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 12 (October 2015 to September 2016)

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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 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 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 degree of monitoring. AEM levels consist of Standard (Level 3), Extensive (Level 2), and Intensive (Level 1).

We conducted AEM at twenty restoration sites in the lower Columbia River and Estuary in 2016. Sixteen restoration sites received Standard Level 3 monitoring. All monitoring was conducted following standardized protocols outlined in Roegner et al. (2009). Using the prioritization process outlined in the AEM Programmatic Plan, four restoration sites and four references were selected for Extensive Level 2 monitoring in addition to receiving Standard Level 3 monitoring. We selected reference sites to implement a Before-After Reference-Impact monitoring design at Level 2 monitoring sites. We also operated a PIT tag array at Horsetail Creek to determine type and residency time of salmonids at the site and address uncertainties related to fish passage through long culverts.

We evaluated emergent wetland vegetation 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 cover was moderately correlated to average marsh elevation, species richness, species diversity, and bare ground. Higher marsh elevations were associated with decreasing percent bare ground. Vegetation species richness was lowest at pre-restoration sites and highest at year three post-restoration sites. After one year post restoration, vegetation species diversity decreased even though species richness increased compared to pre-restoration conditions.

In monitoring areas where marsh lowering restoration activities occurred, the vegetation similarity between pre- and one year post-restoration condition was low. The vegetation community is showing evidence of succession, from predominately bare ground at Year one post-restoration the sites to an emergence of a native plant assemblage similar to reference site conditions at three years post-restoration. In monitoring areas directly impacted by dike breaches, plant communities are changing slowly. At three years post restoration, plant communities are showing change from pre-restoration condition with increased species richness and the appearance of new native wetland species; however, invasive reed canarygrass persists at these sites at a similar abundance observed during pre-restoration.

Benthic and terrestrial macroinvertebrates were evaluated at the site level to determine the status of available salmonid prey at post-restoration sites. Dipteran abundance in benthic samples was consistent across months, but the proportion of sample containing Dipterans was lower than under pre-restoration condition. Terrestrial macroinvertebrate species availability was greater at post-restoration sites in 2016 than under pre-restoration conditions.

The PIT array at Horsetail Creek detected upstream hatchery spring, fall, and summer Chinook; hatchery Coho; steelhead; and summer sockeye. Detections primarily occurred between April and June.

Restoration actions impact wetland emergent habitats both directly and indirectly. The vegetation at sites three years post restoration appear to be following a similar trend toward a vegetation state which has elements of reference conditions and a response to site specific physical drivers. Terrestrial and benthic invertebrate prey communities, influenced by site and larger environmental factors, consist of species consumed by juvenile salmonids. Long-term monitoring data from the Ecosystem Monitoring Program (EMP) will continue to put the results from restoration site monitoring into 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 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 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 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

The objectives of the AEM program in 2016 at the landscape level were to determine similarity of restoration sites and reference sites within the same vegetation zones. At the site scale, objectives were to quantify changes to vegetation related to changes in marsh elevation lowering, determine impacts to existing wetlands within restoration sites, quantify salmonid prey at restoration sites, and determine fish use at selected sites. To incorporate larger spatial scales to examine ecological changes at restoration and reference sites, the Estuary Partnership's AEM Program incorporated data from the 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

Twenty restoration sites received action effectiveness monitoring in 2016 (Table 1 and Table 2). Four restoration sites were selected for Level 2 monitoring (Table 1) using the prioritization criteria outlined in Johnson et al. (2014). 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). Sixteen 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 prior to the establishment of AEM prioritization process (Figure 2).

Table 1. Restoration sites and associated reference sites selected for Level 2 monitoring in 2016

Restoration Site	Location	Pre-Restoration Monitoring Date	Post-Restoration Monitoring Date	Reference Site and Monitoring Dates
Kandoll Farm	Rkm 37 and approximately 5 km up the Grays River	25-28 June 2013	25-26 June 2014 27-28 July 2016	Secret River 24-25 July 2013 14-15 July 2014 6 August 2016
La Center Wetlands	Rkm 140 and approximately 12 Km up the Lewis River	6-7 July 2015	19-20 July 2016	La Center Control 7 July 2015 19 July 2016
Sauvie Island North Unit Phase 1 (Ruby Lake)	Rkm 144	16-17 July 2014	13-15 July 2015 18 July 2016	Cunningham Lake 18 July 2014 28 July 2015 1 August 2016
Sandy River Delta	Rkm 200		22-23 July 2014 2-3 August 2016	Gary Island 24 July 2014 4 August 2016

Table 2. Restoration sites receiving Level 3 monitoring in 2016

Restoration Site	Location	Pre-Restoration Monitoring Year	Post-Restoration Monitoring Year
Skipanon Slough	Rkm 17	2016	
Kandoll Farm	Rkm 37	2013	2014, 2015, 2016
Karlson Island	Rkm 42	2014	2015, 2016
Elochoman	Rkm 60	2015	2016
Elochoman Slough East	Rkm 60	2016	
Kerry Island	Rkm 72	2015	2016
Westport Slough	Rkm73	2016	
Batwater	Rkm 91	2015	2016
Dibblee	Rkm 92	2012	2013, 2015
La Center Wetlands	Rkm 140	2015	2016
Crane-Domeyer	Rkm 142	2016	
North Unit Phase 1	Rkm 144	2013	2014, 2016
North Unit Phase 3	Rkm 145	2015	2016
Willow Bar	Rkm 154	2016	
Buckmire Phase 1	Rkm 158	2015	2016
Horsetail Creek	Rkm 222	2014	2015, 2016, 2017
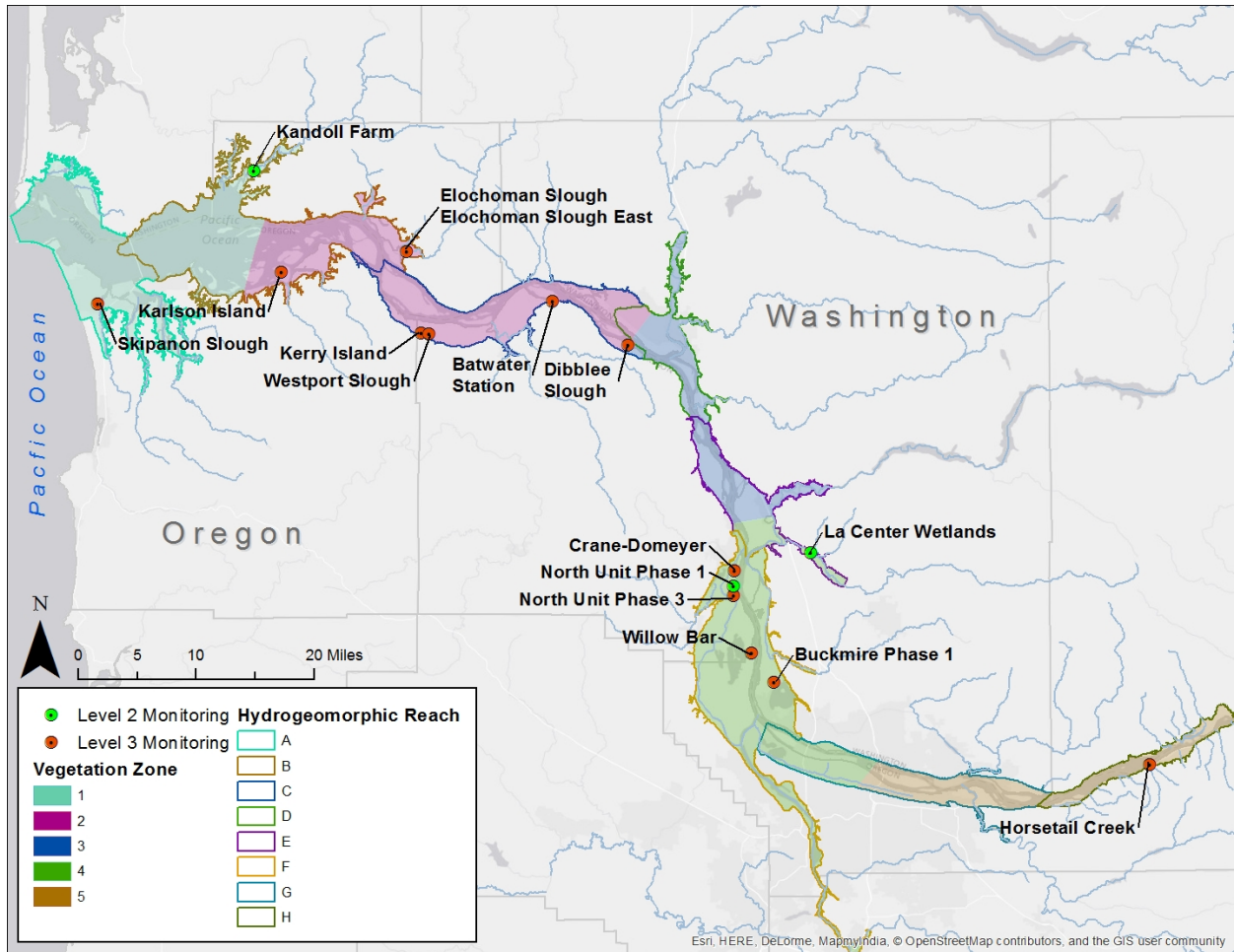
Figure 1. 2016 Level 2 and Level 3 AEM sites
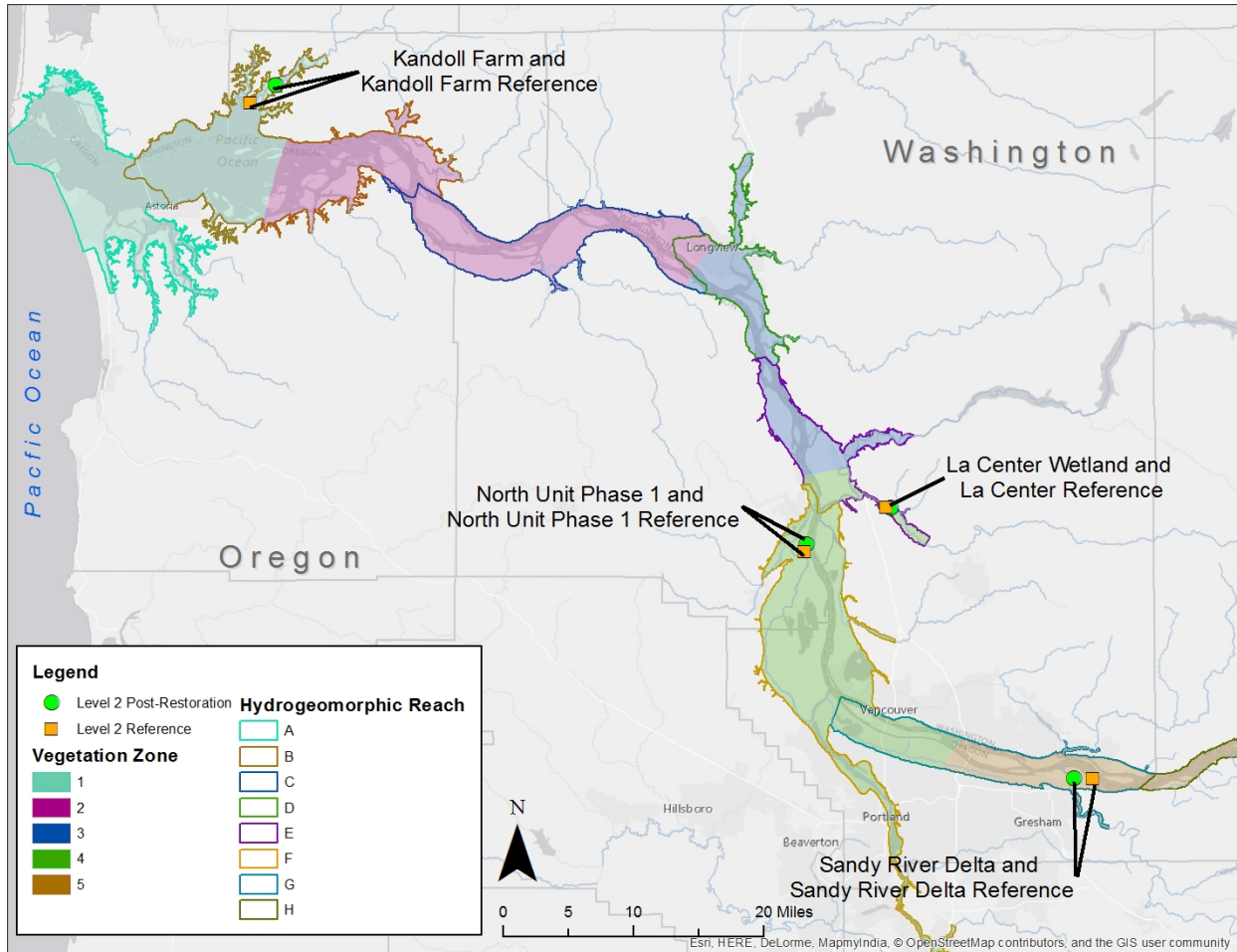
Figure 2. 2016 Level 2 AEM restoration and reference site monitoring locations.

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.

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. 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

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([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.

We collected terrestrial and benthic macroinvertebrates to assess the capacity of a restoration site to provide prey resources for juvenile salmonids. 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 Kandoll Farm, North Unit Phase 1, and La Center Wetland restoration and reference sites terrestrial macroinvertebrates were collected, four macroinvertebrate fall out traps were installed in proximity to each vegetation sampling area to capture species assemblage of invertebrates. At La Center Wetland, 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 site once per 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 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). 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). The vegetation data was 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 33 sample units and 151 vegetation species reported as average percent cover (Table 3). The environmental matrix consisted of 33 sample units and 9 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 large wood debris.

