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 for Year 11 (October 2014 to September 2015)

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Abbreviations and Acronyms

AEM	Action Effectiveness Monitoring
BPA	Bonneville Power Administration
CRD	Columbia River Datum
CREST	Columbia River Estuary Taskforce
EMP	Ecosystem Monitoring Program
ESA	Endangered Species Act
NMS	nonmetric multidimensional scaling
PIT tag	passive integrated transponder tag
RPA	Reasonable and prudent alternative
USACE	U.S. Army Corps of Engineers

Abstract

The goals of the Lower Columbia Estuary Partnership's Action Effectiveness Monitoring (AEM) program are to determine the impact of habitat restoration actions on salmon recovery at the site and landscape scale, identify how restoration techniques address limiting factors for juvenile salmonids, and improve restoration techniques to maximize the effect 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. 2014), employs standardized monitoring protocols, and coordinates between stakeholders to collect and share AEM data. AEM is conducted at one of three levels of intensity to ensure all restoration sites receive some monitoring. AEM levels consist of Standard (Level 3), Extensive (Level 2), and Intensive (Level 1). In 2015 the objectives of the AEM extensive monitoring examined changes in vegetation composition and prey availability at the site and landscape scales related to restoration actions.

Seventeen restoration sites received AEM in the lower Columbia River and Estuary in 2015. Using the prioritization process outlined in the AEM Programmatic Plan, five restoration sites were selected for additional Extensive Level 2 monitoring in addition to receiving Standard Level 3 monitoring. Five associated reference sites were selected to establish a Before After Reference Impact monitoring design. Twelve restoration sites received Standard Level 3 monitoring. All monitoring was conducted following standardized protocols outlined in Roegner et al. (2009). 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.

Emergent wetland vegetation was evaluated at the site scale and at a landscape scale using previously defined emergent wetland vegetation zones (1-5 following the estuarine tidal freshwater gradient; 1 being located closest to the river mouth and 5 being closest to Bonneville Dam). Vegetation data at all sites were strongly correlated with river kilometer and moderately correlated with average marsh elevation, species richness, species diversity, bare ground, and litter. Post-restoration sites had higher species diversity compared to pre-restoration and reference sites. Vegetation at pre-restoration and post-restoration sites was significantly different. Also, vegetation at post-restoration and reference sites was significantly different. At individual restoration sites, vegetation similarity differed pre- and post-restoration depending on restoration actions. Restoration sites with intensive marsh elevation lowering were dissimilar pre- and post-restoration due to removal of dominant reed canarygrass (*Phalaris arundinacea*). Restoration actions focused on tidal reconnection without intensively lowering of marsh elevations were vegetatively similar pre- and post-restoration.

Salmonid prey was evaluated at the site level. Benthic macroinvertebrates were collected at pre-restoration sites and species richness decreased across time at pre-restoration sites and increased during the same period of time at reference sites. Species diversity at pre-restoration sties decreased from May to June. At reference sites, species diversity was higher than pre-restoration sites and did not vary greatly between months. Terrestrial macroinvertebrate

species richness when compared to reference sites was similar pre- and post-restoration condition.

There is evidence upriver salmonid stocks are using Columbia River gorge sites. Tagged fish detected at Horsetail Creek restoration site represented upriver hatchery and wild stocks from Spring, Fall, and Winter runs. Juvenile Chinook (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*) were found to transit the Horsetail Creek culvert in spring. Identified summer detections included hatchery summer steelhead and hatchery Fall Chinook. Species detection at the Horsetail site was consistent with seasonal occurrence data for Chinook (*Oncorhynchus tshawytscha*) and other salmonid species observed at other nearby reference study sites.

Initial analysis indicates physical and ecological changes at restoration sites vary based on the intensity of impact a particular area receives. Restored sites will need to develop to a more ecologically stable state before the impact of restoration actions on juvenile salmonid habitat and prey can be accurately assessed. Long-term monitoring data from the Ecosystem Monitoring Program (EMP) will continue to be necessary to put the results from restoration site monitoring in ecological context. As the number of post-restoration sites monitored under the programmatic plan for AEM increases and the length of time those sites are in a post-restoration condition the resulting dataset will improve our ability to elucidate ecological changes at the site and landscape scale.

Introduction

The Action Effectiveness Monitoring (AEM) Program, part of the Columbia Estuary Ecosystem Restoration Program (CEERP), provides the Bonneville Power Administration (BPA), 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 impact of restoration actions on salmon recovery 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 were 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 effectiveness of hydrologic reconnection restoration. This monitoring is done at all restoration sites within the CEERP.

Level 2 – includes the Level 3 metrics and also 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 also more "intensive" monitoring of realized function at restoration sites, such as fish use, genetics, and diet. Since this 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. 2014), 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

In 2015, the AEM program had specific objectives to quantify ecological changes related to marsh elevation lowering on the control of reed canarygrass, changes to the production of salmonid prey items related to hydrologic re-connection, and the similarity of vegetation at the site and ecosystem scale. Extensive action effectiveness monitoring was used to evaluate changes to habitat site conditions pre- and post-restoration for vegetation composition and salmonid prey items. To incorporate larger spatial scales to examine ecological changes at restoration and reference sites, the Estuary Partnership's AEM Program incorporated data from our Ecosystem Monitoring Program (EMP). The EMP implements monitoring activities to characterize status and trends of relatively undisturbed emergent wetlands and assess juvenile salmonid usage of those habitats.

Methods

Site Selection

Seventeen restoration sites received action effectiveness monitoring in 2015 (Table 1 and Table 2). Five restoration sites were selected for Level 2 monitoring (Table 1) using the prioritization criteria outlined in Johnson et al. (2014). Five 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). Twelve restoration sites were scheduled for Level 3 monitoring. One Ecosystem Monitoring Program site (Campbell Slough) was included in the vegetation analysis for comparison due to its proximity within the same emergent vegetation zone.

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 prior to the establishment of AEM prioritization process (Figure 2).

Table 1. Restoration sites and associated reference sites selected for Level 2 monitoring in 2014

Restoration Site	**Location**	**Pre-Restoration Monitoring Date**	**Post-Restoration Monitoring Date**	**Reference Site and Monitoring Dates**
Wallooskee-Youngs	Rkm 19 and approximately 7 km up the Youngs River	3-4 June 2015		Dagget Point 5 June 2015
Steamboat Slough	Rkm 56	18-19 July 2013	15-16 June 2015	Welch Island 23 July 2013 31 July 2015
Dibblee Slough	Rkm 103		6-7 August 2013 17-18 July 2015	Dibblee Reference 8 August 2013 18 June 2015
La Center Wetlands	Rkm 140 and approximately 12 Km up the Lewis River	6-7 July 2015		La Center Control 7 July 2015
Sauvie Island North Unit Phase 2 (Millionaire and Deep Widgeon Lakes)	Rkm 143	22 August 2013 16-17 July 2014	13-15 July 2015	Cunningham Lake 29 July 2013 18 July 2014 28 July 2015 Campbell Slough 27 July 2013 18 July 2014 29 July 2015

Table 2. Restoration sites receiving Level 3 monitoring in 2015

Restoration Site	Location	Pre-Restoration Monitoring Year	Post-Restoration Monitoring Year
Kandoll Farm	Rkm 37	2013	2014, 2015
Karlson Island	Rkm 42	2014	2015
Wallacut Slough	Rkm 57	2014, 2015	
Lower Elochoman	Rkm 60	2015	
Elochoman	Rkm 60	2015	
Kerry Island	Rkm 72	2015	
Batwater	Rkm 91	2015	
North Unit Phase 3	Rkm 145	2015	
Buckmire Phase 1	Rkm 158	2015	
Thousand Acres	Rkm 200	2014	2015
Multnomah-Wahkeena Phase 1	Rkm 218	2014	2015
Horsetail Creek	Rkm 223	2010	2014, 2015

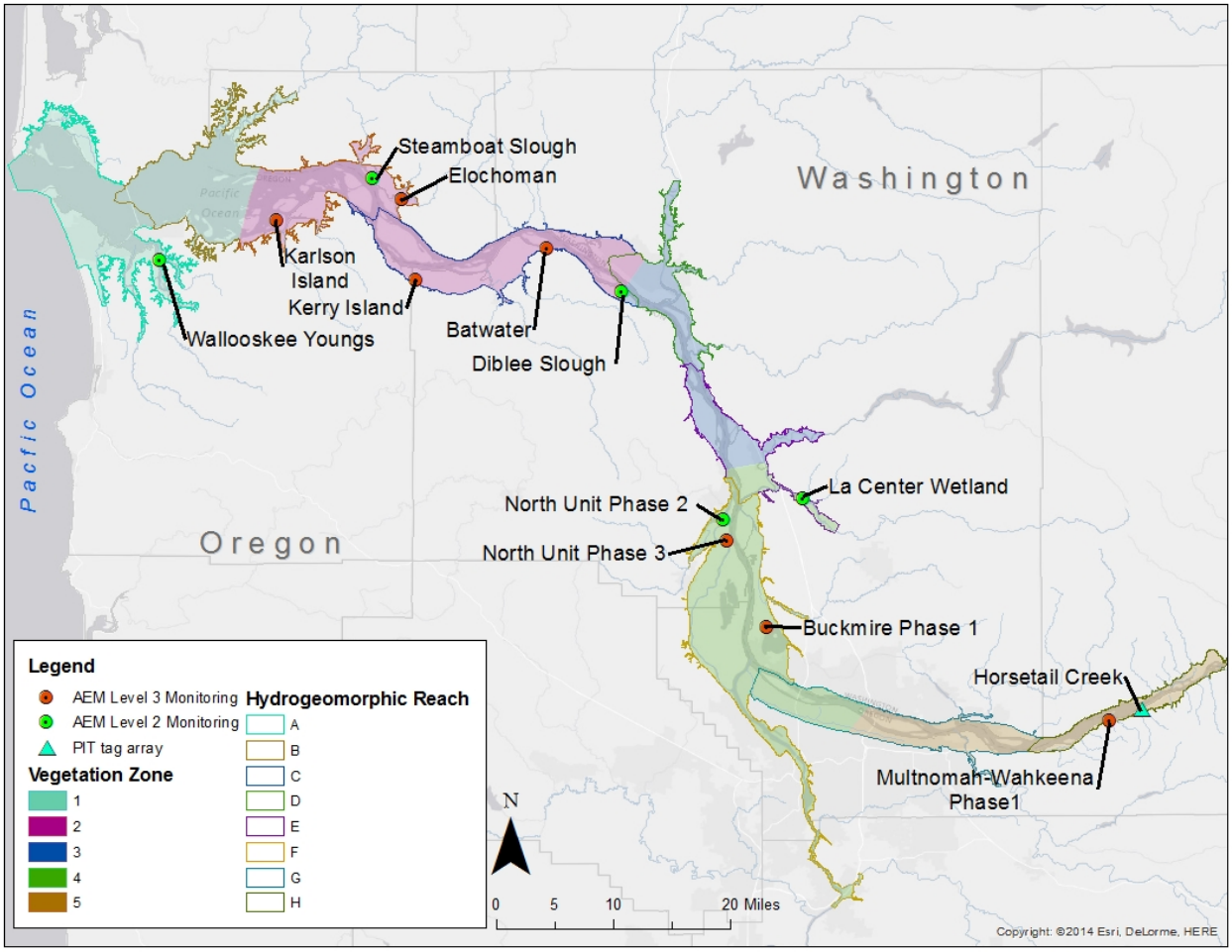

Figure 1. 2015 Level 2 and Level 3 AEM sites

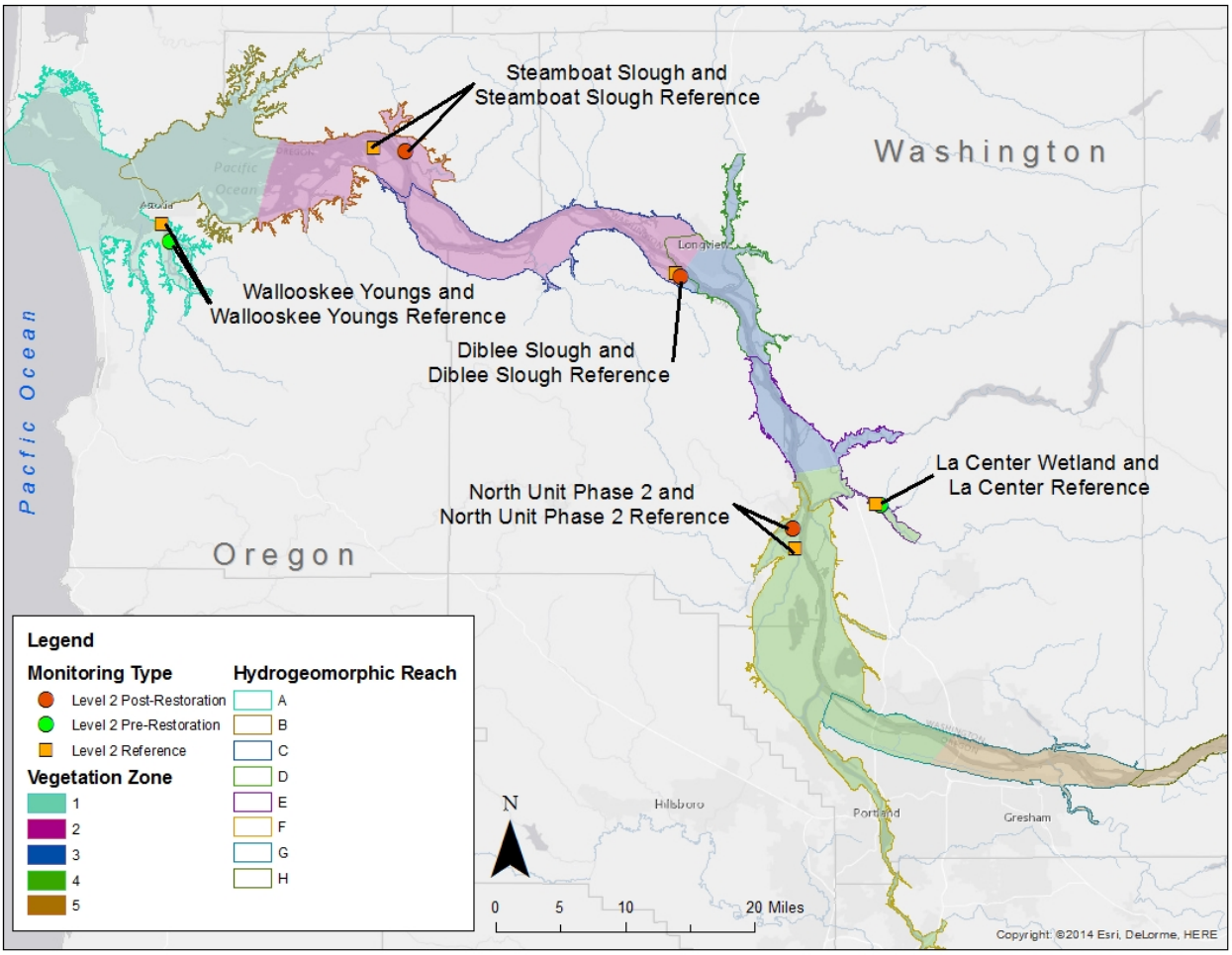

Figure 2. 2014 Level 2 AEM pre-restoration, post restoration, and reference site monitoring locations.

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.

Vegetation cover and composition (Method ID: 822) assessed changes to habitat structure related to restoration actions. Vegetation cover and composition is an indicator of the production of organic matter and the detritus is the base of the food web for many species in the lower Columbia River and estuary (Borde et al. 2010, Maier and Simenstad 2009). Elevation (Method ID: 818) of vegetation plots were recorded to track the effectiveness of lowering marsh elevations (soil scrape down) to control invasive vegetation and promote native plant species. 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. Photo points were established (Method ID: 820) near the vegetation sampling area. 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.

To assess the capacity of a restoration site to provide prey resources for juvenile salmonids, terrestrial and benthic macroinvertebrate were collected. Fall out traps were deployed once for a 48 hour period to sample insects that fall into the water from the aerial environment. Terrestrial macroinvertebrates were collected following methods outlined in "Terrestrial Invertebrates Standard Operating Procedures" (USGS and Nisqually Indian Tribe 2012). At each restoration and reference site terrestrial macroinvertebrates were collected, four macroinvertebrate fall out traps were installed in proximity to each vegetation sampling area to capture species assemblage of invertebrates. Benthic macroinvertebrates were collected following methods outlined in "Benthic Invertebrate Standard Operating Procedures" (USGS 2012). At pre-restoration sites, five sediment cores were collected at each restoration site and associated reference once a month from May to July to track changes in the benthic invertebrate community related to restoration actions.

Fish Monitoring

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

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 rather than hydrogeomorphic reach. Vegetation data collected through the Ecosystem Monitoring Program was included for applicable years and vegetation zones. The inclusion of long term status data establishes a baseline which describes natural variation and puts into context changes related to restoration activities.

PC-ORD version 6.20 was used to conduct non-parametric statistical analysis (McCune and Mefford 2011). Prior to analysis, vegetation data was 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). One weak outlier was detected in the initial percent cover data summary. The vegetation data was arcsine square root transformed to eliminate unequal variance and improve normality (Sokal and Rohlf 1995). Two weak outliers were detected after the data transformation. The outliers were retained in the analysis because the influence on the overall analysis is minimal. The vegetation matrix was constructed of 34 sample units and 147 vegetation species reported as average percent cover (Table 3). The environmental matrix consisted of 34 sample units and 11 environmental characteristics - species richness, Shannon diversity, river Km, average wetland elevation, azimuth of site, average percent cover of bare ground, average percent cover of detritus, average percent cover of drift wrack, average percent cover of litter, average percent cover of large wood debris, average percent cover of standing dead, vegetation zone with site condition, and year.

