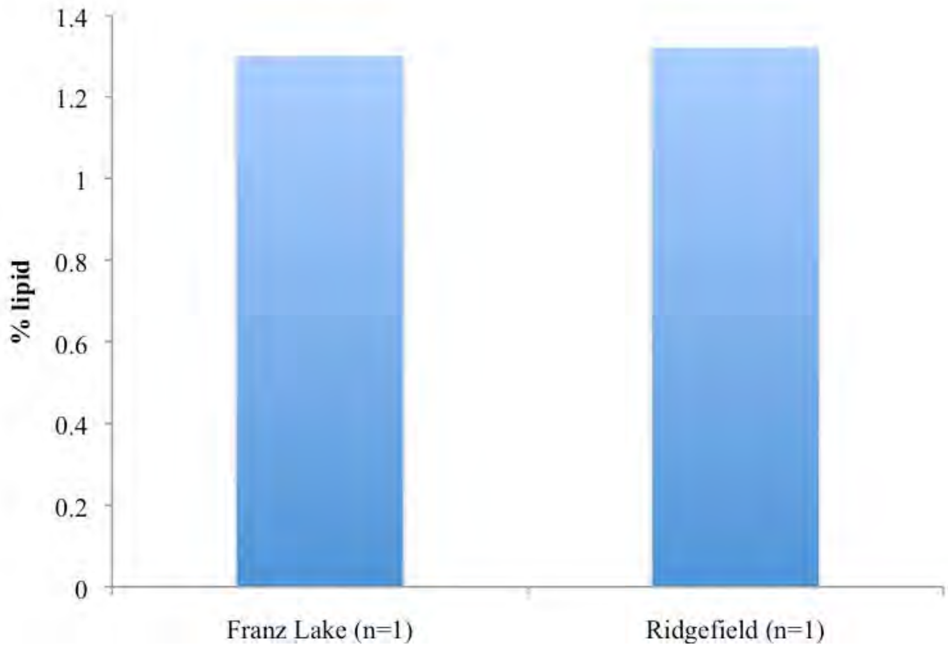



**Figure 35: Lipid content of juvenile Chinook salmon whole body samples from Campbell Slough (Ridgefield) and Franz Lake (Data for Franz Lake only available at this time).**

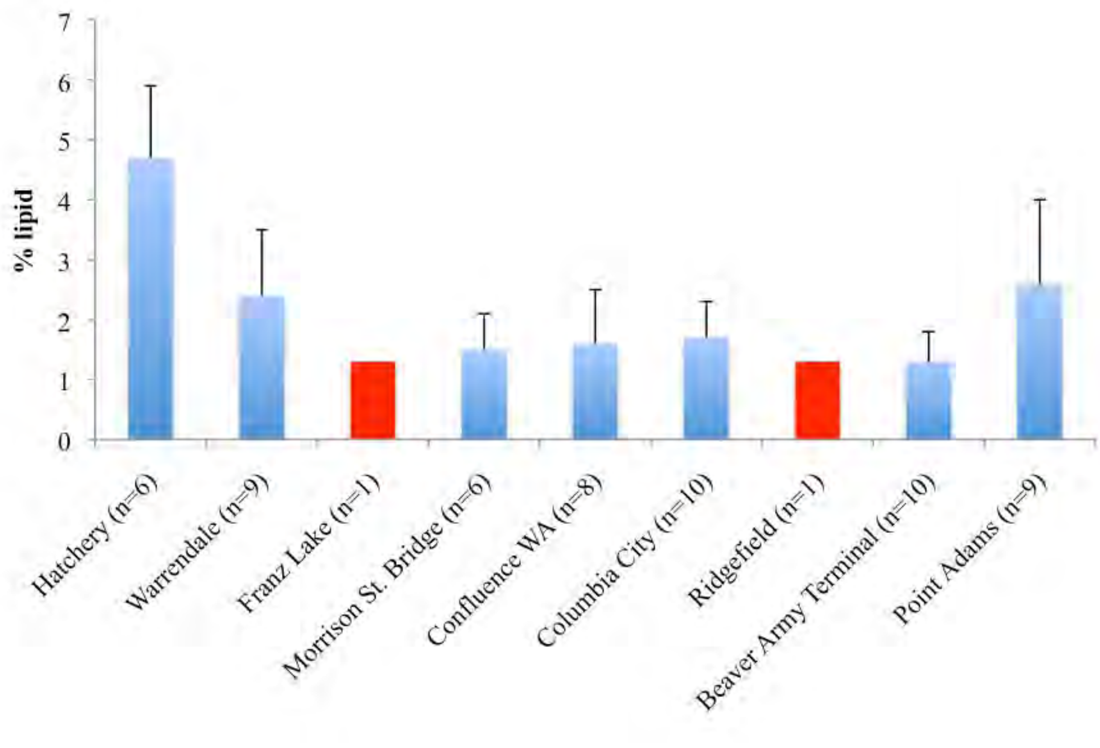



**Figure 36: Lipid content of subyearling Chinook salmon sampled in 2008 from Franz Lake in Reach H and Ridgefield in Reach F, as compared to lipid levels in juvenile chinook salmon sampled as part of the Salmon and Water Quality Study (LCREP, 2007).**

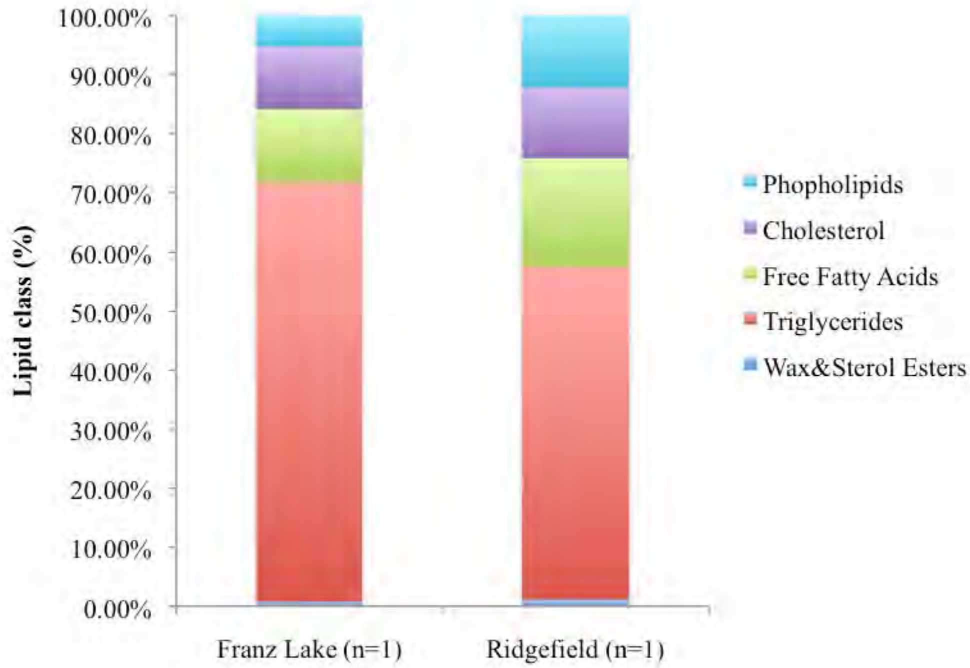



**Figure 37: Lipid classes of juvenile Chinook salmon whole body samples from Campbell Slough (Ridgefield) and 2008 Ecosystem monitoring sites in Reach H (Data for Franz Lake only available at this time).**

**Genetic Stock Identification of Juvenile Salmon Collected in 2009**
In 2009, fin clips were collected for genetic analyses from how 132 juvenile Chinook from Campbell Slough, Franz Lake, Lord/Walker Island, Ryan Island, and White Island (Table 17). Genetic samples collected from juvenile Chinook salmon at the 2009 monitoring sites are currently being analyzed. These data will be included in the 2010 annual report to BPA.

**Contaminants in Whole bodies of Chinook Salmon Collected in 2008**
Concentrations of persistent organic pollutants are being determined in whole bodies of juvenile Chinook salmon collected in 2008 and 2009 from Campbell Slough, Franz Lake, and other sites in Reaches C and H. At this point, data are available for juvenile Chinook from two of the 2008 sites, Campbell Slough and Franz Lake (Figure 38). The major contaminants in the Franz Lake salmon were DDTs, although low levels of PBDEs and PCBs were also detected. In the fish from Campbell Slough, DDTs were also present, at concentrations similar to those found in the fish from Franz Lake. Additionally, bodies of these fish contained PBDEs and PCBs at concentrations several times higher than those observed in fish from Franz Lake (Figure 38). In fish from both sites, however, concentrations of DDTs and PCBs are below estimated effect threshold concentrations (Meador et al., 2002; Johnson et al., 2007; Beckvar et al., 2005), suggesting that contaminant levels at these sites are below those that would harm juvenile Chinook. In comparison to contaminant concentrations measured in juvenile Chinook as part of the Salmon and Water Quality Study (LCREP, 2007), concentrations of PCBs and PBDEs in salmon from Campbell Slough and Franz Lake are relatively low, while concentrations of DDTs are similar to those observed in fish from most of the previously sampled sites (Figure 39).

