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

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Action Effectiveness Monitoring for the Lower Columbia River Estuary Habitat Restoration Program Annual Report (October 2017 to September 2018)

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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
PIT	passive integrated transponder
RPA	Reasonable and prudent alternative
USACE	U.S. Army Corps of Engineers

Summary

The Lower Columbia Estuary Partnership 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, identify how restoration techniques address limiting factors for juvenile salmonids, and improve restoration techniques to maximize the impact of restoration actions. To accomplish AEM program goals, the Estuary Partnership 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 objectives of the AEM annual monitoring objectives were to quantify post-restoration hydrology, temperature, habitat, and vegetation within restoration sites, and determine post-restoration fish use at selected sites.

A total of twenty-five restoration sites received AEM data collection in 2018. All monitoring was conducted following standardized protocols outlined in Roegner et al. (2009). Five restoration sites received Level 2 monitoring, and 20 restoration sites received Level 3 monitoring. A PIT tag array was operated at Horsetail Creek to determine type and residency time of salmonids at the site and address uncertainties related to fish passage through long culverts. Additionally, we conducted status fish sampling at two locations, Kandoll Farm and North Unit Sauvie Island Phase 1 (Ruby Lake) to idenfy fish presents five years post-restoration.

Hydrologic reconnection is intended to restore physical processes that provide site access to juvenile salmonids and restore ecological processes. Water surface elevation (WSE), water temperature, and habitat opportunity are metrics used to measure changes in these hydrologic physical processes at restoration sites. Across all restoration sites post-restoration WSEs showed strong similarity to reference channel and marsh WSEs indicating recovery of lost hydrologic connectivity. Post-restoration water temperatures were also found to be similar to their reference sites. Both restored and reference marsh water temperatures were found to track slightly warmer than the main stem Columbia River temperatures. Combining WSE and water temperature provies a meaningful measure of salmonid habitat opportunity, as defined by the number of days a site has both suitable water temperatures and water levels for salmonids. Across all restoration sites, habitat opportunity was significantly increased post-restoration indicating restoration actions created useable (based on water depth and temperature) habitat for outmigrating juvenile salmonids as soon as one year post-restoration.

Hydrology and wetland elevation drive emergent wetland vegetation cover and composition. Across Level 2 restoration sites monitored in 2018, Wallooskee-Youngs, Kandoll Farm, La Center Wetlands, Sauvie Island North Unit Phase 1 (Ruby Lake), North Unit Flight's End, distinct high and low marsh vegetation zone development was evident based on the collected vegetation data. Correlations in total vegetation cover were identified with average marsh elevation, species richness, and species diversity across all restoration sites 3-5 years post restoration indicating recovery of reference marsh trends in plant community development. Specifically, La Center Wetlands three years post-restoration and Ruby Lake five years post-restoration had similar amounts of native plant cover as the reference site, while areas within Kandoll Farm, five years post-restoration, is trending towards a similar amount of native vegetation as the reference. One year post-restoration, Flights End and Wallooskee-Youngs have low levels of native cover compared to a reference condition, however, more time will be required for reference level trends in plant community development to emerge within these sites. Across all sites, post-restoration, reed canarygrass levels were generally lower or similar to amounts observed at reference sites.

Five years post-restoration, we collected synoptic fish community data to determine if Ruby Lake and Kandoll Farm achieved the goal of fish use. At Kandoll Farm, four salmonid species were captured, marked and unmarked Chinook, chum, coho, and steelhead. At Ruby Lake, both marked and unmarked Chinook salmon were captured. Additionally, the PIT array at Horsetail Creek continued to detect upstream salmonid species, including hatchery spring, fall, and summer Chinook along with hatchery Coho, steelhead, summer sockeye. All 2018 detections at the site showed the fish occupied the area for less than one day. These results indicate trageted salmonid use across the restoration sites, futher highlighting the importance of restoring these lost marsh habitats. Status checks of fish occurrence at other Level 2 AEM sites and PIT array monitoring at Horsetail Creek will continue through 2019.

AEM data shows restoration sites are achieving increases in connectivity and salmonid opportunity, however, plant community recover is more variable with lower elevation areas slowly developing native emergent vegetation and reed canarygrass dominating higher elevation wetland areas. These findings indicate that re-establishment of natural physical processes to sites are accomplished in a relatively short period of time. However, the ecological response to physical drivers can take more time to manifest. Continued monitoring through the AEM program will elucidate and improve our understanding of the connections between physical processes, habitat responses, and the resulting benefits to juvenile salmon.

Management Implications

Action effectiveness monitoring measures changes to physical and ecological processes that influence restoration sites ability to support juvenile salmonids. Also, 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 is leading to the reestablishment of natural physical processes which support juvenile salmonids. It is clear WSE responds immediately to hydrologic reconnection. Water temperatures at the restoration sites included in this analysis generally were 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 results seen at Ecosystem Monitoring Program sites (Kidd et al. 2019). Habitat Opportunity, combining WSE and water temperature, tells a complete story of when and how much of a restoration site is available to juvenile salmonids. Following restoration, all sites included in this report had water levels and water temperature conducive to support juvenile salmonids during the outmigration period in both the channel and floodplain areas.

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 two sites and found juvenile salmonids at both locations. The two sites sampled differed in relative position along the main stem Columbia River. Kandoll Farm, located 6 Km up the Gray’s River, has a strong tidal influence, while Ruby Lake has a greater fluvial influence and is located approximately 2 Km from Multnomah Channel. At sampled restoration sites, regardless of position to the river, the presence of juvenile salmonid indicate some benefit to the fish. The PIT array at Horsetail Creek continues to detect outmigrating upriver juvenile salmonid species visiting the site for periods ranging from a few hours to a couple of days.

AEM shows 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. Re-establishment of natural physical processes to sites can be accomplished in a short period of time, but to understand how the site will respond ecologically will need to take place over a more extended period. Ultimately, 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.

Introduction

The goals of the Lower Columbia Estuary Partnership's Action Effectiveness Monitoring (AEM) program are to determine the impact of habitat restoration actions. The AEM Program, part of the Columbia Estuary Ecosystem Restoration Program (CEERP), provides the Bonneville Power Administration (BPA), the Lower Columbia Estuary Partnership (Estuary Partnership), restoration partners (e.g., USACE and CREST), the Environmental Protection Agency, and others with information useful for evaluating the success of restoration projects. On-the-ground AEM efforts collect the data needed to assess the performance and functional benefits of restoration actions in the lower Columbia River and estuary and addresses RPA 60 of the 2008 Draft Biological Opinion (NMFS 2008).

The goals of the AEM Program are to:

- Determine the benefit of restoration actions for juvenile salmon performance at the site, landscape, and ecosystem scale
- Improve restoration techniques to maximize benefits of habitat restoration actions and better track long term project success
- Use the results of intensive AEM to focus extensive AEM efforts to link fish presence through a lines of evidence approach

In 2008, during the pilot phase of the program, 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.

Level 2 – includes the Level 3 metrics and metrics that can be used to evaluate the capacity of the site 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 and is intended to provide a means of monitoring an "extensive" area.

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 the Level 2 and Level 3 monitoring.

To meet AEM program goals, the Estuary Partnership is engaged in the following tasks:

- 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., Roegner et al. 2009) where applicable
- Developing long-term datasets for restoration projects and associated reference sites
- Coordinating between stakeholders to improve AEM data collection efficiency
- Supporting a regional cooperative effort by all agencies and organizations participating in restoration monitoring activities to create a central database to house monitoring data
- Capturing and disseminating data and results to facilitate improvements in regional restoration strategies

Annual monitoring objectives were to quantify the performance of restoration sites related to water surface elevation, water temperature, habitat opportunity, and vegetation. Additionally, fish data were collected at three sites to determine the composition of the fish community. To put ecological changes at restoration sites into context, the Estuary Partnership's AEM Program incorporated data from reference sites monitored in the Ecosystem Monitoring Program (EMP). The EMP implements monitoring activities to characterize the status and trends of relatively undisturbed emergent wetlands and assess juvenile salmonid usage of those habitats.

Methods

Site Selection 2018

Twenty-one restoration sites received action effectiveness monitoring in 2017 (Table 1 and Table 2). Six restoration sites were selected for Level 2 monitoring (Table 1) using the prioritization criteria outlined in Johnson et al. (2016). Four 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 1). Fifteen restoration sites were scheduled for Level 3 monitoring.

Horsetail Creek was selected for fish monitoring to determine residency time of salmonids in streams in upper reaches of the lower Columbia River and address uncertainty related to fish passage through long culverts. The site was selected for fish monitoring before the establishment of the AEM prioritization process (Figure 2).

Table 1. Restoration sites and associated reference sites selected for Level 2 monitoring in 2018

Restoration Site	Location	Monitoring Locations	Pre-Restoration Monitoring Date	Post-Restoration Monitoring Date	Reference Site and Monitoring Dates
Wallooskee-Youngs	Rkm 19 and approximately 7 km up Youngs River	North South	3-4 June 2015	14, 16 August 2018	Dagget Point 5 June 2015 15 August 2018
Kandoll Farm	Rkm 37 and approximately 5 km up the Grays River	A E	25-28 June 2013	25-26 June 2014 27-28 July 2016 16-Aug-18	Secret River 24-25 July 2013 14-15 July 2014 6 August 2016 2 August 2018
La Center Wetlands	Rkm 140 and approximately 12 Km up the Lewis River	North South	6-7 July 2015	19-20 July 2016 17, 18 July 2018	La Center Control 7 July 2015 19 July 2016 17 July 2018
Sauvie Island North Unit Phase 1 (Ruby Lake)	Rkm 144	North South	16-17 July 2014	13-15 July 2015 18 July 2016 7, 9 August 2018	Cunningham Lake 18 July 2014 28 July 2015 1 August 2016 30 July 2017 7 August 2018
North Unit Flight's End	Rkm 148	North, South, West	14 August 2017	18 July 2018	

Table 2. Restoration sites receiving Level 3 monitoring in 2018

Restoration Site	Location (Rkm)	Restoration Site	Location (Rkm)
Wallacut	5	Elochoman	60
Colewort Creek	19	Kerry Island	72
Otter Point	19	Louisiana Swamp	77
Walluski	27	Germany Creek	90
Liberty Lane	31	Batwater Station	91
Crooked Creek	37	La Center Wetlands	140
Gray's Confluence	37	Flight's End	148
Kandoll Farm	37	Dairy Creek	158
Mill Road	37	McCarthy Creek	163
Bear Mary Ferris	39	Horsetail Creek	222

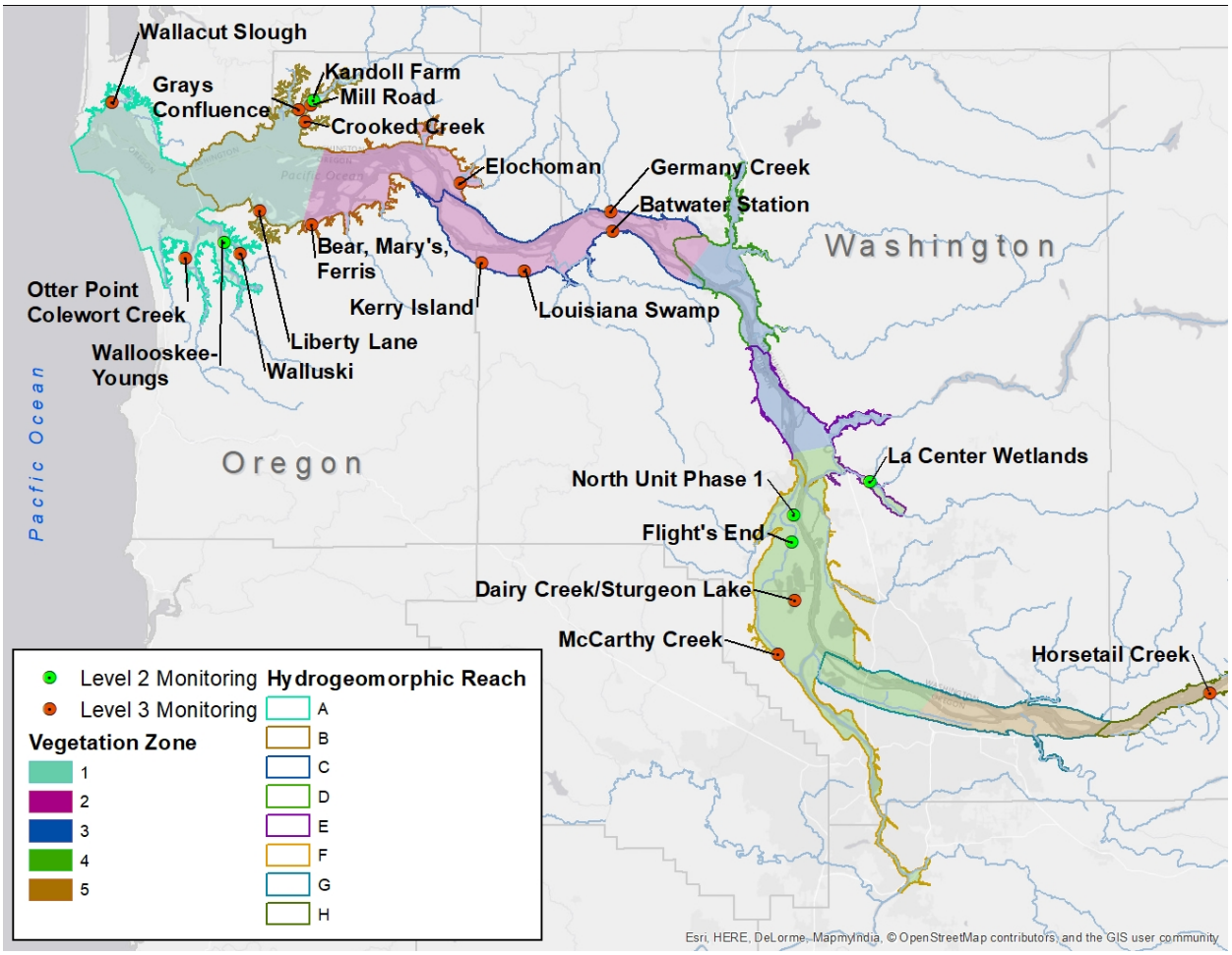


Figure 1. 2018 Level 2 and Level 3 AEM sites

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 (Roegner et al. 2009, Protocol ID: 460). Detailed site sampling reports are in Appendix A.

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 impacted 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. Water Temperature (Method ID 816) was measured to determine habitat suitability for juvenile salmonids. Water Surface Elevation (Method ID 814) was measured to determine opportunity for juvenile salmonid species to access the site and determine timing and level of wetland inundation.

Fish Monitoring

At Kandoll Farm and North Unit Phase 1 (Ruby Lake) sampling was conducted to determine the fish community and whether salmon were present or absent, therefore, no limits were imposed on the number of seine efforts at each site. Fish were collected using a 3 by 38-m variable-mesh bag seine (10.0 mm and 6.3 mm wings, 4.8 mm bag). All sets were deployed using a 17-ft Boston Whaler (Kandoll) or 9-ft inflatable raft (Ruby). All non-salmonid fish were identified to species, counted, and released. All salmonids were measured (fork length, nearest mm), weighed (nearest gram), and released. A genetic sample was taken on all captured Chinook salmon at both Ruby Lake and Kandoll Farm. 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.

A PIT tag detection system was installed at the confluence of Horsetail and Oneonta Creeks to monitor fish passage through a culvert located under the I-84 highway. The system consists of a Biomark FishTRACKER IS1001-MTS distributed Multiplexing Transceiver System (MTS). The MTS unit receives, records, and stores tag signals from 10 antennas, which measure approximately 6' by 6' and are mounted on the north and south sides of the 5-barrel culvert system running under the freeway. The system is powered by an 840-watt solar panel array and supported by 24-volt, 800 amp-hour battery bank backup. The unit is connected to a fiber optic wireless modem that allows for daily downloads of tag data and system voltage monitoring updates.

Analysis

Water-surface elevation (WSE)

Daily maximum water surface elevation (WSE) was graphed against a nearby reference and 2-year flood elevation for the project. WSE is the primary indicator of hydrographic conditions at a site. The expected 2-year flood elevation, or 50% exceedance probability over a 20-year water record, is the basic elevation for determining restoration project size (wetted area) in the CEERP implementation process (ERTG 2013). The method for its calculation is a well-developed, standard procedure that can be consistently applied in both the fluvial and tidal-dominated portions of the estuary. Use of this elevation recognizes the "…ecological importance of the upland-intertidal ecotone, and the processes structuring the assemblage and the organic matter export function" (ERTG 2013). An effective restoration project would have a WSE that matches the conditions nearby outside the site, indicating hydraulics for the site are normal and unmanaged.

Water Temperature

The monthly maximum 7-day moving average maximum (7-DMA) was calculated for sites post-restoration to compare to an outer reference location and main stem conditions. Also, we calculated the maximum 7-DMA temperature for each site and its reference to determine monthly average. The Columbia mainstem data collection station S8 (Washougal, EP) were used for comparison. Previous research has shown that main stem temperatures do not vary substantially, and a single station is an adequate representation of general main stem conditions for any given time period (Sager et al. 2014). Data quality assurance measures included removing times the data logger was not inundated.

Habitat Opportunity

We adapted a habitat opportunity metric developed by Bottom et al. 2011 to determined salmonid habitat opportunity (days/month). Post-restoration the elevation of the channel connection near the

point of reconnection and the average floodplain elevation from the vegetation monitoring area(where the water control structure or levee was removed) was used. Using the post-restoration WSE data the number of days the WSE was at or above 0.5 meters in depth at these post site access elevations were calculated. These data were then used to summarize the post-restoration salmonid access to the site. This analysis was conducted on mean daily WSE data and 7-day average maximum daily water temperatures. When the depth of the water was 0.5 meters or greater than the elevation of the channel or floodplain elevation and the temperature was ≤17.5 C access was considered optimal, when the temperature was 17.5-22 C, access was considered fair, and when depth was ≥0.5 meters and greater than 22 C access was considered poor. When the depth of the water was <0.5 meters, there was no salmonid access.

Vegetation

To assess species richness (number of species) and percent cover for the herbaceous vegetation community at a given restoration site, we categorized plants species by native/non-native. We calculated species richness, species diversity (Equation 1), and relative cover for native and non-native plants out of the total assemblage for sampling episodes before and after restoration for seven restoration sites for which data were available.

Equation 1. Shannon Diversity Index

$$H' = -\sum_{j=1}^{s} p_i \ln p_i$$

where H' = Shannon Diversity Index
p_i = importance probability in column
i= matrix elements relativized by row totals (see Greig-Smith 1983, p.163; based on Shannon and Wiener 1949).

Nonmetric Multidimensional Scaling

Nonmetric multidimensional scaling (NMS, PC-ORDv6.20, McCune and Grace 2010) was used to examine the relationship between emergent vegetation communities and environmental characteristics. For NMS analyses, a random starting configuration was used with 250 runs performed with the real data. The number of dimensions assessed for the analysis was determined by a Monte Carlo randomization test (250 runs) to determine the number of significant axes with a low stress solution.

Site Similarity

A similarity index was constructed to examine the similarity between sites based on wetland emergent vegetation cover. The similarity index compared each vegetation sampling area in each emergent vegetation zone. The NMS represents a dissimilarity index between sites and years and was calculated using a Sorenson (Bray-Curtis) distance measure. The similarity index was calculated by subtracting 1.0 from the dissimilarity matrix.

