Appendix A: Methods Detail

Vegetation

Plant community percent cover was measured using the point intercept method (Godinez-Alvarez et al. 2009) using one meter by one meter quadrats (50 points per quadrat). The identity of every species that touched each vertical point (using a 3 mm diameter dowel) was recorded (Image 2). Note that the point – intercept method measures plants in vertical as well as horizontal space, allowing more than 100% cover, since canopy plants often overhang subcanopy plants. In most uses of this method, the total percent cover values are corrected so that the maximum value is 100%. In this study, however, we have used the raw percent cover scores, as they contain more information about the horizontal and vertical structure of each species within the overall plant community found in each quadrat.

Vegetation data were collected in August (period of maximum aboveground biomass) during 2008, 2009, and 2010. Vegetation plots one meter on a side were offset by one meter perpendicular to the transect line and two diagonally opposite corners outside the boundary of each plot were marked with stakes. At Wells NERR and Narragansett NERR shallow groundwater wells were located one meter perpendicular to the transect line on the opposite side from the plot (Figure 10).

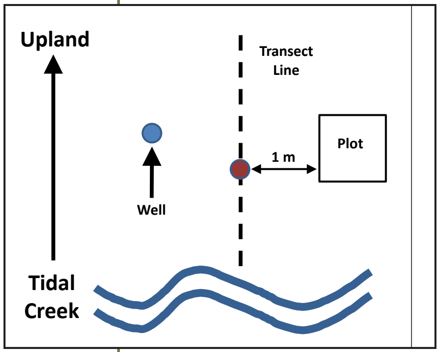

Figure 10. Basic vegetation transect layout and groundwater well location (diagram after Moore 2009).

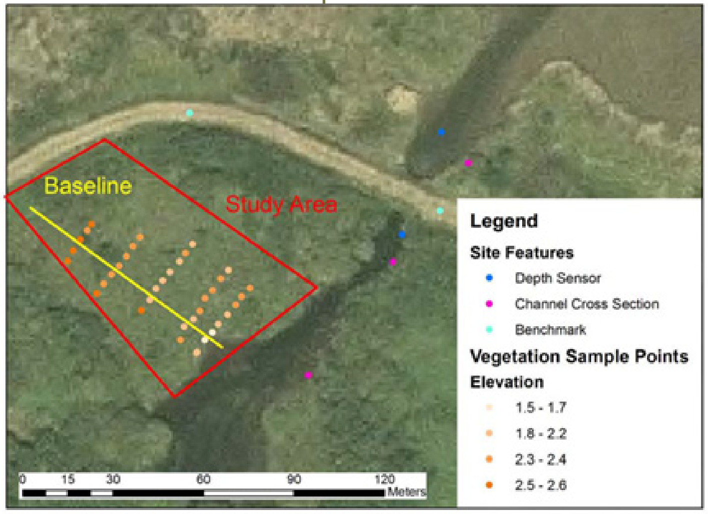

Figure 11. Example of baseline and transect sampling design in an Oregon coast herbaceous tidal wetland (from Roegner et al. 2008).

As noted in the recommendations section, vegetation sampling design methods need to be different for west coast sites than those used in this study. Vegetation transects in west coast emergent tidal wetlands should be oriented parallel to intertidal zonation (e.g., Roegner et al. 2008) (Figure 11). For higher diversity west coast tidal wetland plant communities, we also recommend that a power analysis be conducted to determine the minimum number of vegetation plots needed to detect a specific level of yearly change in percent cover data in.

We also measured (for all participating Reserves for at least one year of the study) plant density and plant height in addition to percent cover in each permanent vegetation plot. Plant density for typical tidal wetland species were measured in 0.25 m^2 or 0.625 m^2 quadrats within the larger 1 m^2 permanent plot, with an exception for the high density species *Spartina patens, Distichlis spicata*, and *Juncus gerardii*, which were counted often in 0.01 m^2 quadrats. Species of concern (e.g. invasive vegetation), were measured directly in the 1 m^2 plots. This was not difficult as these species are large and do not achieve extreme densities in a 1 m^2 area. Plant height was measured for the dominant and subdominant species in the reference marsh, as well as for species of concern. Height was measured for the three longest stems for each species within the 1 m^2 sampling plot.

Salinity

Up to five types of salinity measurements were made (depending on the Reserve:

1) For shallow groundwater wells (installed up to 45 cm depth) water samples were retrieved with a metal tube (perforated at the lower end and fitted with a syringe at the upper end) and measured with a hand-held refractometer.

2) Adjacent to the shallow groundwater wells, pore water was sampled using the perforated metal tube inserted directly into the marsh substrate, to a depth within the top 20 cm (usually six to 16 cm), depending on soil wetness, and salinity measured with a refractometer (measures parts per thousand (ppt) NACL).

3) Adjacent to the deeper groundwater logging wells, porous PVC sippers installed to 20 cm depth in the substrate were used to extract fresh pore water samples. Samples were extracted by clearing the chamber and applying a vacuum using a syringe, and read with a refractometer, or a handheld YSI-85 salinity probe, which measures salinity as Practical Salinity Units (PSU), a dimensionless ratio of conductivity of the sample to an international calibration standard.

4) At groundwater logging wells (installed to one meter depth), salinity was measured as PSU at six- minute intervals during a two week spring-neap tide cycle, using In Situ Aquatroll 200™ instruments.

5) At each vegetation plot, three replicate soil cores, approximated 3.4 cm in diameter, were cut approximately 10-15 cm into the soil. A small section of marsh soil was removed from the bottom of each soil core. Drops of pore water were extracted from the base of the sample using the garlic press and coffee filter method, and salinity was measured with a refractometer (ppt).

Wells and sippers were sampled within 2 hours of low tide, on several dates throughout the June-September sampling period.

Groundwater Level

Spot checks of water level were measured in shallow and deep groundwater wells using a water level probe to locate the water surface during times when Aquatrolls were deployed, as well as for several additional dates throughout the June-September sampling period. Groundwater level was measured at 6 minute intervals in the 1 m deep logger wells using the Aquatroll™ loggers. Percent inundation time for each deep groundwater well was calculated as the percent of time that the water level was higher than the substrate.

Soils

Soil cores were collected by hand with a sharpened, thin-walled, stainless steel tube (3.5 cm diameter) inserted to 20 cm depth. Cores were sectioned longitudinally or horizontally. These sections were used to measure bulk density and organic content by loss on ignition, following standard procedures (Ball 1964, Burt 2004).

Elevation

The position and elevation (NAVD88) of each vegetation quadrat was recorded using survey grade leveling, GPS, or total survey station instruments. Plot elevations were measured as the mean of up to 4 points located within each 1 m^2 plot. Elevations and positions of all wells were measured as single points. Transect profiles marked position and elevation of vegetation zone transitions, channel creek and pool edges, and channel bottom, and points at regular intervals (approximately 10 m) on the marsh platform.

Data Methods

Data Management

Monitoring data collected across five NERRs using standardized data templates were received by the data consultant for series of similar parameters (Vegetation, Pore Water, Groundwater, Soils, and Elevation). Data sheets (Microsoft Excel®) from each Reserve were checked and formatted when necessary to match existing templates. Databases were created for parameters that were collected using similar methodologies. For vegetation data, the data template was repeatedly modified to include newly recorded species, consistency of recorded plant densities and heights, and better overall organization. Once all data sets were standardized to the latest version template, data from each Reserve were combined and housed in an Excel file to create a national database of restoration and reference marsh data. These databases were created for each series of parameters (e.g., vegetation, soils) except for groundwater data collected through Aquatrolls™, which were too extensive to practically combine into one national database. Therefore, groundwater databases remained in files by Reserve.

Data were summarized into means and standard error for each monitored site, yearly, both by marsh zone, and the average of all marsh zones. Summarized data were also housed in Excel® files for each Reserve and sorted by restoration site, along with its paired reference (to facilitate comparison), in separate worksheets within each Reserve file. In instances where several restoration sites shared the same reference site, reference data was duplicated on multiple worksheets. The majority of analyses involved comparing restoration to reference data. These summary databases were intended to provide performance benchmarks for both restoration and reference sites that would be easily transferable to NOAA's Restoration Monitoring Planner.

