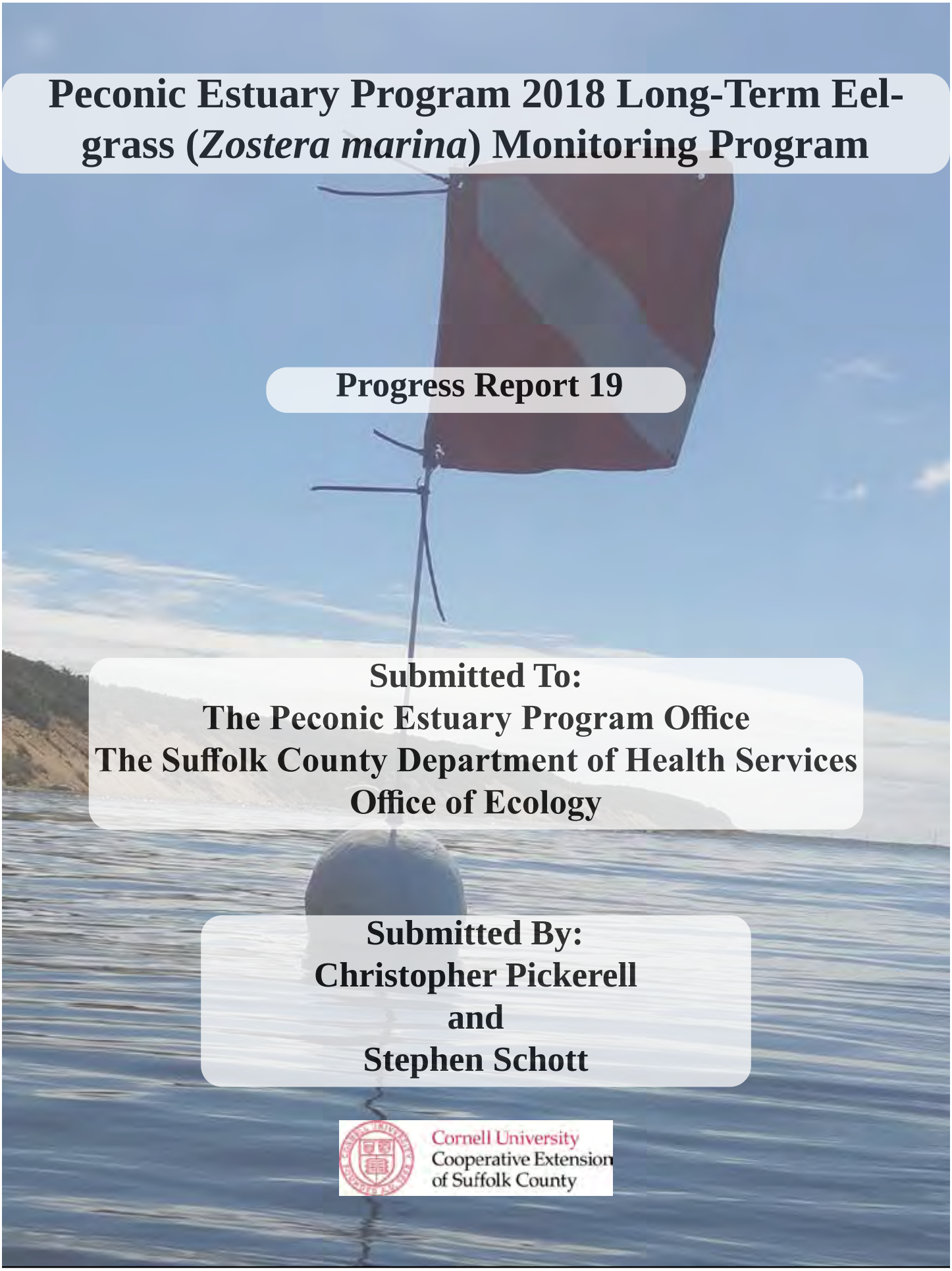

Peconic Estuary Program 2018 Long-Term Eelgrass (*Zostera marina*) Monitoring Program

Progress Report 19

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

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Executive Summary

The 2018 eelgrass monitoring season saw the Peconic Estuary Program Long-term Eelgrass Monitoring Program (PEP LTEMP) retire four former eelgrass meadows (Northwest Harbor, Orient Harbor, Southold Bay, and Three Mile Harbor) from annual monitoring. The program continued in 2018 with nine sites: Bullhead Bay (Southampton), Gardiners Bay (Shelter Island), Three Mile Harbor (East Hampton), Cedar Point (East Hampton), Orient Point (Southold), Coecles Harbor (Shelter Island), Fort Pond Bay (East Hampton), Napeague Harbor (East Hampton), and Sag Harbor Bay (East Hampton and Shelter Island). Monitoring surveys of all sites were completed during the period of the 6-20 September, 2018.

The light availability and water temperature data collected at all sites allows for the monitoring of the two most important parameters for eelgrass health. Overall, the 2018 season provided adequate light to the meadows in the LTEMP. During July, 2018, all of the meadows, except Cedar Point (logger failure resulted in no data), exceeded their minimum daily requirements for both H_{comp} and H_{sat}. The August logger deployment found that only Coecles Harbor and Three Mile Harbor failed to meet daily requirements for both H_{comp} and H_{sat}. September is the month where light availability starts to decline due to the changing of the seasons. In 2018, none of the 9 monitoring sites met the 12.3-hours threshold for H_{comp}, however most sites were close to this level. Four of the nine monitoring sites (Gardiners Bay, Three Mile Harbor, Cedar Point, and Fort Pond Bay) recorded H_{sat} values meeting or exceeding the 8-hour period threshold Water temperatures were significantly higher in 2018 versus the previous years. Bullhead Bay, Three Mile Harbor, Coecles Harbor, and Sag Harbor recorded more than 30 days with water temperatures averaging greater than 25°C. Two additional sites, Gardiners Bay and Napeague Harbor, recorded more than 20 days above 25°C, and Cedar Point experienced temperatures above 25°C for the first time since monitoring had begun at the site.

Eelgrass shoot density collected for all sites showed mixed results for the 2018 monitoring season. Five meadows (Bullhead Bay, Cedar Point, Three Mile Harbor, Coecles Harbor and Napeague Harbor) recorded significant declines in eelgrass shoot densities in 2018. The Gardiners Bay and Orient Point, saw minor increases (but statistically insignificant) in shoot density from 2017 to 2018, while the Fort Pond Bay and Sag Harbor sites experienced the greatest gains in eelgrass shoot density for the 2018 season. Sites that experienced a decline in shoot density typically saw a meadow-wide increase in patchiness or the complete loss of eelgrass cover within one or more monitoring stations.

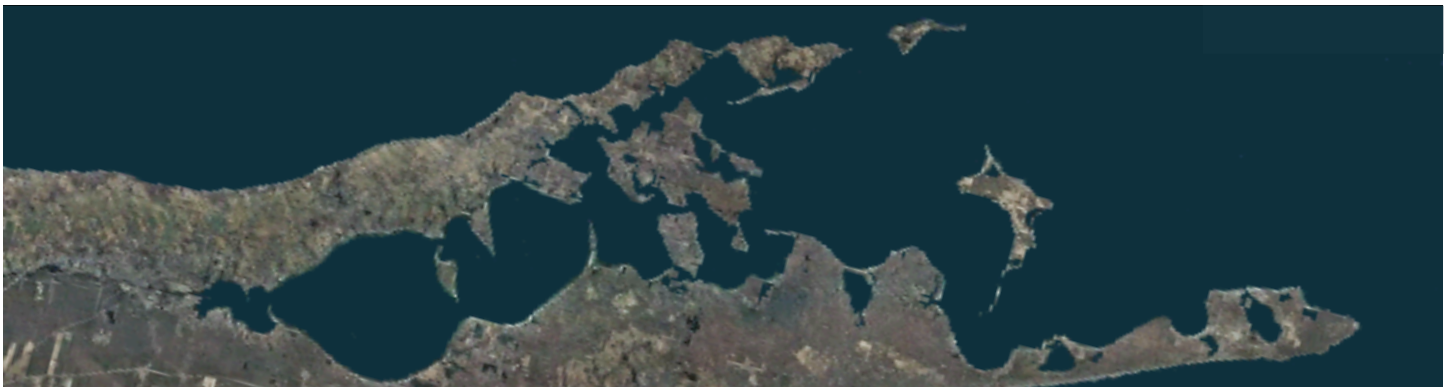
Macroalgae cover recorded mixed results in 2018. Bullhead Bay, Cedar Point and Sag Harbor saw increased macroalgae percent cover in 2018, while Gardiners Bay and Three Mile Harbor reported declines in cover. The remaining meadows were relatively unchanged for macroalgae cover between 2017 and 2018. Macroalgae cover, as a parameter, has been found to be highly variable, both between years and between sites, with the 2018 proving to be no exception.

The delineations of eelgrass meadow extent for the 2018 monitoring season was hampered by the mixed quality of the available aerial imagery for the monitoring sites. Accurate delineations of meadow extent was collected for Bullhead Bay, Gardiners Bay, Three Mile Harbor, Cedar Point, and Napeague Harbor. Aerial image quality for Orient Point, Coecles Harbor, and Sag Harbor were poor, while the imagery for Fort Pond Bay was variable over the extent eelgrass meadow, resulting in incomplete delineations that underestimated the actual extent of these four meadows. Of the meadows with good quality aerial imagery, only Bullhead Bay recorded an increase in areal extent. The Gardiners Bay meadow showed a minimal decline in area and should be considered as maintaining a stable areal extent from 2017 to 2018. The remaining three meadows (Three Mile Harbor, Cedar Point, and Napeague Harbor) had small declines in meadow areas in 2018.

Executive Summary

The health of the nine eelgrass meadows included in the PEP LTEMP was found to be mixed in 2018. Only two meadows should significant increases in shoot density, while two other meadows remained, statistically, unchanged from the 2017 monitoring survey. The remaining five meadows reported various degrees of decline. Of the nine meadows, only one meadow, Bullhead Bay, reported an expansion in areal extent in 2018. The meadows received adequate light for growth, however, water temperatures in 2018 were higher for most meadows, with some of the eastern, cooler meadows reporting daily average temperatures over the critical threshold of 25°C for the first time since they were included in the monitoring program. Even sites that did not experience critically high temperatures, they still were subjected to water temperatures higher than previous years. Meadows on along exposed shorelines in the eastern estuary showed signs of significant physical disturbance in 2018. Increased meadow patchiness was attributed to erosion along meadow edges and within meadows resulting in lower shoot densities and meadow acreage. An increase in the frequency of storms and wind events during 2018 was the likely cause of this damage. The increase in physical disturbance and water temperatures reported for 2018 may be the foreshadowing of the future impacts of climate change on the Peconic Estuary's eelgrass meadows. Historically, we have seen a shift in eelgrass distribution to the eastern half of the estuary which has been attributed to declines in water quality and clarity and increasing temperatures in the western estuary. With the changes climate change may bring to the Peconic Estuary, serious consideration needs to be given to adjust eelgrass management policies to better protect and preserve eelgrass in the Peconic Estuary going into the future.

Introduction and Methods



INTRODUCTION

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

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

METHODS

The PEP Long-term Eelgrass Monitoring Program was revised in 2018 to remove the four monitoring sites that no longer support eelgrass (Northwest Harbor, Orient Harbor, Southold Bay, and Three Mile Harbor) from regular annual monitoring. These four sites will be revisited on a 3-year schedule to verify that eelgrass had not reestablished at the sites in the intervening years. Table Intro-1 has been revised to only include the current active eelgrass monitoring sites presented in this report.

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 cm x 12.5 cm).

In 2000, the methodology for the monitoring program

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

Bullhead Bay (BB)	Southampton
Gardiners Bay (GB)	Shelter Island
Cedar Point (CP)[1]	East Hampton
Orient Point (OP)[1]	Southold
Coecles Harbor (CH)[2]	Shelter Island
Fort Pond Bay (FP)[2]	East Hampton
Napeague Harbor (NAP)[2]	East Hampton
Head of Three Mile Harbor (HTMH)[3]	East Hampton
Sag Harbor Bay (SH)[2]	East Hampton and Shelter Island

[1] Added in 2008, [2] Added in 2017; [3] Added in 2015

Introduction and Methods

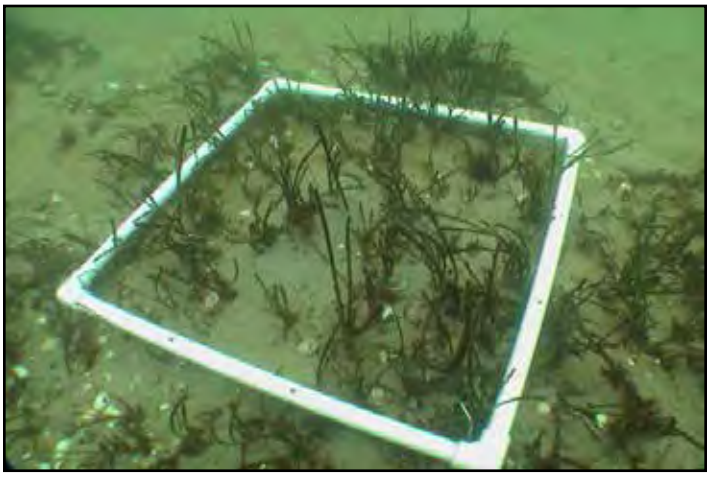


Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

was amended to increase the statistical significance of the data collected. The adjustments reflected an increase in the number of sampling stations per site (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.

Two additional eelgrass meadows were added to the program in 2008. With the loss of eelgrass at four of the original meadows in the program, CCE proposed to take on Cedar Point, East Hampton and Orient Point, Southold as replacement sites. For each of the two new meadows, six monitoring stations were established following the protocols used for the original monitoring sites.

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.

The 2017 LTEMP season saw the inclusion of four new eelgrass meadows to the program. After consultation with the PEP's Natural Resources Subcommittee, Coecles Harbor (Shelter Island), Fort Pond Bay (East Hampton), Napeague Harbor (East Hampton), and Sag Harbor Bay (East Hampton and Shelter Island) were chosen as new monitoring sites (Figure Intro-4). Additionally, a second station was added to the monitoring effort at the head of Three Mile Harbor (East Hampton). For the 2017 monitoring season, it was agreed that all of the LTEMP sites, the original and new, would be monitored, but starting in the 2018 season, the LTEMP sites that no longer support eelgrass (Northwest Harbor, Orient Harbor, Southold Bay, and the original Three Mile Harbor) would be monitored once every 3 years.

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

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

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.

Starting in 2018, water temperature loggers were deployed at all of the monitoring sites. 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 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, Coecles Harbor, Fort Pond Bay, Napeague Harbor, and Sag Harbor Bay. The South-old 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 at least 7 days, with most deployments being 10 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.

For the 2018 season, Odyssey PAR loggers were deployed at all active monitoring sites.

Eelgrass Monitoring

The 2018 monitoring began on 6 September and completed on 20 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.

