Action Effectiveness Monitoring for the Lower Columbia River Estuary Habitat Restoration Program

BPA Project Number: 2003-007-00
Report covers work performed under BPA contract # 80237
Report was completed under BPA contract # 90999
Performance/Budget Period: October 1, 2021 – September 30, 2022

Technical Contact: Sarah Kidd & Sneha Rao
Lower Columbia Estuary Partnership
400 NE 11th Ave
Portland, OR 97232
Phone: (503) 226-1565 x 239
skidd@estuarypartnership.org
snehar@estuarypartnership.org

BPA Project Manager: Anne M. Creason
Fish & Wildlife Project Manager
Bonneville Power Administration
905 NE 11th Avenue
Portland, Oregon – 97208
Phone: (503) 230-3635
amcreason@bpa.gov

Report Created: August 2023

Action Effectiveness Monitoring for the Lower Columbia River Estuary Habitat Restoration Program Annual Report (October 2021 to September 2022)

Sarah Kidd*
Sneha Rao
Ian Edgar
April Silva[1]
Narayan Elasmar [1]
Jeff Grote[2]
Susan Hinton[3]
Curtis Roegner[3]
*Prepared by the Lower Columbia Estuary Partnership
with funding from the Bonneville Power Administration

Lower Columbia Estuary Partnership
400 NE 11th Avenue
Portland, OR 97232

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

This report should be cited as follows:

S. Kidd, S. Rao, I. Edgar, A. Silva, N. Elasmar, J. Grote, S. Hinton and C. Roegner. 2023. Action Effectiveness Monitoring for the Lower Columbia River Estuary Habitat Restoration Program Annual Report (October 2021 to September 2022). Prepared by the Lower Columbia Estuary Partnership for the Bonneville Power Administration. Available from the Lower Columbia Estuary Partnership, Portland, OR

[1] Columbia River Estuary Study Taskforce
[2] NWFSC, NOAA Fisheries

Table of Contents

TABLE OF FIGURES

TABLE OF TABLES

Abbreviations and Acronyms

AEM	Action Effectiveness Monitoring
BPA	Bonneville Power Administration
CEERP	Columbia Estuary Ecosystem Restoration Program
CRD	Columbia River Datum
CREST	Columbia River Estuary Study Taskforce
EMP	Ecosystem Monitoring Program
ESA	Endangered Species Act
NMS	nonmetric multidimensional scaling
ORP	Oxygen Reduction Potential
PIT	passive integrated transponder
RPA	Reasonable and prudent alternative
SEV	Sum Exceedance Value
UAV	Unmanned Aerial Vehicle
USACE	U.S. Army Corps of Engineers
WSE	Water Surface Elevation

Executive Summary

The Lower Columbia Estuary Partnership (LCEP) manages the Action Effectiveness Monitoring (AEM) program with the goals of determining the impact of habitat restoration actions on salmon at the site and landscape scale, identifying how restoration techniques address limiting factors for juvenile salmonids, and improving restoration techniques to maximize the impact of restoration actions. To accomplish AEM program goals, LCEP implements the Columbia Estuary Ecosystem Restoration Program (CEERP) AEM Programmatic plan (Johnson et al. 2016), employs standardized monitoring protocols, and coordinates between stakeholders to collect and share AEM data. The AEM annual monitoring objectives were to quantify post-restoration hydrology, temperature, habitat, and vegetation within restoration sites and to determine post-restoration fish use at selected sites.

Twenty restoration sites in 2022 received AEM data collection (Table 1). All monitoring was conducted following standardized protocols outlined in Kidd et al. 2023, and Roegner et al. 2009. Four restoration sites were selected for Level 2 monitoring (Table 2) in 2022 using the prioritization criteria outlined in Johnson et al. (2016). Three associated reference sites were chosen to establish a before-after reference impact monitoring design, which puts pre- and post-restoration site data into ecological context (Table 2).

To better meet the goals and objectives of the AEM Program, the results of this report are presented in the form of Tableau dashboards. On this platform, LCEP has publicly disseminated multiple datasets and analyses including hydrology, vegetation, sediment accretion, drone analyses, macroinvertebrates, fish, and other datasets. The following section provides a brief overview of the AEM Level 2 Monitoring sites from 2022 (Table 2).

Wallooskee – Youngs Project
Project Sponsor: Cowlitz Indian Tribe

Need for restoration: Historically a dairy farm, the site had been disconnected from active tidal flooding for over a hundred years.

Project goals: Removing the levee and filling the borrow ditch will increase hydrologic connectivity during the tidal cycle and increase the spatial extent of inundation in the wetland. The restoration of a more natural tidal cycle will help restore ecosystem function by supporting a diverse native plant community, improving nutrient cycling, and increasing the quantity and quality of off-channel habitat for aquatic species.

Construction actions taken: In July 2017, tidal flooding was restored throughout the wetland by removing and lowering levees bordering the site. Additional channel enhancements were conducted in areas to expand channel density and access to wetland habitat. **Daggett Point** was selected as the local reference site for this project.

Executive Summary of Results: In just five years post-restoration, the Wallooskee restoration site has dramatically shifted from an agricultural field to a functioning tidal wetland dominated by native wetland plant communities. Using UAV imagery collected in 2020, 3 years post-construction, and 2022, 5 years post-construction, we have captured the full suite of habitat conditions that have developed across the site. In addition to a dramatic shift in plant community composition seen on the ground and through the areal imagery, we have also observed a dramatic shift in soil conditions and sediment accretion and erosion dynamics towards reference site conditions. Water surface elevation and temperature dynamics also match those of the contributing waterways, Youngs Bay and the Wallooskee River. While year 5-post restoration is still early in the life of a restored tidal wetland, results indicate Wallooskee is on a very successful trajectory towards a productive high-quality salmonid habitat.

Dibblee Point Project
Project Sponsor: Columbia River Estuary Study Taskforce

Need for restoration: Dibblee Point consisted of several shallow freshwater wetland habitats that were connected to the mainstem Columbia River only during high pluvial flows.

Project goals: To restore full tidal connectivity to the wetlands, provide off-channel rearing and refuge habitat to juvenile salmonids and to increase habitat complexity in these shallow freshwater habitats.

Project objectives: Specific project objectives were 1) Connecting 12 acres of shallow freshwater wetland habitat (Dibblee Slough) to the mainstem Columbia River. 2) Creation of additional in-stream habitat by constructing a new channel, and 3) Increasing habitat complexity by large wood additions and revegetation.

Construction actions taken: Construction occurred in 2013, actions taken include 1) Excavating 250m of a new channel, creating full tidal access to the shallow habitats. 2) Large wood installations and native plantings in the newly created marshplain and 3) Installation of a 14ft wide culvert under roadway. A location outside the restoration area was chosen as the local reference.

Executive Summary of Monitoring Results: In 2022, Dibblee Point received 10 year post-restoration AEMR L2 monitoring. The objective of year 10 monitoring is to determine whether the site continues to be a functioning wetland dominated by native vegetation, with restored geomorphic processes and nutrient cycling. Hydrological patterns at Dibblee Point are similar to that of mainstem Columbia. Soil conditions were studied only in 2022, but generally are similar across restoration and reference areas. While the elevations at the site have had a positive trajectory, low marsh areas do not keep pace with sea level rise. Vegetation development at Dibblee Point indicates a healthy mix of native and non-native cover. Macroinvertebrate abundance at Dibblee point is far greater than that of the reference site, with Cladocera being the dominant group. A 10-year fish check-in showed that salmon were using the site.

Flight's End Project
Project Sponsor: Columbia River Estuary Study Taskforce

Need for restoration: The site was formerly a ponded habitat with agricultural land management and vegetation to attract waterfowl. Culverts, water control structures and artificial berms prevented salmonid access, regular inundation and altered historic hydrologic and geomorphic processes. These site conditions prevented the establishment of a native wetland vegetation mix, nutrient cycling, and restricted fish access. A vegetation survey undertaken in 2016 (pre-restoration) showed that wetted perimeters and historic prairie zones were dominated by Reed canarygrass (*Phalaris arundinacea*). The National Marine Fisheries Service (NMFS) collected juvenile salmonid data along the mainstem channel of Reach F showing high levels of genetic stock diversity for juvenile Chinook.

Project goals: The overall vision for Flights End wetlands was to increase connectivity to Crane Lake and the larger Multnomah Channel to create a network of habitats for salmonids and other species.

Project objectives: This restoration project aimed to connect 42 acres of floodplain wetlands to the Columbia River. The objectives of the project were: 1) Reestablishing hydrologic connectivity to Crane Lake and Multnomah Channel by the removal of artificial berms and culverts and creating a network of channels, and 2) Establishing a native wetland vegetation community by selective marsh plain lowering and replanting these areas with a native emergent – wet prairie mix.

Construction actions taken: Construction occurred in 2017, and construction actions included the removal of two culverts, the artificial berm, and marsh plain lowering. Target elevations were achieved by using wetlands in the Crane Lake system and the larger Sauvie Island complex as design references. Specific actions included: 1) Remove artificial earth berm and two additional undersized culverts that blocked the historical channel, 2) Create two channel openings from Crane Slough into the wetlands, 3) Retention of a water control structure to allow managers additional stewardship options for a late summer drawdown of water for moist soil management, 4) Lower marsh plain surfaces to increase frequency, duration, and magnitude of water inundation, and 5) Replant lowered marsh plain with native emergent species and wet prairie species. The local reference site for this site is **Cunningham Lake (EMP).**

Executive Summary of Monitoring Results: Five years post restoration, Flight's End continues to have an extremely promising ratio of native to non-native plant communities; however, there is a tremendous quantity of bare ground, likely due to the extreme mowing that the site sees. Additionally, the site continues to have a water control structure active, with water levels remaining significantly elevated at the site (holding water at 3 meters) compared to the reference site, Cunningham Lake (holds water at 2.1 meters). However, based on the restored channel connectivity elevation of 2.4 m, Flight's End now provides salmonid accessibility throughout the year, mirroring habitat accessibility conditions seen at the reference site. Neither the low marsh nor the high marsh at Flight's End are keeping pace with forecasted sea level rise; however, soil conditions remain consistent with the local reference. It is recommended that the land management reduce the extent and the height of mowing to allow for natural plant community development and provide natural detrital flux to occur within the wetland complex. Macroinvertebrate community comprises primarily of Cladocera. A five-year fish check in confirmed that Salmon are using the site.

John R Palensky Project
Project Sponsor: Columbia River Estuary Study Taskforce

Need for restoration: John R Palensky wetland is located in Burlington OR on US Hwy 30, just adjacent to the Multnomah Channel. The site consisted of several structures that restrict fish passage and limit inundation. Water control structures (one each at the North and South of the site), levees and culverts allowed access to a total of 5 acres or less. These structures also hindered historic hydrologic and geomorphic processes and promoted the establishment of invasive vegetation.

Project goals: The overall goal of this restoration project was to reconnect 280 acres pf wetland habitat to the adjacent Multnomah Channel.

Project objectives: Specific project objectives were Re-establish complete hydrologic connectivity and fish access to the site. 2) Maintain amphibian and migratory bird habitats and 3) Promote establishment of native vegetation and increase habitat capacity and complexity.

Construction actions taken: Construction at the site was completed in 2021. Actions taken at the site include 1) Replacing undersized culverts and removing the south water control structure. 2) Targeted marshplain lowering and revegetation to encourage native vegetation development and maintain amphibian habitat and 3) Installation of beaver dam analogs and turtle basking logs.

Executive Summary of Monitoring Results: At year 1- post-restoration, Palensky shows promise to be a fully functioning floodplain wetland habitat. Hydrology at the site typically mirrors it's reference MCNA, however, after the removal of the South water control structure, hydrology at Horseshoe Lake also follows the rest of the site. Due to a large, late freshet, there was a significant percentage of open water and bare ground at the site. Snipe Lake, the area that received scrape-down treatments saw an increase in native cover (from 6% in 2021 to 34% in 2022). However, sediment accretion at the site is not expected to keep pace with sea-level rise, and soil conditions are generally similar to the reference MCNA. These trends will be monitored further in year 3 (2024) to track the evolution of the site.

MANAGEMENT IMPLICATIONS

Action effectiveness monitoring measures changes to physical and ecological processes that influence the ability of restoration sites to support juvenile salmonids. In addition, AEM data provides project managers with vital information to determine if project design elements are meeting goals or if adaptive management is required.

At the site scale, restoration projects are leading to the re-establishment of natural physical processes that support juvenile salmonids. Data has shown that site water levels respond immediately to hydrologic reconnection. Water temperatures at the restoration sites are generally warmer than nearby mainstem waters but were generally suitable during the spring and early summer juvenile outmigration periods. The higher temperature at restoration sites can be attributed to shallower water depths, and this trend is mirrored in results seen at Ecosystem Monitoring Program (EMP) sites (Kidd et al. 2019).

As the goals of restoration activities include improving fish access to historic floodplain habitats and the quality of those habitats, we wanted to verify that fish are using restored sites. We chose to employ a "status check" of fish use at five years post-restoration. We collected fish occurrence data at Wallacut River and La Center Wetlands and found juvenile salmonids at all locations. The presence of juvenile salmonid indicates that restoration benefits fish. The PIT array at Horsetail Creek detected out-migrating upriver juvenile and adult salmonid species visiting the site for a few hours to several days.

AEM research shows that restoration sites are achieving increases in hydrologic connectivity and salmonid opportunity; however, plant community recovery is more variable across sites. Given the inherent inter-annual climate variability, it is difficult to predict specific restoration outcomes on a year-to-year basis. However, clear trends in plant community recovery across restoration sites persist, with high marsh elevations retaining reed canarygrass and other non-native species at years 3 and 5post-restoration. The lack of high marsh plant community recovery is echoed in the soil conditions identified in these locations, which retain lower soil salinity, pH, and greater ORP levels than found at reference sites. Additionally, areas within restoration sites that have undergone heavy construction impacts and grading are seen to recover on a slower timeline. Alternatively, we have observed that both soil and dominant native plant communities recover quickly (within five years post-restoration) in areas found at moderately low to mid-wetland elevations. Across all these findings, wetland elevation is used as a proxy for restored wetland hydrology which, in combination with soil conditions, is the ultimate mechanism driving restoration outcomes throughout the estuary (e.g., Bledsoe and Shear 2000, Neckles et al. 2002, Davy et al. 2011, Mossman et al. 2012, Gerla et al. 2013, Kidd 2017). Through our AEM research, we have found that the re-establishment of natural physical and hydrological processes in sites can be accomplished in a short period of time but understanding how these wetland sites respond ecologically will require long-term monitoring. Ultimately, this continued monitoring will elucidate long-term trends and improve our understanding of the connections between physical processes, habitat responses, and the resulting benefits to juvenile salmon.

AEMR Program Recommendations

Suggestions for Project Design

- Both restoration design and evaluation would benefit from using predictive modeling to determine the restoration of aquatic, marsh, and shrub-scrub plant communities. This type of modeling can be easily accomplished by incorporating anticipated restored hydrology and site elevations, and comparable reference site conditions (Hickey et al. 2015). These data can also provide a platform for evaluating different restoration scenarios, such as considering different levels of hydrologic reconnection or marsh plain lowering and the impacts on multispecies and plant community habitat recovery (Hickey et al. 2015)[3].
    - Across multiple restoration projects, we have seen very high and very low marsh elevations struggle to recover native plant cover within a 5-year timeline. Moving forward, predictive modeling could aid in restoration design (and adaptive management efforts) to maximize the restoration of the mid to moderately low marsh elevations, which have been shown to recover native plant habitat and soil conditions quickly post-restoration (throughout the Estuary).
    - In addition, this will also aid project planning for determining seeding and planting zones in target high marsh areas for non-native species control and shrub-scrub development.
    - Assessing restoration success and goal-reaching post-restoration would also be easier given predictive maps and data could be compared to conditions observed post-restoration.

Suggestions for Project Monitoring

Site topography and Reference Sites

- Accessibility to ground survey technology such as RTK GPS systems has increased dramatically over the last five years, and these systems allow us to efficiently map the overall topography of wetlands and their plant communities and channels. With this technology, we can assess the compatibility of reference and restoration wetland sites. Similar elevation gradients (and hydrology) should be sampled within reference and restoration sites for meaningful comparisons to be made post-restoration (and to aid in project design). In this report, we have highlighted that the reference site elevations have generally been a poor match with each restoration site's restored elevations. Moving forward, we will aim to alter monitoring plans to sample more overlapping elevation gradients between the restoration and reference sites to correct these issues. Additionally,

---

[3] We are currently using this Ecosystem Modeling Approach (Hickey et al. 2015) at Steigerwald National Wildlife Refuge and Multnomah Channel Natural Area to evaluate and design for desired restoration outcomes.

upon choosing reference sites to inform project design and post-restoration project success, elevations and (anticipated) hydrology should be compared to ensure that reference elevation data is an appropriate proxy for hydrologic conditions.

Hydrology

- Hydrology is a critical component of all wetland restoration efforts and should be monitored for project planning, design, and success assessment. During project design, clear hypotheses should be developed to define hydrologic changes anticipated from restoration efforts. For monitoring, data loggers need to be placed in areas that are anticipated to experience these hydrologic changes post-restoration and remain in the same location pre- and post-restoration. Given the number of issues we have experienced through the years with data loggers, we recommend having at least one redundant logger be placed within the site (nearby or at the same location) that can provide additional data in case of equipment failure (which is common). Loggers need to be maintained at least every six months, and we recommend all deployment and retrievals follow the new and more detailed monitoring protocols to avoid data loss (Kidd et al. 2018).

Sediment Accretion and Erosion, Channel Cross-Sections

- Understanding sediment accretion and erosion dynamics across the floodplains of newly restored wetlands is critical for tracking wetland and channel development and longterm topographic trajectories. Sediment dynamics across restoration sites can be highly variable, making it challenging to track meaningful change without intensive and extensive monitoring efforts. We recommend shifting our current approach of sediment monitoring (one or two sediment benches placed within a site) to a more targeted application of these methods. Before restoration occurs, specific areas of interest should be selected, and multiple sediment monitoring benches (a minimum of 6) should be installed along the elevation gradient and within these targeted areas. Within the sediment bench monitoring area (between the pins), we recommend tracking dominant plant community development and soil characteristics to aid data interpretation. Channel cross-section monitoring should be similarly focused, and extreme care should be taken to resurvey the exact location of the cross-section for meaningful results to be obtained. Both channel cross-section and sediment benches need to be resurveyed using RTK GPS technology to provide topographic context and increase data usability.

Wetland Plant Community

- Native wetland plant communities provide a critical base of the salmonid food web and are essential for determining wetland restoration success (Rao et al. 2020). We have found that monitoring a randomized selection of vegetation plots each year creates a great amount of variability in the data and makes determining what change has been caused by the restoration and what change is due to the new randomized sampling difficult. There are two approaches to addressing this issue: (1) continue to randomize the plots annually but significantly increase the overall total number of plots surveyed, or (2) only randomize the plots during the first year of monitoring and re-visit these same plots year after year. We recommend (2)—re-visiting the same plots year after year, which provides a clear path to assessing plant community changes over time and does not increase the overall amount of time required to conduct sampling. Additionally, as shown in this report, the collection of soil data, alongside plant community data, can be very informative when evaluating wetland development and restoration. We recommend integrating soil data collection as an essential metric for Level 2 monitoring across sites. Further vegetation and soil monitoring recommendations are forthcoming as we work on a comprehensive update to the *Protocols for Monitoring Habitat Restoration Projects in the Lower Columbia River and Estuary* (Roegner et al. 2008).

UTILIZING UAV TECHNOLOGY: SITE TOPOGRAPHY, PLANT COMMUNITY MAPPING

- The accessibility and applicability of Unmanned aerial vehicles (UAV) and associated sensor technology have made significant strides in the last several years. Using some of the most affordable equipment and software available, we have shown that large-scale site wetland plant community and topographic mapping are possible and accurate (Kidd et al. 2020). Mapping dominant native and non-native plant communities across large portions of restoration sites can aid the evaluation of project success post-restoration and guide both active restoration project design and post-restoration project adaptive management efforts. Moving forward, we are working to refine our UAV monitoring methods to include tracking channel and floodplain topographic development in our analysis and reporting. We are also exploring ways of evaluating biomass and carbon stores across reference and restored wetlands using our UAV and sensor technologies.

FISH AND MACROINVERTEBRATE MONITORING

- AEMR Level 2 monitoring does not encompass comprehensive fish or macroinvertebrate monitoring as part of the standard habitat monitoring protocol. Level 2 monitoring includes limited macroinvertebrate monitoring (one or two neuston tows a year following the Level 2 monitoring schedule) and a one-time fish sampling event at year five post-restoration. Given the spatial and temporal variability of both fish and macroinvertebrate populations seen across the long-term EMP reference sites (Rao et al. 2020), we have concluded that a more comprehensive macroinvertebrate and salmonid sampling effort is required for meaningful post-restoration food web conditions to be evaluated. Limited fish monitoring shows that juvenile salmonids are present in restoration sites after tidal reconnection. Still, without intensive monitoring efforts, the number of fish using the site can be challenging to ascertain. Furthermore, it is unknown if the number of fish accessing a site increases as the habitat moves toward a reference state. A better understanding of how physical processes influence habitat conditions and how these resulting habitat conditions support juvenile salmonids are vital in quantifying the overall impact of restoration efforts. Adding long-term ecosystem monitoring at a select number of restoration sites would allow these sites to be tracked alongside the Ecosystem Monitoring Program. The EMP sites have years of accumulated status and trends in fish, macroinvertebrate, water quality, and habitat data which could be used for ongoing comparative analysis and evaluation. Selecting focal restoration sites of interest and conducting intensive fish and macroinvertebrate monitoring efforts at these sites, similar to the level of monitoring achieved across EMP sites (Rao et al. 2020), would allow for the recovery of fish use and macroinvertebrate communities to be assessed over the long-term and aid in the interpretation of how physical changes to habitat directly influence the salmonid food web.

FREQUENCY OF MONITORING

- Currently, Level 3 monitoring is conducted 1-year pre-restoration through year 5 post-restoration, and Level 2 monitoring is conducted pre-, 1-, 3-, and 5-years post-restoration. Results from the last six years of the AEMR Level 2 and 3 monitoring indicate that restoration outcomes can be slow and variable, with sites not achieving reference level native plant community conditions by year 5 post-restoration (Johnson et al. 2018, and this report). Given these observations, we recommend that level 3 monitoring continue to occur pre through 5-, 8-, and 10-years post-restoration and that Level 2 monitoring should also be conducted at year 8 and year 10 post-restoration. Adding years 8 and 10 to monitoring for all level 2 and 3 metrics will aid in understanding the long-term impacts of our restoration efforts and allow for monitoring over a broader spectrum of annual climate conditions. Additionally, we recommend UAV plant community mapping occur across all Level 2 and 3 sites pre-restoration and 3-, 5-, 8-, and 10-years post-restoration. These additional data and longer-term monitoring windows will provide greater context to assess restoration actions and outcomes and help us test ongoing hypotheses about how shifts in climate and river discharge conditions impact restoration outcomes. Synthesis reports of site conditions at years 8 and 10 post-restoration will also provide meaningful insight for ongoing adaptive management and restoration efforts.

SYNTHESIZING RESTORATION RESULTS

- The most meaningful analysis of restoration success would incorporate all habitat level monitoring metrics across a site to identify the recovery of salmonid habitat over time. We have developed a site-wide assessment of habitat opportunity that extends across the wetland's active floodplain (Johnson et al. 2018). This incorporates floodplain topography, water surface elevation (water depth), water temperatures, and dominant plant communities to highlight salmonid habitat conditions across the active floodplain of restoration and reference sites. See this tableau link for the habitat opportunity assessment of Wallooskee – Youngs Project. This dynamic floodplain mapping approach could also be used to evaluate the impacts of climate change and shifting river discharge on wetland habitat conditions throughout the Columbia Estuary.

INTRODUCTION

Program History

The Action Effectiveness Monitoring (AEM) program is managed by the Lower Columbia Estuary Partnership (LCEP) under LCEP's Ecosystem Monitoring Program contract with Bonneville Power Administration and the Northwest Power Conservation Council's Fish and Wildlife Program. As part of the Columbia Estuary Ecosystem Restoration Program (CEERP), this program provides the Bonneville Power Administration (BPA), restoration partners (e.g., USACE and CREST), the Environmental Protection Agency, and other stakeholders with data to assess the success of restoration projects in the lower Columbia River and estuary.

In 2008, during the program's pilot phase, the Estuary/Ocean subgroup (EOS) recommended four projects for AEM. The selected AEM sites were monitored annually until 2012 and represented different restoration activities, habitats, and geographic reaches of the river. The initial phase of AEM resulted in site scale monitoring and the standardization of data collection methods but also highlighted the need for expanded monitoring coverage, paired restoration and reference sites, and comparable monitoring to ecosystem status and trends monitoring to evaluate reach and landscape scale ecological uplift.

