



Salt Marsh Vegetation Monitoring at Boston Harbor Islands National Recreation Area

2013 Summary Report for Thompson Island

Natural Resource Data Series NPS/NETN/NRDS—2014/664



ON THE COVER

View of restored marsh on Thompson Island
Photograph by: Kate Miller, NPS

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Abstract

In 2013, the Northeast Temperate Network (NETN) sampled two salt marshes on Thompson Island as part of the long-term salt marsh vegetation monitoring protocol that was first implemented in 2010. A total of 50 vegetation plots were sampled in the pristine marsh, and 35 vegetation plots were sampled in the restored marsh.

The vegetation in the pristine marsh was largely composed of native, halophytic (salt tolerant) vegetation. Vegetation plots in the low marsh were largely dominated by smooth cordgrass (*Spartina alterniflora*). Bare ground had the next highest percent cover in low marsh. Virginia glasswort (*Salicornia depressa*) was relatively frequent in the low marsh, but at very low percent cover.

High marsh vegetation plots were considerably more diverse than plots in the low marsh. Saltmeadow rush (*Juncus gerardii*) and saltmeadow cordgrass (*Spartina patens*) had the highest average cover and occurred in the most vegetation plots in the high marsh. Non-native species that were found rooted in high marsh vegetation plots were fivehook bassia (*Bassia hyssopifolia*), and quackgrass (*Elymus repens*).

The restored marsh was primarily permanent open water (35% of plots), upland (22% of plots) and high marsh (20% of plots). Areas of high marsh dominated by common reed (*Phragmites australis*) and low marsh were also present, with both comprising about 9% of all plots. Vegetation plots in low marsh were largely dominated by smooth cordgrass (*Spartina alterniflora*). Dead grass and bare ground had the next highest percent cover in low marsh.

High marsh vegetation plots were dominated by saltmeadow rush (*Juncus gerardii*), saltmeadow cordgrass (*Spartina patens*), and seaside goldenrod (*Solidago sempervirens*). Non-native species that were found rooted in high marsh vegetation plots were spear saltbush (*Atriplex patula*), quackgrass (*Elymus repens*), broadleaved pepperweed (*Lepidium latifolium*), and climbing nightshade (*Solanum dulcamara*).

The restored marsh had more non-native species present than the pristine marsh, including areas of the invasive common reed and broadleaved pepperweed. At the time of sampling, there was evidence of common reed and broadleaved pepperweed cutting, and we encourage managers to continue in this effort where possible. Given the low level of non-native species in the pristine marsh, management recommendations are minimal.

As high-resolution, low-tide imagery is made available, we will delineate the major marsh habitats (e.g., mudflat, open water, high marsh and low marsh), and include these assessments in annual reports. However, such imagery is rare and recent imagery was not available at the time of this report. In the absence of such imagery, we will continue tracking the extent of each habitat type using random GRTS plots to understand how the marshes on Thompson Island change over time, with special focus on response to sea level rise. More detailed GPS delineations of permanent open water, mudflat, low marsh and high marsh boundaries may also prove helpful for tracking changes in marsh expansion or reduction, but are currently beyond the scope of NETN salt marsh monitoring.

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Introduction

Situated at the transition between terrestrial, freshwater and marine systems, salt marshes and estuarine habitats are highly productive environments that serve important ecosystem functions such as providing breeding habitat to numerous fish and bird species, food sources for migrating birds, and acting as natural hydrologic, nutrient, sediment, storm and wave energy buffers (Gedan et al. 2009). Given their landscape context, salt marsh and estuarine habitats are also threatened by a number of anthropogenic stresses such as nutrient enrichment, poor water quality, sea level rise, tidal restriction/altered hydrology, erosion and sedimentation, and invasive species (Gedan et al. 2011).

The Northeast Temperate Network (NETN) of the National Park Service (NPS) Inventory and Monitoring Program identified salt marsh vegetation as a high priority vital sign for Acadia National Park (ACAD), Boston Harbor National Recreation Area (BOHA), and Saugus Ironworks National Historic Site (SAIR). Using a protocol based largely on the Northeast Coastal Barrier Network (NCBN) salt marsh vegetation monitoring protocol (James-Pirri et al. In Review), NETN monitors salt marsh vegetation using a series of randomly located plots in each marsh of concern to assess species composition and vegetation community structure. The overall goals of this protocol are to monitor status and trends in species composition of marsh vegetation, and to monitor the extent of salt marsh habitats, including mudflat, permanent open water, high marsh and low marsh.

The 2013 field season marks the second visit to the marshes on Thompson Island in BOHA. SAIR was also sampled in 2013 as both the final year of monitoring results from the Turning Basin and tidal marsh restoration project and as the second round of NETN salt marsh vegetation monitoring. The results from SAIR sampling will be summarized in a separate report by the principal investigators on the restoration project. This report summarizes results from this second round of sampling in the two salt marshes on Thompson Island in BOHA.

Methods

Salt marshes in NETN are sampled on a 5-year rotation, with BOHA marshes sampled the first 2 years, the SAIR marsh also sampled the 2nd year, and ACAD wetlands sampled during years 3 and 4 (Table 1). The 5th year in the rotation is skipped to allow for intensive freshwater wetland monitoring in ACAD for the Environmental Protection Agency's National Wetland Condition Assessment. In BOHA, NETN monitors marshes on four islands, with two marshes on Thompson Island, and one marsh each on Peddocks, Snake, and Calf Islands. In SAIR, NETN monitors the restored and natural tidally influenced wetlands in the park. In ACAD, NETN monitors tidally influenced sections of Northeast Creek, Bass Harbor Marsh, and Schoodic Marsh.

Starting in 2013, the sample areas for each marsh in BOHA were expanded beyond the vegetated marsh boundaries that were used in 2010 to better allow us to monitor how marshes respond to sea level rise. First we determined the highest elevation of marsh vegetation in each marsh using 2009 LiDAR imagery for the City of Boston and 2012 leaf-on National Agriculture Imagery Program (NAIP) orthophotography. This elevation was then buffered by twice the upper 95% confidence limit of current sea level rise trends in cm/century (National Oceanic and Atmospheric Administration 2013). A contour was then generated from LiDAR, based on the buffered elevation to delineate the sample area for each marsh. In BOHA the upper extent of vegetated marsh was buffered by 60 cm in elevation, and the resulting contour for the Thompson Island marshes was 2.44 m (8 ft) above the LiDAR mean sea level elevation with UTM NAD83 horizontal and NAVD88 vertical datum. In ACAD, the upper extent of vegetated marsh will be buffered by 50 cm, and in SAIR the upper extent of vegetated marsh will be buffered by 60 cm. This approach will allow us to monitor how marshes respond to sea level rise and determine if marshes are migrating into higher elevations.

Within the sample area delineated for each marsh, we used Generalized Random Tessellation Stratified sampling (GRTS; Stevens and Olsen 2004) to create a large sample of random plots. Using 2009 LiDAR and 2012 NAIP orthophotography, we classified each random plot by the following habitats: permanent open water, upland, mudflat, vegetated marsh, and beach strand/gravel. Plots that clearly fell in open water or upland were recorded by habitat and not visited in the field. Plots that were borderline or unclear were checked and classified in the field. Plots that were mudflat, vegetated marsh, or beach strand/gravel were sampled for vegetation in the field following the Northeast Coastal and Barrier Network protocol (James-Pirri et al. In Review), and these plots counted towards the number of 1m² vegetation plots sampled in each marsh. A total of 50 vegetation plots were sampled in the pristine marsh, and 35 vegetation plots were sampled in the restored marsh. In each vegetation plot, we estimated percent cover class (Table 2) by species of all vascular plants, and estimated percent cover of other features, such as bare ground, wrack, and trash (Table 3). After sampling the vegetation plots, the vegetated marsh habitat was further categorized into low marsh and high marsh, based on species composition. Low marsh vegetation plots were dominated by smooth cordgrass (*Spartina alterniflora*). Vegetation plots classified as high marsh were not dominated by smooth cordgrass, unless the stunted variety of smooth cordgrass was present, and often had at least one of the following species present: saltmeadow rush (*Juncus gerardii*), saltmeadow cordgrass (*Spartina patens*), maritime marsh elder (*Iva frutescens*), or seaside goldenrod

(*Solidago sempervirens*). Plots in high marsh that were dominated by common reed (*Phragmites australis*) were further classified as high marsh – *Phragmites*.