Performance benchmarks (means and standard error) were summarized for each site (all data pooled, and also by zone – low (L), high (M – for mid-marsh platform), and high marsh/upland transition (H – for high marsh perimeter) for the standard suite of performance variables based on all reference site data collected for each NERR, by year, and for all years combined. These benchmarks are housed in separate data sets by restoration site including paired restoration data designed to easily transfer into 1) NOAA's Habitat Restoration Planner and 2) the Restoration Performance Index (RPI). In addition, summary databases were intended to automatically format annual means by marsh zone for instant input into a custom format designed to compute RPI scores by using a series of linking cells.

Prior to generating the performance benchmarks, raw data for each parameter was defined in the metadata and in some cases manipulated (e.g., averaged to eliminate pseudoreplication – the use of multiple, non-independent measures of the same sampling unit as though they were replicate samples).

Hydrologic parameters include: marsh inundation, groundwater level, and maximum tide. Marsh surface inundation (percent) is defined as the percentage of recorded units (or time) during which water levels were at or above the marsh surface using the continuous groundwater level data. Groundwater level (m) is the average groundwater level and maximum tide data (m) is simply the highest observed water level obtained using that same data set over that same discrete time period.

Soils data include bulk density (mg/m^3) and percent organic matter.

Salinity data were collected using steel or PVC 'sippers' inserted directly in the substrate or shallow groundwater wells. Shallow well parameters included both salinity and groundwater level (m) while pore water sipper collected only information on salinity. Salinity from these spot checks was averaged to station over multiple dates annually. Groundwater levels were also averaged annually and were only utilized in the MDS (multidimensional scaling) analyses (described below).

Vegetation parameters include plant cover, species richness, and height and density. Since point intercept data were collected for 50 points, it was converted into plant species cover by multiplying the values by 2 to convert values to 100% cover. Plant cover for the 5 most abundant species were chosen based on the specific restoration/reference marsh comparison. Percent cover included invasive species to provide the total percent cover for all invasive species. Species richness was the mean of the number of unique species per plot.

Plant heights (cm) utilized in the database represented the two dominant native species and also species of concern, determined from the paired reference marsh using 2010 data. The species for plant density (# m^2) data were chosen based on several factors including regional dominance, species of concern, and local Reserve monitoring protocols. For all sites throughout each of the 5 participating Reserves, the following designated species (if present and monitored) were averaged (mean + SE): *Carex lyngbyei, Distichlis spicata, Juncus gerardii, Phragmites australis, Spartina alterniflora, Spartina alterniflora-short form, Spartina patens, Typha angustifolia*. Species richness is defined as the average number of species per 1 m^2 quadrat.

Data Analyses

Data were analyzed using Analysis of Variance (ANOVA), Regression Analysis, Difference analysis, and non-metric multi-dimensional scaling (MDS) with biota-environment analyses (BEST), analysis of similarity (ANOSIM) and similarity percentage analysis (SIMPER). ANOVA and Regression tests were performed using JMP 9.0.1 © 2010 SAS. MDS, BEST, ANOSIM and SIMPER analyses were performed with PRIMER v.6.1.9 (PRIMER-E Ltd). Our general approach to data synthesis was to combine data by Reserve, and compare variables measured across Reserves to provide a regional picture of restoration performance that allowed for the influence of frequently unique features of individual sites. For some variables we combined data from all restoration sites by restoration type to better understand differences in marsh restoration response to altered hydrology and excavation/fill.

Difference Analyses

Differences between reference and restoration sites for vegetation and hydrology parameters were compared directly using Analysis of Variance (ANOVA), using annual means from 2008-2010. ANOVA is used to determine whether mean values from different groups of data are statistically different at a predetermined level of probability. In this case, the probability value chosen was, $p \le 0.05$, so that a significant difference detected by the ANOVA had at most a 5% chance of being incorrect (this is the standard used in ecological research). ANOVA compares the amount of variation within a group of data to the variation in the means between different groups of data, to determine whether the groups come from the same or different populations or data distributions.

Tukey's HSD was used as the post-hoc means comparison test to adjust the significance level for multiple means comparisons. Data were transformed where necessary to meet assumptions of data distributions (normality, homogeneous variance) required by ANOVA. When assumptions could not be met through data transforms, alternative non-parametric tests requiring no such assumptions were used (Kruskal-Wallis).

In the difference analyses, if a parameter for a restoration site was greater than for its paired reference site, the difference was set to zero, indicating that the site was fully restored for that particular parameter. If the restoration site parameter value was lower than the reference value, this difference was reported as a positive value. The one exception is for parameters related to invasive species, where a positive value indicates that the restoration site has a higher value for that parameter than the reference site.

In addition to difference analyses ANOVAs were completed for soils parameters, plant height and density, and Restoration Performance Index scores (see below for a description of the RPI).

Non-metric Multidimensional Scaling (MDS)

MDS analyses provide two-dimensional plots showing similarities between species assemblage groups (species presence and abundance) through the distance between their locations in the plot. The more separated in space two groups are (e.g., plant communities for restoration and reference sites for a particular Reserve), the less similar they are. The more scattered plant community sample points are within a group, the higher the plant community variability within that group (see Figs. 6-9 and captions for examples and explanations). Similarity values were assigned on a scale of 1-5, with 5 being the lowest similarity. Variation values were assigned on a scale of 1 – 3, with 1 being lowest variation. We are interested in similarity between groups to determine the level of convergence between reference and restoration sites for both abiotic (i.e. hydrologic) and biotic (i.e. plant community assemblages) factors. We are interested in variation within groups to indicate the degree which individual abiotic and biotic variables exhibit a central tendency (mean value). Lower variation for a particular group provides a more discernible picture of its ecological state.

In addition to standard MDS analyses, we used several MDS-based analyses to further investigate species assemblage patterns and relationships. The BEST analysis (Biota-Environment Stepped Analysis) related plant community assemblage data to a suite of abiotic parameters (soil bulk density, soil percent organic content, soil pore water salinity, groundwater level, and elevation) that were collected in association with the stations where vegetation data were collected. This analysis identified the key abiotic correlates of the observed plant communities. The strength of the correlation is expressed as the square of r, the correlation coefficient. The value of r2 quantifies the amount of variation in the plant community that is explained by variation in abiotic parameters.

While MDS allows detailed examination of similarity patterns between variables, it does not provide statistical tests of these comparisons. ANOSIM (Analysis of Similarity) provides statistical tests by generating a large number randomly permuted similarity matrices of the species assemblage data to create a probability distribution for the R statistic, which is centered around zero, since randomly created similarity matrices will reflect the null hypothesis of no difference between groups. The created distribution determines the probability that the actually observed similarities will belong to the random (and therefore null) distribution. ANOSIM was used to determine significant differences between plant community assemblages for restoration and reference site pairs, and SIMPER (Similarity Percent) determined which species contributed the most to the observed differences. For the SIMPER analyses, species that, when ranked by percent cover, were not included in the 90% cumulative contribution, were not included in the analyses to prevent rare species from having undue influence on the similarity calculations between samples.

Data input to PRIMER software for all MDS analyses were the average of the 3 years of monitoring (2008-10) for both plant and abiotic parameters, and plant community assemblages, in the form of percent cover data for all species present. Groundwater level data associated with vegetation data for MDS were not available from South Slough and North Carolina, and soil bulk density was not available from North Carolina, so only the remaining abiotic parameters were used for these Reserves.

Restoration Performance Index (RPI)

The Restoration Performance Index (RPI: Moore et al. 2009) is a simple method to measure change over time in restoration sites relative to reference sites or reference benchmarks. Ideally, monitoring begins prior to restoration, but the RPI can be applied to any time series of data. For example, restoration site improvement may slow down as time progresses, and will be reflected as a smaller change from year to year in the RPI.

We calculated the Restoration Performance Index using structural and functional variables measured in more than one year (see above –hydro, vegetation). Since soils and elevation were measured only once during the course of this study, they could not be used in the RPI to measure change. The index is the weighted sum of RPI scores measured for each selected variable over the specified time interval, and can be used to describe restoration trajectories. The RPI score for a given variable, for example, pore water salinity, is described in the sidebar on page four.