Pre-restoration, post-restoration, and reference sites were examined to determine if differences in site condition existed related to emergent marsh vegetation zones. The term “site condition” is used to

distinguish pre-restoration, post-restoration, and reference sites. Emergent marsh vegetation zones (vegetation zones) are defined by distinct vegetation species composition and cover groups as determined by salinity and inundation patterns (Borde et al. 2011). Segregating the river using vegetation zones is a more intuitive method to analyze vegetation at larger spatial scales than hydrogeomorphic reach. We included vegetation data collected through the Ecosystem Monitoring Program for applicable years and vegetation zones. The inclusion of long term status data establishes a baseline which describes natural variation and puts changes related to restoration activities into context.

PC-ORD version 6.20 was used to conduct non-parametric statistical analysis (McCune and Mefford 2011). Before analysis, vegetation data were summarized by calculating the average cover of identified species present in the survey area. Species with less than two occurrences in the dataset were removed. Deleting species that occur in less than 5% of the sample units reduces noise in the dataset without losing much information; furthermore, it often enhances the detection of relationships between community composition and environmental factors (McCune and Mefford 2002). The vegetation data were arcsine square root transformed to eliminate unequal variance and improve normality (Sokal and Rohlf 1995). Three weak outliers were detected after the data transformation; however, the outliers were retained in the analysis because the influence on the overall analysis was minimal. The vegetation matrix was constructed of 42 sample units and 130 vegetation species reported as average percent cover (Table 3). The environmental matrix consisted of 42 sample units and 10 environmental characteristics – average wetland elevation (Columbia River Datum meters), species richness, Shannon diversity, average percent cover detritus, average percent cover of drift wrack, average percent cover of bare ground, average percent cover of litter, average percent cover of standing dead, average percent cover of wood debris.

Table 3. Sites and years included in vegetation analysis

Site	Location	Pre-restoration	Post-restoration	Reference
Wallacut	Mouth	2014	2017	
	Upper	2014	2017	
	Ilwaco			2014, 2017
Steamboat Slough	East	2013	2015, 2017	
	West	2013	2015, 2017	
	Welch			2013, 2015, 2017
Dibblee	Channel		2013, 2015, 2017	
	Pond		2013, 2015, 2017	
	Reference			2013, 2015, 2017
North Unit Phase 2	Millionaire North	2014	2015, 2017	
	Millionaire South	2014	2015, 2017	
	Deep Widgeon North	2014	2015, 2017	
	Deep Widgeon South	2014	2015, 2017	
	Cunningham Lake			2014, 2015, 2017
North Unit Flight's End	North	2017		
	South	2017		
	West	2017		
	Cunningham Lake			2017

Results

2018 Water Year

The 2018 main stem hydrograph was the combination of relatively high flows during the spring freshet, but low flows during the period preceding and following it. Based on the magnitude, timing, and duration of the freshet as well as flows observed during the rest of the year, 2018 was similar to 2011. However, 2018 differed from 2011 in the proportion of flow attributable to tributaries; the Columbia accounted for a greater proportion of flows during the post-freshet, summer, and autumn periods in 2018 than it did in 2011 (Kidd et al. 2019).

Water-Surface Elevation

Restored sites continue to demonstrate complete hydrographic reconnection. Post-restoration WSE mirrored reference water elevations at sites (Figure 2). Sites located lower in the River did not exceed the 2-year flood elevation while sites higher in the river tended to meet or exceed that value (Table 4).

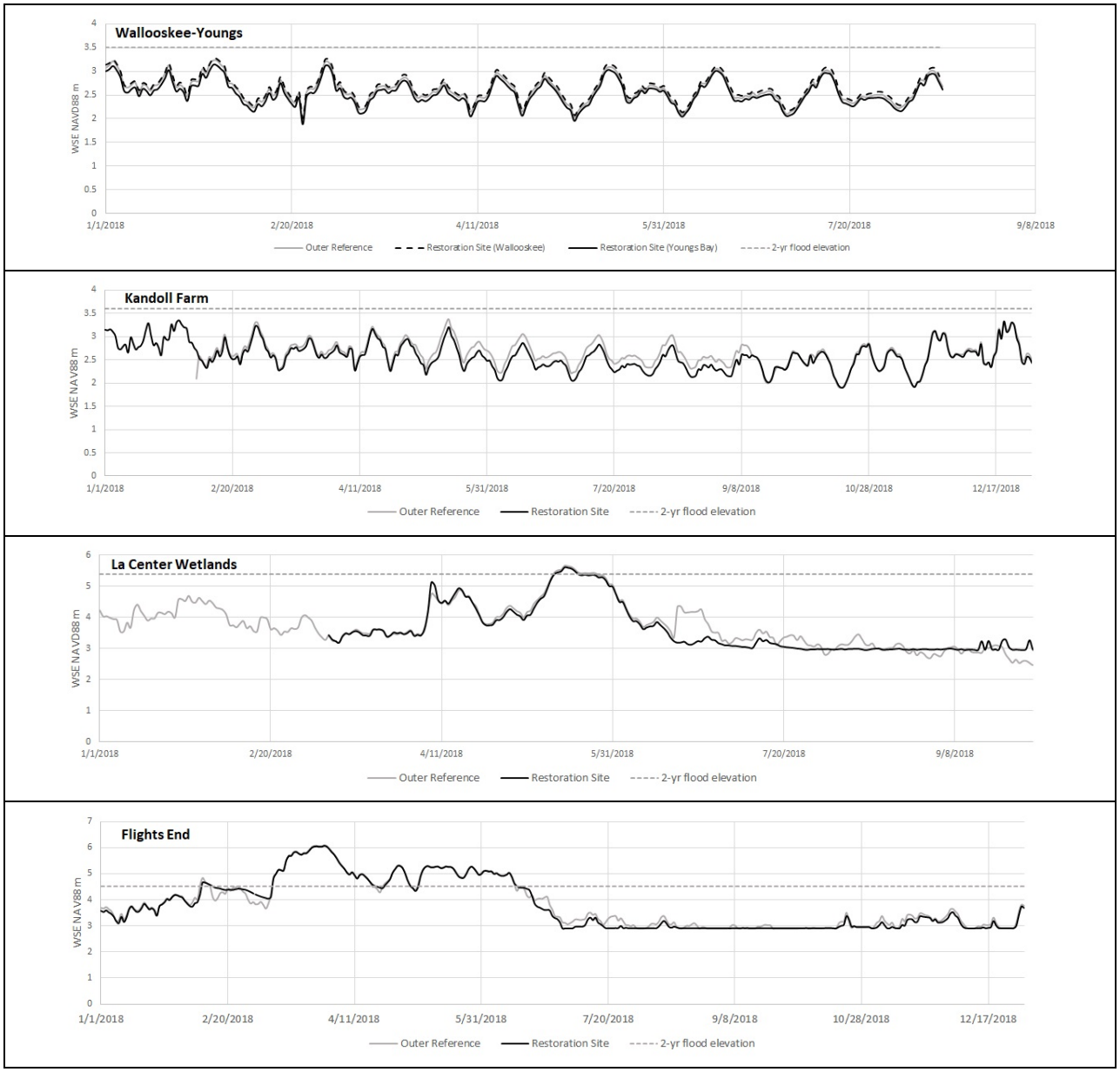


Figure 2. Max water-surface elevation (m, NAVD88) pre/post-elevation with 2-year flood elevation. The "reference" is located in a water body adjacent to the restoration site.

Table 4. Number of days the maximum water-surface elevation exceeded the 2-year flood elevation for the project site. The "reference" is located in a water body adjacent to the restoration site.

Wallooskee-Youngs

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Restored	n (days)	31	28	31	30	31	30	31	14
	Mean Max	2.76	2.48	2.54	2.51	2.52	2.50	2.45	2.56
	Days Exceeded 2 yr Flood Elevation	0	0	0	0	0	0	0	0
Reference	n (days)	31	28	31	30	31	30	31	14
	Mean Max	2.86	2.57	2.62	2.59	2.59	2.55	2.50	2.62

Kandoll Farm

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Restored	n (days)	31	28	31	30	31	30	31	31	30	31	30	31
	Mean Max	2.97	2.67	2.69	2.71	2.61	2.44	2.40	2.37	2.38	2.43	2.52	2.72
	Days Exceeded 2 yr Flood Elevation	0	0	0	0	0	0	0	0	0	0	0	0
Reference	n (days)		23	31	30	31	30	31	31	29	31	30	31
	Mean Max		2.64	2.76	2.76	2.78	2.63	2.58	2.56	2.45	2.46	2.54	2.75

La Center Wetlands

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Restored	n (days)			23	30	31	30	31	31	30	4
	Mean Max			3.47	4.20	4.96	3.63	3.09	2.99	3.03	3.03
	Days Exceeded 2 yr Flood Elevation	0	0	0	0	8	0	0	0	0	0
Reference	n (days)	31	28	31	30	31	30	31	31	30	4
	Mean Max	4.16	3.86	3.53	4.19	5.04	4.01	3.31	3.04	2.86	2.58

Fights End

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Restored	n (days)	31	28	31	30	31	30	31	31	30	31	30	31
	Mean Max	3.64	4.29	5.23	5.02	5.03	4.37	2.99	2.94	2.91	2.96	3.11	3.08
	Days Exceeded 2 yr Flood Elevation	0	5	22	28	28	14	0	0	0	0	0	0
Reference	n (days)	31	28	31	30	31	30	31	31	30	31	30	31
	Mean Max	3.70	4.27	5.18	5.04	5.05	4.46	3.23	3.02	2.94	2.98	3.23	3.17

Water Temperature

Generally, water temperatures among the restored wetlands matched nearby reference conditions (Figure 3). Restoration site water temperatures typically become cooler than the main stem conditions in the early fall and conversely became slighter warmer than the main stem in the early summer (Figure 3). This pattern of seasonal differences between restoration sites and the main stem is reflecting the seasonal influence climate has on these smaller water bodies compared to the main stem conditions. The maximum mean monthly temperatures at most restoration sites stayed below 22°C during March through June; during July and August temperatures regularly exceeded 22°C, this is similar to the trend seen in the main stem temperature conditions during these time periods (Table 5).

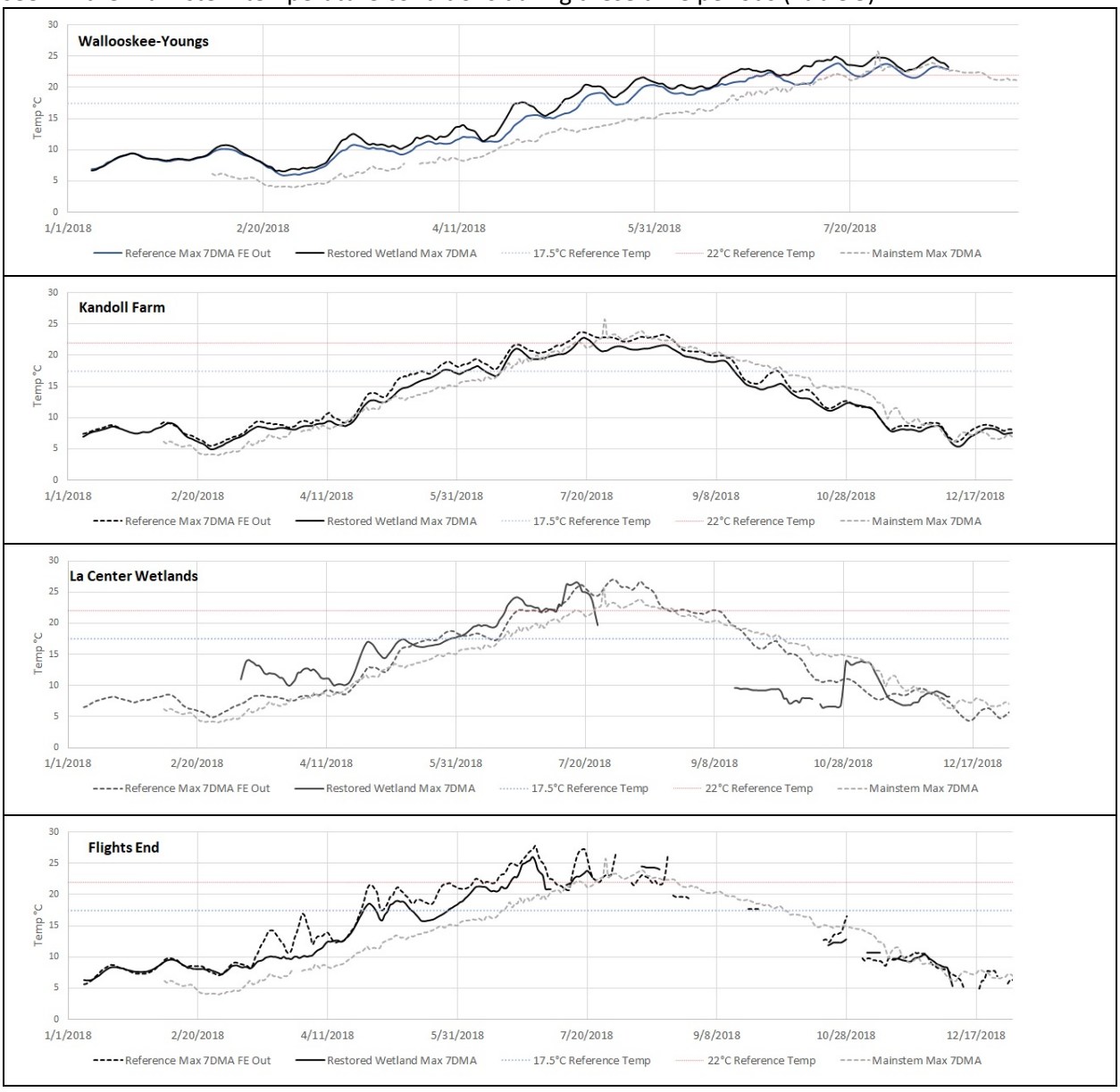


Figure 3. Pre- and post-restoration water temperatures (°C) for restoration sites and main stem estuary.

Table 5. Monthly maximum mean water temperature at restoration, reference, and main stem locations. Temperatures greater than 17.5°C are in yellow and temperatures greater than 22°C are in red.

Wallooskee-Youngs

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Restored Wallooskee	n (days)	31	28	31	30	31	30	31	13
	Mean	8.2	8.1	9.5	12.6	18.0	20.5	22.3	22.4
Reference Wallooskee	n (days)	31	28	31	30	31	30	31	13
	Mean	8.1	7.7	8.9	11.9	17.2	19.6	21.3	21.5
Restored Young's Bay	n (days)	31	28	31	30	31	30	31	14
	Mean	8.3	8.6	10.6	14.1	19.4	21.4	23.7	23.4
Reference Young's Bay	n (days)	31	28	31	30	31	30	31	14
	Mean	8.1	8.0	9.3	12.4	18.2	20.6	22.9	23.2
Main Stem	**n (days)**		22	28	30	31	30	31	14
	Mean		5.1	5.9	9.4	13.7	17.3	21.5	23.0

Kandoll Farm

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Restored	n (days)	31	28	31	30	31	30	31	31	30	31	30	31
	Mean	7.7	7.0	8.0	10.2	15.8	18.7	21.0	20.6	16.6	12.5	9.0	7.2
Reference	n (days)	21	23	31	30	31	30	31	31	29	31	30	31
	Mean	8.0	6.9	8.5	11.0	17.2	19.9	22.5	22.1	17.9	13.1	9.3	7.8
Main Stem	**n (days)**		22	28	30	31	30	31	31	30	31	30	31
	Mean		5.1	5.9	9.4	13.7	17.3	21.5	22.4	19.4	15.8	11.2	7.2

Table 5 Cont. Monthly maximum mean water temperature at restoration, reference, and main stem locations. Temperatures greater than 17.5°C are in yellow and temperatures greater than 22°C are in red.

La Center Wetlands

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Restored	n (days)			23	30	31	30	14				27	2
	Mean			12.0	12.6	16.7	21.3	24.0				9.5	8.2
Reference	n (days)	31	28	31	30	31	30						16
	Mean	7.5	7.8	11.2	15.6	20.0	22.6						6.7
Main Stem	n (days)	31	28	31	30	31	30	31	29				
	Mean	7.4	6.6	7.8	10.1	16.8	19.8	24.2	22.7				

Flights End

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Restored	n (days)	31.0	28.0	26.0	30.0	31.0	27.0	7.0	3.0
	Mean	7.5	8.1	9.3	13.7	17.5	20.6	22.6	24.4
Reference	n (days)	31.0	28.0	28.0	30.0	31.0	30.0	11.0	8.0
	Mean	7.3	7.9	11.9	15.2	19.7	23.0	24.3	22.6
Main stem	n (days)		22.0	28.0	30.0	31.0	30.0	31.0	31.0
	Mean		5.1	5.9	9.4	13.7	17.3	21.5	22.4

Habitat Opportunity

Post-restoration, juvenile salmon had access to suitable habitat within a restoration site, but the amount of time floodplain habitat was available compared to channel habitat differed (Table 6, Figure 4). From April to June post-restoration, site conditions with a channel depth 0.5 m or greater and a temperature threshold less than 17.5°C was 91% on average for all projects combined in April (Table 7). For the same depth and temperature criteria, the average opportunity for the floodplain was 54%. In channel habitats, in May and June, for a 0.5 m channel depth and 17.5°C temperature criteria, post-restoration averages in habitat opportunity were 65% and 7% respectively. A similar trend was observed in floodplain opportunity during the same period of time (Table 7). Restoration channel habitat opportunity for the same depth parameters but a temperature threshold between 17.5°C and 22°C was 5% in April, 35% in May, and 63% June on average (Table 7). The month of June primarily had a temperature threshold greater than 22°C and also had the most periods of no access (i.e. barrier or low water levels) (Figure 4, Table 7).

Table 6. Percent time with 0.5 m water depth and water temperature used to establish site opportunity.

Wallooskee-Young (Youngs Bay) Channel

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Good <17.5 Post	100%	100%	100%	93%	23%	0	0	0
Fair 17.5-22 Post	0	0	0	7%	77%	60%	6%	0
Poor >22 Post	0	0	0	0	0	40%	94%	100%
No Access	0	0	0	0	0	0	0	0

Wallooskee-Young (Youngs Bay) Floodplain

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Good <17.5 Post	100%	89%	90%	83%	16%	0	0	0
Fair 17.5-22 Post	0	0	0	7%	71%	50%	0	0
Poor >22 Post	0	0	0	0	0	40%	87%	86%
No Access	0	11%	10%	10%	13%	10%	13%	14%

Wallooskee-Young (Wallooskee River) Floodplain

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Good <17.5 Post	28%	11%	10%	10%	0	0	0	0
Fair 17.5-22 Post	0	0	0	0	16%	13%	13%	21%
Poor >22 Post	0	0	0	0	0	0	0	0
No Access	72%	89%	90%	90%	84%	87%	87%	79%

Wallooskee-Young (Wallooskee River) Channel

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Good <17.5 Post	100%	100%	100%	100%	58%	0	0	0
Fair 17.5-22 Post	0	0	0	0	42%	100%	77%	93%
Poor >22 Post	0	0	0	0	0	0	23%	0
No Access	0	0	0	0	0	0	0	7%

Kandoll Farm Channel

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good <17.5 Post	100%	100%	100%	100%	90%	33%	0	0	53%	100%	100%	100%
Fair 17.5-22 Post	0	0	0	0	10%	67%	84%	100%	47%	0	0	0
Poor >22 Post	0	0	0	0	0	0	16%	0	0	0	0	0
No Access	0	0	0	0	0	0	0	0	0	0	0	0

Table 6 Cont. Percent time with 0.5 m water depth and water temperature used to establish site opportunity.

