Hatches Harbor Salt Marsh Restoration: 2004 Annual Report

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INTRODUCTION

In cooperation with the Town of Provincetown, Federal Aviation Administration and Massachusetts Aeronautics Commission, the National Park Service (NPS) has been incrementally restoring tidal exchange to the diked portions of Hatches Harbor since March of 1999. The overall objective of this project is to restore native salt marsh functions and values to the tide-restricted wetland to the extent possible without compromising safety at the Provincetown Municipal Airport.

After an hydrodynamic assessment in 1987 (Roman 1995), large culverts were installed through the Hatches Harbor Dike by the NPS in the winter of 1998-99 to accommodate increased tidal flow. The NPS has opened these gated culverts in small increments each year (Table 1-1) to ensure Airport safety from flooding and to control and adaptively manage ecosystem response. Cape Cod National Seashore (CCNS) staff and cooperators have monitored system response intensively since 1999, with base line data collected in 1997 before new culvert construction.

This reports on physical and ecological monitoring undertaken in 2004 and summarizes progress towards habitat restoration. Monitoring has included tide heights, sedimentation, sediment-water quality, wetland vegetation, mosquitoes and nekton (fin-fish and decapod crustaceans) within both natural (unrestricted) and diked portions of the Hatches Harbor flood plain (Fig. 1-1).

Table 1-1. Recent history of incremental culvert gate openings at Hatches Harbor.

Years	Number of open culverts	Dimensions of opening	Opening area (m^2)	Tidal range	
				Meters	% of downstream
Pre-1999	1	2-ft ID old round culvert	0.29		
Mar 1999 – Mar 2000	2	2.13 m wide X 0.10 m high	0.42		
Mar 2000 – Mar 2001	4	2.13 m wide X 0.10 m high	0.85		
Mar 2001- Oct 2003	4	2.13 m wide X 0.40 m high	3.41		
Oct 2003 -	4	2.13 m wide X 0.70 m high	5.96		

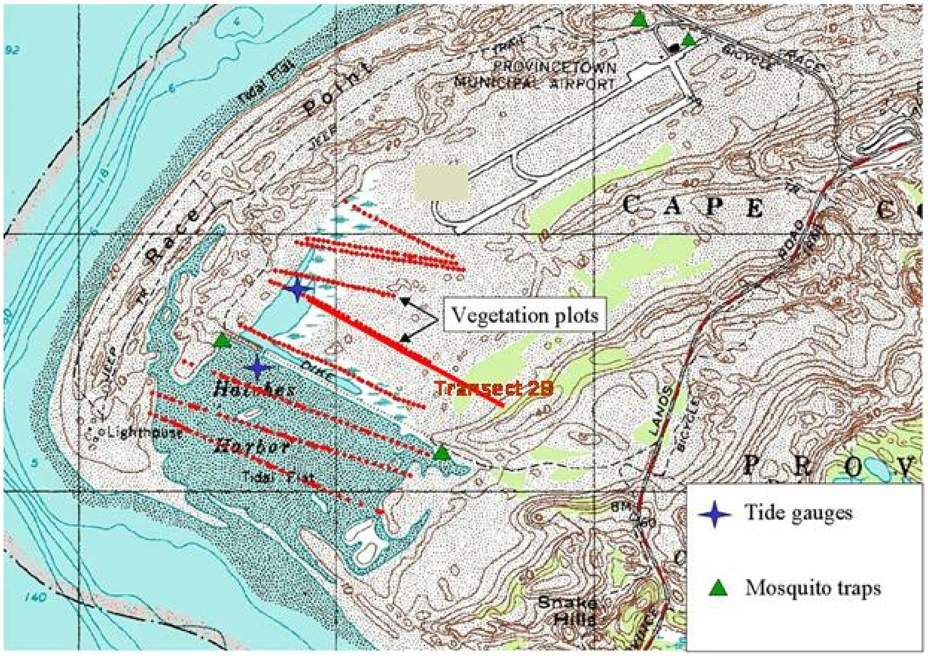

Figure 1-1. Hatches Harbor salt marsh showing locations of tide gauges, transects for vegetation and porewater sampling, and mosquito trapping stations.

SEDIMENT-WATER QUALITY

Salinity and sulfides were monitored before restoration (1997) and annually since 1999 in 10-cm-deep porewater in the vegetation plots of Transects 7 and 2B. Sulfides have been consistently very low (< 60 µmolar), as expected given the sandy, well-drained peat, and well below concentrations that might affect plant growth; therefore, sulfide was not measured in 2004.

In August 2004, we measured porewater salinity in all vegetation plots both above and seaward of the dike. These results are presented for Transect 2B, representative of the restricted marsh, and compared with conditions before restoration (1997) and in 2003 (Fig. 1-2). Root-zone salinity has increased to > 20 ppt over nearly the entire length of Transect 2B. Recent literature indicates that *Phragmites* requires salinity < 15 ppt for long-term survival (Lissner & Schierup 1997).