The RPI value represents the percent similarity between the restoration and the reference site for each indicator variable. If an indicator variable has the same value in the restoration and the reference site at a given time point, the score will be 1. The lowest allowed RPI score is zero, such that negative scores (when restoration parameters values decline relative to their starting point) are reset to zero.

Indicator variable RPI scores were weighted by tidal wetland zone (low, high, and upland transition), by the number of parameters, and the number of component parameter scores to create a single overall RPI summary score. For example, to compute a component score for Vegetation component, the RPI for percent cover of 5 most common reference site species was averaged across zones (e.g. percent cover for low+high+upland transition÷3). Species richness was calculated for mid marsh plots only because of the extremely low richness in the low marsh and high variability of high marsh-upland transition plots. The scores for each parameter were then divided by two and summed to provide a component score with each parameter weighted equally. The same zone-weighting was done for Hydrology component (salinity, percent inundation time, ground water level, high tide level). Since there were four parameters contained in the Hydrology component score, each parameter RPI score was divided by 4 and then summed with the others. Each of the two component scores was divided by two. The maximum score for each of the 2 vegetation parameters would be 0.25, indicating parity with the reference site. The maximum score for each hydrology parameter would be 0.125, indicating full restoration for that parameter. If parameters were missing for a given year, then the RPI score would be weighted by the number of parameters available for that year. The summary RPI score was the simple sum of the two weighted component scores, with a maximum value of 0.5 for each, which would indicate full restoration for that suite of parameters.

Linear Regression Analysis

Linear regression tests the significance and strength of association of two variables, an independent causal variable, and a dependent response variable, by fitting a straight line to the paired independent-dependent variable pairs. RPI vegetation component scores (dependent variable) were regressed individually against two causal variables identified in the BEST analysis (elevation and depth to groundwater). Because the RPI is a proportion, the data were arcsine square-root transformed to meet assumptions of parametric statistics. The specifics of RPI data management are described below and in an overview in the following section. Regression results include the equation for the straight line describing the association, and the correlation coefficient (r), which when squared (r2) quantifies the amount of variation in the dependent variable, is explained by variation in the causal variable.

Appendix B: Results Detail

In this section we present the outcomes of the analyses describe above without interpretation. Interpretation of results is presented in the Project Discussion section.

Restoration Performance Index (RPI)

For this synthesis report, we used the Restoration Performance Index (RPI) data to compare parameters between the two restoration types, hydrologic and excavation/fill, represented in this study. When RPI total scores (vegetation and hydrology subcomponent scores combined for a maximum value of 1) were compared, there was no significant difference between excavation/fill and hydrologic restoration sites. Nor was there any significant difference between restoration types for the individual vegetation or hydrology component scores, either by year (2009, 2010), or by yearly average (Tables 5 and 6; Figures 12-14).

The same was true for pore water salinity difference analyses (Figure 15), although the difference from the reference trended higher for hydrologic compared to excavation/fill restoration sites, and is in a negative direction (i.e. lower than the reference). Salinity data from deep groundwater loggers were not used, as data were only available from three locations, and generally not collected on same dates for restoration-reference site pairs (most sites only had three to four data loggers available).

The difference in percent cover of invasive species (primarily Phragmites) was greater than the reference only for hydrologic restoration sites (Figure 16).

RPI hydrology subcomponent scores (Table 7) from restoration sites are generally similar to the values obtained at their paired reference sites (less than 10 percent difference), with pore water salinity and marsh surface inundation showing the most frequent differences greater than 10

Table 5. RPI component scores for Hydrology and Vegetation, and Total scores. Maximum value for component scores is 0.5, unless only one component used, then maximum value is one.

Reserve	Reference Sites	Restoration Sites	Rest. Type	YEAR 1			YEAR 2			AVERAGE		
				Hydro	Veg	Total	Hydro	Veg	Total	Hydro	Veg	Total
Wells, ME	Webhannet Marsh	Cascade Brook	H	0.3	0.28	0.58	0.24	0.3	0.54	0.27	0.29	0.56
		Drakes Island	H	0.29	0.18	0.47	0.26	0.06	0.32	0.275	0.12	0.395
		Spruce Creek	H	0.25	0.15	0.4	0.35	0.32	0.67	0.3	0.235	0.535
		Wheeler Marsh	H	0.41	0.33	0.74	0.37	0.35	0.72	0.39	0.34	0.73
Narragansett, RI	Nag Marsh	Potter Pond	H		0.69	0.69	0.5	0.37	0.87	0.5	0.53	0.78
		Silver Creek	H	0.25	0.32	0.57	0.2	0.36	0.56	0.225	0.34	0.565
		Walker Farm	H	0.5		0.5	0.4	0.09	0.49	0.45	0.09	0.495
	Coggeshall Marsh	Gooseneck Cove	H	0.44	0.32	0.76		0.23	0.23	0.44	0.275	0.495
	Jacobs Point	Jacobs Point	H				0.14	0.28	0.42	0.14	0.28	0.42
Chesapeake VA	Goodwin Islands	Naval Weapons	E	0.25	0.33	0.58	0.34	0.16	0.5	0.295	0.245	0.54
		Hermitage	E	0.37	0.2	0.57	0.34	0.2	0.54	0.355	0.2	0.555
	Taskinas Creek	Chaetham Annex	E	0.38	0.22	0.6	0.39	0.08	0.47	0.385	0.15	0.535
North Carolina	Middle Marsh	DUMarineLab	E	0.5	0.38	0.88	0.5	0.38	0.88	0.5	0.38	0.88
		NC Marine	E		0.33	0.33	0.5	0.17	0.67	0.5	0.25	0.5
		Pine Knoll	E	0	0.48	0.48	0.33	0.43	0.73	0.165	0.455	0.605
South Slough OR	Danger Point Marsh	Kunz Marsh	H, E		0.11	0.11	0.17	0.03	0.2	0.17	0.07	0.155
	Yaquina 28	Yaquina 27	H		0.11	0.11	0.5	0.14	0.64	0.5	0.125	0.375

RESTORATION TYPE	N	YEAR 1						YEAR 2						AVERAGE					
		Hydro		Veg		Total		Hydro		Veg		Total		Hydro		Veg		Total	
		X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE
Excavation	7	0.34	0.05	0.25	0.05	0.54	0.08	0.3	0.09	0.29	0.05	0.51	0.09	0.37	0.04	0.2	0.04	0.57	0.08
Hydrologic	11	0.33	0.04	0.25	0.04	0.5	0.05	0.35	0.04	0.28	0.06	0.49	0.07	0.31	0.04	0.23	0.04	0.52	0.06
t Ratio		0.09		0.08		0.42		-0.58		0.2		0.12		0.89		-0.35		0.54	
P>|t|		0.93		0.94		0.68		0.57		0.84		0.91		0.39		0.73		0.6	

Table 6 Mean, standard errors, and p values for RPI scores for restoration type comparisons.

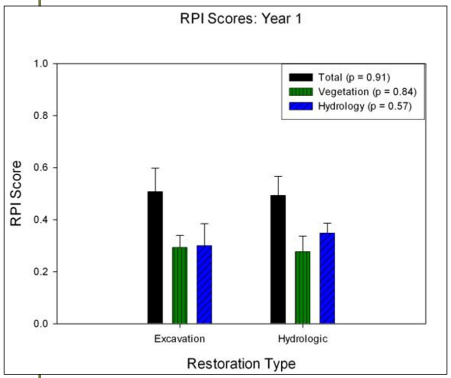

Figure 12. Comparisons of RPI scores for 2008-2009 by restoration type, showing total and component scores (vegetation and hydrology). Restoration types were not significantly different. @ p <= 0.05.

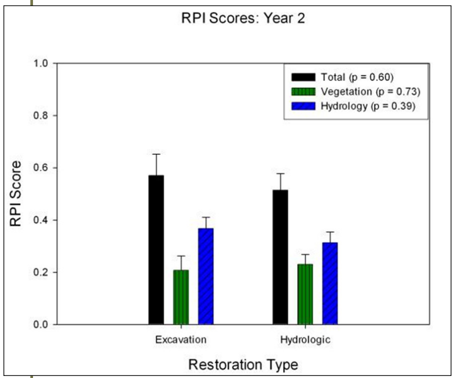

Figure 13 Comparisons of RPI scores for 2009-2010 by restoration type, showing total and component scores (vegetation and hydrology). Restoration types were not significantly different @ p <= 0.05.