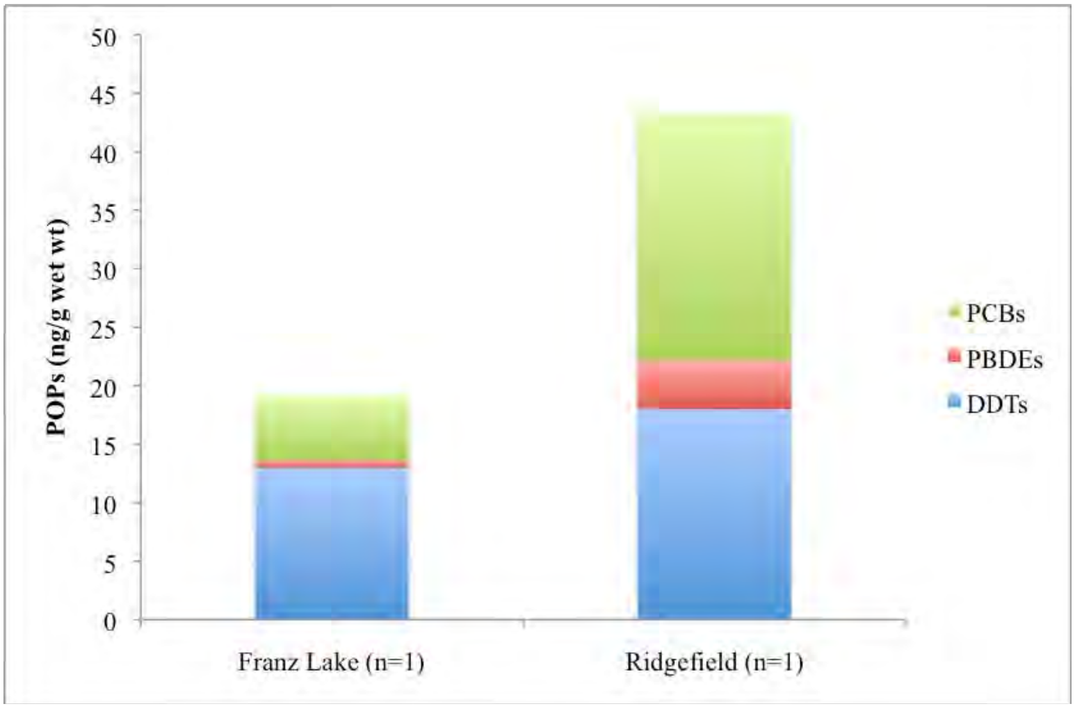



**Figure 38: Concentrations of PCBs, PBDEs, and DDTs (ng/g wet wt and ng/g lipid) in juvenile Chinook salmon collected from Franz Lake in Reach H and Campbell Slough (Ridgefield) in Reach F in 2008.**

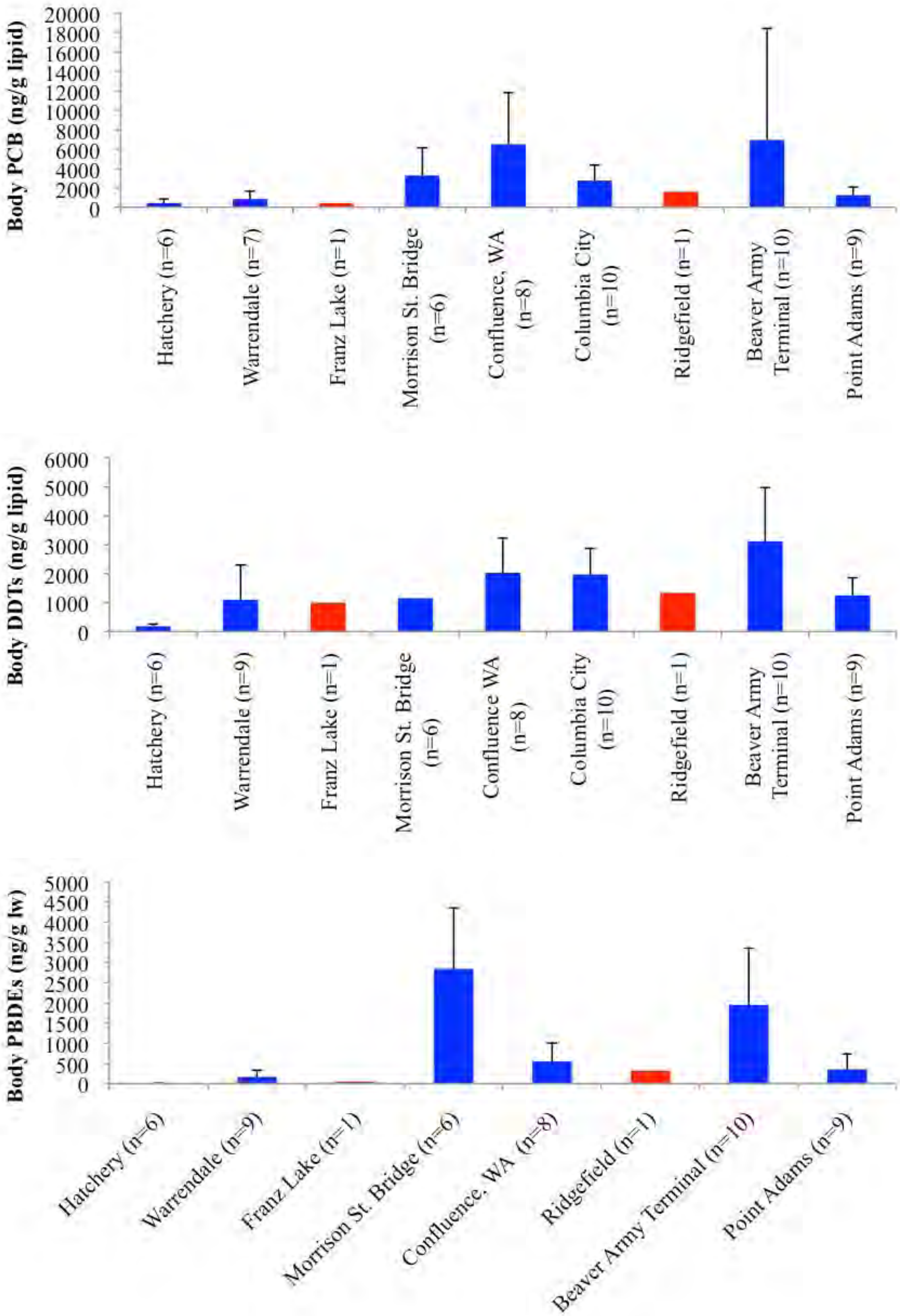



**Figure 39: Concentrations of PCBs, DDTs, and PBDEs (ng/g lipid) in juvenile Chinook salmon from Franz Lake and Ridgefield (Campbell Slough) sites sampled in 2008, as compared to concentrations in juvenile salmon sampled as part of the Salmon and Water Quality Study (LCREP, 2007).**

### 7.5.3 Summary

Our sampling showed that wild juvenile Chinook, coho, and chum salmon are feeding and rearing in representative tidal freshwater sites in Reach C of the LCRE. Chum salmon were present in April and May only, but Chinook were using the sites from April through July, and coho were using the sites from April through the end of August. The sites also appear to function as nursery areas for other fish species. High water temperatures may have limited fish use of some sites in July and August. When reaches were compared, Reach C had a higher proportion of chum salmon than either the Campbell Slough site in Reach F or the Franz Lake site in Reach H, whereas the Franz Lake site in Reach H had a higher proportion of coho salmon than the sites in Reaches C and F. In comparison with Campbell Slough in Reach F, the sites in both Reaches C and H tended to have higher proportions wild Chinook salmon in small size classes. Also, species richness and diversity tended to be higher at Campbell Slough and Franz Lake than at the Reach C sites, and non-salmonid species composition differed among the sites. At all the sampling sites, unmarked juvenile Chinook tended to increase in size over the sampling season, whereas hatchery Chinook did not. Condition factor of juvenile Chinook also ended to increase over the sampling season. Unmarked juvenile Chinook sampled from Franz Lake in 2009 had a lower condition factor than fish from the other sites, although it is not clear whether this was due to site conditions or to the fact that the majority of fish from this sites were captured early in the sampling season. Lipid content was similar in juvenile Chinook from sampled from Franz Lake and Campbell Slough in 2008. The lipid content of these fish was comparable to lipid levels observed in juvenile Chinook from sites between the Columbia Willamette Confluence and Beaver Army Terminal in the Salmon and Water Quality study (LCREP, 2007), but lower than lipid levels report in the same study for fish from Warrendale and Point Adams (LCREP, 2007). Preliminary data on contaminant concentrations in juvenile salmon from Franz Lake and Campbell Slough suggest that exposure to toxicants is somewhat higher in Campbell Slough fish than in Franz Lake fish, body burdens of PCBs, DDTs, and PBDEs are relatively low at both sites in comparison to other areas that have been sampled in previous studies.

## 7.6 Emergent Wetland Monitoring Efforts Planned for 2009-2010

In 2009-2010, monitoring partners will collect datasets at 3-4 new emergent wetlands in a TBD reach of the LCRE and revisit 2-3 previously sampled sites in Reaches C, F, and H. Additionally, the Estuary Partnership and partners will compile multiple years of data for 2 sites (Campbell Slough in Reach F and Franz Lake in Reach H; see Table 5 for a brief summary of sampling effort), and conduct a preliminary synthesis of those datasets. This preliminary synthesis task will support on-going efforts to report monitoring results to BPA and regional partners. The synthesis findings will be presented to the Science Work Group in fall 2010.

# 8.0 Characterization of Forested Tidal Freshwater Wetlands in the LCRE

Freshwater tidal wetlands are a relatively rare ecosystem, existing only where tidal influences extend beyond the reach of saline water. The freshwater tidal forested wetlands of the Columbia River estuary, located on the western coast of North America, have not been studied in detail, despite the fact that they occupy a significant portion of the ~235 km extent of the Columbia River estuary. They provide essential habitats for juvenile salmonids (*Oncorhynchus* spp.), many of which are listed as threatened or endangered under the United State's Endangered Species Act (Bottom et al., 2005). Hydro-regulation of the Columbia River and urbanization of its watershed and floodplain has likely had a tremendous impact on this estuarine ecosystem. While detailed studies have been conducted on emergent marsh ecosystems and physical processes in the lower Columbia River estuary, only preliminary work has explored freshwater tidal forested and scrub-shrub wetlands of the Columbia River estuary, and seldom from a comprehensive community structure perspective (Christy and Putera, 1993; LCREP, 1999; Diefenderfer, 2007). Comprehensive ecological characterizations are necessary to build a baseline data set and conceptual model of the ecosystem components and structure that can be used to assess future changes due to anthropogenic or climatic alterations in the Columbia River watershed.

