Peconic Estuary Program 2013 Long-Term Eelgrass (*Zostera marina*) Monitoring Program

DRAFT Progress Report 14

Submitted To:
The Peconic Estuary Program Office
The Suffolk County Department of Health Services
Office of Ecology

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Introduction and Methods

INTRODUCTION

The decline of eelgrass (*Zostera marina* L.) in the Peconic Estuary over the last 70 years has contributed to the degradation of the estuary as a whole. This submerged, marine plant is inextricably linked to the health of the Estuary. Eelgrass provides an important habitat in near-shore waters for shellfish and finfish and is a food source for organisms ranging from bacteria to waterfowl. To better manage this valuable resource, a baseline of data must be collected to identify trends in the health of the eelgrass meadows and plan for future conservation/management and restoration activities in the Peconic Estuary. The more data that is collected on the basic parameters of eelgrass, the better able the Peconic Estuary Program will be to implement policies to protect and nurture the resource.

The basic purpose of a monitoring program is to collect data on a regularly scheduled basis to develop a basic understanding of the ecology of the target species. Since its inception, the Peconic Estuary Program's Submerged Aquatic Vegetation Monitoring Program, contracted to Cornell Cooperative Extension's Marine Program, has focused on collecting data pertaining to the health of the eelgrass beds in the Peconic Estuary. The development of this program reflects the unique ecology and demography of the eelgrass in the Peconic estuary and varies significantly from other monitoring programs like the Chesapeake and other areas on the east coast, which tend to focus more on remote sensing techniques (i.e., aerial photography) for monitoring.

METHODS

The PEP Long-term Eelgrass Monitoring Program includes eight eelgrass beds located throughout the estuary and represents a range of environmental factors. The name and township location of each of the reference beds are listed in Table Intro-1, with a corresponding aerial perspective of each site found in Figure Intro-3. Included with each image are the locations of the six (eight, in the case of Gardiners Bay) sampling stations within the bed.

The monitoring program has evolved its methodologies from its beginnings in 1997; however the basic parameters of eelgrass health, shoot density, has always been the focus of the program, thus allowing for comparisons between successive years. In the beginning, sampling consisted of the destructive collection of three (four in Bullhead Bay) 0.25 m^2 (50cm x 50cm) quadrats of eelgrass including below-ground and above-ground biomass that was returned to the laboratory for analysis. The sampling in 1998 and 1999 continued to utilize destructive sampling to collect data, however, sample size was increased to a total of twelve quadrats and there was a decrease in the size of the quadrats to 0.0625 m^2 (12.5 x 12.5 cm).

In 2000, the methodology for the monitoring program was amended to increase the statistical significance of the data collected. The adjustments reflected an increase in the number of sampling stations per site

Table Intro-1. The eight reference eelgrass beds and the townships in which they are located.

Bullhead Bay (BB)	Southampton
Gardiners Bay (GB)	Shelter Island
Northwest Harbor (NWH)	East Hampton
Orient Harbor (OH)	Southold
Southold Bay (SB)	Southold
Three Mile Harbor (TMH)	East Hampton
Cedar Point (CP)	East Hampton
Orient Point (OP)	Southold

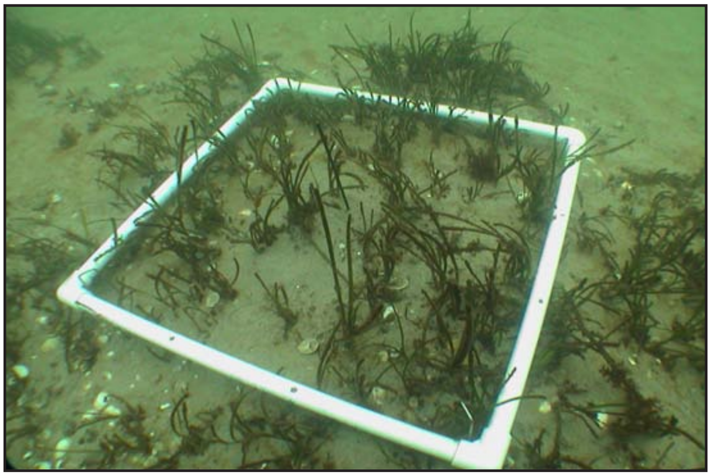


Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

(from 3 to 6), the number of replicate samples per station (from 4 to 10) and the size of the quadrats. However, the 2000 methodology included an increased number of destructively sampled quadrats (24 quadrats) for use in biomass estimations. The 2001 protocols maintained the higher number of replicate samples per bed (60 quadrats) but eliminated the destructive sampling aspect of the program.

Starting in 2012, two additional stations were added to the Gardiners Bay (Shelter Island) site due to the steady inshore migration of the eelgrass meadow. The stations (7 and 8) were selected to support eelgrass based on the March 6, 2012 aerial imagery presented in Google Earth. The location of these new stations is illustrated in Figure GB-1.

Water Temperature Monitoring

Water temperature has been increasingly identified as an important environmental parameter to monitor in regard to eelgrass health. High water temperatures (above 25°C/77°F) have been found to reduce the ability of eelgrass to efficiently produce energy that can be used for growth or stored in its rhizomes. Very high water temperatures, greater than 30°C (86°F), may cause the plants to slough above-ground biomass (i.e., blades) and possibly result in mortality of the entire plant. Temperature effects eelgrass by influencing the plants primary production efficiency. This efficiency is typically represented as the ratio of photosynthesis to respiration (P:R) in a plant. Eelgrass, being a temperate water species, has recorded optimal P:R for temperatures ranging from 10-25°C (50-77°F). When temperatures increase above 25°C, the rate of respiration begins to out-pace the rate of photosynthesis, resulting in a net negative production for the plants. However, the imbalance in P:R at high temperatures can be overcome by the eelgrass if the plants receive enough irradiance. Even given unlimited light, water temperatures reaching and exceeding 35°C (95°F) are lethal to eelgrass.

In the past, water temperature monitoring was included in the LTEMP report due to the placement of temperature loggers primarily within eelgrass meadows that were monitored in the program. In 2010, additional water temperature loggers were purchased and an expanded plan was enacted to cover more of the Peconic Estuary, including areas of extant eelgrass and sites that formerly supported meadows. While the complete temperature survey data will be presented in its own report, the data for the included LTEMP sites is included in this report. Water temperature loggers were deployed at five, current LTEMP monitoring sites (Bullhead Bay, Cedar Point, Gardiners Bay, Orient Point, and Southold Bay) for the 2011 season. A temperature logger was also deployed in Hands Creek, an extant eelgrass meadow adjacent to the Three Mile Harbor LTEMP site. The water temperature results for the above listed sites will be used in conjunction with the light data collected at the sites.

Light Logger Deployment

The 2011 season saw the first deployment of light loggers in the Peconic Estuary, with Bullhead Bay as one of the target sites. While the light logger project is not part of the PEP LTEMP, but rather its own program under the PEP, the data collected at LTEMP sites is included in this report.

The Odyssey® PAR loggers continuously record the

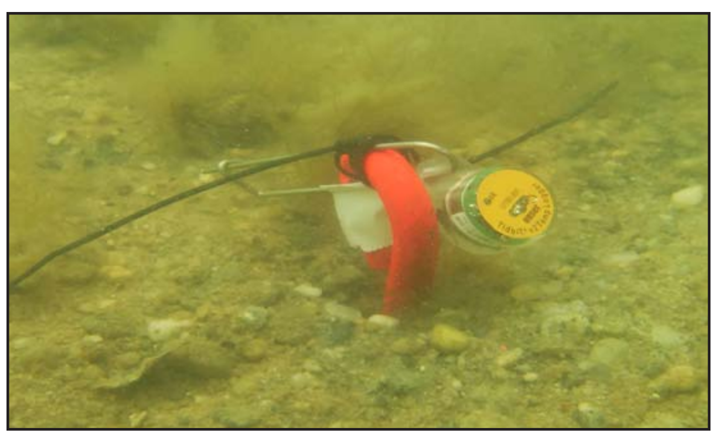


Figure Intro-2. A TidBit v2™ temperature logger attached to a screw anchor, deployed on-site.

amount of Photosynthetically Active Radiation (PAR) that reaches the bottom of an embayment, allowing biologists to determine if a system is receiving enough light, at a given depth (4 feet for this survey) below mean low water (MLW), to support a submerged plant (i.e., eelgrass). Light data was taken primarily at the vegetated sites within the PEP LTEMP including: Cedar Point, Gardiners Bay, and Orient Point. Southold Bay, the site of a recently extinct eelgrass meadow and LTEMP site, was also included in the survey. Bullhead Bay had light loggers deployed only during the summer months, July-September. For the 2012 survey, a 1 week deployment was initiated for Three Mile Harbor in August to evaluate the light conditions at the site of the former meadow. The loggers were deployed for 7 days of recording. The logger measured the quantity of PAR at set intervals throughout each day. The loggers were retrieved after the 7 days and the data was then uploaded to and analyzed in Microsoft Excel®.

The light logger data allows for the determination of two important parameters for plants- H_{comp} and H_{sat}. H_{comp} represents the number of hours that eelgrass spends at or over the level of light intensity that is required for photosynthesis to equal the rate of respiration, also known as the Compensation Point. For the Peconic Estuary, it was decided to use the Compensation Point calculated for an eelgrass population in Woods Hole, Massachusetts, which was reported as 10 $\mu mols \cdot m^{-2} \cdot s^{-1}$ (Dennison and Alberte, 1985). The second parameter is H_{sat}, which is the number of hours eelgrass is exposed to PAR at an intensity at which the rate of photosynthesis is no longer limited by the amount of light the plant is receiving. This is known as the Saturation Point. H_{sat} is where plants generate the energy to support growth and development beyond the basic metabolic requirements. As with the Compensation Point, the light intensity for the Saturation Point was taken from Dennison and Alberte (1985) and considered to be 100 $\mu mols \cdot m^{-2} \cdot s^{-1}$ for the Peconic Estuary. Dennison (1987) calculated that his eelgrass population required a daily average of 12.3 hours (h) H_{comp} over the course of the year, to meet basic metabolic requirements, and this 12.3h period was adopted for the PE eelgrass meadows. In regard to H_{sat}, Dennison and Alberte (1985) calculated that their eelgrass population required a minimum of 6-8h per day. Taking the data collected in the Peconic Estuary in 2010 and comparing it to Dennison and Alberte's calculations, CCE made a conservative estimate that H_{sat} should be closer to 8 hours.

Eelgrass Monitoring

The 2013 monitor was initiated on 23 August and completed on 5 December. Sampling at each site was distributed among six stations that have been referenced using GPS, with the exception of the Gardiners Bay site, as mentioned above. At each of the six stations, divers conducted a total of 10 random, replicate counts of eelgrass stem density and macroalgal percent cover in 0.10 m^2 quadrats. Divers also made observations on blade lengths and overall health of plants that they observed. The divers stayed within a 10 meter radius of the GPS station point while conducting the survey. Algae within the quadrats were identified minimally to genus level and if it was epiphytic or non-epiphytic on the eelgrass. Divers were careful not to disturb the eelgrass, so as not to cause plants to be uprooted or otherwise damaged.

Data was statistically analyzed using MiniTab statistical software. The trends, within sites, were analyzed by comparing the current year's data with the data from the previous years.

Bed Delineation and Areal Extent

A new aerial survey of the Peconic Estuary was scheduled for the Fall 2013 to provide an up-to-date accounting of the extant eelgrass meadows and their areal extent. Unfortunately, water clarity and weather conditions prohibited the flights and the aerial survey has been postponed until Spring 2014. When the flight is conducted, the data will be compared to the trends for the 4 extant eelgrass meadows remaining in the LTEMP: Bullhead Bay, Cedar Point, Gardiners Bay, and Orient Point, determined by available aerial photosets.. The trends analysis used the Suffolk County Aerial Photography for 2004, 2007 and 2010 as a comparison for the initial eelgrass survey conducted in 2000 (Tiner et al., 2003). For the 2012 season, Google Earth aerial imagery (March 6, 2012) was used for delineations. These aerial photographs were not flown under the standard protocols defined by NOAA's C-CAP, resulting in reduced water clarity and contrast needed to accurately delineate submerged vegetation. As such, the results presented should be considered estimates of the areal extent of the target meadows and not exact coverages. Also, where a determination could not be made of where a meadow ended, or if

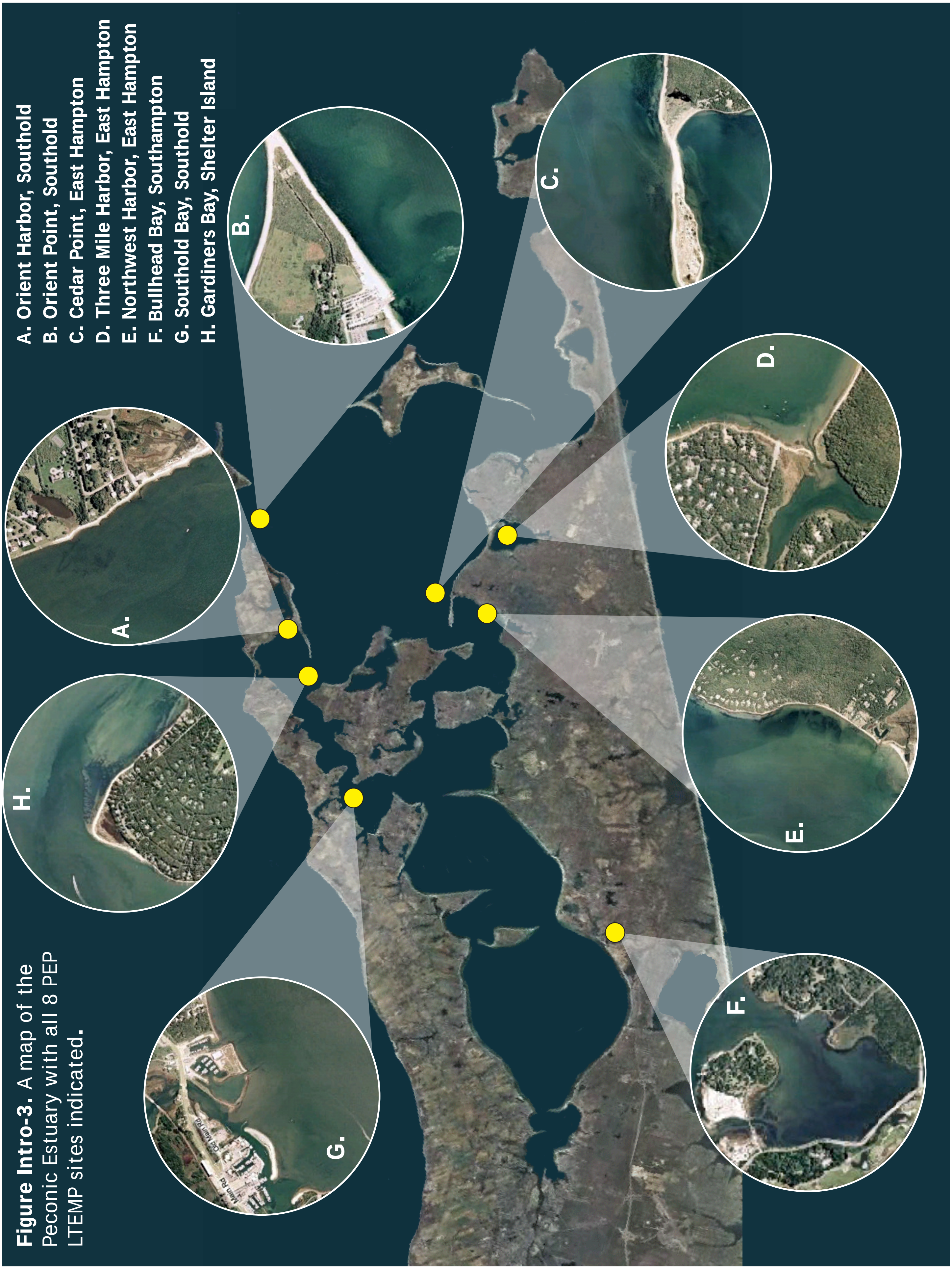


Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

the aerial coverage did not extend offshore far enough to cover the deep edge, a "soft edge" consisting of a dashed line was placed along that edge of the meadow delineation. When available, any GPS data describing a meadow's extent was integrated into the final delineations presented.

Underwater Video

Underwater video was taken of each station for the eight PEP LTEMP sites. Each CCE diver was equipped with a GoPro Hero 2™ digital video camera in an underwater housing. The video clips were edited, combining footage from each station into a thirty second video for each station. The videos can be found on YouTube at SeagrassLI's video page.

Bullhead Bay is a small sheltered embayment located in the western Peconic Estuary and it is connected to Great Peconic Bay via Sebonnac Creek. The eelgrass meadow at this site is the western-most eelgrass population in the Peconic Estuary. This meadow is not only geographically isolated from other extant eelgrass populations, but the environmental conditions under which the eelgrass grows at this site are unique.

Figure BB-1. An aerial view of the Gardiners Bay eelgrass meadow with monitoring stations indicated by the superimposed numbers.