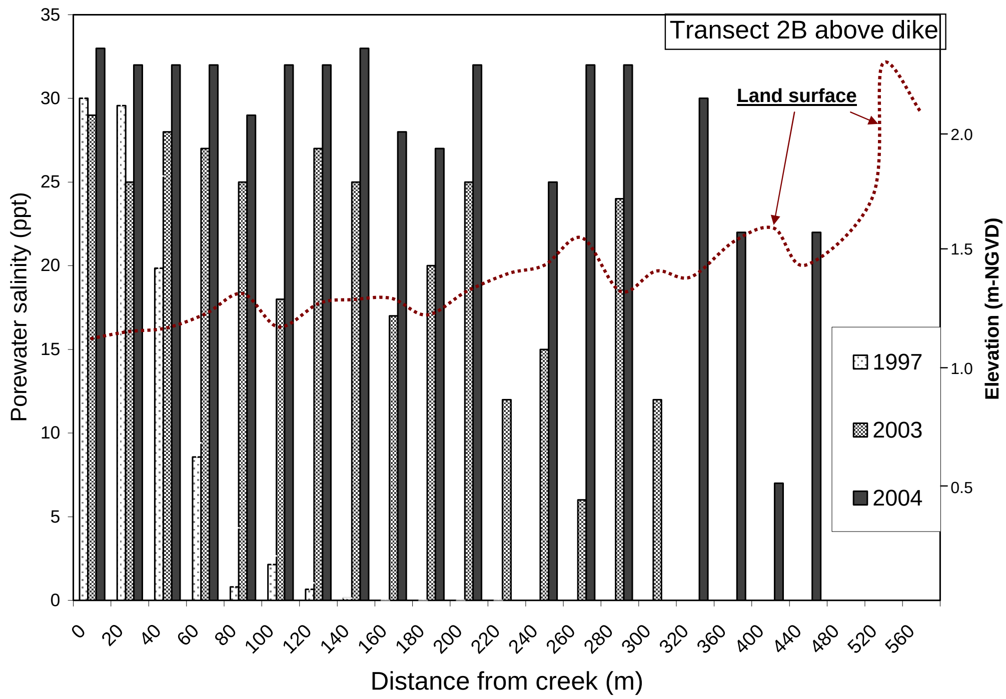

Figure 1-2. Porewater salinity at 10 cm depth along Transect 2B pre-restoration (1997) and after restoration of tidal flow at Hatches Harbor.

MOSQUITOES

The species composition and abundance of floodwater-breeding mosquitoes in coastal marshes is affected by salinity, flooding duration and areal extent, and access to breeding sites by (primarily fish) predators. The objective of mosquito monitoring at Hatches Harbor is to assess whether changes in hydrography caused by the tidal restoration affect mosquito species composition and abundance.

Adult mosquitoes have been monitored throughout July and August from 1997 through 2004 using light/CO_2 traps set at least biweekly within the Hatches Harbor flood plain (Fig. 1-1): at the dike, at the end of the taxiway (discontinued in 2003), and at the airport terminal. The dike station is surrounded by saline breeding habitat. Trapping at the airport terminal represents the upstream and freshest end of the estuarine gradient; it is also the location where people and mosquitoes most frequently meet. [Sampling at the taxiway station was discontinued in 2003 because of access problems related to increased security at the airport.] Two traps were set in each location in the late afternoon and retrieved in early morning. Trapped adult mosquitoes were identified and counted by species.

Prior to 2001, adult mosquitoes were predominantly brackish- and freshwater-breeding species whose annual abundance appeared to correlate with precipitation, especially Jun-Aug rainfall (Fig. 1-3). This is consistent with tide height observations that indicate little tidal flooding of the wetland surface; i.e. floodwater breeding before 2001 was dependent on precipitation, not tidal flooding. This mode of flooding would result in low surface-water salinity, thus, the preponderance of brackish and freshwater, rather than salt marsh, mosquitoes (*Ochlerotatus sollicitans*).

In April 2001 effective culvert opening was increased four fold causing increased tide heights (Table 1-1); consequently, much more water of much higher salinity reached and, in places, remained for weeks on the wetland surface. As an apparent result, very high numbers of brackish-water breeders (*Ochlerotatus cantator*) were captured at the airport terminal in 2001. In 2002, both brackish and saltwater-breeding species (*O. sollicitans*) were abundant at the dike following still more extensive and higher-salinity flooding (Fig.M-3).

Salt marsh mosquito abundance declined significantly at the dike in 2003; however, brackish-water breeders remained high at the terminal. The CCMCP reported ponding of water and high larvae counts on the wetland surface just south of the airport runway, a likely source of brackish water mosquitoes (*O. cantator*). To improve tidal flushing and low-tide drainage in this interior marsh, CCNS and CCMCP planned and completed creek restoration in October 2003.

Besides increasing salinity, which should suppress invasive *Phragmites*, the creek restoration was also expected to improve fish access and tidal flushing and thereby encourage natural mosquito control. Results from 2004 mosquito trapping show significant decreases in brackish species at both the dike and terminal (Fig. 1-3), suggesting that the improved circulation caused a reduction in mosquito breeding in the interior marsh. A 300-m extension of the creek restoration project is planned for winter 2003-4; both 2003 creeks and the planned 2004 extension is mapped (Fig. 1-4).

We submit that the two years of pre-restoration and five years of post-restoration trapping results have shown that increased tide heights and salinities do not lead to increased nuisance mosquito production in the Hatches Harbor flood plain. Thus, the original question and concern voiced during project planning, regarding tide restoration and mosquito production, has been adequately addressed. Consequently, despite some ecologically interesting recent trends, we do not plan to continue mosquito monitoring in 2005.