For each future visit, we will generate a new sample of random plots. These plots will be classified by habitat using the most recent orthophotography and LiDAR data. Plots that cannot be classified using orthophotos will be classified in the field. Plots in target habitats (e.g., mudflat, vegetated marsh and beach strand/gravel) will be sampled in the field. If recent (within 3 years) orthophotos are not available, all plots will be classified in the field. This approach will allow us to track how the extent of each marsh habitat changes over time, regardless of orthophotography. As high-resolution, low-tide imagery is made available, we will delineate the major marsh habitats (e.g., mudflat, open water, high marsh and low marsh), and include these assessments in annual reports. However, such imagery is rare and recent (within 3 years) imagery was not available at the time of this report. More detailed GPS delineations of permanent open water, mudflat, low marsh and high marsh boundaries may also prove helpful for tracking changes in marsh expansion or reduction, but are currently beyond the scope of NETN salt marsh monitoring.

Table 1. Northeast Temperate Network salt marsh vegetation monitoring panel design. Sampling is skipped every fifth year to allow staff to participate in the Environmental Protection Agency's (EPA) National Wetland Condition Assessment (NWCA) in freshwater wetlands in ACAD.

Park	Site	Year									
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ACAD	Bass Harbor Marsh			x		EPA NWCA			x		EPA NWCA
	Northeast Creek				x					x	
	Schoodic			x					x		
BOHA	Calf Island	x					x				
	Peddocks Island	x					x				
	Snake Island	x					x				
	Thompson- Pristine		x					x			
	Thompson- Restored		x					x			
SAIR	Natural and restored		x					x			

Table 2. Modified Braun-Blanquet scale and corresponding midpoint values for determining percent cover of salt marsh vegetation.

Percent cover class	Percent cover range	Midpoint of range
0	0%	0.0%
1	< 1%	0.5%
2	1 – 5%	3.0%
3	6 – 25%	15.5%
4	26 – 50%	38.0%
5	51 – 75%	63.0%
6	76 – 100%	88.0%

Table 3. Cover type categories used during NETN salt marsh vegetation sampling. Table adapted from James-Pirri 2013.

Covertypes	Examples
Live vascular plants	Live vascular vegetation (herbaceous and shrubs) identified to species, if possible.
Standing dead vascular plants	Dead plants are identified by growth form (e.g., rush, grass, herbaceous, etc.). This category only includes standing dead (attached) plants that are from a previous year's growth. Dead plant material that is not attached is recorded as "wrack and litter" (see below).
Macroalgae	This category includes macroalgae such as rockweeds (e.g., <i>Fucus</i> and <i>Ascophyllum</i> species) identified to species, if possible. Microalgae (e.g., diatom mats) and fine filamentous algae are not included in this category.
Bare ground	This category includes dirt, mud, sand, microalgae cover, etc. These are areas that are devoid of standing live, standing dead, or macroalgae and do not have permanent standing water. There can be a small amount (<1cm) of surface water over bare ground, but it is not recorded; only permanent standing water is considered in the "water" category. The "bare" category represents an absence of any type of canopy cover.
Water	This category is for permanent standing water. Permanent standing water is defined as water within a creek, ditch, marsh pool, or any other geomorphic feature that is holding water. This category is used when a plot is partially or entirely within such a feature.
Wrack and litter	Wrack is unattached material that has floated into the plot. This is generally dead (not attached) plant material, but could also be trash. Litter is dead plant material, which could be decomposed, and is not attached. It is not identified to species.
Trash	Items such as logs, old piers, tires, and other assorted trash, etc.
Rock	Boulders or rocks can be found on the surface of northern New England marshes.

To summarize data by marsh, we converted percent cover classes to the midpoint of the percent range (Table 2). We then calculated the average percent cover and the relative percent cover of each species and non-vegetative cover. Average percent cover was the average cover occurring across all of the vegetation plots. Relative percent cover was the percentage of each species or cover type relative to all other species and non-vegetative cover types present in the vegetation plots, such that the sum of the relative percent cover values for all species and cover types equaled 100%. Relative percent cover was included in this report to allow for comparisons with previous reports (e.g., James-Pirri 2013), but were not the focus of summaries in this report.

The results from GIS habitat classifications of all plots will be used to assess current extent of the different salt marsh habitats, and track how habitats change over time. The results from the vegetation plot sampling will be used to monitor status and trends in species composition within the vegetated portions of the marshes.

Results and Discussion

Salt marsh vegetation sampling occurred on August 13, 2013 in both marshes on Thompson Island in BOHA (Figure 1). We sampled 50 vegetation plots in the pristine wetland and 35 vegetation plots in the restored wetland. GIS spatial analyses were performed on both marshes prior to sampling, with a total of 76 plots classified by habitat in the pristine marsh and 81 plots classified by habitat in the restored marsh. The number of plots classified by habitat for each marsh was determined by assessing plots by GRTS priority until the last vegetation plot (based on GRTS priority) was sampled in each marsh. Maps and tables with plot locations overlaid on the 2009 LiDAR and 2012 NAIP imagery are included in Appendix A for the pristine marsh and Appendix B for the restored marsh.

Pristine Marsh

Based on habitat classifications of all plots in the pristine marsh sample area, the two most extensive habitats were low marsh (27% of all plots) and permanent open water (22% of all plots; Table 4, Appendix A: Figures A-1 and A-2). Areas of non-vegetated mudflat and high marsh were also common, making up 18% of all plots and 14% of all plots, respectively. The transition from marsh to upland was fairly abrupt and only 12% of all plots fell in upland.

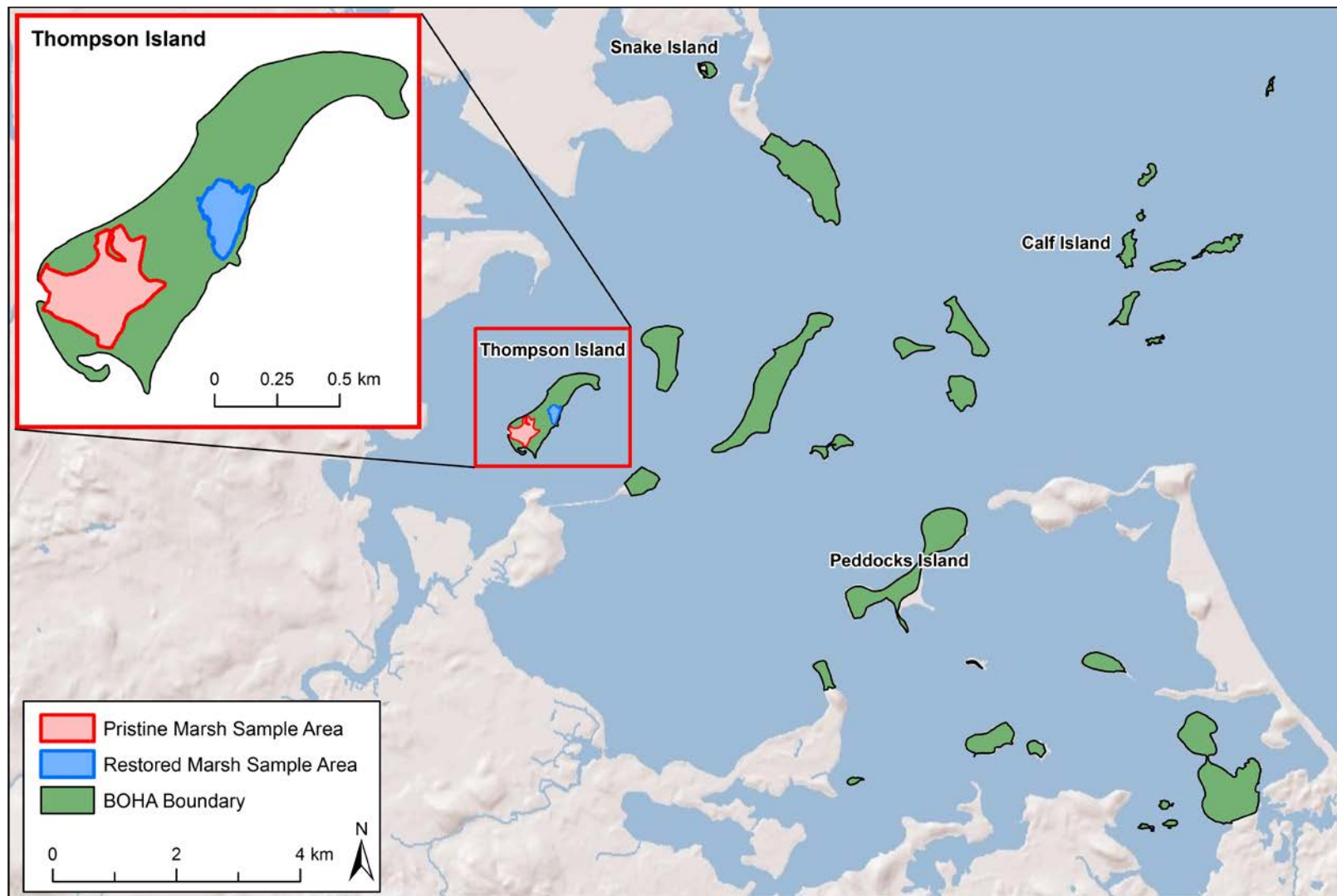
We observed 17 vascular plant species across the 50 vegetation plots in the pristine wetland (Table 5). Smooth cordgrass (*Spartina alterniflora*) was detected in the most vegetation plots, and had the highest average percent cover. Bare ground was the most common non-vegetative cover encountered in the pristine marsh.

