Peconic Estuary Program 2014 Long-Term Eelgrass (*Zostera marina*) Monitoring Program

DRAFT Progress Report 15

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

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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

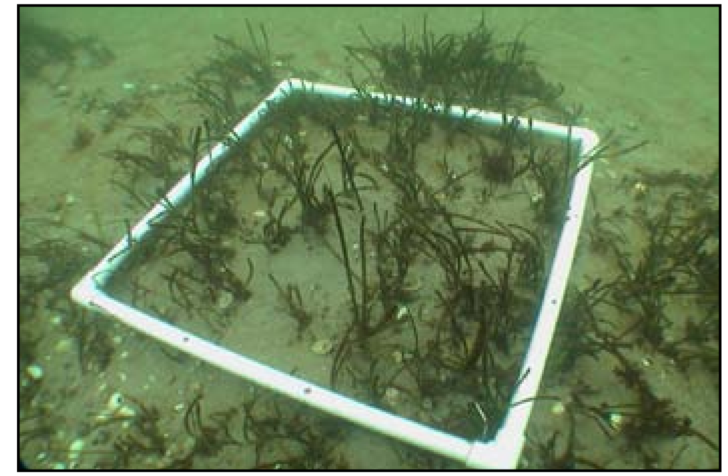

Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

(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

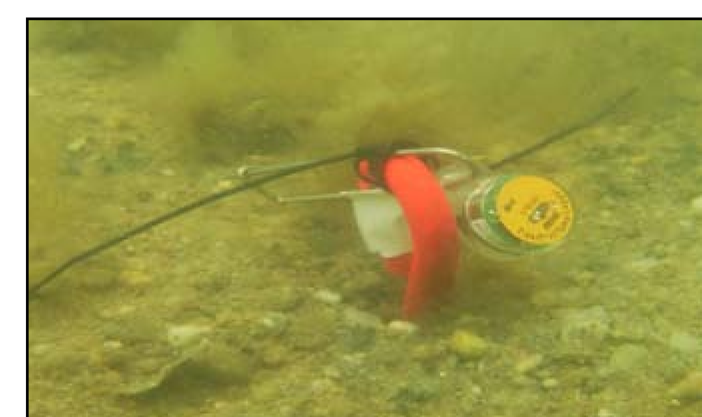

Figure Intro-2. A TidBit v2™ temperature logger attached to a screw anchor, deployed on-site.

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 2014 monitor was initiated on 19 August and completed on 25 November. Monitoring at the four unvegetated sites (Northwest Harbor, Orient Harbor, Southold Bay, and Three Mile Harbor) were suspended until November to give priority to completing the groundtruthing of the 2014 Peconic Estuary eelgrass aerial survey. 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

As no current, or even recent, aerial surveys have been conducted specifically for eelgrass in the Peconic Estuary, for this report, it was decided to look at the trends for the 4 extant eelgrass meadows remaining in the LTEMP: Bullhead Bay, Cedar Point, Gardiners Bay, and Orient Point. The trends analysis used the available 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

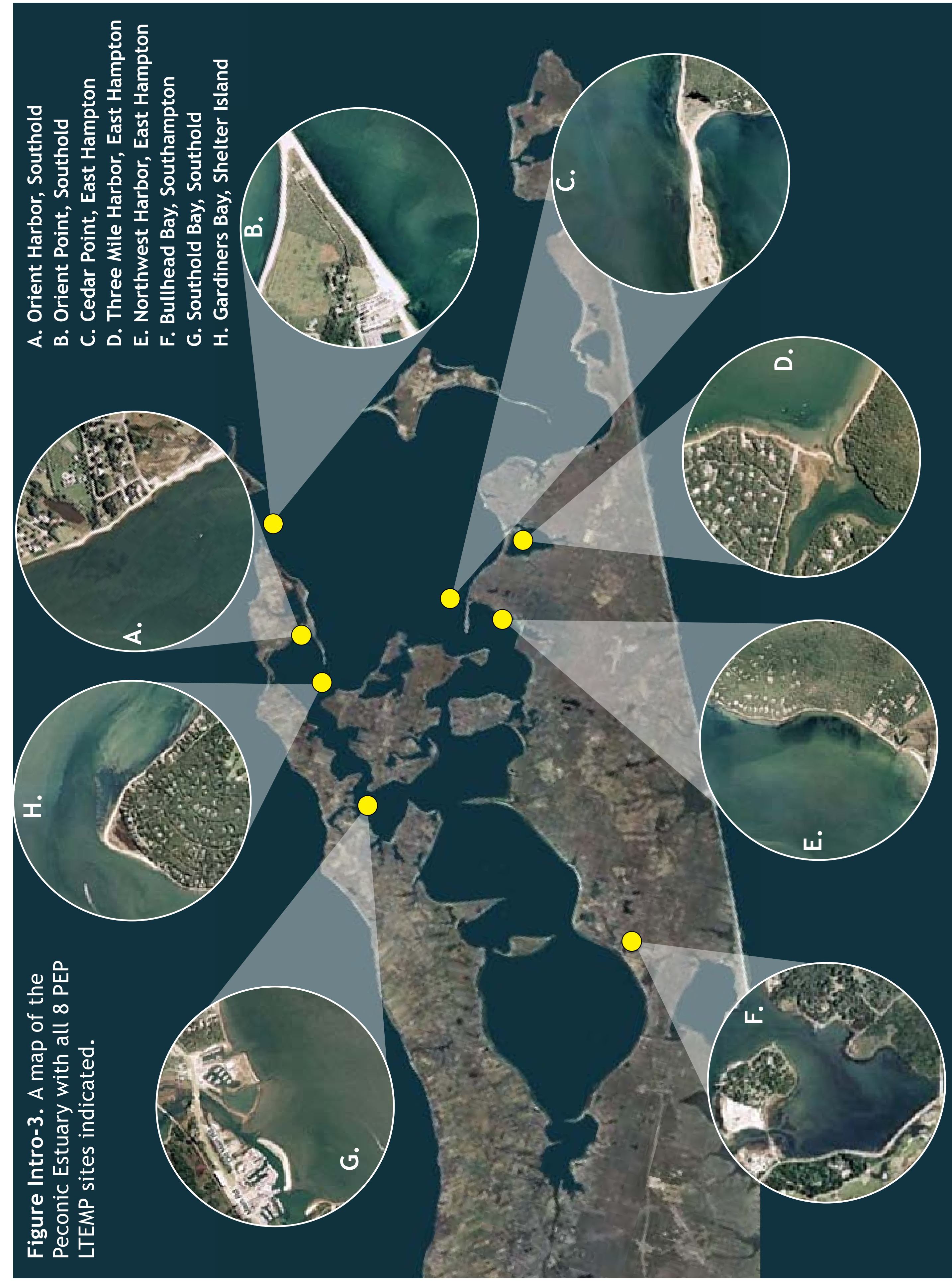

Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

meadow ended, or if 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

The 2012 monitoring effort saw the addition of underwater video of each station for the eight PEP LTEMP sites. Each 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 one to two minute video for each site. 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 Sebonac 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 Sebonac 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

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 for 2014.

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	5.8	-6.5	2.1	-5.9	25.6
August	12.6	0.3	10.5	2.5	25.1
September	11.2	-1.1	6.4	-1.6	22.4

are several significant potential sources of nitrogen 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.

The Bullhead Bay eelgrass survey was conducted on 20 August 2014. Condition on the day of monitoring in Bullhead Bay were good with excellent water clarity and no indications of the Cocchlodinium blooms that had been observed during monitoring over the last two years.

Light Availability and Temperature

Light loggers deployments were conducted monthly for seven days from July-September 2014. The average Hcomp and Hsat for each month is presented in Table BB-1 above. The July light data found Hcomp and Hsat levels to be well below the minimum requirements determined for the Peconic Estuary. Hcomp for July was 6.5 hours below the minimum requirement for eelgrass and the Hsat was 5.9 hours below eelgrass' minimum requirement (Table BB-1). August light data found light levels higher than July, with both Hcomp and Hsat exceeding minimum levels for eelgrass, with Hcomp of 12.6 hours and Hsat of 10.5 hours for the month. In September, light levels showed a decline from August with Hcomp 1.1 hours and Hsat 1.6 hours below requirement (Table BB-1).

The water temperature logger was deployed in late May. Water temperature data found 2014 to be a cooler year than the last two years for Bullhead Bay. While monthly average water temperature exceeded 25°C in July and August (Table BB-1), the eelgrass meadow only experienced 52 days of daily average water temperatures exceeding 25°C, with only 2 days of temperatures above 27°C, compared with 2013, when the meadow experienced 50 days above 25°C, with 21 of those days above 27°C.

Eelgrass Shoot Density

Eelgrass shoot density in Bullhead Bay showed no

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
2014	188	+/-12

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

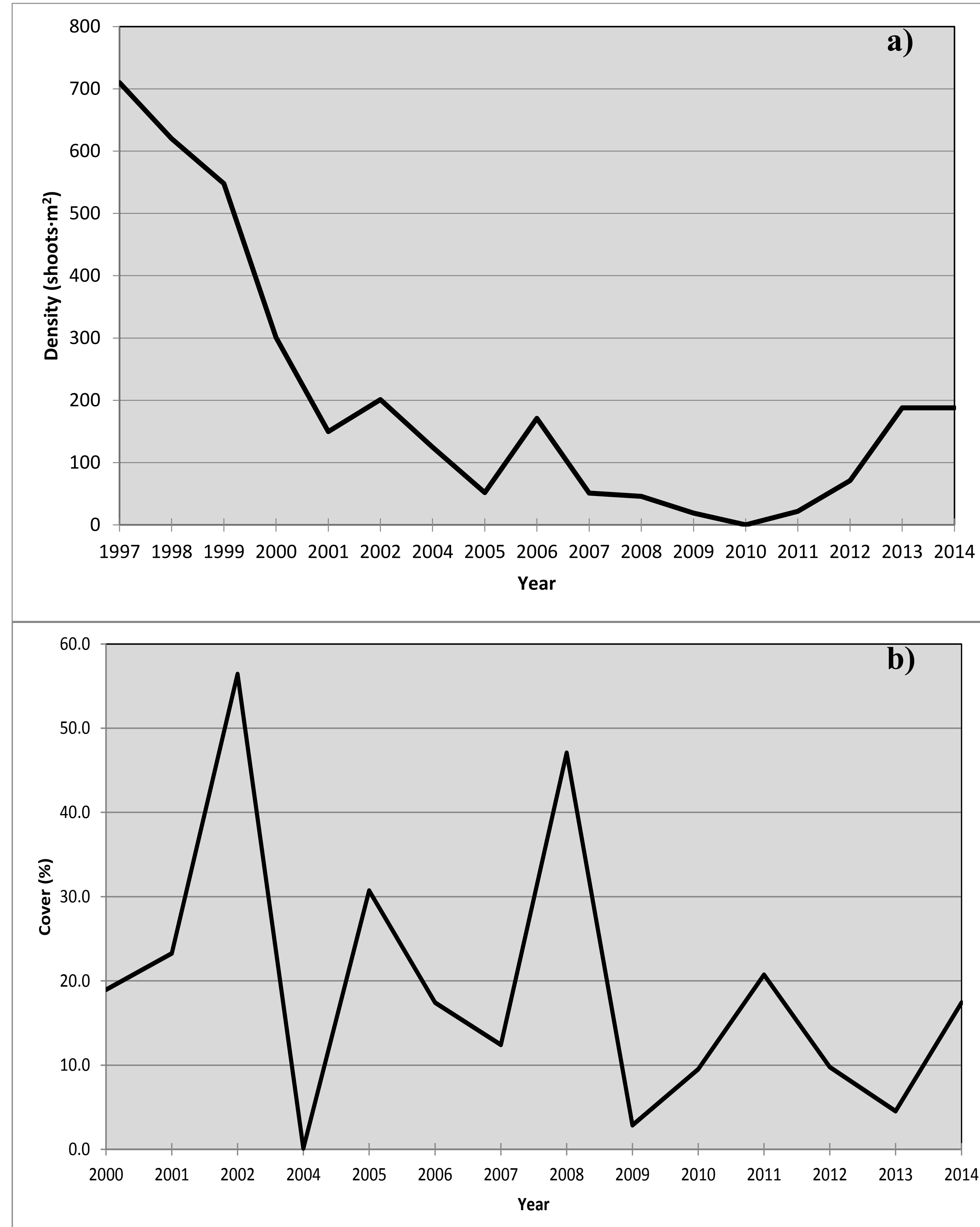

Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

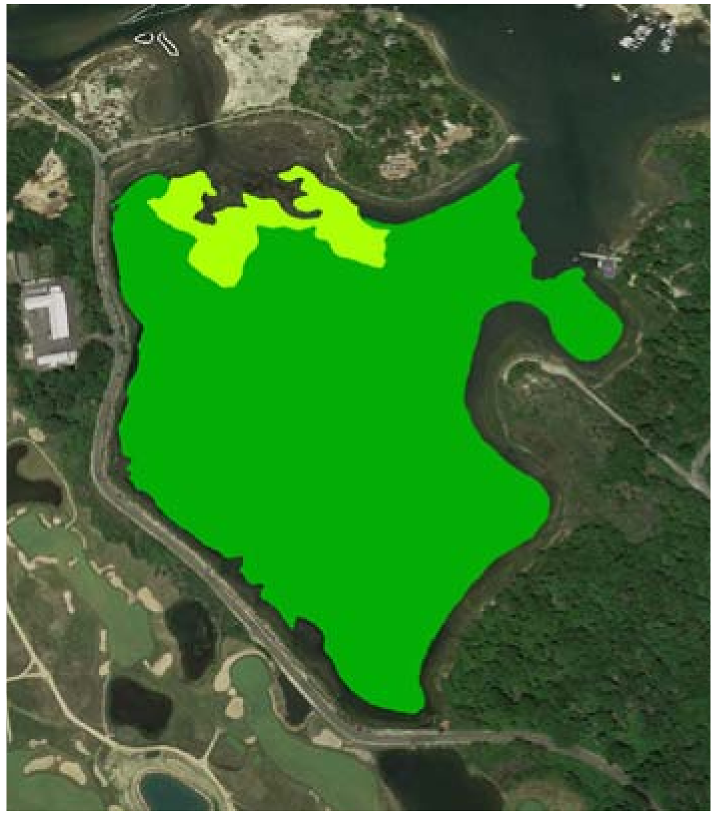

Figure BB-3. The 2014 delineation of the Bullhead Bay eelgrass meadow. The dark green area indicates higher density meadow, while the lower density meadow is identified by the light green.