Kandoll Farm Floodplain

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good <17.5 Post	52%	21%	19%	23%	16%	3%	0	0	0	0	20%	26%
Fair 17.5-22 Post	0	0	0	0	0	0	0	0	0	0	0	0
Poor >22 Post	0	0	0	0	0	0	0	0	0	0	0	0
No Access	48%	79%	81%	77%	84%	97%	100%	100%	100%	100%	80%	74%

La Center Wetlands Channel

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good <17.5 Post	0	80%	94%	0	0	0	0	0	0	0
Fair 17.5-22 Post	0	0	6%	23%	0	0	0	0	0	0
Poor >22 Post	0	0	0	0	0	0	0	0	0	0
No Access	100%	20%	0	77%	100%	100%	100%	100%	100%	100%

La Center Wetlands Floodplain

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good <17.5 Post	0	70%	94%	0	0	0	0	0	0	0
Fair 17.5-22 Post	0	0	6%	23%	0	0	0	0	0	0
Poor >22 Post	0	0	0	0	0	0	0	0	0	0
No Access	100%	30%	0	77%	100%	100%	100%	100%	100%	100%

Flights End Channel

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good <17.5 Post	76%	100%	100%	83%	58%	0	0	0	0	0	0	6%
Fair 17.5-22 Post	0	0	0	17%	42%	67%	0	0	0	0	0	0
Poor >22 Post	0	0	0	0	0	23%	0	0	0	0	0	0
No Access	24%	0	0	0	0	10%	100%	100%	100%	100%	100%	94%

Flights End Floodplain

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Good <17.5 Post	24%	89%	100%	83%	58%	0	0	0	0	0	0	0
Fair 17.5-22 Post	0	0	0	17%	42%	67%	0	0	0	0	0	0
Poor >22 Post	0	0	0	0	0	3%	0	0	0	0	0	0
No Access	76%	11%	0	0	0	30%	100%	100%	100%	100%	100%	100%

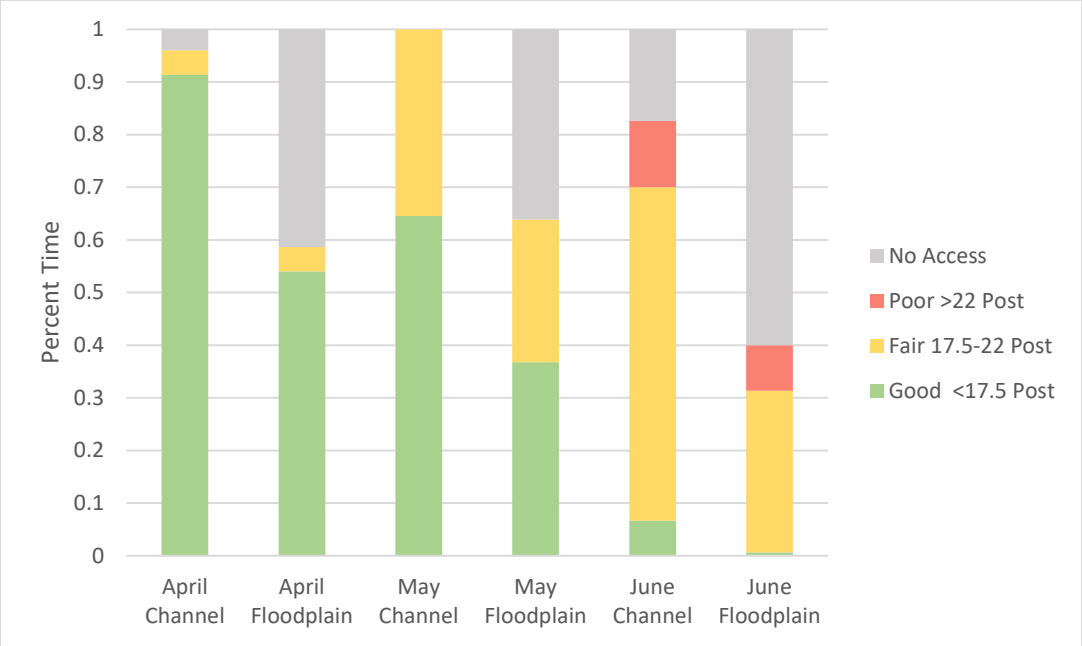


Figure 4. Average Habitat Opportunity for all sites

Table 7. Average habitat opportunity for all sites

Post-Restoration Channel			
Month	Apr	May	June
Good <17.5 Post	91%	65%	7%
Fair 17.5-22 Post	5%	35%	63%
Poor >22 Post	0%	0%	13%
No Access	4%	0%	17%
Post Restoration Floodplain			
Month	Apr	May	June
Good <17.5 Post	54%	37%	1%
Fair 17.5-22 Post	5%	27%	31%
Poor >22 Post	0%	0%	9%
No Access	41%	36%	60%

Vegetation 2018

An NMS ordination with a three-dimensional solution of plots in species space was used (Final stress= 12.47, final stability ≤.000001, number of iterations= 63). The three-axis solution explained 85% of the variation in the data. Restoration sites clustered together based on vegetation zones. The solution was rotated so average marsh elevation, species richness, and species diversity were parallel with axis three (Figure 8). Axis three shows a weak correlation with species richness (r =.465), a weak correlation with average marsh elevation (r =.45), and a moderate correlation with species diversity (r=.68) (Figure 5).

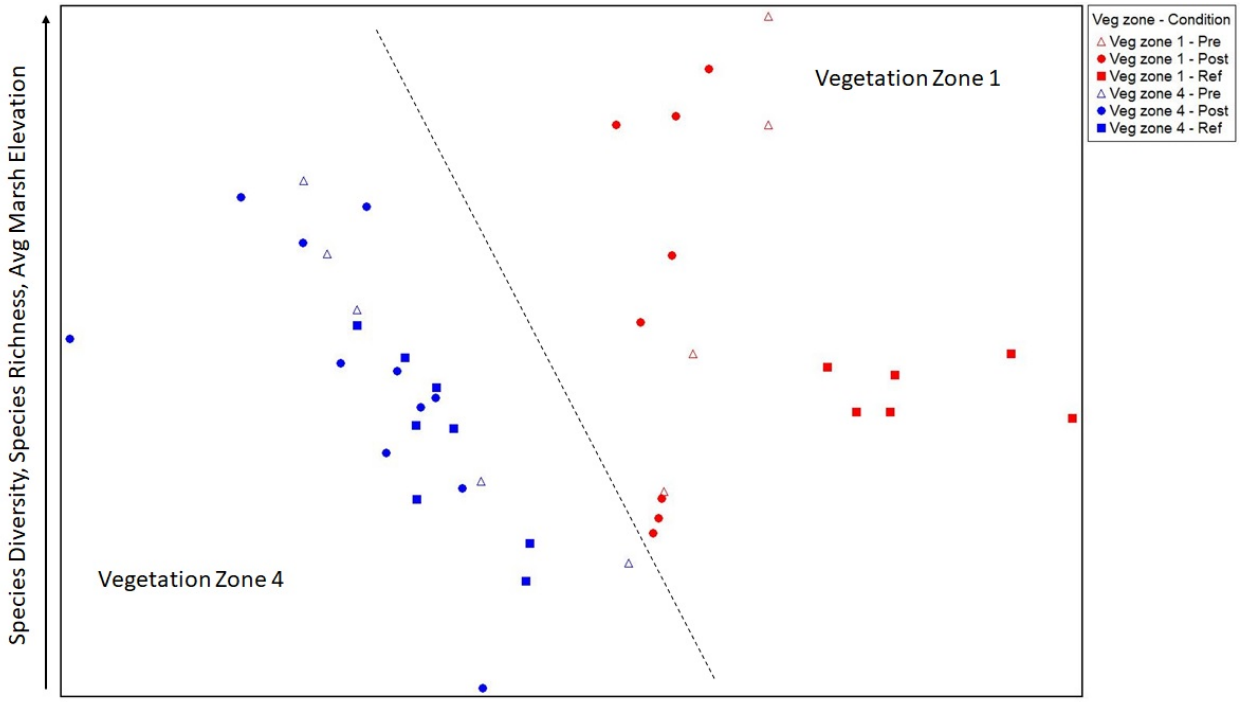


Figure 5. NMS ordination of sample units in species space. The Y axis is correlated with species richness, species diversity, and average marsh elevation. Different vegetation zones are demarcated.

Wallooskee-Youngs

The Wallooskee-Youngs restoration site has two vegetation monitoring areas which were sampled pre-restoration and one-year post-restoration. Vegetation monitoring sites were located on the Young's Bay side of the site (Wallooskee North, WYN) and Wallooskee River (Wallooskee Sough, WYS) side of the site. Both vegetation monitoring locations were established to capture changes related to tidal reconnection related to the removal of water control structures.

Vegetation Similarity

Wallooskee-Youngs and associated reference site were sampled (n=6) once pre-restoration (2015) and one-year post-restoration (2018). Pre-restoration Wallooskee-Youngs had a 56% similarity between the north and south vegetation sampling areas and had less than a 23% similarity with the reference site at Dagget Point (DP, Table 8). Year one post-restoration Wallooskee-Youngs had a 41% similarity between the two vegetation sampling areas. In year one post-restoration, Wallooskee-Youngs had 27% similarity to the reference site (Table 13). At the Wallooskee North site, one-year post-restoration had a 34% similarity to the pre-restoration condition. At the Wallooskee South site, from pre-restoration to year one post-restoration, the vegetation similarity was 38%. At the reference site, when 2015 and 2017 were compared the vegetation similarity was 53%.

Table 8. Similarity index for Wallooskee-Youngs restoration and reference sites.

	DP-18	WYN-15	WYN-18	WYS-15	WYS-18
DP-15	0.53	0.19	0.19	0.23	0.26
DP-18		0.32	0.27	0.36	0.27
WYN-15			0.34	0.56	0.36
WYN-18				0.26	0.41
WYS-15					0.38

DP = Dagget Point Reference
WYN = Wallooskee-Youngs – Youngs Bay
WYS = Wallooskee-Youngs – Wallooskee River

Vegetation Composition

Post-restoration, both species richness and species diversity increased slightly at the Wallooskee North and Wallooskee South sites compared to pre-restoration (Table 9). The average non-native relative cover decreased at the north and south monitoring sites post-restoration. Both relative native species cover and bare ground increased following restoration work (Figure 6).

Table 9. Species richness and species diversity at Wallooskee-Youngs

	Site	Avg. Marsh Elevation (CRD, m)	Overall Species Richness	Overall Species Diversity
Pre-restoration, 2015	WYN-15	1.63	27	1.97
	WYS-15	2.78	18	2.29
	DP-15	2.19	21	1.17
Post-restoration yr-1, 2018	WYN-18	1.77	34	2.36
	WYS-18	2.52	35	2.42
	DP-18	2.33	22	1.78

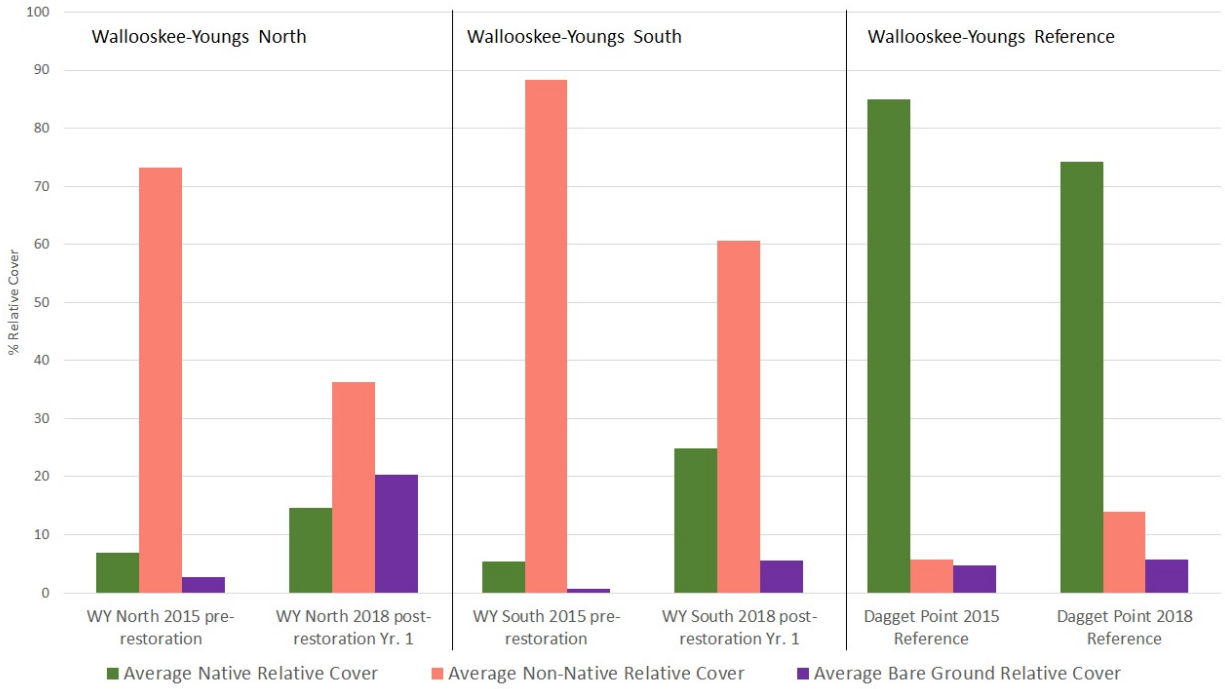


Figure 6. Average relative cover of native vegetation, non-native vegetation, and bare ground for Wallooskee-Youngs and Dagget Point reference site

Kandoll Farm

Kandoll Farm restoration site has two vegetation monitoring areas which were sampled pre-restoration, one, three, and five years post-restoration. Vegetation monitoring at site A (KFA) was established to capture changes related to the addition of microtopography and tidal channels. Vegetation monitoring site E (KFE) was established to capture changes related to the addition of tidal channels at the east end of the site.

Vegetation Similarity

Kandoll Farm and associated reference sites were sampled (n=13) pre-restoration (2013) and three separate years post-restoration (2014, 2016, 2018). Pre-restoration Kandoll Farm had a 47% similarity between the two vegetation sampling areas and had less than a 27% similarity with the reference site at Secret River (SRH, Table 13). Year one post-restoration Kandoll Farm had a 33% similarity between the two vegetation sampling areas, 36% year three post-restoration, and 42% similarity five years post-restoration between sampling areas. In year five post-restoration, Kandoll Farm had less than 18% similarity to the reference site (Table 4). Year one post-restoration at KFA had a 45% similarity to pre-restoration condition and year five post-restoration had a 46% similarity to the pre-restoration condition. At KFE, from pre-restoration to year one post-restoration, the vegetation similarity was 77%, while year five post-restoration had a 46% similarity to the pre-restoration condition. At the reference site, from 2013 to 2014 the vegetation similarity was 81%. When 2013 and 2018 were compared, the vegetation similarity was 58%.

Table 10. Similarity index for restoration and reference sites in vegetation zone one. Yellow highlights represent 60-69% similarity and green represent greater than 70% similarity.

	KFA-14	KFA-16	KFA-18	KFE-13	KFE-14	KFE-16	KFE-18	SRM-13	SRM-14	SRM-15	SRM-16	SRM-18
KFA-13	0.45	0.43	0.46	0.47	0.40	0.28	0.23	0.20	0.21	0.26	0.18	0.20
KFA-14		0.45	0.49	0.35	0.33	0.27	0.26	0.17	0.23	0.18	0.17	0.17
KFA-16			0.52	0.32	0.30	0.36	0.28	0.22	0.22	0.20	0.32	0.17
KFA-18				0.36	0.31	0.33	0.42	0.24	0.28	0.27	0.23	0.23
KFE-13					0.77	0.47	0.46	0.27	0.24	0.30	0.19	0.16
KFE-14						0.47	0.46	0.26	0.26	0.30	0.23	0.18
KFE-16							0.56	0.17	0.22	0.23	0.23	0.15
KFE-18								0.22	0.23	0.23	0.16	0.15
SRM-13									0.67	0.65	0.52	0.58
SRM-14										0.63	0.54	0.64
SRM-15											0.57	0.59
SRM-16												0.59

KFA = Kandoll Farm A
KFE = Kandoll Farm E
SRH = Secret River High Marsh Reference

Vegetation Composition

At Kandoll Farm A, species richness increased from pre-restoration to post-restoration year five (Table 11). The pre-restoration relative native cover was 33%, and the non-native cover was 64% (Figure 10). Five years post-restoration relative native cover increased to 41% while relative non-native decreased to 55%. Overall species richness did not change at Kandoll Farm E, but species diversity decreased five years post-restoration (Table 11). Relative native and non-native cover did not change dramatically from pre-restoration to five years post-restoration. Relative native cover decreased slightly from 17% to 12%, and non-native cover slight increased from 82% to 86% from pre-restoration to post-restoration. At the reference site, relative native cover decreased from 74% in 2013 to 56% in 2018. Relative non-native cover increased from 18% to 24% over the same period (Figure 10).