Vegetation plots in low marsh were largely dominated by smooth cordgrass (Table 6). Bare ground had the next highest percent cover in low marsh (Table 7). Virginia glasswort (*Salicornia depressa*) was relatively frequent in the low marsh, but occupied very low cover. Non-native species were not detected in any low marsh vegetation plots.

As expected, high marsh vegetation plots were considerably more diverse than low marsh plots. Saltmeadow rush (*Juncus gerardii*) and saltmeadow cordgrass (*Spartina patens*) had the highest average cover and occurred in three and four plots (out of 11), respectively. Other common high marsh species included maritime orache (*Atriplex glabriuscula* var. *acadiensis*), Carolina sealavendar (*Limonium carolinianum*), Virginia glasswort, and herbaceous seepweed (*Suaeda maritima*). Non-native species that were found rooted in high marsh vegetation plots were fivehook bassia (*Bassia hyssopifolia*), and quackgrass (*Elymus repens*; Appendix A: Figure A-3).

Table 4. Proportion of plots by habitat in the pristine marsh on Thompson Island.

Plot Type	Habitat	# Plots	% of Sample Area
Sampled	Beach strand/ Gravel	4	5.26
	High Marsh	11	14.47
	High Marsh – <i>Phragmites</i>	0	0.00
	Low Marsh	21	27.63
	Mudflat	14	18.42
Rejected	Permanent Open Water	17	22.37
	Upland	9	11.84



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

Figure 1. Map of Boston Harbor Islands National Recreation Area. Labeled islands are included in the salt marsh monitoring protocol. The Thompson Island inset shows the two marshes monitored in 2013.

Table 5. Plant species and non-vegetative cover types detected in vegetation plots in the pristine marsh on Thompson Island. Average % cover is the average cover over all 50 vegetation plots. Relative % cover is the average percent cover of all cover types relative to the total cover.

Latin Name	Synonym	Common Name	Average % Cover	Relative % Cover	Number of Plots
Live Vegetative Covers					
<i>Ambrosia artemisiifolia</i>		common ragweed	0.01	0.01	1
<i>Atriplex glabriuscula</i> var. <i>acadiensis</i>	<i>Atriplex acadiensis</i>	maritime orache	0.06	0.05	6
<i>Bassia hyssopifolia</i> ¹		fivehook bassia	0.31	0.27	1
<i>Crateagus</i> sp. ²		hawthorn	0.01	0.01	1
<i>Distichlis spicata</i>		inland saltgrass	0.01	0.01	1
<i>Elymus repens</i> ¹		quackgrass	0.12	0.10	2
<i>Iva frutescens</i>		maritime marsh elder	1.78	1.53	1
<i>Juncus gerardii</i>		saltmeadow rush	4.81	4.14	3
<i>Limonium carolinianum</i>	<i>Limonium nashii</i>	Carolina sealavender	1.61	1.39	6
<i>Puccinellia maritima</i>	<i>Puccinellia americana</i>	seaside alkaligrass	1.32	1.14	2
<i>Salicornia depressa</i>	<i>Salicornia virginica</i>	Virginia glasswort	0.90	0.78	10
<i>Solidago sempervirens</i>		seaside goldenrod	1.08	0.93	3
<i>Spartina alterniflora</i>		smooth cordgrass	36.69	31.60	30
<i>Spartina patens</i>		saltmeadow cordgrass	2.91	2.50	4
<i>Suaeda linearis</i>		annual seepweed	2.16	1.86	4
<i>Suaeda maritima</i>		herbaceous seepweed	3.22	2.77	7
<i>Tilia cordata</i> ^{1,2}		littleleaf linden	0.76	0.65	1
Non-vegetative Covers		bare ground	44.97	38.73	48
		dead grass	4.54	3.91	32
		dead rush	0.68	0.59	3
		rock	0.74	0.64	4
		trash	0.06	0.05	1
		unknown algae	0.06	0.05	1
		water	3.56	3.07	3
		wrack	3.76	3.23	9

¹Exotic species

²Species was overhanging plot, but not rooted in.

Averaging over 80% cover, bare ground was the dominant cover in mudflats (Table 7). Mudflat vegetation plots had a minor component of smooth cordgrass, but the grass was usually not rooted in the mudflat plot. Only a few vegetation plots were sampled in the beach strand or gravel habitat, and these plots were only sparsely vegetated by a few high marsh species, such as Carolina sealavender, herbaceous seepweed or Virginia glasswort.

With no major invasive species detected in the pristine marsh, management recommendations are minimal. It will be important to continue tracking the extent of each habitat type over time using random GRTS plots to understand how this marsh responds to sea level rise. If high-resolution, low-tide imagery is made available, we will delineate marsh habitats and include areal extent in annual reports. More detailed GPS delineations of current mudflat and low marsh boundaries may also prove helpful for tracking changes in this marsh, but are beyond the scope of NETN salt marsh monitoring.

Table 6. Plant species detected in vegetation plots in the pristine marsh on Thompson Island by habitat. Average % cover is the average cover of the plots within each habitat type. % Plot frequency is the number of plot occurrences out of the total number of plots sampled in that habitat. The number of vegetation plots sampled in each habitat is in the parentheses below the habitat name.

