Hatches Harbor Salt Marsh Restoration: 2006 Annual Report

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Cape Cod National Seashore

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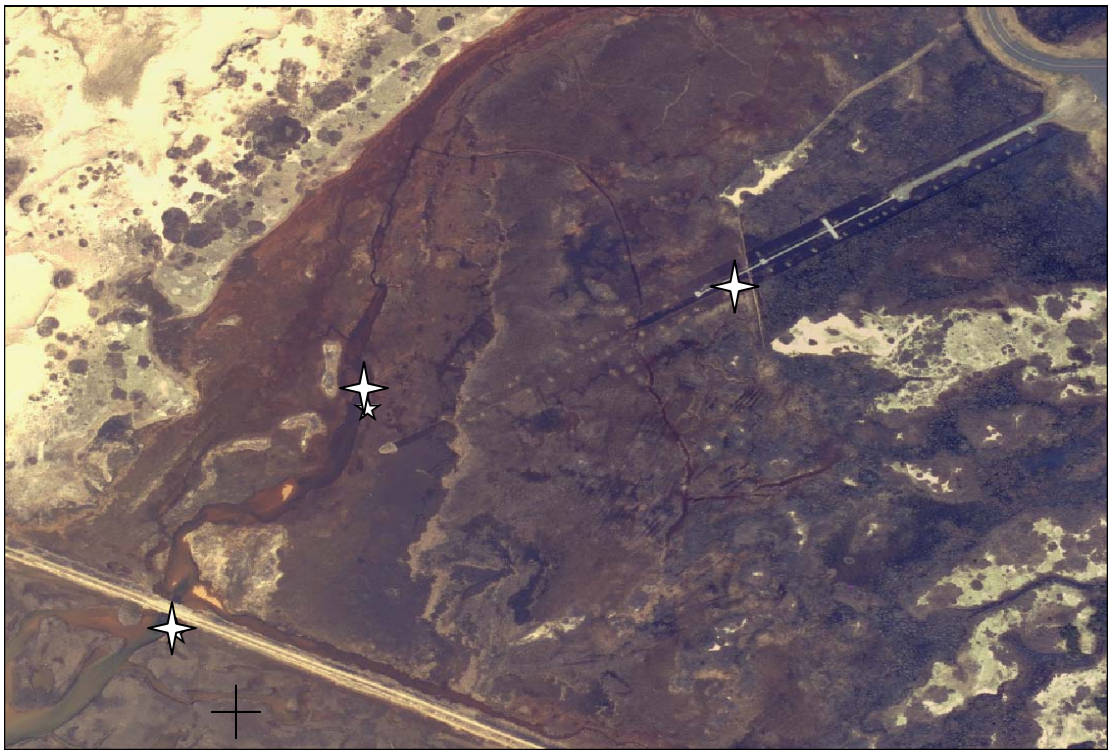
Figure 1-1. Hatches Harbor salt marsh showing tide gauge locations.



TIDE HEIGHTS

Kelly Chapman & John Portnoy

The basic objective of the Hatches Harbor Salt Marsh Restoration is to restore the tide-restricted wetland to the extent possible without compromising safety at the Provincetown Municipal Airport. In order to meet this objective, NPS has monitored tide heights since 1997, and the system's response to incremental tidal restoration since March 1999. This section focuses on tidal height data that were collected in the summer of 2006 at two locations within this salt marsh system.

Methods

In previous years, tidal height data were collected by YSI6000 and YSI6600 multi-parameter data loggers. Since May 2005, HOBO water level recorders were used. The instruments were then deployed in existing stilling wells that were established in 2005. They were deployed at two locations. One was located 10 m seaward of the dike structure (unrestricted side); another was located about 500 meters upstream of the structure on the restricted marsh side (Figure 1-1). Data were uploaded every two weeks for four months. Temperature and absolute pressure (including atmospheric and water

head) data were collected by the instruments at 10-minute intervals. Once the data were uploaded, a pressure correction was completed by the accompanying HOBO software, in order to get corrected tidal heights.

Results & discussion

The final 20-cm increase in culvert opening in June 2005 yielded little increase, over the culverts' prior setting, in mean high- and low-tide heights and in tidal range (Table 1-1). Tidal range in the restricted marsh was 0.63 m, as opposed to about 1.10 in the unrestricted marsh seaward of the dike.

Table 1-1. Mean high, mean low and tidal ranges (m-MSL) from three tide gauge locations in Hatches Harbor salt marsh from 2003 to 2006 (with exception of airport site in 2005).

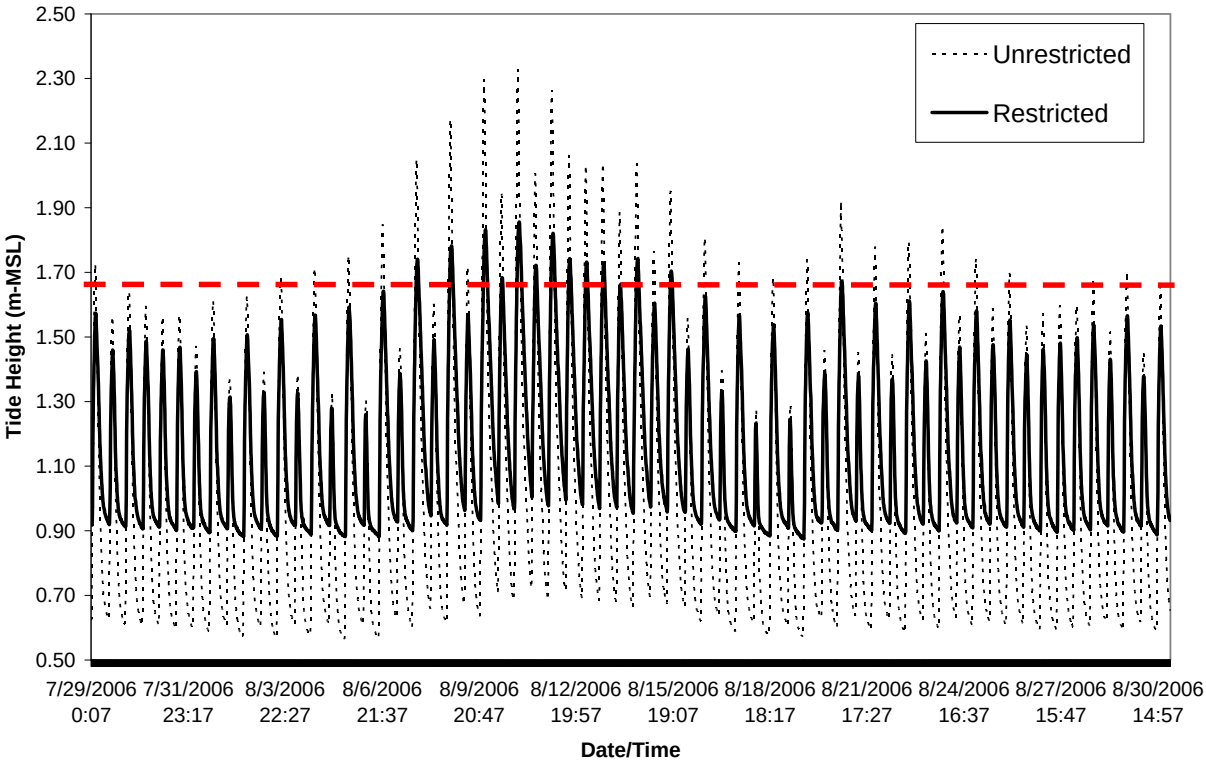
Station	**Mean High**	**Mean Low**	**Tidal Range**
Unrestricted			
October 2003 - June 2005	1.78	0.72	1.06
June 2005 – August 2005	1.72	0.70	1.02
June 2006 – October 2006	1.73	0.63	1.10
Restricted			
October 2003 - June 2005	1.58	0.91	0.67
June 2005 – August 2005	1.57	0.87	0.70
June 2006 – October 2006	1.56	0.92	0.63
Airport			
October 2003 - June 2005	1.03	0.86	0.17
June 2005 onward	1.46	1.27	0.19

