Stability of Wetland Plant Communities in Upper Namskaket Marsh, Town of Orleans, Massachusetts

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Introduction:

Namskaket Marsh is an 80-hectare salt marsh located on the northeastern coast of Cape Cod in the Town of Orleans. It hosts a healthy community of wetland plants, algae, fish, invertebrates, and birds. The main salt marsh is dominated by *Spartina alterniflora* (cordgrass) and *Spartina patens* (salt marsh hay), typical of New England salt marshes and the adjacent Little Namskaket and Rock Harbor marsh systems. The study site was the uppermost tidal reach of Namskaket Marsh, a 7-hectare inland lobe nearly closed off (300^{o}) by upland and the embankment of the bikeway. Tidal water is exchanged through one of the main branches of the Namskaket Marsh channel, with surface freshwater entering through the culvert from brackish Hurley's Bog and through direct groundwater seepage.

A nearby septage treatment facility, (TriTown,) began operation in 1990 (Figure 1, from USGS 1995 report). The facility discharges secondarily treated effluent to rapid infiltration beds. A plume of effluent enriched groundwater has formed as a result of the 25 years of discharge. When the TriTown facility was sited, the concept was that the plume would move towards Cape Cod Bay, although there was concern about a fraction entering Hurley's Bog or discharging to the upper lobe of Namskaket Marsh. As a result the USGS has conducted studies to ascertain plume direction and the discharge location. It appears that at present the plume is headed toward Cape Cod Bay and appears to be mainly confined under a clay layer that was unknown at the time of TriTown construction. However, as the possibility remains that a small fraction may enter the uppermost lobe of Namskaket Marsh in the future, or that a new future discharge might impinge on this small pocket of salt

marsh, monitoring continues. As part of this larger effort by the Town of Orleans and to address recent citizen concerns that the present plume has entered the pocket marsh (somehow missed by the hydrogeological surveys) and has wrought changes to the ecosystem, the present study of the uppermost lobe of Namskaket Marsh was undertaken by Coastal Systems Program scientists at SMAST.

A s much of the concern relates to recent perceptions of change in the plant communities of this small pocket of salt marsh, it was possible to directly address this issue of change by comparison to a USGS report presenting survey results on this same region of Namskaket Marsh and conducted in 1995. The 1995 report includes data on distribution and abundance of wetland plant species and sediment pore water salinity. Salinity being one of the key metrics in evaluating coverage by *Phragmites australis*, a invasive brackish water. The current (2015) study uses the data from the 1995 report as the baseline condition of the marsh, as it was conducted prior to any discharge from TriTown reaching the salt marsh. The current study was modeled to yield the same types of data as the 1995 report in order to allow for direct comparisons of results from which to determine plant community changes, now 20+ years later.

Figure 1. Location of Namskaket Marsh and Creek, adjacent septage-treatment facility, and plume of septage-effluent-contaminated ground water, Orleans, Cape Cod, Massachusetts.

Methods:

In August 2015, the wetland plants of the uppermost lobe of Namskaket Salt Marsh, hereafter termed "Upper Namskaket Marsh", were surveyed to determine the current distribution and abundance of plant communities. In addition, sediment pore water samples were collected to determine salinity of water within the root zone of the marsh plants. The concept is that a freshening of the salt marsh due to increased groundwater inflow may result in a spatial expansion of Phragmites.

The 1995 report divided the marsh into 16 different transects with 114 different sampling sites. The sites were evenly spaced across the marsh as much as possible. The distribution and abundance of wetland plants were determined using $1m^2$ quadrates at each sampling site. This data along with vertical color photographs were used to create a full vegetation map showing upland boundaries, creeks, and major plant communities. Plant communities covering areas smaller than $4m^2$ were not mapped separately. The resulting coverages were then digitized into a GIS data layer, such that major vegetation coverage areas and percent cover of each vegetation type could be calculated.

In August 2015 a comprehensive vegetation survey of Upper Namskaket marsh was completed. The perimeters of all major vegetation patches were surveyed using a RTK GPS. As in 1995, all patches smaller than $4m^2$ were not mapped separately. All GPS points were uploaded into Didger/Surfer Mapping software and a new full vegetation map was created. Didger calculates area for each patch allowing for direct comparison between areas from the 1995 map.