change between 2013 and 2014 (Table BB-2; Figure BB-2a). While average shoot density did not change between years, the overall coverage of eelgrass increased, as the patchiness observed in 2013 decreased in 2014 decreased as eelgrass filled in considerably over the year. The expansion of eelgrass in 2014 could also be the cause of the decline of widgeongrass (R*uppia maritima*) in Bullhead Bay. In 2013, widgeongrass was reported to cover 17% of the monitored area, primarily in the open areas between eelgrass patches. In 2014, it had declined to only 3% cover, with isolated patches reported at Stations 1, 3 and 4; sites that have reported widgeongrass in past monitoring visits. Figure BB-4 shows the

Macroalgae Cover

Macroalgae percent cover in Bullhead Bay increased in 2014 (Figure BB-2b). Macroalgae cover in 2013 was 4.5% and increased in 2014 to 17.4%. Macroalgae species diversity has remained relatively low, with only a few species observed in 2013 and 2014. In 2014, *Spyridia filamentosa* remained the most abundant macroalgae, followed by *Gracilaria* and *Ulva* species. *Cladophora*, a filamentous, green alga, was observed in Bullhead Bay. This species is of note, as it has reached bloom levels in Great South Bay over the last few summers, overgrowing eelgrass meadows with thick mats of green filaments.

Bed Delineation and Areal Extent

The Peconic Estuary aerial survey of eelgrass was completed in 2014. While the initial aerial mapping did not identify the eelgrass meadow in Bullhead Bay, the groundtruthing effort and LTEMP monitoring mapped the extent of the meadow and determined relative percent cover of the entire meadow (Figure BB-3). The changes in the areal extent of the Bullhead Bay meadow is illustrated in Figure BB-4, starting with the 2000 delineations by Tiner (2003). Following the progress of aerial maps in Figure BB-4, one can follow the decline, then resurgence of the meadow over the last 14 years. The Bullhead Bay meadow has increased significantly since 2010, when the meadow was reduced to under 6 acres (Table BB-3). The 2014 meadow covers almost the entire embayment and has extended toward Sebonac Creek (Fig. BB-3), however, for purposes of comparison, the estimated acreage presented in Table BB-3 and the mapped area, only include the area of the Bay that was presented in the 2000 mapping (Fig. BB-4a). The 2014 extent of the meadow was found to be slightly more than the area delineated by Tiner in 2000 at almost 57 acres, and represents a ten-fold increase from just four years ago.

Conclusions

Bullhead Bay has continued its recovery from near extinction just four years ago. The 2014 season proved to

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2014.

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	30.50 acres (12.3 hect.)
2013	44.65 acres (18.07 hect.)
2014	56.92 acres (23.03 hect.)

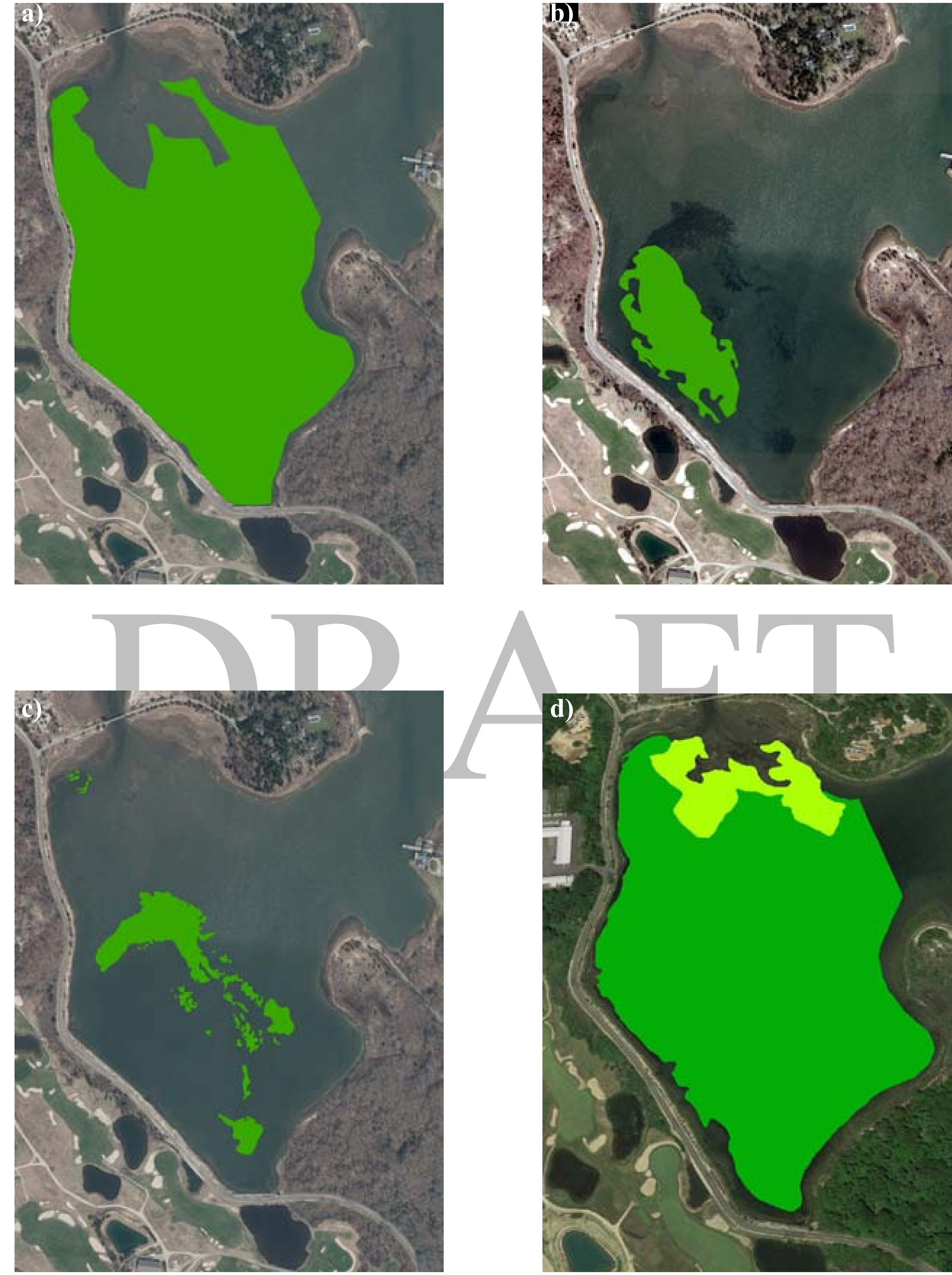

Figure BB-4. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2014. The years represented are a) 2000, b) 2004, c) 2010 and d) 2014.

Figure BB-5. Underwater photographs taken by CCE divers during the 2014 monitoring of the Bullhead Bay meadow. The photograph represents the general conditions within the Bay.

be a good year for eelgrass as the meadow continued to expand and eelgrass shoot density remained constant from 2013. Water quality appeared to be optimal, although Hcomp and Hsat were uncharacteristically low for Bullhead Bay in June. The low light levels in June were likely the result of the light logger being covered by algae or debris for part of the deployment. The August and September light data was relatively good, based on past surveys, indicating that light was likely not a limiting factor in Bullhead Bay in 2014. Water temperatures were moderate compared to the previous two seasons. In 2014, the meadow experienced two more days with water temperatures over 25°C than 2013, but only exceeded 27°C on two days versus 21 days in 2013. These relatively lower temperatures likely benefitted the growth and survival of both seedlings and adult shoots, supporting the continued spread of eelgrass in the Bullhead Bay system.

The monitoring data for 2014 did not indicate much change from 2013 based on eelgrass shoot density numbers, however, observations made during the monitoring reported significant changes between the two years. Overall, the meadow was found to be less patchy in 2014, with fewer, and smaller, open spaces between areas of eelgrass. The reduction of open bottom affected the cover of widgeongrass (*Ruppia maritima*) in the Bay, and its occurrence was reduced by more than eighty percent. The 2014 eelgrass mapping effort was able to accurate capture the expansion of the eelgrass meadow in Bullhead Bay (Fig. BB-3) and noted that the meadow has expanded outside of Bullhead Bay proper and is approaching Sebonac Creek. If the eelgrass meadow continues to expand, there will be eelgrass growing in Sebonac Creek for the first time in more than a decade. Taking into account sources of error, such as subjectivity of aerial interpreter, differences in aerial resolution/clarity, and accuracy of groundtruthing, the Bullhead Bay meadow has recovered to its 2000 extent, however, the current meadow has not yet reached the same density of the 2000 meadow, suggesting that there may be continued recovery in 2015, as environmental conditions allow.

It has been proposed that a genetic survey of Bullhead Bay be conducted, on a limited scale, to determine what, if any, impacts the severe decline of the meadow may have had on the genetic structure of the population. A genetic survey conducted in 2015 could be compared the results of a similar study conducted by the laboratory of Dr. Bradley Peterson (SUNY Stony Brook) from several years ago. Dr. Peterson was contacted regarding the recovery of Bullhead Bay and expressed interest in investigating an changes in the

population genetics of the Bullhead Bay meadow. A "before and after" genetic comparison of the eelgrass population could identify changes in genetic diversity of the Bullhead Bay eelgrass population which may allow for better prediction of how the meadow will respond to change climate conditions and other impacts.

The Bullhead Bay eelgrass meadow highlights the importance of a long-term monitoring program for eelgrass in the Peconic Estuary. In just the last 14 years of the program, we have witnessed the near extinction of this meadow and its rapid recovery. It remains the only meadow in the western Peconic Estuary, growing under conditions that are considered less than optimal for eelgrass growth when compared with the other extant meadows in the Estuary. The recovery of the Bullhead Bay has inspired CCE's Habitat Restoration to revisit the use of seeds for eelgrass restoration in small embayments and creeks, and at least one seed-based test planting is planned for 2015 in the Peconic Estuary. It is expected that we will continue to learn valuable information and lessons from this meadow that would benefit other areas of the Peconic Estuary as we follow the progress of this meadow over the coming years.

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 nutri-

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 for 2014.

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	12.7	0.4	10.1	2.1	22.9
August	12.4	0.1	9.1	1.1	23.3
September	11.7	-0.3	9.2	1.2	21.7

ent concentrations 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, like Brown-Tide.

Light Availability and Temperature

Light loggers were deployed to Gardiners Bay eelgrass meadow for one week each month, July-September 2014. The average Hcomp and Hsat calculated for each month's deployment are presented in Table GB-1. Typically, water clarity is high at the Gardiners Bay site throughout the year and both Hcomp and Hsat data for 2014 support this observation. Hcomp was found to meet the minimum required daily period of 12.3 hours for both July and August, but Hcomp declined in September, resulting in a minor deficit of -0.3 hours (Table GB-1). Hsat levels were better over the course of the three months surveyed, with each month easily meeting the minimum required 8 hours.

Water temperature in the Gardiners Bay eelgrass meadow has rarely been recorded at levels that would stress the plants. Throughout the summer of 2014, the water temperature was cool, with the meadow never experiencing a daily average temperature above 25°C for the year. The highest recorded temperature for the Gardiners Bay meadow was 25.01°C, on 11 July 2014. The monthly averaged July water temperature was almost 2°C lower than in 2013, while a late warming trend in August 2014 brought the water temperature up to 23.3°C, only slightly lower than in 2013.

Eelgrass Shoot Density

The Gardiners Bay eelgrass meadow was visited on 19 August, 2014 for its annual monitoring. Only three monitoring stations within the survey area maintain extant eelgrass population - Station 6, 7, and 8. Eelgrass shoot density for the meadow increased slightly in 2014 from 2013 (Table GB-2; Figure GB-2a). Shoot density averaged 106 shoots·m^2 in 2014 over the meadow. If the nonvegetated stations are removed from the calculations, the shoot density over Stations 6-8 more than doubles to 267 shoots·m^2. This density is a better representation of the eelgrass that remains at

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2014, 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
2014	106	+/-22

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

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.

Figure GB-3. An underwater photograph of one of the patches of eelgrass at Station 8, demonstrating the density of the eelgrasss at the station which it still exists.

the Gardiners Bay site and the higher density is illustrated in the Figure GB-3, which shows the density of one patch at one of the monitoring stations.

Macroalgae Cover

The Gardiners Bay site continues to host the greatest diversity of macroalgae of any of the meadows in the PEP LTEMP. In 2014, 15 species of macroalgae were identified, and *Spyridia filamentosa* was reported as the primary species. The macroalgae communinty within the eelgrass meadow tends to be dominated by filamentous, red macroalgae and one-third of the reported species were from this group. Overall cover of macroalgae in the Gardiners Bay meadow increased slightly in 2014 to 24.2% (Figure GB-2b). This was only a 0.2% increase in macroalgae cover from 2013. Other species common to the meadow were *Sargassum filipendul*a, *Codium fragile*, and *Gracilaria* species.