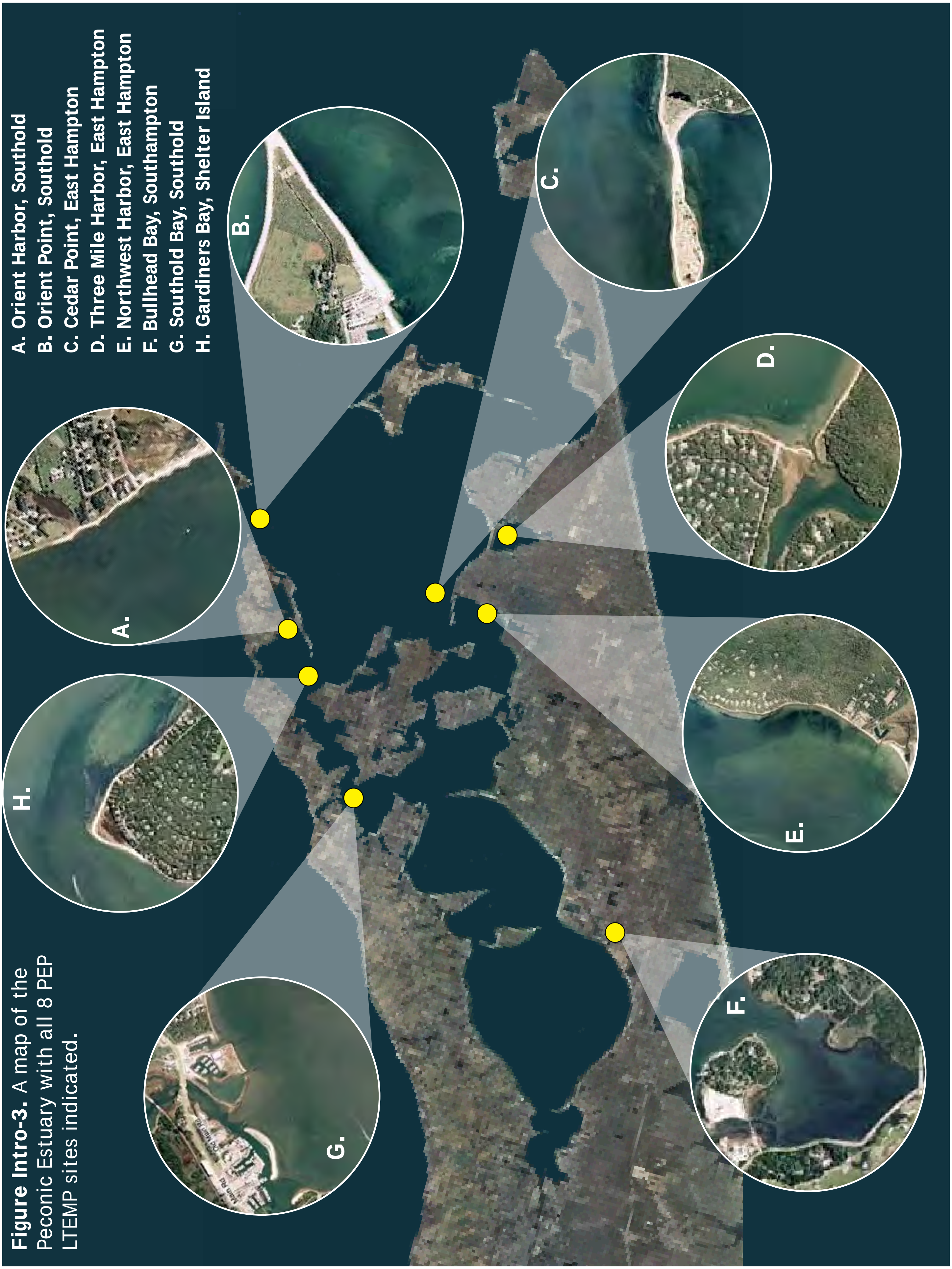


Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

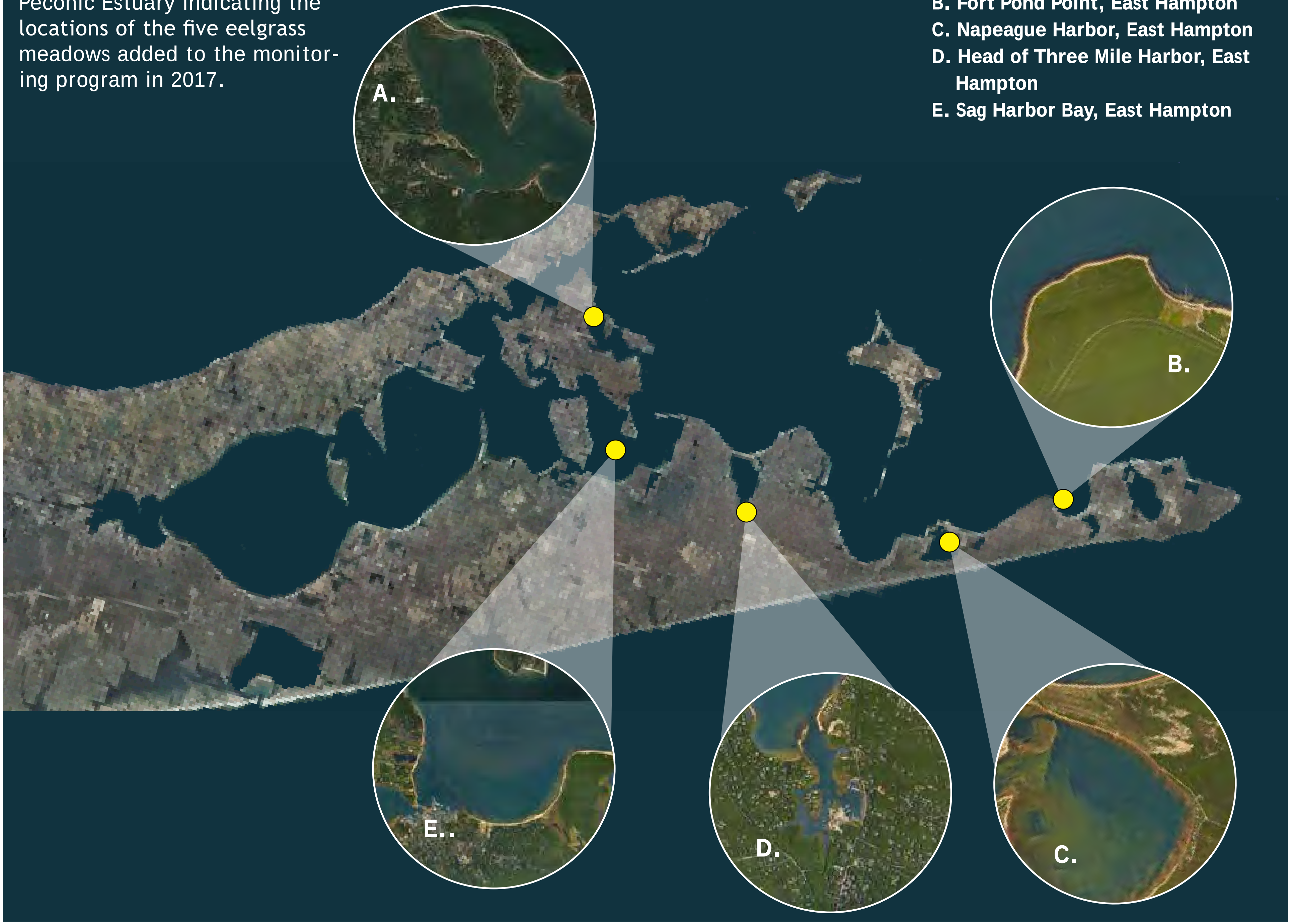


Figure Intro-4. A map of the Peconic Estuary indicating the locations of the five eelgrass meadows added to the monitoring program in 2017.

Bed Delineation and Areal Extent

For the 2018 season, Google™ Earth aerial imagery 29 June, 2018) 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-Hurricane 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

As with previous monitoring efforts eelgrass monitoring, each diver was equipped with a GoPro Hero™ 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 be edited, combining footage from each station into a one to two minute video for each site. The videos will be posted on YouTube at SeagrassLI's video page.

Bullhead Bay 2018

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%. The follow-up sediment analysis conducted in 2017 found similar results, with an average organic content of 7.2%. Locally, sediment organics exceeded 12% in the 2017 analysis. 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.

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 2018.

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	14.2	1.9	12.4	4.4	27.1
August	12.6	0.4	10.1	2.1	27.4
September	11.3	-1.0	7.1	-0.9	23.7

Bullhead Bay also supports significant populations of mute swans and Canada geese that not only add nutrients from their droppings, but also impact the bed by their grazing on eelgrass. Even though there are several significant potential sources of nitrogen 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 logger deployments were conducted monthly for ten days from July-September, 2018, with the average H_{comp} and H_{sat} for each month presented in Table BB-1 above. Similar to conditions reported in 2017, water clarity was good for Bullhead Bay in 2018. July and August 2018 saw the site receiving surplus in both H_{comp} and H_{sat} (Table BB-1), while September recorded a minimal decline in both parameters that could partially be attributed to the changing seasons and the shortening of days.

Water temperature loggers were deployed in Bullhead Bay from late May through early October, 2018. The loggers recorded that the meadow experienced 75 days averaging above 25°C and 44 days above 27°C. The monthly average temperatures for July and August were both above the 27°C threshold (Table BB-1). The highest reported water temperature for the 2018 season was 30.7°C recorded on 5 July, 2018. Based on this data, the 2018 season is the hottest on record for Bullhead Bay, surpassing the 2015 season's 72 days over 25°C and 25 days over 27°C.

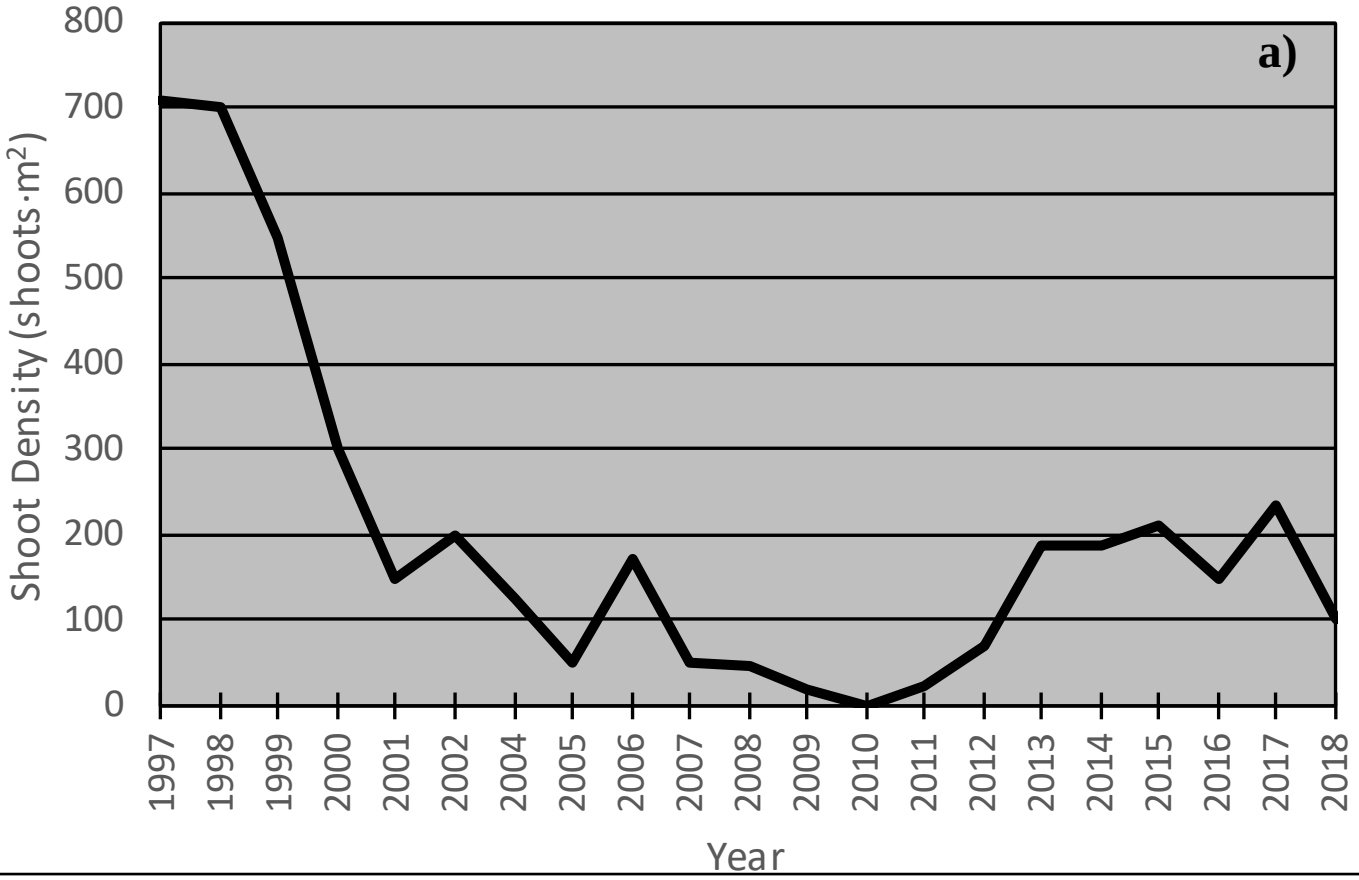
Eelgrass Shoot Density

The Bullhead Bay monitoring visit was conducted on 6 September, 2018. Reported eelgrass shoot densities were found to have significantly declined from 2017 levels (Table BB-2 and Figure BB-2a). Eelgrass densities across the meadow were lower than 2017 resulting in an average shoot density of 100 shoots·m2, but unlike 2017, the 2018 monitoring effort recorded eelgrass at all stations. The lower overall shoot density can be attributed to a consistent low shoot density of eelgrass across the whole meadow, coupled with patchy cover around Station 6.