Data collected during July and August 2006 indicate the dampening effect of the dike and culvert system (Fig 1-2). High tides remain lower and low tides higher in the restricted, than in the unrestricted marsh. This is likely due to the combined impedance of the structure (albeit fully open) plus a shallow sill in the main creek between the culverts and the "restricted" data logger 500 m upstream, which restricts low-tide drainage. Tidal range in the restricted marsh is about 57% of downstream tidal forcing, as compared to only 26% prior to new culvert installation (Table 1-1 and Fig. 1-3). Meanwhile there has been little change in tidal forcing on the seaward side of the dike since at least 2000 (Fig. 1-4).

As hydrodynamic modeling predicted (Roman et al. 1995), extreme high tides that would exceed the Airport's critical threshold (10 ft-MLW = 1.66 m-NGVD) are filtered out by the structure, especially during spring tides (Fig. 1-5).

Figure 1-6 summarizes increases in mean tidal range in the diked marsh with incremental culvert opening, 1998 - 2006.

Figure 1-2. Tide heights just seaward of (unrestricted), and 500 m upstream of (restricted) the Hatches Harbor dike in summer 2006. The horizontal line marks 10 ft-MLW (1.66 m-MSL).



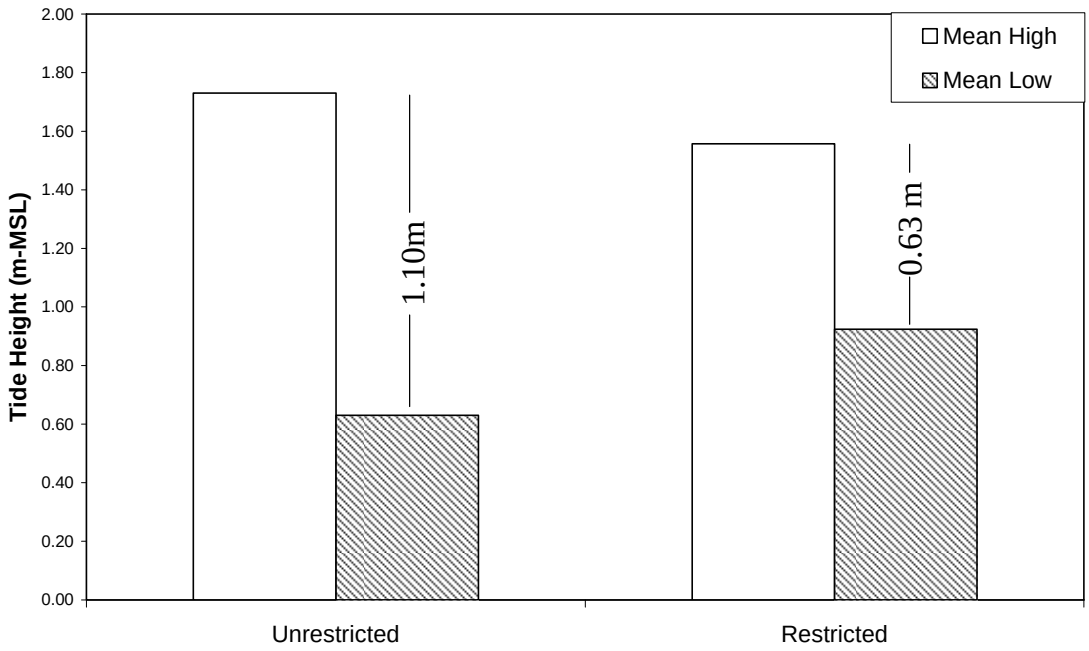


Figure 1-3. Mean high, mean low and mean tidal ranges from tide gauges just seaward and 500 m landward of the Hatches Harbor dike in 2006.

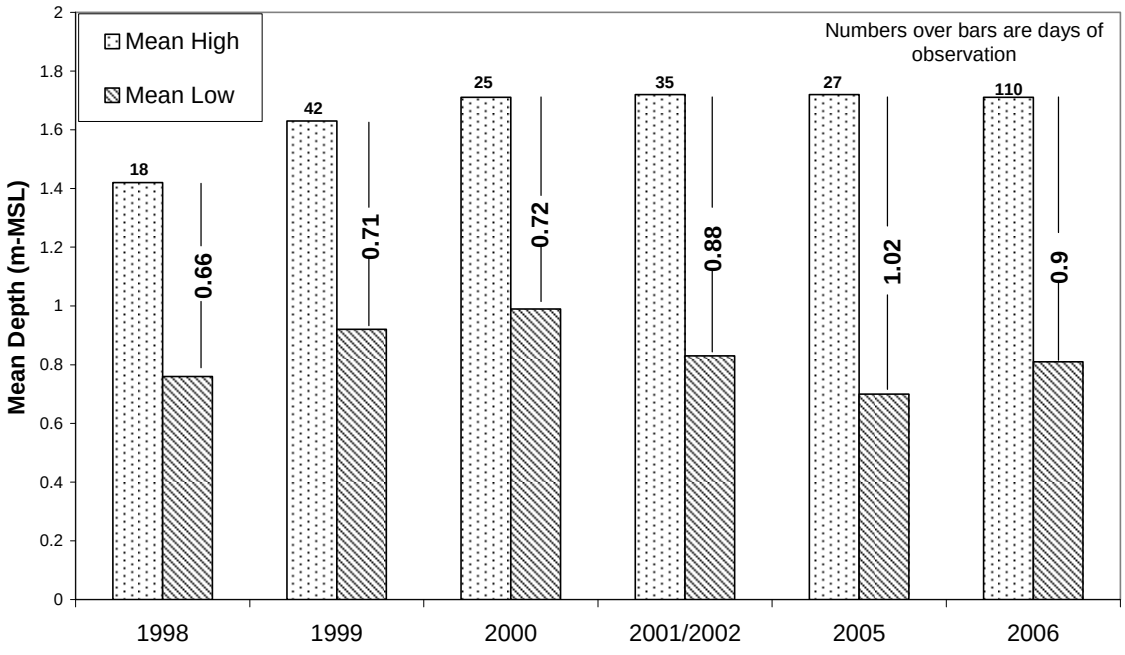
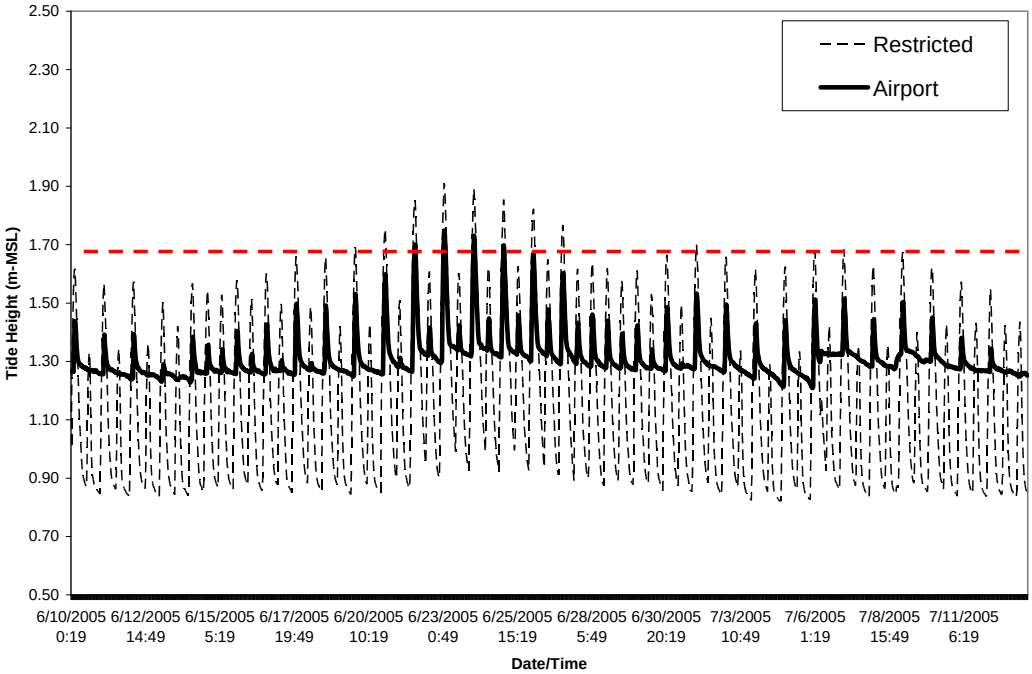