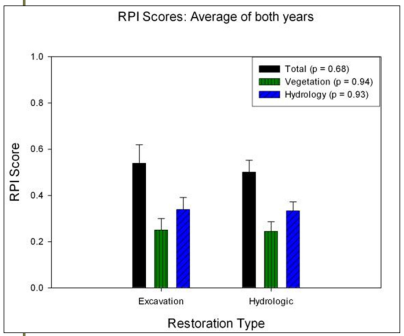

Figure 14 Comparisons of RPI scores for 2008-2010 by restoration type, showing total and component scores (vegetation and hydrology). Restoration types were not significantly different @ p <= 0.05.

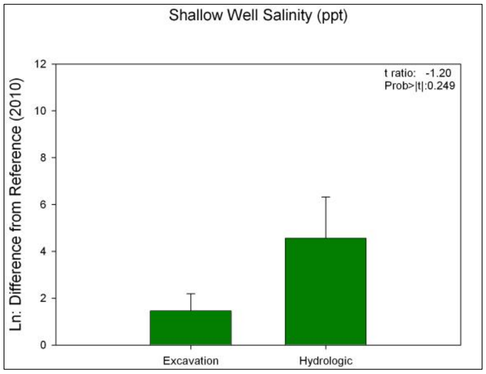

Figure 15. Comparisons of pore water salinity differences between reference and restoration sites by restoration type. Restoration types were not significantly different @ p <= 0.05.

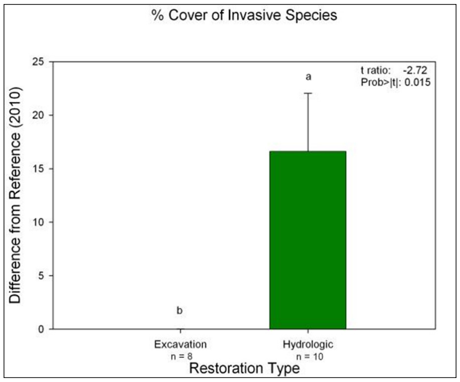

Figure 16. Comparisons of differences in percent cover of invasives between reference and restoration sites by restoration type. Restoration types were significantly different @ p <= 0.05.

Reserve	Restoration Sites	Rest. Type	RPI PARAMETER DIFFERENCES (Reference minus Restoration)							
			Year	PORE-WATER (PSU)	INUNDATION MARSH SURFACE (%)	GROUNDWATER LEVEL (m)	MAX HIGH TIDE (m)	5 DOMINANT PLANT COVER (%)	INVASIVE COVER (%)	SPECIES RICHNESS (# m^{-2})
Wells, ME	Cascade Brook	H	2008	12.22	0	0	0	10	20.13	0
	Drakes Island	H	2008	8.68	0	0	0.12	7.15	11.73	1.11
	Spruce Creek	H	2008	3.44	0	0	0.22	6.69	6.13	0.44
	Wheeler Marsh	H	2008	6.72	0	0	0.16	5.15	0	0
Narragansett, RI	Gooseneck Cove Marsh	H	2008	1.93				4.12	16	0.09
	Jacob's Point Restoration	H	2008	18.23				20.76	75.04	0.69
	Potter Pond	H	2008					9.74	22	0.27
	Silver Creek Marsh	H	2008	8.1				8.02	31.52	0
	Walker Farm	H	2008	9.57				18.7	74.48	0
Chesapeake VA	Chaetham	E	2008	5.37	5.05	0	0	14.84	0	0.6
	Hermitage	E	2008	3.42	0	0.19	0.21	4.02	0	0.77
	Naval Weapons	E	2008	6.91	49.49	0.63	0.63	11.23	1.6	0.8
North Carolina	DUMarineLab	E	2008	0				19.31	0	0
	NC Marine	E	2008	0				4.67	0	0
	Pine Knoll	E	2008	0				23.96	0	0
South Slough OR	Kunz Marsh	H	2008					23.5	2.61	3.51
	Kunz Marsh	E	2008					23.5	0	3.51
	Yaquina 27	E	2008	0				15.17	0	1.71
Wells, ME	Cascade Brook	H	2009	17.39	0	0	0	9.07	53.2	0
	Drakes Island	H	2009	4.83	0	0	0.25	8.45	18.13	0.44
	Spruce Creek	H	2009	7.22	0	0	0.17	3.97	6.67	0.44
	Wheeler Marsh	H	2009	0	0	0	0	5.39	0	0
Narragansett, RI	Gooseneck Cove Marsh	H	2009	0				4.9	9.04	0
	Jacob's Point Restoration	H	2009	24.02						
	Potter Pond	H	2009	0	0	0.03	0.29	8.52	19.21	0
	Silver Creek Marsh	H	2009	5.12				7.23	26.64	0
	Walker Farm	H	2009	3.23	47.52	0.15	0.34			
Chesapeake VA	Chaetham	E	2009	5.68	0	0	0	10.97	0	0.33
	Hermitage	E	2009	4.66	0	0	0	3.79	0	0.47
	Naval Weapons	E	2009	6.15	7.36	0.13	0.22	8.92	2.2	0
North Carolina	DUMarineLab	E	2009	0				12.91	0	0
	NC Marine	E	2009	0				3.39	0	0.12
	Pine Knoll	E	2009	0				13.27	0	0
South Slough OR	Kunz Marsh	H	2009		0	0	0	27.26	2.28	4.31
	Kunz Marsh	E	2009		0		0.06	27.26	0	4.31
	Yaquina 27	E	2009	0	0	0	0	15.2	0	1.4
Wells, ME	Cascade Brook	H	2010	13.58	15.37	0	0.09	12.03	39.33	0
	Drakes Island	H	2010	4.47	16.19	0	0.34	5.84	0	0.67
	Spruce Creek	H	2010	5.17	7.62	0	0	3.55	7.2	0
	Wheeler Marsh	H	2010	0	18.36	0	0	2.4	0	0
Narragansett, RI	Gooseneck Cove Marsh	H	2010		0	0	0	14.39	5.48	0.52
	Jacob's Point Restoration	H	2010	12.11				23.49	47.29	0.63
	Potter Pond	H	2010	0	0	0.01	0	7.12	18	0.02
	Silver Creek Marsh	H	2010	5.72	0	0	0	7.21	30.73	0
	Walker Farm	H	2010	0	0	0	0.02	17.74	16.22	
Chesapeake VA	Chaetham	E	2010	4.87	0	0	0	3.24	0	0.78
	Hermitage	E	2010	3.4	0	0	0	0	0	0.3
	Naval Weapons	E	2010	3.4	20.92	0.11	0.07	0.32	0.1	0.65
North Carolina	DUMarineLab	E	2010	0	0	0.05	0.3	17	0	0
	NC Marine	E	2010	0	0	0	0	16	0	0.09
	Pine Knoll	E	2010	0	0	0	0.25	23.8	0	0
South Slough OR	Kunz Marsh	H	2010	0	0	0	0.24	25.36	1.84	3.76
	Kunz Marsh	E	2010	0	0	0.28	0.62	25.36	0	3.76
	Yaquina 27	E	2010	0	0	0	0	15.71	0	1.19

Table 7 RPI parameter differences between restoration and paired reference sites (reference minus restoration). Negative values (where restoration site value greater than reference) are converted to zeros, indicating that the restoration site has achieved or exceeded the reference value. Note: Percent invasive cover was not an RPI parameter, but is included as a parameter of great interest. Negative values for differences in percent cover were converted to positive values rather than to zero for this variable, as in this case, exceeding the reference value is not a desired outcome. Light blue cells indicate 10-20% difference from reference value. Light green cells indicate > 20% difference from reference value.

percent (six of 54 comparisons or 11 percent, the same for both parameters).

Plant community parameters differed from reference values much more frequently. For percent cover of the five dominant reference plant species, restoration sites differed by at least 10-20 percent for 30 percent of comparisons, and by more that 20 percent for 19 percent of comparisons. Species richness at restoration sites did not differ from the paired reference values by 10 percent or more in any case.