Site Characteristics

Bullhead Bay is a relatively sheltered embayment; however, winds from the north to northwest do influence the bay (Figure BB-1). The sediments of the bay range from coarse sand to loose muck. The sandy bottoms are found along the eastern and southern shore (likely influenced by the winter winds out of the north and northwest) as well as the northern areas of the bay where water is funneled under a bridge. The remaining bay bottom is loose mud of various depths. The mud areas have a relatively high organic content, especially for sediments supporting an eelgrass population. Sediment analysis conducted in 1997 at this site found organic content in some areas exceeded 8%. It seems that this eelgrass population can tolerate these high levels of organics in the sediment. Water quality at the site has always been in question. There is a major golf course (Shinnecock Hills) along the entire west side of Bullhead Bay (separated by a road but with culverts running underneath the road). It is unknown what levels of nutrient/chemical loading may be sourced to the golf course, but it could be significant. Aside from the golf course, the residential housing along Sebonnac Creek could also be a source of nutrient loading for the bay. Bullhead Bay also supports significant populations of mute swans and Canada geese that not only add nutrients from their droppings, but also impact the bed by their grazing on eelgrass. Even though there are several significant potential sources of nitrogen

Bullhead Bay 2013

Table BB-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Bullhead Bay over 7 days for June and August, 2013.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	13.8	+1.5	9.6	+1.6	27.6
August	12.9	+0.6	9.7	+1.7	24.8

loading to Bullhead Bay, the eelgrass continues to populate this system. One factor that may reduce the impact of poor water quality in Bullhead Bay may be its overall shallow profile. With the eelgrass growing at depths of 6 feet or less at MLW, light is not attenuated to a point where it is insufficient for eelgrass photosynthesis.

Light Availability and Temperature

An Odyssey PAR logger and an Onset TidBit temperature logger was deployed within the Gardiners Bay for the 2013 season in the same location used for the previous two seasons. The data collected for July and August is presented in Table BB-1. A September sampling was planned, but the mechanical issues left CCE with no boats available until October. The light survey from July and August found eelgrass in Bullhead Bay met and exceeded the minimal requirements for H_{comp} and H_{sat}. Observations by divers reported that while *Cochlodinium* was present in the bay, it was patchy and not as dense as in previous years, which likely helped water clarity in 2013.

Bullhead Bay experienced extremely high water temperatures in 2013. The meadow spent 50 days with average daily temperatures over 25°C, with 21 days above 27°C. The month of July was one of the hottest reported for the LTEMP in any meadow with water temperatures for the month averaging 27.6°C (Table BB-1). The highest temperature recorded in Bullhead Bay for 2013 was 32.6°C recorded on 17 July. This temperature is well above the limit of eelgrass tolerance and it the water temperature had remained at this temperature for an extended period, it would have resulted in shedding of above-ground biomass and evenetually death of plants.

Eelgrass Shoot Density

The 2013 eelgrass monitoring of Bullhead Bay was conducted on 23 August 2013. While moving into the Bay, eelgrass was observed in increasingly larger patches as the boat moved from Sebonac Creek toward monitoring stations 1 and 2. Water clarity was uncharacteristically good for this time of year, as previous years have had water clarity impacted by Cocchlodinium blooms or simple turbidity. Ruppia maritime flower shoots were observed just below the water's surface throughout the Bay, suggesting extensive coverage of this plant.

Quadrat sampling of the six eelgrass monitoring stations in Bullhead Bay found that the meadow had staged a significant recovery in 2013, with an average eelgrass shoot density 188 shoots•m^2 (Table BB-2; Figure BB-2a). This represents a significant increase from the 71 shoots•m^2 reported in 2012 and is the highest shoot density recorded for the Bullhead Bay meadow since 2002 (Table BB-2). The 2013 season was also the first time since 2002 that all six monitoring stations have supported eelgrass. This recovery is all the more extraordinary as just four years ago (2009) no eelgrass was reported for any of the monitoring stations and divers' observations indicated that eelgrass throughout the bay was minimal.

Eelgrass was not the only submerged rooted vegetation to have flourished in Bullhead Bay since 2012. While its presence had always been noted in previous monitoring reports, *Ruppia maritima* (Widgeongrass) had not been observed in the densities encountered in 2013. Due to its small size and dense branching, determining shoot density for *Ruppia* is extremely difficult; therefore percent cover of *Ruppia* was estimated in each quadrat. The average percent cover of *Ruppia* for 2013 was 17%. Twenty-five of the sixty quadrats sampled for the LTEMP contained *Ruppia* and ten of those quadrats were found to have *Ruppia* cover greater than 50%. *Ruppia* typically occupied the spaces between patches of eelgrass, but it was also found growing within less dense patches of eelgrass.

Macroalgae Cover

Table BB-2. Annual mean eelgrass shoot densities and standard error for Bullhead Bay, Southampton.

Year	Mean Density	S.E.
1997	710	+/- 196
1998	620	+/- 112
1999	548	+/- 79
2000	301	+/- 26
2001	150	+/- 18
2002	201	+/- 14
2004	125	+/- 28
2005	52	+/- 11
2006	171	+/- 34
2007	51	+/- 12
2008	46	+/- 9
2009	19	+/- 8
2010	0*	+/- 0
2011	22	+/- 6
2012	71	+/-12
2013	188	+/-20

*Eelgrass was observed growing at the site, however it was outside the monitoring stations.

While Bullhead Bay experienced a significant increase in submerged rooted vegetation (i.e. eelgrass and *Ruppia*) in 2013, the macroalgae population did not exhibit a significant change over the 2012 population. Even with the eelgrass providing expanded opportunities for anchorage/attachment, macroalgae percent cover saw a modest decline from 2012, from 9.8% to 4.5% (Figure BB-2b). Diversity was also down in 2013. Only three macroalgae species were observed by divers: *Spyridia filamentosa*, *Gracilaria tikvahiae* and *Ulva intestinalis* (listed in order of prevalence).

Bed Delineation and Areal Extent

The initial plans for bed delineation for the four monitoring sites with extant eelgrass was to use the information from the aerial survey of the Peconic Estuary scheduled for the Fall 2013. However, due to poor conditions for all of the fall flight windows, the aerial survey was postponed until Spring 2014. By chance, Google Earth posted imagery captured on 19 September 2013, and, while it is not up to CCAP protocols, allowed for delineation of the meadows in the LTEMP.

While the aerial imagery was not ideal for delineating eelgrass (there was sunglare and chop in some of the image), the meadow was estimated to cover 44.7 acres (Table BB-3). This represents an increase from 2012 of 14.15 acres and marks the return of the meadow to 80% of the areal extent area delineated in 2000 (Table BB-3) by Tiner et al. (2003). The changes in the Bullhead Bay eelgrass meadow for select years from 2004 through 2013 are illustrated in Figure BB-3.

Conclusions

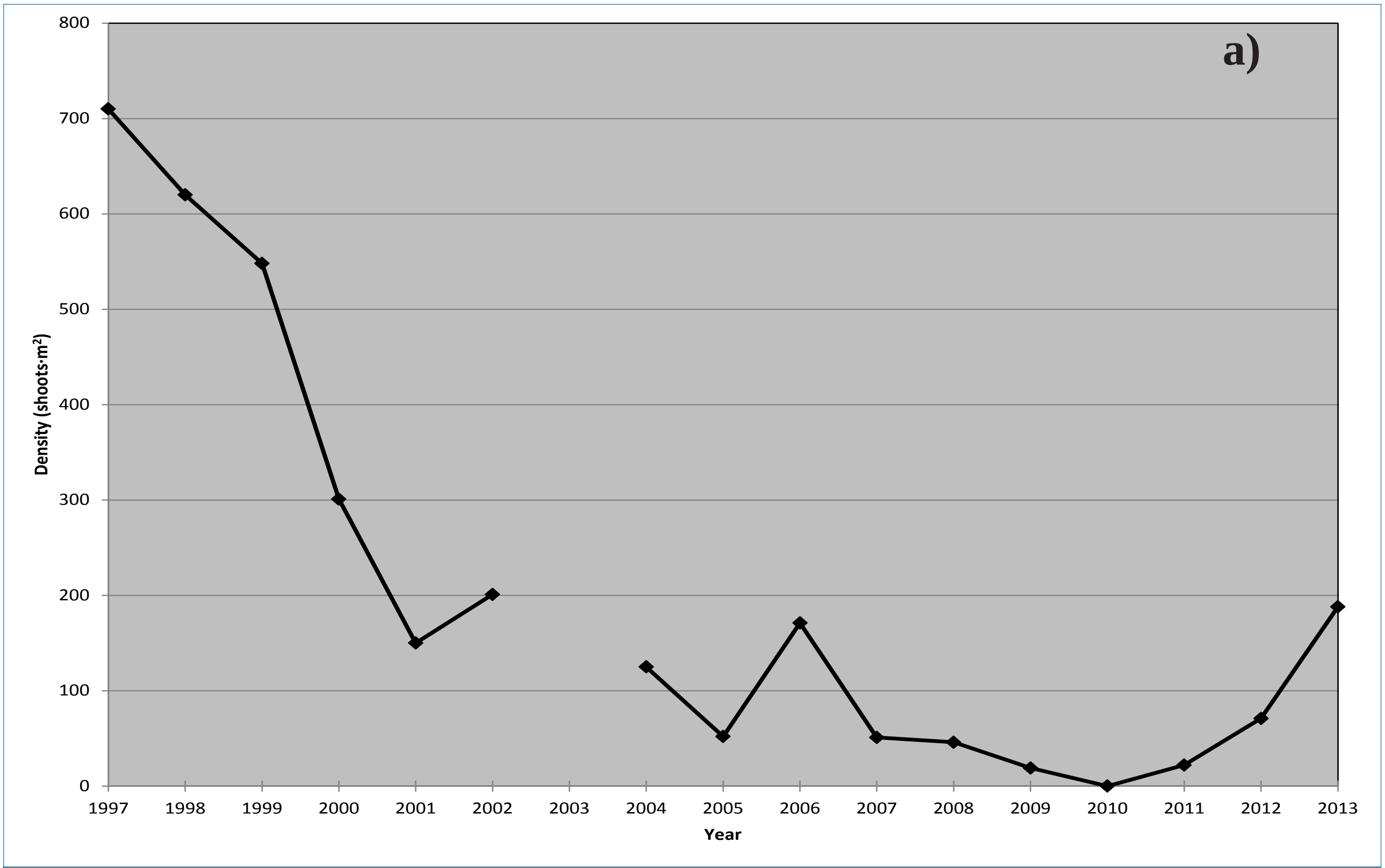
The Bullhead Bay eelgrass meadow has staged a significant recovering from the decline that started between 2002 and 2004. In 2010, the meadow was near extinction with no eelgrass reported in any of the monitoring stations and only small, isolated patches of eelgrass observed by divers. The following year, 2011, saw minimal increase in eelgrass in the bay, followed by a three-fold increase in 2012. The 2013 season saw more than a doubling of the shoot density in the monitoring stations and was the first time in more than a decade that eelgrass was found growing in all six of the monitoring stations. Added to the resurgence of eelgrass in Bullhead Bay is the proliferation of *Ruppia maritima* observed in 2013. *Ruppia* was observed growing within and between patches of eelgrass resulting in an almost complete cover of the bottom of the bay in some areas by rooted vegetation. *Ruppia* was growing in such high densities that it warranted quantification and percent cover data was collected which determined that almost 20% of the bay bottom in the monitoring area was covered by *Ruppia*. All of this expansive growth was accomplished and maintained in water temperatures exceeding the normal tolerance of eelgrass, included over two weeks where water temperatures were upward of 32°C, a lethal temperature for eelgrass.

The areal extent of the meadow, has continued to

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2013.

Year	Estimated Area
2000	54.75 acres (22.16 hect.)
2004	10.87 acres (4.40 hect.)
2007	ND
2010	5.58 acres (2.26 hect.)
2012	30.5 acres (12.3 hect.)
2013	44.65 acres (18.07 hect.)

Bullhead Bay 2013



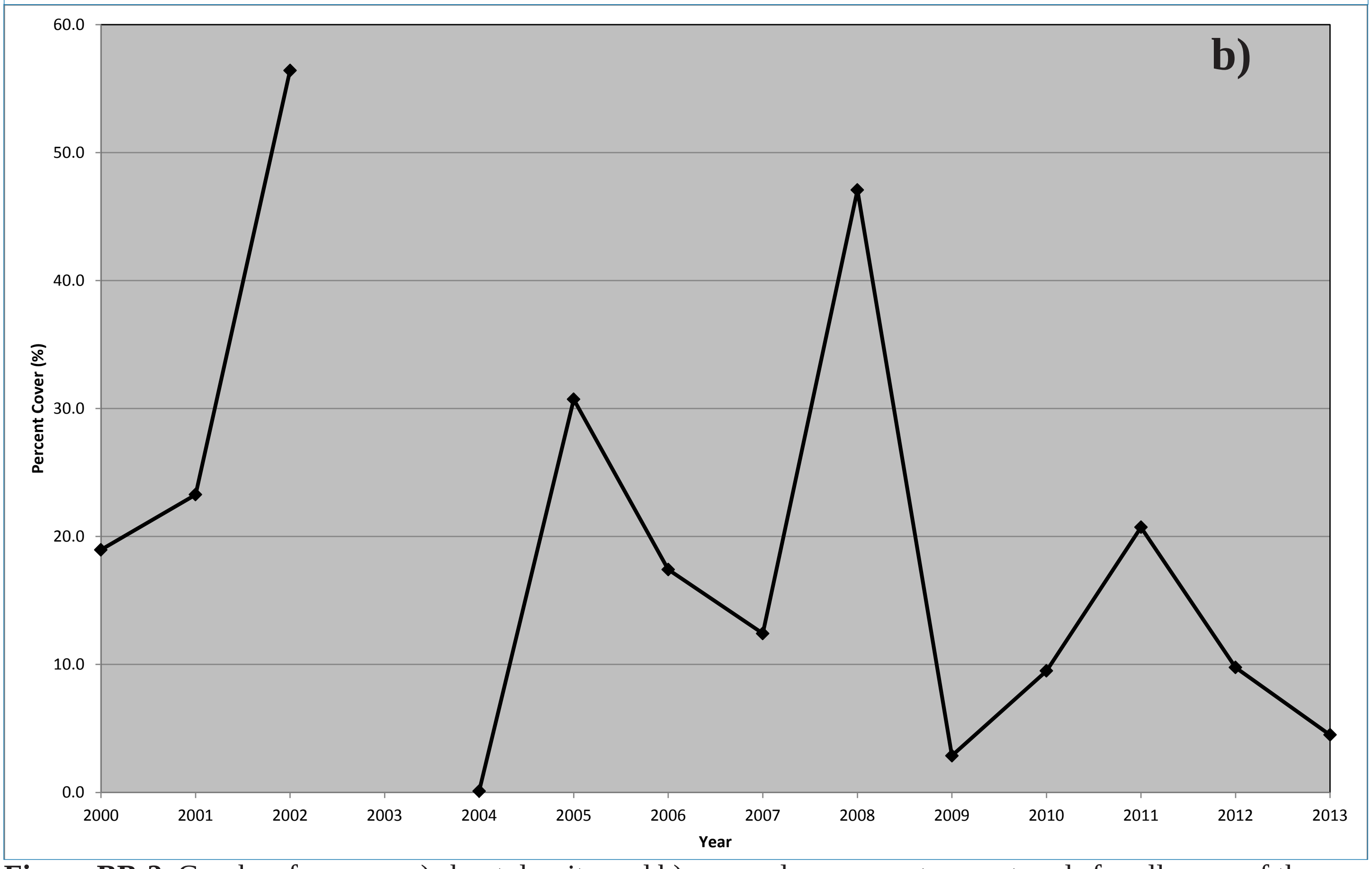


Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

increase since 2010 and the 2013 bed delineations. An accurate delineation of the meadow will be determined in Spring 2014 when the aerial survey will be conducted, but it is expected to support the 2013 observations.

It is apparent that the conditions between 2012 and 2013 were favorable for growth of eelgrass and *Ruppia*. It is possible that the drought conditions that the region was experiencing resulted in a decrease in the water column nutrients in Bullhead Bay, supporting the growth of rooted vascular plants over macroalgae. The light data was not available at this time, but field observations throughout the summer found the water clarity in Bullhead Bay to be the best that has been experienced in almost a decade. Besides the minor bloom encountered in the southern section of the bay, Cocchlodinium's presence was the lowest since it was first reported for Bullhead Bay. It has been suggested in previous reports that the recovery of the meadow was accomplished by successful recruitment of seedlings from a remnant section of the meadow in the northwest section of the bay. It is certain that seeds have played a primary role in re-establishment of the meadow in Bullhead Bay, based on the current rate of recovery and expansion. What initiated the decline of the meadow over a decade ago is still unclear, however, the lack of genetic diversity inherent in old eelgrass meadows may have exacerbated the decline of the meadow and the new growth of eelgrass from seeds will once again establish a meadow with higher genetic diversity that will be better able to cope with and survive future adverse conditions. Research into the genetic diversity of the current meadow would provide important baseline information that could be used to predict future changes in the meadow caused by climate change or other factors, and possibly be applied to other meadows in the estuary to determine their susceptibility to these same factors.