Figure 1-4. Mean high- and low-tide heights and tidal ranges in unrestricted Hatches Harbor seaward of the dike, 1998-2006.

Figure 1-5. Tide heights in the main creek 500 m upstream of the Hatches Harbor Dike and at the berm seaward of the airport's ILS reflectance area. The horizontal line marks 10 ft-MLW (1.66 m-MSL). Note attenuation of high tides, and especially reduced low-tide drainage, near the airport. Although data are from summer 2005, 2006 tidal forcing was similar (see Fig. 1-4).



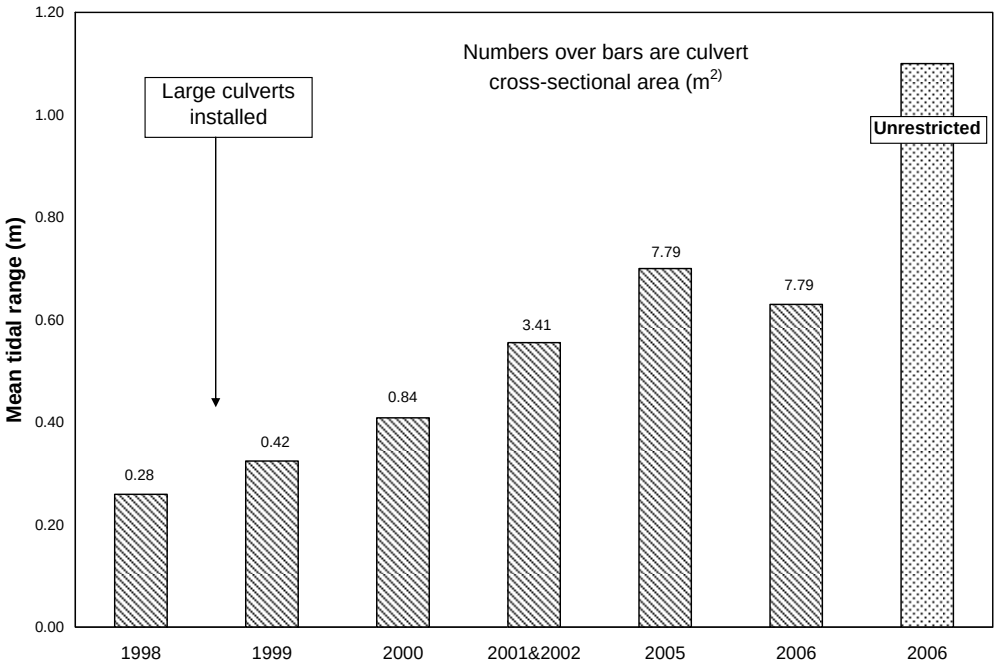


Figure 1-6. Mean tidal ranges in the restricted marsh 1998-2006.

VEGETATION

Stephen Smith

Summary of work completed in 2006

In 2006, another complete vegetation survey (area cover by species in permanent plots) was completed. In addition, stem heights and plant densities of *Phragmites* were recorded in all restricted-side plots (see previous reports for further details on methods). Finally, an experiment on seed dispersal, begun in the fall of 2005, was completed in 2006. In this study, standing dead *Phragmites* and salt-killed shrubs were cut down in large plots to ground level in order to facilitate the movement of wrack (containing seeds of salt marsh plants) across the area.

Results

The restricted-side marsh continues to exhibit substantial change, even though tidal flow has changed very little since 2004. Figure 2-1 shows the degree of similarity in species composition between each restricted-side plot and the unrestricted community as a whole (determined from Bray-Curtis similarity matrices and multidimensional scaling). In general, native salt marsh species (especially *Spartina alterniflora*) continue to expand while *Phragmites* continues to migrate upslope, away from the main tidal creek. A significant area of freshwater shrub and herbaceous vegetation at the distant (interior) ends of the transects has recently died from elevated salinities. *Phragmites* is now becoming dominant in many of these areas. Along the seaward edge of the transects, however, *Phragmites* is still declining (Figure 2-2). Recent analysis of all the vegetation data since 1997 revealed that the degree to which plant species composition in the tide-restricted marsh resembles the unrestricted marsh is most closely related to elevation, which itself determines duration of flooding and porewater salinity conditions.

The seed dispersal experiment suggests that further development of the salt marsh community upstream of the dike appears to be limited by the inability of seeds/propagules to move beyond the physical barrier of standing dead (salt killed) vegetation. Dead stems of *Phragmites* and woody shrubs trap wrack material and prevent the dispersal of seeds across a large portion of the restricted marsh. When this material was removed by cutting, large numbers of salt marsh plants were able to become established (Figure 2-3). Standing dead vegetation may also affect the dynamics of water flow through the marsh and, therefore, influence flood duration and/or salinity. As this material degrades, further shifts in vegetation are expected as seeds and propagules are able to penetrate further into the marsh. One way to accelerate this process would be to burn this zone of vegetation during the fall of 2007, which would allow seeds to penetrate and become established much further into the marsh.

