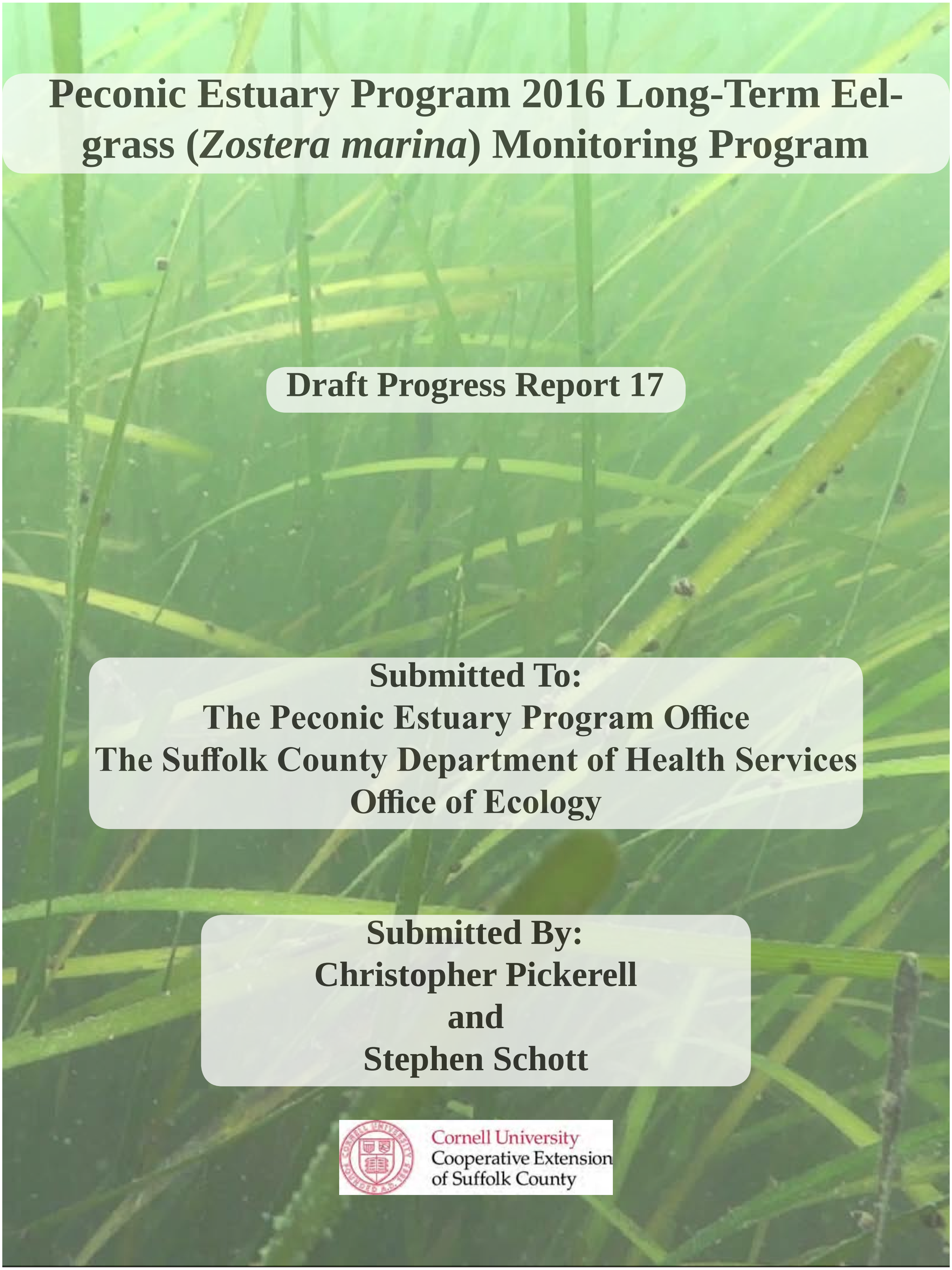

Peconic Estuary Program 2016 Long-Term Eel-grass (*Zostera marina*) Monitoring Program

Draft Progress Report 17

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

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Executive Summary

The 2016 Peconic Estuary Program Long-term Eelgrass Monitoring Program (PEP LTEMP) was initiated in June of 2016 with the set-up of the light and temperature monitoring stations and the deployment of water temperature monitoring equipment at six of the eight monitoring sites in the program. Eelgrass monitoring was conducted over from August 22-September 6, 2016, with all eight sites visited by Cornell Cooperative Extension (CCE) divers, who collected eelgrass shoot density, macroalgae percent cover, and video archiving of each monitoring station within each of the sites. The data and observations collected during the 2016 monitoring effort are presented in this report and summarized below.

Light availability and water temperature are important gauges of eelgrass health and data were collected at 6 of the eight monitoring sites for both of these parameters. Following the same methods set in 2015, all of the sites that support extant eelgrass meadows were monitored, including the additional site that was added in Three Mile Harbor, where small beds were identified during the 2014 Peconic Estuary Aerial Eelgrass Survey. In general, light availability in the monitored meadows met or exceeded the daily requirements for healthy eelgrass meadows for July and August. By September, higher frequency of storms/wind, combined with shortening days and lower sun angle find most meadows running slight deficits in light. This is a general trend that is supported by several years of data for the LTEMP. Water temperatures exceeding 25°C (77°F) stress eelgrass, and research conducted by CCE suggests that sites experiencing more than 30 days of water temperatures above 25°C can not support healthy eelgrass meadows. The 2016 season recorded three sites that experienced more than 30 days above this threshold, Southold Bay, and the two sites in Three Mile Harbor. Two LTEMP site reported incomplete water temperature data for 2016. Bullhead Bay's temperature logger was lost due to vandalism and Orient Harbor's USGS water quality station was missing 41 days between July and August. As these sites both exceeded the 30-day threshold for temperature in 2015, it is likely that they also exceeded it for 2016. While the 30-day threshold is a general rule, meadows like Bullhead Bay and the "new" Three Mile Harbor do not appear to be bound by it, and seem to thrive in spite of the high water temperatures. These sites may be influenced by submarine groundwater discharge occurring in the meadows which moderates high temperatures, and reduces the stress the plants face. This hypothesis is being investigated in Bullhead Bay and at least one other eelgrass meadow in 2017.

Eelgrass shoot density is the primary parameter of the health of a meadow in the PEP LTEMP. The general trend in recent years has been an overall decline in the extant meadows in the monitoring program. These declines have been facilitated by storm damage, climate change/sea level rise, bioturbation, and human impacts. The 2016 LTEMP monitoring found that shoot density trends were mixed with Bullhead Bay experiencing a minimal decline and Gardiners Bay, Cedar Point, Orient Point and the "new" Three Mile Harbor meadows seeing increases in shoot density from 2015 levels. While none of these changes were found to be statistically significant in their scale, for the four LTEMP sites that saw improvements, there can be optimism regarding their general health. For Bullhead Bay, while the decline in shoot density is a set back in the recovery of this meadow, the identification of potential grazer impact (i.e., swans) presents an issues that could be managed, unlike the impacts of water temperature from climate change.

Macroalgae cover within the meadows provides a guage of competition and general water quality at each site. Macroalgae growing within eelgrass meadows and on eelgrass blades compete for nutrients and light. Typically, macroalgae percent cover has been highly variable, both between years and between sites. This trend continued in 2016, with three LTEMP sites (Northwest Harbor, Orient Harbor, and Three Mile Harbor) reporting significant declines in macroalgae cover, three sites (Southold Bay, Cedar Point, and Orient Point) with slight increases, and two sites (Gardiners Bay and "new"Three Mile Harbor) showing nominal changes. Bullhead Bay recorded an increase in macroalgae cover close to 12% for the season.

For the four sites that still support eelgrass meadows, the changes in the areal extent of each of these eelgrass populations is reported annually, when aerial imagery is available. The delineations of the extent of these meadows allows for a comparison between years and can identify significant changes in each meadow and possibly indicate the cause(s) of that change. The general trend in the Peconic Estuary, since 2000, has been one of shrinking eelgrass meadows. With few exceptions, most meadows have lost acreage over the last 15 years. Bullhead Bay lost almost six-acres of meadow between 2015 and 2016, mostly in the shallow sections of the meadow and likely due to swan grazing. Orient Point also reported a loss in area of just under 2-acres, however, this level of loss could be due to errors associated with the quality of aerial imagery and the photo-interpretation resulting in the meadow showing relatively little change in 2016. The remaining three extant eelgrass meadows in the LTEMP, Gardiners Bay, Cedar Point, and the "new" Three Mile Harbor site, all reported minor increases in areal extent. The margin of increase for Gardiners Bay and the "new" Three Mile Harbor site could be within the tolerance of the errors mentioned for Orient Point, resulting in virtually no change in area for 2016. The Cedar Point meadow delineations identified a 5.25 acre increase in area and was able to detect, with groundtruthing from divers, the reconsolidation of the meadow after it had been split for more than two season.

The PEP LTEMP has provided data since the late 1990s that allowed the resource managers at all levels of government to understand the trends in the eelgrass populations in the Peconic Estuary. Overall, eelgrass populations are in decline in the Peconic Estuary, and this is a trend shared with seagrasses globally. With the exception of Bullhead Bay, there are no eelgrass meadows growing west of Shelter Island. Environmental conditions, specifically light availability and water temperature, are no longer within the optimal range for eelgrass in this section of the estuary and, with global climate change and increasing population on the east end of Long Island, conditions may deteriorate in eelgrass meadows that are growing at the upper limits of their tolerance. Additionally, eelgrass meadows are subjected to more frequent and intense storms and increased disturbance by foraging animals and human activities. This, coupled with an inability to regenerate impacted areas at a rate to maintain population extent and integrity, results in the continual decline observed in many of our eelgrass meadows. Eelgrass meadows growing under more favorable conditions in Gardiners Bay appear to be in good health and have changed little in the time between the 2000 and 2014 eelgrass surveys. While little can be done to minimize the impacts of climate change on eelgrass meadows, water quality issues and human disturbance can be addressed to limit the stress they exert on the meadows. Responding to impacts to eelgrass meadows requires "real-time" data. The 2014 aerial survey of the Peconics, while a valuable tool, ended a gap in knowledge spanning fifteen years. During that time, there was almost a fifty percent decline in eelgrass acreage in the Peconic Estuary. While it may not be economical to fly estuary-wide aerial surveys on an annual basis, a time-frame of 3-5 years should be considered. To suppliment the full-scale aerial surveys, drone technology could be utilized to provide more regular data for impacted meadows or gauge impacts from acute distubance events (e.g. storm/hurricanes, harmful algal blooms, etc.) and plan appropriate management responses. Changes also need to be made to the LTEMP to continue providing useful information regarding the health of eelgrass in the Peconic Estuary. The most significant change to the monitoring program should be the removal of LTEMP sites that no longer support eelgrass from the annual monitoring and replacement of these sites with healthy meadows from new areas of the Peconic Estuary. The "extinct" eelgrass sites would be moved to a 3-5 year monitoring cycle. Funding research to better understand our remaining eelgrass meadows by examining their physical environments and population genetics could elucidate the potential responses of Peconic Estuary eelgrass populations to changing climate and water quality conditions and allow resource managers to develop plans to possibly mitigate these impacts, protecting this valuable resource. The impact of groundwater on the quality of the coastal waters in Suffolk County has been a priority topic, and studies focusing on how groundwater may influence the health of eelgrass meadows, both negatively (nitrogen and pesticide input) and positively (modifying water temperatures), could produce valuable information.

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 parameter 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

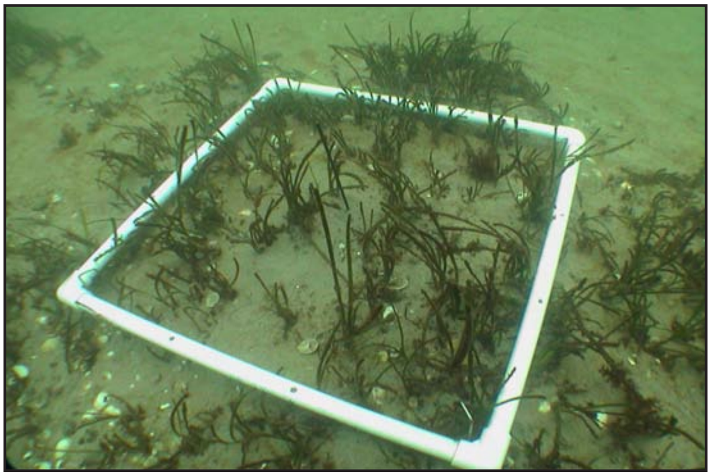


Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

(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.

In 2014, three extant eelgrass beds were identified in the headwaters of Three Mile Harbor, East Hampton during the Eelgrass Aerial Survey. For 2015, the largest of the three beds was included in the monitoring with a diver completing 10 quadrat counts spread, randomly along its length. A light and temperature logger was also deployed in this bed for comparison against light and temperature data collected from the original Three Mile Harbor LTEMP site.

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 affects 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.

Water temperature loggers were deployed at seven, current LTEMP monitoring sites (Bullhead Bay, Cedar Point, Gardiners Bay, Orient Point, Southold Bay, Three Mile Harbor and Three Mile Harbor-New) for the 2016 season. 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 amount of Photosynthetically Active Radiation (PAR) that reaches the bottom of an embayment, allowing

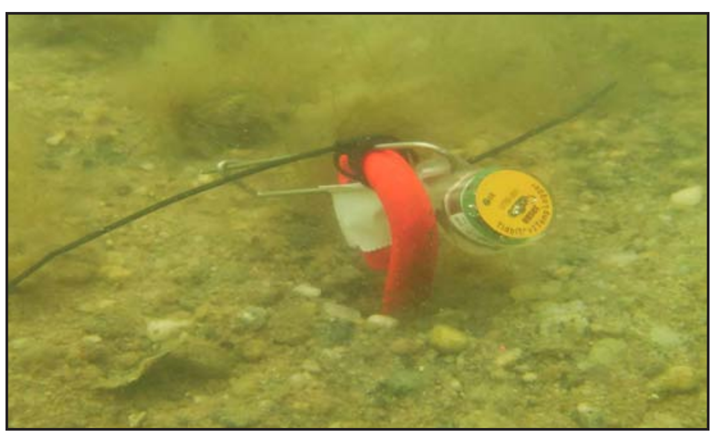


Figure Intro-2. A TidBit v2™ temperature logger attached to a screw anchor, deployed on-site.

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 collected primarily at the vegetated sites within the PEP LTEMP including: Cedar Point, Gardiners Bay, Orient Point, and Three Mile Harbor-New. The Southold Bay and Three Mile Harbor sites (extinct eelgrass meadows) were also included in the survey. The loggers were deployed for 10 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 Peconic Estuary 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 2016 monitor began on 22 August and completed on 6 September. Sampling at each site was distributed among six stations that have been referenced using GPS, with the exception of the Gardiners Bay site, which now supports eight stations. At each of the stations, divers conducted a total of 10 random, replicate counts of eelgrass stem density and macroalgae 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

For the 2016 season, Google™ Earth aerial imagery (11 May , 2016) was used for current delineations. Trend analysis is presented using the results of the first eelgrass aerial survey (2000), the 2010 Suffolk County aerial (representing pre-Hurrican Sandy), the 2014 eelgrass aerial survey and the 2015 imagery. It should be noted that the Google Earth imagery and the Suffolk County aerials 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 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

For the 2016 eelgrass monitoring, each diver was equipped with a GoPro Hero 2™ digital video camera in an underwater housing and video was taken to characterize each station at each of the eight PEP LTEMP sites. The video clips will edited, combining footage from each station into a one to two minute video for

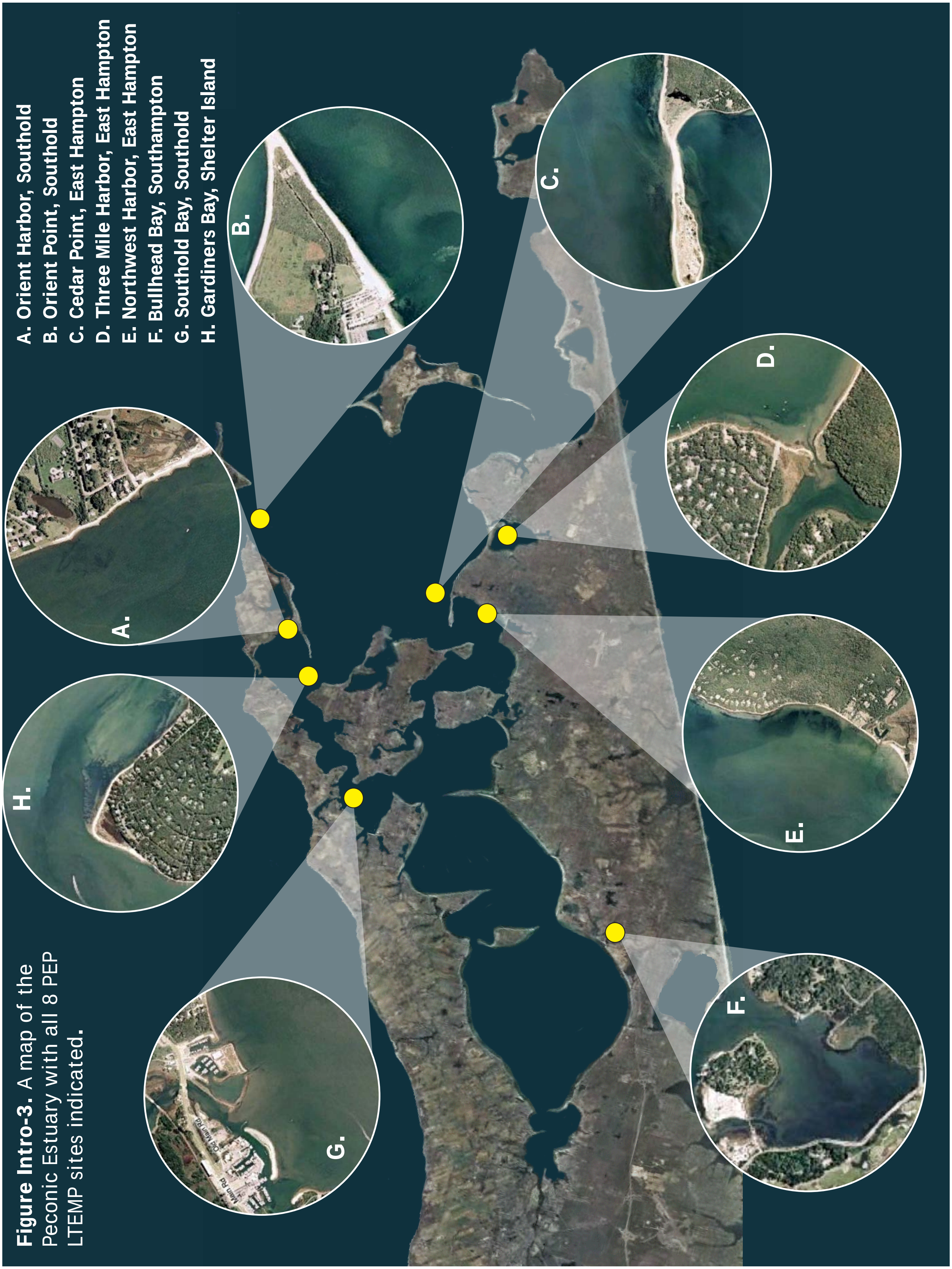


Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

each site. The videos will be posted 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 2016.