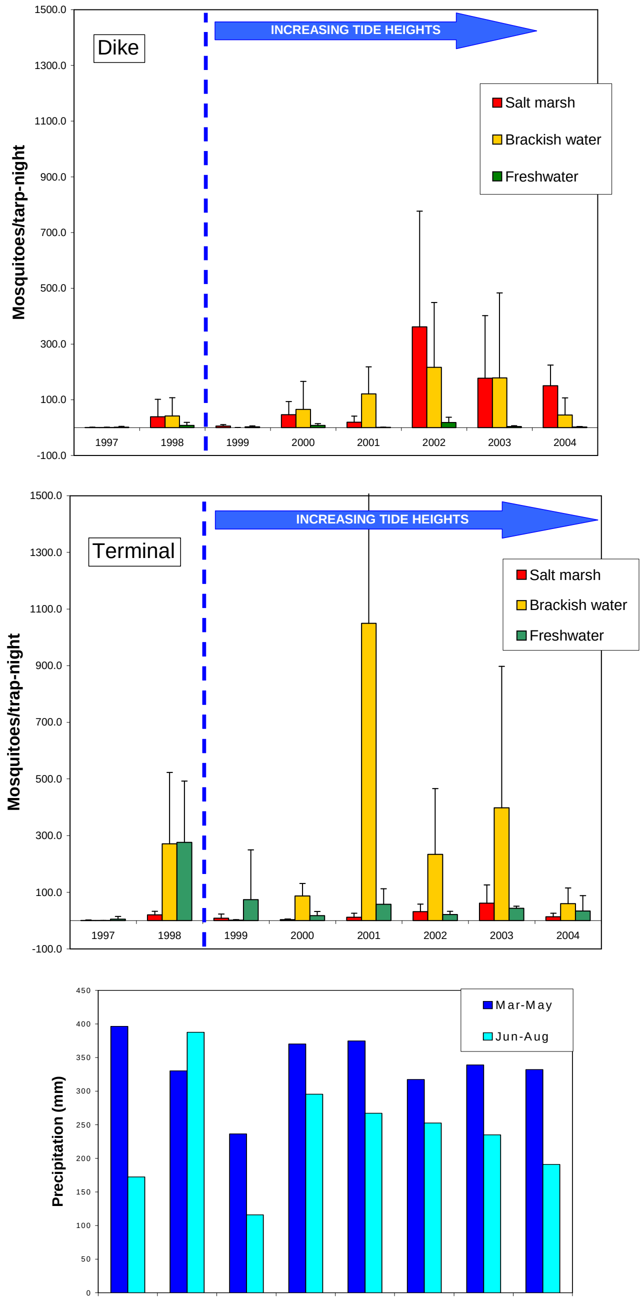

Figure 1-3. Mosquito abundance 1997-2004 at the Hatches Harbor Dike (top) and Provincetown Airport Terminal (middle panel), along with spring and summer precipitation (bottom panel).

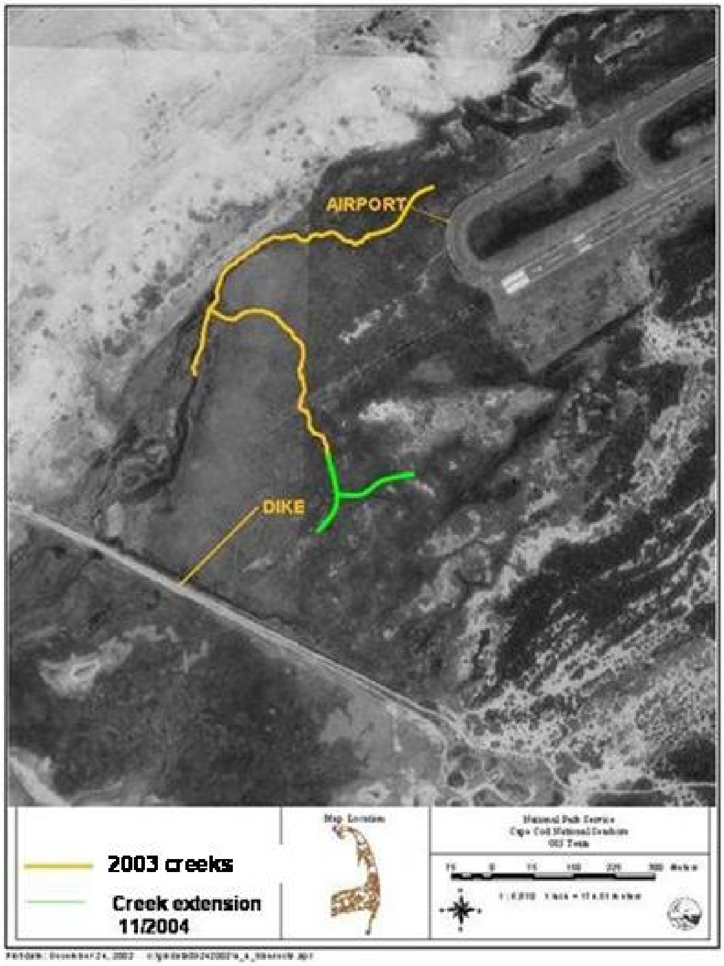

Figure 1-4. Hatches Harbor creeks constructed in 2003 (yellow) and planned in 2004 (green).

INCREASE IN OVERALL WETLAND AREA WITH TIDAL RESTORATION

During the planning process for Hatches Harbor tidal restoration, NPS scientists predicted that increased tidal flow would not only convert *Phragmites*- and freshwater-wetland-dominated habitat to salt marsh, but would also create new wetland around the perimeter of the flood plain (Appendix A). At the request of the FAA, and prior to installation of the new culverts, NPS used existing topography and predictions of restored tide heights to estimate the area of this potential wetland. An increase in regular flooding from elevation 4.26 ft-MSL (1.30 m-MSL), the elevation of discharging groundwater, to 4.42 ft-MSL (1.35 m-MSL), the predicted mean high tide height after restoration, would increase wetland area by about seven acres. This anticipated increase, as a result of tidal restoration, was proposed by FAA as mitigation for wetlands lost as a result of imminent airport improvements.

Since that estimate was made, increased tide heights have been realized, with conspicuous effects on plant communities along the upland border and well above the 4.42 ft (1.35 m) contour. A broad band of beachgrass (*Ammophila breviligulata*) and associated dune species, extending from elevation 4.34 to 5.30 ft-MSL (1.32 to 1.62 m-MSL), has succumbed to seawater flooding, especially during spring tides (Fig. 1-5). This band of dead beachgrass is already being replaced by plants of the high salt marsh (see below). This area of “new” wetland between 4.34 to 5.30 ft-MSL is likely well over the seven acres required for airport mitigation.