Table 3. Sites and years included in vegetation analysis

	Pre-Restoration	Post-Restoration	Reference
Vegetation Zone 1			
Wallooskee-Youngs North	2015		
Wallooskee-Youngs South	2015		
Dagget Point			2015
Vegetation Zone 2			
Dibblee Slough Channel		2013, 2015	
Dibblee Slough Pond		2013, 2015	
Dibblee Slough Reference		2013, 2015	
Vegetation Zone 4			
La Center North	2015		
La Center South	2015		
La Center Control			2015
North Unit Sauvie Island Phase 2 Deep Widgeon North	2014	2015	
North Unit Sauvie Island Phase 2 Deep Widgeon South	2013, 2014	2015	
North Unit Sauvie Island Phase 2 Millionaire North	2014	2015	
North Unit Sauvie Island Phase 2 Millionaire South	2013, 2014	2015	
Cunningham Lake			2013, 2014, 2015
Campbell Slough			2013, 2014, 2015

Non metric 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. ANOSIM (PRIMERv6, Clarke and Gorley 2006) was used to evaluate if significant differences exist between vegetation zones and restoration condition.

Species Richness and Species Diversity

For site scale analysis species richness and Shannon diversity index (species diversity) were calculated for both vegetation and terrestrial macroinvertebrates. Species richness and species diversity were used to track inter-annual variability and changes related to restoration actions. Species Richness is the number of species represented in the sampled ecological community. Shannon diversity index (Equation 1, Shannon and Wiener 1949) represents abundance and evenness of species present in a sampled ecological community.

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).

Results

Vegetation

Non-metric multidimensional scaling

A NMS ordination with a three dimensional solution of plots in species space was used (Final stress= 11.98, final stability ≤.000001, number of iterations= 75). The three axis solution explained 85% of the variation in the data. The solution was rotated so river km (Rkm) was parallel with axis one, average marsh elevation (m-CRD), species richness (SR), species diversity (H), litter, and bare ground (BG) were parallel with axis three (Figure 3). Axis one shows vegetation has a strong positive correlation with river Km (r =.74). Axis three shows a positive

moderate correlation with species richness (r =.66), species diversity (r =.67), bare ground (r=.55), litter (r=.48), and negative moderate correlation with average marsh elevation (r=-.58) (Figure 3).

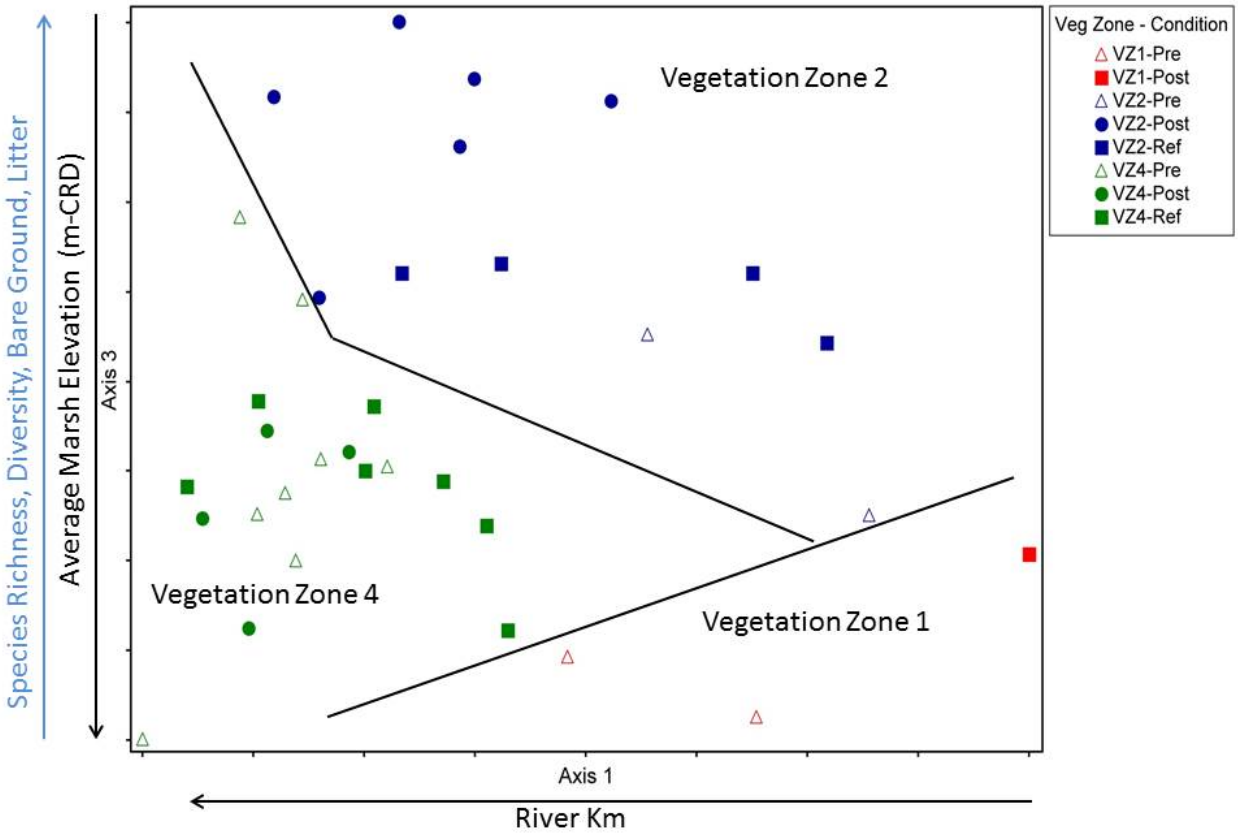

Figure 3. NMS ordination of sample units in species space. Axis 1 is correlated with river Km. Axis 3 is correlated with Average Marsh Elevation, Species Richness, Species Diversity, Bare Ground, and Litter. Different vegetation zones are demarcated.

Similarity and Species Diversity

Vegetation zones one and two were found to be nearly significantly different (ANOSIM; p=.067). Vegetation zone four was found to be significantly different from vegetation zones one and two respectively (ANOSIM; p=.003 and p=.001).

Based on vegetation cover and composition at all sites, pre-restoration site condition was found to be significantly different from reference conditions (ANOSIM; p=.029). Pre- and post-restoration vegetation did not differ significantly (ANOSIM; p=.102). Post-restoration and reference were found to differ significantly based on vegetation (ANOSIM; p=.001).

When species richness, evenness, species diversity, and marsh elevation is averaged across all sites by condition post-restoration sites have the highest species richness and species diversity with the lowest average marsh elevation. Reference sites have similar species diversity and high

species richness compared to pre-restoration. Pre-restoration sites exhibit the lowest average species richness although having a similar average marsh elevation compared to reference sites (Table 4).

Table 4. Average species richness, evenness, and species diversity for all pre-restoration, post-restoration, and reference sites

Site Condition	Species Richness	Evenness	Species Diversity	Average Marsh Elevation (m-CRD)
Pre-Restoration	23	0.64	1.96	1.51
Post-Restoration	37	0.63	2.25	1.35
Reference	33	0.58	1.97	1.50

Vegetation Zone One

The Wallooskee-Youngs and associated reference sites were sampled (n=3) in vegetation zone one in 2015. Pre-restoration, the Wallooskee-Youngs site had a 60% similarity between the two vegetation sampling areas and had less than a 17% similarity with the reference site at Dagget Point (DAG, Table 5).

Table 5. Similarity index for restoration and reference sites in vegetation zone one. Yellow highlights represent 60-69% similarity

Site	WYN	DAG
WYS	0.60	0.12
WYN		0.17

WYN = Wallooskee-Youngs North
WYS = Wallooskee-Youngs South
DAG = Dagget Point

Wallooskee-Youngs

Pre-restoration, species richness was higher at the Wallooskee-Youngs North (WYN) sampling site than Wallooskee-Youngs South (WYS) site (Table 8). The North site has a greater percent cover of invasive reed canarygrass, while the South site had a greater percent cover of invasive common velvet grass (Figure 4). The North sampling site had a lower marsh elevation than the South sampling site. (Table 6, Figure 4). The dominant vegetation species at the reference site was Lyngby's Sedge *(Carex lyngbyei*; Figure 4).

Table 6. Species richness and species diversity pre-restoration condition at Wallooskee-Youngs

	Condition	Species Richness	Species Diversity	Average marsh elevation (m-CRD)
Wallooskee-Youngs South	Pre-restoration	24	2.42	2.45
Wallooskee-Youngs North	Pre-restoration	37	2.20	1.63
Dagget Point	Pre-restoration	28	1.49	2.19

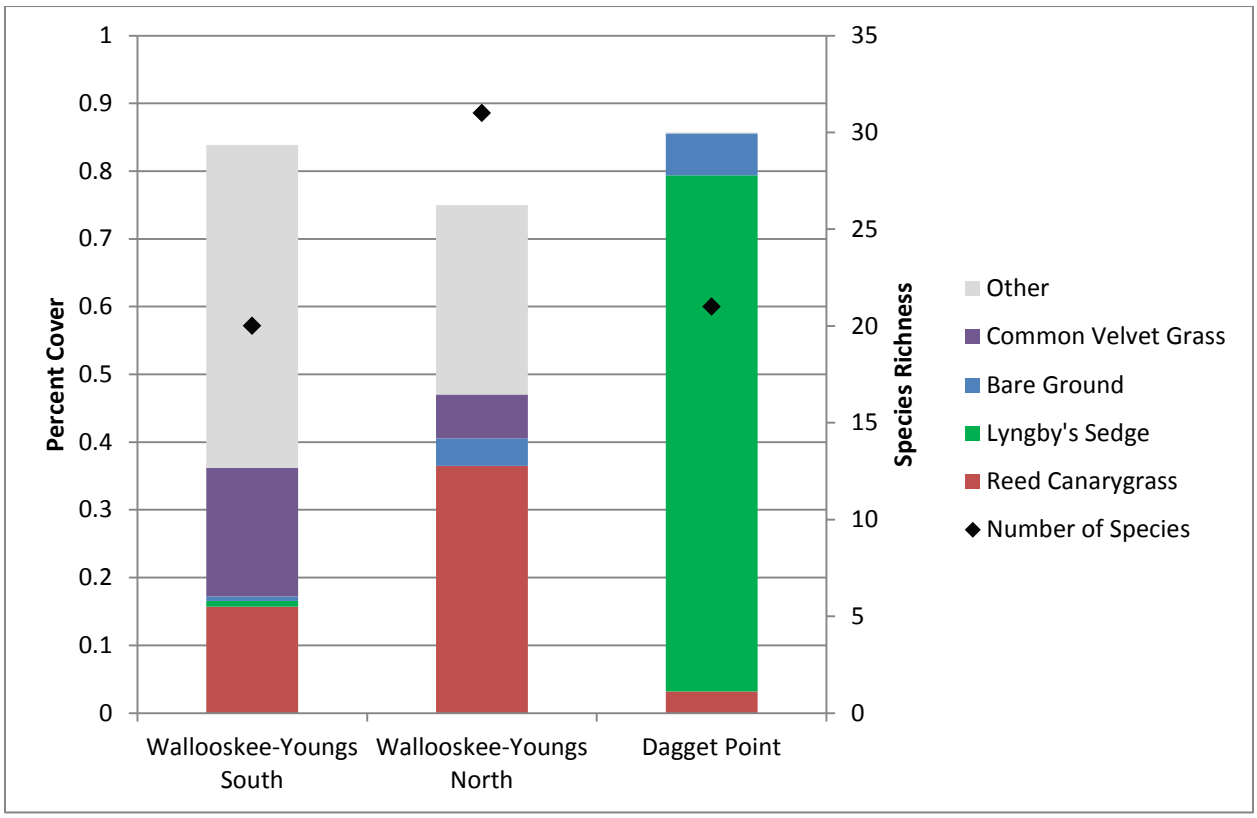

Figure 4. Vegetation cover and composition for Wallooskee-Youngs and Dagget Point Reference site

Vegetation Zone Two

When all years were examined in vegetation zone two, 2 sites (n=66) were found to have a similarity of greater than 60%. The expected reference similarity range for vegetation zone two is between 75% and 84% (Hanson et al. 2016). Dibblee Slough reference (DR) site had a 61% similarity between 2013 and 2015. At the Welch Island reference (WI) site there was a 75% similarity between 2013 and 2015 (Table 7).

Table 7. Similarity index for restoration and reference sites in vegetation zone two. Yellow highlights represent 60-69% similarity and green highlights represent >70% similarity

	SSW-15	DR-15	DibW-15	DibE-15	WI-15	SSE-13	SSW-13	DibW-13	DibE-13	DR-13	WI-13
SSE-15	0.47	0.44	0.32	0.37	0.17	0.44	0.13	0.30	0.44	0.31	0.13
SSW-15		0.26	0.24	0.28	0.10	0.27	0.11	0.32	0.32	0.20	0.08
DR-15			0.33	0.33	0.34	0.27	0.11	0.28	0.32	0.61	0.27
DibW-15				0.46	0.27	0.29	0.20	0.45	0.35	0.36	0.26
DibE-15					0.29	0.32	0.13	0.28	0.51	0.39	0.23
WI-15						0.23	0.11	0.19	0.24	0.46	0.75
SSE-13							0.40	0.23	0.41	0.27	0.18
SSW-13								0.08	0.21	0.10	0.13
DibW-13									0.39	0.34	0.18
DibE-13										0.37	0.16
DR-13											0.36

SSW – Steamboat Slough West
SSE – Steamboat Slough East
WI – Welch Island (Steamboat Slough Reference)
DibW – Dibblee Slough West
DibE – Dibblee Slough East
DR – Dibblee Reference

Steamboat Slough

The Steamboat Slough site has two vegetation sampling areas (Figure 15). The vegetation similarity at the west (SSW) sampling area, located in a soil scrape down, between pre- and post-condition was 11% (Table 7). The vegetation similarity in the east sampling area at Steamboat Slough (SSE), where minimal soil scrape down occurred, was 44% between pre- and post-restoration (Table 7). Post-restoration, the similarity of Steamboat Slough to the Welch Island reference site ranged from 27% at the west sampling area to 29% at the east sampling area for vegetation composition (Table 7).

At Steamboat Slough East, species richness decreased between pre- and post-restoration condition, while species diversity remained relatively the same (Table 8). The marsh elevation decreased .43 m-CRD from pre- to post-restoration condition. There was a slight reduction in reed canarygrass and an increase in spike rush (*Eleocharis palustris*) and bare ground (Figure 5). The Steamboat Slough west site increased in species richness and diversity between 2013 and 2015. The average marsh elevation decreased 1.13 m-CRD due to soil scrape down and channel construction. The vegetation community changed from tall fescue (*Schedonorus arundinaceus*) and reed canarygrass to bare ground (Figure 5). The Steamboat Slough reference site at Welch Island slightly increased in species richness, species diversity, and average marsh elevation between 2013 and 2015 (Table 8).

Table 8. Species richness and species diversity pre- and post-restoration condition at Steamboat Slough

Site	Condition	Year	SR	H	m-CRD
Steamboat Slough East	Pre-restoration	2013	41	2.788	1.11
	Post-restoration	2015	30	2.294	0.68
Steamboat Slough West	Pre-restoration	2013	13	1.662	1.61
	Post-restoration	2015	38	2.446	0.48
Welch Island	Pre-restoration	2013	43	2.426	1.58
	Post-restoration	2015	49	2.649	1.73

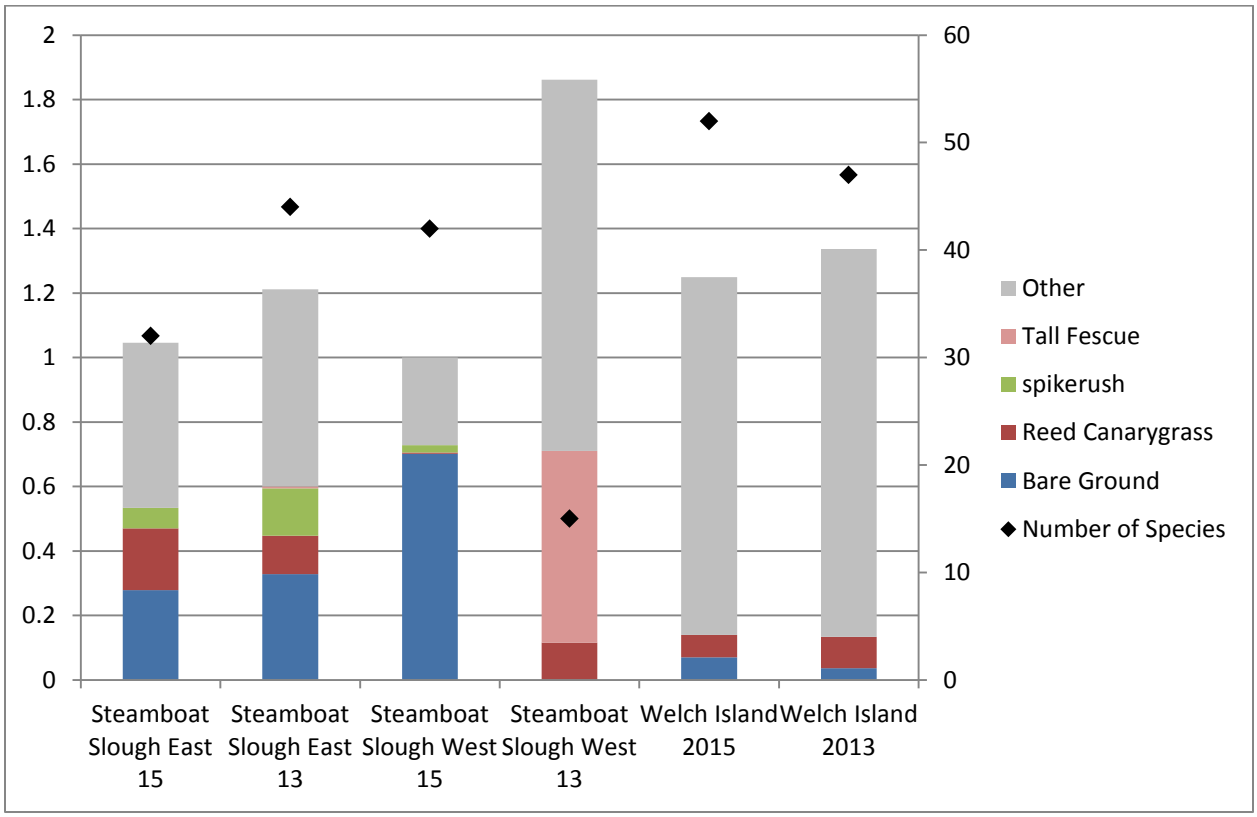

Figure 5. Vegetation cover and composition pre- and post-restoration at Steamboat Slough and Welch Island reference site

Dibblee Slough

The Dibblee Slough site has two vegetation areas sampled at one year and three years post restoration (Figure 16). In the vegetation sampling areas, a subset of plots were randomly assigned to be permanent plots sampled each time the area was visited in order to establish

trends. The remaining plots are randomly re-distributed across the sampling area and represent the vegetation status of the site.