To provide monitoring at all restoration sites, three monitoring levels are implemented at restoration sites as follows:

> Level 3 – includes "standard" monitoring metrics: water surface elevation, water temperature, sediment accretion, and photo points that are considered essential for evaluating the effectiveness of hydrologic reconnection restoration. This monitoring is done at all restoration sites within the CEERP. Project sponsors conduct level 3 monitoring.
>
> Level 2 – includes the Level 3 metrics and metrics that can be used to evaluate the site's capacity to support juvenile salmon. These metrics include vegetation species and cover, macroinvertebrate (prey species) composition and abundance, and channel and wetland elevation. This "extensive" monitoring is done at a selected number of sites chosen to cover a range of restoration actions and locations in the river. It is intended to provide a means of monitoring an "extensive" area. LCEP conducts level 2 monitoring.
>
> Level 1 – includes Level 2 and 3 metrics and more "intensive" monitoring of realized function at restoration sites, such as fish use, genetics, and diet. Since Level 1 monitoring is more expensive, it is conducted at fewer sites with the goal of relating the Level 1 results to the findings of Level 2 and Level 3 monitoring. The USACE conducts level 1 monitoring.

Program Overview

LCEP manages the Action Effectiveness Monitoring (AEM) program with the goals of determining the impact of habitat restoration actions on salmon at the site and landscape scale, identifying how restoration techniques address limiting factors for juvenile salmonids, and improving restoration techniques to maximize the impact of restoration actions.

To accomplish AEM program goals, LCEP implements the Columbia Estuary Ecosystem Restoration Program (CEERP) AEM Programmatic plan (Johnson et al. 2016), employs standardized monitoring protocols, and coordinates between stakeholders to collect and share AEM data. The AEM annual monitoring objectives were to quantify post-restoration hydrology, temperature, habitat, and vegetation within restoration sites and to determine post-restoration fish use at selected sites.

The goals of the AEM program are to:

1. Determine the benefit of restoration actions for juvenile salmonids at the site, landscape, and ecosystem scale.
2. Improve restoration and monitoring techniques to maximize the benefits of habitat restoration projects.
3. Use the results of intensive AEM (Level 1) to focus extensive AEM efforts (Level 2 and 3) and link fish presence and habitat recovery outcomes through a line of evidence approach.

To meet these goals, LCEP is engaged in the following tasks:

1. Implementing AEM as outlined in the Estuary RME plan (Johnson et al. 2008), Programmatic AEM plan (Johnson et al. 2016), and following standardized monitoring protocols (e.g., Kidd et al. 2023, Roegner et al. 2009) where applicable.
2. Developing long term datasets for restoration projects and associated reference sites.
3. Coordinating between stakeholders to improve AEM data collection efficiency.
4. Supporting a regional cooperative effort by all agencies and organizations participating in restoration monitoring activities to create a central database to house monitoring data.
5. Capturing and disseminating data and results to facilitate improvements in regional restoration strategies.

Twenty restoration sites in 2022 received AEM data collection. Level 2 and Level 3 sites for 2023 and 2024 are presented in **Error! Reference source not found.** 2 and Figure 3. The specific monitoring actions involved quantifying water surface elevation, water temperature, habitat opportunity, and vegetation at restoration sites. At years 1, 3, and 5 post-restoration, macroinvertebrate data are collected at a single sampling event to determine community composition at the sites. Additionally, at year 5, post-restoration fish data are collected to determine the composition of the fish community. To put ecological changes at restoration sites into context, the program incorporated data from reference sites monitored in the Ecosystem Monitoring Program (EMP), which focuses on characterizing the status, trends, and juvenile salmonid usage of relatively undisturbed emergent wetlands.

All monitoring was conducted following standardized protocols outlined in Kidd et al. 2023 and Roegner et al. 2009. In 2022, four restoration sites received Level 2 monitoring, and sixteen restoration sites received Level 3 monitoring. Additionally, , we conducted status fish sampling at Flights End Wetlands (year 5 post-restoration) and Dibblee Point (year 10 post-restoration) to identify fish presence.

Figure 1: AEMR Level 2 and 3 monitoring for 2022.

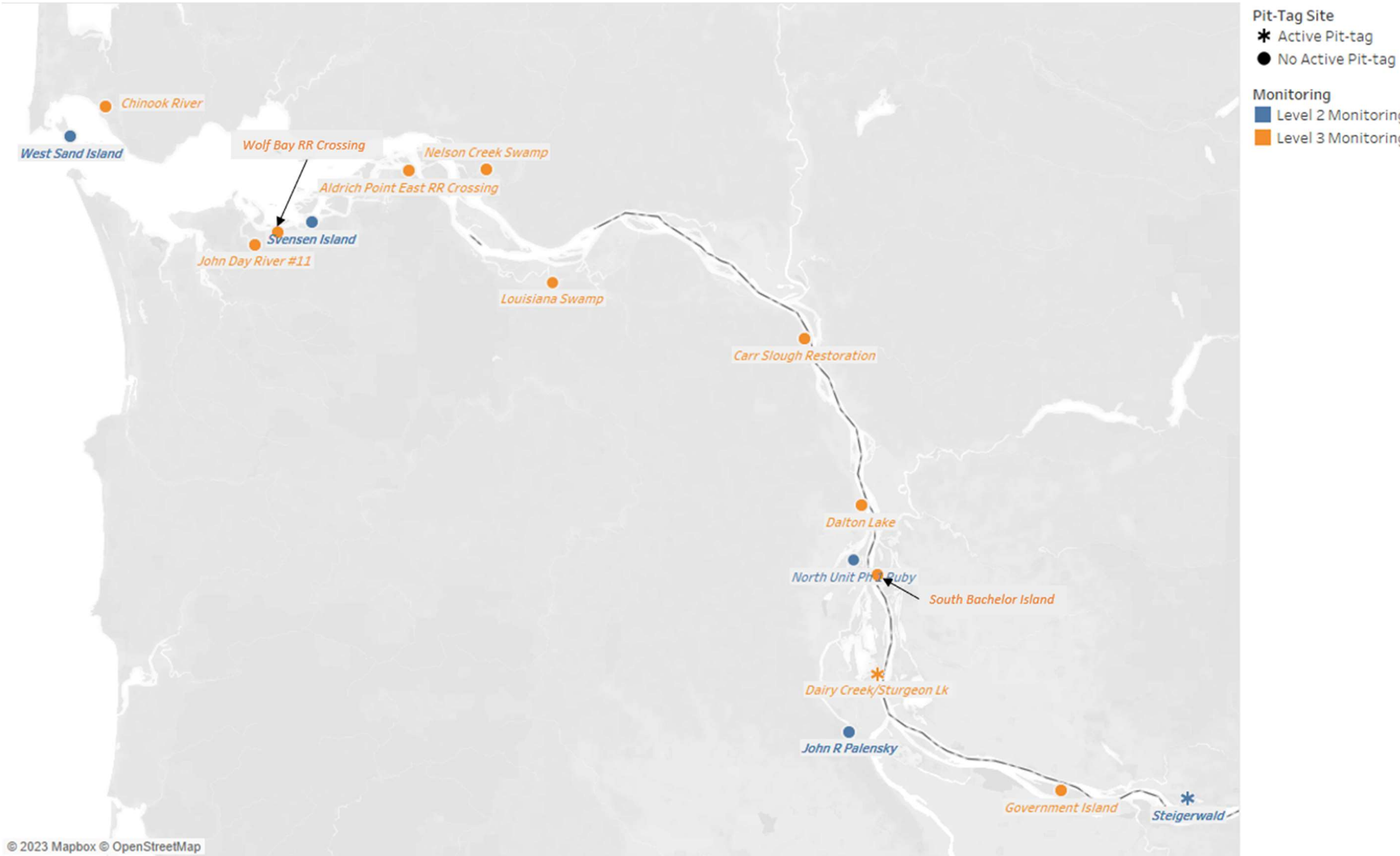


Figure 2: AEMR Level 2 and 3 monitoring planned for 2023.

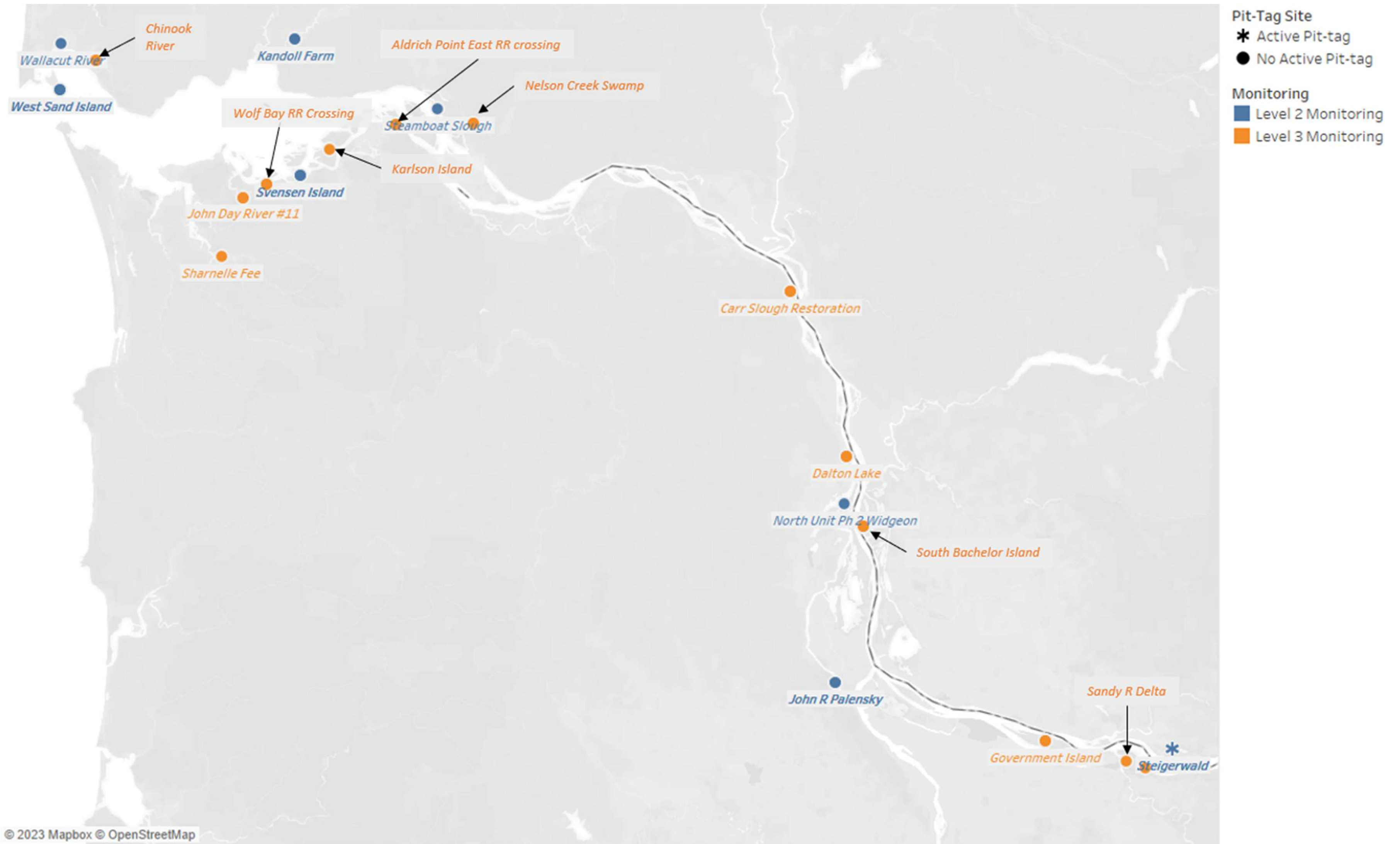


Figure 3: AEMR Level 2 and 3 monitoring planned for 2024.

Table 1. Summary of AEMR accomplished or planned from 2012 through 2023. For a more detailed breakdown, please see the Tableau link

Project Name	Monitoring Agency	Projected Completion Date	Monitoring Year		
			2022	2023	2024
Aldrich Point East RR Crossing	CREST	2022	3	3	3
Bear-Mary’s-Ferris	CREST	2018	3	3	3
Carr Slough Restoration	CREST	2022	3	3	3
Chinook River	WDFW	2014	3	3	3
Colewort Creek	CREST	2012	3	3	3
Dairy Creek/Sturgeon Lk	CREST	2018	3	3	3
Dalton Lake	CREST	2022	3	3	3
Dibblee Point	CREST	2012	2, 3		
Flight's End	CREST	2017	2, 3		
Government Island	CREST	2019	3	3	3
Horsetail	LCEP	2013	3	3	3
John Day River #11	CREST	2020	3	3	3
John R Palensky	CREST	2021	2, 3	2, 3	
Kandoll Farm	CLT	2013			2, 3
Karlson Island	CREST	2014			3
Louisiana Swamp	LCEP	2013		3	
Mill Road	CLT	2011	3		
Mirror Lake	LCEP	2008			3
Nelson Creek Swamp	CLT	2022	3	3	3

Project Name	Monitoring Agency	Projected Completion Date	Monitoring Year		
			2022	2023	2024
North Unit Ph 1 Ruby	CREST	2013		2, 3	
North Unit Ph 2 Widgeon	CREST	2014			2, 3
Otter Point	CREST	2012	3		
Sandy R Delta (dam)	LCEP	2013			3
Sharnelle Fee	CREST	2014			3
South Bachelor Island	WDFW	2019	3	3	3
Steamboat Slough	LCEP	2014			2, 3
Steigerwald	LCEP	2022	3	2, 3	3
Svensen Island	LCEP	2022		2, 3	2, 3
Thousand Acres	LCEP	2014			3
Wallacut River	CLT	2016			3
Wallooskee-Youngs	LCEP	2017	2, 3		
West Sand Island	CREST	2020		2, 3	
Wolf Bay RR Crossing	CREST	2022	3	3	3

Data Visualization and Reporting

To better meet the goals and objectives of the AEM Program, the results of this report are presented in Tableau. Tableau is a user-friendly data visualization software capable of processing, summarizing, and displaying large quantities of geospatial and non- geospatial data. It is an interactive platform that encourages data exploration by researchers and allows the target audience to follow the story presented by analysts and explore the data themselves.

Tableau 2022.2 can store and query vast quantities of data in a user-friendly manner. It requires no knowledge of any coding to start, making it extremely quick and easy to pick up and use; however, if one is more coding inclined, Tableau allows for one to directly write advanced queries and analyses in a variety of languages including SQL, Python, and R. Additionally, Tableau is built for collaboration. Multiple people can connect to and analyze the same datasets and seamlessly contribute to the same workbook. Furthermore, all tableau work is often easily adaptable each year as one collects more data or adds additional sites to the analyses. One simply needs to update the base database (e.g., adding another six months of measurements to a hydrology database), and the graphs, plots, and analyses will all automatically update with the additional data.

While there are multiple software tiers ranging from free to paid with various privacy options, Tableau can and does meet most of LCEP's needs for data QA/QC, analysis, and visualization. At LCEP, we utilize Tableau Desktop for most of our base work; Tableau Online hosts our data and collaborates with fellow researchers; Tableau Prep Builder quickly checks and prepares our data for analysis, and Tableau Public publish our work to the world at large. Of these, Tableau Public is completely free, while Tableau Desktop and Prep Builder cost as little as $70 per year. The online space varies in cost depending on the number of users and quantity of data required.

We have publicly disseminated multiple datasets and analyses including our hydrology, vegetation, sediment accretion, drone analyses, macroinvertebrates, fish, and other datasets and analyses in the form of Tableau dashboards, often designed to accompany reports. These dashboards provide an opportunity for project sponsors, researchers, and other interested parties to visualize and self-explore the evolution of restoration sites from pre-monitoring to their current states as well as share and communicate these results to landowners, project managers, and other members of the public in an easily digestible manner.

The layout of the Results section has also been modified to meet ERTG better Revisit templates' needs. Level 2 site results presented in this report are accompanied by basic project information – background of the project, goals, objectives of restoration, and restoration actions. The experimental design and parameters for monitoring have also been included in this report. The results of these monitored parameters are linked to tableau dashboards in this report.

METHODS

Site Selection 2022

Four restoration sites were selected for Level 2 monitoring (Table 2) in 2020 and 2021 using the prioritization criteria outlined in Johnson et al (2016). Three associated reference sites were chosen to establish a before-after reference impact monitoring design, which puts pre- and post-restoration site data into ecological context (Table 2). This report summarizes the results for level 2 monitoring metrics for all sites surveyed in 2022, except for Steigerwald, which was still under construction.

Table 2. Sites included in Level 2 monitoring in 2022.

RKM	Site	Project Management	Description	Construction	Pre	1 yr	3 yr	5 yr	8yr	10 yr	Reference site
22	Wallooskee-Youngs	LCEP	Tidal reconnection, Dike breaches, channel network development, non-native plant community treatment	2017	2015	2018	2020	2022	*2025*	*2027*	Daggett Point (RKM 22)
103	Dibblee Slough	CREST	Full channel reconnection, increase habitat complexity, native revegetation	2013	-	2013	2015	2017	*2020*	2022	Dibblee Reference (RKM 103)
143	Flight's End Wetlands	CREST	Marsh plain lowering, native revegetation, and new tide gate	2017	2017	2018	2020	2022	*2025*	*2027*	Cunningham Lake (RKM 145, EMP site)
142	John R Palensky	CREST	Targeted marsh plain lowering, removal of water control structures, native revegetation	2021	2021	2022	2024	2026	*2029*	*2023*	Multnomah Channel Marsh Natural Area (MCMNA) (RKM
200	Steigerwald	LCEP	Full channel and tidal reconnection, alluvial fan restoration, and targeted marsh plain lowering	2022	2019	*2023*	*2025*	*2027*	*2030*	*2032*	Reed Island (RKM 200), and Franz Lake (RKM 221, EMP site)

Habitat Monitoring
Methods from the protocol "Lower Columbia River Estuary Habitat Action Effectiveness v1.0" were used to evaluate changes related to restoration actions and quantify ecological uplift (Kidd et al 2023, Roegner et al. 2009, Protocol ID: 460).

We surveyed vegetation cover and composition (Method ID 822) to assess changes to habitat structure related to restoration actions. Vegetation cover and composition is an indicator of the production of organic matter, and the detritus produced by decaying vegetation forms the base of the food web for many species in the lower Columbia River and estuary (Borde et al. 2010, Maier and Simenstad 2009). Vegetation plot elevation (Method ID 818) was recorded to track the effectiveness of lowering marsh elevations (soil scrape down) to control invasive vegetation and promote native plant species growth. At each restoration site, two vegetation monitoring areas were established – one in an area directly impacted by restoration actions and one in an area indirectly affected by restoration actions. Two vegetation sampling areas provide an overview of overall site condition pre- and post-restoration. Sediment Accretion (Method ID 818) was measured to determine if constructed wetlands are self-sustaining by installing sediment benches at the low marsh and high marsh areas of the site. Water Temperature (Method ID 816) was measured to determine habitat suitability for juvenile salmonids. Water Surface Elevation (Method ID 3982) was measured to assess the opportunity for juvenile salmonid species to access the site and determine the timing and level of wetland inundation.

Soil survey - Within each quadrat, in-situ surface soil salinity, conductivity, pH, ORP and temperature were measured. (Bledsoe and Shear 2000, Neckles et al. 2002, Davy et al. 2011, Mossman et al. 2012, Gerla et al. 2013). All soil surveys were conducted in saturated soil conditions, timed near peak low tide (lowest tidal elevation), and surveyed from highest to lowest elevation. Although these soil parameters are dynamic over time depending on the precise environmental conditions present and the duration of tidal flooding, the logic in taking these in-situ samples was to capture the general gradient among the different plant communities. If all samples were collected under similar conditions and at similar intervals of time, they would become more comparable to each other. Redox potential (ORP), pH, conductivity, salinity, and temperature data were collected using Extech soil probes. For detailed information about these soil parameters and tidal wetland restoration, see Kidd 2017.

Macroinvertebrate Monitoring
Sampling
Macroinvertebrate samples were collected using Neuston Tows in 2022 at four restoration and four reference sites to quantify community composition and the availability of prey resources for juvenile salmonids at Level 2 restoration sites and compare these communities to reference sites. Two Neuston samples were collected and combined into one composite sample from emergent vegetation during May at each site. The Neuston net was pulled through a 10 m transect parallel to the water's edge in the water at least 25 cm deep to enable samples from the top 20 cm of the water column. Samples were preserved in plastic containers with 95%

ethanol and rose Bengal solution and transported to the University of Washington for identification. Container lids were wrapped with electrical tape to prevent evaporation during transit and before processing. Sampling procedures were in accordance with USGS Western Ecological Research station SFBE & Nisqually Indian Tribe's Pelagic Invertebrate Standard Operating Procedures.

Laboratory Methods

Invertebrates collected in neuston tows were identified in the lab using high-resolution optical microscopy and taxonomic references (Mason 1993, Kozloff 1996, Merritt and Cummins 1996, Thorp, and Covich 2001, Triplehorn and Johnson 2005). Most individuals were identified to family, although some groups/individuals were identified to coarser (e.g., order) levels. The number of individuals in each taxonomic group was counted for each sample.

Fish Monitoring

Fish presence and community composition were assessed at Wallooskee – Youngs, Dibblee Point and Flights End wetlands between April and July 2022. Wallooskee – Youngs and Flights End fish data were collected at year 5 post-restoration, while Dibblee Point fish data were collected at year 10 post-restoration. Dibblee Point was sampled only once on April 21st due to high water temps in May, June and July. Fish sampling occurred in several areas at each site – sampling locations for each site are depicted below (Figure 4, Figure 5, Figure 6)

Table 3: Sampling efforts at Sites in 2022

RKM	Site	Sampling date	Number of Efforts (Pole Seine or Trap Nets	Temperature (°C)	Dissolved Oxygen (DO) (mg/l)
22	Wallooskee- Youngs	26-Apr-2022	3	-	-
22	Wallooskee- Youngs	31-May-2022	2	15.3	9.3
103	Dibblee Point	21-Apr-2022	4	12.0	12.4
143	Flights End Wetlands	4-May-2022	11	13.8	12.4
143	Flights End Wetlands	7-July-2022	5	20.6	8.3

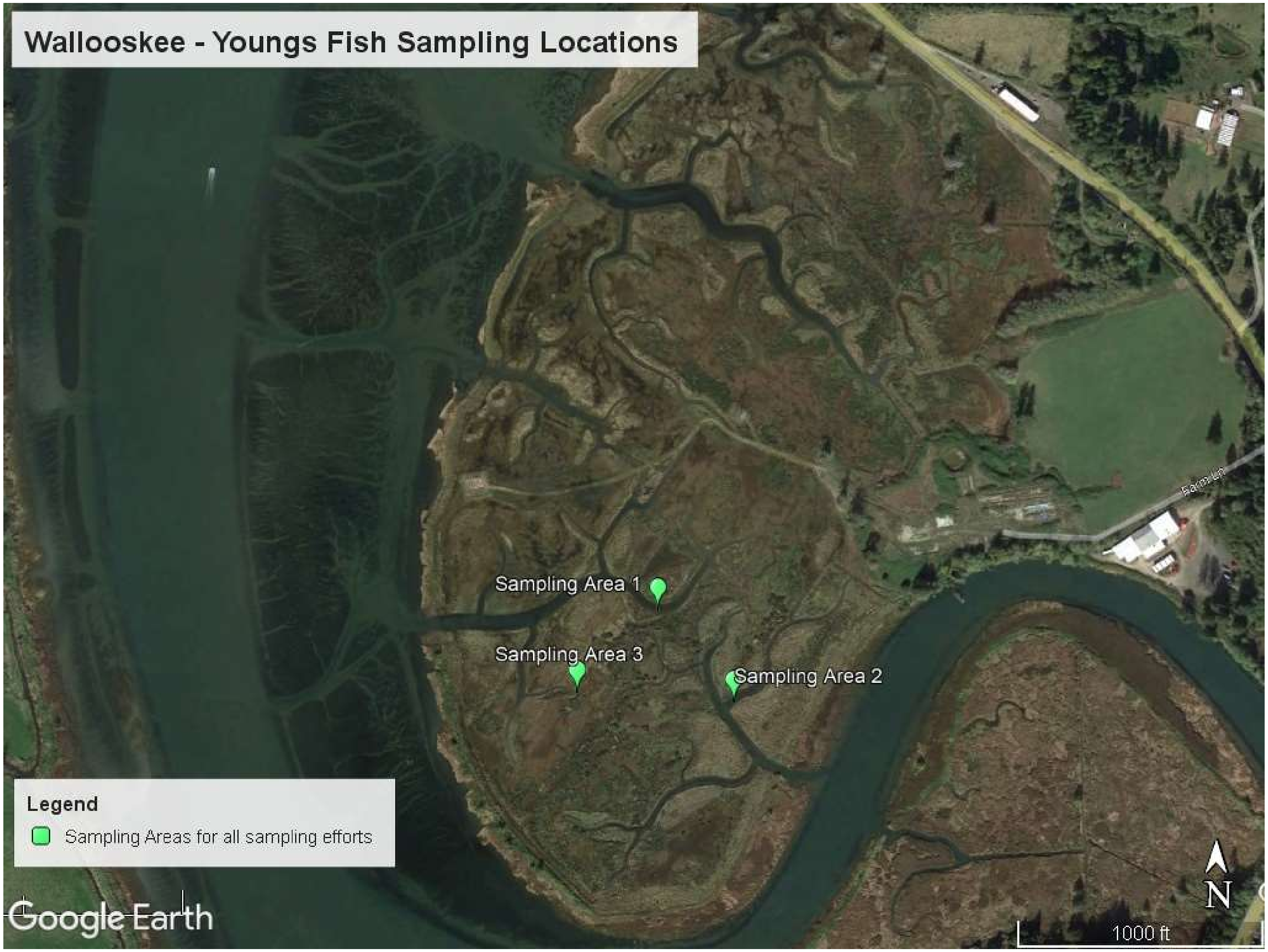


Figure 4: Fish Sampling locations in Wallooskee - Youngs.