Results of individual RPI analyses can be found in each Reserve's site report and will not be presented here. Graphical results from these analyses are included in the data appendices for this synthesis report.

Difference Analyses

When the difference between reference and restoration sites for each variable measured in this study is statistically compared between excavation/fill and hydrologic restoration types (Table 8), only a few parameters differ significantly. In addition to groundwater salinity and invasive percent cover (see above under RPI), the differences in invasive stem density (analyzed for 2010 only) between reference and restoration sites were greater for hydrologic restoration than for excavation/fill sites, with stem densities higher in the restoration sites than in the paired reference sites.

Results of individual difference analyses can be found in each Reserve's site report and will not be presented here. Graphical presentations of results from these analyses are accessible in a Data Appendix submitted to the NOAA Restoration Center.

Table 8. Means, standard errors, and significance levels for parameter value differences (reference minus restoration) by restoration type. Light blue cells indicate significant differences ($p < 0.05$)

			Parameter Differences between Reference and Restoration by Restoration Type											
	N		2008				2009				2010			
	Excavation	Hydrologic	Excavation		Hydrologic		Excavation		Hydrologic		Excavation		Hydrologic	
	N	N	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE
Hydrology														
Salinity	8	9	2.24	1.12	8.61	1.8	2.36	1.12	6.87	2.81	1.46	0.73	4.56	1.76
Inundation Marsh Surface	8	9	18.18	15.72	0	0	1.47	1.47	6.79	6.79	2.61	2.61	6.39	2.7
Ground Water Level	8	9	0.27	0.19	0	0	0.03	0.03	0.03	0.02	0.05	0.03	0	0
Max High Tide	8	9	0.28	0.18	0.13	0.05	0.06	0.04	0.15	0.06	0.16	0.08	0.08	0.04
Vegetation														
5 Dominant Plant Cover	8	10	14.59	2.71	11.38	2.2	11.96	2.66	9.35	2.64	12.68	3.6	11.91	2.58
Invasive Cover	8	9	0.2	0.2	25.97	8.67	0.28	0.28	16.9	6.1	0.01	0.01	16.61	5.42
Species Richness	7	10	0.81	0.47	0.71	0.33	0.75	0.6	0.73	0.47	0.8	0.51	0.68	0.37
Native Stem Density	7	10	-	-	-	-	-	-	-	-	183.2	87.11	143.2	54.37
Invasive Stem Density	2	8	-	-	-	-	-	-	-	-	0.11	0.11	9.48	2.64
Dominant Stem Height	7	7	-	-	-	-	-	-	-	-	6.45	5.49	0.47	0.47
Soils														
Bulk Density	5	10	-	-	-	-	-	-	-	-	1.04	0.43	0.12	0.05
Organic Matter	8	10	-	-	-	-	-	-	-	-	14.83	4.85	14.42	4.84

Multidimensional Scaling (MDS) of Abiotic Factors by Zone and Site

Similarity

Marsh zone abiotic factors (soil bulk density and percent organic content, salinity, depth to groundwater, and marsh surface elevation) were less similar for excavation/fill sites than for hydrologic sites (Table 9-13). Reference restoration site pairs were most similar at Narragansett, with Jacobs Point showing greatest similarity (level 2), the three Nags Marsh pairs showing intermediate similarity (level 3), and Coggeshall showing least similarity to Gooseneck Cove (level 4). Other site pairs showing high similarity included Taskinas Creek-Naval Weapons Station (level 1), Goodwin Islands-Heritage (level 2), both at Chesapeake; and Y-28 - Y-27 associated with South Slough OR (level 2). The degree of similarity between restoration and reference pairs at Chesapeake and South Slough sites pairs is similar to that of Narragansett. Wells and North Carolina showed the least degree of similarity between reference-restoration site pairs (nearly all at level 4 and level 5).

When similarity scores were totaled for each Reserve, and the Reserves ranked, Wells had the greatest similarity among marsh zones, followed by Narragansett, Chesapeake and South Slough (tied), and North Carolina (Table 3). Restoration at Narragansett and Chesapeake emphasized hydrologic restoration; Wells, South Slough and North Carolina focused on excavation/fill. Similarity rankings by reference-restoration site pairs, from high similarity to low similarity, were: Chesapeake, South Slough, Narragansett, Wells, and North Carolina (Table 3).

Table 9. Top: Similarity and variation of abiotic factors by zone and site (based on resemblance of Euclidian distances). Levels were assigned based on visual observation of sample patterns projected on 2-dimensional plots. Bottom: Similarity and variation of plant communities by zone and site (based on resemblance of Bray-Curtis similarities). For variation by site and zone (lower right corner of panel) P represents an assessment for pooled zone data. For both top and bottom panels, similarity and variation levels were assigned based on visual observation of sample patterns projected on 2-dimensional plots. All plots are included in a Data Appendix submitted to the NOAA Restoration Center. Example plots and explanation of pattern interpretations are presented in Figures 19-22.

	Wells ME								
	SIMLARITY						VARIATION		
ABIOTIC	1	2	3	4	5		1	2	3
Zone (low,mid,high)						Zone (low,mid,high)			
L - M		■				L		■	
L - H		■				M		■	
M - H		■				H		■	
Site (ref-rest)						Site			
WB - CB				■		WB	■		
WB - DI				■		CB	■		
WB – SC			■			DI	■		
WB - WM				■		SC	■		
						WM			■

	Wells ME																	
	SIMILARITY					VARIATION												
Community	1	2	3	4	5		1				2				3			
Zone						Zone												
L - M	■					L						■						
L - H					■	M						■						
M - H				■		H										■		
Site																		
L					■													
M			■															
H					■													
							Zone											
							P	L	M	H	P	L	M	H	P	L	M	H
Site (Ref-Rest)						Site												
WB - CB				■		WB		■					■		■			■
WB - DI			■			CB							■	■	■			
WB - SC		■				DI	■		■	■		■						
WB - WM	■					SC		■					■	■	■			
						WM		■						■	■		■	

Narragansett RI									
	SIMLARITY						VARIATION		
ABIOTIC	1	2	3	4	5		1	2	3
Zone (low,mid,high)						Zone (low,mid,high)			
L - M						L			
L - H						M			
M - H						H			
Site (ref-rest)						Site			
NA - PO						NA			
NA - WA						JRF			
NA - SI						CS			
JRF - JR						PO			
CS - GN						WA			
						SI			
						JR			
						GN			

Narragansett RI																		
	SIMILARITY					VARIATION												
Community	1	2	3	4	5		1				2				3			
Zone						Zone												
L - M						L												
L - H						M												
M - H						H												
Site																		
L																		
M																		
H																		
							Zone											
							P	L	M	H	P	L	M	H	P	L	M	H
Site (Ref-Rest)						Site												
NA - PO						NA												
NA - WA						JRF												
NA - SI						CS												
JRF - JR						PO												
CS - GN						WA												
						SI												
						JR												
						GN												

Table 10. Top: Similarity and variation of abiotic factors by zone and site. Bottom: Similarity and variation of plant communities by zone and site. See Table 9 for further details. Unshaded cells represent insufficient data to determine patterns.

Chesapeake VA									
	SIMLARITY						VARIATION		
ABIOTIC	1	2	3	4	5		1	2	3
Zone (low,mid,high)						Zone (low,mid,high)			
L - M						L			
L - H						M			
M - H						H			
Site (ref-rest)						Site			
GI - HE						GI			
TC - NW						TC			
TC - CA						HE			
						NW			
						CA			

Chesapeake VA																		
	SIMILARITY					VARIATION												
Community	1	2	3	4	5		1				2				3			
Zone						Zone												
L - M						L												
L - H						M												
M - H						H												
Site																		
L																		
M																		
H																		
							Zone											
							P	L	M	H	P	L	M	H	P	L	M	H
Site (Ref-Rest)						Site												
GI - HE						GI				\				\				\
TC - NW						TC				\				\				\
TC - CA						HE				\				\				\
						NW												
						CA				\				\				\

Table 11. Top: Similarity and variation of abiotic factors by zone and site. Bottom: Similarity and variation of plant communities by zone and site. See Table 9 for further details. Unshaded cells represent insufficient data to determine patterns. Back slashes indicate no data.