Bed Delineation and Areal Extent

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2014.

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.)
2014	37.65 acres (15.24 hect.)

The aerial eelgrass survey was flown in June 2014 and the Gardiners Bay site's delineations were groundtruthed in late August, after the LTEMP monitoring. The results of the mapping identified more than 37 acres of eelgrass of varying density at the site (Table GB-3). The delineation of the meadow from the 2014 aerial survey is presented in Figure GB-4d. The 2014 eelgrass delineation represents an increase from the 2013 estimate of almost 13 acres (Table GB-3), but the 2014 delineation are not as conservatively drawn as past delineations produced by CCE and may include more unvegetated patches in its estimate of eelgrass, and may account for the projected increase in area from 2013 to 2014.

Conclusions

The 2014 monitoring of the Gardiners Bay eelgrass meadow found the meadow have changed little from 2013 in terms of shoot density or area. Eelgrass at the site has not shown any recovery into the five offshore stations, however the remaining meadow maintained its density and has shown a significant increase since 2012, when the two new stations were added. Water clarity and temperatures continue to fall within optimal ranges for eelgrass providing conditions that support eelgrass growth and survival. The meadow continues to be highly patchy, which is not illustrated in the 2014 aerial mapping image presented in Figure GB-4d, but characterizes many of the eelgrass meadows in the Peconic Estuary which grow at sites subject to moderate to high waves and currents.

The Gardiners Bay eelgrass meadow will likely never recover to the extent it once covered due to continued natural and man-made disturbances at the site. Global climate change has resulted in more frequent/intense storms which cause waves to pound the site,

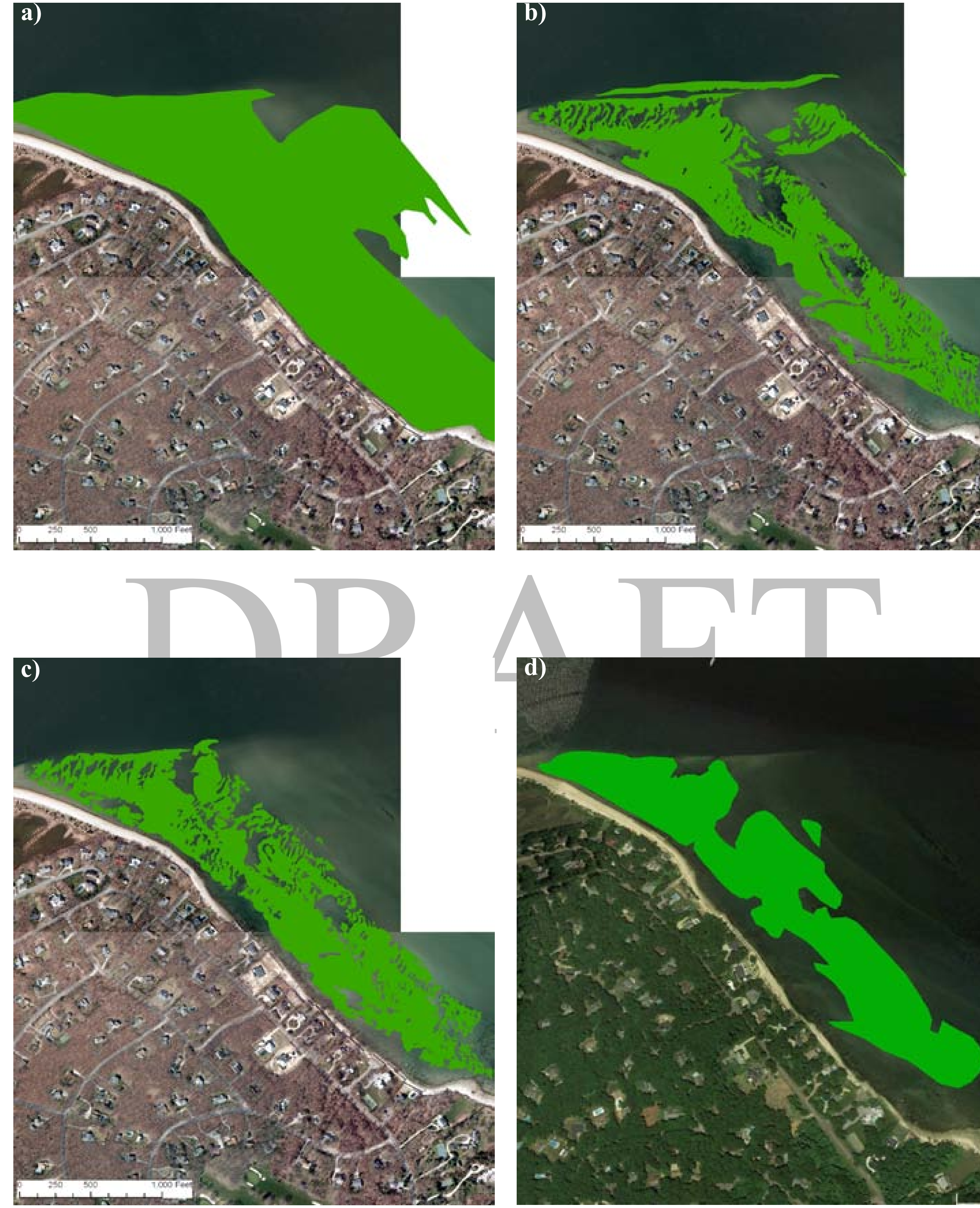

Figure GB-4. A series of aerial delineations of the Gardiners Bay eelgrass from 2000 through 2014. The years represented are a) 2000, b) 2004, c) 2010 and d) 2014.

Figure GB-5. During the 2014 monitoring visit of the Gardiners Bay eelgrass meadow, CCE divers encountered a pile of knobbed whelks laying eggs and possibly spawning.

contributing erosion in the patchy meadow. Boating activity and shellfishing in the meadow has also lead to increased fragmentation of the meadow, increasing the rate that erosion works on the meadow. Another factor of concern is the almost complete hardening of the shoreline along the length of the meadow. In 2014, a large section of the shoreline (inshore of Station 8) was hardened with rock. While the effects of hardened shorelines on seagrass have not been extensively researched, it has been suggested that bulkheads and other hard structures built inshore of seagrass meadows do have an impact on the long term survival of seagrass. It remains to be seen what the effects of the hardening of the shore along the Gardiners Bay meadow will be. Continued long-term monitoring of the site may allow us to identify the effects of all the disturbance factors of the Gardiners Bay site and potentially assist in the development of management actions that would help protect this and other meadows in the future.

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-

Table NWH-1. The average annual eelgrass shoot density for Northwest Harbor from 1997 to 2014, 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
2014	0	+/- 0

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

Eelgrass Shoot Density

The eelgrass monitoring for 2014 in Northwest Harbor was conducted on 25 November, 2014. The monitoring effort was delayed due to the priority given to the groundtruthing of the eelgrass aerial survey. As there has been no eelgrass growing in Northwest Harbor since 2007 (Table NWH-1; Figure NWH-2), the delay did not effect the results when compared to previous years' monitoring efforts.

Macroalgae Cover

Northwest Harbor once maintained a relatively high abundance of macroalgae, when the harbor bottom was covered in eelgrass. Since the loss of eelgrass, the harbor bottom consists of a mostly featureless expanse of silty-sand, with little structure for macroalgae to attach to or trap drifting macroalgae (Figure NWH-2). As a result the macroalgae community in Northwest Harbor has declined and maintained a cover of under 10% for the last nine years (Figure NWH-4)

Conclusions

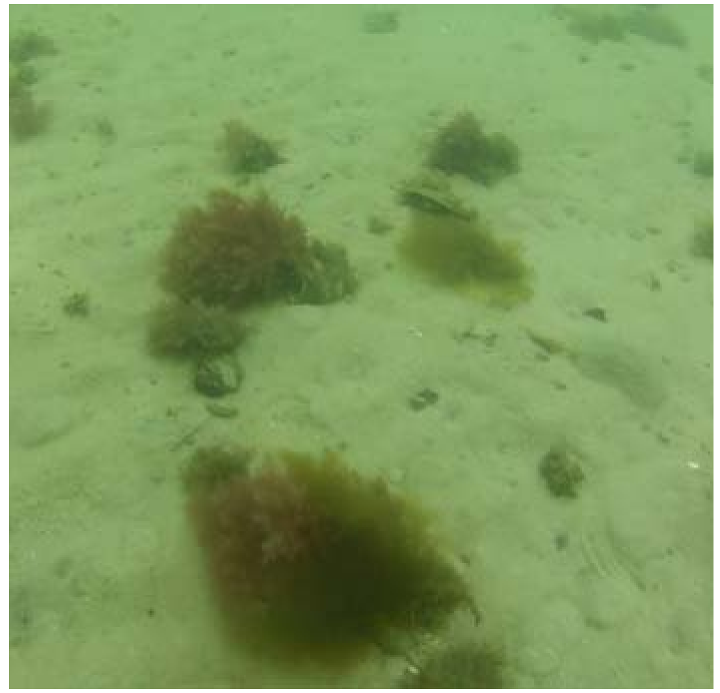

Figure NWH-2. A photograph of the bottom conditions near Stations 1 in Northwest Harbor. *Spyridia filamentosa* (red alga) and "slipgut" (the brown alga *Ectocarpus siliculosus*) are seen growing attached to stacks of *Crepidula* shells.

Northwest Harbor has been without eelgrass within the monitoring area for almost eight years. The cause of the decline and eventual loss is still unknown and appears to have been localized to just the Northwest Harbor area, as eelgrass meadows still exist in adjacent Sag Harbor and Cedar Point. A 2013 survey of Northwest Creek included a station near the LTEMP's Station 1. Light and temperature data collected from this station in 2013 suggested that light conditions in August-October fall below minimal requirements for eelgrass, but temperature was within the optimal range. While the low light levels for the three months surveyed are of concern, it is likely that the rest of the year, Northwest Harbor meets the minimal requirements for light and eelgrass could survive. The only factor holding back concerted restoration efforts in Northwest Harbor is the uncertainty of what caused the rapid decline of eelgrass in the harbor, and if it still present? Until this can be ascertained, any restoration effort is risking a high probability of failure.

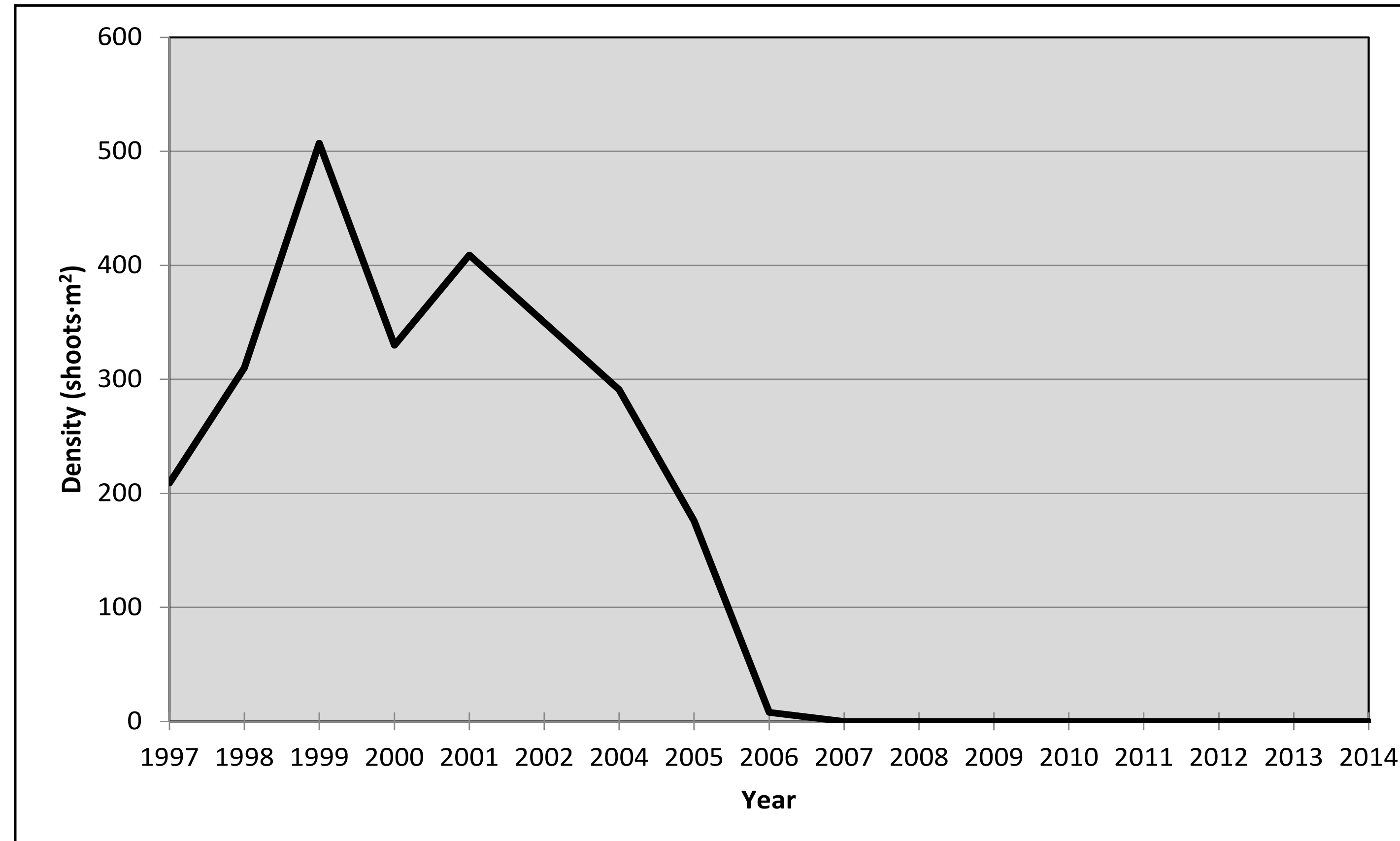

Figure NWH-3. Average annual eelgrass shoot density for Northwest Harbor, East Hampton.

