Ni-les'tun tidal wetland restoration effectiveness monitoring: *Year 4 post-restoration (2015)*

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- revision 1, 12/7/16

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Data availability: Data from this project is available from the Estuary Technical Group (contact Laura Brown, contact information listed above).

Acknowledgments:

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Revision history:

- Revision 1, 12/7/16: corrected percent inundation values and graphs.

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EXECUTIVE SUMMARY

Purpose: This report describes the results of effectiveness monitoring of tidal hydrology, plant community composition, and plant community extent (vegetation mapping), at the Ni-les'tun tidal wetland restoration site, Bandon National Wildlife Refuge, Coquille River estuary, Oregon. The parameters monitored are a subset of the full suite of parameters that have been monitored at Ni-les'tun during the baseline and post-restoration periods. The monitoring described in this report was conducted during 2015, which was the 4th year after the site's dikes and tide gates were removed, restoring tidal flows to the site. Effectiveness monitoring was designed to determine whether the project is meeting its goals, and to provide information to help guide other restoration projects. The results and "lessons learned" through the monitoring at this landmark project are already helping to advance restoration science at many projects in Oregon, the Pacific Northwest, and beyond.

Who did the work: This study was conducted by the Estuary Technical Group of the Institute for Applied Ecology. Laura Brophy led the monitoring effort.

Approach and presentation: To determine project effectiveness, we used a "before-after-control-impact" (BACI) approach, comparing the 2015 and 2013 data to baseline (pre-restoration) data collected in 2010-2011 (or earlier) at Ni-les'tun and the Bandon Marsh Unit reference site. Year 4 post-restoration monitoring of tidal hydrology was conducted from late winter/early spring through summer 2015 (March through September); vegetation was monitored during August 2015. This report provides summaries, representative results, and interpretation of the 2015 monitoring. Additional data are available from the Estuary Technical Group upon request. Throughout this report, we focus on year 4 post-restoration monitoring results, highlighting key comparisons to pre-restoration and year 2 post-restoration conditions. Further details on pre-restoration conditions are contained in the baseline monitoring report (Brophy and van de Wetering 2012), and details on year 2 post-restoration monitoring (which included the full suite of parameters) can be found in Brophy *et al.* (2014).

Summary of results: Post-restoration monitoring in 2015 showed a consistent trajectory towards full recovery of tidal wetland functions at Ni-les'tun. Tidal hydrology was completely restored to the site, with daily maximum tides matching precisely between Ni-les'tun and the adjacent Coquille River. Plant communities remain very dynamic in response to the reintroduction of tidal hydrology and salinity, with salt-tolerant early colonizers spreading across the site and pasture grasses continuing to decline. Plant community changes observed between 2013 and 2015 indicate that plant communities are far from stabilization and can be expected to continue to change substantially for a number of years. Key findings are listed below.

Key findings

To jump to figures or tables illustrating key findings, click on the hyperlink (underlined text). To return to this list, use the “previous view” button (or Alt-left arrow) in Acrobat Reader,

Tidal hydrology and wetland surface elevation

1. The tidal inundation regime at Ni-les’tun was successfully restored to fully match the adjacent river. Average daily high tides inside the restoration site were 2.1 m NAVD88 -- identical to those in the mainstem river, showing the site had full tidal exchange.
2. Even the transects at the highest elevations were tidally inundated for at least part of the year, compared to zero inundation before restoration.
3. Inundation time was higher at all restoration transects in 2015 compared to 2013, supporting our conclusion that the tidal inundation regime has been fully restored.
4. Average wetland surface elevation in sample transects at Ni-les’tun was 2.1 m NAVD88. Samples transects at the Bandon Marsh Unit were slightly higher (2.3 m)..
5. The elevation of sample transects at Ni-les’tun and Bandon Marsh was, on average, 4.6 cm higher in 2015 than 2011. This result could be due to differences in survey methods and survey conditions, or to sediment accretion.

Emergent wetland plant community composition

6. Within vegetation sample transects, there were no significant changes to species richness, total cover, native plant cover, or non-native plant cover from 2013 to 2015.
7. Plant species richness and total cover were still significantly lower in 2015 compared to baseline (2010) at the Ni-les’tun restoration site – the product of reduced diversity as vegetation adjusts to the increased stress of inundation and salinity.
8. Across all transects at Ni-les’tun, percent cover of two species changed significantly between pre-restoration (2010) and year 4 post-restoration (2015): common orache (a native species) increased from 0.1% average cover in 2013 to 10.6% in 2015, and birdsfoot trefoil (a non-native) dropped from 11.7% average cover in 2013 to < 0.01% in 2015.
9. At the Bandon Marsh reference site, cover of two low marsh species increased significantly between 2010 and 2015: fleshy jaumea (5.0% in 2010 versus 11.5% in 2015), and pickleweed (3.1% in 2010 versus 9.6% in 2015).
10. The composition of plant communities at the restoration site appeared to be moving towards low salt marsh rather than precise convergence with the reference site. This result was not unexpected, since the reference site transects were chosen to represent the original high marsh that was found at Ni-les’tun historically, so their elevation is higher than the subsided wetland surface at Ni-les’tun.

Emergent wetland plant community mapping

11. Plant communities at Ni-les’tun changed substantially between 2013 and 2015. Native-dominated communities increased by about 17 ha (42 acres), and non-native dominated communities decreased correspondingly.
12. Salt-tolerant early colonizing species such as brass buttons and common orache dominated a larger area of the site in 2015 compared to 2013, indicating vegetation is far from stabilized and is still changing rapidly in response to the 2011 restoration actions.
13. The area dominated by the non-native pasture species tall fescue was halved in 2015 (39.4 ha) compared to 2010 (94.8 ha). Prior to restoration, tall fescue was the most prevalent grass at the site. In 2015, most areas formerly dominated by tall fescue were dominated by the native high tidal marsh species Baltic rush.
14. Plant community patterns in 2015, even more than in 2013, showed intergraded distributions of individual colonizing species, and corresponding lack of zonation. These characteristics indicate the site is still in the early stages of vegetation recovery.

Lessons learned from 2015 monitoring at Ni-les'tun

We designed our monitoring not only to evaluate the effectiveness of the restoration at Ni-les'tun, but also to provide guidance for other monitoring and restoration efforts. The following "lessons learned" can help others benefit from this project:

1. **Longer duration is better for tidal hydrology monitoring.** Like all monitoring, tidal hydrology monitoring presents a trade-off between cost and interpretive power. For this year's monitoring, our scope of work included one month of tidal hydrology monitoring in winter and one month in summer. Although we monitored for a much longer period (March 2015 through August 2015), we used shorter analysis periods (1 month) for some comparisons. These shorter analysis periods produced some unexpected results, because the observation periods were not necessarily typical of long-term conditions. Even when tides are monitored for a full year, year-to-year variability may obscure site differences or long-term trends. Optimally, we recommend modeling of tidal inundation regimes based on a master station approach (NOAA 2003).
2. **Plant communities at tidal wetland restoration sites may take much more than 5 years to stabilize.** Although some studies have indicated that plant communities may stabilize by 5 years after restoration, this does not appear likely at Ni-les'tun. Year 4 (2015) monitoring showed that plant communities are still changing rapidly in response to the restored tidal inundation and salinity regimes. To gain a reasonable understanding of the trajectory of vegetation recovery, monitoring should be conducted for a period of 10 or more years, rather than just 5 years.
3. **Vegetation monitoring frequency after year 5 post-restoration should be based on field reconnaissance by a knowledgeable botanist.** Vegetation monitoring in this report (year 4) provided valuable information on the trajectory of vegetation change at Ni-les'tun. For cost efficiency, the frequency of future monitoring should be determined through annual qualitative reconnaissance by a tidal wetland vegetation expert. This annual review is recommended for at least 10 years post-restoration. The annual visit should identify major changes in plant communities (if any) that would warrant a new round of monitoring, and reveal undesirable changes in vegetation that may call for adaptive management. In most cases, our experience shows that annual or biennial quantitative monitoring (every 1 or 2 years) is needed during years 1-5 to adequately document early vegetation changes. However, after year 5, the frequency of rigorous quantitative monitoring frequency can be decreased, based on the results of annual reconnaissance.

REPORT ORGANIZATION: RESTORATION AND MONITORING OBJECTIVES

Monitoring at Ni-les'tun is designed to evaluate the project's effectiveness in meeting its **restoration objectives**. These restoration objectives were listed in the 2009 OWEB restoration grant proposal (DU 2009). From these restoration objectives, a series of **monitoring objectives** were built. To address the monitoring objectives, specific **monitoring questions** were developed and suitable **monitoring parameters** were selected that could be used to answer those monitoring questions.

In 2015, funding was available for monitoring of two parameters: tidal hydrology and emergent wetland vegetation (the latter including plant community composition and vegetation mapping). These parameters address restoration objective 1 ("Restoration of coastal tidally influenced wetlands through hydrological reconnection") and 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").

The full text of Restoration Objective 1, Monitoring Objective 1, and the associated monitoring questions and parameters are provided below. The project's other restoration and monitoring objectives are provided in the year 2 monitoring report (Brophy *et al*. 2015).

Restoration Objective 1: Restoration of coastal tidally influenced wetlands through hydrological reconnection

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.

Monitoring Questions:

Q1a) Was tidal hydrology successfully restored?

Parameters: Tidal hydrology (inundation frequency and duration) at restored and reference sites; elevation of wetland surface.

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

Parameters: Wetland plant community composition and extent.

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. Information on the timing of other activities on the Refuge 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
2007[1]	• None	• Benthic macroinvertebrates
2009	• Removal of livestock • Excavation of a few restored tidal channels • Ditch disking (minor ditches)	• None
2010	• Excavation of most restored tidal channels • Ditch filling (major ditches)	• Tidal hydrology • Channel morphology • Emergent wetland plant communities • Groundwater (emergent wetlands) • Soils • Low tide fish density • Juvenile salmonid tidal migration • Benthic macroinvertebrates
2011	• Excavation of the last few restored tidal channels • Filling of lower Fahys Creek ditch • Completion of E and W protection dikes • Dike removal (final removal: 8/18/11) • Tide gate removal (final removal: 8/18/11)	• Tidal hydrology • Groundwater (emergent wetlands) • Forested wetland plant communities • Groundwater (forested wetlands) • Surface water temperature and salinity
2013	• Pilot tests of methods for connecting tidal channels to small pools (mosquito breeding sites)	• Tidal hydrology • Channel morphology • Emergent wetland plant communities • Forested wetland plant communities • Groundwater (emergent and forested wetlands) • Soils • Surface water temperature and salinity • Low tide fish density • Juvenile salmonid tidal migration • In-stream habitat • Wood and non-wood habitat use by fish • Benthic macroinvertebrates
2014	• Excavation of new tidal channels to improve tidal connection and reduce mosquito breeding sites	• None
2015	• Continuation of minor tidal channel excavation	• Tidal hydrology • Emergent wetland plant communities

[1] 2003, 2005 and 2007 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 AND RESULTS BY MONITORING OBJECTIVE

This section presents methods and results organized by monitoring objective and metrics. Methods are described briefly under each objective, and summarized in Table 2. Throughout this report, we focus on year 4 (2015) post-restoration monitoring results, highlighting key comparisons to pre-restoration conditions. Further details on pre-restoration conditions are contained in the baseline monitoring report (Brophy and van de Wetering 2012), and further details on year 2 post-restoration monitoring can be found in Brophy *et al.* 2014.

The term "restoration" can have several meanings. It is often used to refer to the on-the-ground actions taken to reverse impacts due to human activities. "Restoration" can also refer to the ecological process of recovery that follows those actions. In this report, even though we recognize that recovery will take many years, we use the term "post-restoration" to refer to the period after final removal of the dikes and tide gates at Ni-les'tun in fall 2011.

Table 2. Summary of sampling and analysis methods for monitoring at Ni-les'tun during 2015. "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. NOTE: This table is an excerpt from the full table of Ni-les'tun monitoring activities. For the full table, see the year 2 monitoring report (Brophy *et al*. 2014).

Para-meter #	Parameter	Method/equipment	Frequency / timing	Sample locations[1]	Protocol citation
1	Tidal hydrology	Electronic water level logger	15min interval Duration: 1 yr in 2010-11, 2012-2013; 1 mo in summer 2015 & winter 2015[2]	Ch 7 and adjacent Coquille River	Roegner *et al.* 2008
2a	Plant community composition – emergent	% cover by species	1x/yr in 2010, 2013, 2015	18 permanent plots (14 restoration, 4 reference) approx. 30X150 ft; random sampling within plots	Roegner *et al.* 2008
2b	Plant community extent	Area of each plant community	1x/yr in 2010, 2013, 2015	Entire restoration site[3]	Roegner *et al.* 2008

1 Sampling is conducted at Ni-les'tun restoration site and Bandon Marsh Unit reference site, unless otherwise described.
2 Although our scope of work called for only 1 mo of tidal hydrology sampling, we sampled for a longer period (7 mo). See **Tidal hydrology** below for details.
3 Plant community mapping was not conducted at the Bandon Marsh Unit reference site in 2015, as field reconnaissance indicated no substantial change in the extent of plant communities at that site since 2013.

1. Tidal wetland restoration

Monitoring objective 1: Measure tidal wetland restoration

In this objective, we measured the restoration of tidal hydrology and tidal wetland vegetation.

1a. Tidal hydrology

Monitoring question 1a: Was tidal hydrology successfully restored?

Metrics: Tidal hydrology (inundation frequency and duration) at restored and reference sites; elevation of wetland surface. *(Rationale: Tidal hydrology is a major controlling factor for biological and physical characteristics and processes in tidal wetlands. Elevation measurements allow linkage of tide heights to physical and biological site characteristics.)*

Tidal hydrology

Methods

Water levels were measured using automated water level loggers (Onset HOBO© loggers, models U20-001-01) programmed to collect pressure data at 15 minute intervals. In 2015, loggers were located both inside the restoration site (NL Ch7 TG) and outside the restoration site (Coquille River TG) (Table 3, Figures 1 and 2). Water level data were collected from March 1, 2015 through October 1, 2015 at both gauges. The raw pressure data collected were converted to water levels using HOBOWare Pro© software; the conversion included barometric pressure adjustments (using local barometric pressure data) with HOBOWare Pro© software's barometric compensation assistant. Water levels were tied to an orthometric reference frame (NAVD88, GEOID12A) using a high-precision RTK GPS/GNSS system and greater than a 480 second occupation time at 1 Hz. Tested vertical accuracy of water level logger elevation was better than 5.5 cm at the 95% confidence level. The loggers were checked for vertical movement at each logger maintenance interval.

To compare water levels pre- and post-restoration, we obtained water level data for 2009 (both inside and outside the restoration site) from Ducks Unlimited (Randy Van Hoy, personal communication), which were collected using Global© water level loggers (model WL-16), which automatically compensate for barometric pressure variations. Data collected by ETG in 2013 were also included (see Brophy *et al.* 2014 for details). Due to staggered sample timing in previous years (2009 and 2013), the overlapping dates (and therefore the dates used for analysis) for the two gauges (NL Ch7 TG and Coquille River TG) during all three years were March 1- July 8 and August 29-October 1. This is referred to as the "full analysis period" in this report.

Daily maximum water levels were calculated for the full analysis period. Differences among daily maximum water levels were analyzed using Before-After-Control-Impact (BACI) (2-way ANOVA), with site (restoration site *versus* reference site), and year (2009, 2013, and 2015) as categorical independent variables. When distributions did not meet the normality assumptions, a non-parametric test was used.

Percent inundation was calculated for the sample transects at Ni-les'tun and the Bandon Marsh Unit reference site (Table 6, Figures 1 and 2). These sample transects are a major component of the sample design for the overall Ni-les'tun effectiveness monitoring program, as described in the baseline and year 2 monitoring reports (Brophy and van de Wetering 2014, Brophy *et al*. 2015). The same transects have been sampled during baseline (2009), year 2 (2013) and year 4 (2015) monitoring, and percent inundation has been calculated for these transects during each monitoring year. Water level data from inside the site (NL Ch7 TG) were used to calculate percent inundation of sample transects at the restoration site, while data from the Coquille River (Coquille River TG) were used to calculate percent inundation at the Bandon Marsh Unit reference site. Transect elevations measured in 2009 were used to calculate percent inundation for 2009 and 2013 (Brophy *et al.* 2014), and transect elevations measured in 2015 were used to calculate percent inundation for 2015. The analysis period was March 1 through July 8 and August 29 through October 1 (the dates when water level data were available for 2009, 2013, and 2015). Percent inundation was calculated for the full analysis period (3/1 - 7/8 and 8/29 - 10/1); to illustrate seasonal differences, percent inundation was also calculated for a summer analysis period of one month (9/1 - 9/30), and a late winter/early spring analysis period of one month (3/1 - 3/31). All analyses were completed in R (Version 3.1.1) using daily maximum water levels as the dependent variable.