Figure 1-5. Increased tide heights above the Hatches Harbor Dike are causing beachgrass to be replaced by plants of the high salt marsh. Also see Figure 2-5 and discussion below.

VEGETATION

Introduction

Since 1997, when a series of adjustable culverts were installed through a tide-restricting dike, approximately 100 acres of Hatches Harbor has been undergoing hydrologic restoration. During this time, the formerly restricted portion of the marsh has exhibited dramatic changes in the physical, chemical, and biological landscape (Farris and Portnoy 2000, Farris et al. 2002, Portnoy et al. 2003). This report focuses on vegetation data collected in the summer of 2004 as part of a continuing effort to evaluate the restoration process.

Methods

All materials and methods for vegetation monitoring are described in Smith 2004.
As in previous years, vegetation was monitored by point intercept in the $1m^2$ permanent plots. In addition, stem heights and densities of live *Phragmites australis* were recorded in all plots where it occurred.

Data analysis **-** A comprehensive analysis of community-level vegetation changes from 1997-2004 is presently being conducted by Charles Roman (North Atlantic Coast Cooperative Ecosystem Studies Unit, University of Rhode Island). Accordingly, this report summarizes the responses of individual key species in the system. *Spartina* and *Suaeda* spp. cover data are plotted as histograms showing temporal change within individual plots. *Phragmites* cover data were subjected to linear regression to examine relationships with environmental variables. Standard errors corresponding to *Phragmites* stem height values were plotted to indicate statistical relevance of temporal changes. ARCGIS ver. 8.0 was used to depict spatial patterns of *Phragmites* biomass.

Results

Trends in the distribution and abundance of key species - *S. alterniflora* and *S. patens* cover have undergone dynamic change since 1997. A multiyear comparison of *S. alterniflora* shows that considerable variation in cover has occurred, with both losses and gains over time (Figure 2-1). The most plausible explanation for these patterns is that hydrologic conditions continue to change as flow through the culverts is increased with each incremental opening. Conditions that resemble those of “low marsh” areas in the unrestricted area are now occurring across more of the restricted marsh. *S. alterniflora* appears to be following this change, becoming established initially near the creek bank and then expanding outward as evidenced by the many hundreds of new seedlings that have germinated beyond the boundaries of the existing population (Figure 2-2). However, some of the creek bank plants are now being lost due to changes in the morphology of the main tidal creek (e.g., plot HH2A-000; Figure 2-1). More specifically, parts of the channel have widened considerably as a result of increased tidal velocities.

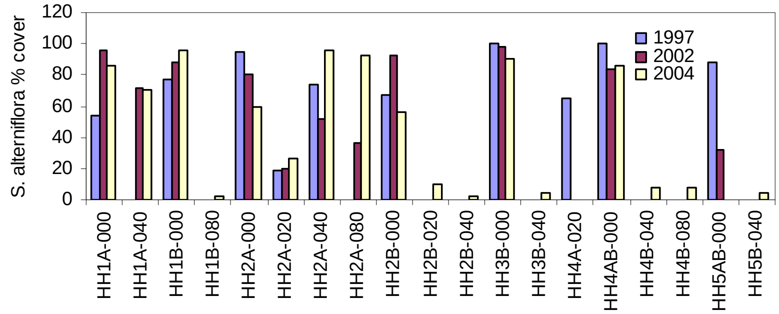

Figure 2-1. Comparison of *S. alterniflora* cover in 1997, 2002, and 2004 (restricted side only).

Figure 2-2. Seedlings of *S. alterniflora* germinating on a mudflat amidst stunted and dead *Phragmites* stems.

S. patens is also expanding into areas distant from the main tidal creek as saltwater begins to reach further into the marsh (Figure 2-3). Like *S. alterniflora*, it is also being lost in places along the downslope edge, primarily because its optimal range of salinity/hydroperiod conditions are moving further upslope. In general, the low marsh/high marsh interface is shifting away from the main tidal creek with each stepwise increase in flow, with concurrent gains and losses on the upslope and downslope edges of these communities.

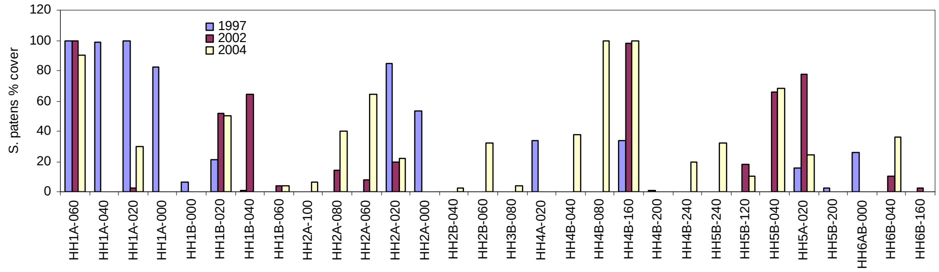

Figure 2-3. Comparison of *S. patens* cover in 1998 and 2004 (restricted side only).

Similar to *Spartina* spp., other native halophytes are expanding their range. In 2004, two species of sea blites (*Suaeda maritima* and *Suaeda linearis*) were observed along all 6 transects above the dike despite the fact that none were recorded prior to the first culvert openings in 1998 (Figure 2-4). *Suaeda* spp. have recently emerged in high numbers amongst the culms of beachgrass that were alive and well in 2003 but salt-killed in 2004 (Figure 2-5). Across the restricted marsh, areas previously dominated by upland dune vegetation are being converted to wetlands, resulting in a significant increase in total salt marsh area.