Table 3. Sites and years included in vegetation analysis

	Pre-Restoration	Post-Restoration	Reference
Vegetation Zone 1			
Kandoll Farm A	2013	2014, 2016	
Kandoll Farm E			
Secret River			2013, 2014, 2016
Vegetation Zone 4			
La Center North	2015	2016	
La Center South	2015	2016	
La Center Control			2015, 2016
North Unit Sauvie Island Phase 1 North	2013	2014, 2016	
North Unit Sauvie Island Phase 1 South	2013	2014, 2016	
Cunningham Lake			2013, 2014, 2016
Vegetation Zone 5			
Sandy River Delta Dam		2014, 2016	
Old Sandy River Mouth		2014, 2016	
Gary Island			2014, 2016

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 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
Based on vegetation composition and cover, vegetation zones one and four were significantly different (ANOSIM; p=.0001). Vegetation zone five was found to be significantly different from vegetation zones one and four respectively (ANOSIM; p=.0001and p=.0001).

A NMS ordination with a three-dimensional solution of plots in species space was used (Final stress= 11.30, final stability ≤.000001, number of iterations= 72). The three-axis solution explained 82% of the variation in the data. The solution was rotated so bare ground and average marsh elevation was parallel with axis one. Species richness and species diversity were parallel with axis three (Figure 3). Axis one shows vegetation has a strong positive correlation with bare ground (r =.77) and a negative moderate correlation average marsh elevation (r=.51).

Axis three shows a positive strong correlation with species richness (r =.71), a moderate correlation with species diversity (r =.55), and weak correlation with Large Woody Debris (r=.41) (Figure 3).
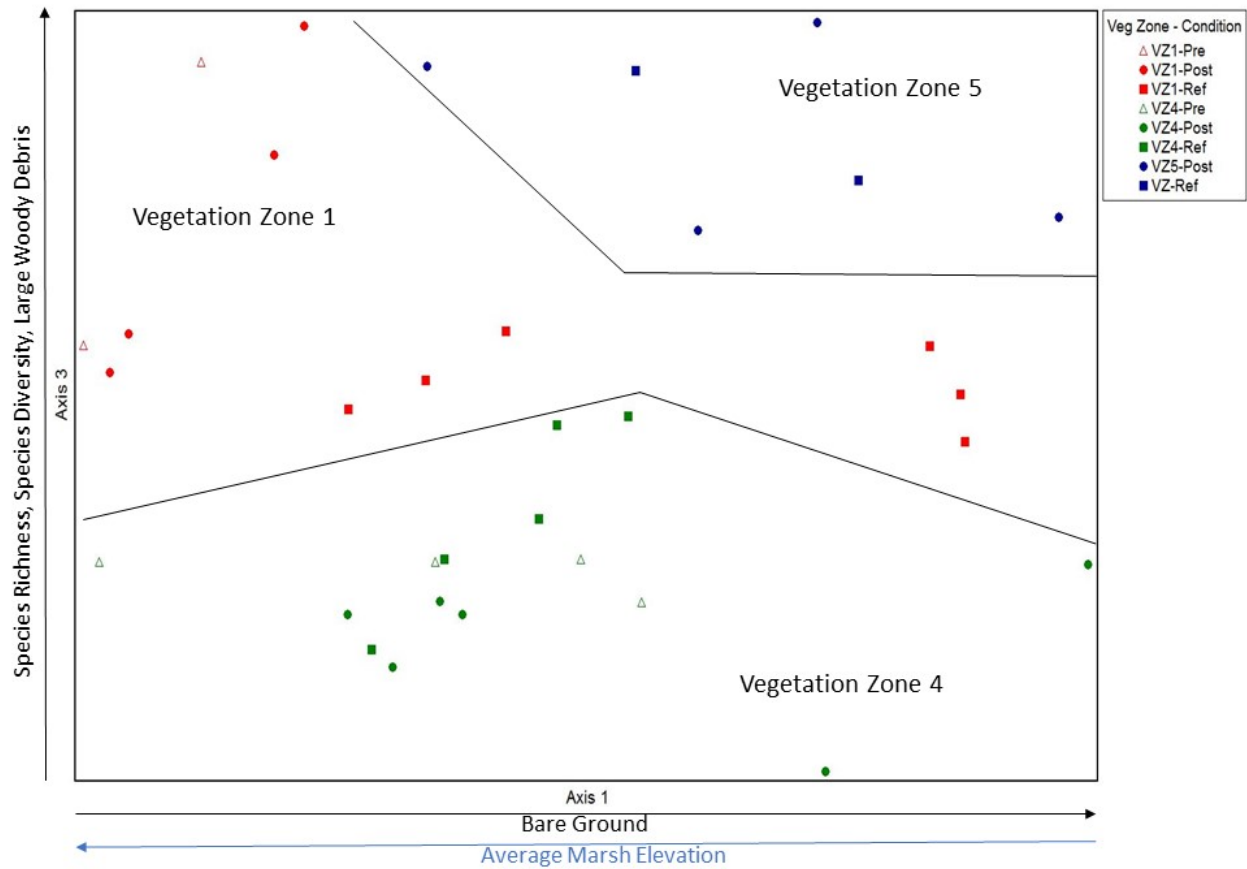
Figure 3. NMS ordination of sample units in species space. Axis 1 is correlated with bare ground and average marsh elevation. Axis 3 is correlated with species richness, species diversity, and large woody debris. Different vegetation zones are demarcated.

Kandoll Farm
The Kandoll Farm restoration site has two vegetation monitoring areas (Figure 16) which were sampled pre-restoration, one year post-restoration, and three 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.

Status
Vegetation Composition
In 2016, the KFA monitoring site was characterized by mix of native and invasive species. Reed canarygrass (*Phalaris arundinacea*) and creeping buttercup (*Ranunculus repens*) were the

dominant vegetation species with an average cover of 55% (Figure 4). Native species Panicaled bulrush (*Scirpus microcarpus*), nodding beggartick (*Bidens cernua*), impatiens spp., and common rush (*Juncus effuses*) had an average cover of 25% (Figure 4). Reed canarygrass was the dominant species at the KFE monitoring site with an average cover of 84% (Figure 4). Together native Wapato (*Sagitaria latifolia*), Impatiens spp., and American skunkcabbage (*Lysichiton americanum*) had an average cover of 13%. At the reference site, Lyngbye's sedge (*Carex lyngbyei*) was the dominant vegetation species with an average cover of 41%, but invasive reed canarygrass had an average cover of 21% (Figure 4).
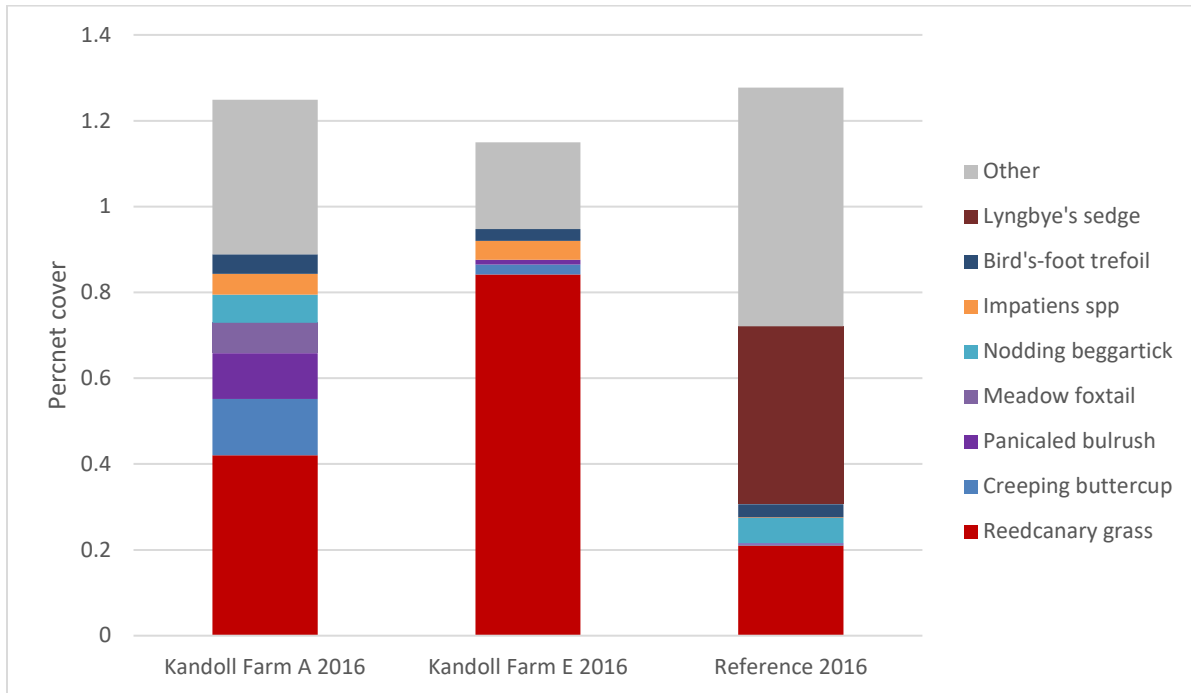
Figure 4. 2016 vegetation Status at Kandoll Farm

Trend

Vegetation Similarity

Kandoll Farm and associated reference sites were sampled (n=9) once pre-restoration (2013) and twice post-restoration (2014, 2016). Pre-restoration Kandoll Farm had a 48% similarity between the two vegetation sampling areas and had less than a 29% similarity with the reference site at Secret River (SRH, Table 4). Year one post-restoration Kandoll Farm had a 40% similarity between the two vegetation sampling areas and 42% similarity between sampling areas year three post-restoration. In year one and three post restoration, Kandoll Farm had less than 29% similarity to the reference site (Table 4). Year one post-restoration at KFA had a 63% similarity to pre-restoration condition and year three post-restoration had a 53% similarity to pre-restoration condition. At KFE, from pre-restoration to year one post-restoration, the vegetation similarity was 73%, while year three post-restoration had a 53% similarity to pre-restoration condition. At the reference site, from 2013 to 2014 the vegetation similarity was 81%. When 2013 and 2016 were compared the vegetation similarity was 65%.

Table 4. Similarity index for restoration and reference sites in vegetation zone one. Yellow highlights represent 60-69% similarity and green represents greater than 70% similarity.

	KFE16	KFE14	KFA14	KFE13	KFA13	SRH13	SRH14	SRH16
KFA16	0.38	0.53	0.55	0.40	0.53	0.28	0.24	0.22
KFE16		0.54	0.29	0.52	0.20	0.26	0.24	0.16
KFE14			0.37	0.73	0.39	0.34	0.31	0.20
KFA14				0.25	0.63	0.13	0.17	0.12
KFE13					0.36	0.32	0.23	0.19
KFA13						0.24	0.26	0.21
SRH13							0.81	0.65
SRH14								0.69

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

Vegetation Composition

At KFA in 2016 species richness increased compared to pre-restoration and year one post restoration and species diversity slightly increased since pre-restoration monitoring (Table 5). Invasive reed canarygrass cover increased from pre-restoration by 16%, while creeping buttercup cover decreased by 10% (Figure 5). Native narrowleaf bur-reed (*Sparganium angustifolium*) which was not present pre-restoration increased 13% post-restoration (Figure 5). At the KFE monitoring area both species richness and species diversity decreased post restoration. Reed canarygrass cover increased from pre-restoration condition by 25% while creeping buttercup decreased by 10% over the same period. Lyngbye's sedge was the dominant vegetation species with an average cover of 41%, but invasive reed canarygrass had an average cover of 21% at the reference site (Figure 5).

Table 5. Species richness and species diversity at Kandoll Farm

Condition	Area	Average marsh elevation (m-CRD)	Species Richness	Species Diversity
Pre-restoration	KFA13	1.87	19	2.2
	KFE13	2.07	15	1.5
Post-restoration 1	KFA14	2.27	18	2.3
	KFE14	2.11	14	1.5
Post-restoration 3	KFA16	2.38	26	2.5
	KFE16	2.46	12	0.9
Reference	SRH13	2.05	32	2
	SRH14	1.94	37	2.2
	SRH16	2.08	47	2.5
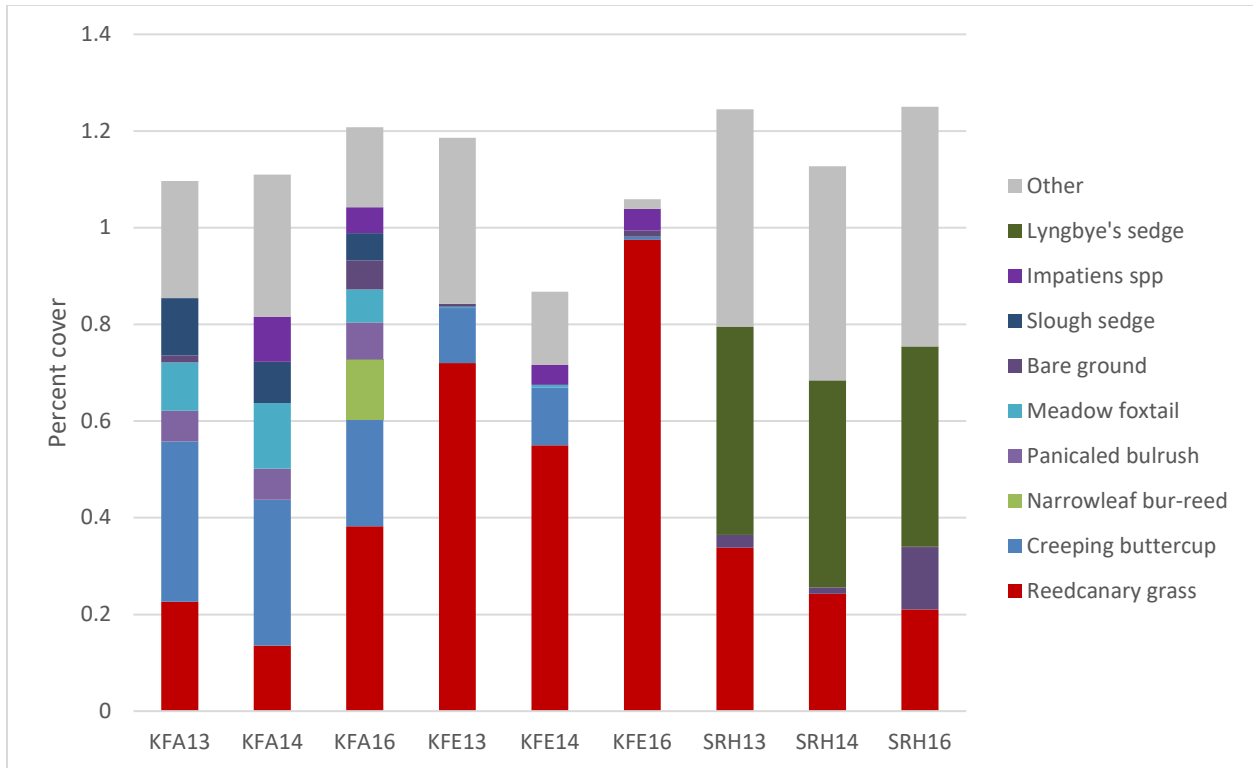
Figure 5. Trend vegetation cover and composition for Kandoll Farm and Secret River Reference site

