Ni-les'tun Tidal Wetland Restoration Effectiveness Monitoring: *Baseline (2010-2011)*

Ni-les'tun Tidal Wetland Restoration site on the highest predicted tide of 2011, 11/25/11. Photo by Roy Lowe.

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This study was a joint effort of Green Point Consulting, the Estuary Technical Group of the Institute for Applied Ecology, and the Confederated Tribes of Siletz Indians.

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Table of contents

EXECUTIVE SUMMARY

This study was a joint effort of Green Point Consulting, the Estuary Technical Group of the Institute for Applied Ecology, and the Confederated Tribes of Siletz Indians. The project's collaborative, multi-disciplinary approach enabled efficient sampling and analysis and broad interpretation of results. In future monitoring reports, this collaboration will enable "big-picture" understanding of the restoration project's effectiveness.

This report describes results of baseline monitoring at the Ni-les'tun tidal wetland restoration site, Bandon National Wildlife Refuge, Coquille River estuary of Oregon. Baseline monitoring provides a basis for comparison to post-restoration conditions, allowing future determination of project effectiveness.

The report focuses on 2010-2011 baseline data, but it also includes information from our team's earlier monitoring efforts during 2003-2005. These earlier monitoring data leverage the 2010-2011 effort, providing a longer-term perspective and better understanding of site dynamics. We also provide some early glimpses of likely post-restoration conditions, based on data from the reference site and some preliminary post-restoration monitoring in fall 2011.

Understanding patterns at Ni-les'tun required sampling many locations, which generated a high volume of data. The main body of this report provides summaries, representative results, and interpretation. Further results and details are provided in the Appendices.

Baseline monitoring revealed striking contrasts between the pre-restoration conditions at Ni-les'tun and reference conditions at the Bandon Marsh Unit. These contrasts are expected to diminish rapidly after restoration, and this report contains some preliminary results supporting that expectation. However, some physical and biological conditions will change more slowly. To accurately assess project effectiveness, our future (post-restoration) monitoring reports will evaluate results at Ni-les'tun by documenting the direction of change ("restoration trajectory") as well as the conditions at the time of monitoring. We will also compare results at Ni-les'tun to other tidal wetland sites in Oregon and the Pacific Northwest. This broad assessment of the Ni-les'tun restoration will provide important perspective and guidance for other restoration projects.

Key findings:

- ***Emergent plant communities*** at Ni-les'tun had a high non-native component; native species dominated in the lower and wetter parts of the pasture, especially where brackish conditions prevailed due to limited tidal inflow through the side-hinged tide gates. Forested wetland plant communities, which had never been ditched or used for pasture, were almost entirely native, with characteristics similar to non-tidal forested wetlands. With the return of the tides and brackish salinities, emergent and forested wetlands are expected to respond *via* shifts in species composition; the changes will be documented *via* post-restoration monitoring.

- ***Soils*** at Ni-les'tun had about half the organic matter content compared to the reference site, and were much less saline. Soil characteristics at the reference site in 2010 showed a trend towards higher organic matter content and lower salinity compared to 2003.
- ***Groundwater*** showed seasonal wetland characteristics across the majority of the Ni-les'tun pasture; forested wetlands and lower portions of the pasture were wet year-round. By contrast, groundwater fluctuated with the tides at the reference site's high marsh; the water table dropped well below the soil surface in summer between spring tide cycles, but each spring tide cycle "reset" the water table to the surface again. These patterns illustrate likely post-restoration conditions at similar elevations on Ni-les'tun.
- ***Channel morphology*** at Ni-les'tun reflected the recent construction of the channel system, with morphology that matched the restoration design. Channel density is expected to increase and channel structure will evolve as the network develops; these developments will be documented during the post-restoration monitoring period.
- ***Fish habitat opportunity*** was limited by the site's tide gates, dikes, and ditch conditions. Temperature and salinity conditions differed sharply from reference conditions, particularly in summer; conditions were often unsuitable for juvenile salmonids. Five miles of restored channels excavated in 2009-2010 are expected to provide significant increases in habitat availability, as measured by channel length, channel volume, and expected inundation frequency. Removal of the tide gates and dikes, completed in August 2011, is expected to improve water quality through restored tidal flushing. The addition of 193 large wood structures will further enhance habitat opportunity during the post-restoration period.
- ***Fish habitat capacity***, as measured by macroinvertebrate abundance and community structure, was distinctly different at the restoration site *versus* the reference site.
- ***Fish habitat utilization*** differed sharply between the restoration site and the reference site. Although Ni-les'tun was used many fish species prior to restoration, limited use by salmonids reflected access and habitat suitability limitations imposed by the restoration site's tide gates, dikes and ditches.

REPORT ORGANIZATION: MONITORING OBJECTIVES

Monitoring at Ni-les'tun is designed to allow evaluation of restoration effectiveness, and provide information to help guide other restoration projects. The information we gain through monitoring at this landmark project helps advance restoration science in Oregon, the Pacific Northwest, and beyond.

This report is organized by the "big picture" **monitoring objectives** listed below. These objectives relate our monitoring activities to the project's **restoration objectives**. Each monitoring objective encompasses several specific **monitoring questions**, which were answered by measuring **monitoring parameters** ("**metrics**"). This report contains those measurements, as well as interpretation and comparison to other projects.

Monitoring Objective 1: Measure restoration of tidal hydrology, tidal wetland vegetation, and the physical attributes that control tidal wetland functions across the 418-acre marsh.

Associated Restoration Objective: Restoration of coastal tidally influenced wetlands through hydrological reconnection

Monitoring Questions:

Q1a) Was tidal hydrology successfully restored?

Metrics: Tidal hydrology (inundation frequency, duration, and depth) at restored and reference sites; elevation of wetland surface and instrumentation; tidal channel morphology (cross-sections, longitudinal sections, length, density, and sinuosity)

Q1b) Are tidal wetlands developing, with physical and biological characteristics trending towards reference conditions?

Metrics: Wetland plant community composition and extent; soil characteristics (stored organic carbon, salinity, pH, texture); groundwater levels; surface water salinity and temperature.

Monitoring Objective 2: Measure habitat recovery and habitat utilization by at-risk and endangered species.

Associated Restoration Objective: Restoration of coastal and marine habitat to recover listed and at-risk species, particularly estuary dependent and anadromous fishes

Monitoring Questions:

Q2a) Did restoration result in increased salmonid habitat opportunity (availability)?

Metrics: Surface area, volume, duration and frequency of salmonid habitat availability (using channel morphology measurements and tidal elevations); surface water salinity and temperature; locations, quantities, and descriptions of large wood habitat restored.

Q2b) Did restoration result in increased salmonid habitat capacity?

Metrics: Benthic macroinvertebrate abundance and community structure within the largest of the three restored basins (Fahys Creek).

Q2c) Did restoration result in increased salmonid habitat utilization?

Metrics: Salmonid standing stock, habitat utilization and migration patterns in restored *vs*. reference basins; salmonid utilization of large wood habitat.

Monitoring Objective 3: Measure extent of resiliency to storm-related flooding and climate change.

Associated Restoration Objective: Improve coastal resiliency to storms, flooding and climate change

Monitoring Questions:

Q3a) Did restoration improve the site’s capacity to moderate storm-related flooding?

Metrics: Channel volume (cross-sections, length); water levels.

Q3b) Do post-restoration site conditions show potential for improved resilience to climate change?

Metrics: Plant community composition and extent; soil characteristics (% organic matter, texture, pH, and salinity); groundwater levels.

PROJECT TIMELINE

The timeline for the Ni-les'tun tidal wetland restoration project extended across several years. Major tidal wetland restoration and monitoring activities are listed in Table 1. Many other important activities have occurred at the site, such as nontidal wetland restoration, undergrounding of the power line, and improvements to North Bank Road. Information on the timing of those activities is available from Bandon Marsh National Wildlife Refuge.

Table 1. Dates of major tidal wetland restoration and monitoring activities at the Ni-les'tun site.

Year	**Restoration activities**	**Monitoring activities**[2]
2003[1]	• None	• Emergent wetland plant communities • Forested wetland plant communities • Soils
2005[1]	• None	• Low tide fish density • Juvenile salmonid tidal migration
2009	• Removal of livestock • Excavation of the first few restored tidal channels	• None
2010	• Excavation of most restored tidal channels • Ditch filling (major ditches) • Ditch disking (minor ditches)	• Tidal hydrology • Channel morphology • Emergent wetland plant communities • Groundwater (emergent wetlands) • Soils • Low tide fish density • Juvenile salmonid tidal migration • Macroinvertebrates
2011	• Excavation of the last few restored tidal channels • Filling of lower Fahys Creek ditch • Completion of east and west protection dikes • Dike removal • Tide gate removal	• Tidal hydrology • Groundwater (emergent wetlands) • Forested wetland plant communities • Groundwater (forested wetlands) • Surface water temperature and salinity

[1] 2003 and 2005 monitoring activities were supported by non-OWEB funding.

[2] Only monitoring activities by our team are listed here. Several other groups are conducting research and monitoring at Ni-les'tun; further information is available from Bandon Marsh NWR.

METHODS OVERVIEW

As described above, this report is organized by monitoring objectives; methods are described under each objective, and summarized in Table B3 (Appendix B). To provide context, sampling locations are described below. Methods were designed for comparability with other projects, and the methods meet regional and national standards for science-based effectiveness monitoring of tidal wetland restoration projects (Rice *et al.* 2005, Roegner *et al*. 2008, Thayer *et al*. 2005, Simenstad *et al*. 1991). Further information on methods is available from the authors (Brophy for tidal hydrology, channel morphology, vegetation, soils, groundwater, and channel water salinity; van de Wetering for fish and macroinvertebrates).

Sampling locations

Sampling at Bandon Marsh NWR was stratified and distributed across all tidal wetland elevation zones and all sub-basins, including Fahys, NoName, and Redd Creek sub-basins at Ni-les'tun, and the Shipwreck and Bayside sub-basins at the Bandon Marsh Unit reference site (Appendix A, Figures A1-A3). Sampling of vegetation, soils, and groundwater was conducted within study transects strategically placed to sample major plant communities and the associated physical and biotic conditions. Within each transect, sampling of vegetation was randomized; groundwater was measured in a central observation well (4ft deep), and soil samples were bulked across the entire transect. Tide gauges were placed just inside and just outside the tide gates on lower Fahys Creek. Four salinity loggers were deployed in the Coquille River at the restoration site and just upstream and downstream, as well as at the Bandon Pier, to characterize tidal and riverine inflows. Ten salinity loggers were deployed in major channels at the Ni-les'tun and Bandon Marsh units to characterize variation in salinity across these large study areas. Sampling of fish and macroinvertebrates was distributed across sub-basins and elevation zones (Appendix A, Figures A4 and A5).

To the extent possible, locations used in our team's 2003 and 2005 early baseline monitoring were re-sampled. This repeated sampling provided valuable perspective on site dynamics and change, and was a strong supplement to the 2010-2011 monitoring. Monitoring parameters in 2003-2005 included vegetation, soils, low tide salmonid density and distribution, and salmonid migration. The 2003 sampling used fewer vegetation/soils transects than the 2010-2011 monitoring (8 transects at the Ni-les'tun restoration site in 2003 compared to 17 in 2010-2011; 2 transects at the Bandon Marsh Unit reference site in 2003 compared to 5 in 2010-2011). Five of the eight 2003 vegetation/soils transects were re-sampled in 2010-2011, using the same ID codes as in 2003: these were NL T2, NL T4, NL T5, NL T6, and NL T7. Transects NL T1 and NL T3 from 2003 could not be re-sampled in 2010-2011 due to temporary damage to vegetation caused by necessary restoration construction activities. A new transect (NL T18) was placed as close as possible to the former location of NL T1, in the lower Fahys Creek zone. Transect NL T8, in the forest north of North Bank Road and east of Fahys Creek, was sampled in 2003 but omitted from 2010-2011 sampling because it was determined to be above tidal range.

RESULTS AND DISCUSSION

1. Tidal wetland restoration

Monitoring Objective 1: Measure tidal wetland restoration

In this objective, we measured the restoration of tidal hydrology, tidal wetland vegetation, and the physical attributes that control tidal wetland functions across the 418-acre marsh.

1a. Tidal hydrology

Monitoring Question 1a: Was tidal hydrology successfully restored?

Metrics for evaluating tidal hydrology:

> Tidal hydrology (inundation frequency, duration, and depth) at restored and reference sites; elevation of wetland surface and instrumentation; tidal channel morphology (cross-sections, longitudinal sections, length, density, and sinuosity). *(Rationale: Elevation measurements allow linkage of tide heights to physical and biological site characteristics; tidal channel morphology strongly affects water movement across a large tidal wetland. Channel morphology data will also be used to quantify salmonid habitat availability.)*

Since this report contains baseline (pre-restoration) monitoring results, this question cannot yet be answered. However, preliminary data suggest that tidal hydrology was successfully restored. These preliminary results are described in the section below.

Tidal hydrology overview

Tidal hydrology is a controlling factor for all tidal wetland functions, so it is a very important monitoring parameter. We measured tidal water levels using automated water level loggers (Onset HOBO® loggers, model U20-001-01) programmed to collect pressure data at 15min intervals. The loggers were installed in lower Fahys Creek (inside the tide gate) and in the mainstem Coquille River just outside the tide gate (gauges labeled “NL TG inside” and “NL TG outside” respectively in Figure A2, Appendix A). Pressure data were converted to water levels using HOBOWare Pro® software; data were also adjusted for barometric pressure (using local barometric pressure data) with HOBOWare Pro® software’s barometric compensation assistant.

During the pre-restoration period, the tide gates and dikes at Ni-les’tun effectively excluded the tides from the site. Maximum water levels during high tides were about 3ft below water levels in adjacent Coquille River (Figure 1). Although the tide gates kept high tides from reaching the Ni-les’tun pasture, water levels in Fahys Creek did fluctuate during the tide cycle, as freshwater flows from the creek backed up behind the closed tide gates during high tides. This “muted” tide signal is typical of tide gated sites with substantial freshwater outflow (Giannico and Souder 2005).

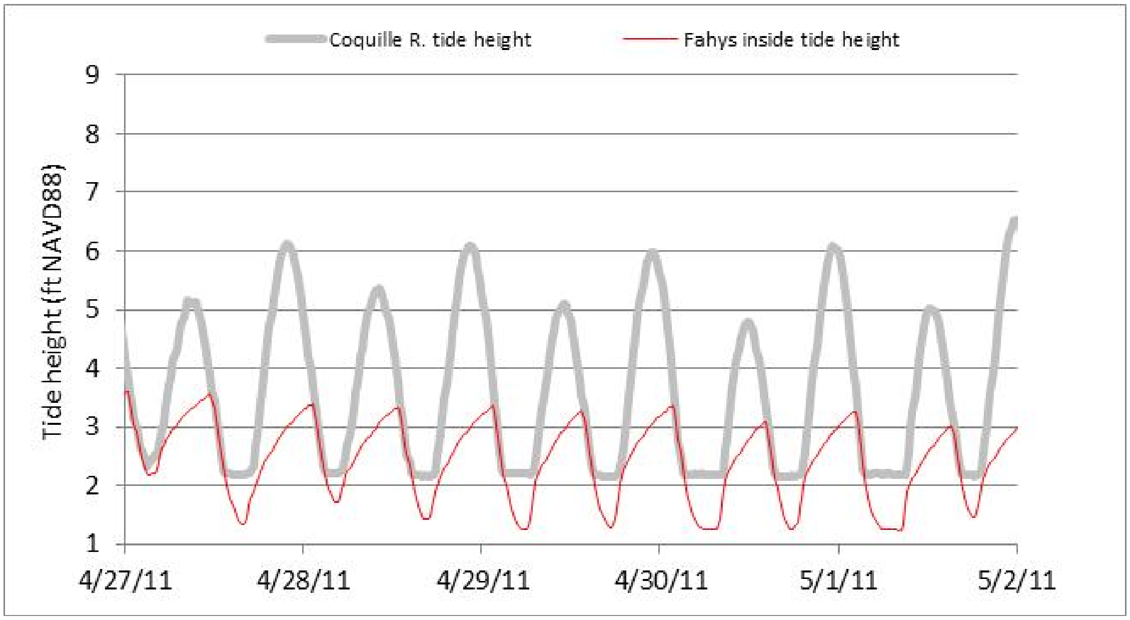


Figure 1. Pre-restoration tide heights in lower Fahys Creek (behind tide gates) and in the adjacent Coquille River, April 27-May 1, 2011. Fahys Creek and Coquille River gauges are labeled “NL TG inside” and “NL TG outside” respectively, in Figure A2, Appendix A.

After removal of the tide gates and dike, high tide water levels inside lower Fahys Creek were approximately the same as the levels in the Coquille River (Figures 2 and 3). During the early post-restoration period, low tides in lower Fahys Creek were considerably higher than prior to restoration (Figure 2), perhaps due to the relatively high elevation of the mud flats outside the newly re-opened mouth of Fahys Creek.

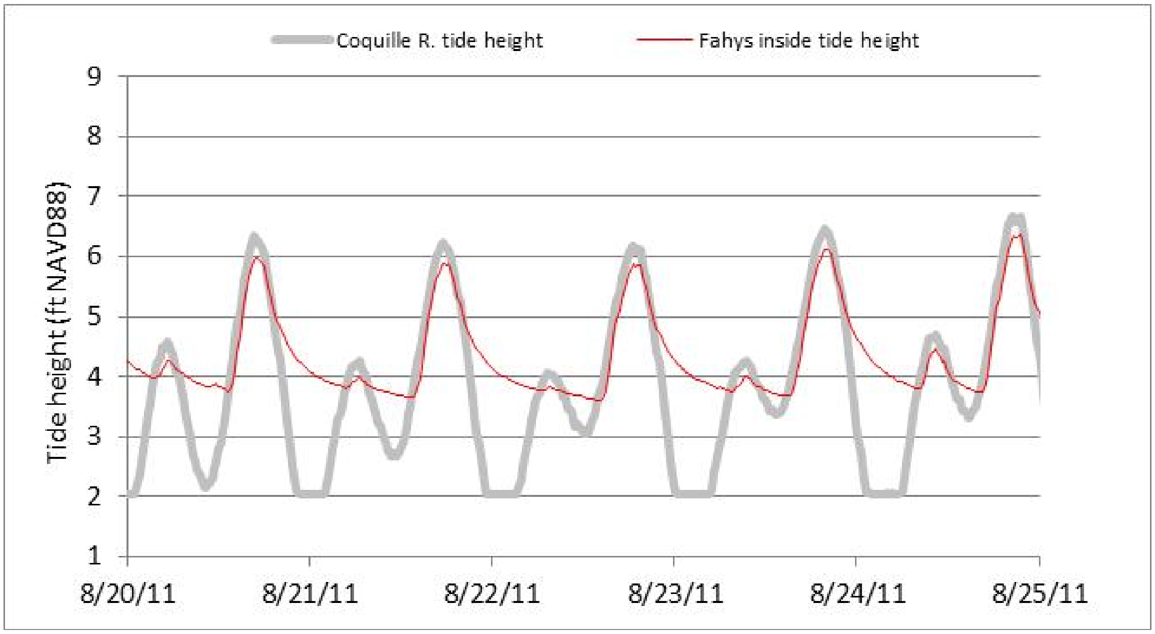


Figure 2. Early post-restoration tide heights in lower Fahys Creek and in the adjacent Coquille River, August 2011. Note high water levels during low tide, most likely due to relatively high elevation of mud flat outside mouth of Fahys Creek. Fahys Creek and Coquille River gauges are labeled “NL TG inside” and “NL TG outside” respectively, in Figure A2, Appendix A.

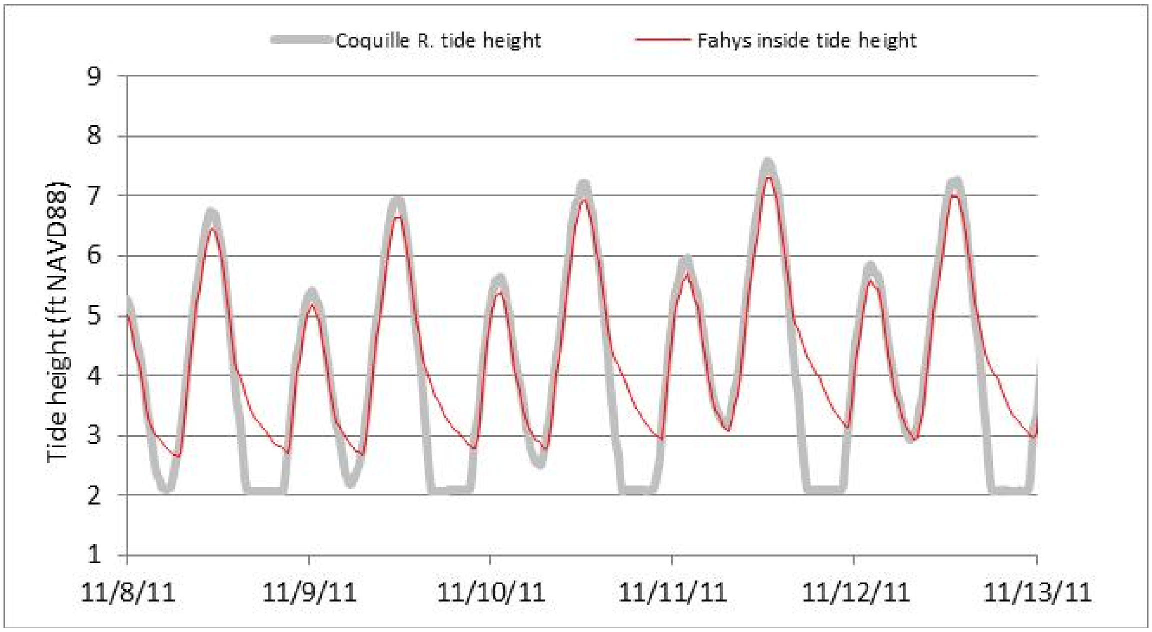


Figure 3. Early post-restoration tide heights in lower Fahys Creek and in the adjacent Coquille River, November 2011. Note decreasing low tide depth compared to August data, probably associated with erosion of the outflow channel through the adjacent mud flats. Fahys Creek and Coquille River gauges are labeled “NL TG inside” and “NL TG outside” respectively, in Figure A2, Appendix A.

During Ni-les'tun's years as a diked pasture, Fahys Creek had drained straight south through dual tide gates; its historic channel to the southwest across the mud flats was reconnected on August 16, 2011. To protect cultural resources and the adjacent undisturbed tidal marsh, these mud flats were not excavated to the low tide level during dike breaching and tide gate removal. The mud flats most likely prevented complete drainage of Fahys Creek during low tides during this early post-restoration period. During the next three months – through November 2011 – there was a gradual reduction in the low tide water levels in Fahys Creek – that is, the restored tide range showed a trajectory moving towards the reference water levels in the adjacent Coquille River (Figure 3; also see Figure A21, Appendix A). The gradual lowering of the low tide elevation reflects erosion of the outflow channel (Photo C1, Appendix C). Continuing erosion of the Fahys channel through these mud flats will gradually re-establish the natural thalweg elevation and full tidal range at the mouth of Fahys Creek.

In post-restoration monitoring reports, we will document tidal flow restoration to the full site using data on vegetation, salinity, groundwater, and channel morphology. These data will supplement the tide gauge data by providing spatially extensive evidence of tidal influence. Our goal is to integrate the interpretation of these key physical and biological factors, which together create valued wetland functions at Ni-les'tun.

Tidal inundation frequency, duration and depth

Because tidal hydrology is a controlling factor for all tidal wetland functions, tidal hydrology data also helps explain results for other monitoring parameters. For example, we used tide heights in combination with channel survey data to evaluate frequency and duration of fish access to tidal channels (see ***Salmonid habitat opportunity*** below). Other relationships are discussed in the relevant "monitoring questions" sections below. Future reports will further explore the linkages between tidal inundation regime and the restoring physical and biological conditions at Ni-les'tun.

Elevation of wetland surface and instrumentation

Elevations are referenced to the geodetic datum (NAVD88), unless otherwise stated.

Wetland elevation overview

In tidal wetlands, elevation strongly affects hydrology and other physical and biological characteristics. As described above, sampling was stratified by elevation and sub-basin; the stratification was based on the 2008 LiDAR digital elevation model (DEM) (Watershed Sciences 2009). The LiDAR DEM shows that the Ni-les'tun pasture surface generally ranged from 6 to 7.5ft (Figure A6, Appendix A), with higher ground (7.5 to 9ft) along the river bank and in the northwest portion of the site. The highest portions of the natural levee and man-made dikes exceeded 10ft. Mean Higher High Water (MHHW) at the nearby NOAA tide station at Bandon is 7.0ft (Figure A7, Appendix A). Brophy *et al*. (2011) measured the elevation of low and high marsh at comparable sites on the Oregon coast and found that low marsh occurred slightly below MHHW, and high marsh occurred near or just above MHHW. This is also true at the Bandon Marsh Unit reference site; low marsh at the site is generally found just below MHHW, and high marsh is found just above MHHW (Figures A6 and A15, Appendix A).

The historic wetland type at Ni-les'tun was "seasonally wet prairie" subject to tidal flooding (Figure A11, Appendix A; Benner 1992) – what we currently call "high marsh." Therefore, the high marsh at the Bandon Marsh Unit – which occurs at about 7 to 8ft – is an appropriate reference area for the pasture. However, the current elevation of the Ni-les'tun pasture (generally around 6-7ft) is about a foot lower than the reference site's high marsh (Figure A6, Appendix A). This suggests that the Ni-les'tun pasture has undergone subsidence (elevation loss). Subsidence is common at diked tidal wetlands in Oregon; it is caused by organic matter oxidation, buoyancy loss, and compaction associated with drainage, grazing, and other land use activities (Frenkel and Morlan 1991). Based on current elevation, we expect the pasture will initially restore to low marsh, but accretion over the course of many years may eventually allow re-establishment of high marsh (Frenkel and Morlan 1991, Thom and Borde 2002). Dynamic vegetation and soil conditions at the reference site suggest that accretion may be fairly rapid in this part of the Coquille River estuary (Brophy 2005a; also see **Emergent wetland plant communities** and **Soils** below). Accretion at Ni-les'tun and the Bandon Marsh Unit is being measured by USGS using high-accuracy SET (Surface Elevation Table) methods (Glenn Guntenspergen, personal communication); results will be discussed in future reports.

Ground survey of transects and instruments

We worked with Ducks Unlimited surveyor Pat Schulte to obtain high-accuracy elevations for transects and instrumentation using RTK-GPS and total station equipment (Photos C2 and C3, Appendix C). The results were used throughout this report to interpret other monitoring data.

Elevations of transects and instrumentation are shown in Tables B1 and B2 (Appendix B). The lowest study transects were those near the mouth of Fahys Creek (NL T2 and NL T18). These transects, at 4.9 to 5.5ft NAVD88, were the most strongly affected by the adjacent tide gates and occasional inflows of brackish waters of the Coquille River. The highest transects were on the natural levee (NL T17, 8.1ft), in the forested wetlands above North Bank Road (NL T7, 9.5ft), and at the Bandon Marsh Unit reference site (6.8-8.2ft). In the sections below, we use these elevation measurements to relate tidal water levels to other monitoring data.

Minimum bin analysis of LiDAR point cloud

In the forested wetlands, dense vegetation made it challenging to survey the elevations of transects and groundwater wells, so we supplemented the survey data with LiDAR analysis. Our initial review of the LiDAR DEM provided by the State of Oregon (Watershed Sciences 2009) suggested the DEM might be somewhat inaccurate in these areas, probably due to vegetation interference (Gopfert and Heipke 2006). We re-analyzed the point cloud for these areas using the "minimum bin" method (Kim *et al*. 2006; http://lidar.asu.edu/points2grid.html). The minimum bin method is recommended for improving the DEM in areas of dense vegetation (NOAA/CSC 2010).

After experimenting with several bin sizes, the 32.8ft (10m) bin size produced the most useful results, removing much of the "noise" in the DEM due to dense herbaceous and shrub vegetation (Figures A8 and A9, Appendix A). The minimum bin method produced ground surface elevations that were generally 1-2ft lower than the State of Oregon DEM (Watershed Sciences 2009) in the forested wetlands – a very large difference in a tidal wetland, and one that is important to our understanding of the likely tidal inundation regime in this area. Although we did not conduct a quantitative analysis, initial review showed that the minimum bin DEM more closely matched the surveyed ground surface elevations at our study transects, particularly in the forested wetlands. In future reports, we will continue to use the minimum bin DEM alongside the State of Oregon DEM to interpret physical and biological responses to tidal restoration at Ni-les'tun.

Channel morphology

Ducks Unlimited surveyor Pat Schulte, along with members of our team, conducted an extensive RTK-GPS survey of the constructed channel system during 2010-2012 (Photos C2 and C3, Appendix C). Over 90% of the restored channel length was surveyed (Figure A10, Appendix A). Data from the RTK-GPS survey dataset was used for analysis of fish habitat availability (see **Salmonid habitat opportunity: Surface area, volume, duration and frequency** below). The RTK-GPS survey provides a powerful basis for evaluation of post-restoration channel development; further analysis will be presented in future monitoring reports. For example, we will be able to use the RTK-GPS baseline survey to calculate future changes in cross-sectional area, channel volume, sinuosity, and density at any location within the surveyed channel system, and compare those metrics to reference conditions at the Bandon Marsh Unit and other sites (e.g. So *et al*. 2009).

1b. Physical and biological conditions at Ni-les'tun

> **Monitoring Question 1b: Are tidal wetlands developing, with physical and biological characteristics trending towards reference conditions?**

Metrics for evaluating physical and biological conditions:

> Wetland plant community composition and extent; soil characteristics (stored organic carbon, salinity, pH, texture); groundwater levels; surface water salinity and temperature. *(Rationale: Soil characteristics, groundwater levels and surface water characteristics are controlling factors in tidal wetland plant community development and many other wetland functions. Note: channel morphology is also a key physical characteristic; it is addressed under Question 1a above.)*

Since this report contains baseline (pre-restoration) monitoring results, this question cannot yet be answered; comparisons will be made during post-restoration effectiveness monitoring.

In this section, we describe pre-restoration conditions, which form the basis for evaluating post-restoration change.

To address this monitoring question, we measured tidal hydrology, channel morphology, plant communities, soils, groundwater, and surface water salinity and temperature. The sections below describe results for each of these parameters, and discuss the relationships among the parameters.

Tidal hydrology

This parameter is discussed under Monitoring Question 1a above.

Emergent wetland plant communities

Plant community composition

As described above, sampling at Bandon Marsh NWR was stratified and distributed across all tidal wetland elevation zones and all sub-basins. Data on emergent wetland plant community composition was collected within study transects 100m long, which were stratified to sample major elevation zones, subwatersheds, and major vegetation zones. Visual estimates of percent cover by species were made within 15 randomly placed 1-sq m quadrats along each transect. Quadrats were placed 1m off the transect's central axis (left or right side randomly determined), at random distances from the transect end post (but at least 3m apart and 3m from the transect end post). Visual cover estimates followed the Oregon Department of State Land's Routine Monitoring Protocol (Oregon DSL 2009). For transects that had been sampled in 2003, we re-sampled 7 of the 2003 quadrats and randomized the other 8 quadrats – the "partial replacement" method, useful for improving detection of change over time (Yates 1964).

During baseline monitoring, strong contrasts were apparent between emergent wetland plant communities at the Ni-les'tun pasture and the Bandon Marsh Unit reference site. Vegetation cover at Ni-les'tun consisted of about half non-native pasture grasses and half native species, while the reference site had much higher cover of native species (Figure 4). Communities with a higher proportion of native species were concentrated on the west end of the site (Figures A12 and A13, Appendix A). The transects near the mouth of Fahys Creek (NL T2, NL T18) had higher soil salinities and more native species – including several of the same species that are dominant at the reference site, such as seashore saltgrass (*Distichlis spicata*) and Pacific silverweed (*Potentilla anserina*) (Table B4, Appendix B). Native species are more competitive in these areas because of the brackish conditions, which negatively affect non-native pasture grasses. Other strongly native-dominated communities occurred in the wettest parts of the pasture, which were less heavily grazed (NL T4, NL T19). Although invasive reed canarygrass (*Phalaris arundinacea*) is present in these wettest areas, it is not dominant, and may actually have decreased since 2003. NL T19, located within a large area mapped as a slough sedge (*Carex obnupta*)-reed canarygrass community in 2003, had less than 5% cover of reed canarygrass in 2010.

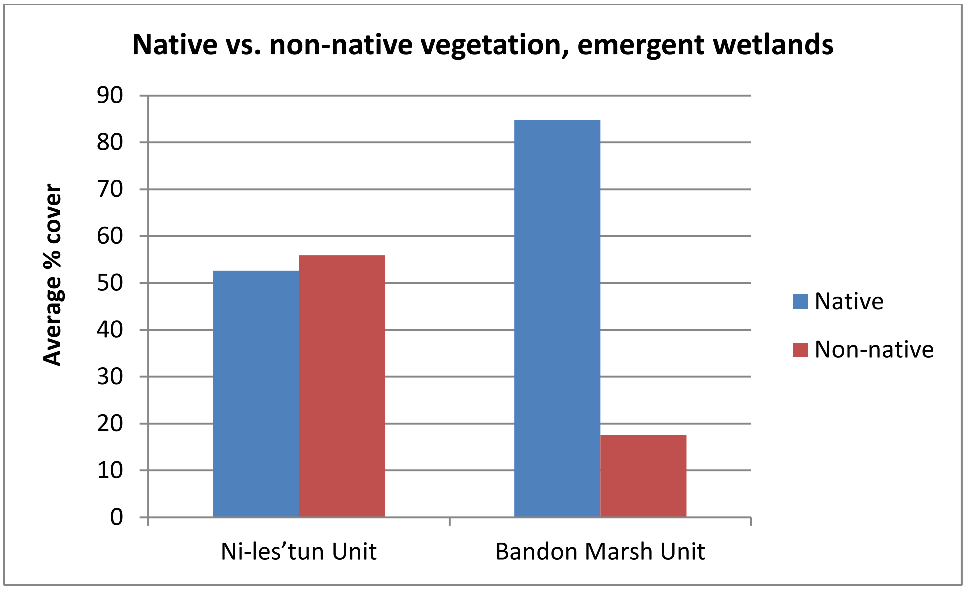


Figure 4. Average percent cover of native *versus* non-native species in emergent wetland transects at Ni-les'tun Unit (n=14) and Bandon Marsh Unit (n=4) (species over 5% cover).

At the Bandon Marsh Unit reference site, the dominant species were typical of Oregon's least-disturbed tidal marshes: Baltic rush (*Juncus balticus*), tufted hairgrass (*Deschampsia cespitosa*), and Pacific silverweed (*Potentilla anserina*) (Table B5, Appendix B). The only non-native species that averaged over 5% cover in any transect at the Bandon Marsh Unit was creeping bentgrass (*Agrostis stolonifera*). This species (often identified as "*Agrostis alba*" in early reports) has long been a major component of least-disturbed high marsh in Oregon (Jefferson 1975); and was probably introduced to our coast very early.

The distribution of plant communities at the reference site (Figures A14 and A15, Appendix A) lacked the clear gradients that are generally present at least-disturbed high marsh sites (Jefferson 1975). (This lack of clearly visible gradients was also true during 2003 monitoring.) Major changes in plant communities between 2003 and 2010 suggest that this area is very dynamic (i.e., in a state of disequilibrium). Further information below (changes in percent cover by species, and changes in soil conditions) suggests the area may be accreting sediment at a fairly rapid pace, which would explain the lack of established vegetation patterns. Areas of rapid accretion are not yet in equilibrium with predominant water levels, and may be dominated by opportunistic species until the system reaches equilibrium (Thom *et al.* 2002, Cornu and Sadro 2002).