Figure 5: Fish sampling areas in Dibblee Point.

Figure 6: Fish sampling areas at Flights End.

Fish were collected at Dibblee Point and Flights End using two different methods, a pole seine (PS; 7.6m x 1.8m, 10 mm mesh size) and a Bag Seine (BS; 37 x 2.4 m, 10 mm mesh size). A Bag seine was the only gear used during the sampling at Wallooskee. Due to the locations and gear selection, a 9 ft Zodiac inflatable raft was used during sampling at Dibblee Point and Flights End. Wallooskee was sampled using a 17ft Boston whaler. All sites were sampled at high tide to ensure maximum daily water levels were reached at each site before sampling. All non-salmonid fish were identified to the species level counted and released. All salmonids were measured (fork length, nearest mm) and released. A genetic sample was taken from the caudal fin on all captured Chinook salmon at both sampled restoration sites. All salmonids were checked for adipose fin clips, or other external marks, coded wire tags, and passive integrated transponder tags to distinguish between marked hatchery fish and unmarked (presumably wild) fish. Due to the soft mud, large amounts of algae and low water levels area swept during sampling was not calculated or standardized.

Gibbons Creek PIT Array

A PIT detection array was installed at new Gibbons Creek in 2022 following the restoration actions at Steigerwald Lake National Wildlife Refuge. The system is a dual array configuration consisting of six antennas total (three antennae in each of two arrays) – one PIT array is at the mouth of the new Gibbons Creek near the Columbia River, and the other is 800ft upstream in the Creek. Each array consists of a 1" diameter cable looped to form a large primary antenna (~85'W by 7.5'H). The lower primary cables of each of the arrays follow the contour of the bank(s) and channel invert, while the upper cables span the channel approximately seven feet above grade and are mounted near the top of the support pilings. Each system consists of triangular antennas on each bank that extend from the support pilings to the bank while following the bottom contour. A typical cross-section depicting the support pilings and cable antenna is provided in Figure 7.

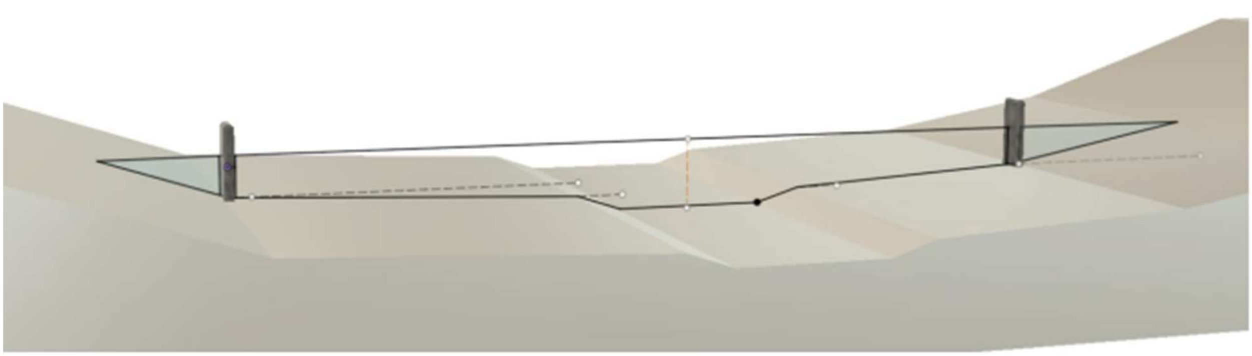


Figure 7: Gibbons Creek PIT Array Design

The array also has a total of 6 aluminum data relay pods that connect the antennas to the job control box which houses all the electronics to transmit power and gather data. The arrays are powered by 4 solar panels.

Data collected at the Gibbons Creek PIT array are intended to document the presence of salmon stocks accessing the restoration site, not to estimate the numbers of salmon using the site. Detection data depend upon the population of salmon in the Columbia River Basin that PIT-tagged each year. The number of salmon and the particular stocks that are PIT tagged varies annually, which impacts the patterns of detections from year to year.

Tagging information for each unique tag ID will be uploaded into the PTAGIS regional PIT tag data depository (www.ptagis.org) and available to the public in the coming future. Data is currently being analyzed and results will be available in the near future.

Analysis

Water-surface elevation (WSE)

WSE is the primary indicator of hydrographic conditions at a site. Continuous pre- and post-restoration water level data were collected at the restoration sites and a nearby outer reference channel. The sensors collecting data were surveyed for elevation so that depth data could be converted to water surface elevation and evaluated against wetland elevations.

Pre- and post-restoration hydrographs for the wetland channel were created and compared to those for the outer reference channel and a nearby reference site ("a site with little or no anthropogenic influence," Borde et al., 2012). An effective restoration project would have a WSE that matches the conditions of the reference site, indicating hydrology for the site was meeting restoration principles.

Water surface elevation was used to study inundation patterns at the sites. The percent of time each marsh was inundated was calculated daily across the elevation gradient at the sites. The average inundation daily, as measured by the average number of hours a day (converted to a %), the water surface level is above the marsh elevation, is a means of comparing sites to each other and over time. This is like the historic sum exceedance value (SEV) analysis; however, it is summarized by day instead of over the entire growing season (Kidd 2017).

Water Temperature

Monthly maximum 7-day moving average maximum (7-DMA) will be calculated for sites post-restoration to compare to an outer reference location and main stem conditions. The Columbia mainstem data collection station S8 (Washougal, EP) will be used for comparison. Previous research has shown that main stem temperatures do not vary substantially, and a single station adequately represents general main stem conditions for any given time period (Sager et al. 2014).

Habitat Opportunity Analysis
Habitat Access and Opportunity models were adapted from previously established analyses and are defined by the depth and temperature of water considered ideal for salmonid access and utilization (Bottom et al. 2011, Schwartz and Kidd et al. 2018). Juvenile Salmonids require ≥0.5 m of water depth above the channel or wetland surface for habitat access and we have defined depths of < 0.5 m of depth inaccessible to fish passage/use. In addition to the required water depths, water temperature ranges were used to determine optimal, marginal, and inhospitable habitat conditions as follows; optimal conditions require a water temperature of less than 17.5 °and C, and marginal conditions were defined by water temperatures greater than 17.5 °C but less than 22 °C, and water temperatures greater than 22 °C were defined as inhospitable to salmonids (Schwartz and Kidd et al. 2018). For this analysis, we used maximum daily water depths and mean daily water temperatures. These water depths and temperatures were averaged across the site to develop a robust water temperature and depth model. These data were then used to summarize the post-restoration habitat opportunity (what are the temperature conditions that define these accessible habitats) across the entire site using the post-restoration wetland elevations collected during aerial surveys (UAV).

Sediment Dynamics and Sea Level Rise
The net accretion or erosion rate for high marsh and low marsh areas of the site was calculated by averaging measurements made along the 1-meter distance between the two sediment pins and finding the difference between a given year's average to the previous average. The net accretion or erosion rates were also compared to average rates of sea level rise to study the development of sites when compared to various sea level rise scenarios.

Understanding how our tidal wetlands and floodplains are keeping track with Sea Level Rise (SLR) is critical for considering how future restoration and management actions can address further potential wetland loss. For this preliminary analysis, we have used the USACE's 2020 Lower Columbia River Adaptive Hydraulics (AdH) Model Scenarios (USACE Model Report). These Scenarios (50, 75, and 100 yr) are slightly more aggressive (greater rates of change) than the Miller et al. 2018 model (https://wacoastalnetwork.com/research-and-tools/slr-visualization/) which focuses on the Oregon and Washington Coast. However, they provide a glimpse into how well our reference and restoration sites may be keeping up with increases in Water Surface Elevation across each reach of the lower Columbia. Further refinement of this analysis is forthcoming.

Vegetation
To assess species richness (defined as the total number of species) and percent cover for the herbaceous vegetation community at a restoration site, we categorized plant species into native/non-native categories. We calculated species richness and relative cover for native and non-native plants out of the total assemblage for sampling episodes before and after restoration for restoration sites for which data were available.

UAV Plant Community Mapping
Quantifying the distribution and abundance of dominant plant communities over time is of fundamental importance to ecological and restoration effectiveness monitoring. Our ability to estimate plant distributions over large areas (i.e., several hectares) using traditional approaches (transect or quadrat methods) is limited because of the time and expense required. In 2022 we conducted aerial surveys at the restoration sites using an unmanned aerial vehicle (UAV) to develop a map of the current extent of dominant native and non-native plant community distributions across the restoration site.

Data Collection
A DJI Phantom 4 was outfitted with a Sentera Near Infrared (NIR) Camera was the UAV chosen to collect multispectral aerial images (visible or RGB, and NIR) of the restoration sites. At each site, Pix4D capture was used to create the flight polygon grid with overlaps of 80% fore-lap and 80% side-lap. The UAV was flown at 300ft above ground level (AGL), producing a high density of images (ground sampling distance (GSD) of 1.68 inches per pixel). Multispectral data was collected between 11 am and12 pm to ensure consistent light conditions at all sites.
Ground control points (GCPs) were placed at sites and surveyed to geo-reference the aerial images. Between 5 to 10 GCPs were placed at each site, depending on the range of terrain elevations at the sites. The GCPs were 1m x 1m, black and white rectangular cardboard cut-outs; the position and elevation of each were captured using a TOPCON Real Time Kinematic (RTK) GPS. Elevations of different vegetation communities were also collected to outline representative dominant plant communities on the site.

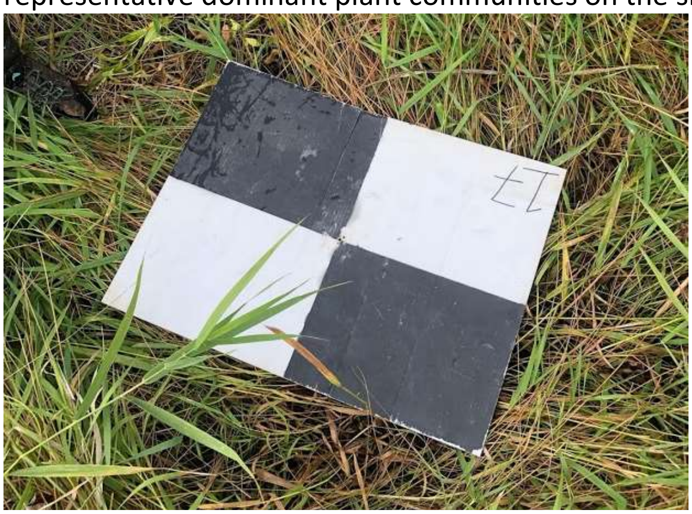


Figure 8: 1m x 1m rectangular ground control point (GCP)

Data Processing
Multispectral images collected by the UAV were imported into PIX4D mapper to create products that will aid in mapping vegetative communities at the site. Images from each camera were processed separately to obtain different products. RGB images were processed to obtain an Orthomosaic and a digital surface model (DSM), while NIR images were processed to determine the normalized difference vegetation indices (NDVI) of the vegetation at the site.

Pix4D Mapper analyzed multiple points in the imported images to triangulate matches and create a 3D point cloud of the sites. The point cloud was then georeferenced using the collected GCP information to create an orthorectified mosaic of RGB data of the site and a corrected elevation model called a Digital Surface Model (DSM) (Figure 10). Pix4D processed NIR images in the same manner; however, in addition to producing an Orthomosaic and a DSM, the software also produced a mosaic of the NDVI for the site (Figure 9). The NDVI is a well-established indicator for presence and condition of vegetation at a site and ranges from -1 to +1. Negative values indicate no green biomass, and positive values indicate lush green biomass. Bare ground areas usually produce values of zero.

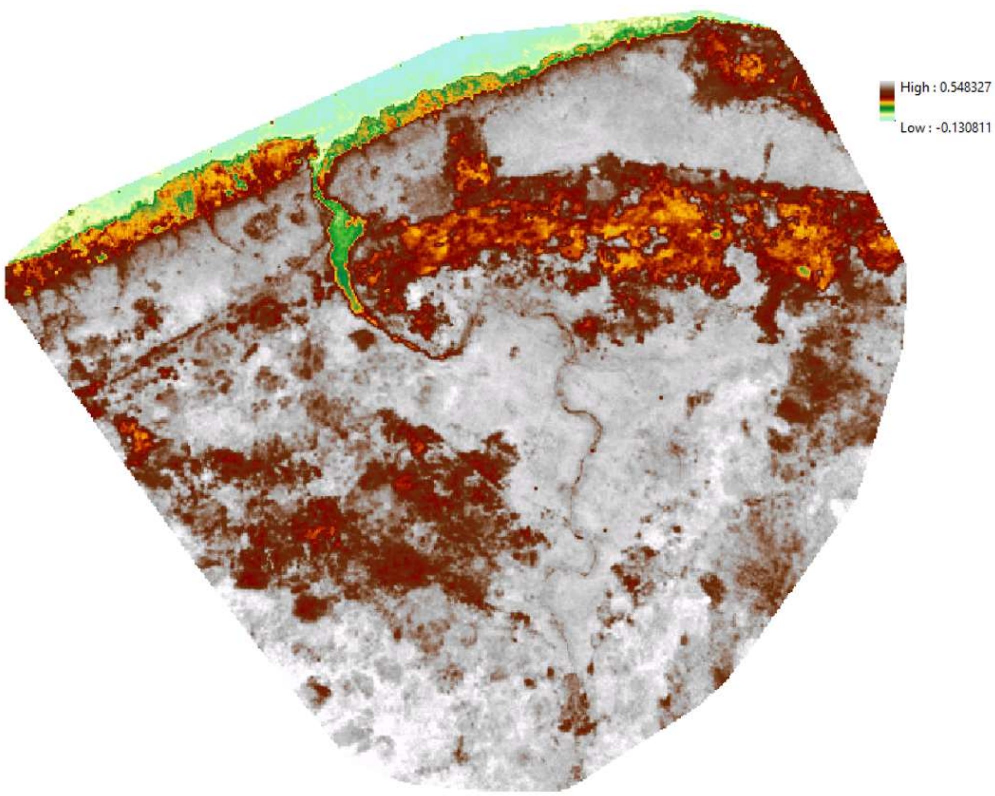


Figure 9: NDVI Mosaic for Wallacut Slough

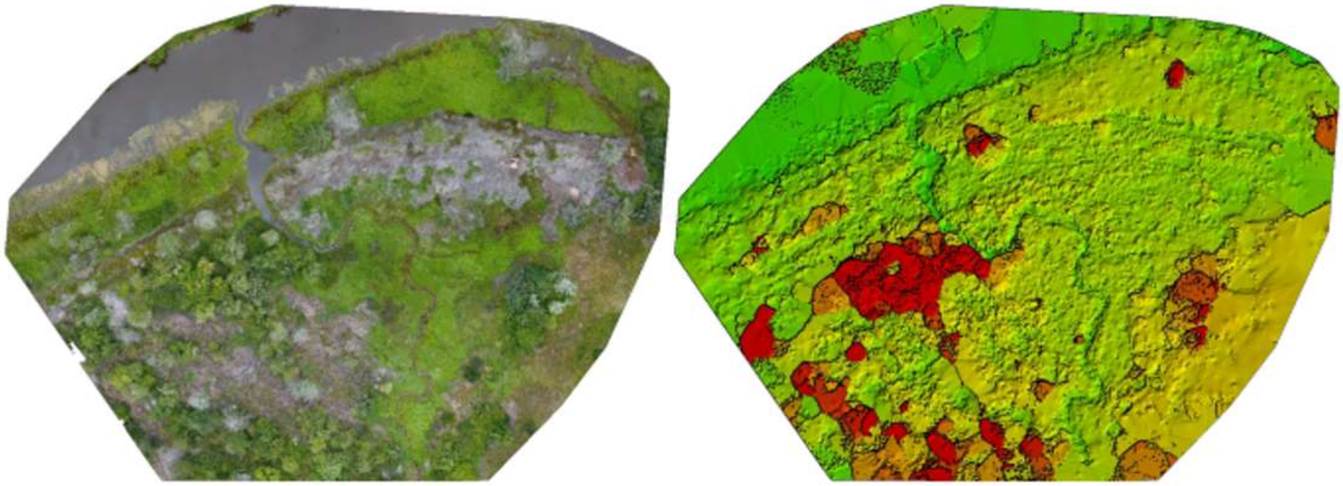


Figure 10: RGB Orthomosaic and Digital Surface model (DSM). The different colors on the DSM represent ranges of elevations present at the site, red color representing higher elevations and green representing low elevations.

Data analysis

RGB and NDVI orthomosaic were combined with the DSM and ground plant community survey data in ArcGIS and R statistical software was used to model the extent of dominant native and non-native plant communities across the site. These data were evaluated for accuracy using the plant community data collected during the ground survey. The final product of this analysis is a dominant plant community map of the site in addition to estimates (in acres) of the extent of these communities.

Macroinvertebrate Community

To assess community development at Level 2 monitoring sites, taxa information was consolidated into Orders and absolute and relative abundance was calculated and compared over time with their reference sites. Data analysis was done using Microsoft Excel and Tableau (2022.1) software.

RESULTS

2022 Water Year Overview

Habitat Restoration and Climate Variability

Long term status and trends monitoring conducted through the Ecosystem Monitoring Program have underscored the importance and influence that shifts in annual climate and discharge conditions in the Columbia River have on tidal wetland food web dynamics and habitat conditions (Kidd et al. 2023, Rao et al. 2020, Kidd et al. 2019). Ongoing synthesis efforts of EMP data have revealed that plant community composition of both reference and restoration sites can be heavily impacted by discharge conditions in the Columbia during the growing season, resulting in annual shifts in both reed canarygrass and native wetland plant community abundance (Kidd et al. 2023, Rao et al. 2020, Kidd et al. 2019).

Annual climatic variations can also cause a shift in wetland and mainstem water temperatures and water biogeochemistry impacting local tidal wetland water quality conditions for salmonids. All wetland restoration sites in the estuary are impacted by these annual shifts in climatic and discharge conditions. This makes simple pre-post restoration comparison challenging to interpret, especially if extreme dry or wet years fall right before or after restoration occurred (Johnson et al. 2018). Comparing pre/post restoration success to that of a reference site tracked during the same time period can be a helpful way to account for the variability in annual conditions; however, it is critical to provide appropriate water year and climatic descriptions for any pre/post or time series analysis and comparison of habitat conditions across sites in the estuary. To aid in this, we have provided an excerpt from the 2023 EMP hybrid report below, highlighting the conditions experienced in 2022. For a more detailed analysis of these data, please visit the EMP Mainstem and Abiotic Site Conditions Ecosystem Monitoring Dashboard here (link).

Overview of 2022 and historical conditions

River flows in the Columbia and its tributaries are influenced by a combination of winter snowpack and pluvial flows driven by rainfall. High snowpack arises from cold and wet winters, while low snowpack arises from dry conditions throughout the winter, which can be either warm or cold. The timing of precipitation and whether it falls as snow or rain influences the timing and magnitude of the spring freshet. Typically, the freshet begins in late April/early May and persists into June. After that, the summer tends to dry, and river flows are low between June and October.

2022 water year consisted of periods of heightened fluvial flows from the Willamette River in the winter, followed by below average flows in early spring. The spring freshet was characterized by above – average flows that peaked in mid-June 2022.

The 2022 water year is defined as,

"*Columbia River discharge at Bonneville Dam was close to the 2009-2022 average during the winter months; after mid-March flows were lower than average and reached minimum values for the time period in mid-April. Flows increased from early and peaked in mid-June at volumes* *close to the long-term maximum, observed in 2017. The decline in river discharge following peak flows was steeper than in 2017, but flow remained above average through the end of August after which they were close to the long-term average. River discharge associated with the Willamette was higher than average during a few peaks in winter and spring (early January, early March, early May, and early June) and was otherwise close to or below average values observed between 2009-2022*"

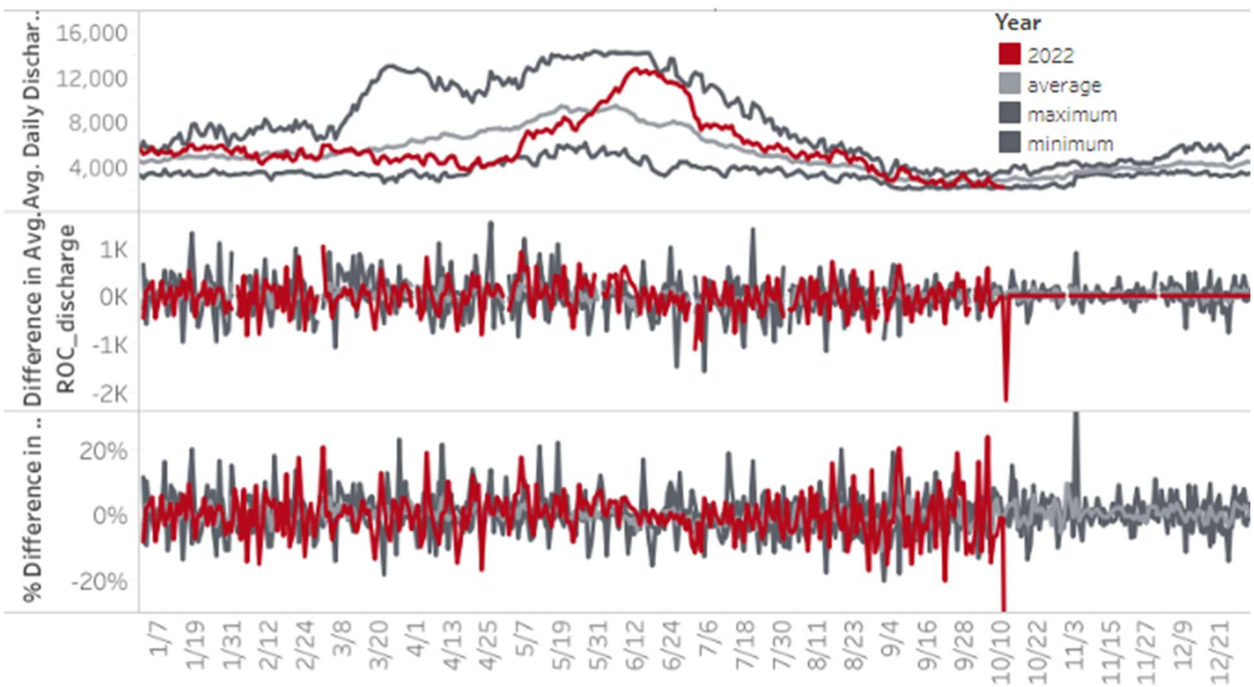


Figure 11. 2022 flows at Bonneville Dam shown in Red, as compared to 2009-2022 min, max and average flows. Top panel shows daily discharge, middle panel show changes in daily discharge and bottom panel shows percent difference in daily discharge.

Wallooskee - Youngs

Basic Project Information

Project Description – Problem Statement, Goals, and Objectives

The Wallooskee restoration site is located in Youngs Bay, near the City of Astoria in Oregon. The 200-acre tidal reconnection restoration project was funded by BPA and is currently owned and managed by the Cowlitz Indian Tribe. Dr. Sarah Kidd, with LCEP, has been conducting restoration effectiveness monitoring at this site in partnership with the Cowlitz Indian Tribe since 2013.

Project goals are defined as:

"Removing the levee and filling the borrow ditch will increase hydrologic connectivity during the tidal cycle and increase the spatial extent of inundation in the wetland. The restoration of a more natural tidal cycle will help restore ecosystem function by supporting a diverse native plant community, improving nutrient cycling, and increasing quantity and quality of off-channel habitat for aquatic species."

Project Construction – Construction Actions

Historically a dairy farm, the site had been disconnected from active tidal flooding for over a hundred years before tidal reconnection. In July of 2017, tidal flooding was restored throughout the wetland by removing and lowering the levees that bordered the site. Additional channel enhancements were conducted in areas to expand channel density and access to wetland habitat.

Monitoring Plan

Experimental Design, Monitored Indicators, and Monitoring locations

Monitoring historically started at the Wallooskee project during pre-construction in 2013; this monitoring was conducted in partnership with the Cowlitz Tribe and Dr. Sarah Kidd, who included the project in her dissertation as a "control site" in the areas within the site that were actively managed for farming and a "reference site" in the fridge wetlands on the exterior of the levee system (not farmed) – results from this pre-restoration monitoring are included in her published dissertation (Kidd 2017). This monitoring entailed hydrologic monitoring with water surface and temperature loggers, sediment accretion and erosion monitoring, and vegetation monitoring.