Bullhead Bay 2013

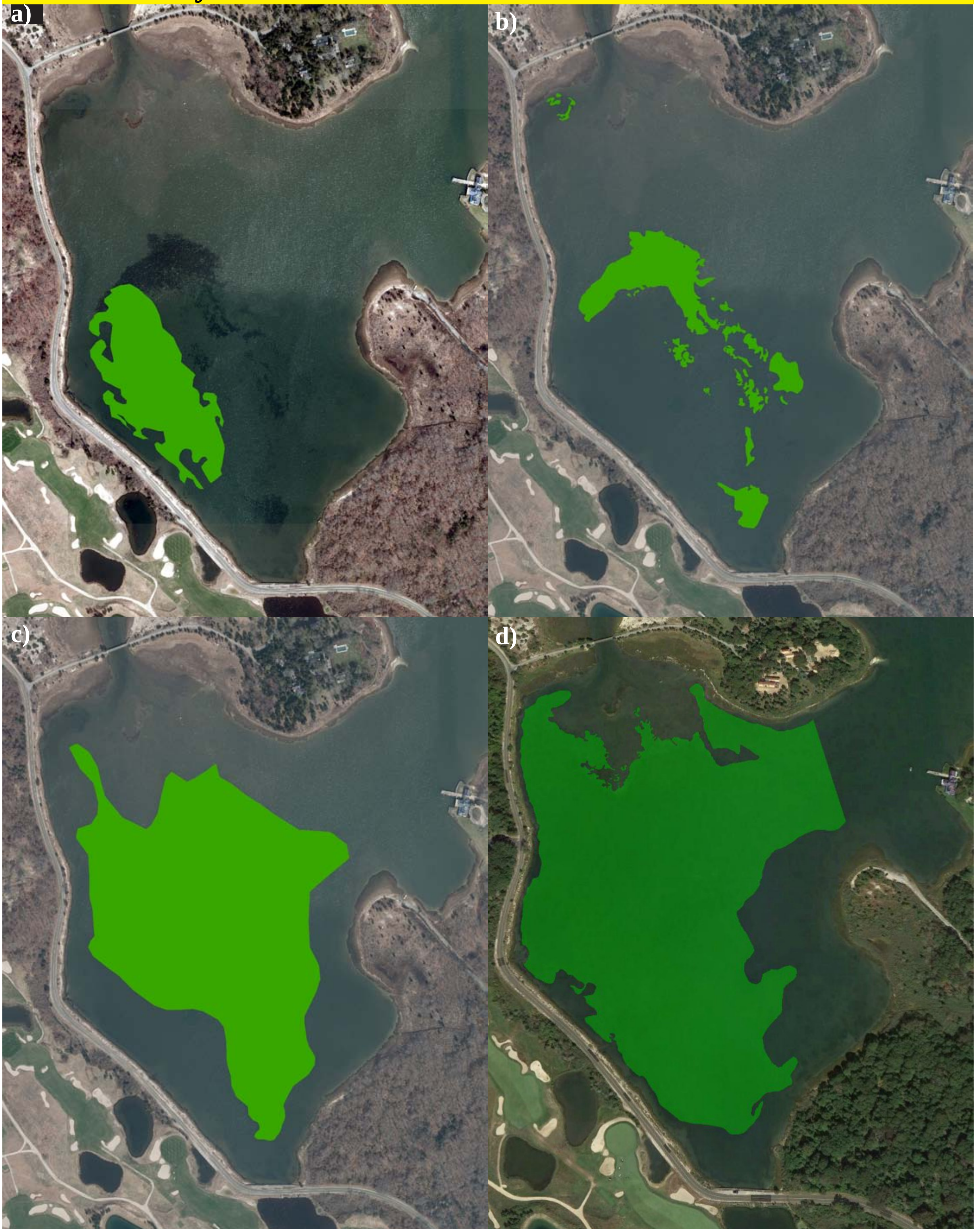


Figure BB-3. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2012. The years represented are a) 2004, b) 2010, c) 2012 and d) 2013.

The Gardiners Bay eelgrass monitoring site is located on the east side of Hay Beach Point on Shelter Island. The eelgrass meadow starts near the channel connecting Greenport Harbor to Gardiners Bay in the north and extends southward toward Cornelius Point (Figure GB-1). This site is the most exposed, high-energy eelgrass meadow of the original six monitoring sites. The eelgrass meadow is very patchy and an aerial view of the meadow (Figures GB-1 and GB-4) illustrates the natural appearance of a majority of the meadow.

Figure GB-1. An aerial view of the Gardiners Bay eelgrass meadow with monitoring stations indicated by the superimposed numbers.

Site Characteristics

The Gardiners Bay eelgrass monitoring site is situated in an area of high current and is exposed to significant fetch from the north to the east. This exposure causes the site to be especially influenced by winter storms. The current at this site is also the highest encountered at any of the monitoring sites. The eelgrass meadow is established on relatively shallow, sand flats to the south and west of one of the two main channels that connect Gardiners Bay to the western Peconic Estuary. Both the high wave exposure and high currents at this site have removed most of the finer sediments leaving the majority of the site's sediment as coarse sand to gravel (and shell). Organic content of the Gardiners Bay site's sediments averaged 0.84% organic material in the sediments with a range of 0.31% to 1.73%. Even this coarse sediment is subject to movement by the hydrodynamic forces acting on this site. Sand waves are readily observable from the air as well as underwater. Mass movement of sediments have been observed to slowly bury eelgrass patches in some areas, while other sections of the meadow experience erosion that leaves eelgrass patches as elevated plateaus. The constant movement of sediments at this site results in a highly patchy eelgrass meadow with an areal coverage that can change significantly over short periods of time.

Water quality has rarely been a factor in the health of this eelgrass meadow. The flushing that this site experiences is more than adequate to maintain nutrient con-

Gardiners Bay 2013

Table GB-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Gardiners Bay over 7-days for each month, July-August, 2013.					
Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	13.8	+1.5	8.7	+0.7	24.3
August	12.7	+0.4	8.8	+0.8	23.5

centrations at ambient levels for the eastern Estuary. Due to its significant fetch to prevailing winter winds, the turbidity can become high during storms, but suspended solids tend to settle quickly or be flushed shortly afterward. Water clarity also tends to decline with the outgoing tide. Depending on the time of year and/or the tide, drift macroalgae can be transported on the currents and significantly reduce clarity. The effects of storms and macroalgae drift are examples of acute events that are infrequent at this site. Chronic water quality issues would be very rare at this site and would likely involve an Estuary-wide event.

Light Availability and Temperature

An Odyssey PAR logger and an Onset TidBit temperature logger was deployed within the Gardiners Bay for the 2013 season in the same location used for the previous two seasons. The data collected for July and August is presented in Table GB-1. A September sampling was planned, but the mechanical issues left CCE with no boats available until October. Water clarity for the two temperature logger deployments, July and August, was found to meet the minimal standards set for H_{comp} and H_{sat} for the Peconic Estuary. The H_{comp} levels at the Gardiners Bay site saw a decline from 13.8 hrs (July) to 12.7 hrs (August) (Table GB-1), but the decline in water clarity through the summer and into the early fall is a recurring trend based on previous light surveys in the Estuary. H_{sat} levels for the two months showed an insignificant changed between the two months (Table GB-1).

Water temperature monitoring at the Gardiners Bay LTEMP site was conducted from June throught the end of October 2013, but only monthly average temperature for July and August are included in Table GB-1, as these are the two months that experience the highest water temperatures which may impact eelgrass health. For 2013, the average water temperature for both months was under 25°C. The site only experienced seven days of water temperatures above 25°C with no day at or above 27°C. The highest reported temperature at the site for 2013 was recorded on 20 July, when the water reached 26.3°C.

Eelgrass Shoot Density

Monitoring of the eelgrass meadow at Hay Beach, Shelter Island was conducted on 27 August 2013. Divers found the condition of the meadow to have been similar to what was reported in 2012. As in 2012, only 3 monitoring stations, out of eight total, supported eelgrass. The vegetated stations included stations 6-8 and were all located within the inshore area of the meadow (Figure GB-1). Averaging the shoot density counts across all the stations found the eelgrass shoot density for 2013 to be 99 shoots•m^2 (Table GB-2; Figure GB-2a). This shoot density was a slight increase over

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2012, including standard error.

Year	Mean Density	S.E.
1999	499	+/- 37
2000	470	+/- 23
2001	373	+/- 16
2002	306	+/- 25
2004	300	+/- 26
2005	320	+/- 26
2006	178	+/- 31
2007	224	+/- 40
2008	131	+/- 25
2009	19	+/- 7
2010	41	+/- 14
2011	28	+/- 10
2012*	74	+/-15
2013	99	+/-24

**Two new stations established (total=8).*

2012, but was not found to be statistically significant. When the stations not supporting eelgrass are factored out of the shoot density calculation, shoot density for 2013 was 263 shoots•m^2 , an increase from the 198 shoots•m^2 from 2012, but not found to be a significant increase. Diver observations found the meadow has experienced a minimal loss along its offshore edge between 2012 and 2013. The meadow was also found to be patchier than 2012 around stations 7 and 8.

Macroalgae Cover

The Gardiners Bay eelgrass meadow has typically supported a large macroalgae population; both in abundance and species richness, and the 2013 survey supported this trend. Quadrat sampling found macroalgae percent cover for the meadow averaged 24%, which was up from 2012 (Figure GB-2b). While all stations reported some coverage of macroalgae in the quadrats sampled, the highest percent cover of macroalgae was recorded at the stations that supported eelgrass. Eelgrass provides anchorage for drift macroalgae swept across the site by the high currents and protection for substrate-attached macroalgae from burial by current-shifting sands, so higher numbers are expected in the presence of eelgrass. The 2013 monitoring survey also identified 13 species of macroalgae, with *Spyridia filamentosa* representing the dominant species. Other species of note included the green macroalgae *Ulva intestinalis* and *U. clathrata*, both relatively widespread on the small hard substrate (e.g. gravel and shell) common at this site.

Bed Delineation and Areal Extent

The initial plans for bed delineation for the four monitoring sites with extant eelgrass was to use the information from the aerial survey of the Peconic Estuary scheduled for the Fall 2013. However, due to poor conditions for all of the fall flight windows, the aerial survey was postponed until Spring 2014. By chance, Google Earth posted imagery captured on 19 September 2013, and, while it is not up to CCAP protocols, the imagery for the Gardiners Bay site was very good and the delineations are expected to be fairly accurate.

The 2013 eelgrass delineations of the Gardiners Bay eelgrass meadow found that the bed had lost nearly 11 acres from March 2012 to September 2013 (Table GB-3). This is the first signifcant loss in areal cover of the meadow since 2004. Figure GB-3 shows increased fragmentation of the meadow between 2012 and 2013 as well as the loss of a large area of the inshore meadow in the middle of the bed. This damage was likely caused by Superstorm Sandy and winter storms of 2013.

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2013.

Year	Estimated Area
2000	78.64 acres (31.83 hect.)
2004	39.03 acres (15.80 hect.)
2007	35.65 acres (14.43 hect.)
2010	34.88 acres (14.12 hect.)
2012	35.62 acres (14.42 hect.)
2013	24.79 acres (10.03 hect.)

Conclusions

The eelgrass meadow at Hay Beach, Shelter Island has experienced an almost steady decline since monitoring began in 1999. The overall trend for the meadow has been one of constant loss of eelgrass from the offshore edge of the meadow. This inshore migration of the meadow has left 5 of the original six monitoring stations without eelgrass and prompted the establishment of two new stations within the remaining meadow in 2012. The cause of this inshore retreat is unclear, however, water quality does not seem to be an issue based on the data collected over several years for light and temperature. The high tidal currents and exposure to storm generated waves have contributed to some of the loss in the meadow due to the movement of sand over extant eelgrass patches and the erosion of meadow edges or disturbance areas. Prop-scarring from boats that have deviated from the marked channel, especially at lower tides, have contributed to the loss of eelgrass at the site. Prop-scars increase the fragmentation of the meadow allowing more surface area for erosional forces to act upon and a greater rate of loss.

The site was once a popular clamming location, both commercial and recreational, and these activities have also contributed to the fragmentation of the meadow, albeit in shallower sections of the meadow than boating damage. Another factor that may prove to negatively impact the meadow at this site is the continued hardening of the shoreline. Currently, bulkheads or rock revetments occupy the majority of the shoreline from Cornelius Point to just several hundred yards

Gardiners Bay 2013

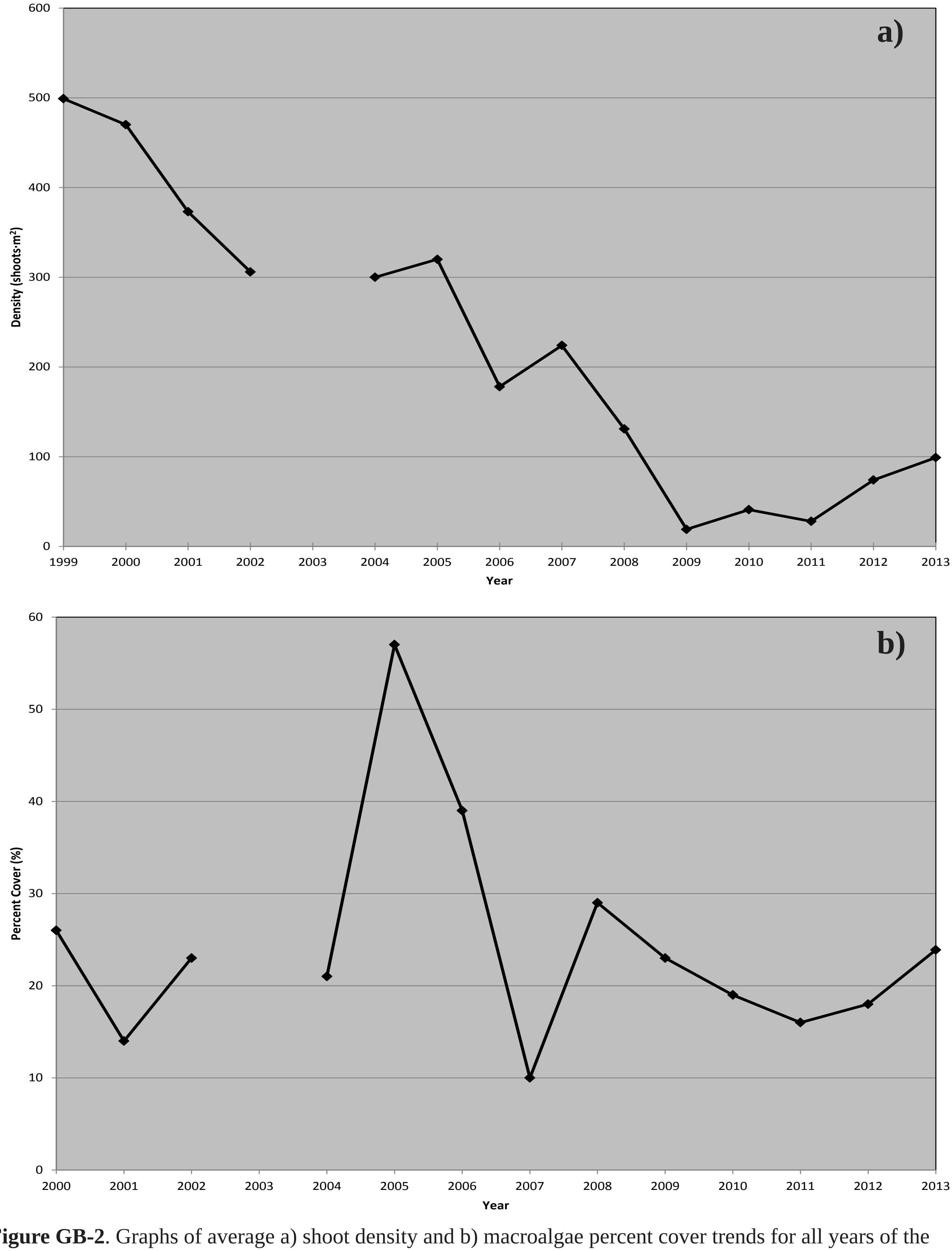


Figure GB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted at the Gardiners Bay site.

from Hay Beach Point. Hardened shorelines have been implicated in the erosion of the inshore edge of eelgrass meadows due to the unnatural reflection of wave energy that would normal be dispersed on a natural, sloping shore. Hardened shorelines also prevent the natural migration of marine communities up the shore in response to sea level rise and could eventually impact the meadow at Hay Beach.

The current state and extent of this meadow may represent its new norm. Trend analysis of aerial photography has shown minimal change in the inshore section of meadow over the years, until 2013, when the damage from Superstorm Sandy and the winter storms of 2013 became evident in the aerial imagery. Boating poses little impact, with the exception of moorings, to the inshore areas of the meadow due to the shallow, rocky nature of the shore, which may allow the storm damaged sections to recover. However, the high current and shifting sediments are not optimal for successful establishment and recruitment of seedlings, and vegetative spread of eelgrass can require decades to see significant gains. The recovery of this meadow would benefit from reductions in human impacts to the site, which, if not curtailed, will continue to fragment this meadow and result in its loss.