The 1995 study included pore water salinity measurements at depths of 10 and 15cm below the marsh sediment surface at each of the sampling locations. This data was used to create a contour map of the pore water salinity (Fig. #2). The

1995 report was used as the baseline salinity condition for comparison to the 2015 survey data. The 2015 pore water salinity measurements were made at 19 sampling sites across the marsh within major vegetation types. Sites were spaced across different areas of the marsh to allow for comparison with the 1995 pore water salinity contour map (Fig. #3)

Results and Discussion:

Pore Water Salinity: Recent concern over changes to plant communities, mainly expansion of Phragmities coverage, in Upper Namskaket Marsh has stemmed from concerns over increased freshwater inflow from discharge of freshwater treated effluent from the adjacent septage-treatment facility. If this concern is valid, the salinity of the rooting zone of the salt marsh vegetation in the upper marsh should be less saline (fresher) in 2015 versus the earlier survey (1995). Since salt marsh vegetation uptakes water through its roots generally over the surface 0-20 cm of the sediment column, the salinity of this water was determined. It is this water in the rooting zone which influences plant physiology, hence growth and distribution. When marsh sediment pore water salinity is low, salt marsh vegetation can lose its competitive advantage, and be replaced by freshwater and brackish species. There is particular concern regarding the brackish water invasive *Phragmites australis* expanding its area of coverage.

Water samples were collected from the plant root zone 15cm below the sediment surface using pore water sippers (with an additional depth in 2015 of 5 cm) and analyzed for salinity. In the 1995 USGS study, a general marsh-wide baseline was being sought to allow future comparisons. Pore water was collected from many sites equally spaced across the marsh to develop a contour map of pore

water salinity (Figure 2). In the more targeted 2015 survey, pore water samples were collected from 19 locations spaced across the marsh to detect any changes in pore water salinity since 1995. Sites were selected within the major vegetation coverage areas of the upper marsh, with more sites to the northeast region of the marsh where most of the direct groundwater seepage occurs and where the TriTown inflow would be discharging should it have reached the marsh. Figure 3 shows the locations of the pore water sampling sites for 2015 and their corresponding salinities.