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
2017	236	±32
2018	100	±9

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



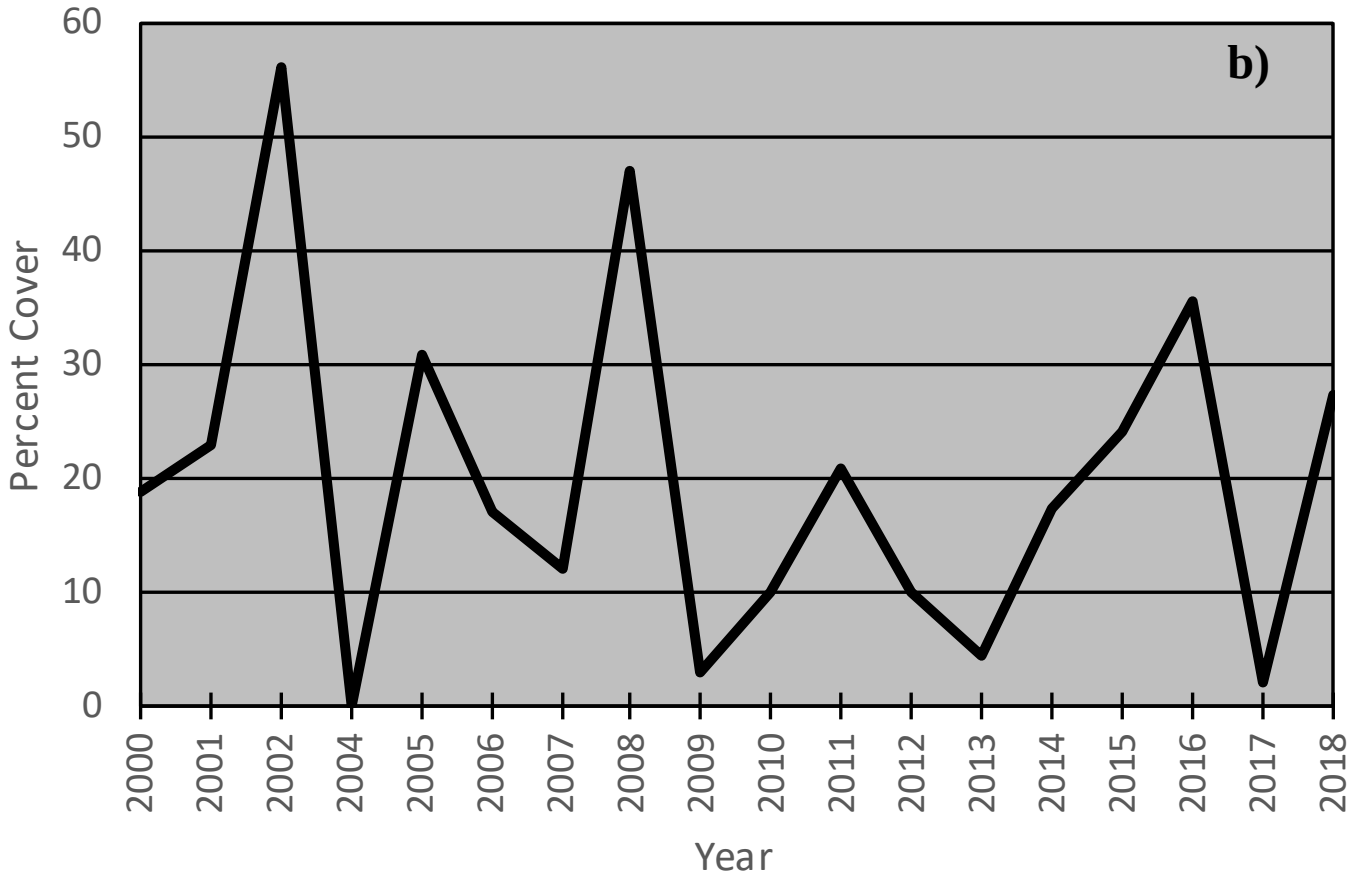


Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

Figure BB-3. The 2018 delineation of the Bullhead Bay eelgrass meadow.

Macroalgae Cover

Macroalgae made a significant recovery in Bullhead Bay from 2017 to 2018. The more than 25% macroalgae cover increase in 2018 (Figure BB-2b) was primarily attributed to *Spyridia filamentosa*. Other species recorded in Bullhead Bay included two species of the green macroalga *Ulva* and the red, filamentous macroalga *Polysiphonia*. Areas of the sediment surface within the meadow were also covered by an unidentified cyanobacterial mat, which has been noted previously at this site.

Bed Delineation and Areal Extent

Delineation of the Bullhead Bay eelgrass meadow was completed using aerial imagery from Google Earth™ taken on 29 June, 2018. The expansion of the Bullhead Bay eelgrass meadow in 2018 was noted on the first visit by CCE in May 2018 to set up the light and temperature monitoring station. While the 2017 extent of the meadow had expanded toward Sebonac Creek to the east, the edge of the meadow had moved even closer to Sebonac Creek and the Southampton Town mooring field bordering Bullhead Bay in 2018 (Figures BB-3 and BB-4f). Based on the delineations from the 2018 aerial imagery, the Bullhead Bay eelgrass meadow expanded from 47 acres (2017) to over 56 acres, in 2018 (Table BB-3). It should be noted that the meadow was not especially dense over most of its area in 2018, as noted in the Eelgrass Shoot Density section, cover was consistent for almost the whole of the area delineated.

Conclusions

The 2018 eelgrass monitoring season in Bullhead Bay found that shoot density had declined from 2017, but, at the same time, the overall area of the meadow had expanded by almost 10 acres. Factors contributing to this recovery may include the limited human impact to the site, as shellfishing, with the exception of crabbing, is no longer allowed in the bay and power boating is minimal. The resident swan population has remained low in 2018, although transient swans could be feeding in the meadow between logger deployments and monitoring visits. Water clarity continued to be high and the change from low clarity, common in Sebonac Creek, to the high clarity, once the eelgrass meadow is entered in Bullhead Bay, was stark. Macroalgae (i.e. seaweed) increased in coverage from 2017 to 2018, but the 2018 cover of macroalgae was not above normal levels for Bullhead Bay and likely not related to the decrease in eelgrass shoot density.

While the Bullhead Bay meadow was found to have declined in eelgrass shoot density from the previous year's monitoring survey, the meadow, overall still ap-

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2018.

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.)
2017	47.0 acres (19.02 hect.)
2018	56.12 acres (22.74 hect.)

Bullhead Bay 2018

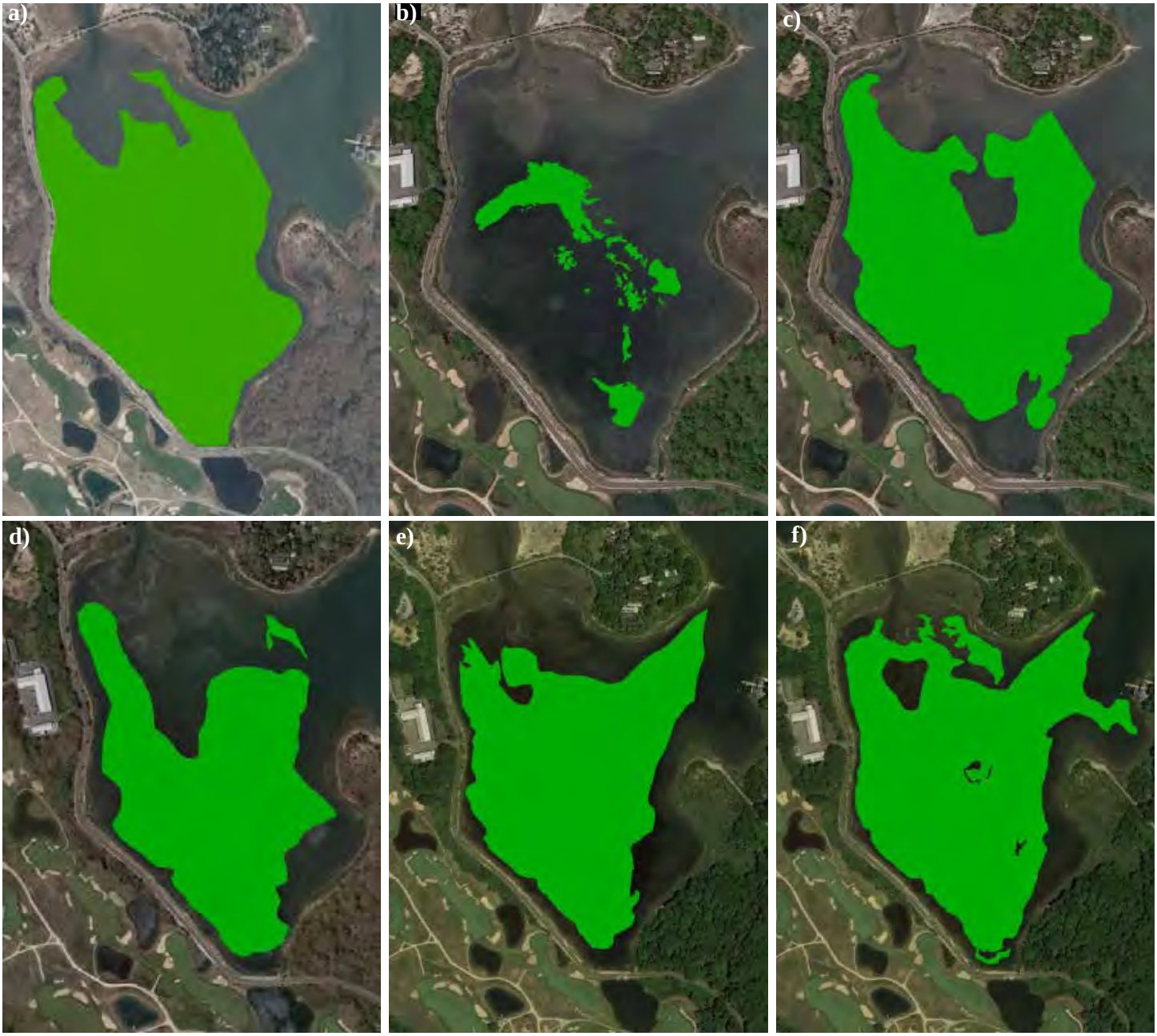


Figure BB-4. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2018. The years represented are a) 2000, b) 2010, c) 2015, d) 2016, e) 2017, and f) 2018.

peared healthy and has continued to show the expansion that has been noted annually since 2010. The low shoot densities observed in 2018 differed from other years with low eelgrass densities in that the meadow didn't present as patchy in 2018; in past years with similar densities, the meadow had small dense patches scattered throughout the bay. In contrast, the meadow in 2018 was nearly continuous, with few unvegetated areas, with healthy eelgrass shoots growing at a much lower density than has been observed in past monitoring surveys. The most concerning of the observations and data collected in the Bullhead Bay eelgrass meadow in 2018 was the water temperature data, Bullhead Bay has always been the warmest of the eelgrass monitoring sites, and it has been noted that the meadow has experienced high water temperatures for extended periods of time that would have likely collapsed the eelgrass population at another site. CCE has promoted the theory of submarine groundwater discharge (SGD) mitigating the effects of potentially lethal summer water temperatures in Bullhead Bay associated with global climate change. However, with the temperatures recorded in 2018 as an indicator, the meadow may be reaching a point where the eelgrass population is exposed to too extreme water temperatures for too long a period of time, surpassing the ability of SGD

Figure BB-5. Underwater photographs taken during the 2018 monitoring survey in Bullhead Bay showing a) station 2 with high percent cover of *Spyridia filamentosa* growing within the eelgrass and b) the cyanobacterial mat that was observed growing around station 4 and covering the eelgrass. The cyanobacterial mat connected eelgrass shoots, providing enough structural support for this spider crab to climb into the eelgrass canopy.

to moderate and resulting in a crash of the meadow. Predictions of the effects of climate change also suggest periods of drought will become more frequent and severe. The high water temperatures coupled with drought (reduced SGD) could be catastrophic for the Bullhead Bay eelgrass population. Given this potentially bleak forecast due to climate change for seagrass meadows locally and globally, including Bullhead Bay, the current condition of the meadow suggests that whatever conditions/parameters lead to the decline in 2007 have been alleviated, at least temporarily, as the meadow continues to show significant expansion and appears to be healthy.

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, taken in 1999, averaged 0.84% organic material in the sediments with a range of 0.31% to 1.73%. The new analysis of sediment characteristics completed in 2017 found that the sediment consisted of 22.5% gravel, 75.6% sand, and 1.9% silt+clay, with 0.41% organic content (lower than 1999). Sediments continue to be 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

Gardiners Bay 2018

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 2018.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	12.4	0.1	7.9	-0.1	23.7
August	12.5	0.2	9.1	1.1	25.3
September	12.0	-0.3	9.5	1.5	22.9

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 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 2018 season were conducted for ten-day periods, monthly, from July-September 2018. The collected light data for 2018 is summarized in Table GB-1. The Gardiners Bay site recorded good water clarity over the three months reported. The only deficits run in 2018 were in September (H_{comp}) and July (H_{sat}). Overall, light conditions should have favored eelgrass growth over the season.

Water temperature monitoring at the Gardiners Bay site found water temperatures in 2018 to have been warmer than those experienced during 2017. In contrast to the Gardiners Bay site recording no days with average water temperatures exceeding 25°C, 2018 recorded 28 days over this critical temperature. There were no days (daily average temperature) where the site was subjected to water temperatures ≥27°C in 2018. However, the highest individual water temperature recorded for the site during 2018 was 27.5°C on 7 August, 2018. The summer of 2018 was the hottest year on record for the Gardiners Bay site, however, the site did not exceed the threshold of 30 days with water temperatures averaging above 25°C.

Eelgrass Shoot Density

The 2018 LTEMP was conducted on 12 September, 2018 at Gardiners Bay. Only three monitoring stations (6,7, and 8) supported eelgrass in 2018, however, as indicated in the 2017 LTEMP report, eelgrass has continued to recolonize the area around monitoring station

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2018, 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	±25
2017	83	±16
2018	96	±16

**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.

Gardiners Bay 2018

Figure GB-3. The 2017 areal delineation of the Gardiners Bay eelgrass meadow on the northeast shore of Shelter Island, NY.

5, but no eelgrass was reported within the 10 sample quadrats. The 2018 eelgrass shoot density data (Table GB-2, Figure GB-2a) found no significant change in the Gardiners Bay meadow from the previous three years' monitoring. The average shoot density for the meadow in 2018 increased to 96 shoots·m^2, which was a minor increase from 2017 and took the meadow back to the same density as 2016. The average shoot density within the three monitoring stations that still supported eelgrass was 257 shoots·m^2, in 2018.

Macroalgae Cover

The Gardiners Bay eelgrass meadow experienced a second consecutive season with a significant decline in macroalgae cover. The average macroalgae percent cover in 2018 declined to 4.1%, down from 9% in 2017. Species diversity at the site has remained stable, with nine macroalgae species identified, but as observed in 2017, the overall biomass of macroalgae had declined.

Bed Delineation and Areal Extent

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2018.

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.)
2017	20.80 acres (8.42 hect.)
2018	19.45 acres (8.42 hect.)

The areal extent of the eelgrass meadow at Gardiners Bay was determined using aerial imagery provided by Google Earth™ and acquired on 29 June, 2018. The quality of the imagery for identifying the signature of eelgrass at the site was good and a total of 19.45 acres of eelgrass was delineated for 2018 (Table GB-3). The eelgrass meadow delineation for 2018 is presented in Figure GB-4g. Based on the imagery, the meadow experienced a minor decline in area from 2017 to 2018, however, field observations and delineations found that eelgrass has continued to recruit to the area around monitoring station 5.

Conclusions

The 2018 monitoring season found that the Gardiners Bay meadow has remained relatively stable with eelgrass shoot densities and bed areal extent showing no significant change since the 2017 season. There may be some recruitment occurring into areas of the site that had lost eelgrass in recent years. Small eelgrass patches were reported around monitoring station 5 in 2017 and eelgrass patches were observed at the same location in 2018. The recruitment and survival of eelgrass to unvegetated areas of the site suggest that conditions in some areas of the site where eelgrass has been lost can still support its growth. The site, overall, should be able to maintain a healthy eelgrass meadow, based on light and water temperature data, and it has been suggested in previous reports that physical disturbance (wave/current induced erosion/accretion, prop scarring, etc) may be the main parameter influencing the overall extent of the meadow.