Comparison of 2003 versus 2010 vegetation data showed significant changes at several transects (Tables B6 and B7, Appendix B). At Ni-les'tun transect NL T2, the transitional species creeping spikerush (*Eleocharis palustris*) increased from zero to 47%. This rapidly-spreading, rhizomatous species is common in formerly diked pastures in the early stages of restoration, as well as diked pastures with leaky tide gates or muted tide cycles (Brophy 2004, 2010). Creeping spikerush is capable of surviving and spreading despite the rapidly-changing hydrology and salinity conditions in these settings. During the same period, soft rush (*Juncus effusus*) decreased from 23% to 6% at NL T2. Soft rush is not tolerant of salinity, so it decreases when brackish tidal flows enter a diked pasture (Brophy 2004, 2010). These changes at NL T2 show the effect of muted tide cycles and fluctuating salinities in the lower Fahys sub-basin (see ***Tidal hydrology*** above, and ***Groundwater*** and ***Channel water salinity and temperature*** below) and show that the area was dynamic even prior to restoration.

At NL T4, slough sedge and Pacific water-parsley (*Oenanthe sarmentosa*) increased greatly from 2003 to 2010 (Table B6, Appendix B). These native species are common herbaceous dominants in Oregon coastal wetlands, including nontidal and freshwater tidal wetlands. Their increase shows that this area is very wet – as evidenced by the groundwater monitoring described below.

At NL T5, the native Baltic rush increased strongly from 2003 to 2010, but non-native tall fescue (*Schedonorus arundinaceus*) also increased. Creeping bentgrass decreased from 28% to 1% (Table B6, Appendix B). No clear reason for these changes could be discerned; post-restoration monitoring will be necessary to reveal the longer-term trajectory here.

At BM T2 on the reference site, seashore saltgrass – a low marsh species – declined, and the high marsh species Baltic rush increased (Table B7, Appendix B). This suggests the community may be moving towards a higher marsh vegetation type, or a more “mature” high marsh as described by Jefferson (1975). Further evidence of this trajectory is provided in ***Soils*** below.

Forested wetland plant communities

We used field measurements and remote LiDAR data to characterize forested wetland vegetation at Ni-les’tun and the Bandon Marsh Unit. Field measurements were made within permanent plots placed along study transects; plots were 30ft wide (15ft on each side of the transect) and the same length as the transect. Transect length varied depending on vegetation density; BM T5 and NL T6 were 174ft long; NL T7 was 225ft long; and NL T20 was 185ft long.

Sample unit size and vegetation measurements varied by stratum (herbaceous, shrub or tree). Sample units were nested within the overall plot following methods described in Peet *et al*. (1998). For shrubs, stems of each species were counted within 15 by 15ft plots placed on a randomly selected side of the transect at random distances from the starting point. Only stems branching below knee height were counted. Trees were counted within the entire plot (30ft wide; length=transect length) except at BM T5, where exceptionally high tree density required a smaller plot size. At BM T5, trees were counted within the same plots as shrubs, but tree plots were extended to 30ft from the transect. At all transects, the diameter of each tree was measured at breast height (dbh). Herbaceous vegetation in forested wetlands was measured using visual estimates of percent cover within 1-sq m plots. Herbaceous vegetation plots were placed 1m off the transect just inside the near and far boundaries of each shrub plot.

Overview

The forested wetlands at the Ni-les'tun Unit were dominated by native species – in fact, non-native species were almost completely absent (Figures A12 and A13, Appendix A; Table B8 through B11, Appendix B). This contrasts with the Ni-les'tun pasture, where non-native species dominated, as described above. Land use history explains this difference: on the pasture, grazing and intensive hydrologic alteration (dikes, tide gates, ditching) discouraged native species and favored non-natives, and non-native grasses were deliberately planted. By contrast, in the forest, little direct manipulation of vegetation appears to have occurred, although timber harvest probably occurred in the past. The primary human influence on the forested wetlands of the Ni-les'tun Unit and north of North Bank Road has been through hydrologic manipulation: Ni-les'tun's dikes and tide gates blocked tidal flow, North Bank Road altered freshwater flows, and the channelization of Fahys Creek reduced floodplain connectivity. These hydrologic manipulations, as well as beaver activity, have led to dynamic conditions in the forests for many years. For example, our team's 2003 monitoring showed many dead and dying Sitka spruce in the area near NL T6 (Brophy 2005a); this trend continued through 2011 (personal observation).

Tree species composition, density and basal area

Sitka spruce (*Picea sitchensis*) and red alder (*Alnus rubra*) were the dominant tree species at transects NL T7, NL T20 and BM T5; Sitka spruce was dominant at NL T6 (Tables B8 and B9, Appendix B). These are the typical dominant trees of Oregon's coastal forested wetlands (Franklin and Dyrness 1988). Brophy (2009) and Brophy *et al.* (2011) found that Sitka spruce was the common dominant tree in Oregon's least-disturbed brackish tidal swamps, but red alder was nearly absent, probably due to alder's sensitivity to salinity (Hutchinson 1986). In freshwater spruce tidal swamps of the lower Columbia River estuary and Puget Sound, Sitka spruce and red alder are often co-dominant (Kunze 1994, Johnson 2010).

Sitka spruce basal area at the forested transects ranged from 32 to 126 sq ft/A, comparable to least-disturbed tidal swamps of the Oregon coast and lower Columbia (53 to 184 sq ft/A in Brophy 2009 and Brophy *et al.* 2011). At NL T6, Sitka spruce density was low (17 trees/A); as described above, this area has had die-back of spruce since at least 2003, probably due to hydrologic changes associated with beaver activity, the Fahys Creek channelization, or other factors (Brophy 2005a). At NL T7 and NL T20, Sitka spruce density was 63 and 129 trees/A respectively. These densities are comparable to Sitka spruce densities of 48 to 129 per acre in least-disturbed tidal swamps studied by Brophy (2009) and Brophy *et al*. (2011), and 77 to 94 per acre in the Columbia River estuary (Johnson 2010).

Shrub species composition and density

Shrub densities in the forested transects ranged from 1000 to over 12,000 stems/A (Table B10, Appendix B). Brophy *et al.* (2011) reported shrub stem densities of 50,000 to 80,000 stems/A in tidal swamps in the Columbia River and Nehalem River estuaries; these study sites were described as "exceptionally dense" in shrubs. Brophy (2009) reported black twinberry (*Lonicera* *involucrata*) densities of 6550 and 6147 stems/A at brackish tidal swamps in the Siuslaw and Yaquina estuaries respectively; other shrub species were much less common at those sites.

Salmonberry (*Rubus spectabilis*) was the predominant shrub at the Ni-les'tun forested wetlands (NL T6, NL T7 and NL T20). Salmonberry is not tolerant of salinity (personal observation), so it is likely to decrease in the transects south of North Bank Road (NL T6 and NL T20) after restoration of brackish tidal flows. This expectation is supported by the absence of salmonberry and dominance of black twinberry and Pacific blackberry (*Rubus ursinus*) at the reference site (BM T5); twinberry and Pacific blackberry are found in least-disturbed brackish tidal swamps (Brophy 2009, Brophy *et al*. 2011). However, change in forested wetland composition at Ni-les'tun may take many years, and species dominance will also be affected by beaver activity (which impounds fresh water).

Although salal (*Gaultheria shallon*) and huckleberry (*Vaccinium* spp.) were abundant at NL T7, NL T20, and BM T5, they grew almost exclusively on fallen logs, and their presence fails to reflect the very wet soil conditions below the woody debris. Brophy (2009) and Brophy *et al.* (2011) also reported abundant growth of these upland shrub species on fallen logs in the Columbia, Nehalem, and Siuslaw estuaries, in contrast to hydrophytic species rooted in the saturated soil.

Shrub data are valuable for interpreting plant community trajectory, because shrub species differ strongly in their tolerance for wetland conditions (Lichvar and Kartesz 2009) and brackish conditions (Hutchinson 1989). Shrub species dominance is most easily determined through stem counts, because percent cover is difficult to estimate visually for diffuse and multi-layered shrub canopies (personal observation). Stem counts are the recommended method for quantifying the shrub layer in established vegetation monitoring protocols, including Roegner *et al*. (2008) and Peet *et al.* (1998). Shrub data is especially important when the dominant trees have broad environmental tolerances – true in Ni-les'tun's forested wetlands, where Sitka spruce and red alder are dominant. Both species have a wetland indicator status of FAC (facultative), meaning that they are equally likely to occur in wetlands and uplands (Lichvar and Kartesz, 2009). Sitka spruce is tolerant of brackish soil and surface water (Brophy 2009, Brophy *et al.* 2011), but also thrives in freshwater conditions; red alder is less tolerant of salinity (personal observation; Hutchinson 1986). However, accurate interpretation of shrub data requires field crews to record where the shrubs are rooted, to distinguish upland shrubs growing on fallen logs from upland shrubs rooted in the soil.

Herbaceous vegetation in forested transects

Slough sedge and skunk cabbage (*Lysichiton americanus*) were the dominant herbaceous understory species in the forested wetlands at both Ni-les'tun and the Bandon Marsh Unit (Table B11, Appendix B). The cover of skunk cabbage at NL T6 and NL T7 approximately doubled between 2003 and 2011 (Table B12, Appendix B). Slough sedge also increased slightly at NL T6 (60% in 2003 *versus* 72% in 2011; Table B12, Appendix B).

Forested wetland dynamics

As described in the **Overview** above, vegetation in the forested wetland south of North Bank Road has been dynamic for many years (Brophy 2005a). The transects in this area (NL T6 and NL T20) offer an opportunity to track future changes, and NL T6 provides some insight into changes since 2003. As described above, herbaceous vegetation changes suggest that NL T6 has gotten wetter since 2003. Woody vegetation also changed at NL T6 since 2003. Stem counts were not conducted in 2003 at NL T6 due to the high density of Pacific crabapple (*Malus fusca*), which made foot travel nearly impossible). In 2011, it was apparent that Pacific crabapple had decreased at NL T6 in 2011; the transect had become “walkable” (though with difficulty, due to very dense and tall slough sedge), and Pacific crabapple made up only about 13% of the total shrub stem count (Table B10, Appendix B). Like the Sitka spruce die-back in the area around NL T6, the reduction in Pacific crabapple since 2003 is probably due to hydrologic change (Fahy’s creek channelization, beaver activity, etc.).

The forested wetlands south of North Bank Road (near NL T6 and NL T20) have been affected by the Ni-les’tun dike/tide gate system in past decades. We expect to see future changes in woody and herbaceous species dominance as the natural tidal inundation and salinity regimes are restored. In the long term, the dominant species will depend on the balance between three major factors: 1) increased salinity and more dynamic groundwater associated with the restored tides; 2) beaver activity (which tends to increase freshwater influence); and 3) dominance of Sitka spruce. Sitka spruce provides fallen logs and root platforms -- drier surfaces above the otherwise-saturated soils, that support non-wetland species (see **Shrub species composition and density** below). Beaver and Sitka spruce act as “system engineers,” interacting with physical controlling factors to alter their environment – and in the process affecting many other species (Wright and Jones 2006; Brophy 2009, Brophy *et al*. 2011, Diefenderfer 2007, Diefenderfer and Montgomery 2008).

Despite the abundant willows (*Salix* spp.) in the wetlands north of North Bank Road and east of Fahys Creek, and the strong presence of willows along the margins of Fahys Creek south of North Bank Road, we found no willows in our study plots. This was also true in 2003 (Brophy 2005a). The dominance of willows along North Bank Road and Fahys Creek may be due to hydrologic change in these areas; North Bank Road and associated beaver activity have impounded surface flows for years (Brophy 2005a).

Willows will be useful in restoration plantings at Ni-les’tun, but their establishment and growth in the former pasture may be somewhat limited by salinity. The most common willow species at Ni-les’tun is Hooker willow (*Salix hookeriana*) (personal observation). Brophy (2009) found that Hooker willow was dominant in those portions of a Siuslaw tidal swamp where summer surface water salinity was 3.5 and soil salinity was 10.4, but absent from areas with slightly higher salinities (summer surface water salinity of 6.5 and soil salinity of 13.1). The salinity differences at that site may have also related to beaver activity (Brophy 2009), since beaver dams impound freshwater flows, reducing salinity.

The reference site's forested wetland at transect BM T5 appears to be changing rapidly, based on the abundance of small trees. Sitka spruce and red alder densities at BM T5 were very high (605 and 774 trees/A respectively; Table B9, Appendix B), and trees were small; basal areas were similar to the Ni-les'tun forested transects. Pacific wax myrtle and cascara were also abundant and small at this transect; both of these species could be classified as large shrubs or small trees. As described in **Emergent wetland plant communities** above, the adjacent marsh surface may be undergoing rapid accretion. If so, the rising elevation of the marsh surface could be causing decreased salinity and decreased frequency of tidal inundation at BM T5, allowing colonization by trees. The dynamic nature of BM T5 reduces its suitability as a reference site, so we will continue to compare the Ni-les'tun forested wetlands to other reference sites across the Oregon coast to provide broader perspective.

LiDAR analysis of the forested wetland canopy

On-the-ground sampling of forested wetland vegetation is very time-consuming, and variability in community composition is high (Roegner *et al.* 2008, Brophy *et al*. 2011). LiDAR data can be useful for forest vegetation analysis and ecosystem studies (Levsky *et al*. 2002), and LiDAR offers the advantage of comprehensive data rather than limited-area sample plots. We explored the possibility of using LiDAR to characterize the forested wetlands at Ni-les'tun, using FUSION software (http://www.fs.fed.us/eng/rsac/fusion/) to generate a canopy model from the 2008 LiDAR point cloud. We stratified the LiDAR analysis using our plant community mapping (Figure 5). The stratified data (FUSION canopy model) were analyzed for canopy height distribution (Figure 6; Table B13, Appendix B), and FUSION tools were used to generate visualizations of canopy structure (Figures 7 and 8). These results provide just a few examples of potential analyses. If further LiDAR data are acquired in the future, the data could be analyzed using similar tools and the results compared to the 2008 data. The efficiency and comprehensive nature of LiDAR analysis is attractive. However, ground-truthing will be necessary to relate the LiDAR data to measurable changes in dominant vegetation.

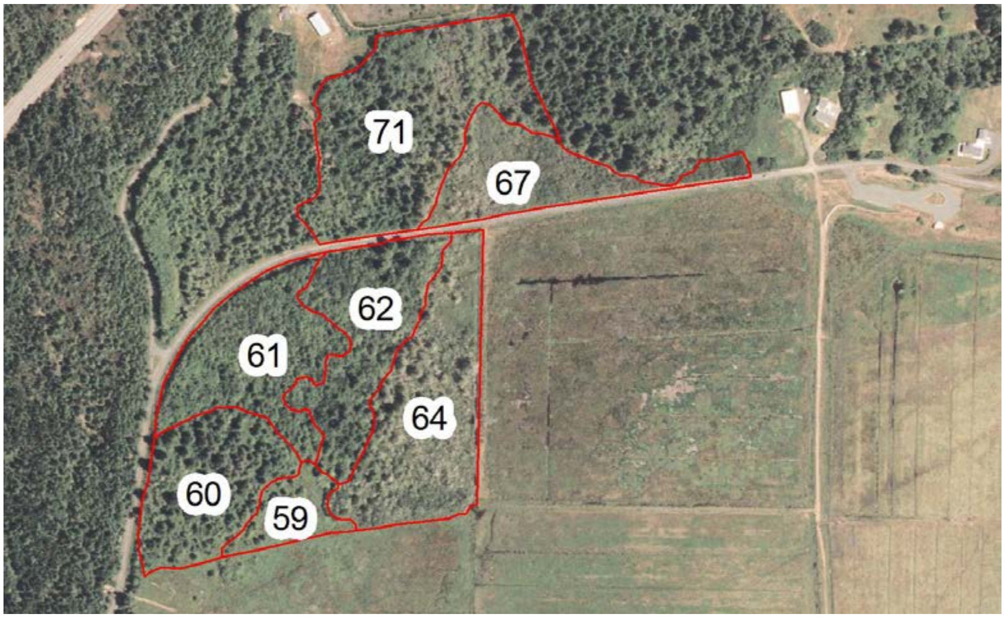


Fig. 5. Forested wetland polygons for analysis of 2008 LiDAR canopy model.

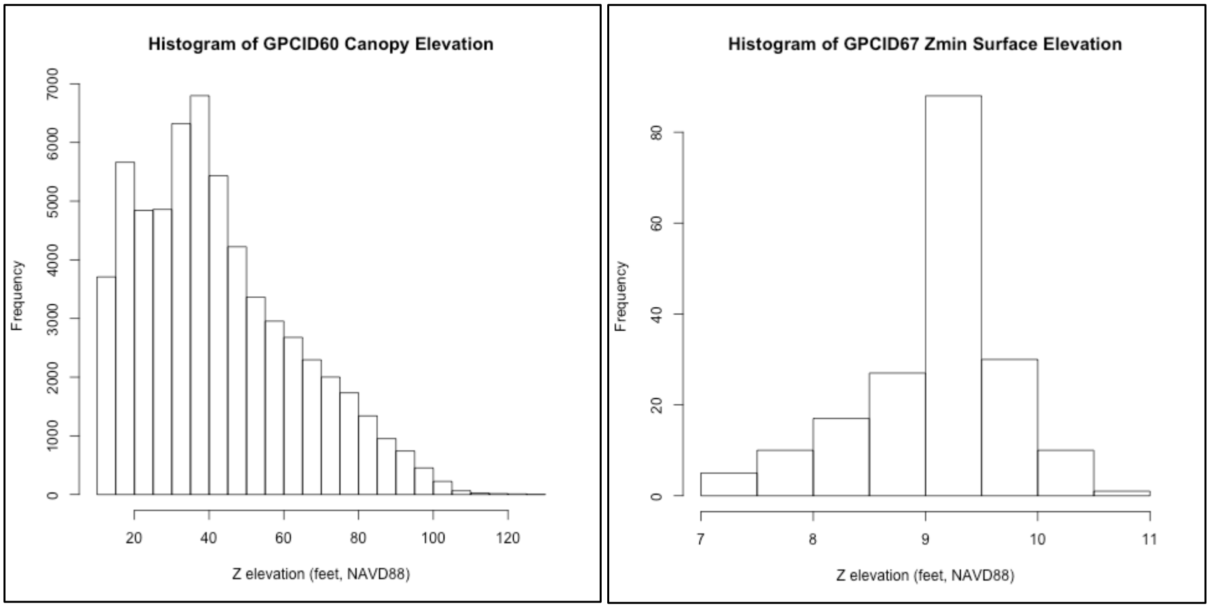


Figure 6. Examples of canopy height histograms created from FUSION canopy model.

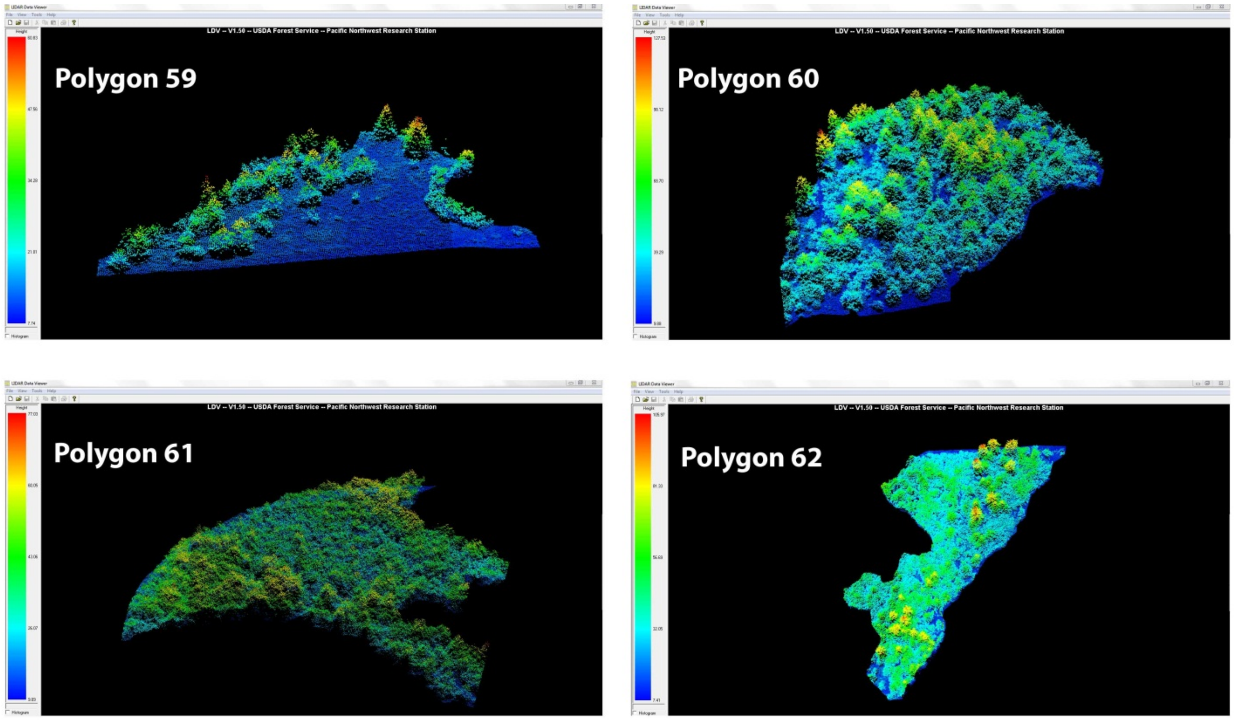


Figure 7. Canopy visualization images from FUSION output (polygons 59-62 of Figure 5).

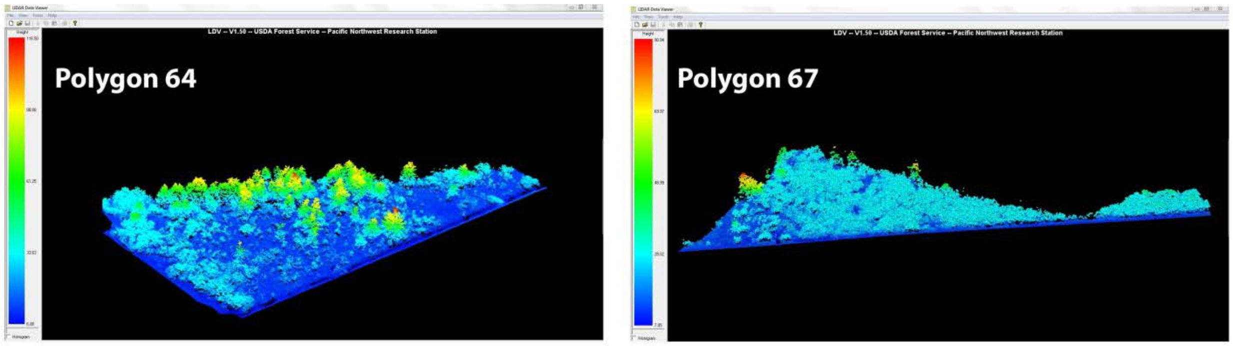


Figure 8. Canopy visualization images from FUSION output (polygons 64 and 67 of Fig.5).

Plant community mapping

We mapped wetland vegetation by traversing the project sites on foot to correlate field vegetation with patterns in June 2010 aerial photographs acquired by Bergman Photographic for this project. The aerial photos were high resolution, with a 6 inch pixel size; they could be enlarged in the GIS to a scale of 1:1000 with no degradation of image quality. Map units were delineated in the field on enlarged printouts of the aerials. Digital vegetation maps were created in ArcGIS 9.3 by georeferencing the field maps and tracing the map unit boundaries into the GIS at a scale of 1:2000; the polygon size threshold was about 0.25A (0.1ha). Vegetation maps were saved as shapefiles (NL_vegmap_2010.shp and BM_vegmap_2010.shp).

Following the National Vegetation Classification Standard (The Nature Conservancy 1994), we used a two-level hierarchical vegetation classification scheme. Plant associations represented fine gradations of dominant species; as in 2003 monitoring, these were finely divided to reflect small differences in community composition. Alliances, the coarser level, were described by a single major dominant species that characterized a larger area. This two-level classification will allow flexibility in tracking future vegetation change.

The majority of the Ni-les'tun pasture was occupied by non-native pasture grass communities, primarily dominated by tall fescue (Figures A12 and A13, Appendix A). Tall fescue is considered potentially invasive in freshwater wetlands in Oregon (Magee *et al*. 1999), and it is very competitive on the Oregon coast, often forming near-monocultures in disturbed areas such as roadsides, vacant lots, and pastures. The proportion of tall fescue across the pasture varied from near-monoculture (e.g. NL T17 and NL T12) to less than 25% of cover (e.g. NL T9, NL T10). Other non-native species that were prominent in the pasture included creeping bentgrass, birdsfoot trefoil (*Lotus corniculatus*), and common velvetgrass (*Holcus lanatus*). The fescue-dominated pasture communities often included a substantial component of two native species, Baltic rush and Pacific silverweed; in some areas, these two native species were co-dominant with non-natives (e.g. NL T5, NL T10).

Native-dominated plant communities were found primarily in the lower Fahys sub-basin, where soils were more strongly saline and/or saturated through late spring (NL T2, NL T4, NL T18), and in less heavily-grazed parts of the pasture (NL T4, NL T9, NL T10, NL T19).

Changes since 2003

At Ni-les'tun, the same general distribution of native and non-native emergent wetland plant communities was observed in 2003 (Brophy 2005a). However, brackish-tolerant species have expanded greatly in the lower Fahys sub-basin since 2003 (Figure A13, Appendix A). Communities dominated by Lyngbye's sedge (*Carex lyngbyei*) – a salt-tolerant species typical of low to mid-elevation tidal marsh – occupied about 4A in 2003, compared to 15A in 2010. A 10A area that had been occupied by a mosaic of Pacific silverweed and saltgrass-dominated associations in 2003 had completely converted to a saltgrass-dominated association in 2010. These changes offer a preview of likely changes over the next decade as tidal marsh vegetation re-establishes at Ni-les'tun.

The mapped plant communities at the Bandon Marsh Unit reference site have also changed since 2003. In 2003, fairly large areas were characterized as an unmappable mosaic of more than one plant community. In 2010, many of these areas have segregated into mappable units – possibly due to differential sediment accretion at this relatively young tidal marsh (see **Soils** below). However, as in 2003, some of the associations are still an odd mixture of high and low marsh species, suggesting the site is still dynamic.

The vegetation map changes between 2003 and 2010 at the Bandon Marsh Unit are also due in part to the much higher-resolution digital aerial photographs used for the 2010 mapping. The 2003 mapping used analog (film) images acquired at a scale of 1:12,000. By contrast, the 2010 mapping used digital images with a 6 inch pixel size, allowing onscreen viewing in the GIS at a scale of 1:1000 with no image quality degradation. Fine distinctions in plant community composition were visible (and mappable) using these 2010 aerials.

Soils

Soil samples from the surface rooting zone (0-12 inches) were collected using a Dutch auger at 10 to 20 random subsample locations along each transect. These subsamples were bulked in the field, then delivered to the Oregon State University Central Analytical Laboratory for analysis. At the lab, large roots were removed, samples were dried and homogenized, and a subsample was removed for analysis. Electrical conductivity and pH of the soil solution were measured using an electrical conductivity meter and a reference electrode with a pH meter, respectively. Percent organic matter was determined by loss on ignition (Craft *et al.* 1991); samples were burned in a kiln at approximately 450°C for eight hours. Particle size analysis was conducted by the quick hydrometer method, after repeated treatment with hydrogen peroxide to remove organic material (Dane and Topp 2002). After receiving results from the lab, we calculated soil salinity from electrical conductivity using a standard formula (Fofonoff and Millard 1983). We calculated percent soil carbon from percent organic matter using a conversion specific to high organic soils (0.68 x %OM) from Kasozi *et al*. (2009).

Baseline data show strong contrasts between soils at the Ni-les’tun pasture compared to the Bandon Marsh Unit reference site. Carbon content in the reference site soils averaged approximately twice as high as the restoration site (Table 2; Table B18, Appendix B). MacClellan (2012) found a similar pattern in 16 tidal wetlands in Oregon; her study included the samples from Bandon NWR. Salinities averaged much higher in the fully tidal reference site, but were measurable (in the oligohaline range) at the restoration site (Table 2) – only two of the 14 pasture transects had salinities in the “fresh” range (less than 0.5 PSU) (Table B18, Appendix B). The low-brackish salinities across the restoration site were probably due to the site’s historic status as tidal wetland, as well as tide gate leakage and salinity retention after occasional dike overtopping events in the recent past.

Table 2. Average soil characteristics across all transects in restoration site and reference site.

Site	# of transects	pH	% OM by LOI	% C	Salinity (PSU)	% sand	% silt	% clay
Ni-les'tun restoration site	14	5.2	9.3	6.3	3.7	18.6	45.3	36.2
Bandon Marsh reference site	4	5.5	17.6	12.0	15.7	13.7	46.8	39.5

Some notable changes were observed in soil characteristics between the early baseline monitoring in 2003 (Brophy 2004) and the 2010 monitoring (Table 3). At Ni-les'tun, the most dynamic conditions were observed at NL T2. At this transect, soil salinity dropped from 14.6 PSU in 2003 to 1.5 PSU in 2010. By contrast, soil salinity at transect NL T18, slightly closer to the mouth of Fahys Creek, was high in 2010 (19.29 PSU; Table B18, Appendix B). The reason for the salinity decrease at NL T2 is unknown. Soil salinity is expected to increase at NL T2 and other Ni-les'tun transects after restoration, since the restored tidal flows will be brackish (see **Channel water salinity and temperature** below).

At the Bandon Marsh Unit, salinity decreased substantially between 2003 and 2010 at the two transects that were sampled both years (transects BM T1 and T2), dropping from the euhaline range (near 40 PSU) to the polyhaline range (20-25 PSU) (Table 3). Organic matter content at these two transects increased, and pH increased slightly (Table 3). Soil texture could not be compared between the two monitoring events due to changes in methods. (2010 analysis used repeated peroxide treatments to remove organic matter prior to textural analysis, a requirement that has become evident to our team over several years of sampling high-organic tidal wetland soils.) These changes, along with the observed vegetation patterns (see ***Emergent wetland plant communities*** above) suggest that the Bandon Marsh Unit is a dynamic system rather than a system in equilibrium. Historic vegetation mapping (Benner 1992) shows that most of the Bandon Marsh Unit was open water in the mid-1800's; apparently, the marsh has accreted since that time. This rapid accretion probably relates to land use change and associated increased sediment loads in the Coquille River watershed; documents reviewed by Benner (1992) show that head of tide in the Coquille River has moved 5 miles downstream since the mid-1800s. The changes we observed between 2003 and 2010 suggest that this accretion continues today. The dynamic nature of the Bandon Marsh Unit reduces its suitability as a reference site, so our post-restoration monitoring reports will compare the Ni-les'tun wetlands to other reference sites across the Oregon coast to provide broader perspective.

Table 3. Comparison between soil characteristics in 2010 *versus* 2003 at transects which were studied both years. 2003 data are in red. See Table B18, Appendix B for full soil test results.

Refuge unit	Year	Transect	pH	% OM by LOI	% C	Salinity (PSU)	Salinity class
Ni-les'tun	2010	NL T2	5.6	10.00	6.80	1.50	oligohaline
Ni-les'tun	2003	NL T2	4.7	7.89	5.37	14.59	mesohaline
Ni-les'tun	2010	NL T4	4.9	8.14	5.53	1.26	oligohaline
Ni-les'tun	2003	NL T4	5.2	9.62	6.54	1.93	oligohaline
Ni-les'tun	2010	NL T5	5.9	4.88	3.32	0.38	fresh
Ni-les'tun	2003	NL T5	5.8	5.25	3.57	1.26	oligohaline
Bandon Marsh	2010	BM T1	5.6	11.65	7.92	22.88	polyhaline
Bandon Marsh	2003	BM T1	5.3	9.19	6.25	42.91	euhaline
Bandon Marsh	2010	BM T2	5.6	20.87	14.19	20.73	polyhaline
Bandon Marsh	2003	BM T2	5.5	12.69	8.63	38.13	euhaline

NRCS soil survey maps (Figures A16 and A17, Appendix A) provide a broad view of soil type distribution at the restoration and reference sites. Austin (2011) profiled soils at two locations on the reference site (near BM T1 and BM T3) and three locations on the restoration site (near NL T2, NL T4, and NL T16) (Photo C5, Appendix C). He found that soils at every location met hydric soil indicator criteria, and soil profiles generally matched the mapped series characteristics. The exception was the soil near BM T1, which is mapped as Coquille but appeared similar to the Willanch series (Austin 2011). Willanch and Coquille soils are geographically associated; Willanch soils are sandier (Soil Survey Staff 2012).

Groundwater

Baseline monitoring revealed strong contrasts between groundwater regimes at the Ni-les’tun pasture and the high marsh at the Bandon Marsh Unit reference site. During the winter, groundwater levels were high throughout the restoration site and reference sites. However groundwater dropped 3 to 4 feet below the soil surface during early to mid-summer at most Ni-les’tun pasture transects, and stayed there until fall rains began (Figure 9). In other words, the pasture showed seasonal wetland characteristics. By contrast, the reference site high marsh water tables were dynamic in summer, rising to the surface during each spring tide cycle (Figure 10). Further details are provided below; transect elevations – important to interpretation – are provided below and in Table B1 (Appendix B).

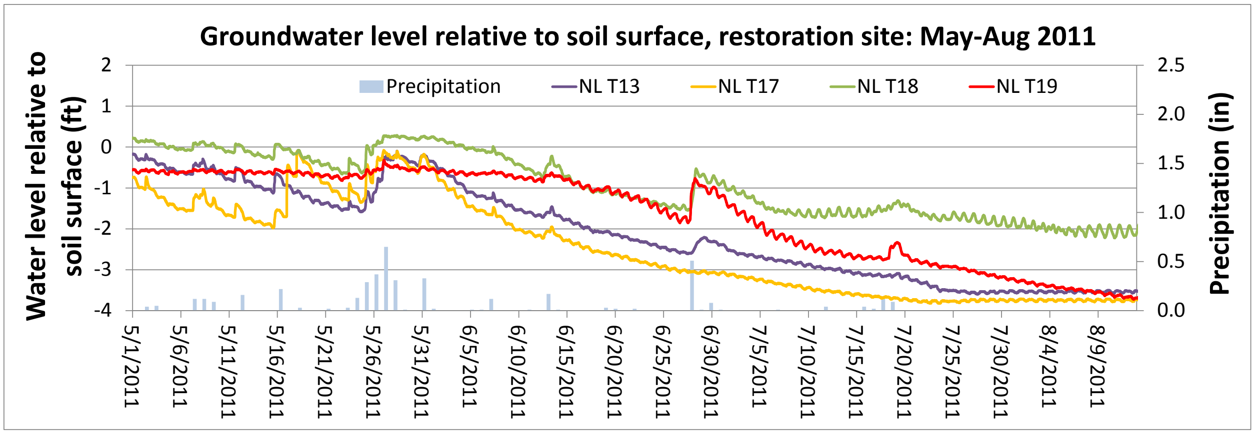


Figure 9. Groundwater relative to the soil surface during May-August 2010 at four representative Ni-les'tun pasture transects. Blue vertical bars show daily precipitation.