Gardiners Bay 2013

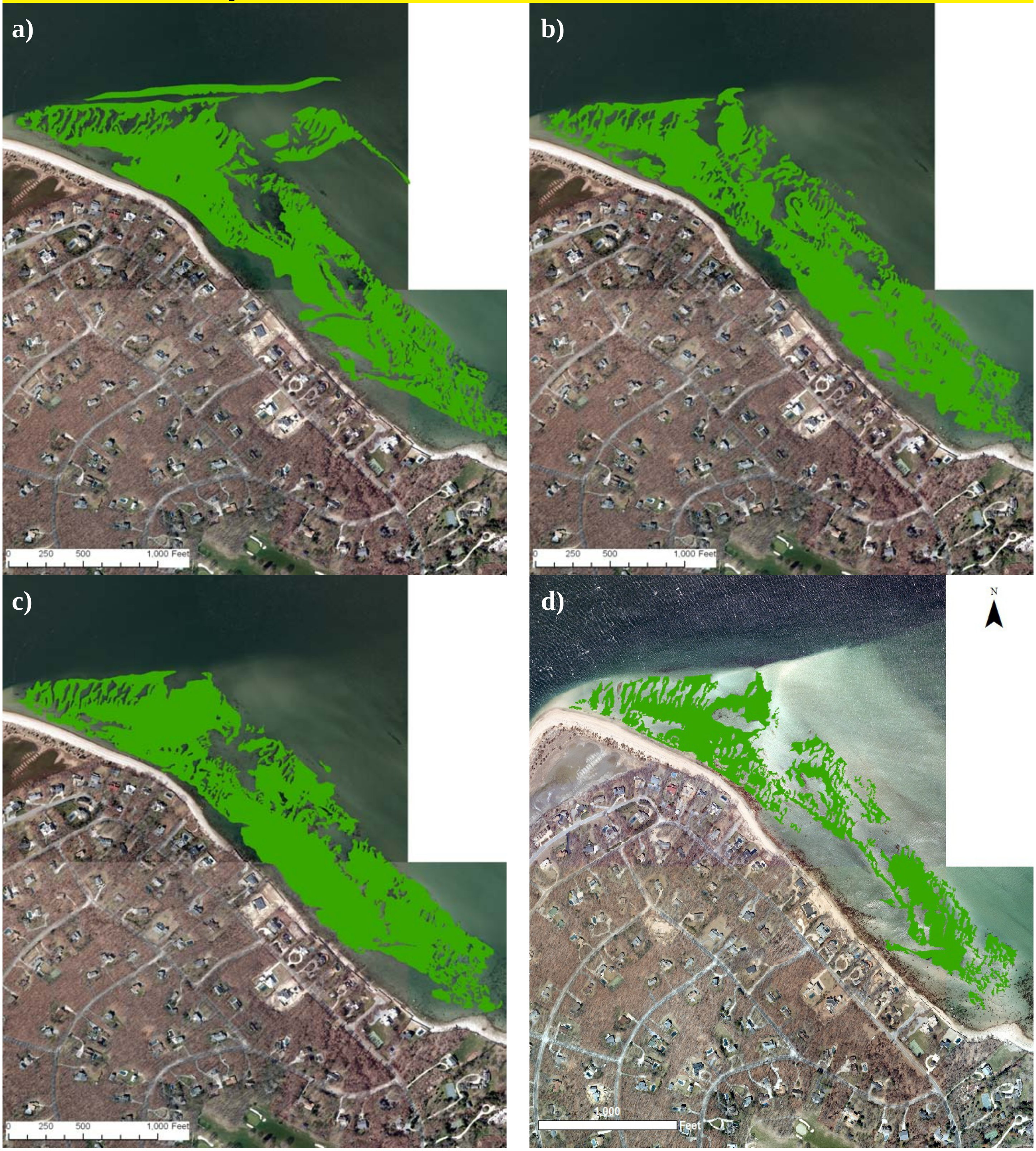


Figure GB-3. A series of aerial delineations of the Gardiners Bay eelgrass from 2004 through 2013. The years represented are a) 2004, b) 2010, c) 2012 and d) 2013.

Northwest Harbor is a moderately sheltered harbor located in western East Hampton Town. The Harbor is separated from Gardiners Bay by Cedar Point. While the site has limited fetch in most directions, summer westerlies can create chop and moderate wave action in the Harbor. Figure NWH-1, shows the area of the Harbor that the monitoring program has focused on since the meadows inclusion into the program in 1997.

Figure NWH-1. An aerial view of the Northwest Harbor eelgrass meadow with monitoring stations indicated by the superimposed numbers.

Site Characteristics

As indicated in Figure NWH-1, the monitoring program in Northwest Harbor is relegated to the southern half of the harbor. Within this half of Northwest Harbor, depths range from 3ft (MLW) in the southern areas (Station 1) to 9ft (MLW) at the northernmost stations. The sediment at the site is almost uniform and is dominated by sand. Organic content of the sediment is low, averaging 0.70%. An increase in shell hash, primarily *Crepidula fornicata* shells, has been observed over the years at the deeper stations. The shallow stations, in the southern areas, show a general lack of coarse sediment or shell. As mentioned above, Northwest Harbor is relatively sheltered in all directions. The Harbor rarely experiences high wave action and most of the monitoring stations are in water deeper than 6ft (MLW), so there is likely limited impact by waves on these areas of the bed. Current in Northwest Harbor is minimal as well.

Water quality in Northwest Harbor is relatively good. There is abundant flushing and development around the Harbor is minimal, resulting in few sources of significant nutrient inputs. Where water quality is not an issue in Northwest Harbor, however, water clarity can be very low at times. Even under the moderate winds that the Harbor experiences, a good amount of mate-

Northwest Harbor 2013

Table NWH-1. The average annual eelgrass shoot density for Northwest Harbor from 1997 to 2012, including standard error.

Year	Mean Density	S.E.
1997	209	+/- 24
1998	310	+/- 21
1999	507	+/- 57
2000	330	+/- 21
2001	409	+/- 20
2002	350	+/- 19
2004	291	+/- 18
2005	176	+/- 16
2006	8	+/- 3
2007	0	+/- 0
2008	0	+/- 0
2009	0	+/- 0
2010	0	+/- 0
2011	0	+/- 0
2012	0	+/- 0
2013	0	+/- 0

rial can be suspended, reducing visibility to a few feet.

Eelgrass Shoot Density

The 2013 eelgrass monitoring survey of Northwest Harbor, conducted on 5 December 2013, recorded no eelgrass in any of the monitoring sites. This has been the trend since 2007 for this site (Table NWH-1; Figure NWH-2) and no sign of extant eelgrass (e.g. floating shoots) was observed in Northwest Harbor in 2013. Scouting along the northern shore of Northwest Harbor, where eelgrass had been reported in recent years, found no evidence of recent growth.

Macroalgae Cover

Macroalgae percent cover continues to be minimal at the Northwest Harbor site (Figure NWH-3). Substrate for macroalgae primarily consists of shell and limits the size and morphology of species present to those exhibiting smaller habits. Substrate availability is also limited in the otherwise sandy sediment of Northwest Harbor. *Spyridia filamentosa* continues to be the dominant species with the more common subordinate species encountered including *Bryopsis plumosa*, *Ectocarpus siliculosus*, *Ulva clathrata*, and *U. intestinalis*. The presence of typically winter species *Bryopsis* and *Ectocarpus* is explained by the late date that the survey was conducted at the site. Normally, these species are more commonly encountered during spring in the Peconic Estuary.

Conclusions

Efforts in 2013 to locate eelgrass in Northwest Harbor failed to identify any extant eelgrass population. It was hoped that the aerial survey scheduled for the Fall 2013 would have been able to locate possible extant eelgrass in Northwest Harbor, but the survey has been postponed until Spring 2014. It is unclear why the eelgrass meadow was lost at this site, but future work by CCE will include deployment of light and temperature loggers to determine if Northwest Harbor has any potential for restoration efforts. A similar effort was conducted in Northwest Creek for the Town of East Hampton over the summer of 2013, but results of that study are still being analyzed. Test plantings in 2014 are being considered for Northwest Creek and possibly Northwest Harbor, but implementation would depend on the results of the planned light and temperature data.

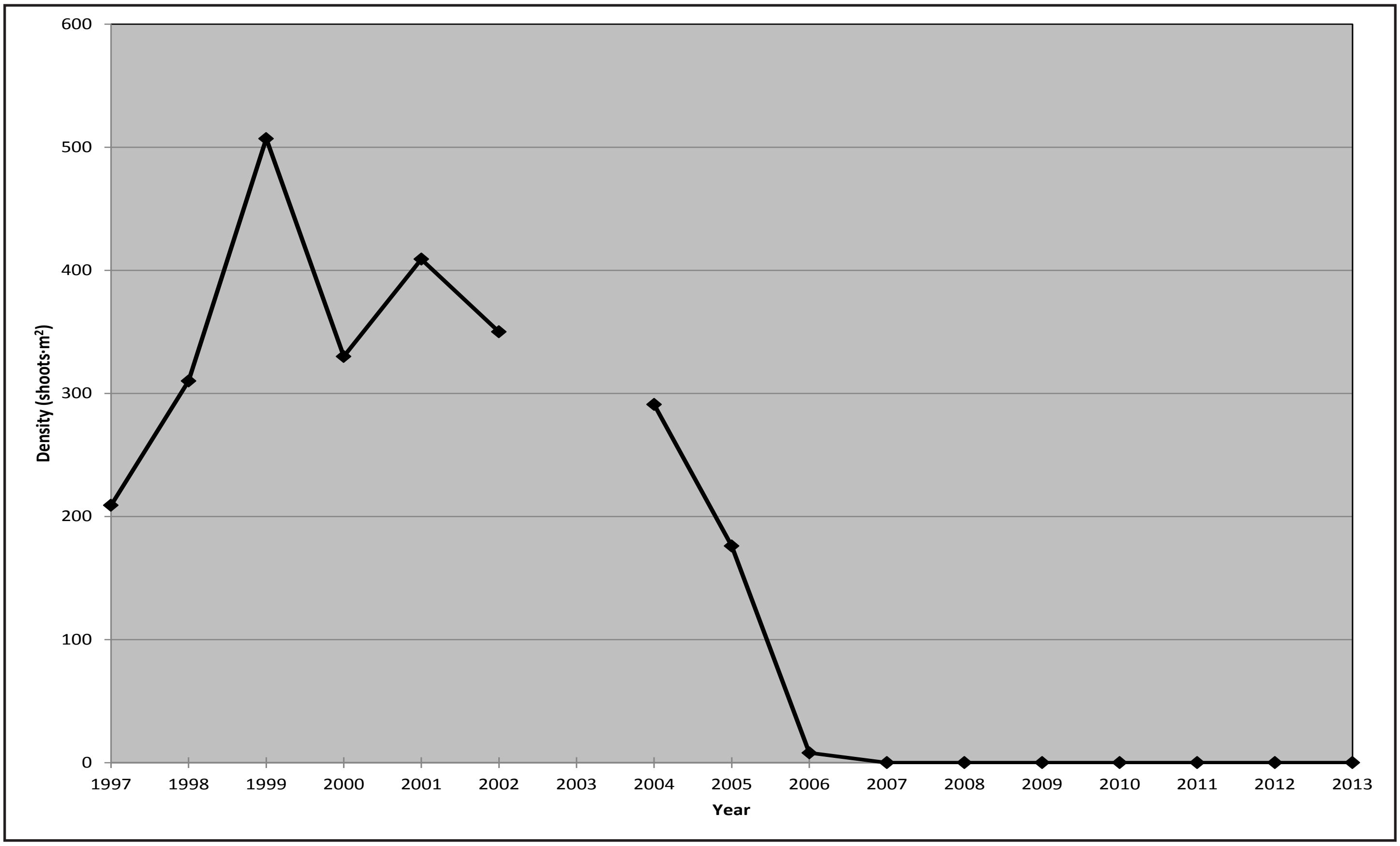


Figure NWH-3. Average annual eelgrass shoot density for Northwest Harbor, East Hampton.

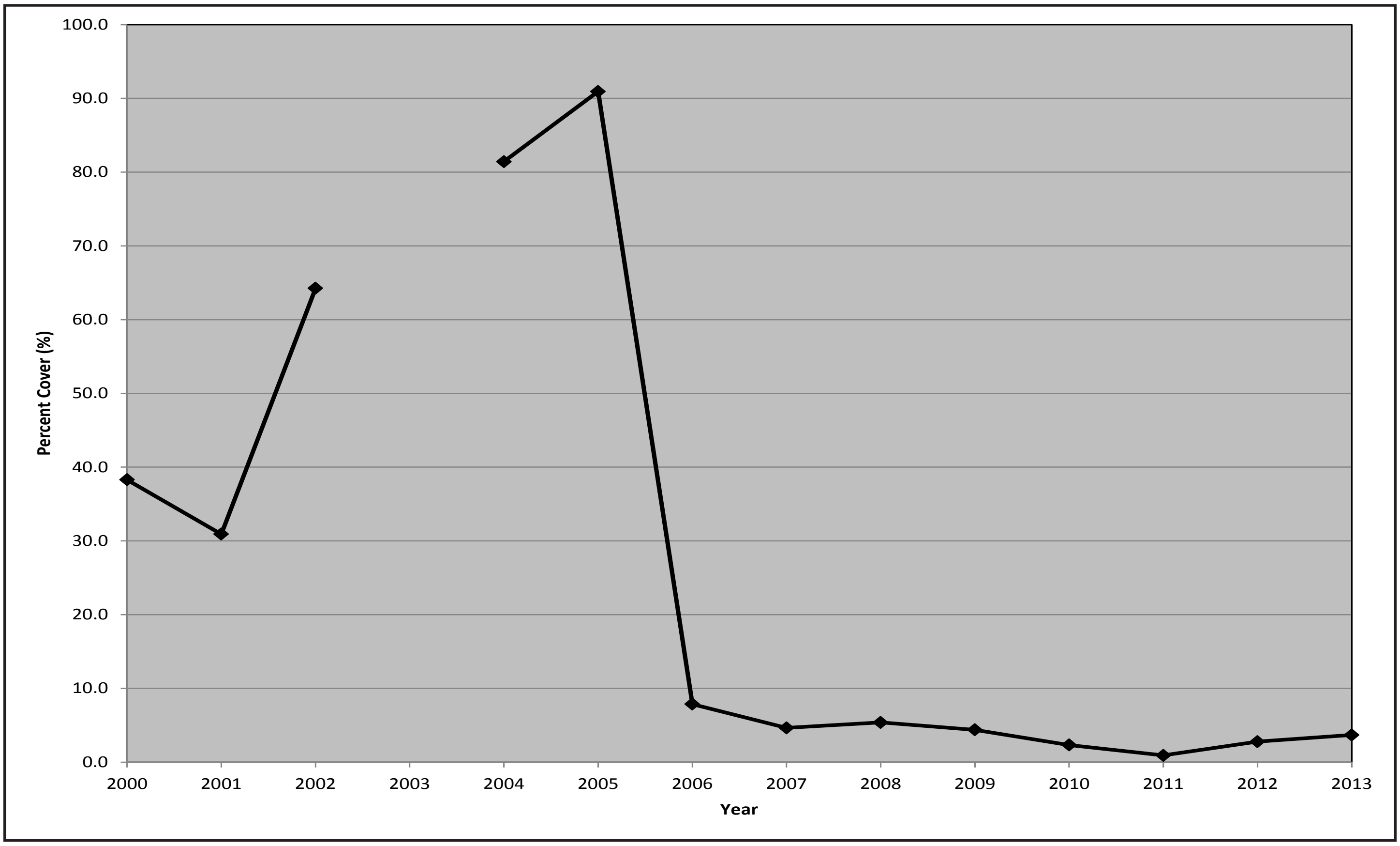


Figure NWH-4. Annual mean macroalgae cover for Northwest Harbor, East Hampton from 2000 to 2013.

Orient Harbor** was one of the largest remaining eelgrass meadows when it was chosen for inclusion in the PEP LTEMP in 1997. The meadow, at the time, stretched from the Orient Yacht Club pier to the mouth of Hallock Bay. The meadow covered from 3ft to 10ft depth (MLW) (observations based on 2000 monitoring season) where it abruptly ended. While patchy in some areas of the meadow, the majority of the meadow was continuous eelgrass. The meadow,

Figure OH-1. An aerial view of the Orient Harbor eelgrass meadow with monitoring stations indicated by the superimposed numbers.

once situated on the eastern shore of Orient Harbor (Figure OH-1), was protected from most of the prevailing winter winds, but northwest, west, and southwest winds have a large fetch across Orient Harbor and moderate wave events are not uncommon. Currents over the site are relatively low.

Site Characteristics

The Orient Harbor eelgrass meadow, while sheltered from most of the prevailing winter winds, does experience moderate wave action from winds out of any of the western directions that blow for a significant duration. The sediment in Orient Harbor is predominantly sand (average of 62.9%), but it also contains a significant gravel fraction of 30.8%. The average organic content is higher than Gardiners Bay and Northwest Harbor, but it is still at a level that is within eelgrass's tolerance at 1.18%. Typically, the coarser sediments are found closer to shore in the shallower waters with the sand and organic content increasing in the offshore portions of the meadow.

Water quality has generally been favorable for eelgrass in Orient Harbor. Since 1997, there has been an increase in the development along Orient Harbor including new homes and hardened shorelines. While there has been no indication in past analysis of water quality data for this site that this development has had any direct impacts, the building of several large new homes with septic systems in close proximity to the harbor represents a potential impact to the eelgrass meadow. A problem identified at the Seagrass Experts Meeting

Orient Harbor 2013

Table OH-1. The average annual eelgrass shoot density for Orient Harbor from 1997 to 2012, including standard error.