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	13.5	+1.2	10.0	+2.0	ND
August	12.1	-0.2	6.0	-2.0	26.9*
September	10.3	-2.0	2.9	-5.1	23.9*

* Incomplete temperature datasets representing less than one month due to lost temperature logger.

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.

Light Availability and Temperature

Light loggers deployments were conducted monthly for ten days from July-September, 2016, with the average Hcomp and Hsat for each month presented in Table BB-1 above. Hcomp for July averaged 13.5h for the deployment, providing a surplus of light for the meadow to meet its basic metabolic needs. During July, the Hsat exceeded the basic daily requirement by 2h, averaging 10h of saturating light per day during the 10-day recording period. August Hcomp saw a minimal decline, -0.2h, but Hsat experienced a 2h deficit during the deployment period (Figure BB-1). By September, there were significant declines in both Hcomp and Hsat, however, both parameters may have been influenced by macroalgae shading the sensor, as divers had to remove *Ulva* from the rebar to which the logger was attached.

The water temperature logger was deployed on June 3, 2016. Unfortunately, when it was to be retrieved for the season, CCE staff found that the marker buoy had been dragged more than twenty feet from its original location and the cement block that the logger was attached to could not be found. The temperature data presented in Table BB-1 above came from the temperature arrays that were stationed throughout Bullhead Bay to investigate the potential influence of submarine groundwater discharge in moderating water temperatures in the eelgrass meadow. Those temperature loggers were deployed for just under one month (16 August-12 September, 2016). The loss of the original temperature logger and the short deployment of the temperature arrays leaves only an incomplete picture of the temperature trends in Bullhead Bay for 2016. Still, given that short period of time, 16 days recorded daily average temperatures over 25°C and 8 days with average temperatures greater than 27°C. In comparison, 2015 had 72 days ≥25°C and 25 days ≥27°C, over a sampling period that was four times longer than in 2016. If the full 2016 dataset would have been analyzed, the data comparison suggests that 2016 would have been close to 2015 in the number of high temperature days.

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
2015	211	+/-27
2016	147	+/-25

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

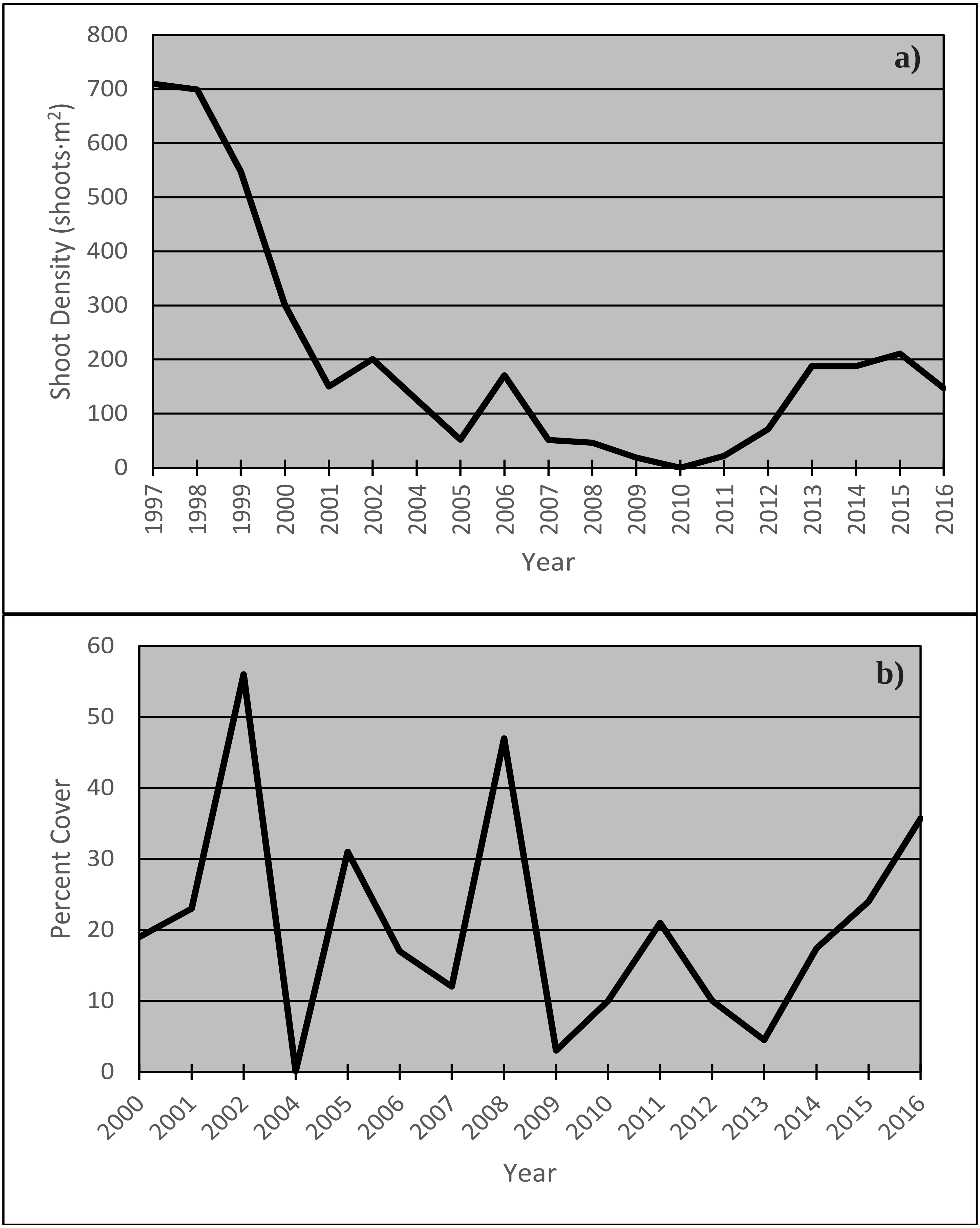


Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

Bullhead Bay 2016

Figure BB-3. The 2016 delineation of the Bullhead Bay eelgrass meadow.

Eelgrass Shoot Density

The LTEMP monitoring was conducted in Bullhead Bay on 26 August, 2016. Diver-conducted quadrat counts found a significant decline in overall eelgrass shoot density compared to 2015 (Table BB-2 and Figure BB-2a). The loss of eelgrass in the northern section of the Bay, which was noted in 2015, had expanded in 2016, resulting in no eelgrass recorded in quadrats for Stations 1 and 2, although small, sparsely vegetated patches were noted by divers in areas adjacent to Station 2. Station 5 had no eelgrass recorded in any quadrats, and the eelgrass patches that were noted in 2015 in this section of the meadow were not evident in 2016. Stations 2 and 5 had evidence of old eelgrass rhizomes, black and brittle, suggesting relatively recent cover of eelgrass in this area, while rhizome fragments were infrequently observed near Station 1, evidence of a longer unvegetated period than the other two stations.

Macroalgae Cover

Macroalgae cover increased in 2016 compared to cover reported in 2015 (Figure BB-2b). The average macroalgae cover for Bullhead Bay in 2016 was 36%, which was up more than 10% from 2015. As in past years, the red, filamentous alga, *Spyridia filamentosa*, was the primary species observed in the meadow. Secondary species recorded include *Gracilaria* and *Ulva* species. *Chaetomorpha linum*, a green filament, was also observed forming tangled masses in the eelgrass canopy. *Cocchlodinium* (a.k.a. rust tide) was only found in isolated patches in Bullhead Bay, at densities much lower than noted in previous years.

Bed Delineation and Areal Extent

During the deployment and retrieval of the temperature arrays in Bullhead Bay in April and May, there were indications that there had been some changes to the extent and overall meadow density from 2015. The aerial imagery obtained from Google Earth™ from 11 May 2016 (Figure BB-3) shows significant changes in the northern section of the meadow, as well as some loss in the southeastern section as well, when compared to 2015 (Figure BB-4). Based on these delineations, there was an almost 6-acre loss of eelgrass in 2016 (Table BB-3), which represents a 14% decrease in acreage from the previous year.

Conclusions

Bullhead Bay saw some significant changes in 2016, with its first recorded decline in shoot density since the meadow started its recovery in 2011, but still, it is in better health than it was just six years ago. While the decrease in shoot density and acreage recorded for 2016 are disappointing, considering the relative health of the meadow over the last several years, there were

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2016.

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.)
2015	39.94 acres (16.16 hect.)
2016	34.21 acres (13.84 hect.)

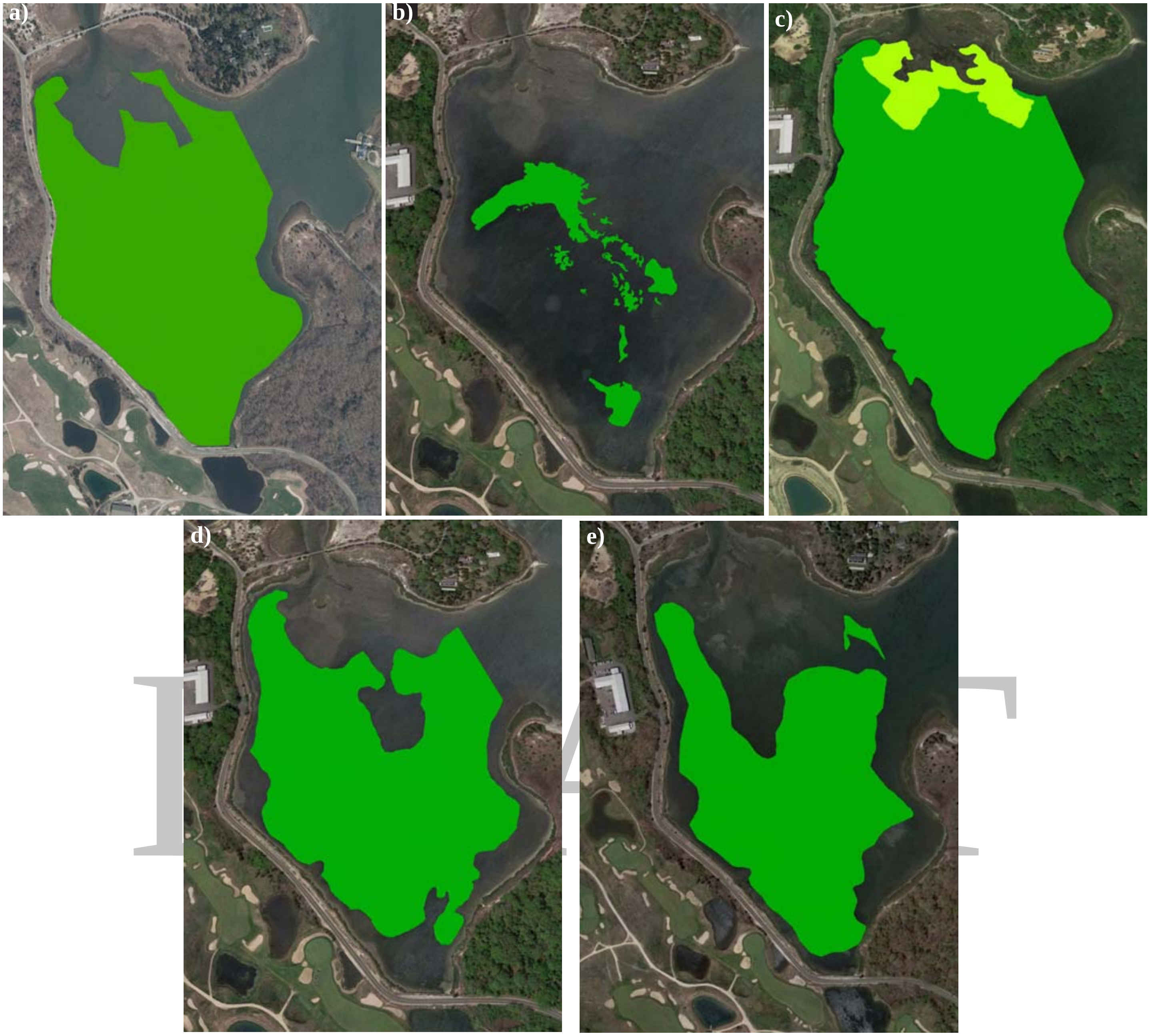


Figure BB-4. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2016. The years represented are a) 2000, b) 2010, c) 2014, d) 2015 and e) 2016.

indications from the monitoring in 2015 that suggested that the meadow might show a decline in 2016. Specifically, there was a significant loss in meadow acreage from 2014 to 2015 that included the complete loss of eelgrass around Station 1, and a substantial decline in the eelgrass around Station 2. The loss of eelgrass in 2015 from the area surrounding Station 1 was attributed to ice scour, but this was not a contributing factor to the continued decline in the northern section of the bay in 2016, as the winter was unusually warm and no significant ice was formed. Instead, the warm winter of 2016 may have provided opportunity for waterfowl to graze in the shallower sections of the meadow, potentially expanding the area of eelgrass loss reported in 2015. This suggestion that waterfowl could be impacting the Bullhead Bay eelgrass meadow is based on observations made by CCE staff while deploying temperature logger arrays in late April, 2016 and througout the summer of 2016. On 21 April, 2016, approximately 42 swans were observed actively grazing eelgrass in the northwest section of Bullhead Bay. The photograph in Figure BB-5 shows more than thirty swans congregated together in this section of the meadow. The presence of such a large number of swans in Bullhead Bay, if it becomes a more frequent event, could significantly impact the eelgrass meadow

Figure BB-5. A photograph of swans that were observed actively grazing on eelgrass in Bullhead Bay on 21 April, 2016. This group, numbering more than thirty swans, was part of a larger flock of forty-two swans encountered on this visit.

as mute swans have been found to consume approximately eight pounds (3.6 kg) of vegetation per day (Willey, 1968). That constitutes almost one square meter of eelgrass per swan per day consumed (based on biomass data from the 1997 LTEMP report taken at eelgrass shoot densities comparable to present densities). Swan grazing could account for a loss in eelgrass cover close to one-tenth of an acre per month with a resident population of two dozen birds. Swans have a feeding depth of approximately one meter, limiting them to the shallower areas of the bay, where the greatest loss in eelgrass cover has been observed. The swan population in late fall 2016 was not as large as observed during the spring and summer, so the presence of a large flock of swans in Bullhead Bay may not be a chronic issue. But, if Bullhead Bay becomes a gathering site for a large population of swans, we could see limited recovery of eelgrass in the shallow sections of the bay.

The eelgrass meadow may also have been impacted by the extended severe drought that the region has been experiencing. Drought conditions result in decreased submarine groundwater discharge which CCE has hypothesized may be one of the factors allowing eelgrass to survive in Bullhead Bay. The temperature array deployments (April-May and August-September) found almost no temperature differences between the sediment surface and loggers positioned within the eelgrass canopy (six and eighteen inches above sediment surface). This is a departure from the preliminary temperature array data that was collected in August and September 2015, that showed an obvious temperature gradient in areas of the meadow that had been determined to have significant submarine groundwater discharge. The drought conditions, coupled with the 2016 record warm temperatures, could have had an impact on the meadow that may not have been obvious during the 2016 monitoring, but may be seen in the 2017 season.

For the 2017 monitoring season, the normal monitoring activities (light and temperature logger deployment and LTEMP) will be continued and the temperature arrays will be deployed to gather more information on the influence of submarine groundwater discharge within Bullhead Bay. Additionally, models for determining eelgrass biomass, using minimally-destructive and non-destructive methods, will be tested to potentially add the ability to estimate eelgrass biomass to future LTEMP efforts, with limited impact to the subject meadow. Biomass calculations will provide another parameter for measuring the health of eelgrass meadows in the estuary and allow for assessment of current/future impacts on meadows, instead of relying on twenty year old data (e.g. the 1997 biomass estimates referred to in this report). Bullhead Bay may also be included in a latitudinal study of tunicate fouling of eelgrass that is being coordinated by researchers from Woods Hole Oceanographic Institution, and is an update to a study that Bullhead Bay was included in in 2014. The 2017 season looks to be a promising year for collecting new, and potentially revealing, information into the health and ecology of the Bullhead Bay eelgrass meadow.

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

Gardiners Bay 2016

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 2016.

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	13.9	+1.6	11.2	+3.2	23.6
August	13.0	+0.7	9.7	+1.7	25.4
September	9.9	-2.4	6.5	-1.5	22.6

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 into the site by 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 logger deployments for the 2016 season were conducted for ten-day periods, monthly, from July-September 2016. Light data is summarized in Table GB-2, above, and shows that the eelgrass meadow at the Gardiners Bay site exceeded its daily requirement for both Hcomp and Hsat for the months of July and August. In September, the site experienced deficit in Hcomp and Hsat, which was expected, based on previous years' data, due to seasonal change in weather patterns (e.g. increased wind and rain) and shortening days.

As stated in the 2015 report, water temperature stress had not been a parameter of concern in the Gardiners Bay meadow due to its location in the estuary, however, 2015 recorded daily eighteen days with average water temperatures greater than 25°C and a high temperature of 26.55°C. The 2016 season exceeded the 2015 season with twenty-four days greater than 25°C and a slightly higher maximum daily average temperature of 26.7°C. This represents a troubling trend for the estuary, if it continues, as with each successive warm year, we may see a shift in the onset date of high water temperatures to earlier in the season, an increase in the duration of the high water temperature period, and increased maximum water temperatures experienced by eelgrass meadows.