Table 3. Tide gauge locations at in the Ni-les'tun restoration site and Coquille River, 2015 (GPS coordinates in meters, NAD83 UTM Zone 10N).

Tide gauge	Location	Easting	Northing
NL Ch7 TG	Ni-les'tun restoration site	387360	4778313
Coquille River TG	Coquille River reference site	386752	4777985

Ni-les'tun monitoring locations, 2015

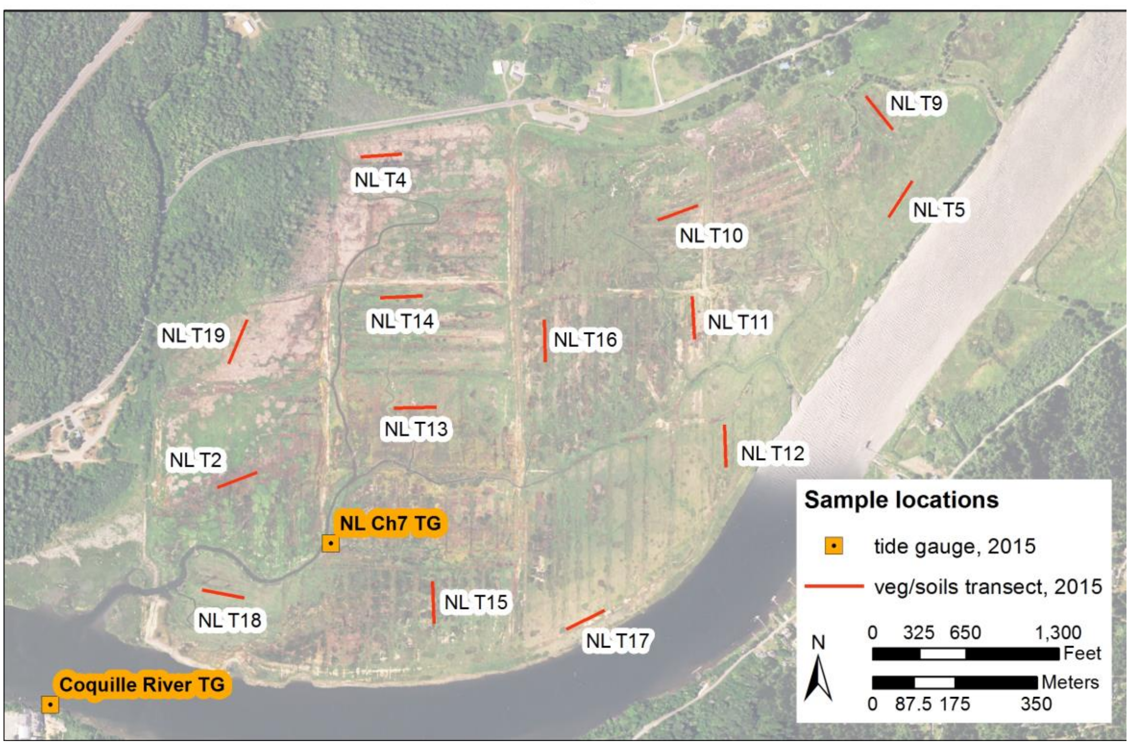

Figure 1. Ni-les'tun restoration site: 2015 sample transects for vegetation monitoring, and tidal hydrology gauge stations. Background: NAIP 2014.

Bandon Marsh Unit monitoring locations, 2015

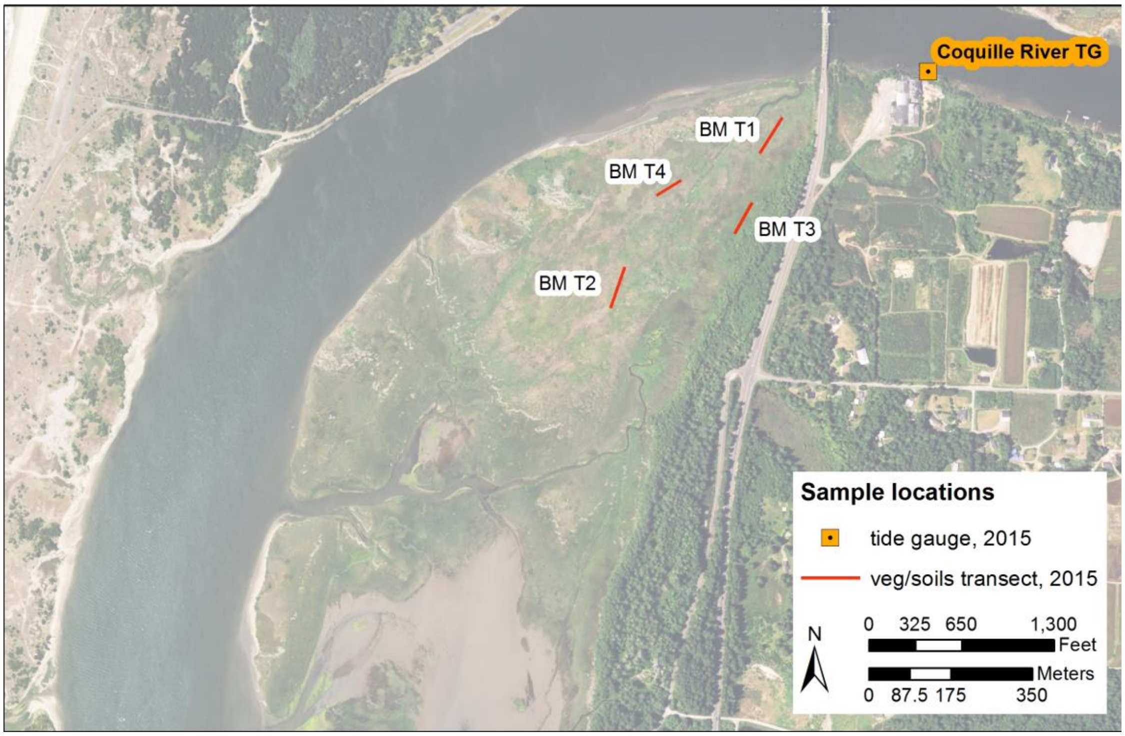

Figure 2. Bandon Marsh Unit reference site: 2015 sample transects for vegetation monitoring, and tidal hydrology gauge station. Background: NAIP 2014.

Results and discussion

Tidal inundation (daily maximum water level) was fully restored at the Ni-les'tun restoration site (Figures 3 and 4). Daily maximum water levels inside the site in 2015 were not statistically different from those outside of the site (2.1 m at both locations). Prior to restoration (2009), daily maximum water levels were lower inside the restoration site compared to the river (1.3 m and 2.1 m, respectively). During year 2 after restoration (2013), daily maximum water levels inside the restoration site had increased significantly, to 2.0 m – much higher than during 2009, but still significantly lower than levels in the river (2.1 m). Year 4 (2015) monitoring showed matching daily maximum water levels in the river and inside the restoration site (Figures 3 and 4).

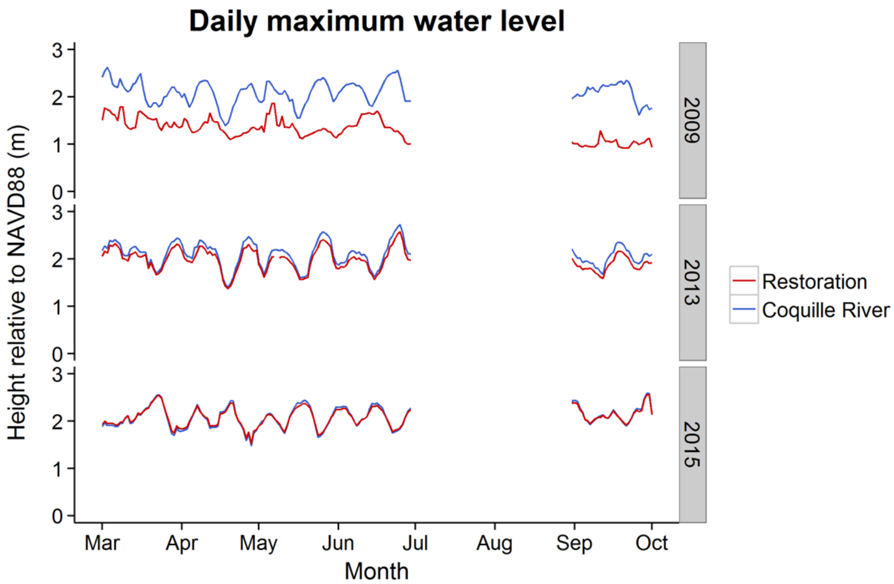

Figure 3. Pre-restoration (2009) and post-restoration (2013 and 2015) daily maximum tide heights for the Ni-les'tun restoration site, compared to the adjacent Coquille River. Restoration occurred on August 17, 2011. Data are shown for the analysis period of March 1 – July 8 and August 29 – October 1.

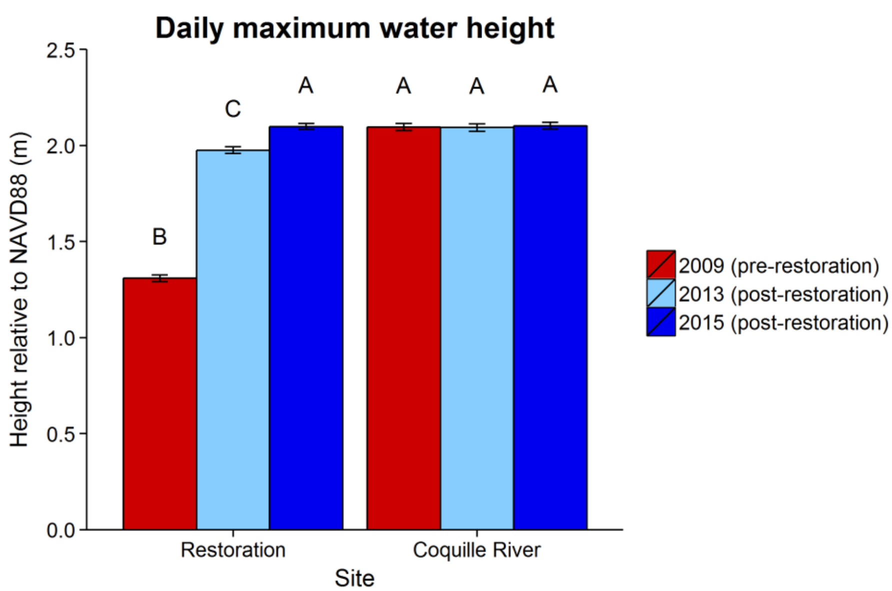

Figure 4. Average daily maximum water heights for the Ni-les'tun restoration site and Coquille River, pre- and post-restoration. Error bars show one standard error; columns with no letters in common are significantly different (ANOVA, $p < 0.05$). Data are averaged from the full analysis period (March 1 – July 8 and August 29 – October 1) in each year.

Analysis of percent inundation revealed clear differences among locations, years, and seasons at Ni-les'tun. Prior to restoration (2009), there was minimal tidal influence at the Ni-les'tun restoration site, but in 2013 and 2015 all transects were tidally inundated across the full analysis period, including both winter and summer (Figures 5-7). The two transects with the highest elevation (NL T12 and NL T17) were never inundated in 2009, but were inundated from 0.2 to 0.9% of the time during the analysis period (March through September) in 2015 (Figures 5-7). The lowest-elevation transects at the restoration site (NL T18 and NL T02) had muted tidal inundation in 2009 (due to a leaky tide gate) and were inundated 3.9 and 0.6% of the time, respectively. In 2015, these transects were inundated 28% and 19% of the time, respectively, indicating the restoration of tidal influence at Ni-les'tun. Tidal inundation at the Bandon Marsh Unit reference site did not change among years.

Percent inundation was higher during 2015 compared to year 2 after restoration (2013) at the restoration site, but not at the reference site (Figure 5). This reflects full restoration of tidal forces at the site, and may also reflect the characteristics of the specific observation periods (see next paragraph).

Surprisingly, percent inundation in September 2015 was similar to March 2015 (Figures 5-7), and considerably greater than September 2013 (Figures 6 and 7). Since late summer precipitation was similar in 2013 and 2015, we expect the higher inundation in September 2015 was probably due to the observation period encompassing two spring tide cycle peaks. (The March observation period encompassed only a single spring tide peak). Typically, Oregon tidal wetlands are inundated more often during winter and spring months compared to dry summer months (Seliskar and Gallagher 1983, Brophy *et al*. 2011); longer observation periods in winter and summer, or modeling of long-term tidal hydrology, would likely have revealed this more typical pattern. Although beyond the scope of this project, modeling tidal hydrology at Ni-les'tun would generate deeper understanding of this important controlling factor and the resulting site development.

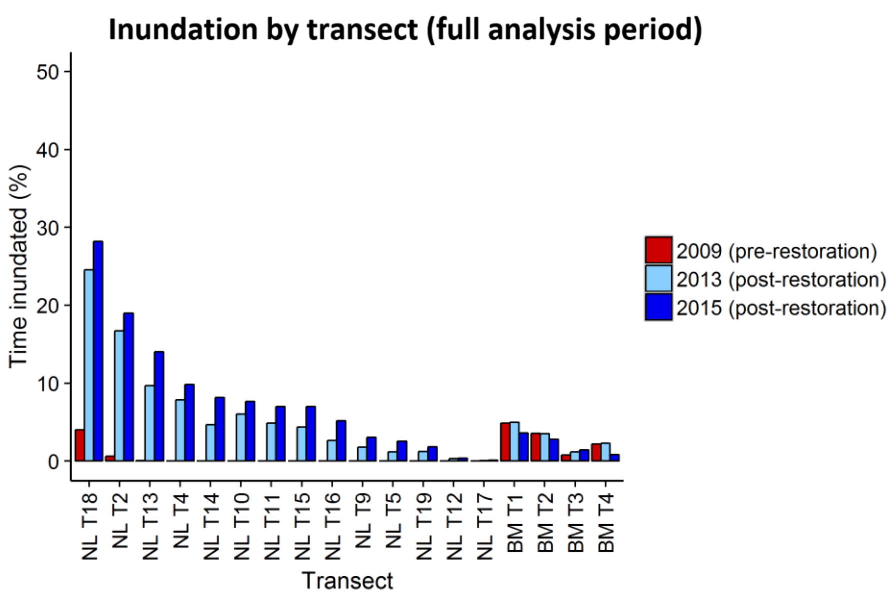

Figure 5. Percent inundation pre- (2009) and post-restoration (2013 and 2015) for sample transects at Ni-les'tun (NL) and the Bandon Marsh Unit reference site (BM). Transects are ordered by ascending elevation (measured in 2015) within each site, with NL T18 and BM T1 having the lowest elevation, NL T17 and BM T4 the highest. Data are averaged from the full analysis period (March 1 – July 8 and August 29 – October 1) for each year.

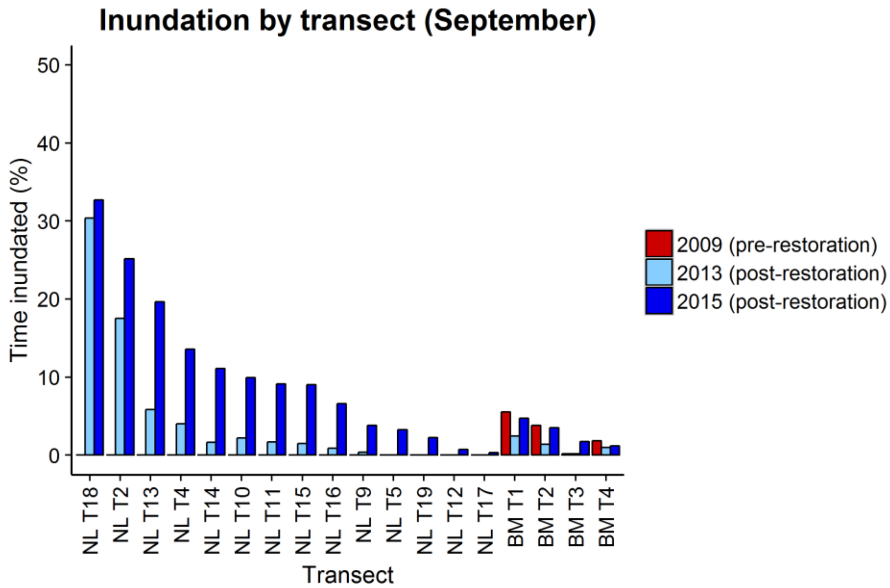

Figure 6. Percent inundation in September during pre- (2009) and post-restoration (2013 and 2015) periods for sample transects at Ni-les'tun (NL) and the Bandon Marsh Unit reference site (BM). Transects are ordered by ascending elevation (measured in 2015) within each site, with NL T18 and BM T1 having the lowest elevation, NL T17 and BM T4 the highest.