Line Point Intercept
Line point intercept monitoring transects were established during the first phase of restoration to track changes in vegetation. The vegetation community shifted following initial and subsequent restoration actions. At KFA 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 6). At KFE a similar trend was observed with mixed field grasses disappearing from the site and wetland plants increasing (Figure 7). At both sites, the occurrence of planted willows (*Salix* spp.) is increasing along both transects (Figure 7).
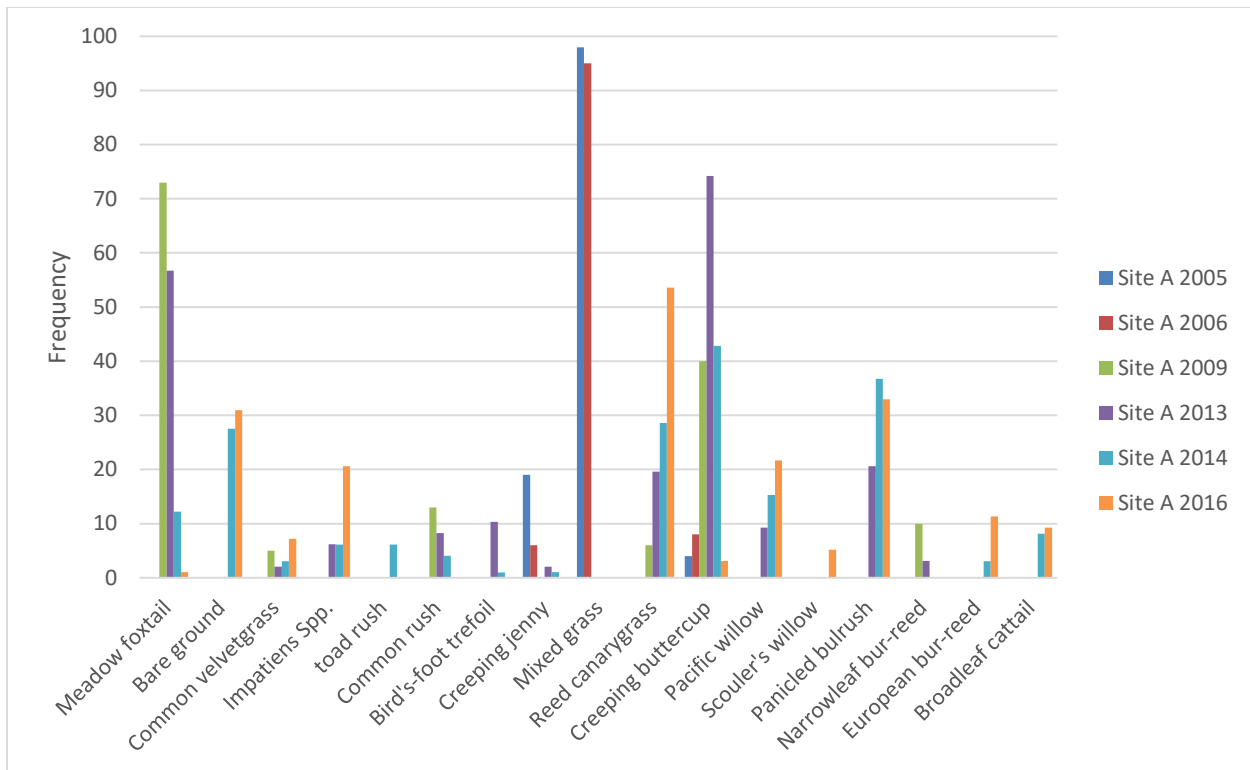
Figure 6. Frequency of occurrence for vegetation at Kandoll Farm A
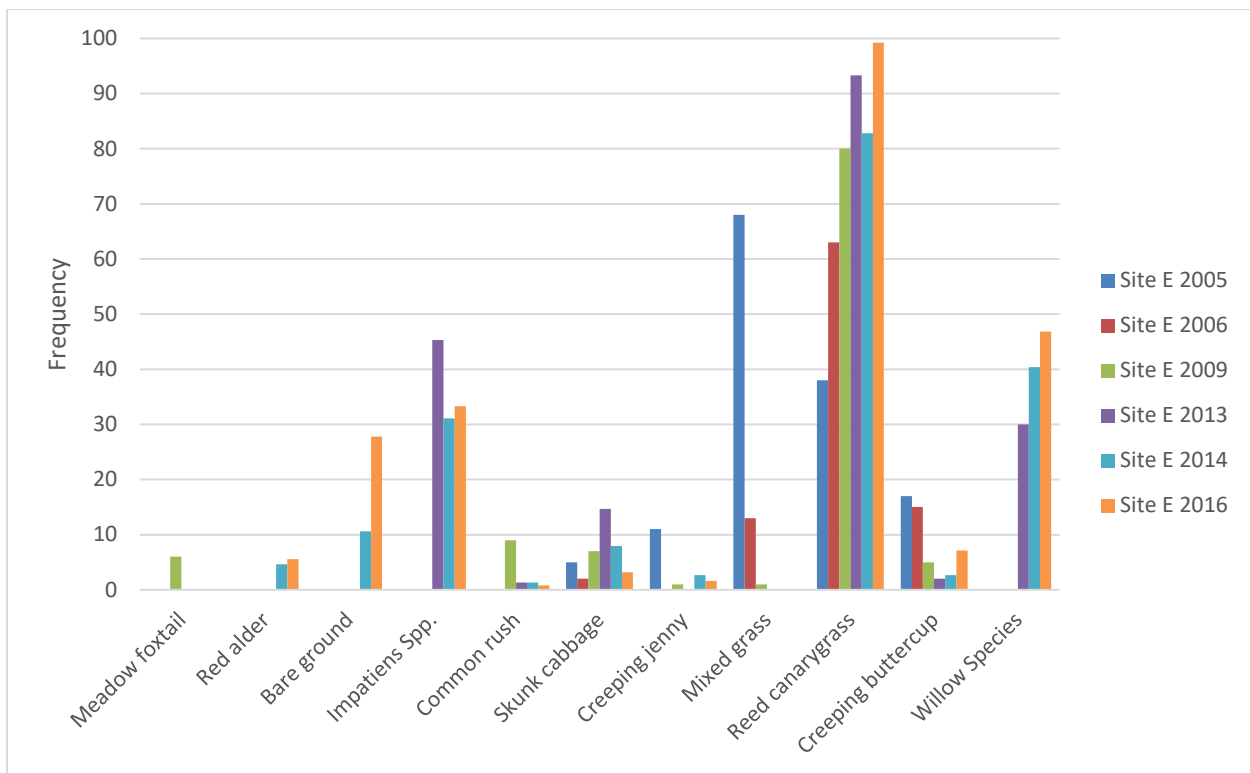
Figure 7. Frequency of occurrence for vegetation at Kandoll Farm E

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 post-restoration, and three 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 indirect changes to established wetland within the restoration site.

<u>*Status*</u>
Vegetation Composition
The RLN site was primarily characterized by bare ground in 2016. Native wapato and ribbonleaf pondweed (*Potamogeton epihydrus*) were the dominant vegetation with an average vegetation cover of 18% and 13%, respectively (Figure 8). The RLS site was characterized by native and invasive vegetation species. Invasive reed canarygrass had an average cover of 64%, while native wapato had an average cover of 50% and spike rush had 8%. At the reference site the average cover of reed canarygrass was 47%. The dominant native species were wapato with an average cover of 28% and spike rush with an average cover of 10% (Figure 8).
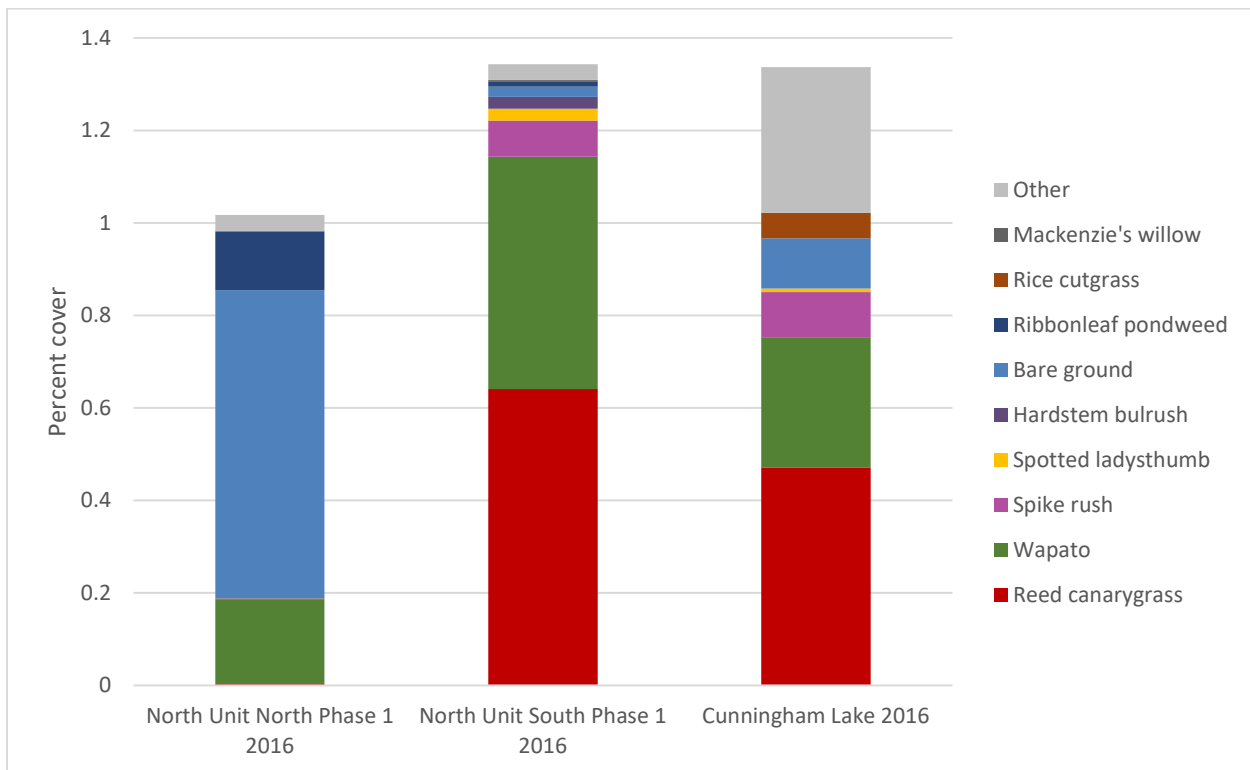
Figure 8. 2016 vegetation status at Sauvie Island North Unit Phase 1

<u>*Trend*</u>
Vegetation Similarity
Ruby Lake and associated reference site were sampled (n=9) once pre-restoration (2013) and twice post-restoration (2014, 2016). Pre-restoration Ruby Lake had a vegetation similarity of

31% between the north and south sampling areas. The north site had 29% similarity to the reference site while south site had a 59% vegetation similarity. Year one post-restoration vegetation similarity decreased to 14% between the north and south site and increased to 25% in year three post-restoration. Pre-restoration Ruby Lake north had a vegetation similarity of 4% to the same area year one and year three post-restoration. The Ruby Lake south site pre-restoration had a vegetation similarity of 86% to year one post-restoration and 66% year three post-restoration. When compared to the reference site, the north and south sampling areas differ dramatically. Pre-restoration Ruby Lake north had a 29% vegetation similarity to the reference site. Year one post-restoration the vegetation similarity increased to 42% but returned to 29% year three post-restoration. At the Ruby Lake south pre-restoration, the vegetation similarity to the reference site was 59%. Post-restoration the vegetation similarity has decreased to 42% year one post-restoration and 49% post restoration year three. Over the same period of time the vegetation similarity at the reference site ranged from 59% to 72% (Table 6).

Table 6. Similarity index for restoration and reference sites in vegetation zone one. Yellow highlights represent 60-69% similarity and green represents greater than 70% similarity.