Table 11. Species richness and species diversity at Steamboat Slough

Condition	Area	Avg. Marsh Elevation (CRD m)	Overall Species Richness	Overall Species Diversity
Pre-restoration, 2013	KFA-13	1.89	24	2.29
	KFE-13	2.09	15	0.97
	SRM-13	2.05	29	1.98
Post-restoration yr-1, 2014	KFA-14	2.24	32	2.64
	KFE-14	2.25	22	0.81
	SRM-14	1.96	30	2.01
Post-restoration yr-3, 2016	KFA-16	2.39	38	2.43
	KFE-16	2.46	18	0.92
	SRM-16	2.08	35	2.30
Post-restoration yr-5, 2018	KFA-18	2.21	34	2.26
	KFE-18	2.42	14	0.66
	SRM-18	1.68	33	2.30

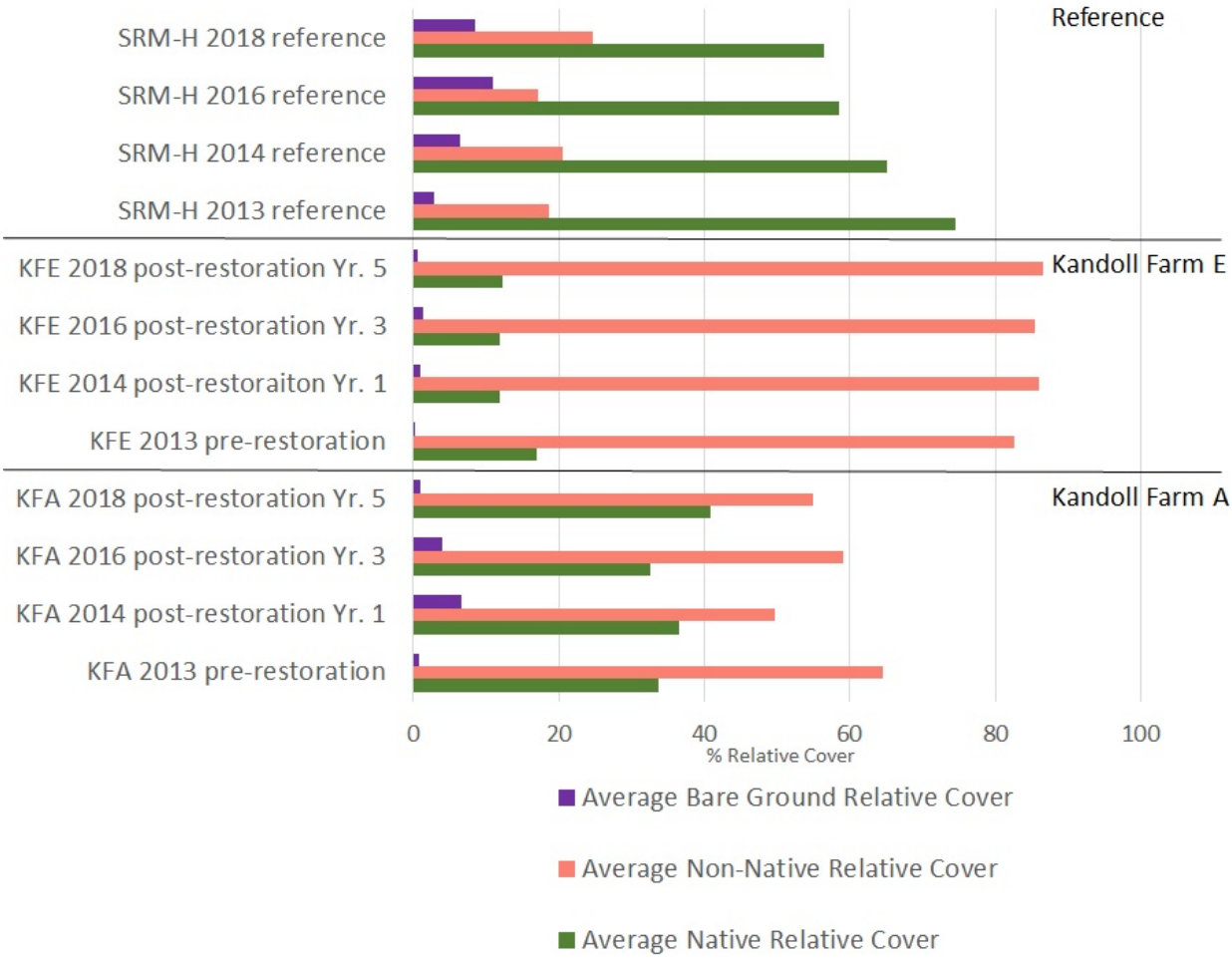
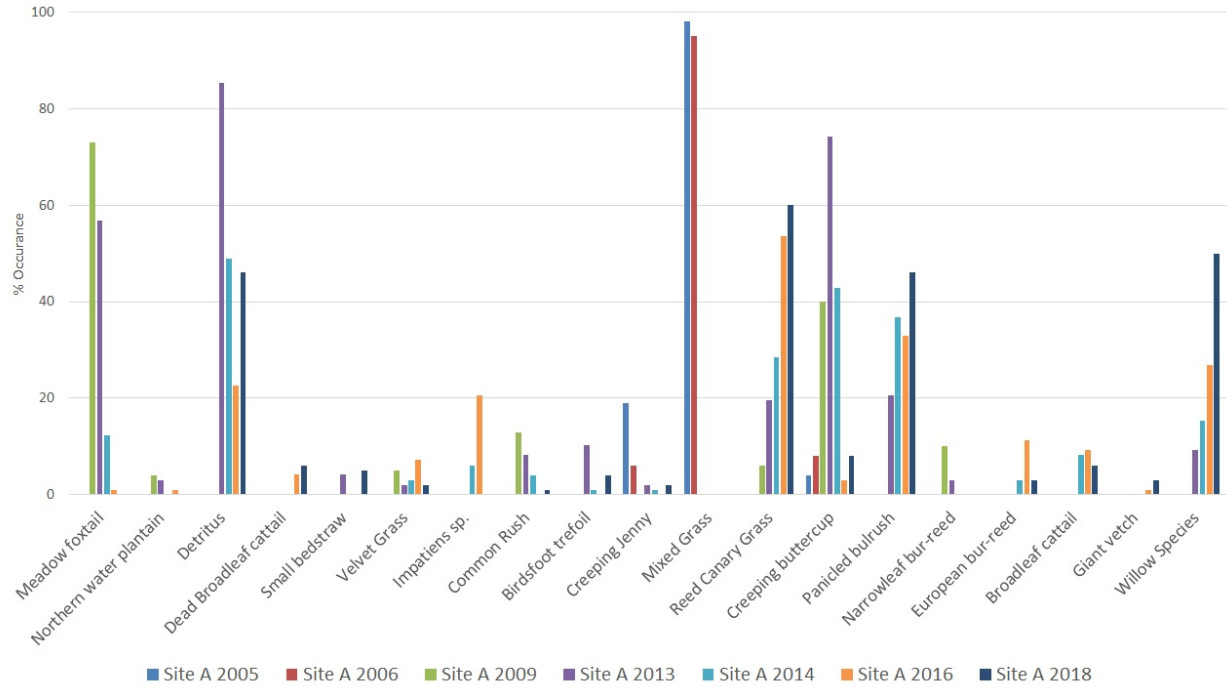


Figure 7. Relative trend vegetation cover and composition for Kandoll Farm and Secret River High Marsh reference site

Long term Vegetation Composition

Line point intercept transects were established during the first phase of restoration at Kandoll Farm to track changes in vegetation. The vegetation community shifted following initial and subsequent restoration actions. At Kandoll Farm A the frequency of occurrence for vegetation species found in predominantly dry sites like mixed field grasses and meadow foxtail decreased while native and invasive wetland plants increased (Figure 8). At Kandoll Farm E a similar trend was observed with mixed field grasses disappearing from the site and wetland plants increasing (Figure 8). At both sites, the occurrence of willows (*Salix* spp.) increased (Figure 8).



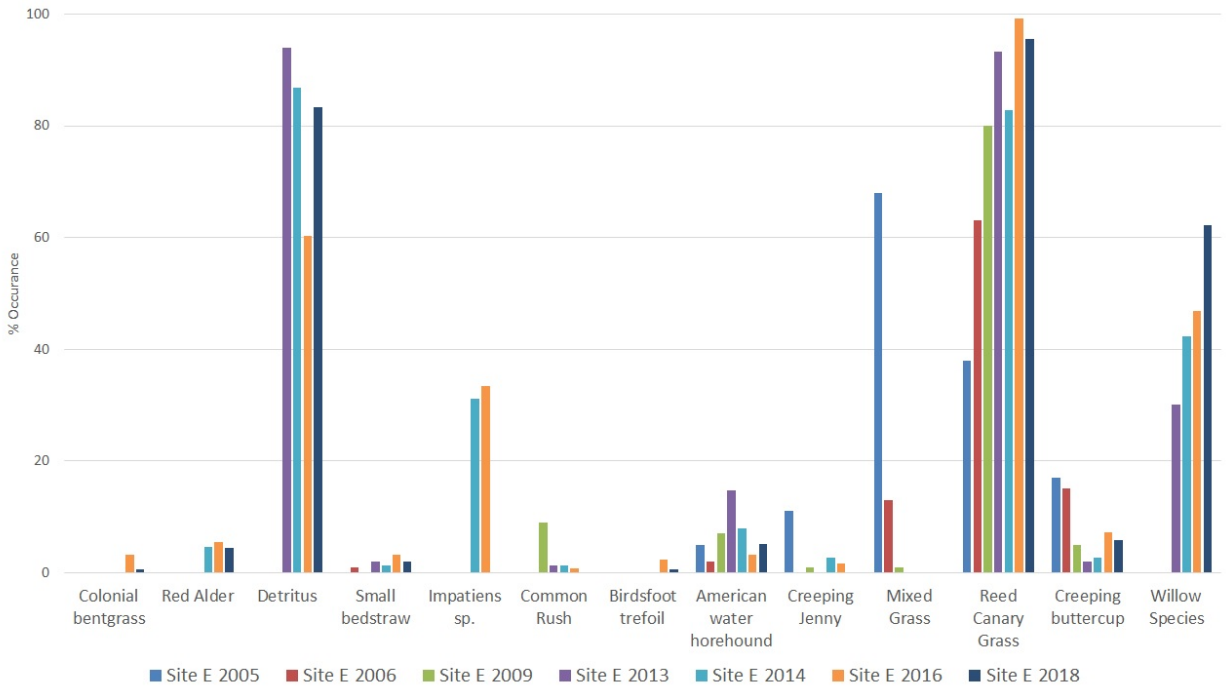


Figure 8. Frequency of occurrence of species for vegetation at Kandoll Farm monitoring sites A and E

La Center Wetlands

The La Center Wetlands restoration site has two vegetation sampling areas, Site 43 and Site 43B, which are bisected by East Fork Lewis River (Figure 20). The vegetation sampling areas were sampled pre-restoration, one-year post-restoration, and three-year post-restoration. The 43 site was established to capture changes in vegetation related to the removal of a water control structure which re-established connection to the E. Fork Lewis River. The 43B site was established to capture indirect changes to vegetation related to removal of an undersized culvert and the addition of a dike breach.

Vegetation Similarity

La Center wetlands and control site were sampled (n=9) pre-restoration, one year, and three years post-restoration. Year one post-restoration the vegetation similarity between the two monitoring areas was 48%. Compared to the control site one-year post-restoration, the 43 site had a 57% similarity, and the 43B site had a 49% similarity (Table 12). Three years post-restoration, the 43 site had a 60% vegetation similarity to the reference site, while the 43B site only had a 49% similarity to the control site. The vegetation similarity between years at the reference site ranged from 45% to 70% (Table 12).

Table 12. Similarity index for restoration and reference sites for La Center Wetlands. Yellow highlights represent 60-69% similarity. Green highlights represent >70% similarity.

	LC43-16	LC43-18	LCB-15	LCB-16	LCB-18	LCC-15	LCC-16	LCC-18
LC43-15	0.40	0.48	0.48	0.28	0.45	0.54	0.39	0.44
LC43-16		0.65	0.36	0.44	0.41	0.37	0.57	0.51
LC43-18			0.34	0.31	0.47	0.40	0.50	0.60
LCB-15				0.38	0.57	0.33	0.35	0.38
LCB-16					0.43	0.29	0.49	0.39
LCB-18						0.41	0.39	0.49

LCC-15							0.42	0.45
LCC-16								0.70

LC43 = La Center Wetlands Site 43
LCB = La Center Wetlands Site 43B
LCC = La Center Control

Vegetation Composition

Overall species diversity at La Center 43 decreased from pre-restoration to post-restoration year three (Table 13). Pre-restoration La Center 43 had similar relative native and non-native cover of 24% and 21% respectively. Year one post-restoration native cover increased to 63% while non-native cover remained similar to pre-restoration values at 23%. Three years post-restoration native relative cover remained above pre-restoration values while relative non-native cover decreased. La Center 43B species richness and species diversity decreased from pre-restoration to post-restoration year three (Table 13). At year three post-restoration, relative native vegetation remains stable at 67%. Non-native relative cover decreased in year three post-restoration to 17%. The control site had increasing native species richness from 2015 to 2018 going from 32% to 52% respectively. Over the same period, relative non-native cover varied between 16% in 2015 to a high of 27% in 2016 (Figure 9).

Table 13. Average marsh elevation, species richness, and species diversity at La Center wetland

Condition	Area	Avg. Marsh Elevation (CRD m)	Overall Species Richness	Overall Species Diversity
Pre-restoration, 2015	LC43-15	2.00	23	2.04
	LCB-15	2.68	21	2.01
	LCC-15	2.58	20	1.22
Post-restoration yr-1, 2016	LC43-16	1.91	17	2.22
	LCB-16	2.63	12	1.27
	LCC-16	2.44	20	1.76
Post-restoration yr-3, 2018	LC43-18	1.99	23	1.88
	LCB-18	2.55	14	1.78
	LCC-18	2.55	20	1.58

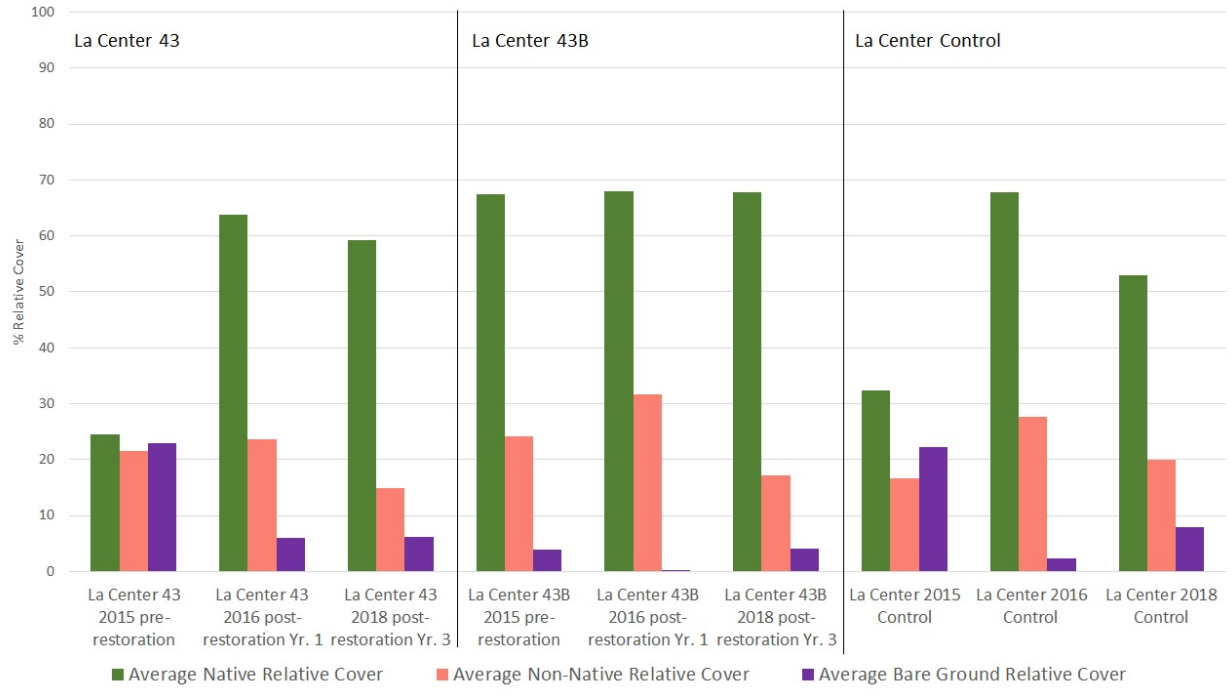


Figure 9. Relative vegetation cover and composition for La Center Wetlands and reference site

Sauvie Island North Unit Phase 1 (Ruby Lake)

Sauvie Island North Unit Phase 1 (Ruby Lake) site has two vegetation monitoring areas (Figure 18) which were sampled pre-restoration, one year, three years, and five years post-restoration. Vegetation monitoring at Ruby Lake North (RLN) was established to capture changes directly related to the lowering of the marsh elevation and unrestricted connection to the Columbia River. Vegetation monitoring at Ruby Lake South (RLS) was established to track changes to established wetland within the restoration site.

Vegetation Similarity Millionaire

Ruby Lake and the reference were sampled (n=13) pre-restoration, and three separate years post-restoration (2014, 2016, 2018). Pre-restoration Ruby Lake North and South had a vegetation similarity of 45%. Post-restoration year one the vegetation similarity between the areas decreased to 14%. Five years post-restoration the two sites were more similar at 40% (Table 14). When compared to the reference site, pre-restoration Ruby Lake North had a 25% similarity, and Ruby Lake South had a 49%. Three years post-restoration Ruby Lake North had a vegetation similarity of 26% but increased to a similarity of 59% five years post-restoration when compared to the reference. Ruby Lake North five years post-restoration had a vegetation similarity of 16% compared to the pre-restoration condition. At Ruby Lake South, vegetation similarity decreased post-restoration from 42% three years post-restoration to 33% five years post-restoration compared to the reference (Table 14). However, five years post-restoration, Ruby Lake South had a high similarity of 62% compared to the pre-restoration condition. At the reference site, the within site vegetation similarity ranged from a low of 55% to a high of 63%.

Table 14. Similarity index for North Unit Sauvie Island Phase 1 restoration and reference sites in vegetation zone one. Yellow highlights represent 60-69% similarity and green represent greater than 70% similarity.

	CLM-14	CLM-16	CLM-17	CLM-18	RLN-13	RLN-14	RLN-16	RLN-18	RLS-13	RLS-14	RLS-16	RLS-18
CLM-13	0.62	0.58	0.59	0.55	0.25	0.25	0.26	0.43	0.49	0.42	0.43	0.37
CLM-14		0.59	0.61	0.61	0.15	0.39	0.30	0.46	0.30	0.30	0.27	0.29
CLM-16			0.63	0.61	0.23	0.14	0.26	0.40	0.46	0.45	0.42	0.47
CLM-17				0.57	0.16	0.21	0.30	0.38	0.36	0.36	0.30	0.35
CLM-18					0.13	0.27	0.33	0.59	0.35	0.31	0.36	0.33
RLN-13						0.10	0.07	0.16	0.45	0.36	0.34	0.30
RLN-14							0.53	0.48	0.15	0.14	0.17	0.11
RLN-16								0.44	0.25	0.23	0.30	0.22
RLN-18									0.37	0.36	0.40	0.40
RLS-13										0.76	0.59	0.62
RLS-14											0.58	0.67
RLS-16												0.59

RLN = Ruby Lake North
RLS = Ruby Lake South
CLM = Cunningham Lake

Vegetation Composition Millionaire

At both Ruby Lake, North and South sampling areas species richness increased from pre-restoration to five years post-restoration. Species diversity also increased at Ruby Lake North over the same period (Table 15). Relative non-native species cover decreased from 100% pre-restoration to 1% post-restoration at Ruby Lake North. Relative native cover followed an opposite trend changing from 0% pre-restoration to 28% post-restoration. The bare ground also increased from pre-restoration to five years post-restoration, changing to from 0% to 35% respectively. At Ruby Lake South, the native cover increased slightly from 41% pre-restoration to 48% five years post-restoration. Relative non-native cover decreased from 51% pre-restoration to 38% post-restoration. The bare ground remained similar from pre-restoration to post-restoration varying between 2% to 4%. At the reference site, relative native

cover increased from 2013 to 2018, and non-native cover and bare ground were more variable over the same period (Figure 10).