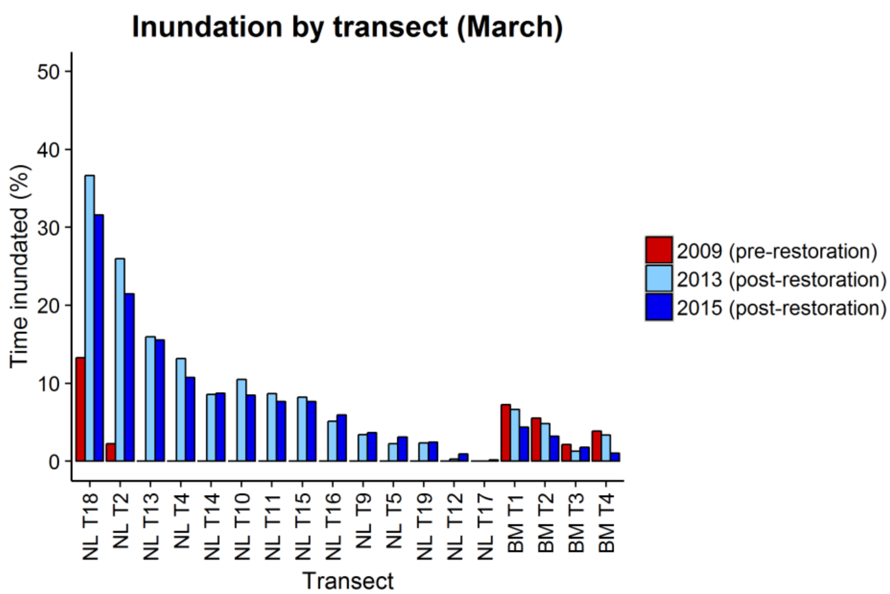

Figure 7. Percent inundation in March pre- (2009) and post-restoration (2013 and 2015) for sample transects at Ni-les'tun (NL) and the Bandon Marsh Unit reference site (BM). Transects are ordered by ascending elevation (measured in 2015) within each site, with NL T18 and BM T1 having the lowest elevation, NL T17 and BM T4 the highest.

Using the tide gauge data, we graphed percent inundation (or "exceedance") for a broad range of elevations at Ni-les'tun and in the adjacent Coquille River. In 2015, tidal inundation of the wetland surface at Ni-les'tun (mostly at elevations of 1.8 to 2.5 m) closely matched the adjacent river, whereas in 2013 (particularly in September), the wetland surface was less frequently inundated (Figures 8-10). The closer match between inundation of the wetland surface and adjacent river levels in 2015 compared to 2013 shows the effectiveness of the restoration actions in restoring full tidal exchange.

Elevations below the general marsh surface (< 2 m NAVD88) – that is, within channels -- were inundated slightly more often than the adjacent river during 2013 and 2015 (Figures 8-10). This indicates a slight "lag" in drainage from the restoration site, typical of restoration sites where tidal channel networks are generally less dense than in least-disturbed tidal wetlands. Over time, as the channel system develops, we expect to see a reduction in this drainage lag.

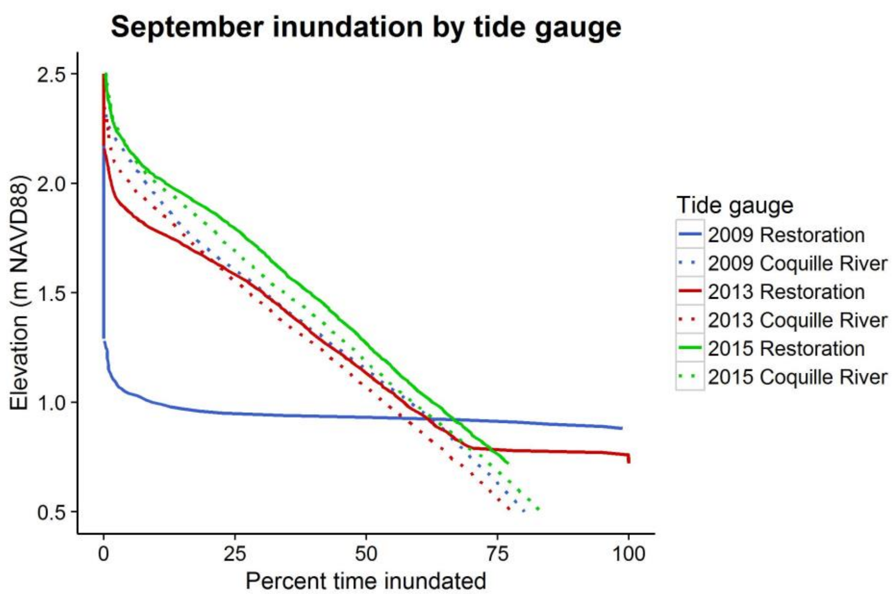

Figure 8. Percent inundation at a range of elevations during the summer period (September) at the restoration site and Coquille River tide gauges, pre (2009) and post-restoration (2013 and 2015). Average wetland surface elevation at Ni-les'tun is 2.08 m NAVD88 (see Table 4).

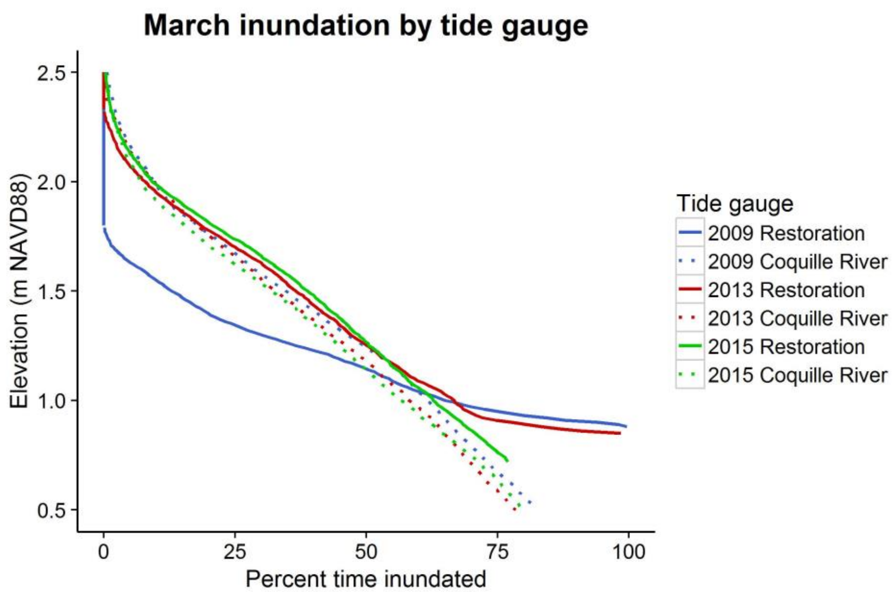

Figure 9. Percent inundation at a range of elevations during March at the restoration site and Coquille River tide gauges, pre (2009) and post-restoration (2013 and 2015). Average wetland surface elevation at Ni-les'tun is 2.08 m NAVD88 (see Table 4). Note: The March curve for the Coquille River is hidden directly under the restoration site curve (i.e., the restoration site and river matched exactly in March).

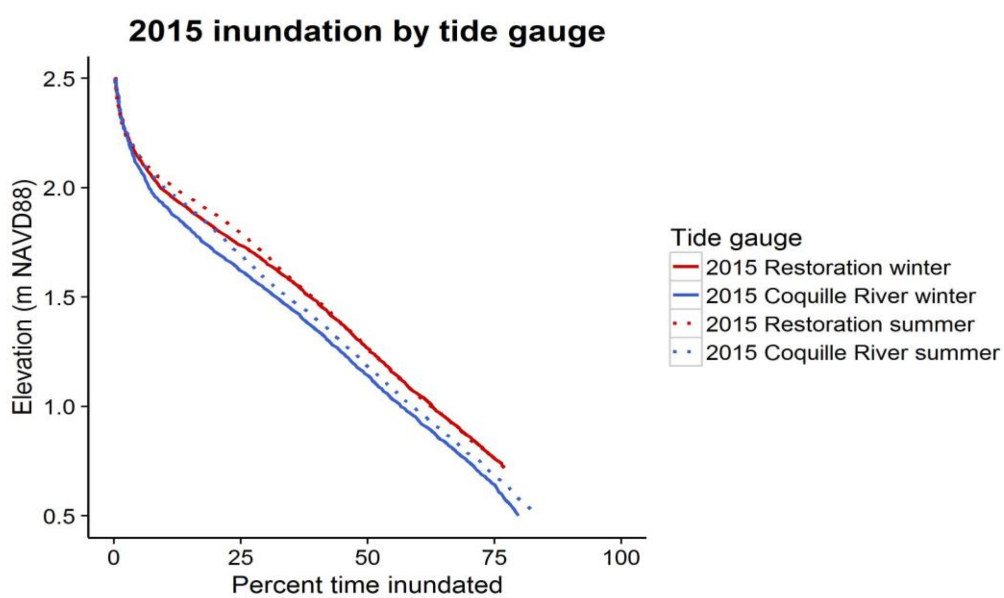

Figure 10. Percent inundation at a range of elevations during 2015 at the restoration site and Coquille River tide gauges, late winter (March) and summer (September). Average wetland surface elevation at Ni-les'tun is 2.08 m NAVD88 (see Table 4).

Overall, tidal influence has been restored to the Ni-les'tun restoration site. Daily maximum water levels at the restoration site matched those at the Bandon Marsh Unit reference site, and tidal influence reached even the highest elevation transects. Although there is still a slight lag in tidal drainage from the site, we expect that to lag decrease as the tidal channel system develops. We also expect to see other parameters, such as plant communities, groundwater dynamics, and soil organic matter content continue to respond to the restored tidal forces.

Elevation of wetland surface

Methods

In 2015, ETG measured the ground surface elevation of each emergent marsh vegetation transect. Ten measurements of the ground surface were evenly distributed along the baseline of each transect. At each ground surface measurement location, vegetation was removed and the survey rod was placed on the sediment surface. The survey rod was fitted with a 10 cm diameter topo shoe to prevent the rod from penetrating the sediment. For each ground surface measurement location, GPS/GNSS data was collected for 10 seconds at 1 Hz and averaged within the receiver. The 10 measurement locations were averaged to derive an average elevation per transect (*i.e.*, 100 seconds total GPS/GNSS measurement time per transect). Tested vertical accuracy of the methods used to collect these data was better than 6.5 cm at the 95% confidence level. Data was collected using the NGS GEOID12A orthometric NAVD88 model.

ETG's 2015 ground surface measurements built on a pre-restoration survey conducted by Ducks Unlimited (DU) in 2011. The DU survey also used high-precision survey-grade equipment and followed similar methods to ETG, however the specific details of their methodology were not provided to us by DU. We expect their data to be similar in accuracy to our own. This assumption was reinforced by a lack of statistical difference between 2011 and 2015 transect elevation standard error estimates (t-test, $p = 0.447$). Pre-restoration (2011) DU measurements were collected using the NGS GEOID 03 orthometric NAVD88 model, therefore we adjusted the 2011 DU data to the NAVD88 (GEOID12A) using the difference between geoid heights relative to the NAD83 ellipsoid at each vegetation transect centroid. Appendix 1 reports these adjustments. The difference between the mean transect elevation from 2011 to 2015 may represent erosion (negative elevation change) or accretion (positive elevation change), and the changes are described in this way, although differences in methodology could also explain the changes.

The elevation change data were all non-normal; therefore differences in elevation change between the Ni-les'tun restoration site and the Bandon Marsh Unit reference site were analyzed using a non-parametric Wilcoxon rank sum test with a Bonferroni adjustment to test differences among sites and years. A simple linear regression was used to model elevation change as a function of mean transect elevation. All statistical analyses were performed in R (version 3.2.1).

Results and discussion

Because the Ni-les'tun site is subsided (Brophy *et al*. 2014, Brophy and van de Wetering 2011), the average elevation across all transects at the Ni-les'tun restoration site was somewhat lower than at the Bandon Marsh Unit reference site. In 2015, the average transect elevations at Ni-les'tun restoration site and the Bandon Marsh Unit were 2.08 m and 2.25 m NAVD88 ([GEOID12A], respectively) (Table 4, Figure 11). In 2011, the average wetland surface elevation (averaged across all transects) was 2.03 m NAVD88 (GEOID12A) at the Ni-les'tun restoration site and 2.23 m NAVD88 (GEOID12A) at the Bandon Marsh reference site.

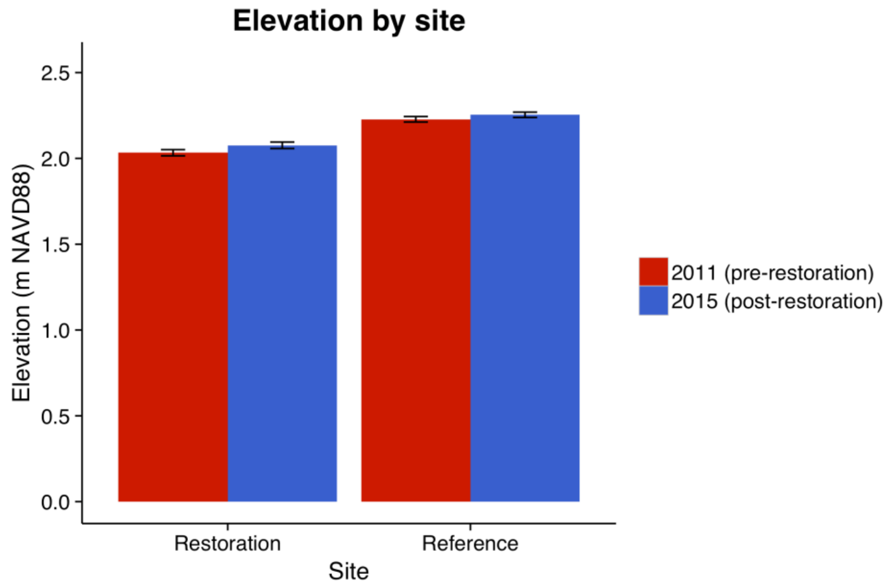

Figure 11. Wetland surface elevation at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Error bars show one standard error. Vertical datum: NAVD88 (GEOID12A).

Table 4. Wetland surface elevation and elevation change at sample transects between 2011 (pre-restoration) and 2015 (post-restoration) at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Vertical datum: NAVD88 (GEOID12A). None of the differences between sites or years were statistically significant (pairwise t-test, $p < 0.05$).

Site	Year	Wetland surface elevation, m NAVD88 (SE)	Wetland surface elevation, ft NAVD88 (SE)	Elevation change from 2011 to 2015, cm	Elevation change from 2011 to 2015, in
Restoration	pre-restoration (2011)	2.03 (0.02)	6.67 (0.06)	4.9 (0.8)	1.9 (0.3)
	post-restoration (2015)	2.08 (0.02)	6.81 (0.06)		
Reference	pre-restoration (2011)	2.23 (0.02)	7.31 (0.05)	3.6 (0.9)	1.4 (0.4)
	post-restoration (2015)	2.25 (0.02)	7.40 (0.05)		

At the Ni-les'tun site, post-restoration wetland surface measurements at sampled transects averaged 4.9 cm above the pre-restoration measurements at these same transects (Figure 12). At the Bandon Marsh Unit reference site, the average wetland surface elevation at sampled transects was 3.6 cm higher in 2015 than in 2011 (Figure 12, Table 5). Results were consistent in terms of direction of change: all transects showed an increase in elevation (although the magnitude of the increase differed [Table 5, Figure 12]). This elevation increase from 2011 to 2015 may have been an artifact of survey methods, survey equipment, or systemic measurement interference due to factors like satellite geometry or atmospheric conditions. Alternatively, this elevation increase could have been due to marsh surface accretion, or a combination of measurement artifacts and accretion.