	RLS16	RLN14	RLS14	RLS13	RLN13	CL13	CL14	CL16
RLN16	0.25	0.51	0.29	0.30	0.04	0.37	0.30	0.29
RLS16		0.06	0.58	0.66	0.27	0.46	0.32	0.49
RLN14			0.14	0.14	0.04	0.33	0.36	0.15
RLS14				0.86	0.28	0.51	0.42	0.48
RLS13					0.31	0.59	0.42	0.50
RLN13						0.29	0.24	0.32
CL13							0.72	0.59
CL14								0.64

RLN = Ruby Lake North
RLS = Ruby Lake South
CL = Cunningham Lake reference site

Vegetation Composition
At Ruby Lake North and South species richness and species diversity increased from pre-restoration to post restoration year three (Table 7). Invasive reed canarygrass was the only vegetation species identified at Ruby Lake North. Year one post-restoration, due to the lowering of the marsh elevation, bare ground was predominant with an average cover of 96%. Year three post-restoration, native wapato became the dominant vegetation with an average cover of 21% and bare ground decreased to an average cover 57% (Figure 9). At Ruby Lake South wapato increased by 50% from pre-restoration to year three post-restoration. Over the same period of time the cover of reed canarygrass remained unchanged and native common spikerush decreased by 29% (Figure 9). At the reference site, bare ground decreased and both reed canarygrass and wapato increased to an average cover of 47% and 28% respectively (Figure 9).

Table 7. Species richness and species diversity at Ruby Lake

Condition	Area	Average marsh elevation (m-CRD)	Species Richness	Species Diversity
Pre-restoration	RLN13	1.81	1	0.0
	RLS13	1.47	7	1.1
Post-restoration 1	RLN14	0.99	3	0.4
	RLS14	1.45	5	0.9
Post-restoration 3	RLN16	0.99	6	1.2
	RLS16	1.43	9	1.4
Reference	CL13	1.51	12	1.6
	CL14	1.24	16	2.0
	CL15	1.48	24	1.7
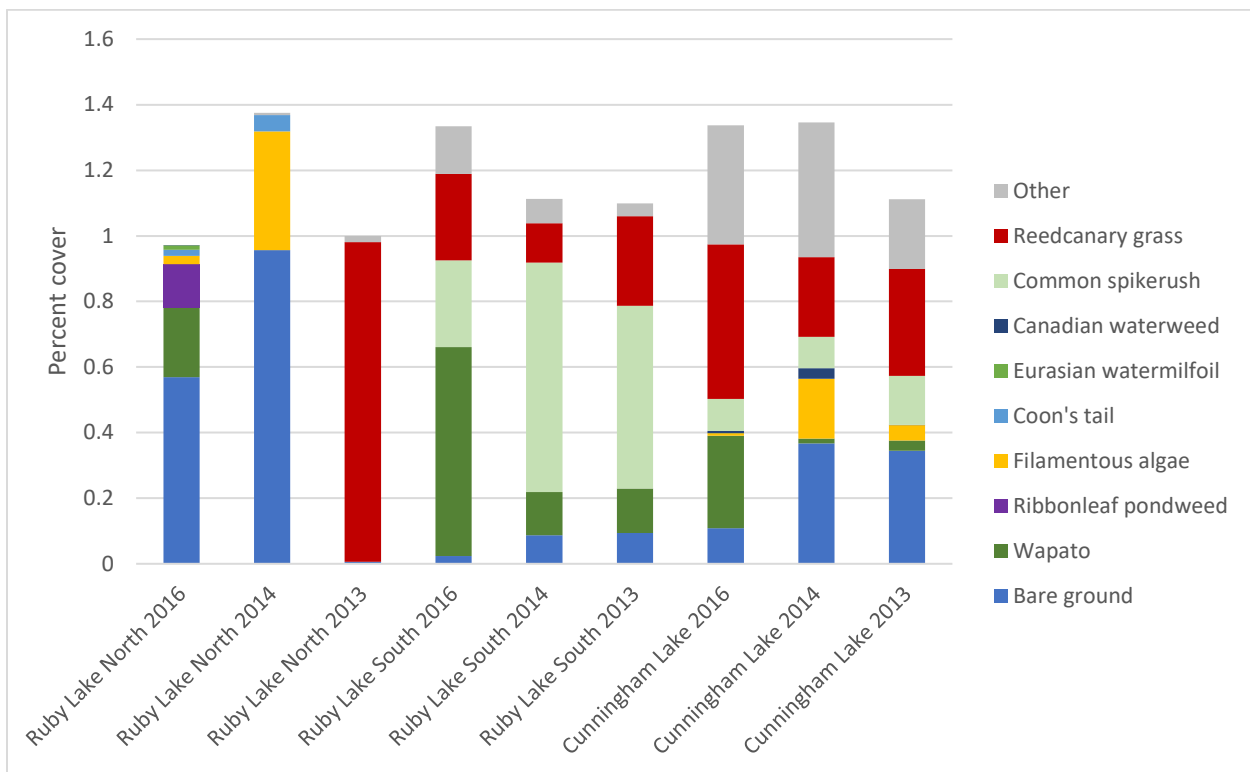
Figure 9. Trend vegetation cover and composition for Ruby Lake and Cunningham Lake Reference site

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 and one 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.

Trend
Vegetation Similarity
The La Center Wetlands and reference site were sampled (n=6) once pre-restoration (2015) and once post-restoration (2016). Pre-restoration La Center Wetlands had a vegetation similarity between 43 and 43B sampling sites of 45% (Table 8). Year one post-restoration the vegetation similarity decreased to 37% between the two restoration sites. Compared to the reference site, site 43 had a 49% similarity and site 43B had a 55% similarity pre-restoration (Table 8). Post-restoration both 43 and 43B had vegetation similarity of 36% and 37%, respectively compared to the reference site. Between 2015 and 2016 the reference site had a 53% vegetation similarity compared to itself (Table 8).

Table 8. Similarity index for restoration and reference sites for La Center Wetlands. Yellow highlights represent 60-69% similarity.

	LACC16	43_15	43_16	43B_15	43B_16
LACC15	0.47	0.49	0.55	0.55	0.48
LACC16		0.62	0.36	0.58	0.35
43_15			0.64	0.45	0.63
43_16				0.56	0.37
43B_15					0.47

43 = La Center Wetlands Site 43
43B = La Center Wetlands Site 43B
LACC = La Center control site

Vegetation Composition
At site 43 species richness decreased and species diversity increased from pre-restoration to post-restoration (Table 9). Native wapato increased from an average cover of 19% to 34%; however, invasive reed canarygrass increased from 11% to 27% (Figure 10). Bare ground decreased by 22% between pre- and post-restoration. Two species, narrowleaf bur-reed and water lily (*Nymphaeaceae spp.*) were not found at the site post-restoration. For site 43B both species richness and species diversity decreased from pre-restoration to post-restoration condition. Wapato increased an average of 20% and reed canarygrass increased an average 13% between pre- and post-restoration. Over the same period of time bare ground decreased and narrowleaf bur-reed disappeared form the sampling area. The reference site followed a similar trend as site 43 with a decrease in species richness and an increase species diversity. Bare ground decreased by 35% between 2015 and 2016. During the same time, wapato increased 9% and reed canarygrass increased 19% (Figure 10).

Table 9. Species richness and species diversity at La Center Wetlands

Condition	Area	Average marsh elevation (m-CRD)	Species Richness	Species Diversity
Pre-restoration 2015	43_15	2.02	25	2.071
	43B_15	2.71	18	1.947
Post-restoration 2016	43_15	1.94	20	2.155
	43B_16	2.61	11	1.26
Reference	LACC15	2.60	23	1.412
	LACC16	2.50	22	1.78
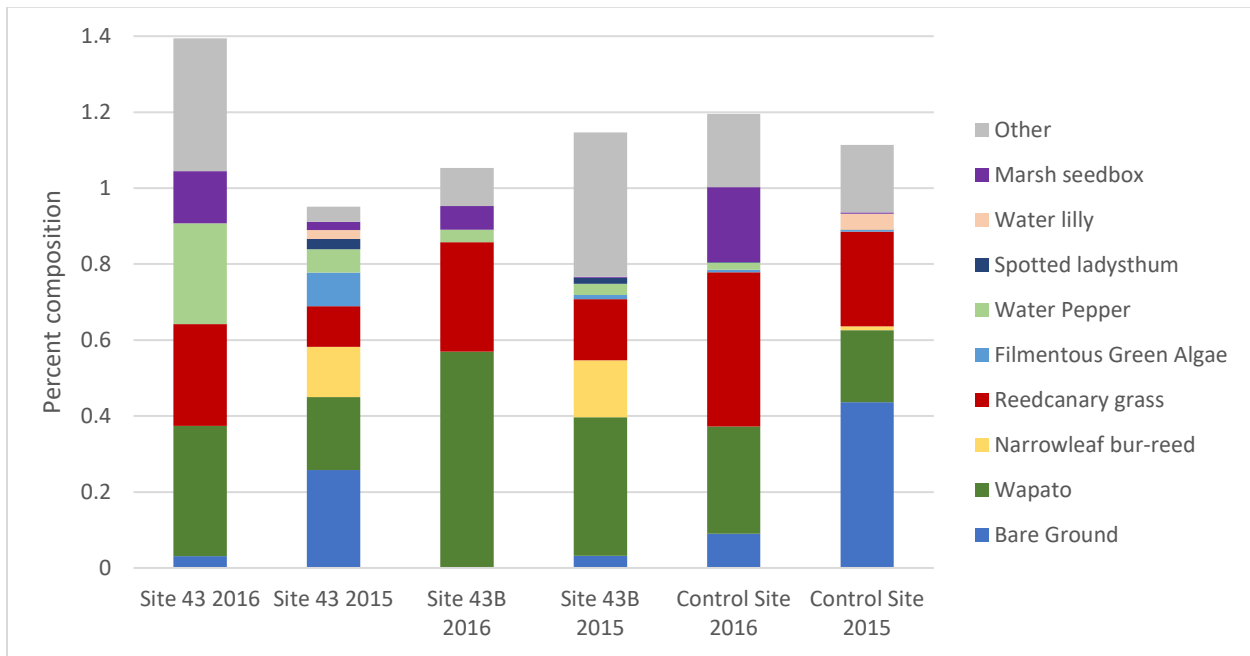
Figure 10. Trend vegetation cover and composition for La Center Wetlands and reference site

Sandy River Delta

Vegetation Similarity
The Sandy River Dam restoration has two vegetation sampling areas, the Sandy Dam site (SRDD) and Old Sandy Mouth (SRDM) site (Figure 22 and Figure 23). The Sandy Dam site was sampled for two years pre-restoration and two years post-restoration. The Sandy Dam site was established to capture changes in vegetation related to the removal of a small dam. The Old Sandy Mouth site was sampled one year pre-restoration and two years post restoration and was established to capture indirect changes related to the removal of the small dam upstream.

<u>Trend</u>
Vegetation Similarity
The Sandy River Delta and reference site were sampled (n=9) twice pre-restoration (2006, 2007) and twice post-restoration (2014, 2016). Pre-restoration the Sandy River Delta site had

vegetation similarity of 30% between the sampling areas (Table 10). Year one post restoration the Sandy River Dam site had a 44% vegetation similarity to the Old Sandy Mouth site (Table 10). Three years post-restoration the vegetation similarity between vegetation sampling sites was 41%. Compared to the reference site, three years post-restoration, the Sandy Dam site had a vegetation similarity of 10% and the Old Sandy Mouth site had a vegetation similarity of 6% (Table 10).

Table 10. Similarity index for restoration and reference sites at Sandy River Delta

	GI16	SRDD14	SRDD16	SRDM14	SRDM16	SRDD06	SRDM07	SRDD07
GI14	0.32	0.43	0.03	0.52	0.07	0.24	0.14	0.09
GI16		0.17	0.10	0.11	0.06	0.30	0.19	0.13
SRDD14			0.21	0.44	0.08	0.22	0.10	0.07
SRDD16				0.01	0.41	0.13	0.05	0.09
SRDM14					0.07	0.13	0.03	0.02
SRDM16						0.03	0.04	0.03
SRDD06							0.34	0.35
SRDM07								0.30

Vegetation Composition

At the Sandy River Dam site and Old Sandy Mouth site species richness increased from pre-restoration to post-restoration. Species diversity remained relatively unchanged between pre- and post-restoration condition at the Sandy River Dam site, but increased at the Old Sandy Mouth (Table 11). Bare ground increased to 51% and reed canarygrass became the dominant vegetation post-restoration at the Sandy River Dam site (Figure 11). At the Old Sandy Mouth site, bare ground decreased to 73% three years post-restoration. Black cottonwood saplings (*Populus balsamifera*) were the dominant vegetation at the site with an average cover of 3% and large wood debris had an average cover of 2% (Figure 11). Rice cutgrass (*Leersia oryzoides*) and Pacific willow (*Salix lucida*) were the dominant vegetation species at the reference site with an average cover of 28% and 24% respectively (Figure 11).