Table 15. Species richness and species diversity at Sandy River Delta and reference

	Area	Avg. Marsh Elevation (CRD, m)	Overall Species Richness	Overall Species Diversity
Pre-restoration 2013	RLN-13	1.85	1	0
	RLS-13	1.52	9	1.2
	CLM-13	1.51	12	1.6
Post-restoration Yr-1, 2014	RLN-14	1.27	16	0.6
	RLS-14	1.50	8	1.2
	CLM-14	1.22	16	2.0
Post-restoration Yr-3 2016	RLN-16	1.11	18	0.9
	RLS-16	1.46	12	1.3
	CLM-16	1.48	20	1.6
Post-restoration Yr- 5 2018	RLN-18	1.13	19	1.8
	RLS-18	1.46	15	1.5
	CLM-18	1.40	29	2.1

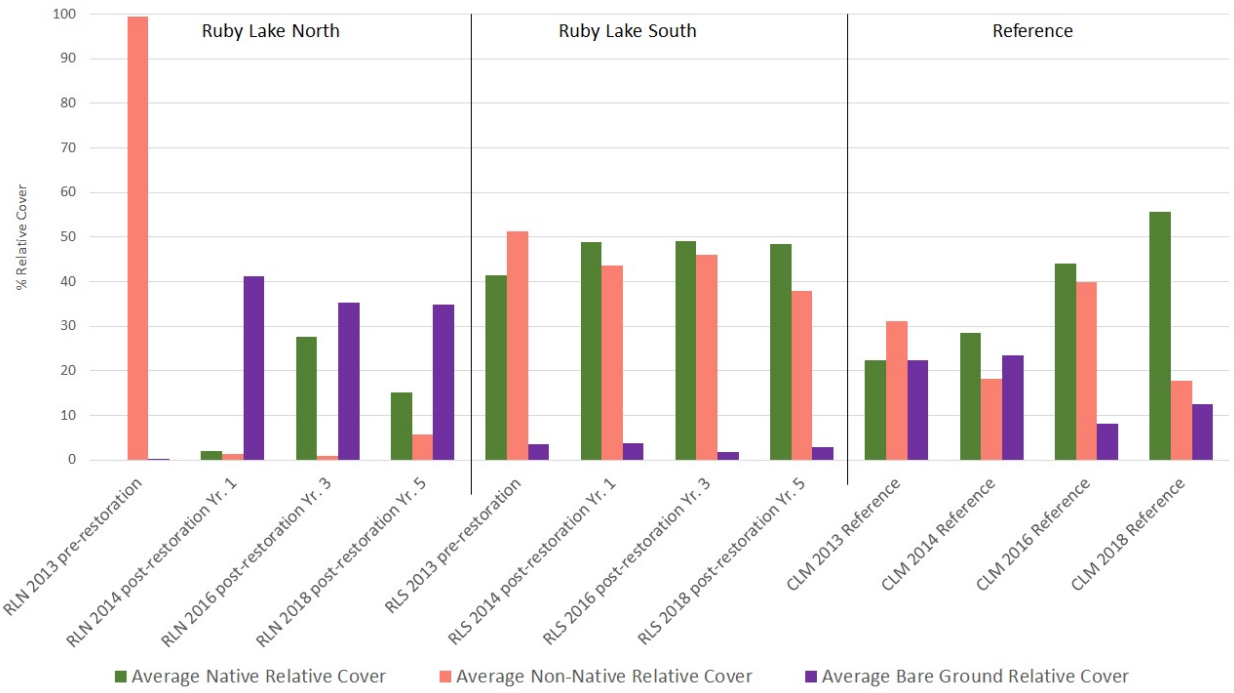


Figure 10. Relative trend vegetation cover and composition for North Unit Sauvie Island Phase 1

Sauvie Island North Unit Flights End

Sampling at Flights End occurred in three areas. Flights End North and West were selected to track the impact of tidal reconnection and lowering of the marsh elevation to promote native wet prairie grass communities. The Flights End South sampling area was chosen to quantify to track changes related to tidal reconnection on the existing wetlands post-restoration.

Vegetation Similarity

Flights End and associated reference site was sample pre-restoration and one-year post-restoration (n=4). Pre-restoration Flight's End vegetation of similarity of 39% when compared to the reference site (Table 16). The vegetation similarity between pre-restoration and post-restoration was 42%. Post-restoration, Flight's End had a 49% vegetating similarity compared to the reference site. Between 2017 and 2018 the reference site had a vegetation similarity of 57% (Table 16).

Table 16. Similarity index for restoration and reference sites in vegetation zone one. Yellow highlights represent 60-69% similarity and green represent greater than 70% similarity.

	CLM-18	FE-17	FE-18
CLM-17	0.57	0.39	0.33
CLM-18		0.37	0.49
FE-17			0.42

FE = Flight's End
CLM = Cunningham Lake

Vegetation Composition

At Flights End species richness and species diversity increased from pre-restoration condition (Table 17). Flights End West had similar species richness and higher species diversity than the reference site. Both native and non-native cover decreased one-year post-restoration, while bare ground increased (Figure 11).

Table 17. Average marsh elevation, species richness, and species diversity at Flights End

Condition	Area	Avg. Marsh Elevation (CRD m)	Overall Species Richness	Overall Species Diversity
Pre-restoration, 2017	FE-17	1.87	26	2.53
	CLM-17	1.53	19	1.80
Post-restoration yr-1, 2018	FE-18	1.66	31	2.71
	CLM-18	1.40	29	2.10

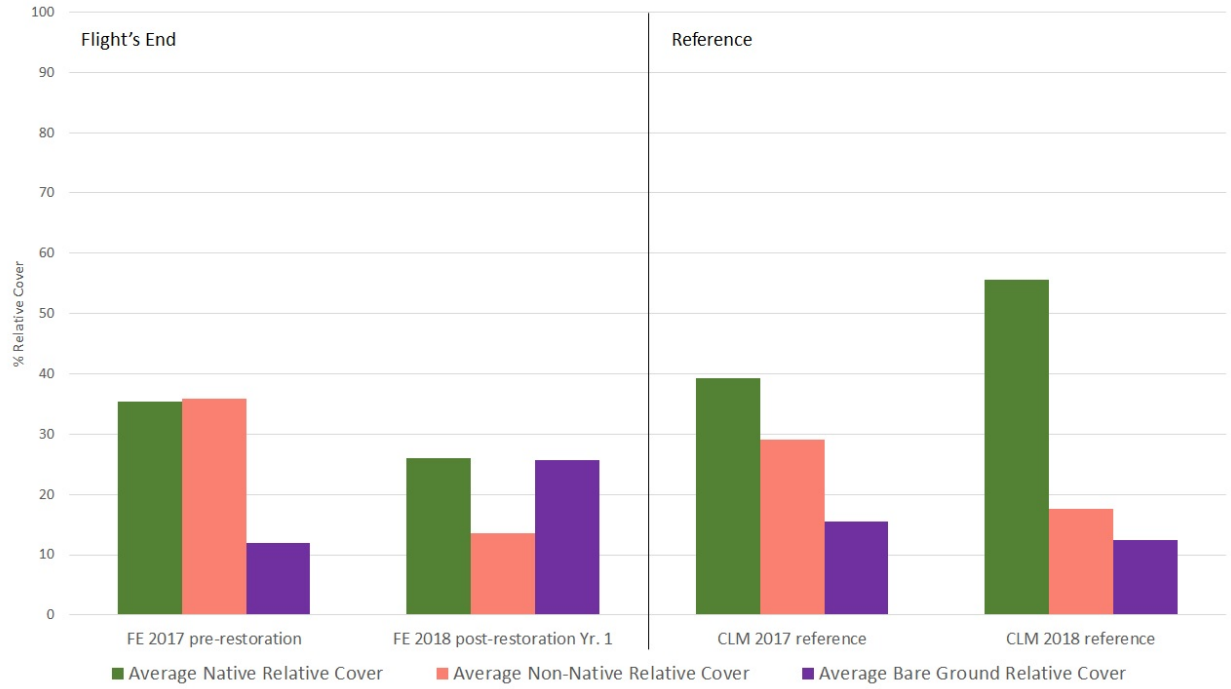


Figure 11. Relative trend vegetation cover and composition for Flight's End and reference site

Vegetation Synthesis 2018

Response ratios were calculated to compare restoration to reference sites. Pre-restoration Wallooskee-Youngs and Kandoll Farm had less native vegetation cover than their associated reference sites. Flight's End, Ruby Lake, and La Center Wetlands had native vegetation cover that fell within the envelope of variability found at reference sites. One year post-restoration, Wallooskee-Youngs had an increase in native vegetation cover, but the total for the site was less than observed at the reference. Kandoll Farm, Ruby Lake, and La Center Wetlands had little change year one post-restoration. Flights End had less native vegetation than it's associated reference one year after restoration (Figure 12). Year three post-restoration La Center Wetlands had native vegetation similar to the reference site. Five years post-restoration Kandoll Farm and Ruby Lake had less native cover compared to their associated reference site. Kandoll Farm shows a trend of increasing native cover across time, while Kandoll Farm shows a neutral to slightly decreasing trend five-year post-restoration (Figure 12).

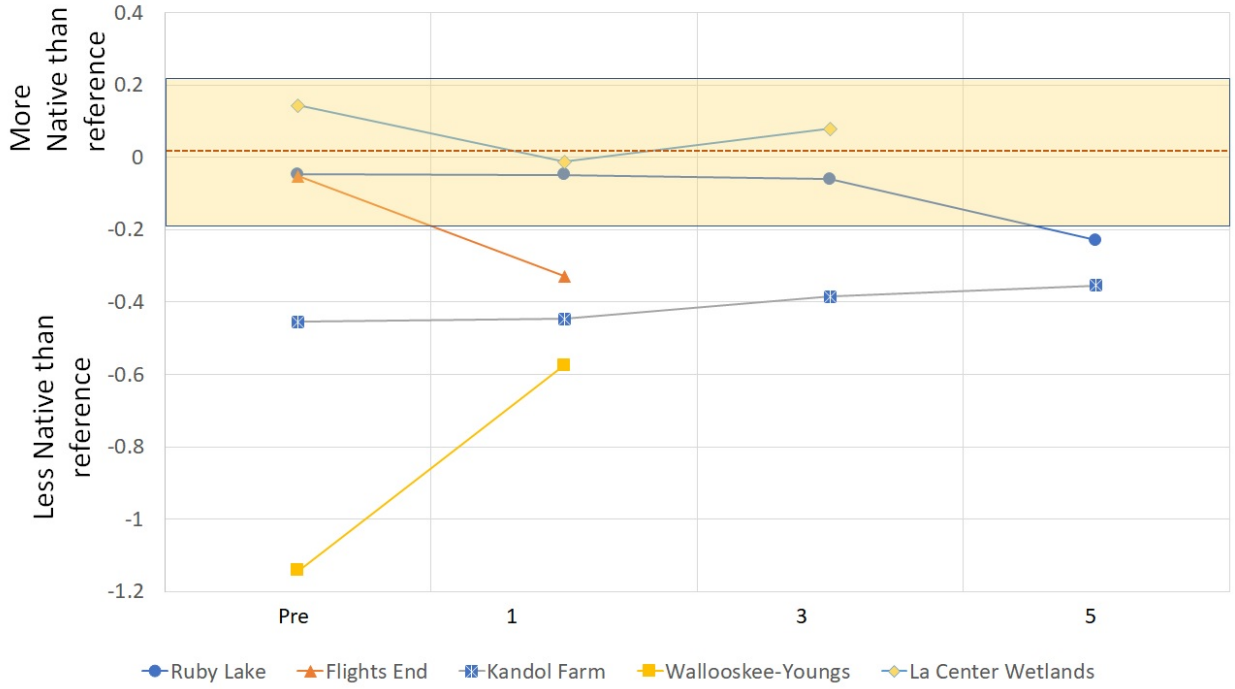


Figure 12. Relative native cover for all sites pre-restoration, post-restoration, and reference.

Reed canarygrass (RCG) relative cover compared to reference associated reference sites varied by time. Ruby Lake and Wallooskee-Youngs had more RCG than the reference site pre-restoration. Year one post-restoration all sites had relative RCG cover similar to the reference site or less RCG than the reference site. Three years post-restoration Ruby Lake and La Center wetlands had less RCG than reference sites, while Kandoll Farm had more RCG than reference. Five years post-restoration Kandoll Farm and Ruby Lake had restoration sites had more RCG than the reference (Figure 13).

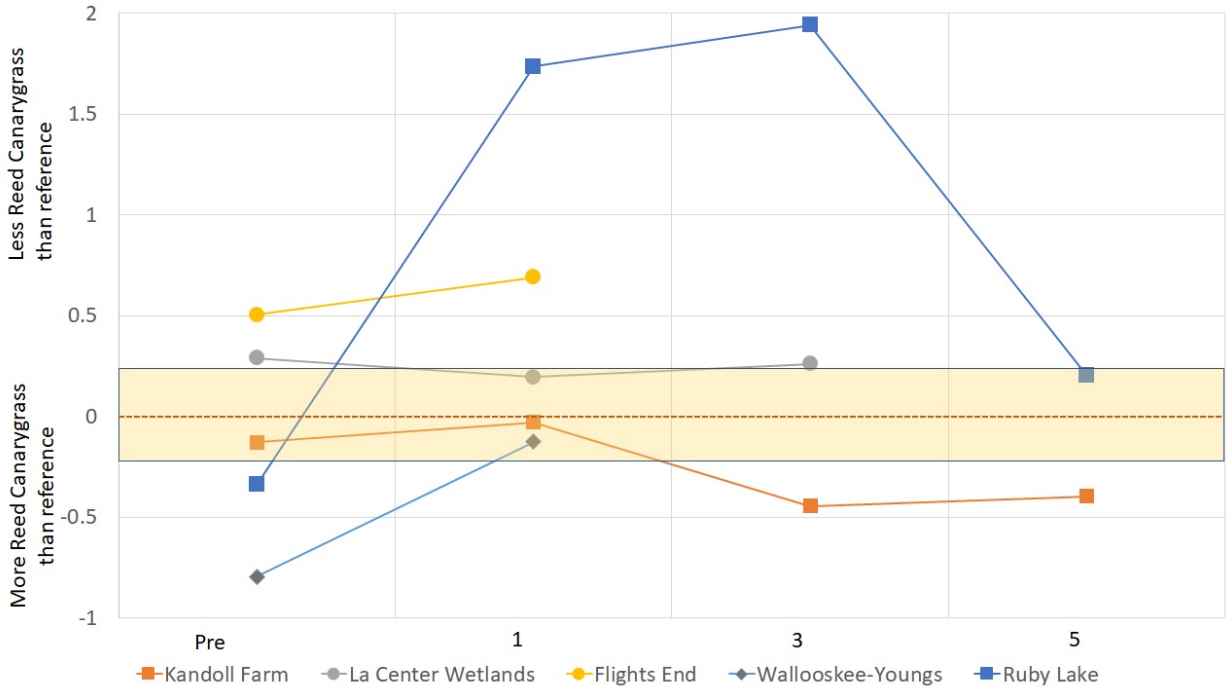


Figure 13. Reed canarygrass cover at pre-restoration, post-restoration, and reference sites

Relative RCG cover was compared to pre-restoration RCG cover to determine withing site change across time post-restoration. Three monitoring sites, Ruby Lake North, Wallooskee-Youngs North, and Flights End, had less RCG than pre-restoration year one post-restoration (Figure 14). Walooskee-Youngs South, Kandoll Farm E, and Ruby Lake South had similar relative RCG cover pre-restoration and post-restoration year one. Only La Center 43 had an increase in relative RCG post-restoration year one. Three years post-restoration most monitoring locations had similar amounts of relative RCG cover to the pre-restoration condition. Ruby Lake North continued to have less RCG than pre-restoration condition while Kandoll Farm A had more relative RCG cover than pre-restoration. Five years post-restoration Ruby Lake North had less relative RCG than pre-restoration but trended closer to the pre-reference condition than previous years. Kandoll Farm A had a more relative RCG cover than pre-restoration and showed a slightly negative trend from year three to year five post-restoration (Figure 14).

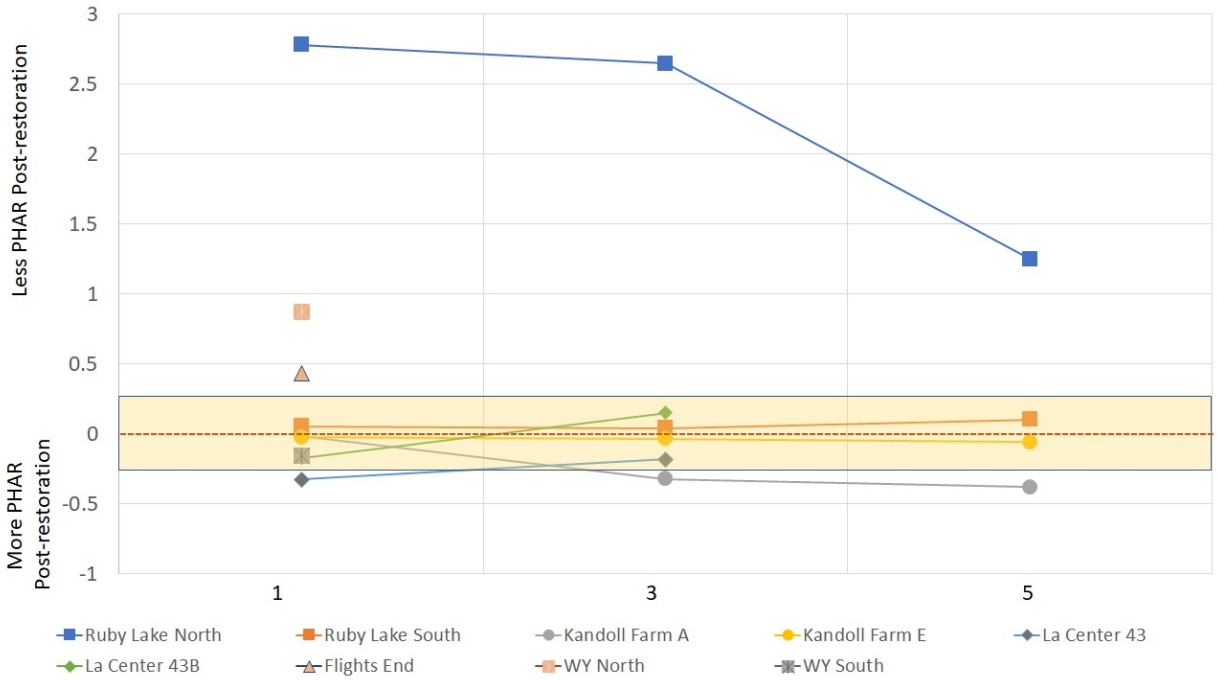


Figure 14. Reed canarygrass relative cover at pre-restoration, post-restoration, and reference sites with independent projects highlighted, only including projects with three or more years of post-restoration project data.

Fish Status and Detection

Kandoll Farm and Ruby Lake

In 2018, Kandoll Farm and Ruby Lake restoration sites were revisited as part of the five-year post-restoration fish community status sampling. The intent of the sampling was to identify the fish communities and whether various salmon species were present following habitat restoration efforts. Kandoll Farm was sampled on April 17th and 18th,and Ruby Lake was sampled on April 24th and 25th.