Status

In 2013, the Dibblee Channel (DibW) had a vegetation similarity of 39% when compared to the Dibblee Pond (DibE). The similarity between the Dibblee Channel and Dibblee Pond sites increased to 46% in 2015 (Table 7). Species richness in Dibblee Channel slightly decreased but the species diversity increased from 2013 to 2015 (Table 9). The Dibblee Pond had an increase in species richness and species diversity during the same period of time. The Dibblee reference site had a decrease in species richness from 2013 to 2015, but species diversity remained the same.

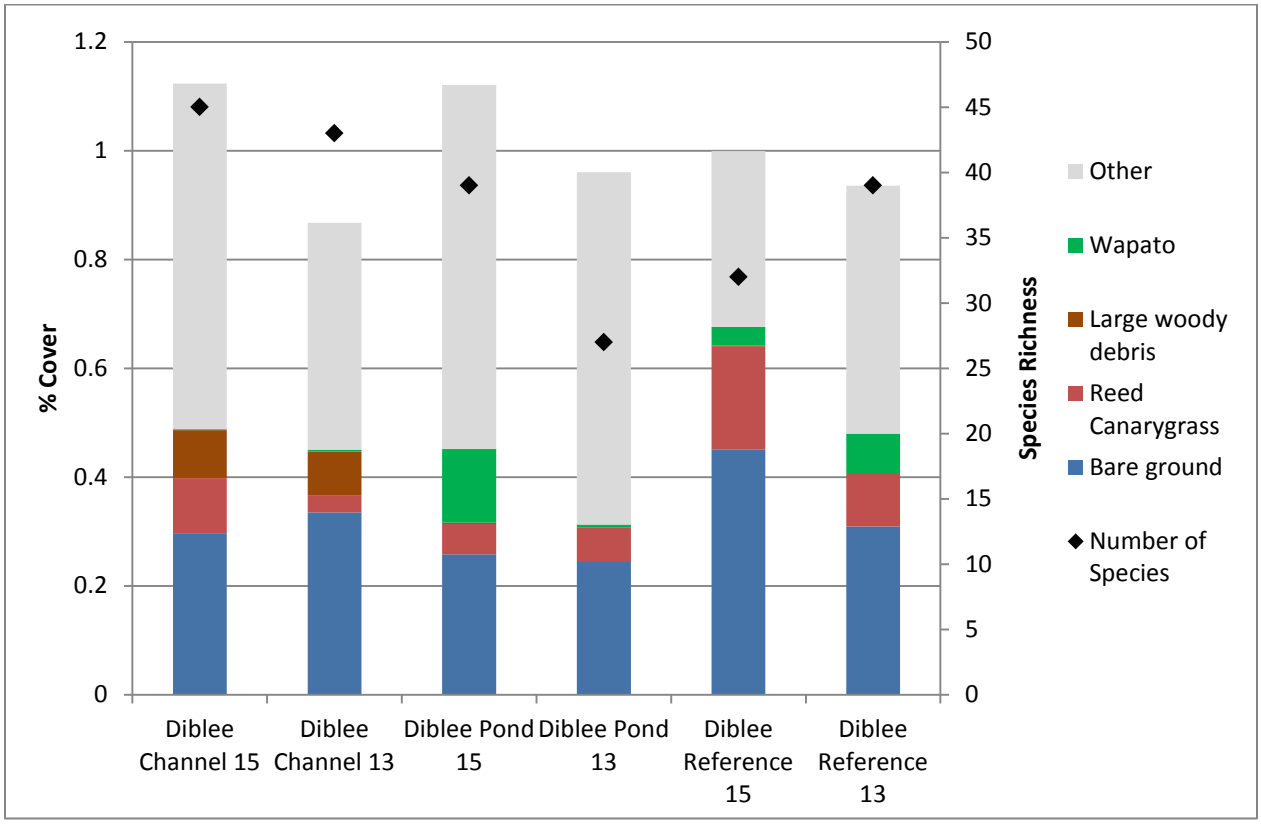

Figure 6. Vegetation cover and composition pre- and post-restoration at Dibblee Slough and reference site

Table 9. Species richness, species diversity, and average marsh elevation pre- and post-restoration condition in status plots at Dibblee Slough restoration and reference site

	Condition	Year	Species Richness	Species Diversity	Average Marsh Elevation (m-CRD)
Dibblee Channel	Post-restoration	2013	59	2.286	1.27
	Post-restoration	2015	57	3.129	1.21
Dibblee Pond	Post-restoration	2013	30	2.258	0.76
	Post-restoration	2015	44	2.849	0.90
Dibblee Reference	Post-restoration	2013	43	2.455	0.56
	Post-restoration	2015	36	2.404	0.64

Trend

The similarity of Dibblee Channel to the reference site increased from 35% in 2013 to 47% in 2015 (Table 10). The Dibblee pond increased in similarity to the reference from 36% to 45% over the same time span. Between 2013 and 2015, the Dibblee Slough Reference site had a similarity of 62% (Table 10).

Table 10. Similarity of permanent Dibblee vegetation plots year one and three post-restoration

	DibE13	DibW15	DibE15	DR15	DR13
DibW13	0.37	0.57	0.37	0.41	0.35
DibE13		0.35	0.58	0.41	0.36
DibW15			0.45	0.47	0.45
DibE15				0.41	0.45
DR15					.62

The permanent plots in the Dibblee Channel had a small increase in species richness and species diversity. In 2013 filamentous green algae was the dominant vegetation type; in 2015 other plant species became dominant. There was an increase in average percent cover of reed canarygrass in the Dibblee channel from 1.9% to 7.6% (Figure 7). The Dibblee Pond had an increase in both species richness and species diversity from 2013 to 2015. The absolute cover of wapato (*Sagittaria latifolia*) and waterpepper (*Polygonum hydropiper*) increased by 10% while bare ground decreased by 7%. The Dibblee reference site had a 17.5% increase in cover of reed canarygrass and an 11.8% increase in bare ground while other plant species average cover decreased between 2013 and 2015 (Figure 7).

Table 11. Species richness, species diversity, and average marsh elevation pre- and post-restoration condition in permanent plots at Dibblee Slough restoration and reference Site

	Condition	Year	Species Richness	Species Diversity	Marsh Elevation (m-CRD)
Dibblee Channel	Post-restoration	2013	21	2.62	1.19
	Post-restoration	2015	23	2.9	1.12
Dibblee Pond	Post-restoration	2013	12	2.23	0.57
	Post-restoration	2015	18	2.89	0.71
Dibblee Reference	Post-restoration	2013	16	2.48	0.64
	Post-restoration	2015	18	2.60	0.54

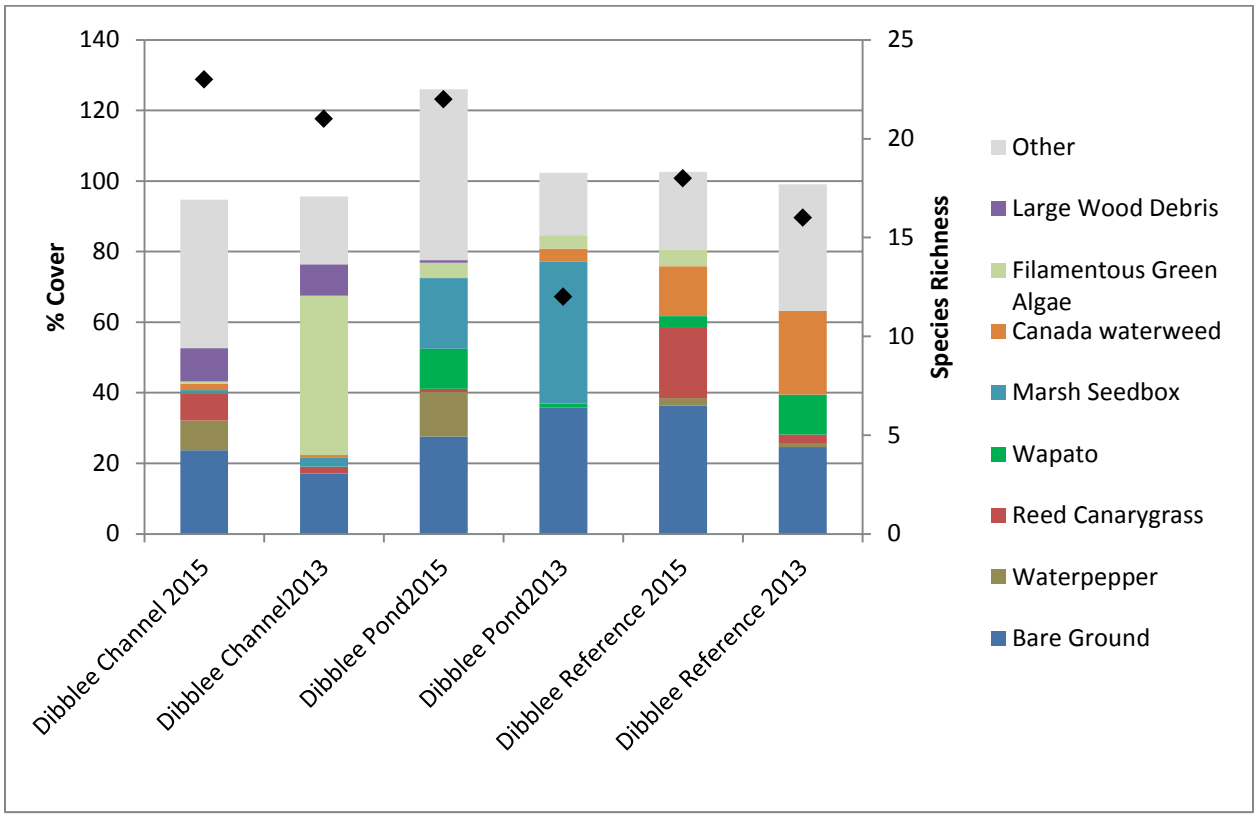

Figure 7. Vegetation cover and composition pre- and post-restoration in permanent plots at Dibblee Slough and reference site

Vegetation Zone Four

When all years and sites were examined in vegetation zone four, 12 sites (n=171) were found to have a similarity greater than 60% (Table 12). The expected reference similarity range for vegetation zone four is between 63% and 74% (Hanson et al. 2016). In 2015, the south vegetation sampling site at Millionaire (MS) south had a 68% similarity to Cunningham Lake (CL)

reference site (Table 12): at the same location, pre-restoration, the similarity was 63%. This sampling area was indirectly impacted by the removal of the water control structure, but it did not have the marsh elevation lowered. Pre-restoration, the north sampling area of Millionaire had a 61% similarity to the reference; following marsh lowering in 2014, the similarity of this sampling area to the reference site was 29% (Table 12). The south sampling site at Deep Widgeon (DWS) in 2015 had a similarity of greater than 64% to the reference site in pre-restoration years 2013 and 2014. Again, this area was impacted by the removal of the water control structure, but no alteration in marsh elevation. At the Deep Widgeon North (DWN) sampling site there was a 30% similarity to the reference site pre-restoration. The Deep Widgeon North had the marsh surface elevation lowered. Post-restoration, the site had a 30% similarity to the Cunningham reference site. At the La Center Wetlands project area, pre-restoration monitoring at the La Center North (LAN) site had a 58% similarity to the control site, while the La Center South (LAS) site had a 45% similarity to the control (Table 12).

Table 12. Similarity index for restoration and reference sites in vegetation zone four. Yellow highlights represent 60-69% similarity and green highlights represent >70% similarity

	LAS-15	LAC-15	DWN-15	DWS-15	MN-15	MS-15	CL-15	CL-14	DWN-14	DWS-14	MN-14	MS-14	CL-13	DWS-13	MS-13	CS-13	CS-14	CS-15
LAN-15	0.53	0.58	0.26	0.29	0.39	0.39	0.44	0.36	0.23	0.39	0.33	0.41	0.42	0.38	0.42	0.30	0.23	0.33
LAS-15		0.45	0.34	0.35	0.37	0.43	0.47	0.40	0.25	0.38	0.39	0.52	0.42	0.37	0.42	0.32	0.30	0.40
LAC-15			0.37	0.50	0.40	0.46	0.44	0.38	0.41	0.50	0.37	0.48	0.41	0.53	0.42	0.33	0.32	0.45
DWN-15				0.40	0.61	0.28	0.29	0.44	0.38	0.47	0.52	0.44	0.32	0.27	0.22	0.25	0.25	0.34
DWS-15					0.44	0.52	0.46	0.42	0.48	0.65	0.52	0.45	0.42	0.64	0.41	0.38	0.34	0.46
MN-15						0.46	0.47	0.48	0.32	0.56	0.51	0.47	0.44	0.40	0.42	0.38	0.33	0.43
MS-15							0.68	0.41	0.18	0.49	0.44	0.57	0.49	0.61	0.61	0.53	0.47	0.60
CL-15								0.51	0.24	0.50	0.42	0.57	0.69	0.58	0.67	0.52	0.46	0.55
CL-14									0.29	0.52	0.61	0.63	0.54	0.38	0.40	0.44	0.40	0.44
DWN-14										0.53	0.43	0.34	0.33	0.25	0.19	0.19	0.21	0.23
DWS-14											0.64	0.53	0.50	0.56	0.46	0.42	0.36	0.47
MN-14												0.55	0.49	0.39	0.40	0.41	0.34	0.44
MS-14													0.58	0.45	0.54	0.51	0.49	0.54
CL-13														0.52	0.61	0.55	0.46	0.43
DWS-13															0.56	0.45	0.33	0.46
MS-13																0.51	0.42	0.52
CS-13																	0.69	0.57

LAW=La Center wetlands west
LAE= La Center wetlands east
LAC= La Center wetlands control
DWN= Deep Widgeon north
DWS= Deep Widgeon south
MN= Millionaire north
MS= Millionaire south
CL= Cunningham Lake
CS= Campbell Slough

Sauvie Island North Unit Phase 2

The Sauvie Island North Unit Phase 2 restoration consists of two vegetation sampling areas, Millionaire and Deep Widgeon, bisected by Cunningham Slough. The two sites were divided into four sampling areas (Figure 20 and Figure 21). Millionaire Lake, in pre-restoration condition, had a vegetation similarity of 55% between the north and south sampling areas. Post-restoration the similarity between the north and south site decreased to 46% (Table 12). Deep Widgeon had a within site similarity of 53% pre-restoration. Post-restoration the similarity between the north and south sampling area decreased to 40% (Table 12).

The marsh elevation was lowered at the Millionaire North site during restoration. Species richness increased from 11 species pre-restoration to 37 species post restoration (Table 13). Species diversity increased as the plant community shifted from reed canarygrass monoculture to a site with more native plant diversity (Figure 8). At the Millionaire South site there was an increase in species richness, but a decrease in species diversity. The reduction in species diversity is likely due to the doubling in reed canarygrass cover (Figure 8). The Millionaire South site was indirectly impacted by the removal of the water control structure which changed the hydrology of the site.

Table 13. Species richness, species diversity, and average marsh elevation pre- and post-restoration condition at Sauvie Island North Unit Phase 2 Millionaire and Cunningham Lake reference

Site	Condition	Year	Species Richness	Species Diversity	Average marsh elevation (m-CRD)
Millionaire North	Pre-restoration	2014	11	1.735	1.56
	Post-restoration	2015	37	2.107	1.56
Millionaire South	Pre-restoration	2013	15	1.843	1.57
	Pre-restoration	2014	21	2.168	1.45
	Post-restoration	2015	31	1.864	1.61
Cunningham Lake	Pre-restoration	2013	11	1.33	1.51
	Pre-restoration	2014	18	2.078	1.23
	Post-restoration	2015	25	1.595	1.47

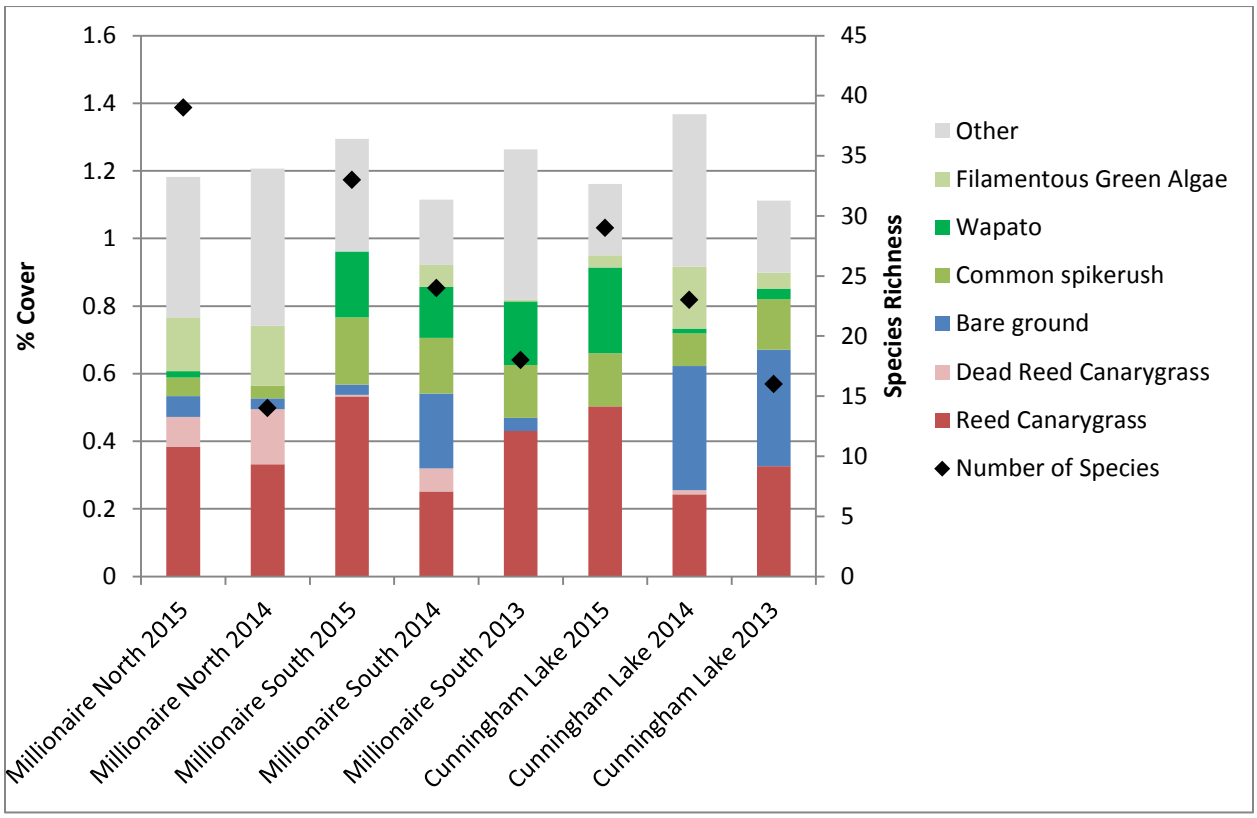

Figure 8. Vegetation cover and composition pre- and post-restoration at Sauvie Island North Unit Phase 2 Millionaire and Cunningham Lake reference site

At the Deep Widgeon North species richness increased from seven species pre-restoration to 31 plant species post-restoration (Table 14). Species diversity increased dramatically due to the reduction in reed canarygrass cover and an increase in bare ground and other native plant species (Figure 9). At Deep Widgeon South there was decrease in species richness and species diversity from pre- to post-restoration condition and is likely a result of an increase in reed canarygrass cover (Figure 9). This site was impacted by the removal of the water control structure, but the marsh elevation was not lowered.