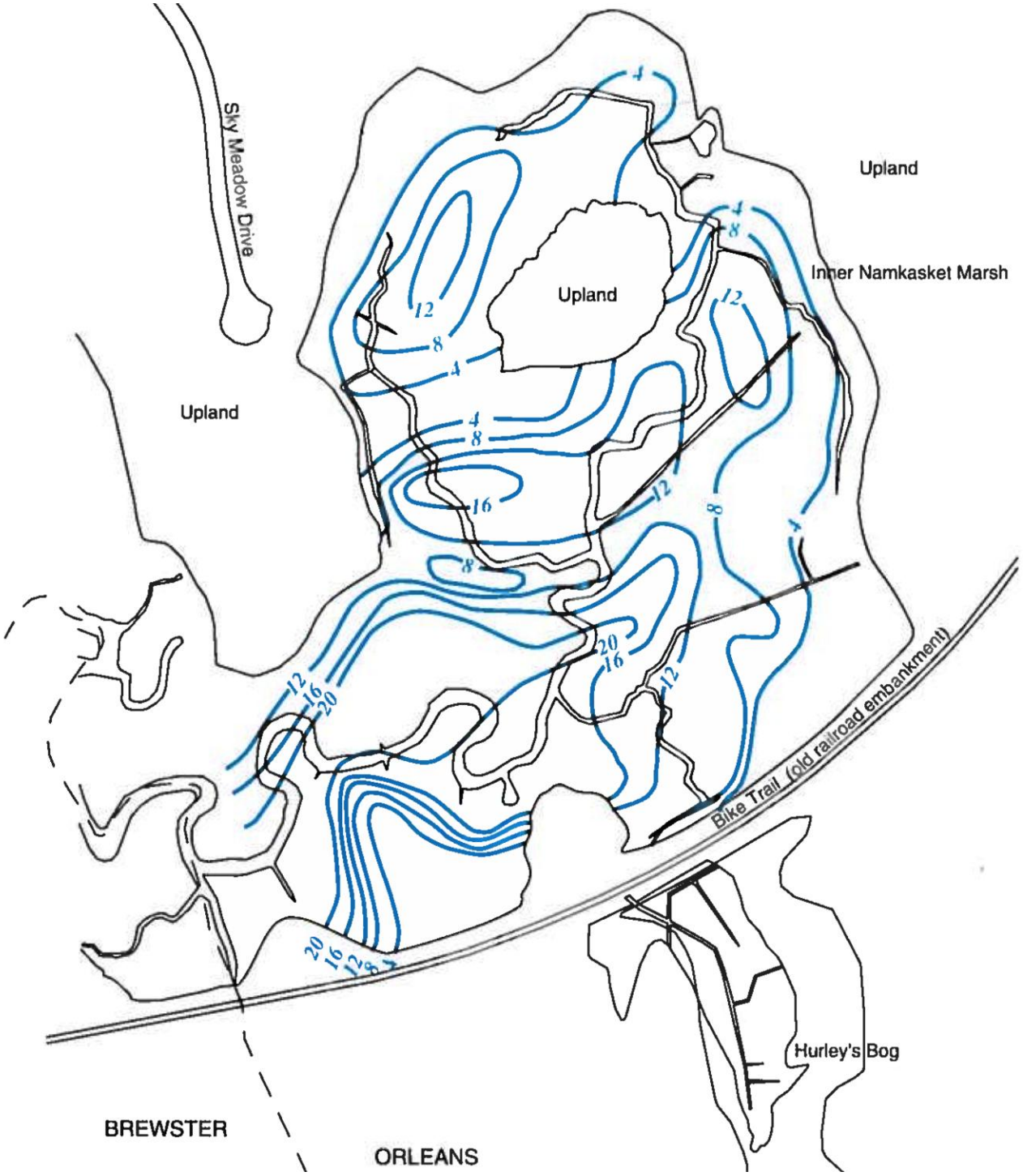

Figure 2. Pore water salinity in peat sediment, Upper Namskaket Marsh, Cape Cod, Massachusetts, peak growing season 1995. Salinities measured at nominal 15 cm, within the plant root zone.