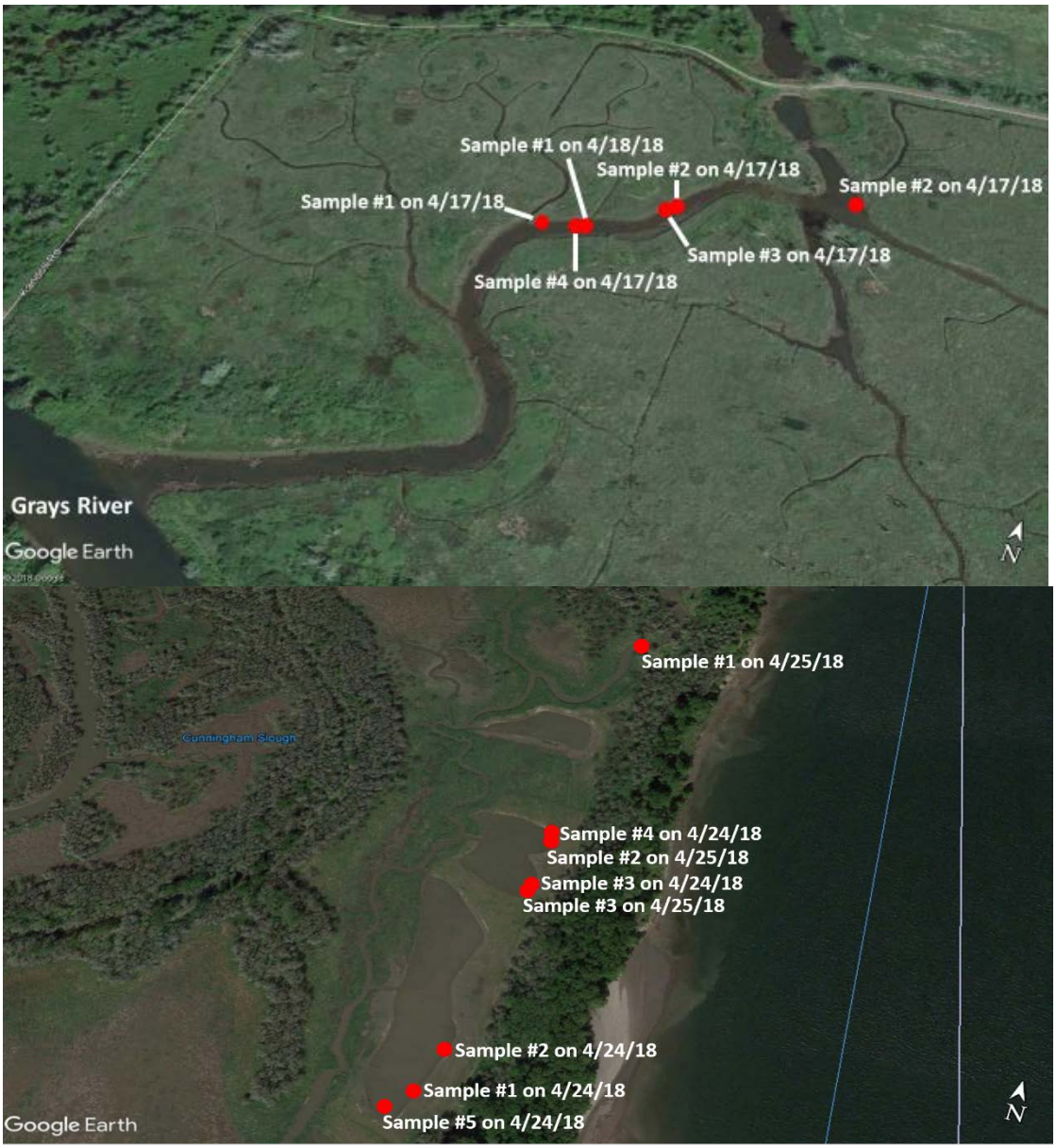


Figure 15. Map of Kandoll Farm (upper) and Ruby Lake (lower) showing the dates and locations of sample sites

Fish Community

We caught a total of six non-salmonid species at Kandoll Farm and 16 species at Ruby Lake. At Kandoll Farm, there was one nonnative species present—banded killifish. At Ruby Lake, there were eleven nonnative fish species present plus one invasive crustacean—the Siberian freshwater shrimp. Threespine stickleback was the most abundant species at both sites. Northern pikeminnow and largemouth bass, adults of which are predatory toward salmon, were captured at Ruby Lake (Figure 16).

Salmon

Four salmonid species were captured at Kandoll Farm: Chinook, chum, coho, and steelhead. Coho was most abundant, followed by Chinook, chum, and steelhead (Figure 17). Most salmonids were unmarked

and presumed wild, except for one adipose-clipped Chinook. All but one of the coho captured at Kandoll Farm were subyearling. Genetics stock identification analysis, with a reporting probability of >=0.90, was completed for five of the seven Chinook caught at Kandoll Farm. Three reporting groups were present: West Cascade fall (N=2), West Cascade spring (N=1), and Willamette River Spring (N=2; one yearling and one subyearling). The presence of Willamette River spring fish indicates that juvenile salmon from the main stem Columbia River may travel up the Grays River to the Kandoll Farm restoration site.

At Ruby Lake, only Chinook salmon were captured. The majority of Chinook were adipose-clipped designating hatchery origin. One Chinook was marked with a coded-wire tag, which revealed that the fish originated from Spring Creek National Fish Hatchery and had been in the river for 15 days. Genetics stock identification analysis, with a reporting probability of >=0.90, was completed for 16 of the 19 Chinook captured at Ruby Lake. Two reporting groups were present: Spring Creek group fall (N=14), and West Cascade fall (N=2). Catch number, average length, weight, and condition factor of observed salmonids are presented in Table 18 and Table 19. CPUE of salmon species at each restoration site is presented in Figure 18.

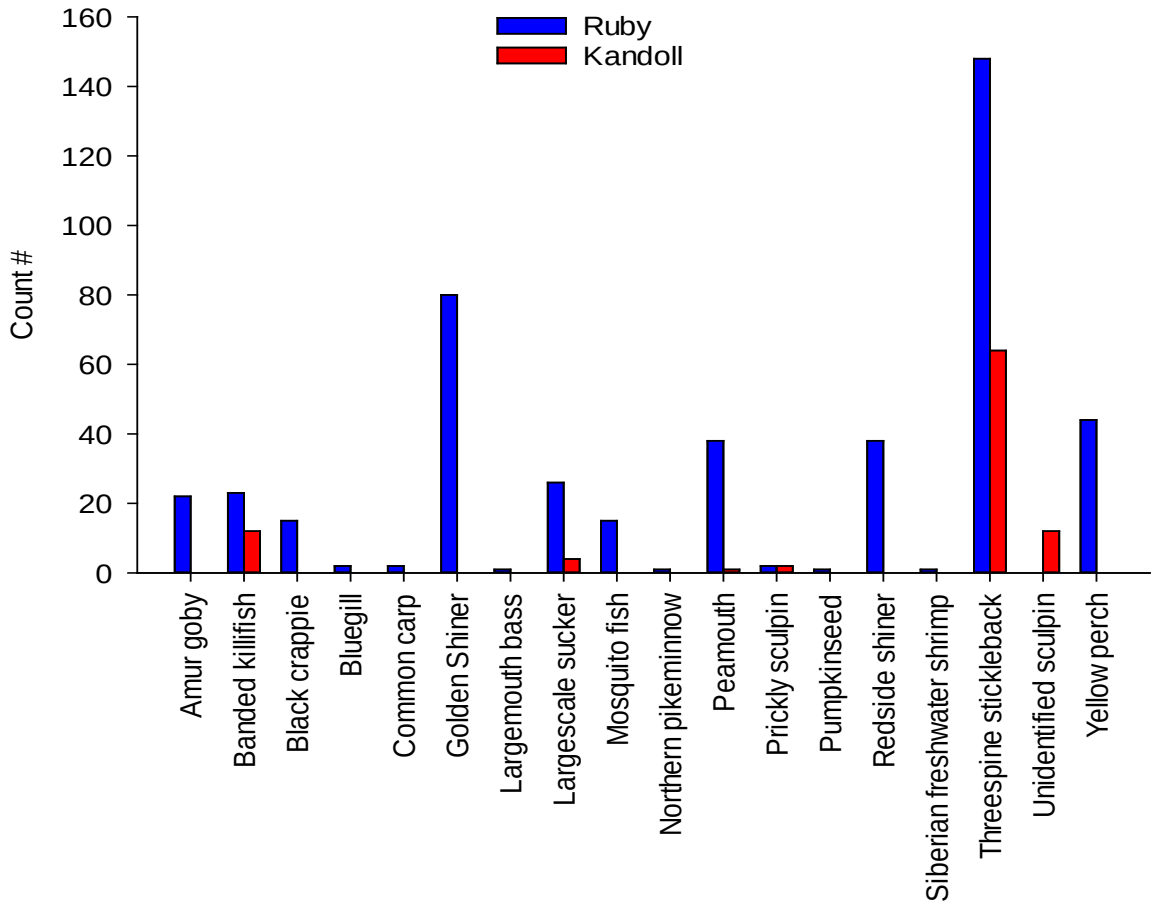


Figure 16. Total number of non-salmonids caught at Ruby Lake and Kandoll farms in April 2018.

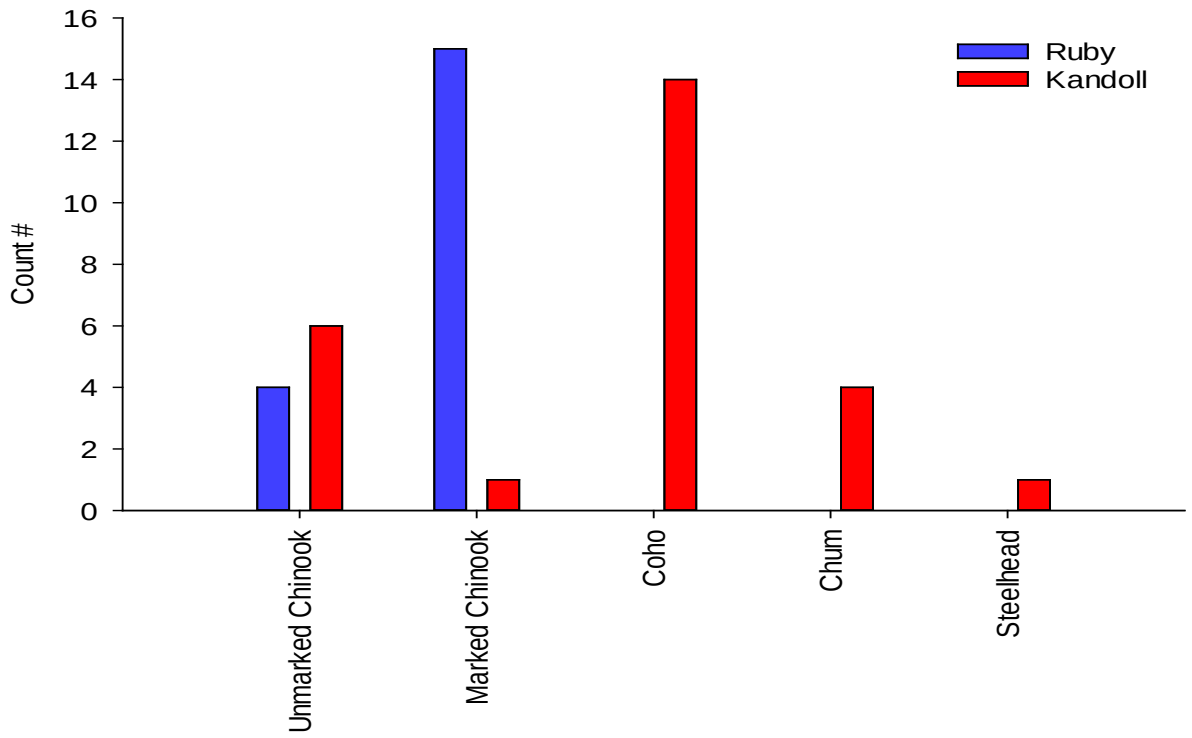


Figure 17. Total number of Chinook, Coho, Chum, and steelhead caught at Ruby Lake and Kandoll farms in April 2018.

Table 18. Total number of Chinook caught, mean Fork length (mm), Mean Weight (g), and mean Fulton's Condition index (k) for Chinook salmon collected from Ruby Lake and Kandoll farms in April 2018. Numbers in parentheses represent one standard error. * Indicates one yearling chinook was included

	Ruby		**Kandoll**	
Variable	Unmarked	Marked	Unmaked	Marked
Number caught	4	15	6	1*
Fork Length (mm)	70 (3.62)	74.73 (0.83)	54.5 (4.57)	176
Weight (g)	3.63 (0.50)	4.18 (0.16)	1.71 (0.48)	58
Condition (k)	1.03 (0.02)	0.99 (0.01)	0.89 (0.08)	1.06

Table 19. Total number of species caught, mean Fork length (mm), Mean Weight (g), and mean Fulton's Condition index (k) for Chum, Coho salmon, and Steelhead collected from Kandoll farms in April 2018. Only Chinook salmon were captured at Ruby Lake. Numbers in parentheses represent one standard error. * Indicates one yearling was included.

Variable	Chum	Coho	Steelhead
Number caught	4	14*	1*
Fork Length (mm)	40.76 (0.85)	44.28 (5.27)	181
Weight (g)	0.38 (0.03)	1.46 (0.90)	55.9
Condition (k)	0.56 (0.05)	0.9 (0.03)	0.94

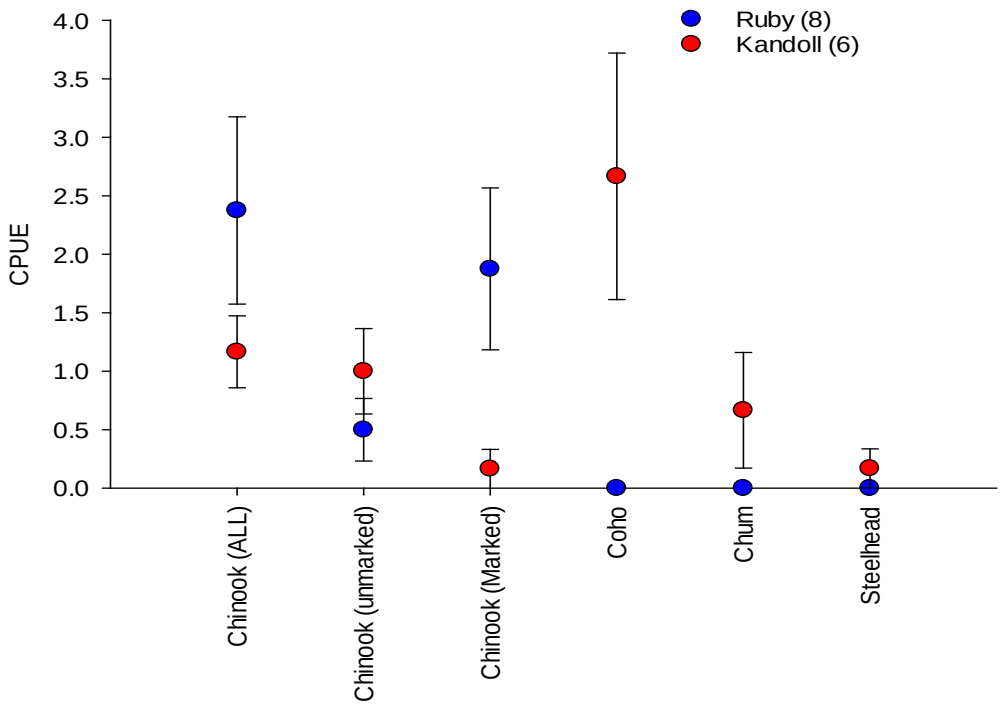


Figure 18. Catch per unit effort of all Chinook caught at Ruby Lake and Kandoll farms in April 2018. Total number of efforts in parenthesis. Error bars represent mean standard error.

Horsetail Creek PIT

The Horsetail Creek PIT detection array was operational from February 28–November 21, 2018. Although not all ten antennas were operating, we had coverage of three antennas on the downstream side and two antennas on the upstream side of the culvert.

Forty individual fish were detected from April 10–August 29. Thirty-eight percent of fish detected were hatchery spring Chinook, one of which originated from the Clearwater River in the Snake Basin. All other spring Chinook salmon originated from the middle Columbia Basin. The second most prevalent category was hatchery fall Chinook at 23%. Hatchery summer steelhead represented 15% of fish detected. One of the hatchery summer steelhead originated from the middle Columbia Basin while the remaining steelhead originated from the Snake River Basin. Three wild steelhead from the middle Columbia Basin were also detected. One hatchery coho and one hatchery summer Chinook, both from the Snake River Basin, were also detected. Additionally, three northern pikeminnow and two unknown (no tag data in the regional database; www.ptagis.org) fish were detected. Detection numbers and residence times are listed in Table 18. Residence times provided are a measure of elapsed time from first to last overall detection.

Table 20. Number and residence time (max and median) of fish detected at Horsetail Creek PIT array in 2018. Residence time is a measure of elapsed time from first to last overall detection, not a measure of time spent upstream of the array. Numbers in parentheses represent the number of known wild origin fish in the total.

		Residence time	
	N	Max	Median
Spring Chinook	15	10.7 d	28 s
Fall Chinook	9	19.1 d	4.65 m
Summer Chinook	1	6.6 h	--
Summer Steelhead	6	67.4 d	8.75 m
Steelhead, unknown run	3 (3)	12.3 d	9.5 m
Hatchery Coho	1	6.9 h	--
Northern Pikeminnow	3	28.2 d	10.9 d
Unknown	2	4.9 h	4.4 h

Discussion

Water-Surface Elevation

Water surface elevation is a proxy for site hydrology and overall connectivity. WSE together with marsh elevations are the strongest predictors of fish access and vegetation communities likely to develop at a site. Post-restoration WSE data show all sites achieving similar hydrology to their reference channels. This indicates an important physical process was established which is a critical step to achieving an ecological reference state. The 2-year flood elevation is a good measure of project wetted area and should be monitored to ensure if that design criterion is achieved, however, it is not necessarily the best indicator for measuring the benefit of restoration actions to out-migrating juvenile salmonids using a site. In 2018 two Level 2 monitoring sites achieved the 2-flood elevation, which occurred between February and June.

Water Temperature

Water temperature is an important environmental factor that can impact if a restoration site is suitable for juvenile salmonids. It is crucial to monitor temperatures to ensure restoration sites are habitable by juvenile salmonids when water levels are high enough to access the channel and floodplain. Level 2 restoration sites exhibited similar 7-day moving average maximum (7DMAM) temperatures as nearby reference areas but were slightly warmer than main stem 7DMAM temperatures. Generally, the 7DMAM at restoration sites did not exceed 22.5°C until July and this similar trend was also observed at EMP sites (Kidd et al. 2019). Climatic conditions strongly influence water temperature and subsequently will be strongly influenced by the depth and amount of time a site is connected to the main stem Columbia River.

Habitat Opportunity

Restored hydrology has an immediate impact of all tidal reconnection projects. Additionally, water temperatures that support juvenile salmonids during critical life stages is a key restoration project objective. Pairing WSE and water temperature together creates a more meaningful measure of habitat opportunity than when examined separately. All Level 2 sites had good habitat opportunity in the channel from January to June. Furthermore, floodplain habitat opportunity was good, but less frequently inundated during the same months. Overall, restoration sites are providing good to fair

habitat opportunity for juvenile salmonids during the early portion of the year and the outmigration period.

Vegetation

In 2018, distinct vegetation zones were evident based on the collected vegetation data. Across all restoration and reference sites regardless of year or conditions, total vegetation cover was correlated with average marsh elevation, species richness, and species diversity. For restoration sites sampled in 2018, on average, species richness was lowest pre-restoration and highest at year one post-restoration. Average species richness for all sites was similar from year three to year five post-restoration. This is likely a result of the vegetation community achieving a new ecological state where a few vegetation species are dominant and other lesser species abundance shift depending on inter-annual variability of the site hydrology.