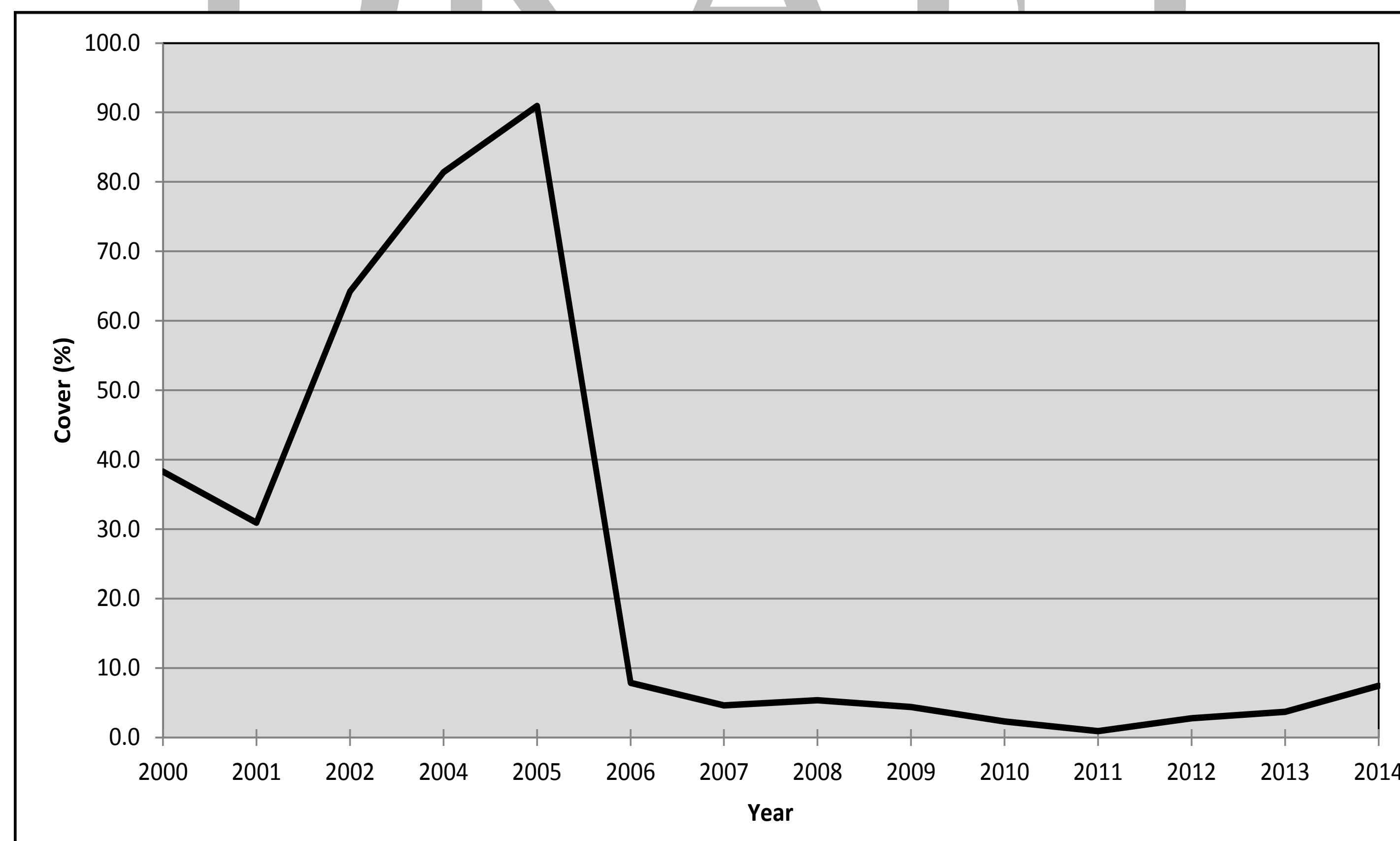

Figure NWH-4. Annual mean macroalgae cover for Northwest Harbor, East Hampton from 2000 to 2014.

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, 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.

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

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 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 monitoring for 2014 in Orient Harbor was conducted on 25 November, 2014. The monitoring effort was delayed due to the priority given to the groundtruthing of the eelgrass aerial survey. As there has been no eelgrass growing in Orient Harbor for several years (Table OH-1; Figure OH-1), the delay caused did not effect the results when compared to previous years' monitoring efforts.

Macroalgae Cover

The macroalgae population in the Orient Harbor site has proved to be dynamic in the past (Figure OH-2). Over the last two monitoring seasons, 2013-2014, the macroalgae cover at the site has remained virtually the same, 5.3% for 2013 and 5% for 2014. Species composition has remained constant with the filamentous, red alga *Spyridia filamentosa* as the dominant species at the site. The 2014 monitoring identified eleven species of macroalgae, with more than half the species being red macroalgae and the remainder primarily green macroalgae.

Conclusions

The conditions in Orient Harbor have changed little since the loss of the eelgrass meadow six years ago. It was suggested in the 2013 LTEMP report that if there was extant eelgrass in Orient Harbor, it would be identified by the 2014 aerial survey. The aerial mapping identified several polygons in Orient Harbor that could have been eelgrass, but groundtruthing found no eelgrass in any of the indicated areas. Based on the finding of the 2014 eelgrass survey, it should be accepted that there is no extant eelgrass in Orient Harbor and recolonization from outside sources is unlikely without assistance.

Table OH-1. The average annual eelgrass shoot density for Orient Harbor from 1997 to 2014, 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
2014	0	+/- 0

Orient Harbor 2014

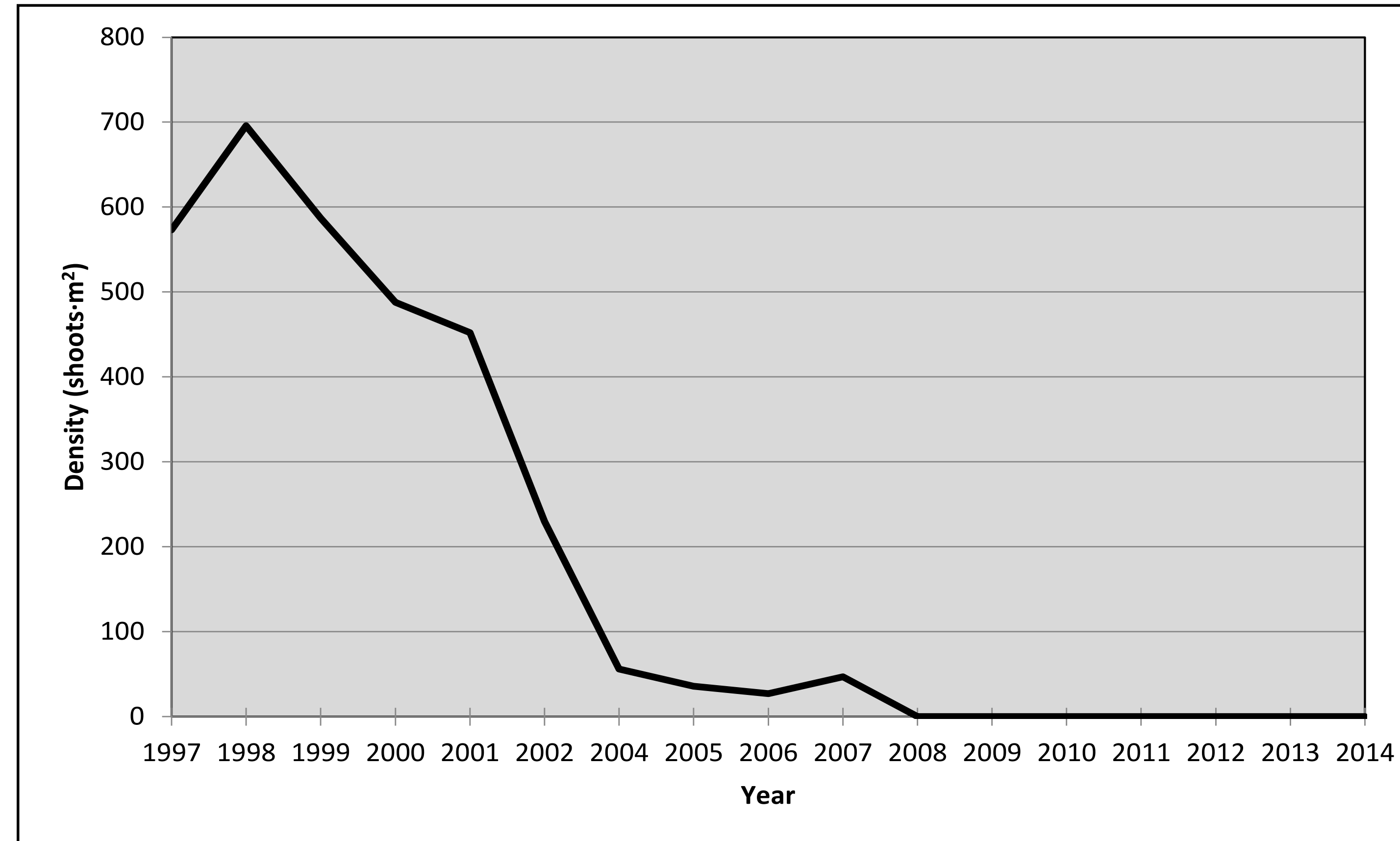

Figure OH-2. Average annual eelgrass shoot density for Orient Harbor, Southold.

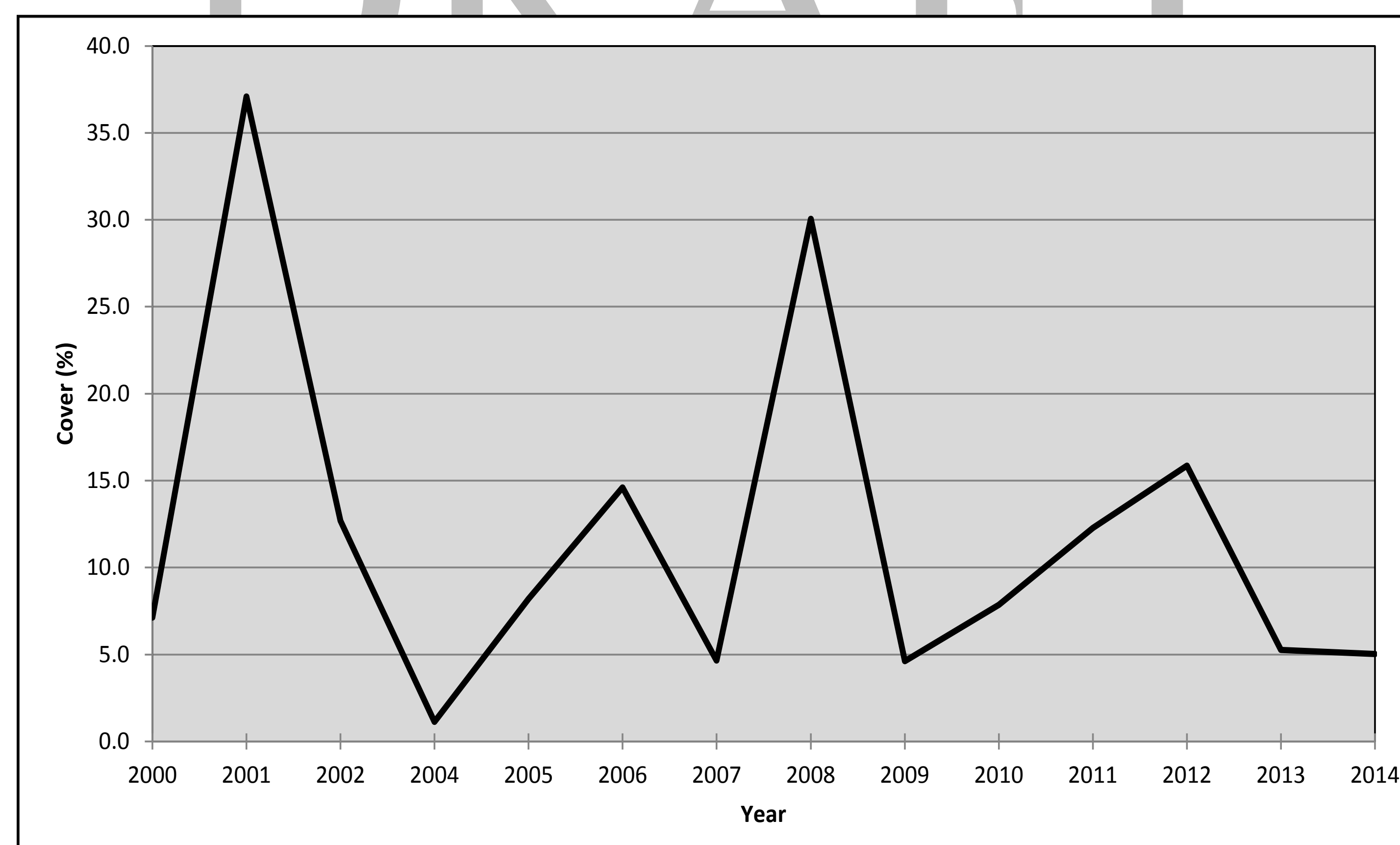

Figure OH-3. Annual mean macroalgae cover for Orient Harbor, Southold from 2000 to 2014.