Habitat	Latin Name	Common Name	Average % Cover	Number of Plots
Mudflat (n=14)	<i>Spartina alterniflora</i>	smooth cordgrass	2.50	5
Low Marsh (n=21)	<i>Salicornia depressa</i>	Virginia glasswort	0.19	3
	<i>Spartina alterniflora</i>	smooth cordgrass	82.26	21
	<i>Suaeda maritima</i>	herbaceous seepweed	0.02	1
High Marsh (n=11)	<i>Ambrosia artemisiifolia</i>	common ragweed	0.05	1
	<i>Atriplex glabriuscula</i> var. <i>acadiensis</i>	maritime orache	0.27	6
	<i>Bassia hyssopifolia</i> ¹	fivehook bassia	1.41	1
	<i>Crateagus</i> sp. ²	hawthorn	0.05	1
	<i>Distichlis spicata</i>	inland saltgrass	0.05	1
	<i>Elymus repens</i>	quackgrass	0.55	2
	<i>Iva frutescens</i>	maritime marsh elder	8.07	1
	<i>Juncus gerardii</i>	saltmeadow rush	21.87	3
	<i>Limonium carolinianum</i>	Carolina sealavender	5.91	5
	<i>Puccinellia maritima</i>	seaside alkaligrass	6.00	2
	<i>Salicornia depressa</i>	Virginia glasswort	2.32	6
	<i>Solidago sempervirens</i>	seaside goldenrod	4.91	3
	<i>Spartina alterniflora</i>	smooth cordgrass	6.55	4
	<i>Spartina patens</i>	saltmeadow cordgrass	13.21	4
	<i>Suaeda linearis</i>	annual seepweed	9.80	4
	<i>Suaeda maritima</i>	herbaceous seepweed	8.86	5
	<i>Tilia cordata</i> ^{1,2}	littleleaf linden	3.45	1
Beach strand/ Gravel (n=4)	<i>Limonium carolinianum</i>	Carolina sealavender	3.88	1
	<i>Salicornia depressa</i>	Virginia glasswort	3.88	1
	<i>Suaeda maritima</i>	herbaceous seepweed	15.75	1

¹Exotic species

²Species was overhanging plot, but not rooted in.

Table 7. Covertypes detected in vegetation plots in the pristine marsh on Thompson Island by habitat. Average % cover is the average cover of the plots within each habitat type. The number of vegetation plots sampled in each habitat is in the parentheses below the habitat name.

Habitat	Covertypes	Average % Cover	Number of Plots
Mudflat (n=14)	bare ground	88.80	14
	dead grass	1.43	5
	water	6.34	1
	wrack	1.11	1
Low Marsh (n=21)	bare ground	24.94	21
	dead grass	4.52	20
	water	4.23	1
	wrack	0.31	3
High Marsh (n=11)	bare ground	21.62	9
	dead grass	2.09	6
	dead rush	3.09	3
	rock	3.09	3
	trash	0.27	1
	water	0.05	1
	wrack	7.00	4
Beach strand/ Gravel (n=4)	bare ground	60.90	4
	dead grass	22.20	1
	rock	0.75	1
	unknown algae	0.75	1
	wrack	22.20	1

Restored Marsh

Based on habitat classifications of all plots in the sample area, the most extensive habitats in the restored marsh were permanent open water (35% of all plots), upland (22% of all plots), and high marsh (20% of all plots; Table 8, Appendix B: Figures B-1 and B-2). In contrast with the pristine marsh, low marsh and mudflat habitats made up only a small portion of the sample area (roughly 9% and 5% of plots, respectively) in the restored marsh. An additional area of high marsh in the restored marsh had a dense stand of common reed (*Phragmites australis*). While common reed is technically native, populations on the East Coast are often the Eurasian haplotype, which has a higher salt tolerance than the native haplotype and can form monotypic stands in salt marshes (Vasquez et al. 2005). Given the monotypic nature of the common reed in this marsh, it is likely the Eurasian haplotype.

We observed 21 vascular plant species across the 35 vegetation plots in the restored marsh (Table 9). Saltmeadow rush, common reed, smooth cordgrass, and seaside goldenrod were detected in the most vegetation plots, and had the highest average percent cover. Bare ground and dead grass were the most common non-vegetative cover encountered in the restored marsh.

Table 8. Proportion of plots by habitat in the pristine marsh on Thompson Island.

Plot Type	Habitat	# Plots	% of Sample Area
Sampled	Beach strand/Gravel	1	1.23
	High Marsh	16	19.75
	High Marsh – <i>Phragmites</i>	7	8.64
	Low Marsh	7	8.64
	Mudflat	4	4.94
Rejected	Permanent Open Water	28	34.57
	Upland	18	22.22

Vegetation plots in low marsh were largely dominated by smooth cordgrass (Table 10). Dead grass and bare ground had the next highest percent cover in low marsh (Table 11), and non-native species were not detected in any low marsh vegetation plots. High marsh vegetation plots were dominated by saltmeadow rush, saltmeadow cordgrass, and seaside goldenrod. Other common species included maritime orache, maritime marsh elder (*Iva frutescens*), annual seepweed (*Suaeda linearis*) and herbaceous seepweed (Table 10). Non-native species that were found rooted in high marsh vegetation plots were spear saltbush (*Atriplex patula*), quackgrass, broadleaved pepperweed (*Lepidium latifolium*), and climbing nightshade (*Solanum dulcamara*; Appendix B: Figure B-3).

As in the pristine marsh, bare ground was the dominant cover in mudflat plots in the restored marsh (Table 11). Wrack was more common in mudflat plots in the restored marsh than the pristine marsh, although this could have been an artifact of low sample size in the restored marsh. Mudflat vegetation plots had a minor component of smooth cordgrass, but the grass was usually not rooted in the mudflat plot. Only one vegetation plot was sampled in the beach strand or gravel habitat, and this plot was not vegetated.

The restored marsh had more invasive and/or non-native species present than the pristine marsh, including areas of the invasive common reed and broadleaved pepperweed. The high marsh plots dominated by common reed tended to have lower plant diversity and lower frequency of wrack than the high marsh plots without common reed. Dead common reed cover was also high in the common reed-dominated plots, which can serve as a barrier to germination/growth of native plant species. Wrack is important for seed dispersal in salt marsh systems, and can be impeded by dense common reed stands, which in turn can hinder recruitment of native species after tidal flow has been restored in a marsh (Wheeler et al. 2012). At the time of sampling, there was evidence of common reed and broadleaved pepperweed cutting, and we encourage managers to continue in this effort where possible. It will also be important to continue tracking the extent of each habitat type over time using random GRTS plots to understand how this marsh responds to sea level rise. If high-resolution, low-tide imagery is made available, we will delineate marsh habitats and include areal extent in annual reports. More detailed GPS delineations of permanent open water, low marsh and high marsh boundaries may also prove helpful for tracking changes in this marsh, but are beyond the scope of NETN salt marsh monitoring.

Table 9. Plant species and non-vegetative covertypes detected in vegetation plots in the restored marsh on Thompson Island. Average % cover is the average cover over all 35 vegetation plots. Relative % cover is the average percent cover of all cover types relative to the total cover.

Latin Name	Synonym	Common Name	Average % Cover	Relative % Cover	Number of Plots
Live Vegetative Covers					
<i>Atriplex glabriuscula</i> var. <i>acadiensis</i>	<i>Atriplex acadiensis</i>	maritime orache	1.37	0.97	6
<i>Atriplex patula</i> ¹		spear saltbush	0.10	0.07	2
<i>Bolboschoenus robustus</i>	<i>Schoenoplectus robustus</i>	sturdy bulrush	0.01	0.01	1
<i>Calamagrostis canadensis</i>		bluejoint	0.01	0.01	1
<i>Calystegia sepium</i>		hedge false bindweed	0.44	0.31	1
<i>Distichlis spicata</i>		inland saltgrass	1.09	0.77	1
<i>Elymus repens</i> ¹		quackgrass	1.17	0.83	2
<i>Iva frutescens</i>		maritime marsh elder	2.84	2.01	7
<i>Juncus gerardii</i>		saltmeadow rush	13.35	9.45	11
<i>Lepidium latifolium</i> ¹		broadleaved pepperweed	0.17	0.12	2
<i>Limonium carolinianum</i>	<i>Limonium nashii</i>	Carolina sealavender	0.03	0.02	2
<i>Phragmites australis</i> ¹		common reed	12.27	8.69	11
<i>Phytolacca americana</i>		American pokeweed	0.01	0.01	1
<i>Rosa multiflora</i> ^{1,2}		multiflora rose	0.44	0.31	1
<i>Salicornia depressa</i>	<i>Salicornia virginica</i>	Virginia glasswort	0.06	0.04	4
<i>Solanum dulcamara</i> ¹		climbing nightshade	0.44	0.31	1
<i>Solidago sempervirens</i>		seaside goldenrod	13.09	9.27	13
<i>Spartina alterniflora</i>		smooth cordgrass	16.19	11.47	12
<i>Spartina patens</i>		saltmeadow cordgrass	10.31	7.30	7
<i>Suaeda linearis</i>		annual seepweed	1.66	1.17	6
<i>Suaeda maritima</i>		herbaceous seepweed	0.57	0.40	5
Non-vegetative Covers		bare ground	15.65	11.08	24
		dead grass	22.03	15.60	16
		dead <i>Phragmites</i>	12.79	9.06	9
		dead rush	7.91	5.60	12
		rock	1.09	0.77	1
		trash	0.87	0.62	6
		unknown algae	1.01	0.72	1
		wrack	4.21	2.98	10

¹Exotic species

²Species was overhanging plot, but not rooted in.