Table 14. Species richness, species diversity, and average marsh elevation pre- and post-restoration condition at Sauvie Island North Unit Phase 2 Deep Widgeon and Cunningham Lake reference

Site	Condition	Year	Species Richness	Species Diversity	Average marsh elevation (m-CRD)
Deep Widgeon North	Pre-restoration	2014	7	0.617	1.95
	Post-restoration	2015	31	2.156	1.84
Deep Widgeon South	Pre-restoration	2013	8	0.826	1.65
	Pre-restoration	2014	13	1.556	1.64
	Post-restoration	2015	11	1.078	1.66
Cunningham Lake	Pre-restoration	2013	11	1.33	1.51
	Pre-restoration	2014	18	2.078	1.23
	Post-restoration	2015	25	1.595	1.47

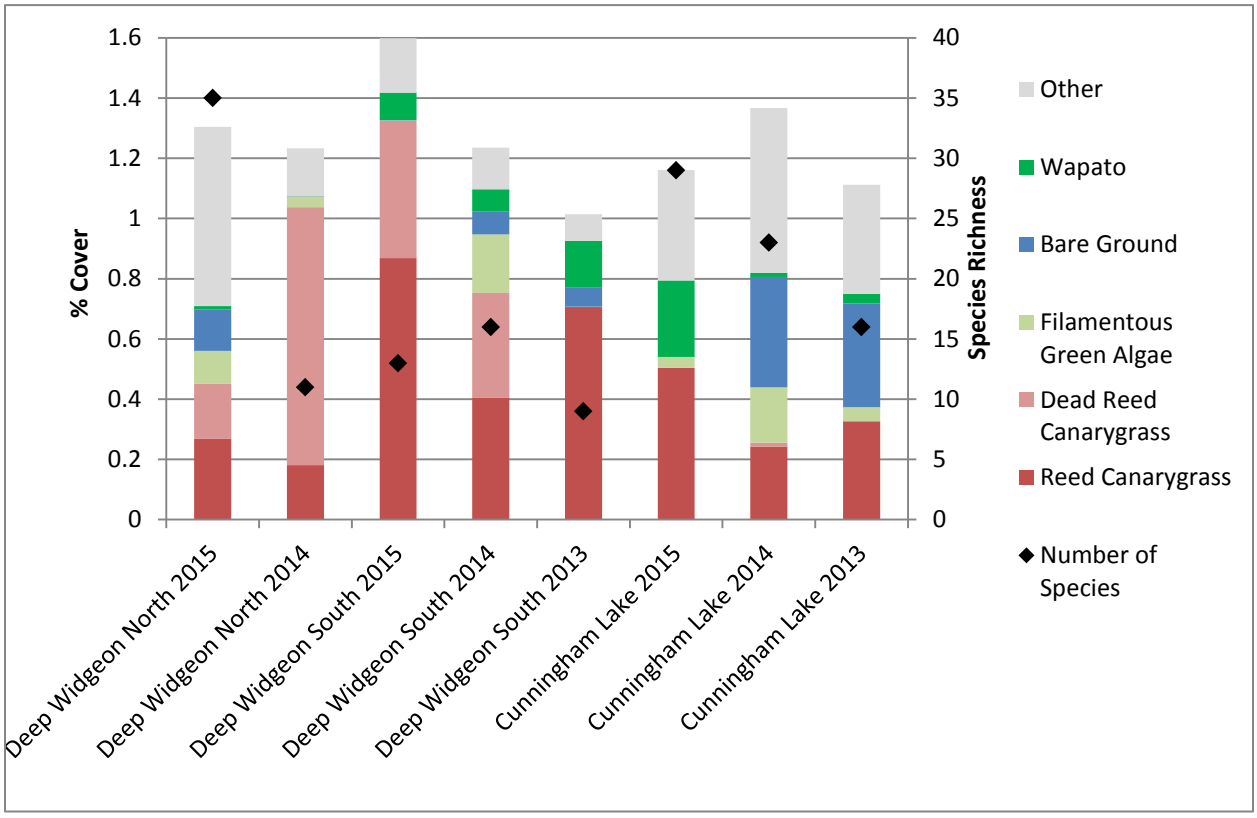

Figure 9. Vegetation cover and composition pre- and post-restoration at Sauvie Island North Unit Phase 2 Deep Widgeon and Cunningham Lake reference site

La Center Wetlands

The La Center Wetlands restoration consists of two vegetation sampling areas, La Center North and La Center South, which are bisected by East Fork Lewis River (Figure 18). Pre-restoration, La Center Wetlands had a vegetation similarity of 53% between the north and south sampling areas (Table 15). Both sampling sites have similar species richness and species diversity (Table 15). The La Center Control is characterized by bare ground and wapato, but has more reed canarygrass present than either of the pre-restoration monitoring sites (Figure 10).

Table 15. Species richness, species diversity, and average marsh elevation pre- and post-restoration condition at La Center Wetlands and control sites

Site	**Condition**	**Year**	**Species Richness**	**Species Diversity**	**Average marsh elevation (m-CRD)**
La Center North	Pre-restoration	2015	31	2.253	0.53
La Center South	Pre-restoration	2015	29	2.145	1.22
La Center Control	Pre-restoration	2015	29	1.765	1.11

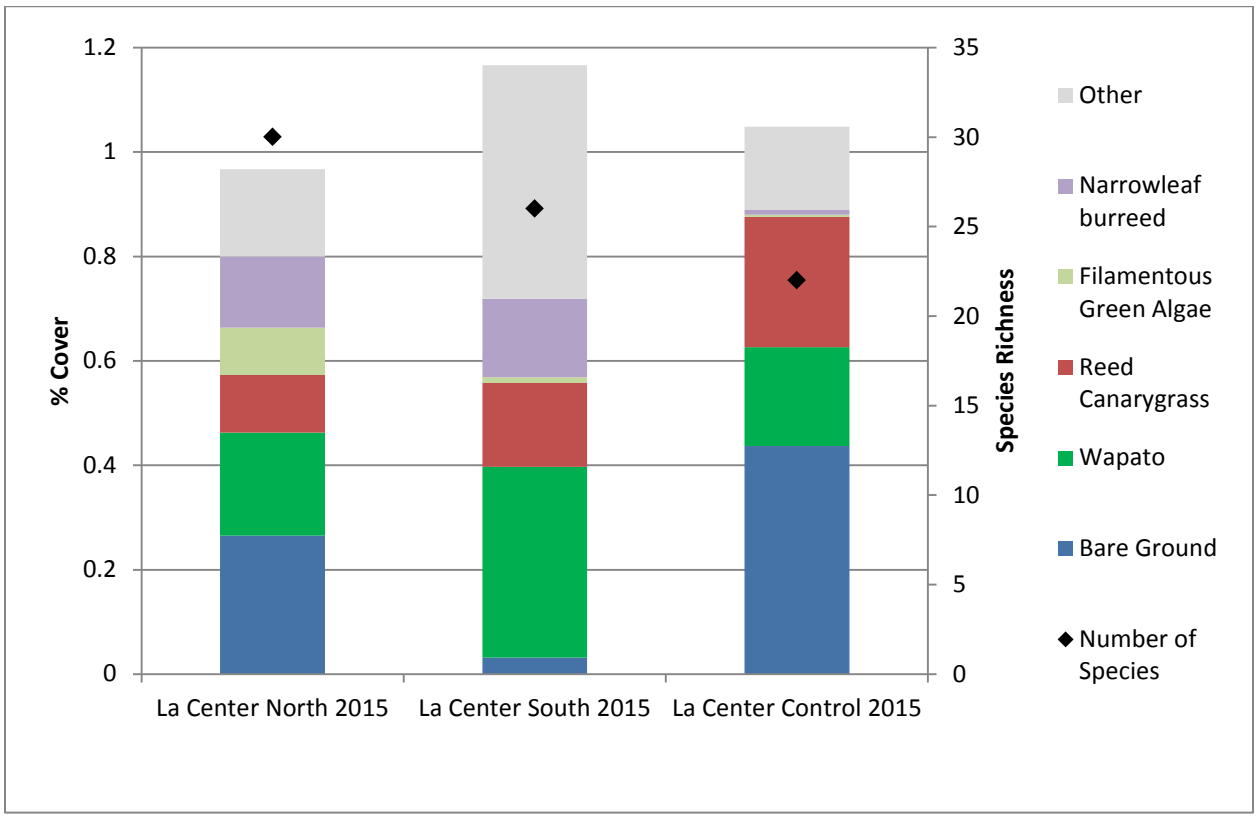

Figure 10. Vegetation cover and composition pre- and post-restoration at La Center Wetland and control site

Salmonid Prey

Benthic Macroinvertebrates

Wallooskee-Youngs and La Center Wetlands were monitored pre-restoration for benthic macroinvertebrates in 2015. Samples were collected in May, June, and July. Overall, species richness decreased across time at pre-restoration sites and increased at reference sites. Species diversity decreased at pre-restoration sties from May to June. At reference sites, species diversity was higher than pre-restoration sites and did not vary greatly between months (Table 16.).

Table 16. Overall benthic macroinvertebrate species richness and species diversity

All Sites - Month	Average Species Richness	Average Species Diversity
Pre-restoration - May	20	1.15
Reference - May	11	1.24
Pre-restoration - June	12	0.86
Reference - June	18	1.23
Pre-restoration - July	9	0.97
Reference - July	18.5	1.33

Wallooskee-Youngs

Each month species diversity at Wallooskee-Youngs restoration site was lower than the reference. Species richness decreased at the restoration site from May to July (Table 17). At the reference site, species richness increased during the same period of time. Dipterans represented 12-18% of the sample at reference site across all sampling months while at pre-restoration sites dipterans represented 6-30% of the sample (Figure 11).

Table 17. Species richness and species diversity pre-restoration condition at Wallooskee-Youngs and Dagget Point reference sites

Site - Month	Species Richness	Species Diversity
Wallooskee-Youngs North May	17	1.01
Wallooskee-Youngs Reference May	11	1.24
Wallooskee-Youngs North June	8	0.63
Wallooskee-Youngs South June	10	0.92
Wallooskee-Youngs Reference June	18	1.23
Wallooskee-Youngs North July	11	1.09
Wallooskee-Youngs South July	10	0.64
Wallooskee-Youngs Reference July	22	1.34

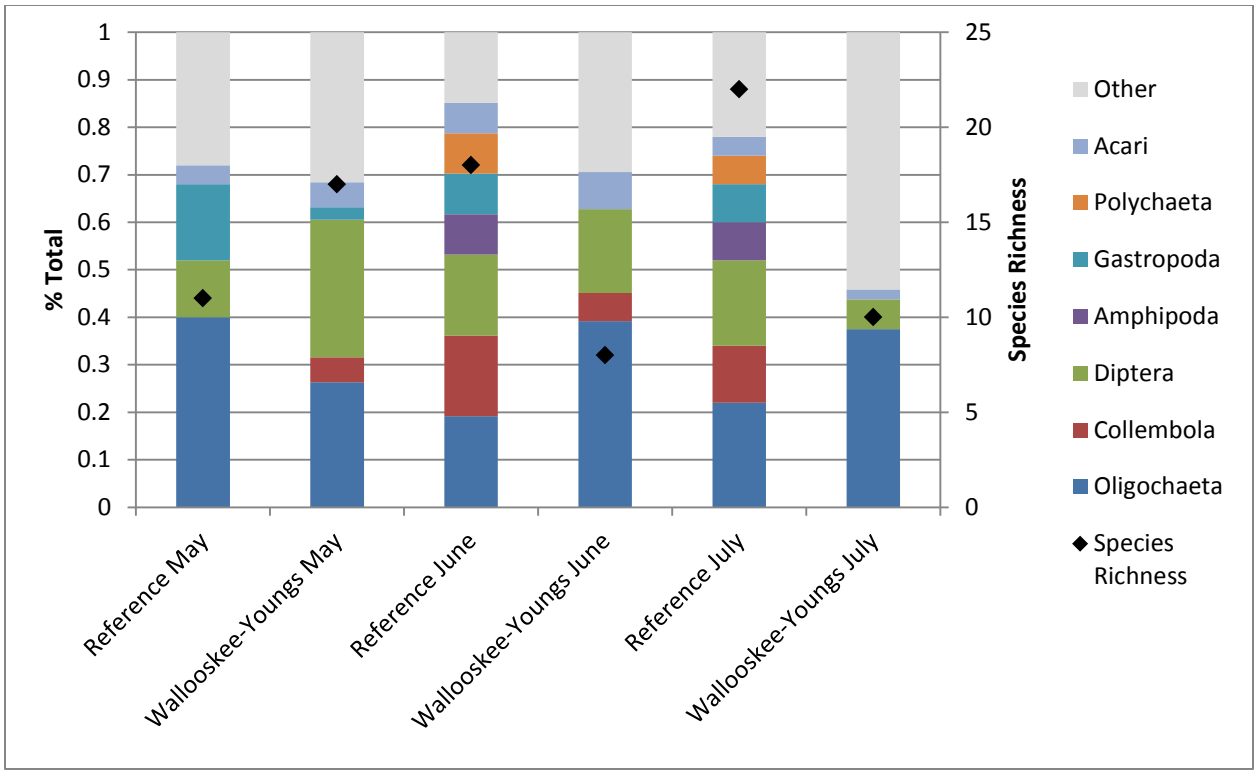

Figure 11. Percent portion of species in benthic samples at Wallooskee-Youngs restoration and reference site

La Center Wetlands

Benthic macroinvertebrate species richness and species diversity decreased from May through July at La Center Wetlands. In July at the control site, species richness and diversity was found to be higher than pre-restoration sites. The proportion of Dipteran species found at the site varied by month, but the taxa maintained a minimum of 25% of total species observed across all months (Figure 11).

Table 18. Pre-restoration species richness and species diversity at La Center Wetlands and control sites

Site - Month	Species Richness	Species Diversity
La Center Wetlands May	23	1.29
La Center Wetlands June	18	1.03
La Center Wetlands July	7	1.00
La Center Pond July	8	1.17
La Center Control July	15	1.33

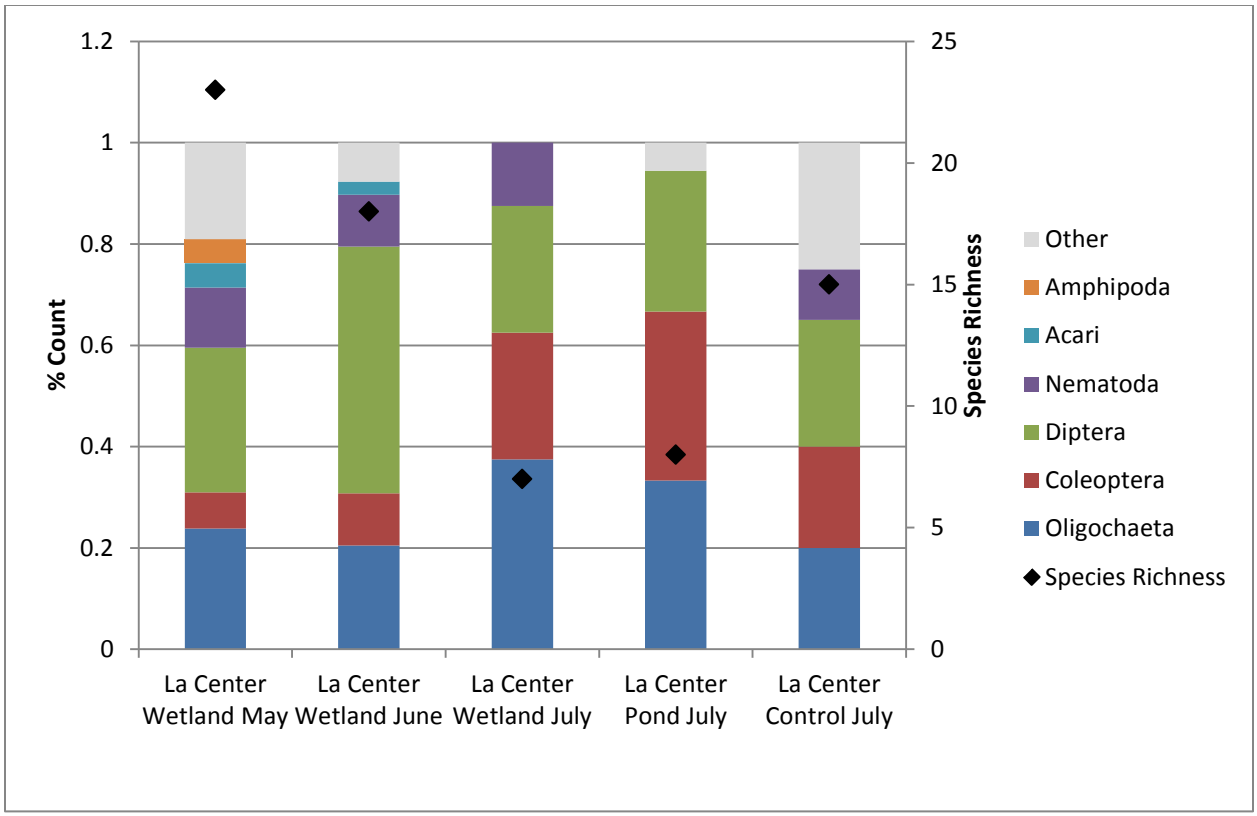

Figure 12. Percent portion of species in benthic samples at La Center Wetlands and control site

Terrestrial Macroinvertebrates

Sauvie Island North Unit Phase 2 (Millionaire and Deep Widgeon) were monitored for terrestrial macroinvertebrates pre-restoration in 2014 and post-restoration in 2015. Diblee Slough was monitored for terrestrial macroinvertebrates post-restoration in 2013 and 2015. Wallooskee-Youngs and La Center Wetlands, and were monitored for terrestrial macroinvertebrates pre-restoration in 2015. Overall, species richness was highest at post-restoration sites. Pre-restoration and reference sites had similar species richness. Species diversity at sites was similar regardless of site condition (Table 19).