Table 11. Species richness and species diversity at Sandy River Delta and reference

Condition	Area	Species Richness	Species Diversity
Pre-restoration 2006	SRDD06	20	2.12
Pre-restoration 2007	SRDD07	22	2.62
	SRDM07	36	2.68
I yr Post-restoration	SRDD14	26	2.55
	SRDM14	23	1.88
3 yr Post-restoration	SRDD16	44	2.50
	SRDM16	52	2.95
Reference	GI14	25	2.34
	GI16	35	2.08
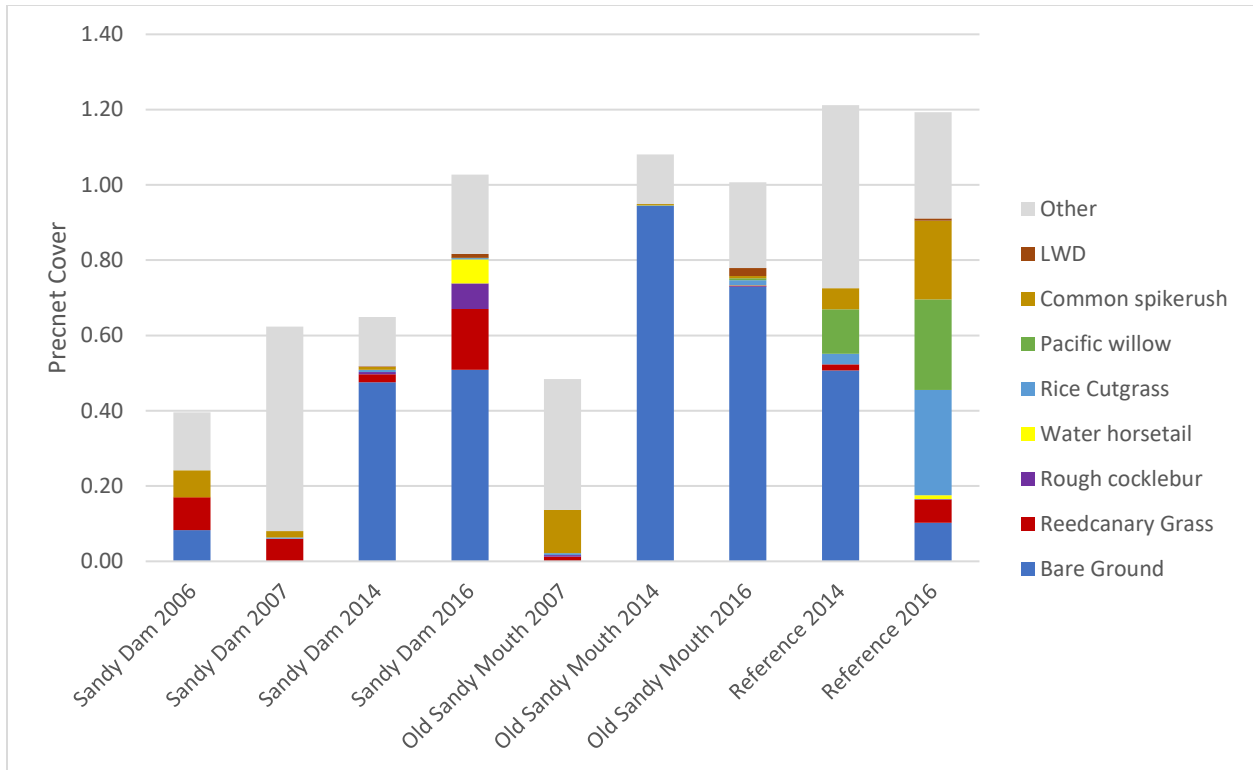
Figure 11. Trend vegetation cover and composition for Sandy River Delta and reference site

Salmonid Prey
Kandoll Farm

Terrestrial Macroinvertebrates
Terrestrial macroinvertebrates were collected at Kandoll Farm pre-restoration in 2013 and two years post-restoration (2014, 2016). In 2016, three years post-restoration, species richness and species diversity was greater than pre-restoration and year one post-restoration (Table 12). Chironomidae were the most abundant taxa group collected in 2016 at 28%, but were less abundant compared to previous years (Figure 12). Greater amounts of Sminthuridae and Isotomidae were present in 2016 than Dolichopodidae, which represented a greater portion of the sample in 2013 and 2014 (Figure 12).

Table 12. Terrestrial macroinvertebrate species richness and species diversity at Kandoll Farm

Site	Date	Species Richness	Species Diversity
Pre-restoration	6/28/2013	20	2.15
Post-restoration	6/27/2014	27	1.40
	7/29/2016	41	2.41
Reference	6/12/2013	16	2.31
	8/19/2016	29	1.54
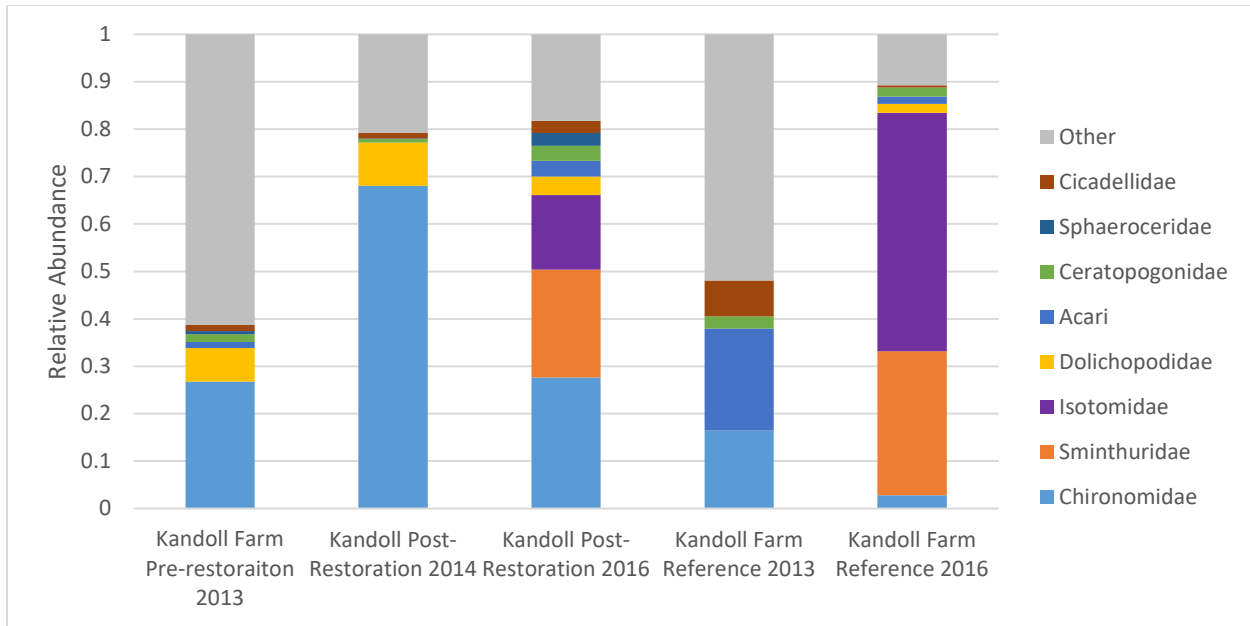
Figure 12. Terrestrial macroinvertebrate species composition at Kandoll Farm

Sauvie Island North Unit Phase 1 (Ruby Lake)

Terrestrial Macroinvertebrates

Ruby Lake was monitored for terrestrial macroinvertebrates pre-restoration in 2013 and two years post-restoration (2014, 2016). Species richness and species diversity were higher three years post-restoration compared to pre-restoration and one year post-restoration condition (Table 13). At the reference site, during the same period of time, species richness also increased, but species diversity decreased slightly (Table 13). In 2016, Sminthuridae was the most abundant species at Ruby Lake and the reference site composing 21% and 47% of the samples, respectively (Figure 13). Chironimidae was the second most abundant species at the reference site at 14% and third most abundant species at the restoration site at 13% (Figure 13).

Table 13. Terrestrial macroinvertebrate species richness and species diversity at Ruby Lake

Site	Date	Species Richness	Species Diversity
Pre-restoration	8/1/2013	32	2.701
Post-restoration	7/31/2014	31	2.046
	7/20/2016	58	2.75
Reference	7/31/2013	24	2.682
	7/31/2014	24	2.682
	7/20/2016	50	2.065
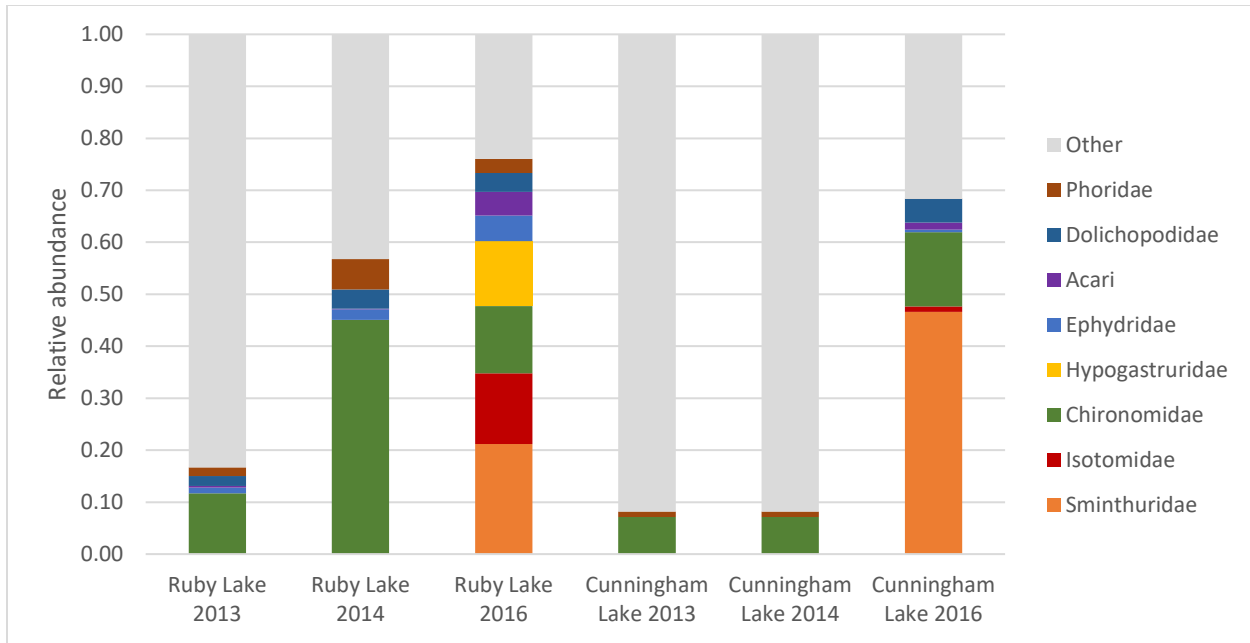
Figure 13. Terrestrial macroinvertebrate species composition at Ruby Lake

La Center Wetlands

Benthic Macroinvertebrates
Benthic macroinvertebrates were collected at two locations post-restoration at La Center Wetlands from May to July and once at the control site in July in 2016 (Figure 14). Post restoration benthic macroinvertebrates generally increased from May to July and species richness was higher at the restoration site than the control site (Table 14). Species diversity also increased across the sampling period post restoration and species diversity was higher at the restoration site than the reference site (Table 14). In 2016 Oligochaeta, was the dominant taxa group in samples collected from the wetland and control areas. In the Pond sampling area in May Amphipoda was more prevelant than Oligochaeta, but in the following months Oligiochaeta was the dominant taxa group. Excluding Oligochaeta, Diptera and Nematoda were the most prevalent taxa present in samples. In July, when all sites were sampled, species composition was comparable between restoration and references sites (Figure 14).

Table 14. Species richness and species diversity at La Center Wetlands and control sites

Site - Month	Condition	Year	Species Richness	Diversity
La Center Wetlands - May	Pre-restoration	2015	23	1.287
	Post-restoration	2016	7	0.609
La Center Pond - May	Post-restoration	2016	6	1.071
La Center Wetlands - June	Pre-restoration	2015	18	1.031
	Post-restoration	2016	17	1.056
La Center Pond - June	Post-restoration	2016	13	1.106
La Center Wetlands - July	Pre-restoration	2015	7	0.999
	Post-restoration	2016	15	0.957
La Center Pond - July	Pre-restoration	2015	8	1.165
	Post-restoration	2016	20	0.931
La Center Control - July	Pre-restoration	2015	15	1.33
	Post-restoration	2016	6	0.791
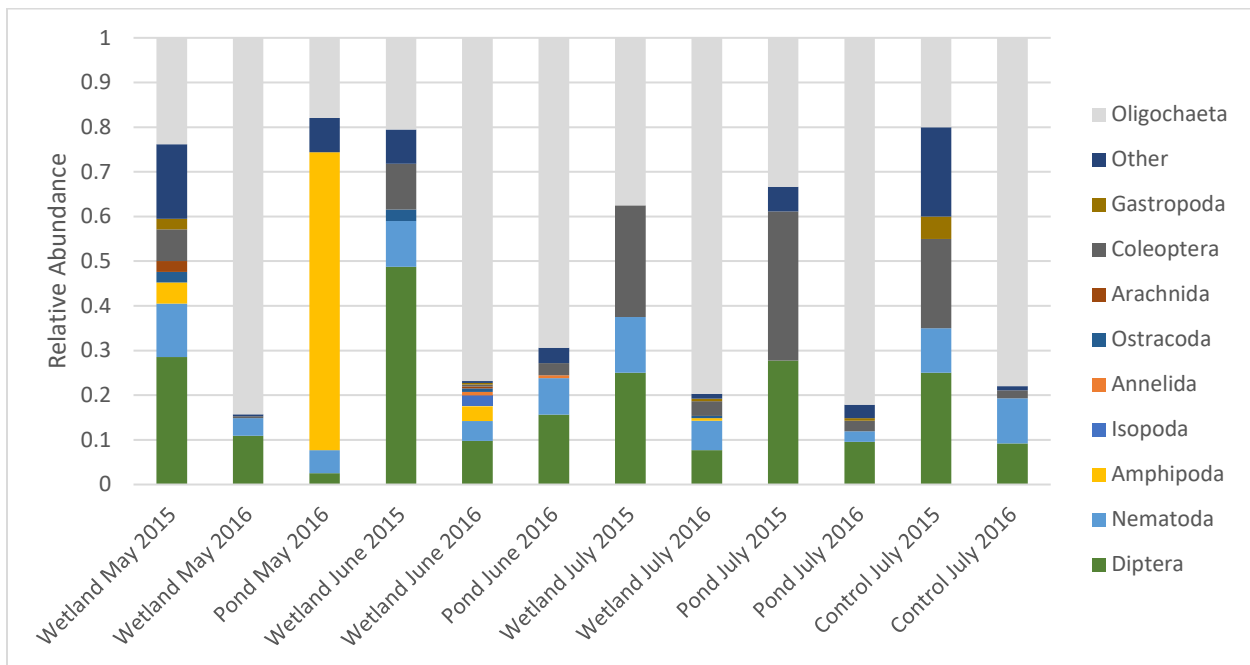
Figure 14. Percent portion of species in benthic samples at La Center Wetlands and control site