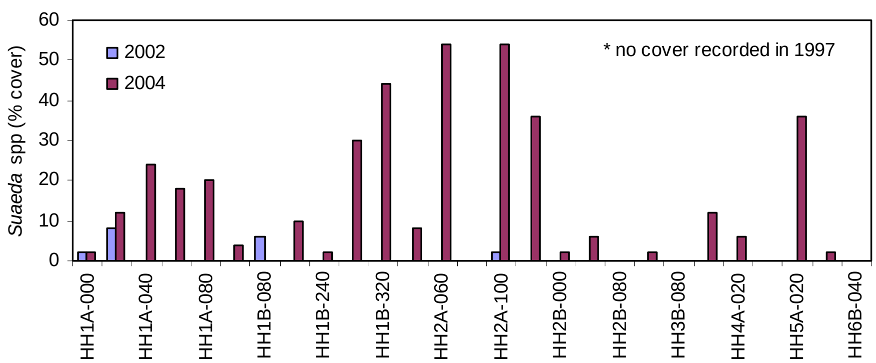

Figure 2-4. Percent cover of previously absent *Suaeda* species in 2002-2004 (restricted side only).

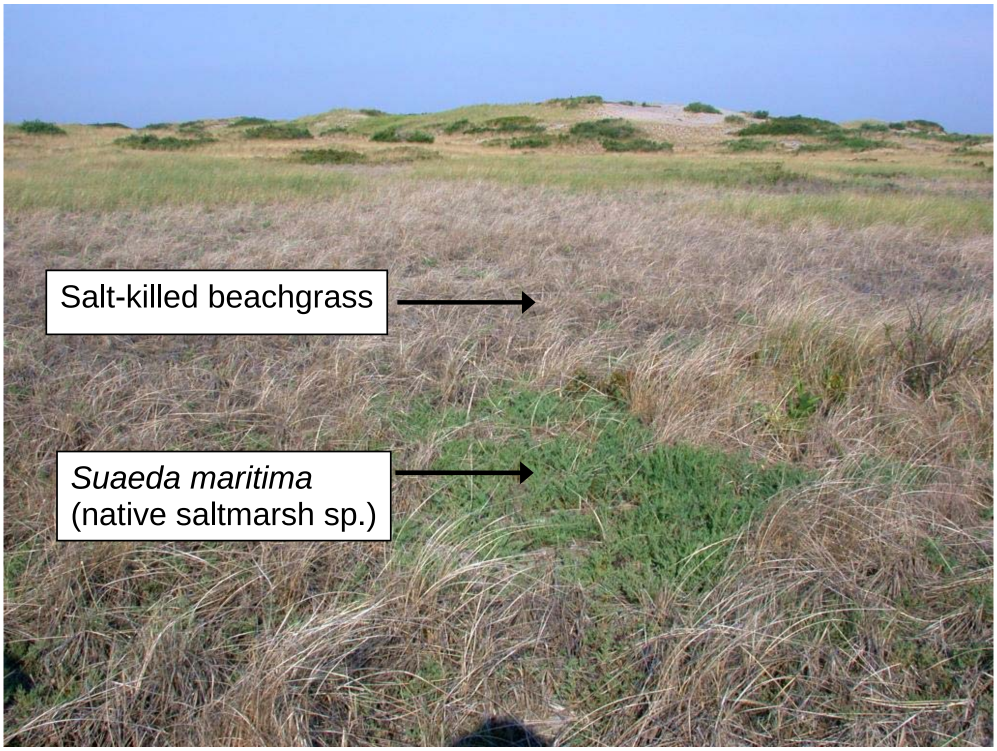

Figure 2-5. Expansion of wetland area since 2003 as indicated by the death of upland dune species and the proliferation of native salt marsh taxa. Also see Figure 1-5.

Changes in the area cover of *Phragmites* from 2002-2004 were significantly correlated with plot distance from the culverts (F=12.2, p=0.0009). The same was true for elevation (F=15.8, p=0.0001) but not 2004 porewater salinity (Figure 2-6). This indicates that instantaneous measures of root zone salinities do not always adequately explain patterns in *Phragmites* cover. Instead the influence of salinity over long periods of time may better reflect distribution and abundance – a metric that is intrinsically tied to distance from the culverts and elevation. The scatter of the data about the trend lines may be due to the confounding influence of hydroperiod since many closer, low-elevation plots may now be draining better, thereby ameliorating some of the salinity affects. Conversely, *Phragmites* may be stressed by the drier conditions of the highest elevation plots in fresher (distant) parts of the system. In addition, salinities continue to change with each enlargement of the culvert openings. As seawater penetrates further and further into the marsh into the marsh, the cover responses (which may not be a good representation of plant biomass since there is no vertical component to this parameter) of salt tolerant vegetation may lag behind those of the physico-chemical environment.

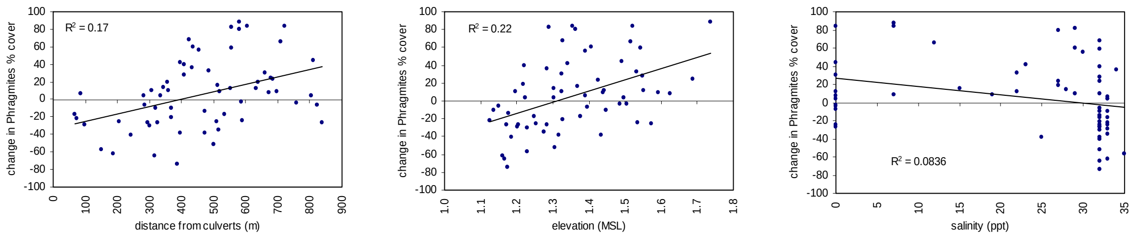

Figure 2-6. Change in *Phragmites* percent cover vs. distance, elevation, and 2004 porewater salinity.