If the wetland surface elevation change we observed at sample transects was solely the result of accretion, the observed rate of elevation change averaged around 12 mm/yr, about twice the rate measured by our team at least-disturbed low and high marsh reference sites in the Siuslaw River estuary (Brophy *et al.* 2014) and Tillamook Bay estuary (Brown *et al.* 2016) using feldspar marker horizons at similar surface elevations. Preliminary data from feldspar marker horizon plots at the Ni-les'tun restoration site and the Bandon Marsh Unit reference site suggest lower rates of accretion from 2009 to 2012, around 1-4 mm/yr (Bill Bridgeland, personal communication). Future measurements from the feldspar marker horizon plots should clarify the actual accretion rates at the site.

There was no significant difference in the change of elevation between the restoration site and reference site (p = 0.37, Figures 13-15).

As the Ni-les'tun site continues to adjust to the reintroduction of tidal influence, wetland surface elevation will likely continue to change. Future monitoring should be designed to capture these changes, and repeated monitoring will establish a trend over time. The addition of feldspar marker horizons at each vegetation transect would provide more precise estimates of accretion rates across the site.

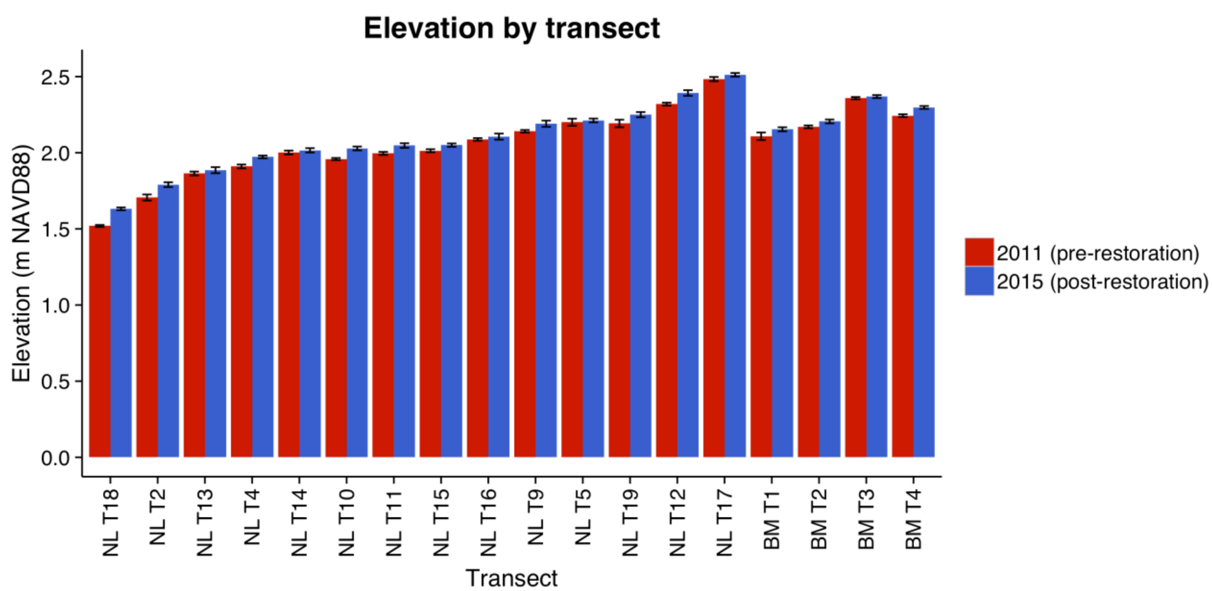

Figure 12. Wetland surface elevations by transect at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Transects are ordered by ascending elevation (measured in 2015) within each site, with NL T18 and BM T1 having the lowest elevation, NL T17 and BM T4 the highest. Error bars show one standard error. Vertical datum: NAVD88 (GEOID12A).

Table 5. Wetland surface elevation by transect at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Transects are ordered by ascending elevation (measured in 2015) within each site, with NL T18 and BM T1 having the lowest elevation, NL T17 and BM T4 the highest. Vertical datum: NAVD88 (GEOID12A).

		Wetland surface elevation (m NAVD88)				**Elevation change**	
		pre-restoration (2011)		**post-restoration (2015)**		**post (2015) – pre (2011)**	
Site	**Transect**	**meters (SE)**	**feet (SE)**	**meters (SE)**	**feet (SE)**	**centimeters (SE)**	**inches (SE)**
Restoration	NL T18	1.52 (0.01)	4.98 (0.02)	1.63 (0.01)	5.35 (0.03)	11.2 (1.1)	4.4 (0.4)
	NL T2	1.71 (0.02)	5.60 (0.07)	1.79 (0.02)	5.87 (0.05)	8.4 (2.5)	3.3 (1.0)
	NL T13	1.86 (0.01)	6.11 (0.04)	1.89 (0.02)	6.19 (0.07)	2.2 (2.4)	0.9 (0.9)
	NL T4	1.91 (0.01)	6.27 (0.04)	1.97 (0.01)	6.47 (0.03)	6.3 (1.5)	2.5 (0.6)
	NL T14	2.00 (0.01)	6.57 (0.04)	2.02 (0.01)	6.61 (0.05)	1.4 (1.9)	0.6 (0.7)
	NL T10	1.96 (0.01)	6.43 (0.02)	2.03 (0.01)	6.65 (0.04)	6.9 (1.4)	2.7 (0.6)
	NL T11	2.00 (0.01)	6.55 (0.03)	2.05 (0.02)	6.72 (0.05)	5.2 (1.8)	2.0 (0.7)
	NL T15	2.01 (0.01)	6.60 (0.03)	2.05 (0.01)	6.73 (0.04)	3.7 (1.5)	1.5 (0.6)
	NL T16	2.09 (0.01)	6.85 (0.03)	2.11 (0.02)	6.91 (0.07)	1.8 (2.2)	0.7 (0.9)
	NL T9	2.14 (0.01)	7.02 (0.03)	2.19 (0.02)	7.19 (0.07)	4.9 (2.2)	1.9 (0.9)
	NL T5	2.20 (0.02)	7.22 (0.08)	2.21 (0.01)	7.26 (0.04)	1.1 (2.6)	0.4 (1.0)
	NL T19	2.19 (0.03)	7.19 (0.08)	2.25 (0.02)	7.38 (0.06)	5.8 (3.0)	2.3 (1.2)
	NL T12	2.32 (0.01)	7.61 (0.03)	2.39 (0.02)	7.85 (0.06)	7.3 (2.1)	2.9 (0.8)
	NL T17	2.48 (0.01)	8.15 (0.05)	2.51 (0.01)	8.24 (0.04)	2.8 (1.8)	1.1 (0.7)
Reference	BM T1	2.11 (0.03)	6.92 (0.08)	2.15 (0.01)	7.07 (0.04)	4.6 (2.8)	1.8 (1.1)
	BM T2	2.17 (0.01)	7.12 (0.03)	2.21 (0.01)	7.24 (0.04)	3.5 (1.6)	1.4 (0.6)
	BM T3	2.36 (0.01)	7.74 (0.02)	2.37 (0.01)	7.77 (0.03)	1.0 (1.2)	0.4 (0.5)
	BM T4	2.24 (0.01)	7.36 (0.03)	2.30 (0.01)	7.54 (0.03)	5.4 (1.3)	2.1 (0.5)

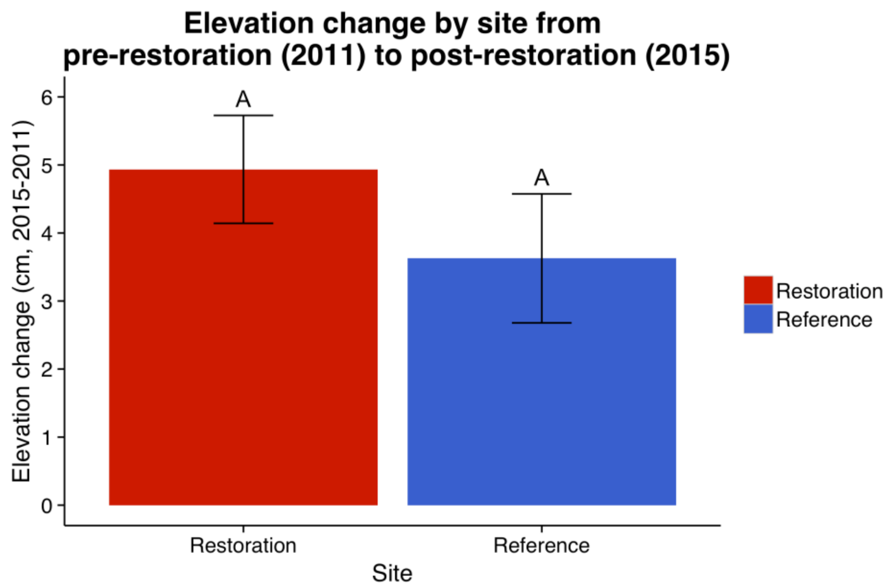

Figure 13. Wetland surface elevation change by site at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Error bars show one standard error; columns with no letters in common are significantly different (Wilcoxon test, $p < 0.05$).

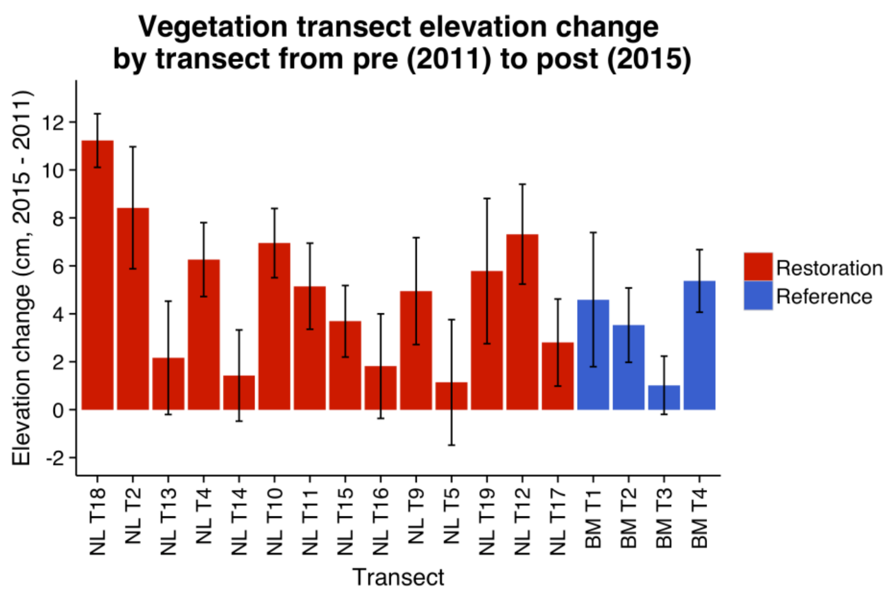

Figure 14. Wetland surface elevation change from pre-restoration baseline (2011) to year 4 (2015), by transect, at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Transects are ordered by ascending elevation (measured in 2015) from left to right within each site, with NL T18 and BM T1 having the lowest elevation, NL T17 and BM T4 the highest. Error bars show one standard error.

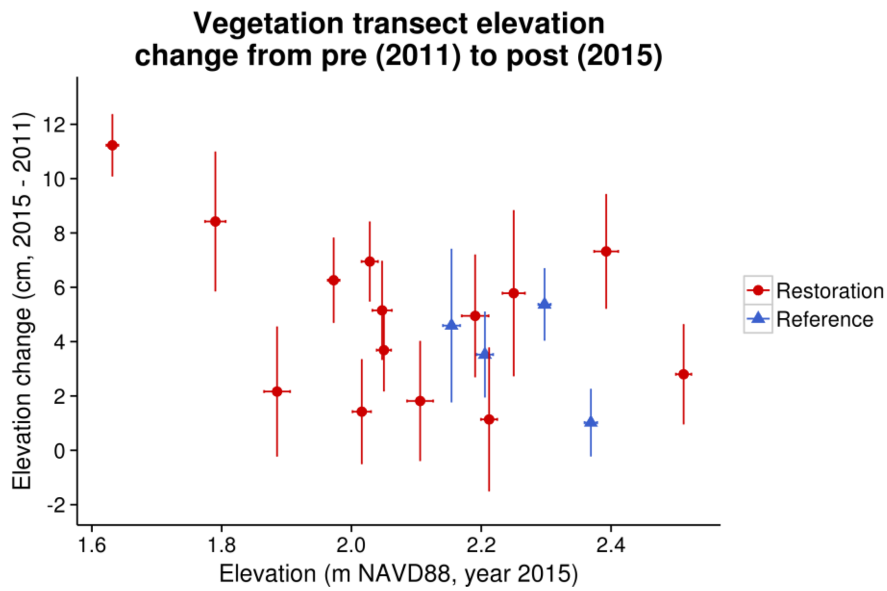

Figure 15. Wetland surface elevation change from pre-restoration baseline (2011) to year 4 (2015), as a function of elevation, at Ni-les'tun (restoration) and the Bandon Marsh Unit reference site (reference). Error bars show one standard error.

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

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

Metrics: Tidal hydrology and wetland plant community composition and extent. *(Rationale: Tidal wetland plant community development is an indicator of soil characteristics, groundwater levels, and surface water characteristics).*

Tidal hydrology

This parameter is discussed under Monitoring Question 1a above.

Emergent wetland plant community composition

Methods

Vegetation sampling for this study was described in the baseline monitoring report (Brophy and van de Wetering 2012). Briefly, sample transects (100 m long) at the Ni-les'tun restoration site and the Bandon Marsh Unit reference site were stratified and distributed across all tidal wetland elevation zones and sub-basins. The same transects were sampled in 2010 (baseline), in 2013 (year 2 post-restoration), and in 2015 (this study, year 4 post-restoration) (Table 6, Figures 1 and 2). Visual estimates of percent cover by species were made within 15 1-sq m quadrats along each transect. Quadrats were placed 1 m off the transect's central axis (left or right side randomly determined), at random distances from the transect end post (but at least 3 m apart and 3 m from the transect end post). Of the 15 quadrats, 8 were randomly placed in 2015 and 7 were re-sampled at approximately the same locations as in 2010 and 2013. Visual cover estimates followed the Oregon Department of State Land's Routine Monitoring Protocol (Oregon DSL 2009).

Pre-restoration *versus* post-restoration plant community metrics (species richness, total percent cover, and native and non-native percent cover) were analyzed using BACI (2-way ANOVA) with site (restoration site *versus* reference site), and year (2010, 2013, and 2015) as categorical independent variables. When distributions did not meet the normality assumptions, a non-parametric test was used. A multivariate technique, non-metric multidimensional scaling (NMDS), was used to summarize differences in plant community composition among transects pre- and post-restoration. A simple linear regression was used to determine the relationship between elevation and species richness at the restoration site and reference sites. All analyses were completed in R (Version 3.1.1) using percent cover per transect as the dependent variable.

As described in the baseline and year 2 post-restoration monitoring reports, locations of sample transects at Ni-les'tun were stratified across elevation zones and sub-watersheds, and their initiation points were randomly selected (although positions of a few were adjusted to avoid areas of disturbance). Therefore, transects can be considered representative of the site as a whole, and statistical analysis is based on this premise.

In the sections below, the term "dominant" was used for species that had the highest percent cover values within the study transect. Species with more than 20% cover are commonly considered dominant, although species with less than 20% cover may be considered dominant when total cover is low (i.e. when bare ground is prevalent). Scientific and common plant names were referenced to the Oregon Vascular Plant Checklist (Cook *et al*. 2015).

Table 6. Locations of sample transects at the Ni-les'tun restoration site and Bandon Marsh Unit reference site. GPS coordinates for transect end posts are shown in meters (UTM Zone 10 N, NAD83).