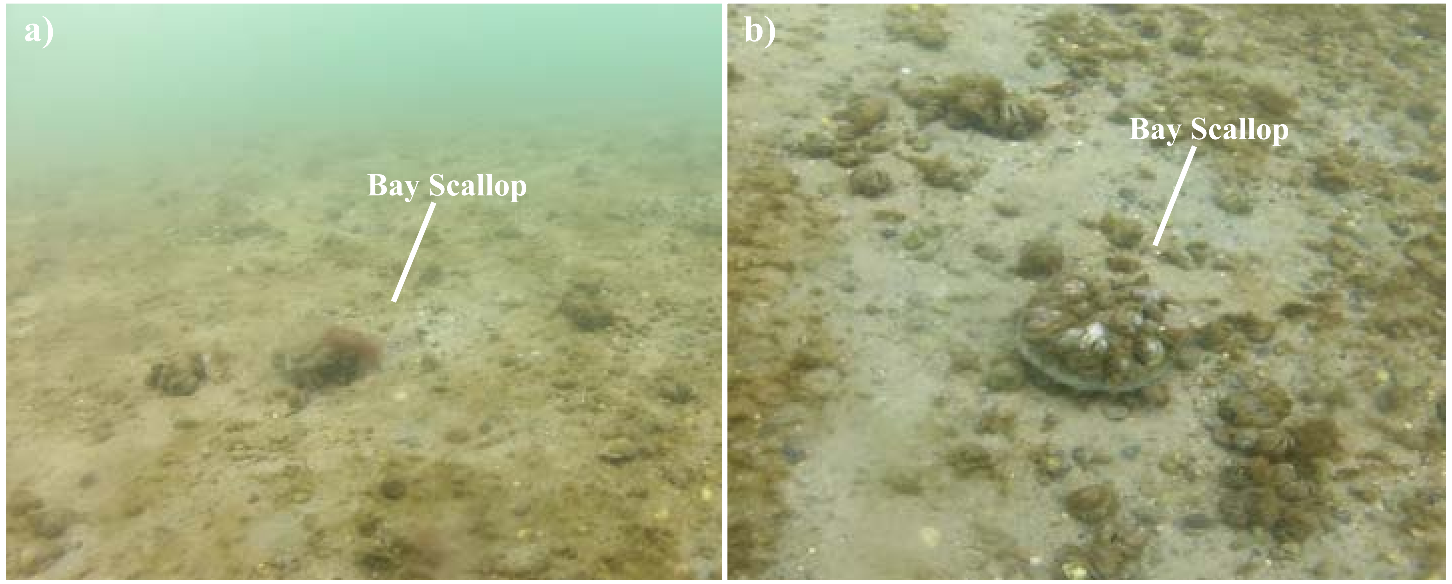

Figure OH-4. Bay Scallops, a) and b), were prevalent in Orient Harbor in 2014, with scallops densities averaging 1 scallop·m^2 over the quadrats sampled during the monitoring visit.

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.

Table SB-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Southold Bay for 2014.

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	12.1	-0.2	6.8	-1.2	24.1
August	12.0	-0.3	7.0	-1.0	23.8
September	11.4	-0.6	7.9	-0.1	22.1

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.

Light Availability and Temperature

Light loggers were placed at the Southold Bay site for one week each month, July through September, 2014. The average Hcomp and Hsat for each month's deployment are presented in Table SB-1, above. Water clarity was less than optimal with average daily Hcomp for all months coming under the minimal requirement of 12.3 hours. Hcomp deficits were less than one hour, with September having the greatest deficit at 0.6 hours. Hsat fared worse than Hcomp. Hsat for both July and August were below the minimal requirement of 8 hours. The September Hsat was better than the other months averaging just under the minimal requirement.

Eelgrass Shoot Density

The eelgrass monitoring for 2014 in Southold Bay was conducted on 25 November, 2014. The monitoring effort was delayed due to the priority given to the groundtruthing of the eelgrass aerial survey. As there is no eelgrass currently growing in the Southold Bay site (Table SB-2; Graph SB-2), the delay caused no impact on results of the monitoring.

Macroalgae Cover

With the loss of eelgrass throughout the Southold Bay site, macroalgae abundance declined sharply (Figure SB-3). The 2014 season found the macroalgae cover in Southold Bay up from 2013, at 10.8%. Most of the macroalgae recorded during the monitoring effort were located at Station 1 and 2, where scattered boulders along the west side of the Goldsmith's Marina channel support dense cover of *Codium fragile* and *Sargassum filipendula*. In total, ten macroalgae species were identified, with 60% of these being red macroalgae.

Conclusions

Conditions at the Southold Bay site had not been conducive to eelgrass growth for some time prior to the establishment of the LTEMP. Prior to the collection of light logger data, qualitative observations found water clarity to be chronically low at the site and water temperature data found that Southold Bay was one of the warmest meadows in the monitoring program. The loss of eelgrass lead to a decline in the macroalgae population which relied on eelgrass for anchorage, but is now faced with minimal hard substrate over this sandy-bottomed site. Global climate change will likely

Table SB-2. The average annual eelgrass shoot density for Southold Bay from 1997 to 2014, 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
2014	0	+/- 0

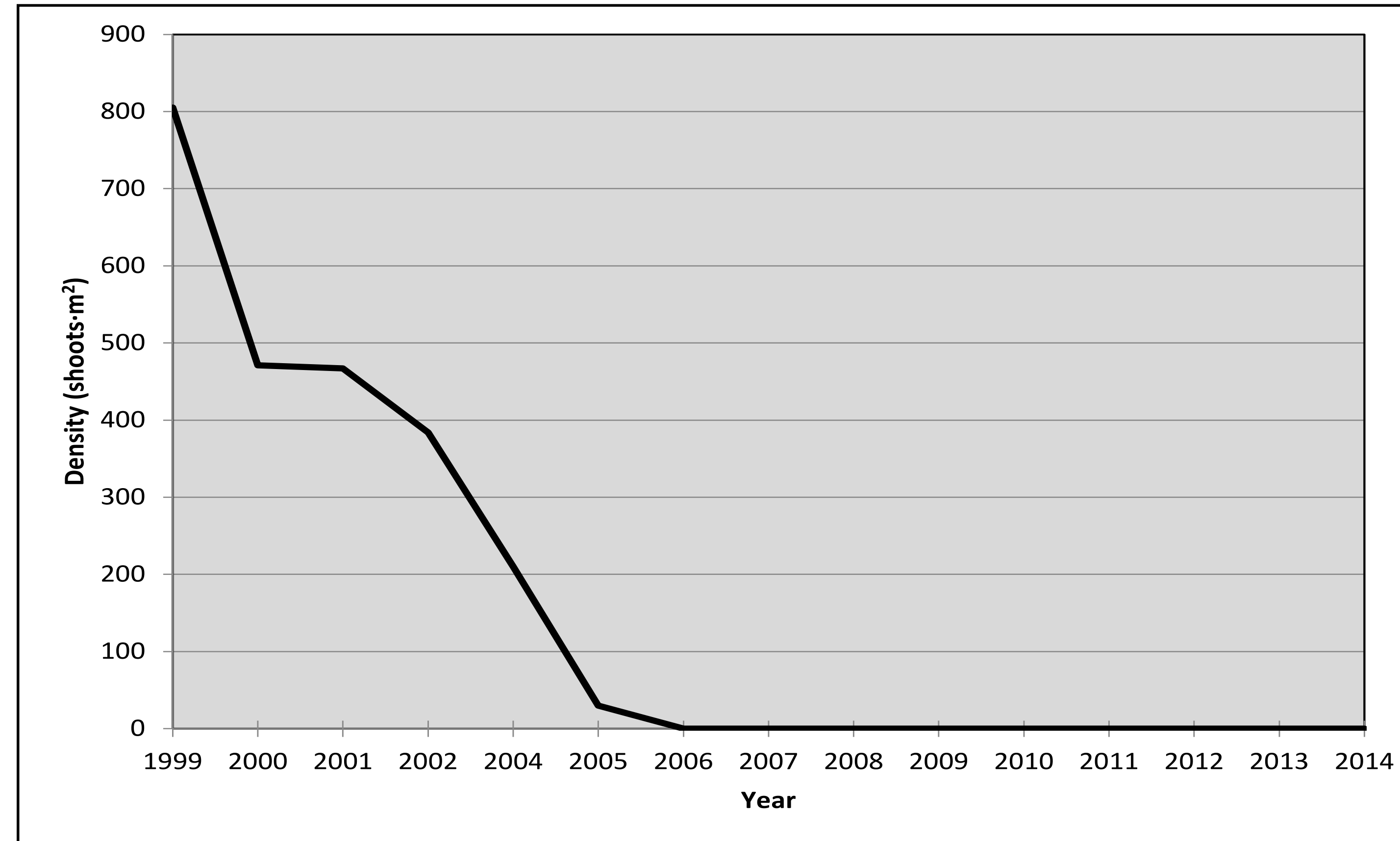

Figure SB-2. Average annual eelgrass shoot density for Southold Bay, Southold.

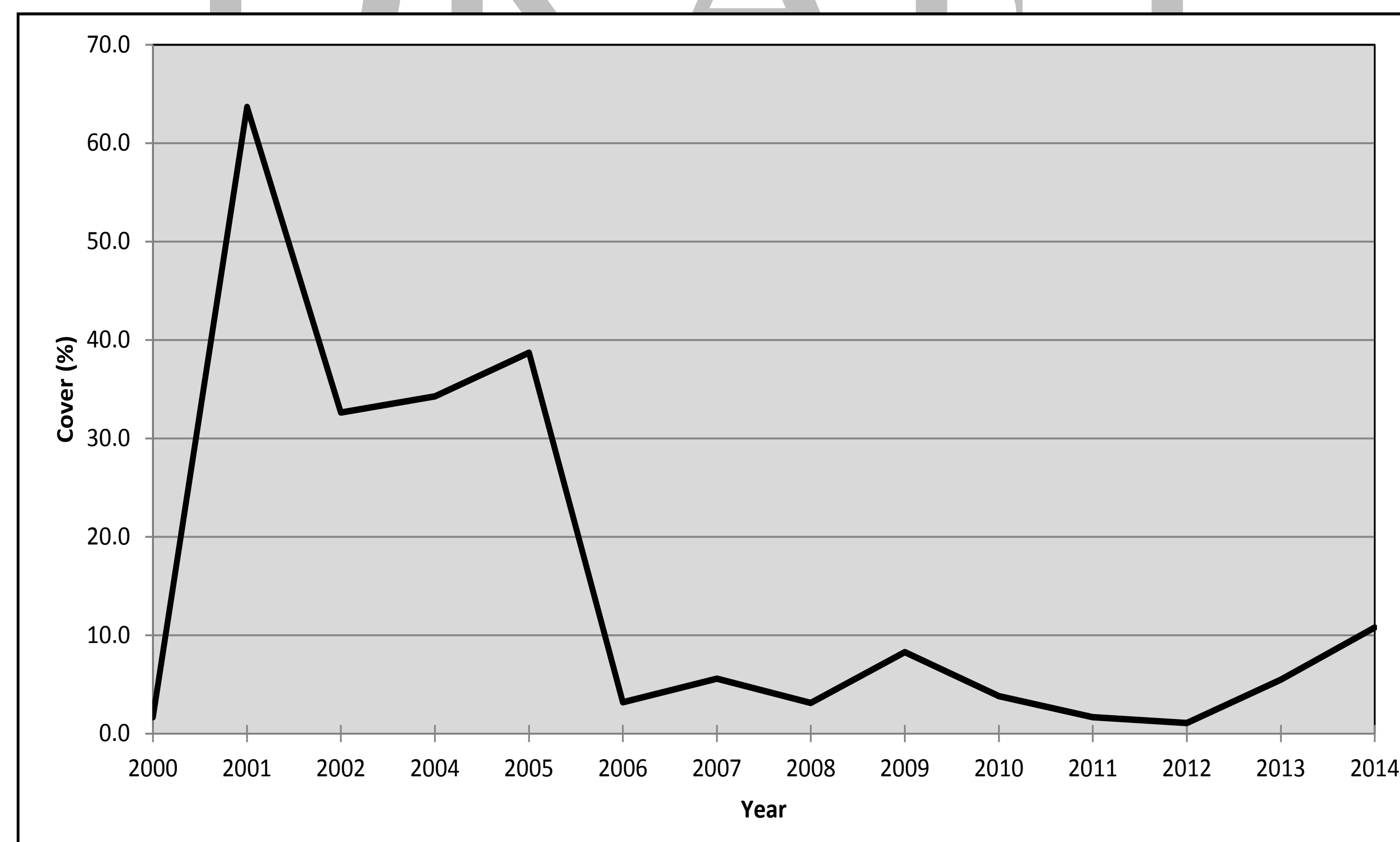

Figure SB-3. Annual mean macroalgae cover for Southold Bay from 2000 to 2014.