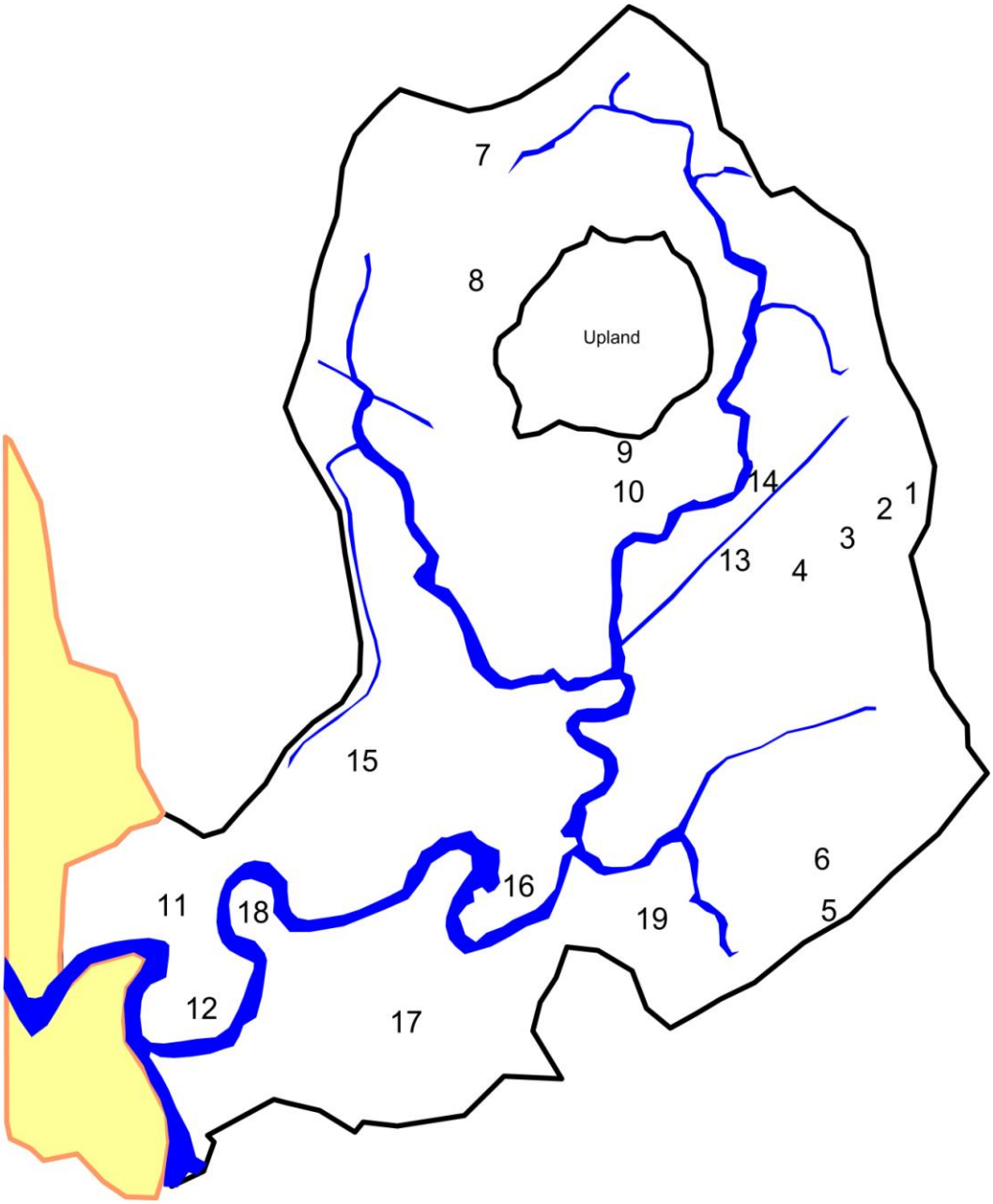

Figure 3. Porewater salinity collection sites within Upper Namskaket Marsh, Cape Cod, Massachusetts. Samples were collected during peak growing season, August 2015, at both 5 cm and 15 cm depths..

Site	5cm (ppt)	15cm (ppt)
1	6.5	8.2
2	12.1	11
3	16.3	17.6
4	22.3	15.4
5	13.4	11
6	13.7	2.1
7	11.7	13.3
8	14.4	14.2
9	18.9	20.6
10	18.5	18.5
11	25.3	33.9
12	22.8	25.7
13	12.3	9.5
14	14.8	19.4
15	23.8	28
16	18.1	17.5
17	18.1	14.7
18	22.9	23.5
19	14.9	12.2

Table 1. Porewater salinities within the rooting zone (5 cm, 15 cm) of the major plant communities of Upper Namskaket Marsh, Cape Cod, Massachusetts, peak growing season 2015. Locations shown in Figure 3. Porewater salinity is determined by the rate of freshwater uptake by plants for evapotranspiration versus the amount of freshwater entry from rain or groundwater seepage and salt "removal" by flooding tides. The fresher waters adjacent the upland edge are attributed to high rates of groundwater discharge, generally to the marsh surface.

It appears from the salinity survey results that within Upper Namskaket Marsh, Phragmities has generally colonized areas with more brackish pore water salinities. This can be seen in that the predominant coverage is found around the margins of the marsh where salinities are lower, with the central, more saline areas, supporting typical salt marsh plants, such as *Spartina alterniflora and Spartina patens* (Figures 2 & 5, Table 1). The relationship between salinity and plant communities in general has been discussed in the literature and in the 1995 USGS

report. The present study is to look at changes in salinity and changes in plant communities to the extent that they have occurred between 1995 and 2015.

To assess potential changes in pore water salinity, the salinity measurements from comparable depths (15 cm) in 1995 and 2015 for the same sites were examined (Figure 4, Table 2). The direct comparison of the two years salinity data indicates that the salinity of the pore water has increased or stayed the same with only a single site (#16) showing a lower salinity in 2015 versus 1995 (-2.5 ppt). Since the 1995 data was determined from the salinity contours (Figure 2) and therefore have a range for each location, the upper value was used to increase the chance of detecting a lowering of salinity. Since this biases the analysis toward detecting a salinity decrease and the results of the site by site comparison indicated that, if anything, there was a slight salinity increase, it can be concluded that salinity conditions have become less optimal for Phragmities and more supportive of salt marsh plants. However, given the actual salinities it appears that major areas, particularly at the marsh margins, remain capable of supporting a Phragmites community. However, the lack of evidence of a decline in salinity suggests that groundwater seepage has not increased significantly over the past 2 decades. This is consistent with the small volume of discharge from TriTown and the lack of any major increases in freshwater input to the groundwater system associated with Upper Namskaket Marsh over this same period.