Terrestrial Macroinvertebrates

Terrestrial macroinvertebrates were collected at La Center Wetlands pre-restoration in 2015 and post-restoration in 2016. Post-restoration, species richness and species diversity were higher at the restoration site than the control site (Table 15). Hypogastruridae was the most prevalent species collected at the restoration site, while none were recorded at the control site

and follows a pattern observed pre-restoration. Chironomidae was observed at both the restoration and reference site in similar relative abundances as pre-restoration conditions (Figure 15)

Table 15. Species richness and species diversity at La Center Wetlands and control sites

Site	Date	Species Richness	Species Diversity
Pre-restoration	7/8/2015	82	3.179
Post-restoration	7/21/2016	63	2.84
Reference	7/8/2015	35	2.762
	7/21/2016	39	2.618
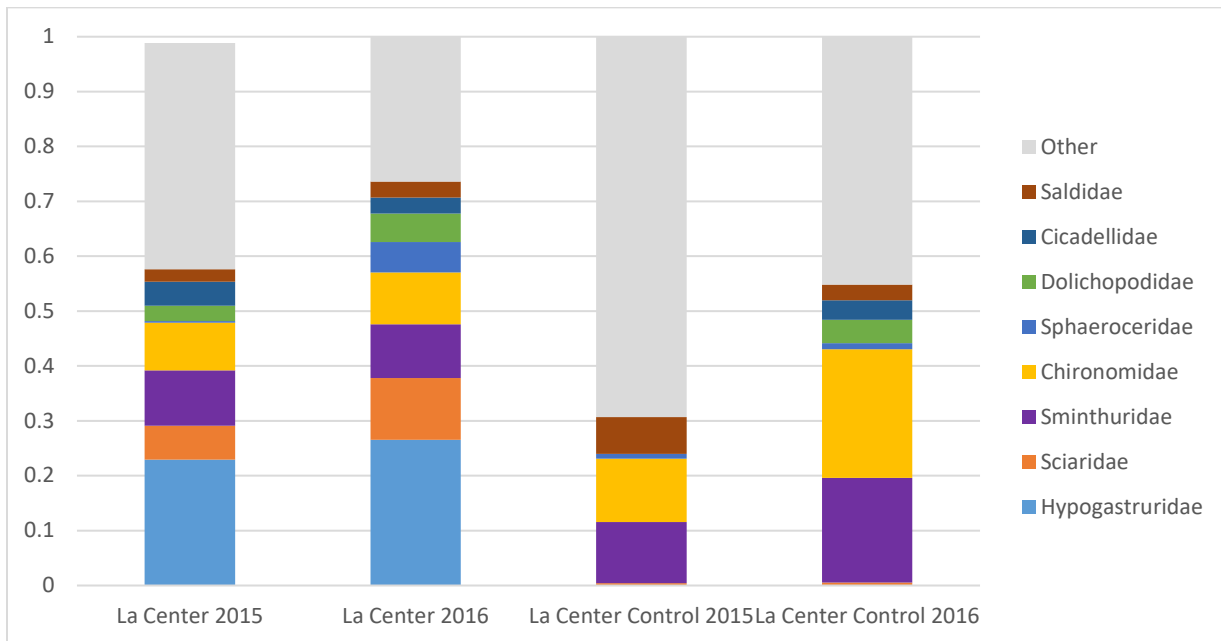
Figure 15. Percent portion of species in fallout trap samples at La Center Wetlands and control site

Fish Detection and Passage

Despite operational issues, the PIT array was operational during the spring downstream migration period (Apr-June). For 2016, the array detected 31 unique tags, however there were 12 tags that were not found in the PTAGIS database. The first detection of 2016 occurred on April 17 and the last one was on September 24. The detections in the early spring (April) were dominated by juvenile hatchery spring Chinook (n=5). The hatchery Spring Chinook salmon originated from the Little White Salmon Hatchery near Stevenson, WA and the Carson National Fish Hatchery on the Wind River near Carson, WA (both above Bonneville Dam). Juvenile hatchery fall Chinook (n=7) were most abundant in late spring (May, June). The hatchery fall Chinook came primarily from the Spring Creek National Fish Hatchery in the Columbia River gorge near Underwood, WA but others originated from the mouth of the Yakima River and from the Lyons Ferry Hatchery on the lower Snake River. Other species detected at the site in

the spring included one juvenile hatchery Coho (from Gold Creek in the Methow River watershed), one juvenile hatchery summer steelhead (from Neal Creek, a tributary to the Hood River), one juvenile hatchery summer sockeye (from the Redfish Lake system in Idaho), and four pike minnows (Table 16). The northern pikeminnow were from the Lewis River area. Most salmon were detected once, or if multiple detections occurred briefly for a few minutes and were not seen at the site for hours or multiple days, which differed from observations in previous years. From early June through late September, the tag detections were comprised of a large group (n=12) of 'unknowns' in the database. The majority of the 'unknown' detections were seen in July and August but continued well into September, and some were successful in passing through the culvert.

Table 16. Fish detected in 2016 at Horsetail/Oneonta PIT-tag array

Species	# Fish Detected	Months Present	Length (mm)	Residency (days)
Juvenile hatchery spring Chinook	5	April	97-124	1
Juvenile hatchery fall Chinook	7	May, June	62-69	1
Juvenile hatchery Coho	1	May	-	1
Juvenile hatchery steelhead	1	April	-	1
Juvenile hatchery summer sockeye	1	May	-	1
Northern Pike Minnow	4	May	210-389	1
Unknown	12	June, July, August, September	n/a	1

Discussion/Conclusion

We monitored four post-restoration sites monitored in 2016. Of those sites, three sites were three years post-restoration and one site was one year post-restoration. To provide an overall characterization of site condition, vegetation monitoring is established in an area directly impacted by restoration actions and at a second site located in an area indirectly impacted by restoration activities to represent reference conditions.

The two actions monitored in 2016 were dike breaches and marsh lowering. In monitoring areas with marsh lowering restoration activities, the vegetation similarity between pre- and one

year post-restoration condition was low. The plant community pre-restoration was characterized by high marsh invasive grasses with some native emergent vegetation. Cover at year one post-restoration sites was predominately bare ground, but at three years post-restoration native plant assemblages similar to reference site conditions began to emerge. In monitoring areas directly impacted by dike breaches, plant communities are changing slowly. One year post dike breach, plant communities maintain a high similarity to pre-restoration condition. However, three years post-restoration, plant communities are showing change from pre-restoration condition with increased species richness and the appearance of new native wetland species. Invasive reed canarygrass has persisted at these sites at a similar abundance observed during pre-restoration.

Monitoring areas incidentally impacted by restoration tracks the indirect impact of restoration activities. For example, pre-restoration many diked sites have developed native wetlands due to the impoundment of water. The reconnection of the site to the river changes the hydrology which may cause the existing native wetland plant communities to change to an invasive plant community. Another common pre-restoration scenario involves areas at with established invasive plant communities pre-restoration. Post-restoration these established invasive communities are exposed to regular inundation. In 2016, in established wetlands within restoration sites, there was a decrease in native vegetation, but the observed change was comparable to variability seen at reference sites. This indicates restoration actions did not negatively impact wetlands that existed within the site prior to restoration. Incidentally impacted areas at higher marsh elevations did not show significant shifts in vegetation community. Most high marsh sites were characterized by reed canarygrass pre-restoration, a vegetation type that persists post-restoration.

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 moderately correlated to average marsh elevation, species richness, species diversity, and bare ground. Increasing marsh elevation was associated with decreasing bare ground. Species richness was lowest at pre-restoration sites and highest at year three post-restoration sites, but species diversity decreased from year one post-restoration. This likely a result of the vegetation community approaching a new stable ecological state where a few vegetation species are dominant and other species are present depending on inter-annual variability of the site hydrology.

The collection of benthic macroinvertebrates characterizes prey items produced at a restoration site. At La Center pre-restoration sites, benthic macroinvertebrate species richness decreased throughout the spring, while at the control site species richness increased over the same period. The opposite seasonal trend occurred at post-restoration sites. At the site post-restoration, species richness increased through the spring to summer, while lower species richness was observed at the control site. The abundance of Dipterans was consistent across months, but the proportion of Dipterans in the sample was lower than pre-restoration

condition. It is likely the increased inundation post-restoration of the site reduced and temporally shifted the abundance of Dipterans.

Terrestrial macroinvertebrate collection tracks the status of available salmonid prey items pre- and post-restoration. In 2016, there were more macroinvertebrate species available at post-restoration sites than pre-restoration except at La Center wetlands. At all post-restoration sites, the number of species available were greater than species observed at reference sites. Chironomids, a preferred prey item of salmonids, were prevalent at all restoration and reference sites which indicate the ubiquity of the species.

The PIT array at Horsetail Creek continued to detect upstream salmonid species. Hatchery Spring, Fall, and Summer Chinook visited the site between April and June. Hatchery Coho, steelhead, summer sockeye was also detected at the site. All detections at the site showed the fish occupied the area for less than one day. Northern Pike Minnow were detected at the site in May.

Restoration actions impact wetland emergent habitats both directly and indirectly. Vegetation data indicates five years post-restoration sites reach an established vegetation state which is a mix of reference condition similarities and a site specific ecological state. The vegetation at sites three years post restoration appear to be following similar trend toward a vegetation state which has elements of reference conditions and a response to site specific physical drivers. Terrestrial and benthic invertebrate prey items observed at the sites consist of species preferred by juvenile salmonids and community structure is influenced by site and larger environmental factors. The continued monitoring of post-restoration sites will draw a clearer picture of the rate and degree of ecological change related to restoration actions and illustrate the longer-term resilience of restoration actions.

Adaptive Management & Lessons Learned

Post-restoration sites are trending towards a new stable ecological state. Tidal reconnection actions have an immediate impact through unrestricted tidal and river access to sites. Tidal inundation patterns have a strong influence on other metrics (e.g., vegetation, macroinvertebrate community) and a longer period is required to assess the impact of restoration actions on these metrics. Monitoring the effectiveness of restoration actions at a smaller scale has been successful. For example, tidal reconnection at Kandoll Farm established opportunity for juvenile salmonids to access the site and the quality of the habitat is beginning to change. At Sauvie Island North Unit Phase 1, the lowering of the marsh elevation prevented the return of reed canarygrass in that area. Selecting incidentally impacted areas was a first step in monitoring overall change at the site related to the implementation of a full suite of restoration actions. Although this method has been sufficient, it limits the inference to whole site condition. Moving forward, especially as post-restoration sites move towards five years

post restoration and an new steady stat condition it will be necessary to employ tools that allow for an efficient full site assessment.

The PIT array at Horsetail Creek continues to be challenging to operate, but provides valuable fish presence and stock data. Since the installation of PIT array, we have recorded out migrating upriver species visiting the site for periods ranging from a few hours to couple of days. However, due to natural and human factors, keeping the PIT array functional year round is difficult. We continue to maintain and repair the array and attempt to manage the system in a manner to continuously provide pertinent fish data.

To adaptively mange restoration projects it is necessary to monitor at regular intervals post-restoration and use standardized monitoring protocols. The programmatic approach to monitoring provides a framework for consistent monitoring across time and has created a dataset which captures the slower developing metrics. However, in any given year, the small number of monitored sites limits analysis and the ability to infer changes in ecological condition. Analysis continues to show 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.

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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.

<u>Equipment</u>

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

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.

Dates of Sampling in 2016
27-28 June

Types of Sampling in 2016
- *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
- *Photo Points:*

- photographed three previously established photo points near Seal Slough culverts and two previously established photo points on Grays River dike.
- Established new photo points at the following locations:
  - Area A Veg Sampling area at 0 m on 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. In addition, 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
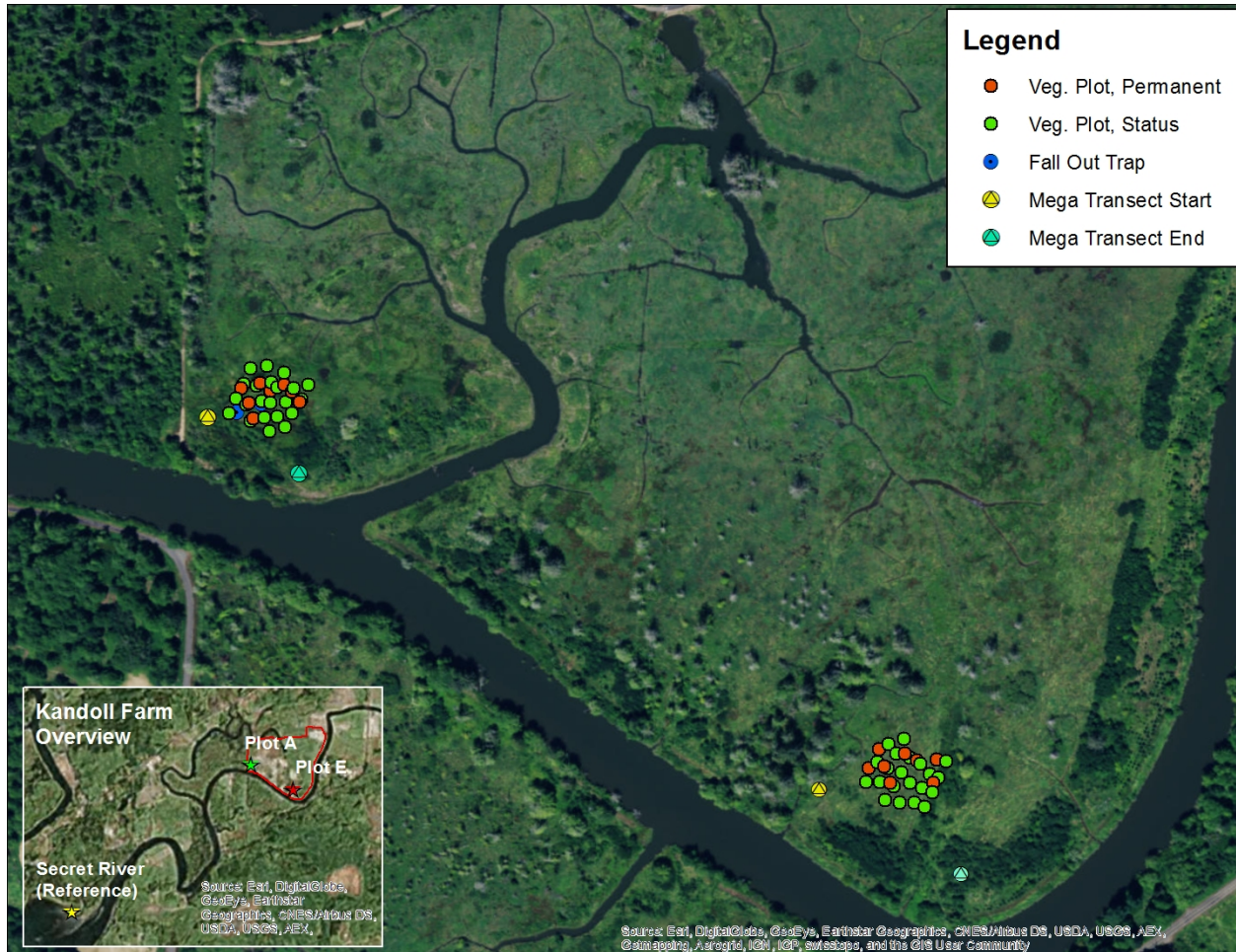- Azimuth 101° magnetic
- Sampled every meter