The four Ni-les'tun pasture transects in Figure 9 cover the full range of elevations across the pasture. All pasture transects showed a response to precipitation events, but they diverge in other characteristics, illustrating four major groundwater regimes on the pasture:

- ***Low, wet pasture with tide gate "backup" effect***: NL T18 (elevation 5ft NAVD88) was the lowest and wettest transect, located near the mouth of Fahys Creek. During spring, groundwater at this transect showed a very muted response to tidal cycles, due to freshwater outflows backing up behind the closed tide gates. NL T2 also showed a muted tidal response, due to its location near lower Fahys Creek.
- ***Upslope pasture edge, with seepage influence***: NL T4 and NL T19 were noticeably wetter than other transects at comparable elevations (6.2 and 7.1 ft NAVD88 respectively). Water tables at both transects remained high until late June (NL T19) or mid-July (at NL T4), probably due to non-channelized, subsurface drainage from adjacent forested wetlands.
- ***Natural levee (river bank):*** NL T17 was the highest pasture transect, located close to the Coquille River on the natural levee (elevation 8ft). Groundwater at this transect responded to the tides during spring, but dropped below the rooting zone earlier than other transects (in May). NL T17 was the only transect that showed this groundwater pattern.
- ***Main pasture seasonal wetland***: The remainder of the Ni-les'tun pasture transects (NL T5 and NL T9 through NL T16) fell into this seasonal wetland group. Groundwater at these transects was high in winter; responded primarily to precipitation events during the fall and spring; and dropped at least 3 or 4ft below the soil surface during summer. NL T13 (elevation 6ft) was a typical example.

As shown in Figure 9, the wet spring in 2011 allowed water tables to stay relatively high at most locations on the pasture until early June. However, the water table dropped more than a foot below the soil surface by late June throughout the pasture, with the few exceptions listed above. A water table more than a foot below the soil surface generally indicates non-wetland conditions at the time of observation (Environmental Laboratory 1987). Few other studies have measured groundwater levels in diked former tidal wetlands in the Pacific Northwest. Brophy and Lemmer (2011) found that groundwater in a diked former tidal wetland in the Siuslaw River estuary dropped more than a foot below the soil surface during May and June, even though the sample locations were low relative to tidal range.

All of the transects showed small daily groundwater peaks throughout the summer. These were probably due to plant evapotranspiration (Gribovszky *et al*. 2010), since they do not align with tide peaks. Larger daily peaks due to tidal cycles were seen at the reference site only, and were clearly aligned with the tides, as described below and shown in Figure 10.

Groundwater regimes at the reference site were very different from the restoration site (Figure 10). Two major groundwater regimes were evident:

- ***"Spring tide reset" pattern***: BM T1, BM T2, and BM T4 (elevation 6.8-7.3ft), in the reference site's high marsh, show strong tidal influence on groundwater. Groundwater dropped 1-3 ft below the soil surface during summer neap tide cycles, but each spring tide cycle "reset" groundwater to the soil surface. This groundwater regime has been called a "spring tide reset" pattern (Brophy *et al.* 2011, Brophy 2009). Groundwater responded to the tides even when there was no surface inundation (e.g., BM T4, 6/30/11-7/2/11). This highly dynamic groundwater regime is likely to produce active soil biota, since it involves frequent wetting and drying cycles (Mitsch and Gosselink 1993). Soil biota are important to many wetland functions, including salmonid habitat, nutrient cycling and shorebird habitat.
- ***Seepage-influenced, seasonally-tidal groundwater regime***: In the forested tidal wetland along the east margin of the Bandon Marsh Unit (BM T5, elevation 8ft) and at nearby high-elevation brackish marsh (BM T3, elevation 7.7ft), tidal influence was apparent only during fall, winter and spring. Summer groundwater remained stable and very high at BM T5, probably due to non-channelized subsurface flow (e.g. seepage) from adjacent hillslopes. At BM T3, groundwater dropped more than a foot below the soil surface during late summer.

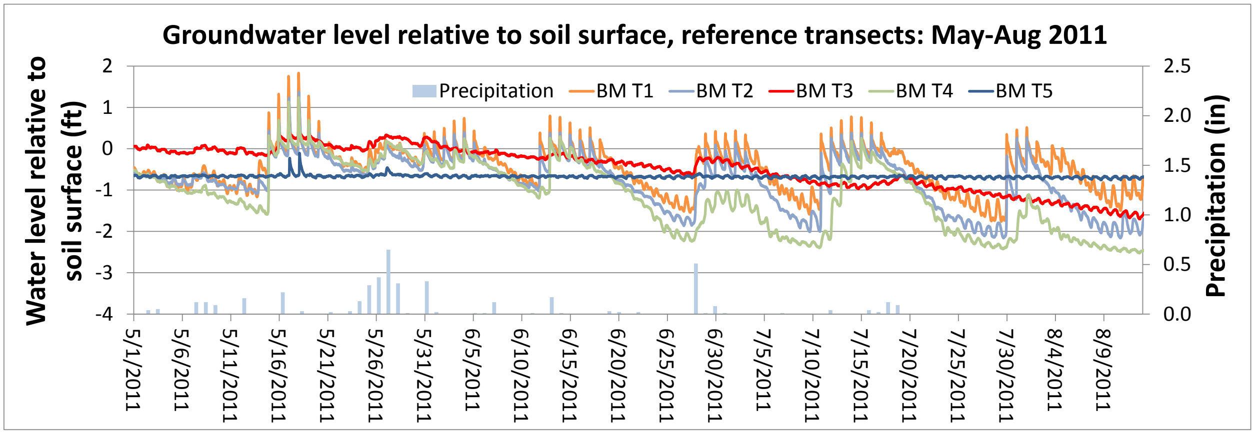


Figure 10. Groundwater relative to the soil surface during May-August 2010 at the five Bandon Marsh Unit reference transects. Blue vertical bars show daily precipitation.

Forested wetlands at Ni-les’tun showed two distinct groundwater patterns (Figure 11). Like most of the pasture transects, NL T6 and NL T20 showed seasonal wetland characteristics, with groundwater levels dropping steadily during the late spring/early summer drawdown period. NL T7, like the reference forested wetland at BM T5, had consistently high groundwater levels even during the dry summer period. NL T7 is located north of North Bank Road and is influenced by beaver activity in this reach of Fahys Creek. Brophy (2005b) described similar year-round high water tables at Tom’s Creek, a beaver-influenced, least-disturbed coastal swamp at South Slough National Estuarine Research Reserve.

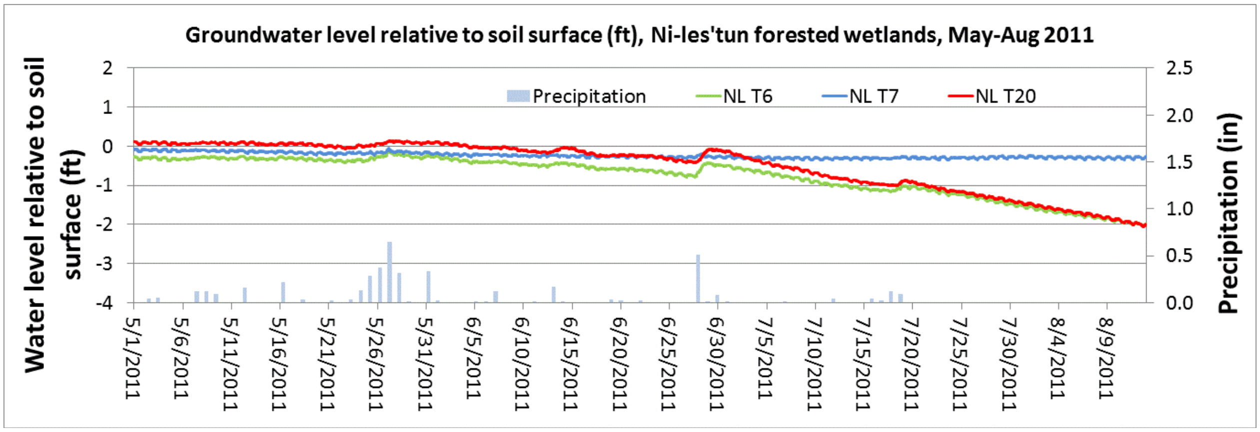


Figure 11. Groundwater relative to the soil surface during May-August 2010 at the three Ni-les’tun forested wetland transects. Blue vertical bars show daily precipitation.

The elevation at NL T7 is high (9.5ft), and given its location (north of North Bank Road) and the prevalence of beaver activity in the area, it may seldom undergo tidal inundation even after restoration. However, groundwater in the forested wetlands south of North Bank Road (NL T6 and NL T20) is expected to become more dynamic after restoration. Previous studies found that groundwater regimes at least-disturbed tidal swamps in Oregon vary depending on habitat class and landscape setting. In Sitka spruce tidal swamps in the Siuslaw, Yaquina, Nehalem, and Columbia estuaries, summer water tables dropped about a foot below the soil surface during neap tide cycles, but were “reset” to the soil surface by spring tide cycles (Brophy *et al*. 2011, Brophy 2009). Willow tidal swamps – often areas of heavy beaver activity -- were sampled in the Columbia and Siuslaw estuaries; these swamps had water tables at or very near the surface all summer long (Brophy *et al*. 2011, Brophy 2009). The high water tables in these willow swamps were probably the result of nearby beaver dams and/or hillslope seepage. All of these factors – tides, hillslope seepage, and beaver activity – will strongly influence post-restoration groundwater dynamics within Ni-les’tun’s forested wetlands.

Channel water salinity and temperature

Baseline monitoring showed strong contrasts between channel water salinities and temperatures at Ni-les'tun and the Bandon Marsh Unit. This section provides a brief summary of results. Since water temperature and salinity strongly affect juvenile salmonid habitat use, further discussion is provided under ***Salmonid habitat utilization*** below.

The middle and upper tidal reaches of Fahys Creek were fresh prior to restoration (Figures 12 and 13). In lower Fahys Creek, spring salinities were slightly brackish (Figure 12) but reached the polyhaline range (up to 20) during high tides in late summer (Figure 13) – probably due to limited tidal inflow through the side-hinged tide gate (Figure 35). Preliminary post-restoration data (Figure 14) suggest that salinities are on a trajectory towards reference conditions following tidal reconnection.

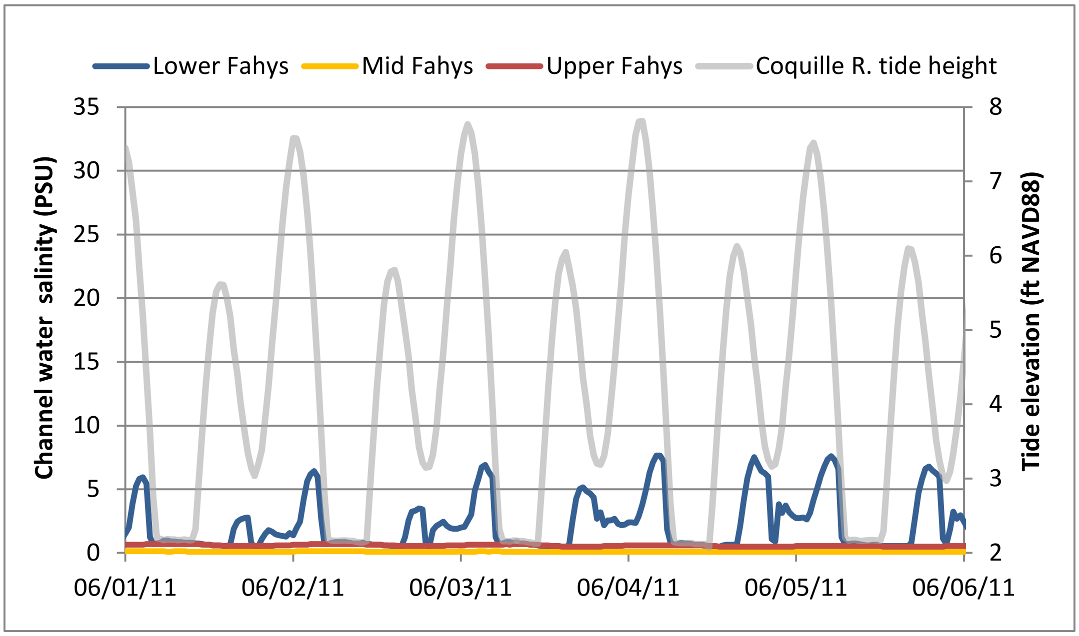


Figure 12. Pre-restoration salinities in lower, middle and upper Fahys Creek, early June 2011. Middle and upper Fahys were fresh, and lower Fahys showed low-brackish salinities (0-6). Sample locations are labeled "Fahy Mth 8239," "Fahy Mid 8230" and "Fahy Road 8241" respectively in Figure A2, Appendix A.

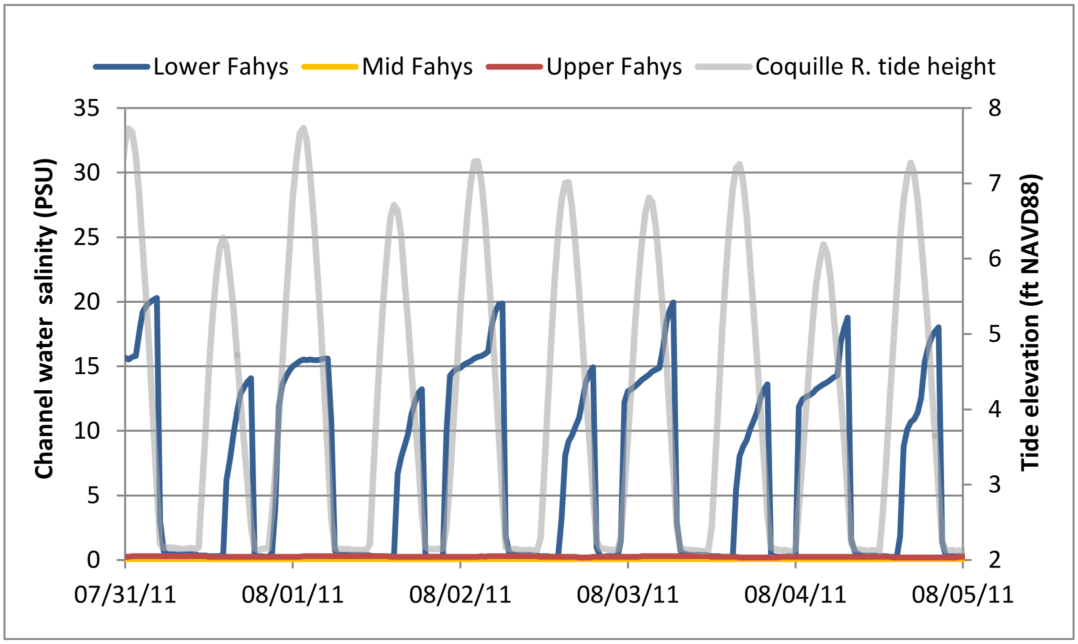


Figure 13. Pre-restoration salinities during early August in lower, middle and upper Fahys Creek (same sample locations as in Figure 12). Middle and upper Fahys still showed no salinity; lower Fahys increased to the high mesohaline range (15-18) during high tides.

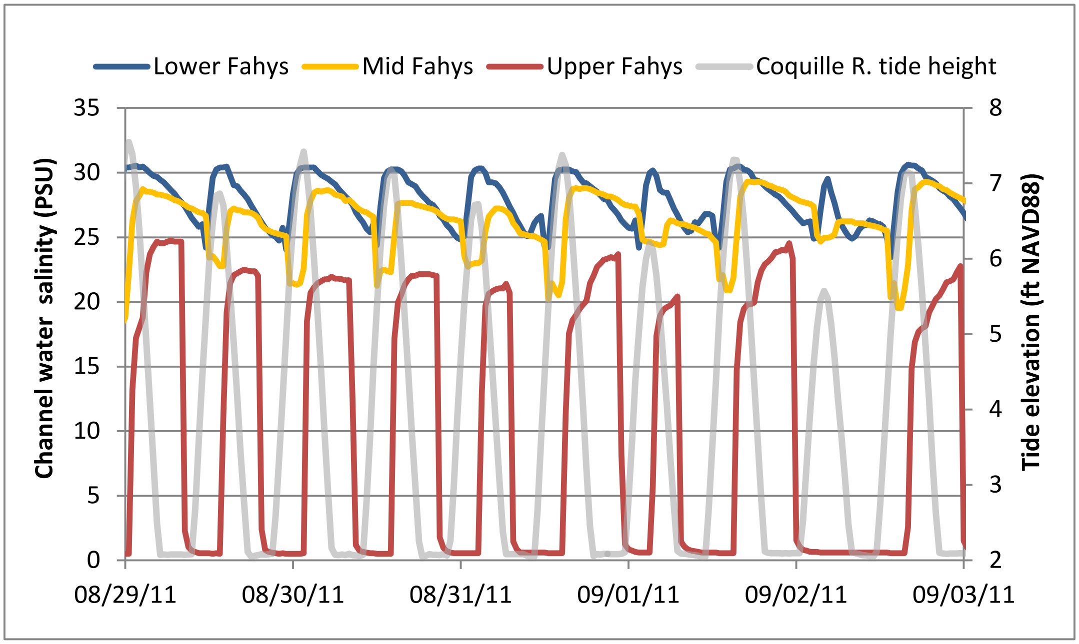


Figure 14. Preliminary post-restoration salinities in lower, middle and upper Fahys Creek, August 29-September 3, 2011 (same sample locations as in Figure 12). High tide salinities in upper Fahys Creek (at North Bank Road) were in the polyhaline range (20-25) during this low stream flow period; at low tide, freshwater flows predominated. Salinities were more stable (and higher) in middle and lower Fahys, where marine influence is stronger.

At the reference site, salinities showed a strong gradient from tidal channel mouths to the channels' upper reaches. At the mouth of the Shipwreck channel ("Shipwreck A"), salinities were strongly brackish (25-30 PSU) during spring and summer high tides (Figures 15 and 16), while salinities were in the oligohaline to low-brackish range (5-15 PSU) in the channel's upper reaches ("Shipwreck B"). Similar patterns were seen at the site's other main tidal channel ("Unknown") in June, but salinities in the upper and lower reaches of this channel converged in August, probably because this channel has less freshwater inflow from seepage. The wide range of salinities within an individual channel is probably typical of many tidal marshes in Oregon, where freshwater hillslope seepage continues through the summer. The broad range of salinities available in these channels may have considerable habitat value for juvenile salmonids undergoing physiological adjustment to saline waters prior to ocean entry.

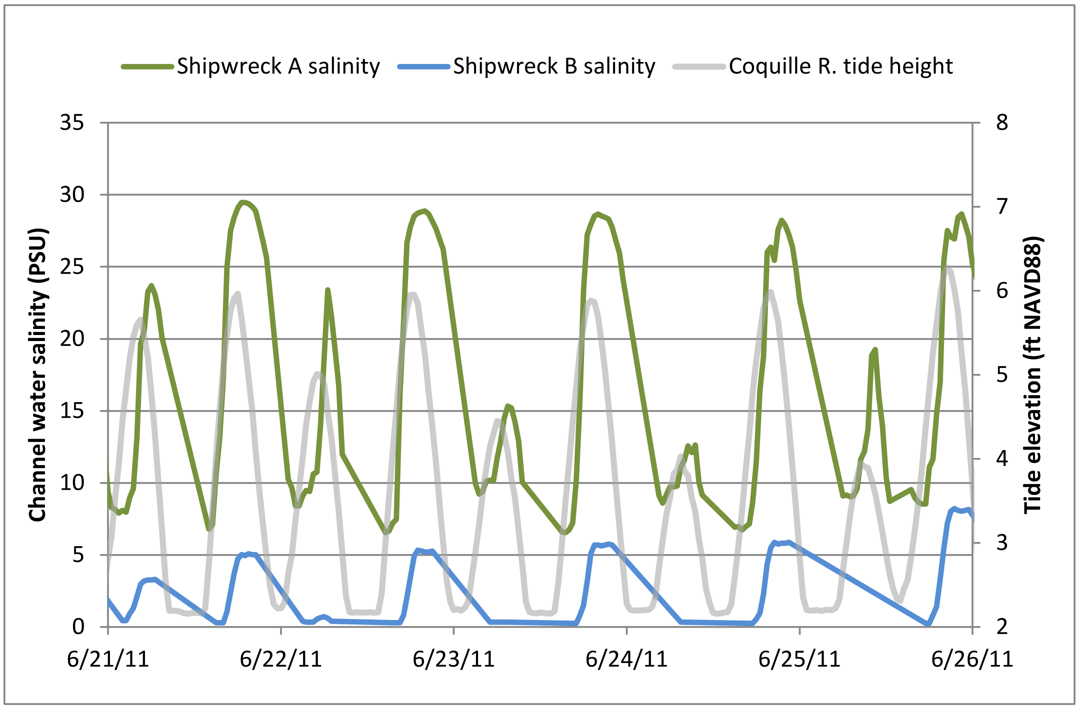


Figure 15. Bandon Marsh Unit: Salinities at Shipwreck A and B, June 2011. Sample locations are labeled "Shpwrk A 8238" and "Shpwrk B 8229" in Figure A3, Appendix A.

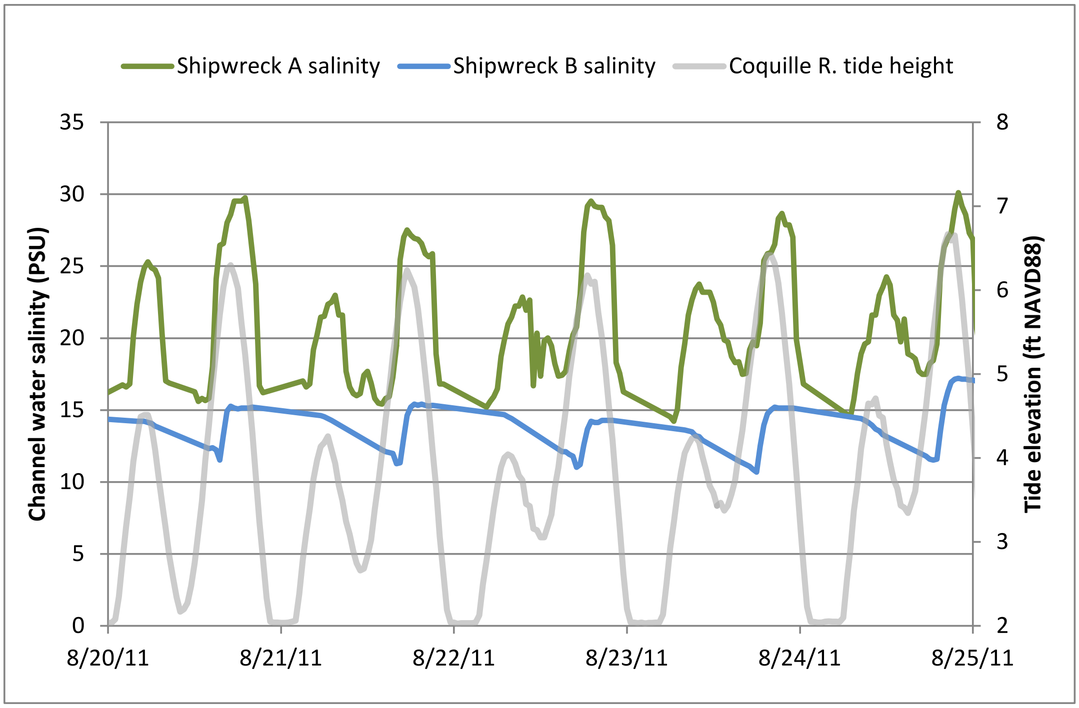


Figure 16. Bandon Marsh Unit: Salinities at Shipwreck A and B, August 2011.

2. Salmonid habitat functions

Monitoring Objective 2: Measure habitat recovery and habitat utilization by at-risk and endangered species

2a. Salmonid habitat opportunity (availability)

Monitoring Question 2a: Did restoration result in increased salmonid habitat opportunity (availability)?

Metrics for evaluating habitat availability:

Surface area, volume, duration and frequency of salmonid habitat availability (using channel morphology measurements and tidal elevations); surface water salinity and temperature; locations, quantities, and descriptions of large wood habitat restored. *(Rationale: Habitat availability is determined by analyzing water levels and channel volumes; surface water salinity and temperature affect habitat utilization; large wood location and size correlate strongly to salmonid behavior and habitat use.)*

Because this report contains baseline (pre-restoration) monitoring results, this question cannot yet be answered in full. *In this section, we provide a general description of the pre-restoration habitat types and abiotic conditions for those habitats - on a spring through summer* *seasonal basis; and availability of those seasonal habitats based on limiting factors such water depths, temperatures and salinities.*

In this section fish habitat conditions prior to ditch filling and new channel construction are described (based on our team's work at the site during 2005 and early 2010). Data from tide gauges and salinity and temperature loggers, prior to and after dike removal, were used to evaluate pre and immediate post-restoration conditions; and detailed RTK-GPS surveys of the restored channels were used to provide a preliminary estimate of post-restoration habitat availability.

Findings:

- The historical presence of the dikes, tide gates, and ditches created a series of disturbed habitats that are typical of other Oregon salt marsh lands managed for agriculture.
- Estimates of surface area and volume across newly dug channel reaches show significant increases in habitat availability (4.9 linear miles) for juvenile salmonids.
- Estimates of frequency of inundation across newly dug channel reaches suggest significant increases in habitat availability for juvenile salmonids.
- Prior to restoration, temperature and salinity were greatly affected by the presence of the dikes and tide gates, resulting in reduced water quality during specific seasons of the year.
- Temperature and salinity reached near natural regimes immediately after dike removal.
- No large wood structures were present in the pre-restoration channel/ditch network.
- One hundred ninety-three wood structures were placed in restored marsh channels.

Surface Area, Volume, Duration, and Frequency

More than 13 miles of drainage ditches were filled during the multiyear restoration process. Of the original 13 miles (20,920 meters) of ditches at Ni-les'tun, 3.1 miles (5,031 meters) were estimated to be potentially habitable by juvenile fish during the winter and early spring seasons (Figures A18 and A19, Appendix A). During 2009-2010, the larger ditches were filled, the smaller ditches were disked to reduce their impact on site drainage, and approximately five miles of restored channels were excavated (Figure A20, Appendix A).

Duration was examined by describing the Lower Fahys channel water elevations (Lower Fahys TG = NL Inside TG) in comparison to those in the adjacent mainstem channel (Figure 17). For this section of the report we focused on two tidal cycles found during a typical month of May tide series. The first was when the difference in height between the two daily cycles was the greatest, and the second was when the difference in height between the two daily cycles was the least. Prior to restoration, tidal elevation in Lower Fahys was muted (Figure 17). Reductions in flood tide elevations were 3-5 ft during the example higher high tides and 2-4 ft during the example lower high tides. Low tides were muted as well and never reached an elevation below 1 ft (Figure 17). The result of this tidal muting pattern was a reduction in available fish habitat – solely based on water availability. Analysis of tidal duration and timing

relative to fish use will be expanded in the post-restoration report. Frequency was summarized in the above tidal hydrology section.
We used tide gauge and channel survey data to provide an example of predicted habitat availability (i.e. water depth) during a typical tide cycle in the early spring juvenile salmonid peak use period (Figure 19), at three example sites (Figure 18). Using example site number one, the available water depth in the marsh channel at a lower high tide is expected to be 5.3 ft (Figure 19, top graph). At a higher low tide, the water depth will be 1.6 ft (Figure 19, top graph). *We focus on these tide positions (lower high and higher low) because they provide an understanding of a portion (12 hrs) of the daily high low cycle for which a fish could reside continuously in the marsh – otherwise reduced water depths would require twice daily in and out migration).* At example site two, the water depth at lower high tide will be 4.7 ft, while at a higher low tide the depth will be 1.0 ft (Figure 19, middle graph). At example site three, the water depth will be 2.9 ft at a lower high tide and 0.0 ft (no accessible habitat) at a higher low tide (Figure 19, bottom graph).

Example sites one and two offer adequate habitat (at least 1.0 ft depth) during the higher low tide and much greater depths during the lower high tide. Anecdotal field observations suggest the reference marsh (Shipwreck) channel mouth elevation is approximately 0.0 ft. The above examples (sites 1 and 2) suggest post-restoration habitat availability (water depth) across a large portion of the Ni-les'tun marsh will be greater than that observed for the more mature reference marsh and could result in greater low tide refuge availability.

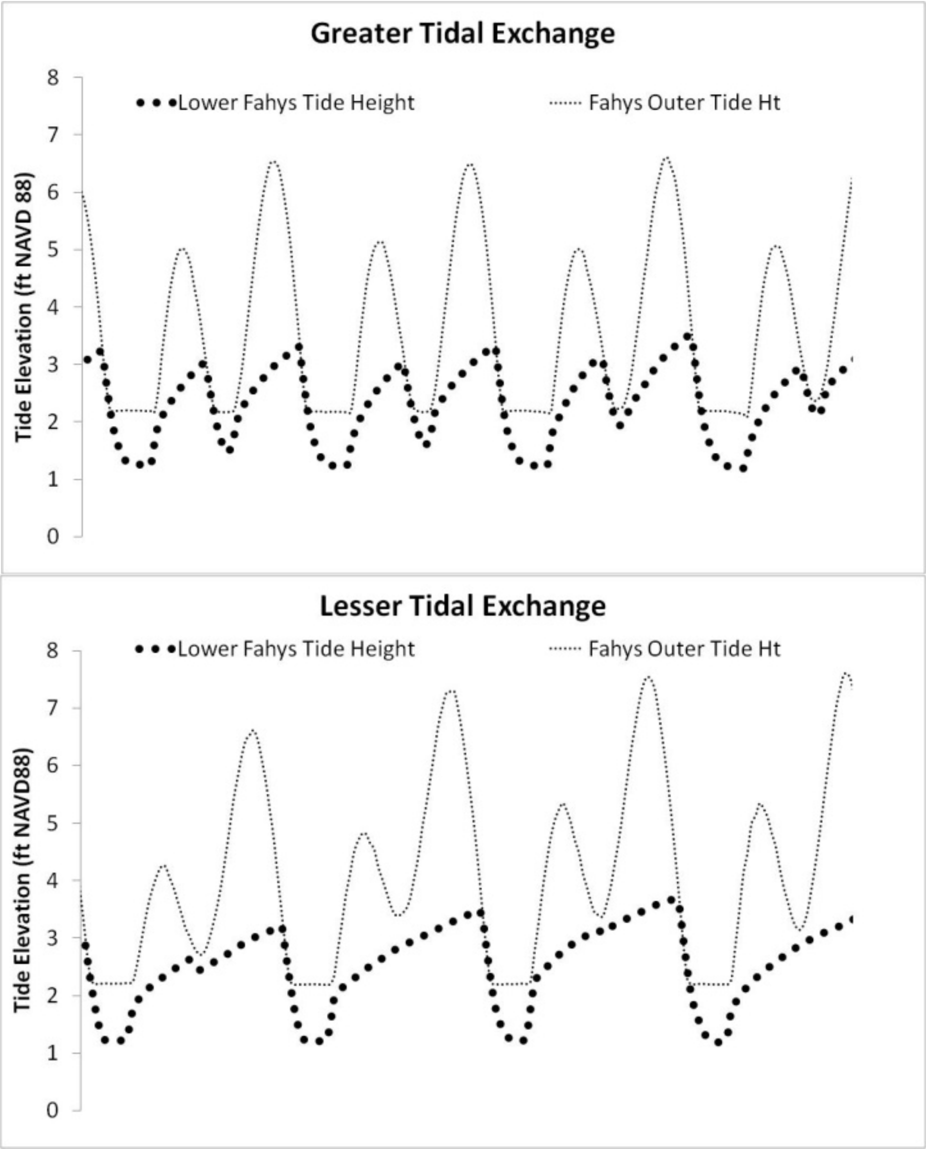


Figure 17. Observed tidal elevations prior to restoration at the Lower Fahys tide gauge (inside dike) and in the mainstem river (outside dike) during a spring period of greater and lesser tidal exchange. Gauges are marked “NL TG inside” and “NL TG outside” in Fig. A1 of Appendix 1.

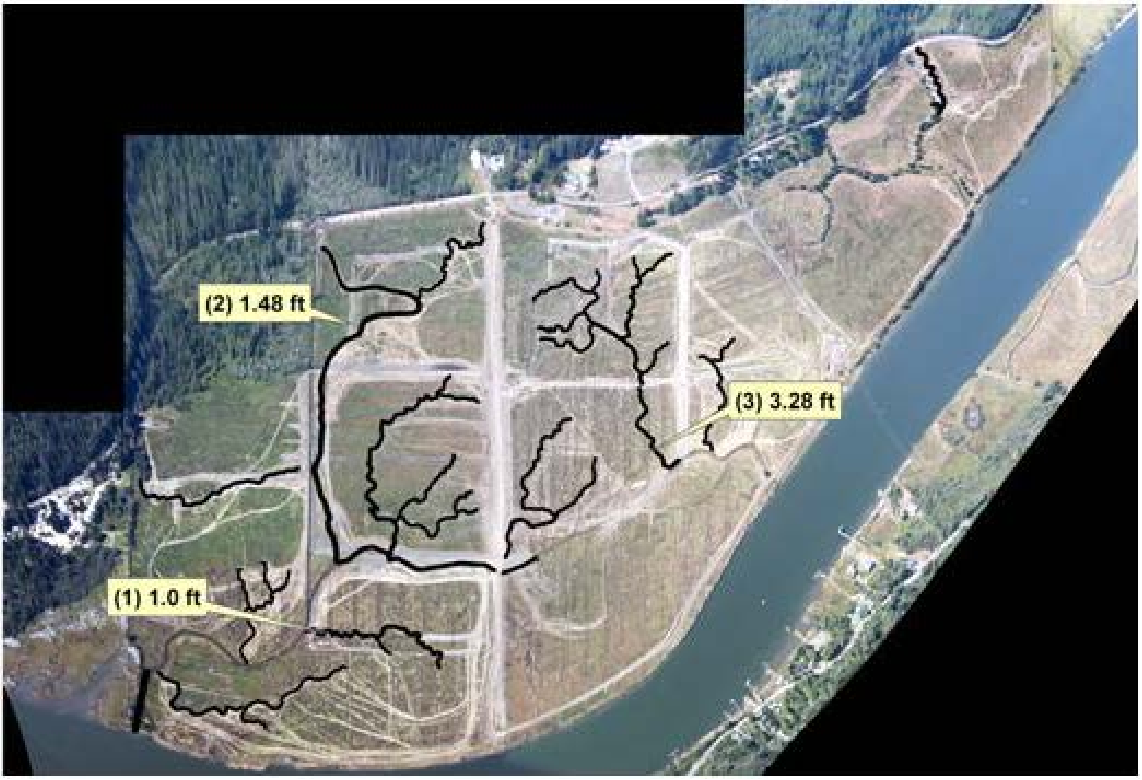


Figure 18. Three example sites used to describe predicted post-restoration tidal inundation, showing channel bottom elevation in feet (NAVD88 datum). Aerial image: August 2010, Roy Lowe.