Table 19. Overall terrestrial macroinvertebrate species richness and species diversity

	Species Richness	**Species Diversity**
Pre-restoration	39.2	2.7
Post-restoration	47.0	2.5
Reference	38.3	2.1

Wallooskee-Youngs

The Wallooskee-Youngs site had a higher species richness and species diversity compared to the reference site (Table 20 and Figure 13). Dipterans were the most prevalent order at each site, but dipterans composed a larger portion of the sample at the restoration site.

Table 20. Terrestrial macroinvertebrates species richness and diversity at Wallooskee-Youngs

Site	Condition	Year	Species Richness	Species Diversity
Wallooskee-Youngs	Pre-restoration	2015	56	2.283
Dagget Point Reference	Pre-restoration	2015	40	1.733

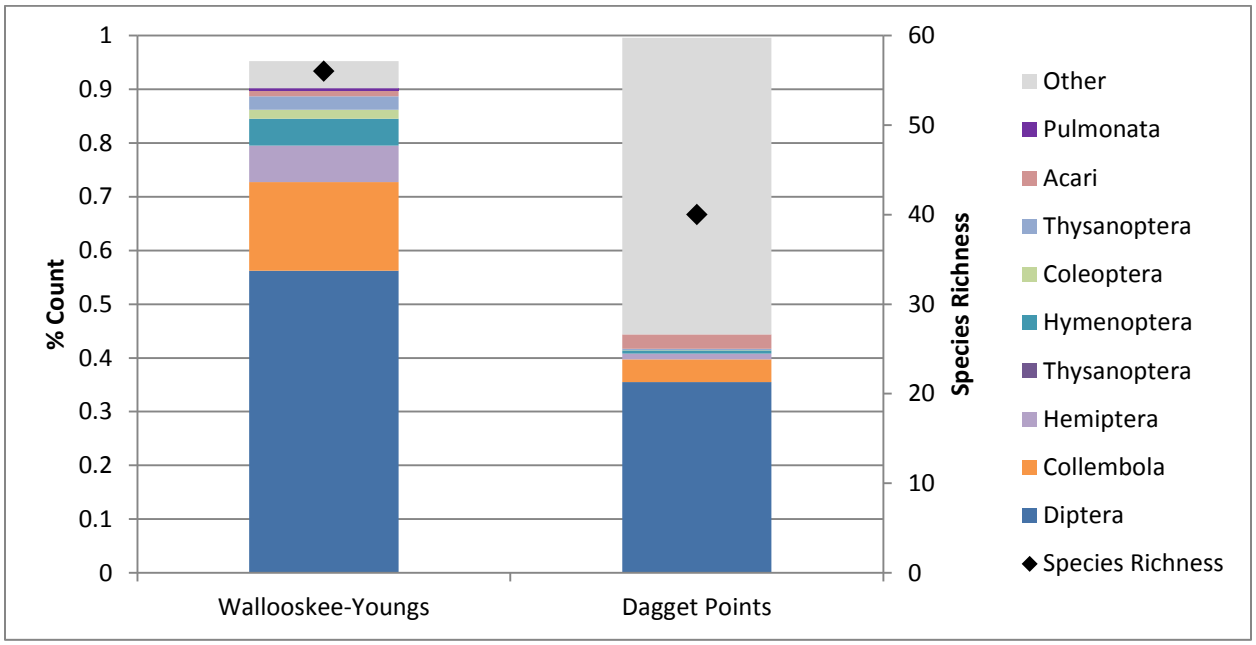

Figure 13. Percent portion of terrestrial macroinvertebrates species at Wallooskee-Youngs and reference site.

Steamboat Slough

At Steamboat Slough species richness was similar between pre- and post-restoration condition with a decrease in species diversity. At the reference site, there was an increase in species richness between 2013 and 2015, but a decrease in species richness (Table 21). Dipteran abundance was slightly higher post-restoration as Steamboat Slough, but the abundance of hymenoptera increased dramatically. At the reference site, dipteran abundance was higher in 2015 than in 2013 and hymenoptera abundance was the same between years (Figure 14).

Table 21. Terrestrial macroinvertebrates species richness and diversity at Steamboat Slough

Site	Condition	Year	Species Richness	Species Diversity
Steamboat Slough	Pre-restoration	2013	32	2.579
	Post-restoration	2015	30	1.14
Welch Island Reference	Pre-restoration	2013	34	2.172
	Post-restoration	2015	45	1.639

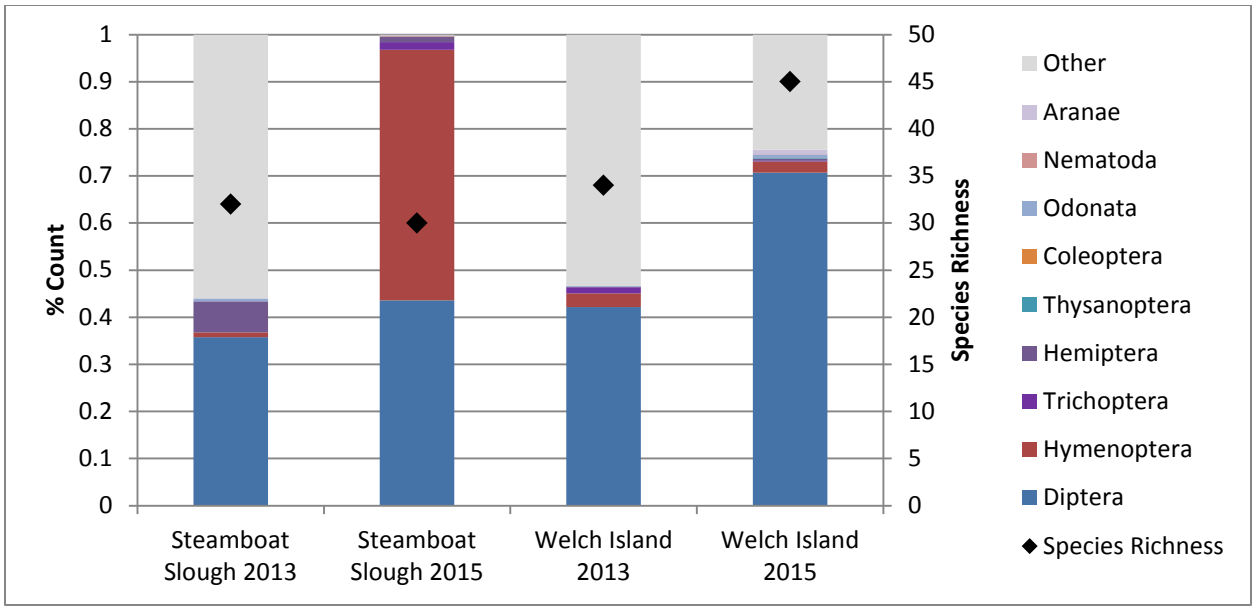

Figure 14. Percent portion of terrestrial macroinvertebrates species pre- and post-restoration at Steamboat Slough and reference site

Diblee Point

In 2015 species richness was higher at Diblee Point restoration and reference site than 2013, but species diversity was similar between years (Table 22). The abundance of dipterans at the restoration site between years was similar. At the reference site, dipteran abundance was lower than restoration site in 2015 and the 2013 reference site. There was a large increase of Collembola at the reference site in 2015. Collembola was present at the restoration site, but abundance was much lower (Figure 15).

Table 22. Terrestrial macroinvertebrates species richness and diversity at Diblee Slough

Site	Condition	Year	Species Richness	Species Diversity
Diblee	Post-restoration	2013	29	2.923
	Post-restoration	2015	66	3.009
Diblee Reference	Post-restoration	2013	25	2.527
	Post-restoration	2015	46	1.06

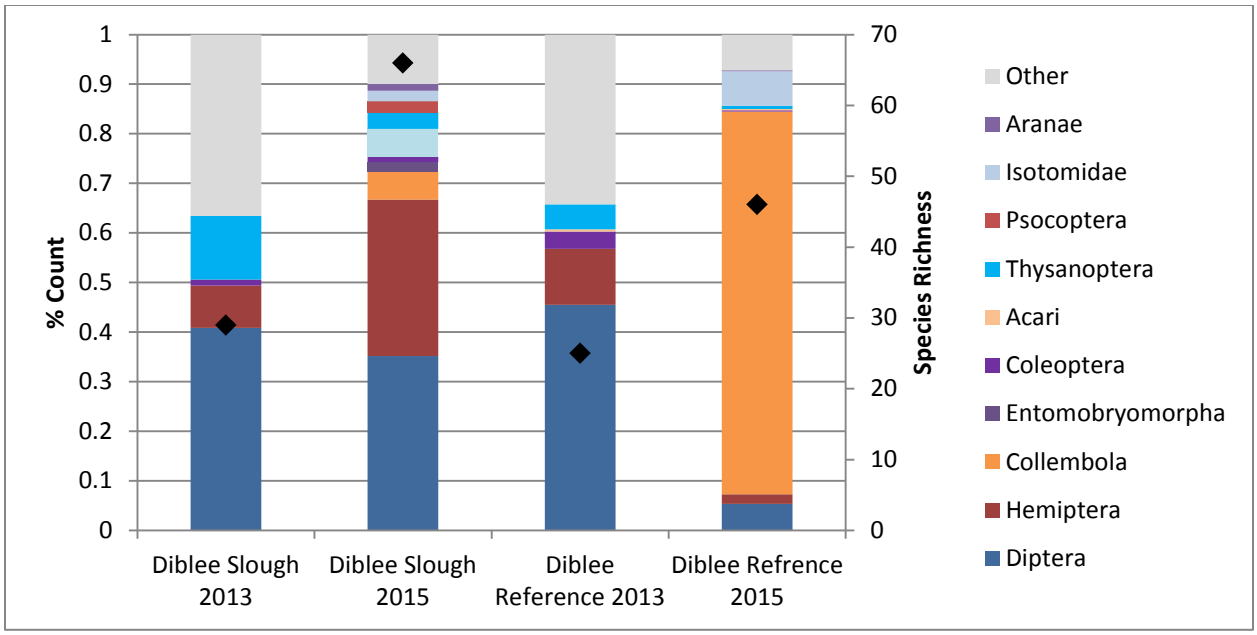

Figure 15. Percent portion of terrestrial macroinvertebrates species pre- and post-restoration at Diblee Slough and reference site

Sauvie Island North Unit Phase 2

Overall, species richness was higher in 2015 at the restoration and reference site. Species diversity decreased at Millionaire and the reference site, but increased at Deep Widgeon (Table 23). Dipteran abundance followed a similar trend. At Millionaire and the reference site, dipteran abundance decreased from 2013 to 2015, while increasing at Deep Widgeon. Collembola increased at all sites in 2015, but there was a significant increase at Millionaire and the reference site (Figure 16).

Table 23. Terrestrial macroinvertebrates species richness and diversity at North Unit Phase 2

Site	Condition	Year	Species Richness	Species Diversity
Deep Widgeon	Pre-restoration	2014	28	2.33
	Post-restoration	2015	58	3.35
Millionaire	Pre-restoration	2014	24	2.54
	Post-restoration	2015	34	2.32
Cunningham Lake Reference	Pre-restoration	2014	24	2.68
	Post-restoration	2015	59	1.82

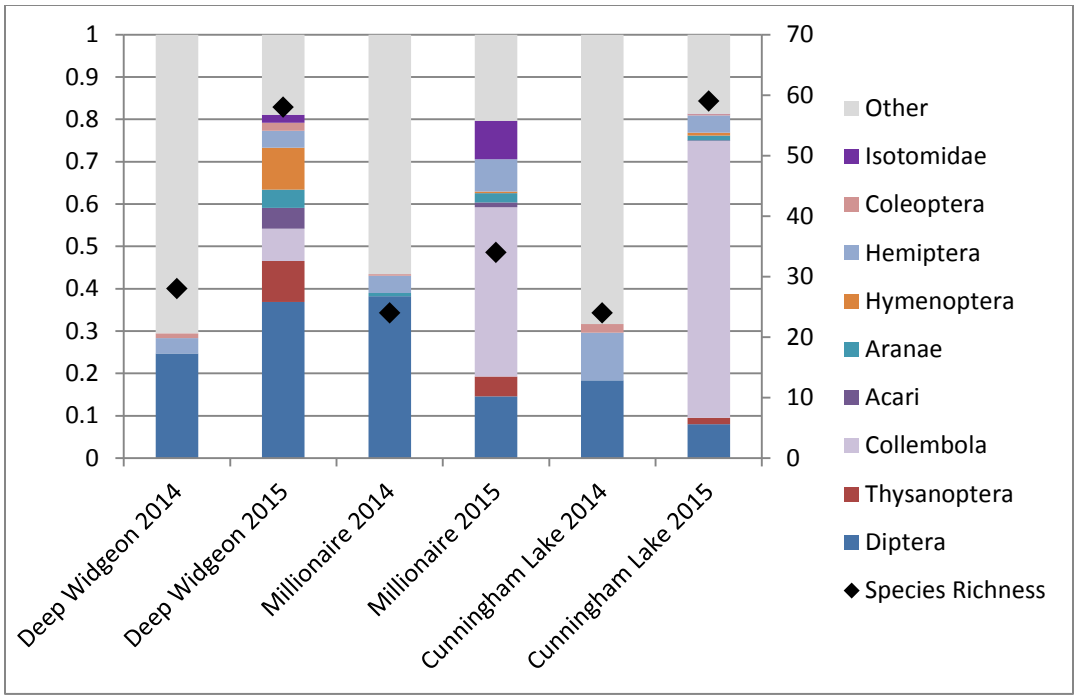

Figure 16. Percent portion of terrestrial macroinvertebrates species pre- and post-restoration at North Unit Phase 2 and reference site

La Center Wetlands

The La Center Wetlands site had a higher species richness and species diversity compared to the reference site (Table 24 and Figure 17). Dipterans were the most abundant order at the restoration site. Coleoptera was the most abundant order at the reference site and the second most prevalent order was dipterans.

Table 24. Terrestrial macroinvertebrates species richness and diversity at La Center Wetlands

Site	Condition	Year	Species Richness	Species Diversity
La Center Wetlands	Pre-restoration	2015	83	3.187
La Center Control	Pre-restoration	2015	35	2.762

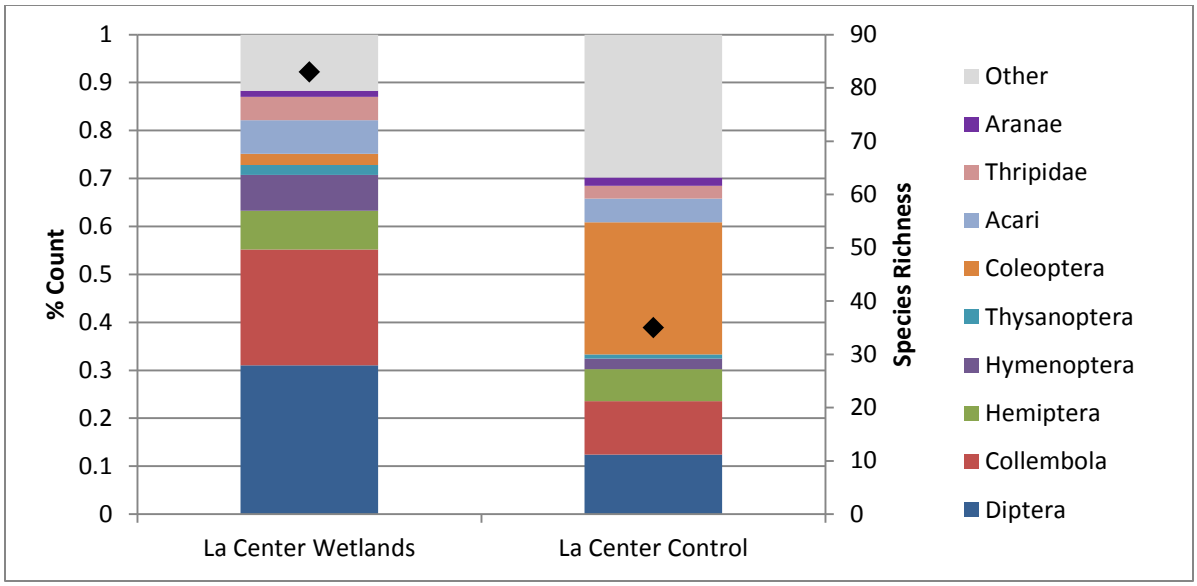

Figure 17. Percent portion of terrestrial macroinvertebrates species at La Center Wetlands and reference sites

Fish Detection and Passage

In 2015, the PIT (passive integrated transponder) tag array recorded more than 7,500 tag detections that corresponded to 54 unique tags (Table 25). The first detection of 2015 occurred in April and the last detection in September. Nineteen tags were not found in the PTAGIS database.