Table 10. Plant species detected in vegetation plots in the restored marsh on Thompson Island by habitat. Average % cover is the average cover of the plots within each habitat type. % Plot frequency is the number of plot occurrences out of the total number of plots sampled in that habitat. The number of vegetation plots sampled in each habitat is in the parentheses below the habitat name.

Habitat	Latin Name	Common Name	Average % Cover	Number of Plots
Mudflat (n=4)	<i>Spartina alterniflora</i>	smooth cordgrass	0.75	1
Low Marsh (n=7)	<i>Limonium carolinianum</i>	Carolina sealavender	0.07	1
	<i>Salicornia depressa</i>	Virginia glasswort	0.07	1
	<i>Spartina alterniflora</i>	smooth cordgrass	77.74	7
High Marsh (n=16)	<i>Atriplex glabriuscula</i> var. <i>acadiensis</i>	maritime orache	3.00	6
	<i>Calamagrostis canadensis</i>	bluejoint	0.03	1
	<i>Distichlis spicata</i>	inland saltgrass	2.38	1
	<i>Elymus repens</i> ¹	quackgrass	2.56	2
	<i>Iva frutescens</i>	maritime marsh elder	0.66	6
	<i>Juncus gerardii</i>	saltmeadow rush	28.23	10
	<i>Lepidium latifolium</i> ¹	broadleaved pepperweed	0.38	2
	<i>Limonium carolinianum</i>	Carolina sealavender	0.03	1
	<i>Phragmites australis</i> ¹	common reed	0.59	4
	<i>Salicornia depressa</i>	Virginia glasswort	0.09	3
	<i>Solidago sempervirens</i>	seaside goldenrod	27.66	12
	<i>Spartina alterniflora</i>	smooth cordgrass	1.22	4
	<i>Spartina patens</i>	saltmeadow cordgrass	20.18	6
	<i>Suaeda linearis</i>	annual seepweed	3.44	5
	<i>Suaeda maritima</i>	herbaceous seepweed	1.25	5
High Marsh – <i>Phragmites</i> (n=7)	<i>Atriplex patula</i> ¹	spear saltbush	0.50	2
	<i>Bolboschoenus robustus</i>	sturdy bulrush	0.07	1
	<i>Calystegia sepium</i>	hedge false bindweed	2.21	1
	<i>Iva frutescens</i>	maritime marsh elder	12.69	1
	<i>Juncus gerardii</i>	saltmeadow rush	2.21	1
	<i>Phragmites australis</i> ¹	common reed	60.01	7
	<i>Phytolacca americana</i>	American pokeweed	0.07	1
	<i>Rosa multiflora</i> ^{1,2}	multiflora rose	2.21	1
	<i>Solanum dulcamara</i> ¹	climbing nightshade	2.21	1
	<i>Solidago sempervirens</i>	seaside goldenrod	2.21	1
	<i>Spartina patens</i>	saltmeadow cordgrass	5.43	1
	<i>Suaeda linearis</i>	annual seepweed	0.43	1
Beach strand/ Gravel (n=1)	no species recorded		---	---

¹Exotic species

²Species was overhanging plot, but not rooted in.

Table 11. Covertypes detected in vegetation plots in the restored marsh on Thompson Island by habitat. Average % cover is the average cover of the plots within each habitat type. % Plot frequency is the number of plot occurrences out of the total number of plots sampled in that habitat. The number of vegetation plots sampled in each habitat is in the parentheses below the habitat name.

Habitat	Covertypes	Average % Cover	Number of Plots
Mudflat (n=4)	bare ground	88.80	4
	unknown algae	2.69	2
	wrack	15.75	1
Low Marsh (n=7)	bare ground	12.93	6
	dead grass	40.50	7
	trash	0.43	1
	unknown algae	0.76	1
	wrack	5.86	2
High Marsh (n=16)	bare ground	1.25	10
	dead grass	29.51	8
	dead <i>Phragmites</i>	3.38	3
	dead rush	17.11	11
	trash	1.53	4
	wrack	2.34	5
High Marsh – <i>Phragmites</i> (n=7)	bare ground	2.71	3
	dead grass	2.21	1
	dead <i>Phragmites</i>	56.24	6
	dead rush	0.43	1
	trash	0.43	1
	wrack	0.43	1
Beach strand/Gravel (n=1)	bare ground	63.00	1
	rock	38.00	1
	wrack	3.00	1

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Appendix A. Maps of plot locations for the pristine marsh