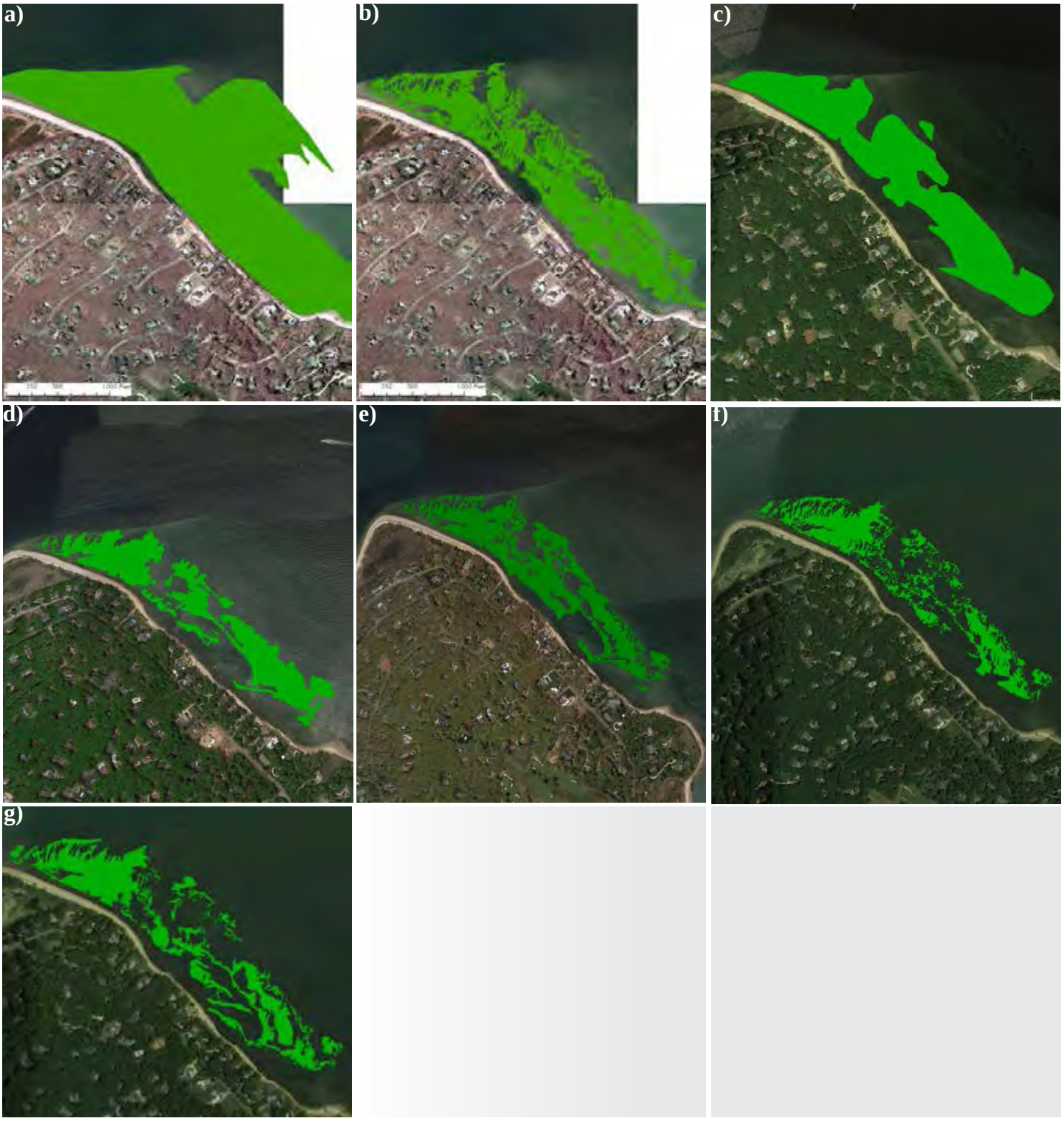


Figure GB-4. A series of aerial delineations of the Gardiners Bay eelgrass from select years from 2000 through 2018. The years represented are a) 2000, b) 2010, c) 2014, d) 2015, e) 2016, f) 2017, and g) 2018.

The evidence of recruitment at the site suggests that restoration activities to enhance the overall meadow could be successful. Planning for any restoration effort should identify the best methodology for the site (seed versus adult shoot), where the donor material will be collected (solely from the existing meadow or combined with other donor sites), and the size and location of the restoration at the site to ensure the best possible chance of success. The potential for conducting a restoration activity at the Gardiners Bay site should also be presented to the appropriate committees/subcommittees of the PEP for input.

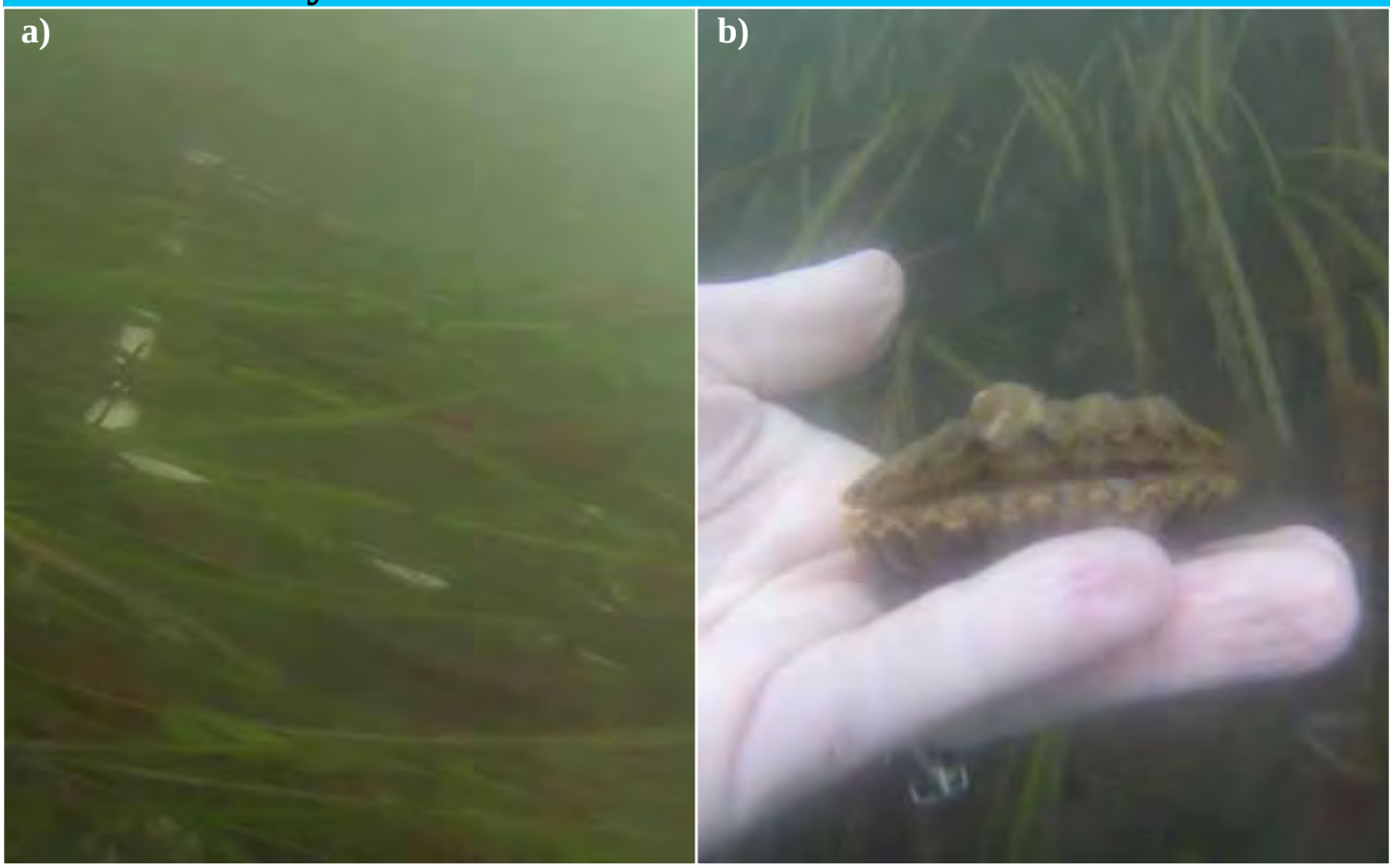


Figure GB-5. a) A photograph showing the eelgrass laying over in the high current and partially obscuring the sampling quadrat. b) Despite the high currents at the site, bay scallops are abundant and divers regularly observe them sheltering in the eelgrass meadow.

Three Mile Harbor-2018

The original Three Mile Harbor LTEMP site (located near Hands Creek) included in the program from 1999 through 2017 but was retired after the 2017 season due to more than 10 years without supporting eelgrass. During the 2014 Peconic Estuary aerial eelgrass survey, two meadows of eelgrass were identified in the headwaters of Three Mile Harbor, East Hampton, that were previously unknown to CCE (Figure TMH-3a). In order to supplement the loss of the original site from the LTEMP program, two new monitoring stations were created for the 2015 monitoring season (NTMH-1 and NTMH-2) within the larger of the eelgrass beds identified in 2014 at the harbor's headwaters. The new eelgrass monitoring site is located along the western edge of the boating channel leading from the headwaters into Three Mile Harbor proper. The meadow starts in relatively shallow water and extends partially into the deeper waters of the channel. The bottom over the site is silty-sand to mud.

Figure TMH-1. An aerial photograph showing the location of the new Three Mile Harbor eelgrass meadow and its two monitoring stations.

Site Characteristics

The new Three Mile Harbor eelgrass meadow grows along the western edge of the channel that connects the headwaters of the harbor to the main harbor. The meadow starts close to shore, and extends into the deeper water of the channel. This area includes four marinas, so boat traffic during the season is high, although impact from boating is minimal due to the enforced 'No Wake' zone. Considering the location of the meadow and its distance from the mouth of the harbor, water temperatures have the potential to reach dangerous levels, however, it appears that there may be some submarine groundwater discharge at the site which may mitigate high water temperature.

Sediment samples for the 'new' meadow were collected in 2017. The sediment grain size analysis found that the site's sediment was composed of 0.1% gravel, 73.7% sand, and 26.2% silt+clay. The sediment organic content was found to be 6.1%, within published tolerance for eelgrass.

Light Availability and Temperature

Table TMH-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers for the 'new' Three Mile Harbor site for 2018.

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	14.2	+1.9	12.4	+3.4	24.2
August	12.1	-0.2	6.9	-1.1	25.4
September	11.8	-0.5	9.0	+1.0	23.0

Light availability and water temperature were recorded with deployed loggers at the new Three Mile Harbor site. The Odyssey PAR loggers were deployed for 10 days during July, August, and September, 2018 (Table TMH-1). Based on the collected data, the eelgrass meadow received ample light in July, but ran a deficit in both August and September for H_{comp}. The site met its H_{sat} requirements for July (surplus of 3.4 hours) and September (surplus of 1 hour), but fell short of the H_{sat} optimal of 8 hours in August, 2018.

The Onset Hobo water temperature logger was deployed in Three Mile Harbor in early June, 2018. The 2018 summer was extremely warm and the site spent 34 days with water temperatures above 25°C. There was also one day where the average temperature exceeded 27°C. Even with the extreme temperatures experienced during the summer of 2018, the eelgrass meadow experienced five fewer days above 25°C than was reported in 2017.

Eelgrass Shoot Density

Three Mile Harbor was visited on 11 September, 2018 and the annual monitoring was conducted at the two stations (NTMH-1 and NTMH-2) in the 'new' site at the head of the harbor. Divers reported a significant decline in eelgrass shoot density from 2017 to 2018 (Table TMH-2; Figure TMH-2a). The average shoot density calculated for 2018 was 79 shoots·m^2, down from 120 shoots·m^2 in 2017. Monitoring station NTMH-2 (the southernmost station) was found to have become extremely patchy compared to 2017, resulting in lower density counts for the station, and the overall site in 2018.

Table TMH-2. The average annual eelgrass shoot density for Three Mile Harbor (new site) from 2015 to 2018, including standard error.

Year	Mean Density	S.E.
2015	177	±17
2016	209	±20
2017	120	±17
2018	79	±20

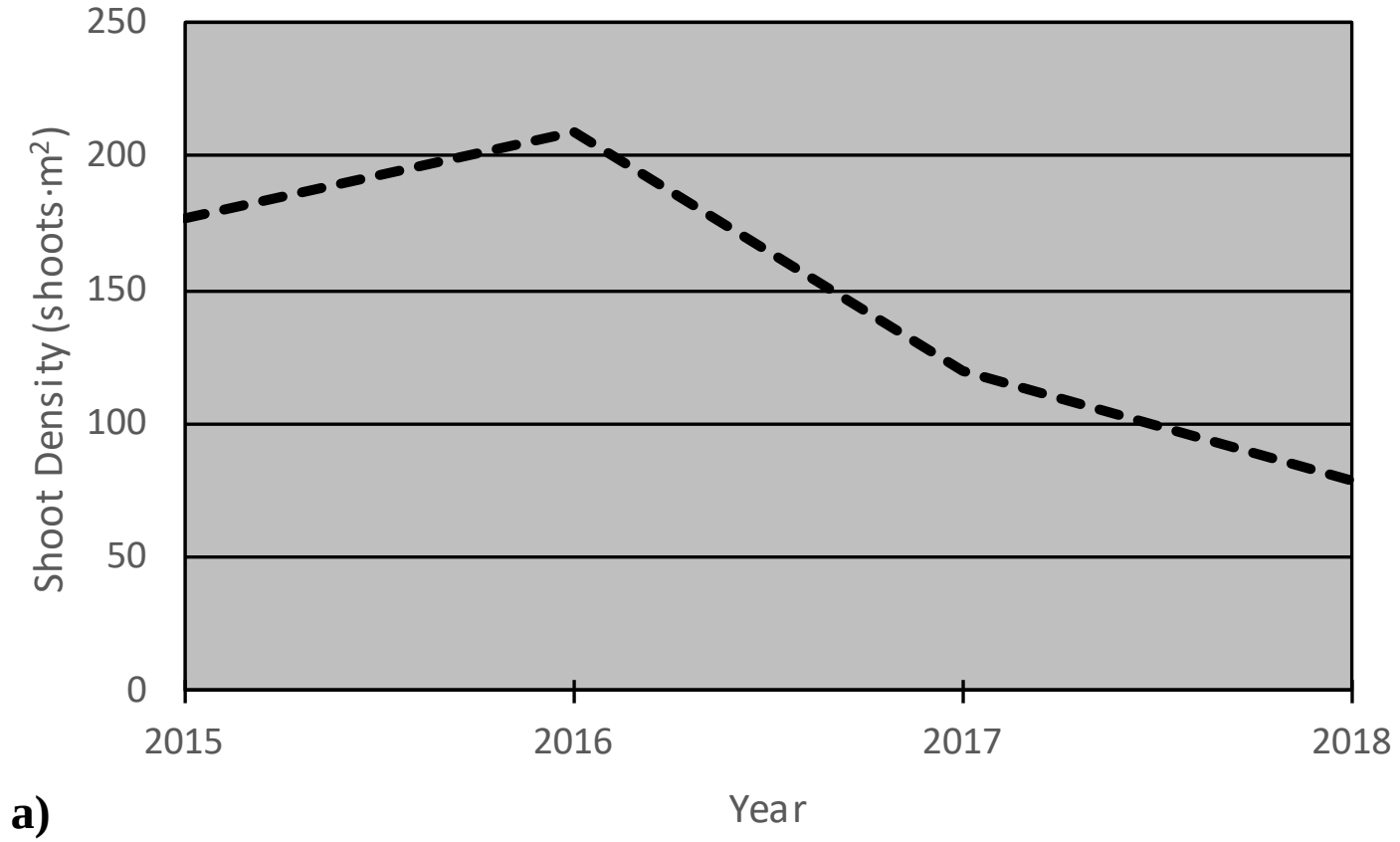
Macroalgae Cover

Macroalgae cover at the new Three Mile Harbor site was reported to have declined for the second straight year (Figure TMH-2b). While the macroalgae percent cover was still high, 75%, in 2018, it is down from 85.5% in 2017. The dominant seaweed species at the site continued to be *Spyridia filamentosa*, with only the green, filamentous alga *Cladophora sericea* reported as a subordinate species. Percent cover of *Spyridia* correlated to presence of eelgrass in the sampling quadrat. Quadrats with no eelgrass had low cover of macroalgae. This correlation between eelgrass shoot density and macroalgae cover, and specifically *Spyridia* cover, has been noted in past reports for meadows that were in decline. The eelgrass provides an anchorage for macroalgae, especially in soft bottom systems, and a loss in eelgrass coverage typically results in a corresponding decline in macroalgae cover.