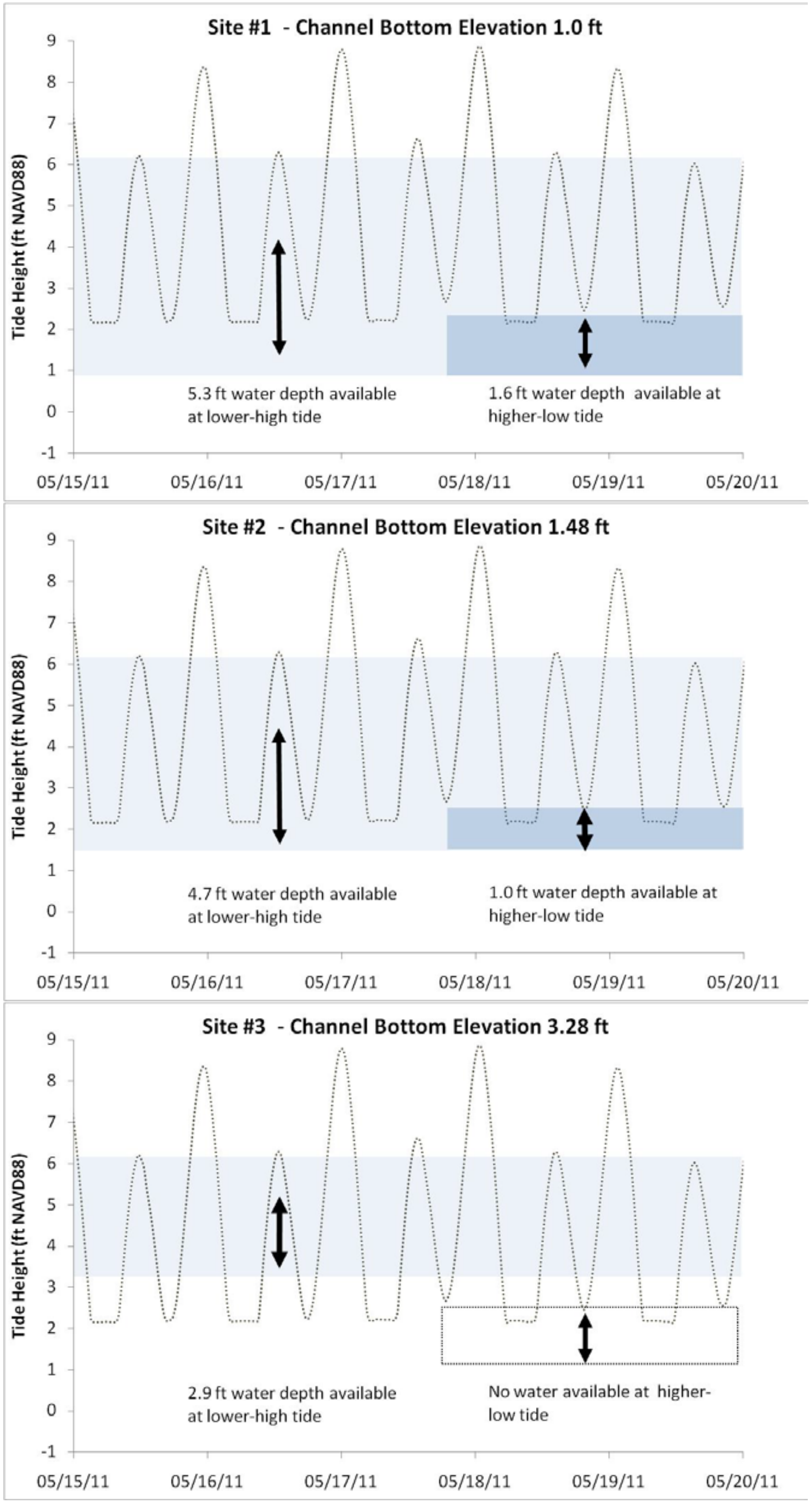


Figure 19. Predicted post-restoration channel water depths for example sites 1, 2 and 3 during a May tidal series.

Temperature and salinity

Temperature and salinity were measured with automated conductivity/temperature loggers installed in three locations in the mainstem river. These locations were: 1) near the reference marsh channel mouth at the Bullards Beach boat ramp (Ramp T 8228 in Figure A3 of Appendix A); 2) just upstream of the mouth of Fahys Creek (Coq Fahy T 8234 in Figure A2) and 3) just upstream of the mouth of Redd Creek at the Rocky Point boat ramp (Rocky 8236 in Figure A2). Additional loggers were installed in the mouths of the reference channel, Fahys Creek, NoName Creek, and Redd Creek (Shpwrk A 8238, Figure A3; Fahy Mth 8239, NoNam Mth 8231, and Redd Mth 8240 in Figure A2, respectively). Two loggers were installed in the middle and upper reaches of Fahys Creek (Fahy Mid 8230 and Fahy Mth 8239 in Figure A2, respectively). Additional loggers were installed in the reference site (Figure A2, Appendix A); selected results from the reference site loggers are presented above (Figures 15 and 16), and data from these loggers will be compared to restoration site results in future reports.

Data were collected at 30min intervals during spring, summer and fall 2011 (prior to dike removal, and just after dike removal). Many loggers were out of water (exposed to air) at low tide; for consistency, data from these “out of water” periods were omitted from the analysis. To illustrate habitat suitability, salinity and temperature are shown as the number of 30 minute intervals logged for each salinity or temperature unit. Data are presented for the last two weeks of a given month during the April – September period to show month-to-month variation. Migration and rearing temperatures for juvenile salmonids (Oregon DEQ 1996) are included in the temperature graphics to assist with interpretation. To allow for a brief summary of results we present only those temperature and salinity patterns for the mainstem, Lower Fahys, and the lower reference marsh reaches during a subset of the broader season.

Restoration site water temperature

Fahys mouth showed temperatures similar to the mainstem during April (Figure 20, top graph). As the season progressed Fahys experienced higher temperatures overall and for longer durations (Figure 20, middle graph). Upon removal of the dike during early August, Fahys began to shift toward a pattern very similar to the mainstem (Figure 20, bottom graph).

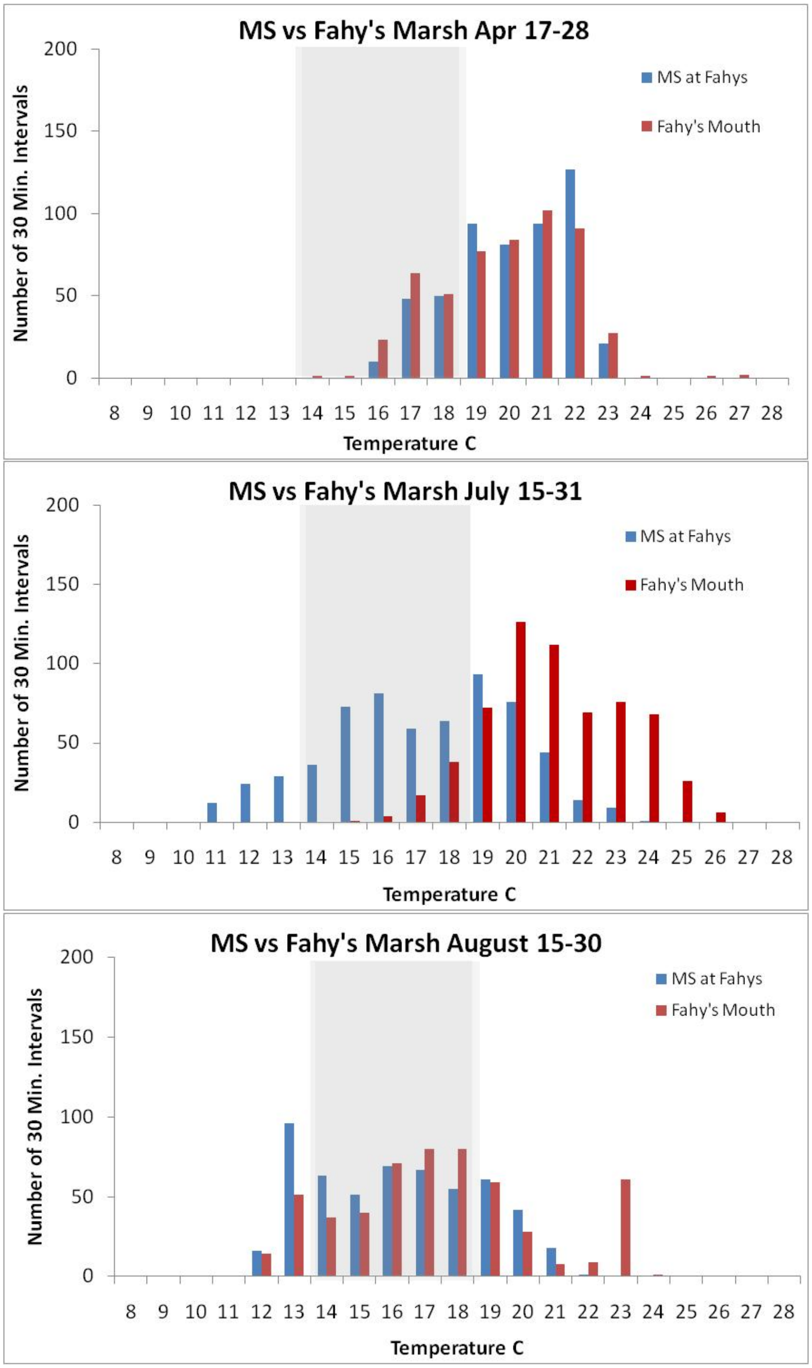


Figure 20. April, July and August 2011 stream temperatures for the mainstem Coquille River just upstream of Fahys Creek mouth (“MS at Fahys” above; “Coq Fahy T 8234” in Figure A2, Appendix A) and Lower Fahys Creek (“Fahys Mouth” = “Fahy Mth 8239” in Figure A2, App. A). Gray block shows temperatures suitable for migration and rearing of juvenile salmonids (Oregon DEQ 1996).

Reference site water temperature

The reference marsh showed a temperature regime similar to the mainstem early in the season (data not shown). By August, the reference marsh temperatures were reaching higher highs than those of the mainstem (Figure 21, top graph). During September, the reference marsh temperatures had dropped and were more similar to the early spring period (Figure 21,bottom graph).

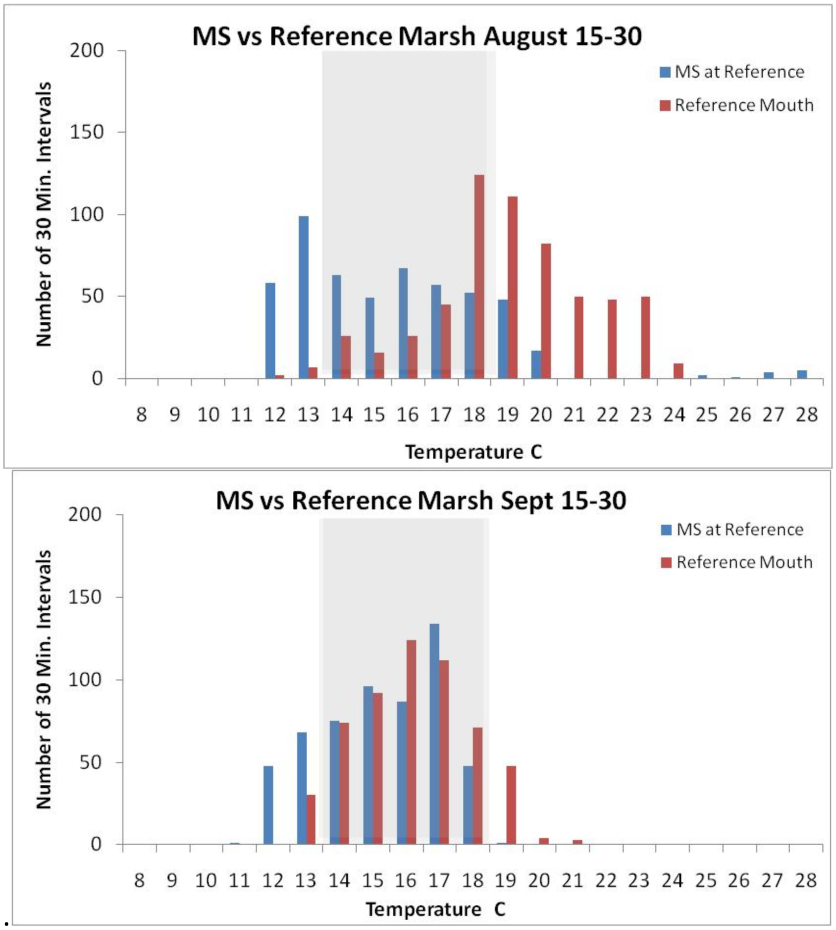


Figure 21. August and September 2011 stream temperatures for the mainstem (“MS at Reference” above; “Ramp T 8228” in Figure A3, Appendix A) and the reference marsh channel itself (“Reference Mouth” above, “Shipwreck A 8238” in Figure A3, Appendix A). Gray block shows temperatures suitable for migration and rearing of juvenile salmonids (Oregon DEQ 1996).

Restoration site salinity

Salinities at Ni-les’tun prior to restoration were strongly affected by the dikes and tide gates. During early April both the Fahys Marsh (“Fahys Mouth”) and the mainstem provided lower oligohaline range habitats (Figure 22, top graph). By July stream flow volumes decreased, nearshore saline waters had penetrated the mainstem study zone resulting in a bimodal curve, with mesohaline and polyhaline peaks at low and high tides respectively (Figure 22, middle graph). Because the Fahys tide gate was still in place, peak salinities at the Lower Fahys logger were half that of the mainstem. Salinities in Lower Fahys were slightly bimodal. Upon removal of the dike (early August) and initial restoration of the main Fahys channel system, Fahys salinities closely matched those of the mainstem (Figure 22, bottom graph). The highest values for Fahys were greater than those of the mainstem during August. This pattern increased during September (not shown). These higher salinities inside the marsh could be a result of evaporative concentration of salts in ponded high tide waters on the newly restored marsh surface, but this is speculative. Post-restoration effectiveness monitoring will determine whether this trend continues.

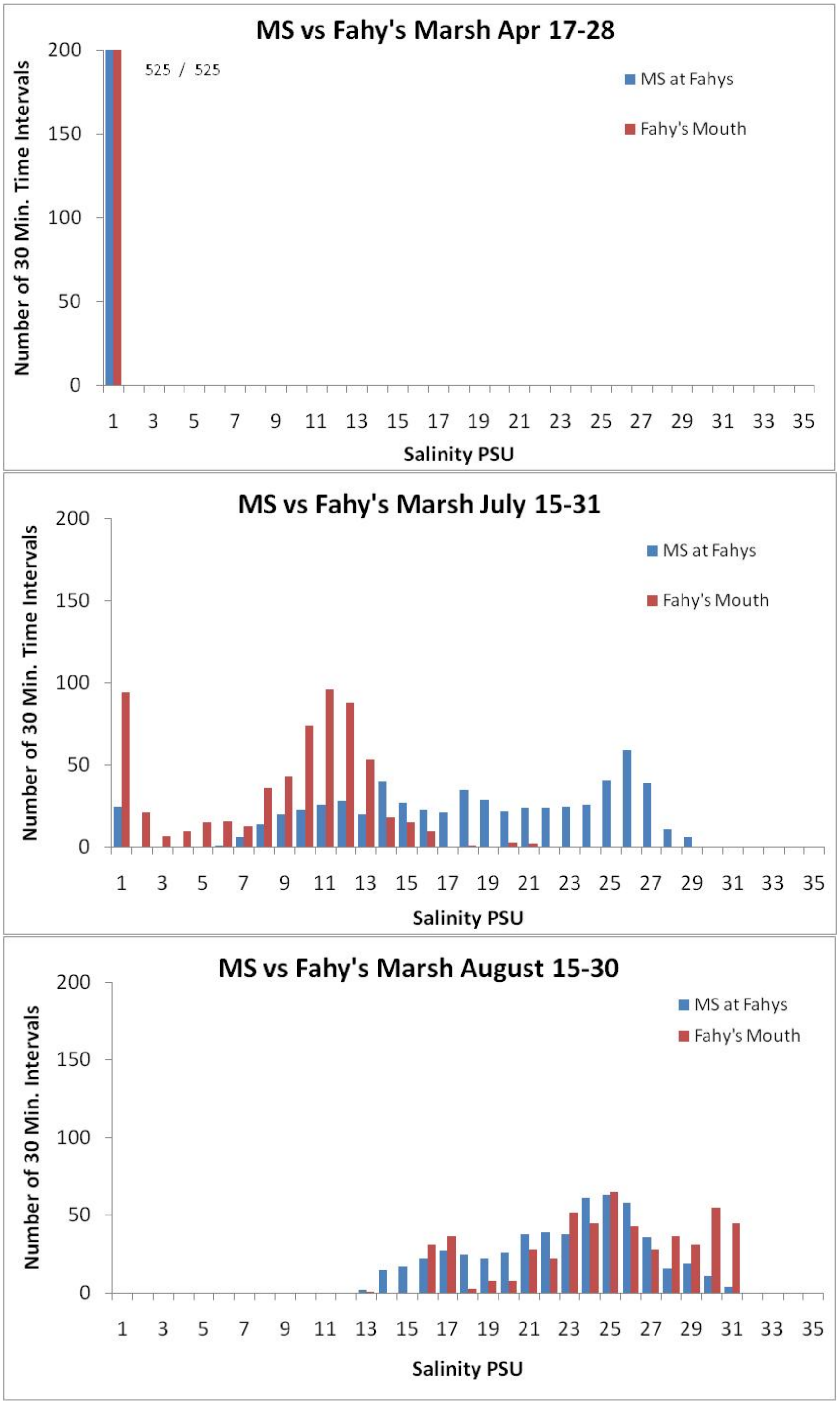


Figure 22. April, July and August 2011 stream salinities for the mainstem Coquille River just upstream of Fahys Creek mouth (“MS at Fahys” above; “Coq Fahy T 8234” in Figure A2, Appendix A) and Lower Fahys Creek (“Fahys Mouth” above; “Fahy Mth 8239” in Figure A2, Appendix A).

Reference site salinity

In contrast to Fahys, the reference marsh mouth showed very similar salinity patterns to that of the mainstem channel (Figure 23). Both were very fresh during April (data not shown). Both increased by May and continued to have a wider bimodal curve through July (Figure 23, top graph) with the reference marsh experiencing slightly higher values. We suggest these were a result of high tide sheet flows picking up salts from marsh soils. During August the reference marsh mouth salinities were lower than those of the mainstem channel (Figure 23, middle graph). It is unclear what drove the difference observed during August. Both sites had similar profiles during September (Figure 23, bottom graph).

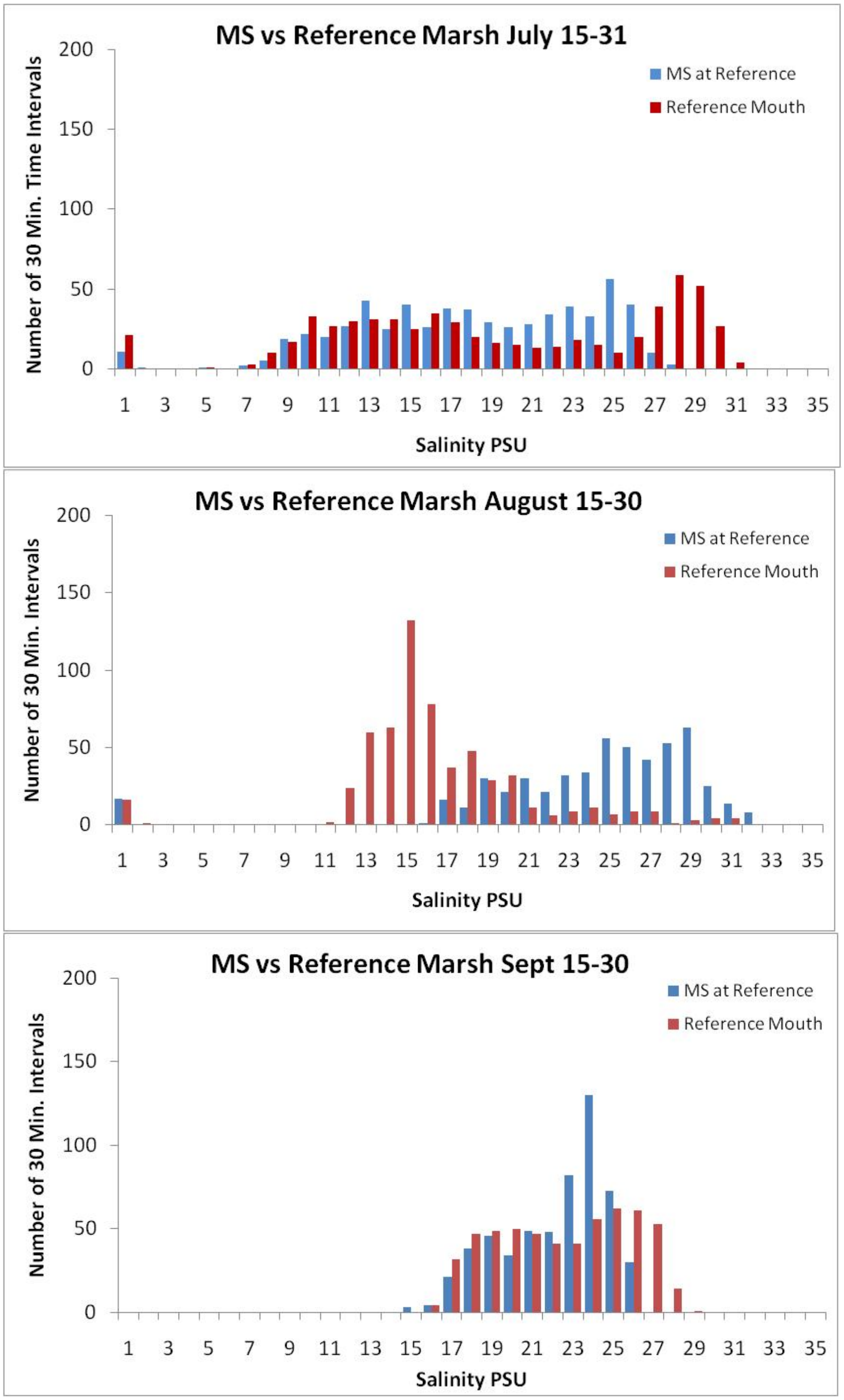


Figure 23. July, August and September 2011 stream salinities for the mainstem ("MS at Reference" above; "Ramp T 8228" in Figure A3, Appendix A) and the reference marsh channel itself ("Reference Mouth" above; "Shipwreck A 8238" in Figure A3, Appendix A).

Large Wood

One hundred thirty root mass logs and 63 stem logs were placed in marsh channels in the restoration site's three sub-basins. A total of 12 monitoring reaches were constructed (Figures 24, 25 and 26). Data will be collected during post-restoration effectiveness monitoring.

Figure 24. Ground view of restored in-stream wood habitats.

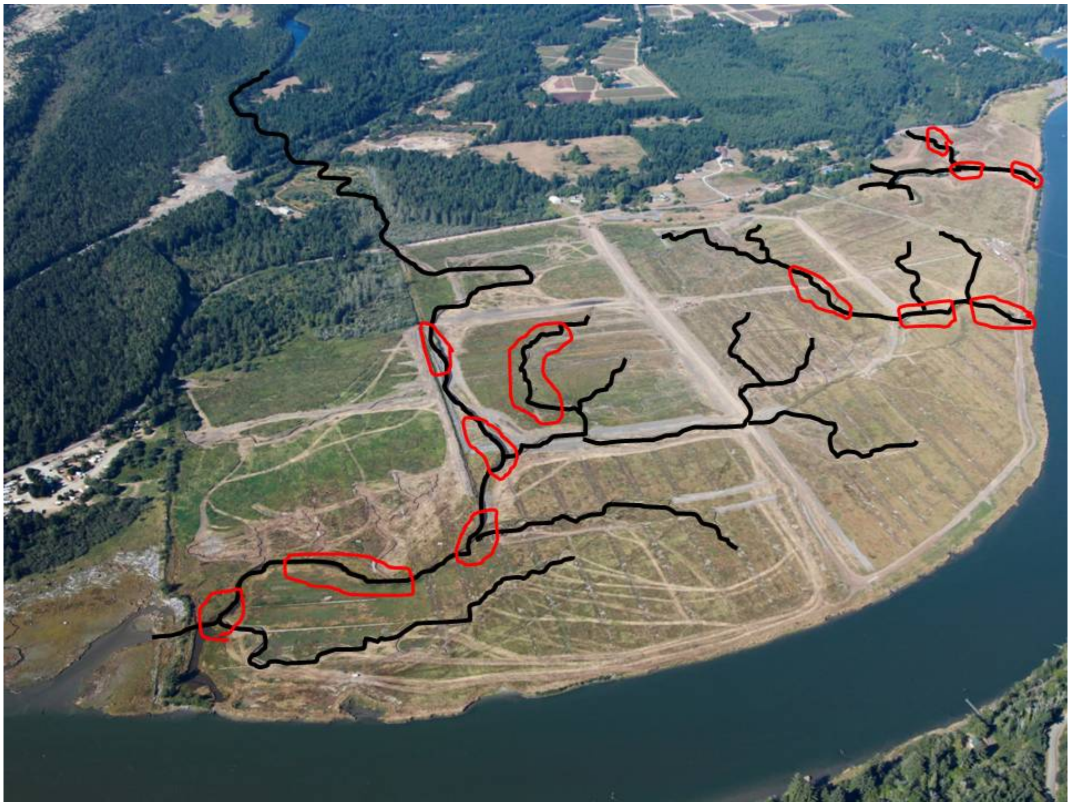


Figure 25. Locations of in-stream large wood monitoring reaches (red polygons).

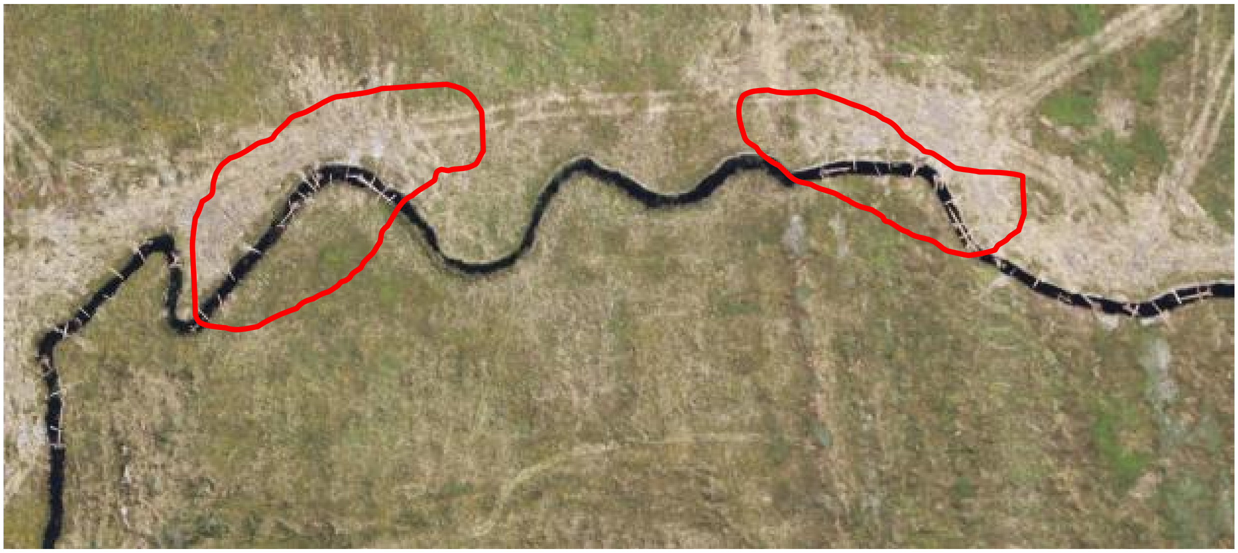


Figure 26. Aerial view of restored in-stream wood habitat monitoring reaches (red polygons).

Future Analyses

Restored surface area, depth and volume estimates will be completed for specific reach sites in future reports. Elevation data will be used in conjunction with channel cross section data (Figure 27) to describe reach based habitat availability and complexity (surface area, depth and volume). These will also be used in conjunction with low tide fish presence and migration data to suggest use rates associated with habitat availability across the full NoName and Reference watersheds, and for a portion of the Fahys watershed.

Expectations for the Future

We anticipate significant increases in daily use of the marshes (by juvenile fish) based on the large shifts in tidal exchange - pre to post-restoration. We anticipate salinity and temperature changes to increase over those observed during late August 2011 after dike removal. We expect lower daily temperatures in Fahys and NoName during the warmer months of July and August, as a result of greater salt water intrusion. We project these shifts will create habitat that is more desirable to smolting salmonids and that smolts and other fish that normally use deep water habitats of the bay will increase their use within Fahys. Based on early observations of scour associated with wood structures we anticipate significant shifts in channel morphology within the middle and lower reaches of Fahys as well as the lower reaches of NoName and Redd Creeks.

Length of Monitoring Needed

Shifts in tidal inundation were observable immediately after dike removal. Measurable shifts in duration and frequency will be observable by the 2013 field season. Based on early observations (spring 2012) we expect to see measurable differences in channel morphologies by year 2013. We also expect the channels to be experiencing measurable changes in channel morphology, temperature, and salinity for at least 10-15 years. Progress towards physical equilibrium will likely be in the form of a dramatic change for at least ten years, compared to a more moderate change thereafter.

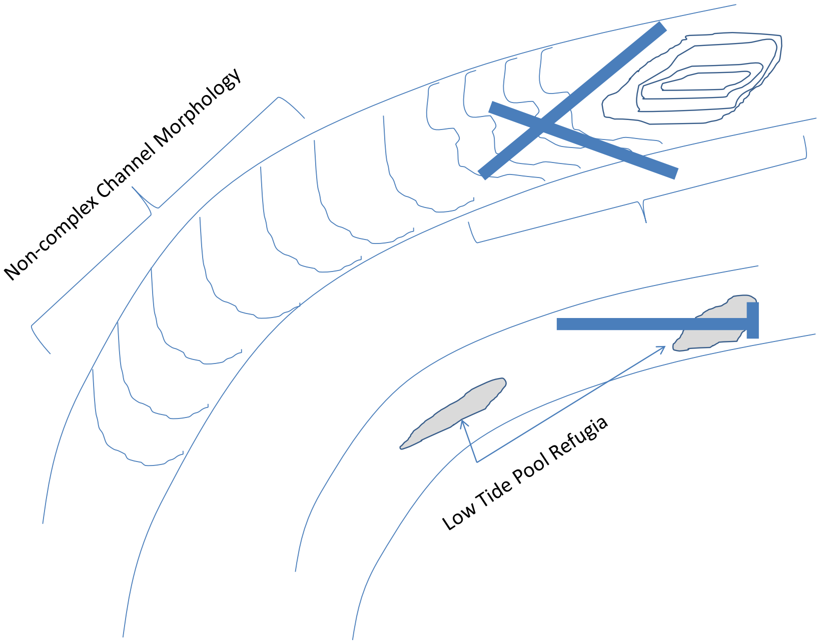


Figure 27. Schematic of typical variation in the cross sectional channel bed profile that will be used to develop a three dimensional description of in-channel habitat availability.

2b. Salmonid habitat capacity

Monitoring Question 2b: Did restoration result in increased salmonid habitat capacity?

Metrics for evaluating habitat capacity:

Benthic macroinvertebrate abundance and community structure within the largest of the three restored basins (Fahys Creek). *(Rationale: benthic macroinvertebrates constitute a large proportion of salmonid prey; prey availability is a controlling factor in salmonid growth rate and ocean survival.)*

Because this report contains baseline (pre-restoration) monitoring results, this question cannot yet be answered; comparisons will be made during post-restoration effectiveness monitoring. In this section, we describe pre-restoration conditions, which form the basis for evaluating post-restoration change.

Findings:

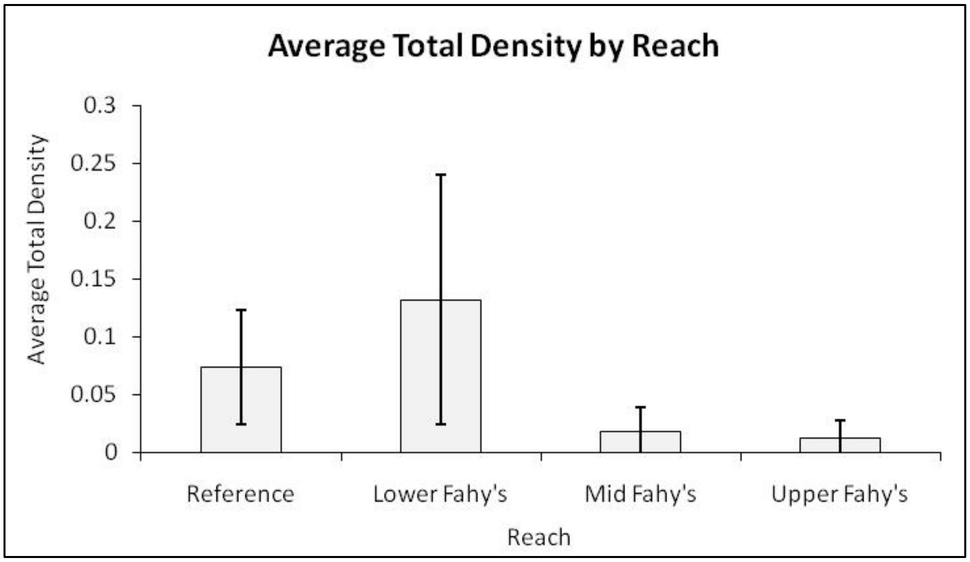
- Distinct patterns were present for benthic macroinvertebrates sampled across the Reference and Fahys marshes.

Macroinvertebrate abundance and community structure

Macroinvertebrates have been used to characterize ecosystems and infer ecological health by comparing abundance, and taxonomic and functional composition between reference and restored conditions. Since invertebrates have a variety of physiological needs, their presence/absence reflects the condition of the surrounding environment, and for this reason they have been thought of as integrators of ecosystem variability and possible descriptors of ecosystem function. In aquatic environments, biotic metrics have been applied to freshwater biomonitoring to assess the condition of stream environments (Karr and Chu 1999) and groups of indicator species, or assemblages, have been used to determine biotic integrity (Karr 1981). Invertebrates, as biotic indicators, represent popular "litmus" tests for determining ecosystem status and state, and have been widely applied with a variety of taxa in many different ecosystems (see review, Carignan and Villard 2002). Invertebrates may make useful indicators of reference tidal wetland condition, as they are strongly influenced by environmental variation and react mainly to disturbances on fine spatial scales (Carignan and Villard 2002). Benthic macroinvertebrate samples were gathered from four reaches, which were selected to represent habitat strata based on tidal exchange, salinity, temperature and depth (Figure A5, Appendix A).

Results

Based on data obtained from 18 useable, processed samples (20 total collected), we evaluated total density, taxonomic richness, and percent composition. Eleven taxonomic groups were collected, including three amphipods, two dipterans, and a clam. Total density and taxonomic richness were summarized by reach (Figure 28). There were significant differences in total density (p=0.01) but no difference in taxonomic richness (p=0.71) based on ANOVA. Total density was highest in the Lower Fahys Reach and lowest in the Upper Fahys Reach. Taxonomic richness was also highest in the Lower Fahys Reach but comparable in all other reaches. Average percent composition was determined using density and summarized by reach (Figure 29). The Reference Reach was dominated by the amphipod, *Corophium* spp. and Lower Fahys Reach was mostly composed of polychaetes and *Corophium* spp. Mid Fahys Reach was dominated by oligochaetes, but there was an increasing proportion of Diptera from the lower to the mid and upper reaches. Upper Fahys Reach also contained gastropods and the mussel Veneroida, Pisidiidae.



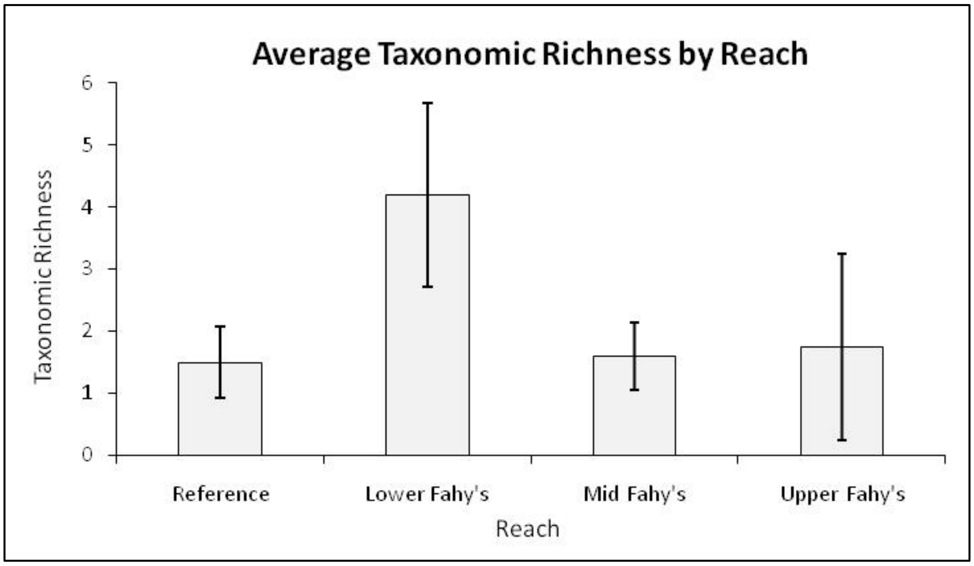


Figure 28. Average total macroinvertebrate density and taxonomic richness for the reference marsh and three Fahys monitored reaches (Lower, Middle and Upper) in 2010.