La Center Wetlands had a relative cover similar to reference conditions. Ruby Lake had a native relative cover similar to the reference conditions one year and three years' post-restoration but shifted to having less native cover year five post-restoration. Kandoll Farm has less native vegetation than its associated reference but shows a slight trend towards increased native vegetation on site. Wallooskee-Youngs and Flights End had less native vegetation than their reference site one-year post-restoration. Kandoll Farm, La Center Wetlands, Flights End, and Wallosskee-Youngs had less reed canarygrass than their reference sites post-restoration. Kandoll Farm had slightly more reed canarygrass than the reference site. Overall vegetation at sites is within or near the variability observed at reference sites for native cover and reed canarygrass cover.

Juvenile Salmonids

In April 2018, both wild and hatchery Chinook were captured at Kandoll Farm and Ruby Lake restoration sites. Additionally, chum, Coho, and steelhead were observed at Kandoll Farm. There was a greater number of non-native fish species observed at Ruby Lake than Kandoll Farm.

The PIT array at Horsetail Creek continued to detect upriver salmonid species. Hatchery Spring, Fall, and Summer Chinook were detected at the site. Hatchery Coho, steelhead and Northern Pike Minnow were also detected. All detections at the site showed the fish, except for the Northern Pike Minnow, occupied the area for less than one day.

Conclusion

The establishment of functional wetland processes and habitat that support juvenile salmonids is the goal of restoration efforts. Action effectiveness monitoring is tracking the ecological impact of restoration work and providing valuable information to manage restoration sites adaptively. Furthermore, AEM shows the rate at which physical processes and habitats recover after restoration activities vary. For example, physical processes like water surface elevation, water temperature, and habitat opportunity change immediately after the wetland is reconnected and have shown a positive trend when compared to reference conditions. Although physical processes change quickly, other aspects of the wetland recover more slowly. Changes in vegetation community occur over a longer time scale. The trend for sites five years post-restoration indicates sites have slightly less native cover and a similar amount of reed canarygrass as reference sites. Limited fish monitoring shows juvenile salmonids are present in restoration sites after tidal reconnection, but 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.

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Appendix

Wallooskee-Youngs

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

Types of Sampling in 2018

- Vegetation: Herbaceous cover (2 sample areas of 36 quadrats each, 72 quadrats total)
- Insect Fall out Traps: 4 fall out traps, 2 per vegetation sample area
- Benthic Macroinvertebrate Cores: 5 cores per vegetation sampling area
- Elevation: collected elevation at all vegetation quadrats

Vegetation Sampling Design

Two 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 18)

- Located in an 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
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

South Veg Sample area (Figure 18)

- 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
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

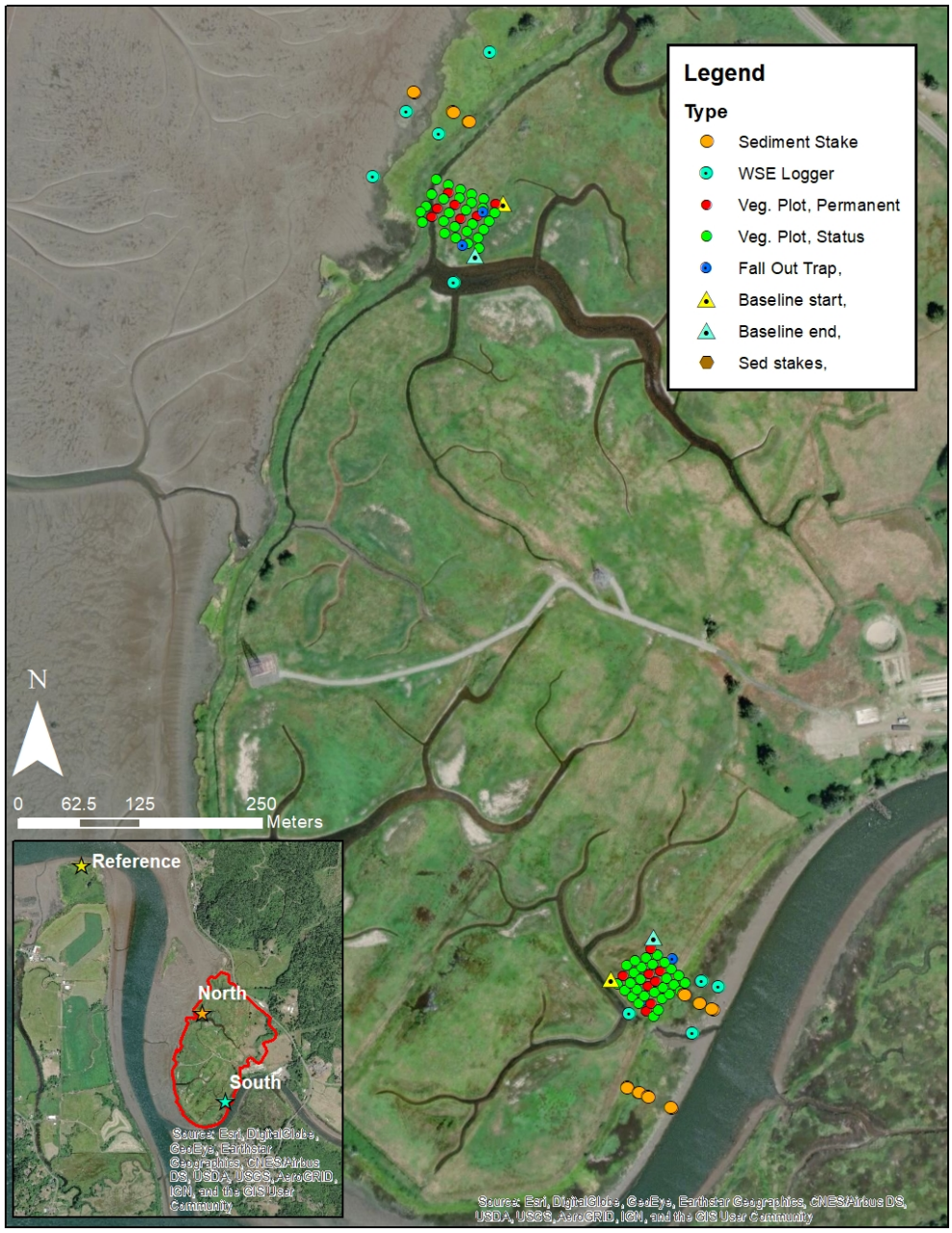

Figure 19. Wallosskee-Youngs sampling areas

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
Terrestrial macroinvertebrate fall out traps were placed in two separate locations. Two fall out traps were placed at the North vegetation sampling area. Two fall out traps were placed at the South sampling area.

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 2015

5 June

Types of Sampling in 2015

- Vegetation: Herbaceous cover (1 sample areas, 36 quadrats total)
- Insect Fall out Traps: 2 fall out traps
- Benthic Macroinvertebrate Cores: 5 cores per vegetation sampling area
- Sediment Accretion Rate: measured one previously installed pair of stakes
- Photo Points:
- Elevation: collected elevation at all vegetation quadrats

Vegetation Sampling Design

One 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 19)

- 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
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Figure 20. Wallooskee-Youngs Reference (Dagget Point) sampling areas

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
Two terrestrial macroinvertebrate fall out traps were placed in the vegetation sampling area.

Kandoll Farm

General Site Location
The site is located approximately 5.5 km up the Grays River, which empties into Grays Bay at rkm 37.

Ecosystem Type
Restoration site, formerly diked.

Types of Sampling in 2018

- *Vegetation*: Herbaceous cover (2 sample areas, 66 quadrats total) and point intercept of all species (2 lines, 97 meters (m) and 150 m long)

- *Insect Fallout Traps:* 2
- *Sediment Accretion Rate:* measured one previously installed pair of stakes
- Established new photo points at the following locations:
- Area A Veg Sampling area at 0 m on the baseline
- Area E Veg Sampling area at 0m on point intercept and
- Area E Veg Sampling area at 70 m on transect baseline
- *Elevation*: collected elevation at all vegetation quadrats and the end points of the point intercept lines

Vegetation Sampling Design

Status Sampling. This site had been previously monitored as part of the Phase 1 restoration. However, the previous vegetation sample areas were in a location that was completely modified by the Phase 2 restoration. Therefore, new vegetation sample areas were established in 2013 to capture the current condition and potential change that would occur with Phase 2. The status plots were re-randomized in 2016 to document the vegetation status.

Area A Veg Sample area (Figure 16)

- Located in area near the dike removal and the channel excavation; in the area where "mounds" will be created.60 m x 60 m, with 36 quadrat locations
- Baseline azimuth: 101° magnetic
- Transect azimuth: 11° magnetic
- Transect spacing: 10m, random start: 9
- Quadrat spacing: 10 m, random starts: 5, 7, 6, 6, 4, 9
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Area E Veg Sample area (Figure 16)

- Located in area that will be affected by the dike removal, but away from the channel excavation.
- 70 m x 60 m, with 36 quadrat locations
- Baseline azimuth: 101° magnetic
- Transect azimuth: 11° magnetic
- Transect spacing: 12m, random start: 5
- Quadrat spacing: 10 m, random starts: 0, 7, 6, 6, 7, 4
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Trends Sampling. Within the new vegetation sample areas, permanent quadrats that were established in 2013 were re-monitored. Also, two line intercept transects that were previously sampled in 2005, 2006, 2009, and 2013 were resampled as part of this effort. The transect specifications are as follows:
Area A Line Intercept -

- 97 m long, with 0 at the western end
- Azimuth 101° magnetic
- Sampled every meter

Area E Line Intercept -

- 150 m long, with 0 at the western end
- Azimuth 101° magnetic
- Sampled every meter

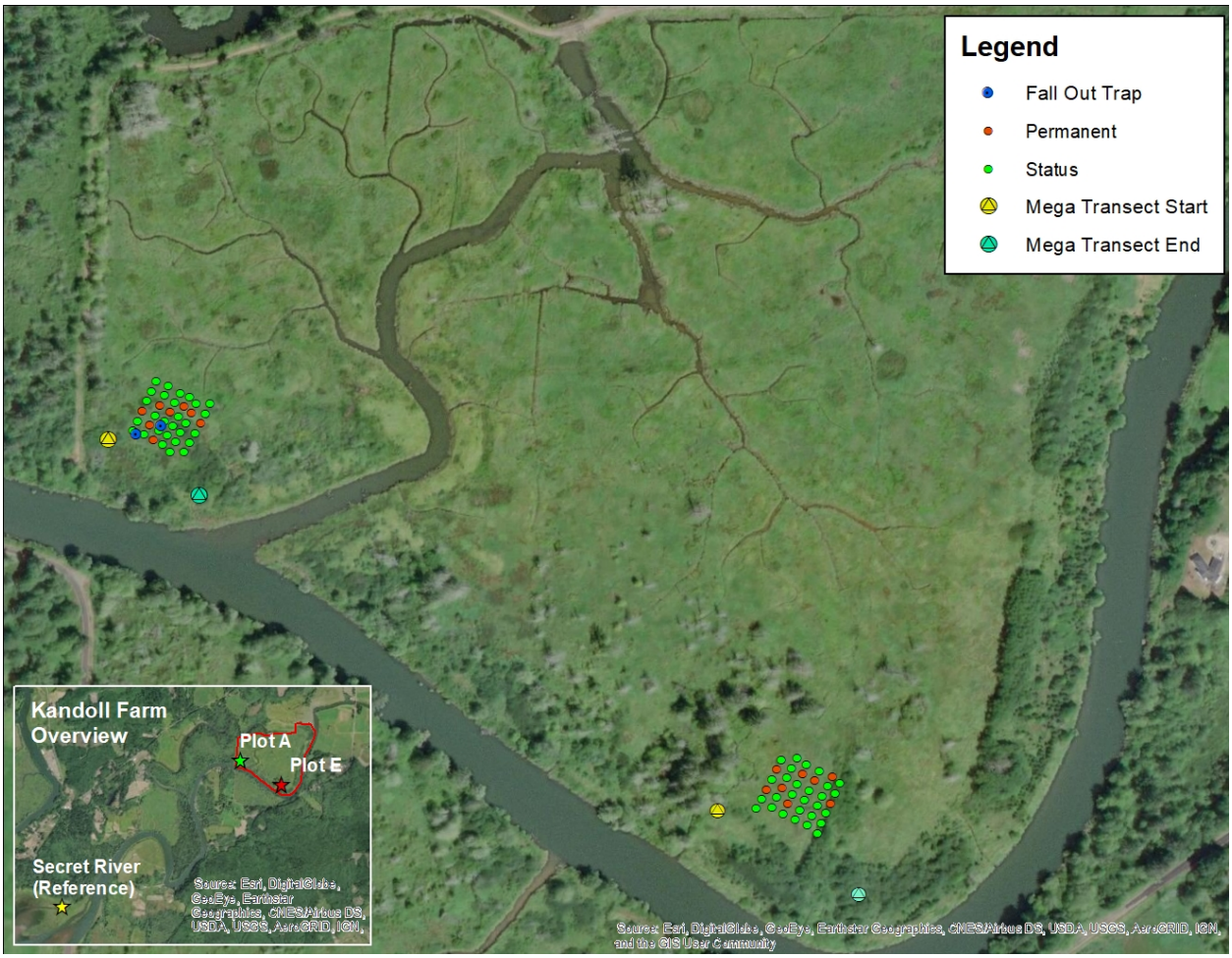

Figure 21. Kandoll Farm sampling areas

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).
- End stakes of the point intercept transects.

In addition, the gray 1 inch PVC sediment stakes that were placed at the site in Area B in 2005 were measured and left at the site.

Macroinvertebrate Sampling

Macroinvertebrate fall out traps were placed in two separate locations. Two fall out traps were placed in site A vegetation sampling area. The large constructed channel eliminated two additional traps locations. The lost trap locations were not redeployed.

Kandoll Farm Reference (Secret River)

General Site Location
The Secret River site is located at rkm 37 on the north side of Grays Bay.

Ecosystem Type
Reference site, tidal emergent wetland

Types of Sampling in 2018
Vegetation: Herbaceous cover (2 sample areas of 20 quadrats, 40 quadrats total)
Elevation: collected elevation at all vegetation quadrats
Vegetation Sampling Design - The sampling design implemented for the EMP was used for monitoring. This sampling design is similar to that used for the AEMR sampling except that the same quadrats are sampled from year to year to evaluate trends.

High Marsh Sample area (Figure 18)
Located in the higher elevation area of the marsh closer to the swamp area of the channel. Vegetation sample area covered a mixed Carex lyngbyei zone.

- 60 m x 50 m, with 20 quadrat locations
- Baseline azimuth: 263° magnetic
- Transect azimuth: 173° magnetic
- Transect spacing: 15m, random start: 7
- Quadrat spacing: 10 m, random starts: 3, 1, 7, 8

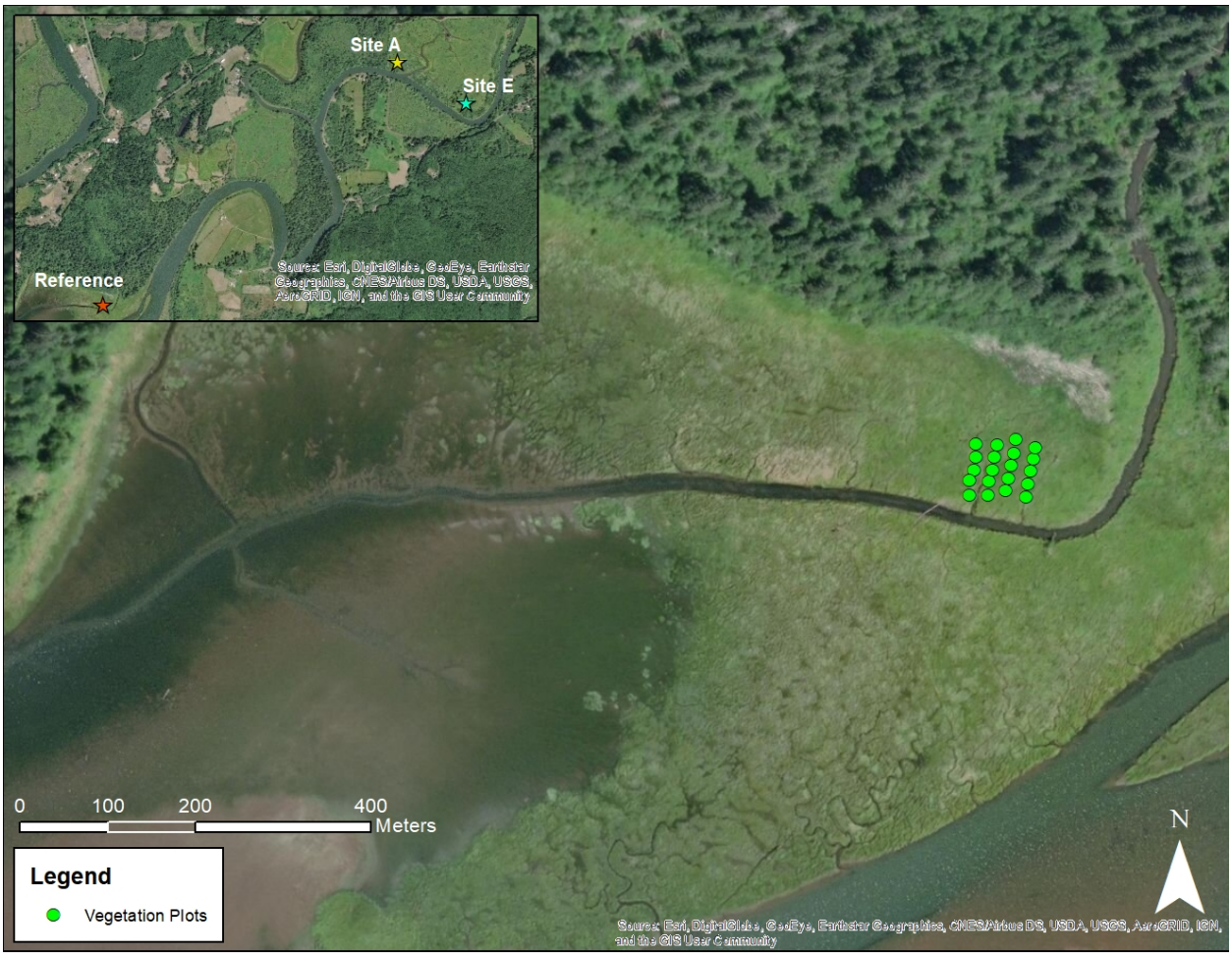

Figure 22. Kandoll Farm Reference (Secret River) sampling areas

Markers Left on Site
All marking stakes are white ¾ inch PVC. We marked the following locations:
End stakes of the baseline for the vegetation sample areas.
In addition, 6 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.

La Center Wetlands
General Site Location
The site is located approximately 7.5 Km on the East Fork Lewis River, which empties into the Lewis River rkm 8.5. The Lewis River enters the Columbia at rkm 140.

Ecosystem Type
Diked, planned restoration site

Types of Sampling in 2018
Vegetation: Herbaceous cover (2 sample areas of 36 quadrats each, 72 quadrats total)
Insect Fall out Traps: 6 fall out traps - 4 in the north sampling area, 2 in the south sampling area
Elevation: collected elevation at all vegetation quadrats

Vegetation Sampling Design

North Vegetation Sample Area (Figure 20)

Located on the north side of the East Fork Lewis River.

- 60m x 60m, with 36 quadrat location
- Baseline azimuth: 190° magnetic
- Transect azimuth: 100° magnetic
- Transect spacing: 10 m, random start: 4
- Quadrat spacing: 10m, random starts: 3, 8, 1, 9, 2, 5
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

South Vegetation Sample Area (Figure 20)

Located on the south side of the East Fork Lewis River.