Given that seed dispersal dynamics and a variety of other physical, chemical, and biological process will continue to change, it is obvious that the present vegetation in Hatches Harbor does not represent an end point to the restoration. Taken as a whole, the restricted-side of Hatches Harbor is still very dissimilar to the unrestricted marsh. While the expectation is for continuing change, total restoration of the entire 47 ha. of restricted marsh is unrealistic since the dike still remains and complete tidal restoration is not possible. As it stands today, however, the Hatches Harbor tidal restoration project has succeeded in converting a sizeable portion of degraded, fresh-brackish wetland back to a plant community that closely resembles its healthy downstream counterpart.

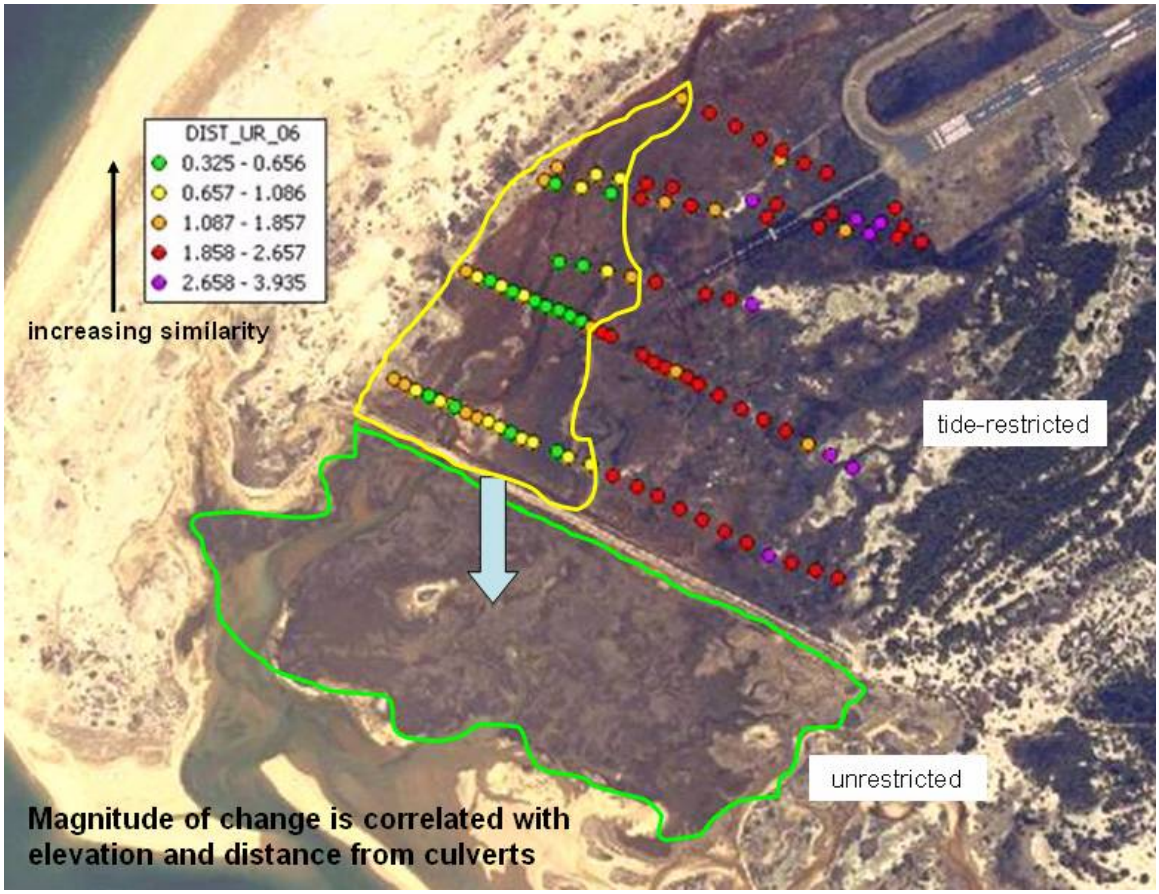


Figure 2-1. Plant community similarity of the restricted to the unrestricted marsh (plots represented by circles, which are color coded according to their similarity to the unrestricted community)..

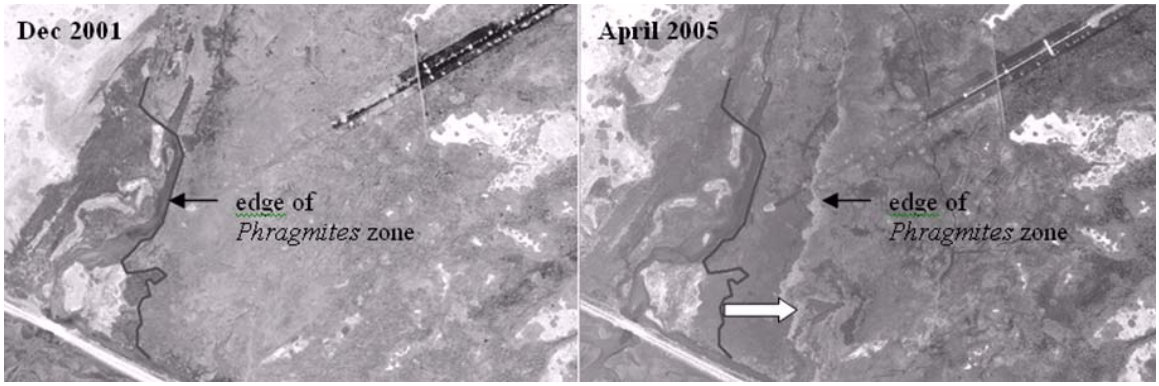


Figure 2-2. Movement of *Phragmites* upslope (away from main tidal creek) from 2001-2005.

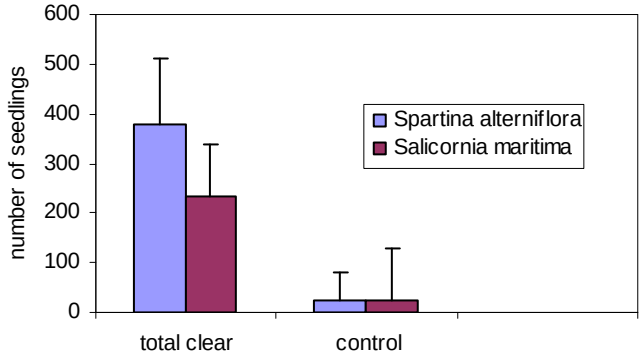


Figure 2-3. Number of seedlings of *Spartina alterniflora* and *Salicornia maritima* established in plots where standing dead biomass had been cut (total clear) vs. plots where no cutting was done (control) (n=5).

<u>Future monitoring</u>

- Another complete vegetation survey of all plots in 2008
- Continued *Phragmites* monitoring (annually)

Nekton (Fish and Decapod Crustaceans)

Evan Gwilliam

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 2001a).