The goal of the study is to quantitatively characterize six tidal forested wetlands along the freshwater tidal portion of the Columbia River estuary. A community profile will be constructed from the quantitative assessment, focusing on associations among particular species within the ecosystems and the environmental factors that determine these associations. Sites were selected to capture variation among the 8 hydrogeomorphic reaches of the estuary delineated by the Classification (Figure 1; Simenstad et al., 2007). Remotely sensed imagery will be used to discern how patterns present in the tree canopy topography and shoreline geomorphology relate to physical factors present in the river system such as landscape setting, extent of tidal inundation, and seasonal flooding, and potentially utilized to extrapolate the site-specific characterization to broader areas of tidal forested wetlands in the estuary. The field studies will gather data on both biotic and abiotic components at the sites 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 design. The completed community profile will provide a better understanding of the relationships between biotic and abiotic components of the Columbia River ecosystem.

## 8.1 Sites

Candidate sites for field studies were selected by examining current satellite imagery of the Columbia River estuary 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, Estuary Partnership, and field visits. Sites were selected based upon the presence of relatively un-impacted 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 40; Table 25). Results from research in 2008 demonstrated that Big Creek, which is a Sitka spruce tidal swamp, differed dramatically from the black cottonwood-dominated riparian floodplain forests located at Willow Bar and Mirror Lake. Three additional sites, Julia Butler Hansen Wildlife Refuge, Robert W. Little Preserve, and Willow Grove, were selected for data collection in the 2009 field season. All of the 2009 sites were located between Big Creek and Willow Bar in order to capture the transition in forested wetlands that was found to occur between those two sites.

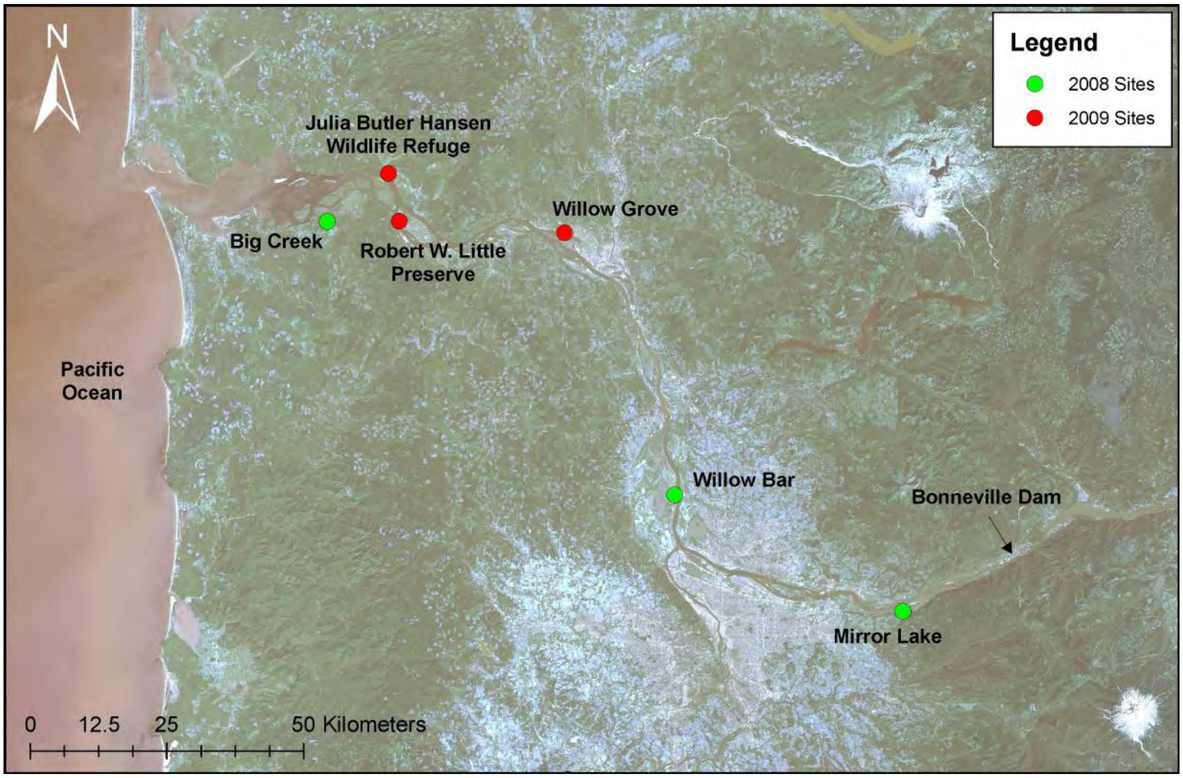



**Figure 40: Study site locations for community characterization of tidal forested wetlands of the Columbia River estuary.**

**Table 25: Coordinates (DD MM.SS) of tidal forested wetland samplings sites.**

| Site Name | Latitude (N) | Longitude (W) |
|---|---|---|
| Big Creek | 46 11.070 | 123 35.61 |
| Julia Butler Hansen | 46 15.86 | 123 26.91 |
| Robert W. Little | 46 11.14 | 123 25.38 |
| Willow Grove | 46 16 | 123 01.87 |
| Willow Bar | 45 44.15 | 122 46.29 |
| Mirror Lake | 45 32.56 | 122 14.31 |

**Julia Butler Hansen Wildlife Refuge.** Julia Butler Hansen Wildlife Refuge is located at approximately RKm 53, near Cathlamet, Washington. The Refuge was established in 1972 to protect the endangered Columbian white-tailed deer, and is managed by the United States Fish and Wildlife Service. The Refuge contains over 6,000 acres including Sitka spruce tidal swamps that were once common in the Columbia River estuary. The wetland vegetation assemblage at the Refuge is similar to that of Big Creek, consisting primarily of Sitka spruce (*Picea sitchensis*), Sitka willow (*Salix sitchensis*), red osier dogwood (*Cornus stolonifera*), and red alder (*Alnus rubra*), with the addition of black cottonwood trees (*Populus balsamifera* spp. *trichocarpa*) (Figure 41). The sampling location selected for this study is situated on the mainland portion of the Refuge across from Price Island. Tidal fluctuation at this location, based on the nearby tidal gauge at Skamokawa, Washington, is approximately 1.9-2.3 m.

**Figure 41: Tidal forested wetlands at Julia Butler Hansen Wildlife Refuge.**

**Robert W. Little Preserve.** The Robert W. Little Preserve is positioned at approximately RKm 63 on Puget Island, Washington. The Preserve is owned and managed by the Nature Conservancy, and contains about 30 acres of native Sitka spruce tidal forested wetlands. Tidal fluctuation at the site is approximately 1.8-2.1 m, based on the nearby tidal station at Wauna, Oregon. The vegetation assemblage at the Preserve is dominated by Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), black cottonwood (*Populus balsamifera* spp. *trichocarpa*), red osier dogwood (*Cornus stolonifera*), and Pacific willow (*Salix lucida ssp. Lasiandra*) (Figure 42).

**Figure 42: Tidal forested wetlands at the Robert W. Little Preserve.**

**Willow Grove.** Willow Grove, located at approximately RKm 97, was acquired by the Columbia Land Trust for conservation purposes in August 2008. Willow Grove contains 312 acres and includes a variety of wetland habitats including tidal channels, emergent marshes, and tidal forested wetlands. The forested wetland vegetation assemblages are the focus of this study, and are composed primarily of black cottonwood (*Populus balsamifera* spp. *trichocarpa*), Pacific willow (*Salix lucida ssp. Lasiandra*), and Oregon ash (*Fraxinus latifolia*) (Figure 43). Tidal fluctuation at the site is estimated to be 1.1-1.4 m, based on the nearby tidal station at Longview.

**Figure 43: Tidal forested wetlands at Willow Grove.**

## 8.2 Methods

### 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. 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, the sites studied in 2009 tended to transition immediately to emergent vegetation zones, resulting in no data for the aquatic zone at those sites.
Sediment Percent Organic Content. Along each transect and zone, we collected sediment cores which will be analyzed for percent organic content, using standard laboratory procedures to burn and weigh sediments. The results will contribute to the physical profile of the sites, and will be used to test for similarity between forested wetland sites. The samples will be analyzed in September or October 2009.
Sediment Grain Size. We will also analyze the sediment cores described above for grain size, using a Sedigraph 5100 machine. The sediment grain size results will contribute to the physical profile of the sites, and will be used to test for similarity between forested wetland sites. The samples will be analyzed in September or October 2009.

### Vegetation

We use 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.

**Benthic Macroinvertebrates**
We acquired one 5-cm dia. (19.6 $cm^2$) benthic core to 10-cm 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. All of the samples collected in the field have been analyzed in the laboratory.

**Terrestrial Insects**
One insect fall-out trap was placed 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. All of the samples collected in the field have been analyzed in the laboratory.

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

**Avifauna**
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 bird surveys at this year's study sites will be conducted in October 2009.

**Small Mammals**
We surveyed small mammals present at the sites using visual sightings and track 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).

## 8.3 Results

**Status of Statistical Analyses and Final Results**

Statistically supported results for the all of the sites are unavailable at this time, because 2009 sites are still in the data gathering and laboratory analysis phase. Results will be available in spring 2010, after the completion of data collection and statistical analysis. Data analysis will be accomplished using multivariate statistics methods such as ordination and cluster analysis. The analyses will test site similarity and the relationship of vegetative and faunal assemblages to physiochemical factors such as soil texture and amount of tidal inundation. Due to the incomplete nature of the laboratory analysis for sediment grain size and percent organic content, preliminary results or impressions are not yet available for these categories.