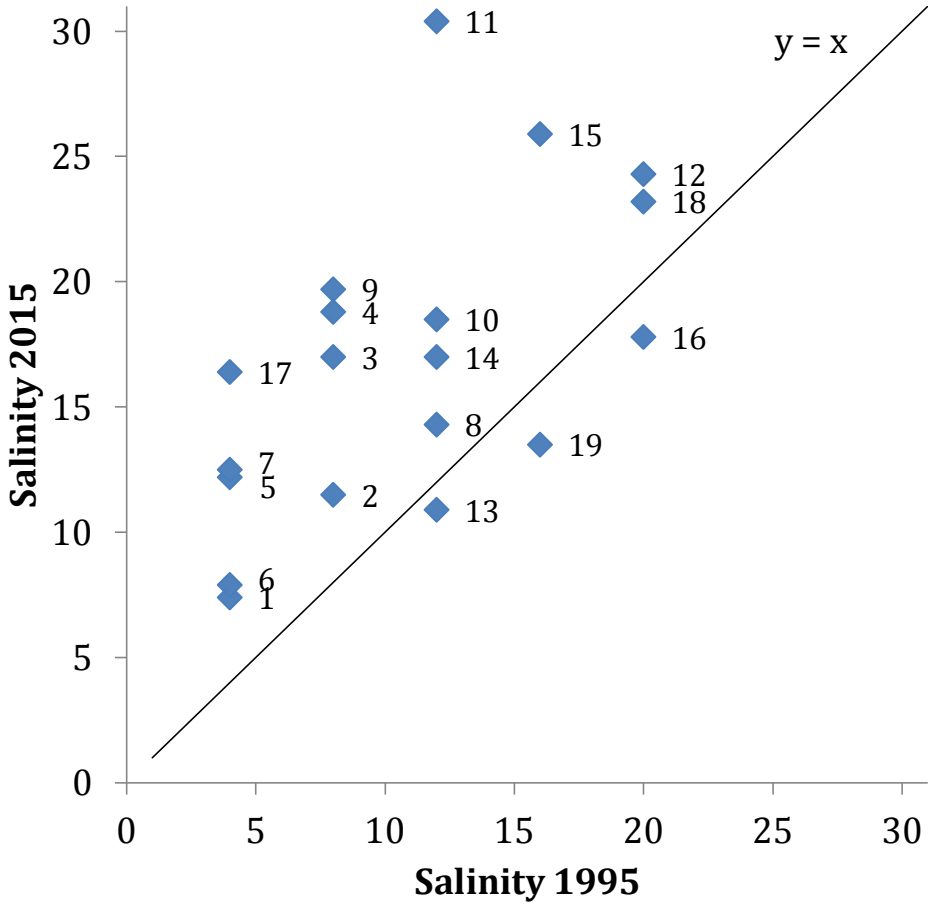

Figure #4. Pore water salinity from the plant rooting zone of major plant communities within upper Namskaket Marsh, 1995 vs. 2015 at each of the 19 sample locations shown in Figure #2. Points above the line indicate salinity levels in 2015 greater than in 1995. The only sites showing significant change, show increased salinity in 2015 vs. 1995.

Site	1995 (ppt)	2015 (ppt)	Diff.
1	0-4	8.2	4.2
2	4-8	11	3
3	4-8	17.6	9.6
4	4-8	15.4	7.4
5	0-4	11	7
6	0-4	2.1	0
7	0-4	13.3	9.3
8	8-12	14.2	2.2
9	4-8	20.6	12.6
10	8-12	18.5	6.5
11	12+	33.9	-
12	20+	25.7	-
13	8-12	9.5	0
14	8-12	19.4	7.4
15	12-16	28	12
16	20+	17.5	-2.5
17	0-4	14.7	10.7
18	20+	23.5	-
19	12-16	12.2	0

Table 2. Pore water salinity within the rooting zone of plant communities within upper Namskaket Marsh measured in 1995 vs. 2015 surveys. The site numbers (1-19) relate to the sites shown in Figure 3. Values from the 1995 USGS study were taken from the salinity contours based on salinity at nominal 15 cm depth (Figure 2) and therefore show a range. The 2015 salinities shown are also from 15 cm depths. The difference is calculated as the upper value of the 1995 range minus the 2015 value. Most sites showed increases in salinity, seen as positive differences. Data is graphically represented in Figure 4.

Wetland Plants Distribution and Abundance: To assess changes in the plant communities and their coverages within Upper Namskaket Marsh from 1995 to 2015, a comparison of the field survey data was undertaken. While the plant surveys were conducted to produce comparable data, it must be stressed that small differences related to determining siting and plant species mixes can result. However, the surveys produced data that are sufficiently robust to detect any

ecologically important changes (more than a few percent) within this semi-enclosed salt marsh.

To improve the ability to detect small differences between the surveys, the 1995 vegetation maps were re-digitized and identical color schemes used for the 1995 and 2015 coverage maps (Figure 5). This allows for easier visual comparisons between the years. From the digitized maps it was possible to calculate coverages by major species (e.g. *Phragmites, Spartina alterniflora, Spartina patens*, etc) and major species mixes (e.g. *S. alterniflora/S. patens, Phragmities/S. robustus*, etc). The coverages by species mixes is particularly important when evaluating potential community shifts, since species are generally not replaced instantaneously, but through an initial colonization of a new species A into a formally pure stand of species B. Over time if conditions are stable, these species mixes can then become pure stands of the newly colonizing species or remain as mixed stands. It is worth noting here that there were more mixed stands than in 1995 and that plant communities overall appear to have shifted to greater coverage by salt marsh plants.