Site	Transect end	Easting	Northing
Ni-les'tun restoration site	NL T2 E	387194	4778472
Ni-les'tun restoration site	NL T2 W	387108	4778441
Ni-les'tun restoration site	NL T4 E	387501	4779152
Ni-les'tun restoration site	NL T4 W	387413	4779145
Ni-les'tun restoration site	NL T5 N	388591	4779094
Ni-les'tun restoration site	NL T5 S	388540	4779017
Ni-les'tun restoration site	NL T9 N	388491	4779275
Ni-les'tun restoration site	NL T9 S	388549	4779204
Ni-les'tun restoration site	NL T10 E	388133	4779042
Ni-les'tun restoration site	NL T10 W	388047	4779011
Ni-les'tun restoration site	NL T11 N	388121	4778848
Ni-les'tun restoration site	NL T11 S	388126	4778756
Ni-les'tun restoration site	NL T12 N	388190	4778575
Ni-les'tun restoration site	NL T12 S	388193	4778483
Ni-les'tun restoration site	NL T13 E	387575	4778612
Ni-les'tun restoration site	NL T13 W	387484	4778610
Ni-les'tun restoration site	NL T14 E	387546	4778850
Ni-les'tun restoration site	NL T14 W	387454	4778846
Ni-les'tun restoration site	NL T15 N	387575	4778240
Ni-les'tun restoration site	NL T15 S	387571	4778149
Ni-les'tun restoration site	NL T16 N	387806	4778799
Ni-les'tun restoration site	NL T16 S	387808	4778707
Ni-les'tun restoration site	NL T17 E	387934	4778179
Ni-les'tun restoration site	NL T17 W	387852	4778149
Ni-les'tun restoration site	NL T18 E	387166	4778205
Ni-les'tun restoration site	NL T18 W	387080	4778217
Ni-les'tun restoration site	NL T19 N	387172	4778799
Ni-les'tun restoration site	NL T19 S	387132	4778705
Bandon Marsh Unit ref. site	BM T1 N	386440	4777880
Bandon Marsh Unit ref. site	BM T1 S	386390	4777802
Bandon Marsh Unit ref. site	BM T2N	386101	4777558
Bandon Marsh Unit ref. site	BM T2 S	386072	4777472
Bandon Marsh Unit ref. site	BM T3 N	386374	4777696
Bandon Marsh Unit ref. site	BM T3 S	386337	4777630
Bandon Marsh Unit ref. site	BM T4 N	386224	4777746
Bandon Marsh Unit ref. site	BM T4 S	386172	4777714

Results and discussion

In 2015, derived plant community metrics were similar to 2013 at the restoration and reference sites. Species richness was significantly lower at the restoration site in 2015 compared to 2010 (2.9 and 5.0, respectively, Table 7, Figure 16), as was plant cover (84.7% and 115.8%, respectively, Figure 17).

Native and non-native percent cover at the restoration site did not significantly differ among years (Figures 18 and 19), and while bare ground significantly increased from 2010 to 2013 (from 0.9% to 18.6%, respectively), it did not significantly differ from either year in 2015 (10.1%, Figure 20).

In 2015, species richness at the restoration site was still significantly lower compared to the reference site (2.9 and 6.9, respectively), though total plant, native, and non-native plant cover did not differ between sites. Total bare ground cover did not differ in 2015 between restoration and reference sites (10.1% and 0.7% respectively) (Table 7).

Table 7. Summary of plant community metrics (species richness, total cover, native cover, and non-native cover) at Ni-les'tun restoration site and Bandon Marsh Unit reference site transects. Means with no letters in common are significantly different ($p < 0.05$).

Site	Year	Average plant species richness	Average total plant cover (%)	Average native plant cover (%)	Average non-native plant cover (%)
Restoration	pre-restoration (2010)	5.0 a	115.8 a	56.6 a	58.8 b
Reference	pre-restoration (2010)	6.5 a	112.1 ab	94.3 a	17.7 ab
Restoration	post-restoration (2013)	3.0 b	87.1 b	47.1 a	39.9 ab
Reference	post-restoration (2013)	6.9 a	104.0 ab	92.3 a	11.7 ab
Restoration	post-restoration (2015)	2.9 b	84.7 b	50.6 a	34.1 ab
Reference	post-restoration (2015)	6.4 a	99.3 ab	96.0 a	3.3 a

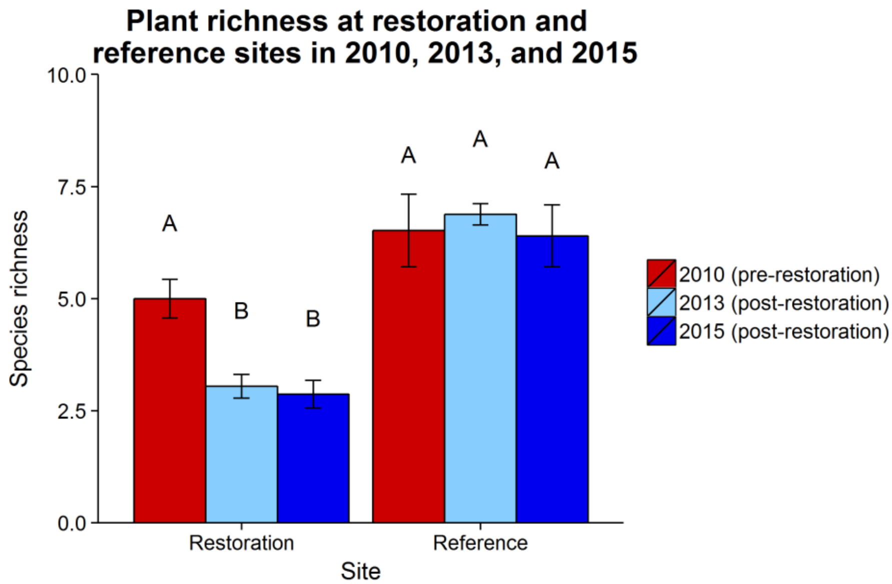

Figure 16. Average plant species richness for the Ni-les'tun restoration site and Bandon Marsh Unit reference site, pre- and post-restoration. Error bars show one standard error; columns with no letters in common are significantly different (ANOVA, $p < 0.05$).

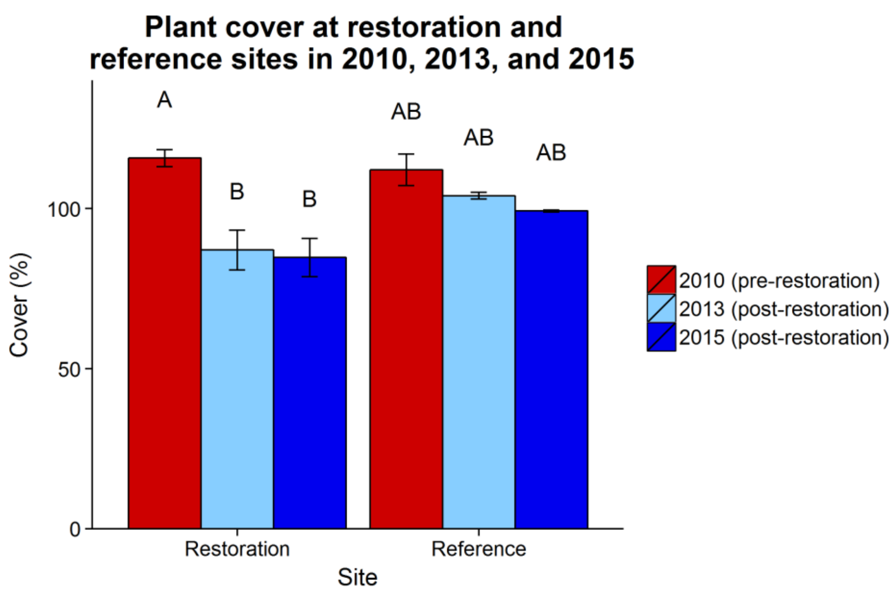

Figure 17. Average plant cover for the Ni-les'tun restoration site and Bandon Marsh Unit reference site, pre- and post-restoration. Error bars show one standard error; columns with no letters in common are significantly different (ANOVA, $p < 0.05$).

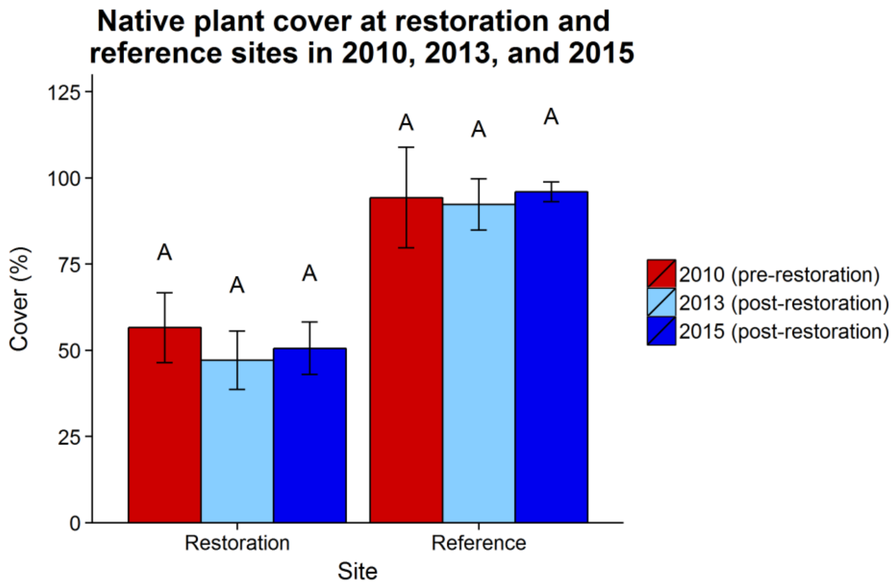

Figure 18. Average native plant cover for the Ni-les'tun restoration site and Bandon Marsh Unit reference site, pre- and post-restoration. Error bars show one standard error; columns with no letters in common are significantly different (ANOVA, $p < 0.05$).

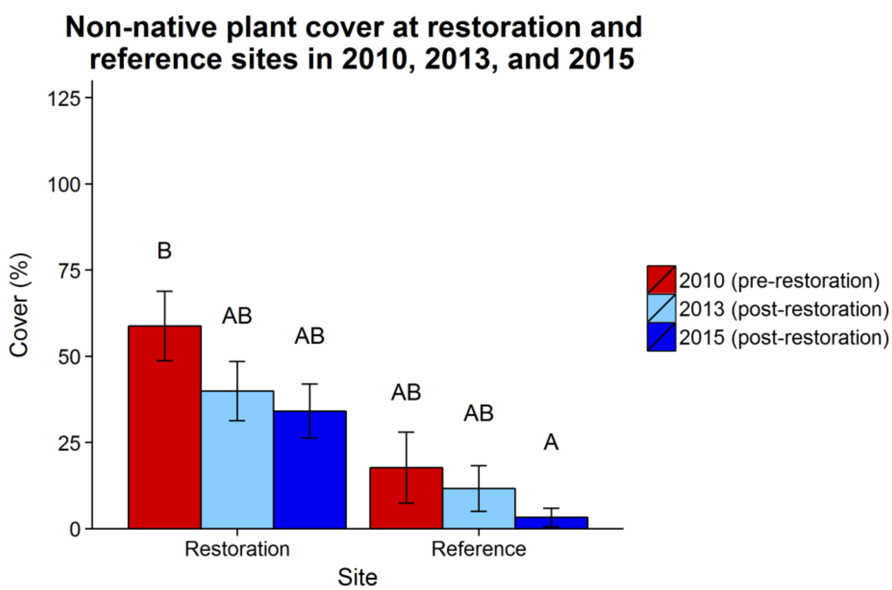

Figure 19. Average non-native plant cover for the Ni-les'tun restoration site and Bandon Marsh Unit reference site, pre- and post-restoration. Error bars show one standard error; columns with no letters in common are significantly different (ANOVA, $p < 0.05$).

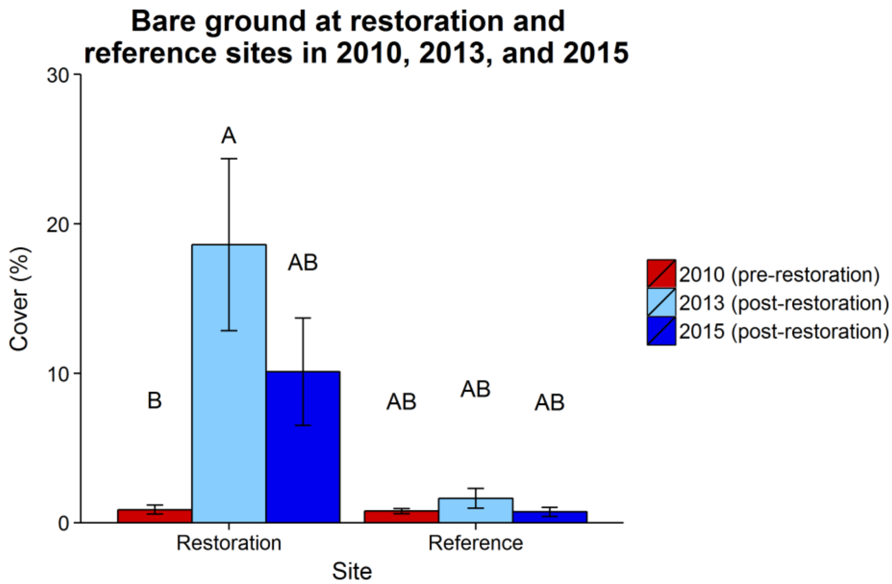

Figure 20. Average bare ground cover for the Ni-les'tun restoration site and Bandon Marsh Unit reference site, pre- and post-restoration. Error bars show one standard error; columns with no letters in common are significantly different (ANOVA, $p < 0.05$).

Due to the reintroduction of brackish tidal flows at Ni-les'tun, we expected to see decreasing cover of salt-intolerant plants during the first few years after restoration, and increasing cover of native and non-native salt-tolerant species. This was clearly documented across transects for the restoration site as a whole (Table 10), within individual transects (Table 11), and in the plant community mapping (see **Emergent wetland plant community mapping** below).

Across Ni-les'tun as a whole, dominant species in 2015 included native species such as Baltic rush and common orache, and non-natives like tall fescue, brass buttons, and creeping bentgrass (Tables 8 and 10). Of species averaging over 5% cover in any single transect, two species showed significant changes in cover from 2010 to 2015, and their changes reflected the site's increased salinity. Common orache (a native species) increased from 0.1% in 2010 to 10.6% in 2015 (Table 10). Also known as spreading orache, this species is quick to colonize bare ground and is a common dominant during the early post-restoration period (Cornu and Sadro 2002). Common orache increased by 10% or more in five transects from 2013 to 2015 (Table 11, Figure 21); its increased dominance was also reflected in the greater land area dominated by this species in 2015 (see Table 15 in **Emergent wetland plant community mapping** below). By contrast, salt-intolerant species decreased at Ni-les'tun. Cover of birdsfoot trefoil (a non-native) decreased significantly, from 11.7% in 2010 to < 0.01% in 2015 (Table 10). At NL T4, salt-intolerant slough sedge dominated the transect in 2010 (60.6% cover) and has since decreased to only 2.9% in 2015 (Table 11).

Non-native species frequently colonize new tidal wetland restoration sites, but if they are expected to be ephemeral, or if they are broadly found in coastal wetlands (and thus control is not warranted), they are not a cause for major concern. Brass buttons was the only new non-native species at Ni-les'tun in 2015 that had more than 5% cover; it was found in transects that also had high percentages of bare ground and were slightly below MHHW (Table 8, Table 11). Brass buttons was dominant in two transects (NL T11 and NL T13, with 22.9% and 41.4% cover, respectively; Table 11); it dominated 19.4 ha of

Ni-les'tun, a rapid increase since 2013 when it was not mapped as dominant anywhere on the site (Table 15). Brass buttons is a salt-tolerant, low-growing species that commonly colonizes bare ground in brackish restoring tidal wetlands; it is generally replaced by more competitive species over several years (Cornu and Sadro 2002). Tall fescue and creeping bentgrass (non-native grasses) continued to be dominant in some transects (Table 11), but their cover decreased since 2013 across the entire site, and they are not expected to present obstacles to site recovery.

At the Bandon Marsh Unit reference site, typical high tidal marsh species continued to dominate; these included tufted hairgrass, Baltic rush, and Pacific silverweed (Table 9). Only two species (fleshy jaumea and pickleweed) showed significant change in cover at the reference site from 2010 to 2015; jaumea increased from 3.6% in 2010 to 11.5% in 2015, and pickleweed increased from 4.8% to 9.6% (Table 10).

The NMDS analysis showed that plant communities in Ni-les'tun transects were gradually moving towards low salt marsh component of the reference transects (stress = 0.18, Figure 22). The ellipses in Figure 22 group each year's samples at the restoration site, showing the transition from associations dominated by agricultural grasses (HOLLAN and SCHARU) to associations dominated by low marsh plants communities (JAUMAR and DISSPI) (Figure 22). This result was expected, since the reference site transects were chosen to represent the original high marsh that was found at Ni-les'tun historically, so their elevation is higher than the subsided wetland surface at Ni-les'tun. The increase in salt-tolerant species at Ni-les'tun (such as saltgrass and common orache) is leading to closer similarity to low salt marsh found at the reference site (but not currently sampled), rather than the high salt marsh represented by the Bandon Marsh Unit transects. Over time, accretion at Ni-les'tun may lead to recovery of high salt marsh, but the process is expected to take many decades.