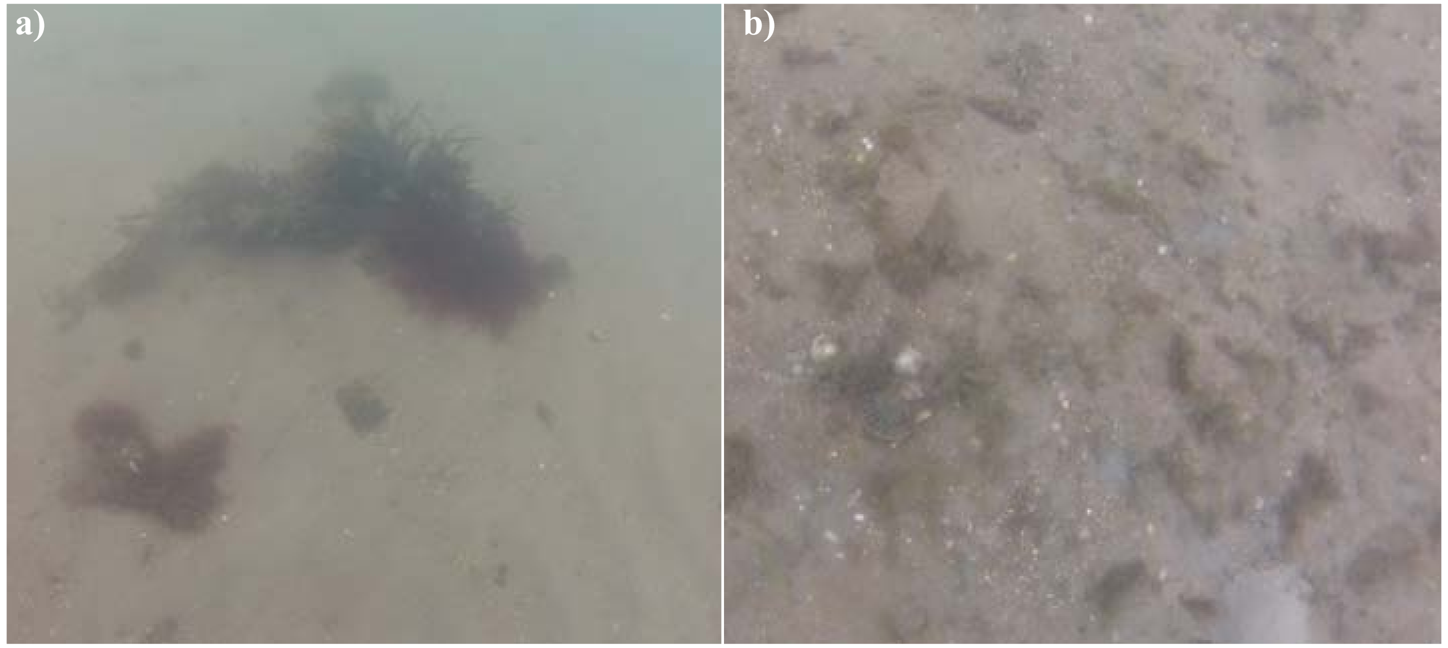

Figure SB-4. Photographs of the bottom conditions at the Southold Bay LTEMP site taken during the 2014 monitoring visit by divers.

continue the decline in water quality at this site.

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-

Table TMH-2. The average annual eelgrass shoot density for Three Mile Harbor from 1997 to 2014, 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
2014	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 eelgrass monitoring survey in the Three Mile Harbor was conducted on 6 November, 2014. CCE divers did not observe any eelgrass within the monitoring area (Table TMH-1; Figure TMH-2). While there has been no eelgrass in the immediate vicinity of the monitoring area in Three Mile Harbor, the 2014 Peconic Estuary eelgrass aerial survey identified three small eelgrass beds at the southern end of the harbor.

Macroalgae Cover

The macroalgae population in Three Mile Harbor has been on a decline over the last several years (Figure TMH-3), and in 2014 the macroalgae cover was recorded at 1.9%. Macroalgae diversity was also found to be low with only five species of macroalgae identified. The species reported for Three Mile Harbor were the green algae *Ulva lactuca* and *Codium fragile*, the red algae *Gracilaria* species and *Spyridia filamentosa*, and the brown alga *Sargassum filipendula*, which was likely drift from outside of the harbor.

Bed Delineation and Areal Extent

The 2014 eelgrass aerial survey identified three, small eelgrass beds in the southern end of Three Mile Harbor (Figure TMH-4). Two of the meadows are growing in shallow water along the sides of the boating channel, while the third, smallest bed is just along the edge of the channel. In total, the three eelgrass beds cover 0.66 acres (0.27 hect.).

Conclusions

While the Three Mile Harbor monitoring area has not supported eelgrass in 8 years, past reports had indicated the possibility that eelgrass still existed in the harbor complex and the 2014 aerial survey located three small beds in the least likely area of the harbor. These last remnants of eelgrass in Three Mile Harbor represent an opportunity to compare conditions between the extant meadows and the monitoring area and possibly determine what changed in the monitoring area that lead to the extinction of the meadow at that site. For 2015, the monitoring will include deployments of light and temperature loggers and an analysis of the sediment to determine basic differences in between the locations. Should the testing of these parameters yield no significant differences, a more comprehensive survey of water quality parameters may recommended.

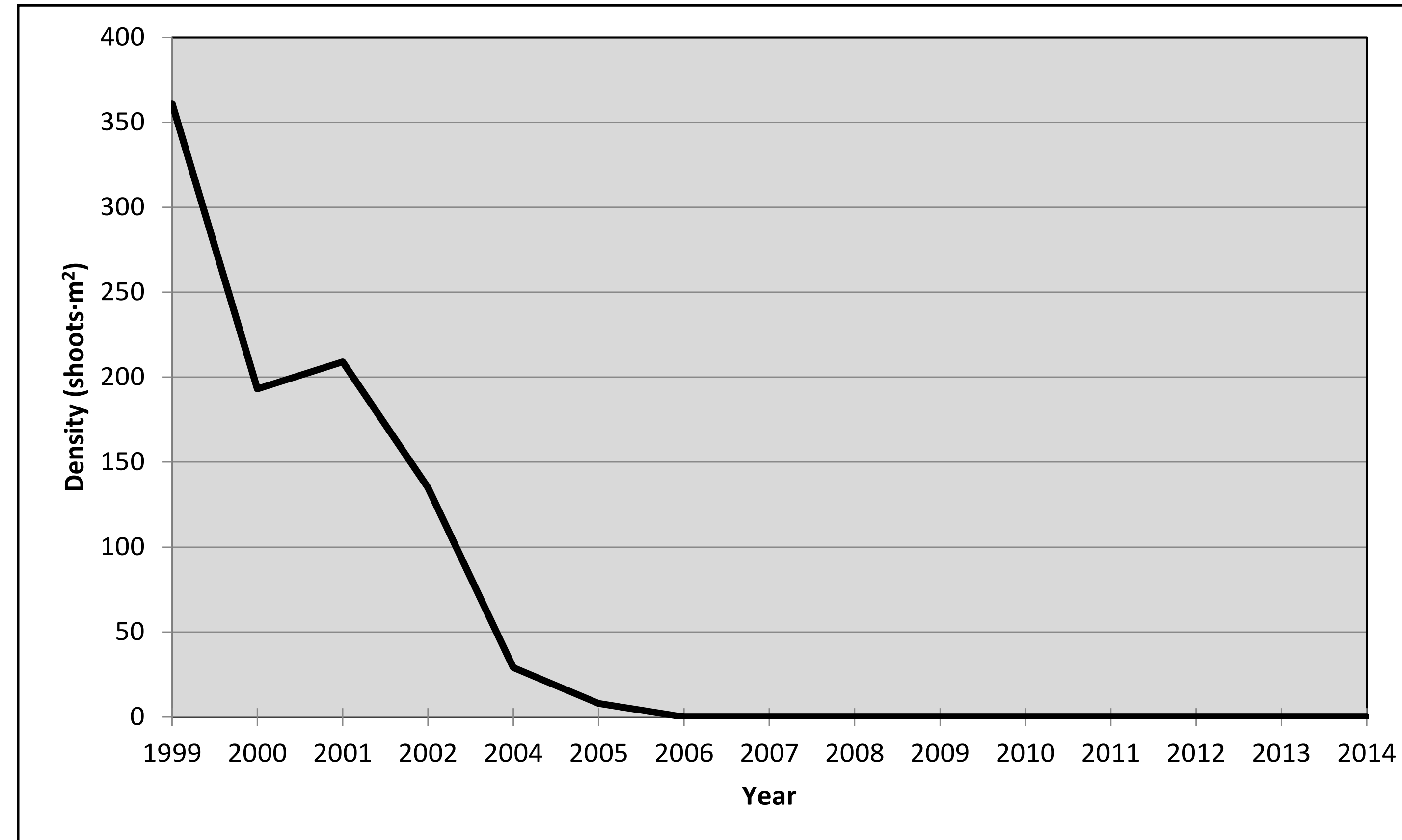

Figure TMH-2. Average annual eelgrass shoot density for Three Mile Harbor, East Hampton.

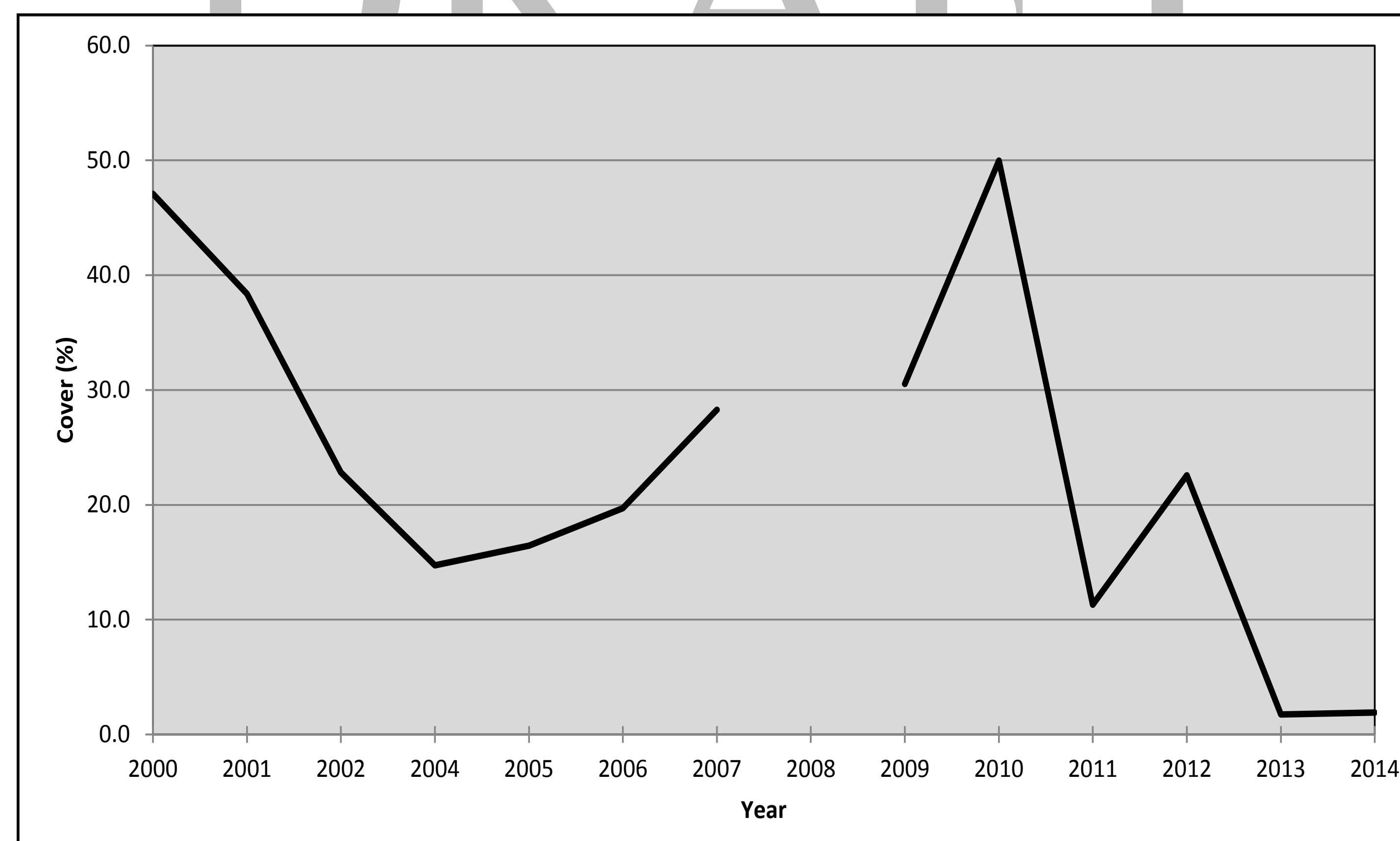

Figure TMH-3. Annual mean macroalgae cover for Three Mile Harbor from 2000 to 2014.

Figure TMH-4. An aerial image of Three Mile Harbor indicating the location of the three, small eelgrass beds that were identified during the 2014 aerial survey. The PEP LTEMP area is enclosed in the white box and the individual eelgrass beds are identified by the numbers.

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 Temperature

Light loggers were deployed for one week, monthly, from July-September 2014, and the TidBit temperature logger was deployed from May-November 2014. The Hcomp, Hsat and monthly average water temperature

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, for 2014.

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	12.7	0.4	11.0	3.0	22.0
August	13.0	0.7	10.5	2.5	22.8
September	11.3	-1.0	7.9	-0.1	20.7

for the summer of 2014 are presented in Table CP-1. Water clarity in the Cedar Point eelgrass meadow was high for July and August, but saw a minor decline in September. Hcomp exceeded the minimum daily required period of 12.3 hours for July and August, but was at a deficit in September. The eelgrass meadow experienced high Hsat for July and August with net daily Hsat levels of 3.0 and 2.5 hours, respectively. Hsat saw a minor decline in September when levels were just under the minimum requirement of 8 hours (Table CP-1).