**Preliminary Results for 2008 Sites**

Preliminary statistical analyses of the three sites studied in 2008 indicate that while all sites are distinct from one another in terms of vegetation and faunal assemblages, Willow Bar and Mirror Lake are more similar to one another than Big Creek is to either site. Willow Bar and Mirror Lake both appear to function as a riparian floodplain forest, while Big Creek functions as a Sitka spruce/Western red cedar tidal swamp. Both Willow Bar and Mirror Lake 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 as well. The birds and small mammals observed at the two sites are more similar to one another than to those 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 two 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.

Tidal fluctuations and peak river flows also differ greatly between the two upriver sites and Big Creek. Both Willow Bar and Mirror Lake have tidal fluctuations of less than one meter, while Big Creek experiences tidal fluctuation of 2-2.6 meters. The amount of tidal fluctuation is a physical characteristic that most likely drives a large amount of variation in these forested wetlands. Additionally, the spring freshet has a much larger effect on the amount of water present in the forested wetlands at the upriver sites, as evidenced by the inaccessibility of these sites during peak river flows in 2008. In conclusion, we view the tidal forested wetlands at the three 2008 sites falling into two basic categories: (1) coniferous tidal swamp as seen at Big Creek; and (2) deciduous tidal riparian floodplain forest, as seen at Willow Bar and Mirror Lake.

**Initial Impressions of 2009 Sites**

The intent of placing all three of the 2009 sites between Big Creek and Willow Bar was to capture the transition that occurs between the coniferous tidal swamp and the deciduous tidal riparian floodplain forests. Initial impressions of the three 2009 sites formed during surveying, sampling, and sample laboratory analysis are that the three sites will help to explain the transition in tidal forested wetlands that was observed between Big Creek and Willow Bar. Both the Julia Butler Hansen Wildlife Refuge and the Robert W. Little Preserve are dominated by Sitka spruce and black cottonwood, and are expected to show statistical similarity to one another in terms of vegetation assemblages. These two sites will likely provide information about the vegetation and faunal assemblages present in the transitional tidal forested wetlands. Furthermore, GIS analyses indicate that the Robert W. Little Preserve is the furthest upriver Sitka spruce vegetation assemblage in the Columbia River estuary. A transition similar to the one apparent in the 2008 sites is expected to occur between the Robert W. Little Preserve and Willow Grove, which has a vegetation assemblage dominated by deciduous species such as black cottonwood, Oregon ash, and Pacific willow. The variation in types of tidal forested wetlands present at the 2009 sites is likely caused by physical factors such as tidal fluctuation and hydrologic features.

## 8.4 Tidal Forested Wetland Efforts for 2009-2010

The final product of the field ecology component of the 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 a larger Columbia River Estuary Ecosystem Classification effort currently in progress (Simenstad et al., 2007). The Classification is a GIS data-based system that provides a structure that could aid in predicting distinct ecological communities present in different hydrogeomorphic reaches. The Classification's Level III hydrogeomorphic reaches (A-H) are delineated by major hydrologic features, historical floodplain, and tidal extent (Figure 1). The results of the study will help to ground-truth the ecological component of the hydrogeomorphic reach classification system.

Data emerging from the study is being entered in a Microsoft Access database that will be delivered to LCREP at the completion of the study, after appropriate Quality Assurance/Quality Control screening. Preliminary presentations on the results will be presented to LCREP and interested parties in autumn 2009, following the completion of data collection. Final presentations will occur in spring 2010, at completion of the study and the UW graduate student degree program.

## 9.0 Planned Ecosystem Monitoring Project Efforts for 2009-2010

For a summary of the activities in 2008-2009, see the Executive Summary. In 2009-2010, the EMP plans to expand the Classification to other reaches, and collect the datasets needed to complete the Classification. UW and USGS will delineate Level 4 (Ecosystem Complexes) for most hydrogeomorphic reaches, depending on bathymetry data availability. USGS will delineate draft Level 5 (Geomorphic Catena) for most reaches. The Estuary Partnership will coordinate the collection of the key bathymetry and landcover datasets. On-the-ground data collection in 2009-2010 is anticipated to include vegetation, water chemistry relevant to salmonids, primary productivity, and salmon in TBD Reach(es) of the LCRE. 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 synthesize multi-year datasets for 2 emergent wetland sites (Campbell Slough and Franz Lake; see Table 5 for dataset summary) in order to characterize undisturbed emergent wetlands as juvenile salmon habitat in the LCRE. UW will synthesize community data collected at 6 forested tidal freshwater wetlands and compile those data into a profile of the biological community and habitat conditions.

## 10.0 EMP Budget

**Table 26: Budget for Estuary Partnership's EMP contract (#33854), including the USGS EMP contract (#39594).**

*BPA Project Number: 2003-007-00*
*Contract Numbers: Estuary Partnership #33854, USGS #39594*
*Performance/Budget Period: September 1, 2008 – August 31, 2009*
*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 | Funds Received To Date | Contract Balance |
|---|---|---|---|
| **I. Direct Costs** | | | |
| Personnel | $ 105,148.00 | $105,272.35 | $ (124.35) |
| Travel | $2,196.94 | $2,722.78 | $ (525.84) |
| Office Supplies | $2,136.00 | $2,136.00 | $ - |
| Vehicles | $1,020.00 | $741.88 | $ 278.12 |
| Project Supplies or Equipment | $ 17,140.00 | $10,840.05 | $ 6,299.95 |
| Rent Utilities | $ 9,996.00 | $9,996.00 | $ - |
| *Sub Total* | *$ 137,636.94* | *$131,709.06* | *$ 5,927.88* |
| Overhead | $55,054.58 | $26,341.81 | $ 28,712.77 |
| *Sub Total Direct Costs* | *$ 192,691.52* | *$158,050.87* | *$ 34,640.65* |
| **II. Sub Contracts** | | | |
| Battelle | $92,633.00 | $78,567.85 | $ 14,065.15 |
| Univ of Washington | $203,077.00 | $135,215.96 | $ 67,861.04 |
| NOAA | $95,000.00 | $87,182.00 | $ 7,818.00 |
| USGS | $86,000.00 | $86,000.00 | $ - |
| David Evans & Associates | $ 230,994.00 | $230,281.71 | $ 712.29 |
| *Sub Contracts Sub Total* | *$707,704.00* | *$617,247.52* | *$90,456.48* |
| Project Management | $74,604.48 | $74,604.48 | $ - |
| **Totals** | **$ 975,000.00** | **$849,902.87** | **$ 125,097.13** |

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**Appendix A: Vegetation Species Code and Percent Cover Data.**

Site elevation (in meters, relative to the vertical datum NAVD88) and vegetation species percent cover. The three dominant cover classes are bolded in red for each site. Non-native species are shaded in yellow. Native species that are considered "weedy/invasive" are denoted by "**."

| Code | Scientific Name | Common Name | Wetland Status | Native | Ryan Is. | | Whites Is. | | Lord Is. 1 | | Lord Is. 2 | | Campbell Slough | | Cunningham Lake | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Percent Cover | | | | | | | | | | | | | |
| Code | Scientific Name | Common Name | Wetland Status | Native | Avg | 80% CI | Avg | 80% CI | Avg | 80% CI | Avg | 80% CI | Avg | 80% CI | Avg | 80% CI | Avg | 80% CI |
| AGEX | *Agrostis exarata* | spike bentgrass | FACW | yes | 1.68 | 0.70 | 4.00 | 1.48 | | | | | | | | | | |
| ALTR | *Alisma triviale* | northern water plaintain | OBL | yes | | 0.48 | 0.36 | 1.00 | 0.83 | 0.02 | 0.02 | | | | | | | |
| ALRU | *Alnus rubra* | Red alder | FAC | yes | | | | | 1.53 | 1.95 | | | | | | | | |
| BESY | *Beckmannia syzigachne* | American sloughgrass | OBL | yes | 0.04 | 0.05 | | | 0.08 | 0.11 | 3.26 | 3.64 | | | | | 0.69 | 0.87 |
| BICE | *Bidens cernua* | Nodding beggars-ticks | FACW+ | yes** | | | 0.60 | 0.77 | | | | | | | | | | |
| CACO | *Carex comosa* | Bearded sedge | OBL | yes | | | | | | | | | | | 0.15 | 0.20 | 1.25 | 1.22 |
| CAHE | *Callitriche heterophylla* | Water starwort | OBL | yes | 0.44 | 0.51 | 1.64 | 1.80 | 0.02 | 0.02 | | | | | | | | |
| CAOB | *Carex obnupta* | Slough sedge | OBL | yes | | | | | | | | | | | | | 6.83 | 2.73 |
| CALY | *Carex lyngbyei* | Lyngby sedge | OBL | yes | **17.4** | **5.24** | **8.28** | **5.20** | | | | | | | | | | |
| CAPA | *Caltha palustris* | Yellow marsh marigold | OBL | yes | 0.36 | 0.27 | | | | | | | | | | | | |
| CASP | *Carex sp.* | Carex | mixed | yes | | | | | 0.10 | 0.11 | 0.04 | 0.06 | 0.66 | 0.51 | | | | |
| CIAR | *Cirsium arvense var. horridum* | Canada thistle | FACU+ | no | | | | | 0.34 | 0.26 | | | | | | | | |
| COST | *Convolvulus sepium* | Hedge bindweed | FAC | no | | | | | | | | | | | | | | |
| CEDE | *Ceratophyllum demersum* | Coontail | OBL | yes | | | | | 0.03 | 0.03 | | | | | | | | |
| DECE | *Deschampsia cespitosa* | Tufted hairgrass | FACW | yes | 5.40 | 3.98 | | | | | | | | | | | | |
| ELAC | *Eleocharis acicularis* | Needle spikerush | OBL | yes | | | 0.80 | 1.03 | | | | | | | 0.85 | 0.62 | 2.63 | 1.05 |
| ELCA | *Elodea* | Canada | OBL | yes | 0.08 | 0.07 | 2.52 | 1.56 | **16.8** | **5.49** | | | 0.16 | 0.15 | | | | |