- 60m x 60m, with 36 quadrat location
- Baseline azimuth: 39° magnetic
- Transect azimuth: 129° magnetic
- Transect spacing: 10 m, random start: 7
- Quadrat spacing: 10m, random starts: 5, 8, 7, 0, 6, 2
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

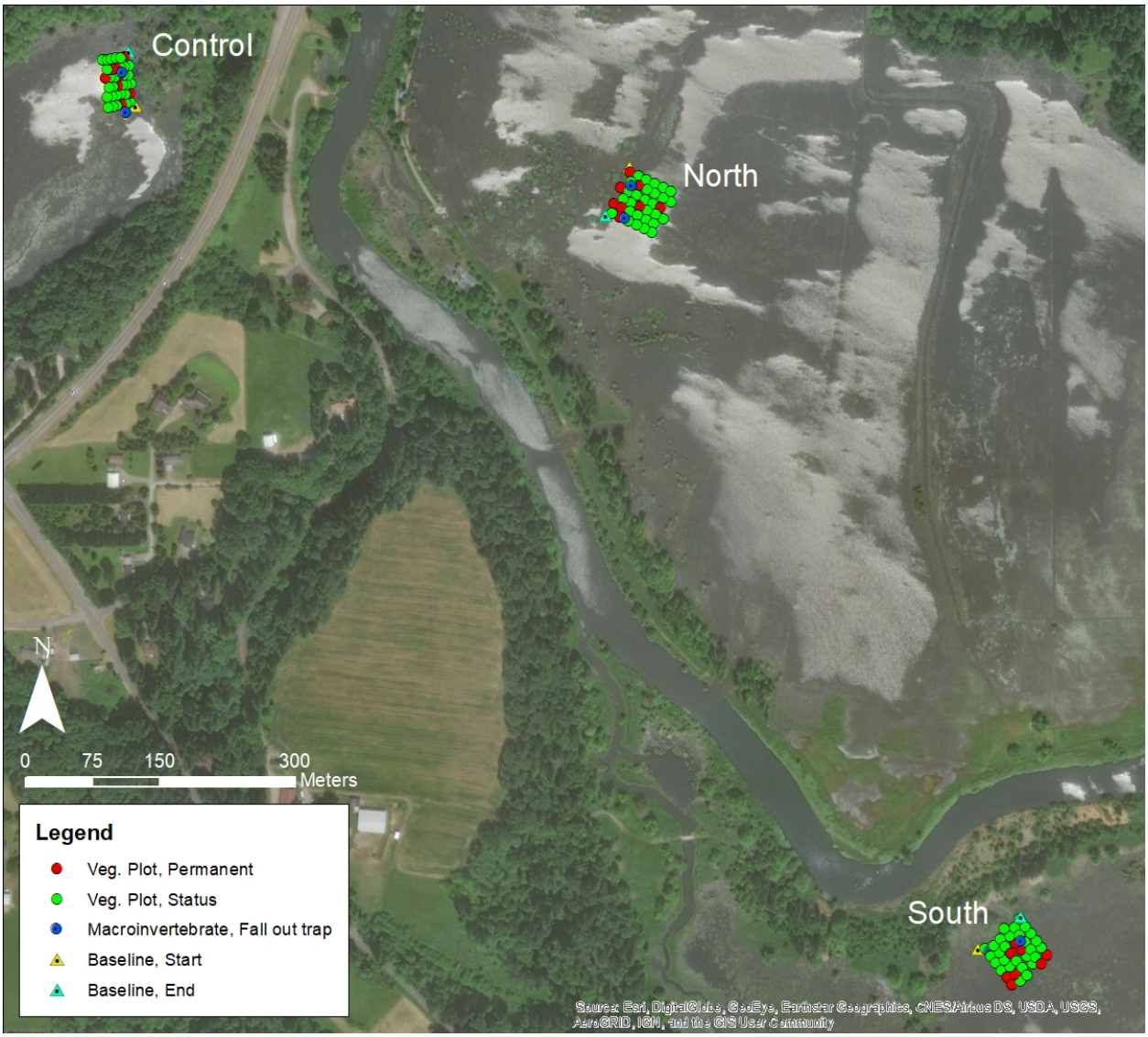

Figure 23. La Center Wetlands sampling areas

All marking stakes are white ¾ inch PVC. Marks left:
Start and End stakes at each of the transects in the vegetation sample area.

Macroinvertebrate Sampling
Terrestrial- Four macroinvertebrate fall out traps were placed in two separate locations within the north vegetation sampling area. Two macroinvertebrate fall out traps were placed in south vegetation sampling area.

La Center Reference

General Site Location
The site is located approximately 7.5 Km on the East Fork Lewis River, which empties into the Lewis River rkm 8.5. The Lewis River enters the Columbia at rkm 140.

Ecosystem Type
Emergent Wetland

Types of Sampling in 2018

- *Vegetation*: Herbaceous cover (1 sample area, 36 quadrats total)
- *Insect Fall out Traps:* 2
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
Veg Sample area (Figure 21)

- Located on the west side of East Fork Lewis
- 60 m x 30 m, with 36 quadrat locations
- Baseline azimuth: 334° magnetic
- Transect azimuth: 244° magnetic
- Transect spacing: 10 m, random start: 4
- Quadrat spacing: 5 m, random starts: 4, 3, 0, 2, 0, 4
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Markers Left on Site
All marking stakes are white ¾ inch PVC. Marks left:

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

Macroinvertebrate Sampling
Terrestrial- Two macroinvertebrate fall out traps were placed in two separate locations within the vegetation sampling area.

Sauvie Island North Unit Phase 1

General Site Location
North End of Sauvie Island on the Oregon Side of the River at rkm 144.

Ecosystem Type
Post-restoration, emergent tidal wetland

Types of Sampling in 2018

- *Vegetation*: Herbaceous cover (2 sample areas of 36 quadrats, 72 quadrats total)
- *Insect Fallout Traps:* 4 traps
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
North Veg Sample area (Figure 19)

- Located at north end of the southern part of the site. Veg sample area spanned elevation gradient which contained only reed canarygrass and would be scraped down to an elevation to prevent recolonization of reed canarygrass.
- 70 m x 60 m, with 36 quadrat locations
- Baseline azimuth: 180° magnetic Transect azimuth: 270° magnetic
- Transect spacing: 11m, random start: 2

- Quadrat spacing: 10 m, random starts: 9, 1, 5, 2, 3, 5
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

South Veg Sample area (Figure 19)

- Located at the southern end of the southern part of the site. Veg sample area spanned elevation gradient from lowest elevation SAV and bare mud through low marsh up to an elevation dominated by reed canarygrass.
- 70 m x 80 m, with 36 quadrat locations
- Baseline azimuth: 191° magnetic
- Transect azimuth: 281° magnetic
- Transect spacing: 11m, random start: 3
- Quadrat spacing: 13 m, random starts: 0, 10, 1, 2, 7, 8
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

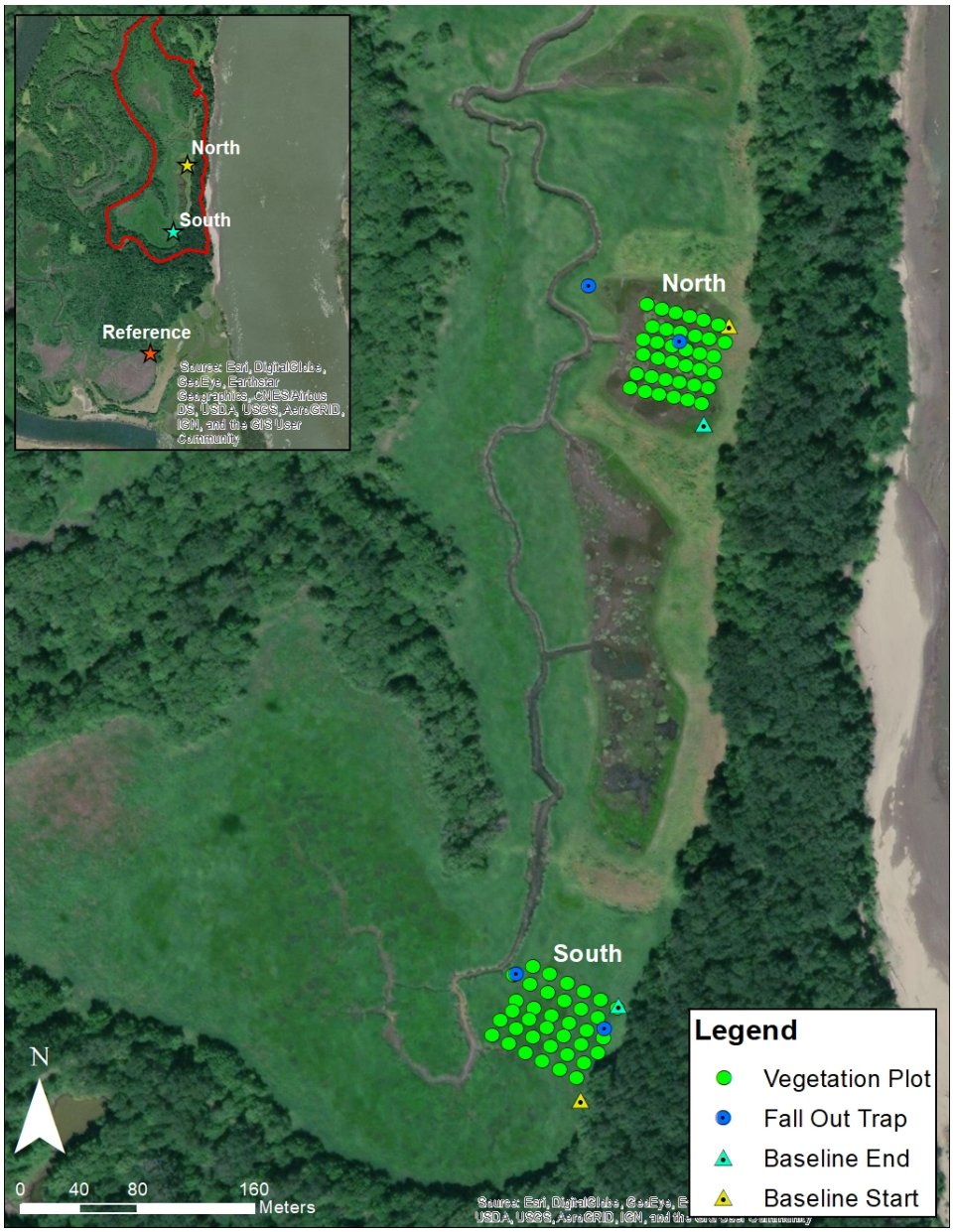

Figure 24. North Unit Sauvie Island Phase 1 sampling areas

Markers Left on Site

All marking stakes are white ¾ inch PVC with orange duct tape or flagging at the top were left on site from previous year's marking. Marks left:

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

Macroinvertebrate Sampling

Insect fall out traps were placed in the same locations as 2013. Two traps each were placed at the North and South vegetation sampling areas to characterize the macroinvertebrate species richness and diversity.

Sauvie Island North Unit Reference (Cunningham Lake)

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"

Types of Sampling in 2018
See map below for sampling locations (Figure 19).

- *Vegetation*: Herbaceous cover (70 quadrats total)
- *Insect Fall out Traps:* 4
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
Veg Sample area (Figure 19)

- 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

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.

Macroinvertebrate Sampling
Four macroinvertebrate fall out traps were placed in the vegetation sampling area.

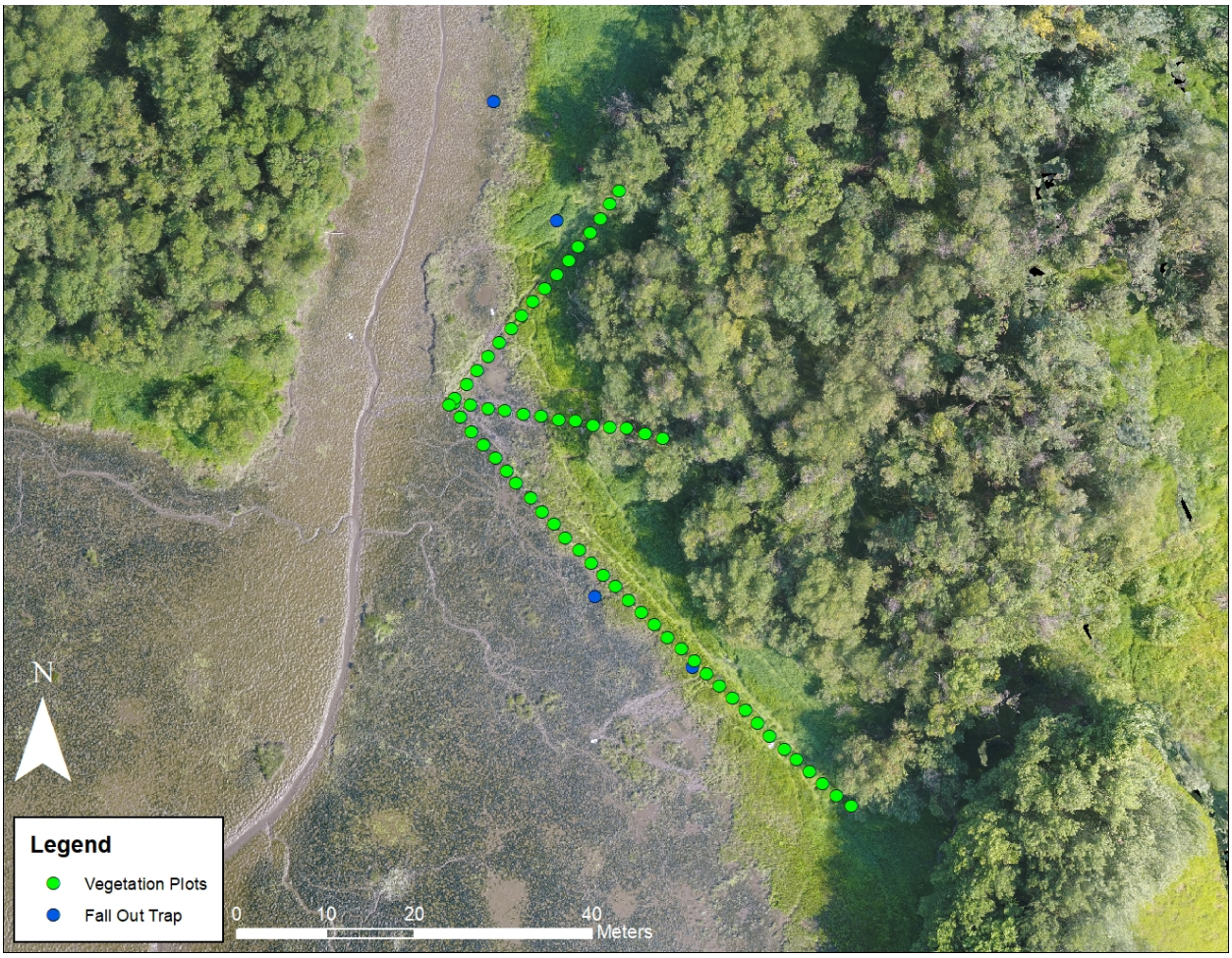

Figure 25. Sauvie Island North Unit Reference (Cunningham Lake) sampling area

Flights End

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

Ecosystem Type
Post-restoration, emergent tidal wetland

Types of Sampling in 2018

- *Vegetation*: Herbaceous cover (3 sample transects of 20 quadrats, 60 quadrats total)
- *Elevation*: collected elevation at all vegetation quadrats

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

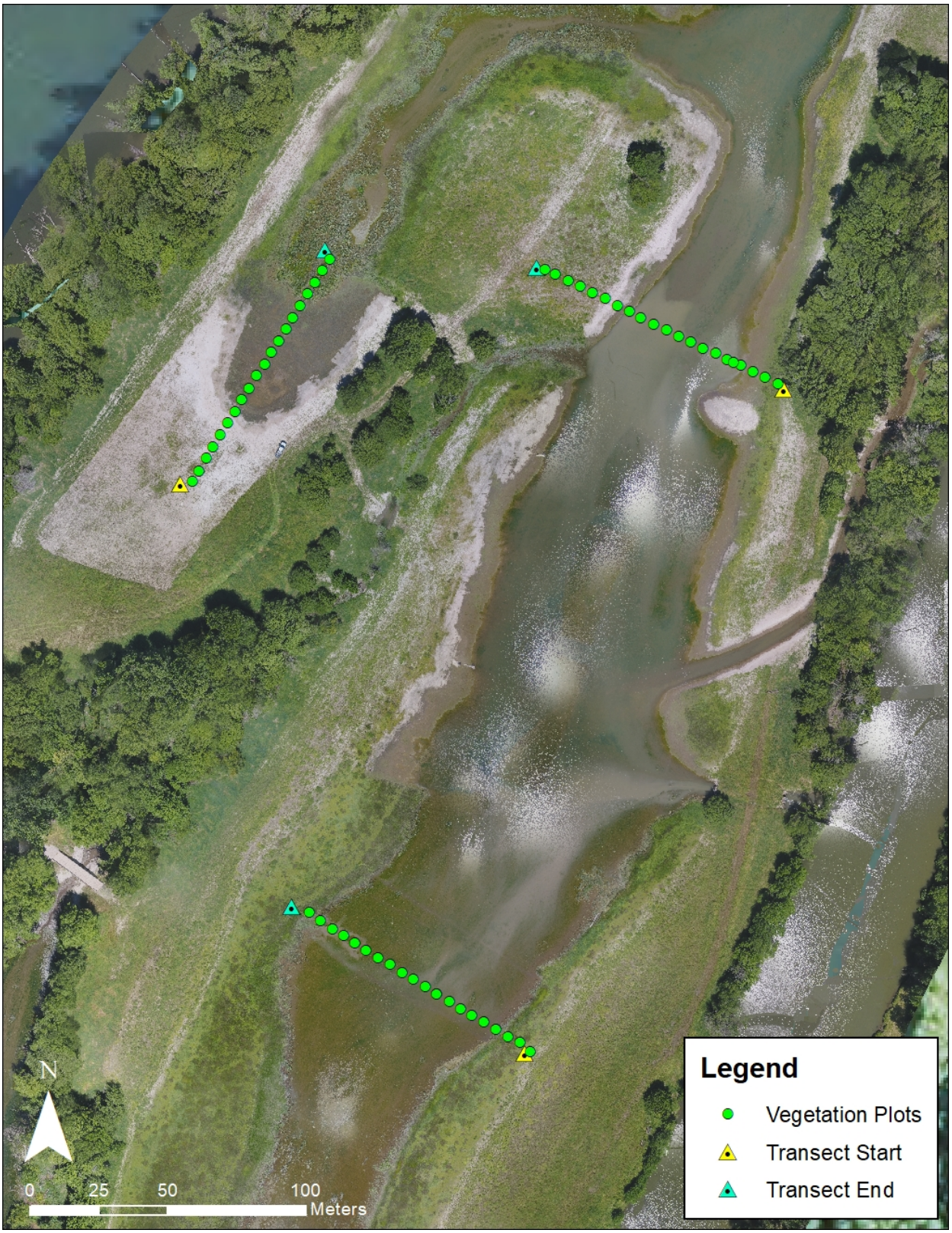

Figure 26. North Unit Sauvie Island Flights End sampling areas