Cedar Point water temperatures are typically moderate, rarely reaching or exceeding 25°C. Temperature data for 2014 found that trend continued with monthly average water temperature well below 25°C from July-September 2014. The highest temperature recorded for the site was 24.8°C and the highest daily average temperature was just over 24°C.

Eelgrass Shoot Density

Eelgrass monitoring of the Cedar Point meadow was conducted on 25 August 2014. Eelgrass shoot densities showed a significant increase from 2013 with the average shoot density of meadow reaching almost doubling in 2014 at 382 shoots·m^2 (Table CP-2; Figure CP-2). The meadow had suffered significant damage during Hurricane Sandy and the winter storms of 2013, as indicated by the low shoot density for 2013 (Table CP-2), but it appears the meadow has recovered. While the meadow remains patchy, the small patches evident in 2013 have coalesced into larger, denser patches in 2014.

Macroalgae Cover

The Cedar Point eelgrass meadow supports a significant macroalgae community, dominated by the brown alga, *Sargassum filipendula*. The rocky sediment of the site supports a wide range of species and 12 macroalgae species were identified in the sampling quadrats in 2014. Macroalgae cover at Cedar Point experienced a minor decline of 6.1% from 2013, with cover estimates averaging 30.6% for 2014 (Figure CP-3).

Bed Delineation and Areal Extent

The Cedar Point meadow was accurately mapped in 2014, the first time in 14 years, with the completion of the Peconic Estuary aerial eelgrass survey. Aerial mapping, combined with groundtruthing conducted by CCE provided the mapped area presented in Figure CP-5d, which only represents the extent of the meadow within the monitoring area. The complete Cedar Point meadow covers more than 2 miles of shore. Estimates of areal extent of the meadow from the 2014 survey found that the meadow lost approximately 10

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 and 2014, 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
2014	382	+/-39

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for 2000, 2004, 2010, and 2012, 2013, and 2014

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.)
2014	85.76 acres (34.71 hect.)

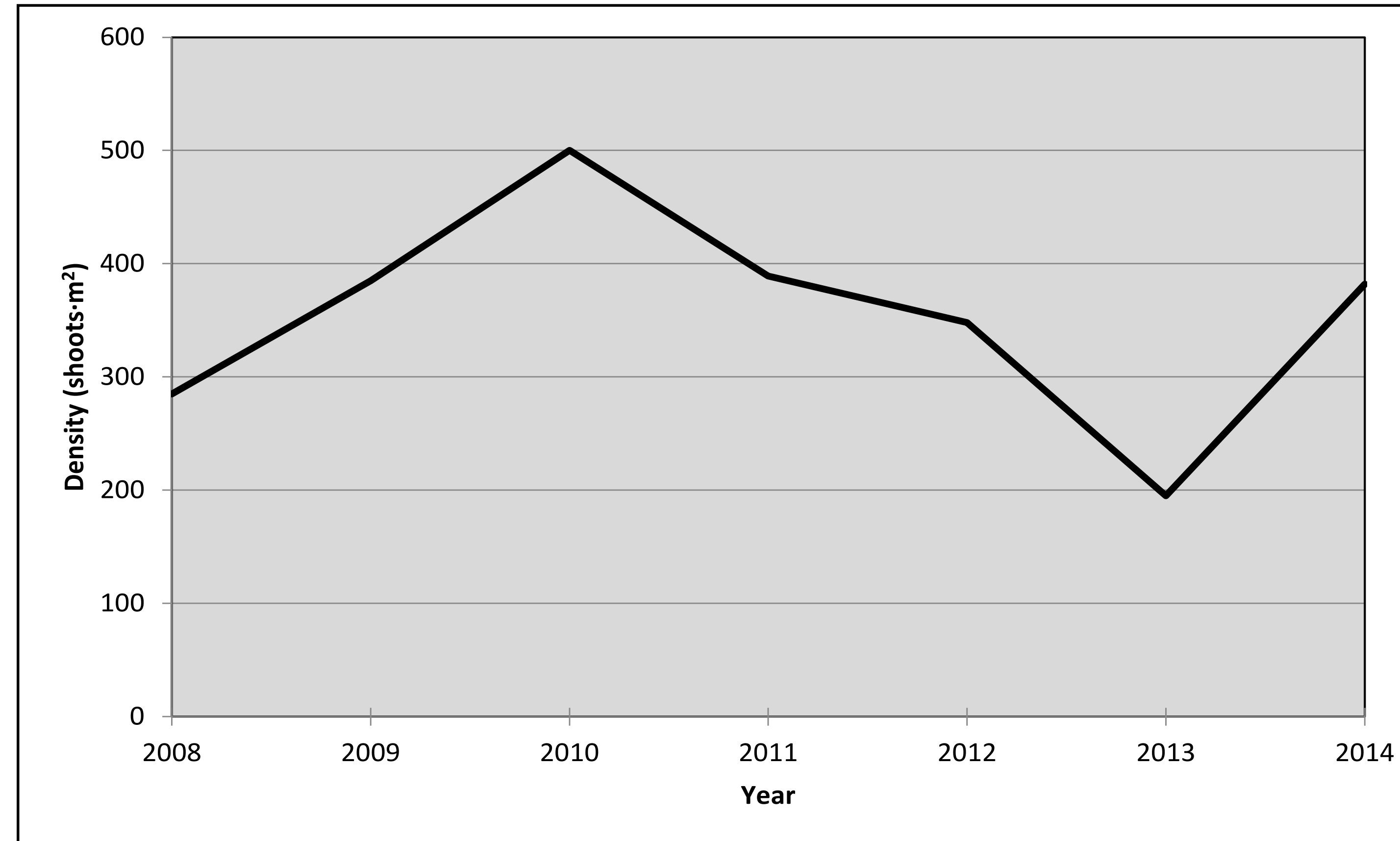

Figure CP-2. The average annual eelgrass shoot density for Cedar Point for 2008-2014.

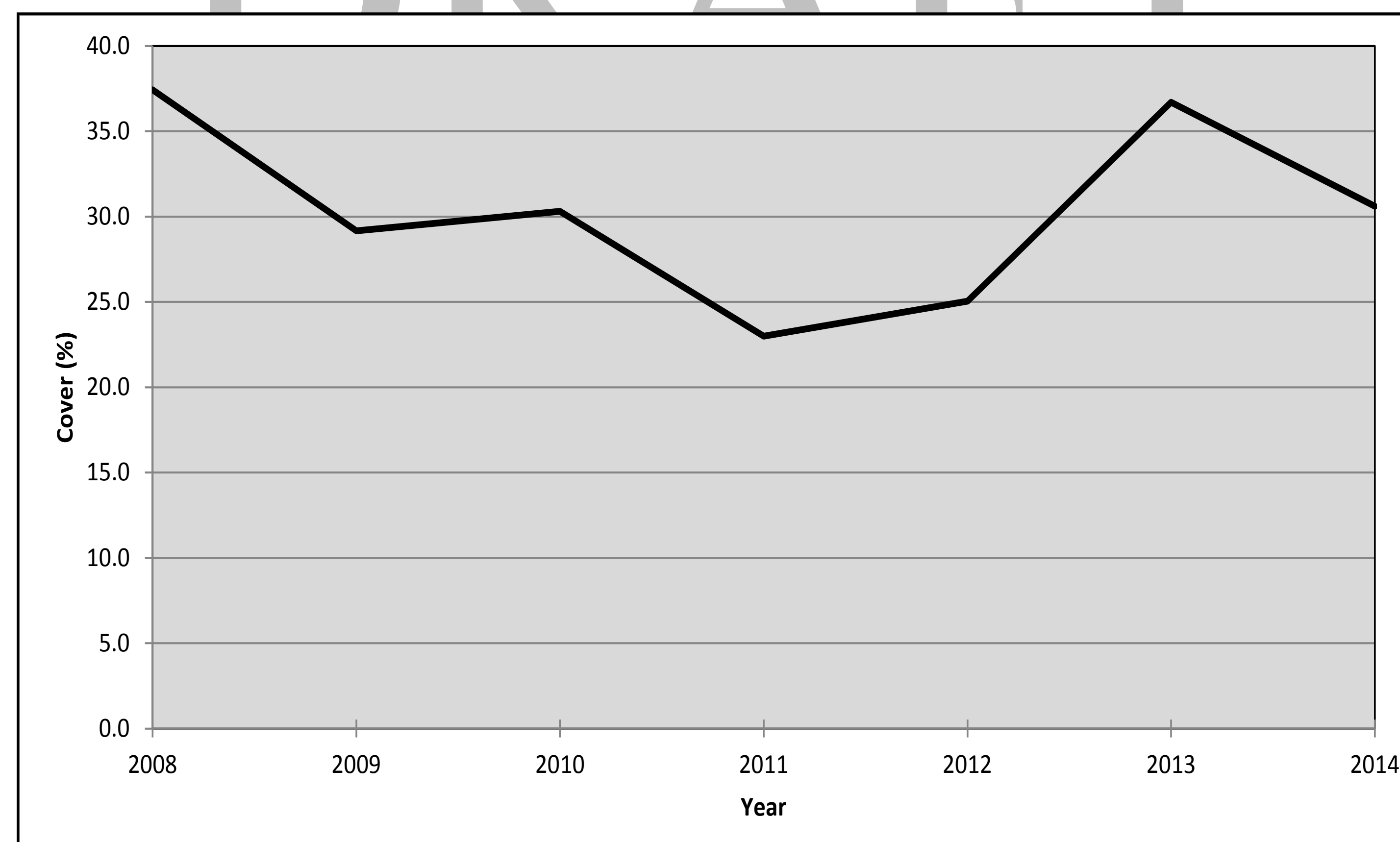

Figure CP-3 Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2014.

Figure CP-4. An underwater photograph taken of the eelgrass meadow at Cedar Point near Station 5 in 2014.

acres from 2013 to 2014 (Table CP-3). Based on the aerial delineations presented in Figure CP-5, there has been a continual loss of eelgrass in the central are of the meadow since at least 2010 and it continued into 2014, resulting in the meadow being divided into two separate sections.

Conclusions

There was concern for the condition of the Cedar Point eelgrass meadow after the 2013 monitoring report the dramatic decline in eelgrass density following Hurricane Sandy and a severe winter 2013. The findings of the 2014 season suggest that the meadow has recovered, although not without significant loss to the overall extent of the meadow since 2010. Based in the 2014 aerial survey and the subsequent groundtruthing, it was determined that the meadow has been divided into two section by an area that was once vegetated by eelgrass (seed Figure CP-5), but has rapidly lost eelgrass since 2010. Storm damage from Hurricane Sandy and the 2013 winter storms likely increased the rate of loss in this section of the meadow. The 2014 aerial survey and groundtruthing also provided an accurate estimate of the areal extent of the meadow for the first time. The 2014 groundtruthing of the more than 2 miles of the Cedar Point meadows deep edge by CCE suggests that past delineations likely overestimated the deep edge of the meadow, therefore, the extent of meadow in 2014 compared to previous years, is likely lower than the estimates presented in Table CP-3.

It has been established since Cedar Point was added to the LTEMP, that water quality would not be a factor impacting the meadow, and the 2014 light and temperature data supports this trend. The greatest impact to the site will be from storm damage due to the site's northern exposure. Global climate change will bring more frequent and stronger storms to our area and this trend may have been responsible for the slow erosion and loss of the central section of the eelgrass meadow over time. Future monitoring of this site will include an underwater survey conducted by CCE divers of this central section of the meadow to document any recolonization of eelgrass to the area.

The Cedar Point eelgrass meadow has recovered from the damage sustained between 2012 and 2013 with shoot densities at the site achieving pre-Hurricane Sandy numbers. The meadow has been completely severed into two sections by an unvegetated area which will need to be monitored in the future for recolonization of eelgrass from the surrounding eelgrass meadow.

Figure CP-5. Delineations of the Cedar Point eelgrass meadow from aerial photographs for a) 2004, b) 2007, c) 2010, and d) 2014 (continued on next page).

Figure CP-4. Continued.

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

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 2014.

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	12.8	0.5	11.0	3.0	20.9
August	13.0	0.7	10.0	2.0	21.7
September	11.4	-0.9	8.4	0.4	20.9

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 Temperature

Light loggers were placed on site for 7-day deployments each month, July-September, 2014. The monthly average Hcomp and Hsat for 2014 are included in Table OP-1. Water clarity conditions at Orient Point were good for most of the period, similar to conditions reported for the Cedar Point and Gardiners Bay meadows. Hcomp levels met the minimum requirement of 12.3 hours for both July and August, but fell short of the minimum for September by almost and hour (Table OP-1). The average Hsat for each month exceeded the minimum requirement of 8 hours, with July and August experiencing 3.0 and 2.0 hours over the minimum, respectively.

Water temperatures in the Orient Point eelgrass meadow are typically moderate with high temperatures rarely reach the upper limit of eelgrass' optimal range near 25°C. Monthly average water temperatures for 2014 were cooler that 2013, with average temperature for each month under 22°C (Table OP-1). The highest reported temperature for Orient Point was 23.7°C.