Figure 16. 2016 vegetation and macroinvertebrate sampling locations at Kandoll Farm restoration 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).
- 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

Dates of Sampling in 2016
6 August

Types of Sampling in 2016
- *Vegetation*: Herbaceous cover (2 sample areas of 20 quadrats, 40 quadrats total)
- *Photo Points:*
    - 2 photo points at the high marsh sampling area
        - 360° panorama taken at channel bank out from sediment stakes and cross- section end stake at the southwest corner of sampling area
        - 360° panorama taken at 0 m on baseline
    - 2 photo points at the low marsh sampling area
        - 360° panorama taken on log/mound near baseline
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
Status Sampling. 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

Low Marsh Sample area (Figure 18)
- Located in the lower elevation area of the marsh close to the mouth of the channel.
- 60 m x 50 m, with 20 quadrat locations
- Baseline azimuth: 263° magnetic
- Transect azimuth: 353° magnetic
- Transect spacing: 15m, random start: 7
- Quadrat spacing: 10 m, random starts: 3, 1, 7, 8

Trends Sampling. No permanent plots were placed at this site. Future trends monitoring will be conducted according to the EMP sample design.

Figure 17. 2016 vegetation sampling locations at the Secret River marsh reference 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.

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.

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

Dates of Sampling in 2016
18 July

Types of Sampling in 2016
- *Vegetation*: Herbaceous cover (2 sample areas of 36 quadrats, 72 quadrats total)
- *Insect Fallout Traps:* 4 traps
- *Photo Points:*
  - 1 photo point at the North Veg Sample area - 360° from 2 m north of the 0m baseline stake
  - 2 photo points at the South Veg Sample area
    - 180° from permanent plot 47-59, looking south
    - 360° from 2 m northwest of the 0m baseline stake
- *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

Trends Sampling. we established and marked permanent quadrats locations for future trends sampling.
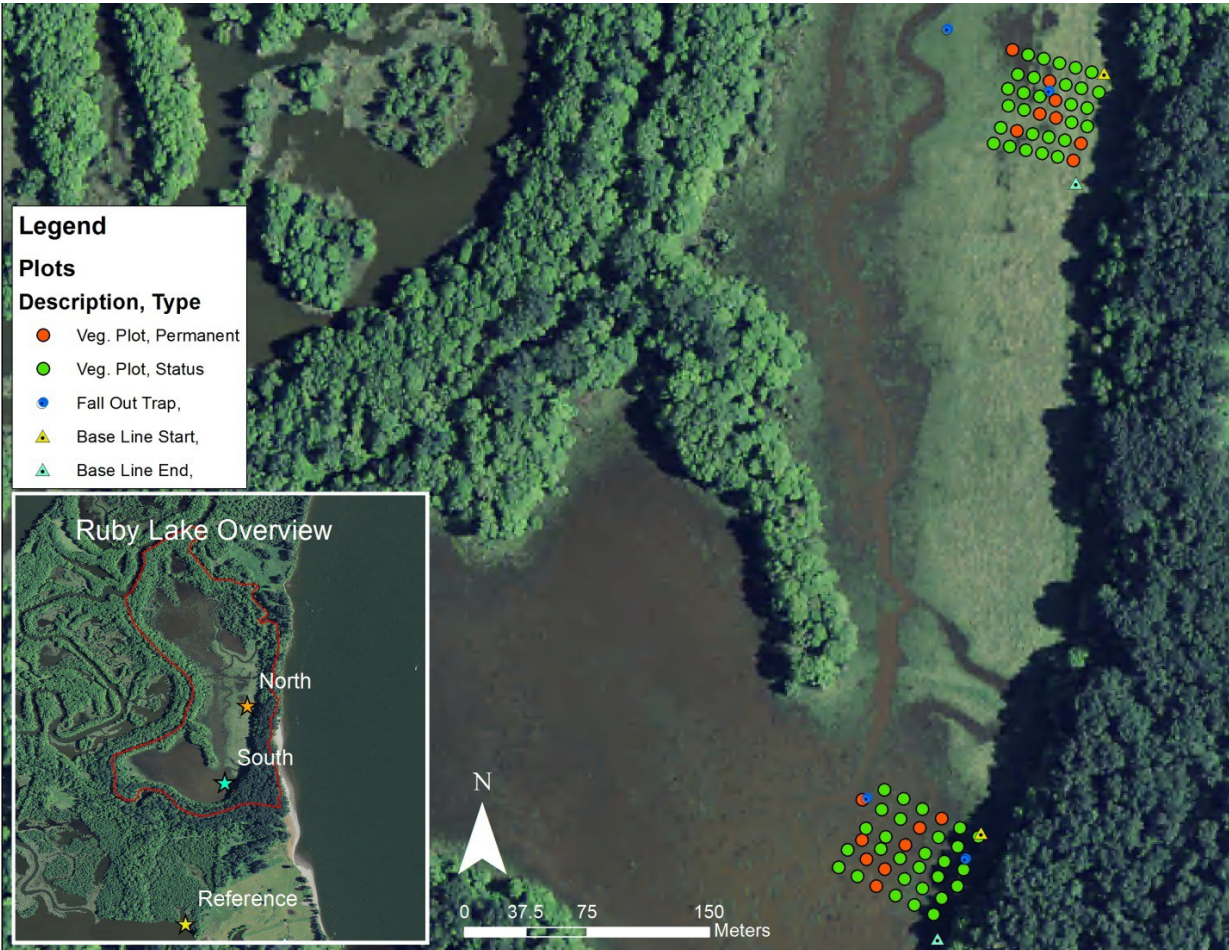

Figure 18. 2016 vegetation and macroinvertebrate sampling locations at the North Unit Phase 1 (Ruby Lake) restoration site.

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
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"

Dates of Sampling in 2016
28 July

Types of Sampling in 2016
See map below for sampling locations (Figure 19).
- *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 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
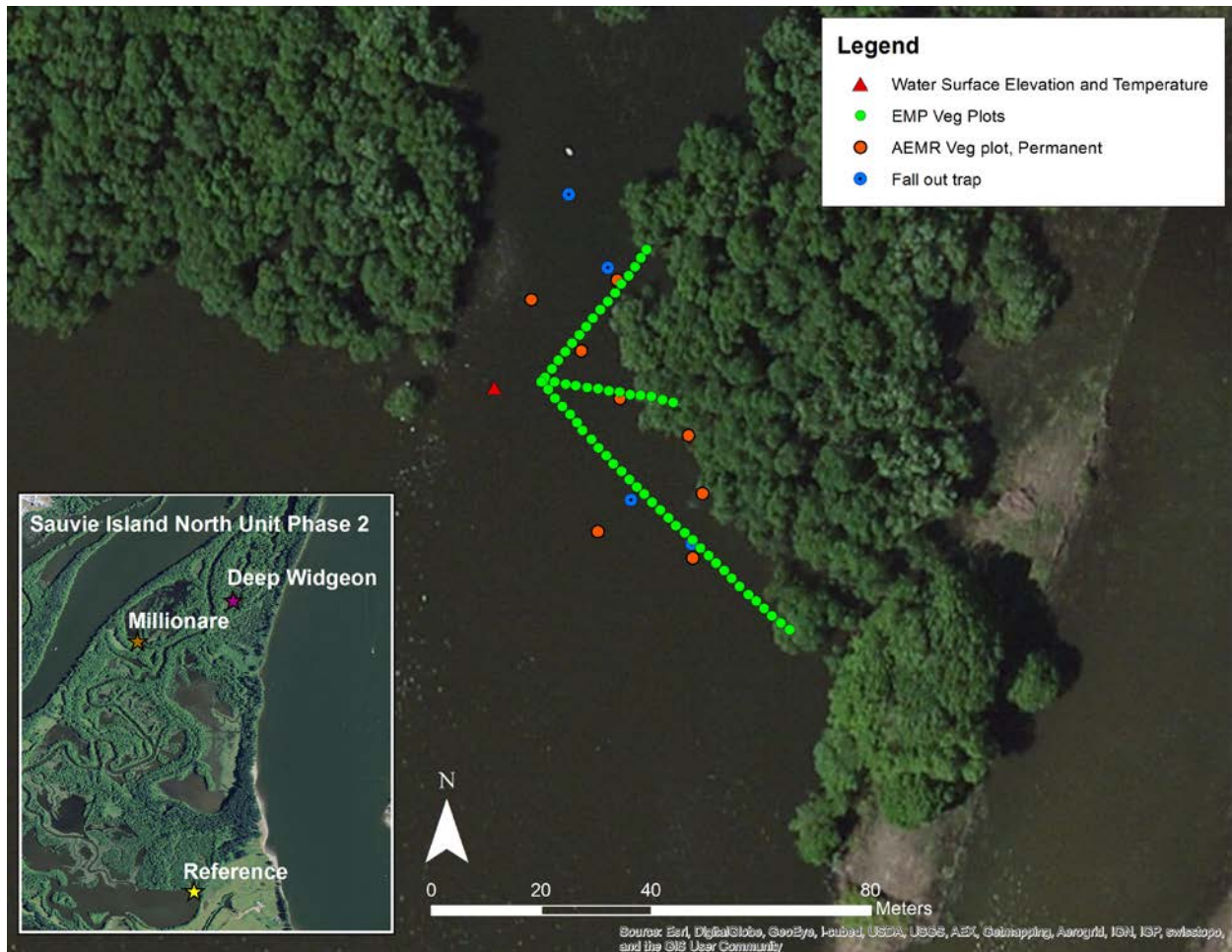- 8 permanent quadrats established for AEMR were monitored

Figure 19. 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.

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 2016

19-20 July

Types of Sampling in 2016
- *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 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

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

Figure 20. 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 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

Dates of Sampling in 2016
2 August

Types of Sampling in 2016
- *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 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

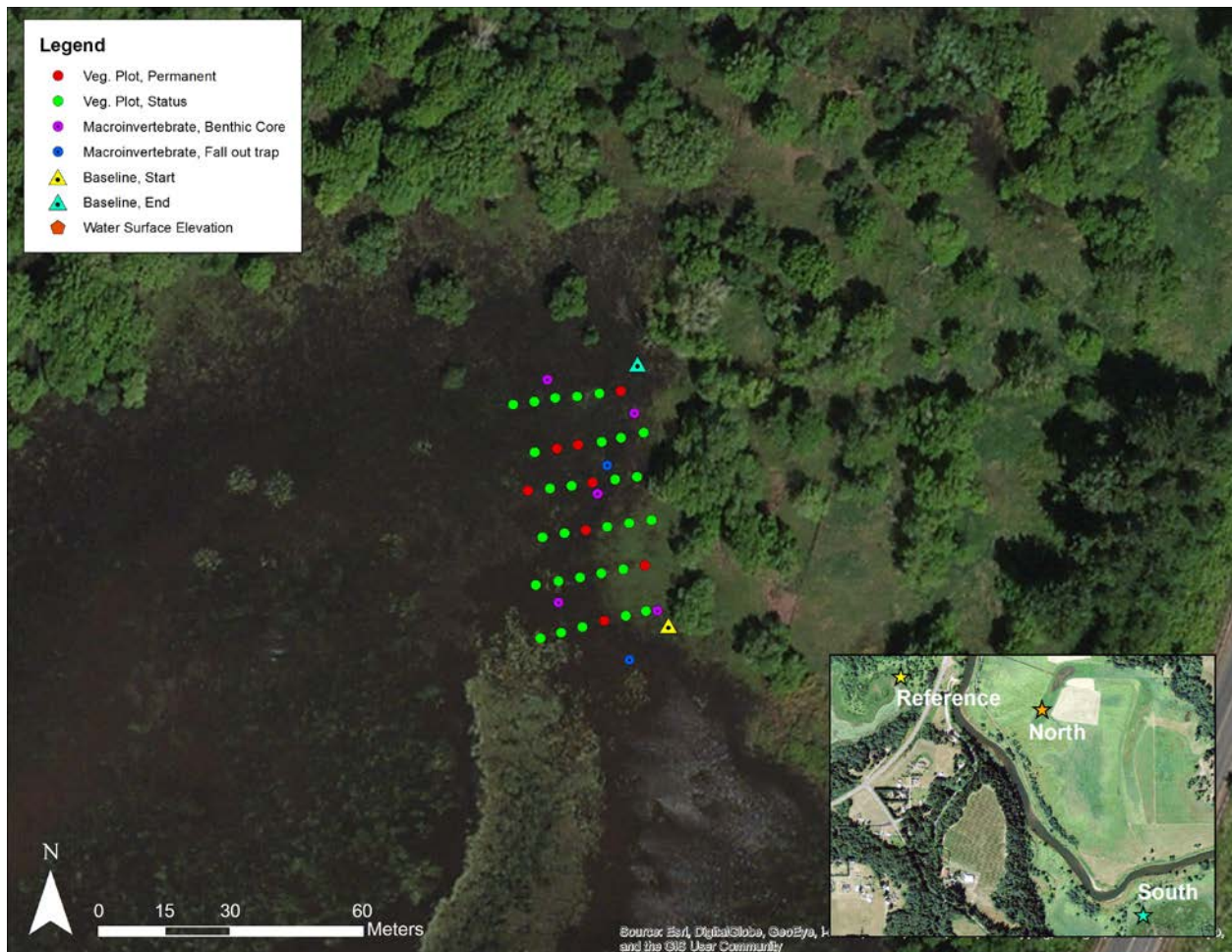Trends Sampling. Within the vegetation sample areas, we revisited trend sampling plots.