Compared to area cover, suppression of height growth appears to be a much more rapid response to increased tidal flow. From 2002 to 2004, *Phragmites* stem heights continued to decrease in the majority of plots along transect 2 (Figure 2-7). As in previous years, the magnitude of reduction was highest in plots closest to the main tidal creek.

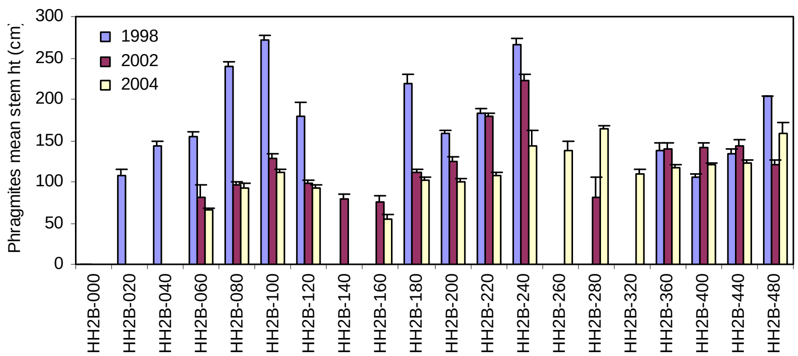

Figure 2-7. Change in *Phragmites* mean stem length along transects 1 and 2 from 2002-2004.

Phragmites biomass (estimated from stem densities and stem heights as per Thursby et al. 2002) in 2004 showed a clearly discernible pattern with respect to porewater salinity, even though this relationship was not statistically significant by regression analysis (Figure 2-8). Notwithstanding, biomass generally peaked where salinities were lower than full-strength seawater, but were still high enough to exclude other salt-intolerant taxa. In this way, *Phragmites* seems to be exploiting a niche where salinity stress is significantly reduced and interspecific competition is largely absent. However, chronic exposure to elevated salinities and the gradual encroachment of native salt marsh vegetation into these areas are likely to eventually affect *Phragmites* in a negative way.

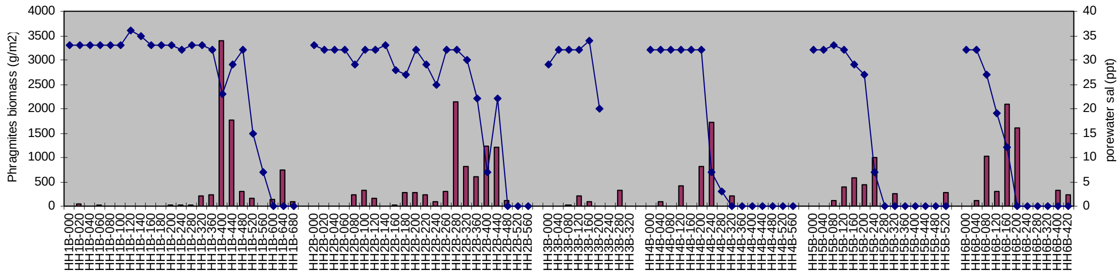

Figure 2-8. 2004 *Phragmites* biomass and porewater salinity by plot.

From a marsh-wide perspective, *Phragmites* is responding to increased tidal influence primarily by shifts in its distribution (Figure 2-9). While *Phragmites* near the main tidal creek is disappearing or exhibiting stunted growth, the far edge of the population is encroaching upon the freshwater wetland community behind it. In other words, Zone 2 (see Figure 2-10) of the population is moving away from the creek bank and toward the freshwater-upland transition zone, although the degree to which this is occurring is different along each transect. In essence, the greatest change is observed along transects 1 and 2, which are most influenced by seawater entry through the nearby culverts.

Figure 2-9. Changes in *Phragmites* biomass (estimated from stem heights and densities) from 2002-2004 (arrow indicates direction of movement of peak biomass).

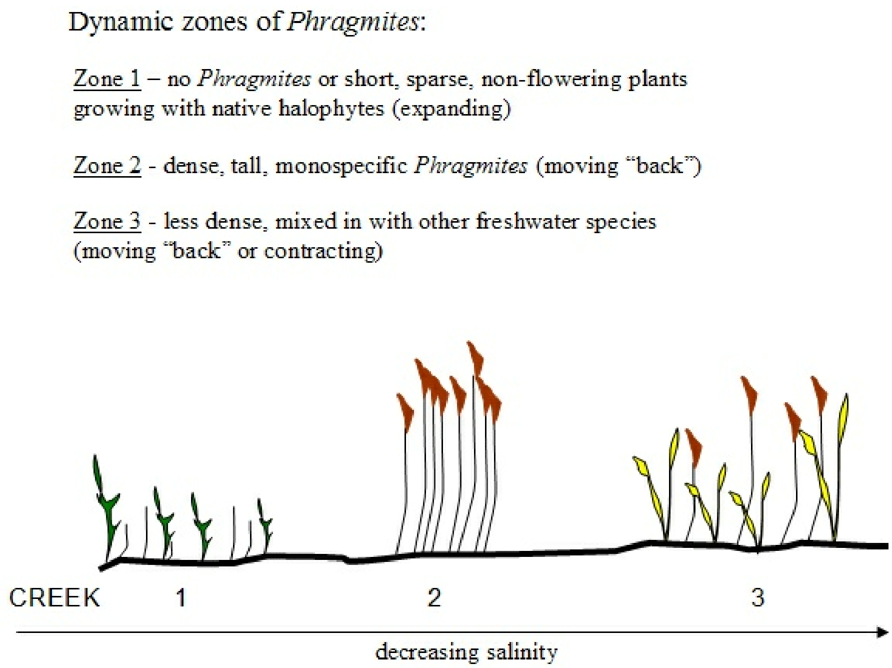

Figure 2-10. Schematic diagram of zones defining Phragmites population vigor and abundance.