Year	Mean Density	S.E.
1997	573	+/- 68
1998	696	+/- 82
1999	587	+/- 50
2000	488	+/- 26
2001	452	+/- 16
2002	230	+/- 13
2004	56	+/- 15
2005	36	+/- 12
2006	27	+/- 12
2007	47	+/- 22
2008	0	+/- 0
2009	0	+/- 0
2010	0	+/- 0
2011	0	+/- 0
2012	0	+/- 0
2013	0	+/- 0

in 2007 identified that groundwater inputs of nutrients (i.e. nitrogen) and herbicides could have direct impact on eelgrass in some areas of the Estuary. A preliminary study by Suffolk County in 2000-2001 indicated that Orient Harbor had some significant areas of groundwater upwelling. Given the amount of farming that has historically occurred in Orient, it is possible that upwelling water in Orient Harbor may contain contaminants harmful to eelgrass. There are future plans to pursue this issue throughout the Peconic Estuary, with Orient Harbor as a potential site for analysis.

Eelgrass Shoot Density

The eelgrass survey for Orient Harbor was conducted on 3 December 2013. As with the previous several years of monitoring, no eelgrass was recorded at any of the monitoring stations (Table OH-1; Figure OH-2). At the time the survey was conducted, water clarity was extremely high allowing for the bottom to be clearly viewed from the boat. During transit between monitoring stations, no evidence of extant eelgrass was observed.

Macroalgae Cover

The macroalgae community showed a significant decline from the previous year with a percent cover of just over 5% (Figure OH-3). Since the loss of eelgrass from the site, the macroalgae community has declined in percent cover and species (Figure OH-3). The 2013 survey recorded 6 species of macroalgae with the dominant species being Spyridia filamentosa and Ectocarpus siliculosus. Concentrated scallop dredging over the monitoring area may have dislodged any larger macroalgae.

Conclusions

No eelgrass has been reported for the Orient Harbor monitoring area since 2007. Field surveys have failed to locate extant eelgrass in the area, however, the large area over which eelgrass used to cover in Orient Harbor is difficult to cover with this method and the scheduled 2014 aerial survey would be better able to detect any remaining eelgrass within Orient Harbor.

The site holds some potential for restoration efforts, however, further evaluation of light and temperature to determine whether conditions are suitable for eelgrass growth is required.

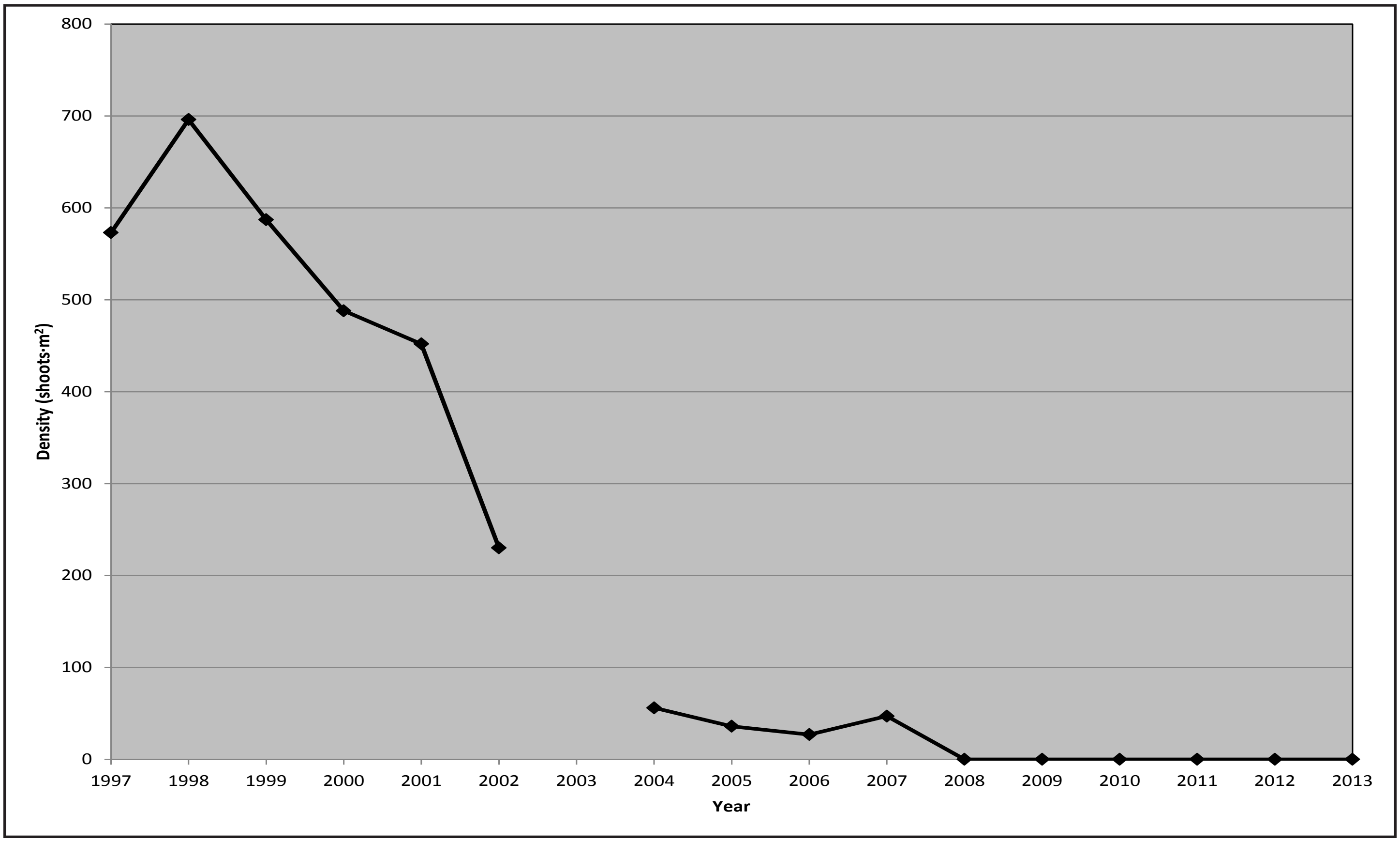


Figure OH-3. Average annual eelgrass shoot density for Orient Harbor, Southold.

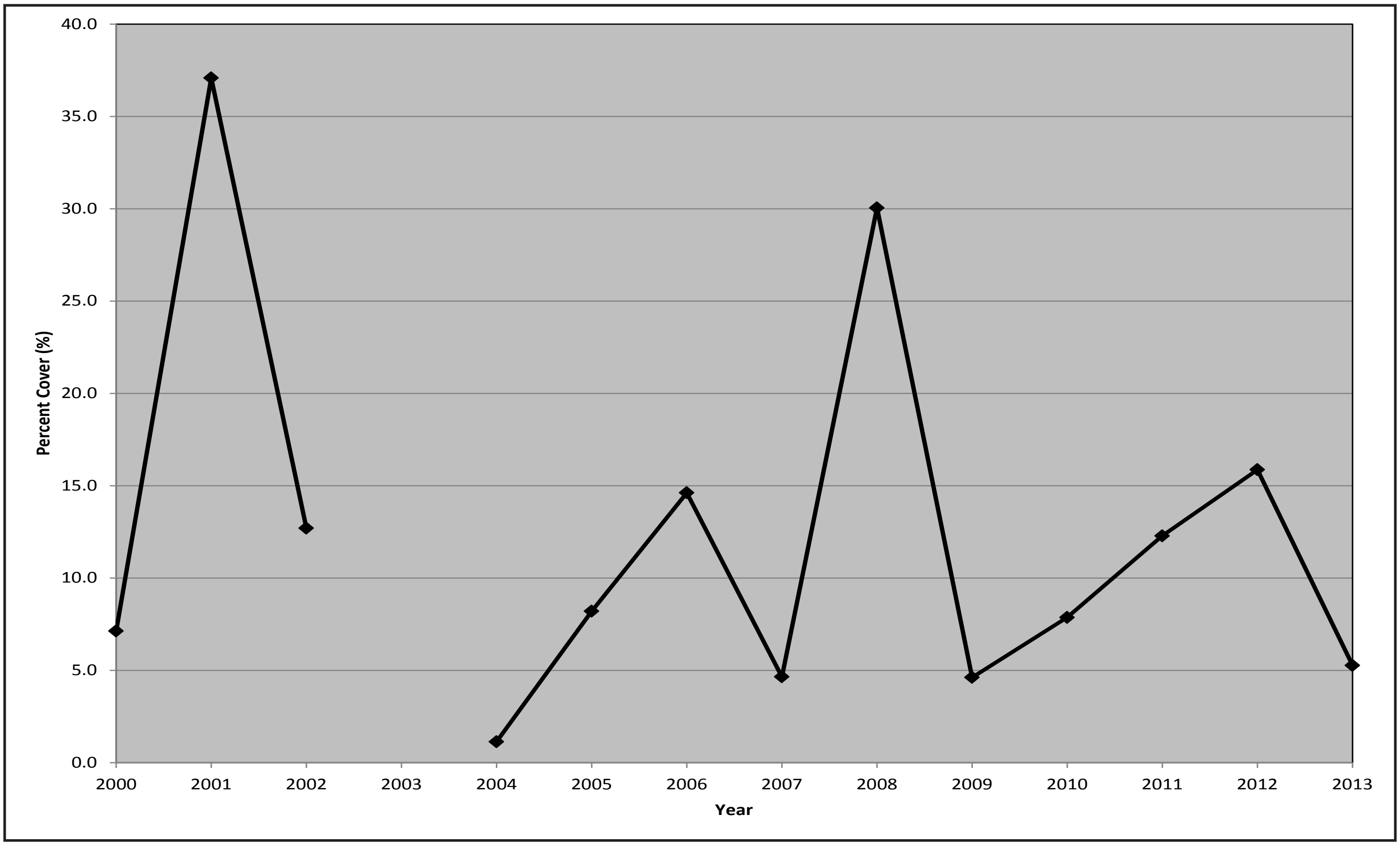


Figure OH-4. Annual mean macroalgae cover for Orient Harbor, Southold from 2000 to 2013.

Southold Bay was the western-most eelgrass meadow on the north shore of the Peconic Estuary when it was added to the monitoring program in 1999. The meadow was situated at the mouth of Mill Creek, Southold, which connects Hashamomack Pond to Southold Bay (Figure SB-1). This meadow was located in a high boat traffic area and has three boating channels that divide it. The site is relatively shallow, especially on the eastern side of the meadow, except for the boat channels.

Figure SB-1. An aerial view of the Southold Bay monitoring site with monitoring stations indicated by the superimposed numbers.

Site Characteristics

The former Southold Bay eelgrass bed was sheltered from most prevailing winds, so wave exposure was generally low to moderate. However, some storm events in the past, when positioned correctly, have exposed this meadow to high wave action that lead to substantial erosion of the barrier beach and mass movement of sediment within the meadow. The sediment composition of this site is predominantly sand (~80%) with a minimal amount of organic content included in the mix (0.81%). On the eastern side near the channel to Goldsmith's Boat yard and Mill Creek Marina, are boulders, submerged and emergent, that are dense close to shore but decrease in frequency moving offshore. Across the main channel to Mill Creek toward the area of Budds Pond, the sediment becomes less firm, indicating an increase in the finer silt/clay fraction and organic content.

The monitoring site is also significantly influenced by its proximity to Hashamomack Pond, which empties into Southold Bay via Mill Creek. The warm water flushing into the meadow from Hashamomack Pond may influence the temperature experienced by this site. Water temperatures within the Southold Bay meadow are thought to have contributed to the chronic stress that the eelgrass population faced, before its extinction at the site, during the summer months. The shallow nature of the bed also allowed for rapid warming, especially on calm, summer days and leading to stress in the shallowest areas.

Southold Bay 2013

The waters that the Southold Bay meadow receive from the flushing of Hashamomack Pond not only influence temperature, as noted above, but also exposed the site to nutrient-laden water that has been found to negatively impact eelgrass meadows by indirectly reducing eelgrass growth due to a decrease in light availability due to increased phytoplankton and macroalgae biomass at the site.

Table SB-2. The average annual eelgrass shoot density for Southold Bay from 1997 to 2012, including standard error.

Year	Mean Density	S.E.
1999	805	+/- 69
2000	471	+/- 31
2001	467	+/- 32
2002	384	+/- 16
2004	210	+/- 23
2005	30	+/- 8
2006	0	+/- 0
2007	0	+/- 0
2008	0	+/- 0
2009	0	+/- 0
2010	0	+/- 0
2011	0	+/- 0
2012	0	+/- 0
2013	0	+/- 0

Eelgrass Shoot Density

Southold Bay was visited on 3 December 2013. The monitoring of the site found no new sign of eelgrass growth in or near the monitoring stations, as has been the case since 2006 (Table SB-2; Figure SB-2).

Macroalgae Cover

Macroalgae percent cover at Southold Bay experienced a minor, yet significant increase from 2012 (Figure SB-3). Macroalgae cover averaged 5.5% for the meadow with *Ectocarpus siliculosus* accounting for the majority of the macroalgae recorded from the quadrats. The invasive green macroalga, *Codium fragile*, was observed in station 1 where boulders provided hard substrate for attachment. In total, 9 species of macroalgae were identified at the site, with a majority of the species occurring as drift.

Conclusions

The 2013 season was the eight season that no eelgrass was recorded for the Southold Bay site. The site was another site that was in decline from its indiction into the LTEMP in 1999. Water quality has been indicated as the primary factor in the decline of the meadow, as water clarity has been very poor and water temperatures high for most summers. At this time, the Southold Bay site would not be considered suitable for eelgrass restoration at this time. High summer water temperatures alone would make survival of transplanted eelgrass very difficult.

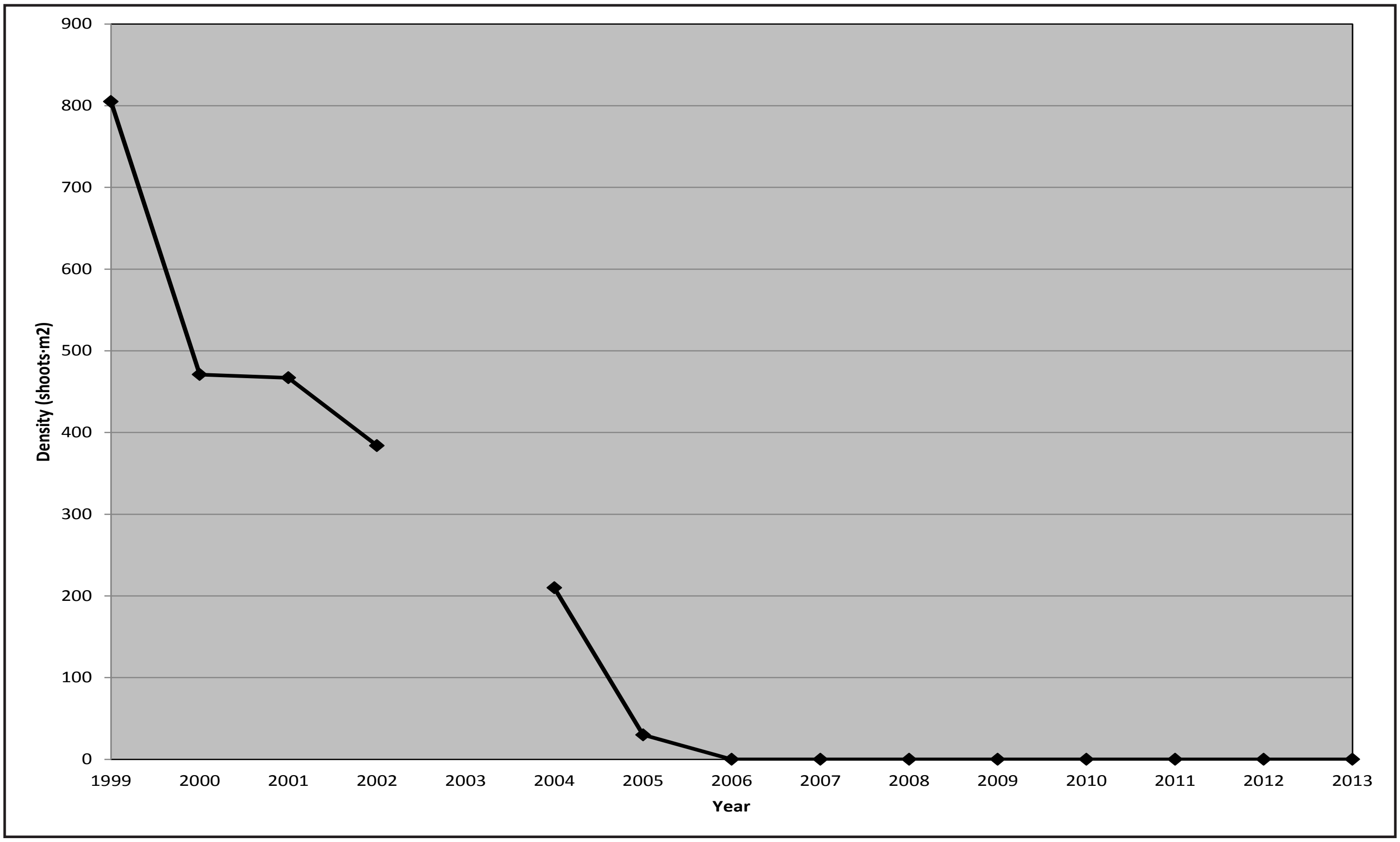


Figure SB-3. Average annual eelgrass shoot density for Southold Bay, Southold.