A full list of species found at both the Ni-les'tun restoration site and Bandon Marsh Unit reference site is found in Table 13.

Table 8. Tidal elevations of study transects at Ni-les'tun restoration site (from 2015 RTK-GPS measurements and 2013 tidal datum calculations at Coquille River TG2 in Brophy *et al*. 2014), and dominant species (from 2015 vegetation survey). Each elevation is the average of ten surveyed points distributed along each transect. See Table 5 for NAVD88 elevations.

Site	Transect	Transect elevation relative to MHHW (m)	Transect elevation relative to MHHW (ft)	Habitat description	Dominant species or cover
Ni-les'tun	NL T2	-0.38	-1.26	restored tidal marsh	bare ground common spikerush
Ni-les'tun	NL T4	-0.20	-0.66	restored tidal marsh	wrack
Ni-les'tun	NL T5	0.04	0.12	restored tidal marsh	Baltic rush tall fescue
Ni-les'tun	NL T9	0.02	0.05	restored tidal marsh	Baltic rush common orache
Ni-les'tun	NL T10	-0.15	-0.48	restored tidal marsh	Baltic rush common orache
Ni-les'tun	NL T11	-0.13	-0.42	restored tidal marsh	Bare ground brass buttons common orache
Ni-les'tun	NL T12	0.22	0.72	restored tidal marsh	tall fescue
Ni-les'tun	NL T13	-0.29	-0.95	restored tidal marsh	bare ground brass buttons
Ni-les'tun	NL T14	-0.16	-0.52	restored tidal marsh	bare ground creeping bentgrass
Ni-les'tun	NL T15	-0.12	-0.41	restored tidal marsh	Baltic rush creeping bentgrass
Ni-les'tun	NL T16	-0.07	-0.22	restored tidal marsh	Baltic rush creeping bentgrass
Ni-les'tun	NL T17	0.34	1.11	restored tidal marsh	tall fescue
Ni-les'tun	NL T18	-0.54	-1.78	restored tidal marsh	saltgrass
Ni-les'tun	NL T19	0.08	0.25	restored tidal marsh	slough sedge

Table 9. Tidal elevations of study transects at Bandon Marsh Unit reference site (from 2015 RTK-GPS measurements and 2013 tidal datum calculations at Coquille River TG2), and dominant species (from 2015 vegetation survey). Each elevation is the average of ten surveyed points distributed along each transect. See Table 5 for NAVD88 elevations.

Site	Transect	Transect elevation relative to MHHW (m)	Transect elevation relative to MHHW (ft)	Habitat description	Dominant species or cover
Bandon Marsh Unit	BM T1	-0.02	-0.06	high tidal marsh	pickleweed
Bandon Marsh Unit	BM T2	0.03	0.10	high tidal marsh	tufted hairgrass Baltic rush
Bandon Marsh Unit	BM T3	0.19	0.64	high tidal marsh	Baltic rush Pacific silverweed
Bandon Marsh Unit	BM T4	0.12	0.41	high tidal marsh	Baltic rush

Table 10. Emergent wetlands, Ni-les'tun restoration site and Bandon Marsh Unit reference site: changes in percent cover across all transects, 2010, 2013, and 2015. Native species are highlighted in green, non-native species in orange. "Year" indicates pre-restoration (2010) *versus* post-restoration (2013 and 2015). Means with a no letter in common are significantly different among years (but within that species only) ($p < 0.05$). Table includes only species with more than 5% average cover in any single transect.

		Percent cover					
		restoration site			reference site		
Scientific name	**Common name**	**pre-restoration (2010)**	**post-restoration (2013)**	**post-restoration (2015)**	**pre-restoration (2010)**	**post-restoration (2013)**	**post-restoration (2015)**
Agrostis stolonifera	creeping bentgrass	11.3 a	16.6 a	11.3 a	17.7 a	10.2 a	3.0 a
Atriplex patula	common orache	0.1 a	2.9 ab	10.6 b	0.6 ab	1.9 ab	1.0 ab
Carex lyngbyei	Lyngbye's sedge	0.0 b	0.0 b	0.0 b	0.1 ab	1.6 a	1.9 a
Carex obnupta	slough sedge	10.8 a	11.2 a	7.1 a	0.0 a	0.0 a	0.0 a
Cotula coronopifolia	brass buttons	0.0 a	0.0 a	5.1 a	0.0 a	0.0 a	0.0 a
Deschampsia cespitosa	tufted hairgrass	0.0 b	0.0 b	0.0 b	11.5 ab	16.5 a	14.0 a
Distichlis spicata	saltgrass	6.0 a	7.2 a	9.5 a	11.9 a	9.5 a	6.1 a
Eleocharis palustris	common spikerush	4.3 a	1.7 a	2.9 a	0.0 a	0.0 a	0.0 a
Glaux maritima	sea milkwort	0.0 b	0.0 b	0.0 b	1.5 ab	2.0 a	2.5 a
Jaumea carnosa	fleshy jaumea	0.0 b	0.0 b	0.0 b	5.0 a	3.6 ab	11.5 c
Juncus balticus	Baltic rush	17.3 a	19.0 a	16.6 a	36.0 a	33.7 a	31.2 a
Lotus corniculatus	birdsfoot trefoil	11.7 a	0.6 b	0.0 b	0.0 ab	0.2 ab	0.0 ab
Potentilla anserina	Pacific silverweed	12.3 a	4.4 a	2.1 a	22.0 a	16.1 a	13.5 a
Phalaris arundinacea	reed canarygrass	0.4 a	0.8 a	0.4 a	0.0 a	0.0 a	0.0 a
Sarcocornia perennis	pickleweed	0.0 b	0.0 b	0.3 b	3.1 ab	4.8 a	9.6 c
Schedonorus arundinaceus	tall fescue	31.2 a	21.2 a	16.6 a	0.0 a	0.0 a	0.0 a
bare ground		0.9 b	18.6 a	10.1 ab	0.8 ab	1.6 ab	0.7 ab

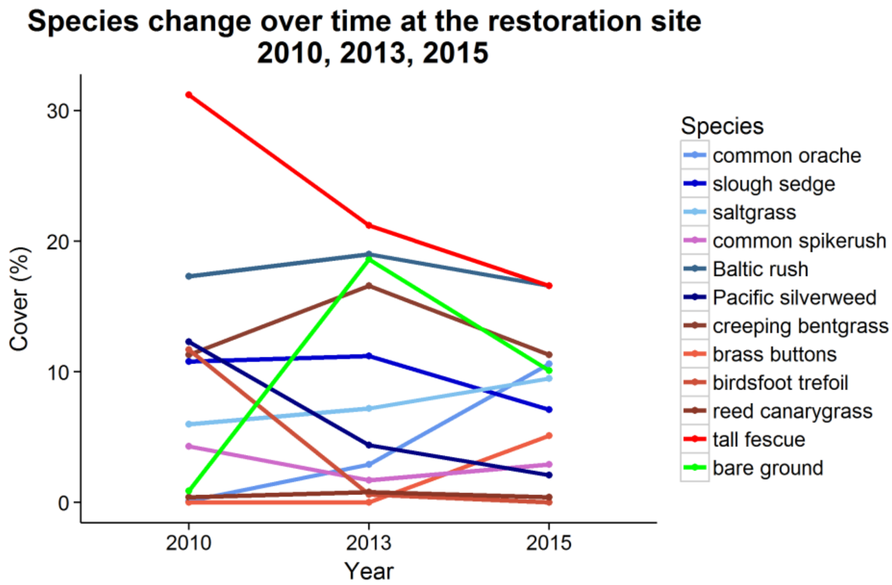

Figure 21. Species change in percent cover at the Ni-les'tun restoration site from 2010 to 2015. Native species are in blues and purples, while non-native species are in reds and oranges. Figure includes only species with more than 5% average cover in any single transect.

Table 11. Composition of plant communities by transect in emergent wetlands (percent cover by species), Ni-les'tun restoration site, July 2015. Native species are highlighted in green, non-natives in orange. For each transect, species with a change in cover of more than 10% between 2013 and 2015 are marked with an upward arrow (indicating > 10% increase in cover) or downward arrow (indicating > 10% decrease in cover). Table includes only species with more than 5% average cover in any single transect.

Scientific name	Common 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
Agrostis stolonifera	creeping bentgrass	0.0 ↓	0.1	1.0	13.1	9.1	7.8	0.0	4.1 ↓	44.7 ↓	39.1 ↑	39.3 ↑	0.4	0.0	0.0
Atriplex patula	common orache	0.0	7.7	0.1	25.4 ↑	39.5 ↑	25.5 ↑	0.1	1.6	15.3	18.5 ↑	15.0 ↑	0.0	0.0	0.0
Carex obnupta	slough sedge	0.0	2.9 ↓	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	81.5
Cotula coronopifolia	brass buttons	5.3	0.1	0.0	0.0	0.0	22.9 ↑	0.0	41.4 ↑	0.2	2.1	0.0	0.0	0.0	0.0
Distichlis spicata	saltgrass	8.4	0.0	0.0	0.0	10.3	0.0	0.0	12.7 ↑	2.7	0.0	0.0	0.0	99.1	0.0
Eleocharis palustris	common spikerush	27.2 ↑	0.0	0.0	0.0	0.0	0.0	0.0	10.5	2.6	0.0	0.0	0.0	0.0	0.0
Juncus balticus	Baltic rush	9.0	9.4	30.2	41.6 ↓	32.4 ↓	13.1	19.6	0.5	4.4	35.0	27.8	9.8	0.0	0.0
Phalaris arundinacea	reed canarygrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
Potentilla anserina	Pacific silverweed	0.1	0.0	2.3	13.9 ↓	0.0	0.0	0.1	0.5	4.8	0.0	0.0	0.0	0.0	7.3
Schedonorus arundinaceus	tall fescue	0.0	0.0	47.1 ↑	2.6	0.0	1.8 ↓	76.1	0.0	0.0	0.0	17.9 ↓	86.6	0.0	0.0
bare ground		41.5	7.1	1.7	1.7	8.7	28.7	0.0	20.9	25.1	5.3	0.0	0.0	0.9	0.0

Table 12. Composition of plant communities by transect in emergent wetlands (percent cover by species), Bandon Marsh Unit reference site, July 2015. Native species are highlighted in green, non-native in orange.

Scientific name	Common name	BM T1	BM T2	BM T3	BM T4
Agrostis stolonifera	creeping bentgrass	11.3	0.6	0.0	0.0
Carex lyngbyei	Lyngbye's sedge	5.3	0.6	1.5	0.0
Deschampsia cespitosa	tufted hairgrass	18.3	35.9	1.7	0.0
Distichlis spicata	saltgrass	11.4	0.77	0.0	12.1
Glaux maritima	sea milkwort	1.1	1.5	0.0	7.5
Jaumea carnosa	fleshy jaumea	15.9	11.2	0.0	18.8
Juncus balticus	Baltic rush	10.7	20.6	48.1	45.3
Potentilla anserina	Pacific silverweed	0.0	14.1	40.0	0.0
Sarcocornia perennis	pickleweed	17.1	8.5	0.0	12.7

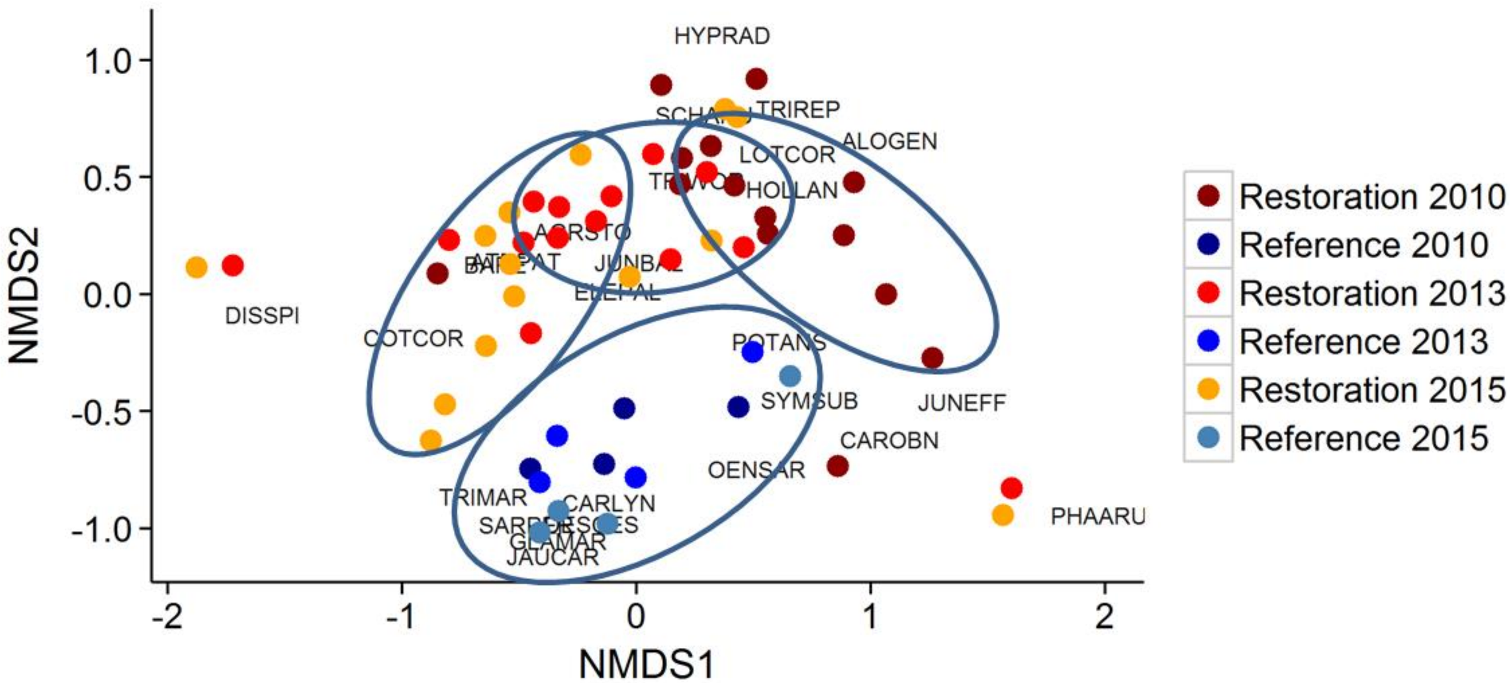

Figure 22. Non-metric multidimensional scaling (NMDS) plot for pre-restoration (2010) and post-restoration (2013 and 2015) plant communities at the Ni-les'tun restoration site and Bandon Marsh reference site. Red/orange dots represent transects from the restoration site; blue dots indicate transects from the reference site. Each point represents a single transect, with percent cover averaged for all quadrats per transect. Points closer together are more similar compositionally. The centroid positions of species used in the analysis are also indicated by six letter species codes on the plot. Restoration site transects from 2015, for instance, are near the COTCOR centroid, indicating they have greater cover of *Cotula coronopifolia* than most reference transects.

Table 13. Complete list of species found in vegetation monitoring plots at the Ni-les'tun restoration site and Bandon Marsh Unit reference site in 2015. Common names, native/non-native status (N or NN respectively), and abbreviated codes are shown. Two-letter codes were used for prevalent species in field mapping and the mapping shapefile.