Eelgrass Shoot Density

The 2016 LTEMP was conducted on 30 August, 2016 at Gardiners Bay. As mentioned in previous reports, currently only three monitoring stations (6,7, and 8) support eelgrass at this time. The quadrat survey found no significantl change in eelgrass shoot den-

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2016, 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
2015	70	+/-15
2016	96	+/-20

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

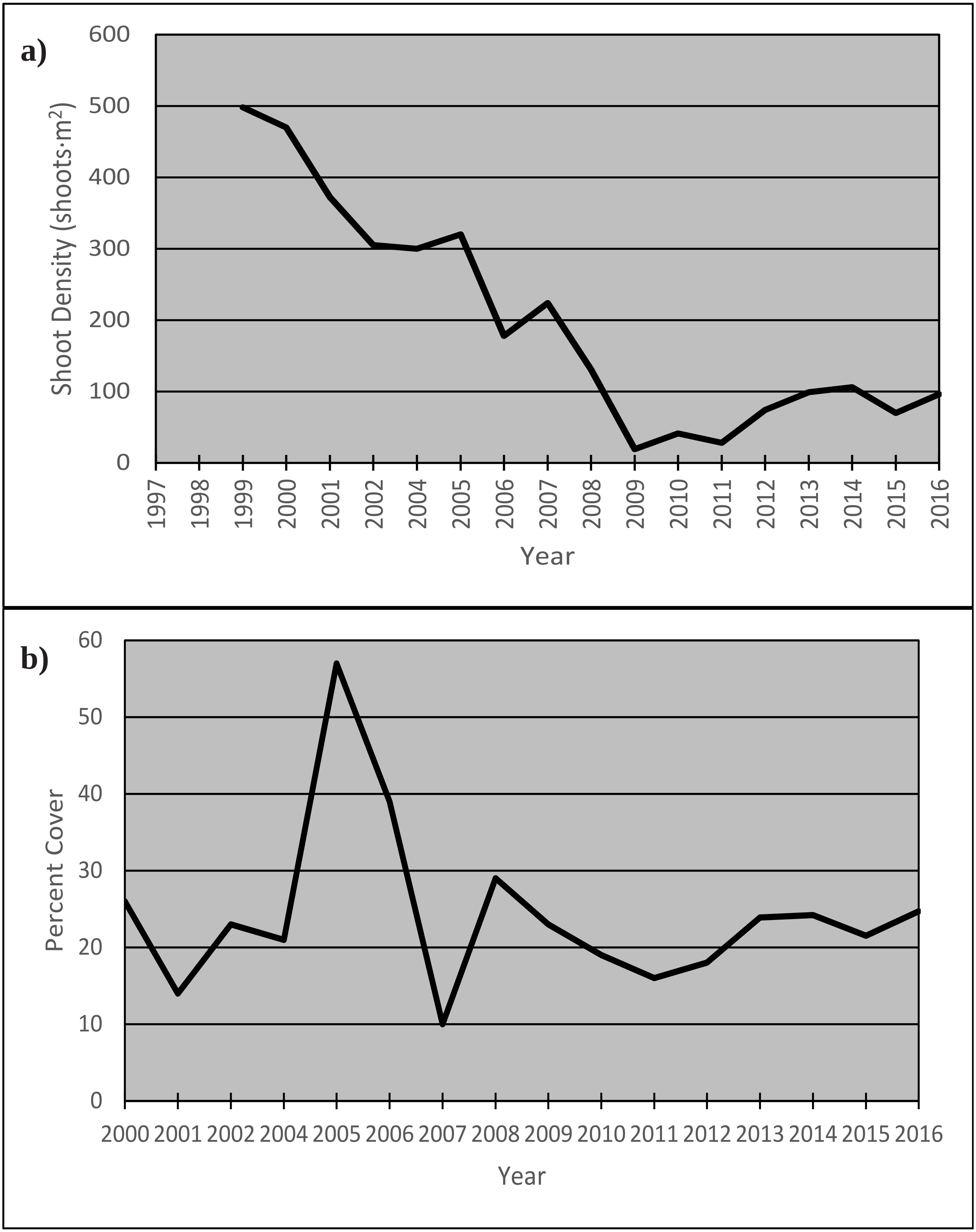


Figure GB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted at the Gardiners Bay site.

Figure GB-3. The 2016 areal delineation of the Gardiners Bay eelgrass meadow on the northeast shore of Shelter Island, NY.

sity from 2015 to 2016 (Table GB-2; Figure GB-2a). The average shoot density for the meadow was up slightly to 96 shoots·m^2 from 70 shoots·m^2 in 2015. When considering just the three stations that recorded eelgrass, the average shoot density for 2016 was 251 shoots·m^2, almost recovering to the 2014 density of 267 shoots·m^2.

Macroalgae Cover

Macroalgae cover saw little change between 2015 and 2016 (Figure GB-2b) with a 3.2% increase in 2016. Fourteen species of macroalgae were identified in 2016 with the most common species including the red seaweeds *Spyridia filamentosa, Agardhiella tikvahiae* and *Gracilaria* species. As with previous years, drift macroalgae dominates the site as they are caught in the eelgrass meadow as they are carried by the high currents. Species that were transported from outside of the meadow by the current include *Chondrus crispus*, *Fucus distichus,* and *F. vesiculosus*, which require larger, hard substrate for attachment. The invasive, red seaweed *Grateloupia turuturu* observed at the site in 2015, was not identified in 2016.

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2016.

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.)
2015	27.25 acres (11.03 hect.)
2016	29.08 acres (11.77 hect.)

Bed Delineation and Areal Extent

The 2016 bed delineation was completed using Google™ Earth imagery taken on 11 May, 2016. The imagery over the Gardiners Bay site was better than the 2015 imagery in terms of sun glare and waves over the site, making delineation easier, and likely more accurate. The delineation for 2016 shows an estimated areal coverage of 29.08 acres, an increase of just under 2 acres from 2015. This increase likely represents little actual change in the overall acreage of the meadow, but instead may reflect the better quality of the 2016 imagery. With that said, the 2016 imagery does show some consolidation in the middle of the meadow, especially along the inshore edge, where in 2015, unvegetated patches occupied much larger areas. While the center of the meadow may be recolonizing open areas, we are seeing more unvegetated patches continuing to open up along the offshore edge of the meadow, especially in the northwest and southeast sections.

Conclusions

The 2016 monitoring season found the Gardiners Bay eelgrass meadow had shown some recovery from the minor decline reported in 2015. The 2016 shoot density almost recovered to the recent high level achieved in 2014. Water temperature stress, once not a threat to this meadow, may need to be added to the list of factors negatively impacting this meadow along with exposure to storms, high currents, and anthropogenic impacts. With this trend (though only two years), we may expect to see water temperatures to exceed eelgrass optimal tempertures earlier in the season and maintain these high temperatures for longer periods

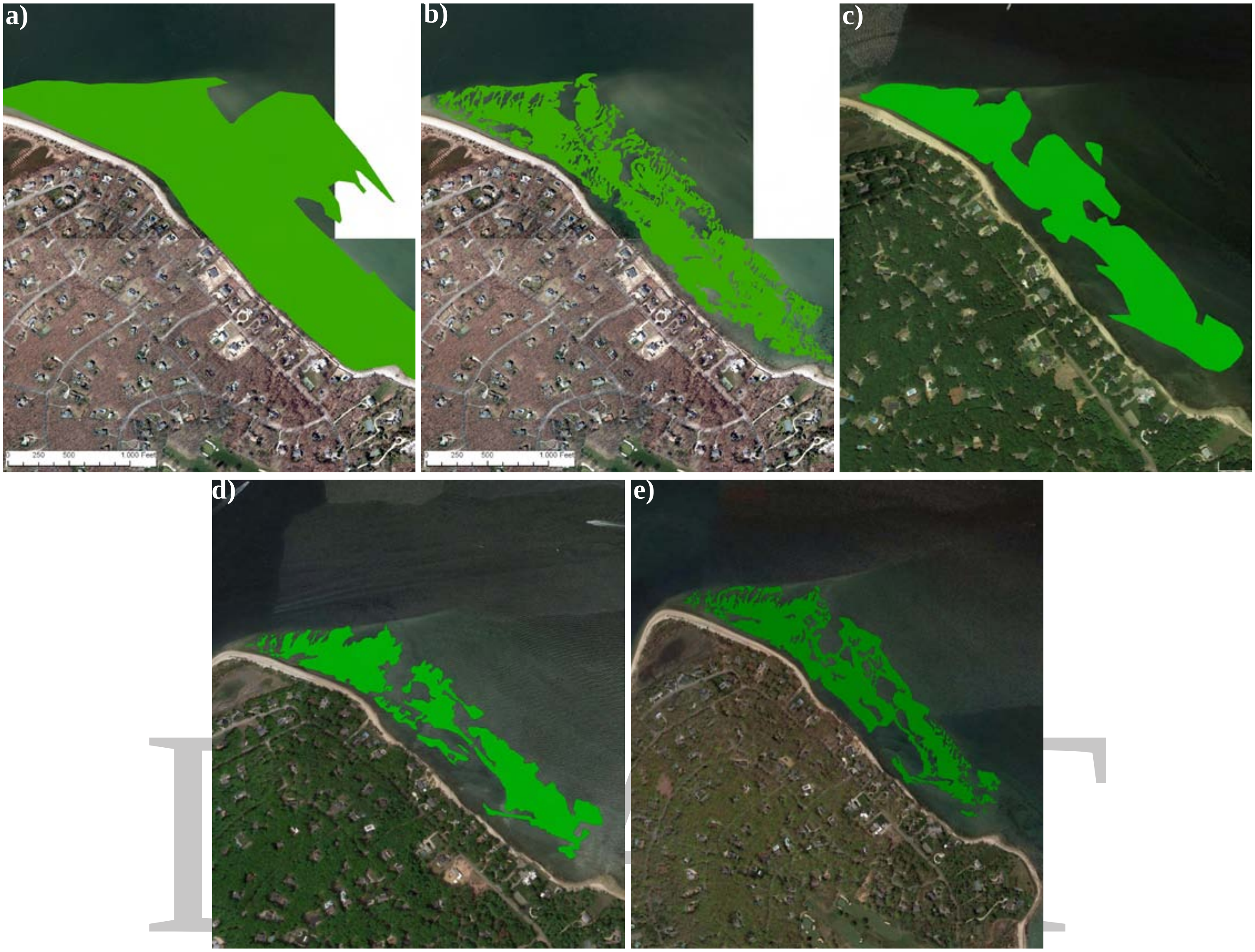


Figure GB-4. A series of aerial delineations of the Gardiners Bay eelgrass from select years from 2000 through 2016. The years represented are a) 2000, b) 2010, c) 2014, d) 2015, and e) 2016.

of time. Based on the light and temperature work that CCE has conducted in the Peconic Estuary, thirty days, or more, with temperatures above 25°C, may be one of the thresholds that indicates that an eelgrass meadow may begin to decline. Areal extent of the meadow was not found to have changed significantly from 2015. Inshore sections of the meadow that were patchy in 2015 seemed to have consolidated in 2016, while, at the same time, the offshore edge has become more patchy, as is evident in Figures GB-4d and e.

While there is little that can be done in the short term to deal with climate-related stresses to this meadow, steps can be taken to reduce human-induced impacts that have been an issue for this meadow and have been discussed in previous LTEMP reports. The reduction of boat traffic close to and through the eelgrass meadow could significantly decrease the rate of fragmentation of the meadow. Actions to reduce anthropogenic impact would include new aid-to-navigation outside of the meadow that directs boat traffic to the main channel and working with the Town of Shelter Island to assess the impacts of moorings and shellfishing on the eelgrass meadow at this site.

Figure GB-5. Underwater photographs taken during the 2016 monitoring at the Gardiners Bay LTEMP site of a) a bug scallop attached to a clam shell within the eelgrass meadow and b) a scup/porgy foraging outside of an eelgrass patch near Station 8.

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 meadow's 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 on the bottom. 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 generally not an issue in Northwest Harbor, water clarity can be very low at times. Even under the moderate winds that the Harbor experiences, a good amount of

Northwest Harbor 2016

Table NWH-1. The average annual eelgrass shoot density for Northwest Harbor from 1997 to 2016, 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
2015	0	+/- 0
2016	0	+/- 0

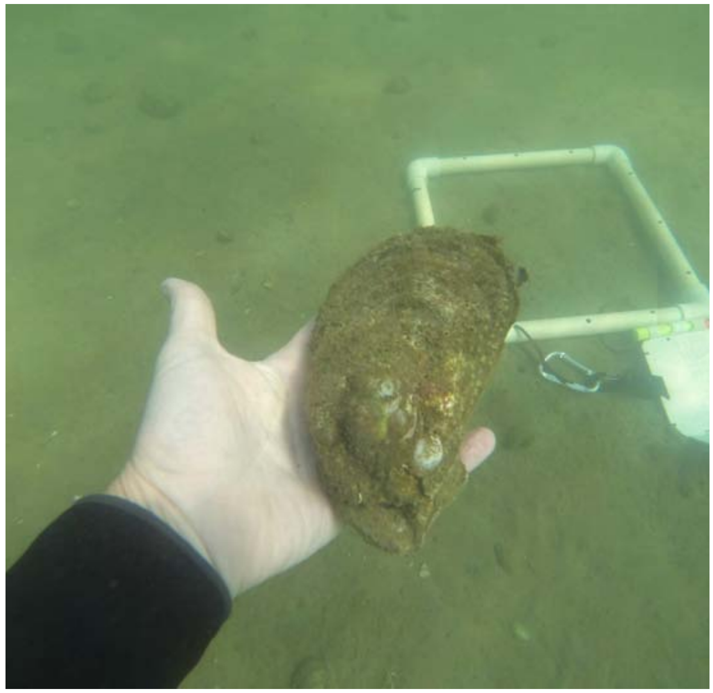


Figure NWH-2. With relatively little macroalgae or scallops on the bottom, this large oyster made for an exciting find.

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

Eelgrass Shoot Density

The monitoring visit to Northwest Harbor took place on 6 September, 2016. No eelgrass or evidence of eelgrass (floating shoots or rhizomes sticking out of the sediment) was observed (Table NWH-1 and Figure NWH-3).

Macroalgae Cover

Macroalgae was at its lowest recorded cover in 2016 with an average percent cover of only 0.5% (Figure NWH-4). Hard substrate (e.g. shell, worm tubes, etc.) for macroalgae to attach to is scarce over much of the bottom in Northwest Harbor, which, with the loss of eelgrass, greatly reduces the opportunities for macroalgae to recruit to the site.

Conclusions

There is little possibility that there is extant eelgrass or the potential of recruitment into Northwest Harbor from nearby meadows. During visits to Northwest Harbor for the monitoring and other projects, no signs of eelgrass, either exposed rhizomes on the bottom or floating shoots on the surface, have been observed. Based on this current assessment, and those of the previous nine years, it may be time to consider removing Northwest Harbor from active monitoring and replace it with an extant meadow at another site in the estuary. This site could be added to the group of other former eelgrass meadows that could be monitored at a frequency of every three to five years, instead of annually. This would allow for the LTEMP to monitor sites supporting populations of eelgrass, while periodically checking in on these former meadow sites to verify that they have not seen recruitment of a new eelgrass population.

The restoration potential of Northwest Harbor has not been recently evaluated. With the new hypothesis that submarine groundwater discharge may mitigate temperature stress in eelgrass, there may be sections of the harbor that are viable candidates for eelgrass test plantings, if they can be identified. Also, a current assessment of temperature and light regimes within the harbor will need to be completed to identify if these parameters may have attributed to the rapid decline of eelgrass or if it was another factor(s) that have not

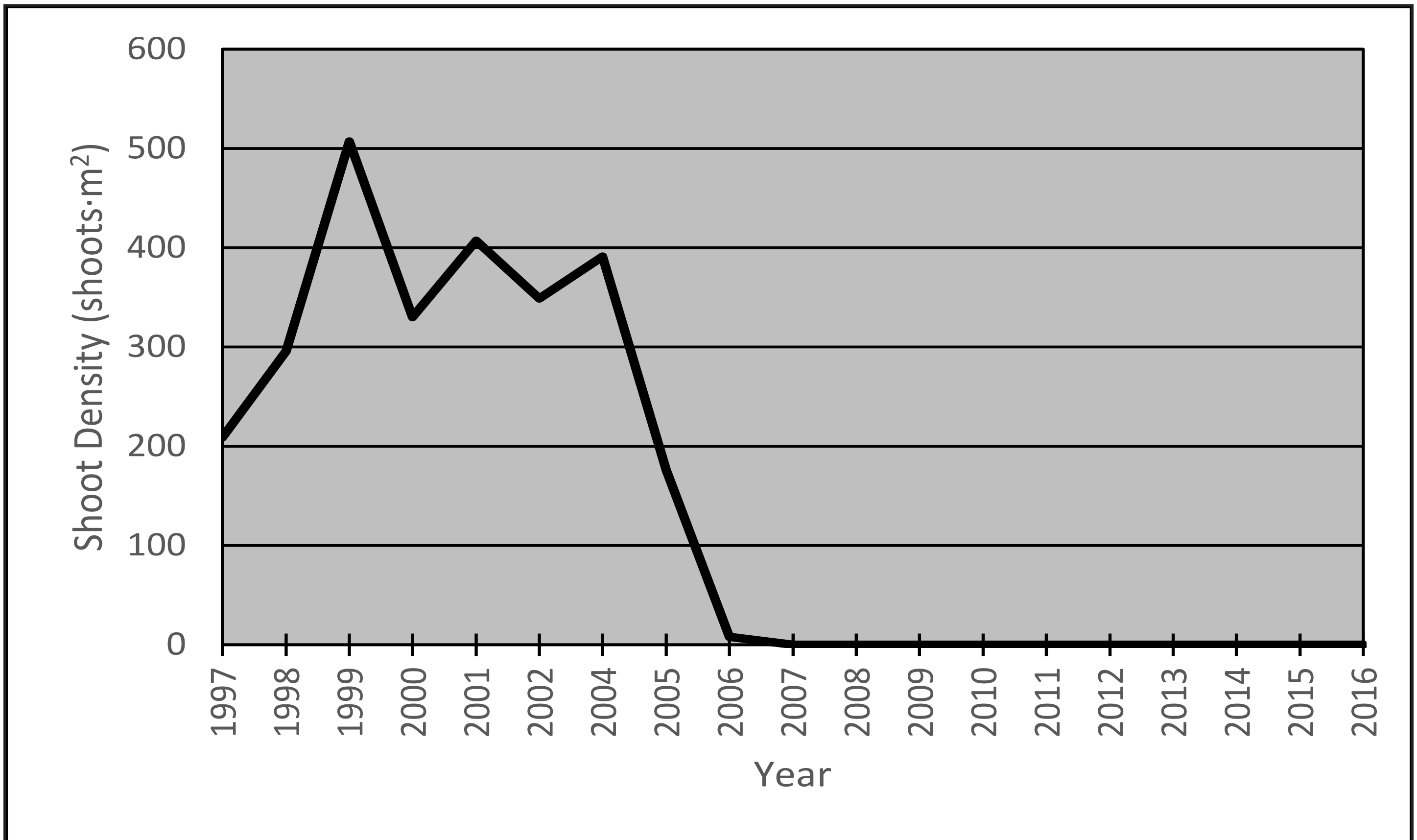


Figure NWH-3. Average annual eelgrass shoot density for Northwest Harbor, East Hampton.