Eelgrass Shoot Density

Table OP-2. 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
2014	229	+/-30

The Orient Point eelgrass meadow was visited on 19 August, 2014 for its annual monitoring. The results of the monitoring of eelgrass shoot density for 2014 are presented in Table OP-2 and Figure OP-2. Eelgrass shoot density saw a minor increase in 2014. The shoot density increased from 201 shoots·m^2 in 2013 to 229 shoots·m^2 in 2014. The offshore stations of the monitoring area have the lowest shoot densities due to the patchiness of the deep edge of the meadow, while the inshore sections of the meadow support larger, dense patches with shoot densities up to 800 shoots·m^2.

Macroalgae Cover

The Orient Point supports a healthy and diverse macroalgae population which coexists with the eelgrass meadow. Macroalgae cover for 2014 was 18.3%, which was a decline of 4.7% from 2013 (Figure OP-3). This site has the second highest diversity of macroalgae, behind the Gardiners Bay meadow. During the 2014 monitoring visit, CCE divers identified 13 species of macroalgae at Orient Point. The most prevalent species observed in the Orient Point meadow were the red algae *Chondrus crispus* and *Spyridia filamentosa* and the brown algae *Sargassum filipendula* and *Fucus distichus*.

Bed Delineation and Areal Extent

The 2014 Peconic Estuary aerial eelgrass survey was completed in 2014 and a current, accurate map of the Orient Point eelgrass meadow was generated from the project. Figure OP-5d shows the current extent of the eelgrass meadow. Based on the 2014 aerial survey, the meadow covers 21.6 acres and represents an increase from the mapped area in 2013. The 2014 aerial survey has confirmed previous reports that the Orient Point meadow's deep edge has moved inshore since 2000 (Figure OP-5), resulting in a significant reduction in meadow extent (Table OP-3).

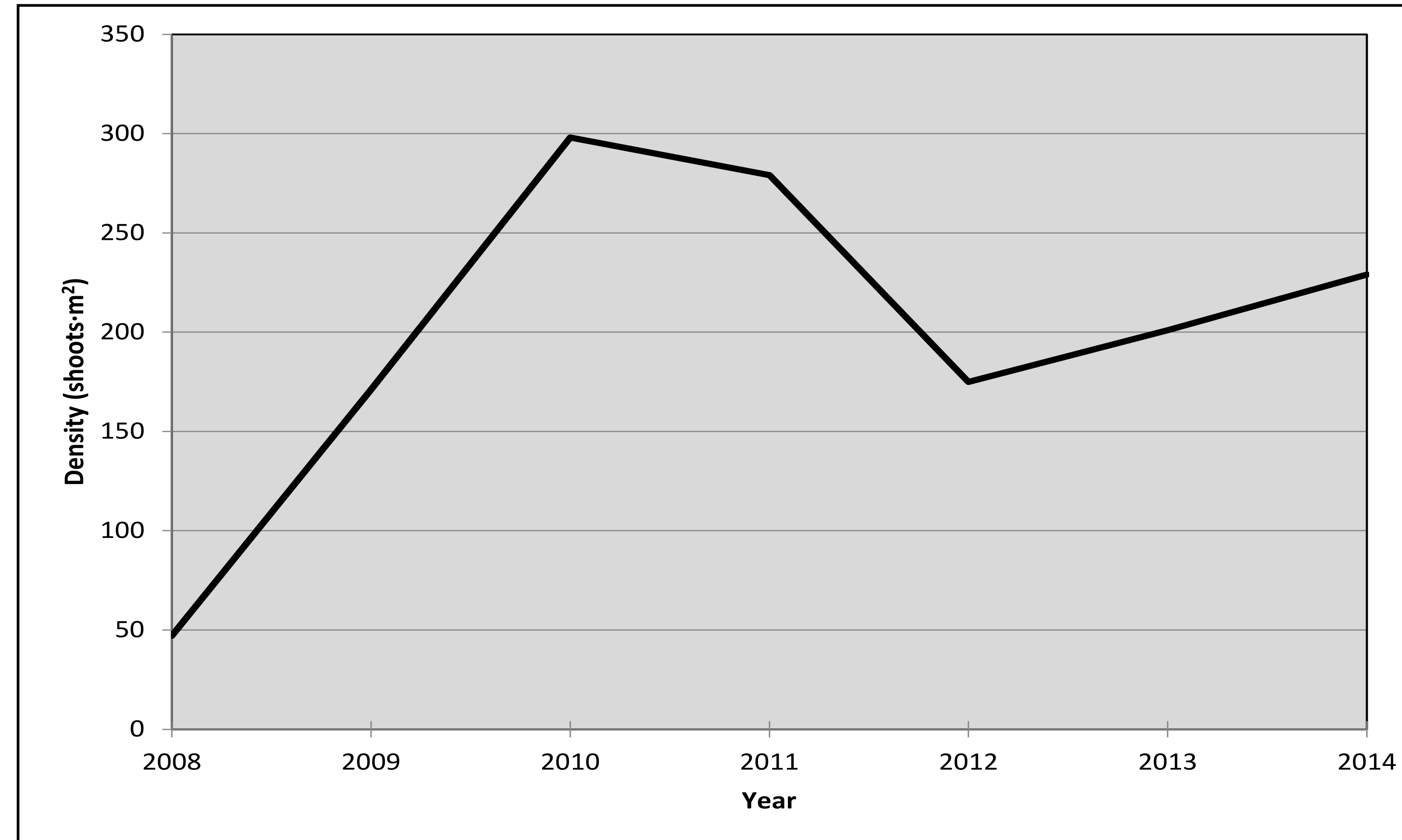

Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2014.

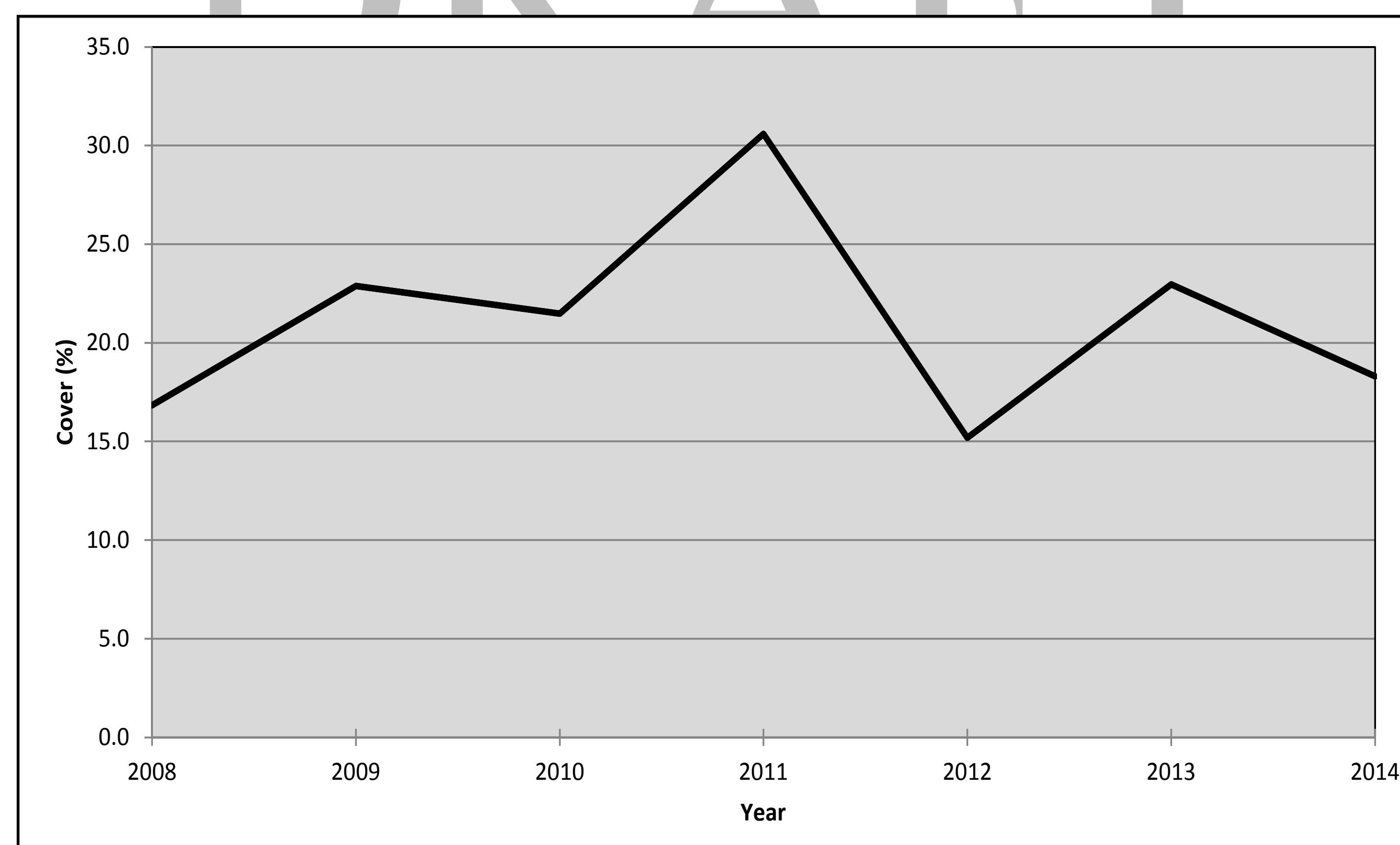

Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2014.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2014.

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.)
2014	21.60 acres (8.74 hect.)

Conclusions

The Orient Point eelgrass meadow has continued its recovery from the damage that it sustained during Hurricane Sandy and the winter storms of 2013. The deep edge section of the meadow continues to suffer storm damage from waves that have slowed its recovery and maintained the patchiness that is characteristic of this area of the meadow. The inshore section of the meadow has recovered quickly and currently supports large, dense patches of eelgrass up to 800 shoots·m^2. Water quality parameters generally support the vigorous growth of eelgrass at this site, however, water clarity in the offshore sections of the meadow was observably lower and is likely slowing the recovery in these areas. The lower water clarity appears to be a result of the loss of eelgrass in these area which allows the fine sediments that were once trapped within stands of eelgrass, free to be resuspended with only moderate wave action.

The deeper sections of the meadow are becoming progressively more rocky over time. The increase in sediment coarseness is related to the loss of eelgrass cover in these areas, which allows the fine sediments to be suspended and moved by waves and current, gradually exposing the rocks buried below. The change in sediment has benefitted the macroalgae community by providing more hard substrate for attachment. As a result, the macroalgae cover is higher at the offshore sections of the meadow. If eelgrass becomes re-established, then there should be a decline of the macroalgae population along the deep edges of the meadow.

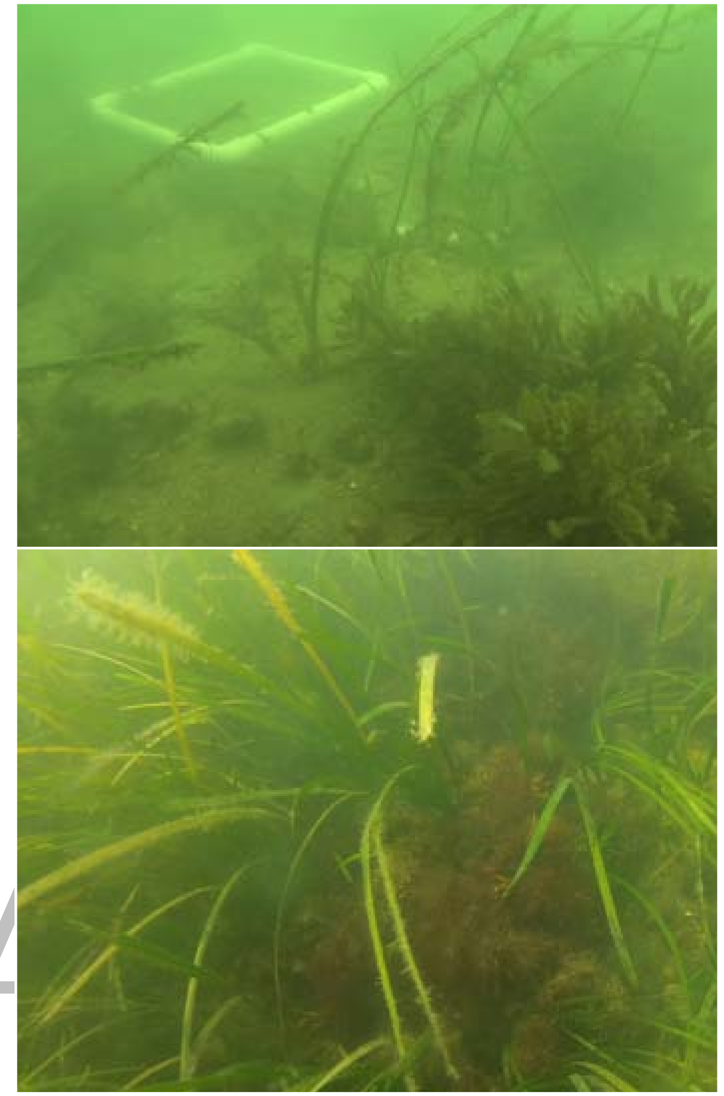

Figure OP-4. Underwater photographs illustrating conditions within the Orient Point eelgrass meadow during the 2014 monitoring visit.

The Orient Point meadow has continued its recovery since the severe storm damage it suffered in 2006. Even with the set back of Hurricane Sandy, the meadow has become less patchy and shoot densities have increase significantly since 2008. The areal extent of the meadow has declined, however, the potential for the meadow to spread back into deeper water exists given the optimal light and temperature conditions recorded for the site.

Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2007, c) 2010 and d) 2012, showing inshore migration of the meadow and loss of eelgrass from the area near the tip of the point. The dashed lines in a) and b) 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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