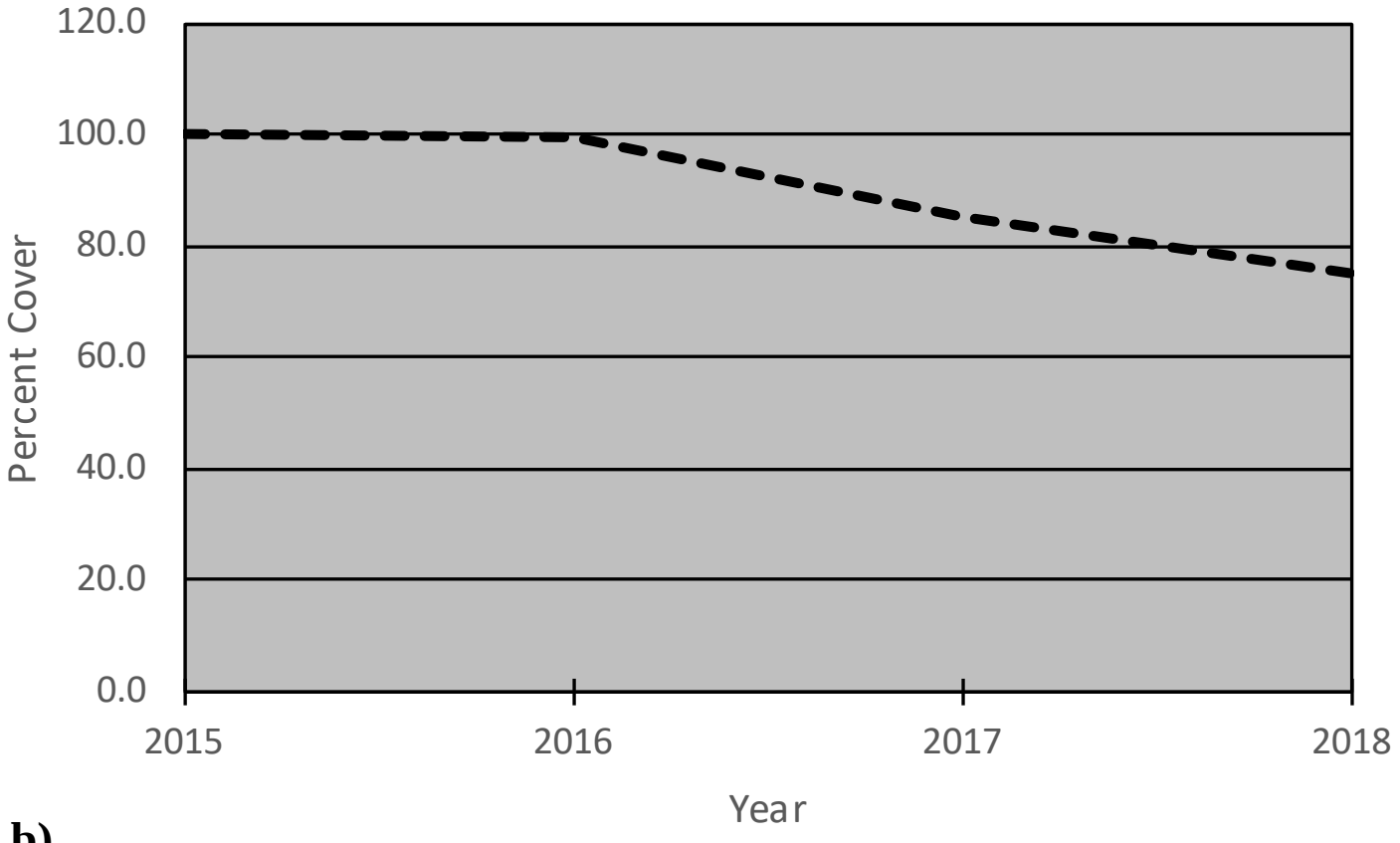
Bed Delineation and Areal Extent

The eelgrass meadow for the new Three Mile Harbor site was delineated using Google™ Earth imagery taken on 29 June 2018. A progression of aerial delineations of the meadow is presented in Figure TMH-3. There was a decline in the overall extent of the meadow from the 0.81-acres reported in 2017 to 0.67-acres in 2018. Most of the meadow loss has been on its southern end, with additional loss of eelgrass cover along its shoreward edge (TMH-3d). The eelgrass in the southern section of the meadow could be impacted by activities related to the two docks present, or be

Three Mile Harbor-2018



a)



b)

Figure TMH-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted at the 'new' Three Mile Harbor site.

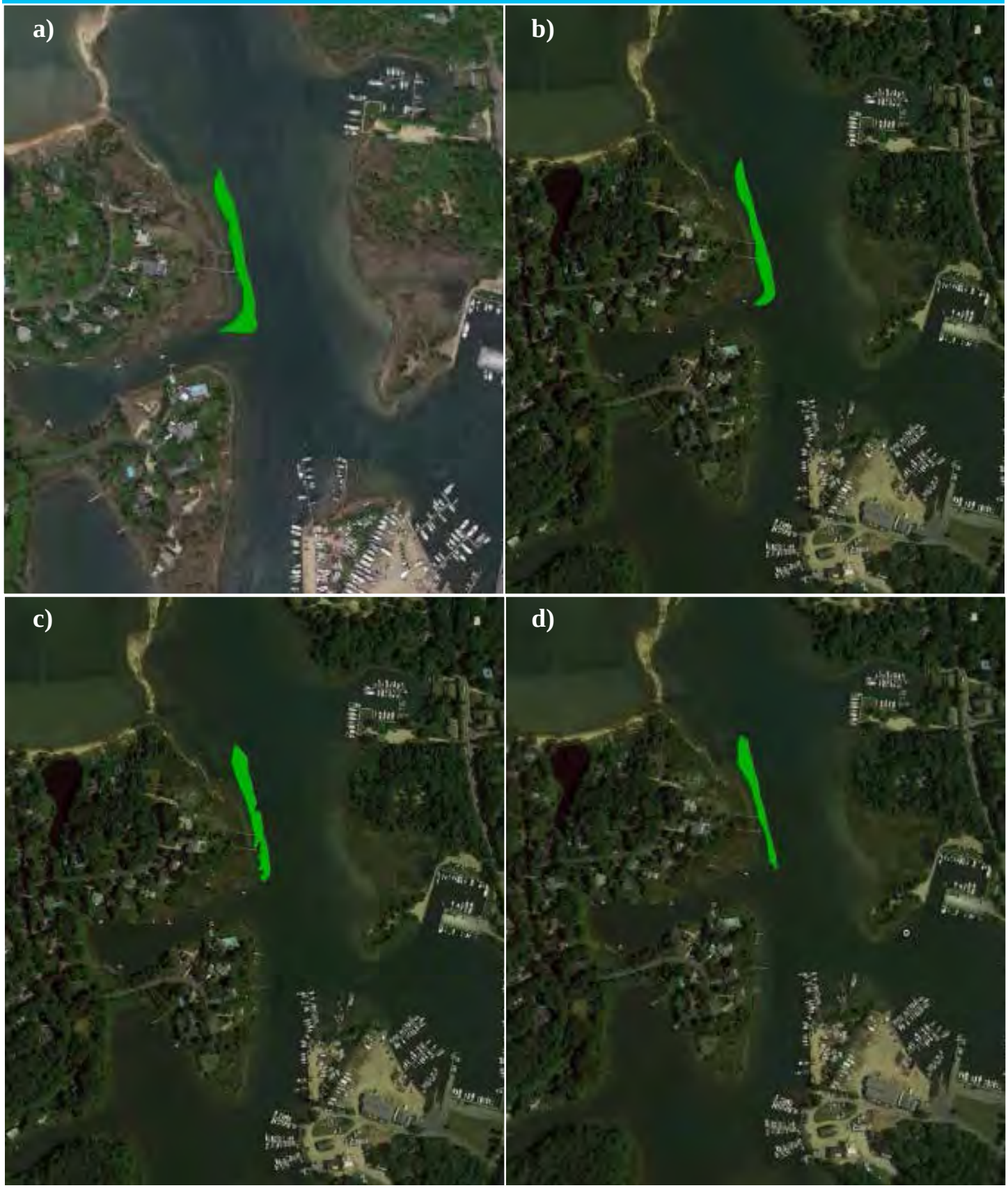


Figure TMH-3. Aerial views of the eelgrass meadow (new Three Mile Harbor) at the head of Three Mile Harbor presenting the a) 2014, b) 2016, c) 2017, and d) 2018 meadow delineations.

part of the natural dynamics of the meadow.

Conclusions

The 2018 monitoring season found that the new Three Mile Harbor eelgrass meadow had declined from its 2017 density and areal extent numbers. As monitoring

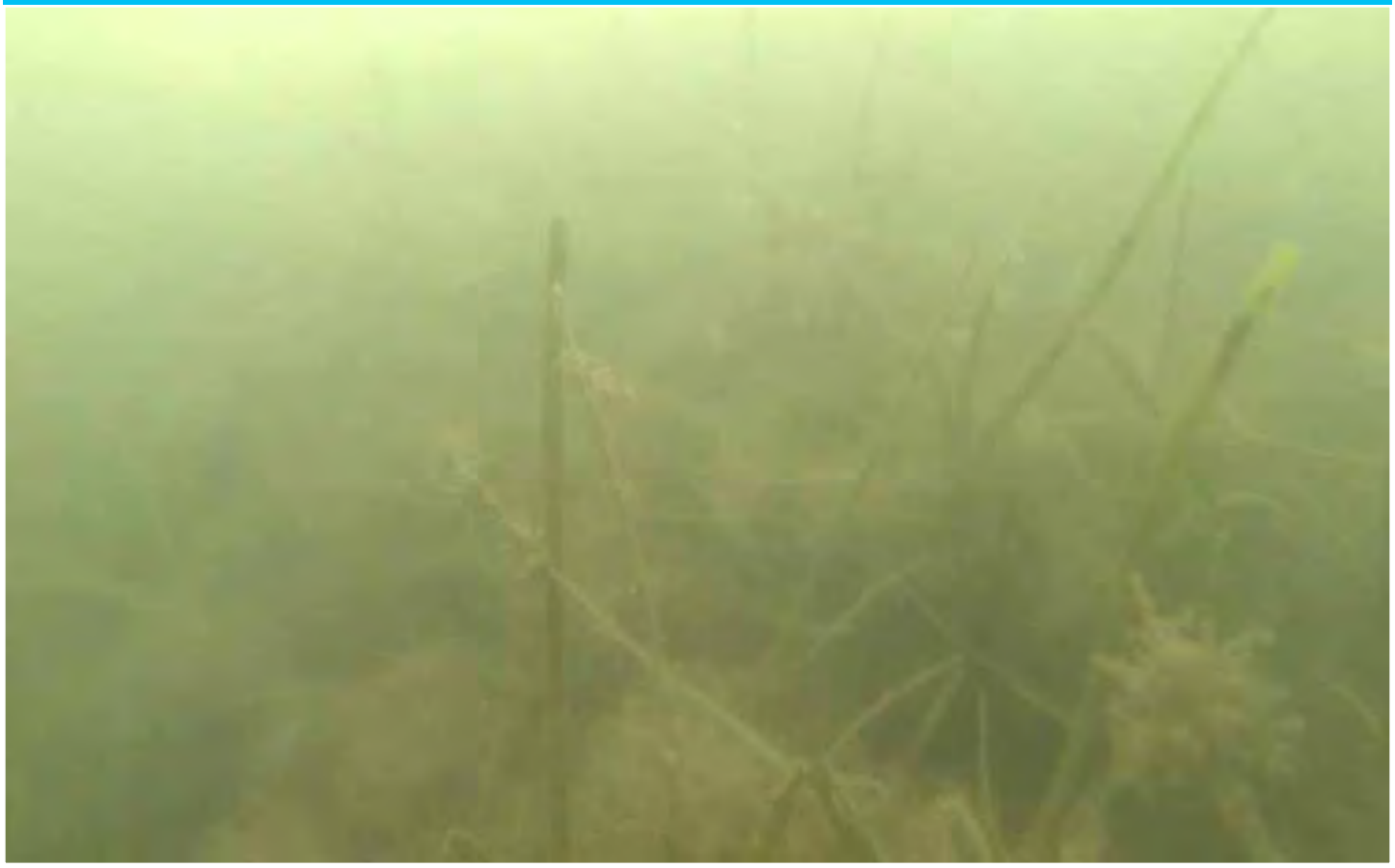
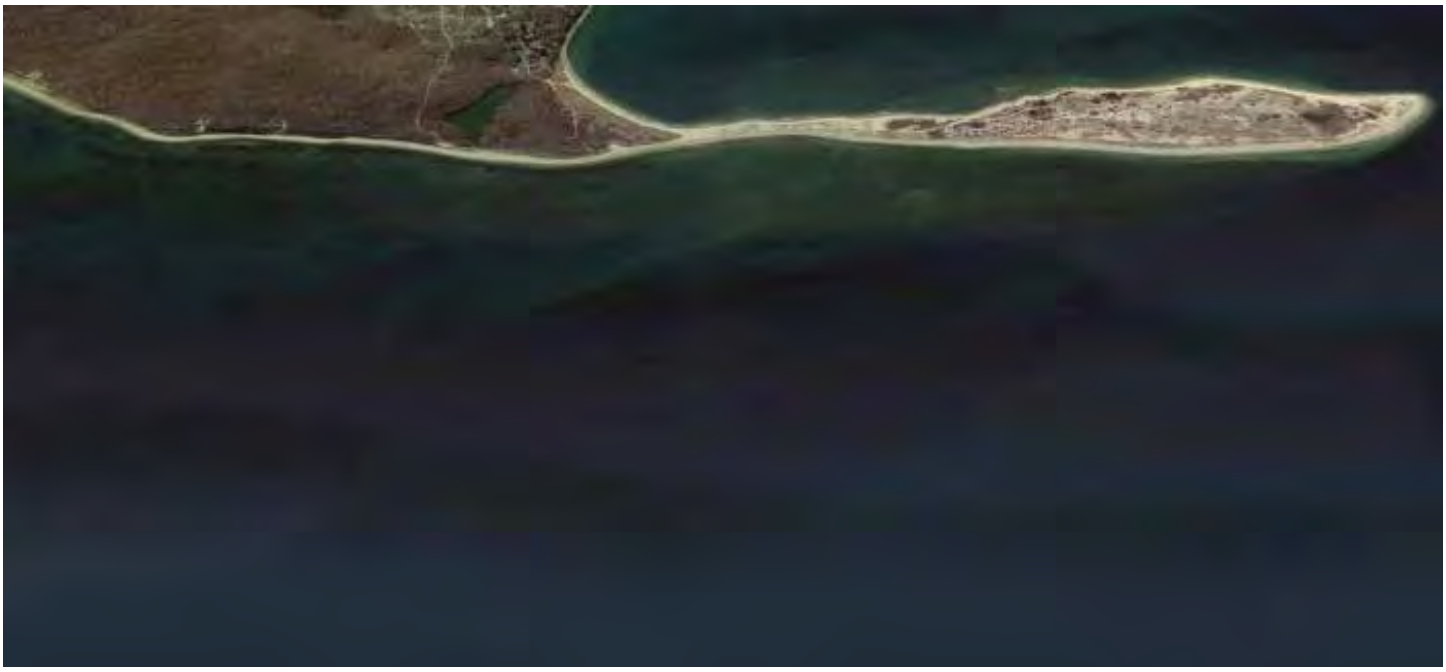


Figure TMH-4. Photograph of the general conditions observed at monitoring station NTMH-1 in Three Mile Harbor. The eelgrass bed supports a high biomass population of the red filamentous macroalga *Spyridia filamentosa* as illustrated in the photograph.

has only been conducted at the site for four years, it is difficult to make any definitive conclusions on the long-term trend of this meadow. The last four summer seasons have been some of the hottest on record, resulting in a picture of the meadow, at least over the last two seasons, that may be on the verge of decline. However, there may be similarities between this meadow and the Bullhead Bay meadow relating to SGD moderating water temperature during the periods of high water temperature, which should be investigated further.