Figure 21. 2016 vegetation and macroinvertebrate sampling locations at La Center Control.

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.

Sandy River (Mouth)

General Site Location
  Near the mouth of the restored Sandy River channel between Gary and Sundial Islands at rkm 198

Ecosystem Type
Post-restoration condition, channel construction

Dates of Sampling in 2016
3 August

Types of Sampling in 2016
- *Vegetation*: Herbaceous cover (1 sample area of 36 quadrats)
- *Insect Fallout Traps:* 0
- *Photo Points:*
    - 360° from the veg hub
    - From T-3 100 m end stake
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
Vegetation Sample Area (Figure 23)
Located on the west side of the mouth of the restored channel.
- 3 Transects with 36 quadrat locations
    - T-1: 149° magnetic, 20 m
    - T-2: 200° magnetic, 70 m
    - T-3: 250° magnetic, 95 m (end stake at 100 m)
- Quadrat spacing: 5 m, random starts: 3
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects (T1-18, T2-3, T2-33, T2-63, T3-38, T3-48, T3-78, T3-83)

Trends Sampling. We sampled the previously established transects from 2007 to the extent possible to look at change historically. All plots were monitoring in 2016 to evaluate trends post-restoration.

Figure 22. 2016 vegetation and macroinvertebrate sampling locations at the Sandy River mouth restoration site.

Markers Left on Site
All marking stakes are white ¾ inch PVC. Marks left:
- Only the end stake at 100m on transect 3 was left due to the dynamic nature of the site.

Macroinvertebrate Sampling
The site was not scheduled for macroinvertebrate sampling.

Sandy River (Dam Removal)

General Site Location
Near the earthen dam removal on the old channel of the Sandy River at rkm 198

Ecosystem Type
Post-restoration condition, channel construction

Dates of Sampling in 2016
4 August

Types of Sampling in 2016
- *Vegetation*: Herbaceous cover (2 sample areas, 46 quadrats total)
- *Insect Fallout Traps:* 0
- *Photo Points:*
    - 360° from 2m west of 0 m on the new baseline
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design

New Veg Sample area (Figure 24)
- Located on the north side of the channel just downstream of the removed dike. Transect 77 overlaps with T-1 from the previous veg sample area.
- 80 m x 30 m, with 36 quadrat locations
- Baseline azimuth: 56° magnetic
- Transect azimuth: 146° magnetic
- Transect spacing: 13 m, random start: 12
- Quadrat spacing: 5 m, random starts: 2, 2, 0, 0, 2, 2
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Trends Sampling. We sampled the previously established transects from 2006 and 2007 to the extent possible and overlapped one of the original transects with one of the new transects to be able to look at change historically. The new transects will be monitored in the future to evaluate trends post-restoration.
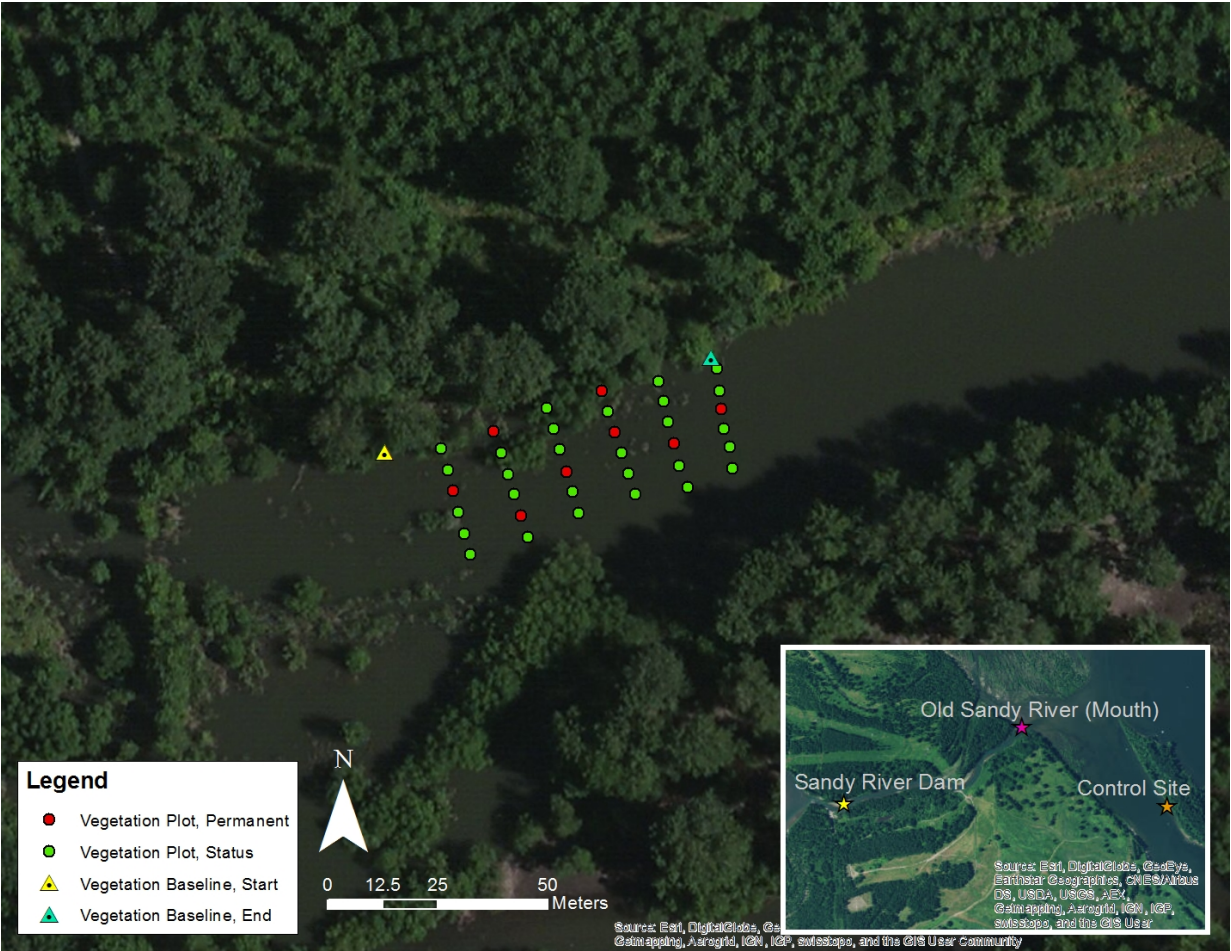
Figure 23. 2016 vegetation and macroinvertebrate sampling locations at the Sandy River dike breach restoration site.

Markers Left on Site
All marking stakes are white ¾ inch PVC. Marks left:
- End stakes of the baseline for the vegetation sample areas.
- Permanent plot stakes were not left due to heavy human use of site.

Macroinvertebrate Sampling
The site was not scheduled for macroinvertebrate sampling.

Sandy River Reference (Gary Island)

General Site Location
Gary Island is located in the Columbia River, upstream from the restored Sandy River channel at rkm 200.

Ecosystem Type
Island fringing wetland

Dates of Sampling in 2016
4 August

Types of Sampling in 2014
- *Vegetation*: Herbaceous cover (1 sample area of 36 quadrats)
- *Insect Fallout Traps:* 0
- *Photo Points:*
    - 360° from 0m on the baseline
- *Elevation*: collected elevation at all vegetation quadrats

Vegetation Sampling Design
Veg Sample area (Figure 25)
- Located on the southwest side of the island. Veg sample area spanned elevation gradient from the water to the trees.
- 100 m x 24 m, with 36 quadrat locations
- Baseline azimuth: 132° magnetic
- Transect azimuth: 38° magnetic
- Transect spacing: 20 m, random start: 0
- Quadrat spacing: 5 m, random starts: 2, 2, 1, 1, 1, 1
- 8 permanent quadrats, randomly selected, systematically to ensure coverage on all transects

Trends Sampling
We sampled the previously established 4 transects from 2008 to the extent possible to evaluate change historically. In addition we added 3 new transects to the east. In future years the former T-4 will be eliminated because it is very narrow, and only the remaining 6 transects will be surveyed. The permanent plots on these same transects will be monitored in the future to evaluate trends post-restoration.
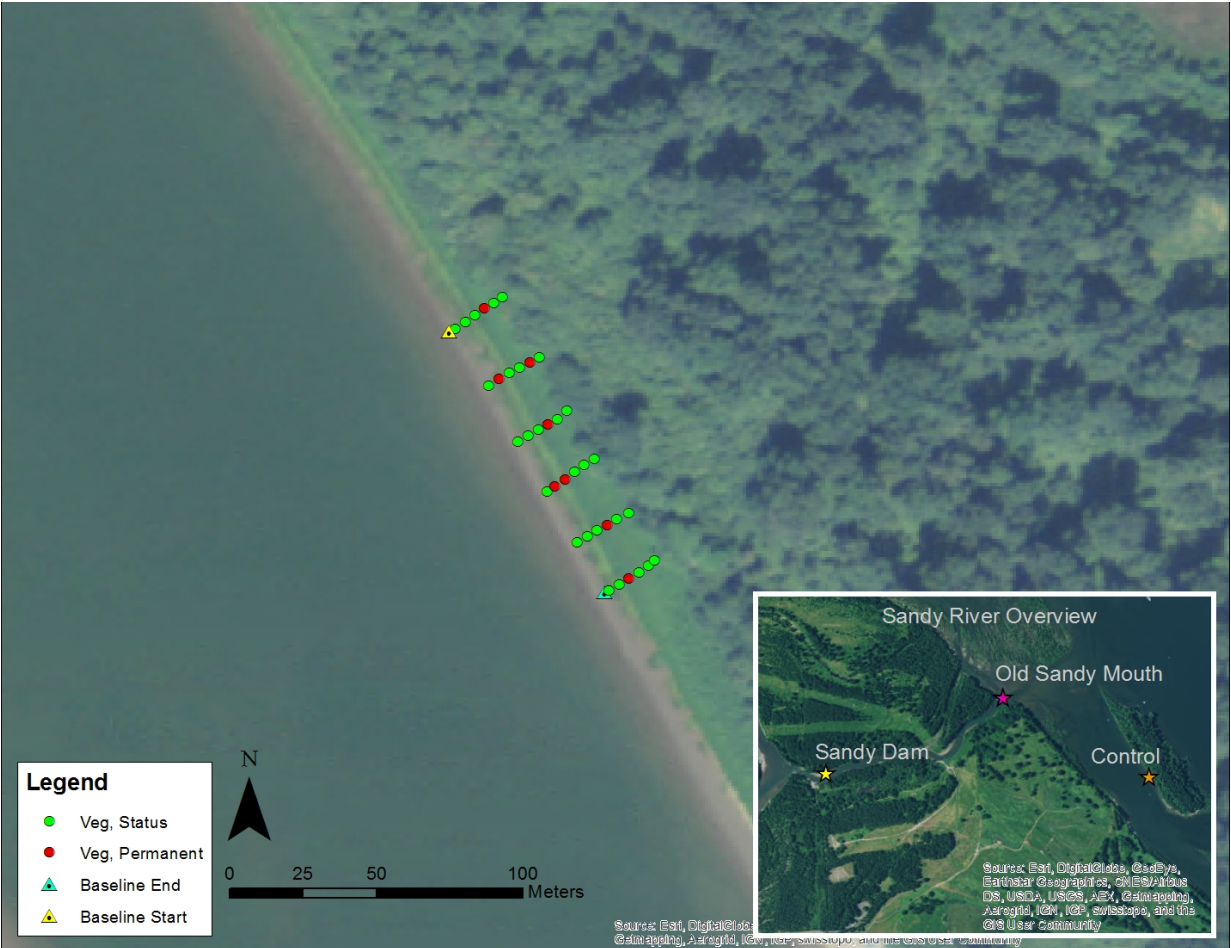
Figure 24. 2016 vegetation and macroinvertebrate sampling locations at the Gary Island control site.

Markers Left on Site

All marking stakes are white ¾ inch PVC. Marks left:

- Stakes at the 24 m end of 0 m and 100 m transects (in the trees). Baseline was in the water, but decided to leave stakes at other end of transects to reduce visibility of stakes and potential for water hazards to boaters.
- Permanent quadrat stakes; 1 stakes per location in the SW corner.

Macroinvertebrate Sampling

The site was not scheduled for macroinvertebrate sampling.