Since the reintroduction of tidal flow into the restricted section of the Hatches Harbor marsh, the nekton community has responded to the changes in water levels and increase in salt marsh habitat. Nekton community structure in habitat strata (i.e., creeks and pools) has shifted to more closely resemble unrestricted counterparts (Portnoy et al. 2003; Portnoy et al. 2005).

This is a report of nekton abundance and diversity data collected in June and August of 2006 in the Hatches Harbor salt marsh using several active trapping methods—throw traps in pools and creeks and lift nets in the ditches and on the marsh surface. Both of these methods yield repeatable and quantifiable measures of nekton density (Rozas and Minello 1997). It is the first year that the lift trap method has been used at Hatches Harbor.

This report includes the following summaries and questions that address important new aspects of nekton ecology in Hatches Harbor during 2006:

- Summary of 2006 sampling data
- Summary comparison of nekton densities in 2006 to previous years
- Summary of lift trap results from new creeks in restricted portion of the marsh
- Summary of marsh surface lift trap results

Methods

Methods used in sample design are generally similar to those used in previous sampling years. Please consult previous Hatches Harbor Annual reports for details. The following methods were used in 2006:

Sample Design
Nekton were collected at randomly selected stations in creeks, pools and on the marsh surface within each sample site (i.e., Hatches Harbor Restricted sample site and Hatches Harbor Unrestricted sample site). One hundred and four sites distributed in creeks, pools, on the marsh surface were sampled twice during the 2006 season (Figure 3-1; Table 3-1).

Sample stations were randomly selected in polygons drawn from suitable sampling habitat (pools and tidal creeks with depth < 0.5 m and areas of the marsh surface that drained completely at low tide) using a color orthophotograph and field site visits. Random points were generated using the NPS Alaska Pack extension to the ArcView 9 GIS software package. Points were assigned UTM coordinates using the NAD 1983 projection. UTM coordinates were loaded onto a 12 channel WAAS enabled Garmin IV or GPSmap76S GPS unit. Sample stations were navigated to in the field; accuracy was typically better than 2.5 m.

Sampling Period
Sampling was conducted twice (late spring and summer) in 2006 (Table 3-2). Each sampling session was conducted over several days, each session lasting three to six hours. All data were collected from the midpoint of the ebbing tide after all water was off the marsh surface.

Sampling equipment and methods
Throw trap—Nekton was collected in tidal creeks and marsh pools using a 1-m^2 x 0.5-m high aluminum throw trap, open on the top and bottom (Figure 3-2a). Nekton was removed from the trap using a 1-m wide x 0.5-m deep aluminum framed dip net. Mesh size of the trap was 3 mm, the dip net mesh size was ~1 mm. One or two teams of two workers, each with a throw trap, would navigate to the sampling station with a GPS unit. Approaching from the creek bank, one worker would wait one or two minutes to throw the trap to minimize disturbance, then throw the trap. The worker then would remove nekton with the dip net, assisted by the other worker. All nekton were considered collected after three consecutive empty dip net pulls (Rapoza and Roman 2001a).

Lift net (marsh surface)—Nekton was collected from the marsh surface using bottomless lift nets 2 m x 1.5 m constructed of 3 mm nylon netting (Figure 3-2b). A lift trap consists of two 2” x 4” x 8’ lengths of wood driven into the marsh surface 2 m apart, each connected with nylon rope to a 1.5 m (1” diameter) wooden dowel supporting the netting between. The trap was set by pushing the net flush with the surface; a spade was used to create a small trench so the net could be set flush with the marsh sediment surface, intended to lessen the impediment to nekton accessing the sample area. A collection cup (a plastic cup ~25cm in diameter) was inserted into the marsh surface. Two workers would carefully approach the trap at high tide. Each worker simultaneously pulls the rope leading to each end of the net, quickly pulling it up from the marsh surface and enclosing any nekton in the sample station. The workers wait until the marsh drains, then they inspect the site, including both the sample cup and the marsh surface for nekton. All nekton are processed and returned alive back into a nearby creek. (Rozas 1992).

Lift net (creek) — the net (3-mm nylon mesh) was set in the small creek located in the restricted area of Hatches Harbor, suspended by four stakes carefully set in the sediment (Figure 3-2c). The doors of the net are pushed down into the bottom of the creek, so as not to impede the passage of nekton through the net, and the lines from the doors are laid out on the marsh surface. The dimensions between the stakes are measured (to calculate the area of water that is sampled). After 30 min, each worker quietly approached the lines to the doors that have been laid out on the marsh surface. Each worker then simultaneously pulls on the lines, causing the doors of the net to rise and enclose a portion of the water column. As the lines are being pulled, the net is approached, and once the doors are completely up, the stakes are grabbed and pulled from the ditch, trapping all nekton in the net. The net is then laid on the marsh surface, and all nekton within the net are processed. All nekton are returned alive back into the creek (James-Pirri et al. 2004).

In each sampling method, nekton was identified by species (or genus), counted, and a representative number (up to 15 individuals) of each species were measured for length (mm) (fish and shrimp–total lengths, crabs–carapace width). Unknown specimens were brought back to the lab and identified.

Environmental parameters

Water quality parameters, temperature (C), dissolved oxygen, and salinity were collected with the YSI 556 multi-parameter hand held water quality datalogger. Depth of the water was measured at three trap corners with a meter stick with the throw trap, and at the approximate center of the creek lift trap (not reported) . Sediment composition was estimated in the field to the nearest 10% for sand and fine (not reported here). Before using the dip-net, the species of any rooted plant is identified and cover estimates are made for each species of plant and algae (not reported here). Adjacent dominant poolside/creek bank vegetation was identified (not reported here).

Data analysis

The total number, relative density, mean density (animals/m^2) and length of each nekton type (i.e., decapods and fish) and species were calculated for all sampling strata in both sample areas; creek, pool and marsh surface in the restricted and unrestricted sections of the Hatches Harbor salt marsh. Comparisons of nekton density and length are made between habitat (e.g., creek width < 1 m vs. creek width > 1m) and treatment (i.e., restricted vs. unrestricted). Tests for linear correlation were made using Pearson's coefficient of rank correlation and comparisons using the non-parametric Kruskal-Wallis test (similar to ANOVA); many of the comparisons violated parametric assumptions of normalcy and equal variance (Sokal and Rohlf 1981). The XLSTAT add-on to Microsoft Excel program was used for statistical calculations (XLSTAT 7.5 2005). Many comparisons were conducted; only statistically significant results are presented and discussed.

Results and Discussion

Summary of 2006 sampling data

During the 2006 sample period, two species of fish and two of crustaceans were collected (Table 3-3 a-d), with the common mummichog (*Fundulus heteroclitus*) the dominant fish species, and the sand shrimp (*Crangon septemspinosa*) the dominant crustacean (Table 3-4). The sand shrimp was found most commonly in the wide, shallow sandy creeks of the unrestricted portion of the marsh, while the *F. heteroclitus* was encountered where there was shelter close at hand. This is typical of northeastern salt marsh systems; at Hatches Harbor, as the main creek in the restricted sample area gradually becomes wider and sandier bottomed, the shore shrimp is expected to increase in abundance. Also observed, but not sampled, were menhaden (*Brevoortia tyrannus*), sand eel (*Ammodytes americanus*), longfin inshore squid (*Loligo pealeii*).