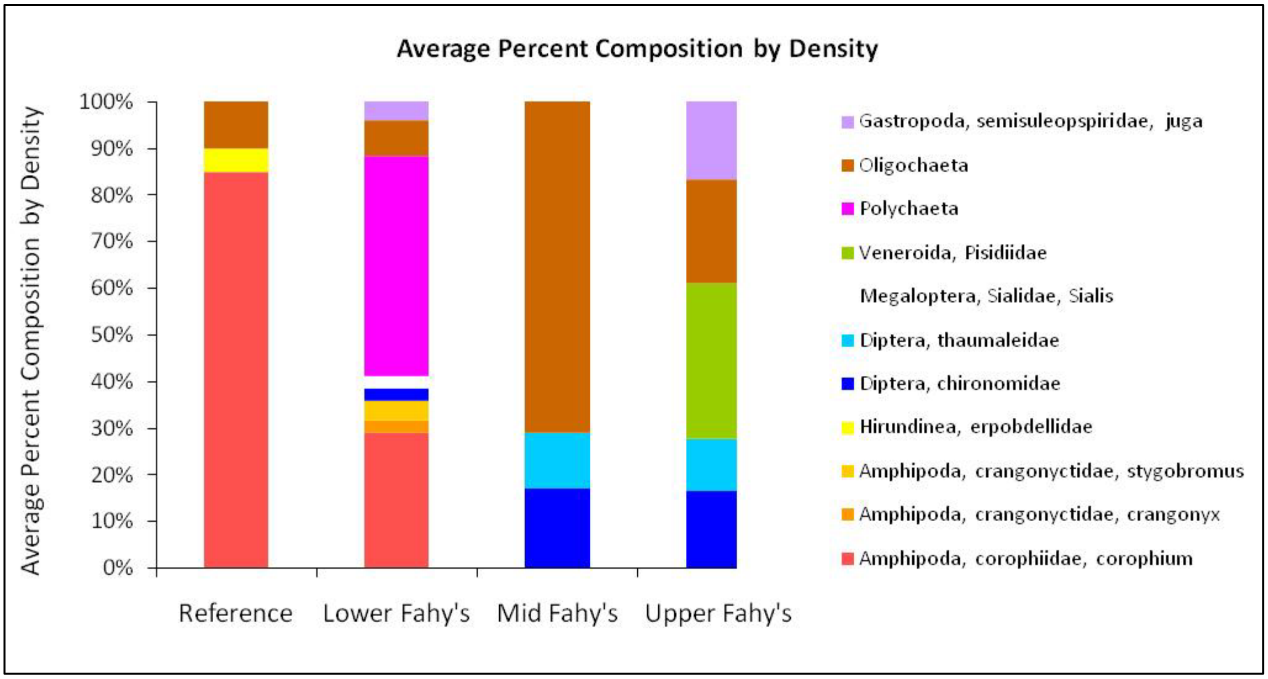


Figure 29. Macroinvertebrate percent composition by density for the reference marsh and the three reaches of Fahys (Lower, Middle and Upper) in 2010.

Future Analyses

We anticipate using density, taxonomic richness and percent composition to characterize shifts in the three pre-treatment reaches of Fahys Marsh. We anticipate collecting more samples than are budgeted for in the current grant with the hope that additional funding can be secured to improve the overall pre-post analyses and create a finer scale of understanding relative to both temporal rates of recovery and the dynamics of reach specific recovery.

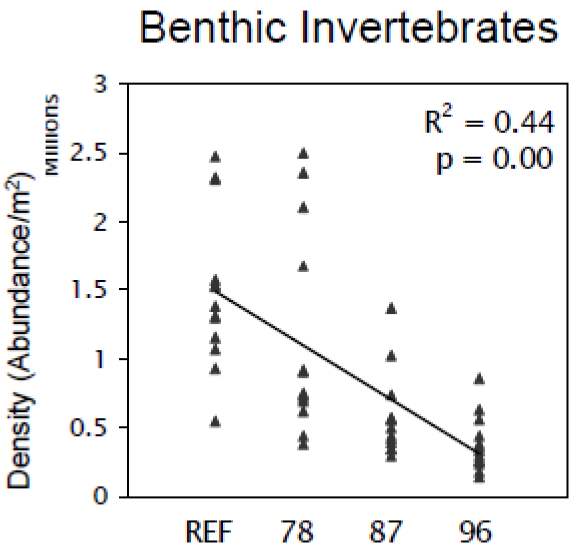
Expectations for the Future

Gray compared benthic macroinvertebrates in a newly restored (1996) salt marsh with those found in a series of older restored (1978 & 1987) and reference marshes (Gray 2005). Gray found a linear relationship between the post-restoration period and benthic macroinvertebrate density as well as taxonomic richness (Figure 30). When examining the newly restored salt marsh Gray also found the dominant macroinvertebrates available were from the genus *Diptera.* The Diptera were largely associated with the decaying plant materials that resulted from the influx of higher salinity tidal flows after dike removal. Gray found high marsh to marsh variability but concluded there were distinct marsh to marsh differences based predominantly on key indicator species. Gray also concluded restoration of the benthic community operates on a scale uniquely different from that of the marsh plant community and is dependent on the development and restoration of channel sediments.

Cooksey (2006) examined juvenile fish use in the Duwamish River, Washington, USA. The seasonal range of temperatures and salinities were similar to what we observed along the mainstem Coquille between Fahys mouth and Rocky Point boat ramp. The most prevalent species observed by Cooksey (2006) included age zero chinook, shiner perch, stickleback, staghorn sculpin, and starry flounder. Two questions Cooksey attempted to address with his evaluation of restored sites on the Duwamish provide some insight into the Ni-les'tun restoration process. These were 1) are there discernable overlaps in the diets of chinook salmon and the most abundant fish species and 2) do the diets of nonsalmonids that use the restored sites change after juvenile salmonids have migrated out?

Cooksey completed extensive diet analyses examining within and between species differences, both within site, between sites and between seasons using several means of analyses. Using ordination Cooksey's conclusions were that chinook diets were clearly separate from the other species. Cooksey's ANOSIM analyses suggested similar results to his ordinations, with chinook showing the most significant difference between all species. Using a SIMPER analyses to determine which prey items were most responsible for the above chinook diet differences Cooksey's suggested that when adult Diptera (true flies) were available they resulted in the greatest contribution while immature Diptera were next. Having noted the above, the analysis did show that similar to chinook, staghorn sculpin diets were composed of a high portion of amphipods. Other SIMPER analyses describing "responsible" diet items for specific species to species comparisons led Cooksey to conclude that staghorn ate more amphipods and polychaetes and fewer diptera; shiner perch ate more plant matter, polychaetes and ostracods, and fewer amphipods; stickle back ate more polychaetes, plant matter, diptera and amphipods and consumed it more evenly. His site to site conclusions also suggested chinook were opportunistic feeders overall. Based on these results Cooksey concluded there was little evidence of competition for prey resources between chinook and nonsalmonids and that nonsalmonids utilize the same prey resources whether juvenile salmonids are present and competing in the same habitat or not.

If prey resource use in the Ni-les'tun marsh and the adjacent mainstem river is similar to that observed in the Duwamish (Cooksey 2006) future marsh production may benefit age zero chinook to the greatest extent, followed by staghorn sculpin and shiner perch. Our hypothesis here is based on a few observations. The first is that age zero chinook and staghorn sculpin appear to utilize prey resources (amphipods and polychaetes) that are likely to significantly expand when the restored marshes become mature. In addition chinook appear to be opportunistic feeders that could gain greatly from additional insect prey not found in Cooksey's study – this would be due to the extensive anticipated marsh surface tidal sheet flow and the insects that will be washed into the channels during that tidal process. These insect prey resources typically offer three times the caloric value of that provided by the prey reviewed above (Cooksey 2006). Shiner perch prey resources are also expected to increase with the presence of the restored channel network. Plant matter may be more prevalent due to the increase of shallow habitats allowing for increased light. Stickleback might receive the lowest level of benefit simply based on reduced presence of slow water habitats and our observations of their preference for these same habitats. Although the salt marsh feeding habits of age zero and 1+ coho have not been well documented, in part due to severally reduced populations these past two decades, it is logical that being a closely related species, coho would also receive the greatest feeding benefits from marsh restoration.



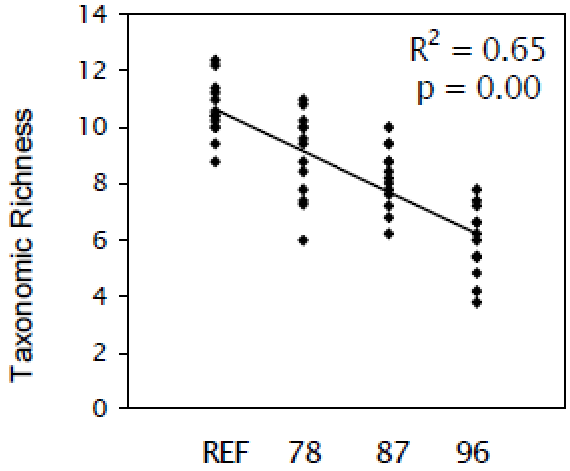


Figure 30. Benthic invertebrate density and taxonomic richness for four different salt marshes in the Salmon River Estuary (Oregon). Graphic was taken from Gray (2005).

Length of Monitoring Needed

Based on early channel morphology observations (spring 2012) we expect to see measurable differences in benthic macroinvertebrate distributions by 2013. In addition we expect reach based species compositions to move closer to natural patterns by 2021 as the channel habitats approach a more stable status relative to bed load scour and fill.

Monitoring Question 2c: Did restoration result in increased salmonid habitat utilization?

Metrics for evaluating salmonid habitat utilization:

Salmonid standing stock, habitat utilization and migration patterns in restored *vs*. reference basins; salmonid utilization of large wood habitat. *(Rationale: Direct measurements of salmonid use of the variety of habitats at Ni-les'tun will provide valuable information on restoration effectiveness and value of large wood placement.)*

Because this report contains baseline (pre-restoration) monitoring results, this question cannot yet be answered; comparisons will be made during post-restoration effectiveness monitoring. In this section, we describe pre-restoration conditions, which form the basis for evaluating post-restoration change.

Findings:

- The presence of the dikes and tide gates resulted in abnormal species compositions, distributions, temporal presence, and daily migrations compared to reference conditions.

Fish Use of the Mainstem River

Juvenile fish were monitored for their presence along the mainstem river during 2005 and 2010, using low tide seine sampling. These data provide a basis for understanding seasonal distribution patterns relative to those species that may make use of the available marsh habitats. Juvenile fish presence in the lower river is predominantly a result of a need for nursery habitats. Species such as but not limited to, chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhyncus kisutch*), cutthroat trout (*Oncorhyncus clarki*), steelhead trout (*Oncorhyncus mykiss*), shiner perch (*Cymatogaster aggregata*), threespine stickleback (*Gasterosteus aculeatus*), Pacific staghorn sculpin (*Leptocottus armatus*), and starry flounder (*Platichthys stellatus*) utilize these habitats as nurseries. Temperature and salinity are two of the key factors that drive estuarine habitat use by fish. The species we observed vary in their preferred habitat characteristics but overlap is present when habitats are dynamic and shifting hourly each day. The distribution of salmonids across the tidal zone is in part reflective of distinct patterns in salinity tolerance at key developmental points during their first year of life. As juvenile salmonids complete their smolting process they become tolerant to full strength sea water. In Oregon estuaries pre-smolts such as age 0+ chinook utilize edge habitats and are widely distributed, whereas smolting age 0+ chinook tend to seek deeper water habitats and schooling behavior is more common (van de Wetering 2002). During these final riverine rearing periods, use of marsh habitat becomes more limited (van de Wetering, unpublished, 2002). These fish distributions are also representative of trigger points along the temperature scale - once a habitat begins to approach lethal temperature levels (i.e. mid 20s (C°) for chinook) fish are unable to use that habitat or are forced to endure increased levels of stress.

Fish Use of the Marshes

Presence of juvenile fish was monitored in the marshes during 2005 and 2010, using low tide seine sampling. Marsh habitat seasonal juvenile fish use data provide a basis for understanding seasonal distribution patterns between marshes and between adjacent mainstem sites. Fish presence in natural salt marshes is thought to be the result of daily migration for food and basic habitat resources (Gray *et al*. 2002). In natural marshes it is uncommon to have more than a portion of the channel habitat available during the full flood tide, due to higher channel elevations. This effectively forces fish to move in and out of marsh nursery habitats twice daily with the flood and ebb of the tides. When habitats have been altered for improved drainage, via dikes, ditching, and the use of tide gates, normal tidal patterns result in muted high tides as well as muted low tides creating a less dynamic habitat, but a more consistent volume of habitat, due to the more consistent, moderate water depths. However, this higher volume of habitat is in turn limited by two factors. Because tide gates severely reduce daily tidal exchange, they affect fish passage and water quality as described above. Tide gates also strongly affect water temperature and salinity, which in turn influence fish use. Observed pre-treatment temperature and salinity shifts were described above in the habitat section. We compare these to fish use in our conclusions below.

Sampling

The seasonal distribution data were summarized from two monitoring years to provide the most representative pre-treatment description. During 2005 the Tribe used NOAA funds to provide an initial understanding of distributions across the proposed Ni-les'tun restoration site. Because we have an interest in describing the key use periods, a subset of the 2005 and 2010 data are presented with a focus toward the early and late spring, followed by the early and late summer periods. This allows for an easier comparison to the above description of habitat conditions in monitoring question 2a. Data are presented as Catch Per Unit Effort (CPUE) values because each site has a somewhat unique channel morphology, which affects available habitat, and CPUE values allow for month to month comparisons within a site. Sampling sites are shown in Figure A4, Appendix A. There were three mainstem river sample reaches (lower, middle and upper) which formed a boundary ranging from below the lower river reference marsh to above the mouth of Fahys, to upstream of the mouth of Redd Creek near Rocky Point. Each reach contained three sample sites. There were three Fahys marsh reaches with three sample sites per reach. Sampling in NoName and Redd Creeks consisted of one continuous reach with seven and five sample sites, respectively. Sampling of the reference marsh during the low tide did not occur during any months due to higher natural channel bottom elevations resulting in complete or near complete drainage .

Results

The data were summarized by peak use for each species, to simplify the reporting process. The presence of a species in a given sample reach during a given period represents the peak use for that species relative to all four periods. Double representation describes peak use at equal rates across two periods. During early spring, chinook and staghorn peaked in Redd and NoName, and coho peaked in Redd (Figure 31, top graphic). During late spring chinook and staghorn peaked in the mainstem while chinook, coho, cutthroat, staghorn, and stickleback peaked in several marsh reach sites (Figure 31, bottom graphic). By early summer coho had passed their peak in Redd Creek but were at peak numbers in lower and upper Fahys (Figure 32). During early summer stickleback peaked in three of the marshes while shiner perch peaked in the mainstem (Figure 32, top graphic). Late summer resulted in overall reduced fish presence in the marshes with stickleback at peak values in the mid and upper Fahys reaches. Shiner perch remained at high numbers in the mainstem (Figure 32, bottom graphic).

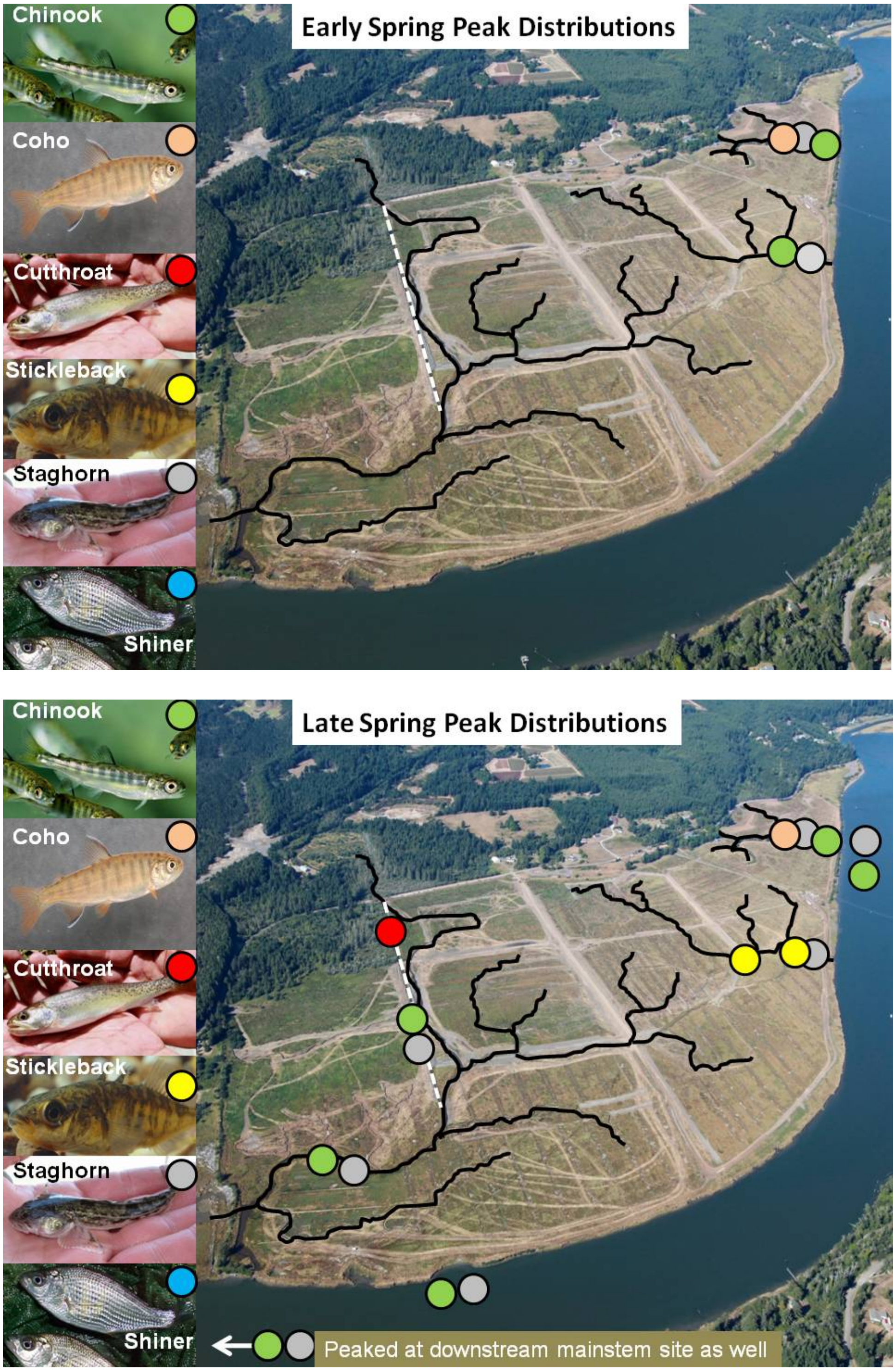
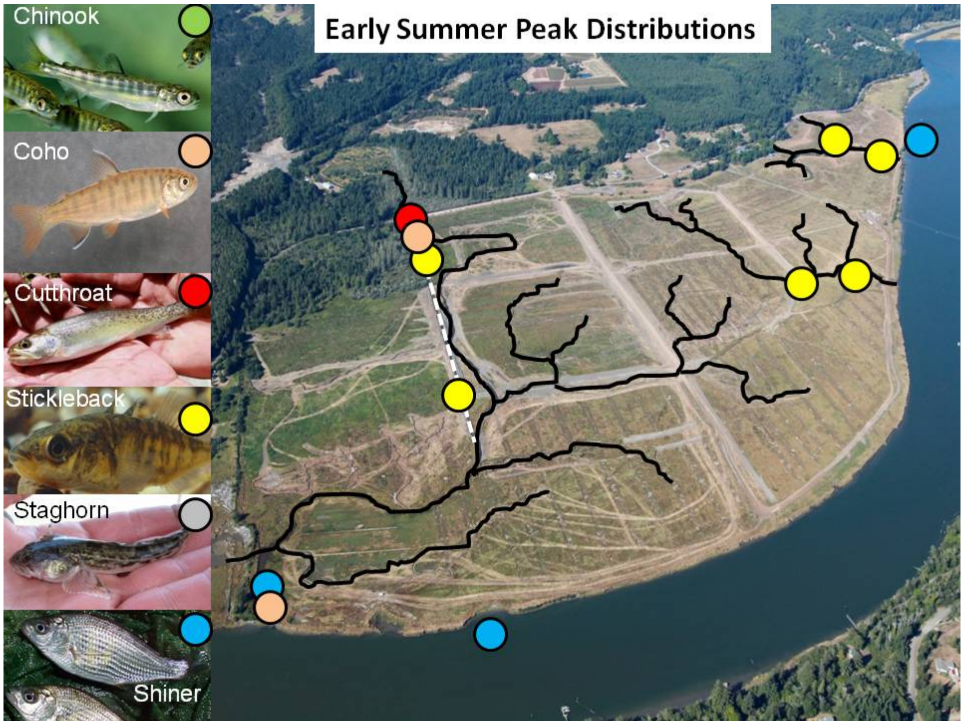


Figure 31. Early and late spring peak fish distributions for Ni-les'tun Marsh, 2005 and 2010.



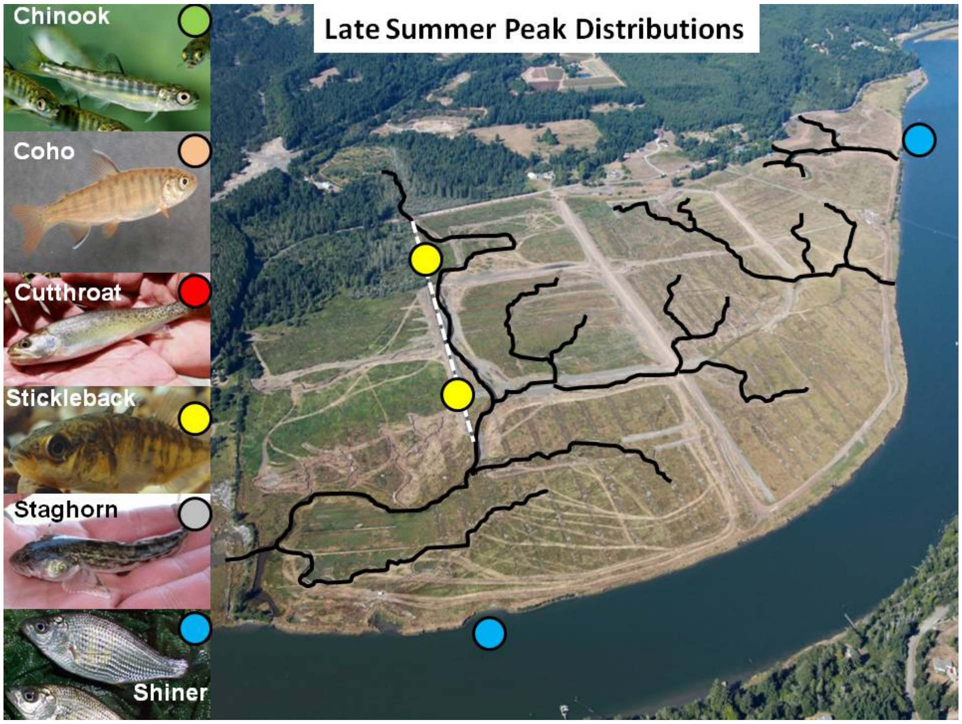


Figure 32. Early and late summer peak fish distributions for Ni-les'tun Marsh, 2005 and 2010.

Tidal Migrations

Underwater video was used to monitor tidal migration of fishes. One or two days of tidal migration sampling was carried out for each of the four marsh channels. In 2005 sampling occurred in late May and in 2010 sampling was carried out in early June. The summary data shown below are only from 2010 (Figures 33 and 34). The data are presented as raw camera counts for the portion of habitat sampled by the camera transects rather than full population expansion estimates. We present the data in this manner to allow for a simpler representation of the patterns of migration during pre-restoration. In future reports full estimates will be provided to allow for a statistical comparison of migratory population size(s).

The day time tidal migration monitoring results (Figure 33) show the reference marsh is being accessed by juvenile salmonids, adult and juvenile stickleback, adult and juvenile shiner perch, and staghorn sculpin (not shown). Migration patterns were similar to those observed by the authors in previous studies of natural marsh systems on the Oregon Coast (van de Wetering and French, 2002; van de Wetering *et al*. 2007). These patterns include an entry into the channel during the morning flood tide after minimum water depths (>1 ft) were available, followed by use of the channel through the later portion of the afternoon ebb tide. Tidal inundation (water depth), water quality (temperature and salinity) are all controlling factors for migratory fish that use salt marsh networks. The Reference channel showed less migration than the authors have observed in other marsh channels positioned farther upriver - where salinities are more appropriate for chinook not yet physiologically ready to smolt. Aside from the lower numbers, the overall migration patterns observed in the reference marsh match those observed in other Oregon reference marshes, which will allow for a useful tool to analyze post-migration recovery rates in the three treatment channels.

Fahys, NoName and Redd treatment channels showed very limited tidal migrations (Figures 33 and 34). When comparing the treatment marshes to the reference marsh (Figure 33) it is apparent that limited tidal exchange resulted in limited migration during both the flood and ebb tides. Traditional top hinged tide gates commonly prevent or greatly reduce migration during the flood tide, but allow an initial movement both in and out shortly after the tide begins to ebb and the flap opens. Once the ebb begins to flow at full force, the velocities are typically great enough that migration again slows or terminates. An exception to this was the movement observed in NoName during the ebb tide - fish were able to move into and out of a sheltered area (30 ft pipe) that was downstream of the camera station but inside the tide gate. We suggest this movement occurred to a much greater extent in NoName because this sub-basin has very limited freshwater flow, so ebb tide velocities were low. By contrast, the freshwater flows carried by Fahys and Redd Creeks resulted in very high velocities during full ebb tide.

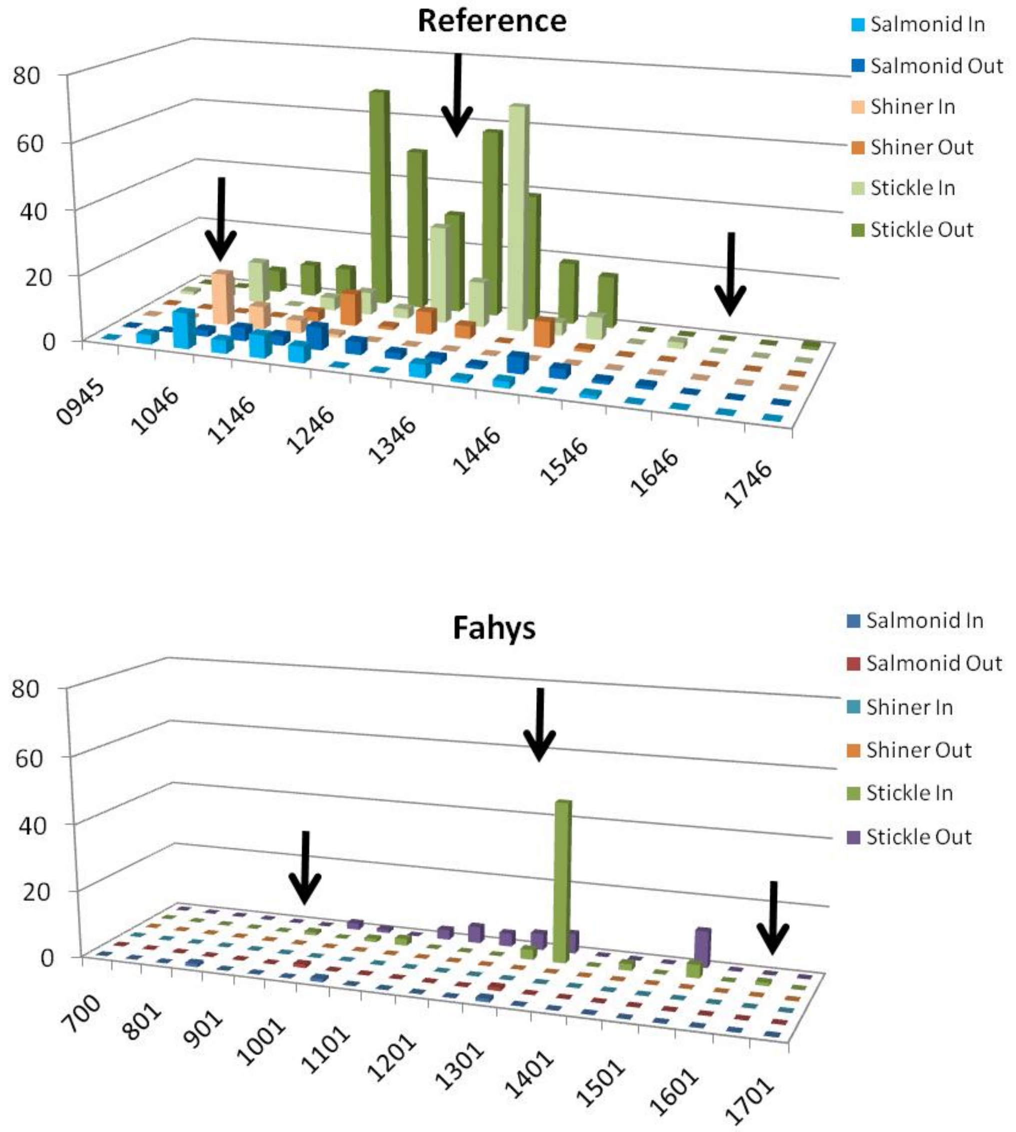
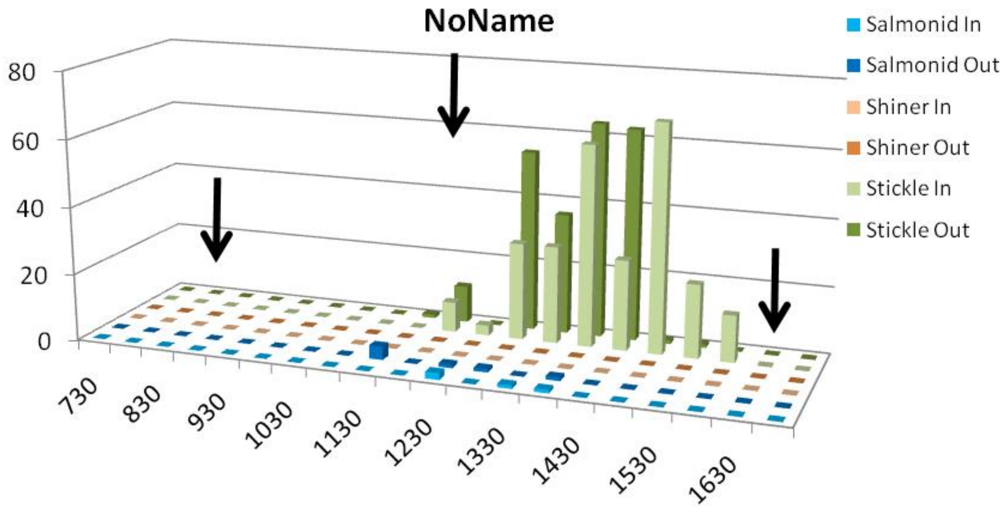


Figure 33. Early June 2010 tidal migration patterns for the mouths of the Reference (Shipwreck) channel and Fahys Creeks. Bars represent unexpanded into marsh and out of marsh migration (raw camera counts) at 30 minute intervals. Arrows denote morning low, afternoon high and afternoon low tides.



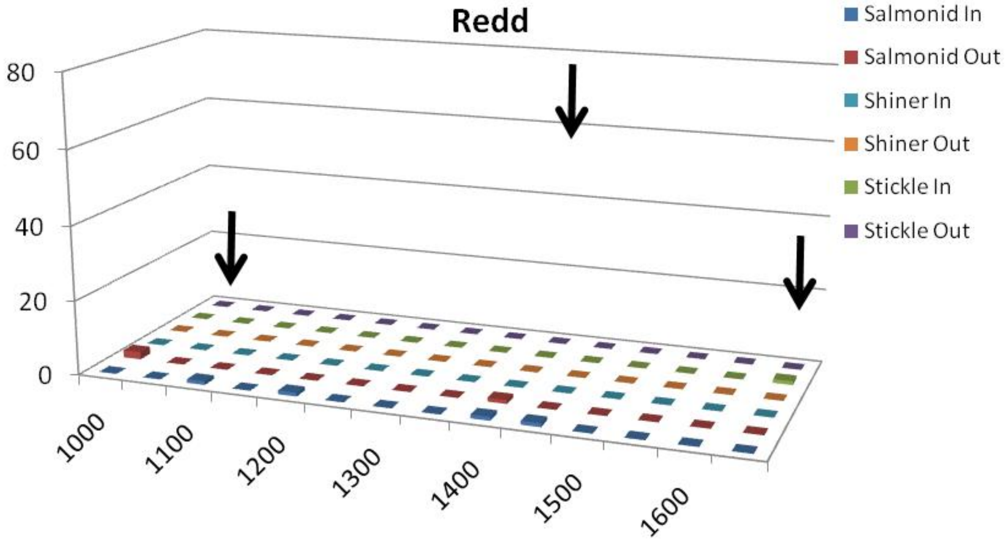


Figure 34. Early June 2010 tidal migration patterns for the mouths of NoName and Redd Creeks. Bars represent unexpanded into marsh and out of marsh migration (raw camera counts) at 30 minute intervals. Arrows denote morning low, afternoon high and afternoon low tides.

Overall Fish Use Summary

Restoration marsh fish use during the early spring through late summer pre-restoration period reflected tide gate presence (Figure 35) and its effect on migration; gate maintenance; gate influence on temperatures and salinities; and ditch maintenance. Young of the year salmonids emerge from gravels upstream in various tributaries. These age 0+ salmonids migrate downstream throughout the spring and early summer. These age 0+ salmonids and other species (staghorn sculpin, shiner perch and stickleback) enter marsh habitats during windows of limited opportunity (tide gate openings) and during high flow events that overtop dikes. At past study sites we have observed that age 0+ coho will utilize marsh habitats without carrying out daily migrations as long as water depths are great enough and temperatures and salinities are low enough. These circumstances are usually found in marsh channel habitats that are associated with a perennial stream where beaver activity is present at the tidal boundary. Under these circumstances, coho can rear continuously throughout the summer and following winter if the habitat quality remains high. Fahys and Redd Creeks both offered these conditions during the pre-restoration period – Fahys in the upper reach and immediately inside the tide gate.   The age 0+ chinook and staghorn sculpin were able to use the lower and middle Fahys reaches until water quality became too poor or habitat too limited. These same species were able to use Redd Creek until water volumes became too limited in late summer. Stickleback were able to make use of nearly all degraded habitats in Fahys, NoName and Redd Creeks. Shiner perch depend on broader daily tidal migration opportunities to make use of marsh habitats and we suggest they were therefore significantly limited in their ability to use Fahys, NoName and Redd marshes for nursery habitat during pre-restoration. NoName Creek offered adequate salmonid habitat, yet poor access, into the late spring at which time flows dropped, aquatic macrophyte and periphyton growth increased and temperatures began to rise. Limited tide gate access most likely resulted in NoName having the lowest salmonid and staghorn sculpin use rates.

Figure 35. Fahys tide gate during mid-ebb tide in late spring. Note the elevation drop from the pipe to the pool level downstream.

Future Analyses

Future reports will focus on specific restored reaches during pre and post-treatment using low tide distributions, large wood habitat use rates, and marsh sub-basin migration data. Habitat metrics will be incorporated to identify potential causal factors relative to shifts in rates of use.