Table 12. Top: Similarity and variation of abiotic factors by zone and site. Bottom: Similarity and variation of plant communities by zone and site. See Table 9 for further details. Unshaded cells represent insufficient data to determine patterns. Back slashes indicate no data.

	North Carolina								
	SIMILARITY						VARIATION		
ABIOTIC	1	2	3	4	5		1	2	3
Zone (low,mid,high)						Zone (low,mid,high)			
L - M						L			
L - H						M			
M - H						H			
Site (ref-rest)						Site			
MM - PK						MM			
MM - DU						PK			
MM - NC						DU			
						NC			

	North Carolina																	
	SIMILARITY					VARIATION												
Community	1	2	3	4	5		1				2				3			
Zone						Zone												
L - M						L												
L - H						M												
M - H						H												
Site																		
L																		
M																		
H																		
							Zone											
							P	L	M	H	P	L	M	H	P	L	M	H
Site (Ref-Rest)						Site												
MM - DU						MM												
MM - NC						DU				\				\				\
MM - PK						NC												
						PK												

Table 13. Top: Similarity and variation of abiotic factors by zone and site. Bottom: Similarity and variation of plant communities by zone and site. See Table 9 for further details. Unshaded cells represent insufficient data to determine patterns. Back slashes indicate no data.

	South Slough OR								
	SIMLARITY						VARIATION		
ABIOTIC	1	2	3	4	5		1	2	3
Zone (low,mid,high)						Zone (low,mid,high)			
L - M						L			
L - H						M			
M - H						H			
Site (ref-rest)						Site			
Y28 – Y27						Y28			
DP – KM						DP			
						Y27			
						KM			

	South Slough OR																	
	SIMILARITY					VARIATION												
Community	1	2	3	4	5		1				2				3			
Zone						Zone												
L - M						L												
L - H						M												
M - H						H												
Site																		
L																		
M																		
H																		
							Zone											
							P	L	M	H	P	L	M	H	P	L	M	H
Site (Ref-Rest)						Site												
Y28 – Y27						Y28		\		\		\		\		\		\
DP – KM						DP												
						Y27		\				\				\		
						KM		\				\				\		

Variation

Low and mid marsh zones displayed intermediate variation at most sites across Reserves (Table 9-13). Highest variation (level 3) was observed (for low marsh) at Chesapeake and North Carolina (excavation/fill), and (for high marsh) at Narragansett (hydrologic) and South Slough (excavation/fill). Lowest variation (level 1) was observed for the mid-marsh platform in North Carolina and South Slough.

Abiotic variation was lowest (level 1) for the majority of sites at Wells, Chesapeake, and North Carolina (all sites at level 1). All reference sites at these Reserves showed low (level 1) variation.

Narragansett displayed the widest range of variation for both reference and restoration sites (level 1 to level 3), and South Slough sites were the most uniform (all level 2).

When variation scores were totaled for each Reserve and the Reserves ranked, Wells, North Carolina and South Slough were tied for the lowest variation within marsh zones, followed by Narragansett and Chesapeake. Individual sites showed lowest variation in North Carolina, followed by Wells, Chesapeake, Narragansett and South Slough.

Multidimensional Scaling of Plant Communities by Zone and Site

Similarity

Observed similarities among plant communities across zones were intermediate to low (level 3 to level 5) among Reserves (Table 9-13). The few exceptions were high similarity (level 1) between low- and mid marsh plots at Wells, and high to intermediate similarity (level 2) between mid-marsh platform and high marsh (upland transition) at North Carolina and South Slough.

Similarity within zones across sites followed a comparable pattern, with all but one Reserve showing intermediate to low similarity (level 3 to level 5). The one exception was for low marsh at North Carolina, with high to intermediate similarity (level 2) across sites. Similarity for restoration-reference pairs ranged from level 3 to level 5 for the most part. The most similar site pairs occurred in Wells, for Wheeler Marsh (level 1), and Spruce Creek (level 2); in North Carolina for NC Maritime (level 2); and in South Slough for Kunz Marsh (level 2).

When similarity scores were totaled for each Reserve and the Reserves ranked, Chesapeake showed the highest similarity across zones, followed by South Slough and North Carolina (tied), Wells, and Narragansett. Reference and restoration site pairs were most similar in Wells, followed by North Carolina, South Slough, Chesapeake, and Narragansett.

For individual sites, greatest similarity occurred in North Carolina, then Chesapeake and South Slough (tied), Narragansett and Wells.

Variation

Variation within low and mid marsh zones was mostly at the intermediate level, with the high marsh/upland transition zone at all sites showing high variation (Table 9-13). The one instance of low variation occurred for low marsh at Narragansett Bay.

Variation within sites (pooled across zones) was generally high (level 3) for both reference and restoration sites. However, Narragansett reference sites all showed intermediate variation, as did Goodwin's Island reference site at Chesapeake, and middle marsh reference site at North Carolina. Danger Point reference marsh at South Slough showed the lowest variation. Sites showing low variation included Drakes Island (level 1) at Wells; those showing intermediate variation (level 2) were Gooseneck Cove at Narragansett, NC Maritime at North Carolina, and Kunz Marsh at South Slough.

When variation scores were totaled for each Reserve and the Reserves ranked, Narragansett showed the lowest variation within zones, followed by North Carolina and Wells (tied), Chesapeake, and South Slough (Table 3). Individual sites were least variable at South Slough, then higher in Wells, Narragansett and North Carolina (tied), and Chesapeake.

Analysis of Similarity (ANOSIM) and Similarity Percentage (SIMPER) of Plant Communities

Analysis of similarity for all reference-restoration pairs revealed significant differences in plant communities, based on the complete percent cover data set, and with species not included in the 90 percent cumulative cover eliminated. There were two exceptions. The Wheeler Marsh restoration site was not significantly different from the paired Webhannet Marsh reference site at Wells, and the Hermitage restoration site was not significantly different from the paired Goodwin Islands reference site at Chesapeake (Table 4).

The number of species contributing to the 90 percent cumulative cover in each reference-restoration site assemblage varied considerably between the Reserves. Mean species number across reference and restoration site pairs for each Reserve (from north to south, east to west) was Wells (18 species), Narragansett (11), Chesapeake (6), North Carolina (10), and South Slough (11).

Average percent dissimilarities indicate the total contribution from each species in the combined species assemblage to the difference between the reference-restoration site pairs, and ranged from 51 percent to 89 percent. The five species contributing the most to the dissimilarity for each reference-restoration site pair totaled more than 50 percent of the dissimilarity for each comparison, with two exceptions of 41 percent and 48 percent (Tables 14-18).

Of the 85 species, the top five identified contributors to dissimilarity between 17 restoration sites and their reference pairs were: *Spartina*

WELLS ME		Percent Dissimilarity and Abundance					Cum %
Reference	Restoration	Species 1	Species 2	Species 3	Species 4	Species 5	
Webhannet	Cascade	SPAPAT	PHRAUS	SPAALT*	DISSPI*	SPAALS	
		6.88 ref	6.79 res	6.42 ref	5.86 res	5.86 ref	42
	Drakes	SPAALT*	SPAALS	SPAPAT*	BARE	DEAD	
		8.43 res	8.30 res	7.85 ref	5.71 ref	4.28 res	55
	Spruce	SPAPAT*	SPAALT	SPAALS	BARE*	DISSPI	
		8.63 res	8.21 ref	7.44 ref	6.18 ref	5.00 res	51
	Wheeler	SPAPAT*	SPAALT	SPAALS	BARE*	JUNGER	
		7.92 ref	7.63 ref	7.52 ref	5.45 ref	4.94 res	48

Table 14. Dissimilarity percent contributions for top 5 species at Wells NERR that distinguish restoration sites from paired reference sites at Wells NERR. Comparisons where the species abundance was greater for the reference site are designated “ref”, and where greater for the restoration site by “res”. The cumulative contribution to total dissimilarity is also indicated. Species codes: SPAPAT – Spartina patens, PHRAUS – Phragmites australis, SPAALT – Spartina alterniflora, DISSPI – Distichlis spicata, SPAALS – Spartina alterniflora short, JUNGER – Juncus gerardii.