Discussion

The vegetation community in Hatches Harbor continues to exhibit significant responses to incremental restoration of tidal flow. The most recent enlargement of culvert cross sectional area in October 2003 resulted in a notable increase in area subject to inundation. This resulted in the death of salt-intolerant wetland and upland plants, coinciding with the establishment of native halophytes in these areas.

The *Phragmites* population continues to "migrate" away from the main tidal creeks toward the freshwater wetland-upland boundary. In effect, this has allowed salt marsh vegetation, including *Spartina* and *Suaeda* spp., to greatly expand their range. The plethora of *S. alterniflora* seedlings that emerged in areas originally occupied by dense *Phragmites* speaks to the magnitude of change.

Overall, a substantial portion of the formerly-restricted marsh now resembles the unrestricted landscape with respect to vegetation communities. Moreover, as restoration proceeds it is expected that there may be some positive feedback whereby the establishment of desirable taxa in new places enhances their capacity for further expansion by the production of new seeds and propagules. In turn, this may eventually result in enough competitive pressure to encourage further withdrawal of the *Phragmites* population. Any further increase in tidal flow would presumably enhance the rate and magnitude of these kinds of changes.

NEKTON

INTRODUCTION

Nekton is an effective and powerful sample population for monitoring the results of tidal restoration in the Hatches Harbor salt marsh, ongoing since spring 1999. Changes in nekton abundance, density and species composition reflect perturbations in multiple ecosystem processes, and comprise an efficient proxy for monitoring changes in these complex processes that would be too difficult or costly to monitor individually. Nekton responds rapidly to ecological changes, especially to changes in hydrology, i.e., increasing tidal range in the restricted area of Hatches Harbor. They also respond to disturbances in food chain dynamics, from the bottom up; e.g. removal/change in primary producer populations by anthropogenic impact to estuarine water quality, or from the top down; e.g. removal of predator, an important feature not present in other sample populations (Raposa and Roman 2001).

Nekton data were collected before tidal restoration (1997) and three times after the initial increase in tidal flushing through the new culverts (1999, 2003 and 2004). Monitoring nekton will continue for the long term; full implementation of the nekton monitoring protocol is planned for 2005, with subsequent sampling proposed for 2006 and 2007, then every three years thereafter.

METHODS

During 2004, nekton was sampled from subtidal creeks and marsh pools using a $1m^2$ x 0.5 m high throw trap, with a 3 mm mesh frame. Thirteen creek and 12 marsh pool stations were randomly established within the unrestricted marsh and 22 creek and 4 pool stations in the restricted marsh. These sites were sampled in August 2004.

In 2003 several of the original sampling stations (established in 1997 and re-visited in 1999 and 2003) were not re-sampled because of changes in the morphology of the marsh surface, creeks and channels. Changes in the morphology in the tidally restricted salt marsh area, i.e., changes in the course of marsh creeks, and disappearance and formation of tidal pools, were expected as the culverts were opened; however, similar changes observed in the pools and creeks of the unrestricted salt marsh were unexpected.

A new inlet (Fig. 3-1) formed in the barrier beach, approximately a kilometer to the NW of the former inlet, close to Race Point Light and directly adjacent to the main channel in the marsh. It is suspected that this new inlet changed the hydrodynamic processes in the unrestricted marsh leading to morphologic changes in the creeks and pools—as tidal water scoured and deposited sediment, creeks disappeared or changed course and pools no longer contained water through the tidal cycle. In addition, it was observed that former creeks and pools were becoming vegetated by *Spartina. alterniflora*. Similar changes in salt marsh morphology have been observed in other NPS units throughout the region.

In response to this major habitat change, National Park Service and University of Rhode Island staff conducted a review of the nekton study design. Based on the results of this review, the sampling design was changed from re-sampling the original permanent plots, to randomly establishing new sites for each sample year. This new method results in a data set directly comparable to previous sampling years and as powerful in its ability to detect changes in nekton abundance (James-Pirri and Roman, in review).

Comment [ELG1]: The comparisons are made between mean parameter values for the entire marsh (or subset of pools or creeks), not between the individual sample plot parameter values. If we were comparing a particular sample station across years, then there would be a problem, but, since both designs use the mean parameter of randomly (independent) selected samples (either selected initially [permanent stations] or each sample period [randomized each sample period]), for analysis it's "more or less" the same thing--I think the difference is that the variance is larger with re-randomizing the sample sites each sample period (year), but increasing the # of samples compensates for the increased variance. Of course, this is subject to debate…

Nekton sampling at Hatches Harbor in 2004 focused on testing new sample techniques and logistics; the complete sampling regime suggested by the nekton monitoring protocol was not conducted (see Raposa and Roman 2001). Results must be interpreted with this fact in mind. Please note that these data represent nekton densities from only creeks and pools; methods for accurately accessing nekton densities on the marsh surface, and in small creeks (<1m wide) are being developed.

RESULTS AND DISCUSSION

During the 2004 sample period, five species of fish and four of crustaceans were collected (Table 3-1), with the common mummichog (*Fundulus heteroclitus*) as the dominant species in the unrestricted marsh, and the common mummichog and the striped killifish (*Fundulus majalis*) co-dominant in the restricted marsh. There was a decrease in density (animals/m^2) of common species (e.g. common mummichog) and species richness in the restricted area of the marsh. In the unrestricted area of the marsh, densities and species richness recorded in the 2004 sample period were similar to previous sample periods.

Caution must be exercised in the interpretation of 2004 data; spatial variability of nekton densities is high (Raposa and Roman 2001), and density data were collected during only one sample period. Two sample periods per year are suggested by the nekton protocol to account for spatial variability in nekton density. Thus the observed decrease in species richness and densities could be an artifact of methods used in 2004.