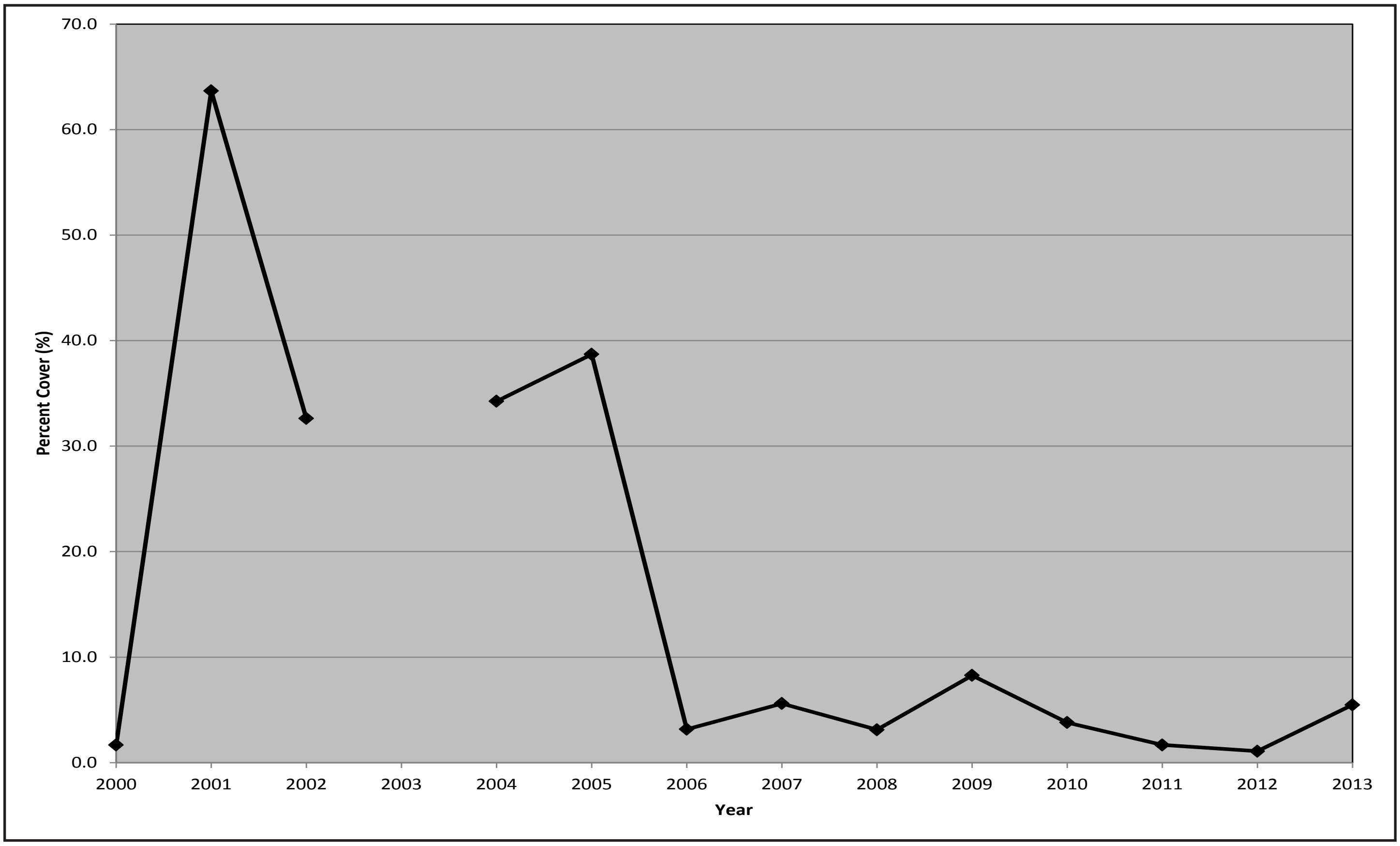


Figure SB-4. Annual mean macroalgae cover for Southold Bay from 2000 to 2013.

Three Mile Harbor is the eastern-most meadow in the eelgrass monitoring program. Situated inside a large, protected harbor, eelgrass once thrived throughout this system. The monitoring site for the PEP is located on the western side of the Harbor near the mouth of Hands Creek (Figure TMH-1). The area includes an East Hampton Town mooring field as well as a designated water ski area that has been extended over the years to include the water over Stations 1 and 2 (Figure TMH-1).

Figure TMH-1. An aerial view of the Three Mile Harbor monitoring site with monitoring stations indicated by the superimposed numbers.

Site Characteristics

The monitoring site in Three Mile Harbor has minimal fetch in all directions and is considered a low wave exposed site. The sediments over much of the monitoring area would support this sheltered classification as they tend to be higher in silt/clay and organic material than the some of the other more energetic sites. The sediments within the eelgrass meadow were composed of 86% sand and 13% silt/clay. The organic content averaged to 1.78% (with a maximum of 2.3%). Generally, the inshore stations have the lower silt/clay and organic content and the outer stations, especially Station 2, have the finer sediments with higher organic content.

Water temperature at this site has never been directly monitored by deployed instruments, however anecdotal evidence suggests that this meadow rarely experienced temperatures higher than 25°C. Temperature has never been considered a significant stressor for this eelgrass meadow.

Water quality, specifically nutrient loading, in Three Mile Harbor has generally been good. Pump-out facilities at the marinas and an East Hampton Town pump-out boat have assisted in the maintenance of good water quality by providing the boating population in the harbor with convenient and environmentally responsible methods of disposing their wastes. While nutrient loading may not have been a significant stress to the eelgrass meadow in Three Mile Harbor, water clarity may have been a contributing factor to the loss of eel-

Three Mile Harbor 2013

Table TMH-1. The average annual eelgrass shoot density for Three Mile Harbor from 1997 to 2011, including standard error.

Year	Mean Density	S.E.
1999	361	+/- 49
2000	193	+/- 17
2001	209	+/- 13
2002	135	+/- 10
2004	29	+/- 6
2005	8	+/- 3
2006	0	+/- 0
2007	0	+/- 0
2008	0	+/- 0
2009	0	+/- 0
2010	0	+/- 0
2011	0	+/- 0
2012	0	+/- 0
2013	0	+/- 0

grass at this site. The proximity of the water ski area, which had been expanded to include the eastern portion of the former meadow (Stations 1 and 2; Figure TMH-1), along with the boats moored in the meadow area, would have had an influence on water clarity, and subsequently, light availability. Mooring chains sit on the bottom, but as the buoy or boat moves in response to the wind, the chain scribes an arc through the eelgrass, eventually removing a complete circular area around the mooring anchor. Given enough moorings placed in an eelgrass meadow, the damage can result in a significant increase in the patchiness of a meadow. Ski boats running this area at low tide readily fluidize and suspend the finer sediments which, in turn, reduce the light penetration at the site. As it may take hours for fine particles to settle back out of the water column, it is possible that eelgrass at this site could suffer lower light availability for a considerable length of time after the initial point of disturbance.

Eelgrass Shoot Density

The Three Mile Harbor site was visited on 2 December 2013. The diver survey found no eelgrass within the monitoring site, as has been the case since 2006 (Table TMH-1; Figure TMH-2). The last known eelgrass meadow in the Three Mile Harbor complex was in Hands Creek, adjacent to the Three Mile Harbor, but a Spring 2013 survey of the creek found not eelgrass.

Macroalgae Cover

The macroalgae percent cover was found to be the lowest recorded for the site (Figure TMH-3). Macroalgae biomass at the site is typically concentrated on the inshore monitoring stations (4-6) where the sediment is coarse and provides a suitable substrate, but the 2013 season found minimal biomass at these sites. Five species of macroalgae were reported with *Spyridia filamentosa* representing the dominant species.

Conclusions

No eelgrass has inhabited the monitoring area of Three Mile Harbor since 2006 and the last known eelgrass meadow, Hands Creek, was reported in 2013 to no longer support eelgrass. The decline of the meadow was, in part, aggravated by human activities at the site (e.g. boat moorings and water skiing), but water quality issues were likely the main factor. Water clarity and temperature appear to still be an issue, with current conditions unable to support restoration activities at the site.

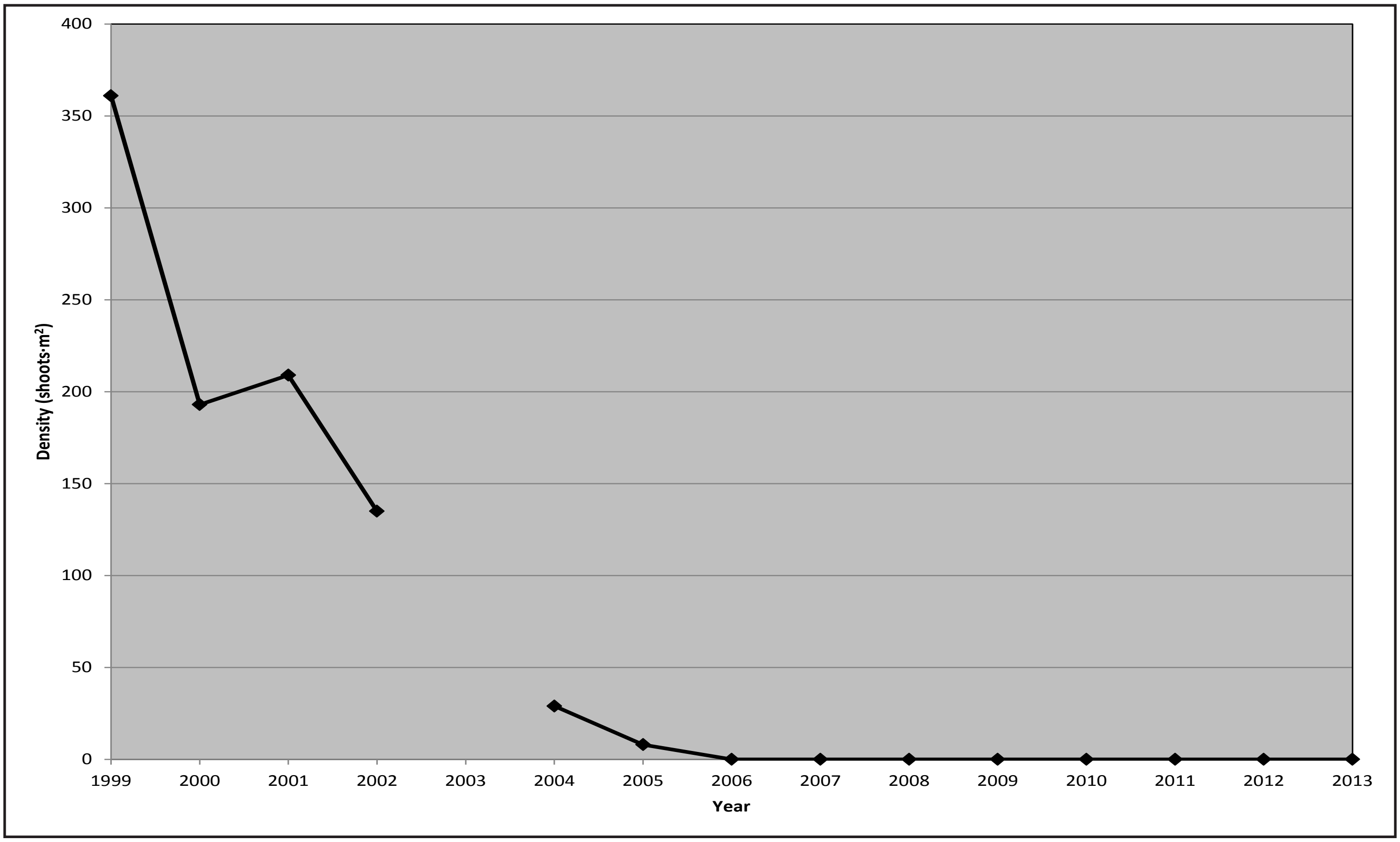


Figure TMH-2. Average annual eelgrass shoot density for Three Mile Harbor, East Hampton.

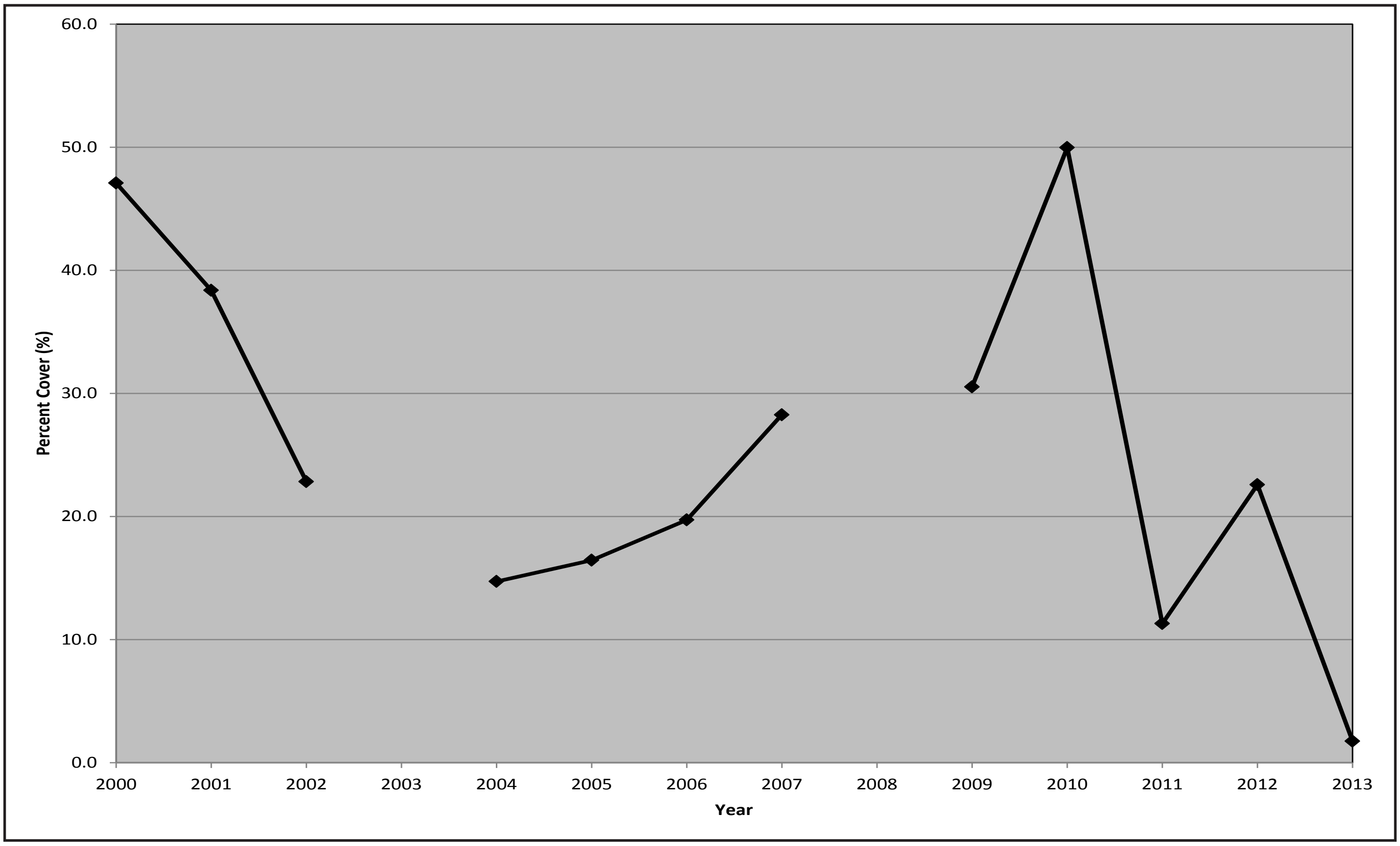
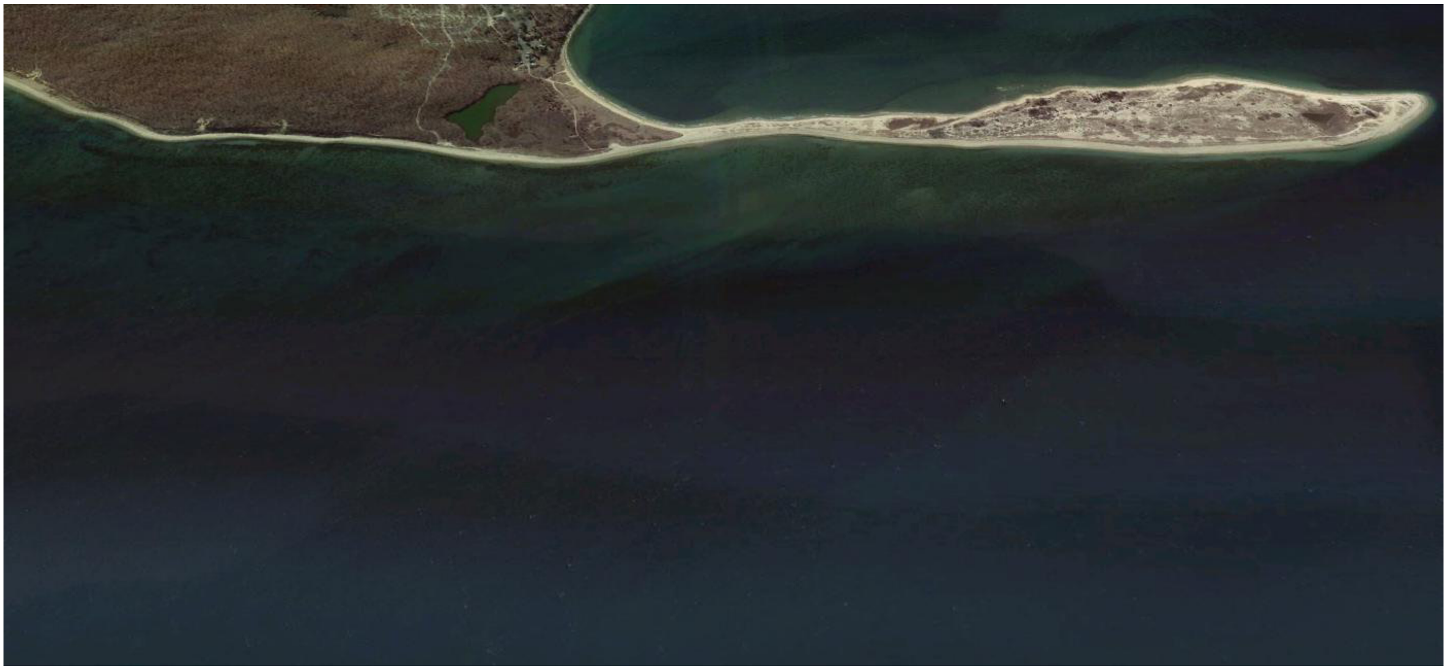


Figure TMH-3. Annual mean macroalgae cover for Three Mile Harbor from 2000 to 2013.