Areas (m^2) of major plant species and species mixes were determined from the digital maps, as was their percent cover (Table 3). In both the surveys Phragmites represents the largest community, by area, but showed only a very small increase (780 m^2) over the past 2 decades. In contrast S. alterniflora increase its areal coverage by almost 2000 m^2. However, closer examination reveals more complex changes.

A key finding is that the distribution of *Phragmites* has changed and shifted counter-clockwise around the perimeter of the marsh (red highlighted area in Figure 6). The southern border was dominated by *Phragmites* in 1995, and now this

area has become a mix of *Phragmities, Scirpus robustus,* and *Spartina cynosuroides.* It is a positive finding that *Scirpus* and *Spartina* are now colonizing areas formerly dominated by *Phragmites,* because these are non-invasive typical salt marsh species of Cape Cod and New England salt marshes. In contrast, as part of this spatial shift, an area that used to be dominated by salt marsh vegetation now has been invaded by *Phragmites (*yellow highlighted area in Figure 6*)*. The upland/marsh border of this area was dominated by *Iva frutescens* in 1995, a woody shrub typical of the upland margin so salt marshes. Most of this Iva coverage had shifted to Phragmites by the 2015 survey, which may result from activities in the upland or sea level rise affects at the upland marsh border (sea level is ~6 cm higher in 2015 vs. 1995). However, the total area of *Phragmites* coverage has increased only 780m^2 in the last 20 years. This is a small increase considering the total area surveyed is over 56,000m^2 and is at the resolution of the survey method.

The most significant ecological change was found within the central area of Upper Namskaket Marsh. The major shift appears to be a loss of bare (panne) or wrack covered areas (1995=8020m^2; 2015=1789m^2) with a parallel colonization by salt marsh plants, as these areas were mainly in the middle of the marsh (Figure 6). This can been seen in Figure 6 within the area highlighted in purple, which was dominated by wrack in 1995, but is now dominated by healthy salt marsh vegetation, mostly *Spartina* species. Total wrack coverage alone has decreased more than 6000 m^2 allowing approximately an additional 5400 m^2 of salt marsh vegetation to re-colonize this area. In addition pure stands of *S. patens* were significantly reduced and had become more typical of lower salt marsh dominated by a mix of *S. patens* and *S. alterniflora*.