| Code | Scientific Name | Common Name | Wetland Status | Native | Ryan Is. | | Whites Is. | | Lord Is. 1 | | Lord Is. 2 | | Campbell Slough | | Cunningham Lake | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Percent Cover** | | | | | | | | | | | | | |
| | *canadensis* | waterweed | | | | | | | | | | | | | | | | |
| ELOV | *Eleocharis ovata* | Ovoid spikerush | OBL | yes | | | | | | | | | | | | | 1.14 | 0.91 |
| ELPA | *Eleocharis palustris* | Common spikerush | OBL | yes | 2.24 | 1.61 | 3.20 | 2.51 | 4.02 | 2.57 | 1.09 | 1.14 | **40.0** | **6.53** | **35.3** | **5.30** | 5.51 | 1.85 |
| EPCI | *Epilobium ciliatum* | Willow herb | FACW- | yes | 1.08 | 0.82 | 0.12 | 0.09 | 0.81 | 0.43 | 0.65 | 0.84 | | | | | 0.01 | 0.01 |
| EQFL | *Equisetum fluviarile* | Water horsetail | OBL | yes | 1.84 | 1.04 | 2.96 | 1.09 | | | | | | | | | | |
| EQHY | *Equisetum hyemale* | scouringrush horsetail | FACW | yes | | | | | 11.49 | 3.88 | | | | | | | | |
| EQSP | *Equisetum spp.* | Horsetail | mixed | yes | | | | | 1.39 | 0.53 | 0.26 | 0.28 | 1.02 | 0.61 | 3.95 | 1.19 | 1.09 | 0.37 |
| FRLA | *Fraxinus latifolia* | Oregon ash | FACW | yes | | | | | | | | | | | | | 0.11 | 0.15 |
| GAAP | *Gallium aperine* | Cleavers bedstraw | FACU | yes** | 3.00 | 1.89 | | | | | | | | | | | | |
| GASP | *Gallium spp* | Pacific bedstraw; cleavers; small bedstraw | mixed | yes | 0.04 | 0.05 | | | | | | | | | | | | |
| GATR2 | *Gallium triflorum* | fragrant bedstraw | FACU | yes | 0.04 | 0.05 | 5.32 | 2.34 | | | | | | | | | | |
| GLST | *Glyceria striata* | Fowl mannagrass | OBL | yes | | | 0.20 | 0.26 | | | | | | | | | | |
| GLGR | *Glyceria grandis* | American mannagrass | OBL | yes | | | 0.44 | 0.51 | | | | | | | | | | |
| HEAU | *Helenium autumnale* | common sneezeweed | FACW | yes | | | | | | | | | 0.51 | 0.29 | | | 1.08 | 0.66 |
| HYSC | *Hypericum scouleri* | Western St. Johns wort | FAC | yes | 0.04 | 0.05 | | | 0.68 | 0.50 | | | | | | | | |
| IMSP | *Impatiens capensis,Impatiens noli-tangere* | Spotted touch-me-not, Common touch-me-not | FACW | yes | 7.48 | 3.50 | 0.04 | 0.05 | 0.34 | 0.30 | | | | | 0.31 | 0.39 | | |
| IRPS | *Iris pseudacorus* | Yellow iris | OBL | no | 7.00 | 2.62 | 5.80 | 2.93 | | | | | | | 0.02 | 0.02 | | |
| JUEF | *Juncus effusus* | Soft rush | FACW | mixed | | | 0.20 | 0.26 | 0.02 | 0.02 | | | | | | | | |
| JUOX | *Juncus oxymeris* | Pointed rush | FACW+ | yes | 1.28 | 1.06 | 1.00 | 0.83 | | | | | 0.84 | 0.45 | | | | |
| JUSP | *Juncus spp.* | Rush | mixed | mixed | 0.24 | 0.26 | | | | | | | | | | | | |

| Code | Scientific Name | Common Name | Wetland Status | Native | Ryan Is. | | Whites Is. | | Lord Is. 1 | | Lord Is. 2 | | Campbell Slough | | Cunningham Lake | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Percent Cover | | | | | | | | | | | | | |
| LEOR | *Leersia oryzoides* | Rice cutgrass | OBL | yes | 0.84 | 0.60 | | | | | 0.91 | 0.87 | 0.11 | 0.11 | 1.11 | 0.72 | 1.97 | 0.58 |
| LIOC | *Lilaeopsis occidentalis* | Western lilaeopsis | OBL | yes | | | 0.04 | 0.05 | 0.03 | 0.03 | | | 0.05 | 0.04 | | | | |
| LIAQ | *Limosella aquatica* | Water mudwort | OBL | yes | | | | | | | | | | | | | 0.01 | 0.01 |
| LOCO | *Lotus corniculatus* | Birdsfoot trefoil | FAC | no | 2.12 | 1.60 | 3.84 | 2.43 | 1.36 | 0.76 | | | 0.02 | 0.02 | | | | |
| LUPA | *Ludwigia palustris* | False loosestrife | OBL | yes | 0.04 | 0.05 | 0.08 | 0.07 | 0.07 | 0.04 | 0.09 | 0.08 | 0.90 | 0.30 | 7.20 | 1.50 | 1.89 | 0.84 |
| LYAM | *Lysichiton americanum* | Skunk cabbage | OBL | yes | 1.60 | 1.27 | | | | | | | | | | | | |
| LYNU | *Lysimachia nummularia L.* | Moneywort, Creeping Jenny | FACW | no | | | | | | | | | 1.00 | 0.93 | 0.09 | 0.10 | | |
| LYSA | *Lythrum salicaria* | Purple loosestrife | FACW+ | no | 0.04 | 0.05 | | | 0.25 | 0.24 | | | | | | | | |
| MEAR | *Mentha arvensis* | wild mint | FACW- | yes | 6.00 | 3.05 | | | | | | | 0.66 | 0.44 | | | 0.06 | 0.07 |
| MAFU | *Malus fusca* | Pacific crab apple | FACW | yes | | | | | | | | | | | | | 1.14 | 1.46 |
| MESP | *Mentha spp.* | Mint (field mint, spearmint) | mixed | mixed | | | | | | | | | | | 0.08 | 0.10 | | |
| MIGU | *Mimulus guttatus* | Yellow monkeyflower | OBL | yes | 0.64 | 0.56 | 0.04 | 0.05 | | | | | | | | | | |
| MYSP2 | *Myriophyllum spp.* | Milfoil | OBL | mixed | 0.84 | 0.60 | 0.04 | 0.05 | 0.44 | 0.45 | | | | | | | | |
| MYSP | *Myosotis laxa, M. scorpioides* | Small forget-me-not, Common forget-me-not | mixed | mixed | 3.12 | 1.27 | **9.24** | **3.57** | 0.36 | 0.43 | 1.57 | 1.47 | | | | | | |
| OESA | *Oenanthe sarmentosa* | Water parsley | OBL | yes | 2.20 | 1.26 | 5.72 | 1.84 | | | | | | | | | | |
| PHAR | *Phalaris arundinacea* | Reed canary grass | FACW | no | **34.6** | **8.52** | **43.0** | **7.71** | **22.4** | **5.78** | 9.39 | 7.36 | **37.9** | **7.51** | **38.5** | **6.79** | **36.3** | **5.62** |
| PLDI | *Platanthera dilatata* | white bog orchid | FACW+ | yes | 0.04 | 0.05 | | | | | | | | | | | | |
| PLMA | *Plantago major* | common plantain | FACU+ | no | | | | | | | | | 0.02 | 0.02 | | | | |