The water temperature was generally cooler in the creeks (~20º C) than in the restricted pools (~27º C) and unrestricted pools and smaller creeks (~23º C). Dissolved oxygen was low in the restricted creek, however, observations were limited due to equipment malfunctions. Expectedly, salinity decreased with distance from the source of tidal water: 30 ppt in the main creeks to 21 ppt in small creeks (Table 3-4).

Summary comparison of nekton densities in 2006 versus previous years

There was an apparent decrease in nekton density (Figure 3-3 a-b) and number of species (Table 3-5) in the restricted creeks and pools in 2006 compared to previous years; however, none of these trends is significant (alpha = 0.05). It should also be noted that large fluctuations in density and species composition have been documented in other restoring marshes (Raposa and Roman 2001b).

Statistical tests (Kruskal-Wallis) were conducted to test the significance of observed differences in *F. heteroclitus* density between 2005 and 2006 in salt marsh habitat strata (i.e., pools and creeks). *F. heteroclitus* is the most abundant nekton species and is ubiquitous throughout the entire marsh system; it is the major species involved in transfer of energy from primary producers to higher trophic levels (i.e., predators like herons and striped bass). Significant decreases in the density of *F. heteroclitus* were noted in unrestricted creeks ($p=0.002$), restricted creeks ($p=0.0001$) and restricted pools ($p=0.008$) between 2005 and 2006. The decrease in unrestricted creek, and restricted creek and pool *F. heteroclitus* density may indicate an marsh-wide (i.e. not dependant on restriction) inter-annual response by *F. heteroclitus* to changing environmental variables (e.g., increased predation, disease, recruitment).

An explanation for these fluctuating values may lie with habitat change. At Hatches Harbor, there has been a rapid increase in the restricted area salt marsh habitat since the maximum opening in the culvert gates (June 2005). The nekton community continues to adjust to these new favorable conditions in tidal range, surface elevation and vegetation community across the floodplain. It was observed during sampling and field visits that portions of the marsh do not completely dewater during every low tide; this provides additional areas for the nekton to forage and hide. Current sample design assumes that nekton leave the marsh surface and enter the creeks and pools as the tide ebbs and the

marsh surface dewaters, making the throw trap method an effective way to capture nekton. If the rapidly changing marsh morphology and vegetation habitat provide areas that do not completely dewater or are extensively vegetated, it effectively renders portions of the nekton population inaccessible to current sampling methods. In the case of the 2006 sampling season, large numbers of *F. heteroclitus* were observed on the marsh surface in areas that did not completely dewater on every ebb tide. It therefore is suspected that the low density, and species richness data collected during the 2006 season is due to animals using the marsh surface more than the creeks and pools on ebbing tides.

Summary of lift trap results from new creeks in restricted portion of the marsh
A new sampling technique was used for the first time in 2006; lift net traps were deployed in the new creeks that were created in 2003 and 2004 (Portnoy et al. 2004). The density and number of species were less in these new creeks compared to other restricted habitats, however, the *F. heteroclitus* sampled were larger (mean value 43mm vs. 20 mm), indicating that this habitat was favored by adult fish, while the creeks and pools were favored by the juveniles (Table 3-3 a-b). This sampling technique is very effective; it is used by the NPS, and other state and federal agencies throughout the northeast (James-Pirri et al. 2004). Lift net nekton sampling will continue in 2007, yielding results on the utilization of new habitat created by the restoration project.

Summary of marsh surface lift trap results
The utilization of the marsh surface by nekton has been an important unanswered question in monitoring nekton response to restoration. In 2006, lift nets were used to sample nekton on the marsh surface in both the restricted and unrestricted portions of Hatches Harbor salt marsh. The results were disappointing; only a few green crabs were sampled (Table 3-3 a-d). In 2007, sampling the surface with lift nets will continue, and the sampling design, timing and techniques of sampling will be refined.

Conclusion
The restoration of Hatches Harbor is having a positive effect on the nekton community by greatly increasing the area of habitat, as documented by this and previous Hatches Harbor Annual reports. The increase in habitat provides new areas that are used as a nursery areas and for feeding and breeding. The results that were collected in 2005 and 2006 will be used to learn more about the response of nekton to the restoration process, and will be used to refine the monitoring protocol to make future sampling more effective. The work in 2006 focused on continuing implementation of the nekton monitoring protocol, testing new sampling techniques and methods, and the collection and analysis of data collected from habitat previously not sampled. Sampling will continue in 2007 in the pools, creeks and on the marsh surface.

- Hatches Harbor is a dynamic estuarine system with a nekton community typical of Lower Cape estuaries; in 2006 mummichog, shore shrimp, green crab and American eel were sampled. In addition, menhaden, sand lance and long fin squid were observed, but not sampled.
- Rapid changes are continuing in hydrology and morphology in both restricted and unrestricted sample areas, indicated by sedimentation data (Portnoy et al. 2004) and interpretation of aerial photography.

- In the restricted marsh, increased tidal range and new creeks allow nekton access to a greater area of habitat.
- Increase in habitat area, changes in morphology and perhaps other unknown variables have resulted in decreased effectiveness of sampling methods (i.e., nekton are staying on the marsh surface and not returning to the creeks at low tide). The decrease in sampling effectiveness may be the reason for a significant decrease in *F. heteroclitus* densities between 2005 and 2006 in portions of the Hatches Harbor marsh.
- Lift nets were effective at sampling nekton in restored creek habitat. This method will be employed in 2007 with sampling will be expanded to more creeks.
- Lift trap methods were not effective on the marsh surface in 2006; sampling design, timing and techniques will be refined in 2007

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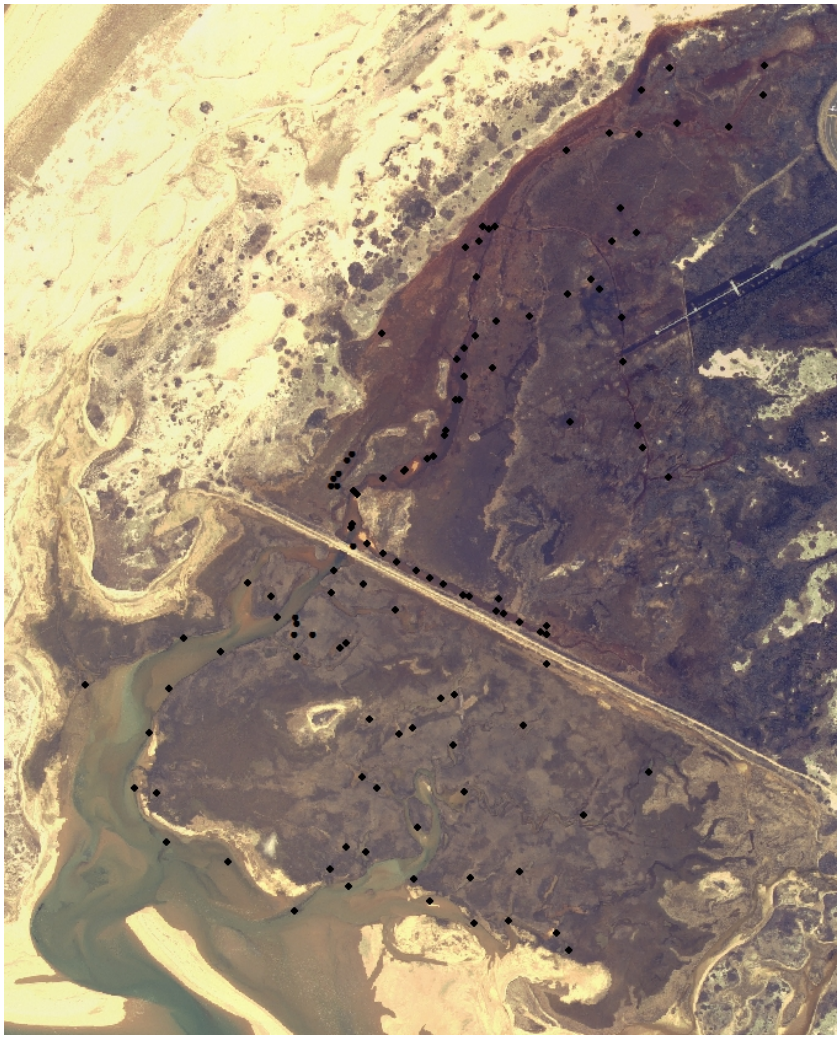