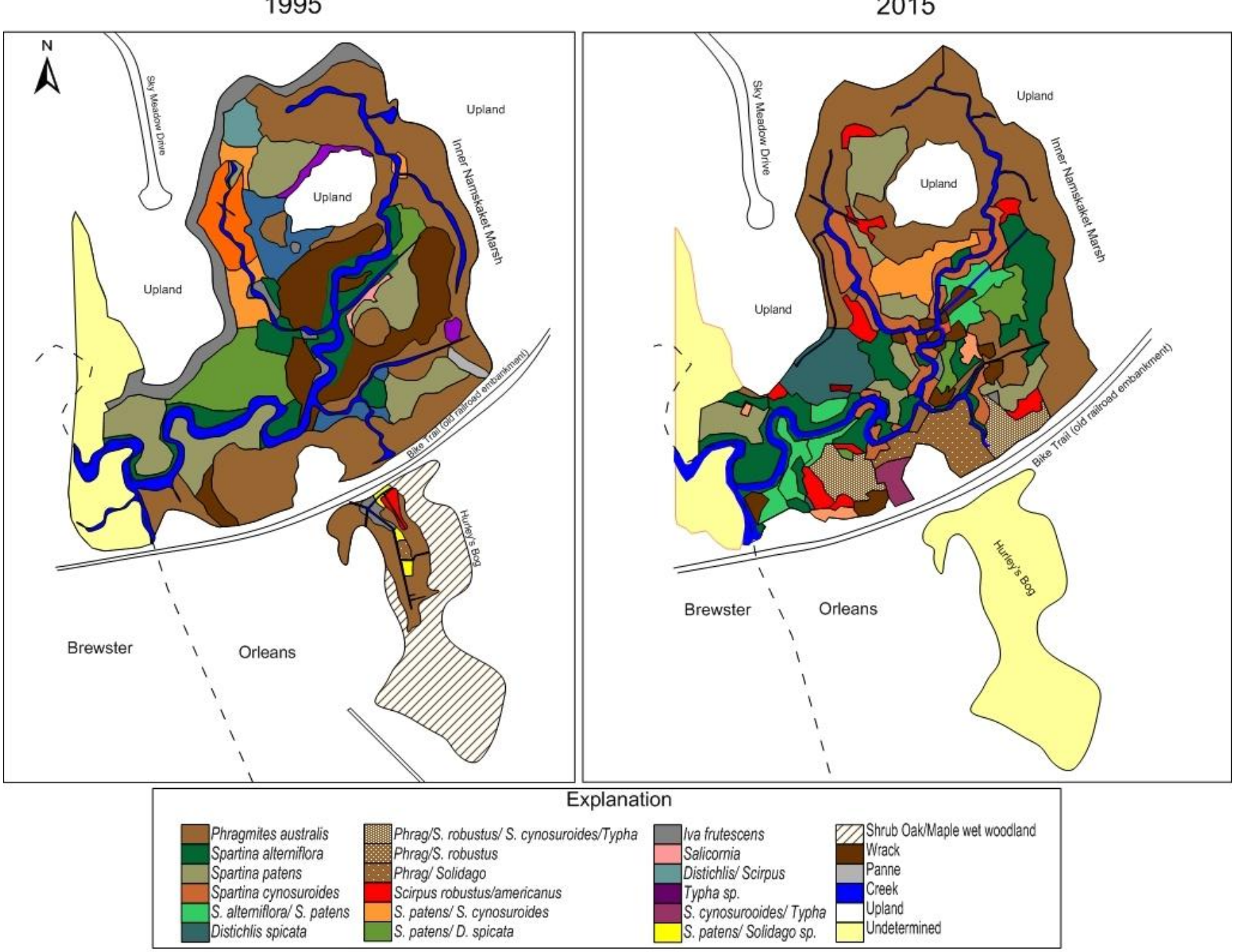

Figure #5: Full vegetation maps from 1995 and 2015 with same color key.

Species	1995		2015		Difference
	M^2	% Cover	M^2	% Cover	2015-1995
P. australis	21600	38.3	22380	39.6	780
S. patens	8300	14.7	5308	9.4	-2992
S. alterniflora	4300	7.6	6274	11.1	1974
S. Patens/ D. spicata	3800	6.7	1349	2.4	-2451
S.alt/ S.pat	0	0	2747	4.9	2747
cyno/rob/typha/phrag	0	0	2534	4.4	2534
cyno/typha	0	0	601	1.1	601
Iva frutescens	3000	5.4	137	0.2	-2863
D. spicata	2300	4.1	2648	4.7	348
S. cynosuroides	2200	3.9	3997	7.1	1797
S. patens/ S. cynosuroides	1400	2.5	1681	3	281
D. spicata/ S. robustus	840	1.5	0	0	-840
P.australis/ S. robustus	0	0	2267	4	2267
Scirpus sp.	0	0	2198	3.9	2198
Typha sp.	550	1	0	0	-550
Salicornia	200	0.35	557	1	357
Wrack	7800	13.7	1789	3.2	-6011
Panne	220	0.4	0	0	-220
Creek	5300		5072		-228
Upland	3300		3367		67
Undetermined	7300		7250		-50
Total	72410		72156		-254
talNoCreek/upland/Undetermine	56510	100.15	56467	100	-43

Table 3. Areas (m^2) and percent cover for each major species and species mix observed in 1995 and 2015 surveys and the difference in areal coverage between the surveys.