The new Three Mile Harbor eelgrass meadow does have several factors that potentially work against its long-term survival. Its location in the headwaters of the harbor result in minimal water exchange with Gardiners Bay, which influences water quality and water temperature at the site. The shore along the meadow is developed and human activities (e.g. boating, application of lawn products, active septic systems), could pose, if they do not already, problems for the meadow. Even with these potential impacts and the decline reported for this meadow for the 2018 season, it is still a relatively healthy eelgrass population given its location in a harbor where other eelgrass meadows have disappeared.

Cedar Point 2018



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 sites 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.

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 June-October, annually, and that data is presented below.

Sediment analysis of the site conducted in 2017, characterized the Cedar Point eelgrass meadow. Sediment samples were collected within the meadow at each of the monitoring stations, and the average grain size and organic content were found to be: 26.1% gravel, 71.0% sand, and 2.9% silt+clay. The organic content of the sediment at the site was very low, 0.44%. The coarse sediment grain size and low organic content are consistent with a site that experiences high wave energy and has a significant current.

Light Availability and Temperature

Light loggers were deployed for ten days, monthly, from July-September 2018. The first light logger

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 2018.

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	FAILED TO RECORD				22.4
August	12.4	+0.1	9.0	+1.0	24.8
September	11.6	-0.7	8.8	+0.8	22.4

deployment in July 2018 resulted in no data due to the equipment failing to record, however, based on light data from other locations in the area, it is probable that the meadow received at least its minimal light requirement for the month. The loggers deployed for August and September 2018 both functioned properly and the average daily H_{comp} and H_{sat} values are presented in Table CP-1. August 2018 found the meadow receiving sufficient light to meet its basic needs and also provide a surplus for both H_{comp} and H_{sat}. The September light data found that H_{comp} was at a minor deficit, while H_{sat} ran a slight surplus.

As in previous years, the water temperature logger was deployed to the site in early June 2018. Water temperatures at the Cedar Point meadow were significantly higher than temperatures recorded in 2017. The site did remain below 25°C for the monthly average temperatures in 2018 (Table CP-1), however, the site recorded 15 days with average daily water temperatures greater than 25°C, compared with no days in 2017. The highest water temperature recorded for 2018 at Cedar Point was 26.9°C on 10 August, 2018.

Eelgrass Shoot Density

The Cedar Point eelgrass meadow was surveyed on 11 September, 2018. The average eelgrass shoot density for 2018 was calculated as 225 shoots·m^2 (Table CP-2; Figure CP-2). The 2018 density represents a significant decline in the meadows from its density in 2017. The decline in shoot density resulted from no eelgrass recorded at station 6 in 2018. This station just reported the recovery of eelgrass in 2017 after being unvegetated in 2016. The monitoring survey also found that station 2 had suffered significant decline in both the size and density of eelgrass patches, resulting in much lower density numbers for 2018 at this station.

Macroalgae Cover

Macroalgae cover in 2018 showed a significant increase over cover in 2017 (Figure CP-3). The dominant species within the Cedar Point meadow continues to be the brown alga *Sargassum filipendula*. Exposure of previously buried rock and boulders at station 6 appears to have provided increased substrate for *Sargassum,* and other species, to attach, resulting in

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 and 2018, 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
2017	341	±41
2018	225	±36

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for select years from 2000-2018.

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.)
2017	77.1 acres (31.20 hect.)
2018	73.6 acres (29.80 hect.)

Cedar Point 2018

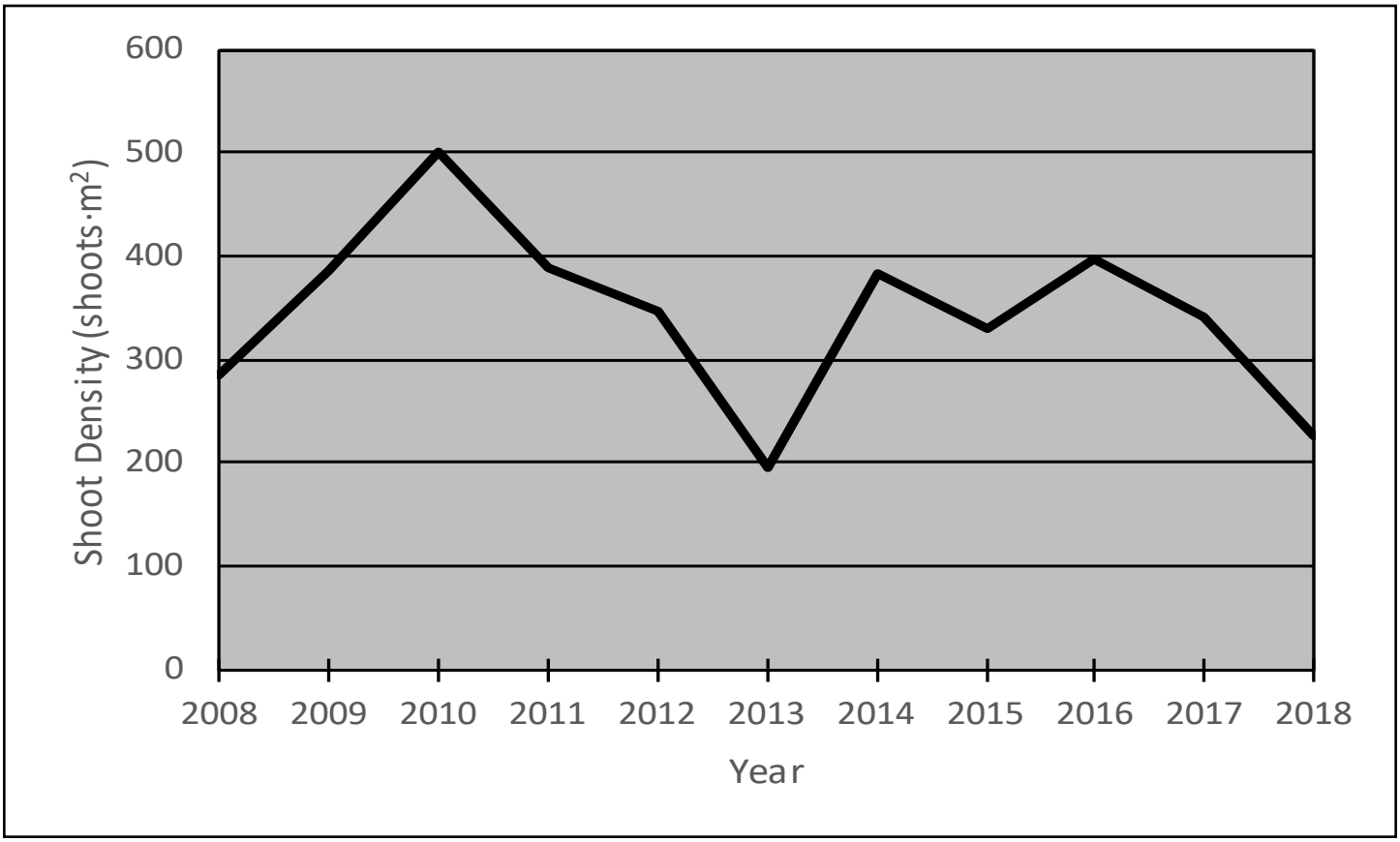


Figure CP-2. The average annual eelgrass shoot density for Cedar Point for 2008-2018.

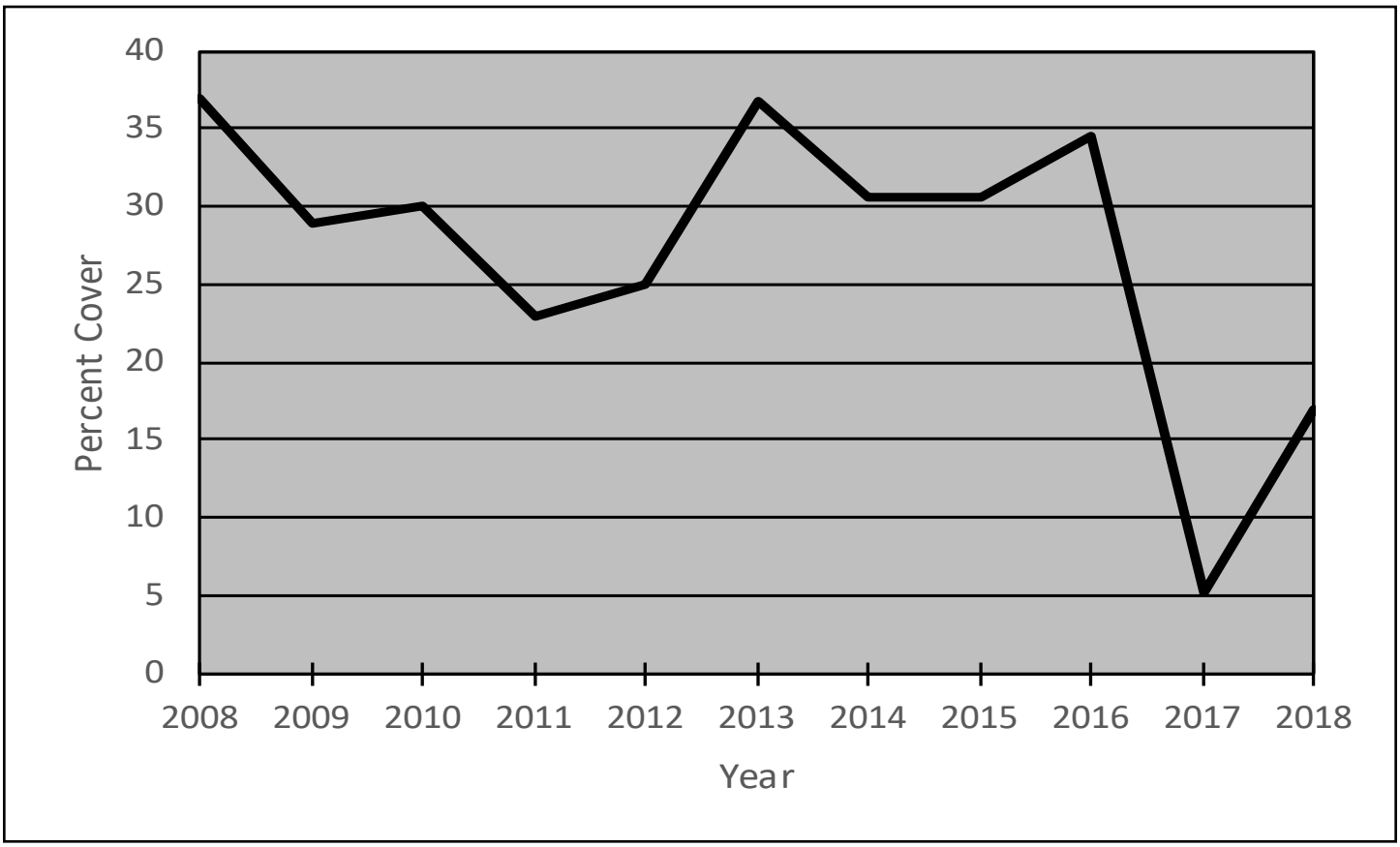


Figure CP-3 Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2018

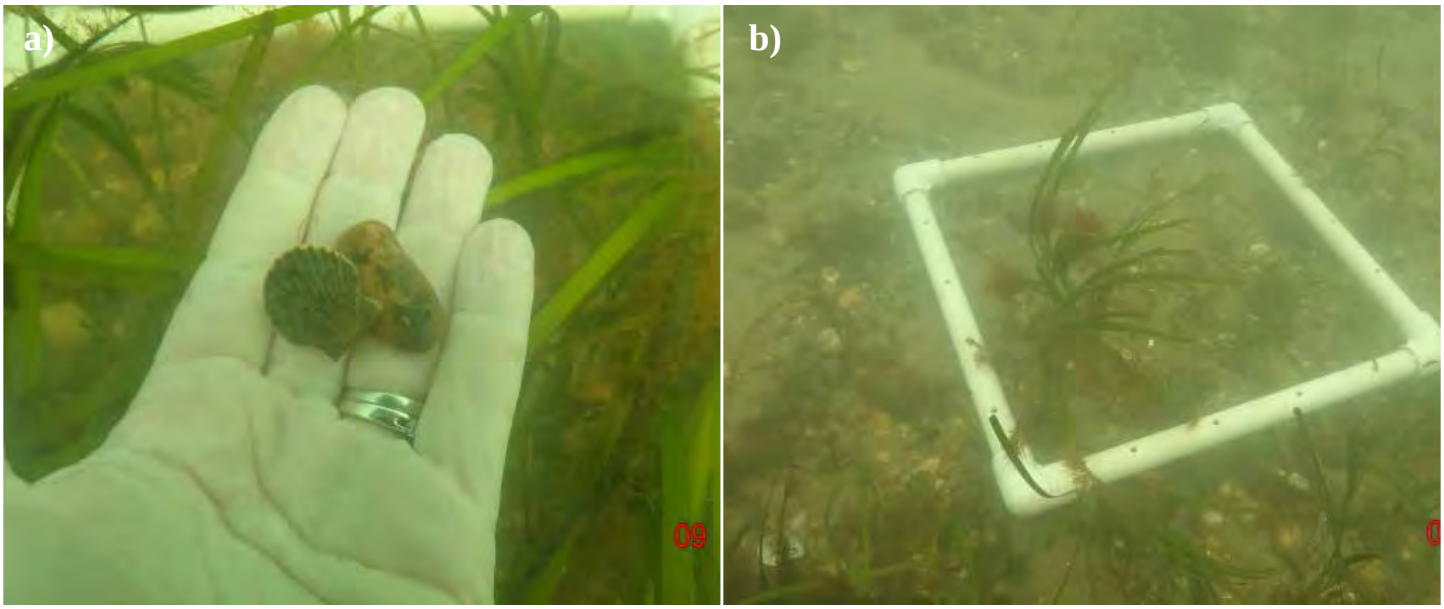


Figure CP-4. a) A 'bug' scallop removed from a sampling quadrat prior to taking a shoot density count at station 2. b) A quadrat at station 5 shows the patchiness of some areas of the meadow at Cedar Point.

a significantly higher macroalgae cover for 2018 at this station, and increasing the overall average for the meadow. A total of eight macroalgae species were identified during sampling for the site.