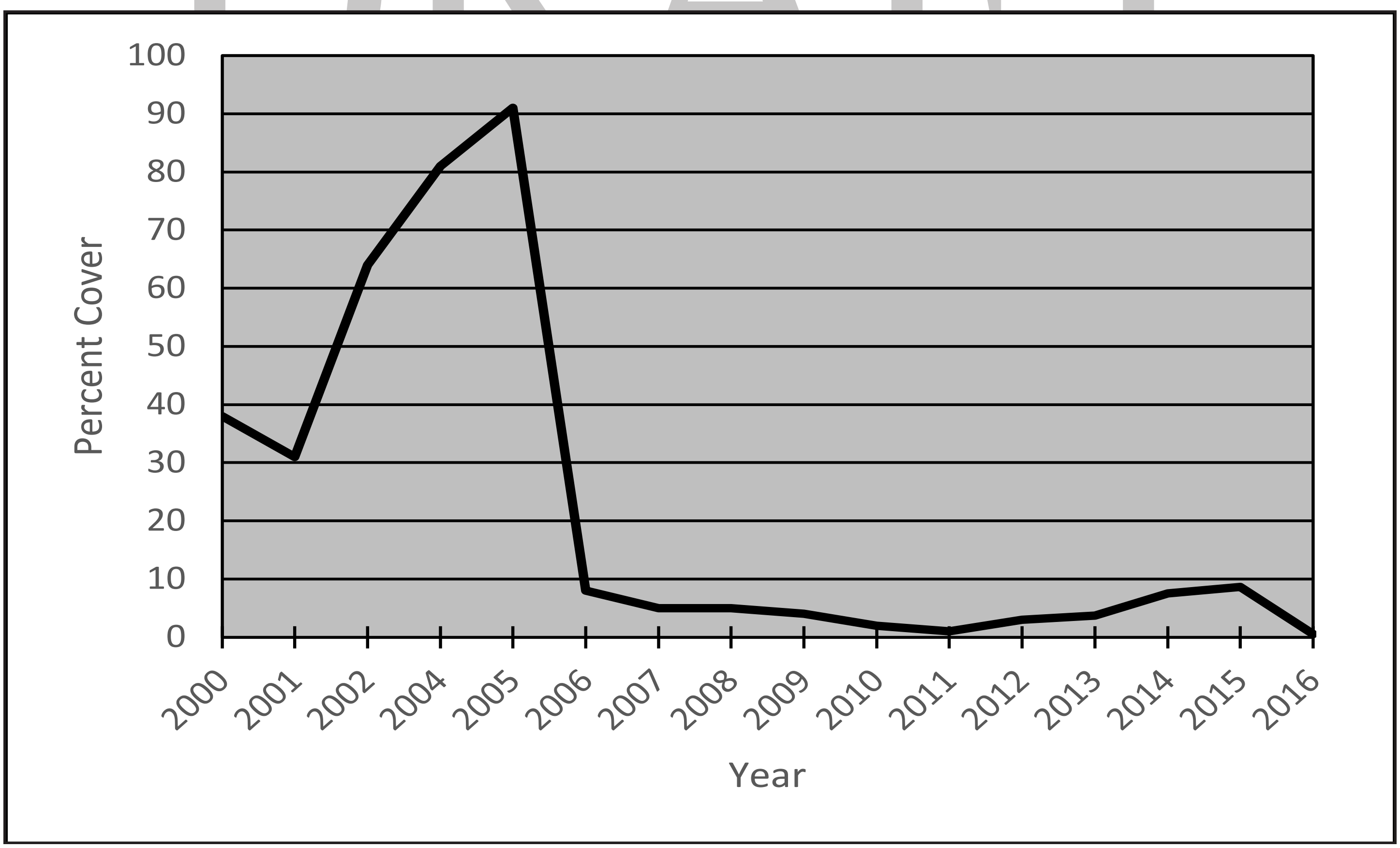


Figure NWH-4. Annual mean macroalgae cover for Northwest Harbor, East Hampton from 2000 to 2016.

yet been identified. If any restoration efforts are to be made in Northwest Harbor, it will require time to properly evaluate the potential of the site.

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 LTEMP site, 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 was that groundwater inputs of nutrients (i.e. nitrogen) and herbicides could have a direct impact on eelgrass in some areas of the Peconic 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 study this issue throughout the Peconic Estuary, with Orient Harbor as a potential site for analysis.

In the past several years, phytoplankton blooms, *Cochlodinium polykrikoides* (aka, rust tide), have been a common occurrence during late summer in Orient Harbor. The extent of the blooms have varied from scattered ribbon-like bands to concentrated, large patches. The impact of these blooms on a system are not fully understood, but they can influence shellfish health and could shade any plants, seagrasses or macroalgae, occurring under them.

Temperature

Water temperature data for Orient Harbor was collected by the USGS water quality monitoring station (USGS 01304200 Orient Harbor at Orient, NY) located at the Orient Yacht Club pier, which collects a suite of water quality data and reports in real time. Data from the station was downloaded and average monthly temperatures were calculated and presented in Table OH-1. August 2016 was the only month where water temperatures averaged above 25°C, and monthly average temperature may actually be higher, as the station's data for the month was incomplete (20 days were not recorded). The number of days with water temperatures greater than 25°C were tallied (Table OH-1). Orient Harbor experienced at least fourteen days with temperatures greater than 25°C in 2016, leaving it well below the 30 day threshold, however with the incomplete dataset for August, this number is likely higher, given that twenty days during the middle of August were not recorded. Without the missing temperature data, an accurate comparison to 2015, with 33 days greater than 25°C recorded, can not be made. However, given that 2016 was the warmest year on record, and trends seen at other LTEMP sites, the likelihood that Orient Harbor reached the 30 day point is high.

Table OH-1. The monthly average water temperatures take by the USGS water quality buoy stationed in Orient Harbor for June-September 2016. Also noted is the total days that daily average water temperatures met or exceeded 25°C.

Month	**Ave. Water Temperature (°C)**	**Days ≥ 25°C**
June	19.7	0
July	23.8	3
August	25.4*	10
September	22.6	1

**Incomplete monthly dataset*

Eelgrass Shoot Density

The 2016 eelgrass monitoring in Orient Harbor was conducted on 30 August, 2016. No evidence of eelgrass, floating shoots or exposed rhizomes, was recorded within the monitoring area (Table OH-2; Figure OH-2). Interviews with two baymen that scallop extensively in Orient Harbor found that no eelgrass

Table OH-2. The average annual eelgrass shoot density for Orient Harbor from 1997 to 2016, 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
2015	0	+/- 0
2016	0	+/- 0

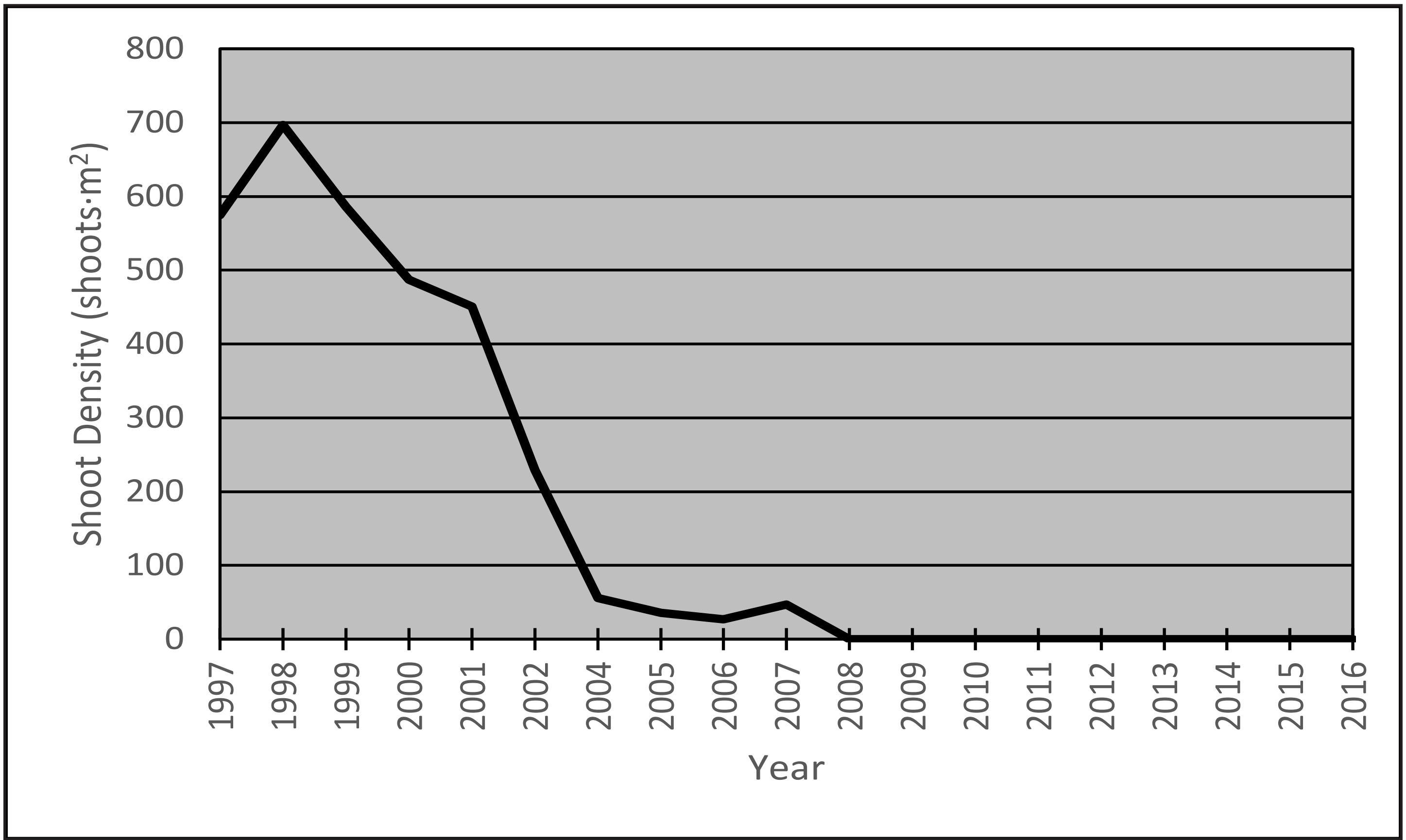


Figure OH-2. Average annual eelgrass shoot density for Orient Harbor, Southold.

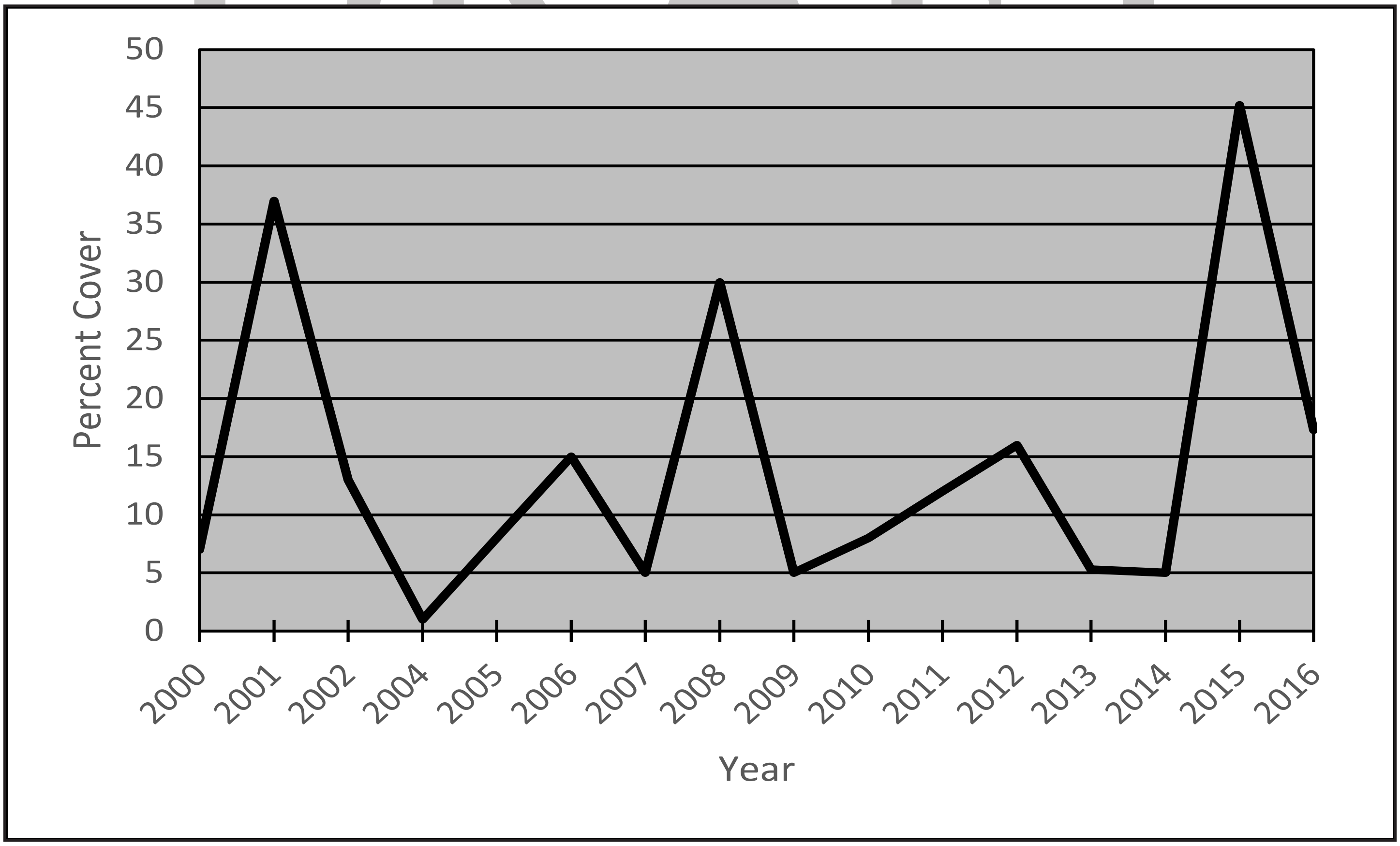


Figure OH-3. Annual mean macroalgae cover for Orient Harbor, Southold from 2000 to 2016.

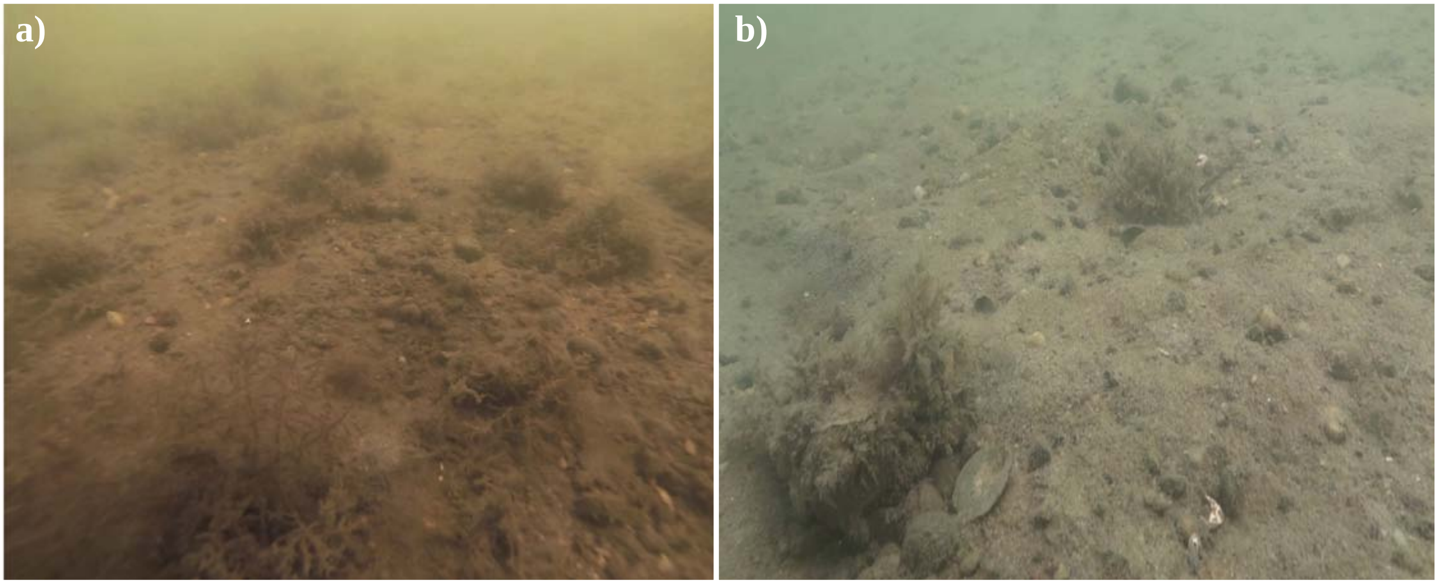


Figure OH-4. Photographs illustrating bottom conditions in Orient Harbor in 2016 at a) Station 2 and b) Station 4. The overall macroalgae cover was down in 2016, leaving the bottom with relatively few places for fish to hide.

has been seen in several seasons. The reports of "new meadows" in Orient Harbor from 2015 could not be substantiated.