NARRAGANSETT RI		Percent Dissimilarity and Abundance					Cum %
Reference	Restoration	Species 1	Species 2	Species 3	Species 4	Species 5	
Coggeshall	Gooseneck	SPAPAT*	SPAALT	DISSPI	BARE*	PHRAUS	
		12.72 ref	10.6 ref	8.21 ref	7.03 ref	5.86 ref	70
Jacobs Point	Jacobs Point	DISSPI*	PHRAUS*	SPAPAT	JUNGER	IVAFRU	
		18.25 ref	17.13 res	11.54 ref	7.03 ref	4.95 ref	74
Nag Marsh	Potters Pond	SPAPAT*	SPAALT	DISSPI*	PHRAUS	BARE	
		14.09 ref	11.67 ref	9.16 ref	6.57 res	5.77 res	71
	Silver Creek	SPAALT*	SPAPAT*	DISSPI*	PHRAUS	IVAFRU	
		12.57 ref	12.31 ref	8.71 res	8.09 res	5.71 res	65
	Walker Farm	PHRAUS*	SPAPAT*	SPAALT	DISSPI	SALEUR	
		17.04 res	15.25 ref	13.2 ref	8.94 ref	4.23 res	73

Table 15. Dissimilarity percent contributions for top 5 species at Narragansett Bay NERR that distinguish restoration sites from paired reference sites at Wells NERR. Comparisons where the species abundance was greater for the reference site are designated “ref”, and where greater for the restoration site by “res”. The cumulative contribution to total dissimilarity is also indicated. Species codes: SPAPAT – Spartina patens, PHRAUS – Phragmites australis, SPAALT – Spartina alterniflora, DISSPI – Distichlis spicata, SPAALS – Spartina alterniflora short, JUNGER – Juncus gerardii, IVAFRU – Iva frutescens, SALEUR – Salicornia europaea.

CHESAPEAKE VA		Percent Dissimilarity and Abundance					Cum %
Reference	Restoration	Species 1	Species 2	Species 3	Species 4	Species 5	
Goodwin Isld	Hermitage	SPAALT*	SPAPAT*	DISSPI	ATRPAT	BACHAM	
		18.47 res	17.98 ref	15.10 ref	2.23 res	1.55 ref	92
Taskinas Crk	Cheatham Anx	SPAPAT	DISSPI*	SPAALT*	SCIAME	SCIROB	
		16.30 ref	14.51 ref	14.39 res	11.03 res	4.62 ref	92
	Naval Wpns	SPAPAT	SPAALT*	DISSPI*	SCIROB	SCIAME	
		15.21 ref	15.17 res	12.71 ref	5.50 res	3.7 ref	79

Table 16. Dissimilarity percent contributions for top 5 species at Chesapeake VA NERR that distinguish restoration sites from paired reference sites at Wells NERR. Comparisons where the species abundance was greater for the reference site are designated “ref”, and where greater for the restoration site by “res”. The cumulative contribution to total dissimilarity is also indicated. Species codes: SPAPAT – Spartina patens, PHRAUS – Phragmites australis, SPAALT – Spartina alterniflora, DISSPI – Distichlis spicata, ATRPAT – Atriplex patula, BACHAM – Bacharris halmiifolia, SCIAME – Scirpus americanus (now Schoenoplectus americanus), SCIROB – Scirpus robustus (now Schoenoplectus robustus), SPAALS – Spartina alterniflora short.

alterniflora (14 sites), *Spartina patens* (12), *Distichlis spicata* (11), bare ground (8), and *Phragmites australis* (7). These five species account for 61 percent of the species contributing to dissimilarity, and 77 percent of the best indicator species identified in Table 5.

For *S. alterniflora*, *S. patens, D. spicata*, and bare ground, abundance was greater in reference sites for the majority of cases, while the opposite was the case for *Phragmites*.

NORTH CAROLINA		Percent Dissimilarity and Abundance					Cum %
Reference	Restoration	Species 1	Species 2	Species 3	Species 4	Species 5	
Middle Marsh	Duke Marine	SPAALT*	OYSTER	BARE	DEAD*	WRACK	
		10.95 ref	6.94 res	6.43 res	5.38 ref	4.83 res	59
	NC Museum	SPAALT*	OYSTER	BARE	WRACK	DEAD*	
		9.7 ref	8.64 res	7.58 ref	5.88 res	5.12 ref	71
	Pine Knoll	SPAALT	SALSP	BARE*	WATER	DEAD*	
		11.27 ref	8.67 res	8.14 ref	6.36 res	5.69 ref	67

Table 17. Dissimilarity percent contributions for top 5 species at North Carolina NERR that distinguish restoration sites from paired reference sites at Wells NERR. Comparisons where the species abundance was greater for the reference site are designated "ref", and where greater for the restoration site by "res". The cumulative contribution to total dissimilarity is also indicated. Species codes: SPAPAT – Spartina patens, SPAALT – Spartina alterniflora, SALSP – Salicornia species.

SOUTH SLOUGH OR		Percent Dissimilarity and Abundance					Cum %
Reference	Restoration	Species 1	Species 2	Species 3	Species 4	Species 5	
Danger Point	Kunz Marsh	TRIMAR*	AGRSTO*	DESCAE	DISSPI	CARLYN	
		8.19 res	8.11 res	7.82 res	6.02 res	4.20 ref	53
Yaquina 28	Yaquina 27	CARLYN	AGRSTO*	PHAARU	ELEPAL	ARGEGE*	
		11.14 res	11.09 res	7.79 ref	7.53 res	6.23 ref	49

Table 18. Dissimilarity percent contributions for top 5 species at South Slough NERR that distinguish restoration sites from paired reference sites at Wells NERR. Comparisons where the species abundance was greater for the reference site are designated "ref", and where greater for the restoration site by "res". The cumulative contribution to total dissimilarity is also indicated. Species codes: TRIMAR – Triglochin maritimum, AGRSTO – Agrostis stolinifera, DESCAE – Deschampsia caespitosa, DISSPI – Distichlis spicata, CARLYN – Carex lyngbyei, PHAARU – Phalaris arundinacea , ELEPAL – Eleocharis palustris , ARGEGE –Argentina egedii .

Plant Community-Abiotic Factor Correlations

Associations between plant communities and abiotic factors were explored with Spearman rank correlations (note – groundwater data collected in association with plant community data not available for South Slough or Chesapeake). Correlations were carried out for all sites at each Reserve (both reference and restoration), and then again just for the restoration sites. R values were low to modest, but the combination of factors contributing to the highest correlations, groundwater level and elevation, were consistent across Reserves (Table 5). Preliminary screening with bivariate plots and resemblance matrices ensured that these factors were not auto-correlated—that is, they were not duplicating the same information (correlation between all paired variables < 0.95).

Linear regression of RPI vegetation component score against mid-marsh elevation was significant, with a correlation r = 0.41, and a non-significant linear relationship of RPI = 0.20 + 0.07 ⍰ elevation (in) (Figure 17). Linear regression of the RPI vegetation component score against depth to groundwater was significant (p = 0.04), with a correlation r = 0.45, and a linear relationship of RPI = 0.17 + 0.009 ⍰ groundwater depth (cm) (Figure 18).

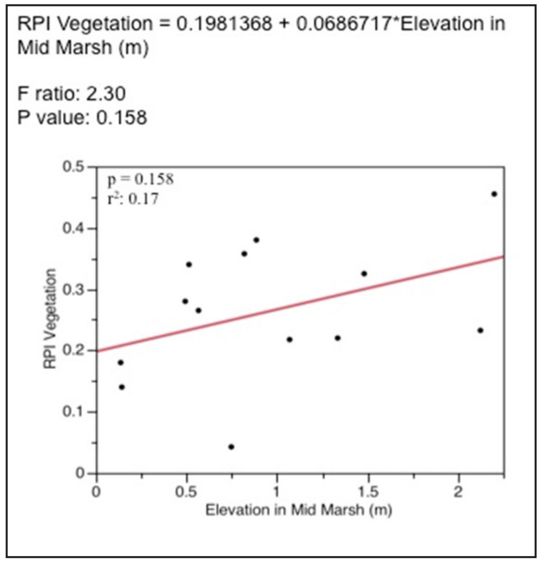

Figure 17. Linear regression of RPI vegetation component score against mid-marsh elevation across all restorations sites.