Figure 3-1. Locations of all sample stations during 2006 sampling in Hatches Harbor salt marsh

a b c

Figure 3-2 a-c. Photographs of sampling gear used in 2006 nekton sampling in Hatches Harbor marsh; throw trap and dip net (a), lift net on the marsh surface (b) and a lift net in a narrow creek (c).

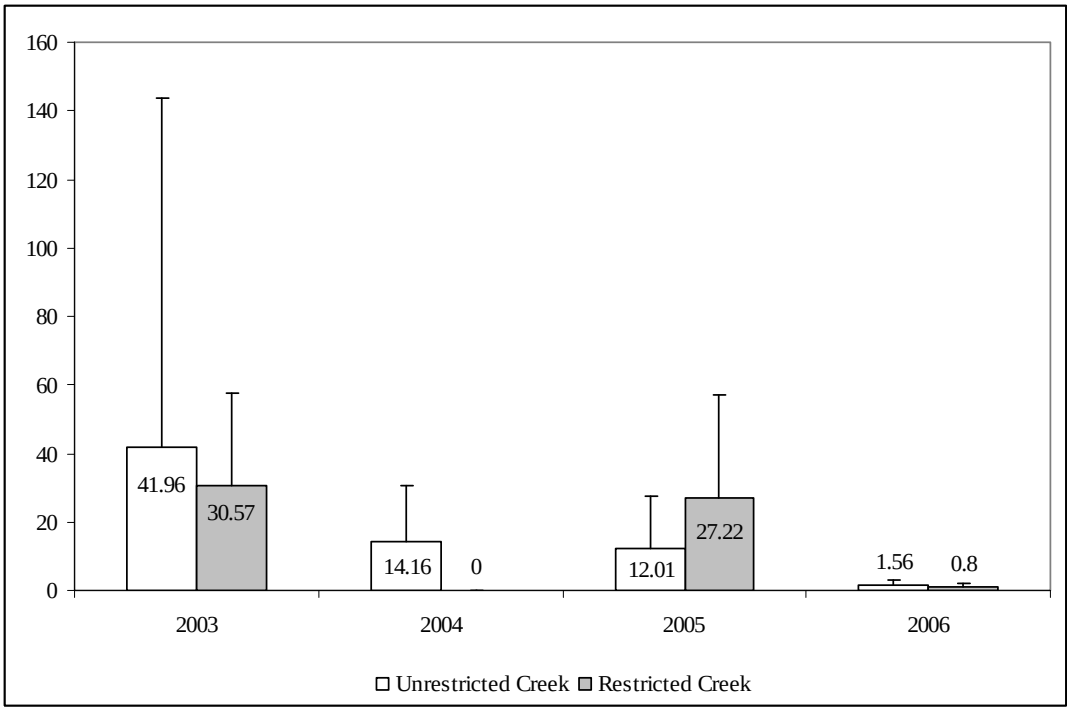

Figure 3-3a. Mean total nekton density in creek habitat strata 2003 to 2006

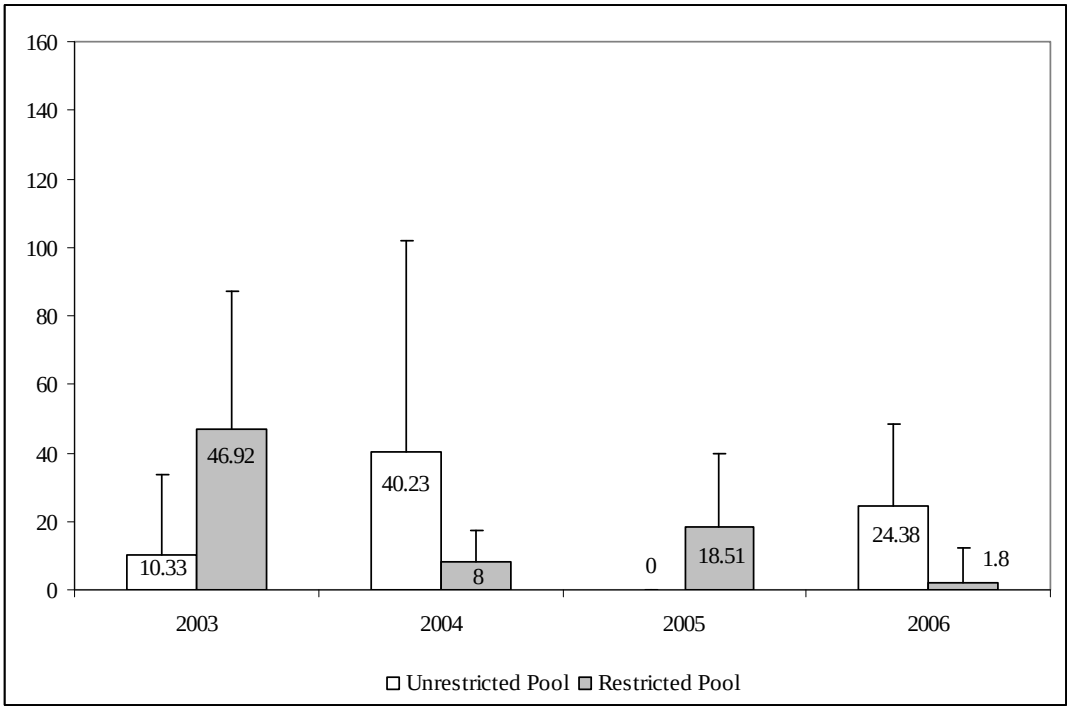

Figure 3-3b. Mean total nekton density in pool habitat strata 2003 to 2006

Figure 3a-b. Mean total nekton density, 2003 to 2006 by habitat strata (e.g., creek) and sample area (e.g., restricted portion of Hatches Harbor salt marsh). Numbers on bars are density values, error bars indicate standard deviation.