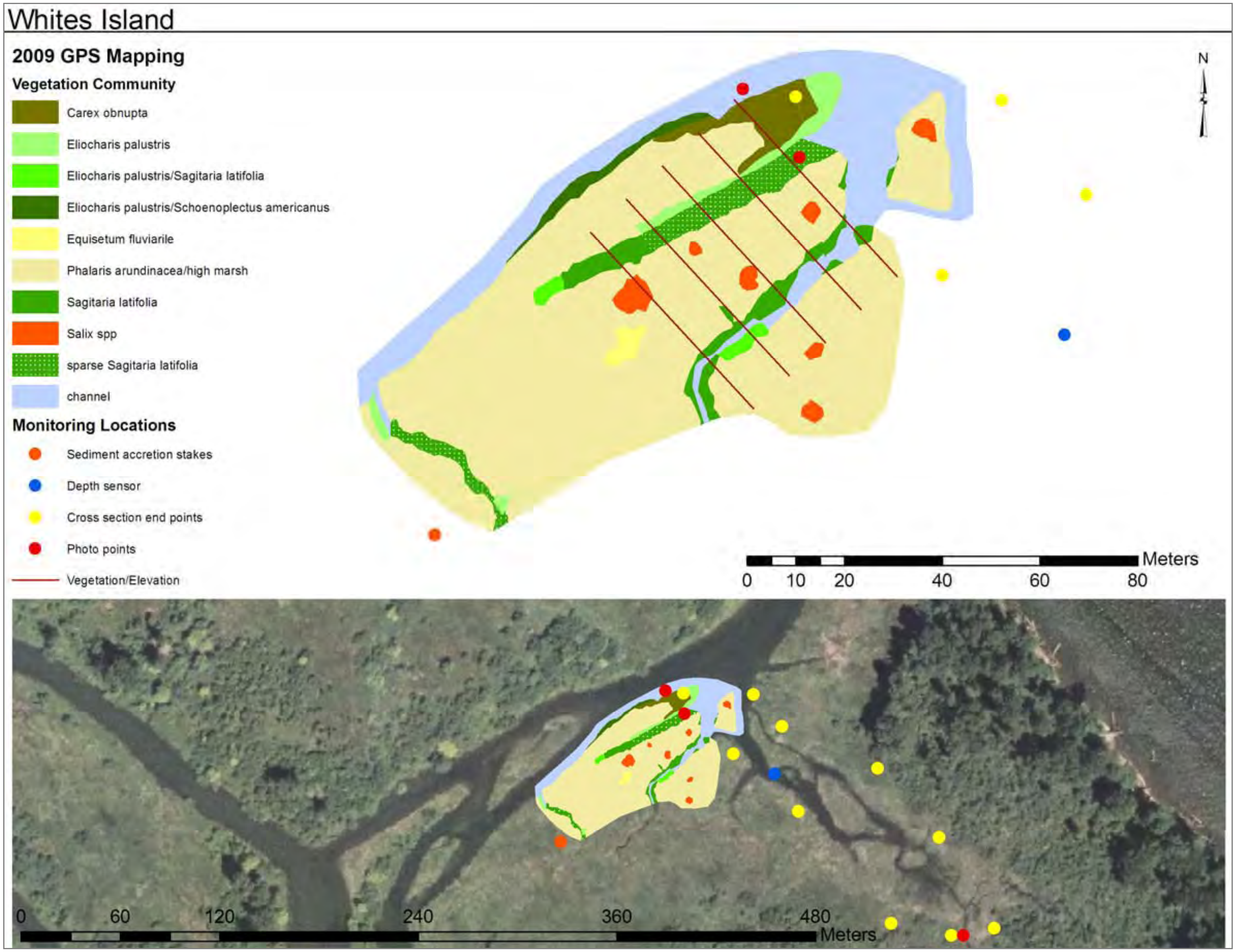
| Code | Scientific Name | Common Name | Wetland Status | Native | Ryan Is. | | Whites Is. | | Lord Is. 1 | | Lord Is. 2 | | Campbell Slough | | Cunningham Lake | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Percent Cover | | | | | | | | | | | | | |
| POAM | *Polygonum amphibium* | water ladysthumb, water smartweed | OBL | yes | | | | | | | | | | | | | **13.1** | **3.33** |
| POAN | *Potentilla anserina ssp. Pacifica* | Pacific silverweed | OBL | yes | | | 0.40 | 0.51 | | | | | | | | | 0.17 | 0.12 |
| POAN2 | *Poa annua* | annual bluegrass | FAC | no | | | | | 0.08 | 0.11 | | | | | | | | |
| POCR | *Potamogeton crispus* | Curly leaf pondweed | OBL | no | 1.40 | 1.55 | | | 1.73 | 0.99 | | | 0.43 | 0.27 | | | | |
| POHY | *Polygonum hydropiper, P. hydropiperoides* | Waterpepper, mild waterpepper, swamp smartweed | OBL | mixed | 0.60 | 0.56 | 0.08 | 0.07 | | | **11.3** | **6.32** | | | 0.08 | 0.10 | | |
| POMU | *Polystichum munitum* | Sword fern | FACU | yes | | | | | 0.02 | 0.02 | | | | | | | | |
| PONA | *Potamogeton natans* | Floating-leaved pondweed | OBL | yes | | | | | | | | | | | 0.55 | 0.29 | | |
| POPE | *Polygonum persicaria* | Spotted ladysthumb | FACW | no | | | 0.20 | 0.26 | | | 1.52 | 1.17 | 0.28 | 0.18 | 1.17 | 0.47 | 1.66 | 0.89 |
| POSP | *Polygonum sp.* | Knotweed, Smartweed | mixed | mixed | 0.08 | 0.07 | | | | | | | 0.28 | 0.18 | | | | |
| RARE | *Ranunculus repens* | Creeping buttercup | FACW | no | | | | | | | | | 0.33 | 0.25 | | | | |
| RUCR | *Rumex crispus* | Curly dock | FAC+ | no | 0.40 | 0.35 | | | | | | | 0.10 | 0.11 | | | | |
| RUDI | *Rubus discolor* | Himalayan blackberry | FACU | no | | | | | | | | | | | 0.38 | 0.49 | | |
| RUMA | *Rumex maritimus* | Golden dock, seaside dock | FACW+ | yes | | | | | | | | | | | | | | |
| SALA | *Sagitaria latifolia* | Wapato | OBL | yes | 0.64 | 0.42 | 4.24 | 2.33 | 0.27 | 0.24 | **23.7** | **3.63** | 14.28 | 2.74 | 8.68 | 1.43 | 8.09 | 2.12 |
| SALU* | *Salix lucida* | Pacific willow | FACW+ | yes | | | | | | | | | | | | | | |
| SASI | *Salix sitchensis* | Sitka willow | FACW | yes | | | | | 1.86 | 1.50 | | | | | | | | |
| SASP | *Salix spp.* | Willow | mixed | yes | | | | | 1.95 | 1.98 | 1.09 | 1.39 | 0.16 | 0.21 | 2.77 | 2.49 | 2.22 | 1.62 |

| Code | Scientific Name | Common Name | Wetland Status | Native | Ryan Is. | | Whites Is. | | Lord Is. 1 | | Lord Is. 2 | | Campbell Slough | | Cunningham Lake | | Franz Lake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Percent Cover | | | | | | | | | | | | | |
| POZO | *Potamogeton zosteraformis* | Eelgrass pondweed | OBL | yes | | | 0.04 | 0.05 | 0.20 | 0.16 | | | | | | | | |
| SCAM | *Schoenoplectus americanus* | American bulrush, threesquare bulrush | OBL | yes | 0.20 | 0.26 | | | 0.25 | 0.24 | 0.09 | 0.08 | 0.02 | 0.02 | | | | |
| SCCY | *Scirpus cyperinus* | woolly sedge | OBL | yes | | | | | | | | | | | | | 0.57 | 0.43 |
| SCMI | *Scirpus microcarpus* | Small-fruited bulrush | OBL | yes | | | | | 0.34 | 0.34 | | | | | | | | |
| SCTA | *Schoenoplectus tabernaemontani* | Softstem bulrush, tule | OBL | Yes | | | | | | | 0.22 | 0.28 | | | 0.02 | 0.02 | 0.06 | 0.07 |
| SISU | *Sium suave* | Hemlock waterparsnip | OBL | yes | 1.52 | 1.01 | 0.60 | 0.77 | | | | | | | | | | |
| SOCA | *Solidago canadensis* | Canada goldenrod | FACU | yes | | | | | 1.78 | 0.86 | | | | | | | | |
| SODU | *Solanum dulcamara* | Bittersweet nightshade | FAC+ | no | 1.60 | 1.42 | | | | | | | | | | | | |
| SPEM | *Sparganium emersum* | Narrowleaf burreed | OBL | yes | 0.20 | 0.26 | | | | | | | | | 0.25 | 0.22 | | |
| TYAN | *Typha angustifolia* | Narrowleaf cattail | OBL | no | 2.24 | 1.43 | 0.60 | 0.56 | | | | | | | | | | |
| TYLA | *Typha latifolia* | Common cattail | OBL | yes | | | | | | | **14.4** | **6.73** | | | | | | |
| URDI | *Urtica dioica* | Stinging Nettle | FAC+ | yes | | | | | | | | | | | | | 0.23 | 0.29 |
| VEAM | *Veronica americana* | American speedwell | OBL | yes | | | 0.44 | 0.27 | 0.03 | 0.03 | 0.04 | 0.06 | | | | | 5.92 | 2.17 |
| | | | | | | | | | | | | | | | | | | |
| Algae | | Algae | | | 0.40 | 0.51 | 1.00 | 0.64 | 0.19 | 0.15 | 0.43 | 0.56 | 2.38 | 1.79 | 0.92 | 0.50 | 0.23 | 0.29 |
| MOSS | | Moss | | | | | 0.20 | 0.26 | 0.86 | 0.41 | | | 0.33 | 0.20 | 0.23 | 0.30 | | |
| BG | | Bare ground | | | 9.52 | 5.71 | 6.60 | 4.10 | **25.8** | **6.05** | 3.70 | 2.80 | **15.1** | **4.11** | **16.6** | **4.34** | **19.4** | **4.56** |
| DW | | Drift wrack | | | **9.80** | **6.07** | 3.00 | 1.57 | 0.19 | 0.15 | | | | | 1.62 | 1.49 | | |
| Litter | | Litter | | | 0.40 | 0.51 | | | 8.22 | 2.74 | | | 1.72 | 0.72 | 0.54 | 0.40 | | |
| LWD | | Large woody debris | | | | | 1.80 | 1.43 | | | | | | | 1.15 | 0.83 | 1.31 | 0.65 |
| UID Grass | | Unidentified grass | | | 0.04 | 0.05 | 0.24 | 0.26 | 0.03 | 0.03 | | | 0.10 | 0.11 | | | 0.40 | 0.20 |