Macroalgae Cover

After a spike in macroalgae cover was recorded in 2015, Orient Harbor recorded a significant drop in macroalgae percent cover in 2016 (Figure OH-3). Macroalgae averaged 17.3% in 2016, down from 45% in 2015. Only five species of algae were identified at the site, all red, with *Spyridia filamentosa* the most common species reported in Orient Harbor.

Conclusions

The 2016 monitoring season was the ninth season that no eelgrass had been reported in Orient Harbor. The 2014 aerial survey failed to identify extant eelgrass in the bay and reports from two baymen have yielded no leads to the location of eelgrass in Orient Harbor. Environmental conditions in the harbor are becoming less favorable to eelgrass recruitment with high water temperatures in the last two years persisting for extended periods of time, making it less likely that natural recruitment or focused restoration would be successful.

It may be time to reduce the frequency of monitoring at this site in favor of adding an extant meadow to the LTEMP. While Orient Harbor would not be abandoned, monitoring visits would be reduced to once every 3-5 years. If eelgrass were to be re-established in the harbor, it could be returned to an annual monitoring schedule.

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 former meadow from Hashamomack Pond may influence the temperature experienced by this site. Warm water temperatures within the Southold Bay are thought to have contributed to the chronic stress that the eelgrass population faced, before its extinction at this site. The shallow nature of the bed also allowed for rapid warming, especially on calm, summer days.

Southold Bay 2016

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 2016.

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	13.0	+0.7	7.7	-0.3	24.9
August	12.2	-0.1	6.5	-1.5	26.2
September	10.2	-2.1	4.4	-3.6	22.8

The waters that the Southold Bay site receive from the flushing of Hashamomack Pond not only influence temperature, as noted above, but also expose the site to nutrient-laden water. Nutrient-laden water causes increased phytoplankton and macroalgae biomass, which can decrease light availability and reduce eelgrass growth.

Light Availability and Temperature

Light loggers were placed at the Southold Bay site for one week each month, July through September, 2016, and the average Hcomp and Hsat for each month's deployment are presented in Table SB-1, above. The light logger data for 2016 found poorer water clarity, compared to 2015, with the site running deficits for Hcomp for August and September, and Hsat level failing to meet the minimum requirements for the three month period. It was suggested in the 2015 report that the drought conditions may have been responsible for improved water clarity in 2015, but, as the drought has extended into 2016 and clarity has declined, this may not be the case.

The 2016 monitorng season recorded a greater number of days with the site experiencing water temperatures above 25°C in Southold Bay, than 2015. Daily average water temperatures exceeded 25°C forty-nine days in 2016, with a maximum daily average temperature of of 27.6°C (a full degree greater than 2015). This may be due to the very mild winter of 2016 allowing local waters to start at a warmer temperature, earlier in the season.

Eelgrass Shoot Density

The 2016 monitoring visit reported no eelgrass within the monitoring area, or adjacent areas, for the Southold Bay site (Table SB-2; Figure SB-2). Due to its relatively isolated location from extant meadows, it is unlikely that natural recruitment would occur and conditions are unfavorable for restoration.

Macroalgae Cover

Macroalgae cover remained below 10% for the second straight season (Figure SB-3). A total of nine species of macroalgae were identified in 2016, with *Sargassum filipendula* dominating the northern section of the meadow (primarily attached to boulders), and the filamentous, red seaweeds, *Spyridia filamentosa* and *Polysiphonia* species becoming more common on shell and gravel outside of that area.

Conclusions

Water quality conditions in Southold Bay continue to be sub-optimal for eelgrass survival and would likely prove lethal to natural or artificial attempts to establish eelgrass at the site. It has been suggested in this report for other LTEMP sites that no longer support eelgrass

Table SB-2. The average annual eelgrass shoot density for Southold Bay from 1997 to 2016, 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
2015	0	+/- 0
2016	0	+/- 0

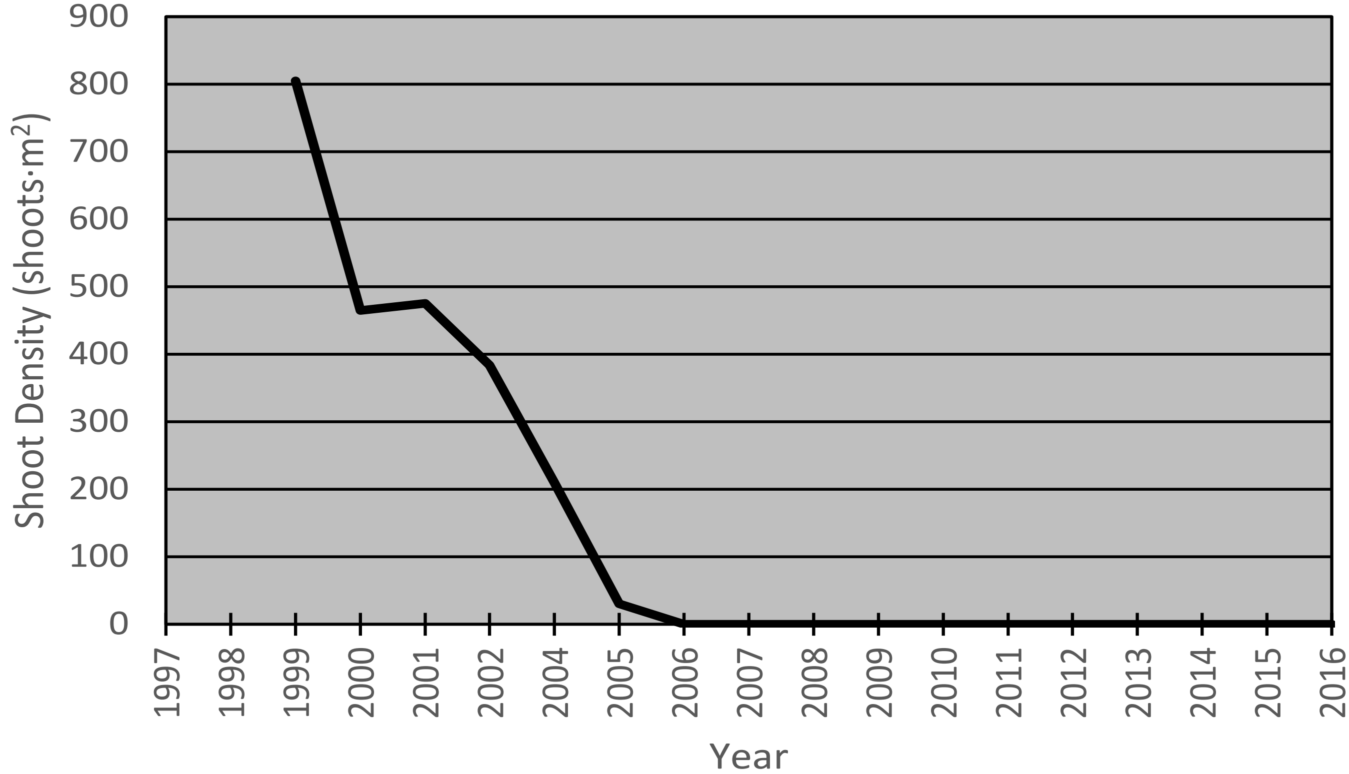


Figure SB-2. Average annual eelgrass shoot density for Southold Bay, Southold.

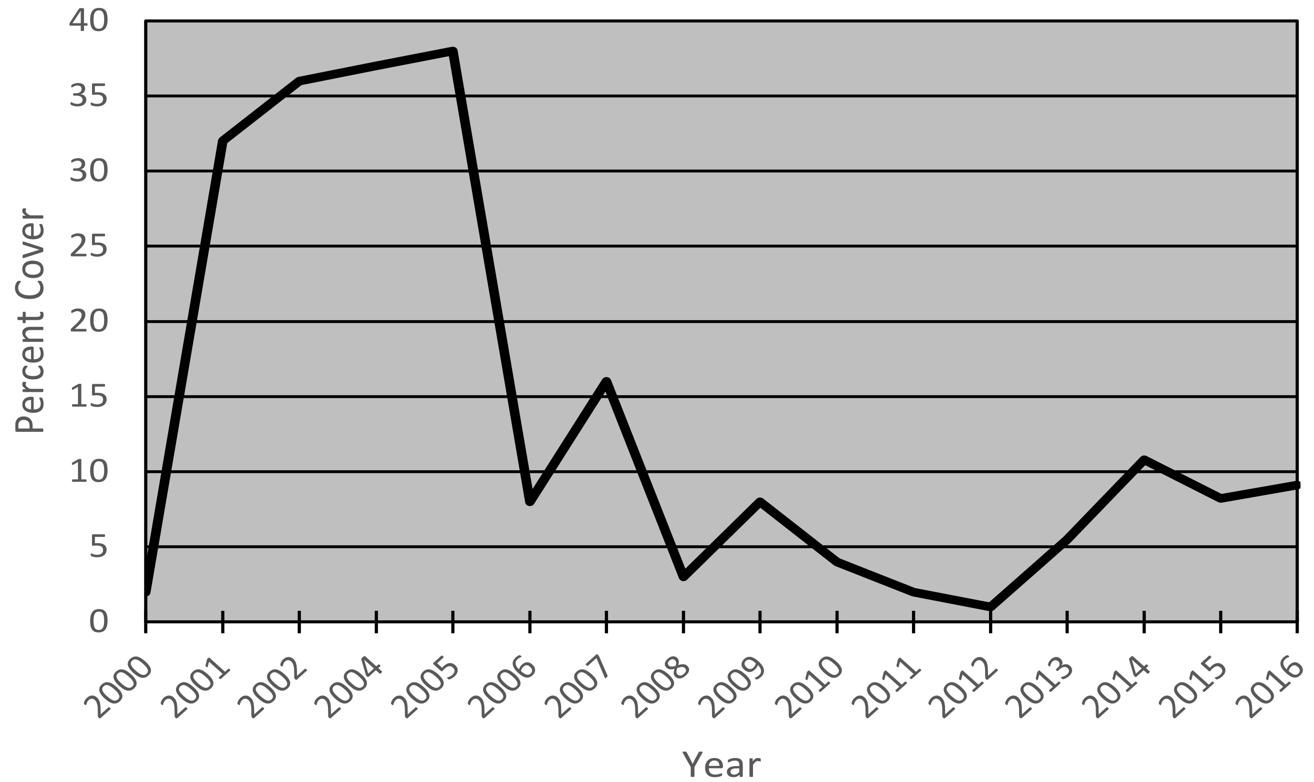


Figure SB-3. Annual mean macroalgae cover for Southold Bay from 2000 to 2016.

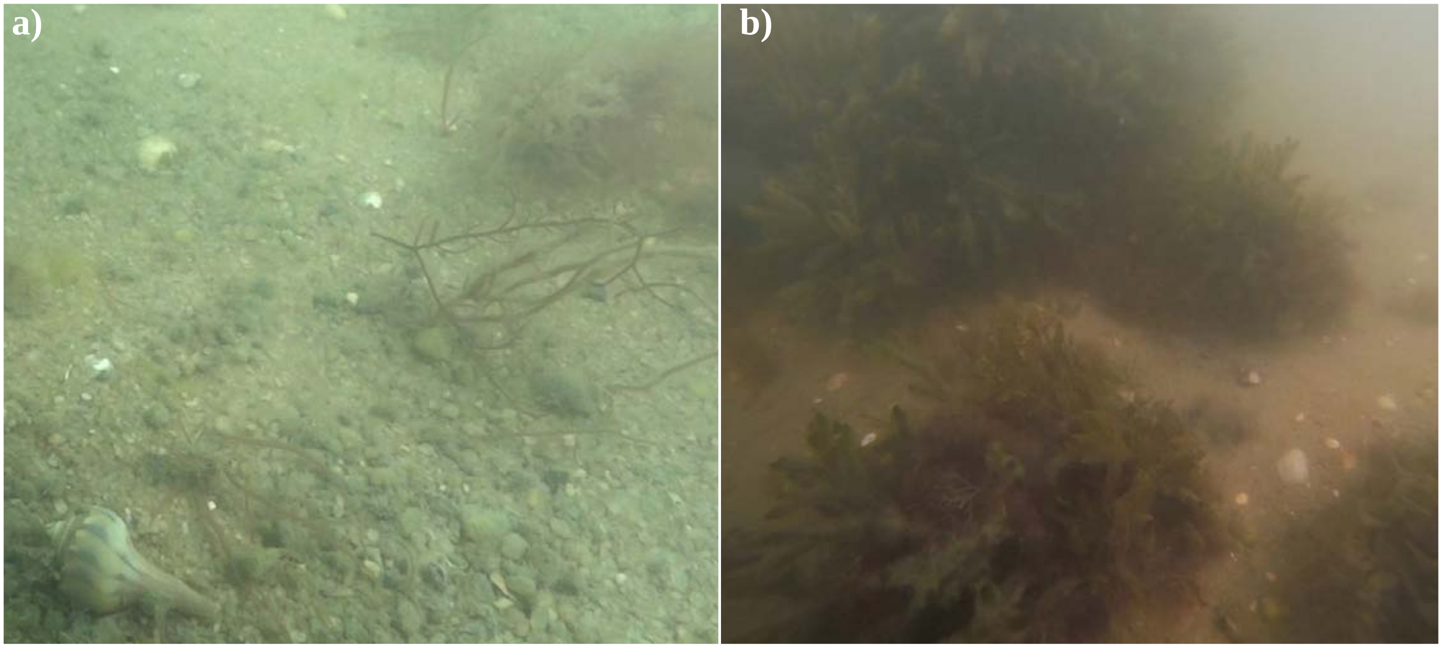


Figure SB-4. Photographs taken during the 2016 LTEMP monitoring of Southold Bay. a) A juvenile knobbed whelk forages for food. b) Macroalgae growing on boulders located at the northern end of the site near Station 1.

meadows that the frequency of monitoring visits be reduced to once in a 3-5 year period, and Southold Bay would be a good candidate for this measure as well. In its place, a site supporting a healthy meadow would better serve to provide valuable data on the health of eelgrass populations in the estuary and allow for better management of this resource.

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).

During the 2014 Peconic Estuary Eelgrass Aerial Survey, three extant eelgrass meadows near the headwaters of Three Mile Harbor were identified (Figure TMH-2). During the 2015 monitoring season, one of these meadows (indicated in Figure TMH-2 within the white oval) had temperature and light loggers deployed to it and ten quadrat counts were completed along its length.The deployment of temperature and light loggers to this meadow were continued in 2016, as was the quadrat survey.

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

Figure TMH-2. An aerial view of the headwaters of Three Mile Harbor showing the three extant beds of eelgrass discovered during the 2014 aerial survey.

Three Mile Harbor 2016

Table TMH-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers for two sites in Three Mile Harbor for 2016.

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)
Three Mile Harbor LTEMP Site					
July	14.0	+1.7	11.7	+3.7	24.4
August	13.2	+0.9	11.2	+3.2	25.7
September	11.00	-1.3	7.6	-0.4	22.2
Three Mile Harbor New Meadow					
July	14.0	+1.7	11.6	+3.6	24.7
August	13.0	+0.7	10.7	+2.7	25.7
September	Logger Failed	ND	Logger Failed	ND	22.4

Site Characteristics

The LTEMP 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 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.

Sediment samples for the new meadow have not been taken, but they will be collected in 2017 when a complete sediment survey will be conducted for all LTEMP sites.

Light Availability and Temperature

The light and temperature logger deployment at both the original Three Mile Harbor LTEMP site and the "new" meadow were continued in 2016 (Table TMH-1). The two sites showed similar results in Hcomp and Hsat for the season's deployments. Both sites experienced light levels that exceeded minimum requirements for Hcomp and Hsat for July and August. September light data reported a deficit at the LTEMP site, with no data collected at the "new" meadow due to a failure of the logger to collect data. With the light data from both sites trending so closely, it is likely that the "new" meadow did not meet the minimums for Hcomp or Hsat for the month of September.

Water temperature loggers were deployed to both the LTEMP and "new" sites on 8 June, 2016. Water temperatures did not differ significantly between the two sites, with monthly averages separated by only a few tenths of a degree (Table TMH-1). The "new" site recorded a higher maximum daily temperature of 28.5°C, with the LTEMP site almost a degree lower at 27.8°C. The "new" site also experienced more days with temperatures ≥25°C, with a total of 39. The LTEMP spent 35 days above 25°C.

Table TMH-2. The average annual eelgrass shoot density for Three Mile Harbor from 1997 to 2016, 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
2015	0	+/- 0
2016	0	+/- 0

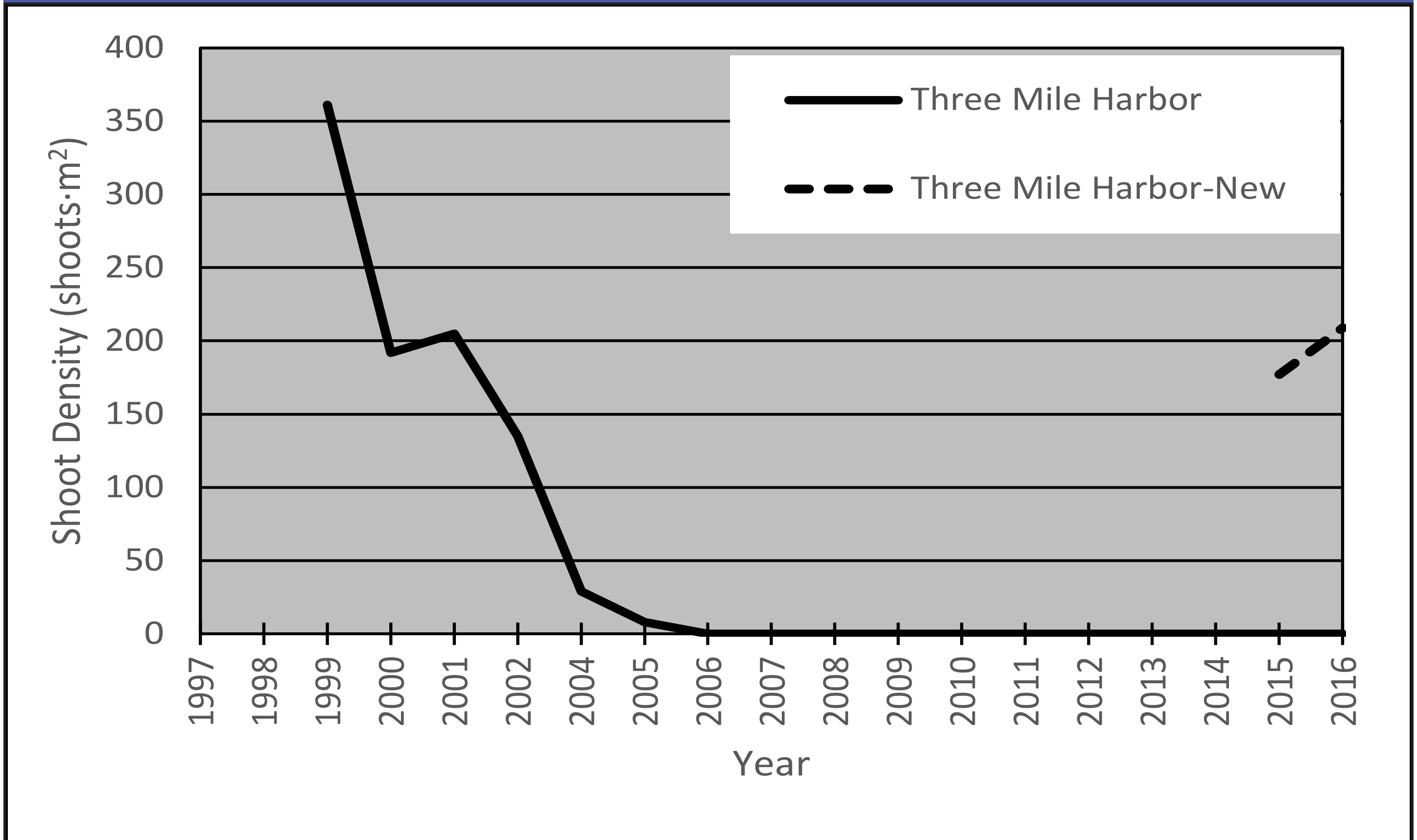


Figure TMH-3. Average annual eelgrass shoot density for Three Mile Harbor, East Hampton.