Scientific name	Common name	Native/ non-native	6 letter code	2 letter code
Achillea millefolium	yarrow	N	ACHMILL	
Agrostis stolonifera	creeping bentgrass	NN	AGRSTO	AS
Angelica lucida	sea watch	N	ANGLUC	
Atriplex patula	common orache	N	ATRPAT	AP
Carex lyngbyei	Lyngbye's sedge	N	CARLYN	CL
Carex obnupta	slough sedge	N	CAROBN	CO
Cotula coronopifolia	brass buttons	NN	COTCOR	CC
Cuscuta pacifica	Salicornia dodder	N	CUSPAC	
Deschampsia cespitosa	tufted hairgrass	N	DESCES	DC
Distichlis spicata	saltgrass	N	DISSPI	DS
Eleocharis palustris	common spikerush	N	ELEPAL	EP
Galium aparine	stickywilly	N	GALAPA	
Galium trifidum	small bedstraw	N	GALTRI	
Glaux maritima	sea milkwort	N	GLAMAR	
Holcus lanatus	velvet grass	NN	HOLLAN	HL
Hordeum brachyantherum	meadow barley	N	HORBRA	
Isolepis cernua	low clubrush	N	ISOCER	
Jaumea carnosa	fleshy jaumea	N	JAUCAR	JC
Juncus balticus	Baltic rush	N	JUNBAL	JB
Juncus effusus	common rush	N	JUNEFF	JE
Lotus corniculatus	birdsfoot trefoil	NN	LOTCOR	LC
Lotus uliginosus	greater birdsfoot trefoil	NN	LOTULI	
Oenanthe sarmentosa	Pacific water parsley	N	OENSAR	OS
Phalaris arundinacea	reed canarygrass	NN	PHAARU	
Potentilla anserina	Pacific silverweed	N	POTANS	AE*
Rumex occidentalis	Rocky Mountain western dock	N	RUMOCC	
Ruppia maritima	beaked ditch-grass	N	RUPMAR	
Sarcocornia perennis	pickleweed	N	SARPER	SP
Schedonorus arundinaceus	tall fescue	NN	SCHARU	SA
Senecio glomeratus	New Zealand burnweed	NN	SENGLO	
Senecio minimus	Australian burnweed	NN	SENMIN	
Spergularia canadensis	Canadian sandspurry	N	SPECAN	
Symphyotrichum subspicatum	Douglas' aster	N	SYMSUB	
Triglochin maritima	seaside arrow-grass	N	TRIMAR	TM
Typha latifolia	common cattail	N	TYPLAT	TL
*Vaucheria sp.***	yellow-green alga			
Vicia nigricans	giant vetch	N	VICNIG	

* On field maps, the code AE was used for *Potentilla anserina* (formerly *Argentina egedii*) to distinguish it from PA, the code used for *Phalaris arundinacea*.

** Native/non-native status was not evaluated for nonvascular plants.

Emergent wetland plant community mapping

Methods

Wetland vegetation was mapped using aerial photography and field ground-truthing. High-resolution digital aerial photographs (15 cm pixel size) of Bandon National Wildlife Refuge were flown during the last week of May 2015 and orthorectified by Eagle Imaging of Corvallis, Oregon. Images were taken at low tide from a vertical angle, using onboard GPS for automated georeferencing. The project site was traversed on foot to correlate field vegetation with patterns in the aerial photographs. Map units were delineated in the field on enlarged printouts of the aerials. Digital vegetation maps were created in ArcGIS 10.3 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 0.1 ha (0.25 ac). The vegetation map was saved as a shapefile (NL_vegmap_2015.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 2010 and 2013 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 allows flexibility in tracking future vegetation change.

We also characterized plant communities as native-dominated or non-native-dominated, based on the alliance level classification. Native-species alliances such as Baltic rush and slough sedge were considered native-dominated, and non-native alliances such as tall fescue were considered non-native-dominated. The percent cover of native species versus non-native species varied within these alliances.

At the Bandon Marsh Unit reference site, 2015 field reconnaissance showed that the distribution and extent of plant communities had not changed substantially since 2013. Therefore, vegetation was not mapped at the reference site in 2015. Field reconnaissance is recommended for future monitoring events, and re-mapping is recommended when that reconnaissance shows substantial change in the distribution or extent of plant communities.

Results and discussion

Ni-les'tun restoration site

In 2015, four years after restoration, vegetation was still changing rapidly at the Ni-les'tun restoration site. Native-dominated plant communities covered 86.8 ha of the site (Figure 23), up from 69.6 ha in 2013, while non-native dominated communities declined correspondingly (88.0 ha in 2015, down from 102.7 ha in 2013; Table 14). The site was vegetated by complex and intergrading plant associations (Figures 23-25) that were still responding strongly to the 2011 restoration of tidal inundation and salinity regimes, and recovering from the inevitable site disturbances that occur during restoration activities. Ephemeral or "fugitive" species such as brass buttons and common orache -- early colonizers of restoration sites (Cornu and Sadro 2002) -- were much more widespread in 2015 compared to 2013 (Table 15). Accompanied by very salt-tolerant species like saltgrass and pickleweed, these "fugitive" species had even expanded into areas that were dominated in 2013 by the very competitive and opportunistic species, creeping bentgrass. The expansion of these salt-tolerant "fugitive" species strongly suggests the site's vegetation is still far from stabilization.

As expected with restoration of a strongly brackish salinity regime (in summer 2013, daily maximum salinities at Ni-les'tun were 20-30 PSU), 2015 saw continued decline of tall fescue, the non-native pasture grass that had once dominated the majority of the site. The area dominated by tall fescue was halved in 2015 compared to pre-restoration (39.4 ha in 2015 versus 94.8 ha in 2010), showing a consistent trajectory of decline (Table 15). Two prevalent plant associations at Ni-les'tun in 2015 included as dominants either Baltic rush and tall fescue, or Baltic rush and common orache (Table 16). Our field observations indicated that in 2015, associations dominated by common orache had replaced tall fescue on mid-elevation marsh surfaces at the site. Common orache associations had also replaced slough sedge and other herbaceous freshwater wetland associations in the site's northwest corner (near NL T4, Figure 1). Other plant associations that were increasingly prominent across the site in 2015 compared to 2013 were those dominated by brass buttons and creeping bentgrass, both salt-tolerant non-native species (Table 16). Brass buttons is expected to decline with establishment of more competitive species within a few years (Cornu and Sadro 2002), but our field work at other sites indicates that creeping bentgrass may remain dominant for decades (Brophy 2007, 2010).

Spatial vegetation patterns at Ni-les'tun in 2015 consisted mainly of intergraded distributions of individual species, based on their various tolerances of the site's physical conditions, rather than the clear zonation found at least-disturbed tidal wetlands -- or the more consistent groupings of species that might be traditionally called "associations." In other words, the species present varied gradually across the site's elevation, salinity, and channel system density/proximity gradients. This gradual variation presented challenges in mapping. Broad patterns were clearly visible at the alliance level, such as areas still dominated by tall fescue, versus areas dominated by pre-existing Baltic rush where tall fescue has declined. But below the alliance level, there were a multitude of slightly differing mixtures of opportunistic colonizing species (Figure 25), all competing for newly available space under the site's new physical conditions. Because of the resulting large number of associations and their gradual intergradation across the site, the lower-resolution alliance level of mapping may be more useful for visualizing broad vegetation patterns (Figure 24) at this stage of the site's restoration trajectory. After a number of years, we expect vegetation to "sort itself out" into the more organized, zoned patterns seen at least-disturbed tidal wetlands. We recommend monitoring at 3 to 5 year intervals until the rate of change slows, indicating stabilization.

Shapefiles of plant community mapping are available from the Estuary Technical Group on request.

2015 plant communities at Ni-les'tun, colored by native-dominated (green) versus non-native dominated (orange) areas (alliances). Alliance numbers are labeled. Background: 2014 NAIP aerials.

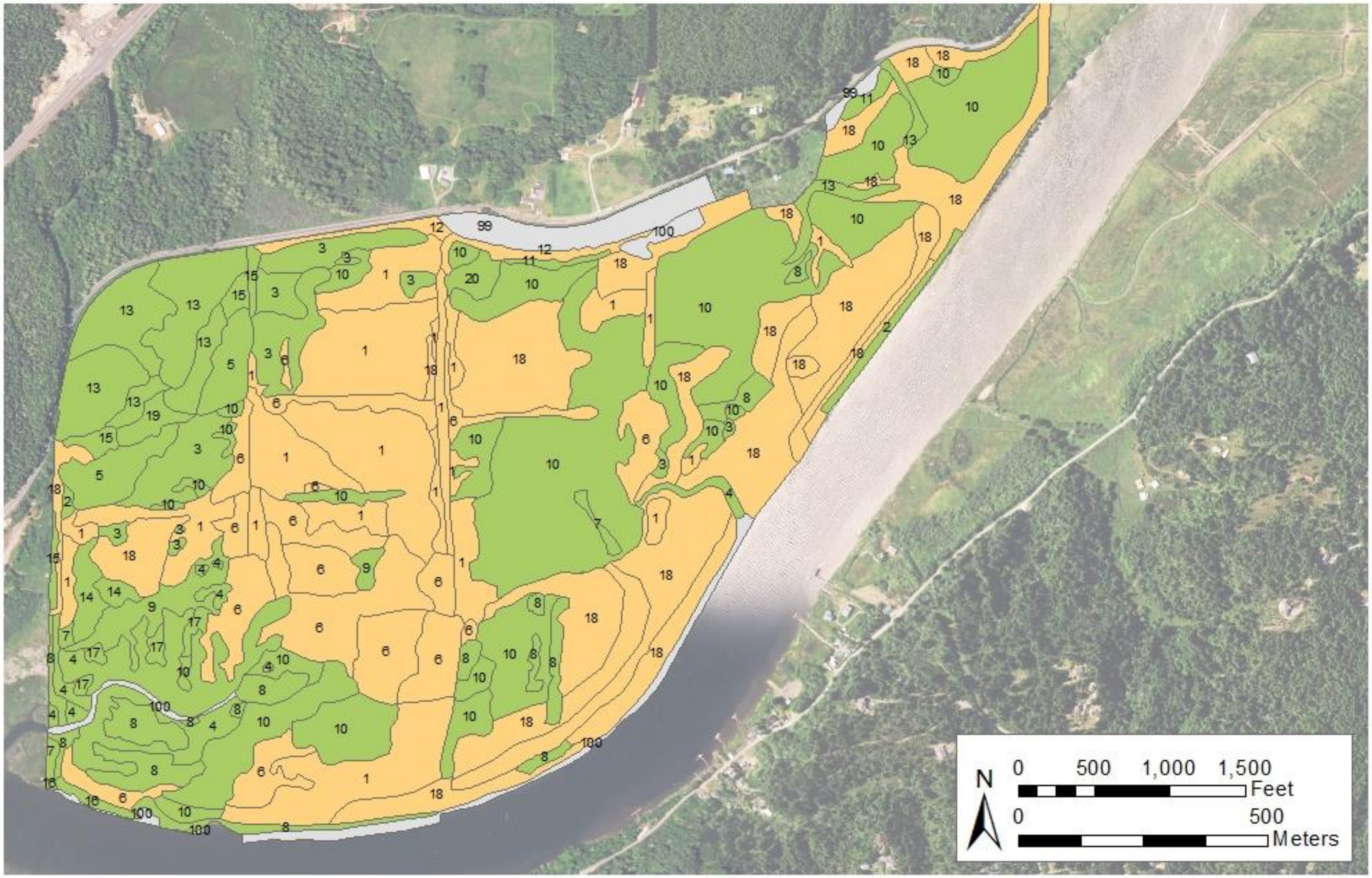

Figure 23. Plant communities at Ni-les'tun in 2015, showing areas dominated by native versus non-native species. Labels show alliance numbers (see Appendix 2, Table A2-1).

2015 plant communities at Ni-les'tun, colored by allliance. Blue/green tones indicate native alliances; orange/pink indicates non-native. Alliance numbers are labeled. Background: 2014 NAIP aerials.

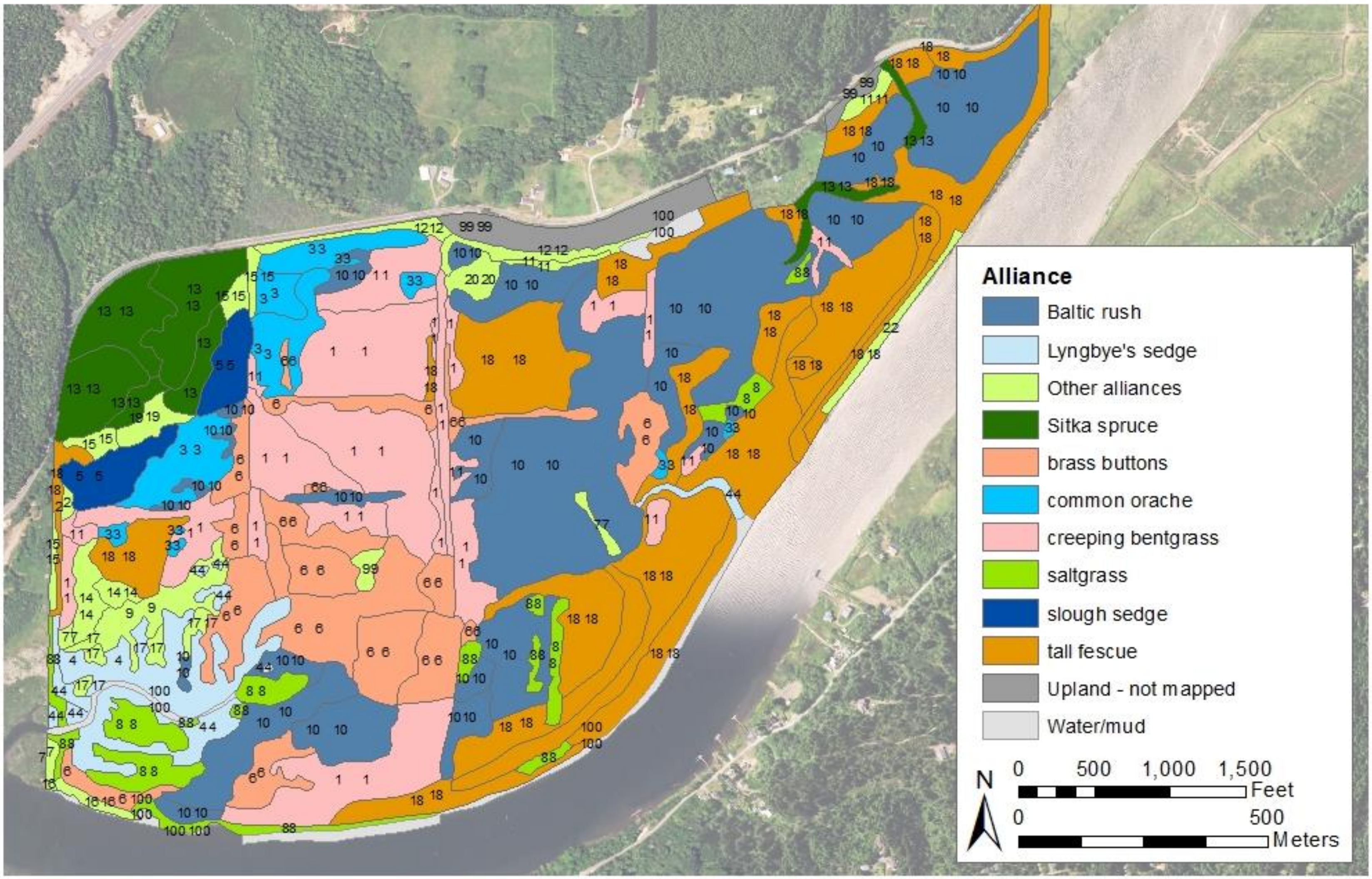

Figure 24. Plant communities at Ni-les'tun in 2015, colored by alliance. Blue/green tones indicate native alliances; orange/pink indicates non-native. Labels show alliance numbers (see Appendix 2, Table A2-1).