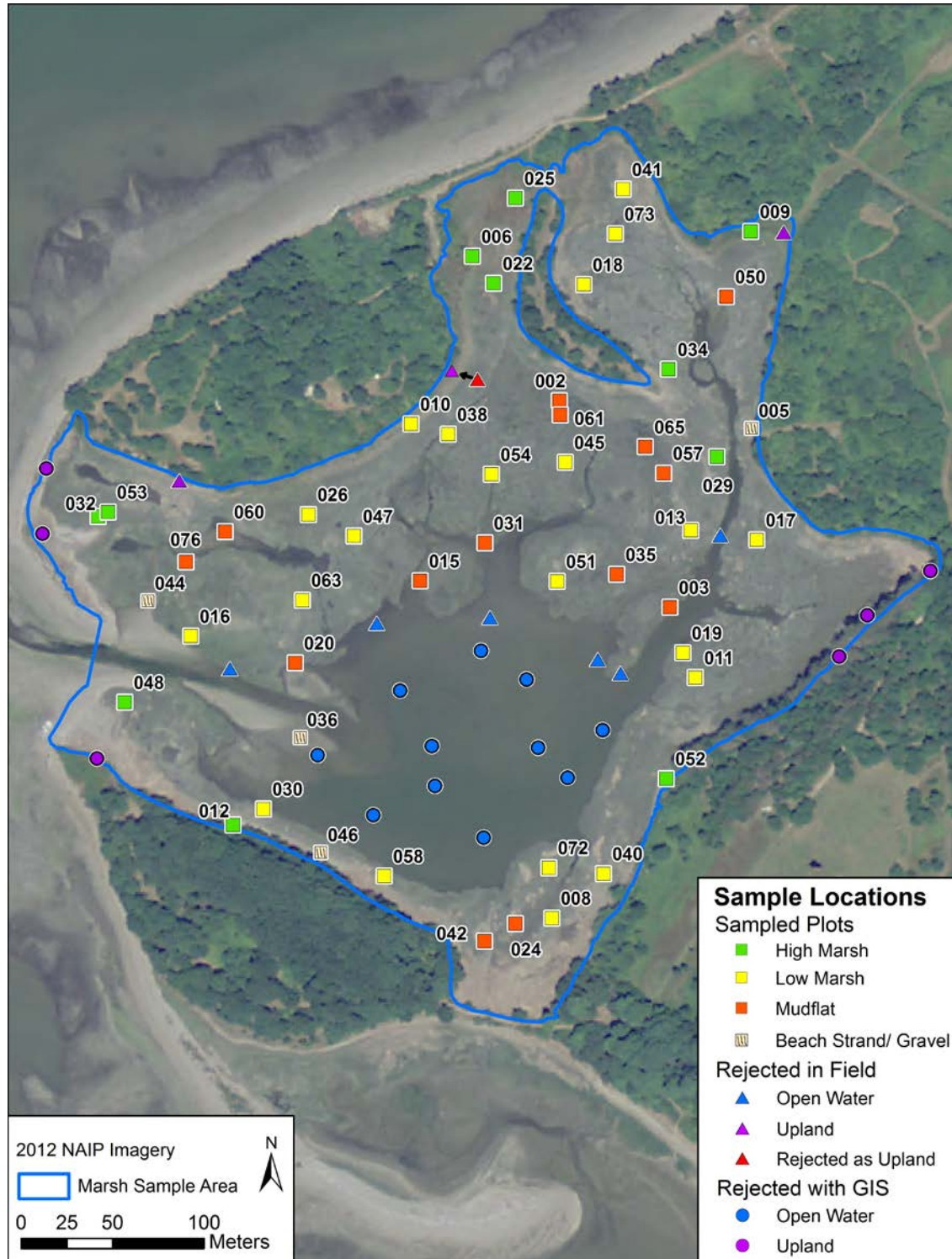


Figure A-1. Map of all plots in the pristine marsh on Thompson Island overlaid on 2012 NAIP orthophotography. Plots that were sampled as vegetation plots are numbered according to the GRTS priority. Plots not numbered were classified by habitat either in the field or using GIS. The red triangle symbol is a GPS error, and the purple triangle is the actual location that the plot was visited and rejected.

Appendix A. Maps of plot locations for the pristine marsh (continued).

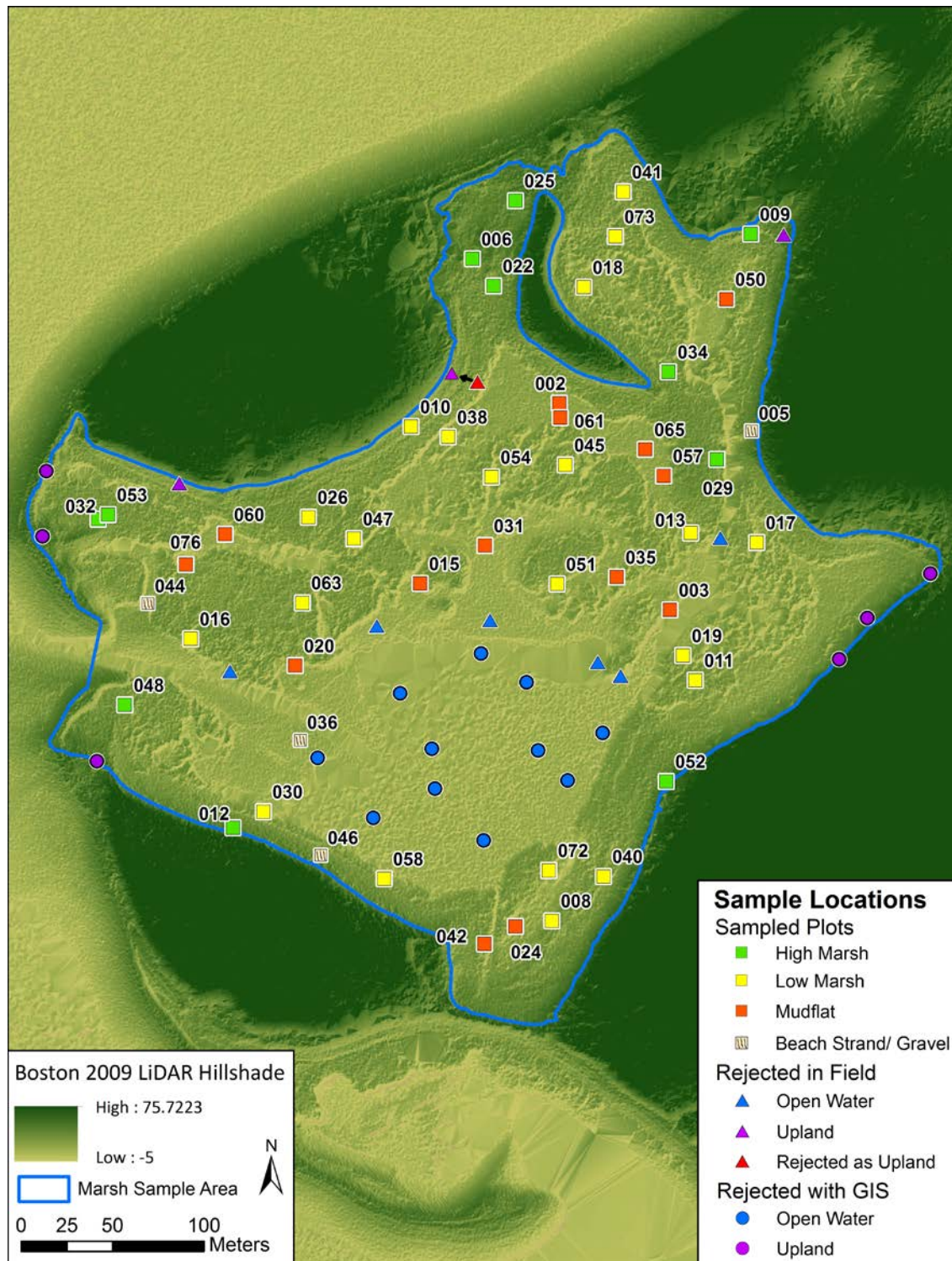


Figure A-2. Map of all plots in the pristine marsh on Thompson Island overlaid on 2009 LiDAR bare earth imagery. Plots that were sampled as vegetation plots are numbered according to the GRTS priority. Plots not numbered were classified by habitat either in the field or using GIS. The red triangle symbol is a GPS error, and the purple triangle is the actual location that the plot was visited and rejected.

Appendix A. Maps of plot locations for the pristine marsh (continued).



Figure A-3. Map of vegetation plots in the pristine marsh on Thompson Island overlaid on 2012 NAIP imagery. Plots with a square symbol indicate the presence of at least one non-native species, and the non-native species are listed next to the plot. Species are coded as the first 3 letters of the genus and first 3 letters of the species.

Appendix A. Maps of plot locations for the pristine marsh (continued).

Table A-1. Vegetation plot location information. GPS Coordinates are in UTM NAD83.

Site	GRTS Plot Number	Datasheet Station Number	GPS Coordinates		Habitat
			X	Y	
PRIS	032	1	333823	4686492	High Marsh
PRIS	053	2	333828	4686494	High Marsh
PRIS	044	3	333850	4686445	Beach strand
PRIS	060	4	333892	4686483	Mudflat
PRIS	016	5	333873	4686426	Low Marsh
PRIS	020	6	333930	4686411	Mudflat
PRIS	015	7	333999	4686456	Mudflat
PRIS	031	8	334034	4686477	Mudflat
PRIS	054	9	334038	4686515	Low Marsh
PRIS	038	10	334014	4686536	Low Marsh
PRIS	010	11	333994	4686542	Low Marsh
PRIS	002	12	334075	4686555	Mudflat
PRIS	061	13	334075	4686547	Mudflat
PRIS	045	14	334078	4686521	Low Marsh
PRIS	057	15	334132	4686515	Mudflat
PRIS	029	16	334161	4686524	High Marsh
PRIS	034	17	334135	4686572	High Marsh
PRIS	018	18	334088	4686618	Low Marsh
PRIS	041	19	334110	4686670	Low Marsh
PRIS	025	20	334051	4686666	High Marsh
PRIS	036	21	333933	4686371	Beach strand
PRIS	063	22	333934	4686446	Low Marsh
PRIS	047	23	333963	4686481	Low Marsh
PRIS	026	24	333938	4686493	Low Marsh
PRIS	072	25	334069	4686299	Low Marsh
PRIS	009	26	334180	4686647	High Marsh
PRIS	073	27	334106	4686646	Low Marsh
PRIS	076	28	333871	4686467	Mudflat
PRIS	006	29	334027	4686634	High Marsh
PRIS	022	30	334039	4686619	High Marsh
PRIS	050	31	334166	4686612	Mudflat
PRIS	005	32	334180	4686540	Beach strand
PRIS	017	33	334183	4686479	Low Marsh
PRIS	013	34	334147	4686484	Low Marsh
PRIS	003	35	334135	4686442	Mudflat
PRIS	035	36	334106	4686460	Mudflat
PRIS	051	37	334074	4686456	Low Marsh
PRIS	065	38	334122	4686530	Mudflat

Appendix A. Maps of plot locations for the pristine marsh (continued)

Table A-1. Vegetation plot location information. GPS Coordinates are in UTM Nad83 (continued).