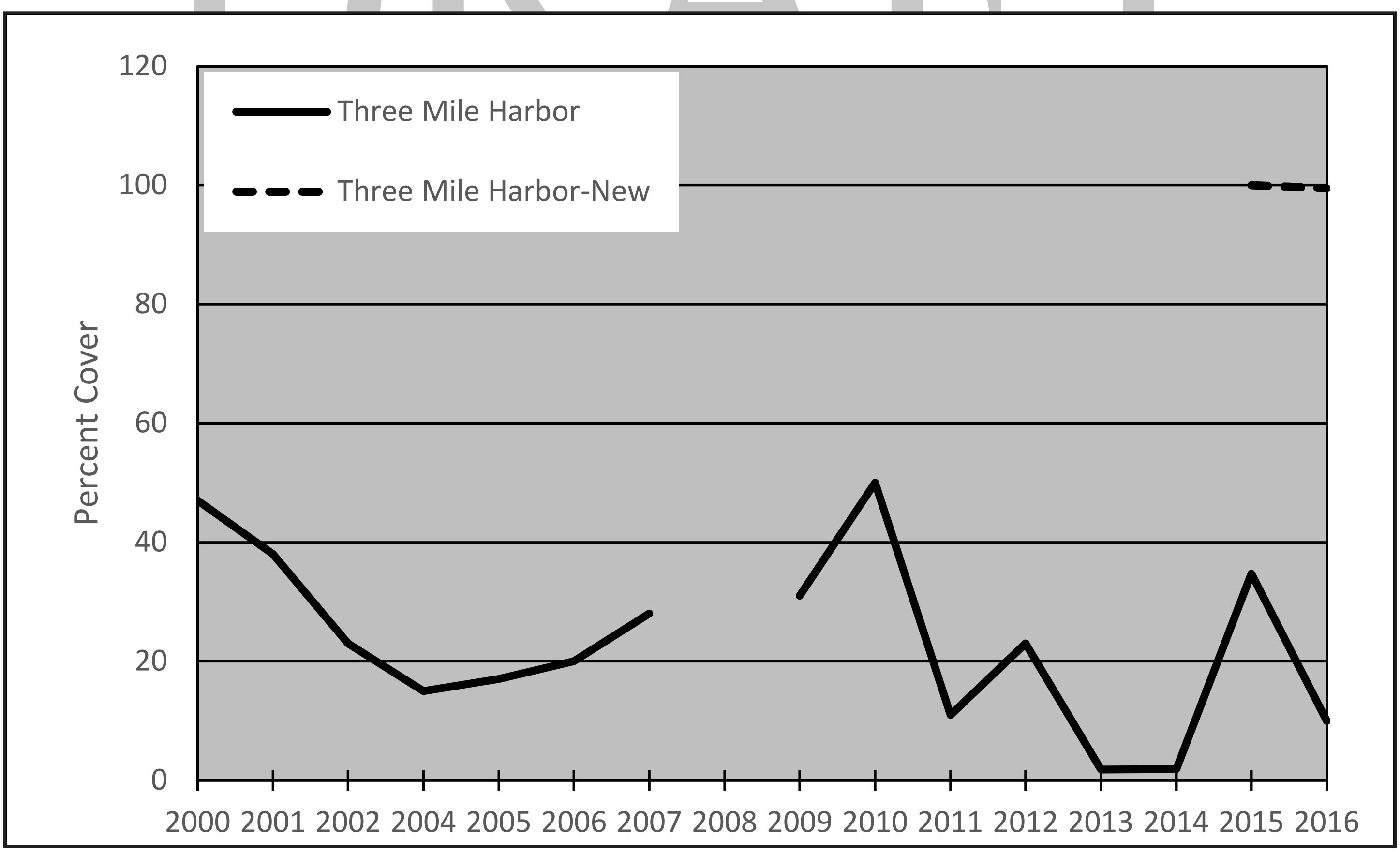


Figure TMH-4. Annual mean macroalgae cover for Three Mile Harbor from 2000 to 2016.

Figure TMH-5. An aerial view of the head of Three Mile Harbor and the location of the small meadow that constitutes the “new” meadow monitored during the LTEMP.

Eelgrass Shoot Density

Three Mile Harbor was visited on 23 August, 2016 for its annual monitoring visit. Both the LTEMP site and “new” meadow were surveyed. The LTEMP site had no observable eelgrass for the eleventh season (Table TMH-2; Figure TMH-3). The “new” site reported an average eelgrass shoot density of 209 shoots·m^2, an increase from the 2015 density of 177 shoots·m^2 (Figure TMH-3). Unlike in 2015, *Ruppia maritima* (widgeongrass) was not observed wihin the quadrats sampled, however, divers did report seeing *Ruppia* scattered throughout this meadow in small patches.

Macroalgae Cover

Macroalgae cover experienced a significant decline in 2016 from the previous year (Figure TMH-4) with the average percent cover dropping almost 25% at the LTEMP site. The primary species observed was the red, filamentous algae, *Spyridia filamentosa.* Including *Spyridia*, only 5 species of macroalgae were observed at the LTEMP site for 2016.

The “new” site saw minimal changes from 2015 to 2016 (Figure TMH-3). The macroalgae cover declined slightly from 100% cover in 2015 to 99.5% cover in 2016. The “new” meadow continued to be dominated by the red algae *Spyridia filamentosa*, with only one other species observed within the meadow, *Chaetomorpha linum* (green, filamentous alga).

Bed Delineation and Areal Extent

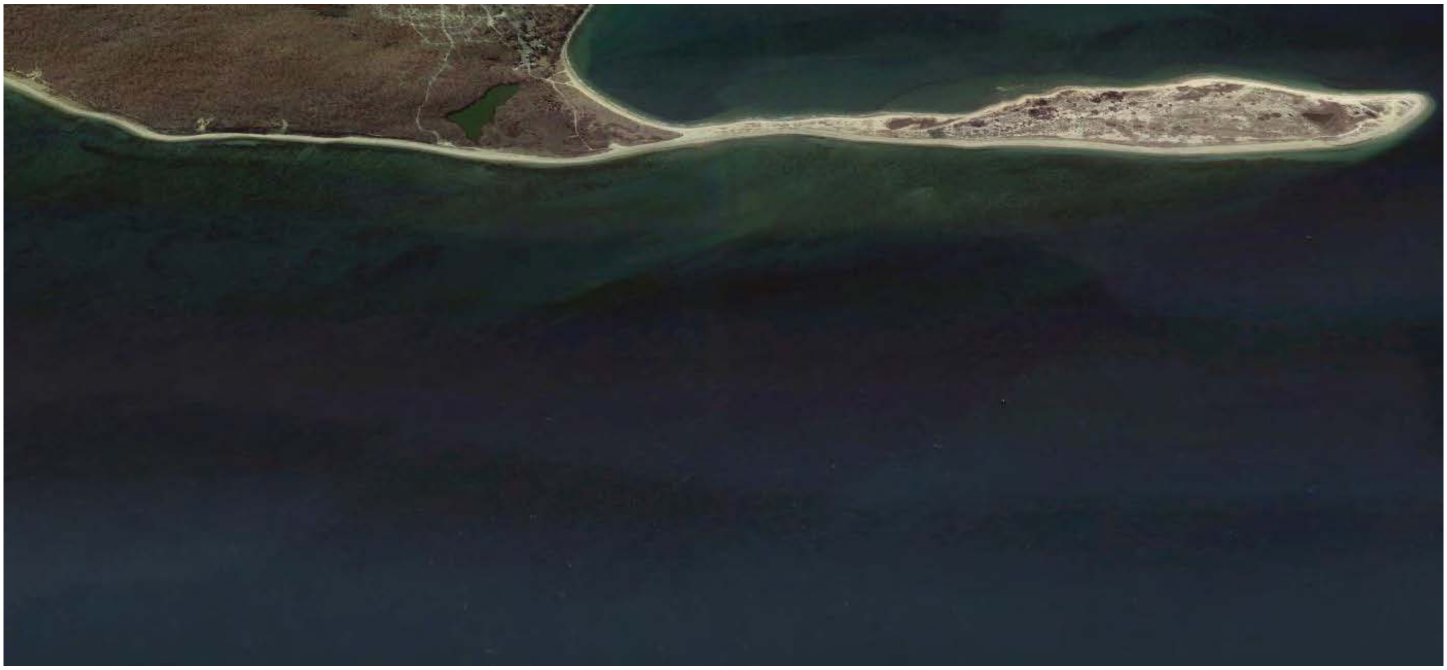
Google™ Earth imagery taken on 11 May, 2016 was analyzed and the “new” meadow was delineated (Figure TMH-5). The “new” meadow was found to cover 0.68 acres, which was a slight increase of 0.10 acres from the 2014 aerial survey that initially identified the meadow. The difference in area between the two delineations may be the result of a more accurate deep edge groundtruthing by CCE divers in 2016.

Conclusions

There were no significant changes in either the LTEMP site or the “new” meadow in 2016. The two sites saw similiar trends in light conditions, while the “new” meadow had a higher maximum daily temperature and experienced four more days above 25°C than the LTEMP sites. The areal extent of the “new” meadow was found to extend further into the channel than what was originally delineated in 2014 by the aerial survey, resulting in an increase in the size of the meadow.

Going forward with the LTEMP, the original Three Mile Harbor site, which has not supported eelgrass for almost 11 years could be removed from annual monitoring and placed on a 3-5 year schedule, as recommended for other LTEMP sites that no longer support eelgrass. In its place, another meadow could be added to the LTEMP or, the monitoring of the “new” meadows at the head of Three Mile Harbor could be expanded. The relative small sizes of these three eelgrass patches would not allow for six monitoring stations to be established, but at least three stations, possibly four, could be created in the three patches (Figure TMH-2). The only difficulty in monitoring the southern patch is that it is located in a boat channel next to an active marina, which poses a safety concern for divers, even with proper precautions (e.g. dive flags and on-boat spotters).

Figure TMH-6. A underwater photograph of the “new” eelgrass meadow at the head of Three Mile Harbor. There is a high percent cover of the red, filamentous alga *Spyridia filamentosa* within the eelgrass, as illustrated in the photograph.



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. 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 characteristic of 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, 2016, and that data is presented below.

Light Availability and Temperature

Light loggers were deployed for ten days, monthly, from July-September 2016. The Cedar Point meadow experienced what is now understood to be the general seasonal trend with higher light availability during the summer months, then declining light availability into the fall due to shorter day lengths, lower sun angle and increased wind-driven turbidity. For 2016, Hcomp

Cedar Point 2016

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 2016. The temperature logger was lost between the July light logger deployment and the August light logger deployment

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	14.0	+1.7	11.5	+3.5	ND
August	13.1	+0.8	10.3	+2.3	24.7
September	10.3	-2.0	6.0	-2.0	22.2

showed modest surpluses in light availability for July and August, with Hsat reporting more than two hours above the minimum requirement for the same months (Table CP-1). September reported a deficit of two hours for both Hcomp and Hsat.

The temperature logger for Cedar Point was deployed in early June 2016, and was present when the light logger was retrieved in July, but by the August light logger deployment, both the temperature logger and the marker buoy were gone. As the buoy and logger are both anchored by screw anchors and held very securely in the bottom, it is likely that they were intentionally removed from the site. The lost temperature logger was replaced near the end of August, resulting in almost two and a half months of lost temperature data. The data that was collected recorded only one day in which the daily water temperature surpassed the 25°C boundary, compared to two days in 2015. The high temperature recorded during this limited period was 26.2°C and was only one-tenth a degree higher than the maximum temperature for 2015. Considering the temperature data from 2016 at other LTEMP sites compared with 2015, it is probable that there were more days that exceeded 25°C at Cedar Point.

Eelgrass Shoot Density

Cedar Point was visited on 23 August, 2016 for the annual monitoring. Eelgrass shoot densities were found to be the second highest since 2010 with a reported density of 396 shoots·meter^2 (Table CP-2; Figure CP-2). This increase in shoot density was the result of high shoot densities (some counts greater than 1000 shoots·meter^2) in the shallower monitoring station, and in spite of the complete loss of eelgrass around Station 6.

Macroalgae Cover

There was a slight increase (4%) in percent cover of macroalgae in 2016 from the previous two seasons (Figure CP-3), at 34.5%. A significant increase in macroalgae was recorded for Station 6, and may be due to the loss of eelgrass in this area opening up space for new algae recruitment. *Sargassum filipendula* remains the dominate species covering most available substrate in the Cedar Point meadow. Filamemtous red algae were found within eelgrass patches, which provide some protection from waves, attached to shell or smaller rocks.

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 and 2016, 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
2015	331	+/-31
2016	396	+/-41

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for select years from 2000-2016.

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.)
2015	84.80 acres (34.32 hect.)
2016	90.05 acres (36.44 hect.)

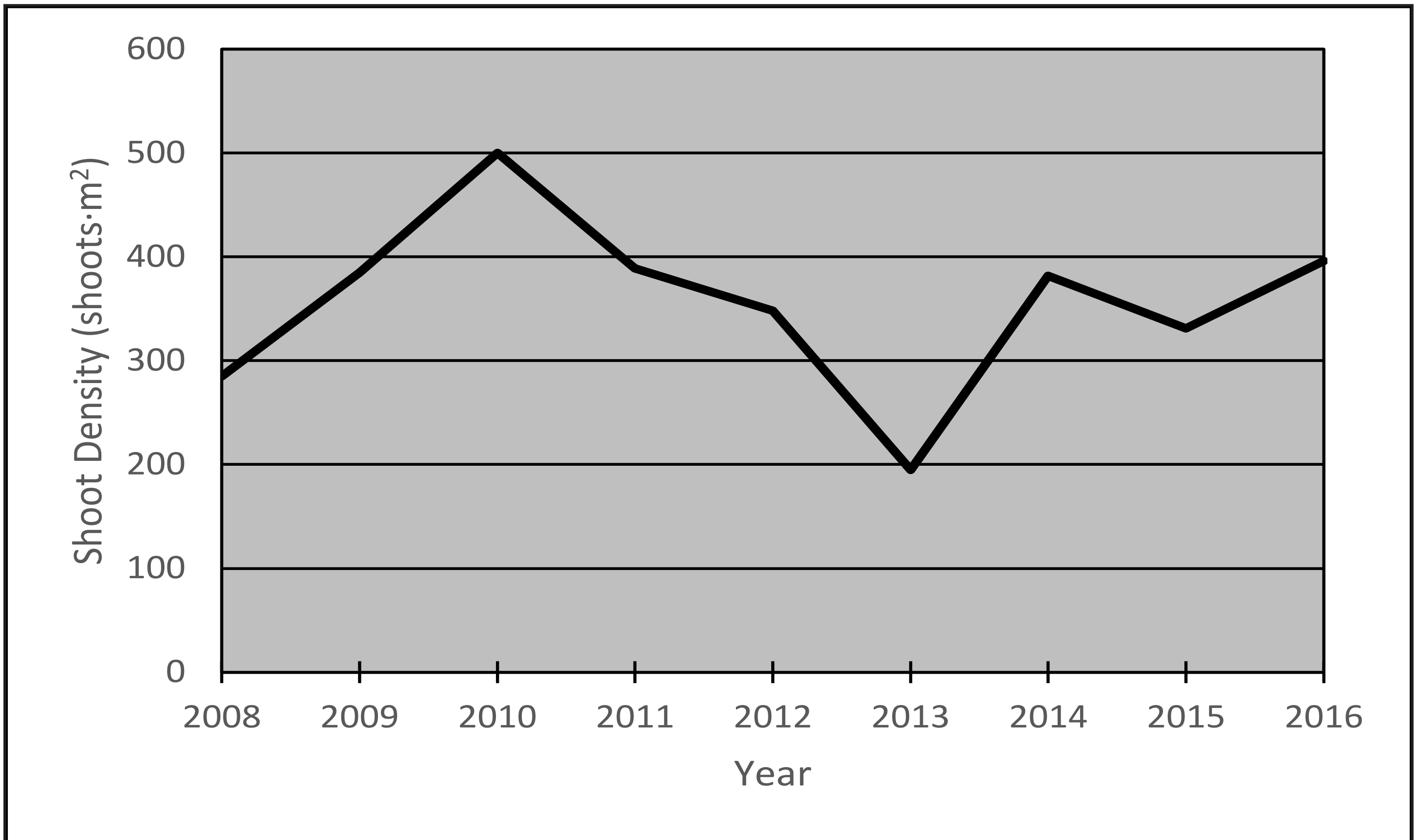


Figure CP-2. The average annual eelgrass shoot density for Cedar Point for 2008-2016.