	Creek (throw trap)	Pool	Marsh Surface	Creek (lift net)
Restricted	30	15	6	17
Unrestricted	22	8	6	0

Table 3-1. Number of sample sites by type, habitat strata (e.g., creek) and sample area (e.g., restricted portion of Hatches Harbor salt marsh)

Gear	**Sample Dates**
Throw trap	June 19—23 and August 8—16th
Ditch Net	June 26—27 and August 23—24
Lift Trap	August 9—11 and August 23—25

Table 3-2. Dates of nekton sampling in 2006

	Restricted Sample Area Nekton Density (animals/m^2)			
	Creeks	Pools	Marsh Surface	Creek (lift trap)
Decapods	0.3 ± 0.84 (10)		1 ± 1.55 (3)	0.07 ± 0.21 (3)
Fish	1.27 ± 2.83 (38)	5.6 ± 11.53 (84)	0 ± 0 (0)	0.76 ± 1.55 (34)
All nekton	0.8 ± 1.42 (48)	4.8 ± 10.65 (84)	0.75 ± 1.25 (3)	0.49 ± 0.89 (37)
Anguilla rostrata	0.07 ± 0.25 (2)			
Carcinus maenas	0.3 ± 0.84 (9)		1 ± 1.55 (3)	0.07 ± 0.21 (3)
Crangon septemspinosa	0.03 ± 0.18 (1)			
Fundulus heteroclitus	1.2 ± 2.85 (36)	5.6 ± 11.53 (84)		0.76 ± 1.55 (34)

Table 3-3a. Density of nekton sampled in 2006 from restricted sample area

	Restricted Sample Area Nekton Length (mm)			
	Creeks	Pools	Marsh Surface	Creek (lift trap)
Decapods	29.38 ± 10.29 (10)		14.25 ± 10.25 (3)	25.5 ± 23.33 (3)
Fish	31.39 ± 18.56 (38)	20.25 ± 19.35 (84)		43 ± 16.38 (34)
All nekton	30.42 ± 16.27 (48)	20.25 ± 19.35 (84)	14.25 ± 10.25 (3)	41.87 ± 18.32 (37)
Anguilla rostrata	60 ± 21.21 (2)			
Carcinus maenas	30.88 ± 10.36 (9)		14.25 ± 10.25 (3)	25.5 ± 23.33 (3)
Crangon septemspinosa	17 ± 0 (1)			
Fundulus heteroclitus	25.03 ± 11.15 (36)	20.25 ± 19.35 (84)		43 ± 16.38 (34)

Table 3-3b. Length of nekton sampled in 2006 from restricted sample area

	Unrestricted Sample Area Nekton Density (animals/m^2)		
	Creeks	Pools	Marsh Surface
Decapods	2.2 ± 4.93 (58)	0.25 ± 0.46 (2)	0.5 ± 1.22 (1)
Fish	0.64 ± 2.36 (14)	36.38 ± 45.83 (291)	0 ± 0 (0)
All nekton	1.56 ± 2.75 (72)	24.38 ± 23.91 (293)	0.5 ± 1.22 (1)
Carcinus maenas	0.64 ± 1.94 (14)	0.25 ± 0.46 (2)	0.5 ± 1.22 (1)
Crangon septemspinosa	2 ± 5.35 (44)		
Fundulus heteroclitus	0.64 ± 2.36 (14)	36.38 ± 45.83 (291)	

Table 3-3c. Density of nekton sampled in 2006 from unrestricted sample area

	Unrestricted Sample Area Nekton Length (mm)		
	Creeks	Pools	Marsh Surface
Decapods	21.4 ± 11.87 (58)	20 ± 14.14 (2)	60 ± 0 (1)
Fish	15.5 ± 8.23 (14)	31.33 ± 5.99 (291)	
All nekton	19.76 ± 11.41 (72)	29.3 ± 6.71 (293)	60 ± 0 (1)
Carcinus maenas	11.62 ± 13.28 (14)	20 ± 14.14 (2)	60 ± 0 (1)
Crangon septemspinosa	28.12 ± 2.97 (44)		
Fundulus heteroclitus	15.5 ± 8.23 (14)	31.33 ± 5.99 (291)	

Table 3-3d. Length of nekton sampled in 2006 from unrestricted sample area

Table 3a-d. Density, length and number of species sampled by habitat strata and sample area. First number is the mean density (nekton/m2) followed by the standard deviation of the mean. The number in parenthesis is the total number of type (decapod or fish) of nekton species sampled.

	Unrestricted Creek	Restricted Creek	Restricted Creek (lift)	Unrestricted Pool	Restricted Pool	Unrestricted Surface	Restricted Surface
Decapod	81	21	8	1	0	100	100
Fish	19	79	92	99	100		
Anguilla rostrata		4	0		0		
Carcinus maenas	19	19	8	1	0	100	100
Crangon septemspinosa	61	2	0	0	0		
Fundulus heteroclitus	19	75	92	99	100		

Table 3-4. Relative abundance (percent) of nekton by habitat strata and sample area

	Unrestricted	
	Creek	Pool
Temperature (C)	19.28 ± 2.55 (23)	23.62 ± 4.07 (8)
Salinity (ppt.)	27.18 ± 4.32 (22)	30.35 ± 1.83 (8)
Dissolved oxygen (mg/L)	7.80 ± 1.71 (22)	9.22 ± 1.6 (8)

3-4a. Environmental Variables unrestricted area of Hatches Harbor

	Restricted		
	Creek	Pool	Creek (lift net)
Temperature (C)	20.04 ± 2.46 (30)	27.9 ± 1.54 (15)	23.15 ± 2.05 (17)
Salinity (ppt.)	25.08 ± 4.4 (30)	24.36 ± 6.95 (15)	21.52 ± 3.29 (11)
Dissolved oxygen (mg/L)	No data	11.05 ± 2.68 (15)	5.03 ± 2.73 (11)

3-4b. Environmental Variables restricted area of Hatches Harbor

Table 3-4 a-b Environmental variables for Hatches Harbor marsh by habitat strata and sample area.

	2003				2004				2005				2006						
	R		U		R		U		R		U		R				U		
Species	C	P	C	P	C	P	C	P	C	P	C	P	C^1	C^2	MS	P	C	MS	P
American eel									X				X						
Green crab				X			X	X	X	X	X		X	X	X		X	X	X
Sand shrimp			X				X	X	X	X	X		X				X		
Sheepshead minnow	X																		
Mummichog	X	X	X	X		X	X	X	X	X	X		X	X		X	X		X
Striped killifish		X	X	X		X	X		X		X								
Atlantic silverside							X	X	X		X								
White perch									X										
Shore shrimp	X		X																
Winter flounder							X		X		X								
Total species	3	2	4	3	0	2	6	4	8	3	6	0	4	2	1	1	3	1	2

Table 3-5. Species sampled at Hatches Harbor 2003 to 2006. R-restricted area of marsh; U-unrestricted area of marsh; C^1-creek habitat >1m wide; C^2-creek habitat <1m wide; P-pool habitat; MS-marsh surface habitat