Expectations for Future Fish Use

We suggest the three reaches of Fahys will shift in habitat condition resulting from high tidal exchange rates in the lower and middle reaches. These greater exchange rates will scour and fill the channel resulting in lower channel bottom elevations and potential low tide refugia – especially those areas associated with wood structures. We suggest greater tidal exchange will result in overall cooler temperatures as the mainstem drops in flow (summer months) and cooler near shore waters penetrate the estuary. Overall this will shift the middle and lower reaches toward habitat preferred by age 0+ chinook, coho smolts, staghorn sculpin, and shiner perch and at the same time provide much greater access to this habitat. We suggest initial habitat shifts in the upper Fahy's reach will be affected by scour and fill of the channel, which has a higher elevation, and a higher percent of sands. In addition, damming of the channel by beaver could shift the habitat toward that preferred by age 0+ coho and 1+ trout.

In comparison, we suggest the habitat of NoName will shift toward age 0+ coho preference during the late winter and into early spring followed by a shift to that preferred by age 0+ chinook, staghorn sculpin and shiner perch during late spring and summer. This is based on limited freshwater input after late winter. Summer use by these species will be limited by mainstem surface water temperatures for the tides that feed NoName marsh. Lastly we suggest Redd Creek habitat will shift toward warmer temperatures as maximum salinities tend to be 10 PSU lower than that of Fahys during late summer – as a result of fewer cool salt water intrusions. Beavers became active in a tributary channel of Redd Creek immediately after restoration. This habitat will likely attract age 0+ coho that will be able to utilize this resource throughout the year if water levels remain high enough.

Length of Monitoring Needed

Based on early observations (spring 2012) we expect to see measurable differences in fish use by 2013. In addition we expect the species compositions and temporal use patterns to move closer to natural patterns by 2021 based on the channel habitats approaching more of a state of equilibrium.

3. Climate change and ecosystem services

Monitoring Objective 3: Measure extent of resiliency to storm-related flooding and climate change

3a. Moderation of storm-related flooding

Monitoring Question 3a: Did restoration improve the site's capacity to moderate storm-related flooding?

Metrics for evaluating moderation of storm-related flooding:

Channel volume (cross-sections, length); water levels. *(Rationale: Pre-restoration LIDAR elevation data, pre- and post-restoration water level data, pre-restoration ditch volumes and newly dug restored channel volumes will be used to build a simple model describing storage volumes for typical storm events, e.g. 2 year, 5 year, 10 year and 100 year floods.)*

This question will be addressed during post-restoration monitoring.

3b. Climate change resilience

Monitoring Question 3b: Do post-restoration site conditions show potential for improved resilience to climate change?

Metrics for evaluating potential for resilience to climate change:

Plant community composition and extent; soil characteristics (% organic matter, texture, pH, and salinity); groundwater levels. *(Rationale: Native brackish marsh plant communities show higher resilience to climate change compared to non-native pastures, because they are tolerant of increased salinity and flooding. Accretion of organic matter in soils allows marsh elevations to rise in equilibrium with sea level rise, so it is central to marsh resilience. Soil texture, pH and salinity are controlling factors for organic matter accumulation and carbon sequestration, as well as other wetland functions related to moderation of perturbation and habitat resilience. Groundwater levels affect flood storage capability.)*

This question will be addressed during post-restoration monitoring. However, baseline monitoring revealed information suggesting that restoration will enhance resilience:

- <u>Plant community composition and extent</u>: Native species are broadly present at the restoration site (Figures A12 and A13, Appendix A), though they are not dominant on much of the site (Tables B4, B14 and B15, Appendix B). This suggests that the restoration site will quickly recover native plant communities, resulting in increased resilience to climate change due to these species' tolerance of salinity and flooding.
- <u>Soil characteristics</u>: Organic matter content of restoration site soils was only about half that at the reference site (Table 2; Table B18, Appendix B), and the OM content of the reference site soils was actually lower than typical high marsh in Oregon (Brophy 2009, Brophy *et al*. 2011, MacClellan 2011). We expect organic matter to increase after restoration at Ni-les'tun, since grazing and drainage cause loss of organic matter and removal of these alterations is likely to reverse that loss (MacClellan 2011). Organic matter accumulation improves resilience to sea level rise, since a high proportion of marsh accretion is due to organic accumulation (Cahoon *et al*. 2006).
- <u>Groundwater</u>: Restoration of tidal wetlands at Ni-les'tun will enhance organic matter accumulation and accretion rates, leading to improved resilience to climate change (particularly sea level rise). Tidal wetlands sequester carbon at high rates (Whiting and Chanton 2001, Brigham *et al.* 2006), and carbon accumulation is a strong contributor to wetland surface equilibration with sea level (Cahoon *et al*. 2006).

Appendix A. Additional figures

List of figures

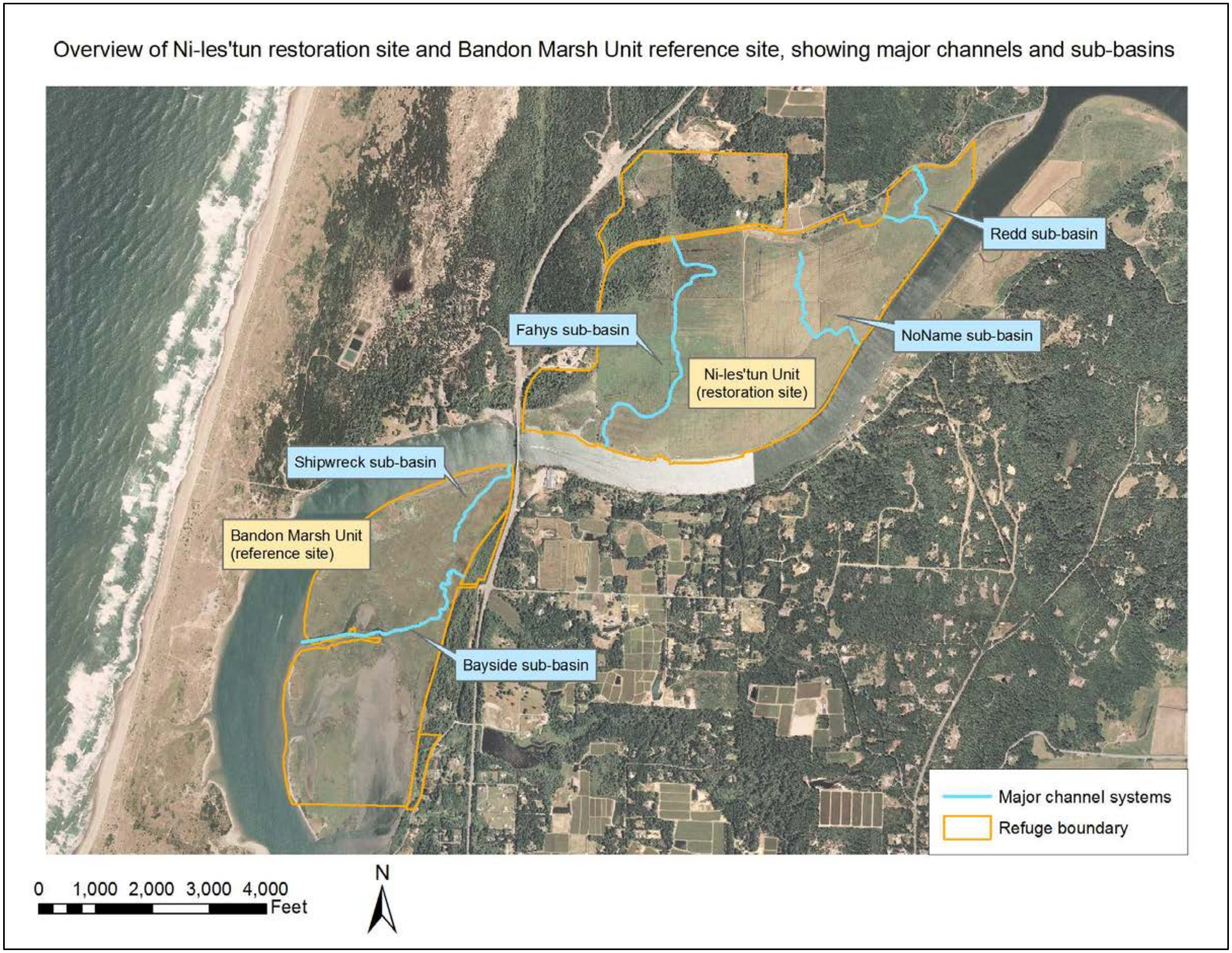


Figure A1. Overview of the Ni-les'tun restoration site, Bandon Marsh Unit reference site, and sub-basins

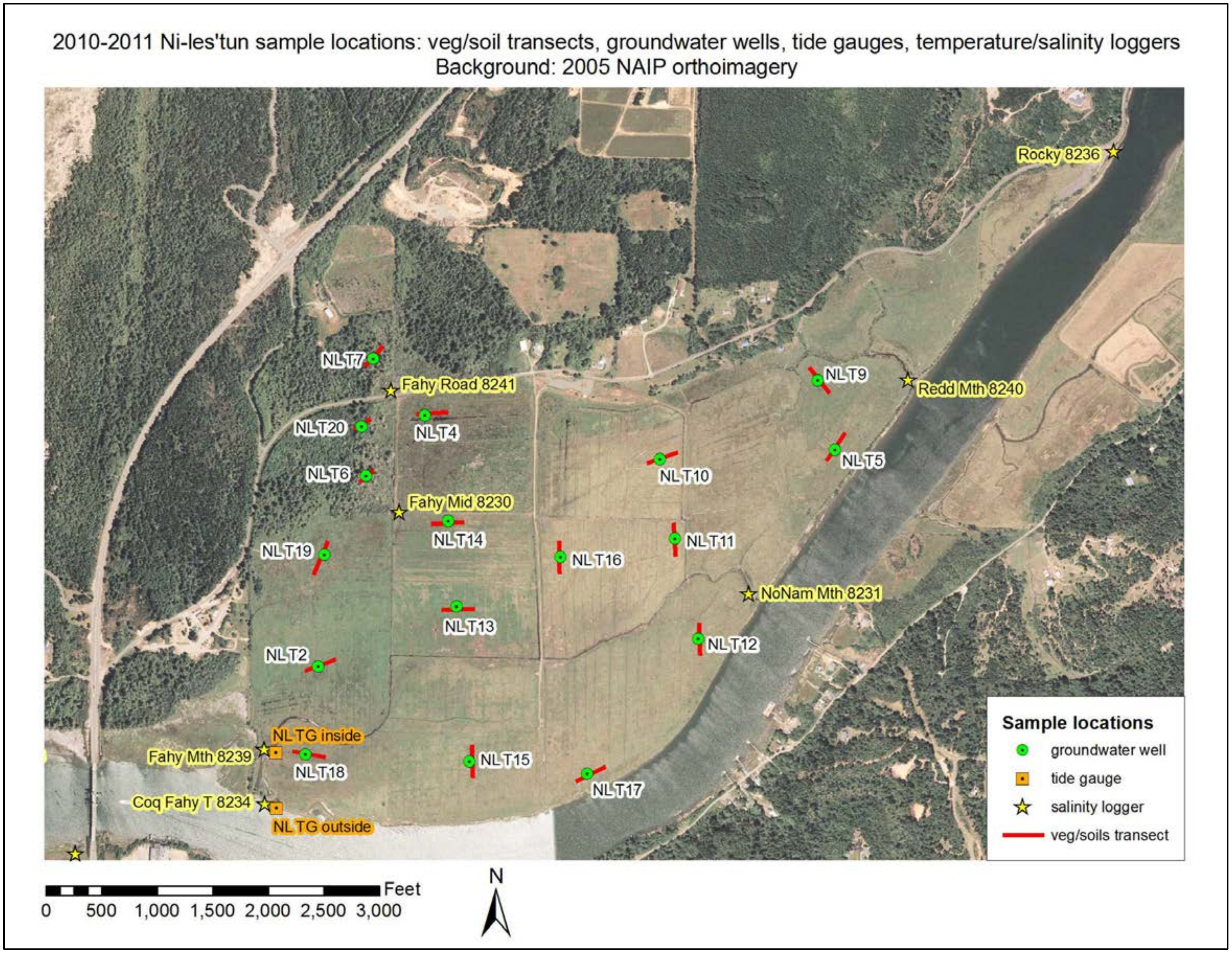


Figure A2. Ni-les'tun restoration site: 2010-2011 sample locations for vegetation, soils, groundwater, tidal hydrology, and surface water temperature and salinity

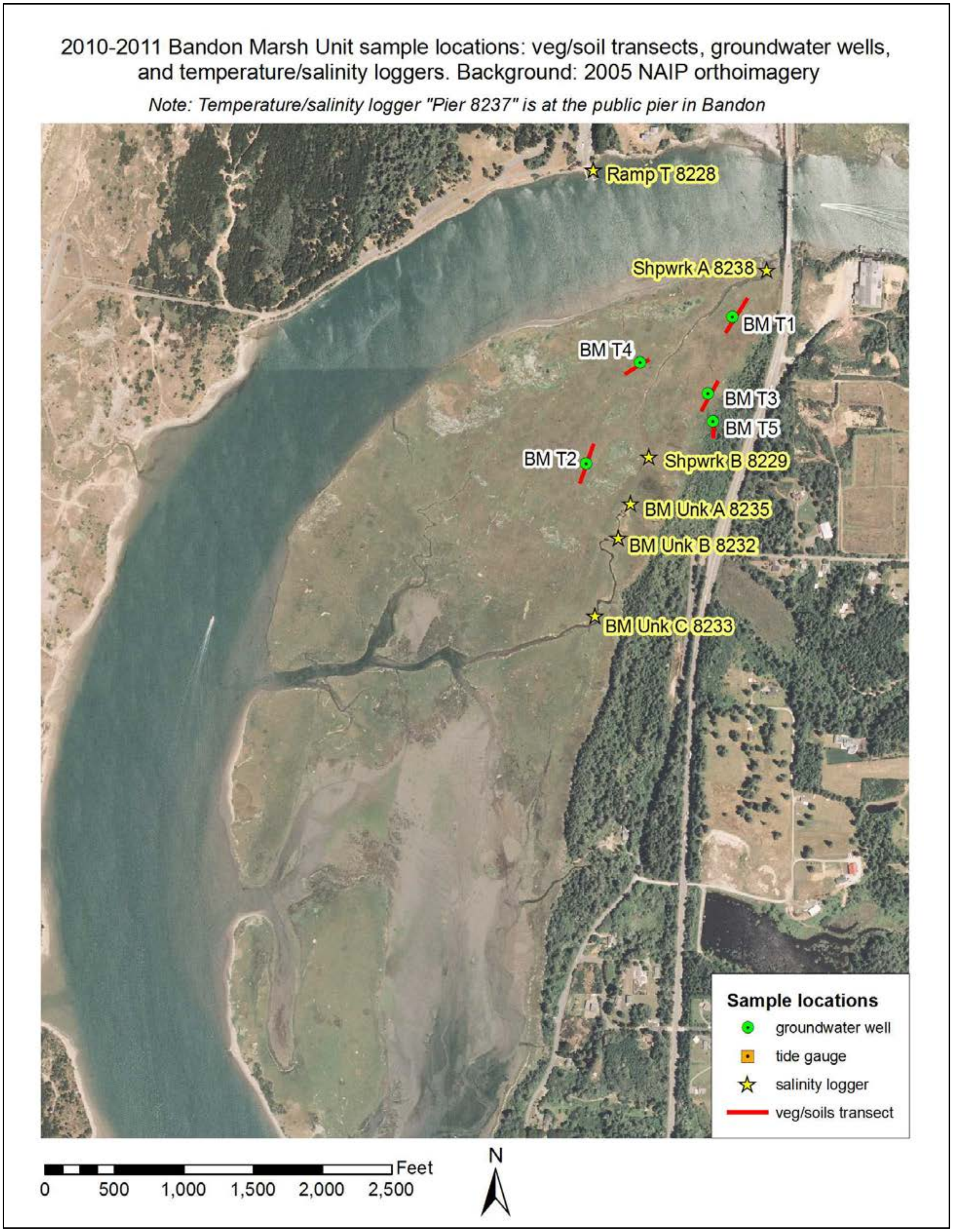


Figure A3. Bandon Marsh Unit reference site: 2010-2011 sample locations for vegetation, soils. groundwater, and surface water temperature and salinity.

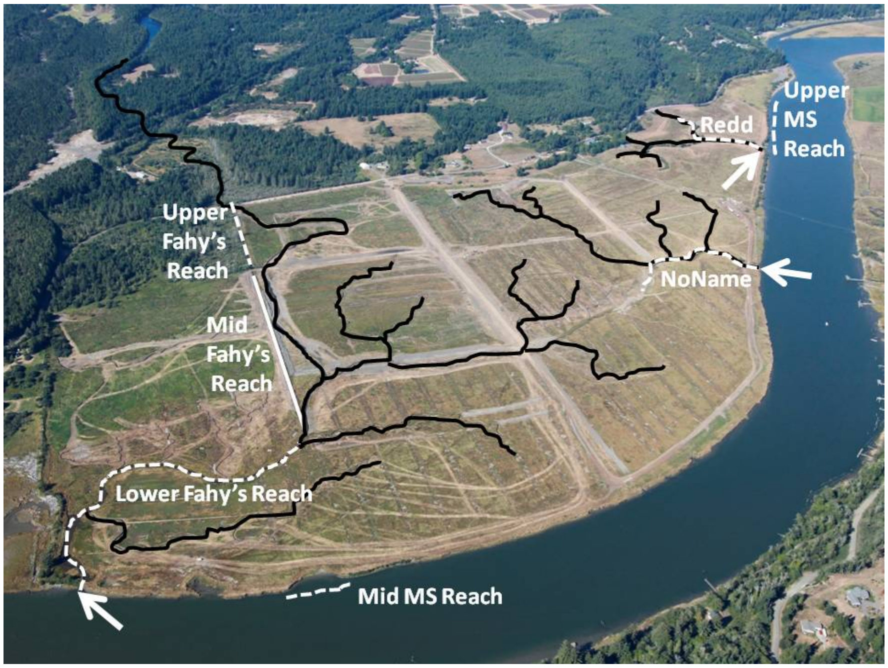


Figure A4. 2010-2011 fish sampling locations. Black lines (top image) represent restored tidal channels. Low tide seine sampling sites are represented by white dotted and solid lines. Arrows represent videography sample sites. Top: Restoration site. Bottom: Reference site.

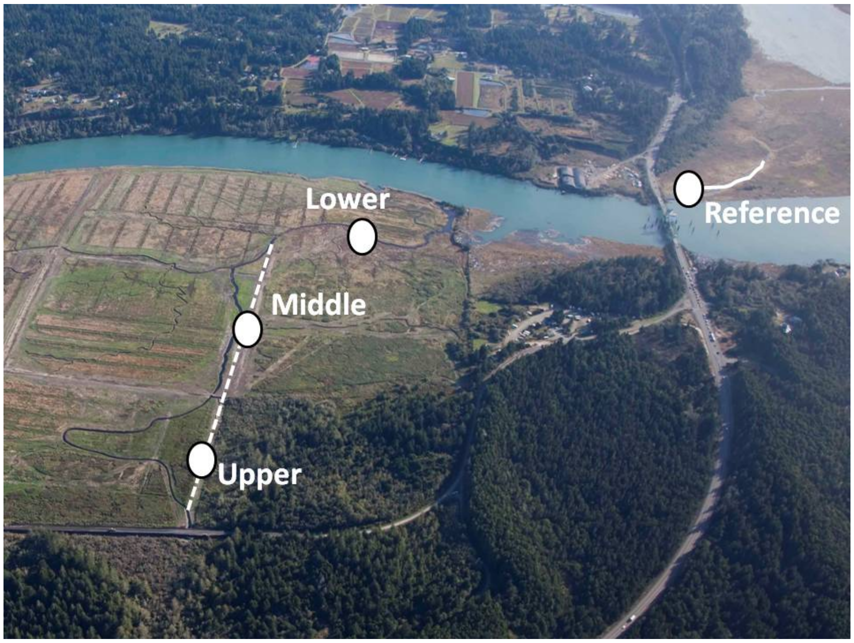


Figure A5. 2010 benthic macroinvertebrate sample sites.

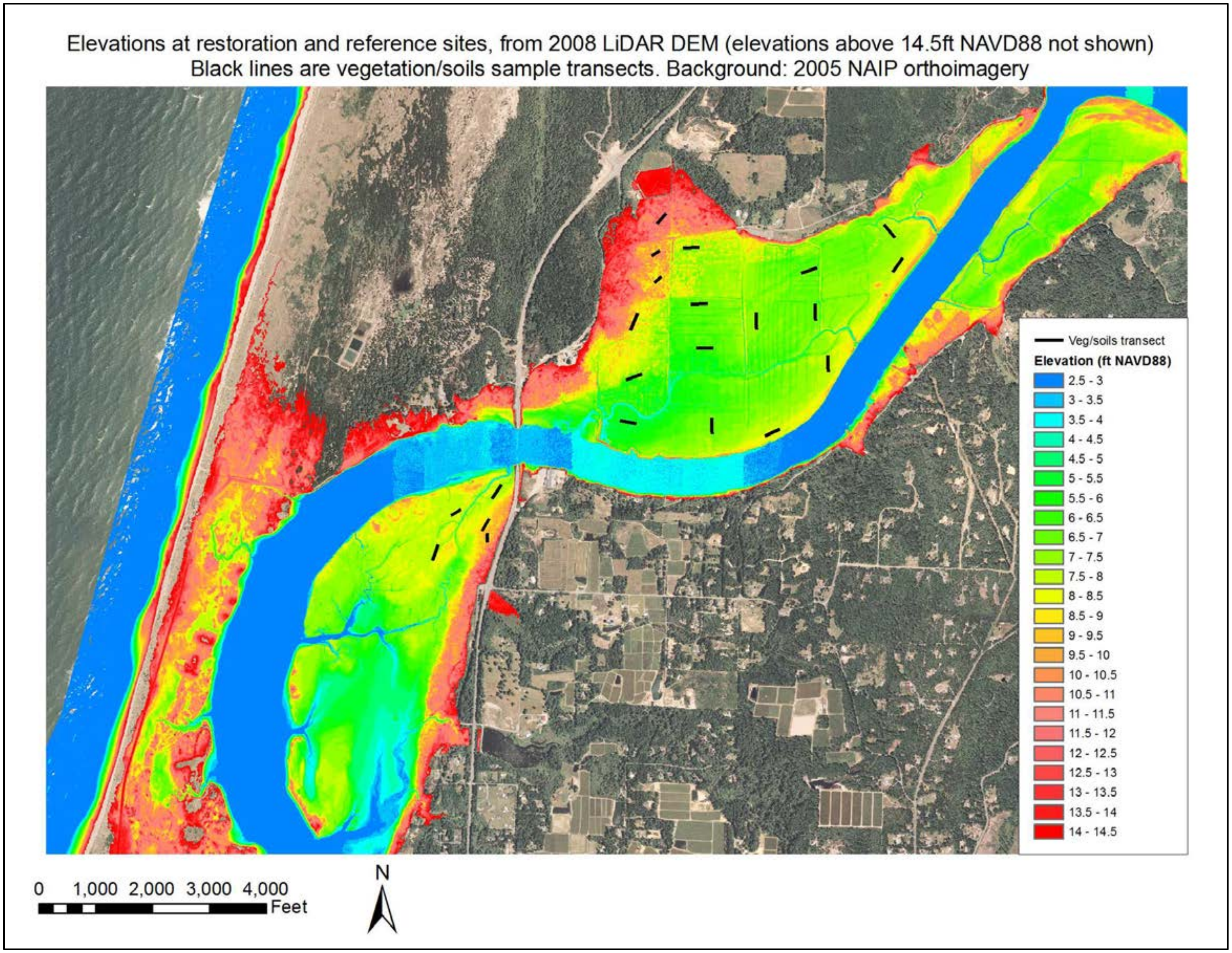
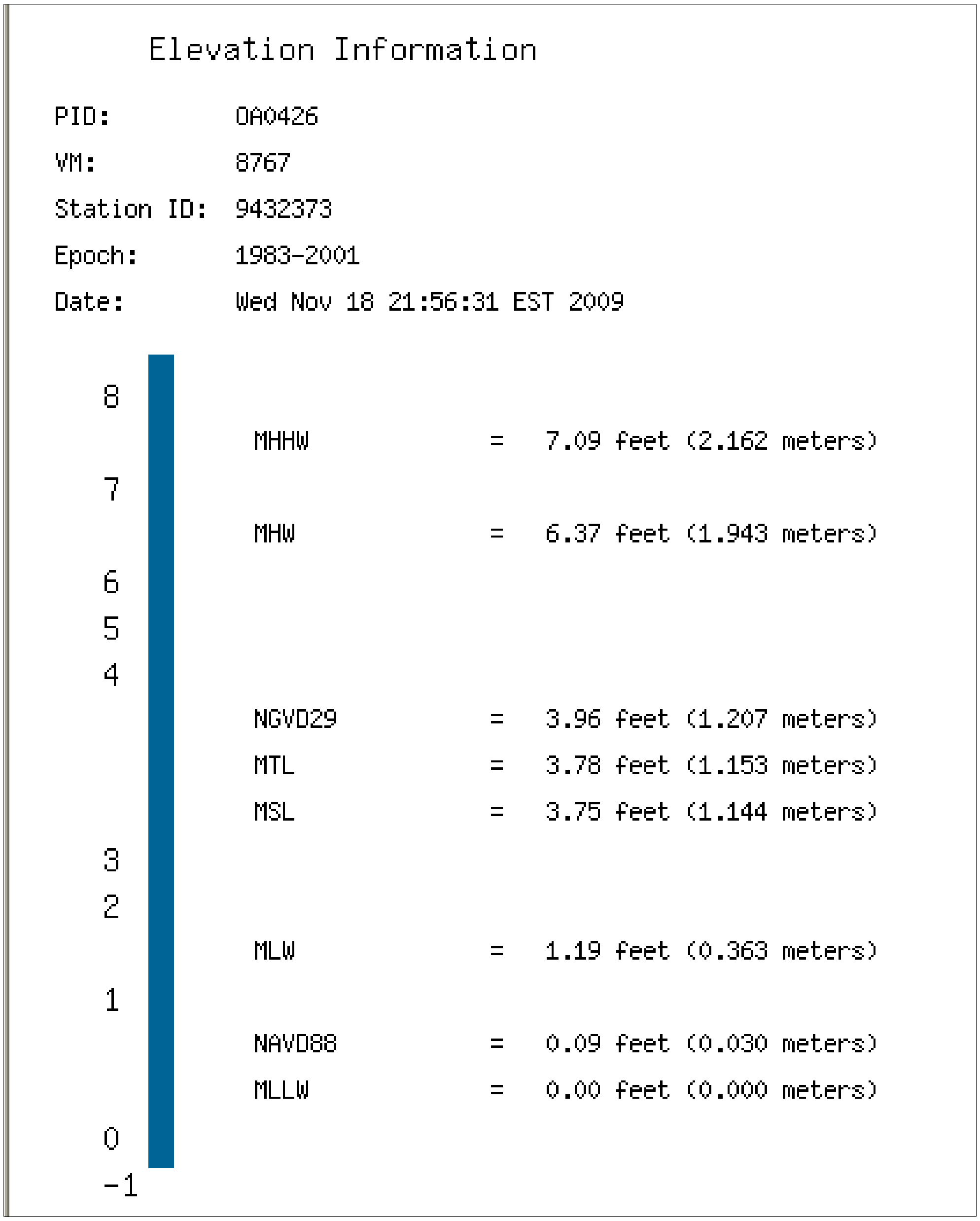


Figure A6. Elevations at the Ni-les'tun restoration site and Bandon Marsh Unit reference site, from 2008 LiDAR DEM. Black lines are vegetation/soils sample transects; see Figures A2 and A3 for transect numbers.



Elevation Information

PID: 0A0426

VM: 8767

Station ID: 9432373

Epoch: 1983-2001

Date: Wed Nov 18 21:56:31 EST 2009

MHHW = 7.09 feet (2.162 meters)

MHW = 6.37 feet (1.943 meters)

NGVD29 = 3.96 feet (1.207 meters)

MTL = 3.78 feet (1.153 meters)

MSL = 3.75 feet (1.144 meters)

MLW = 1.19 feet (0.363 meters)

NAVD88 = 0.09 feet (0.030 meters)

MLLW = 0.00 feet (0.000 meters)

Figure A7. Tidal datums at the Bandon NOAA tide station (Station ID 9432373), in reference to Mean Lower Low Water (MLLW). To obtain datums relative to NAVD88, subtract the NAVD88 value shown on the diagram (0.09ft). For example, Mean Higher High Water at this station is 7.09ft – 0.09ft = 7.00ft NAVD88. Source: http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=9432373%20BANDON,%20COQUILLE%20RIVER,%20OR&type=Datums

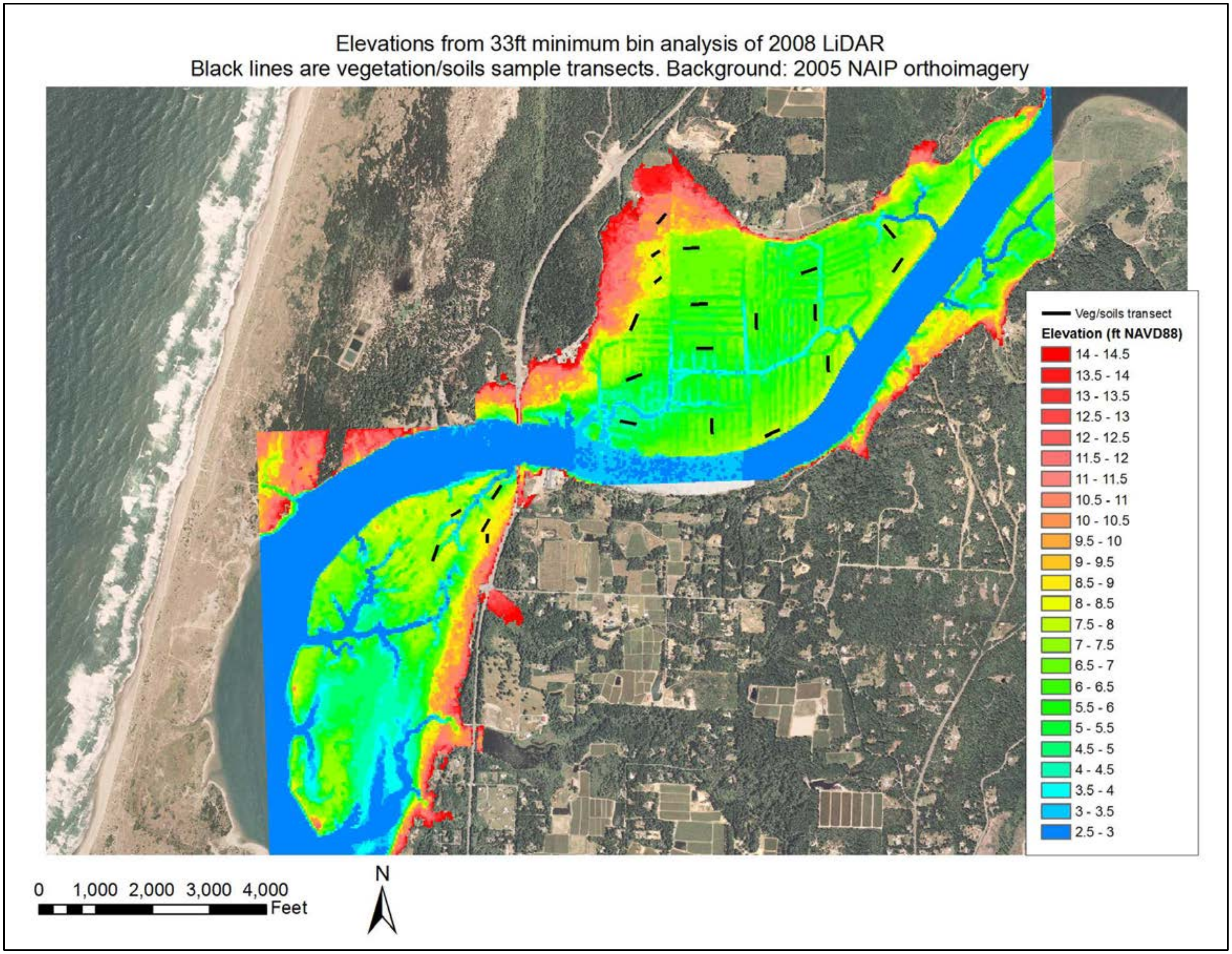


Figure A8. Surface elevation using 33ft (10m) minimum bin analysis of 2008 LiDAR point cloud for the Ni-les'tun restoration site and Bandon Marsh Unit reference site. Black lines are vegetation/soils sample transects; see Figures A2 and A3 for transect numbers.

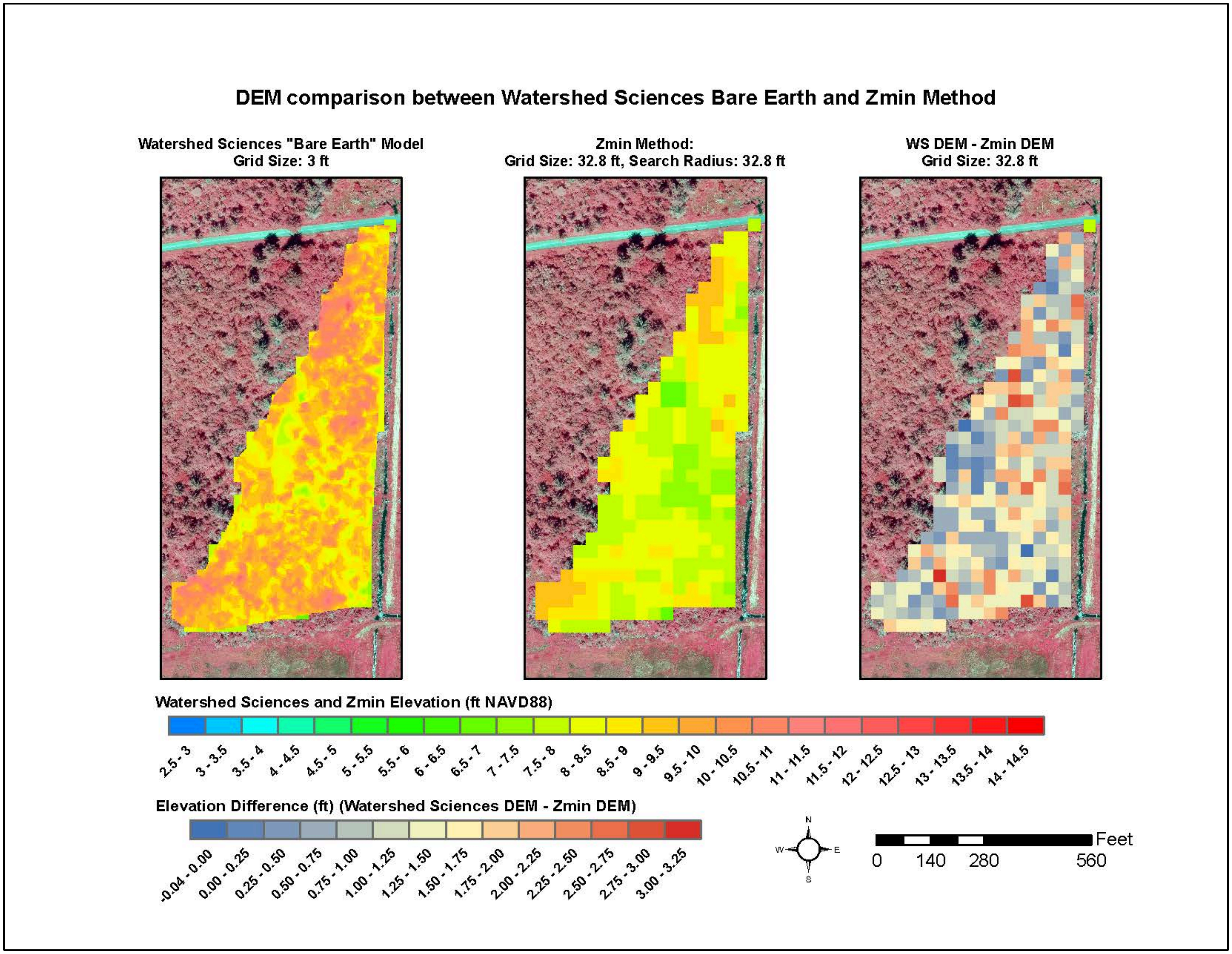


Figure A9. Comparison of ground surface elevations from minimum bin (”Zmin”) method (33ft bin size), and DEM provided by the State of Oregon (produced by Watershed Sciences, Inc.). L to R: original DEM, minimum bin DEM, and difference between the two.