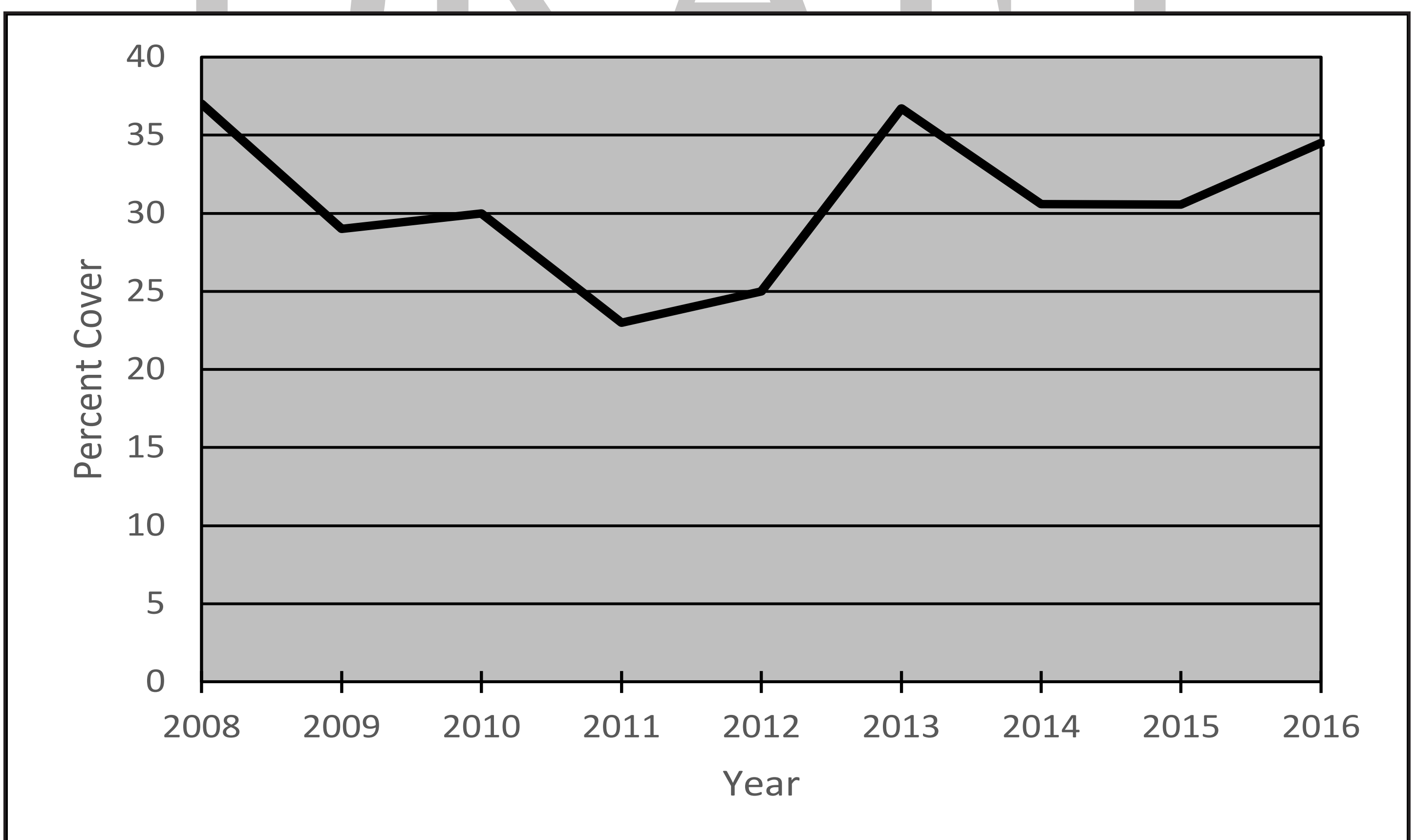


Figure CP-3 Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2016.

Cedar Point 2016

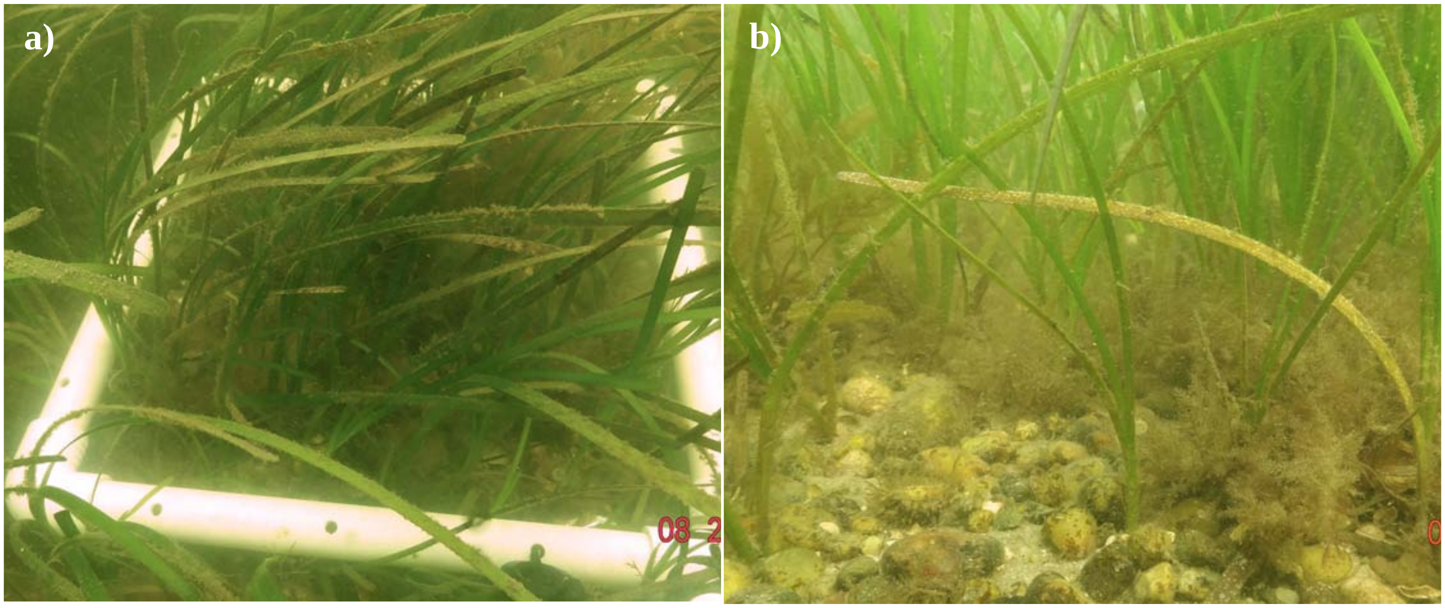


Figure CP-4. Underwater photographs taken in the Cedar Point eelgrass meadow in 2016 showing a) a quadrat at Station 2 prepared for sampling and b) eelgrass growing in the coarse sediment of the site.

Bed Delineation and Areal Extent

The aerial delineation of the Cedar Point meadow was completed using Google™ Earth imagery (11 May, 2016), and it found an increase in acreage of 5.25 acres from 2015 (Table CP-3). The in-field observations by CCE divers, found that the Cedar Point meadow, which had split in half in 2015 (Figure CP-5d) had show signs of reconnecting the two halves in 2016 (Figure CP-5e). The bridge between the halves consisted of scattered, small patches of eelgrass, presumably recruited from seed, throughout this area. There was some loss of eelgrass along the deep edge in the eastern half of the meadow, which was especially evident around Station 6 (refer to Figure CP-1). No eelgrass was recorded for this station and the meadow was found to have migrated 130-150 feet inshore of the station. Due to the patchy nature of the deep edge of this meadow, aerial delineations and casual mapping could miss patches and underestimate the extent of the meadow. Accurate delineation of the meadow edge would require a more intensive method, such as the diver groundtruthing method used in the 2014 aerial survey.

Conclusions

The Cedar Point eelgrass meadow appears to have made some modest progress toward improving its overall areal extent and the density of its population in 2016. The meadow is no longer is split in half due to the recruitment of seedlings into this area. These small patches are more susceptible to erosional forces, having less root and rhizome structure than mature, established plants, so their survival over the winter of 2017 will depend on the severity of winter storms. If there is good survival of these patches, and successful recruitment from 2016 seeds, the central gap in the meadow could revegetate in a relatively short period of time. With a mild winter, there may also be regeneration of eelgrass along the deep edge of the meadow and divers will be looking for these seedling patches, especially around Station 6 duing the 2017 LTEMP monitoring.

Environmental parameters, light and temperature, within the meadow remain well within the optimal range for eelgrass, however, the last two seasons have shown that even eelgrass meadows that are located in the eastern half of the estuary are not immune to the potential effects of climate change. Water temperatures exceeding 25°C had not been recorded at Cedar Point before 2015, but over the last two seasons, this trend was broken. The 2016 season is missing data from two and a half months of the season, yet it still recorded one day above 25°C, indicating that the meadow likely experienced more days above this temperature than the previous year. There is however, no expectation that the Cedar Point eelgrass population will be impacted by high water temperature stress in the near future.

Figure CP-5. Delineations of the Cedar Point eelgrass meadow from aerial photographs for a) 2004, b) 2010, c) 2014, d) 2015, and e) 2016 (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 an eelgrass meadow that was added to the Peconic Estuary Program Long-term Eelgrass Monitoring Program in 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. CCE had established a sentinel site at Orient Point to monitor the recovery of the meadow along three permanent transects, but it was 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 shows the locations of the established monitoring stations within the Orient Point eelgrass meadow.

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. 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

Orient Point 2016

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 2016.

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	13.9	+1.6	11.4	+3.4	21.2
August	12.8	+0.5	9.9	+1.9	23.4
September	9.9	-2.4	7.2	-0.8	21.8

was predominantly sand (68.5%) with a significant 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 deployed from July-September 2016 and collected ten days of data for each month. The daily average Hcomp and Hsat were calculated from this data and are presented in Table OP-1. The Orient Point meadow experienced the same trends evident with other LTEMP sites in that light conditions during July and August provided eelgrass with sufficient light to meet their minimum requirements. By September, both Hcomp and Hsat were below minimum thresholds, and has been attributed to the change of seasons with shorter day lengths and more turbulent weather reducing light at the site.

Water temperature loggers were deployed in early June 2016. The summer temperatures for 2016 topped the high daily average water temperature recorded in 2015 at 24.3°C by three-tenths of a degree to become the new record high of 24.6°C for Orient Point. With 2016 being the warmest year on record, the site still benefits from its proximity to cooler, ocean water and it experienced no days where daily temperatures moved out of the optimal temperature range. Orient Point remains the only eelgrass meadow in the LTEMP that has not experienced a day with temperatures exceeding the 25°C threshold.

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
2015	224	+/-30
2016	247	+/-27

Eelgrass Shoot Density

The 2016 monitoring was conducted on 22 August, 2016. Eelgrass shoot density displayed a minimal increase from 2015, increasing from 224 shoots·m^2 (2015) to 247 shoots·m^2 in 2016 (Table OP-2; Figure OP-2). The meadow has shown progress in recovering from the damage it sustained during Suprestorm Sandy with all monitoring stations, except Station 6, recording eelgrass in the quadrat counts. Even though eelgrass was not recorded for Station 6, divers did observe small, scattered patch in areas outside of the monitoring station that indicate that the meadow may be slowly recovering in this section of the meadow as well.

Macroalgae Cover

Macoralgae cover at Orient Point for 2016 was up slightly from 2015 (Figure OP-3). Percent cover in 2016 rose to 22.2% from 19.5% in 2015. Sixteen species of macroalgae were identified in 2016, with the brown seaweed *Sargassum filipendula* dominating the site. Subordinate species included *Chondrus crispus* (red), *Agardhiella tikvahiae* (red), and the invasive, non-native species *Codium fragile* (green) and *Grateloupia turuturu* (red).

Bed Delineation and Areal Extent

Meadow delineation from Google Earth™ imagery (11 May, 2016) determined that the meadow lost two acres (0.11 hectares) from the delineation in 2015 (Tabler OP-3).The maps of the meadow delineation, Figure OP-5, show how the meadow has changed with loss in the northeastern, offshore area, but some gain in offshore section in the middle of the meadow. This

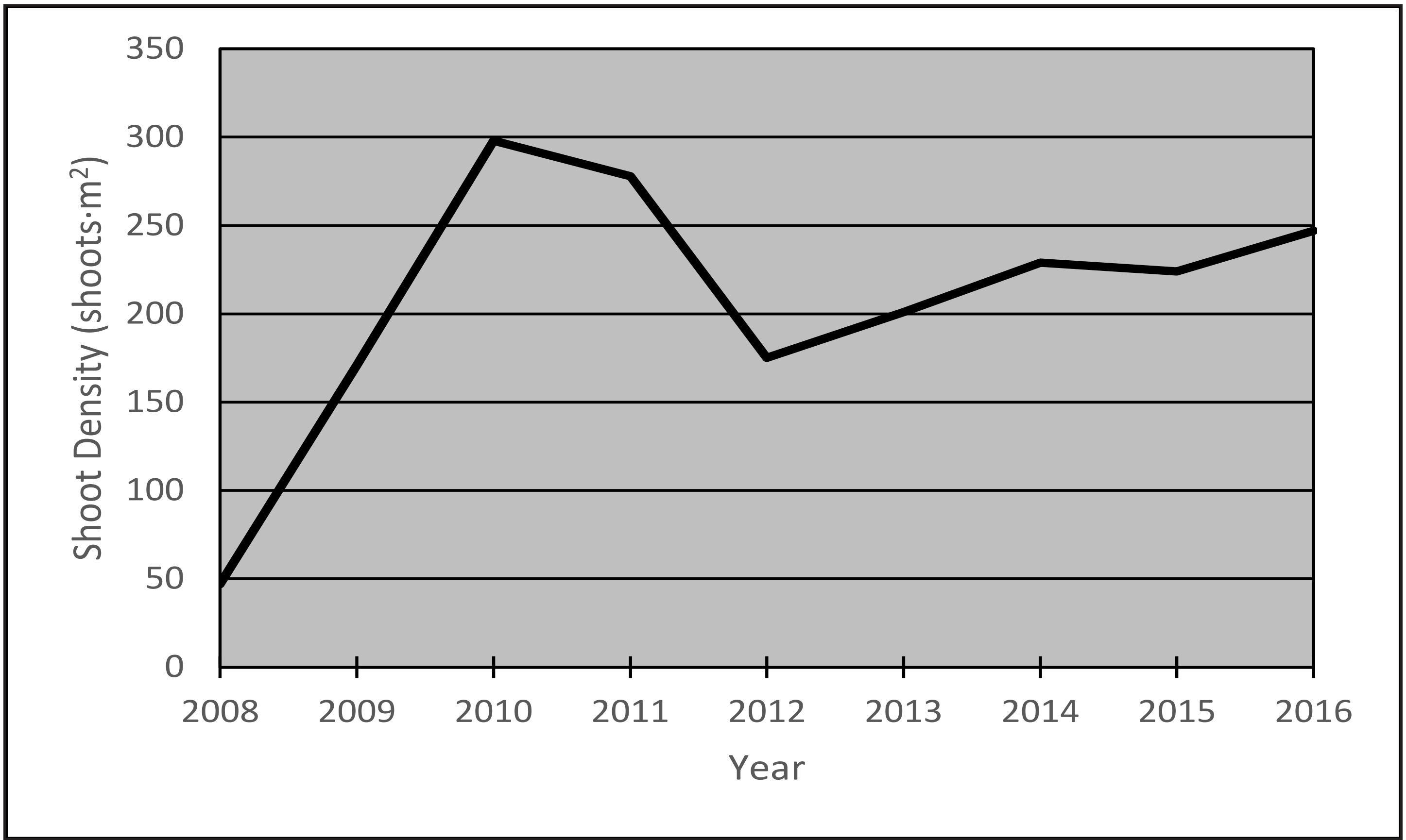


Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2016.

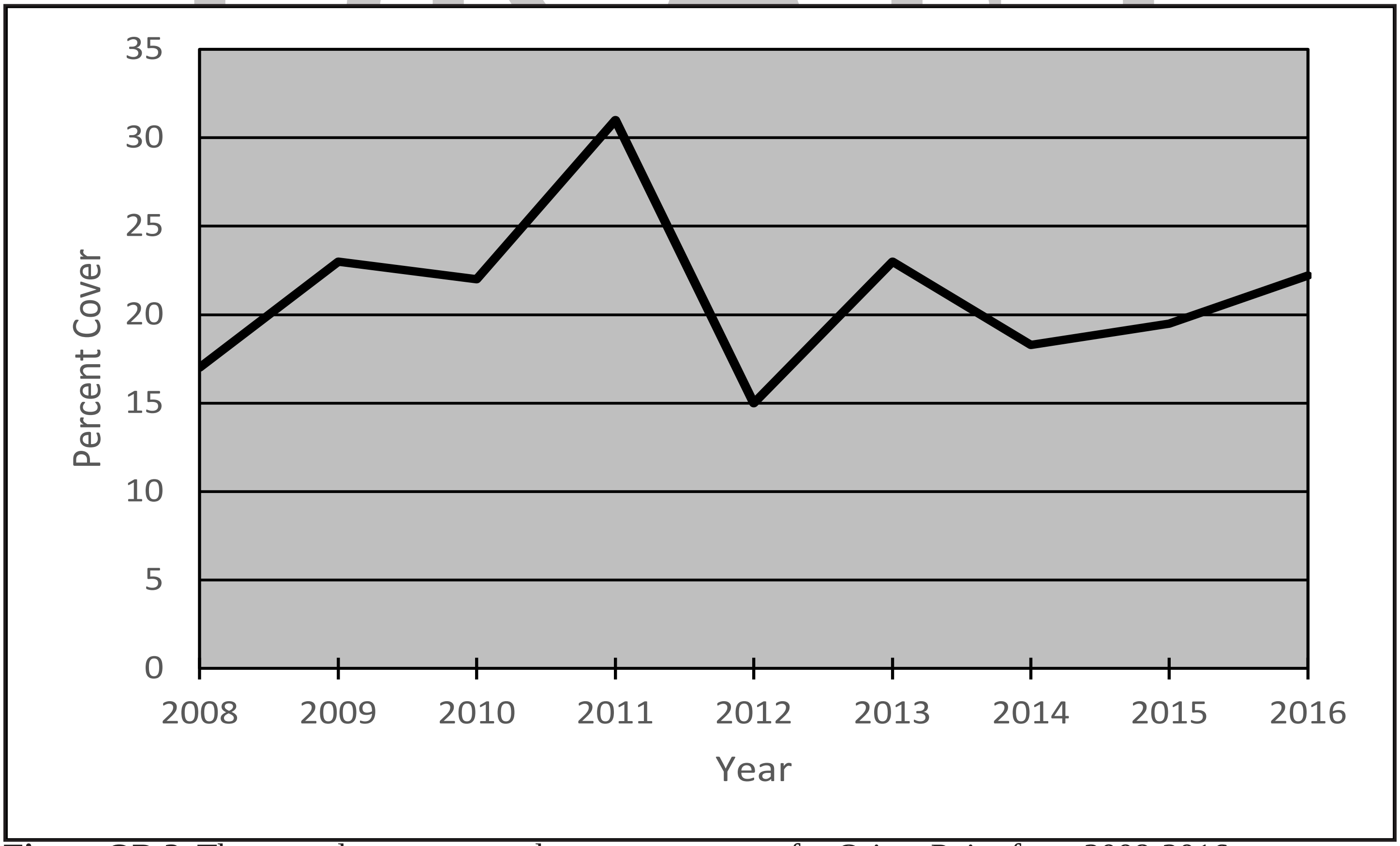


Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2016.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2016.