Cedar Point is a narrow peninsula that separates Gardiners Bay from Northwest Harbor in East Hampton Town. The north shore of Cedar Point (Gardiners Bay side) supports a large, but patchy, eelgrass meadow. The site is highly exposed to winds out of the north and there is a moderate current. The Cedar Point site was added to the PEP LTEMP in 2008. It has supplied the program an extant eelgrass meadow, providing data on eelgrass health, which can no longer be collected from the several meadows that have lost their eelgrass. An overview of the site and the monitoring stations can be found in Figure CP-1, below.

Site Characteristics

Figure CP-1. An aerial view of the Cedar Point monitoring site with monitoring stations indicated by the superimposed numbers.

Cedar Point is open to all northern fetches across Gardiners Bay. High wave exposure during winter storms would be common and the sediments and eelgrass patch dynamics support this fact. Although the sediment analysis for this site have not been completed at the time of this draft, they will be included in the 2013 LTEMP report. Observations made during the eelgrass monitoring survey and other activities suggested that the overall sediment texture will be coarse. The first impression one gets is of diving on a rocky shore along the eastern Long Island Sound. There are plentiful boulders, rock and gravel. Sand would likely be the dominant substrate, but gravel will likely be the secondary sediment in some sections of the meadow. Whatever the results, the large rocks and boulders that characteristic at Cedar Point will not be sampled, as they are too large for the sediment corers.

Water temperature and quality should be similar to Gardiners Bay. The water should be relatively low in nutrients (specifically nitrogen) and the summer high water temperatures are similar to Orient Point. Cedar Point was included in the Peconic Estuary Light and Water Temperature Survey conducted from May-October, 2011, and that data is presented below.

Light Availability and Water Temperature

The light/temperature logger station at Cedar Point was established in early May, 2013, but, with light logger deployments planned for each month, July-September, 2013. The light logger deployed in July

Cedar Point 2013

Table CP-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Cedar Point, E. Hampton, over 7-days for July and August, 2013. There is no light data for July, as the light logger was lost, possibly due to tampering.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	ND	ND	ND	ND	23.5
August	12.9	+0.6	10.2	+2.2	23.0

was not recovered after its 7-day deployment. Divers searched the area over two days and could not locate the logger. A new logger was deployed in August 2013, and the data found that the site met the minimum requirements for H_{comp} and exceeded the minimum for H_{sat} by 2.2 hours (Table CP-1). A planned September deployment was cancelled as mechanical issues left CCE with no boats available for field work from mid-September into October 2013.

The daily average temperatures for Cedar Point, East Hampton are presented in Figure CP-2. The temperature loggers recorded two days with daily average temperatures exceeding 25°C, 16 and 17 July. The highest temperatures recorded by the logger were on the same days and reached 27°C, which had not been reached at this site previously.

Eelgrass Shoot Density

The eelgrass survey for Cedar Point was conducted on 28 August 2013. Diver-counted quadrats at the six monitoring stations yielded an average eelgrass shoot density of 195 shoots•m^2 (Table CP-2; Figure CP-3). This was a significant decrease from the density recorded in 2013, 348 shoots•m^2 (Table CP-1;Figure CP-3). Early diver observations of the meadow in early April 2013 reported that the meadow appeared to have suffered significant damage over the winter 2013-2013, or possibly from Hurricane Sandy, with eelgrass in several section of the meadow showing indications of having been buried under several inches of sediment. During the August visit to the site, while shoot density numbers had significantly declined from 2012, the overall condition of the meadow at Cedar Point was much improved from the early Spring 2013 visit.

Macroalgae Cover

The macroalgae community at Cedar Point did not show the impact from storm damage that the eelgrass meadow experienced. Macroalgae percent cover was significantly higher in 2013, with percent cover reported as 36.7% which was the second highest algae cover at the site since it was included in the LTEMP (Figure CP-4). The dominate macroalgae at the site has been the perennial, brown alga, *Sargassum filipendula*. This species attaches to large substrate, cobble and boulders, and is adapted to surviving high wave energy and even burial of its holdfast, which would allow this species to recover and flourish after the storms impacting this site. In total, nine species of macroalgae were recorded for the site in 2013, including *Codium fragile*, *Champia parvula*, and several species of filamentous, red algae.

Bed Delineation and Areal Extent

The initial plans for bed delineation for the four monitoring sites with extant eelgrass was to use the information from the aerial survey of the Peconic Estuary scheduled for the Fall 2013. However, due to poor conditions for all of the fall flight windows, the aerial survey was postponed until Spring 2014. By chance, Google Earth posted imagery captured on 19 September 2013, and, while it is not up to CCAP protocols, allowed for delineation of the meadows in the LTEMP.

The 2013 imagery found that the Cedar Point meadow suffer significant loss in area from 2012 to 2013 (Table OP-3). While the 2013 aerial image was not of the

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 and 2011, including standard error.

Year	Mean Density	S.E.
2008	285	+/-28
2009	385	+/-34
2010	500	+/-34
2011	389	+/-19
2012	348	+/-31
2013	195	+/-26

best quality for delineating eelgrass due to sunglare and waves obscuring sections of the meadow, divers' observations in April 2013 found that many previously continuous sections of the meadow had become fragmented and discontinuous areas (i.e. patchy areas) had suffered loss of all but the largest of their patches. The 2013 delineations found the Cedar Point meadow shrank to 96.55 acres, a loss of almost 31 acres from the March 2012 delineation (Table OP-3).

Conclusions

The Cedar Point eelgrass meadow sustained significant loss between 2012 and 2013 with the likely causative factors being Superstorm Sandy and several intense winter storms. Evidence of the extent of Superstorm Sandy damage to the site was evident in April 2013 when the site was first visited in 2013. The sandy bluff that lines the shore of Cedar Point County Park lost several feet of material during the winter, which may have been washed offshore and into the eelgrass meadow. The movement of such a large amount of sediment could have caused the burial of near-shore eelgrass patches, which would have been reverting to their smaller, winter morphology. The offshore, deeper portion of the meadow could have been impacted by sediment movement caused by the large waves from storms interacting with the bottom in deeper water resulting in movement of sediment into the eelgrass and subsequent burial of some of the shoots or erosion along the exposed edges.

The macroalgae community fared better than the eelgrass meadow in 2013. The emphemeral nature of most species of macroalgae make their recovery to a disturbed area much faster than a rooted, vascular plant. By August, when the monitoring was conducted, the macroalgae would have regrown on all available hard substrate. The dominant macroalga, *Sargassum*, is adapted to living in high energy habitats. This species reduces its size in winter, consequently reducing the drag forces that are exerted on the plants and reducing the chances that they are detached from the substrate. *Sargassum*, like many rockweeds, can also regenerate from its attached holdfast its blade is lost. *Sargassum* also exhibits the ability to survive burial of its holdfast and stipe by translocation of metabolites from the unburied blade. These life history strategies have likely allowed the macroalgae at this site to recover and increase in cover as new substrate was made available by the storms.

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for 200, 2004, 2010, and 2012.

Year	Estimated Area
2000	35.20 acres (14.25 hect.)
2004	164.18 acres (66.44 hect.)
2007	224.46 acres (90.84 hect.)
2010	144.96 acres (58.66 hect.)
2012	127.27 acres (51.50 hect.)
2013	96.55 acres (39.07 hect.)

The 2013 aerial survey of the Peconic Estuary was supposed to be conducted during one of several flight windows during the Fall 2013; however, poor water clarity during the early flight windows and adverse weather conditions later in the fall, delayed the survey until the Spring 2014. Imagery available on Google Earth from September 2013 proved to be sufficient for delineating eelgrass at the site. However, said delineation should be considered a conservative estimate as conditions presented in the imagery was not always optimal. From the images, it is apparent that the meadow lost a significant amount of eelgrass from the cent section of the meadow, which could be attributed to the severe weather experienced from Fall 2012 through Winter 2013.

The condition of meadow was found to have declined in 2013 in terms of eelgrass shoot density and patchiness due to storm damage from the previous fall and winter. While shoot density in August was found to be lower than that of 2012, the August densities were higher than observed in April 2013 by CCE divers. Cedar Point has been used as a donor meadow for eelgrass restoration activities in the Peconic Estuary, but collection at the site was suspended indefinitely based on the state of the meadow as observed in April 2013. Considering the magnitude of the storms impacting the site, damage to the meadow could have been more severe and the August monitoring visit found that the eelgrass was already recovering from its condition observed in April. Water quality at Cedar Point is within the optimal range for light and water temperature to support the healthy growth and recovery of an eelgrass meadow, so it is expected that this site will likely continue to show signs of recovery into the 2014 season.

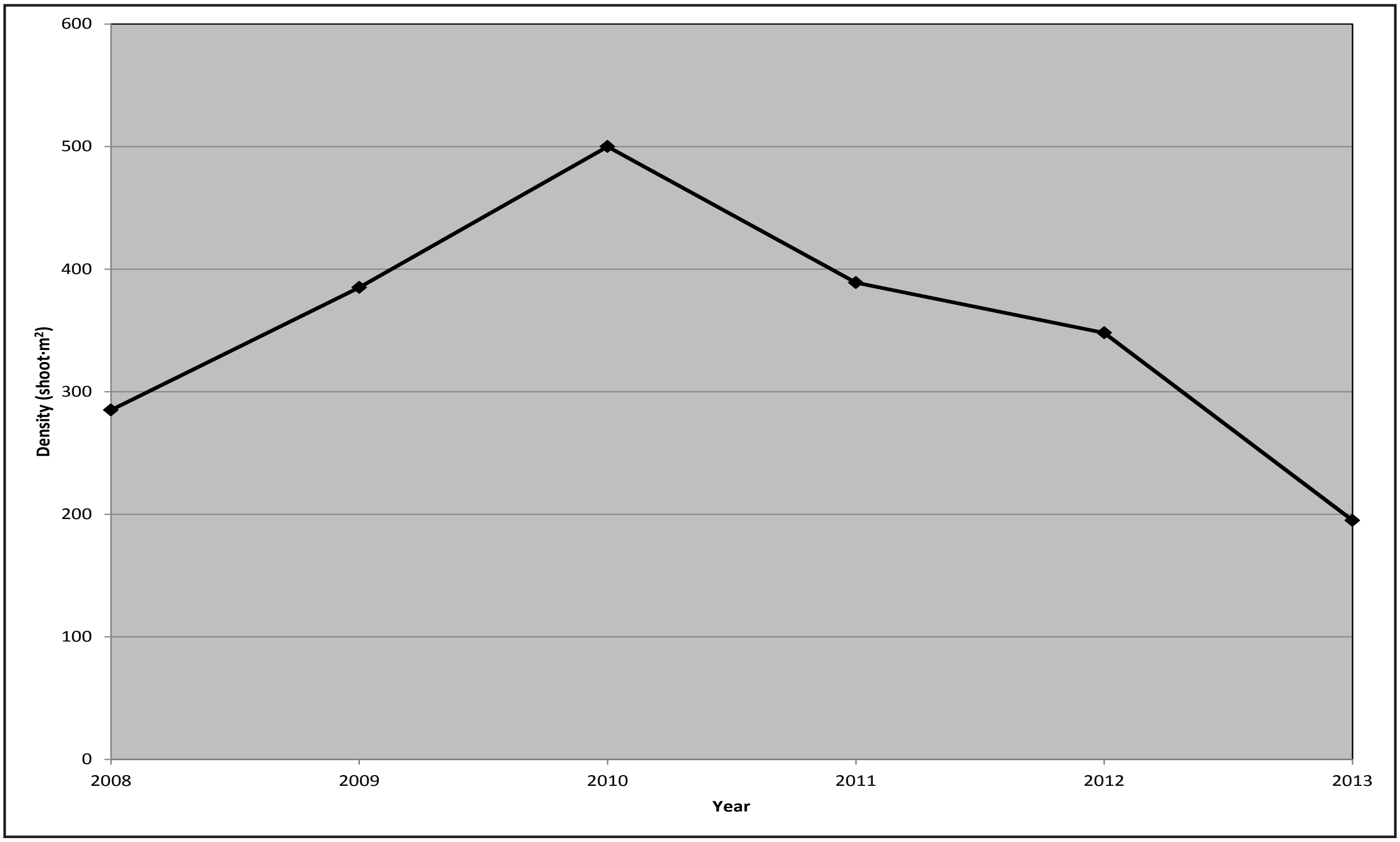


Figure CP-3. The average annual eelgrass shoot density for Cedar Point for 2008-2013.

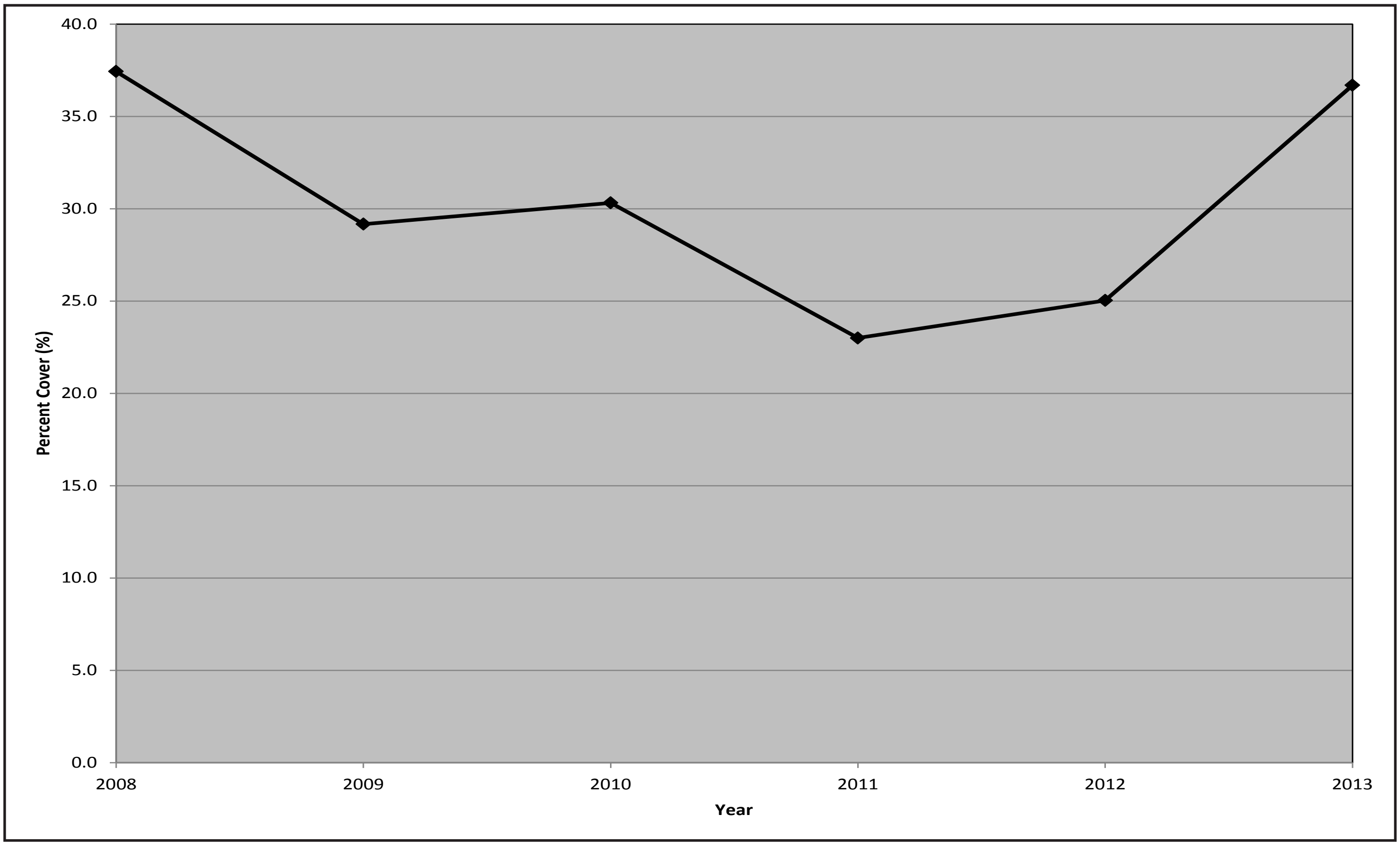


Figure CP-4. Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2013.