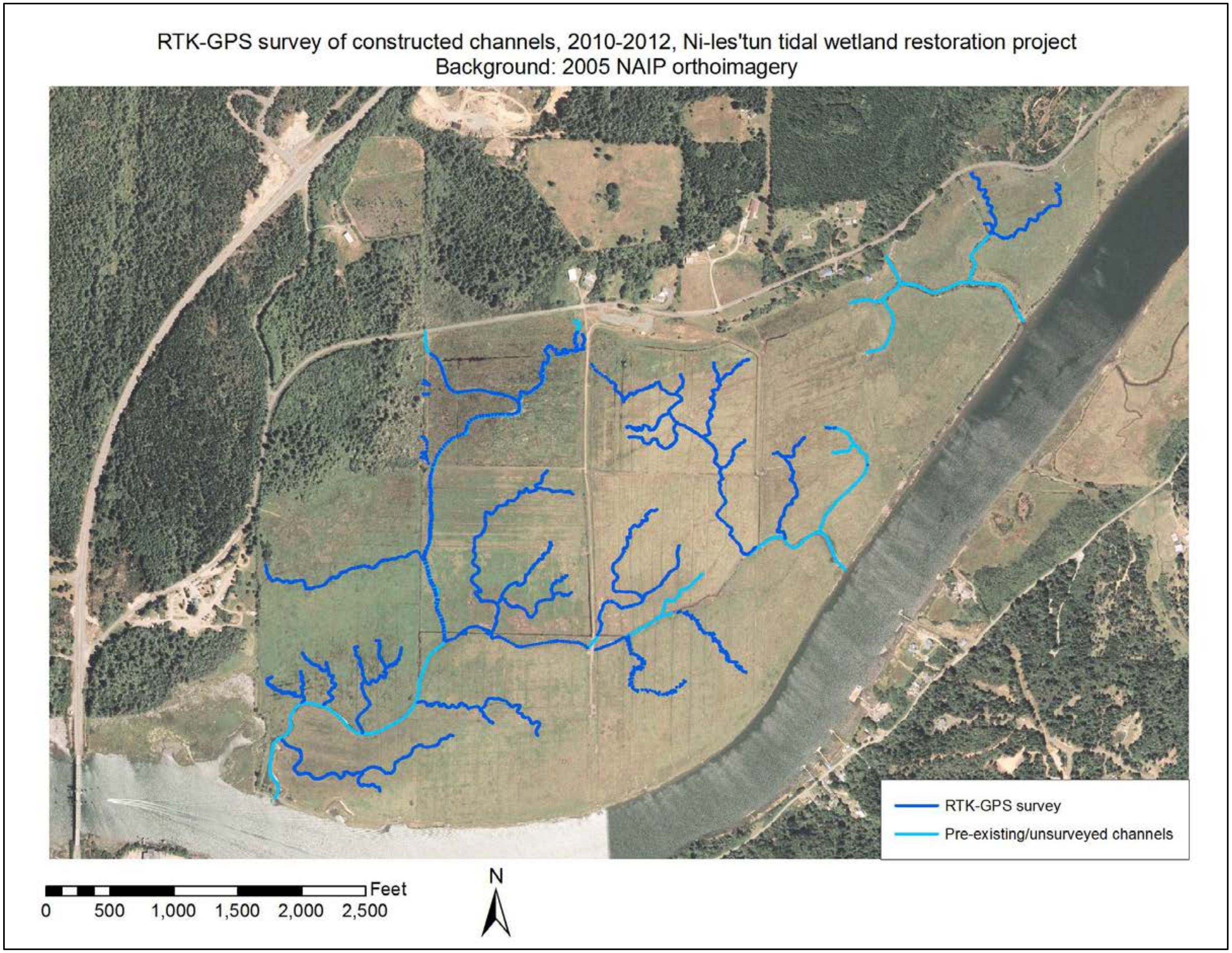


Figure A10. Ni-les’tun restoration site: RTK-GPS survey of restored channels, 2010-2012.

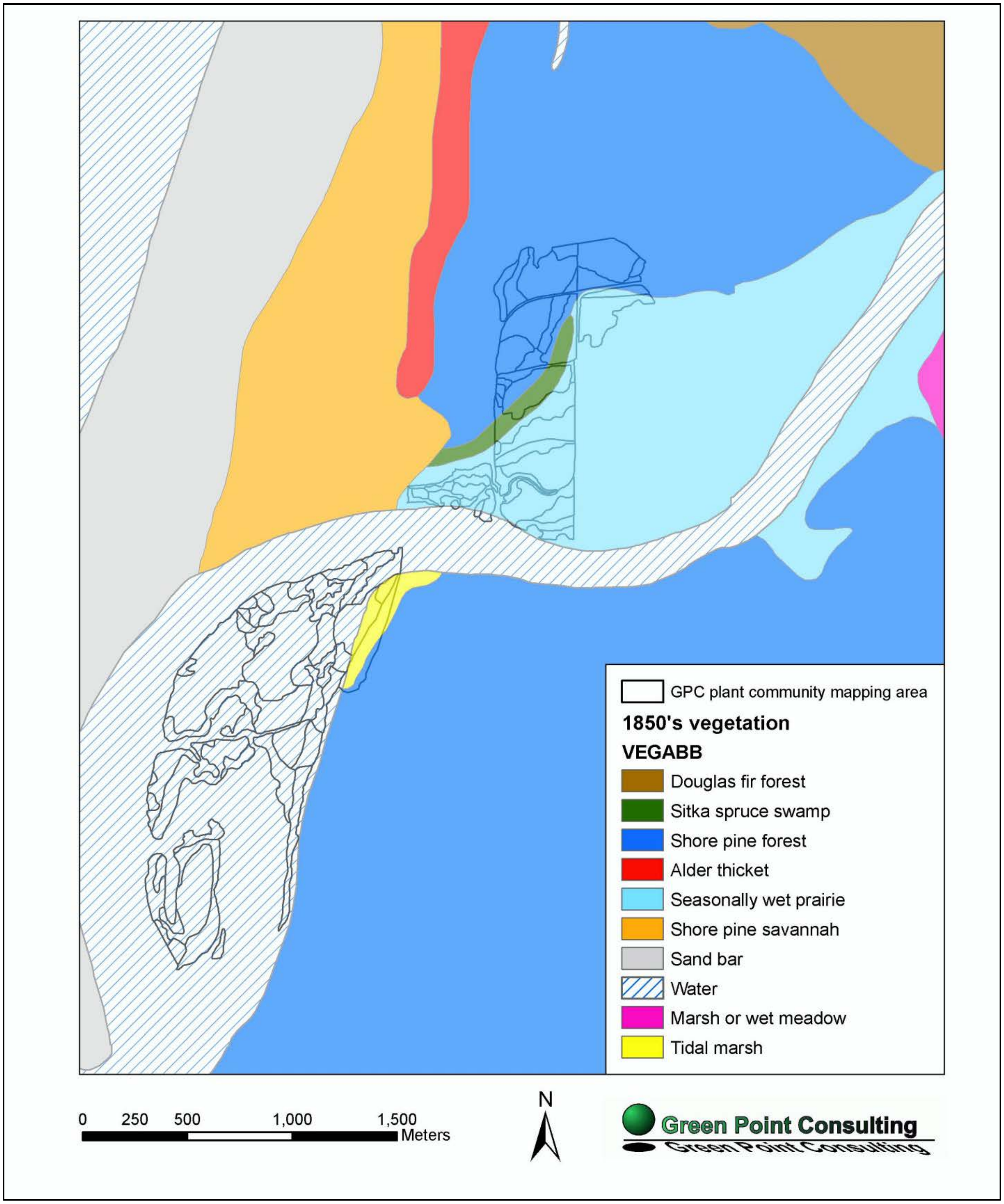


Figure A11. Historic vegetation at the Bandon Marsh NWR, from Hawes *et al*. 2008.
Figure reproduced from 2003 monitoring report (Brophy 2005a).

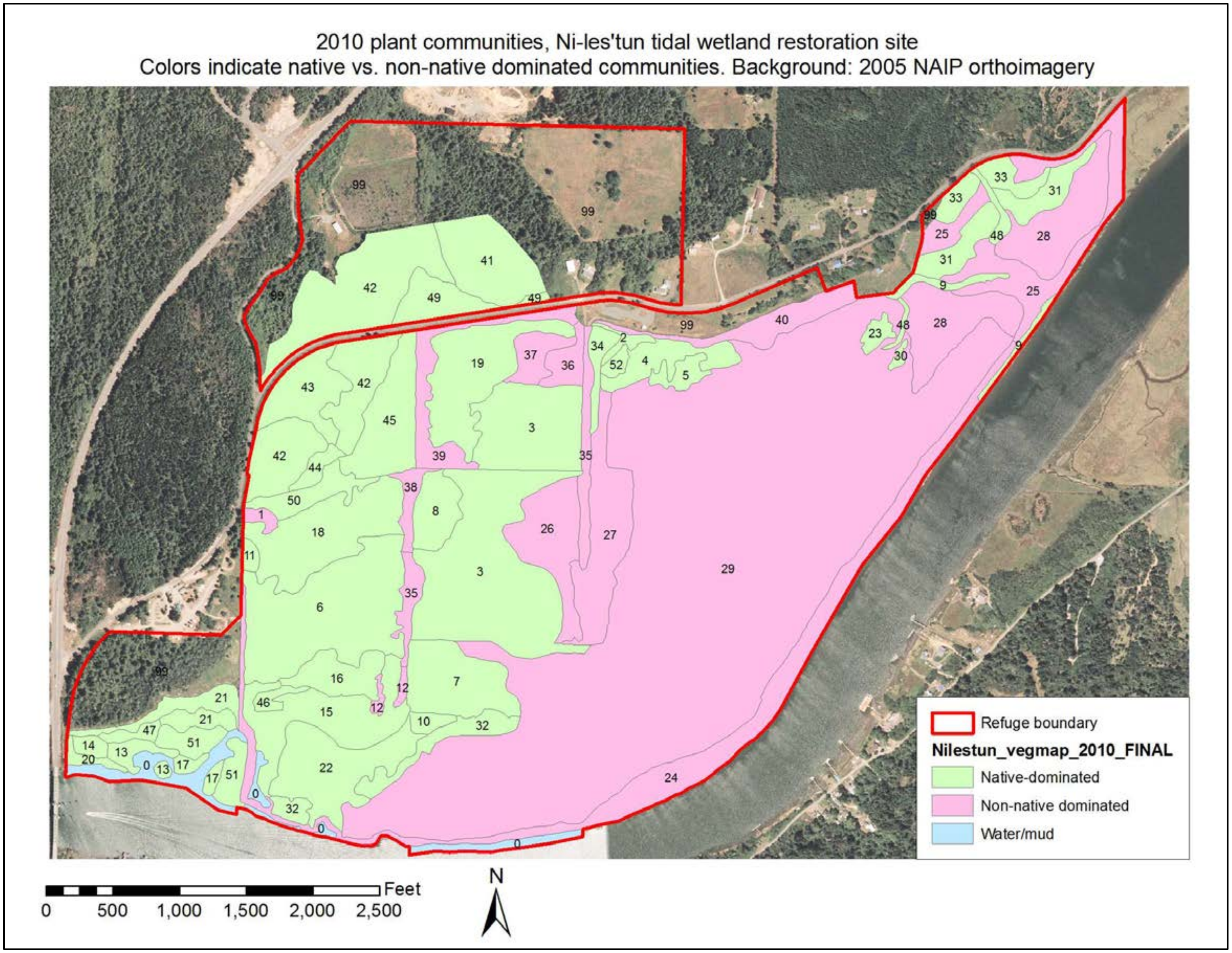


Figure A12. Plant communities at the Ni-les'tun restoration site, July 2010, showing areas dominated by native vs. non-native species. Unmapped areas are outside restoration project area. Labels show association numbers (see Table B14, Appendix B).

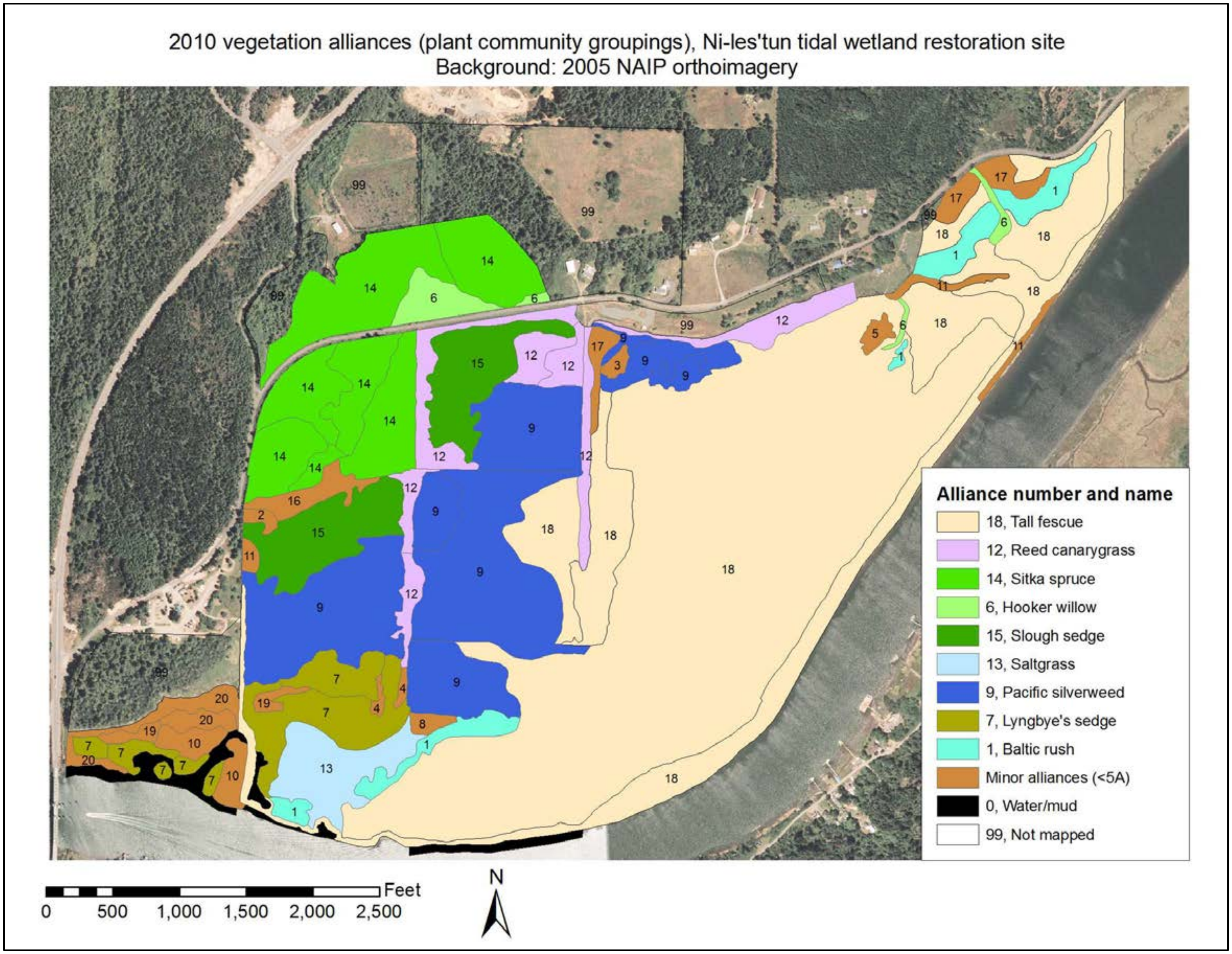


Figure A13. Vegetation alliances (plant community groups) at the Ni-les'tun restoration site, July 2010. Labels show alliance numbers; see Table B15, Appendix B for key to numbers.

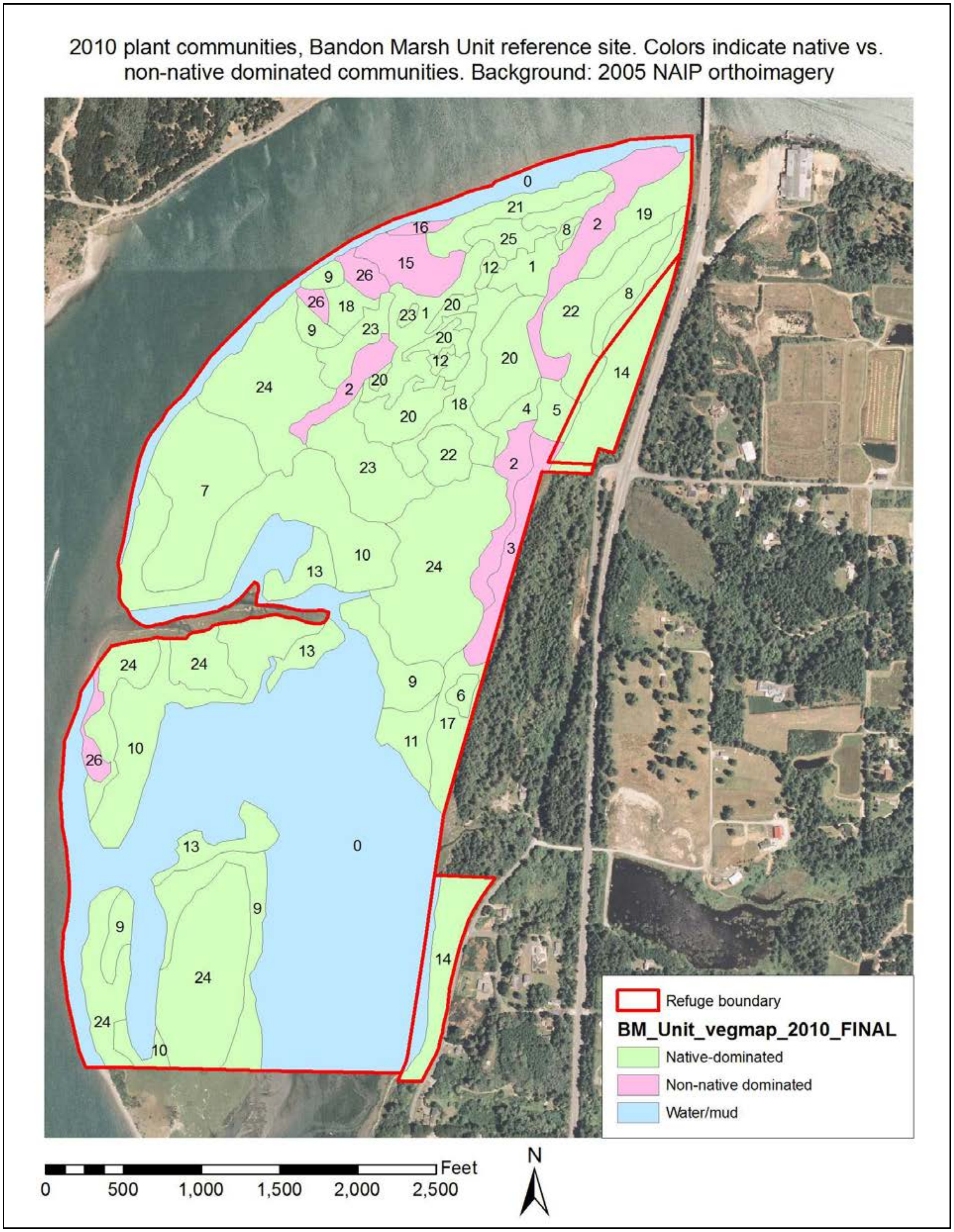

2010 plant communities, Bandon Marsh Unit reference site. Colors indicate native vs. non-native dominated communities. Background: 2005 NAIP orthoimagery

Figure A14. Plant communities at the Bandon Marsh Unit reference site, July 2010, showing areas dominated by native vs. non-native species. Labels show plant association numbers; see Table B16, Appendix B for key to numbers.

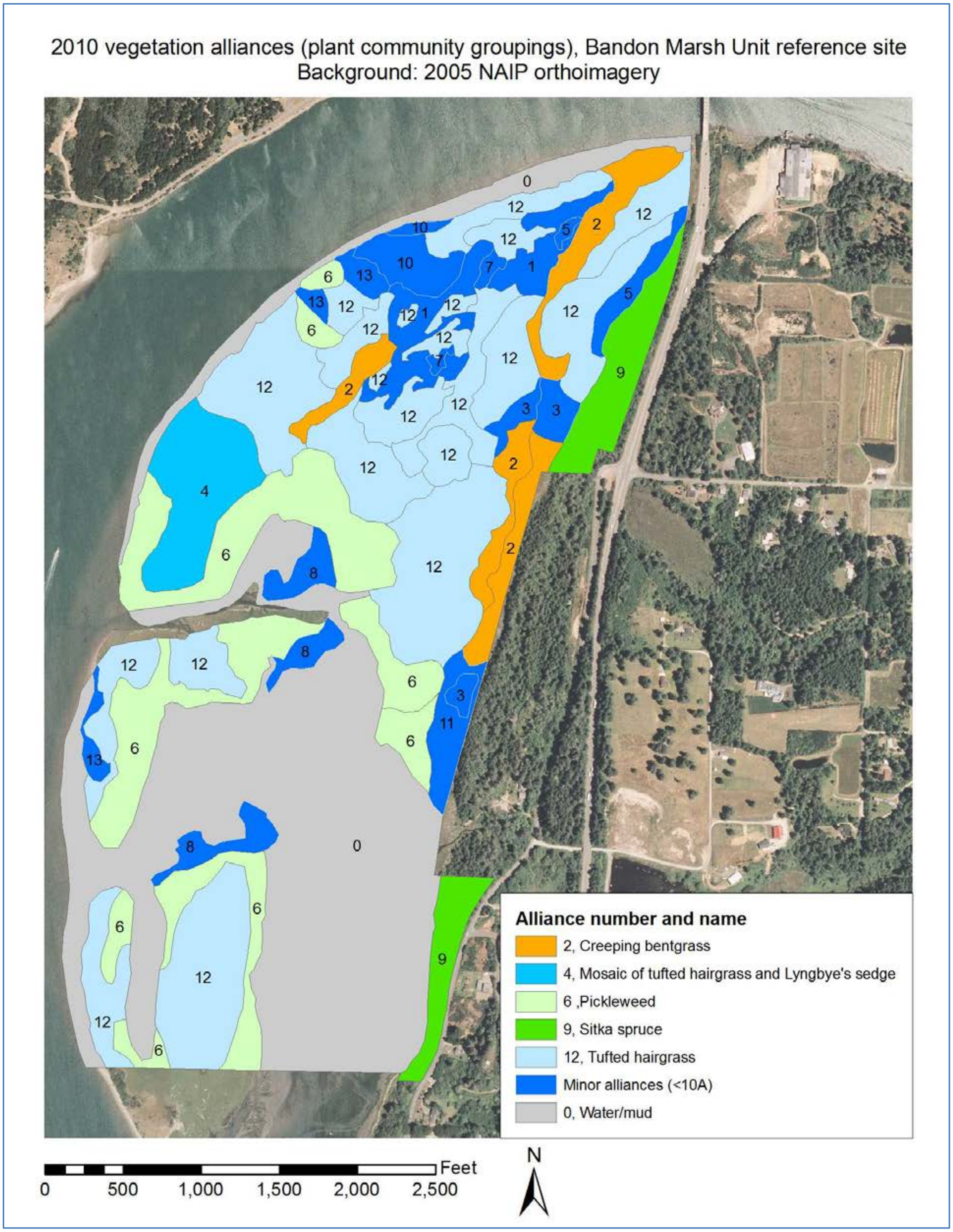


Figure A15. Vegetation alliances (plant community groups) at the Bandon Marsh Unit reference site, July 2010. Labels show alliance number; see Table B17, Appendix B for key to numbers. Non-native associations are orange, native associations are green to blue.

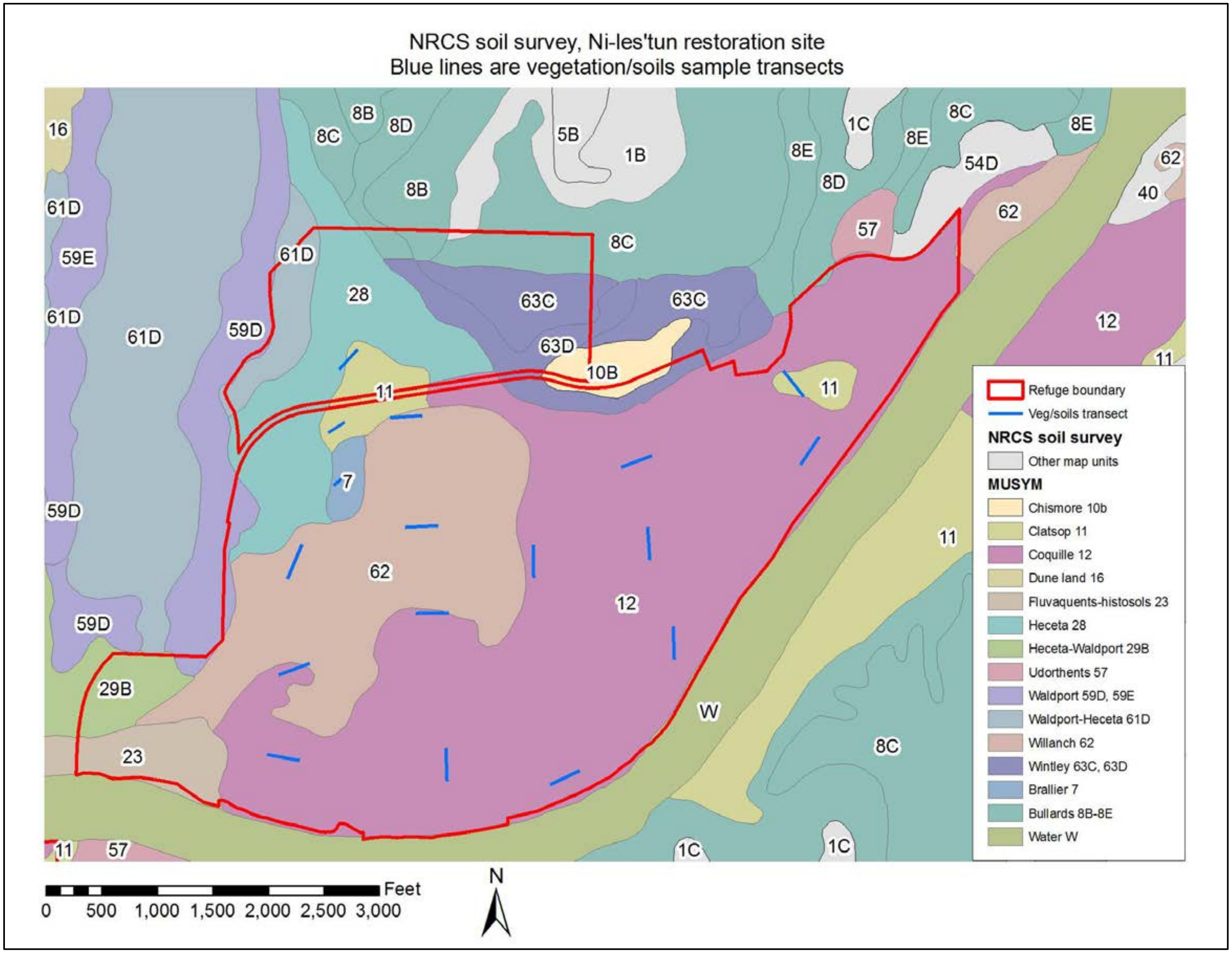


Figure A16. NRCS soil survey data for the Ni-les'tun restoration site. Labels show soil map units; blue lines are vegetation/soils sample transects. For transect numbers, see Figure A2 above.

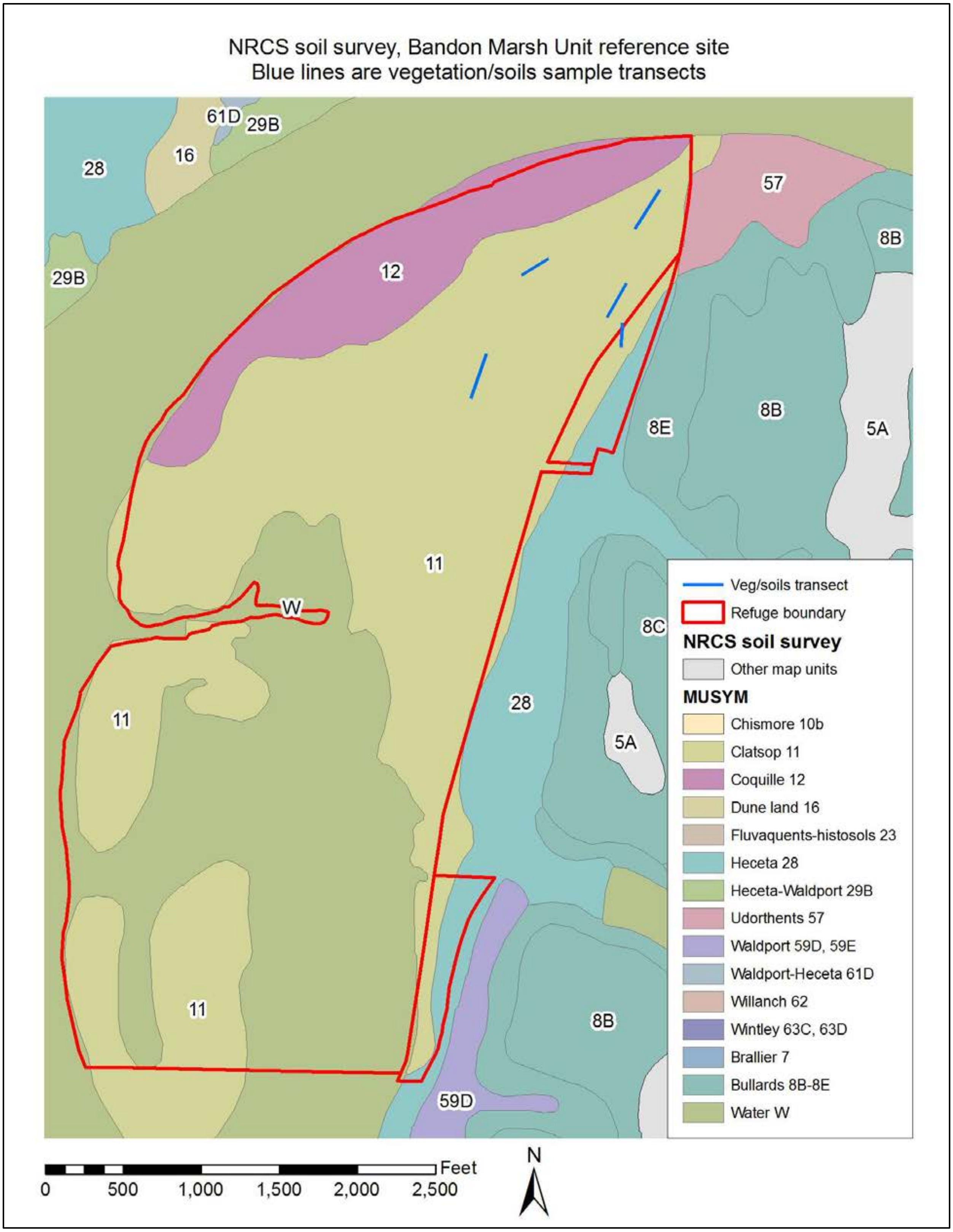


Figure A17. NRCS soil survey data for the Bandon Marsh Unit reference site. Soil map units are labeled; blue lines are vegetation/soils sample transects. See Figure A3 for transect numbers.

Figure A18. One of the larger ditches that was cleaned of aquatic macrophytes and fine sediments one year prior to fish rescue and the restoration fill actions.

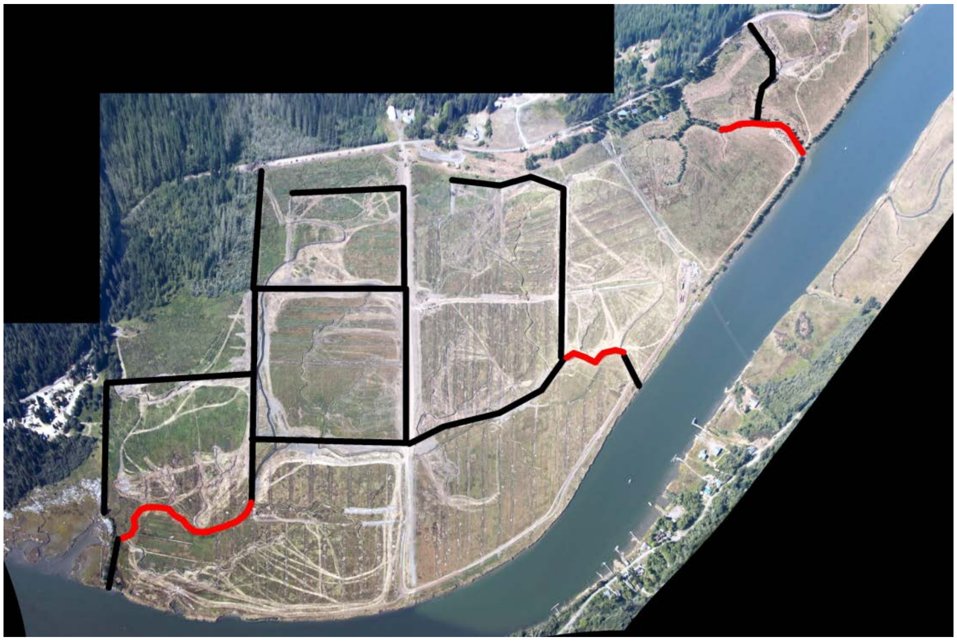


Figure A19. Channels that were available for fish use during early and late spring during the pre-restoration period (black lines). Red lines show semi-natural channel reaches. Background: August 2010 aerial by Roy Lowe.

Figure A20. Top: Restored (excavated) marsh channels (black lines). Background is August 2010 aerial by Roy Lowe. Bottom: Newly dug channel form.