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.)
2015	19.40 acres (7.85 hect.)
2016	17.40 acres (7.04 hect.)

gain in the middle of the meadow is supported by the quadrat counts for Station 4, located in this middle section, which reported eelgrass for the first time in several seasons. Any eelgrass recovery located near Station 6 would not be identifiable in aerial imagery at this time due to the low density and scattered nature of the patches, observed by divers, not providing a strong enough signature to detect.

Conclusions

The overall trend in the Orient Point eelgrass meadow since it was included in the LTEMP in 2008, has been one of recovery. Shoot densities have been slowly increasing since 2012, especially in the shallower, inshore sections of the meadow where densities approaching 800 shoots$\cdot$m^2 were reported. Sections of the meadow that were lost or damaged by Superstorm Sandy, are showing new recruitment. However, Superstorm Sandy caused significant losses along the offshore edge of the meadow and those offshore sections of the meadow have been slow to recover. These offshore sections of the meadow were surviving at the depth limit for eelgrass at this site, and with sea level rise, these areas may not be able to support to eelgrass anymore, or at least new recruitment from seed. If this is the case, the slow shrinking, or inshore migration of the meadow may be the new trend we see in this, and other meadows, throughout the region.

Water temperature may also become a problem for this meadow, as it has been at other sites within the Peconic Estuary. So far, the site has not experienced temperatures that are outside of the tolerance for eelgrass, although over the last two seasons, there have been

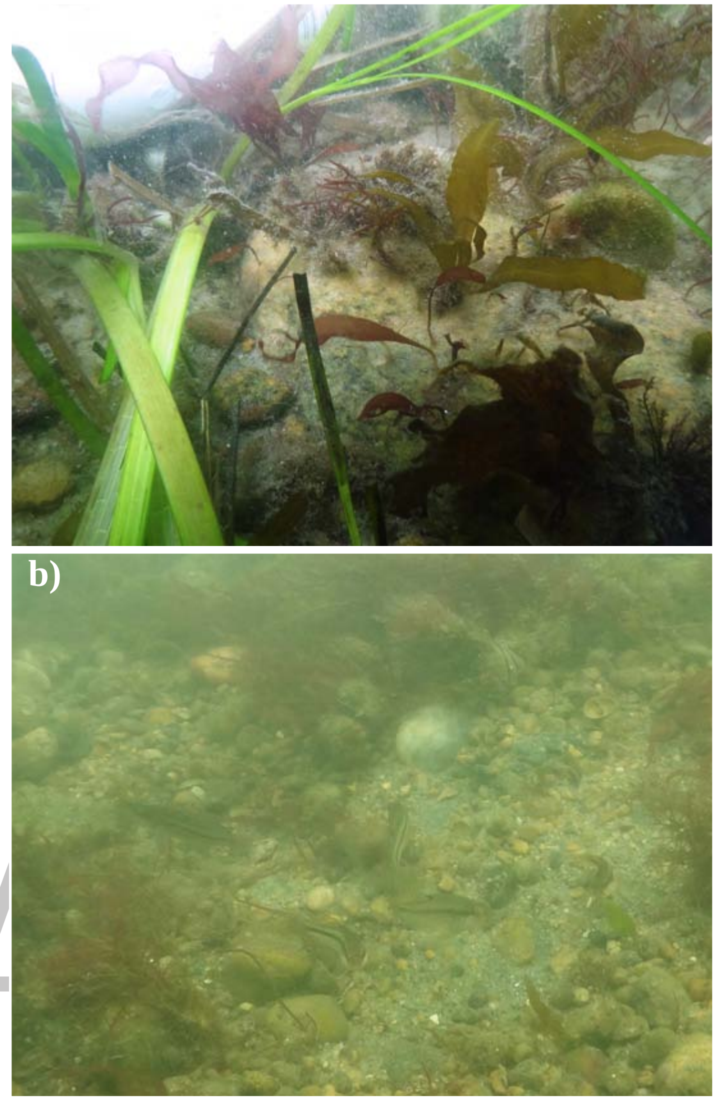


Figure OP-4. Underwater photographs illustrating the a) mixed eelgrass-macroalgae community within the Orient Point eelgrass meadow and b) juvenile black sea bass that use the meadow as refuge.

days where the average temperature approached that threshold of 25°C. The mild winter of 2016 resulted in warmer spring water temperatures and produced not only higher water temperatures than 2015, but also an increase in the duration of high water temperatures, as experienced at other sites in the estuary. If the current climate trends continue, we may begin to see a temperature impact on the Orient Point meadow.

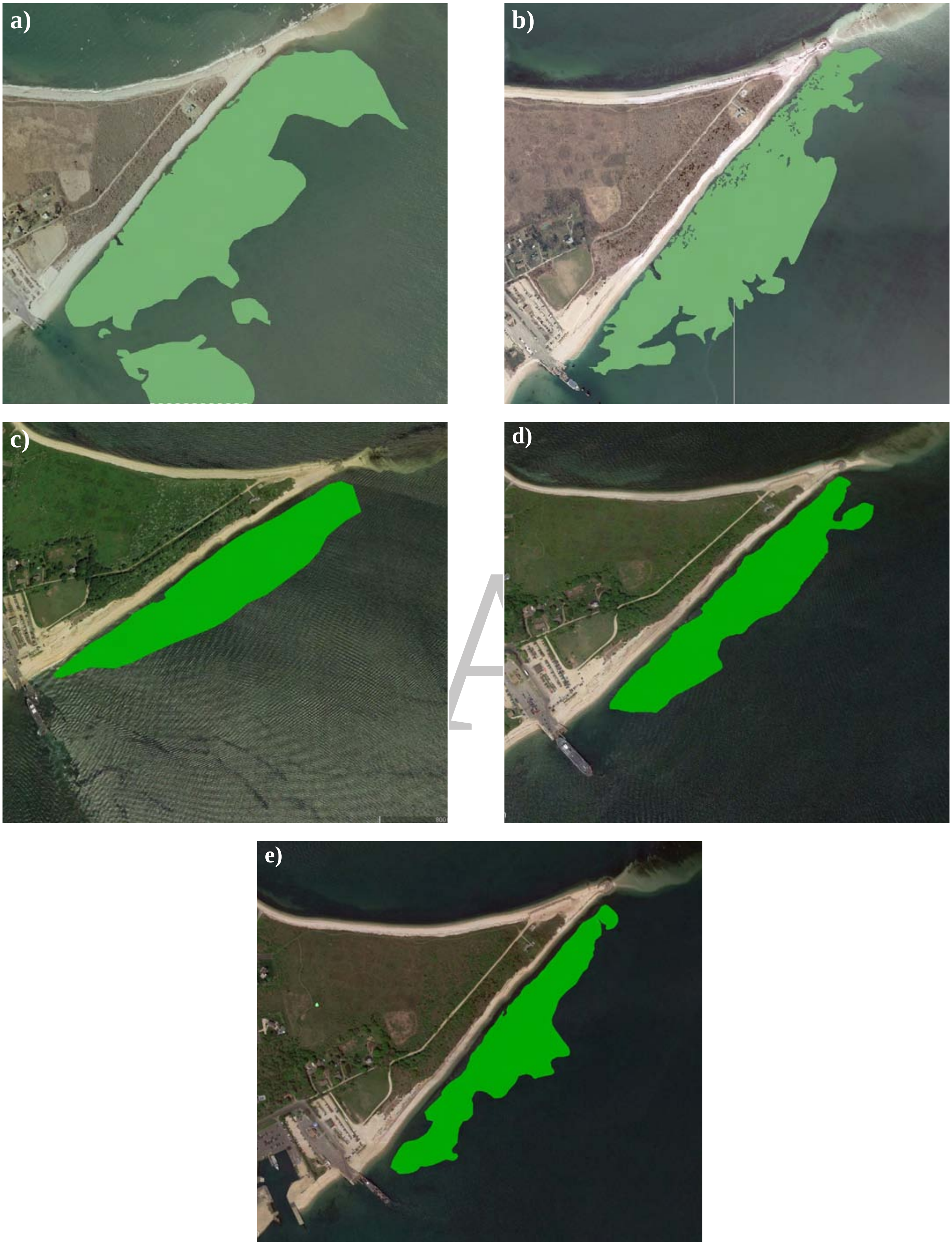
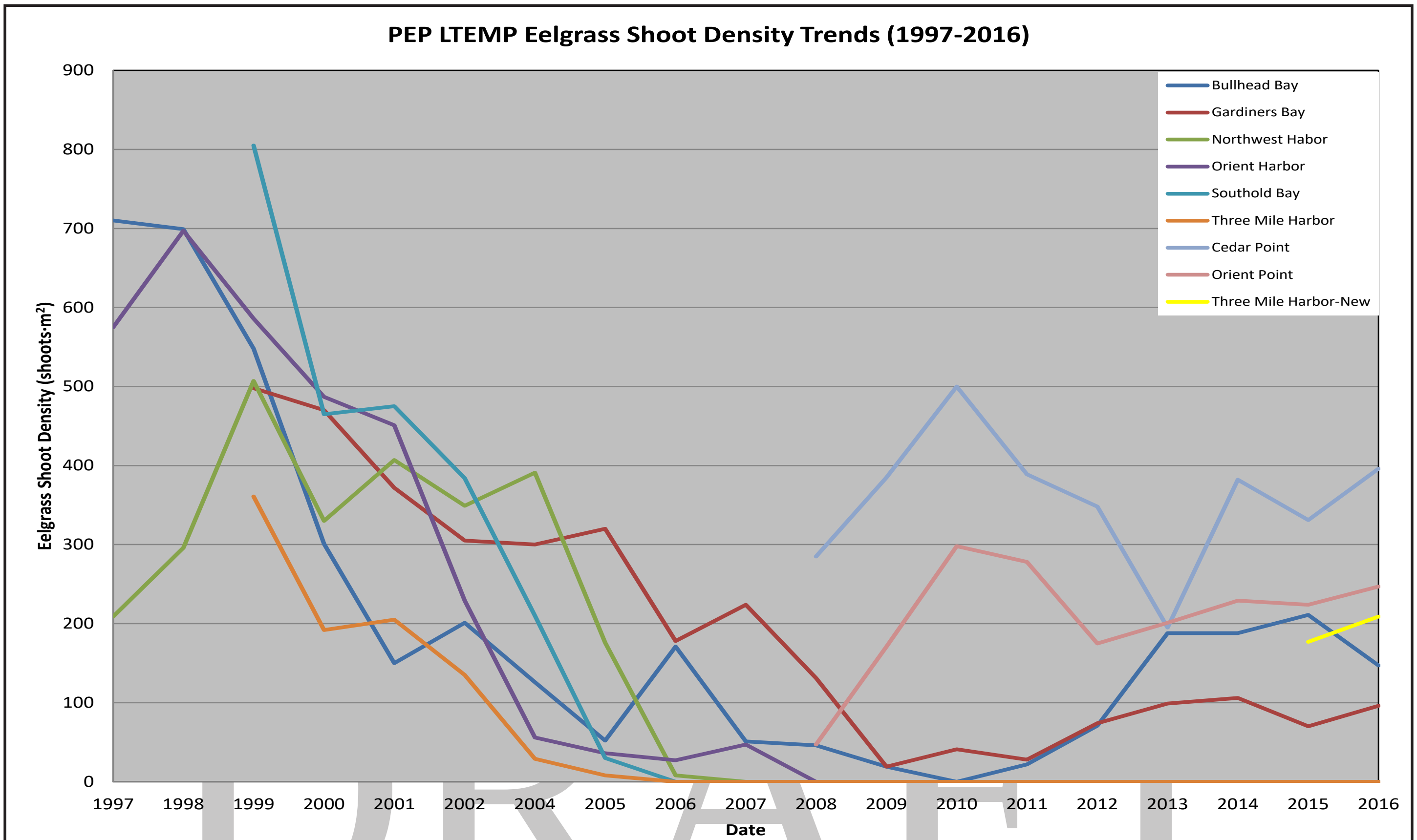
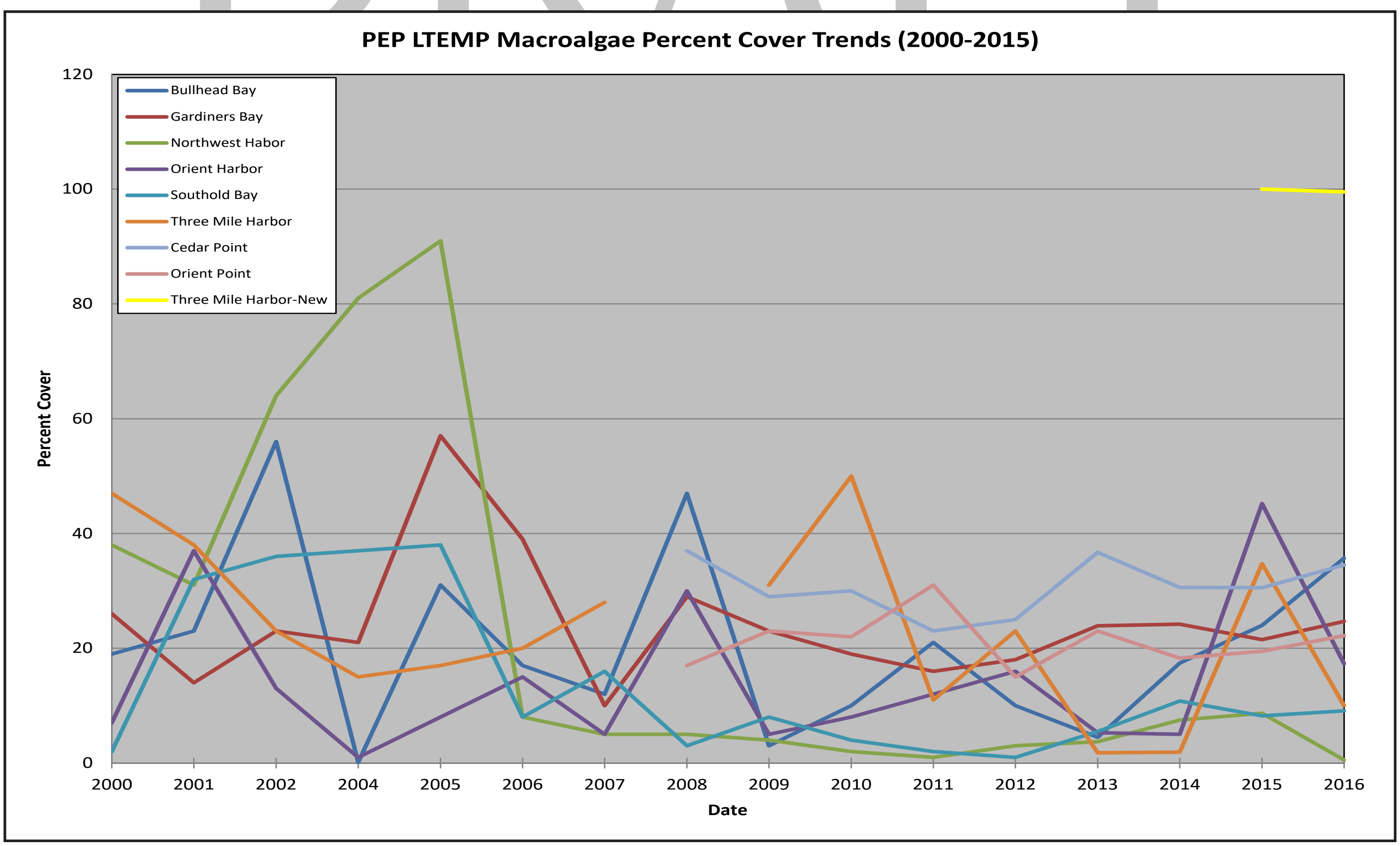


Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2010, c) 2014, d) 2015, and e) 2016.

Appendix

Appendix 1: Eelgrass Shoot Density and Macroalgae Percent Cover Trends for all years.





References

Dennison, W.C., 1987. Effects of light on seagrass photosynthesis, growth and depth distribution. Aquatic Botany, 27: 15-26.

Dennison, W.C. and R.S. Alberte, 1985. Role of daily light period in the depth distribution of *Zostera marina* (eelgrass). Marine Ecology Progress Series, 25: 51-61.

Stark, N.H., J.M. Durand, T.-f. Wong, J. Wanlass, and R.J. Paulsen, 2012. Submarine groundwater dis charge in relation to the occurrence of submerged aquatic vegetation. Data Report for Site 4, Bullhead Bay. Prepared for the Peconic Estuary Program, Suffolk County Department of Health Services. 29pp.

Tiner, R.W., H.C. Bergquist, D. Siraco, and B.J. McClain. 2003. An Inventory of Submerged Aquatic Vegetation and Hardened Shorelines for thePe conic Estuary, New York. U.S. Fish and Wildlife Service, Northeast Region, Hadley,MA. Prepared for the Peconic Estuary Program of the Suffolk County Department ofHealth Services, Office of Ecology, Riverhead, NY. 47 pp.

Willey, C.H. 1968. The ecological significance of the mute swan in Rhode Island. Transactions of the Northeast Wildlife Conference 25:121-134.