In 2017, this monitoring effort was transitioned into the BPA AEMR monitoring format, and vegetation grids were added in two areas within the site. One focal plant community monitoring area was in the "North" of the site near a channel re-connection with Youngs Bay, and the other was located on the "South" portion of the site near a channel re-connection with the Wallooskee River (Figure 13, Figure 14). Additionally, Dagget Point was included in the monitoring effort as a nearby un-impacted reference site (Figure 12).

Figure 12: Wallooskee - Youngs Restoration Project Overview Map, depicting the locations of Wallooskee wetland and reference Dagget Point.

Figure 13: Map of "North" Sampling area at Wallooskee. Map shows vegetation grid and fall-out traps deployed during years 0 and 1. For years 4 and 5, the Macroinvertebrate sampling method was changed to neuston tows.

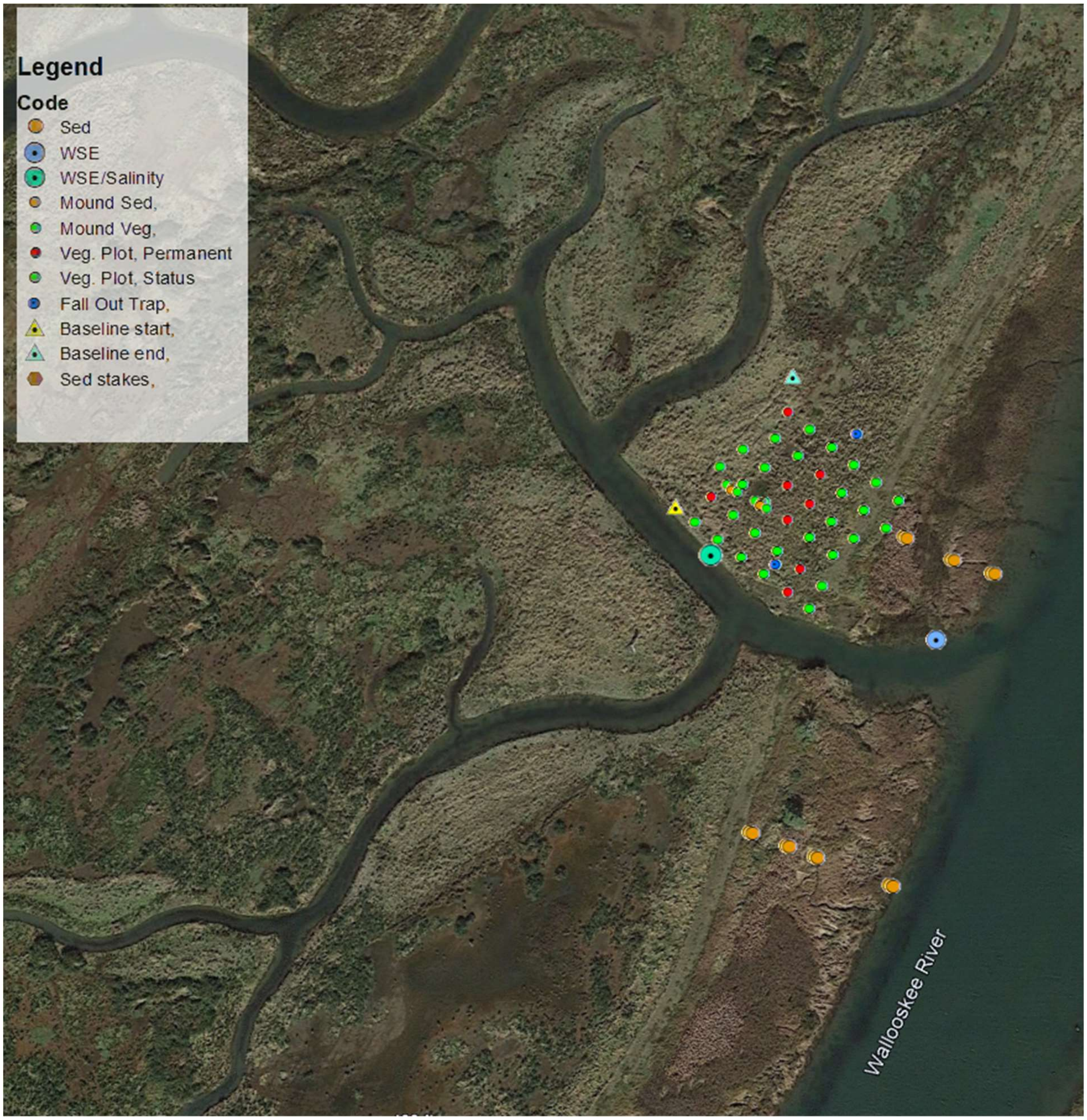


Figure 14: Map of Wallooskee "South" Sampling area. Map shows vegetation grid and fall-out traps deployed during years 0 and 1. For years 4 and 5, the Macroinvertebrate sampling method was changed to neuston tows.

The AEMR pre-restoration vegetation monitoring occurred in June of 2017. In accordance with the established BPA level 2 and 3 monitoring protocols, water surface elevation and temperature monitoring have occurred continuously since pre-construction (2014-2022), sediment accretion and erosion monitoring has been conducted annually. Vegetation monitoring has occurred in years 0, 1, 3, and 5 post-restoration. Due to the extreme tidal and sediment movement at the site, channel cross-sections were not collected (safety concerns). However, UAV imagery was collected in 2020 (Year 3) and in 2022 (Year 5), providing full site digital terrain and vegetation models. Macroinvertebrate monitoring with fall-out traps has been conducted in years 0, 1, and neuston tows have been conducted in years 4 and 5 (year 3 was delayed due to Covid-19). Additionally, a fishing check-in was performed by NOAA in year 5.

In addition to the BPA AEMR plant community monitoring, three high and three low marsh monitoring areas were established to evaluate how plant communities, soil conditions, and sediment accretion/erosion dynamics varied specifically between these two different constructed elevation ranges (Figure 15). Previous research on tidal wetland restoration in Young Bay (Kidd 2017) has noted a lag in high marsh recovery across restoration sites in the region. Directly monitoring these outcomes at Wallooskee provided an opportunity to further investigate this hypothesis and the mechanisms driving these potential outcomes. Additionally, understanding how topographic mounding influences the trajectory of restoration sites has been identified as a critical uncertainty in the lower Columbia River through the CEERP program (Diefenderfer et al. 2016).

Map of High and Low Marsh Monitoring

Figure 15: Overview Map showing locations of high and low marsh monitoring areas.

In this study, the high marsh monitoring areas were situated in areas that were mounded to create high marsh conditions during restoration and paired with nearby low marsh zones to capture similar flooding dynamics (between the high and low marsh zones) across the site. Based on previous literature and data collected at the site (Kidd 2017), it was generally established that elevations above 1.9 meters were considered high marsh zones, while below this elevation, they were regarded as low marsh. Elevations greater than 1.9 meters generally receive significantly less flooding than those at this elevation (Kidd 2017).

Three vegetation plots were monitored within these high and low marsh groupings, paired with soil data collection and one sediment accretion bench monitoring area. This resulted in 9 vegetation and soil monitoring locations and 3 sediment accretion/erosion bench monitoring locations across the constructed high marsh zones and the adjacent low marsh zones for a total of 18 vegetation and soil monitoring locations and 6 sediment bench locations that were monitored annually between 2017-2022. It should be noted that the third monitoring area in the southern portion of the site has a low marsh zone located in a small pond excavated during construction. This presents a perched low marsh condition at a much higher elevation than the other "low marsh" zones, the designation as low marsh was retained as the area remains flooded (due to the perched nature of the pond) and exhibits similar soil and plant community development as the other low marsh zones.

Reference conditions are those monitored on the site's fringe wetlands- which are established on the river sides of the levee. Reference plots were also co-located with vegetation, soil, and sediment accretion monitoring. Sediment accretion monitoring at these locations was established in 2013; in 2018 vegetation and soil monitoring were added. This resulted in three high marsh and four low marsh reference plots.

Monitoring Results

The monitored parameters described above have been reported in a tableau dashboard that provides a detailed site trajectory and displays a dynamic site-wide habitat opportunity model. For detailed results, please click on this link: Wallooskee - Youngs Restoration Project Research Dashboard

Dibblee Slough

Basic Project Information

Project Description – Problem Statement, Goals, and Objectives

Dibblee Point is located in Oregon, on US Hwy 30, just past the Lewis and Clark Bridge near Longview, WA. The restoration project connected 12 acres of shallow freshwater wetlands to the mainstem Columbia River. The restoration was sponsored by CREST and funded by BPA, with construction actions completed in 2013.

Dibblee Point consisted of several shallow freshwater wetland habitats that were formed due to dredge material placements over many years. These habitats were connected to the mainstem Columbia River only during high pluvial flows.

The overall goal of the restoration project was to restore full tidal connectivity to the wetlands, provide off-channel rearing and refuge habitat to juvenile salmonids and to increase habitat complexity in these shallow freshwater habitats.

Specific project objectives included:

1. Connecting 12 acres of shallow freshwater wetland habitat (Dibblee Slough) to the mainstem Columbia River.
2. Creation of additional in-stream habitat by constructing a new channel.
3. Increasing habitat complexity by large wood additions and revegetation.

Project Construction – Construction Actions

Construction occurred in 2013, actions taken are included below, depicted in Figure 16:

1. Excavating 250m of a new channel, creating full tidal access to the shallow habitats.
2. Large wood installations and native plantings in the newly created marshplain.
3. Installation of a 14ft wide culvert under roadway

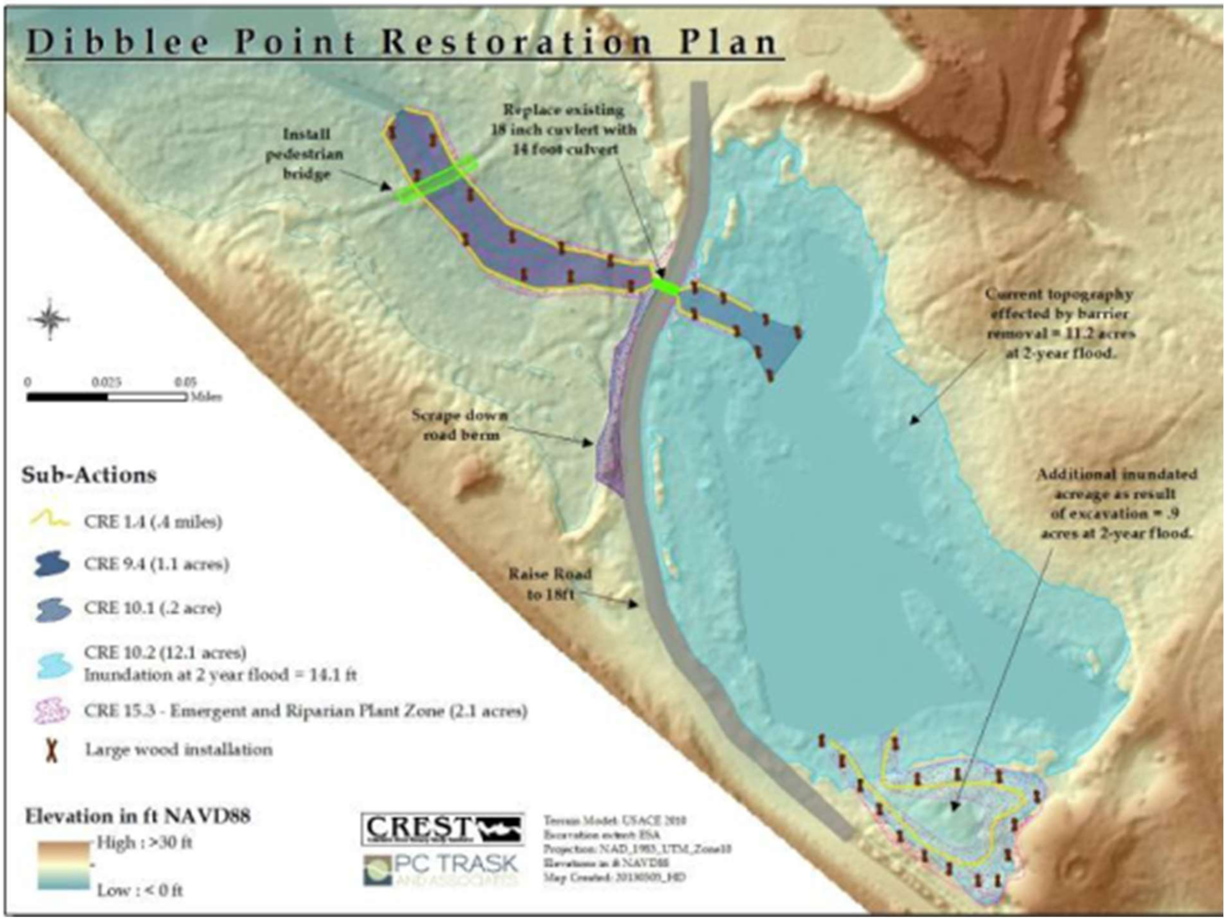


Figure 16: Dibblee Point restoration plan *(Courtesy: Tom Josephson, CREST)*

Monitoring Plan

Experimental Design, Monitored Indicators, and Monitoring locations

Dibblee Point has received Level 2 monitoring since 2013. 2022 marks year 10 post-restoration monitoring. Two vegetation grids were surveyed – Dibblee West is located in the excavated channel outside the culvert. Dibblee East is located on the other side of the culvert – on the north side of the ponded area (Figure 17, Figure 18). A vegetation grid was established to the northwest of the restoration area, to act as the reference (Figure 17, Figure 19).

In accordance with the established BPA level 2 and 3 monitoring protocols, water surface elevation and temperature monitoring have occurred continuously since construction (2013-2022), sediment accretion and erosion monitoring has been conducted annually. Vegetation monitoring and macroinvertebrate sampling through fall – out traps have occurred in years 0, 1, 3, and 5 post-restoration. UAV imagery was collected in 2017 (Year 5) in 2022 (Year 10) which has provided full site digital terrain and vegetation models. An additional fish check-in was conducted in 2022.

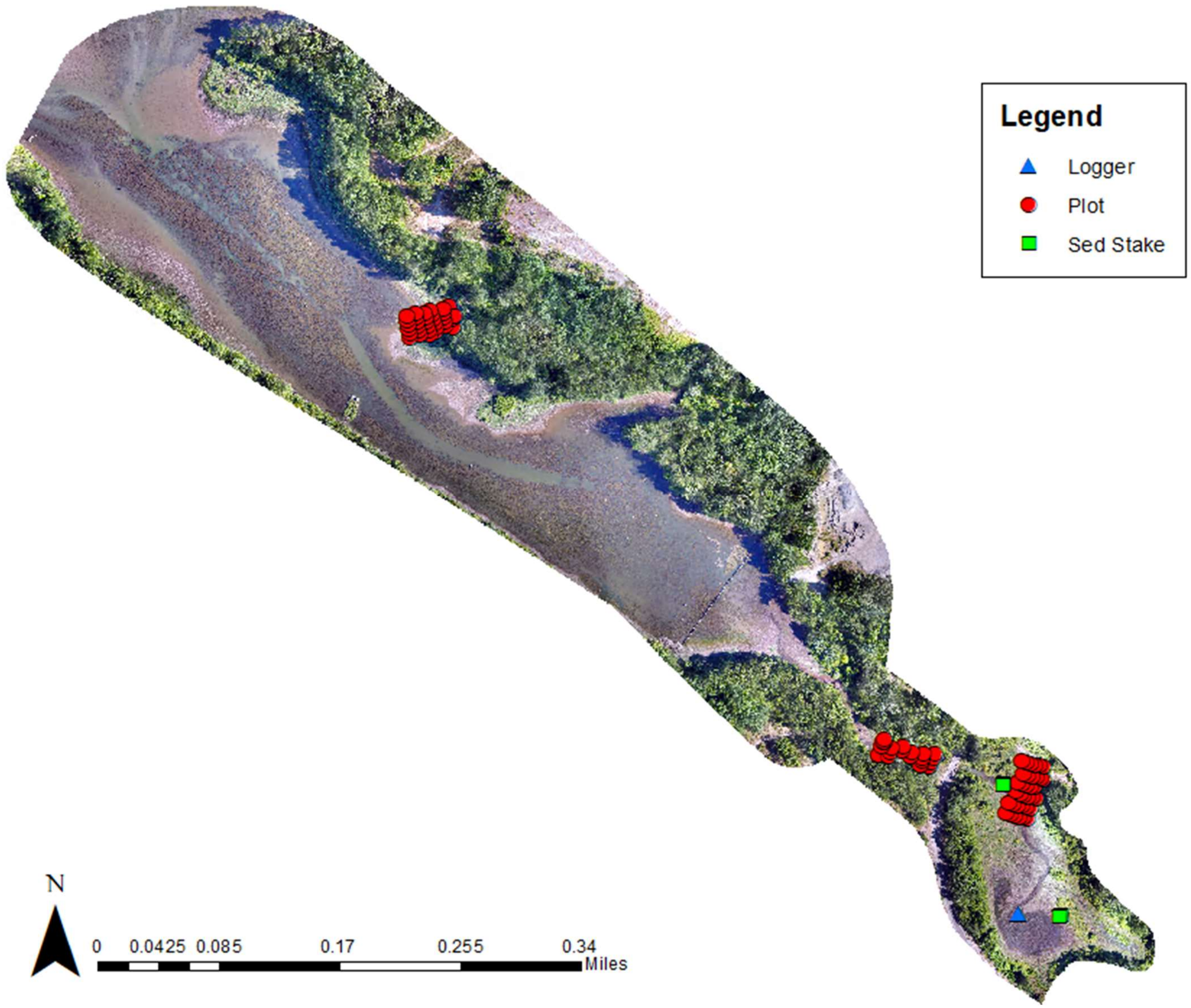


Figure 17: Perspective map depicting the habitat monitoring grids at Dibble Reference (Northwest) and Dibblee Point. *(Orthomosaic created using 2022 UAV data)*

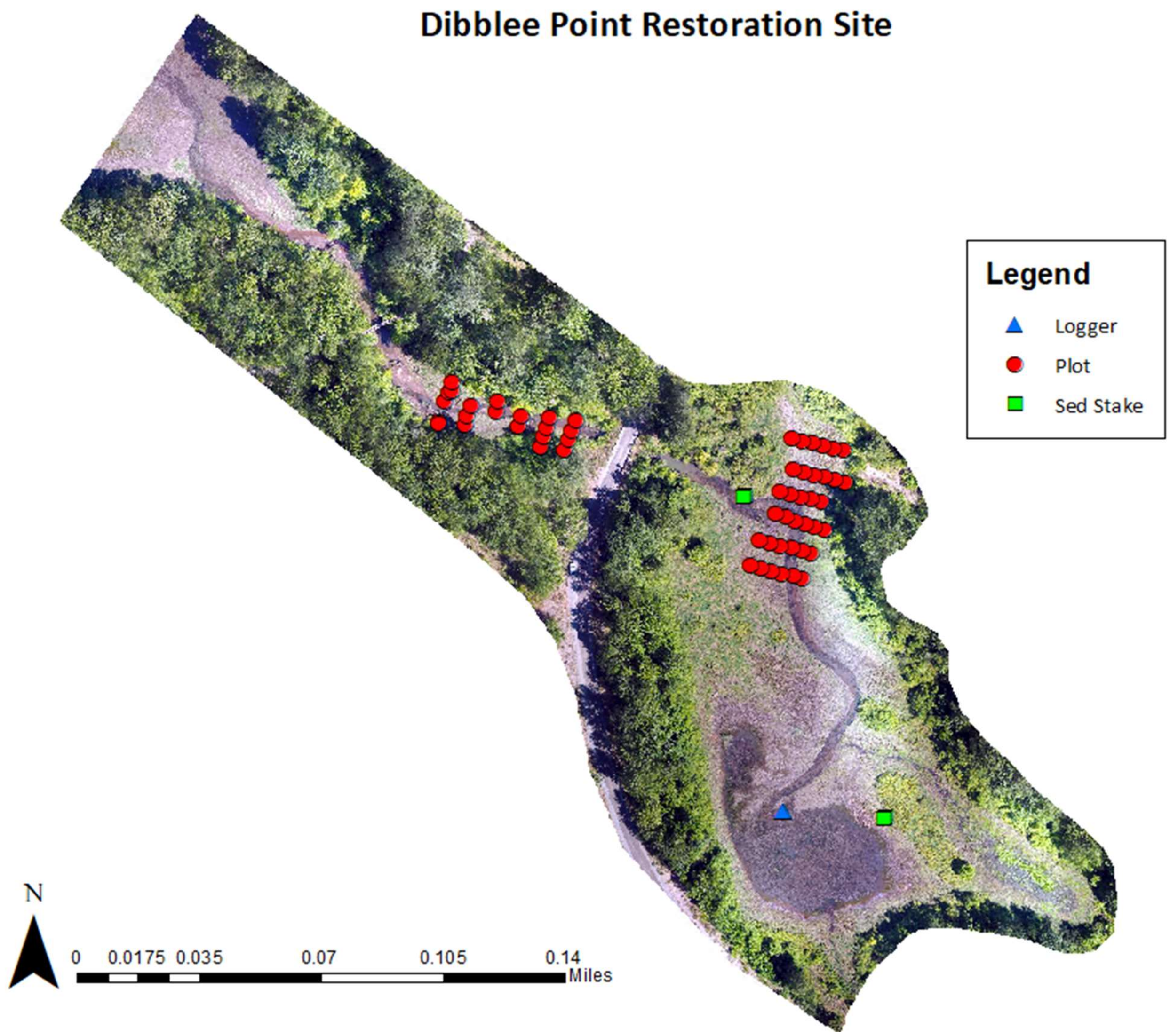


Figure 18: Dibblee Point Habitat Survey Map *(Orthomosaic created from 2022 UAV flight)*

Figure 19: Dibblee Reference Habitat Survey Map. Datalogger not shown in view. *(Orthomosaic created using 2022 UAV data)*

Monitoring Results
The monitored parameters described above have been reported in a tableau dashboard that provides a detailed site trajectory and displays a dynamic site-wide habitat opportunity model. For detailed results, please click on this link: AEMR Dashboards

Flights End Wetlands

Basic Project Information

Project Description – Problem Statement, Goals, and Objectives

Flights End wetlands are located north of Crane Lake in Sauvie Island, OR (Figure 20). This restoration project, sponsored by CREST and funded by Bonneville Power Administration (BPA), was part of a landscape effort to restore the connectivity of Sauvie Island Wildlife Area to Multnomah Channel and the final phase of improving the hydrologic conditions of the Crane Lake System.

The site was formerly a ponded habitat with agricultural land management and vegetation to attract waterfowl. Culverts, water control structures and artificial berms prevented regular inundation and altered historic hydrologic and geomorphic processes that prevented the establishment of a native wetland vegetation mix, nutrient cycling, and restricted fish access. A vegetation survey undertaken in 2016 showed that wetted perimeters and historic prairie zones were dominated by reed canarygrass (*Phalaris arundinacea*). The National Marine Fisheries Service (NMFS) collected juvenile salmonid data along the mainstem channel of Reach F showing high levels of genetic stock diversity for juvenile Chinook.

The overall vision for Flights End wetlands was to increase connectivity to Crane Lake and the larger Multnomah Channel to create a network of habitats for salmonids and other species. This restoration project aimed to connect 42 acres of floodplain wetlands to the Columbia River. The objectives of the project were:

1. Reestablish hydrologic connectivity to Crane Lake and Multnomah Channel by removal of artificial berms and culverts and create a network of channels
2. Establish a native wetland vegetation community by selective marsh plain lowering and replanting these areas with a native emergent – wet prairie mix.
3. Retain recreational uses at the site

Project Construction – Construction Actions

Construction occurred in 2017, and construction actions included removal of two culverts, the artificial berm, and marsh plain lowering. Target elevations were achieved by using wetlands in the Crane Lake system and the larger Sauvie Island complex as design references. Specific actions included:

- Remove artificial earth berm and two additional undersized culverts that blocked the historical channel
- Creating two channel openings from Crane Slough into the wetlands
- Retention of water control structure to allow managers additional stewardship options for a late summer drawdown of water for moist soil management
- Lower marshplain surfaces to increase frequency, duration, and magnitude of water inundation
- Replant lowered marsh plain with native emergent species and wet prairie species
- Design beaver analog structures to prolong the duration of inundation

- Install channel-spanning light duty bridge in replacement of earth berm and culvert to retain recreational and hunting access at the site.

Monitoring Plan

Experimental Design, Monitored Indicators, and Monitoring locations

Monitoring in Flights End has occurred since 2017, with three transects in the site's North, South, and West areas (Figure 21). Sediment dynamics are measured by two pairs of sediment benches. Cunningham Lake was included in the study as the un-impacted reference site (Figure 20).

Flight’s End Project Overview Map

Figure 20: Overview map of Flights End Project and Reference Cunningham

The AEMR pre-restoration vegetation monitoring occurred in 2017. In accordance with the established BPA level 2 and 3 monitoring protocols water surface elevation and temperature monitoring has occurred continuously over since pre-construction (2017-2022), sediment accretion, and erosion monitoring has been conducted annually, and vegetation monitoring has occurred in years 0, 1, 3, and 5 post-restoration. UAV imagery was collected in 2020 (Year 3) and 2022 (Year 5) which has provided full site digital terrain and vegetation models. A year 5 fish check-in was also conducted at the site in 2022.