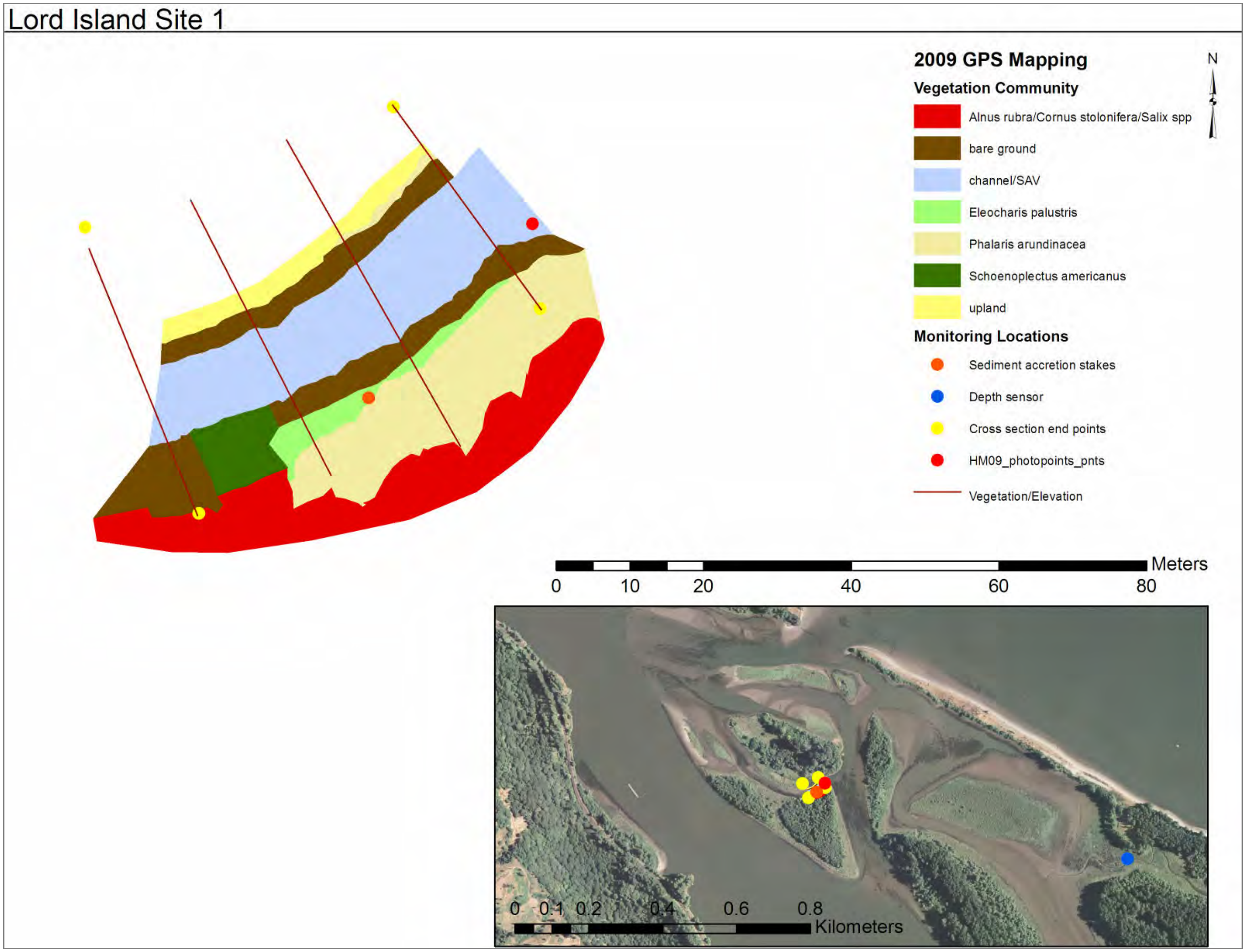
| Code | Scientific Name | Common Name | Wetland Status | Native | Ryan Is. | Whites Is. | Lord Is. 1 | Lord Is. 2 | Campbell Slough | Cunningham Lake | Franz Lake |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Percent Cover | | | | | | |
| UID Herb | | Unidentified herb | | | | | 0.25 0.33 | | | | 0.07 0.07 |
| | | | | | Elevation (m, NAVD88) | | | | | | |
| | | | | Min | 1.08 | 1.25 | 0.40 | 2.05 | 2.76 | 2.16 | 3.72 |
| | | | | Avg | 2.12 | 2.01 | 2.46 | 2.28 | 3.26 | 2.50 | 4.99 |
| | | | | Max | 2.46 | 2.49 | 4.33 | 2.68 | 4.34 | 2.93 | 7.29 |