It should also be stressed that these data relate only to tidal creeks and marsh pools and not to densities throughout the entire system. The marsh surface is an important habitat for estuarine fishes, especially the common mummichog. Only seven acres (3 ha) of *Spartina alterniflora* marsh habitat were available to nekton in the restricted area before tide restoration, while 60 acres (25 ha) were available in the unrestricted area. The increase in tidal range since 1999 has expanded the area of *S. alterniflora* marsh in the restricted area; an increase in utilization of *S. alterniflora* marsh habitat by nekton is expected (Portnoy et al. 2003). Marsh surface densities of nekton will be studied in 2005.

Figure 3-1. Aerial view of Hatches Harbor looking northeast and showing the new inlet in the center of the image.

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Appendix A

Estimation of areal increase in saturated soils and wetland habitat behind the Hatches Harbor Dike as a result of tidal restoration

The FAA has requested that NPS attempt to estimate the likely increase in saturated soil area that may result from increasing tide heights in the diked Hatches Harbor flood plain during salt marsh restoration. Salt marsh restoration is achieved physically by increasing tidal prism and tidal range. Higher high tides will not only extend the area of wetland flooded by tidal water, but will also potentially extend the area of saturated soils and wetland plant cover around the floodplain's edges.

Because salt marsh diking causes wetland water levels to drop from the elevation of mean high tide to mean sea level, i.e. the elevation of discharging groundwater, tidal restoration will conversely increase wetland water levels from the present elevation of discharging groundwater to the elevation of the restored high tide. Therefore, one would expect increased soil saturation in the flood plain area between the present contour of groundwater discharge and the predicted contour of mean high tide (9.0 ft-MLW or 4.45 ft-MSL).

Limited groundwater level data, i.e. nine observations from November 1990 to September 1994, for the area just seaward of the Airport runway were provided by Don Schall of ENSR. Water table elevations from ENSR monitoring wells 2 and 3 were around 4.3 ft-MSL. We therefore computed, using existing topographic information in the Park GIS, the area between contours 4.3 and 4.45 ft-MSL. [Actually elevations 4.26 and 4.42 were used because they were already resident as discrete intervals in the data base.] The result was an estimated area of about 7 acres (see attached map).

The 7-acre increase in saturated soil area should be considered a very rough estimate for several reasons:

1) Average groundwater levels are probably higher than those measured during the limited monitoring by ENSR. To assess how well these fragmentary data reflect long-term means for the months of record, we looked at data from the Cape Cod Commission's 20 years of observations from well PZW78, their closest index well behind the Park Maintenance yard on Race Point Road. Water levels in PZW78 during the period of observation for airport wells was 0.2 to 0.4 ft below the 20-year November mean of 4.62 ft-MSL. It seems reasonable to assume that groundwater elevations at Hatches Harbor measured in ENSR wells 2 and 3 were also low during this period. Use of a below-average groundwater elevation would produce an over-estimate of the area between the contours of groundwater discharge and high tide.

2) Soil organic content and texture (particle size) will also affect the extent of soil saturation and wetland increase. These variables have not been mapped, but have the potential to affect water movement in the soil profile <u>above</u> the water table. As one

moves upward and outward from the flood plain, soil organic content likely decreases, reducing the upward capillary movement of water. Wetland development may therefore lag behind increases in mean water level, and the response may not be linear.

3) Because of the flood plain's low relief, the extent of soil saturation, as well as surface flooding, is very sensitive to the spatial resolution and accuracy of topographic mapping. Although our topography is now based on over 600 point elevations, areal estimates are still subject to error. Predictions will improve as the effects of initial increases in tidal range are observed in the field.

SPECIES	Restricted Marsh (n=90) 1997	Restricted Marsh (n=90) 1999	Restricted Marsh (n=16) 2003	Restricted Marsh (n=26) 2004	Unrestricted Marsh (n=120) 1997	Unrestricted Marsh (n=120) 1999	Unrestricted Marsh (n=16) 2003	Unrestricted Marsh (n=25) 2004
Fundulus heteroclitus (mummichog)	22.84	28.38	44.31	0.43	18.99	14.77	50.13	19.17
Carcinus maenas (green crab)	0.46	1.47	0.06	0.00	1.38	1.69	0.06	0.35
Crangon spp. (sand shrimp)	0.18	0.14	0.31	0.00	2.16	0.69	0.00	13.04
Fundulus majalis (striped killifish)	0.10	0.36	0.56	1.29	0.28	0.58	1.00	0.09
Menidia menidia (Atlantic silverside)	0.12	0.20	0.00	0.00	0.65	0.18	0.00	0.30
Anguilla rostrata (American eel)	0.36	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Apeltes quadracus (4-spine stickleback)	0.20	0.09	0.00	0.00	0.00	0.00	0.00	0.04
Gasterosteus aculeatus (3-spine stickleback)	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Mugil curema (white mullet)	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.00
Syngnathus fuscus (pipefish)	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Neopanopeus sayii (mud crab)	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Pseudopleuronectes americanus (winter flounder)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.09
*Cyprinodon variegatus (*sheepshead minnow)	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Palaemonetes spp.(shore shrimp)	0.00	0.00	0.69	0.00	0.00	0.00	2.00	0.00
SPECIES RICHNESS	10	9	6	2	7	6	4	7
Total Nekton (m^2)	24.41	30.86	46.00	1.71	23.50	17.93	53.19	33.09

Table 3-1. Nekton densities (animals/m^2) and species richness (number of species observed) for Hatches Harbor nekton monitoring. Nekton data from pre-restoration (1997) and post restoration (1999) are average densities from sampling in June and September. Nekton data from 2003 and 2004 are from one sample collected in September and August respectively.