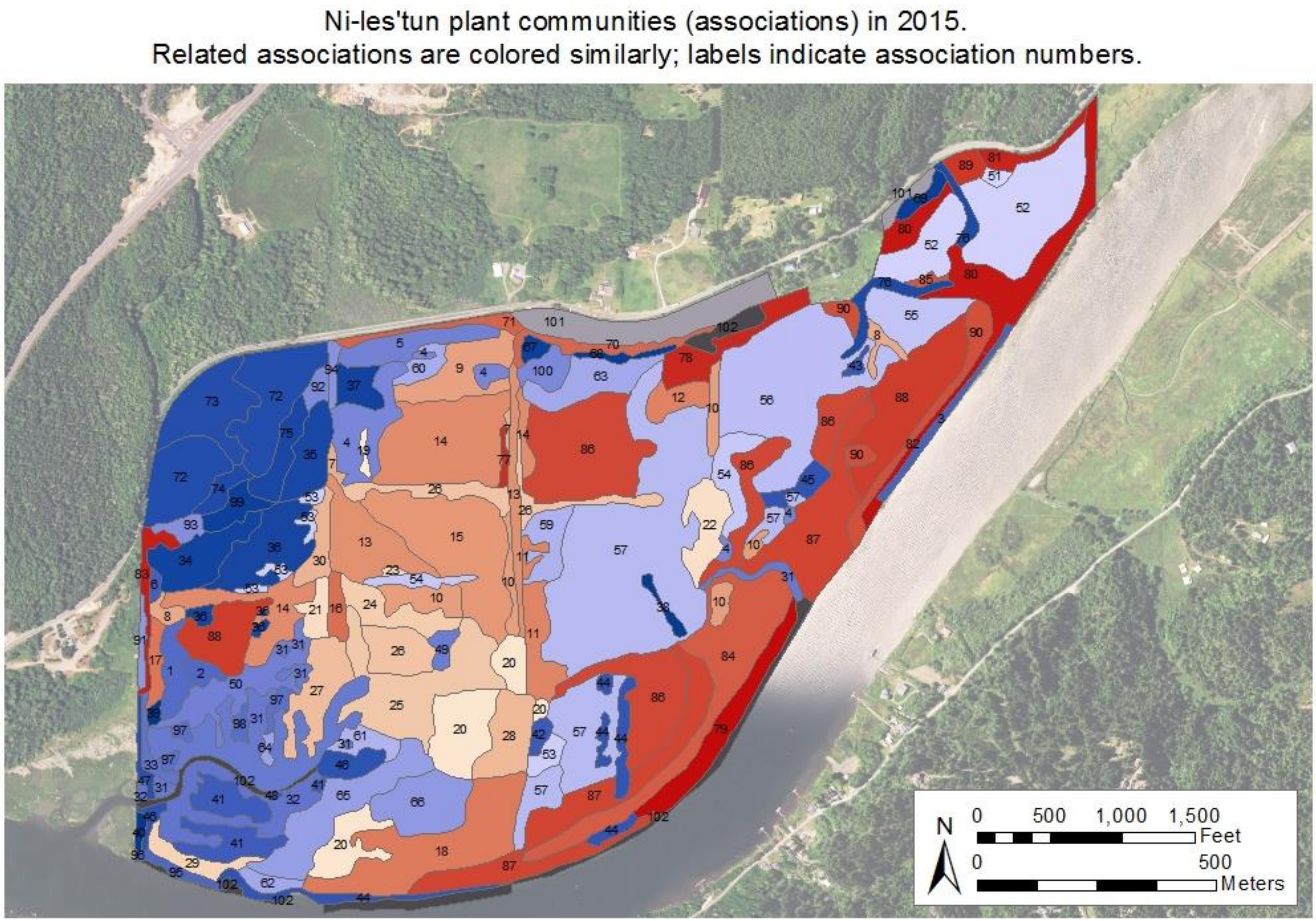

Figure 25. Plant communities (associations) at Ni-les'tun in 2015. Related associations are colored similarly. Blue tones indicate native-dominated associations; orange/red tones indicate non-native. Labels show association numbers (see Appendix 2, Table A2-2).

Table 14. Area of native and non-native-dominated plant communities at Ni-les'tun during pre-restoration (2010), post-restoration year 2 (2013), and post-restoration year 4 (2015). Area figures are for Ni-les'tun only (excluding areas north of North Bank Road and the "Osprey site").

	Area (ha)		
Plant community type	**pre-restoration (2010)**	**post-restoration (2013)**	**post-restoration (2015)**
Native dominated	72.4	69.6	86.8
Non-native dominated	104.2	102.7	88.0
Not mapped (upland/offsite or water/mud)	4.6	8.8	6.3
Grand total	**181.1**	**181.1**	181.1

Table 15. Area of major vegetation types (alliances) at Ni-les'tun during pre-restoration (2010), post-restoration year 2 (2013), and post-restoration year 4 (2015), ordered by area in 2015. Native species are highlighted in green, non-natives in orange. Area figures are for Ni-les'tun only (excluding areas north of North Bank Road and the "Osprey site"). See Table 13 for scientific names of plant species.

Common name	2010 area (ha)	2013 area (ha)	2015 area (ha)
Baltic rush	4.54	26.99	43.22
tall fescue	94.84	68.69	39.43
creeping bentgrass	0.33	31.40	27.71
brass buttons	0.00	0.00	19.42
Sitka spruce	10.94	11.33	10.17
Lyngbye's sedge	5.90	6.29	7.49
common orache	0.39	0.00	7.12
saltgrass	4.22	3.17	6.47
slough sedge	9.40	12.37	3.19
creeping spikerush	0.40	0.00	2.32
reed canarygrass	8.73	2.29	1.41
Pacific silverweed	30.71	3.72	1.26
coastal willow	0.51	0.00	1.22
other alliances (<1 ha)	5.67	5.46	4.34
upland - not mapped	3.27	3.26	3.26
water/mud	1.29	2.77	3.07
grand total	**181.11**	**181.11**	**181.11**

Table 16. Top 20 plant communities (associations) at Ni-les'tun in 2015, ordered by area. A full list of associations is provided in Appendix 2 (Table A2-2). Area figures are for Ni-les'tun only (excluding areas north of North Bank Road and the "Osprey site").

Association #	Association	Area (ha)
57	Baltic rush - common orache - saltgrass - creeping bentgrass	15.83
86	tall fescue - Baltic rush - common orache - creeping bentgrass	9.70
87	tall fescue - Baltic rush - creeping bentgrass	8.08
56	Baltic rush - common orache - creeping bentgrass - creeping spikerush	7.12
14	creeping bentgrass - common orache - creeping spikerush - brass buttons - Baltic rush	6.66
52	Baltic rush - Pacific silverweed - common orache	6.30
88	tall fescue - Baltic rush - creeping bentgrass - Pacific silverweed	5.39
72	Sitka spruce - red alder / slough sedge - skunk cabbage	5.19
15	creeping bentgrass - common orache - Baltic rush - Pacific silverweed	4.84
31	Lyngbye's sedge	4.82
84	tall fescue - Baltic rush	4.82
18	creeping bentgrass - saltgrass - common orache - Baltic rush	4.67
20	brass buttons - common orache	4.13
25	brass buttons - saltgrass – pickleweed	4.02
80	tall fescue - common velvetgrass - colonial bentgrass - birdsfoot trefoil	3.68
13	creeping bentgrass - common orache - creeping spikerush - brass buttons	3.35
26	brass buttons - saltgrass - pickleweed - common orache	3.00
65	Baltic rush - saltgrass - creeping bentgrass	2.99
36	slough sedge (dead/dying) - common orache	2.57
73	Sitka spruce - red alder / coastal willow - salmonberry / slough sedge - skunk cabbage	2.43

CONCLUSIONS AND RECOMMENDATIONS

Year 4 (2015) post-restoration monitoring at Ni-les'tun showed a consistent trajectory towards full recovery of tidal wetland functions at the site. Tidal hydrology was completely restored to the site, with daily maximum tides matching precisely between Ni-les'tun and the adjacent Coquille River. Plant communities remain very dynamic in response to the reintroduction of tidal hydrology and salinity, with salt-tolerant early colonizers spreading across the site and pasture grasses continuing to decline. Plant community changes observed between 2013 and 2015 indicate that plant communities are far from stabilization and can be expected to continue to change substantially for a number of years.

In 2015, only two parameters were monitored (tidal hydrology and emergent vegetation). For all other parameters, post-restoration monitoring has occurred only once (in 2013). To allow accurate evaluation of project effectiveness, we recommend monitoring be continued in 2018 as outlined in our October 2015 monitoring proposal to the Oregon Watershed Enhancement Board (OWEB). That proposal builds on previous OWEB-funded monitoring to track the most important parameters and locations -- those that are especially dynamic during early phases of site recovery, that previously lacked clear trajectory; or that did not approach reference conditions during past monitoring. These include fish use, fish habitat opportunity and capacity, fish prey availability, forested wetland plant communities, channel morphology, salinity, water temperature, groundwater, and soils. Results will provide accountability for OWEB's investments in this project, and through the extensive outreach described in the proposal, will help advance restoration practices and guide other projects.

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APPENDICES

Appendix 1. NAVD88 GEOID model adjustments

Table A1-1. NAVD88 GEOID model adjustments used in 2015 monitoring

Transect	NAD83 transect centroid North latitude	NAD83 transect centroid West longitude	GEOID12A relative to NAD83, m	GEOID09 relative to NAD83, m	GEOID03 relative to NAD83, m	Subtract from NAVD88 to convert from GEOID03 to GEOID12A, m
BM T1	43.144806	124.39680	-26.669	-26.662	-26.692	0.023
BM T2	43.141771	124.40080	-26.688	-26.681	-26.712	0.024
BM T3	43.143184	124.39750	-26.671	-26.664	-26.695	0.024
BM T4	43.143777	124.39943	-26.683	-26.675	-26.706	0.023
NL T2	43.150444	124.38790	-26.626	-26.618	-26.646	0.020
NL T4	43.156719	124.38426	-26.610	-26.603	-26.629	0.019
NL T5	43.156045	124.37062	-26.531	-26.526	-26.552	0.021
NL T9	43.157698	124.37122	-26.536	-26.531	-26.556	0.020
NL T10	43.155717	124.37642	-26.565	-26.558	-26.584	0.019
NL T11	43.153694	124.37600	-26.561	-26.554	-26.581	0.020
NL T12	43.151232	124.37510	-26.554	-26.547	-26.575	0.021
NL T13	43.151889	124.38330	-26.602	-26.593	-26.621	0.019
NL T14	43.154019	124.38370	-26.605	-26.597	-26.625	0.020
NL T15	43.148122	124.38265	-26.594	-26.586	-26.615	0.021
NL T16	43.153188	124.37988	-26.583	-26.575	-26.603	0.020
NL T17	43.147873	124.37870	-26.571	-26.564	-26.593	0.022
NL T18	43.148235	124.38820	-26.626	-26.617	-26.647	0.021
NL T19	43.153111	124.38793	-26.628	-26.620	-26.648	0.020

Appendix 2. Plant alliances and associations

Table A2-1. Full list of vegetation alliances used in plant community mapping at Ni-les'tun in 2015

Alliance #	Alliance name
1	creeping bentgrass
2	red alder
3	common orache
4	Lyngbye's sedge
5	slough sedge
6	brass buttons
7	tufted hairgrass
8	saltgrass
9	creeping spikerush
10	Baltic rush
11	soft rush
12	reed canarygrass
13	Sitka spruce
14	Pacific silverweed
15	coastal willow
16	pickleweed
17	Olney's three-square bulrush
18	tall fescue
19	small-fruited bulrush
20	common cattail
99	Upland - not mapped
100	Water/mud

Table A2-2. Full list of plant associations used in plant community mapping at Ni-les'tun in 2015.

Note: In most cases, associations at Ni-les'tun in 2015 consisted of intergrading distributions of individual species rather than firm groupings. Many of the associations listed below could be "lumped" into lower-resolution groupings, but these would not fully reflect the gradients present on the site. To gain an understanding of broad plant community patterns, use the alliance-level mapping.

Assn #	Association name
1	Pacific silverweed - common orache
2	Pacific silverweed - creeping bentgrass - Baltic rush - common orache
3	Red alder - Sitka spruce / willow
4	Common orache
5	Common orache - Baltic rush
6	Red alder / cascara - willow
7	Creeping bentgrass
8	Creeping bentgrass - Pacific silverweed - common orache
9	Creeping bentgrass - Pacific silverweed - common orache - creeping spikerush
10	Creeping bentgrass - common orache
11	Creeping bentgrass - common orache - saltgrass
12	Creeping bentgrass - common orache - saltgrass - creeping spikerush
13	Creeping bentgrass - common orache - creeping spikerush - brass buttons
14	Creeping bentgrass - common orache - creeping spikerush - brass buttons - Baltic rush
15	Creeping bentgrass - common orache - Baltic rush - Pacific silverweed
16	Creeping bentgrass - tufted hairgrass - saltgrass - pickleweed - common orache
17	Creeping bentgrass - saltgrass - common orache - brass buttons - tufted hairgrass - rabbits-foot grass
18	Creeping bentgrass - saltgrass - common orache - Baltic rush
19	Brass buttons
20	Brass buttons - common orache
21	Brass buttons - common orache - pickleweed
22	Brass buttons - common orache - (sandspurry)
23	Brass buttons - creeping bentgrass - creeping spikerush
24	Brass buttons - saltgrass - creeping spikerush
25	Brass buttons - saltgrass - pickleweed
26	Brass buttons - saltgrass - pickleweed - common orache
27	Brass buttons - saltgrass - pickleweed - common orache - seaside arrowgrass - Baltic rush
28	Brass buttons - saltgrass - pickleweed - creeping bentgrass - common orache
29	Brass buttons - pickleweed
30	Brass buttons - sandspurry
31	Lyngbye's sedge
32	Lyngbye's sedge - saltgrass
33	Lyngbye's sedge - Baltic rush - creeping bentgrass
34	Slough sedge - Pacific silverweed

35	Slough sedge (dead/dying)
36	Slough sedge (dead/dying) - common orache
37	Slough sedge (dead/dying) - reed canarygrass (dead/dying) - common orache
38	Tufted hairgrass - creeping bentgrass
39	Tufted hairgrass - saltgrass - pickleweed - creeping bentgrass
40	Tufted hairgrass - pickleweed - Lyngbye's sedge
41	Saltgrass
42	Saltgrass - common orache
43	Saltgrass - common orache - creeping spikerush
44	Saltgrass - creeping bentgrass
45	Saltgrass - creeping bentgrass - common orache
46	Saltgrass - pickleweed
47	Saltgrass - pickleweed - Lyngbye's sedge
48	Saltgrass - common threesquare
49	Creeping spikerush - brass buttons
50	Creeping spikerush - Baltic rush - saltgrass - brass buttons
51	Baltic rush - (soft rush) - Pacific silverweed - common orache
52	Baltic rush - Pacific silverweed - common orache
53	Baltic rush - common orache
54	Baltic rush - common orache - creeping bentgrass
55	Baltic rush - common orache - creeping bentgrass - Pacific silverweed
56	Baltic rush - common orache - creeping bentgrass - creeping spikerush
57	Baltic rush - common orache - saltgrass - creeping bentgrass
59	Baltic rush - creeping bentgrass - common orache - (tall fescue)
60	Baltic rush - creeping bentgrass - common orache - creeping spikerush
61	Baltic rush - creeping bentgrass - brass buttons - saltgrass - pickleweed
62	Baltic rush - creeping bentgrass - saltgrass - pickleweed
63	Baltic rush - creeping bentgrass - creeping spikerush - common orache
64	Baltic rush - saltgrass
65	Baltic rush - saltgrass - creeping bentgrass
66	Baltic rush - saltgrass - creeping bentgrass - common orache
67	Soft rush - Pacific silverweed - water parsley
68	Soft rush - creeping spikerush
69	Soft rush - common velvetgrass - creeping buttercup - birdsfoot trefoil
70	Reed canarygrass
71	Reed canarygrass - slough sedge - soft rush - birdsfoot trefoil
72	Sitka spruce - red alder / slough sedge - skunk cabbage
73	Sitka spruce - red alder / coastal willow - salmonberry / slough sedge - skunk cabbage
74	Sitka spruce - red alder / small-fruited bulrush - soft rush - slough sedge - skunk cabbage
75	Sitka spruce / slough sedge
76	Sitka spruce / coastal willow / tall fescue - Baltic rush - creeping bentgrass

77	Tall fescue - Pacific silverweed
78	Tall fescue - common orache - creeping bentgrass - Pacific silverweed
79	Tall fescue - creeping bentgrass
80	Tall fescue - common velvetgrass - colonial bentgrass - birdsfoot trefoil
81	Tall fescue - common velvetgrass - Pacific silverweed - birdsfoot trefoil
82	Tall fescue - common velvetgrass - creeping bentgrass
83	Tall fescue - common velvetgrass - birdsfoot trefoil
84	Tall fescue - Baltic rush
85	Tall fescue - Baltic rush - Pacific silverweed - common orache
86	Tall fescue - Baltic rush - common orache - creeping bentgrass
87	Tall fescue - Baltic rush - creeping bentgrass
88	Tall fescue - Baltic rush - creeping bentgrass - Pacific silverweed
89	Tall fescue - Baltic rush - creeping bentgrass - common orache - Pacific silverweed
90	Tall fescue - Baltic rush - birdsfoot trefoil - creeping bentgrass - Pacific silverweed - common velvetgrass
91	Coastal willow - Sitka willow
92	Coastal willow / slough sedge
93	Coastal willow / reed canarygrass - slough sedge - Pacific silverweed - birdsfoot trefoil
94	Coastal willow / reed canarygrass - common velvetgrass - soft rush - birdsfoot trefoil - small-fruited bulrush
95	Pickleweed
96	Pickleweed - saltgrass - jaumea - (seaside arrowgrass - Lyngbye's sedge)
97	Olney's three-square bulrush
98	Olney's three-square bulrush - Baltic rush
99	Small-fruited bulrush - soft rush - slough sedge - birdsfoot trefoil - Pacific silverweed
100	Common cattail - Pacific silverweed - water parsley
101	Upland - not mapped
102	Water/mud