Site	GRTS Plot Number	Datasheet Station Number	GPS Coordinates		Habitat
			X	Y	
PRIS	019	39	334142	4686417	Low Marsh
PRIS	011	40	334149	4686403	Low Marsh
PRIS	052	41	334133	4686348	High Marsh
PRIS	040	42	334099	4686296	Low Marsh
PRIS	008	43	334071	4686272	Low Marsh
PRIS	024	44	334051	4686269	Mudflat
PRIS	042	45	334034	4686259	Mudflat
PRIS	058	46	333979	4686295	Low Marsh
PRIS	046	47	333944	4686308	Beach strand
PRIS	012	48	333896	4686323	High Marsh
PRIS	030	49	333913	4686332	Low Marsh
PRIS	048	50	333837	4686390	High Marsh

Appendix B. Maps of plot locations for the restored marsh

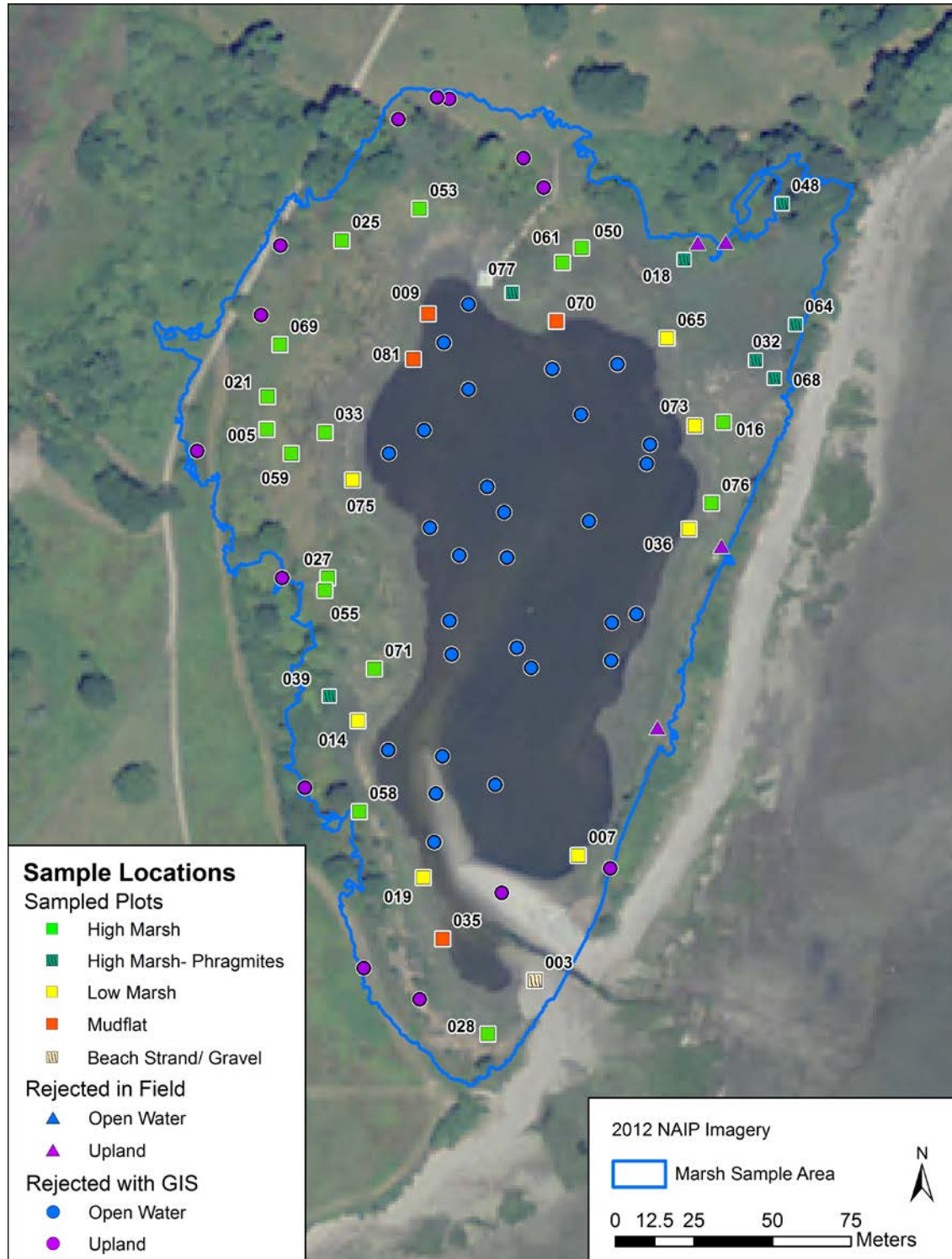


Figure B-1. Map of all plots in the restored marsh on Thompson Island overlaid on 2012 NAIP orthophotography. Plots that were sampled as vegetation plots are numbered according to the GRTS priority. Plots not numbered were classified by habitat either in the field or using GIS.

Appendix B. Maps of plot locations for the restored marsh (continued).