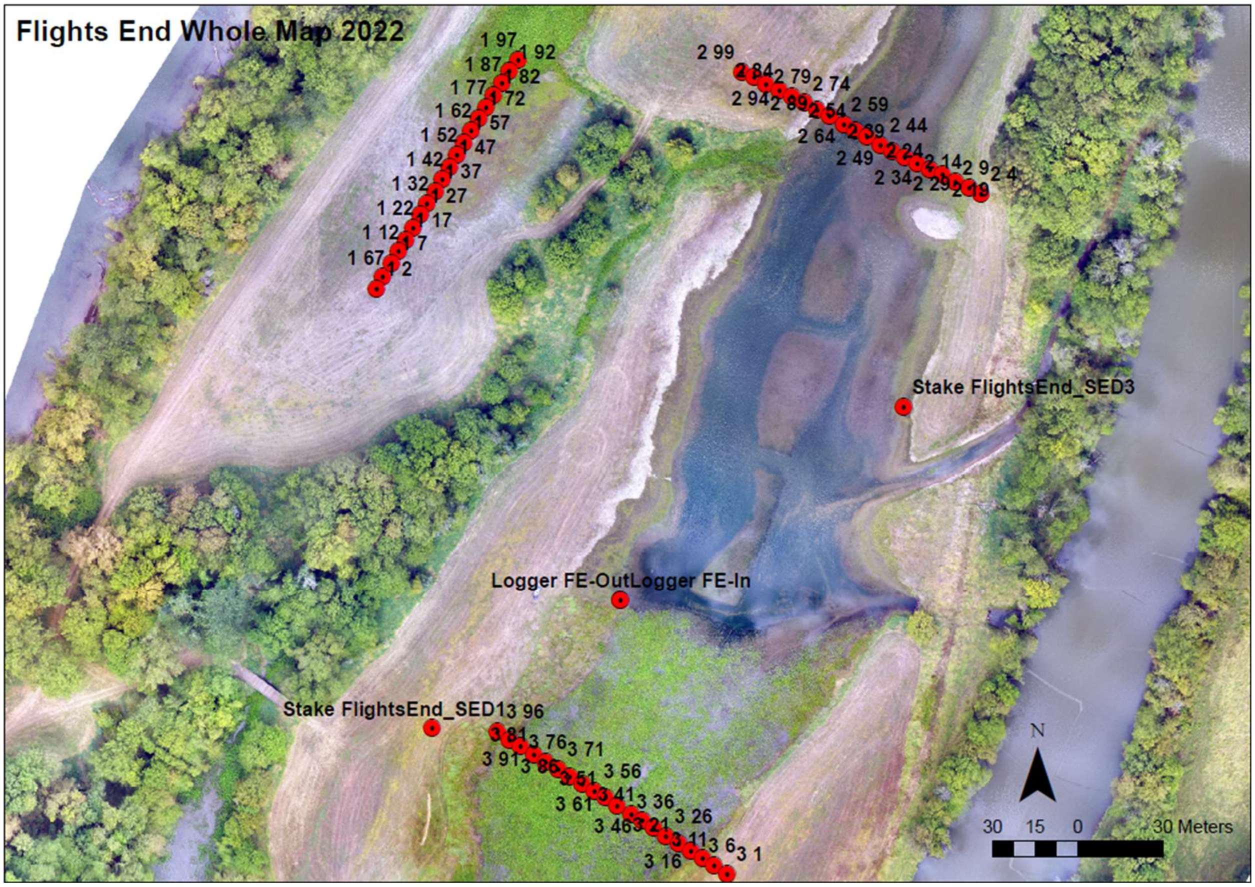


Figure 21: Flight's End Vegetation Survey Map.

Monitoring Results

The monitored parameters described above have been reported out in the form of a tableau dashboard that provides detailed site trajectory and displays a dynamic site-wide habitat opportunity model. For detailed results please click on this link: [AEMR Dashboards]

John R Palensky Wetland

Basic Project Information

Project Description – Problem Statement, Goals, and Objectives

John R Palensky wetland is located in Burlington OR on US Hwy 30, just adjacent to the Multnomah Channel. The Project, at the southern confluence of Willamette River and Columbia River, was sponsored by CREST and funded by BPA. The site is regularly maintained by ODFW. The site is also adjacent to McCarthy Creek (restored in 2019), and together the area has the potential of providing over 650 acres of floodplain habitat.

The site consisted of several structures that restrict fish passage and limit inundation. Water control structures (one each at the North and South of the site), levees and culverts allowed access to a total of 5 acres or less. These structures also hindered historic hydrologic and geomorphic processes and promoted the establishment of invasive vegetation.

The overall goal of this restoration project was to reconnect 280 acres pf wetland habitat to the adjacent Multnomah Channel. Project objectives were as listed below:

1. Re-establish complete hydrologic connectivity and fish access to the site.
2. Maintain amphibian and migratory bird habitats.
3. Promote establishment of native vegetation and increase habitat capacity and complexity.

Project Construction – Construction Actions

Construction at the site was completed in 2021. Actions taken at the site include:

1. Replacing undersized culverts
2. Removing the South water control structure
3. Targeted marshplain lowering and revegetation to encourage native vegetation development and maintain amphibian habitat.
4. Installation of beaver dam analogs and turtle basking logs.

Monitoring Plan

Experimental Design, Monitored Indicators, and Monitoring locations.

Palensky has received monitoring since 2021. In 2021, pre-construction monitoring was conducted by establishing 4 vegetation survey transects (2 at Snipe Lake and 2 at Bur Reed Lake). Six pairs of sed stakes were installed in Bur Reed Lake in 2021 and Multnomah Channel Natural Area (MCNA), located to the north of Palensky, was included in the study as an unimpacted reference site (Figure 22).

In 2022, Palensky and MCNA received AEMR L2 Monitoring. 4 additional pairs of sed stakes were installed at Snipe Lake.

John R Palensky Project Overview Map

Figure 22: Overview map of the JR Palensky wetland and reference MCNA.

Year 1 monitoring occurred in 2022. In accordance with the established BPA level 2 and 3 monitoring protocols water surface elevation and temperature monitoring has occurred continuously over since pre-construction (2019-2022), sediment accretion, and erosion monitoring has been conducted annually, and vegetation monitoring has occurred in years 0 and 1 year post-restoration and is planned for year 3 (2024). UAV imagery was collected in 2021 and 2022 which will provide full site digital terrain and vegetation models. Macroinvertebrate sampling was conducted using neuston tows in 2022.

Monitoring Results
The monitored parameters described above have been reported out in the form of a tableau dashboard that provides detailed site trajectory and displays a dynamic site-wide habitat opportunity model. For detailed results please click on this link: AEMR Dashboards

CONCLUSION

The final goal of AEM restoration efforts is the establishment of functional wetland processes and habitat that support juvenile salmonids. Action effectiveness monitoring tracks the ecological impact of restoration work and provide valuable information to manage restoration sites adaptively. Furthermore, AEM shows that the rate at which physical processes and habitats recover after restoration activities vary, depending on location in the estuary, degree of tidal reconnection, and pre-existing site conditions. For example, physical processes in a wetland like water surface elevation (duration, frequency, depth, and timing of flooding), water temperature, and overall habitat opportunity change rapidly after reconnection and become closer to conditions in reference sites. Other aspects of wetlands recover over a longer period, such as changes in the vegetation community and soil conditions. The trend for sites five years post-restoration indicates that they have slightly less native cover and a similar amount of reed canarygrass as reference sites. Limited fish monitoring shows that juvenile salmonids are present in restoration sites after tidal reconnection, but, without intensive monitoring efforts, the number of fish using the site can be difficult to ascertain. Furthermore, it is not known if the number of fish accessing a site increases as the habitat moves toward a reference state. A better understanding of how physical processes influence habitat conditions and how these resulting habitat conditions support juvenile salmonids are key to quantifying the overall impact of restoration efforts.

MANAGEMENT IMPLICATIONS

Action effectiveness monitoring measures changes to physical and ecological processes that influence the ability of restoration sites to support juvenile salmonids. In addition, AEM data provides project managers with vital information to determine if project design elements are meeting goals or if adaptive management is required.

At the site-scale, restoration projects are leading to the reestablishment of natural physical processes that support juvenile salmonids. Data has shown that site water levels respond immediately to hydrologic reconnection. Water temperatures at the restoration sites are generally warmer than nearby main stem waters but were generally suitable during the spring and early summer juvenile outmigration periods. The higher temperature at restoration sites can be attributed to shallower water depths, and this trend is mirrored in results seen at Ecosystem Monitoring Program (EMP) sites (Kidd et al. 2023).

As the goals of restoration activities include improving fish access to historic floodplain habitats and the quality of those habitats, we wanted to verify that fish are using restored sites. We chose to employ a “status check” of fish use at five years post-restoration. We collected fish occurrence data at Wallooskee-Youngs, Dibblee Point and Flights End, and found juvenile salmonids at all locations. The presence of juvenile salmonid indicates that restoration benefits fish.

AEM research shows that restoration sites are achieving increases in hydrologic connectivity and salmonid opportunity; however, plant community recovery is more variable across sites. Given the inherent inter-annual climate variability, it is difficult to predict specific restoration outcomes on a year-to-year basis. However, clear trends in plant community recovery across restoration sites persist, with high marsh elevations retaining reed canarygrass and other non-native species at year 3 and 5 post restoration. The lack of high marsh plant community recovery is also echoed in the soil conditions identified in these locations, which retain lower soil salinity, pH, and greater ORP levels than found at reference sites. Additionally, areas within restoration sites that have undergone heavy construction impacts and grading have also been shown to recover on a slower timeline. Alternatively, we have observed that both soil and dominant native plant communities recover quickly (within 5 years post-restoration) in areas that are found at moderately low to mid wetland elevations. Across all these findings, wetland elevation is used as a proxy for restored wetland hydrology which, in combination with soil conditions, is the ultimate mechanism driving restoration outcomes throughout the estuary (e.g., Bledsoe and Shear 2000, Neckles et al. 2002, Davy et al. 2011, Mossman et al. 2012, Gerla et al. 2013, Kidd 2017). Through our AEM research we have found that the re-establishment of natural physical and hydrological processes to sites can be accomplished in a short period of time but understanding how these wetland sites respond ecologically will require long-term monitoring. Ultimately, this continued monitoring will elucidate long-term trends and improve our understanding of the connections between physical processes, habitat responses, and the resulting benefits to juvenile salmon.

AEMR Program Recommendations

Suggestions for Project Design

- Both restoration design and evaluation would benefit from the use of predictive modeling to determine the restoration of aquatic, marsh, and shrub-scrub plant communities. This type of modeling can be easily accomplished by incorporating anticipated restored hydrology and site elevations and comparable reference site conditions (Hickey et al. 2015). These data can also provide a platform for evaluating different restoration scenarios, such as considering different levels of hydrologic reconnection and/or marsh plain lowering and the impacts of this for multispecies and plant community habitat recovery (Hickey et al. 2015)[4].
    - Across multiple restoration projects we have seen very high and very low marsh elevations struggle to recover native plant cover within a 5-year timeline. Moving forward predictive modeling could aid in restoration design (and adaptive management efforts) to maximize the restoration of the mid to moderately low

[4] We are currently using this Ecosystem Modeling Approach (Hickey et al. 2015) at Steigerwald National Wildlife Refuge and Multnomah Channel Natural Area to evaluate and design for desired restoration outcomes.

marsh elevations which have been shown to recover native plant habitat and soil conditions quickly post-restoration (throughout the Estuary).

- In addition, this will also aid project planning for determining seeding and planting zones in target high marsh areas for non-native species control and shrub-scrub development.
- Assess restoration success and goal-reaching post-restoration would also be easier given predictive maps and data could be compared to conditions observed post-restoration.

Suggestions for Project Monitoring

Site topography and Reference Sites

- Accessibility to ground survey technology such as RTK GPS systems has increased dramatically over the last five years and these systems allow us to easily map the overall topography of wetlands and their plant communities and channels. With this technology, we can assess the compatibility of reference and restoration wetland sites. Similar elevation gradients (and hydrology) should be sampled within reference and restoration sites for meaningful comparisons to be made post-restoration (and to aid in project design). In this report we have highlighted that the reference site elevations have generally been a poor match with each restoration site's restored elevations, moving forward we will aim to alter monitoring plans to sample more overlapping elevation gradients between the restoration and reference sites to correct these issues. Additionally, upon choosing reference sites to inform project design and post-restoration project success elevations and (anticipated) hydrology should be compared to ensure the use of reference elevation data is an appropriate proxy for hydrologic conditions.

Hydrology

- Hydrology is a critical component to all wetland restoration efforts and should be monitored for project planning, design, and to assess project success. During project design clear hypotheses should be developed to define hydrologic changes anticipated from restoration efforts. For monitoring data loggers need to be in placed areas that are anticipated to experience these hydrologic changes post-restoration and remain in the same location pre- and post-restoration. Given the number of issues we have experienced through the years with data loggers we recommend having at least one redundant logger be placed within the site (nearby or at the same location), that can provide additional data in case of equipment failure (which is common). Loggers need to be maintained at least every six months and we recommend all deployment and retrievals follow the new and more detailed monitoring protocols to avoid data loss (Kidd et al. 2018).

Sediment Accretion and Erosion, Channel Cross-Sections

- Understanding sediment accretion and erosion dynamics across the floodplain of newly restored wetlands is critical for tracking wetland and channel development and long term topographic trajectories. Sediment dynamics across restoration sites can be extremely variable making it difficult to track meaningful change without intensive and extensive monitoring efforts. We recommend shifting our current approach of sediment monitoring (one or two sediment benches placed within a site) to a more targeted application of these methods. Before restoration occurs specific areas of interest should be selected, and multiple sediment monitoring benches (minimum of 6) should be installed along the elevation gradient and within these targeted areas. Within the sediment bench monitoring area (between the pins), we also recommend tracking dominant plant community development and soil characteristics to aid data interpretation. Channel cross-section monitoring should be similarly focused, and extreme care should be taken to resurvey the exact location of the cross-section for meaningful results to be obtained. Both channel cross-section and sediment benches need to be resurveyed using RTK GPS technology to provide topographic context and increase data usability. Updated monitoring protocols are currently in development for these methods (Kidd and Rao 2019).

Wetland Plant Community

- Native wetland plant communities provide a critical base of the salmonid food web and are essential for determining wetland restoration success (Rao et al. 2020). We have found monitoring a randomized selection of vegetation plots each year creates a great amount of variability in the data and makes determining what change has been caused by the restoration and what change is due to the new randomized sampling difficult to determine. There are two approaches to addressing this issue, one would be to 1) continue to randomize the plots annually but significantly increase the overall total number of plots surveyed or 2) to only randomize the plots the first year of monitoring and re-visit these same plots year after year. We recommend (#2) re-visiting the same plots year after year, which provides a clear path to assessing plant community changes overtime and does not increase the overall amount of time required to conduct sampling. Additionally, as shown in this report, the collection of soil data, alongside plant community data, can be very informative when evaluating wetland development and restoration. We recommend integrating soil data collection as an essential metric for Level 2 monitoring across sites.

Utilizing UAV Technology: Site Topography, Plant Community Mapping

- The accessibility and applicability of Unmanned aerial vehicles (UAV) and associated sensor technology have made significant strides in the last several years. Using some of the most affordable equipment and software available we have shown that large scale site wetland plant community and topographic mapping is possible and accurate (Kidd et al. 2020). Mapping dominant native and non-native plant communities across large portions of restoration sites can aid evaluation of project success post-restoration, and guide both active restoration project design and post-restoration project adaptive management efforts. Moving forward we are working to refine our UAV monitoring methods to include tracking channel and floodplain topographic development into our analysis and reporting. We are also exploring methods of evaluating biomass and carbon stores across reference and restored wetlands using our UAV and sensor technologies.

Frequency of Monitoring

- Currently, Level 3 monitoring is conducted pre- through year 5 post-restoration and Level 2 monitoring is conducted pre, 1, 3, and 5 years post restoration. Results from the last 6 years of the AEMR level 2 and 3 monitoring indicate that restoration outcomes can be slow and variable, with sites not achieving reference level native plant community conditions by year 5 post-restoration (Johnson et al. 2018, and this report). Given these observations, we recommend level 3 monitoring continue to occur pre through 5, 8, and 10 years post-restoration and that Level 2 monitoring should also be conducted at year 8 and year 10 post-restoration. Adding year 8 and 10 to monitoring for all level 2 and 3 metrics will aid in understanding the long term impacts of our restoration efforts and allow for monitoring to occur over a wider spectrum of annual climate conditions. Additionally, we recommend UAV plant community mapping occur across all Level 2 and 3 sites pre-restoration, and 3, 5, 8, and 10 years post-restoration. These additional data and longer-term monitoring windows will provide greater context to assess restoration actions and outcomes and help us test ongoing hypotheses about how shifts in climate and river discharge conditions impact restoration outcomes. Adding synthesis reports of site conditions at year 8 and 10 post-restoration will also provide meaningful insight for ongoing adaptive management and restoration efforts.

FISH AND MACROINVERTEBRATE MONITORING

- AEMR Level 2 monitoring does not encompass comprehensive fish or macroinvertebrate monitoring as part of the standard habitat monitoring protocol. Level 2 monitoring includes limited macroinvertebrate monitoring (one or two neuston tows a year following the Level 2 monitoring schedule) and a one-time fish sampling event at year five post-restoration. Given the spatial and temporal variability of both fish and macroinvertebrate populations seen across the long term EMP reference sites (Rao et al. 2020), we have concluded a more comprehensive macroinvertebrate and salmonid sampling effort is required, for meaningful post-restoration food web conditions to be evaluated. Limited fish monitoring shows that juvenile salmonids are present in restoration sites after tidal reconnection, but, without intensive monitoring efforts, the number of fish using the site can be difficult to ascertain. Furthermore, it is not known if the number of fish accessing a site increases as the habitat moves toward a reference state. A better understanding of how physical processes influence habitat conditions and how these resulting habitat conditions support juvenile salmonids are key to quantifying the overall impact of restoration efforts. The addition of long-term ecosystem monitoring at a select number of restoration sites would allow for these sites to be tracked alongside the Ecosystem Monitoring Program. The EMP sites have years of accumulated status and trends fish, macroinvertebrate, water quality, and habitat data which could be used for ongoing comparative analysis and evaluation. Selecting focal restoration sites of interest and conducting intensive fish and macroinvertebrate monitoring efforts at these sites, similar to the level of monitoring conducted across EMP sites (Rao et al. 2020), would allow for the recovery of fish use and macroinvertebrate communities to be assessed over the long-term and aid in the interpretation of how physical changes to habitat directly influence the salmonid food web.

Synthesizing Restoration Results

- The most meaningful analysis of restoration success would be one that incorporates all habitat level monitoring metrics across a site to identify recovery of salmonid habitat over time. We have developed a site wide assessment of habitat opportunity that extends across the wetland's active floodplain (Johnson et al. 2018). This incorporates floodplain topography, water surface elevation (water depth), water temperatures, and dominate plant communities to highlight salmonid habitat conditions across the active floodplain of restoration and reference sites. See this tableau link for the habitat opportunity assessment of Wallooskee – Youngs Project. This active floodplain mapping approach could also be used as a tool to evaluate the impacts of climate change and shifting river discharge on wetland habitat conditions throughout the Columbia Estuary.

REFERENCES

Bledsoe, Brian P., and Theodore H. Shear. 2000. Vegetation along Hydrologic and Edaphic Gradients in a North Carolina Coastal Plain Creek Bottom and Implications for Restoration. Wetlands 20 (1): 126–47. https://doi.org/10.1672/0277-5212(2000)020[0126:VAHAEG]2.0.CO;2.

Borde A.B., S.A. Zimmerman, R.M. Kaufmann, H.L. Diefenderfer, N.K. Sather, R.M. Thom. 2011. Lower Columbia River and Estuary Ecosystem Restoration Program Reference Site Study: 2010 Final Report and Site Summaries. Prepared for the Lower Columbia River Estuary Partnership by Pacific Northwest National Laboratory, Richland, Washington.

Borde A.B., V.I. Cullinan, H.L. Diefenderfer, R.M. Thom, R.M. Kaufmann, J. Sagar, and C. Corbett. 2012a. Lower Columbia River and Estuary Ecosystem Restoration Program Reference Site Study: 2011 Restoration Analysis. Prepared for the Lower Columbia River Estuary Partnership by Pacific Northwest National Laboratory, Richland, Washington.

Bottom D.L., A. Baptista, J. Burke, L. Campbell, E. Casillas, S. Hinton, D. A. Jay, M. A. Lott, G. McCabe, R. McNatt, M. Ramirez, G. C. Roegner, C. A. Simenstead, S. Spilseth, L. Stamatiou, D. Teel, J. E. Zamon. 2011. Estuarine Habitat and Juvenile Salmon: Current and Historical Linkages in the Lower Columbia River and Estuary: Final Report 2002-2008. Prepared for the U.S. Army Corps of Engineers by the Fish Ecology Division, Northwest Fisheries Science Center.

Cordell, Jeffery R., Sarah A. Kidd, Jason D. Toft, Amy B. Borde, Valerie I. Cullinan, Jina Sagar, and Catherine A. Corbett. 2023. Ecological Effects of Reed Canarygrass in the Lower Columbia River. Biological Invasions, July. https://doi.org/10.1007/s10530-023-03119-y.

Davy, Anthony J., Michael J. H. Brown, Hannah L. Mossman, and Alastair Grant. 2011. “Colonization of a Newly Developing Salt Marsh: Disentangling Independent Effects of Elevation and Redox Potential on Halophytes.” Journal of Ecology 99 (6): 1350–57. https://doi.org/10.1111/j.1365-2745.2011.01870.x.

Dufrêne, M, and P. Legendre. 1997. Species Assemblages and Indicator Species: The need for a Flexible Asymmetrical Approach. Ecological Monographs 67, no. 3 (8): 345-366.

Gerla, P. J. 2013. “Can PH and Electrical Conductivity Monitoring Reveal Spatial and Temporal Patterns in Wetland Geochemical Processes?” Hydrology and Earth System Sciences Discussions 10 (1): 699–728.

Hanson, A.C., A.B. Borde, L.L. Johnson, T.D. Peterson, , J.A. Needoba, J. Cordell, M. Ramirez, S.A. Zimmerman, P.M. Chittaro, S.Y. Sol, D.J. Teel, P. Moran, G.M. Ylitalo, D. Lomax, and C.E. Tausz, M. Schwartz, H.L. Diefenderfer, C.A. Corbett. 2016. Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 11 (October 1, 2014 to September 30, 2015). Prepared by the Lower Columbia Estuary Partnership for the Bonneville Power Administration. Available from the Lower Columbia Estuary Partnership, Portland, OR.

Hickey, John T., Rochelle Huff, and Christopher N. Dunn. 2015. "Using Habitat to Quantify Ecological Effects of Restoration and Water Management Alternatives." Environmental Modelling & Software 70 (August): 16–31. https://doi.org/10.1016/j.envsoft.2015.03.012.

Johnson GE and KL Fresh (eds.). 2018. Columbia Estuary Ecosystem Restoration Program, 2018 Synthesis Memorandum. 95% draft submitted by PNNL and NMFS to U.S. Army Corps of Engineers, Portland District, Portland, Oregon. Available at: https://www.cbfish.org/EstuaryAction.mvc/Index.

Johnson, G.E., C.A. Corbett, J.A. Doumbia, M.S. Schwartz, R.W. Scranton, and C.A. Studebaker. 2014. A Programmatic Plan for Restoration Action Effectiveness Monitoring and Research in the Lower Columbia River and Estuary. Lower Columbia Estuary Partnership.

Johnson, G.E., H.L. Diefenderfer, B.D. Ebberts, C. Tortorici, T. Yerxa, J. Leary, and J.R. Skalski. 2008. Federal Columbia River Estuary Research, Monitoring, and Evaluation Program (ERME). Available from PNNL, Portland, OR.

Kidd, S. 2011. Summary of standard parameter ranges for salmonid habitat and general stream water quality. Water Quality Monitoring Grant Report, Oregon Watershed Enhancement Board, Salem, Oregon. Published July 2011.

Kidd, S., I. Edgar, S. Rao, and A. Silva (Eds.). 2023. Protocols for Monitoring Juvenile Salmonid Habitats in the Lower Columbia River Estuary. Portland, Oregon: Lower Columbia Estuary Partnership.

Kidd, S., and J. Yeakley. 2015. Riparian Wetland Plant Response to Livestock Exclusion in the Lower Columbia River Basin. Natural Areas Journal, October, 504–14. https://doi.org/10.3375/043.035.0403.