**Appendix B: Vegetation Community Maps.**

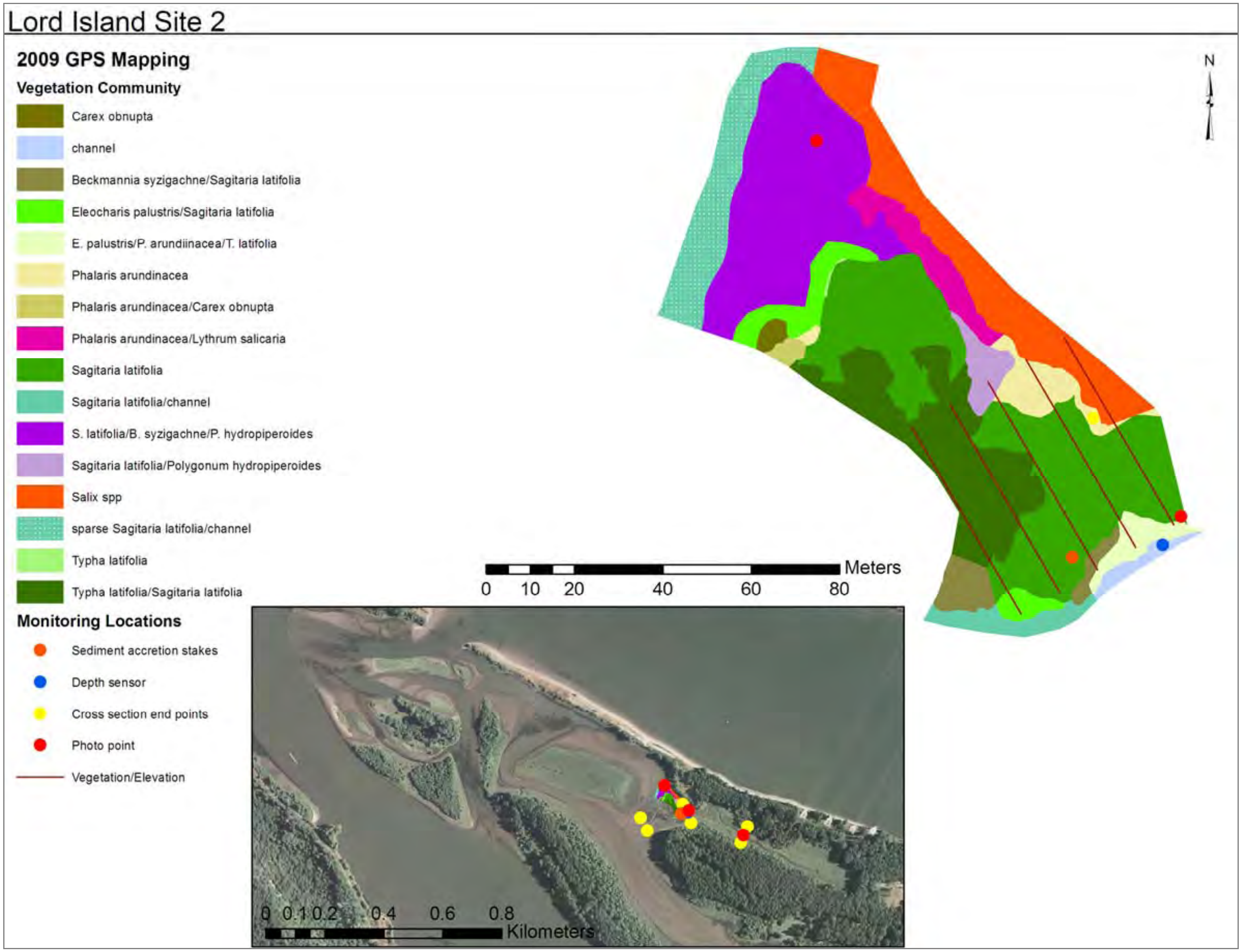

**Vegetation distributions at Ryan Island, 2009.**



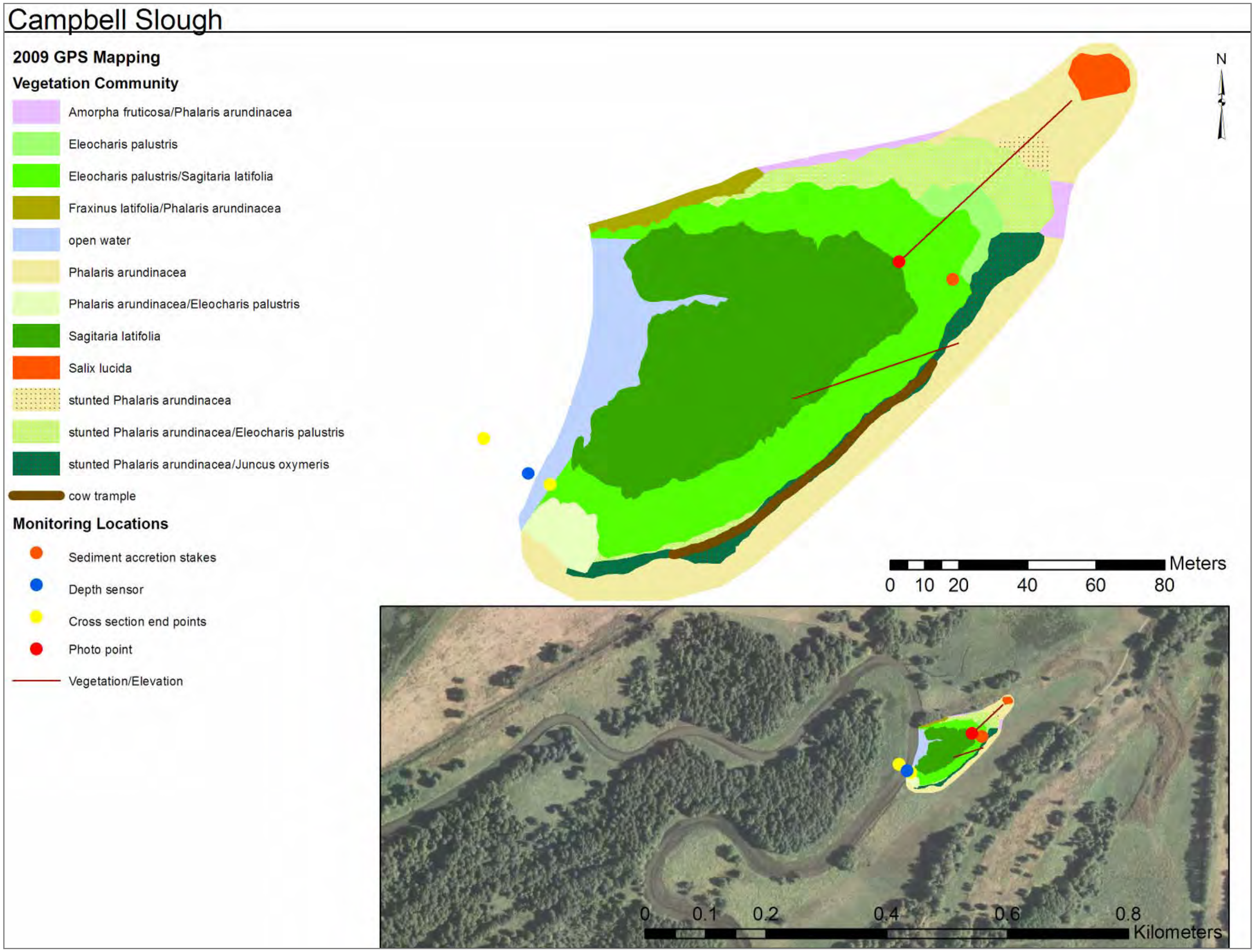

**Vegetation distributions at Whites Island, 2009.**



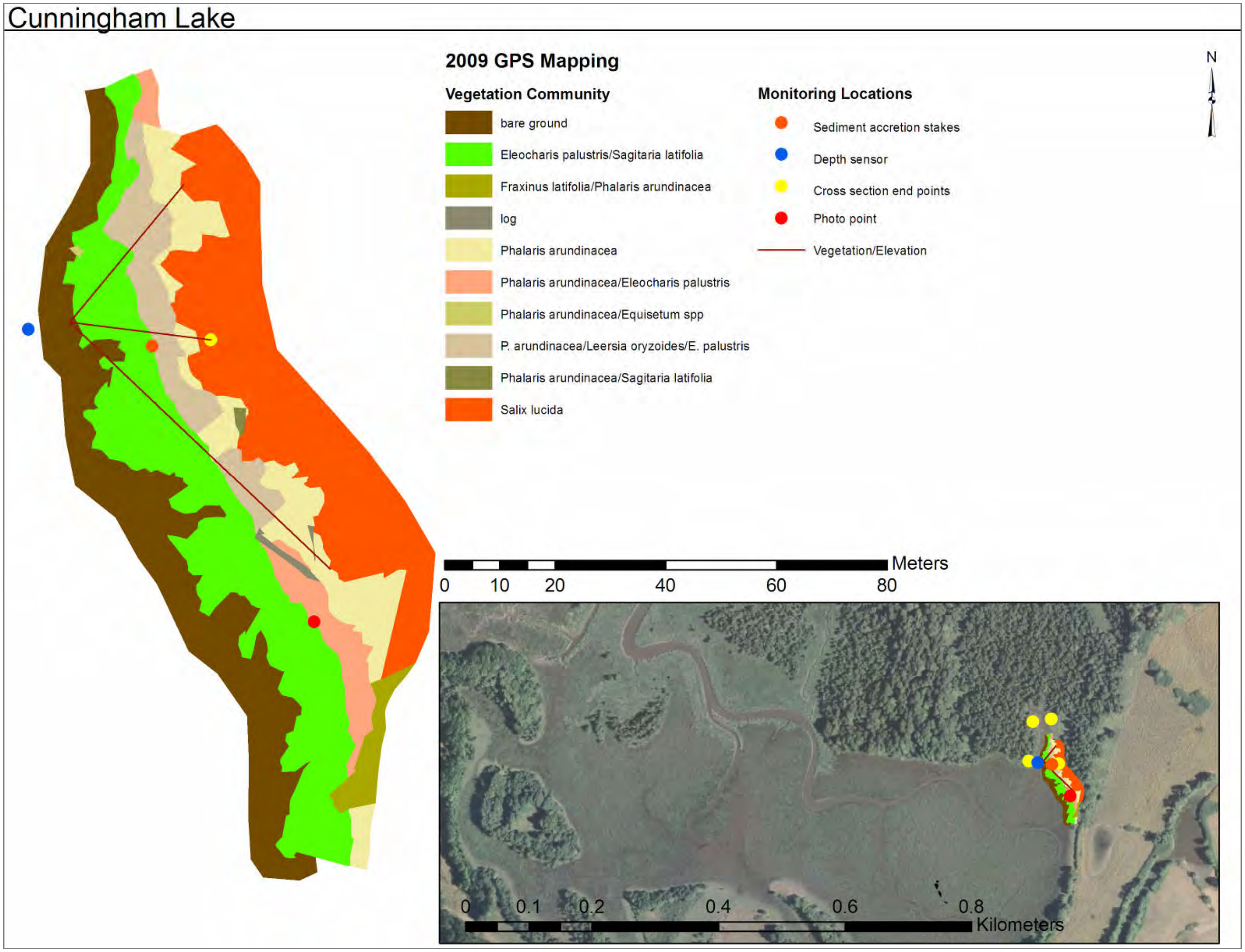

**Vegetation distributions at Lord Island 1, 2009.**



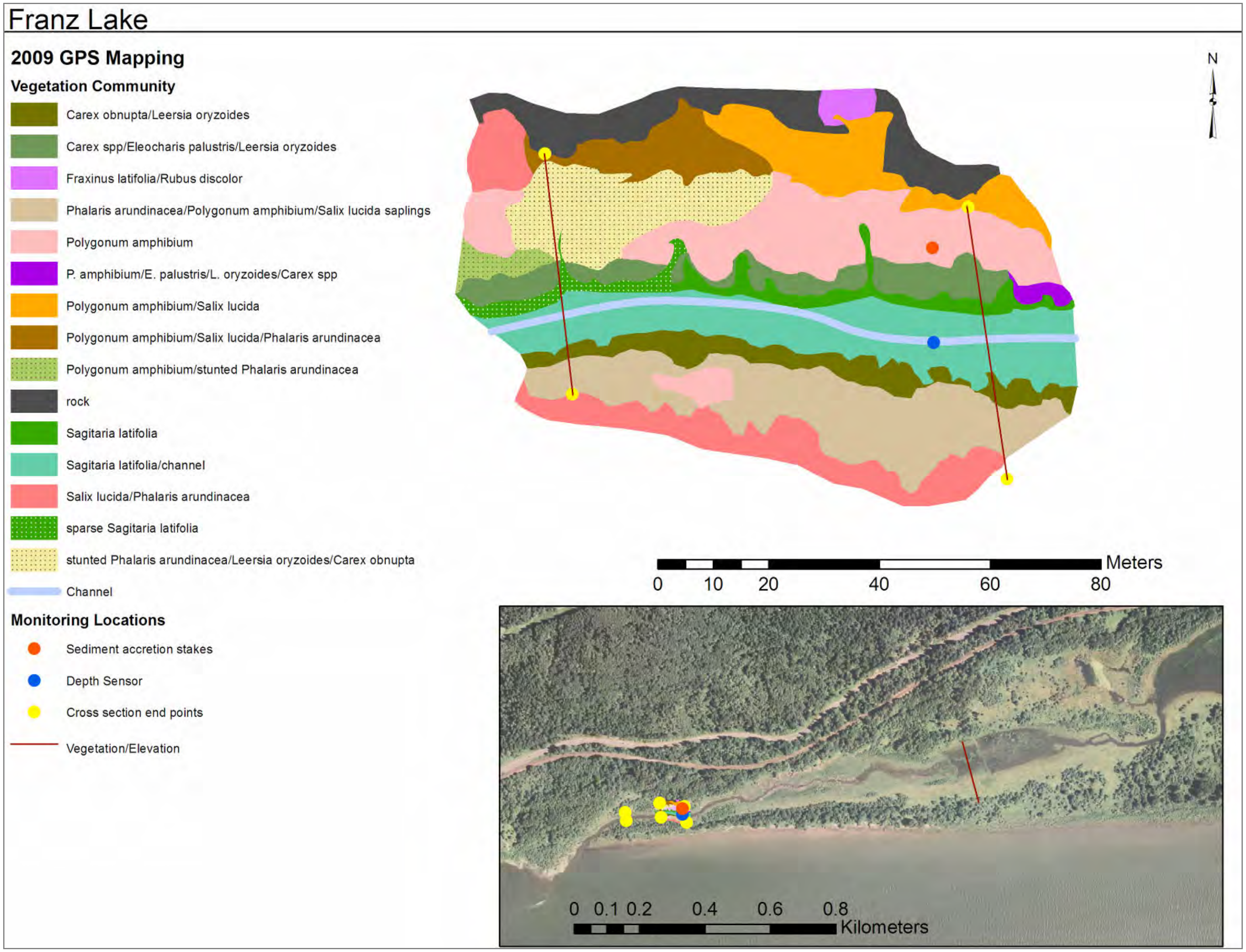

**Vegetation distributions at Lord Island 2, 2009.**




**Vegetation distributions at Campbell Slough, 2009.**




**Vegetation distributions at Cunningham Lake, 2009.**




**Vegetation distributions at Franz Lake, 2009.**