Bed Delineation and Areal Extent

The Cedar Point eelgrass meadow delineation for 2018 was completed using Google Earth™ imagery taken on 29 June, 2018. The overall quality of the imagery was adequate and allowed for an accurate assessment of the meadow at this site and the delineation presented in Figure CP-4f. The 2018 areal extent of the meadow covers 73.6-acres (Table CP-3), and represents a less than 10% change from the areal extent mapped in 2017. A significant amount of the reported difference between years could be attributed to inconsistent aerial imagery quality. The 2018 imagery, while adequate for delineation, was not as clear as the 2017 imagery. Based on this evaluation, the reported 3.5-acre difference between years should be considered as no change.

Conclusions

The Cedar Point eelgrass monitoring survey for 2018 found that the meadow had suffered a significant decline in eelgrass shoot density resulting from the complete loss of eelgrass from one station, and a significant decline in the eelgrass population at a second station. This loss appears to be the result of physical disturbance, likely wave-induced, as evidenced by the increased erosion along eelgrass patch edges and the exposure of once buried rock and boulders, indicated movement of sediments within the site. Physical disturbance is currently the most prominent impact to the site, however, water temperature data from 2018 showed a notable increase in higher water temperature events at Cedar Point than had previously been reported, which raises concern regarding the potential impacts of climate change on the eelgrass meadow.

Climate change does not correlate to just increased temperature, it will change weather patterns which could impact Cedar Point and other sites in the LTEMP The Cedar Point meadow is subjected to impacts from storm events that produce large waves. The frequency and intensity of these storms are projected to increase in coming years, resulting in increased physical damage at exposed eelgrass meadows, like Cedar Point. Eelgrass does grow at sites exposed to high wave energy, seemly having the ability to adapt to these conditions, but it may take time and significant changes in meadows should be expected for the near future.

Cedar Point 2018

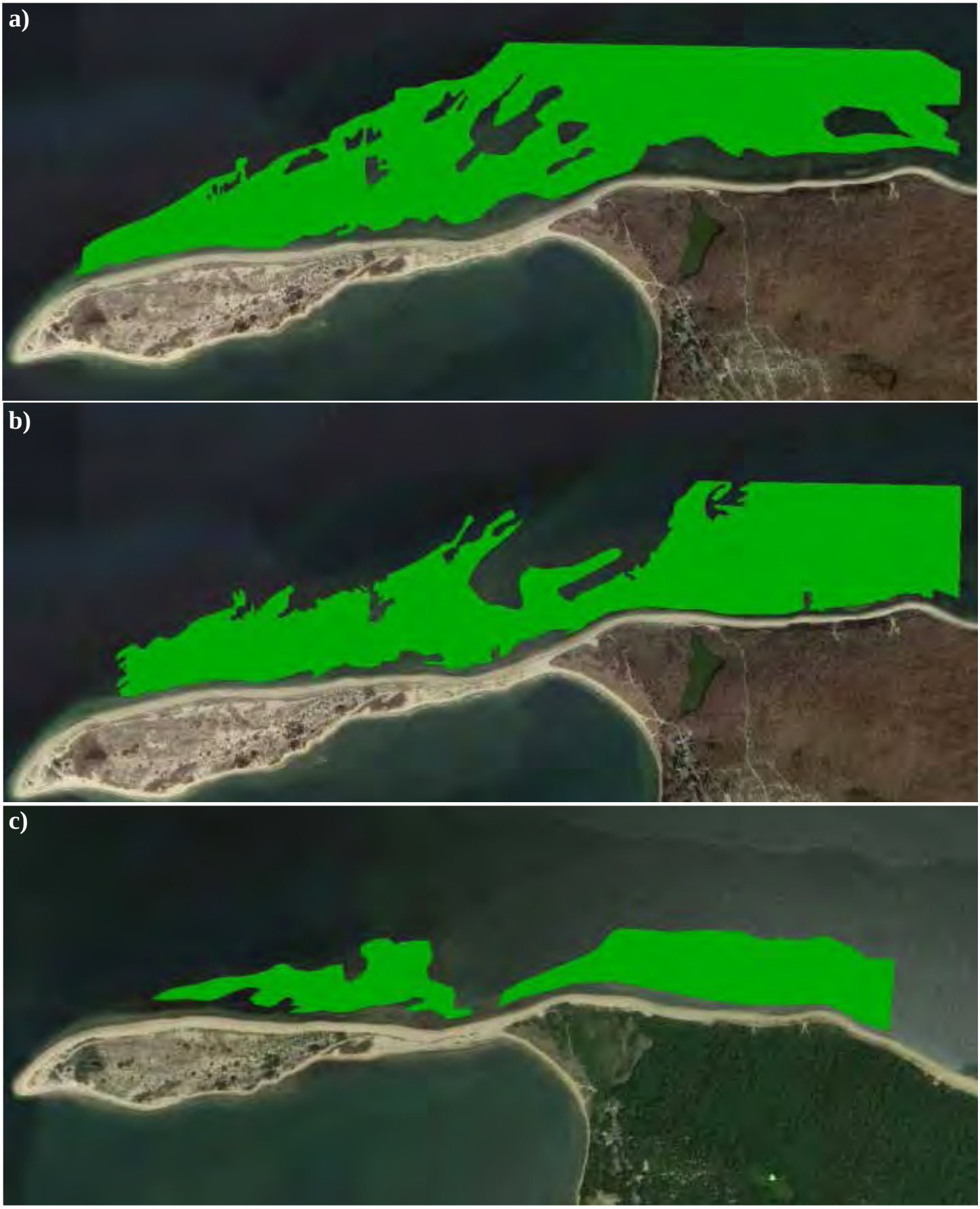


Figure CP-5. Delineations of the Cedar Point eelgrass meadow from aerial photographs for a) 2004, b) 2010, c) 2014, d) 2016, e) 2017, and f) 2018 (continued on next page).

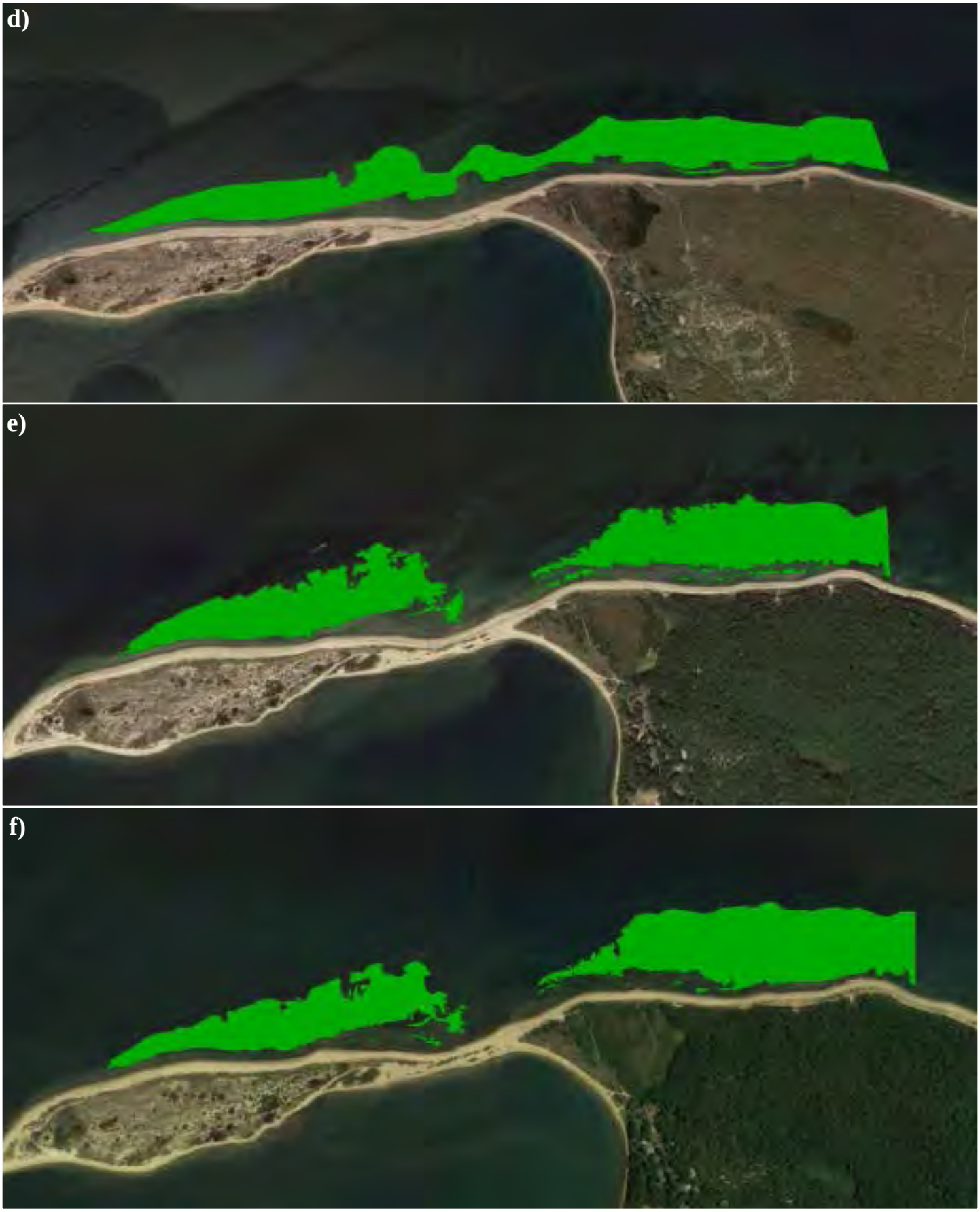


Figure CP-4. Continued.

Orient Point 2018

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 sediment 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 sediment at this site was analyzed initially in 1997, when the site was considered for the monitoring program. The 1997 analysis found that the sediment

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 2018.

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	14.3	+2.0	12.2	+4.2	21.6
August	12.4	+0.1	7.3	-0.7	23.4
September	11.5	-0.8	7.4	-0.6	22.1

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%. The follow-up sediment analysis conducted in 2017 found that the site had changed minimally in the intervening years. The sediment was composed of 23.5& gravel, 73.7% sand, and 2.8% silt+clay, with an organic content of 0.63%.

Light Availability and Temperature

Light logger deployments were similar to previous years, with a logger deployed for 10-day periods, once monthly from July-September for the current monitoring season. The daily average Hcomp and Hsat were calculated from this data and a daily average for each monthly deployment are presented in Table OP-1. Light availability in the Orient Point site showed an improvement over the finding of the 2017 monitoring report. July 2018 found that the site had received ample light and both H_{comp} and H_{sat} ran surpluses for the month. The light conditions in August were mixed with H_{comp} reporting just over the its minimal threshold while H_{sat} ran a deficit of 0.7 hours. September, a time when shortening daylength and sun angle becomes noticeable, typically runs deficits for both parameters, and this held true for the 2018 season.

The 2018 season experienced another hot summer, and while the Orient Point meadow was not subject to water temperatures above its optimal range, monthly average water temperatures were found to be higher than those reported for the same interval in 2017. The average monthly temperature for August 2018 was 1.6°C higher than in 2017. The highest water temperature recorded for the Orient Point meadow was 25.4°C was taken on 5 September, 2018. The Orient Point meadow recorded no daily average temperatures reaching 25°C in 2018.

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
2017	94	±16
2018	97	±18

Eelgrass Shoot Density

The 2018 Orient Point eelgrass monitoring was conducted on 17 September, 2018. The average eelgrass shoot density calculated for the meadow was 97 shoots·m^2 (Table OP-2; Figure OP-2). This shoot density represents no change from the 2017 meadow density (94 shoots·m^2). As stated in the 2017 monitoring report, two stations, 4 and 6, no longer support eelgrass, and there was no signs of recovery at either station in 2018. In addition, station 1 suffered a major decline in the eelgrass population around the site. This condition was reported in 2017 for the station, but it appears to have intensified in the intervening year. Based on diver observations of the station, storm/wave damage in this area of the meadow seems to be more evident than the rest of the meadow, suggesting that the decline of eelgrass may be related to physical disturbance.

Macroalgae Cover

The macroalgae cover for the Orient Point eelgrass meadow remained stable between 2017 (18.4%) and 2018(18%), with a less than 0.5% decline in 2018 (Figure OP-3). A total of seven species were identified during the survey, with the brown alga *Sargassum filipendula* reported as the dominant species, followed

Orient Point 2018

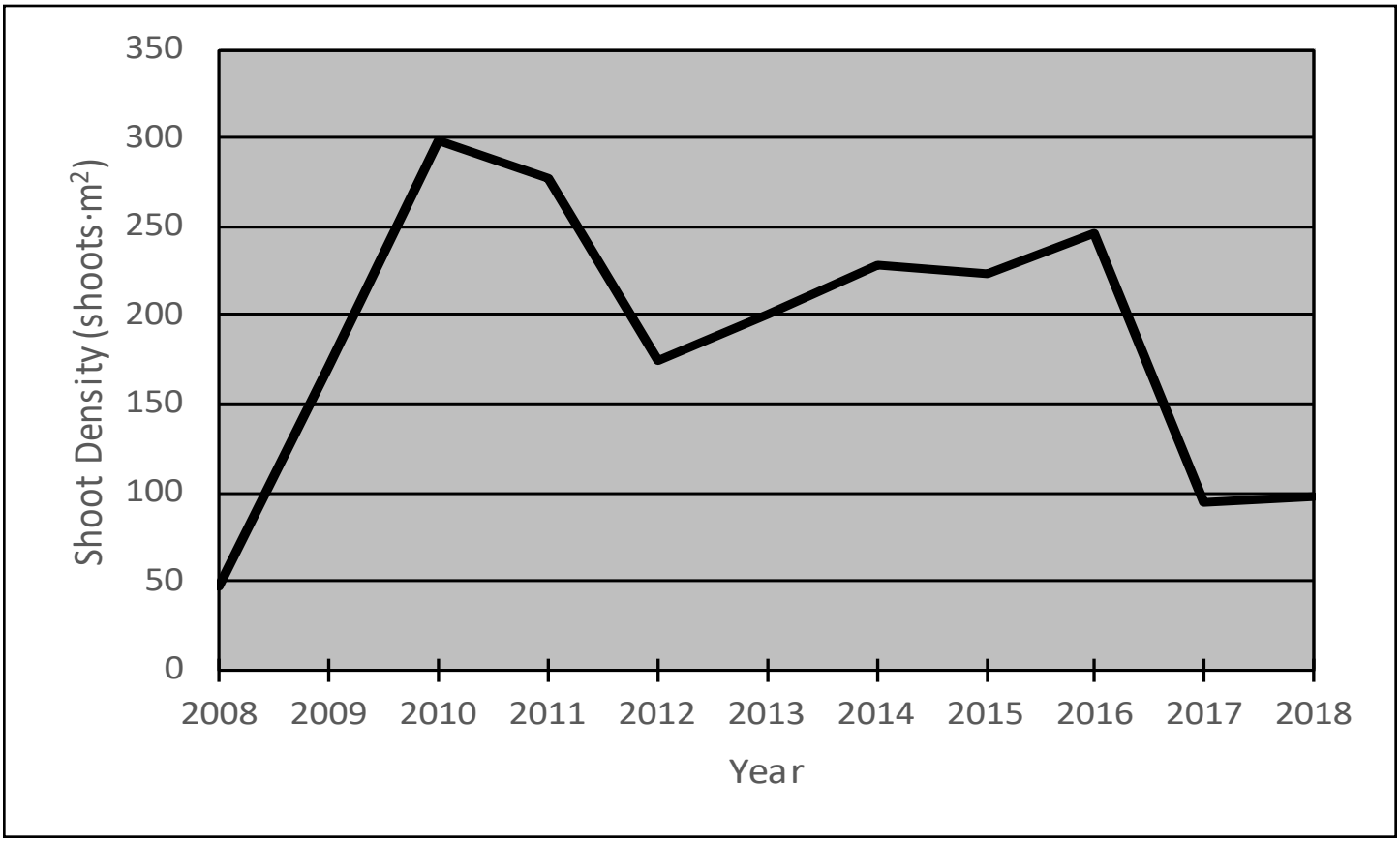


Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2018.