Kidd, S., and S. Rao. 2019. Re-visiting Monitoring Protocols for Wetland Restoration. LCEP Science Work Group Meeting Presentation, Dec 18, 2019. Portland, Oregon. Link

Kidd, S., S. Rao, P. Kolp, T. Thio, N. Elasmar, and M. Schwartz. 2020. UAV Field Applications and Vegetation Mapping. LCEP Science Work Group Meeting Presentation, March 23, 2020. Portland, Oregon. Link

Kidd, S.A., M. Schwartz, and G. Brennan. 2018. Best Practices – A Quick Guide to Water Surface Elevation and Temperature Data Collection. Prepared by the Lower Columbia Estuary Partnership for the Bonneville Power Administration. Available from the Lower Columbia Estuary Partnership, Portland, OR. Link

Kidd, S.A., M.D. Schwartz, R.N. Fuller, R. McNatt, K. Poppe, T.D. Peterson, J.A. Needoba, L. Cook, J. Cordell, M. Ramirez, A.C. Hanson, A.B. Borde, S.A. Zimmerman, S. Hinton, J. Grote, P.M. Chittaro, D. Kuligowski, G.M. Ylitalo, D. Lomax, V.I. Cullinan, L.L. Johnson, H.L., and C.A. Corbett. 2019. Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 14 (October 1, 2017 to September 30, 2018). Prepared by the Lower Columbia Estuary Partnership for the Bonneville Power Administration. Available from the Lower Columbia Estuary Partnership, Portland, OR.

Kidd, Sarah. 2017. Ecosystem Recovery in Estuarine Wetlands of the Columbia River Estuary. Dissertations and Theses, June. https://doi.org/10.15760/etd.5521.

Maier, G.O. and C.A. Simenstad. 2009. The role of marsh-derived 62icrodetritus to the food webs of juvenile Chinook salmon in a large altered estuary. Estuaries and Coasts 32:984-998

McCune, B. and J.B. Grace. 2002. Analysis of Ecological Communities. Gleneden Beach, Or: MjM Software Design.

McCune, B. and M. J. Mefford. 2011. PC-ORD, Multivariate analysis of ecological data, version 6.20, MjM Software, Gleneden Beach, Oregon, U.S.A.

Mossman, H. L., M. J. H. Brown, A. J. Davy, and A. Grant. 2012. Constraints on Salt Marsh Development Following Managed Coastal Realignment: Dispersal Limitation or Environmental Tolerance? Restoration Ecology 20 (1): 65–75.

National Marine Fisheries Service (NMFS). 2008. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation; Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(I)(A) Permit for Juvenile Fish Transportation Program (Revised and reissued pursuant to court order, NWF v. NMFS, Civ. No. CV 01-640-RE (D. Oregon).

Neckles, Hilary A., Michele Dionne, David M. Burdick, Charles T. Roman, Robert Buchsbaum, and Eric Hutchins. 2002. "A Monitoring Protocol to Assess Tidal Restoration of Salt Marshes on Local and Regional Scales." Restoration Ecology 10 (3): 556–563. https://doi.org/10.1046/j.1526-100X.2002.02033.x.

Rao S., Kidd, S.A., R.N. Fuller, R. McNatt, K. Poppe, T.D. Peterson, J.A. Needoba, L. Cook, J. Cordell, M. Ramirez, A.C. Hanson, A.B. Borde, S.A. Zimmerman, S. Hinton, J. Grote, P.M. Chittaro, D. Kuligowski, G.M. Ylitalo, D. Lomax, V.I. Cullinan, L.L. Johnson, H.L., and C.A. Corbett. 2019. Lower Columbia River Ecosystem Monitoring Program Annual Report for Year 15 (October 1, 2018 to September 30, 2019). Prepared by the Lower Columbia Estuary Partnership for the Bonneville Power Administration. Available from the Lower Columbia Estuary Partnership, Portland, OR.

Roegner, G.C., H.L. Diefenderfer, A.B. Borde, R.M. Thom, E.M. Dawley, A.H. Whiting, S.A. Zimmerman, and G.E. Johnson. 2009. Protocols for monitoring habitat restoration projects in the lower Columbia River and estuary. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-97, 63 pp.

Roman, C.T., and D.M. Burdick. 2012. A Synthesis of Research and Practice on Restoring Tides to Salt Marshes. In Tidal Marsh Restoration, 3–10. Springer.

Seybold, Cathy A., Wondi Mersie, Jayie Huang, and Clyde McNamee. 2002. Soil Redox, PH, Temperature, and Water-Table Patterns of a Freshwater Tidal Wetland. Wetlands 22 (1): 149–58. https://doi.org/10.1672/0277-5212(2002)022[0149:SRPTAW]2.0.CO;2.

Shannon, C.E. and W. Wiener. 1949. The Mathematical Theory of Communication. The Bell System Technical Journal. 27 (3) 379-423.

Simenstad, C.A., Burke, J.L., O'Connor, J.E., Cannon, C., Heatwole, D.W., Ramirez, M.F., Waite, I.R., Counihan, T.D., and Jones, K.L., 2011, Columbia River Estuary Ecosystem Classification—Concept and Application: U.S. Geological Survey Open-File Report 2011-1228, 54 p. https://pubs.usgs.gov/of/2011/1228/

Sokal R.R. and F.J. Rohlf. 1995. Biometry. W. H. Freemand & Co., New York

Spencer, K.L., and G.L. Harvey. 2012. Understanding System Disturbance and Ecosystem Services in Restored Saltmarshes: Integrating Physical and Biogeochemical Processes. Estuarine, Coastal and Shelf Science 106 (0) (June 20): 23–32.

US Geological Survey and Nisqually Indian Tribe. 2012. Terrestrial invertebrates, fall-out trap standard operating procedures. Unpublished protocols. USGS, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA. Nisqually Indian Tribe Natural Resources Office, Olympia, WA. http://www.tidalmarshmonitoring.org/pdf/USGS-WERC-Terrestrial-Invertebrates-SOP.pdf

US Geological Survey. 2012. Benthic invertebrate standard operating procedures. Unpublished protocols. USGS, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA.

Washington Department of Ecology. 2012. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC. https://fortress.wa.gov/ecy/publications/summarypages/0610091.html

Wisheu, Irene C., and Paul A. Keddy. 1991. Seed Banks of a Rare Wetland Plant Community: Distribution Patterns and Effects of Human-Induced Disturbance. Journal of Vegetation Science 2 (2): 181–88. https://doi.org/10.2307/3235950.

Appendix

Appendix A: Site Sampling Reports

The summaries are presented in order starting from the mouth of the estuary to up-river. Additional background information about the sites sampled in the AEMR Program is often available in restoration project planning documents and reports, or in previous monitoring reports. To the extent possible, these are cited in the descriptions of each site.

Equipment

Equipment for each of the metrics sampled is outlined below.

- *Vegetation*: 100-m tapes for the baseline and transects, a compass for determining the baseline and transects azimuth, 1-m quadrat, data sheets, and plant books for species identification. GPS to identify location of base stakes and quadrats.
- *Sediment Accretion Rate*: 2 gray 1-inch PVC conduit pipes, at least 1.5m long, construction level, meter stick. GPS to identify location of stakes.
- *Neuston Tows:* To assess the availability of salmon prey at sites, we conducted neuston tows in both open water (OW; in the center of the channel) and emergent vegetation (EV; along the edge of the wetland channel among vegetation). Samples were preserved in 95% ethanol.
- *Photo Points:* camera, stake for including in photo, previous photos at location for reference, GPS to identify location of point.
- *Elevation*: Topcon GPS with real-time kinematic (RTK) correction. Other survey equipment in case GPS equipment is non-functional, including an auto-level, tripod, and stadia rod.

Survey Dates 2020

Wallooskee – July 21 – July 22, 2020
Dagget Point – July 23, 2020
Flights End – August 10, 2020
La Center Wetlands and Reference – August 11 – August 12, 2020
Cunningham Lake – August 21, 2020

Survey Dates 2021

Ilwaco Slough – July 26, 2021
Wallacut Slough –July 27, 2021
Cunningham – August 17, 2021
North Unit Phase 1 – August 18, 2021

Survey Dates 2022

Wallooskee Youngs – July 12 - July 14, 2022
Daggett Point –
Flights End – July 20, 2022

Cunningham Lake – July 21, 2022
Dibblee Slough and Reference – July 25 – July 26, 2022
Palensky – July 27 – July 28, 2022
Daggett Point – July 29, 2022
MCNA – August 1-2, 2022

Wallooskee-Youngs

2022 Notes

- Wallooskee is owned by Cowlitz Tribe, Access has a locked gate, Site Contact is Rudy Salakory, Habitat Restoration and Conservation Program Manager, rsalakory@cowlitz.org
- Dagget Slough, State of Oregon, no permits needed for access
- Tides follow Astoria NOAA gage
- **KML of all sampling locations**, sed benches, WSE, etc: https://www.dropbox.com/s/4qaj2jpxy6pmfts/WY_Dagget_2020_Monitoring.kmz?dl=0
    - Some old data logger housings remain on the site but have been retired (no longer have loggers in them), I have only included active logger locations in this KML (2020).
    - All data points should be re-surveyed with the RTK
    - As time allows, soil data and vegetation notes should be collected at Sed Bench Locations
    - As time allows, soil data should be collected at all Veg survey locations
    - **Wallooskee Maps (PDF)** https://www.dropbox.com/sh/je5bme1fr6t7u9x/AADG388ZdeRvK6FLyJnl3iuXa?dl=0
    - **Dagget Map (PDF)** https://www.dropbox.com/sh/je5bme1fr6t7u9x/AADG388ZdeRvK6FLyJnl3iuXa?dl=0
- **AEMR Species Lists:** https://www.dropbox.com/s/ap0tp279ank1fnf/WYDagget_SpeciesListandData_2020.xlsx?dl=0
- **Additional Monitoring – Mound Study:** Two sed benches and three veg quadrants have been set up at paired high and low marsh elevations across three locations at the Wallooskee site (total of 6 veg quads and 2 sed benches at each location, split between high and low marsh elevations). Veg data (% cover) is collected at 1m2 quads at the location of the Sed Benches and then 1-meter offset to either side of the Sed Bench locations. The exact sed bench and veg monitoring areas can be found in the KML above. Soil ORP, pH, Con, Sal, and Temp should also be recorded at each mound study veg quad location.

General Site Location
The site is located approximately 6 Km on the Young's River, which empties into Young's Bay, at approximately Columbia River Km 19.

Ecosystem Type
Diked, planned restoration site

Dates of Sampling in 2020
July 21 – July 22, 2020

Types of Sampling in 2020

- Vegetation: Herbaceous cover (2 sample areas of 36 quadrats each, 72 quadrats total)
- Elevation: collected elevation at all vegetation quadrats

Vegetation Sampling Design
2 sampling areas were set up. New vegetation sample areas were established to capture the current condition and potential change that would occur as follows:

*North Veg Sample area (*Figure 23*)*
- Located in area near channel and tide gate removal on Young's River
- 60 m x 80 m, with 36 quadrat locations
- Baseline azimuth: 188° magnetic
- Transect azimuth: 278° magnetic
- Transect spacing: 10 m, random start: 3
- Quadrat spacing: 13 m, random starts: 7, 3, 4, 5, 6, 0

*South Veg Sample area (*Figure 23*)*
- Located in area between the culvert removal and dike breach
- 60 m x 60 m, with 36 quadrat locations
- Baseline azimuth: 29° magnetic
- Transect azimuth: 119° magnetic
- Transect spacing: 10 m, random start: 1
- Quadrat spacing: 10 m, random starts: 8, 6, 1, 3, 9, 6

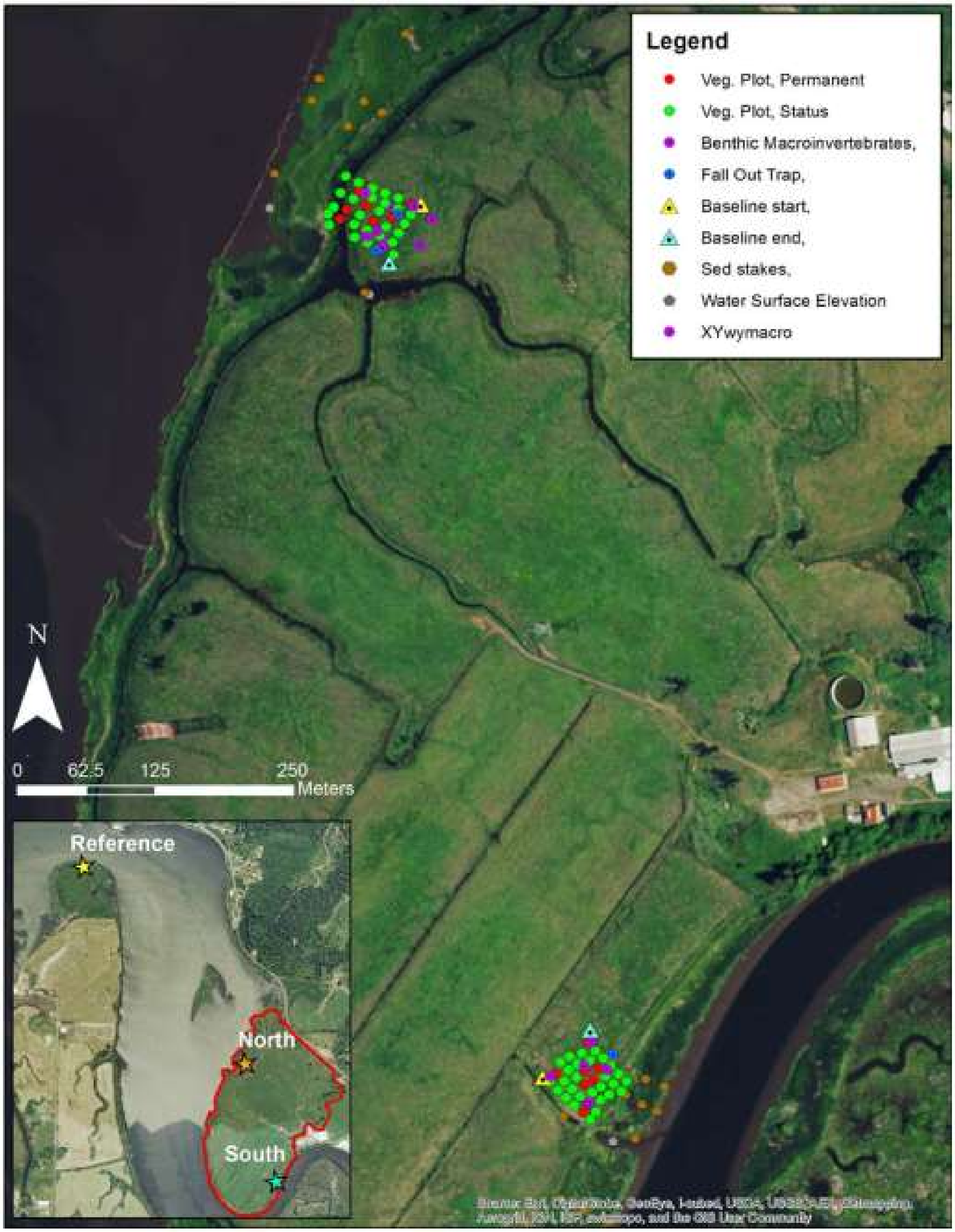


Figure 23: Vegetation and macroinvertebrate sampling locations at the Wallooskee-Youngs Restoration site (Fallout traps from 2015 – 2018, Neuston Tows in 2020).

Markers Left on Site

All marking stakes are white ¾ inch PVC. We marked the following locations:

• Start and End stakes of the baseline for the vegetation sample areas.

Macroinvertebrate Sampling

To assess the availability of salmon prey at sites, we conducted neuston tows in both open water (OW; in the center of the channel) and emergent vegetation (EV; along the edge of the wetland channel among vegetation). Samples were preserved in 95% ethanol.

Wallooskee-Youngs Reference (Dagget Point)

General Site Location

The site is located approximately 1.5 km up the Young's River, which empties into Young's Bay at Columbia River km 19.

Dates of Sampling in 2022

July 12 - July 14, 2022

Types of Sampling in 2022

- Vegetation: Herbaceous cover (1 sample areas, 36 quadrats total). Drone and Veg monitoring by LCEP
- Sediment Accretion Rate: measured previously installed pairs of stakes
- Elevation: collected elevation at all vegetation quadrats

Vegetation Sampling Design

1 sampling area was set up. New vegetation sample areas were established to capture the current condition and potential change that would occur as follows:

*Veg Sample area (*Figure 24*)*

- 60 m x 70 m, with 36 quadrat locations
- Baseline azimuth: 81° magnetic
- Transect azimuth: 351° magnetic
- Transect spacing: 10m, random start: 4
- Quadrat spacing: 10 m, random starts: 2, 2, 4, 6, 7, 1

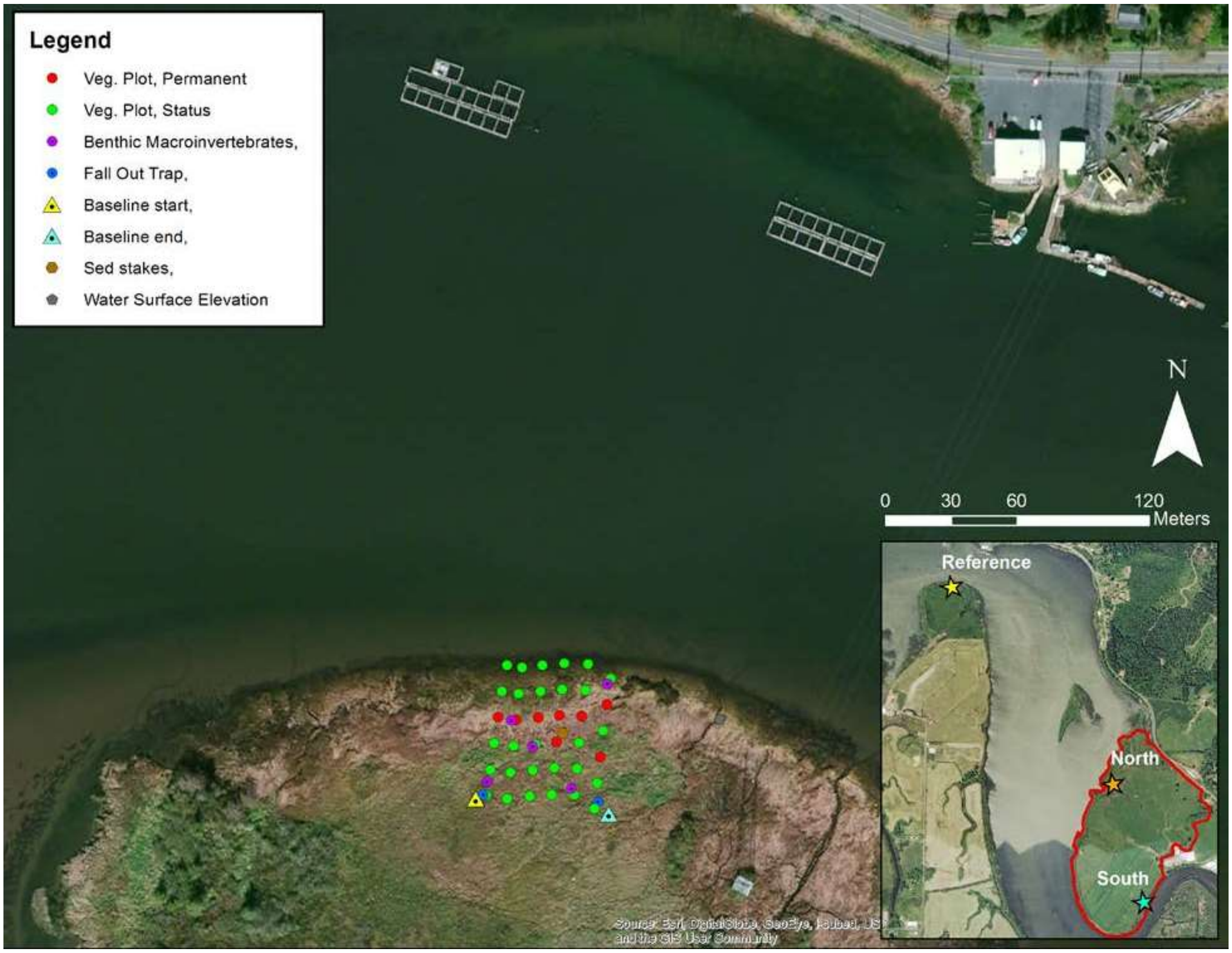


Figure 24: Vegetation and macroinvertebrate sampling locations at the Wallooskee-Youngs reference site

Markers Left on Site

All marking stakes are white ¾ inch PVC. We marked the following locations:

• Start and End stakes of the baseline for the vegetation sample areas.

• Permanent quadrat stakes; 2 stakes per location in the diagonal corners.

Macroinvertebrate Sampling

To assess the availability of salmon prey at sites, we conducted neuston tows in both open water (OW; in the center of the channel) and emergent vegetation (EV; along the edge of the wetland channel among vegetation). Samples were preserved in 95% ethanol.

Flights End

Monitoring Data 2022

- Water levels follow St. Helens gage
- Species Lists: https://www.dropbox.com/s/wogp88mx86k5hi6/FlightsEnd_SpeciesListandData_2018.xlsx?dl=0
- Maps: https://www.dropbox.com/s/bjwwbfjjcow0c42/FlightsEnd_MapAll.pdf?dl=0
- KML: https://www.dropbox.com/s/y9fumpikwgxj3et/Flights_Veg_Tran2018.kmz?dl=0
- Permits: Permissions provided through CREST (project manager)
- Reference Site – Cunnignham Lake
- Drone and Veg Monitoring by LCEP
- SED/WSE/Temp - CREST

Figure 25: Vegetation sampling locations at the Flights End restoration site

General Site Locations
North End of Sauvie Island on the Oregon side of the river at rkm 143

Ecosystem Type
Post-restoration, emergent tidal wetland

Types of Sampling in 2022
- *Vegetation*: Herbaceous cover (3 sample transects of 20 quadrats, 60 quadrats total)
- *Elevation*: collected elevation at all vegetation quadrats
- *Sed Benches*: One pair of sed stakes (Flights_End_SED_1) was measured. SED_2 was not found in 2018. A third set was installed for 5-year post. Usually surveyed by CREST.

Vegetation Sampling Design
North Veg Sample Transect
- Veg sample area spanned elevation gradient which contained reed canarygrass to bare ground.
- 100 m transect, with 50 quadrat locations
- Transect azimuth: 278° magnetic
- Quadrat spacing: 5 m, random start: 4

South Veg Sample Transect
- Veg sample area spanned elevation gradient which contained reed canarygrass to bare ground.
- 100 m transect, with 50 quadrat locations
- Transect azimuth: 282° magnetic
- Quadrat spacing: 5 m, random start: 1

West Veg Sample Transect
- Veg sample area spanned elevation gradient which contained was dominated with reed canarygrass and would be scraped down to an elevation to promote wet prairie grass and prevent recolonization of reed canarygrass.
- 100 m transect, with 50 quadrat locations
- Transect azimuth: 31° magnetic
- Quadrat spacing: 5 m, random start: 2

Macroinvertebrate Sampling
Two macroinvertebrate neuston tows were collected in the Flights End vegetation sampling areas.