The detections in the spring (Apr – Jun) were dominated by juvenile hatchery Spring Chinook (*Oncorhynchus tshawytscha*) (n=10) and hatchery and wild steelhead (*Oncorhynchus mykiss*) (n=12). The hatchery Spring Chinook salmon originated from as far away as the Rapid River Hatchery in Idaho and as nearby as the Little White Salmon Hatchery near Stevenson, WA. The juvenile steelhead detected at the site represented both hatchery and wild stocks from summer and winter runs. Steelhead came from the nearby Hood River watershed, but others came from as far away as the Pahsimeroi River, a tributary to the Salmon River in Idaho. Higher numbers of both Chinook and steelhead species were more successful in passing through the culvert than in prior years. Most fish were at the site for 1-2 days, but several were detected multiple times during extended visits lasting a week or longer. Other species detected at the site during the spring timeframe included hatchery Summer Chinook, hatchery Coho (*Oncorhynchus kisutch)*, summer sockeye (*Oncorhynchus nerka)*, pikeminnow (*Ptychocheilus oregonensis*), and adult steelhead (Table 1). The sockeye were from the Redfish Lake system in Idaho and the Coho came from the Umatilla River. One of the adult steelhead, released as a juvenile in 2012, was also detected at various upriver locations throughout 2014/15 and had also been barge transported.

While the majority of detections in the spring were migrating juvenile salmon and steelhead, the summer detections from late June to August were dominated by a large number of ‘unknowns’ and represented a considerably higher number of summer detections at our site

than in previous years. The unknown tag numbers were reported to Biomark (a large supplier of tags to BPA, hatcheries and researchers) and it appears a majority were sold to a company called Merck / Schering Plough which is a pharmaceutical company and deals with animal health. This suggests that these tags may have been associated with pets or other domestic animals that were present in the area. Identified summer detections included hatchery summer steelhead and hatchery Fall Chinook.

There was only one detection for the month of September, a returning adult Fall Chinook that had been tagged/released from the Spring Creek Hatchery in 2013. Unlike the previous two years of operation, we had zero detections at the site in October, November or December. This is attributed to technical challenges we encountered in the Fall keeping the array operational (e.g, reduced daylight to maintain solar power, damaged solar panels). However, it is also possible that returning adult Coho that are typically present during this time frame were not tagged this past year for upstream migration studies.

Table 25. PIT-tagged fish detected in 2015 at Horsetail Creek PIT-tag array

Species	**# Fish Detected**	**Months Present**	**Length (mm)**	**Residency (days)**	
				Range	**Mean**
Juvenile hatchery Spring Chinook	10	April, May, June	61-157	1-3	1.2
Juvenile hatchery Summer Chinook	1	May	119	1	1
Juvenile hatchery Fall Chinook	3	May, July	62-87	1	1
Adult hatchery Fall Chinook	1	September	n/a	2	2
Juvenile hatchery Coho	2	May, August	149	1	1
Juvenile hatchery steelhead	7	April, May, July	108-167	1-2	1.3
Juvenile wild steelhead	5	April, June	113-207	1-2	1.4
Summer sockeye	3	May, June	123	1	1
Pike Minnow	1	May	408	1	1
Adult steelhead	3	April, May	725	1-2	1.3
Unknown	19	June, July, August	n/a	1-34	2.9

Discussion/Conclusion

To provide an overall characterization of site condition, vegetation monitoring was established in an area directly impacted by restoration actions and a second site located in an area indirectly impacted by restoration activities. As expected, in monitoring areas directly impacted by restoration activities, there was low vegetation similarity between pre- and post-restoration condition. The plant community changed from a mix of invasive field grasses to bare ground with some native emergent vegetation. In areas indirectly impacted by restoration actions, there was a high similarity between pre- and post-restoration condition with plant communities that contained native emergent marsh vegetation. Pre-restoration and post-restoration sites were found to be significantly different from each other based on vegetation composition. However, post-restoration and reference site vegetation were also all found to significantly differ from each other. Given the short period of time sites have been in a post-restoration condition, vegetation at the restoration sites do not have enough time to mature and approach a reference state.

Distinct vegetation zones were evident based on the collected vegetation data. The presence of distinct emergent marsh vegetation zones provides a method to examine how restoration sites and reference sites at a larger ecosystem scale compare given inherent inter-annual variability. Vegetation was strongly correlated to River KM. Vegetation was moderately correlated to average marsh elevation, species richness, species diversity, bare ground, and litter. Increasing marsh elevations were associated with decreasing species richness and diversity, bare ground, and litter. Species richness was lowest at pre-restoration sites and highest at post-restoration sites. Construction disturbance and replanting a mix of native plant species are the likely drivers of higher species richness post-restoration. A larger number of vegetation species at the site were also reflected in higher species diversity. Species diversity at pre-restoration and reference sites was similar, which is indicative of sites at equilibrium with the existing environmental conditions.

The collection of benthic macroinvertebrates pre-restoration characterizes conditions and establishes a baseline to determine how restoration actions influence the production of macroinvertebrates at the site. At pre-restoration sites, benthic macroinvertebrate species richness decreased throughout the spring, while at reference sites species richness increased over the same period of time. However, across months, the proportion of dipterans found at both sites was similar.

Terrestrial macroinvertebrate collection tracks available salmonid prey items pre- and post-restoration. Overall, there are more macroinvertebrate species available at post-restoration sites than pre-restoration or reference sites. At the site scale, the number of species available varies by year, but the difference in total number of species between restoration and reference sites is minimal even when site condition is considered. Dipterans, a preferred prey item of salmonids, were prevalent at all restoration and reference sites which indicate the ubiquity of the species.

The PIT tag detections at Horsetail Creek were dominated by upriver juvenile hatchery Spring Chinook and steelhead in the spring. Juvenile steelhead detected at the site represented both hatchery and wild stocks from summer and winter runs. The higher number of detections of both Chinook and steelhead species at the Creekside end of the culvert would indicate salmon are transiting long culverts and utilizing the restoration site. Most fish were at the site for 1-2 days, but several were detected multiple times during extended visits lasting a week or longer. Other species detected at the site during the spring timeframe included hatchery Summer Chinook, hatchery Coho, summer sockeye, pikeminnow and adult steelhead. Identified summer detections included hatchery summer steelhead and hatchery Fall Chinook. There were zero detections at the site in October, November or December. This was attributed to either the technical challenges we encountered during the fall keeping the array operational or no tagged returning adult Coho for upstream migration studies.

Changes to wetland emergent habitat metrics as a result of restoration actions varied. It will take time to determine how vegetation communities respond to hydrologic reconnection and marsh lowering. As more sites are monitored post-restoration and existing restoration sites begin to mature, a clearer picture of the rate and degree of ecological change related to restoration actions will emerge.

Adaptive Management & Lessons Learned

Post restoration sites will need to achieve a new stable ecological state before restoration impacts related to vegetation composition and available salmonid prey can be fully determined. However, restoration actions do have an immediate impact to a site. For tidal reconnection projects, unrestricted inundation is observed immediately after a project is completed. Unrestricted tidal and river access to the site makes these restored sites available to juvenile salmonids. Other metrics (e.g., vegetation, macroinvertebrate community) require more time to assess the true impact. Sauvie Island North Unit Phase 2 lowered marsh elevation to control reed canarygrass. Since the site is one year post restoration, in areas with soil scrape down, bare ground is the predominant cover type. It will take time for a new plant community to become established and reach a stable ecological state. The increasing number of sites providing data from scrape down areas will provide insight into the long-term effectiveness of marsh lowering in the control of reed canarygrass. To adaptively mange restoration projects it is necessary to monitor at regular intervals post restoration; however, the rate of change of the physical and ecological metric dictates the amount of time necessary before a realistic assessment of the post restoration ecological uplift occurs.

In any given year the small number of monitored sites limits analysis and the ability to infer changes in ecological condition due to restoration efforts. Overall, the number of sites with pre- and post-restoration monitoring is increasing annually and a larger long term dataset will help quantify the impact of restoration. Initial analysis shows the necessity for reference sites and

Ecosystem Monitoring Program (EMP) sites to accurately characterize changes at the site and larger spatial scales. The Estuary Partnership's EMP continues to monitor many parameters included in AEM (e.g. vegetation, water quality, food web, and salmon) and the collection of comparable datasets by the two programs (where possible) continues to fill data gaps and add to our understanding of habitat conditions and juvenile salmonids in the lower river. Additionally, the EMP provides valuable guidance for improving restoration effectiveness monitoring and pertinent information regarding which extensive monitoring metrics are most germane to realized function of juvenile salmonids. Reference site and EMP data set the range of values a "restored" site should achieve given the location of the site in the river. The ability to compare restoration sites to ecosystem monitoring and reference sites provides a method to determine the suitability of restoration sites to juvenile salmonids. With a lack of fish monitoring at AEM sites, comparing habitat metrics between restoration and reference sites is currently the only method of linking restoration actions to realized fish use.

The PIT (passive integrated transponder) tag detection system installed at the confluence of Horsetail and Oneonta Creeks was more reliable than prior years. The amount of days the system was operational in 2015 was greater, however there were still periods of limited functionality and several times when it had to be shut down to preserve the batteries. The array was taken offline in December 2014 and was powered back on in March 2015. Overall the PIT tag system at Horsetail continues to show which stocks of upriver fish species are using the restoration sites in the Columbia Gorge and the residency time of these fish.

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Appendices

Appendix A: Site Sampling Reports

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

Equipment

Equipment for each of the metrics sampled is outlined below.

- *Vegetation*: 100-m tapes for the baseline and transects, a compass for determining the baseline and transects azimuth, 1-m quadrat, data sheets, and plant books for species identification. GPS to identify location of base stakes and quadrats.
- *Insect Fall out Traps:* 4 tubs (26.7x15.8 inches) for trapping macroinvertebrates. 125µm sieve, garden sprayer, 96% denatured ethanol, and plastic jars with lids were used to field process macroinvertebrates for transport back to the lab for identification.
- *Sediment Accretion Rate:* 2 gray 1-inch PVC conduit pipes, at least 1.5m long, construction level, meter stick. GPS to identify location of stakes.
- *Photo Points:* camera, stake for including in photo, previous photos at location for reference, GPS to identify location of point.
- *Elevation*: AshTech ProMark 200 GPS with real-time kinematic (RTK) correction. Other survey equipment in case GPS equipment is non-functional, including an auto-level, tripod, and stadia rod.

Sites

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

Dates of Sampling in 2015

3 – 4 June

Types of Sampling in 2015

- *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

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

North Veg Sample area (Figure 18)

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

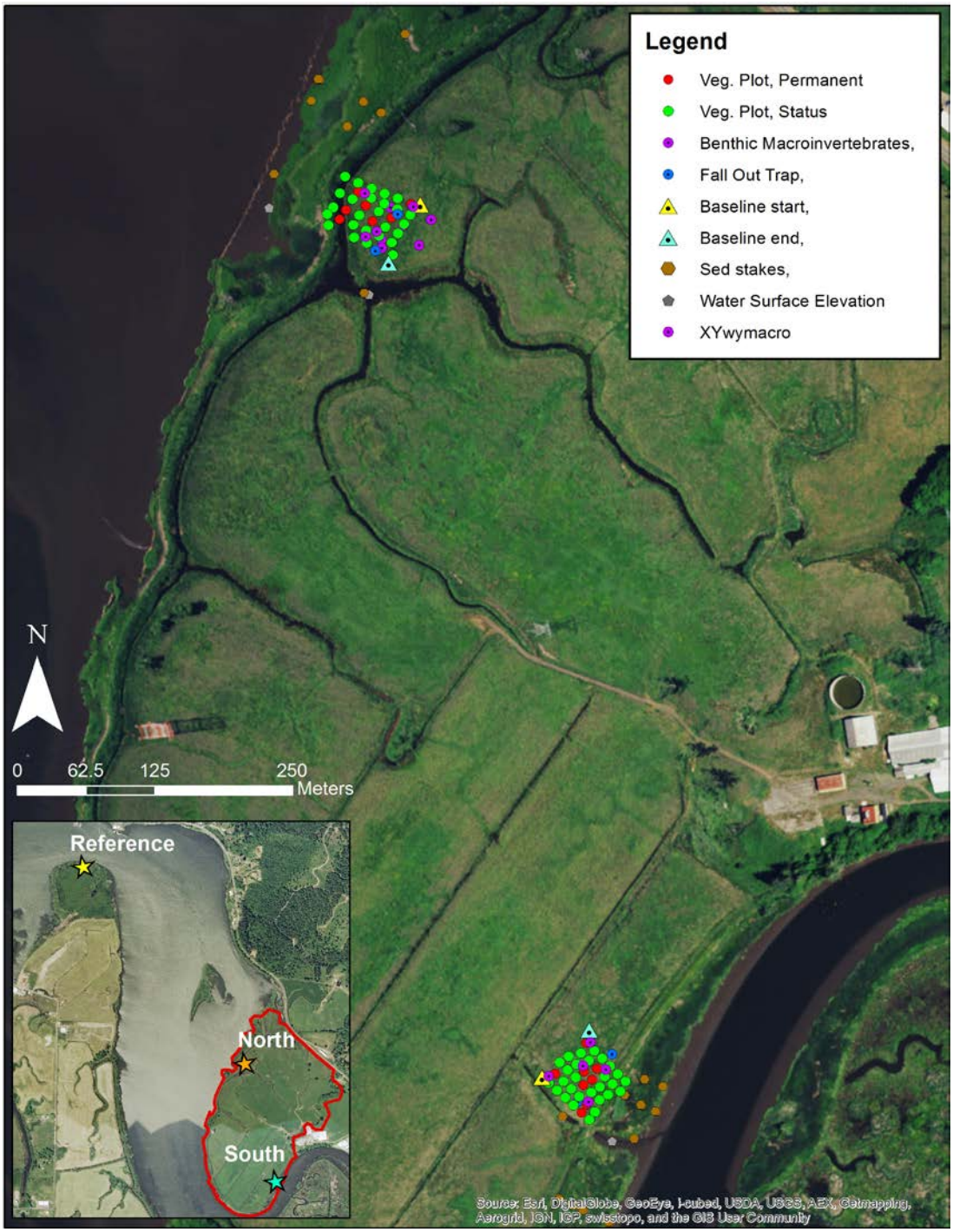

Figure 18. Vegetation and macroinvertebrate sampling locations at the Wallooskee-Youngs restoration site

Markers Left on Site

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

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

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.

Benthic Cores- At the north vegetation sampling site, five benthic macroinvertebrate cores were taken across the sampling area in May, June, July. At the south vegetation sampling site, five benthic macroinvertebrate cores were taken across the sampling area in June and July.

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

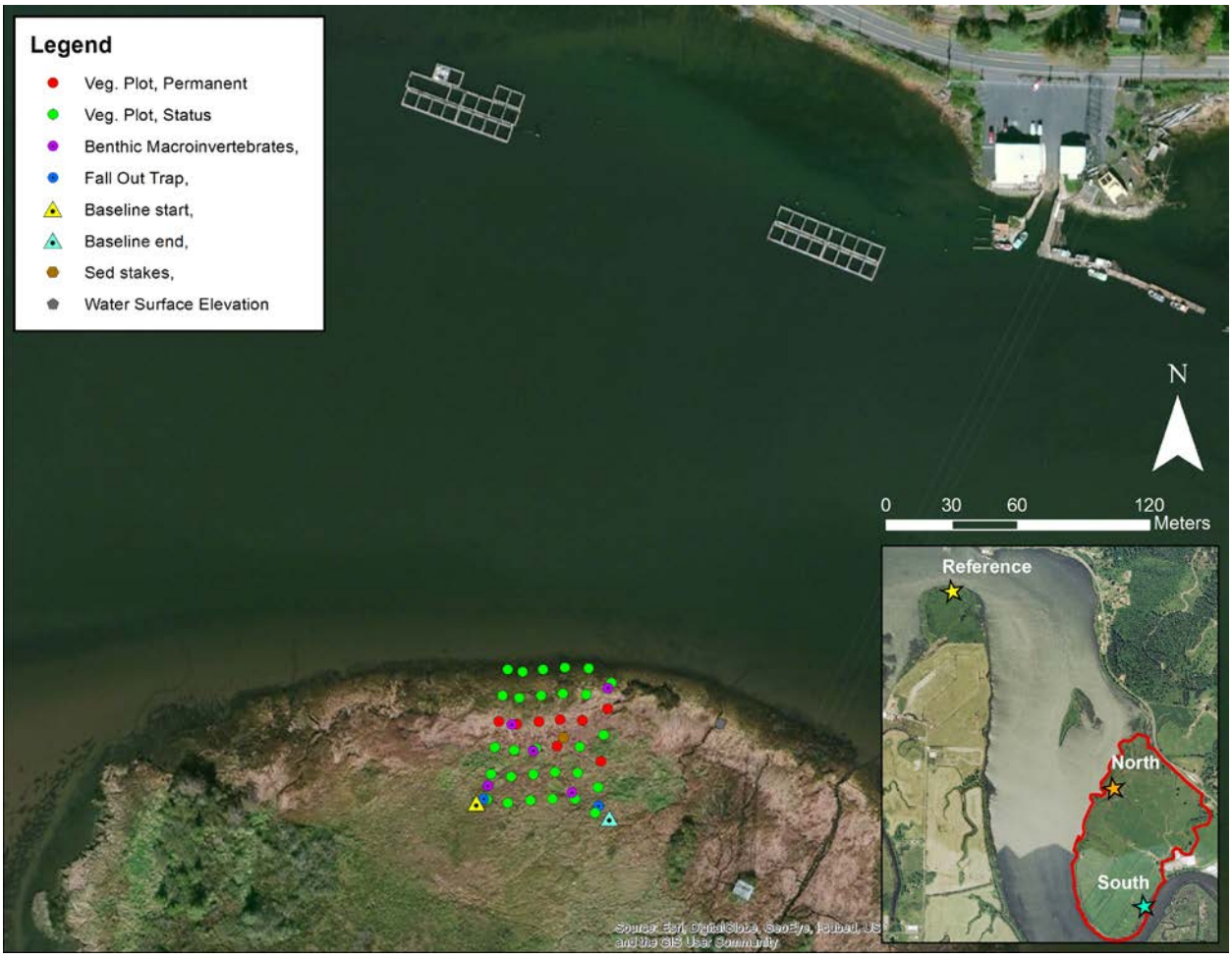

Figure 19. Vegetation and macroinvertebrate sampling locations at the Wallooskee-Youngs reference site

Markers Left on Site

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

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

Macroinvertebrate Sampling

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

Benthic- Five benthic macroinvertebrate cores were taken across the elevation gradient in May, June, July.