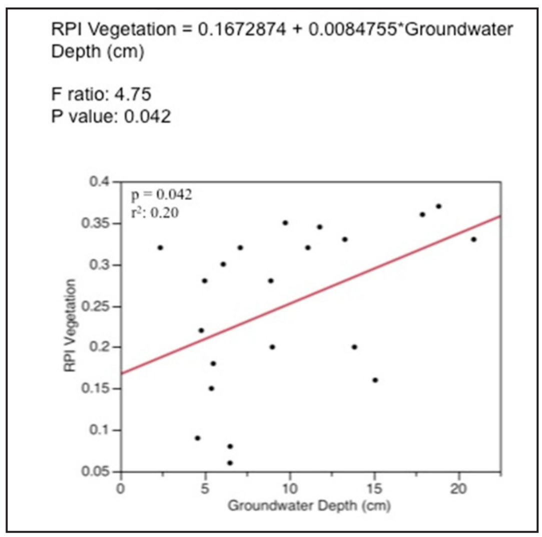

Figure 18 Linear regression of RPI vegetation component score against groundwater depth across all restorations sites.

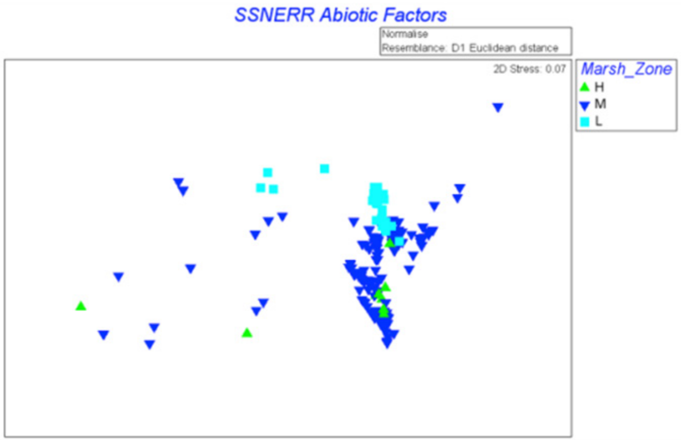

Figure 19. Example of similarity and variation patterns (based on resemblance matrix of Euclidean distance) for marsh zone abiotic factors at South Slough NERR study sites. Due to overlap of mid (M) and high marsh/upland transition zones (H) for many of the samples, a similarity level of 2 (out of 5, with 5 being lowest similarity) was assigned. Low (L) to mid marsh points (M) showed separation, but were spatially adjacent, so these zones were assigned an intermediate similarity level of 3. Low (L) and high marsh -upland transition zones (H) show intermediate separation, so received a similarity level of 4. Variation levels (from 1 being low to 3 being high) were assigned based on the level of clustering (taking into account the number of data points). Here the mid-marsh (M) showed the tightest clustering (variation level 1), followed by low marsh (level 2), and high marsh (H) (level 3).

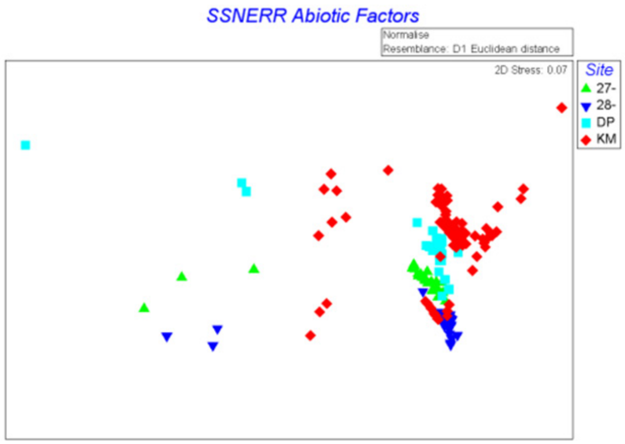

Figure 20. Example of similarity and variation patterns (based on resemblance matrix of Euclidean distance) for reference and restoration site abiotic factors at South Slough NERR. Many samples within each site were tightly clustered and directly adjacent, so the reference – restoration pairs were assigned similarity levels of 3 – intermediate (DP reference vs. KM restoration), and 2 – intermediate/high (Y28 reference - Y27 restoration). Here, all 4 sites displayed a similar pattern of spatial variation, with outlying points at intermediate distance from the main clusters, and were assigned a variation level of 2 - intermediate.

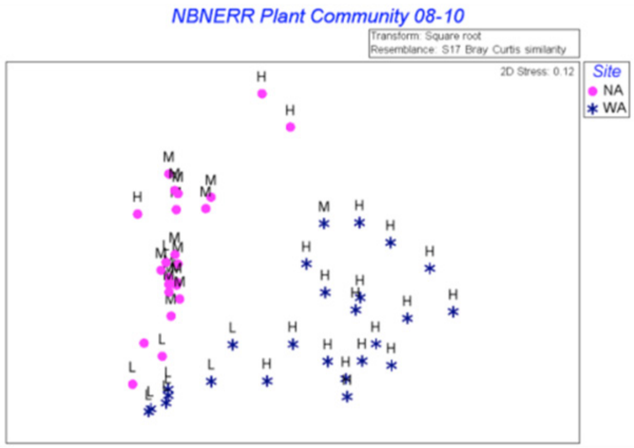

Figure 21. Example of similarity and variation patterns (based on rank order resemblance matrix) for plant communities from the Nag Marsh-Walker Farm reference-restoration pair at Narragansett Bay NERR. Due to the separation between the points from the two sites, a similarity level of 4 was assigned. Pooled variation (all zones combined) was intermediate (level 2) for Nag Marsh, and high (level 3) for Walker Farm.

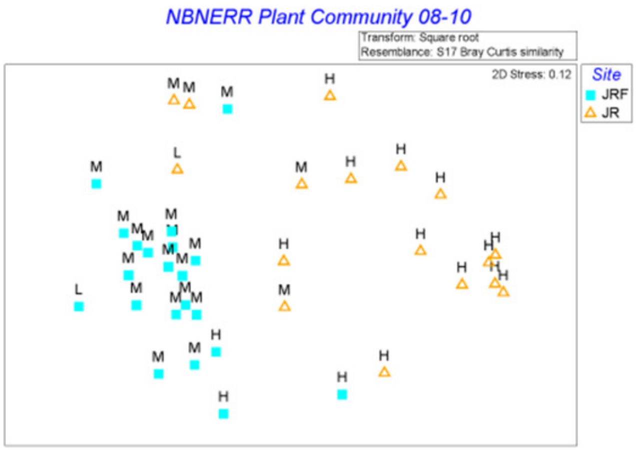

Figure 22. Example of similarity and variation patterns (based on rank order resemblance matrix) for plant communities from the Jacobs point reference-restoration pair at Narragansett Bay NERR. Due to the greater separation of the points between the two sites, relative to other reference-restoration site pairs, a similarity of 5 (low) was assigned. Variation across zones (Low, Mid, High) was intermediate (2) for Jacobs Point reference site, and high (3), for Jacobs Point restoration site.

Appendix C: Data Management

A Data Appendix is provided as a series of digital files and has been submitted to the NOAA Restoration Center.

In the Data Appendix, reference site benchmark values for all parameters and for all sites are provided, including:

Hydrology
Salinity (shallow and deep wells, pore water sippers),
Groundwater Level (shallow wells)
    Groundwater Level (deep wells, continuous)
Channel Tide Level (continuous)
Vegetation
% Cover all plant species and other cover types
Stem Density (by species)
Stem Height (by species)
% Invasives
Soils
    % Organic Carbon, Bulk Density
Elevation and Location
    Vegetation plots
    Sampling wells
    Transects
Data Templates with Metadata
Graphics
Restoration Performance Index Figures
Difference Analyses Figures
    Multidimensional Scaling Plots
    Plant Height and Density Figures