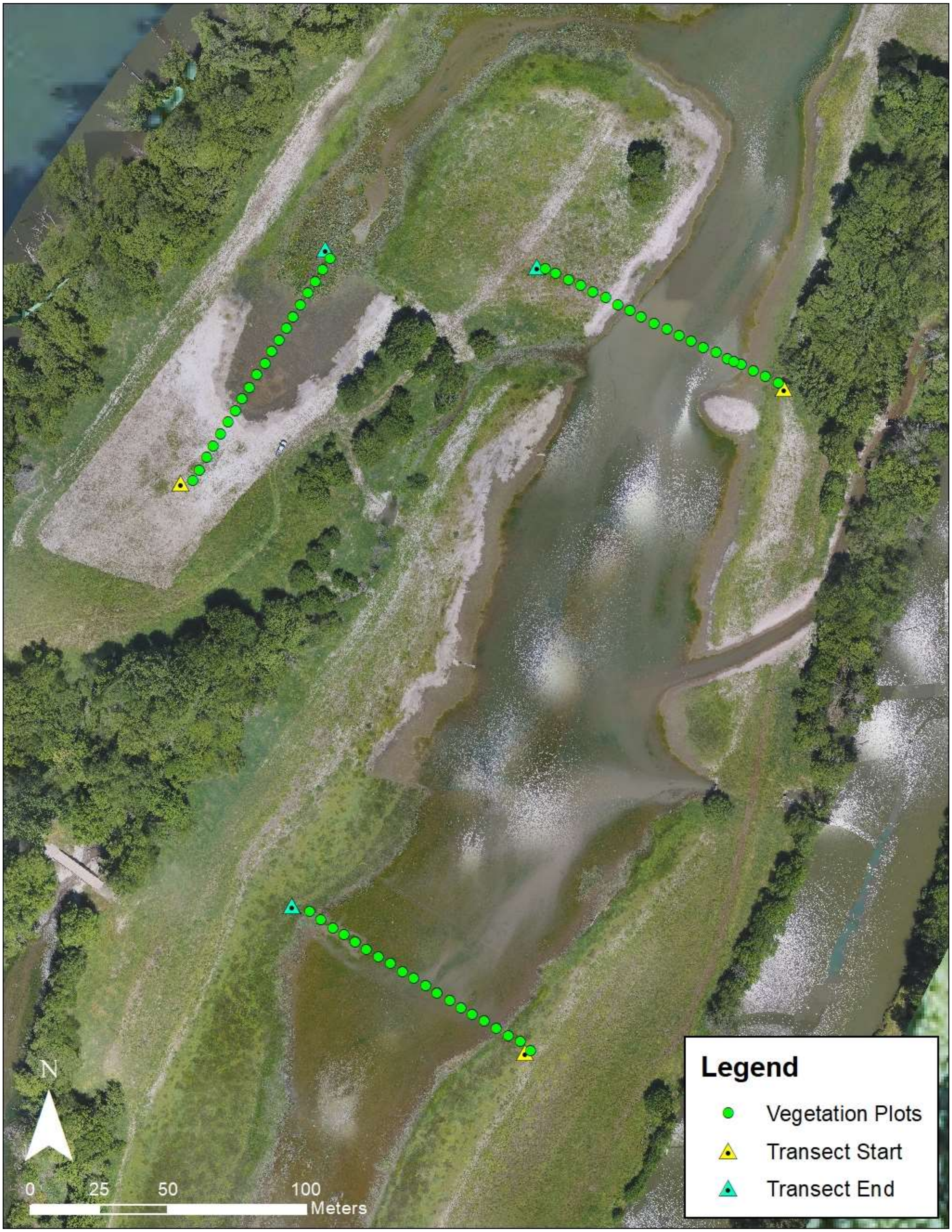
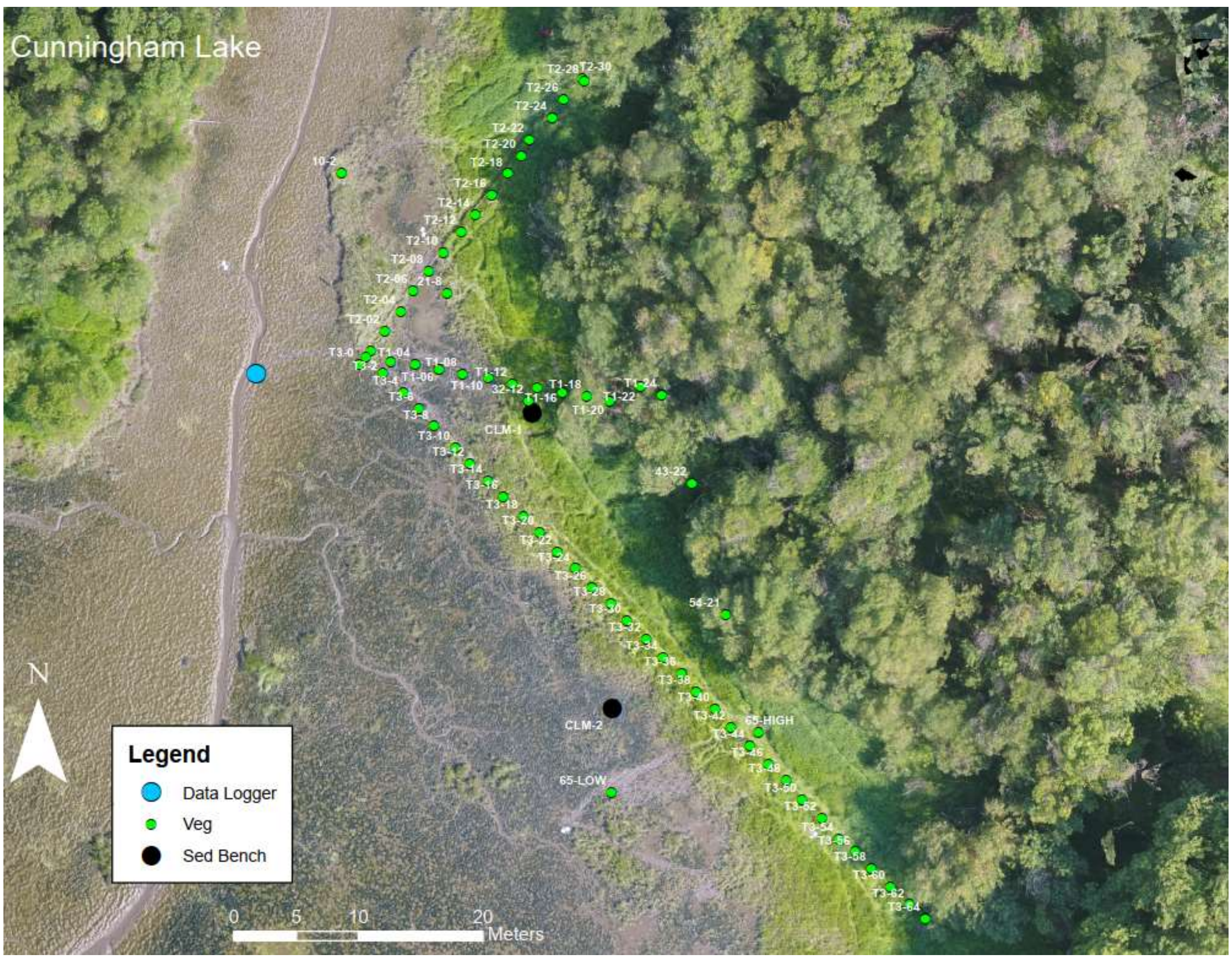


Figure 26. Sauvie Island Flights End vegetation sampling locations

Cunningham Lake
Monitoring Data 2022

- Water levels follow St. Helens gage
- Species Lists: https://www.dropbox.com/s/002ibwqh16eucyd/Cunningham_SpeciesListandData_2019.xlsx?dl=0
- Maps: https://www.dropbox.com/s/kppvysmis0009ne/EMP_Map_Cunningham.pdf?dl=0
- KML: https://www.dropbox.com/sh/m03s0zkrgw9xv7z/AABcXowbAh5WlLIn93awBAtha?dl=0
- Permits: Ongoing agreement, CREST normally picks up key for gate access
- Long-term EMP site and Reference site for all Sauvie Island restoration sites
- LCEP responsible for all monitoring except Macros, CREST does Macro sampling when needed.



<u>Older Survey Notes</u>

General Site Location

Cunningham Lake is a floodplain lake located at rkm 145 on Sauvie Island in the Oregon DFW Wildlife Area. The mouth of the Slough is located between rkm 142 and 143 close to where Multnomah Channel meets the Columbia River. The end of Cunningham Slough is approximately 8.7 km from Multnomah Channel.

Ecosystem Type

Reference Site, Fringing Emergent Marsh at the upper extent of the extremely shallow "lake"

Dates of Sampling in 2022

21 July

Types of Sampling in 2022

See map below for sampling locations (**Error! Reference source not found.**).

- *Vegetation*: Herbaceous cover (70 quadrats total)
- *Insect Fall out Traps:* 4
- *Photo Points:* 1 photo point
    - 360° panorama taken at location near south end of vegetation sample area.
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design

Veg Sample area (**Error! Reference source not found.**)

- Located along the fringe of the very shallow Cunningham Lake. Vegetation sample area spanned elevation gradient from unvegetated flats to the shrub/tree zone.
- 70 m x 25 m, with 36 quadrat locations
- Transect spacing: 2m, random start: 0
- Quadrat spacing: 2 m
- 8 permanent quadrats established for AEMR were monitored

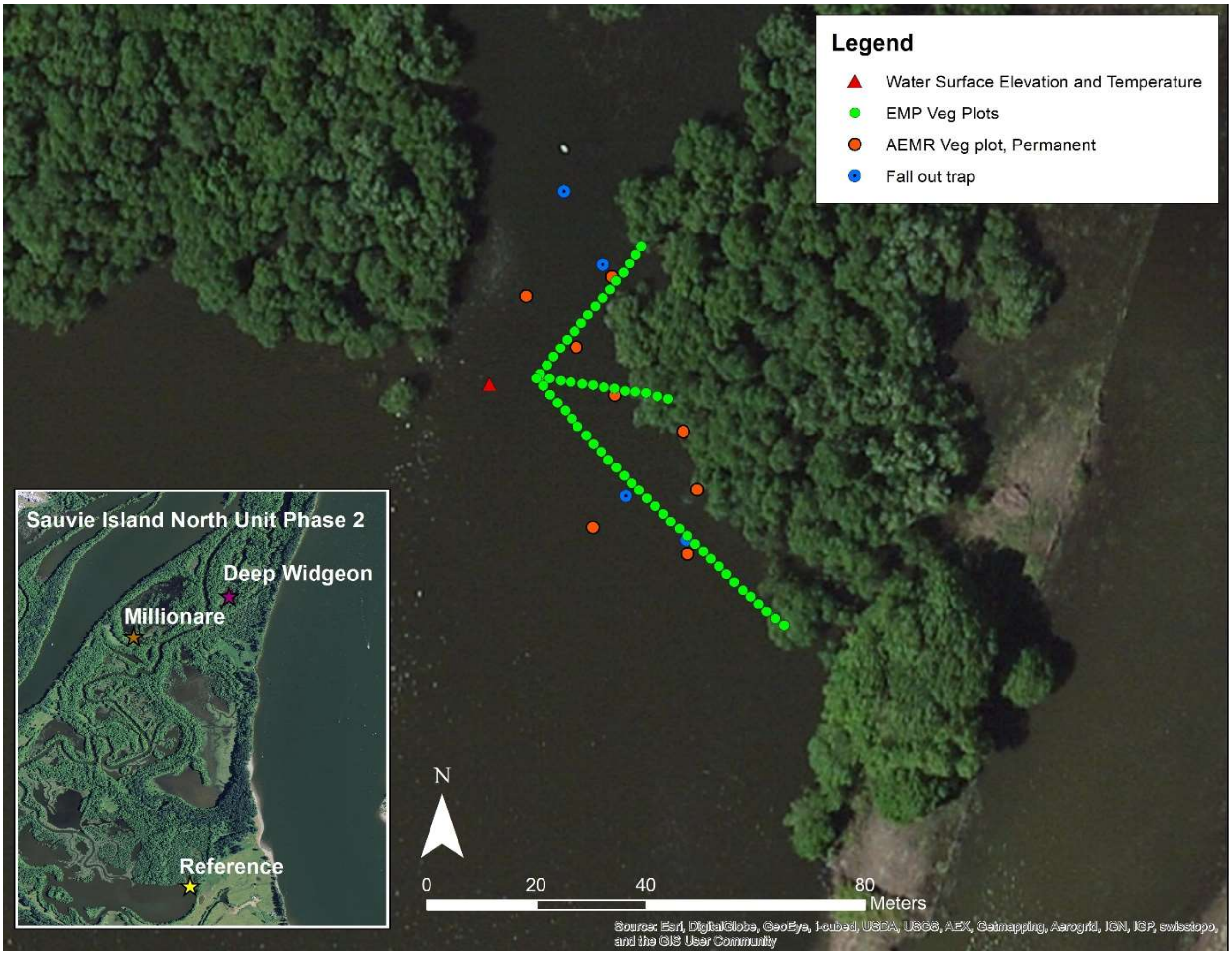


Figure 27. Vegetation and macroinvertebrate sampling locations at the Cunningham Lake reference site.

Markers Left on Site
All marking stakes are white ¾ inch PVC with orange duct tape or flagging at the top. We marked the following locations:

- End stakes of the baseline for the vegetation sample areas.
- Permanent quadrat stakes; 2 stakes per location in the diagonal corners (SW and NE).

In addition, 2 1" gray pvc sediment accretion stakes are located on the site and a depth sensor is located inside 1 ½" PVC on a t-post in the channel.

Appendix B: Tableau Example

For archival purposes and to ensure long-term accessibility, we have provided a static snapshot of a Tableau dashboard here in this appendix. In the digital realm, Tableau provides a dynamic and interactive experience, enabling users not only to engage directly with the data for deeper analysis and insights but also to access written explanations and further details with a simple click on specific sections of the analysis. While this static representation offers a valuable overview, we strongly recommend engaging with the online version to fully benefit from the additional context and detailed explanations embedded within the interactive platform. For the full hybrid report please see this link.

Welcome to the Dibblee Point Project Research Dashboard

Developed for Bonneville Power Administration
Authors (Lower Columbia Estuary Partnership): Sarah Kidd, Ian Edgar, Sneha Rao
Major Contributors (Columbia River Estuary Study Taskforce): April Silva, Narayan Elsmar

This is currently a working draft - and was last updated 8/11/2023
For more information please contact skidd@estuarypartnership.org

2023 AEMR Report citation: S. Kidd, S. Rao, I. Edgar, A. Silva, N. Elasmar, J. Grote, S. Hinton and C. Roegner. 2023. Action Effectiveness Monitoring for the Lower Columbia River Estuary Habitat Restoration Program Annual Report (October 2021 to September 2022). Prepared by the Lower Columbia Estuary Partnership for the Bonneville Power Administration. Available from the Lower

Dibblee Point Project Overview Map

Site Type
AEMR
Reference

Dibblee Point Project Description

Project Sponsor: Columbia River Estuary Study Taskforce

Need for restoration: Dibblee Point consisted of several shallow freshwater wetland habitats that were connected to the mainstem Columbia River only during high pluvial flows.

Project goals: To restore full tidal connectivity to the wetlands, provide off-channel rearing and refuge habitat to juvenile salmonids and to increase habitat complexity in these shallow freshwater habitats.

Project objectives: Specific project objectives were 1) Connecting 12 acres of shallow freshwater wetland habitat (Dibblee Slough) to the mainstem Columbia River. 2) Creation of additional in-stream habitat by constructing a new channel, and 3) Increasing habitat complexity by large wood additions and revegetation.

Construction actions taken: Construction occurred in 2012, actions taken include 1) Excavating 250m of a new channel, creating full tidal access to the shallow habitats. 2) Large wood installations and native plantings in the newly created marshplain and 3) Installation of a 14ft wide culvert under roadway. A location outside the restoration area was chosen as the local reference.

Dibblee Point has received AEMR L2 monitoring since 2013. A vegetation grid was established outside the restoration area, in the Dibblee Point peninsula, as the reference to the restoration project.

Executive Summary of Results

In 2022, Dibblee Point received 10 year post-restoration AEMR L2 monitoring. The objective of year 10 monitoring is to determine whether the site continues to be a functioning wetland dominated by native vegetation, with restored geomorphic processes and nutrient cycling. Hydrological patterns at Dibblee Point are similar to that of mainstem Columbia. Soil conditions were studied only in 2022, but generally are similar accross restoration and reference areas. While the elevations at the site have had a positive trajectory, low marsh areas donot keep pace with sea
elevations at the site have had a positive trajectory, low marsh areas donot keep pace with sea
level rise. Vegetation development at Dibblee Point indicates a healthy mix of native and non-native cover. Macroinvetebrate abundance at Dibblee point is far greater than that of the reference site, with Cladocera being the dominant group. A 10-year fish check-in showed that salmon were using the site.

This Dashboard Provides a Brief Methods Overview and Links to all the Results Summaries: Click
This Dashboard Provides a Brief Methods Overview and Links to all the Results Summaries: Click any of the buttons below to access more data.

Navigate to Hydrology data

Navigate to Sediment Accretion and Erosion

Navigate to Soil Development

Navigate to Vegetation Development

Navigate to Macroinvertebrate Communities

Navigate to Fish Communities

Action Effectiveness Monitoring for the Lower Columbia River Estuary Habitat Restoration Program

Return to Results Guide

Water Surface Elevation and Temperature

Data Logger Locations

Summary: Water surface elevation (WSE), water depth, and water temperature data were collected in 1 hour intervals across both Dibblee Point (Dibblee_In) and Dibblee Reference (Dibblee_Out). Construction was completed in 2013. In the map and graph below you can find the loggers located at Dibblee reference colored orange and the logger inside the restoration site colored in blue. Periodic datalogger losses and failures have resulted in an incomplete hydrograph. After construction in 2013, the hydrological patterns were similar accross Dibblee Point and Dibblee reference. However, due to the lack of data at the reference site since 2013, a full comparison cannot be made. When compared to St.Helens gage on the mainstem, the hydrological patterns in the restoration area between 2013 - 2022 follow a similar pattern. After reconnection, habitat opportunity at the site has increased to 31% in 2022.

Interactive Data: Toggle these data logger locations and monitoring years on/and off (check the box) to see how any one specific monitoring location shifted pre- and post-restoration. These data were used in our salmonid habitat access and opportunity model – and show a significant increase in habitat access and opportunity post-restoration. Keep scrolling to the bottom of this dashboard to see a summary of habitat opporunity results for the same time period.

Year
- ☑ (All)
- ☑ 2012
- ☑ 2013
- ☑ 2014
- ☑ 2018
- ☑ 2022
- ☑ 2023

Logger Location
- Dibblee_In
- Dibblee_Out

Mean Daily Water Surface Elevation, Temperature, and Salinity

Dibblee Point restored in 2013. 2022 marks 10 years post-restoration

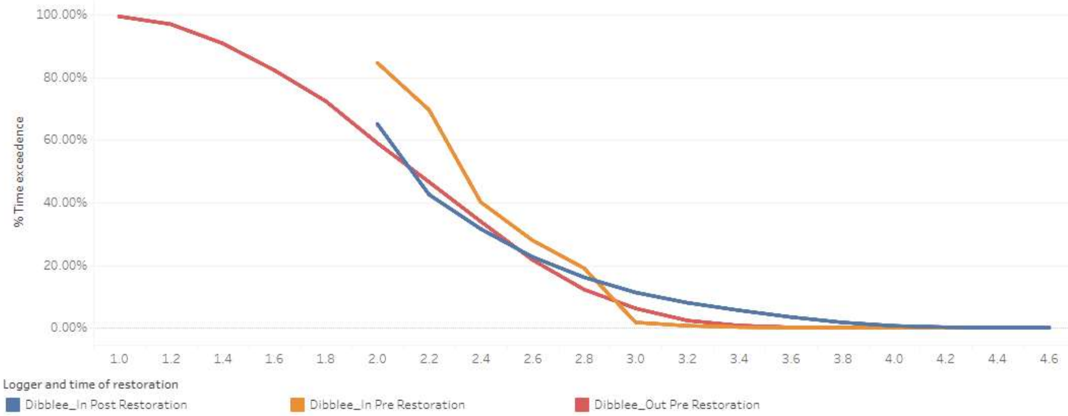
Percent Exceedance

Utilize the filters below to adjust the time period being taken into account for the analysis. Observe the changes from Pre restoration to Post restoration.
Click an item in the legend to highlight it.

Years
(All)

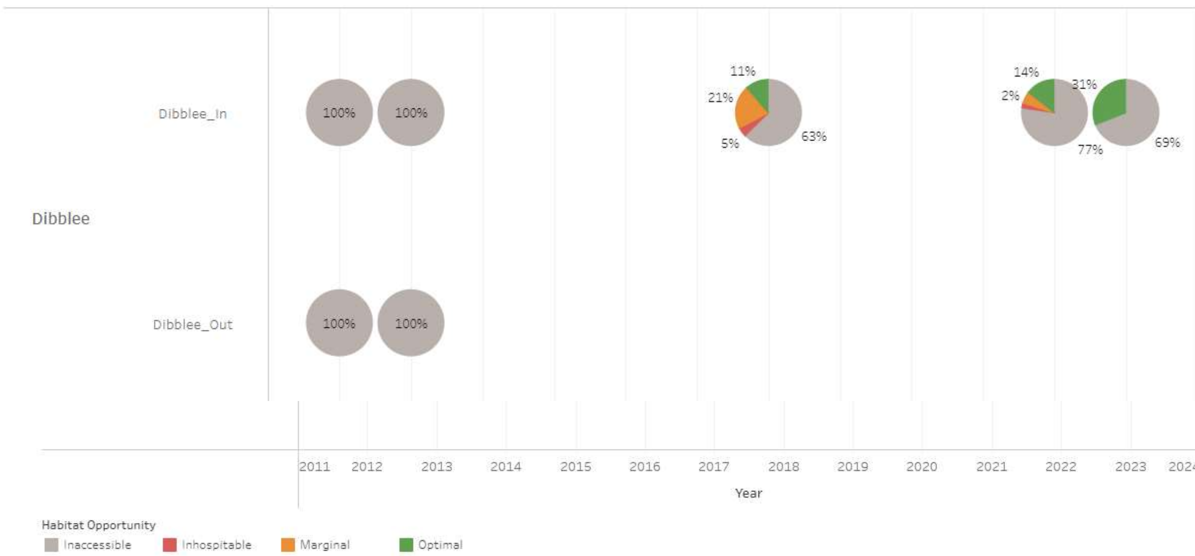
Dibblee Point and Dibblee Reference between 2013 - 2022

Percent Exceedance is the percent of time that the elevation gradient is fully inundated with water.



Annual Habitat Opportunity (% of time, hourly data) - 2007, 2008, 2009 and 14 more

Toggle years above to see how conditions change overtime. Years without a complete dataset are excluded.



Salmonid Habitat Opportunity

Results: Prior to restoration, Dibblee Point was inaccessible for most of the year. After restoration, habitat opportunity at the site increased overtime to 31% in 2022. This could be attributed to the consistently high summer time temperatures that are above 22 °C at Dibblee Point.

Analysis: Habitat Opportunity was adapted from previously established analyses and is defined by the depth and temperature of water that is considered ideal for salmonid access and utilization (Bottom et al. 2011, Schwartz and Kidd et al. 2018). Juvenile Salmonids require ≥0.5 m of water depth above the channel or wetland surface for habitat access and we have defined depths of < 0.5 m of depth inaccessible to fish passage/use. In addition to the required water depths, water temperature ranges were used to define optimal, marginal, and inhospitable habitat conditions as follows; optimal conditions require a water temperature of less than 17.5 °C, marginal conditions were defined by water temperatures greater than 17.5 °C but less than 22 °C, and water temperatures greater than 22 °C were defined as inhospitable to salmonids (Schwartz and Kidd et al. 2018). For this analysis, we used the hourly mean water depth and temperature data to calculate the % of each year that these habitats were both accessible to salmonids and the water temperatures were in the ideal, marginal or inhospitable ranges, at the location of monitoring.

Developed for Bonneville Power Administration

Authors (Lower Columbia Estuary Partnership): Sarah Kidd, Ian Edgar, Sneha Rao
Major Contributors (Columbia River Estuary Study Taskforce): April Silva, Narayan Elsmar

Lower Columbia Estuary Partnership

Sediment Accretion and Erosion

Sediment Accretion and Erosion Monitoring - Overview Map

Return to Results Guide

High vs. Low Marsh Sediment Accretion and Erosion

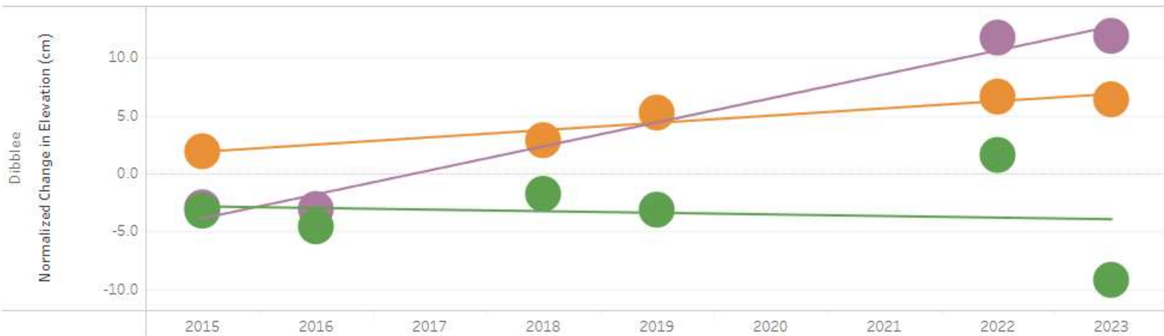
Results: Over 10 years, Dibblee Point has seen a gain in elevation accross all marsh zones, with mid marsh showing the largest change. However, the low marsh at Dibblee Point does not seem to be keeping pace with sea level rise.

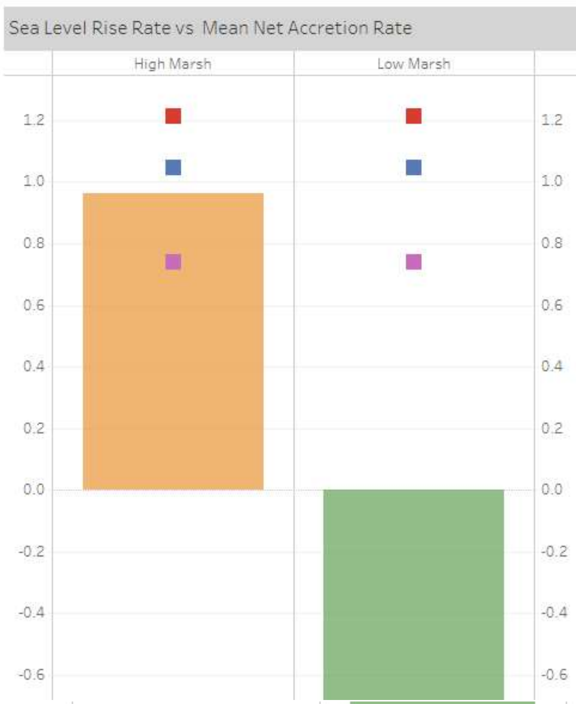
Normalized change in elevation is the amount of elevation gained (accretion) or loss (erosion) from the first year of the survey period. Average Net Accretion is the rate at rate at which this change takes place in cm/yr.