Steamboat Slough

General Site Location

Julia Butler Hanson (JBH National Wildlife Refuge

Ecosystem Type
Formerly diked, restoration site

Dates of Sampling in 2014
16-17 June

Types of Sampling in 2014
See map below for sampling locations (Figure 17).

- *Vegetation*: Herbaceous cover (2 sample areas of 36 quadrats, 72 quadrats total)
- *Insect Fall out Traps:* 4
- *Photo Points:*
- *Sediment Accretion Rate:*
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design

East Vegetation Sample Area (Figure 20)

- Located at east end of site in former constructed wetland low elevation area. Vegetation sample area spanned elevation gradient from lowest elevation with submerged aquatic vegetation (SAV) and bare mud through low marsh up to high elevation that was not formerly excavated.
- 70 m x 60 m, with 36 quadrat locations
- Baseline azimuth: 330° magnetic
- Transect azimuth: 240° magnetic
- Transect spacing: 12 m, random start: 10
- Quadrat spacing: 10 m, random starts: 7, 8, 1, 1, 1, 0

West Vegetation Sample Area (Figure 20)

- Located in area that will be affected by the dike removal, near proposed site of excavated channel.
- 70 m x 60 m, with 36 quadrat locations
- Baseline azimuth: 312° magnetic
- Transect azimuth: 42° magnetic
- Transect spacing: 12 m, random start: 10
- Quadrat spacing: 10 m, random starts: 0, 7, 3, 9, 1, 5
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Trends Sampling. Within the vegetation sample areas, we revisited trend sampling plots.

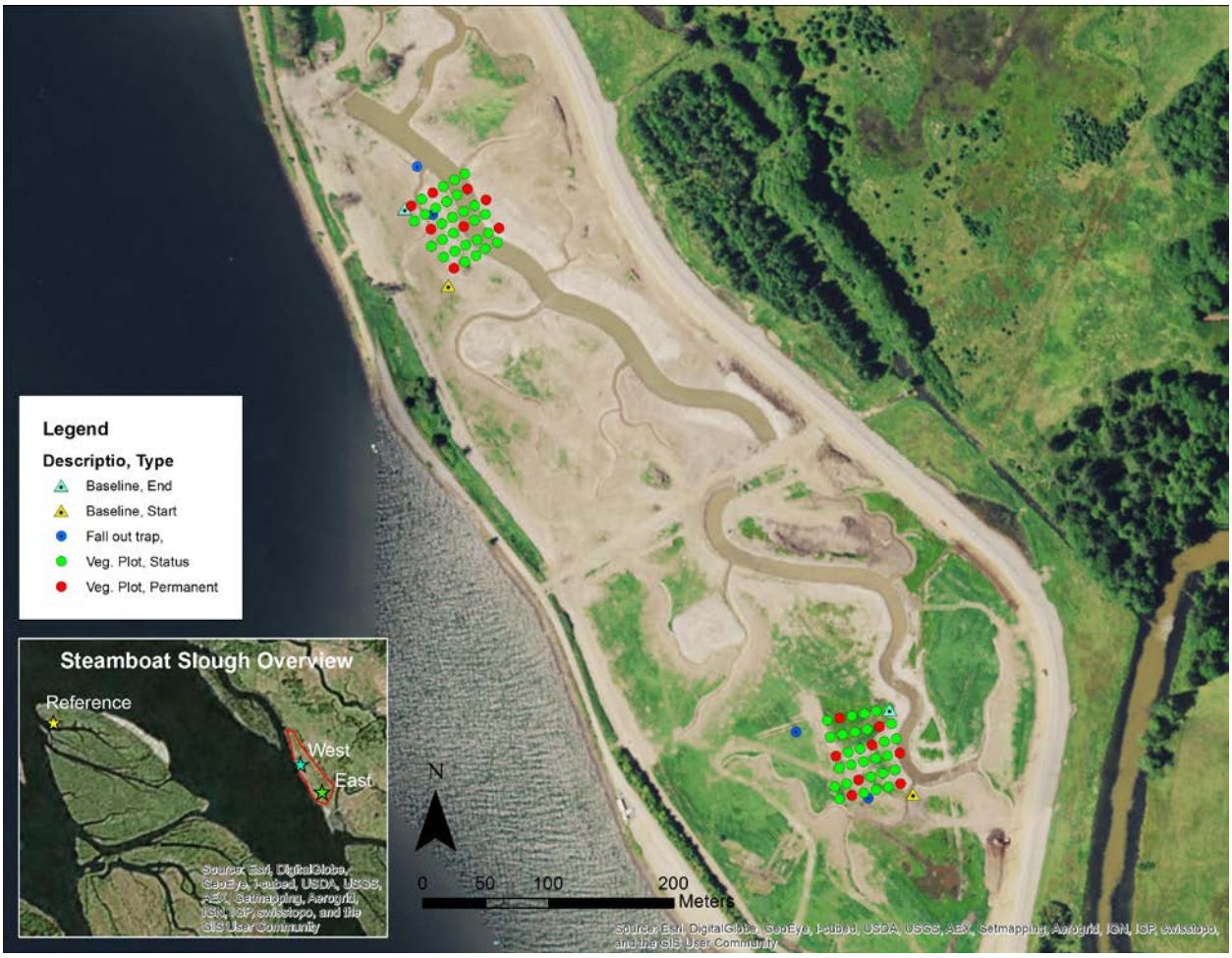

Figure 20. Vegetation and macroinvertebrate sampling locations at the Steamboat Slough restoration site.

Markers Left on Site

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

Benthic

Dibblee Slough

General Site Location

Downstream from Longview, WA on the Oregon side of the river at rkm 104

Ecosystem Type

Restored tidal emergent wetland

Dates of Sampling in 2015
17 June

Types of Sampling in 2015

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

Vegetation Sampling Design

West Vegetation Sample Area (Figure 21)

- Located outside the culvert. Veg sample area spanned elevation gradient from one side of the channel to the bank on the other side.
- 74 m x 30 m, with 36 quadrat locations
- Baseline azimuth: 90° magnetic
- Transect azimuth: 0° magnetic
- Transect spacing: 12m, random start: 6
- Quadrat spacing: 10 m, random starts: 3, 6, 9, 1, 2, 3
- 8 permanent quadrats were re-sampled

East Vegetation Sample Area (Figure 21)

- Located on north side of area inside culvert in the upper end of herbaceous wetland vegetation in natural inlet.
- 74m x 30m, with 36 quadrat locations
- Baseline azimuth: 180° magnetic
- Transect azimuth: 270° magnetic
- Transect spacing: 12m, random start: 1
- Quadrat spacing: 5 m, random starts: 0, 8, 7, 3, 5, 2
- 8 permanent quadrats were re-sampled

Trends Sampling. Marked permanent quadrats locations were resampled for trends sampling.

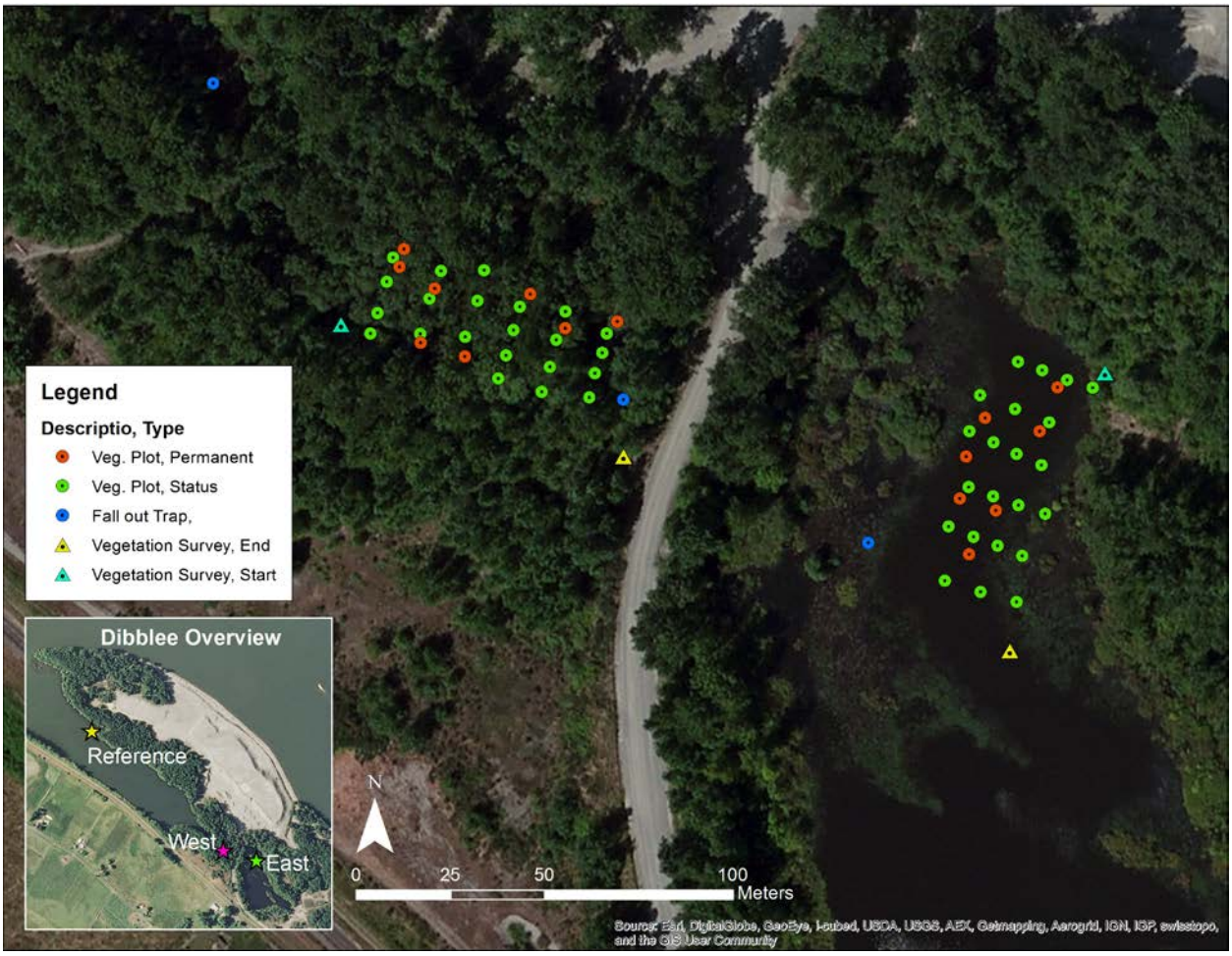

Figure 21. Vegetation and macroinvertebrate sampling locations at the Dibblee Slough restoration site.

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.
- Permanent quadrat stakes; 2 stakes per location in the diagonal corners (SW and NE).

Macroinvertebrate Sampling

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

Dibblee Slough Reference

General Site Location

Downstream from Longview, WA on the Oregon side of the river at rkm 104.

Ecosystem Type

Tidal emergent wetland

Dates of Sampling in 2014
18 June

Types of Sampling in 2014

- *Vegetation*: Herbaceous cover (1 sample area of 36 quadrats)
- *Insect Fall out Traps:* 3 traps
- *Photo Points:*
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design

- Located along the wetland fringe in the inlet inside Dibblee Point. Vegetation sample area spanned elevation gradient from unvegetated flats up to the shrub/tree zone..
- 60 m x 30 m, with 36 quadrat locations
- Baseline azimuth: 240° magnetic
- Transect azimuth: 330° magnetic
- Transect spacing: 10m, random start: 3
- Quadrat spacing: 5 m, random starts: 7, 1, 9, 8, 7, 1
- 8 permanent quadrats were re-sampled

Trends Sampling. Marked permanent quadrats locations were resampled for trends sampling.

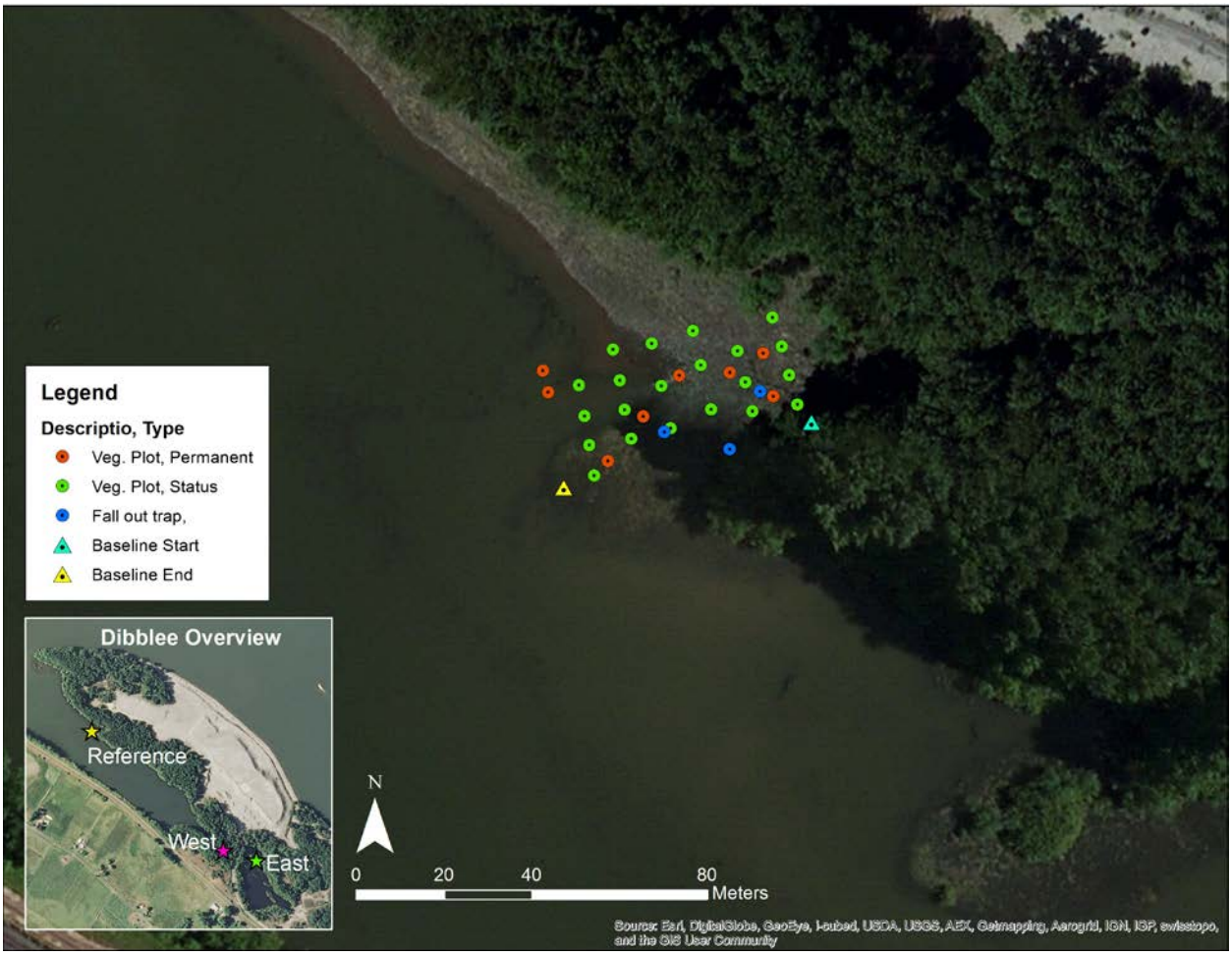

Figure 22. Vegetation and macroinvertebrate sampling locations at the Dibblee Slough reference site.

Markers Left on Site

All marking stakes are white ¾ inch PVC. 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

Terrestrial- 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.

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

Dates of Sampling in 2015
6-7 July

Types of Sampling in 2015

- *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
- *Benthic Macroinvertebrate Cores:* 10 cores in the north vegetation sampling area
- *Photo Points:*
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
North Vegetation Sample Area (Figure 23)

- 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 23)

- 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

Trends Sampling. Within the vegetation sample areas, we revisited trend sampling plots.

Figure 23. Vegetation and macroinvertebrate sampling locations at the La Center Wetlands restoration site.

Markers Left on Site

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.

Benthic- At the north macroinvertebrate sampling site, five benthic macroinvertebrate cores were taken across the vegetation sampling area in May, June, July. At the north vegetation sampling site, five benthic macroinvertebrate cores were taken across the sampling area July.

La Center Reference

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
Emergent Wetland

Dates of Sampling in 2015
7 July

Types of Sampling in 2015

- *Vegetation*: Herbaceous cover (1 sample area, 36 quadrats total)
- *Insect Fall out Traps:* 2
- *Benthic Macroinvertebrate Cores:* 5 cores per vegetation sampling area
- *Photo Points:*
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
Veg Sample area (Figure 24)

- 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

Trends Sampling. Within the vegetation sample areas, we revisited trend sampling plots.