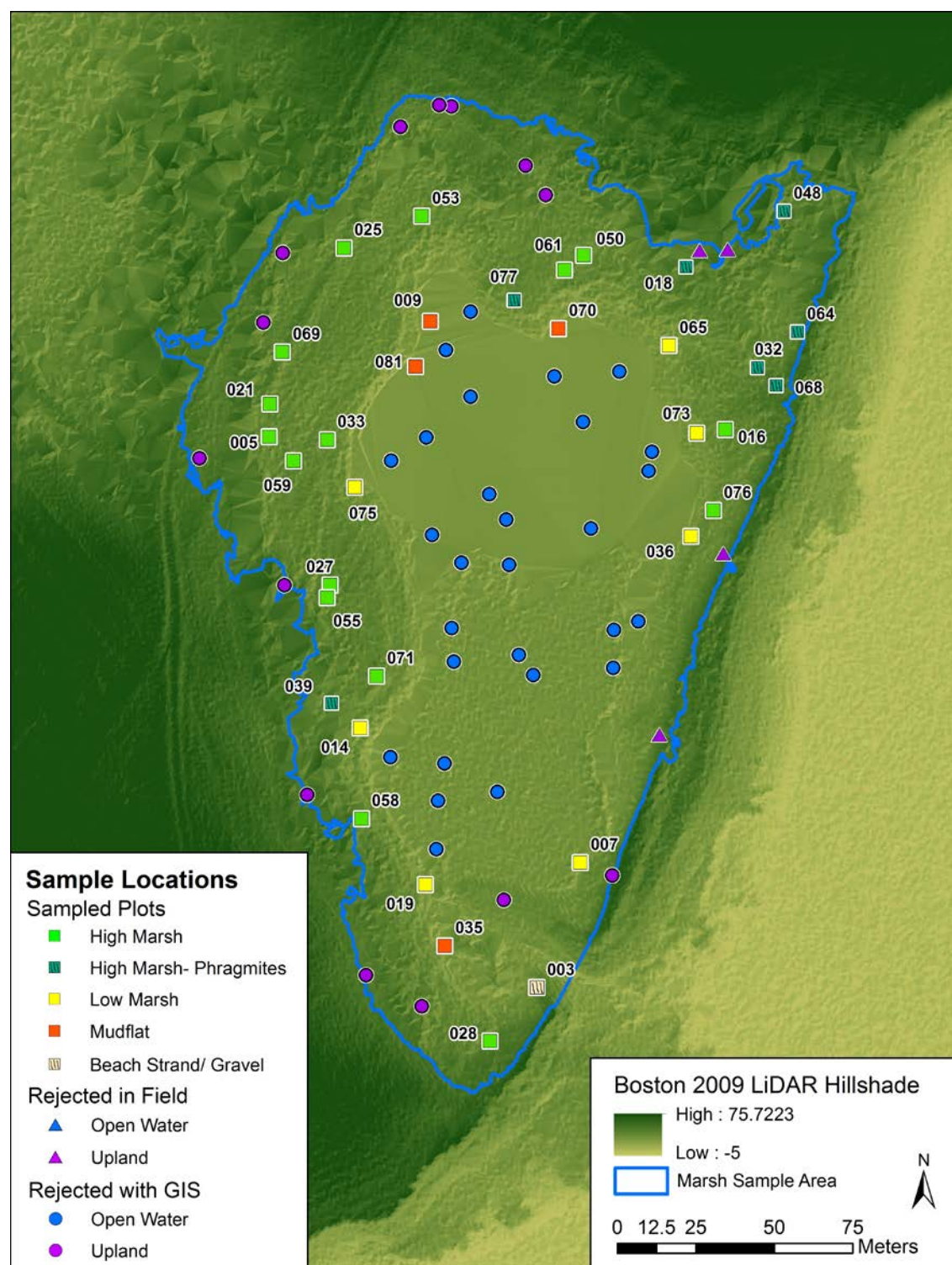


Figure B-2. Map of all plots in the restored marsh on Thompson Island overlaid on 2009 LiDAR bare earth imagery. Plots that were sampled as vegetation plots are numbered according to the GRTS priority. Plots not numbered were classified by habitat either in the field or using GIS.

Appendix B. Maps of plot locations for the restored marsh (continued).

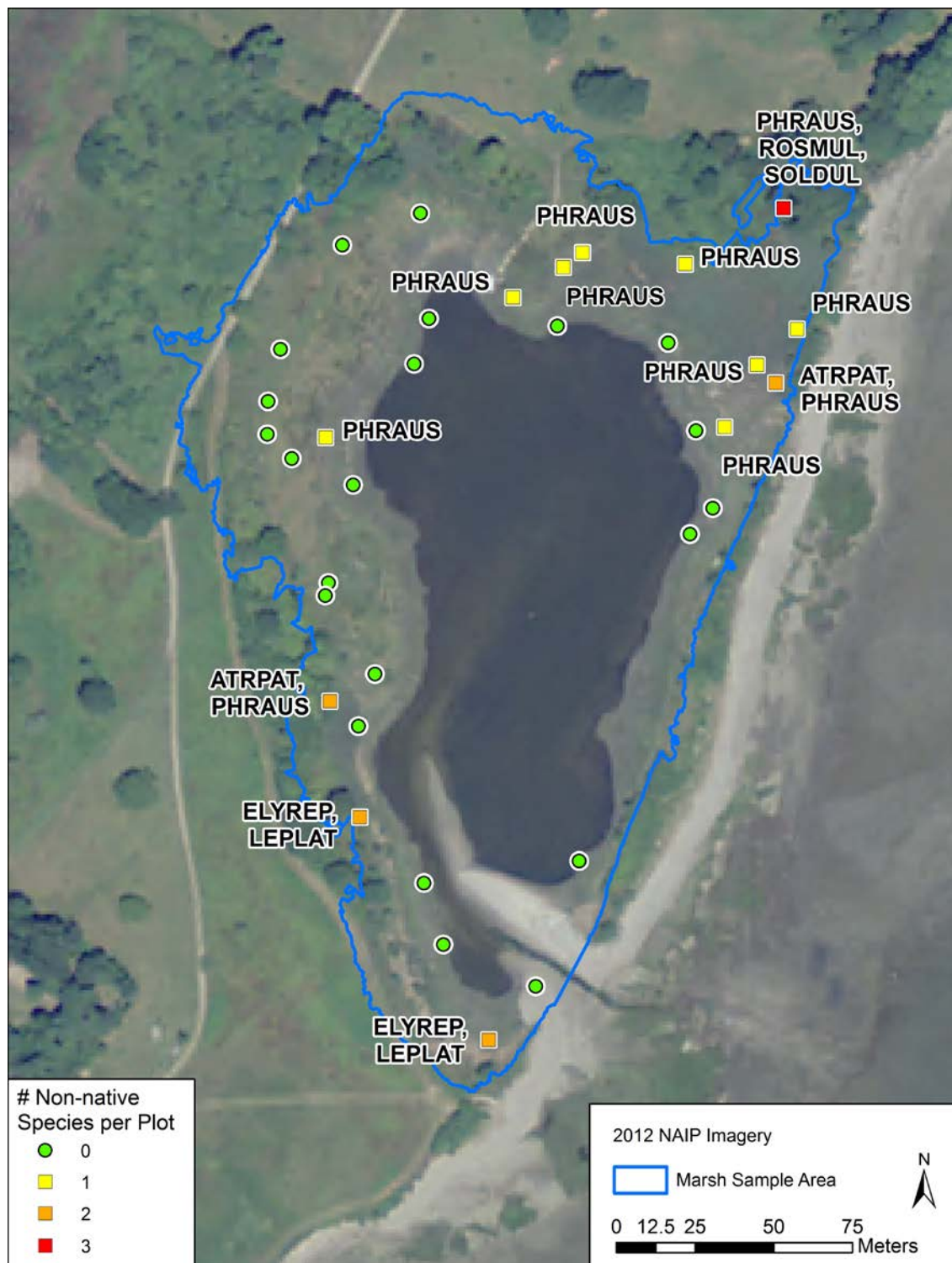


Figure B-3. Map of vegetation plots in the restored marsh on Thompson Island overlaid on 2012 NAIP imagery. Plots with a square symbol indicate the presence of at least one invasive and/or non-native species, and the invasive or non-native species are listed next to the plot. Species are coded as the first 3 letters of the genus and first 3 letters of the species.

Appendix B. Maps of plot locations for the restored marsh (continued).

Table A-1. Vegetation plot location information. GPS Coordinates are in UTM Nad83.

Site	GRTS Plot Number	Datasheet Station Number	GPS Coordinates		Habitat
			X	Y	
REST	005	1	334450	4686778	High Marsh
REST	021	2	334450	4686789	High Marsh
REST	069	3	334454	4686805	High Marsh
REST	025	4	334474	4686838	High Marsh
REST	053	5	334499	4686849	High Marsh
REST	061	6	334544	4686831	High Marsh
REST	070	7	334542	4686813	Mudflat
REST	018	8	334583	4686832	High Marsh-Phrag
REST	065	9	334577	4686807	Low Marsh
REST	048	10	334614	4686850	High Marsh-Phrag
REST	064	11	334618	4686812	High Marsh-Phrag
REST	032	12	334606	4686800	High Marsh-Phrag
REST	068	13	334612	4686795	High Marsh-Phrag
REST	016	14	334595	4686781	High Marsh
REST	073	15	334586	4686779	Low Marsh
REST	036	16	334584	4686747	Low Marsh
REST	007	17	334549	4686643	Low Marsh
REST	028	18	334520	4686586	High Marsh
REST	003	19	334535	4686603	Gravel
REST	035	20	334506	4686616	Mudflat
REST	019	21	334500	4686636	Low Marsh
REST	058	22	334480	4686657	High Marsh
REST	014	23	334479	4686686	Low Marsh
REST	039	24	334470	4686694	High Marsh-Phrag
REST	071	25	334484	4686702	High Marsh
REST	055	26	334469	4686727	High Marsh
REST	027	27	334470	4686731	High Marsh
REST	075	28	334477	4686762	Low Marsh
REST	059	29	334458	4686771	High Marsh
REST	033	30	334469	4686777	High Marsh
REST	009	31	334501	4686815	Mudflat
REST	077	32	334528	4686822	High Marsh-Phrag
REST	050	33	334550	4686836	High Marsh
REST	076	34	334592	4686755	High Marsh
REST	081	35	334497	4686801	Mudflat

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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