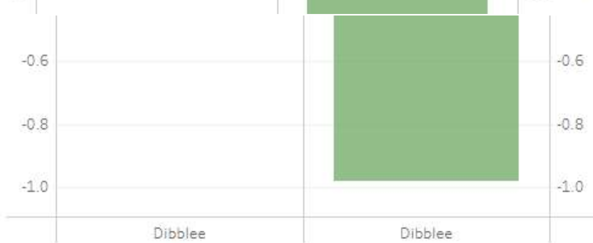
Marsh Location - Site Accretion and Erosion - Accretion Rate (cm/yr)

Marsh Location - Site Accretion and Erosion- Trends Over-time

Marsh Location - Site Accretion and Erosion- Trends Over-time







Keeping Pace with Sea Level Rise

Understanding how our tidal wetlands and floodplains are keeping track with Sea Level Rise (SLR) is critical for considering how future restoration and management actions can address further potential wetland loss. For this preliminary analysis, we have used the USACE's 2020 Lower Columbia River Adaptive Hydraulics (AdH) Model Scenarios (Link to USACE model report here: https://erdc-library.erdc.dren.mil/jspui/bitstream/11681/36295/1/ERDC-CHL%20TR-20-6.pdf).

These Scenarios (50, 75, and 100 yr) are slightly more aggressive (greater rates of change) than the Miller et al. 2018 model (https://wacoastalnetwork.com/research-and-tools/slr-visualization/) which focuses on the Oregon and Washington Coast. However, they do provide a glimpse into how well our reference and restoration sites may be keeping up with increases in Water Surface Elevation across each reach of the Lower Columbia. **Further refinement of this analysis is forth coming.** Note that it has been well established in the literature that sediment accretion rates can be greater during the first few years of restoration – and then stabilize long-term (e.g., Roman & Burdick 2012).

be greater during the first few years of restoration – and then stabilize long-term (e.g., Roman & Burdick 2012).

For more analysis of SLR impacts to wetland across the LCR using the same model scenarios see our online report here:

Burdick, David M., and Charles T. Roman. 2012. "Salt Marsh Responses to Tidal Restriction and Restoration." The Science and Practice of Ecological Restoration. Island Press/Center for Resource Economics. http://www.springerlink.com.proxy.lib.pdx.edu/content/p70568084lmv5463/abstract/.

Developed for Bonneville Power Administration
Authors (Lower Columbia Estuary Partnership): Sarah Kidd, Ian Edgar, Sneha Rao
Major Contributors (Columbia River Estuary Study Taskforce): April Silva, Narayan Elsmar

Lower Columbia Estuary Partnership

Soil Development

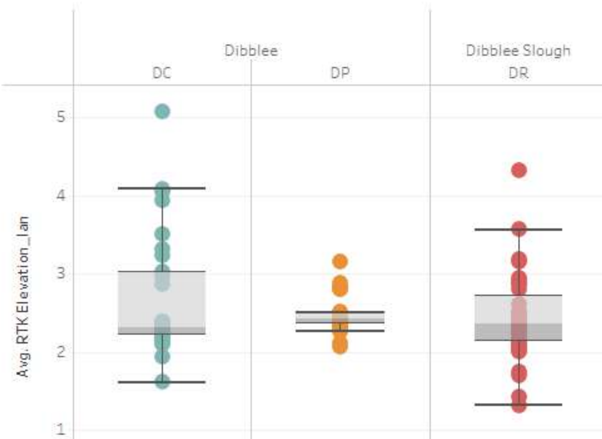
Vegetation Development Overview Map

Return to Results Guide

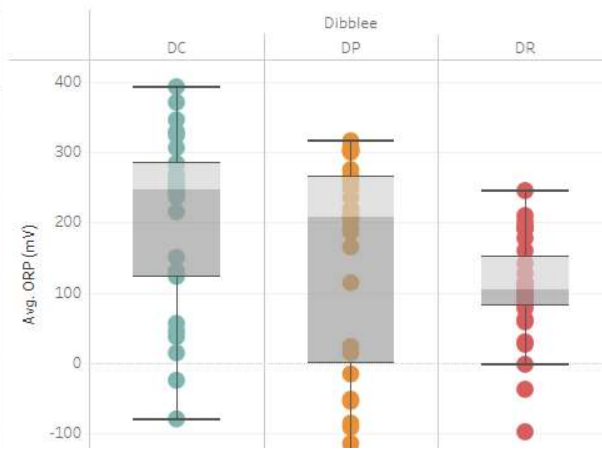
Results: Soil conditions were monitored for the first time in 2022 at two locations in Dibblee Point - Dibblee Channel (DC) - located outside the culvert in the excavated channel and Dibblee Pond (DP) - located on the other side of the culvert. Soil conditions were also monitored at Dibblee Reference (DR) in 2022. Generally, soil conditions were pretty similar accross all three monitoring locations. Soil temperature was slightly elevated in Dibblee Pond.

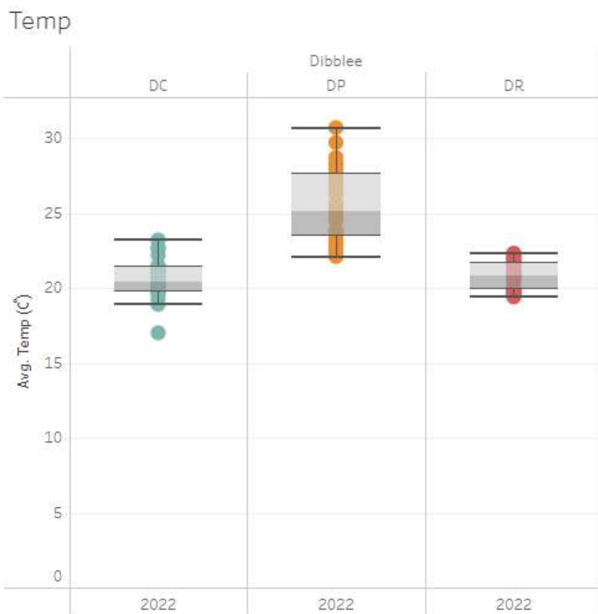
Why Study the Soil: Re-introducing flooding to previously drained agricultural soils has significant impacts on soil characteristics and creates the biogeochemical template needed for wetland plant community and habitat restoration. Additionally, restoration actions such as scrapping down the topsoil to created lower elevations and channels can alter soil composition, revealing mineral soils and causing compaction. These restoration actions and soil manipulations can further impact plant community recovery. Monitoring soil conditions pre- and post-restoration can provide insight into the mechanisms causing restoration success and failure and we have recently begun consistently monitoring soil conditions as part of all Level 2 AEMR. For this high and low marsh study we were particularly interested in tracking how soil conditions changed across these different restored wetland habitats. For more background on the importance of soil monitoring in tidal wetland restoration see Kidd

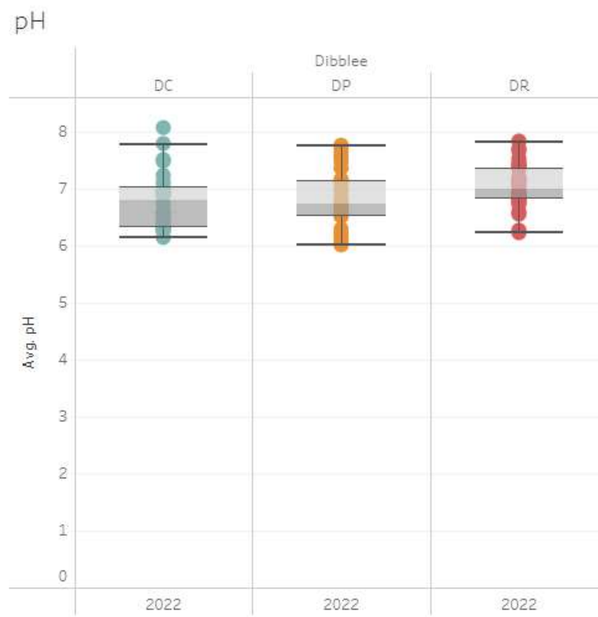
Site Elevations



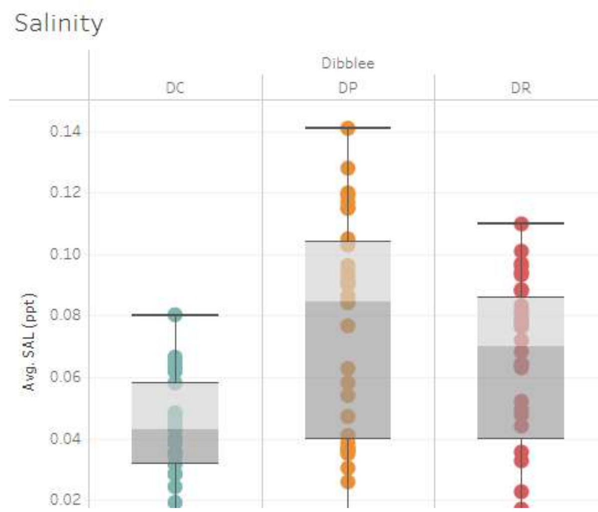
ORP



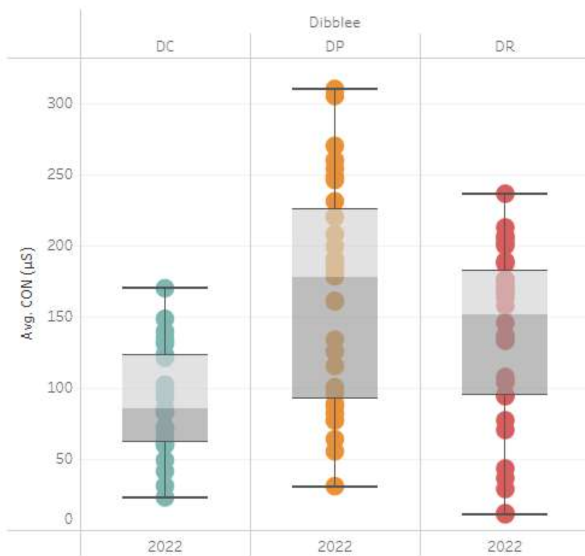

Temp
Dibblee
DC
DP
DR
Avg. Temp (C)
30
25
20
15
10
5
0
2022
2022
2022


pH
Dibblee
DC
DP
DR
Avg. pH
8
7
6
5
4
3
2
1
0
2022
2022
2022

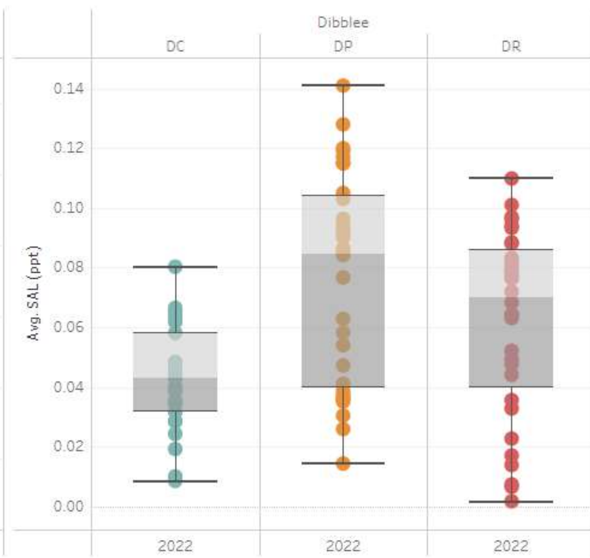

Conductivity
Dibblee
DC
DP
DR
Avg. CON (µS)
300
250
200
150
100


Salinity
Dibblee
DC
DP
DR
Avg. SAL (ppt)
0.14
0.12
0.10
0.08
0.06
0.04
0.02

Conductivity



Salinity



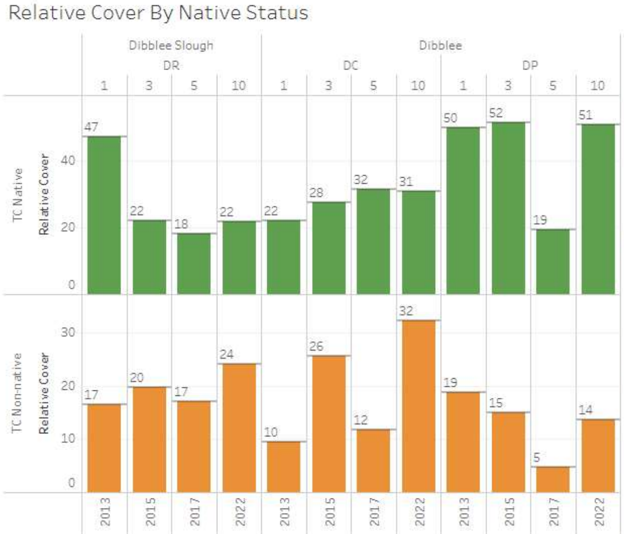
Developed for Bonneville Power Administration

Authors (Lower Columbia Estuary Partnership): Sarah Kidd, Ian Edgar, Sneha Rao
Major Contributors (Columbia River Estuary Study Taskforce): April Silva, Narayan Elsmar

Lower Columbia Estuary Partnership

Dibblee Point Vegetation Development

Relative Cover By Native Status

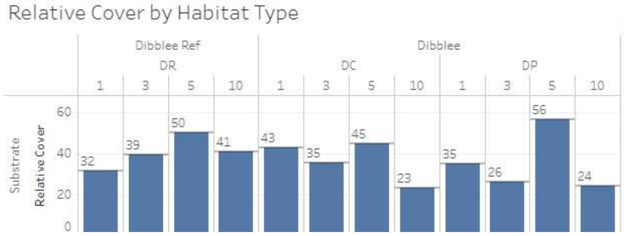


Return to results guide

Vegetation Development Overview Map

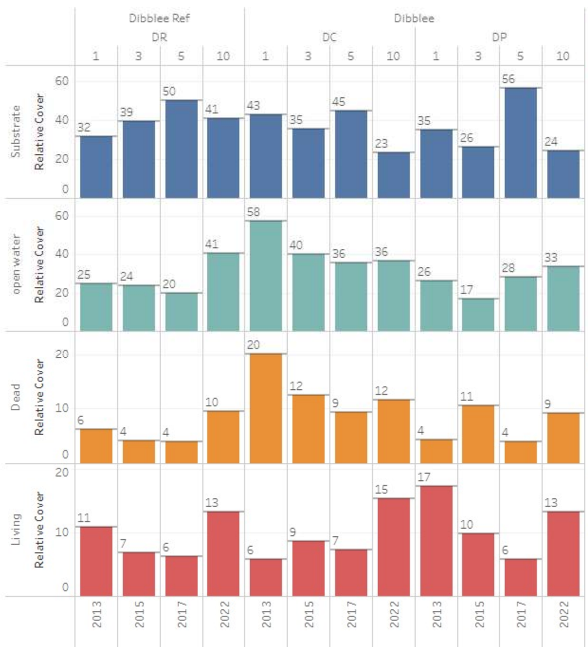
Site ID NEW
DC DP DR

Relative Cover by Habitat Type



Results: The vegetation development at Dibblee Point shows a healthy ratio of na
native cover at year 10 post-restoration. Dibblee Pond has a native cover of 51%
while Dibblee Channel has a native cover of 31%. Overall living cover at the resto
has increased in 2022, eventhough a large amount of bareground exists at Dibble

Relative Cover by Habitat Type



Site ID NEW
DC DP DR

Results: The vegetation development at Dibblee Point shows a healthy ratio of na native cover at year 10 post-restoration. Dibblee Pond has a native cover of 51% while Dibblee Channel has a native cover of 31%. Overall living cover at the resto has increased in 2022, eventhough a large amount of bareground exists at Dibble

For a plant species specific breakdown of the results please look to the tables bel

Summary: At Dibblee Point and Dibblee reference, we surveyed vegetation cover composition to assess changes to habitat structure related to restoration action Vegetation cover and composition is an indicator of the production of organic ma detritus produced by decaying vegetation forms the base of the food web for ma the lower Columbia River and estuary (Borde et al. 2010, Maier and Simenstad 2C Vegetation plot elevation was recorded to track the effectiveness of lowering ma elevations (soil scrape down) to control invasive vegetation and promote native species growth. At each restoration site, two vegetation monitoring areas were – one in an area directly impacted by restoration actions (Dibblee Channel - DC) a area indirectly impacted by restoration actions (Dibblee Pond - DP). Two vegetati areas provide an overview of overall site condition pre- and post-restoration.

Observe the differences between pre and post construction at restoration sites a comparisions one can draw between Palensky and MCNA reference in each year c restoration.

Dibblee Point Relative Cover by Species and Status - Organized by Paired Mean % Abundance across Restoration and Reference Site

Dibblee Point Relative Cover by Species and Status - Organized by Paired Mean % Abundance across Restoration and Reference Site

			Average	2013 1	2015 3	2017 5	2022 10
bare ground	Dibblee Slough	DR	40	32	39	50	41
	Dibblee	DP	35	35	26	56	24
		DC	37	43	35	45	23
open water	Dibblee Slough	DR	27	25	24	20	41
	Dibblee	DC	42	58	40	36	36
		DP	26	26	17	28	33
Phalaris arundinacea	Dibblee Slough	DR	34	21	37	29	49
	Dibblee	DP	27	32	22	25	27
		DC	17	13	15	8	33
Ludwigia palustris	Dibblee Slough	DR	2	2	1		
	Dibblee	DP	14	31	11	1	12
		DC	3	7	3	1	3
Eleocharis palustris	Dibblee Slough	DR	15	24	13	10	12
	Dibblee	DP	13		4	1	34
		DC	1			1	
Sagittaria latifolia	Dibblee Slough	DR	9	17	7	5	8
	Dibblee	DP	16	10	27	12	14
		DC	4	4	1	2	8
Agrostis stolonifera L.	Dibblee	DP	16	16			
		DC	12			1	23
Polygonum persicaria	Dibblee Slough	DR	19				19
Lysimachia nummularia L.	Dibblee	DP	4				4
		DC	3		7	1	1
Schoenoplectus americanus	Dibblee Slough	DR	1			1	
	Dibblee	DP	4			1	6
Hypochaeris radicata	Dibblee Slough	DR	6	6			
	Dibblee	DC	5	2	8		
Lythrum portula	Dibblee	DP	1			1	
Polygonum amphibiu..	Dibblee	DC	1	1			

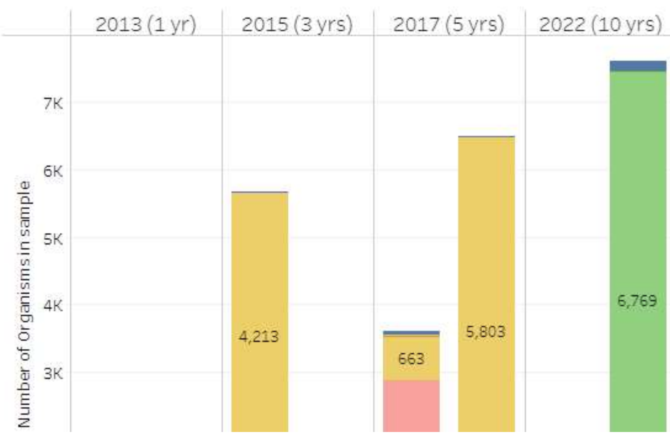
Developed for Bonneville Power Administration
Authors (Lower Columbia Estuary Partnership): Sarah Kidd, Ian Edgar, Sneha Rao
Major Contributors (Columbia River Estuary Study Taskforce): April Silva, Narayan Elsmar

Lower (Estu Partn

Macroinvertebrate Community Composition

Overview Map of Macroinvertebrate Sampling Locations

Total Abundance of Macroinvertebrates



Return to results selection

Results: Salmon prey abundance has steadily increased between 2013-2022 at Dibblee Point, and in 2022, the restoration site had significantly larger abundance of macroinvertebrates in comparison to the reference site. Until 2017, Collemba was dominant, however, in 2022 Cladocera was dominant. This change could be attributed to change in sampling methodology.

About: To assess the capacity of the restoration site to provide prey resources for juvenile salmonids, terrestrial and benthic macroinvertebrate were collected between 2015 and 2021.Fall out traps (FOT) were deployed in proximity to each vegetation sampling area for a 48 hour period to sample insects that fall into the water from an aerial environment. Terrestrial macroinvertebrates were collected following methods outlined in "Terrestrial Invertebrates Standard Operating Procedures" (USGS and Nisqually Indian Tribe 2012). Benthic macroinvertebrates were collected following methods outlined in "Benthic Invertebrate Standard Operating Procedures" (USGS 2012).Sediment cores were collected once a month between April and June to track changes in the benthic invertebrate community related to restoration actions.

Beginning in 2020, the sampling methods were altered to Nueston Tows. At each site, 2 Nueston tows were deployed at the edge of the wetland channel among vegetation in May. Samples were combined into one composite sample and preserved in 95% ethanol.

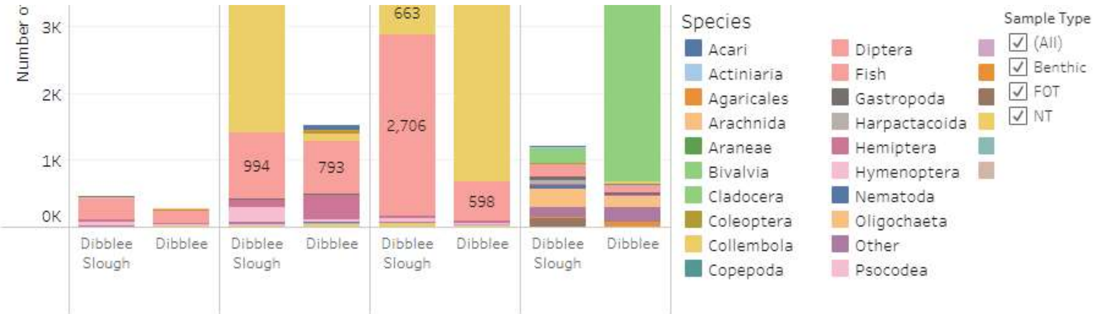
Juvenile Salmonid diets in the Columbia River Estuary predominantly consist of Diptera and Amphipods, with diets transitioning from dipterans to Amphipods as they move towards the mouth of the River (Rao et al 2020). Copepods, Collembola, Cladocera and Oligocheates are also

Species

Acari
Actiniaria
Diptera
Fish

Sample Type

(All)
Benthic



Relative Abundance of Macroinvertebrates

	2013 (1 yr)		2015 (3 yrs)		2017 (5 yrs)		2022 (10 yrs)	
	Dibblee Slough	Dibblee	Dibblee Slough	Dibblee	Dibblee Slough	Dibblee	Dibblee Slough	Dibblee
Acari	0.2%		0.2%	4.5%	1.9%	0.0%	1.2%	1.9%
Actiniaria							1.9%	
Arachnida	1.1%	4.0%	0.2%	1.1%	0.1%			
Araneae								0.2%
Cladocera			0.1%				17.6%	88.9%
Coleoptera	2.7%	1.5%	0.3%	2.2%	0.1%	0.1%	0.2%	
Collembola			74.3%	7.7%	18.4%	89.5%	0.1%	0.5%
Copepoda							0.2%	0.2%
Diptera	71.5%	71.3%	17.5%	53.4%	74.9%	9.2%	16.2%	1.3%
Gastropoda			0.0%	0.1%			5.2%	0.7%
Harpactacoida							3.6%	
Hemiptera	6.5%	5.5%	2.2%	25.2%	1.0%	0.4%	0.1%	0.3%
Hymenoptera	14.7%	8.7%	3.9%	2.5%	1.6%	0.3%		0.0%
Nematoda				0.1%			6.9%	0.1%
Oligochaeta							22.7%	2.1%
Symphypleona							0.2%	1.0%
Tardigrada			0.1%				11.9%	
Thysanoptera	2.9%	7.6%	0.6%	2.8%	1.6%	0.5%	0.1%	0.0%
Other	0.4%		0.5%	0.1%	0.3%		11.5%	2.7%
Unknown		1.5%						

Fish Community Composition

Fish Sampling Map

Return to Results Selection

Results: Majority of the community sampled at Dibblee Point consisted of Non-salmonids.
Threespine stickleback made up 89% of community composition. 4% of the community was comrised of Chinook Salmon, indicating that other salmonids use the site.

Methods: Dibblee Point Fish check-in was not conducted at year 5 post-restoration. At year 10 post resotration, 4 locations (3 at the pond, 1 near the pedestrian bridge) were sampled.
All non-salmonid fish were identified to the species level counted and released. Sampling was conducted only in April, as water temperatures were too high in May and July 2022. All salmonids were measured (fork length, nearest mm), checked for adipose fin clips, or other external marks, coded wire tags, and passive integrated transponder tags to distinguish between marked hatchery fish and unmarked (presumably wild) fish and released. A Genetic sample was taken from the caudal fin on all captured Chinook salmon. Temperature in degree Celsius and Dissolved Oxygen (DO, mg/l) was measured.

Fish Community Composition at Year 5 Post-restoration