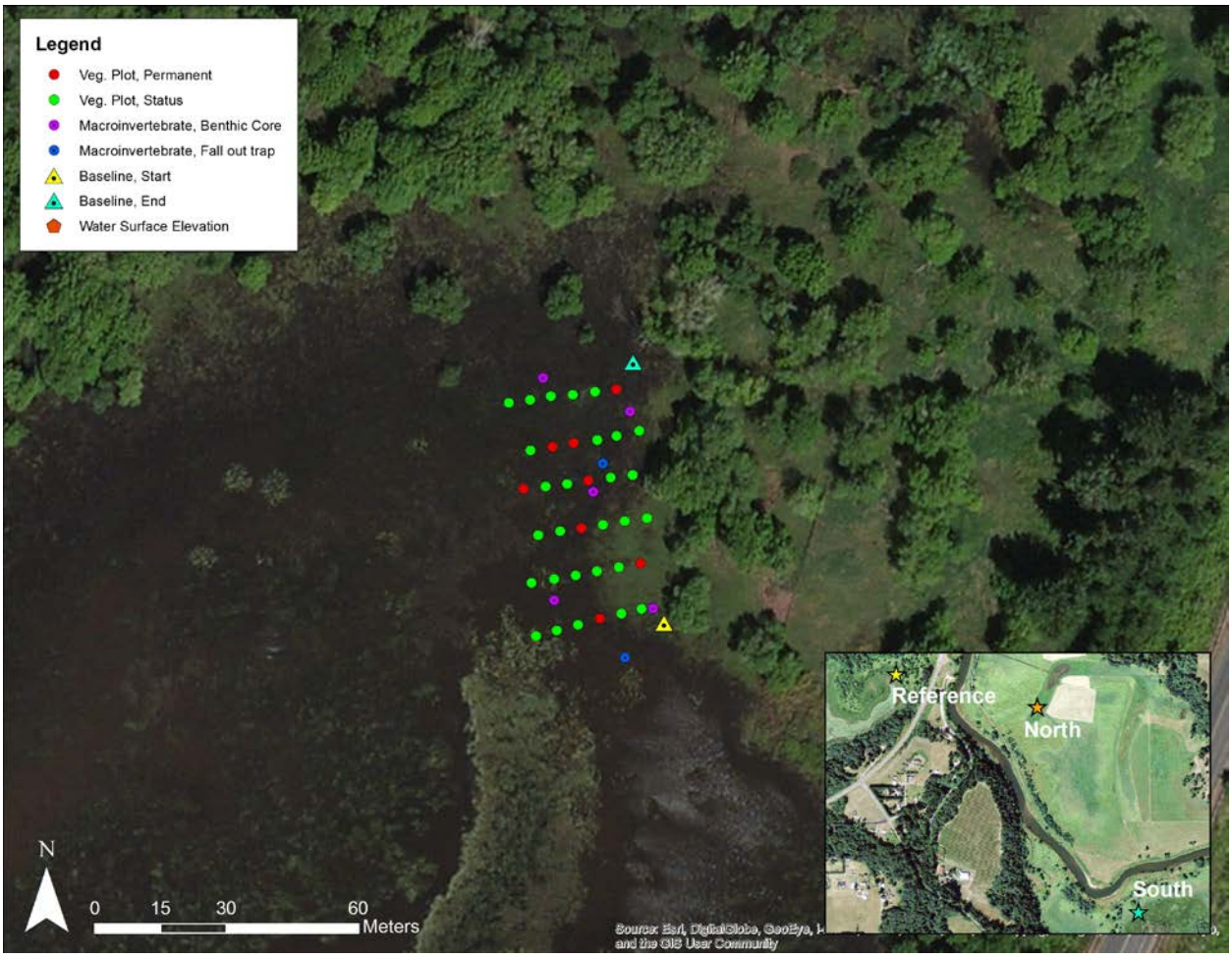

Figure 24. 2014 vegetation and macroinvertebrate sampling locations at the Sandy River dike breach restoration site.

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.

Benthic - At the control vegetation sampling site, five benthic macroinvertebrate cores were taken across the sampling area July.

Sauvie Island North Unit Phase 2 (Deep Widgeon)

General Site Location
North End of Sauvie Island on the east side of Cunningham Slough at rkm 144.

Ecosystem Type
Formerly diked, restoration site

Dates of Sampling in 2015
14 July

Types of Sampling in 2015
See map below for sampling locations (Figure 25)

- *Vegetation*: Herbaceous cover (2 sample areas, 72 quadrats total)
- *Insect Fall out Traps:* 4 traps
- *Photo Points:*
    - 1 photo point at the North Veg Sample area - 360° from 2 m northeast of the 0 m baseline stake
    - 1 photo points at the South Veg Sample area - 360° from 2 m south of 0 m baseline stake
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
North Veg Sample area (Figure 25)

- 40 m x 50 m, with 36 quadrat locations
- Baseline azimuth: 229° magnetic
- Transect azimuth: 319° magnetic
- Transect spacing: 10m, random start: 4
- Quadrat spacing: 5 m, random starts: 4, 0, 4, 1
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects. Permanent plot 4-15 was moved to 14-30 to capture scrape down area.

South Veg Sample area (Figure 25)
Veg sample area spanned the proposed elevation gradient which currently is covered by reed canarygrass and will be scraped down to an elevation to prevent recolonization.

- 50 m x 50 m, with 28 quadrat locations
- Baseline azimuth: 57° magnetic
- Transect azimuth: 327° magnetic
- Transect spacing: 8m, random start: 6
- Quadrat spacing:
    - 4 transects with 5 quadrats at 10 m spacing
    - 2 transects with 4 quadrats at 12 m spacing
    - Random starts: 6, 5, 10, 3, 2, 2
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

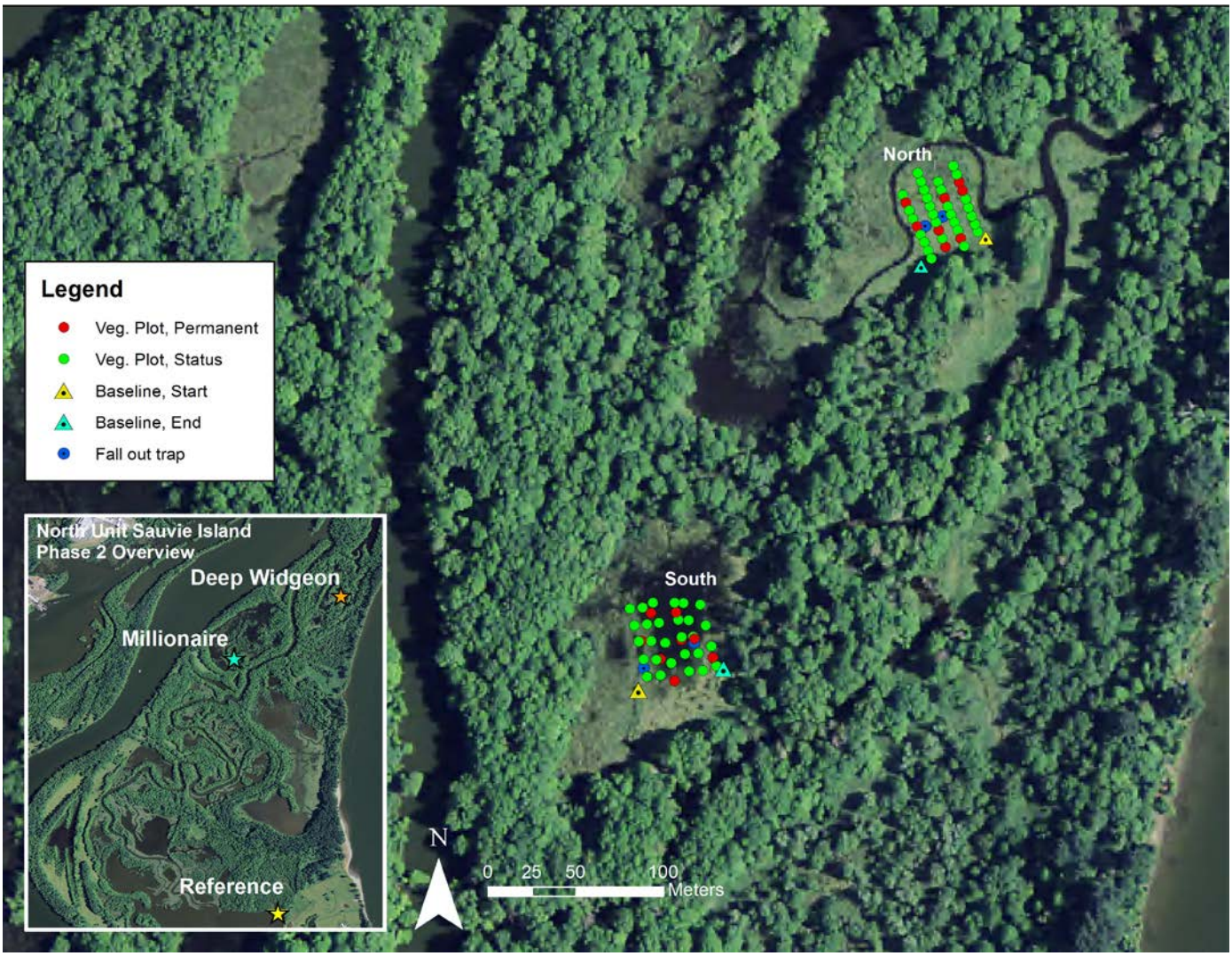

Figure 25. Vegetation and macroinvertebrate sampling locations at the North Unit Phase 2 (Deep Widgeon) restoration site.

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.
- Permanent quadrat stakes; 2 stakes per location in the diagonal corners (SW and NE).

Macroinvertebrate Sampling

Macroinvertebrate fall out traps were placed in two separate locations. Two fall out traps were placed in the Deep Widgeon North vegetation sampling area. Two fall out traps were placed in the Deep Widgeon South vegetation sampling area.

Sauvie Island North Unit Phase 2 (Millionaire Lake)

General Site Location

North End of Sauvie Island on the west side of Cunningham Slough at rkm 144.

Ecosystem Type
Formerly diked, restoration site

Dates of Sampling in 2015
13, 15 July

Types of Sampling in 2015
- *Vegetation*: Herbaceous cover (2 sample areas, 72 quadrats total)
- *Insect Fall out Traps:* 4 traps
- *Photo Points:*
    - 1 photo point at the North Veg Sample area - 360° from 2 m east of the 0 m baseline stake
    - 1 photo points at the South Veg Sample area - 360° from 2 m southwest of 0 m baseline stake
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
North Veg Sample area (Figure 26)
- Located at north end of the southern part of the site. Veg sample area spanned elevation gradient which was scraped down to an elevation to prevent recolonization of reed canarygrass.
- 60 m x 50 m, with 36 quadrat locations
- Baseline azimuth: 343° magnetic
- Transect azimuth: 253° magnetic
- Transect spacing: 10m, random start: 8
- Quadrat spacing: 8 m, random starts: 0, 5, 4, 5, 2, 0
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

South Veg Sample area (Figure 26)
- 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.
- 80 m x 70 m, with 28 quadrat locations
- Baseline azimuth: 323° magnetic
- Transect azimuth: 233° magnetic
- Transect spacing: 13m, random start: 2
- Quadrat spacing:
    - 4 transects with 5 quadrats at 14 m spacing
    - 2 transects with 4 quadrats at 18 m spacing
    - Random starts: 5, 8, 2, 4, 5, 10
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

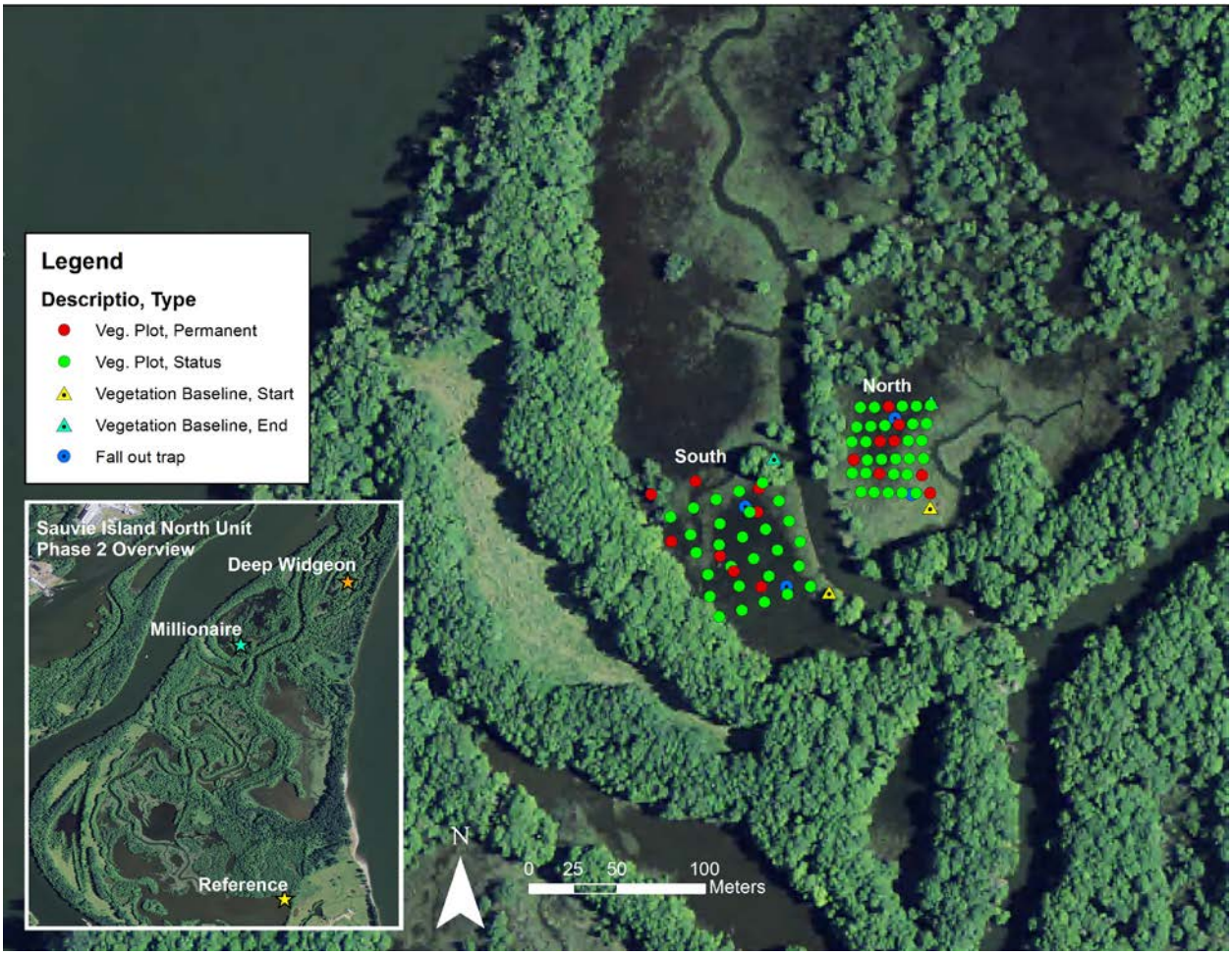

Figure 26. Vegetation and macroinvertebrate sampling locations at the North Unit Phase 2 (Millionaire Lake) restoration site.

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

Macroinvertebrate fall out traps were placed in two separate locations. Two fall out traps were placed in the Millionaire North vegetation sampling area. Two fall out traps were placed in the Millionaire South vegetation sampling area.

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"

Dates of Sampling in 2015
28 July

Types of Sampling in 2015
See map below for sampling locations (Figure 27).

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

Vegetation Sampling Design
Veg Sample area (Figure 27)

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

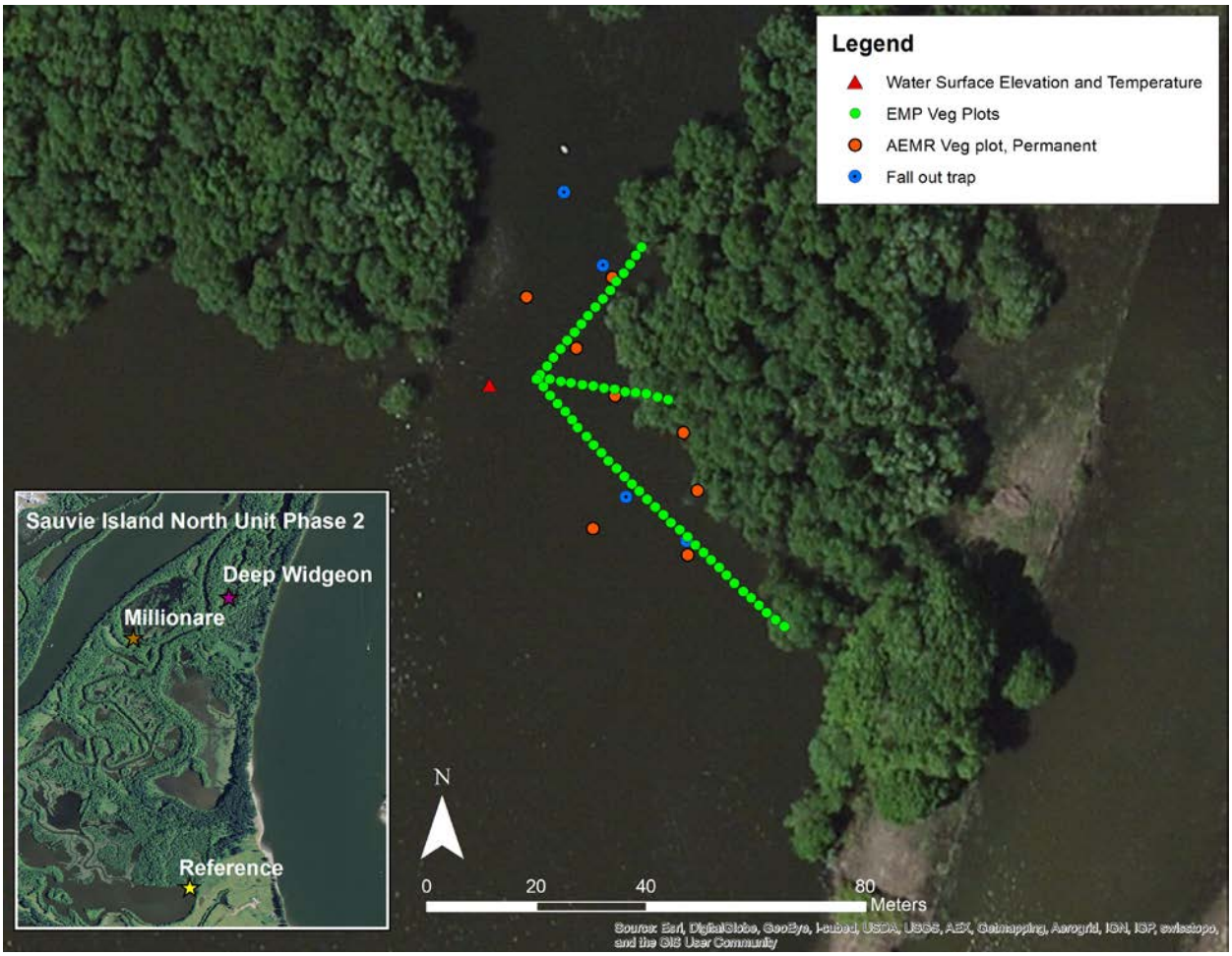

Figure 27. Vegetation and macroinvertebrate sampling locations at the Cunningham Lake reference site.

Markers Left on Site

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

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

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

Macroinvertebrate Sampling

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