Figure CP-5. Delineations of the Cedar Point eelgrass meadow from aerial photographs for a) 2004, b) 2010, c) 2012, and d) 2013 (continued on next page).

Cedar Point 2013

Orient Point is the eastern tip of the north fork of Long Island. To the south of the point is Gardiners Bay and the eelgrass meadow that was added to the Peconic Estuary Program Long-term Eelgrass Monitoring Program for 2008. The meadow was a large, relatively dense meadow until October of 2006, when, after a week of strong winds out of the east, the meadow suffered extensive losses from the mid-bed to the deep edge. The nearshore area of the meadow saw minimal loss, but the result was that three-quarters of a large, healthy eelgrass meadow was devastated in a short period of time. Since that time, CCE has established a sentinel site at Orient Point to monitor the recovery of the meadow along three permanent transects (Fig. OP-4). It was also decided around this same time to add two new meadows to the PEP LTEMP to balance the loss of eelgrass at four of the six monitoring meadows and Orient Point was chosen for the opportunity to monitor a meadow in recovery.

Figure OP-1. An aerial view of the Orient Point monitoring site with monitoring stations indicated by the superimposed numbers.

Site Characteristics

The Orient Point meadow has large fetches in almost all directions; except for winds out of the west and northwest, the site will feel the influence of almost any wind at the site. Waves, such as those experienced during the storm event in October 2006, can be large and result in mass movement of sediments at this site. Orient Point is considered to be a high wave exposure and moderate current site. The meadow shows obvious indications that the wave and current forces influence the meadow. Erosional "blowouts" are common throughout the shallow portions of the meadow. Where these blowouts occur, the eelgrass meadow abruptly ends at a drop off of several inches to one foot. The edge of the meadow is often left hanging over the "blow-out."

The sediments at this site were analyzed initially in 1997, when the site was considered for the monitoring program. The 1997 analysis found that the sediment was predominantly sand (68.5%) with a significant

Orient Point 2013

Table OP-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Orient Point over 7-days for July and August, 2013. The temperatures presented are from Long Beach, Orient (approx. 3 miles west of Orient Point site) due to malfunction of TidBit deployed at Orient Point.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.1	+1.8	10.7	+2.7	22.4
August	12.6	+0.3	8.9	+0.9	22.2

amount of gravel (26.7%). Organic content of the sediment was found to be relatively low at an average of 0.86%.

Light Availability and Water Temperature

The light/temperature logger station was set up in early June, 2013 and light logger deployments were scheduled for the middle of each month from July through September. Mechanical issues with the CCE fleet prevented the deployment of a light logger in September. The light data collected for July and August 2013 is presented in Table OP-1 above. Conditions in the Orient Point meadow were good for both months as Hcomp and Hsat exceeded their minimum requirements for eelgrass. Divers reported unusually good water clarity at the site for this time of year on multiple visits.

The Onset Tidbit logger deployed to Orient Point malfunctioned and failed to collect water temperatures during its 2013 deployment. Water temperature data from a nearby site (approx. 3 miles west of Orient Point) was analyzed and presented in Table OP-1. This substitute site, Long Beach, Orient, supports a healthy eelgrass meadow and is similar to the Orient Point eelgrass meadow in most parameters. During the summer of 2013, the Long Beach site experienced no days with daily average temperatures reaching or exceeding 25°C. The highest daily average temperature recorded was 24.4°C on 10 July 2013. This is consistent with temperature data collected in previous years at Orient Point.

Eelgrass Shoot Density

The eelgrass survey of Orient Point, conducted on 27 August 2013, experienced a minor increase in shoot density from 2012 (Table OP-1; Figure OP-3). The average shoot density for 2013 was 201 shoots•m^2 (Table OP-1). With the exception of station 2, the higher shoot densities were found in the inshore monitoring stations. This patchiness was overshadowed by very high shoot densities at station 5, which average 472 shoots•m^2.

Macroalgae Cover

The Orient Point site experienced significant impact form Superstorm Sandy and several winter storms resulting in the movement of sediment throughout the site. In the offshore sections of the meadow, boulders and cobble that was once buried was exposed, providing new substrate on which macroalgae could settle. The 2013 survey found the average percent cover of macroalgae to have increased from 15% in 2012 to 23% in 2013 (Figure OP-3). Eleven species of macroalgae were identified with *Chondrus crispus* and *Sargassum filipendula* reported as the most prevalent species. Also noted was the increased presence of the invasive, red seaweed, *Grateloupia turuturu* throughout the site. This species has been known to displace other native species, like *Chondrus*, so it bear attention in future surveys.

Bed Delineation and Areal Extent

The initial plans for bed delineation for the four monitoring sites with extant eelgrass was to use the information from the aerial survey of the Peconic Estuary scheduled for the Fall 2013. However, due to poor conditions for all of the fall flight windows, the aerial survey was postponed until Spring 2014. By chance, Google Earth posted imagery captured on 19 Septem-

Table OP-1. The annual, average eelgrass shoot density for Orient Point, including standard error.

Year	Mean Density	S.E.
2008	47	+/-9
2009	171	+/-28
2010	298	+/-33
2011	279	+/-30
2012	175	+/-22
2013	201	+/-40

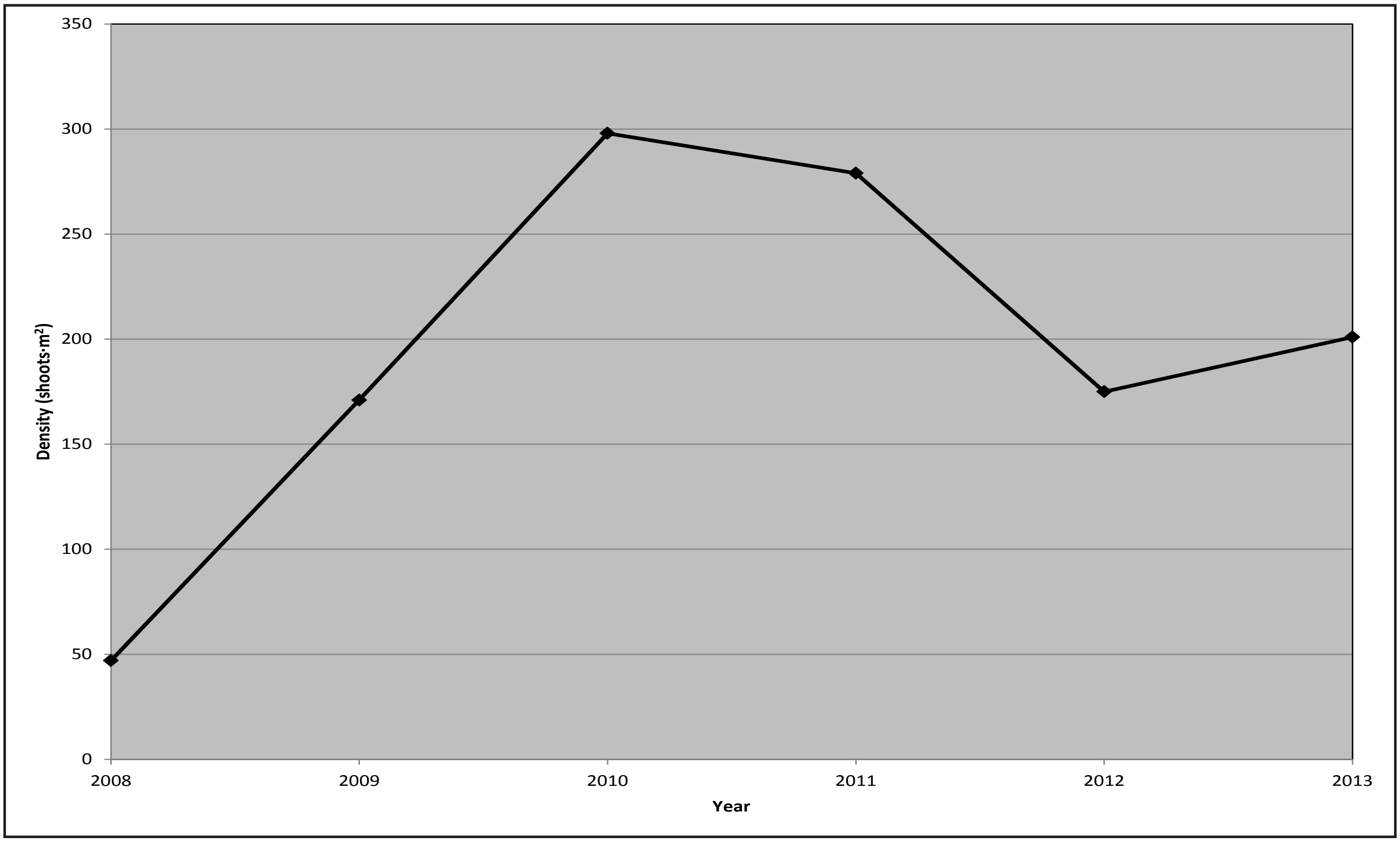


Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2013.

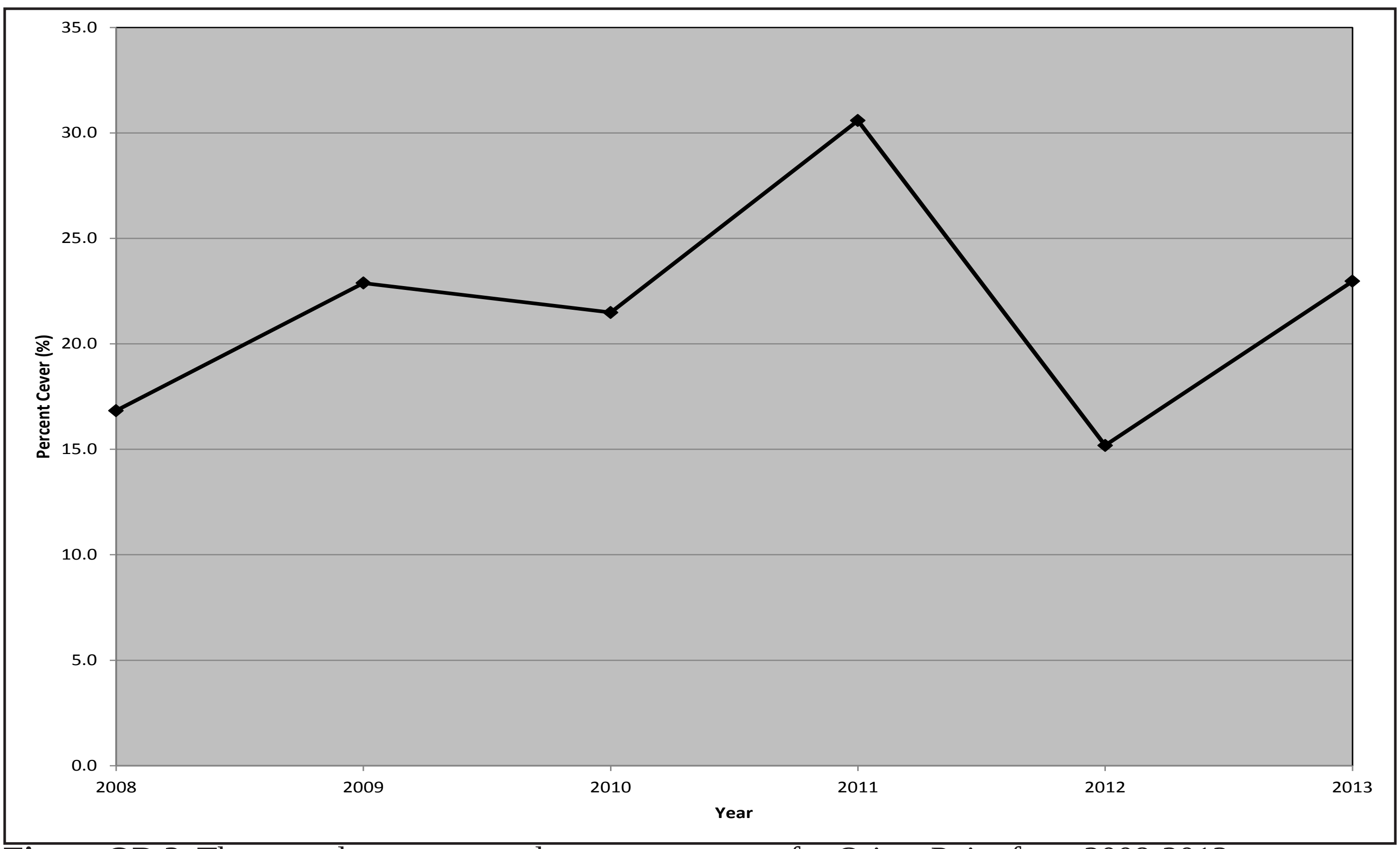


Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2013.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2012.

Year	Estimated Area
2000	*7.59 acres (3.07 hect.)
2004	62.24 acres (25.19 hect.)
2007	55.80 acres (22.58 hect.)
2010	31.39 acres (12.70 hect.)
2012	17.18 acres (6.95 hect.)
2013	16.40 acres (6.64 hect.)

ber 2013, and, while it is not up to CCAP protocols, allowed for delineation of the meadows in the LTEMP. The accuracy of these delineations will have to be compared to those scheduled to be flown in Spring of 2014, as conditions in the 2013 imagery made it difficult to determine deep edge or some of the non-vegetated patches in the meadow. The 2013 delineations did show a minor loss in area of the Orient Point meadow from 2012 (Table OP-3), however, it was less than expected given the severity of the storms impacting the site from Fall 2012 through Spring 2013. Diver observations suggest that the patchiness of the meadow has increased and that the offshore sections of the meadow seemed to have suffered the most damage/loss. The quality of the aerial imagery from September 2013 was not high enough to identify patchiness in the meadow, so the estimated areal extent determined will be found to be lower than the 16.4 acres reported when the Spring 2014 aerial survey is completed.

Conclusions

The Orient Point site experienced significant impacts from storms from Fall 2012 into the winter of 2013. Superstorm Sandy hit the site especially hard, resulting in a large section of Orient Point being washed over and severe erosion of the upland edge of the shore along the meadows entire length (Figure OP-4). The sediment moved by the waves may have buried eelgrass throughout the meadow and observations made during shoot collection in the Spring 2013 by CCE divers found that, in extant patches of eelgrass, shoots were buried deeper than normal suggesting that sediment had been caught and accreted in the eelgrass meadow. The storm-produced waves would have also caused significant erosion of the meadow. The edges of eelgrass patches are susceptible to erosion and extreme wave events, like Superstorm Sandy, could undermine and remove large sections of meadow in a relatively short time.

While the Orient Point meadow is greatly impacted by storms and wave exposure, it benefits in the summer from the lowest temperatures and some of the best water clarity in the estuary. Typically, the site does not experience any days over 25°C, reducing the stress on the plants and allowing them to continue vegetative spread through laterals throughout the summer, when some other estuary meadows have slowed or stopped growth due to temperature. As the meadow is typically not light limited, the plants can take advantage of optimal growth conditions throughout the summer. This prolific growth was evident in 2013 with several high shoot densities recorded, including one exceeding 1400 shoots•m^2. This high shoot density was due to the tremendous production of lateral shoots in meadow sections that appeared to have been "thinned out."

The Orient Point meadow has suffered setbacks in recent years, but considering where the meadow

Figure OP-4. Aerial images of Orient Point a) pre-Superstorm Sandy and b) September 2013. The shaded box in b) show the area that was washed through by the hurricane in October 2012. The arrows indicated areas where the upland was eroded, exposing a seawall.

started in 2008, when it was introduced to the LTEMP, it has made significant gains. The meadow seems to be experiencing a trend seen in other meadows in the estuary, an inshore migration and consolidation of the bed. Water quality at this site is possibly the most optimal for eelgrass growth of any of the meadows in the LTEMP and will support eelgrass recovery if the meadow. However, the exposed nature of this site to waves and storms, will continue to impede recovery, especially with storm frequencies and intensities predicted to increase with climate change.

Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2010, c) 2012 and d) 2013, showing inshore migration of the meadow and loss of eelgrass from the area near the tip of the point. The dashed line in a) indicates that the deep edge of the meadow was not distinct and may extend further offshore, but could not be definitively identified from the aerial photograph used.

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