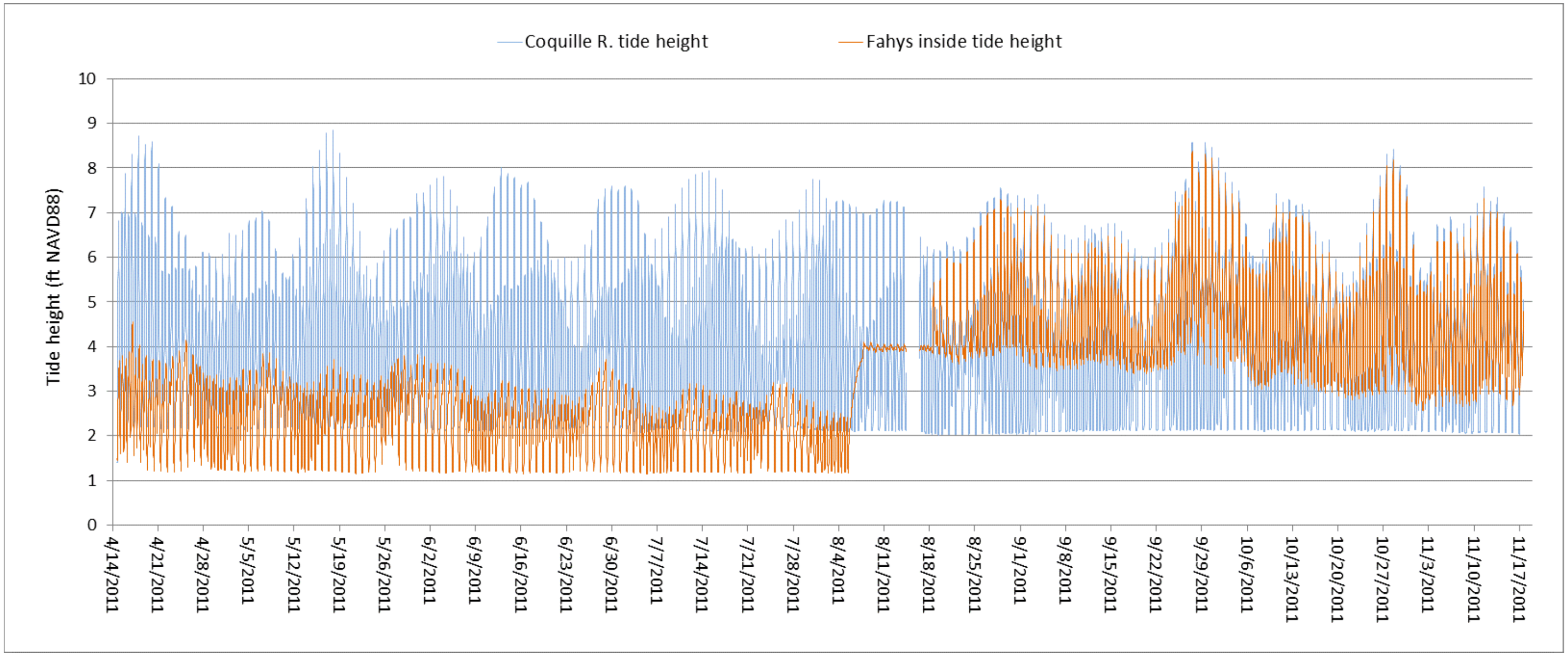


Figure A21. Pre-restoration water levels in Fahys Creek inside tide gate (orange line) from 4/14/11 – 8/18/11, and early post-restoration tide heights at same location after tide gate removal (8/18/11 – 11/17/11). Blue line shows reference tide cycle in the Coquille River just outside the Ni-les'tun site. Note decreasing low tide elevations in Fahys Creek as erosion deepens the channel during October and November 2011, allowing the tide cycle to move towards reference conditions.

Appendix B. Additional tables

List of tables

Table B1. 2010-2011 elevations of study transects at Ni-les'tun and Bandon Marsh Units, from RTK-GPS and total station survey. Each elevation is the average of several surveyed points; the number of points is listed in the far right column.

Site	**Transect**	**Transect elevation (ft NAVD88)**	**Vegetation type**	**Habitat description**	**# of survey points**
Ni-les'tun restoration site	NL T2	5.53	emergent	diked pasture	14
Ni-les'tun restoration site	NL T4	6.20	emergent	diked pasture	8
Ni-les'tun restoration site	NL T5	7.13	emergent	diked pasture	8
Ni-les'tun restoration site	NL T6	7.30	forested	forested wetland	1
Ni-les'tun restoration site	NL T7	9.49	forested	forested wetland	1
Ni-les'tun restoration site	NL T9	6.96	emergent	diked pasture	16
Ni-les'tun restoration site	NL T10	6.36	emergent	diked pasture	14
Ni-les'tun restoration site	NL T11	6.48	emergent	diked pasture	13
Ni-les'tun restoration site	NL T12	7.54	emergent	diked pasture	14
Ni-les'tun restoration site	NL T13	6.05	emergent	diked pasture	13
Ni-les'tun restoration site	NL T14	6.50	emergent	diked pasture	12
Ni-les'tun restoration site	NL T15	6.54	emergent	diked pasture	16
Ni-les'tun restoration site	NL T16	6.78	emergent	diked pasture	14
Ni-les'tun restoration site	NL T17	8.08	emergent	diked pasture	15
Ni-les'tun restoration site	NL T18	4.92	emergent	diked pasture	14
Ni-les'tun restoration site	NL T19	7.13	emergent	diked pasture	17
Ni-les'tun restoration site	NL T20	8.13	forested	forested wetland	2
Bandon Marsh Unit reference site	BM T1	6.84	emergent	high tidal marsh	7
Bandon Marsh Unit reference site	BM T2	7.04	emergent	high tidal marsh	11
Bandon Marsh Unit reference site	BM T3	7.66	emergent	high tidal marsh	10
Bandon Marsh Unit reference site	BM T4	7.29	emergent	high tidal marsh	10
Bandon Marsh Unit reference site	BM T5	8.20	forested	forested tidal wetland (tidal swamp)	2

Table B2. 2010-2011 elevations of monitoring instruments at Ni-les'tun and Bandon Marsh Units, from RTK-GPS and total station survey.

Site/ location	Instrument type	Map code (Figures A2 and A3, Appendix A)	Location description	Sensor elevation (ft NAVD88)
Ni-les'tun restoration site	tide gauge	NL TG INSIDE	Fahys Creek mouth, inside tide gate	1.24
Coquille River	tide gauge	NL TG OUTSIDE	Coquille River, outside Fahys Cr tide gate	2.02
Ni-les'tun restoration site	salinity logger*	FAHY MTH 8239	Fahys Creek mouth, inside tide gate	0.90
Ni-les'tun restoration site	salinity logger	FAHY MID 8230	Fahys Creek, midway to N Bank Road	1.78
Ni-les'tun restoration site	salinity logger	FAHY RD 8241	Fahys Creek at N Bank Road	3.42
Ni-les'tun restoration site	salinity logger	NONAM MTH 8231	NoName Creek mouth, inside tide gate	1.20
Ni-les'tun restoration site	salinity logger	REDD 8240	Redd Creek mouth, inside tide gate	1.31
Bandon Marsh Unit reference site	salinity logger	SHPWRK A 8238	Shipwreck channel at mouth	1.25
Bandon Marsh Unit reference site	salinity logger	SHPWRK B 8229	Shipwreck channel (upper)	3.67
Bandon Marsh Unit reference site	salinity logger	BM UNK A 8235	Unnamed tidal channel, upper	3.50
Bandon Marsh Unit reference site	salinity logger	BM UNK B 8232	Unnamed tidal channel, middle	1.65
Bandon Marsh Unit reference site	salinity logger	BM UNK C 8233	Unnamed tidal channel, lower	3.06
Coquille River	salinity logger	COQ FAHY T 8234	Coquille River outside Fahys Cr tide gates	2.06
Coquille River	salinity logger	RAMP T 8228	Bullards' Beach boat ramp	0.76
Coquille River	salinity logger	ROCKY 8236	Rocky Point boat ramp	0.74
Coquille River	salinity logger	PIER T 8237	Bandon public pier (floating dock)*	n/a

* Salinity loggers measured both salinity (conductivity) and temperature

** The salinity logger at Bandon Pier was mounted to the floating dock, so its elevation varied.

Table B3. Summary of sampling and analysis methods for monitoring at Ni-les'tun during 2010-2011. "Frequency/timing" shows years for which funding has been obtained. At least 5 years of post-restoration monitoring are recommended; funding is being sought for this work.

Para-meter #	**Parameter**	**Method/equipment**	**Frequency / timing**	**Sample locations***	**Protocol citation**
1	Tidal hydrology	Electronic water level logger	15min interval Duration: 1 yr in 2010-11, 2012	Fahys Cr and adjacent Coquille River	Roegner *et al.* 2008
2	Channel morphology	Traditional or RTK-GPS survey and leveling; airphoto analysis	1x/yr in 2011, 2013	Stratified random and strategic sampling near permanent plots; airphoto analysis of entire site	Roegner *et al.* 2008
3a	Plant community composition – emergent	% cover by species	1x/yr in 2010, 2013, 2015	18 permanent plots (14 restor., 4 ref.) approx. 30X150ft; random sampling within plots	Roegner *et al.* 2008
3b	Plant community composition – forested and scrub-shrub	Stem density (quadrat/transect); diameter tape	1x/yr in 2011, 2013	4 permanent plots (3 restor., 1 ref.) approx 30 by 150ft; random sampling in plots	Roegner *et al.* 2008
3c	Plant community extent	Area of each plant community	1x/yr in 2010, 2013, 2015	Entire restoration site and reference site	Roegner *et al.* 2008
4	Groundwater depth	Electronic water level logger	15min interval, April-Nov. 2010, 2013	22 shallow observation wells in permanent plots (17 restor., 5 ref.)	Sprecher 2000; Brophy 2009
5	Soil organic matter, salinity and texture	%OM by loss on ignition; salinity (conductivity) by probe; texture by hydrometer.	1x/yr in late summer 2010, 2013	10 soil cores from root zone (upper 30cm) in each of 22 permanent plots (17 restor., 5 ref.)	Dane and Topp 2002; Sparks 1996
6	Water temperature and salinity	Continuous temperature/salinity datalogger	30min. interval; April-Nov. 2011, 2013	14 stations in tidal channels near permanent plots (5 restoration, 9 reference)	Roegner *et al.* 2008; OPSW 2001
7a	Low tide salmonid density and distribution Peak Use (June)	Pole seine	June 2010, 2013	5 samples for each of the wood and non-wood habitat reaches for Fahys and Overlook Basins (70 samples); plus 9 mainstem samples	Roegner *et al.* 2008
7b	Low tide salmonid distributions (non-peak months)	Pole seine	May, July, Aug Sept 2010, 2013	5 samples per Reference, Fahys, Overlook and Redd basins; 9 mainstem samples	Roegner *et al.* 2008

Para-meter #	Parameter	Method/equipment	Frequency / timing	Sample locations*	Protocol citation
8	Salmonid tidal migration Peak Use (June)	Underwater videography	June 2010, 2013	Mouth Fahys (8 cameras), Mouth Overlook (6 cams), Middle Reach Overlook (4 cams), Upper Reach Overlook (4 cams)	Van de Wetering *et al.* 2007.
9	In-stream habitat	Tape measure, measuring rod, GPS, Existing RTK monuments	Winter 2010, 2013	3 wood and 3 non-wood reaches in each of Fahys and Overlook basins	Roegner *et al.* 2008
10	Wood and non-wood habitat use	Underwater videography	June 2010, 2013	3 wood & 3 non-wood habitats in each of the 3 reaches of Overlook basin (18 cam samples); 5 wood and 5 non-wood habitats in the lower reach of Fahys basin (20 cam samples)	Van de Wetering 2007
11	Macroinverte-brate density and composition	Channel core samples	Summer 2010, 2013	4 habitat zones in mainstem and lower Fahys (matching pre-treatment samples) – 32 cores	Gray 2005

* Sampling is conducted at restoration site and reference site, unless otherwise described

Table B4. Emergent wetlands, Ni-les'tun Unit restoration site: Plant community composition, July 2010. Native species are highlighted in green, non-natives in orange.

		Average percent cover*													
Common name	**Scientific name**	**NL T2**	**NL T4**	**NL T5**	**NL T9**	**NL T10**	**NL T11**	**NL T12**	**NL T13**	**NL T14**	**NL T15**	**NL T16**	**NL T17**	**NL T18**	**NL T19**
creeping bentgrass	*Agrostis stolonifera*	13.1					13.8		29.6	26.4	7.4	31.8	5.2	20.9	
water foxtail	*Alopecurus geniculatus*								13.4						
slough sedge	*Carex obnupta*		60.6	6.9											83.5
seashore saltgrass	*Distichlis spicata*													79.0	
creeping spikerush	*Eleocharis palustris*	46.7							8.4						
common velvetgrass	*Holcus lanatus*								6.7	8.7					5.3
hairy cat's-ear	*Hypochaeris radicata*												8.8		
Baltic rush	*Juncus balticus*		9.2	55.5	30.3	66.7	16.5				30.1	18.7	5.1		
common rush	*Juncus effusus***	5.7	7.2							6.1					
birdsfoot trefoil	*Lotus corniculatus*			29.2	47.5		5.1	12.5	23.5	12.4	20.7				
pacific water-parsley	*Oenanthe sarmentosa*		28.4												
Pacific silverweed	*Potentilla anserina*	59.0		6.5	24.0				14.2	49.5					13.8
tall fescue	*Schedonorus arundinaceus*			34.4	15.4	22.4	70.4	96.9			59.5	48.9	85.7		
white clover	*Trifolium repens*								6.8						
springbank clover	*Trifolium wormskjoldii*					5.6									

*   Table includes only species with more than 5% cover in any single transect

** Native and non-native varieties of *Juncus effusus* are found in Oregon, but distinguishing them is time-consuming and was not attempted in this study.

Table B5. Emergent wetlands, Bandon Marsh Unit reference site: Plant community composition, July 2010. Native species are highlighted in green, non-native species in orange.

		Average percent cover*			
Common name	**Scientific name**	**BM T1**	**BM T2**	**BM T3**	**BM T4**
creeping bentgrass	*Agrostis stolonifera*	46.7	17.9		5.9
Pacific silverweed	*Argentina egedii*		6.7	64.7	16.7
tufted hairgrass	*Deschampsia cespitosa*	18.6	25.1		
seashore saltgrass	*Distichlis spicata*	12.1			30.8
fleshy jaumea	*Jaumea carnosa*		15.2		
Baltic rush	*Juncus balticus*	14.0	27.1	54.3	48.7
American glasswort	*Salicornia virginica*				5.3

* Table includes only species with more than 5% cover in any single transect

Table B6. Emergent wetlands, Ni-les'tun restoration site: Changes in plant community composition, 2003 to 2010. Native species are highlighted in green, non-native species in orange.

Plot	Common name	Scientific name	# of samples (2003, 2010)	P-value	Direction of change	Percent cover, 2003	Percent cover, 2010
NL T2	common rush	*Juncus effusus*	10, 15	<0.05	Decrease	22.5	5.7
NL T2	creeping spikerush	*Eleocharis palustris*	10, 15	<0.01	Increase	0.0	46.7
NL T4	creeping spikerush	*Eleocharis palustris*	10, 18	<0.01	Decrease	42.0	0.7
NL T4	Pacific water-parsley	*Oenanthe sarmentosa*	10, 18	<0.01	Increase	1.7	28.4
NL T4	slough sedge	*Carex obnupta*	10, 18	<0.01	Increase	14.2	60.6
NL T5	creeping bentgrass	*Agrostis stolonifera*	10, 15	<0.01	Decrease	27.7	1.3
NL T5	Baltic rush	*Juncus balticus*	10, 15	<0.01	Increase	17.0	55.5
NL T5	tall fescue	*Schedonorus arundinaceus*	10, 15	<0.05	Increase	9.0	34.4

Table B7. Emergent wetlands, Bandon Marsh Unit: Changes in percent cover, 2003 (early baseline) to 2010 baseline. Native species are highlighted in green.

Plot	Common name	Scientific name	# of samples (2003, 2010)	P value	Direction of change	Percent cover, 2003	Percent cover, 2010
BM T2	seashore saltgrass	*Distichlis spicata*	10, 15	<0.01	Decrease	20.3	4.5
BM T2	Baltic rush	*Juncus balticus*	10, 15	<0.05	Increase	8.8	27.1

Table B8. Forested wetlands, Ni-les'tun Unit (NL T6, NL T7, NL T20) and Bandon Marsh Unit (BM T5): Basal area for tree species, July 2011. All trees in plots were native species.

Tree species		**Tree basal area (sq ft/A)**			
Common name	**Scientific name**	**BM T5**	**NL T6**	**NL T7**	**NL T20**
red alder	*Alnus rubra*	36.7		30.6	41.1
Pacific wax myrtle	*Myrica californica*	29.0			
Sitka spruce	*Picea sitchensis*	31.9	55.1	98.6	126.1
cascara	*Rhamnus purshiana*	9.6		5.4	0.8
western hemlock	*Tsuga heterophylla*	0.0			
	Total	**107.3**	**55.1**	**134.6**	**168.0**

Table B9. Forested wetlands, Ni-les'tun Unit (NL T6, NL T7, NL T20) and Bandon Marsh Unit (BM T5): Tree density by species, July 2011. All trees in plots were native species.

Tree species		**Tree density (trees/A)**			
Common name	**Scientific name**	**BM T5**	**NL T6**	**NL T7**	**NL T20**
Oregon alder	*Alnus rubra*	774		110	317
Pacific wax myrtle	*Myrica californica*	702			
Sitka spruce	*Picea sitchensis*	605	17	129	63
cascara	*Rhamnus purshiana*	944		32	24
western hemlock	*Tsuga heterophylla*	24			
	Total	**3049**	**17**	**271**	**404**

Table B10. Forested wetlands, Ni-les'tun Unit (NL T6, NL T7, NL T20) and Bandon Marsh Unit (BM T5): Stem density for shrub species, July 2011. All shrubs in plots were native species.

Shrub species		**Shrub/sapling density (stems/A)**			
Common name	**Scientific name**	**BM T5**	**NL T6**	**NL T7**	**NL T20**
salal*	*Gaultheria shallon**			2759	
black twinberry	*Lonicera involucrata*	194		242	
Oregon crabapple	*Malus fusca*		194		
salmonberry	*Rubus spectabilis*		1162	2275	1646
Pacific blackberry	*Rubus ursinus*	145			
red elderberry	*Sambucus racemosa*		194		
evergreen blueberry*	*Vaccinium ovatum*	726		2662	1549
red huckleberry	*Vaccinium parvifolium*	97		2614	
huckleberry	*Vaccinium* sp.			1791	
	Total	1162	1549	12342	3194

*Evergreen blueberry and salal were generally growing on fallen logs, not in the soil.

Table B11. Forested wetlands, Ni-les'tun Unit (NL T6, NL T7, NL T20) and Bandon Marsh Unit (BM T5): Percent cover of herbaceous (understory) species, July 2011. All herbaceous species with >5% cover were native.

		Average percent cover			
Common name	**Scientific name**	**BM T5**	**NL T6**	**NL T7**	**NL T20**
slough sedge	*Carex obnupta*		71.9	20.5	75.4
skunk cabbage	*Lysichiton americanus*	6.3	27.9	59.5	11.6
Pacific water parsley	*Oenanthe sarmentosa*	10.1			
Pacific blackberry	*Rubus ursinus*	8.3		8.4	

* Table includes only species with more than 5% cover in any single transect

Table B12. Forested wetlands, Ni-les'tun Unit: Changes in percent cover, herbaceous understory species, 2003 (early baseline) to 2011 baseline. Native species are highlighted in green. All species listed are native.

Plot	**Common name**	**Scientific name**	**# of samples (2003, 2010)**	**P-value**	**Direction of change**	**Percent cover, 2003**	**Percent cover, 2011**
NL T6	slough sedge	*Carex obnupta*	7, 8	n/a*	Increase	60.0	71.9
NL T6	skunk cabbage	*Lysichiton americanus*	7, 8	n/a*	Increase	11.6	27.9
NL T7	slough sedge	*Carex obnupta*	11, 8	n/a*	Decrease	29.1	20.5
NL T7	skunk cabbage	*Lysichiton americanus*	11, 8	n/a*	Increase	39.8	59.5

* Statistical comparisons were not made between 2003 and 2011 for forested wetlands, due to differing sample methods.

Table B13. Example of LiDAR statistics from Ni-les'tun forested wetlands. Statistics were generated for each sample area using R software, using canopy model output from FUSION (2012). Transect sample area was 30ft wide (15ft buffer on both sides).

Sample area (transect/ polygon ID)	canopy # of pts	canopy standard deviation	canopy min elevation	canopy median elevation	canopy mean elevation	canopy max elevation	average elevation of lowest 1% of pts	average elevation of lowest 2% of pts	average elevation of lowest 5% of pts
BM T5	1242	4.8	8.9	26.3	26.8	52.8	16.7	18.0	20.2
NL T6	1289	24.3	7.5	12.6	27.2	98.3	8.5	9.1	9.7
NL T7	1851	16.0	11.1	30.3	32.0	89.3	12.1	12.3	12.7
NL T20	1360	17.8	10.3	47.0	47.1	97.7	12.9	14.6	18.3
GPCID59	21406	9.3	8.2	12.6	16.9	60.8	9.3	9.5	9.8
GPCID60	60698	21.0	10.6	38.7	42.4	127.5	12.0	12.7	14.4
GPCID61	75397	11.8	9.7	39.7	38.6	77.0	12.4	13.0	14.5
GPCID62	69880	15.5	8.5	42.0	40.7	106.0	10.5	11.1	12.6
GPCID64	90380	17.9	6.3	14.0	22.1	116.5	7.5	7.7	9.0
GPCID67	54427	7.7	7.1	19.7	20.0	90.9	9.7	10.0	10.7
GPCID71	118431	19.6	9.5	38.6	41.1	116.0	11.7	12.3	13.1

Table B14. Mapped emergent and forested wetland plant communities (plant associations) at Ni-les'tun restoration site in 2010. Associations in the adjacent forested wetlands and adjacent tidal marsh outside west dike ("Osprey site") are also included.

Map Unit	Association	Area (acres)
0	Water/mud	7.1
1	Colonial bentgrass - spotted cats-ear	0.7
2	Pacific silverweed	0.8
3	Pacific silverweed - creeping bentgrass - birdsfoot trefoil	36.4
4	Pacific silverweed - creeping bentgrass - birdsfoot trefoil - common velvetgrass	4.1
5	Pacific silverweed - creeping bentgrass - orache - water foxtail	1.6
6	Pacific silverweed - common velvetgrass - tall fescue - creeping bentgrass	20.5
7	Pacific silverweed - Baltic rush - creeping bentgrass	8.6
8	Pacific silverweed - soft rush - creeping bentgrass	3.9
9	Red alder - Hooker willow	2.1
10	Orache - brass buttons	1.0
11	Red alder - Sitka spruce / Hooker willow - salmonberry / slough sedge - skunk cabbage	0.6
12	Creeping bentgrass	0.8
13	Lyngbye's sedge	1.7
14	Lyngbye's sedge - creeping bentgrass - seaside arrowgrass - saltgrass - pickleweed	0.8
15	Lyngbye's sedge - Baltic rush - Pacific silverweed - creeping bentgrass	10.4
16	Lyngbye's sedge - Baltic rush - Pacific silverweed - creeping bentgrass - creeping spikerush	4.1
17	Lyngbye's sedge - seaside arrowgrass	1.1
18	Slough sedge - Pacific silverweed - reed canarygrass - (tall fescue - common velvetgrass)	12.0
19	Slough sedge - water parsley - Baltic rush - (soft rush)	11.2
20	Tufted hairgrass - saltgrass - pickleweed - creeping bentgrass	0.8
21	Tufted hairgrass - Baltic rush - silverweed - creeping bentgrass	4.5
22	Saltgrass - creeping bentgrass	10.4
23	Creeping spikerush - creeping bentgrass	1.0
24	Tall fescue-common velvetgrass	19.8
25	Tall fescue - common velvetgrass - colonial bentgrass - birdsfoot trefoil	11.7
26	Tall fescue - common velvetgrass - creeping bentgrass - birdsfoot trefoil - Pacific silverweed	8.1
27	Tall fescue - Baltic rush - creeping bentgrass - (common velvetgrass)	10.1
28	Tall fescue - Baltic rush - birdsfoot trefoil - Pacific silverweed	16.8
29	Tall fescue - Baltic rush - birdsfoot trefoil - creeping bentgrass - (Pacific silverweed - velvetgrass)	168.5
30	Baltic rush - Pacific silverweed	0.3

Map Unit	Association	Area (acres)
31	Baltic rush - Pacific silverweed - creeping bentgrass - creeping spikerush	6.2
32	Baltic rush - seashore saltgrass - creeping bentgrass	4.7
33	Soft rush - common velvetgrass - creeping buttercup - birdsfoot trefoil	3.5
34	Soft rush - birdsfoot trefoil - water parsley	1.7
35	Reed canarygrass	4.9
36	Reed canarygrass - Pacific silverweed	2.1
37	Reed canarygrass - Pacific silverweed - creeping bentgrass - birdsfoot trefoil	2.6
38	Reed canarygrass - Pacific silverweed - soft rush - creeping bentgrass	1.6
39	Reed canarygrass - slough sedge - water parsley - birdsfoot trefoil - soft rush	5.5
40	Reed canarygrass - tall fescue - common velvetgrass - birdsfoot trefoil	4.9
41	Transition: Sitka spruce / slough sedge - skunk cabbage to Sitka spruce / huckleberry	8.6
42	Sitka spruce - red alder / slough sedge - skunk cabbage	26.4
43	Sitka spruce - red alder / Hooker willow - salmonberry / slough sedge - skunk cabbage	6.0
44	Sitka spruce - red alder / small-fruited bulrush - soft rush - slough sedge - skunk cabbage	1.2
45	Sitka spruce / slough sedge - skunk cabbage	8.2
46	Threesquare	0.9
47	Threesquare - saltgrass - Lyngbye's sedge	0.9
48	Hooker willow	1.2
49	Hooker willow - Sitka willow / slough sedge - skunk cabbage	4.3
50	Small-fruited bulrush - soft rush - slough sedge - Pacific silverweed	3.3
51	Pickleweed - saltgrass - jaumea (seaside arrowgrass - Lyngbye's sedge)	4.0
52	Common cattail	0.7
99	Not mapped (upland/above tide range, or outside project area)	87.6
Grand Total		**578.3**

Table B15. Mapped vegetation alliances (association groupings) at Ni-les'tun restoration site in 2010. Adjacent forested wetlands and tidal marsh outside west dike are also included.

Alliance number	**Alliance**	**Area (acres)**
0	Water/mud	7.1
1	Baltic rush	11.2
2	Colonial bentgrass	0.7
3	Common cattail	0.7
4	Creeping bentgrass	0.8
5	Creeping spikerush	1.0
6	Hooker willow	5.5
7	Lyngbye's sedge	18.2
8	Orache	1.0
9	Pacific silverweed	75.9
10	Pickleweed	4.0
11	Red alder	2.7
12	Reed canarygrass	21.6
13	Saltgrass	10.4
14	Sitka spruce	50.5
15	Slough sedge	23.2
16	Small-fruited bulrush	3.3
17	Soft rush	5.2
18	Tall fescue	235.1
19	Threesquare	1.8
20	Tufted hairgrass	5.3
99	Not mapped	93.1
	Grand Total	**578.3**

Table B16. Mapped emergent and forested wetland plant communities (plant associations) at Bandon Marsh Unit reference site in 2010.

Map unit	Association	Area (acres)
0	Water/mud	105.6
1	Baltic rush - saltgrass	9.9
2	Creeping bentgrass	11.7
3	Creeping bentgrass - Lyngbye's sedge - saltgrass - seaside arrowgrass	4.0
4	Lyngbye's sedge - Baltic rush - seaside arrowgrass - creeping bentgrass - tufted hairgrass	1.3
5	Lyngbye's sedge - Baltic rush - threesquare	1.9
6	Lyngbye's sedge - threesquare - pickleweed - jaumea - Baltic rush	0.8
7	Mosaic of tufted hairgrass-saltgrass-pickleweed-jaumea and Lyngbye's sedge-seaside arrowgrass	12.5
8	Pacific silverweed - Baltic rush	2.8
9	Pickleweed - saltgrass - jaumea	14.1
10	Pickleweed - saltgrass - jaumea - (seaside arrowgrass - Lyngbye's sedge)	29.7
11	Pickleweed - saltgrass - jaumea - threesquare	2.8
12	Saltgrass	0.9
13	Seaside arrowgrass - pickleweed	7.0
14	Sitka spruce - red alder - California wax myrtle	13.6
15	Tall fescue - common velvetgrass - creeping bentgrass - Pacific silverweed	4.0
16	Tall fescue - European beachgrass - American dunegrass	0.6
17	Threesquare - saltgrass - Lyngbye's sedge - pickleweed	3.8
18	Tufted hairgrass - Baltic rush	7.0
19	Tufted hairgrass - Baltic rush - creeping bentgrass	3.9
20	Tufted hairgrass - Baltic rush - Pacific silverweed	10.7
21	Tufted hairgrass - Baltic rush - Pacific silverweed - (Douglas aster - yarrow - sea-watch angelica)	4.0
22	Tufted hairgrass - Baltic rush - Pacific silverweed - creeping bentgrass	9.3
23	Tufted hairgrass - Baltic rush - Pacific silverweed - pickleweed - saltgrass - jaumea	9.4
24	Tufted hairgrass - saltgrass - pickleweed - jaumea	52.5
25	Tufted hairgrass - saltgrass - pickleweed - jaumea - Lyngbye's sedge	1.8
26	Upland weedy grasses	3.2
	Grand Total	**328.9**

Table B17. Mapped vegetation alliances (association groupings) at Bandon Marsh Unit reference site in 2010.

Alliance number	**Row Labels**	**Area (acres)**
0	Water/mud	105.6
1	Baltic rush	9.9
2	Creeping bentgrass	15.7
3	Lyngbye's sedge	4.0
4	Mosaic of tufted hairgrass and Lyngbye's sedge	12.5
5	Pacific silverweed	2.8
6	Pickleweed	46.6
7	Saltgrass	0.9
8	Seaside arrowgrass	7.0
9	Sitka spruce	13.6
10	Tall fescue	4.6
11	Threesquare	3.8
12	Tufted hairgrass	98.6
13	Upland weedy grasses	3.2
	Grand Total	**328.9**

Table B18. Soil characteristics at Ni-les'tun and Bandon Marsh Unit transects, July 2010.

Site	Transect	pH	% OM by LOI	% C*	Salinity (PSU)	Salinity class	% sand	% silt	% clay	Texture class
Ni-les'tun restoration site	NL T2	5.6	10.00	6.80	1.50	oligohaline	13.8	55.0	31.3	silty clay loam
Ni-les'tun restoration site	NL T4	4.9	8.14	5.53	1.26	oligohaline	31.3	40.0	28.8	loam
Ni-les'tun restoration site	NL T5	5.9	4.88	3.32	0.38	fresh	35.0	38.8	26.3	loam
Ni-les'tun restoration site	NL T9	5.3	6.99	4.75	0.96	oligohaline	5.0	56.3	38.8	silty clay loam
Ni-les'tun restoration site	NL T10	5.2	10.25	6.97	3.06	oligohaline	3.8	42.5	53.8	silty clay
Ni-les'tun restoration site	NL T11	5.1	9.11	6.20	6.30	mesohaline	7.5	46.3	46.3	silty clay
Ni-les'tun restoration site	NL T12	5.5	7.76	5.28	4.69	oligohaline	25.0	43.8	31.3	clay loam
Ni-les'tun restoration site	NL T13	5.1	9.41	6.40	1.80	oligohaline	10.0	52.5	37.5	silty clay loam
Ni-les'tun restoration site	NL T14	4.8	19.44	13.22	4.03	oligohaline	25.0	38.8	36.3	clay loam
Ni-les'tun restoration site	NL T15	5.0	9.25	6.29	1.93	oligohaline	10.0	57.5	32.5	silty clay loam
Ni-les'tun restoration site	NL T16	5.1	9.48	6.45	4.03	oligohaline	10.0	42.5	47.5	silty clay
Ni-les'tun restoration site	NL T17	5.8	6.16	4.19	1.56	oligohaline	12.5	51.3	36.3	silty clay loam
Ni-les'tun restoration site	NL T18	4.8	8.74	5.94	19.29	polyhaline	52.5	23.8	23.8	sandy clay loam
Ni-les'tun restoration site	NL T19	5.1	10.28	6.99	0.38	fresh	18.8	45.0	36.3	silty clay loam
Bandon Marsh reference site	BM T1	5.6	11.65	7.92	22.88	polyhaline	20.0	48.8	31.3	silty clay loam/clay loam
Bandon Marsh reference site	BM T2	5.6	20.87	14.19	20.73	polyhaline	10.0	46.3	43.8	silty clay
Bandon Marsh reference site	BM T3	5.2	22.00	14.96	5.62	mesohaline	6.3	47.5	46.3	silty clay
Bandon Marsh reference site	BM T4	5.7	15.84	10.77	13.56	mesohaline	18.4	44.7	36.8	silty clay loam

Appendix C. Additional photographs

Photo C1. Lower Fahys Creek on September 2, 2011, showing location of inside and outside tide gauges (red dots). Former mouth of Fahys Creek is at upper right ("tidegate removed"). Photo by Bill Bridgeland, USFWS.

Photo C2. Monitoring channel morphology: Ducks Unlimited surveyor Pat Schulte (center) briefs field crew on RTK-GPS survey methods. L to R: Volunteer Curt Beyer, Stan van de Wetering (Confederated Tribes of Siletz Indians), Rachel Schwindt (Institute for Applied Ecology), Pat Schulte, Megan MacClellan (Oregon State University), Khemarith So (USFWS), Brady Smith (Confederated Tribes of Siletz Indians). Photo by Laura Brophy.

Photo C3. Monitoring channel morphology: RTK-GPS survey of constructed channels. L to R: Oregon State University graduate student Megan MacClellan, Americorps volunteer Curt Beyer, Khemarith So of USFWS. Photo by Laura Brophy.

Photo C4. Monitoring vegetation: Craig Cornu of South Slough National Estuarine Research Reserve (R) and volunteer Casey Seyb (L) monitor forested wetlands at NL T7. Photo by Laura Brophy.

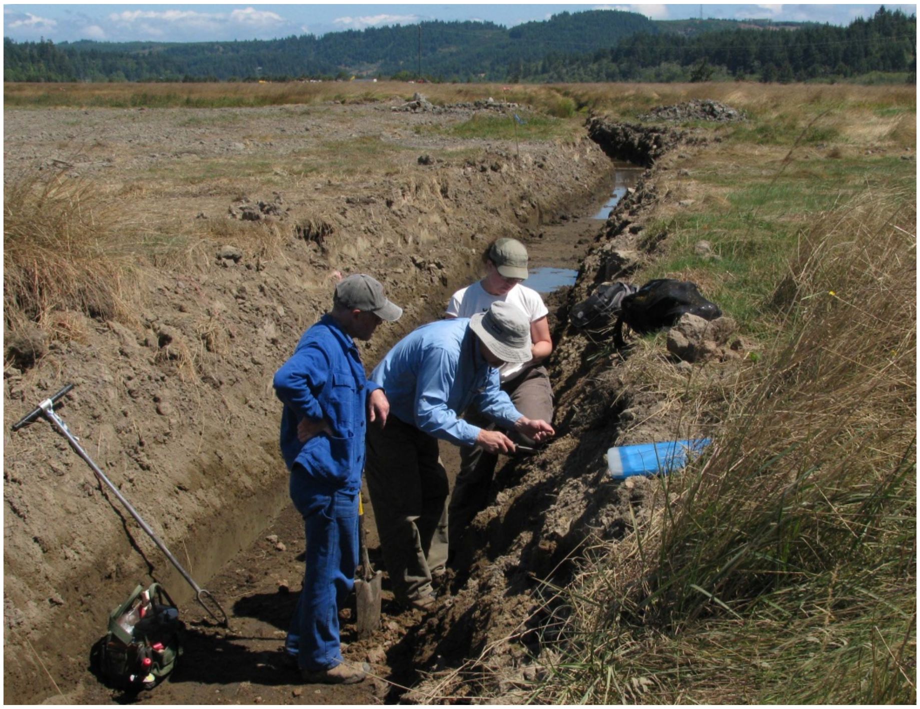


Photo C5. Monitoring soils: Oregon State University team examining soil profiles at Ni-les'tun. L to R: Markus Kleber, Will Austin, Megan MacClellan. Photo by Laura Brophy.

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