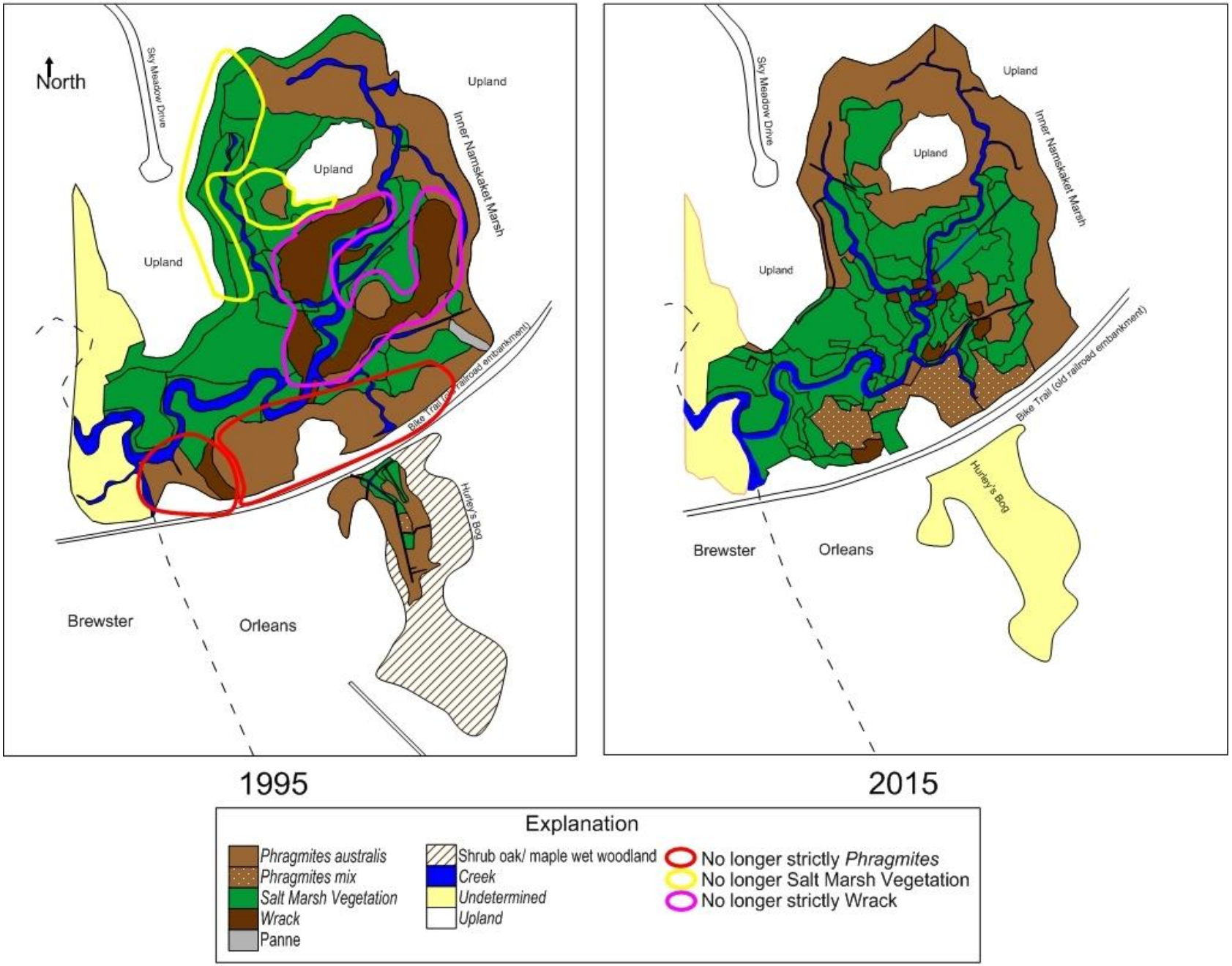

Figure #6: Simplified vegetation maps from 1995 and 2015 grouping *Phragmites* by itself and all other salt marsh vegetation together.

Conclusion:

It appears from both the salinity and vegetation surveys that Upper Namskaket Marsh is a dynamic system that has experienced changes over the past 2 decades. However, the direct measurements do not support the contention that the invasive plant *Phragmites australis* has increased its distribution and abundance within Upper Namskaket Marsh from 1995 to 2015. Comparing the surveys it appears that the specific areas colonized have shifted but that the total area covered has not changed significantly (780 m^2 within a 56,000 m^2 marsh). The changes, especially the spatial shifts, can be best seen in the simplified vegetation coverages showing areas of pure *Phragmites* and all other salt marsh vegetation combined (Figure 6). The results do show an increase in salt marsh vegetation, mainly resulting from the re-colonization of previously wrack covered marsh. Equally important to ecosystem health is that previously pure stands of Phragmites are becoming mixed stands due to the colonization by endemic (non-invasive) wetland species.

The vegetation results are consistent with the salinity data which showed a potential increase in pore water salinity or stable conditions. A freshening of the root zone of the marsh would be of concern relative to Phragmities expansion, but this was not the case in Upper Namskaket Marsh. The salinity results are consistent with the lack of significant new sources of freshwater inflow to the marsh over the past 2 decades (TriTown is a small discharge relative to the watershed recharge).

Given the results it appears that Upper Namskaket Marsh will continue to show cyclical vegetation shifts due primarily to periodic natural deposition of wrack and its subsequent natural removal on extreme tides and changes at the

upland/marsh border due to sea level rise. These types of changes are typical of New England pocket marshes. It appears that this region of marsh will continue in its present state (as delimited by the 1995 and 2015 surveys) unless a major change in tidal exchange or within the upland occurs. Upper Namskaket Marsh continues to be a productive salt marsh and home to countless invertebrates, fish, and birds as a tributary to the larger Namskaket Marsh system.