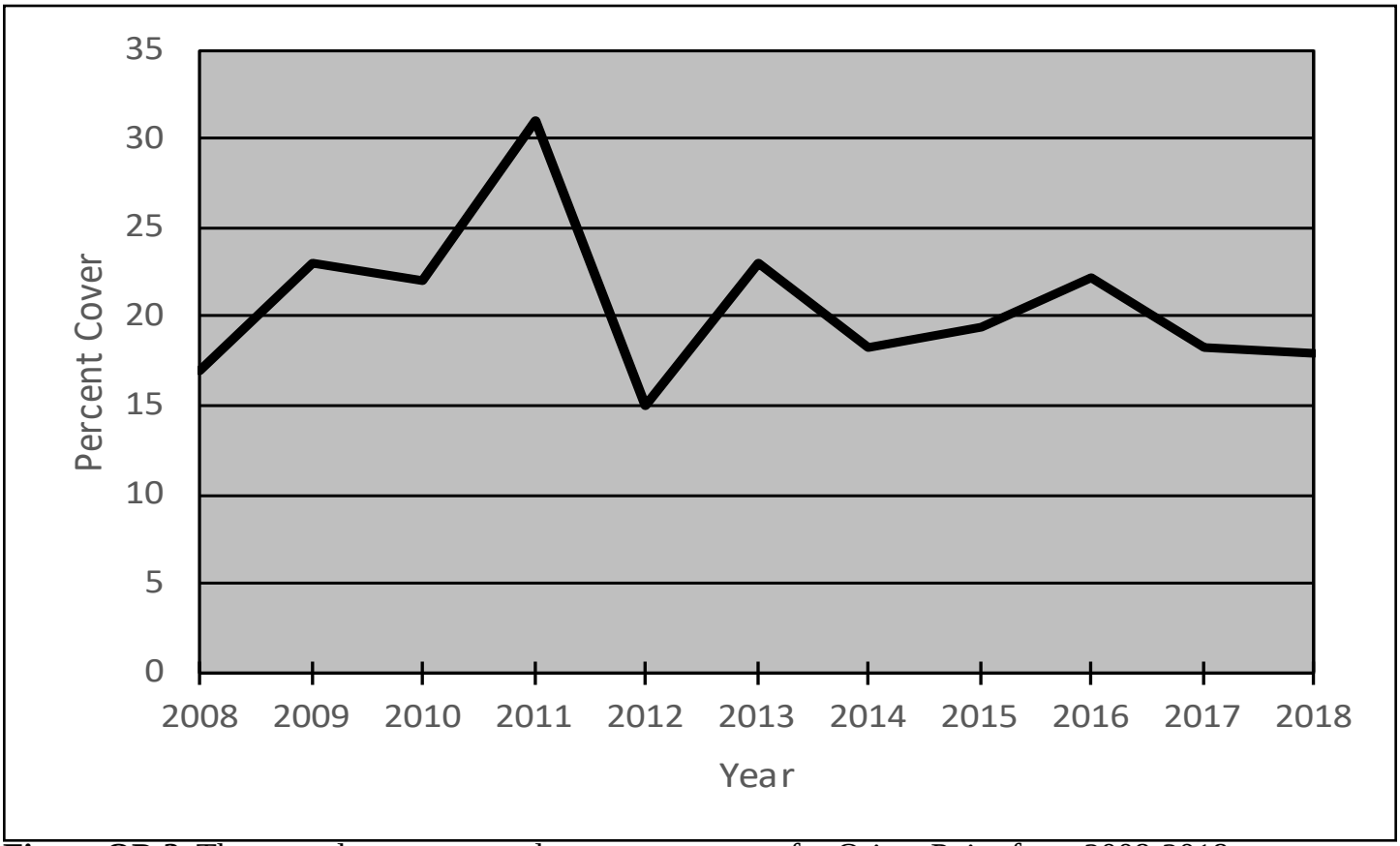


Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2018.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2018.

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.)
2017	14.70 acres (5.95 hect.)
2018	10.8 acres (4.37 hect.)

*Area of meadow was significantly underestimated in aerial survey.

by the red, turf-forming seaweed *Chondrus crispus*. The larger seaweed species were confined to areas of the meadow where larger rocks provided substrate for attachment, whereas the small, filamentous species observed at the site could be found in the generally sandy open patches in the meadow attached to gravel and shell.

Bed Delineation and Areal Extent

The delineation of the Orient Point eelgrass meadow for 2018 was created using aerial imager provided on Google Earth™ and taken on 29 June, 2018. The quality of the aerials for Orient Point, and other LTEMP sites, were generally of poor quality, making the task of accurately delineating the meadow, especially on the deeper, offshore edge, difficult. For Orient Point, even the shallow, inshore sections of the meadow did not present the strong eelgrass signature present in past aerial images. The resulting delineation of the meadow for 2018 is likely underestimated at only 10.8-acres (Table OP-3). This is a decline of almost 5-acres from 2017. The decline between the two years was likely overstated by the poor imagery for the site preventing an accurate delineation of the actual extent of the meadow.

Conclusions

The 2018 monitoring survey of the Orient Point eelgrass meadow found that the eelgrass shoot density and macroalgae cover had not changed significantly from the 2017 survey. Since the precipitous decline in shoot density from 2016 to 2017, there does not appear to have been much recovery in the meadow in the subsequent two years. Much of this can be blamed on the increased frequency and intensity of storms produced as a result of climate change. Due to its exposed location in the estuary, the Orient Point eelgrass meadow is especially susceptible to storm damage, with waves causing erosion of the meadow in some areas, while shifting sediment buries eelgrass in other areas. The frequent intense storms have also been causing erosion along the upland edge of the shoreline, with the displaced, terrestrial sediments being deposited in the meadow and potentially contributing to burial of eelgrass.

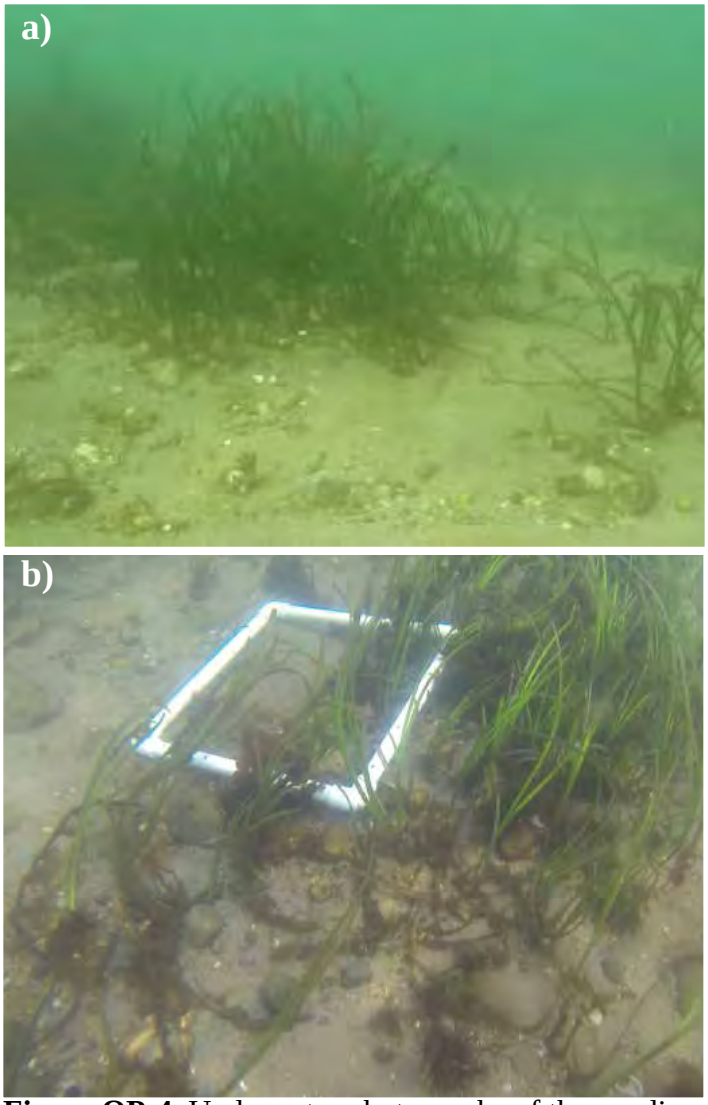


Figure OP-4. Underwater photographs of the conditions at a) station 2 and b) station 5 within the Orient Point eelgrass meadow.

Orient Point 2018

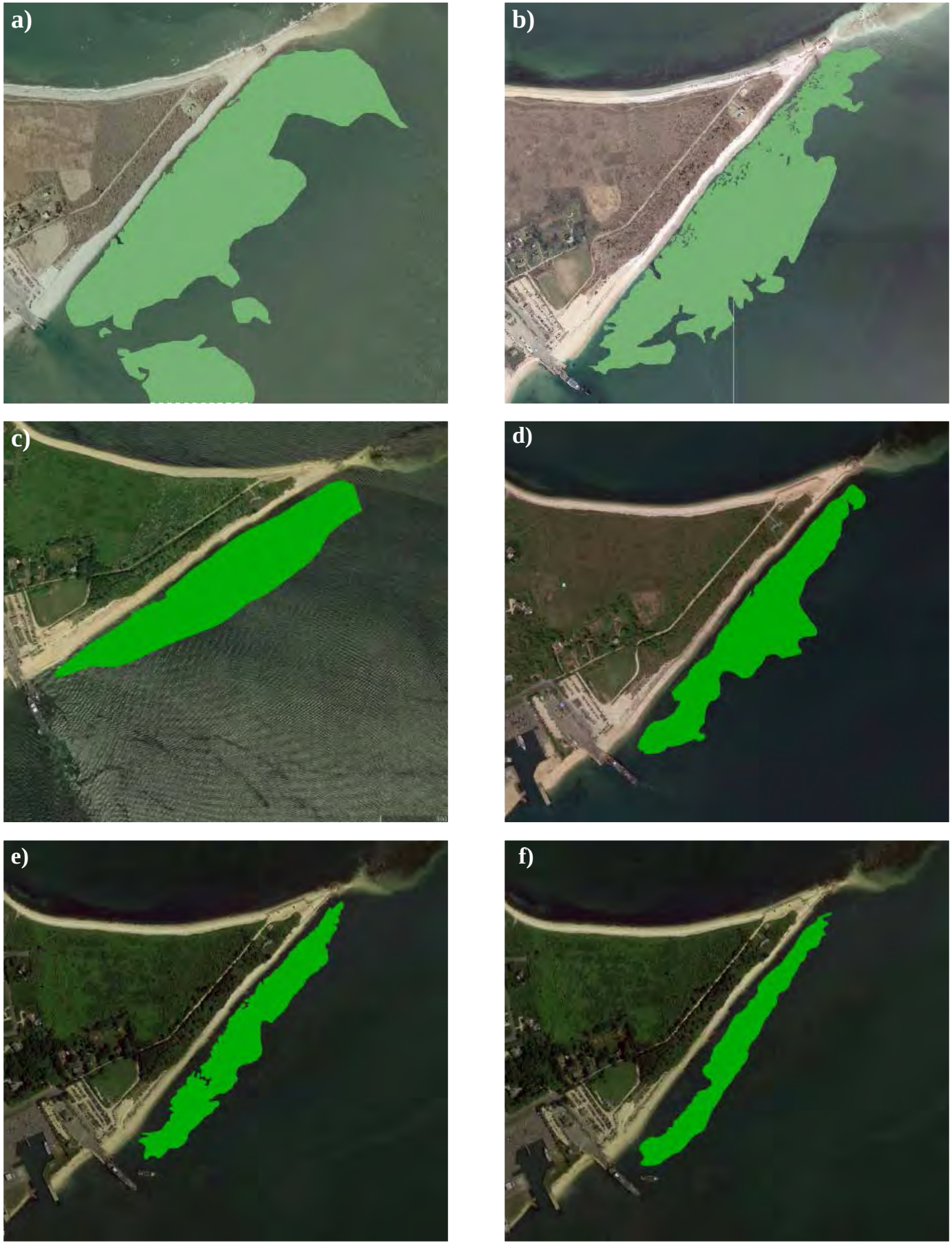


Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2010, c) 2014, d) 2016, e) 2017, and f) 2018.

Climate change may also be starting to effect the meadow with temperature changes. The Orient Point meadow has minimal exposure to stressful water temperatures, but the 2018 temperature data has shown that the site is starting to experience the warming trend that other meadow in the Peconic Estuary have been experiencing for the past few seasons. The increase in the average, monthly temperature for August of 1.5℃ between 2017 and 2018 was the first increase of this scale at the site. While the Orient Point eelgrass meadow did not record any days in 2018 with average daily temperatures reaching 25℃, one day in early September averaged 24.5℃. This meadow may still be years away from experiencing the full effects of climate change on the water temperatures it experiences, but, if the data from 2018 is any prediction of the future trend at the site, continued increases in temperature should be expected in the coming monitoring surveys.

Based on the observations from the 2018 monitoring season, climate change is the greatest threat to the Orient Point eelgrass meadow. Anthropogenic disturbance at the site is minimal, and while damage by crabs has been observed to have increase erosion, it is still a minor impact on the meadow. The largest impact on the meadow, resulting in loss is from storm damage, which, if climate predictions are true, may only intensify in the coming years.

Coecles Harbor 2018

Coecles Harbor is an enclosed embayment located on the eastern side of Shelter Island, connected to Gardiners Bay by a narrow, dredged inlet. The eelgrass meadow covers 111.5 acres (2014 PEP eelgrass survey) in the northern part of the harbor and includes two separate mooring fields within its boundaries.

Site Characteristics

The sediment characteristics determined from sampling during the 2017 season found that the Coecles Harbor meadow grows in a predominately silty-sand (28%:70%) with a relatively low organic content of 4.24%. The site is protected from wind and storms on all sides, minimizing wave impacts on the meadow. Water quality appears to be within the optimal range for eelgrass, based on the extensive meadow at the site, but observation made throughout the season suggest that water clarity can be moderate to poor during the growing season. Also, the site has had a history of *Cochlodinium polykrikoides* (rust tide) blooms in resent years. As this is a new site for the LTEMP, and CCE has minimal past experience working in this meadow, factors influencing the health and extent of this meadow will be identified in subsequent monitoring seasons.

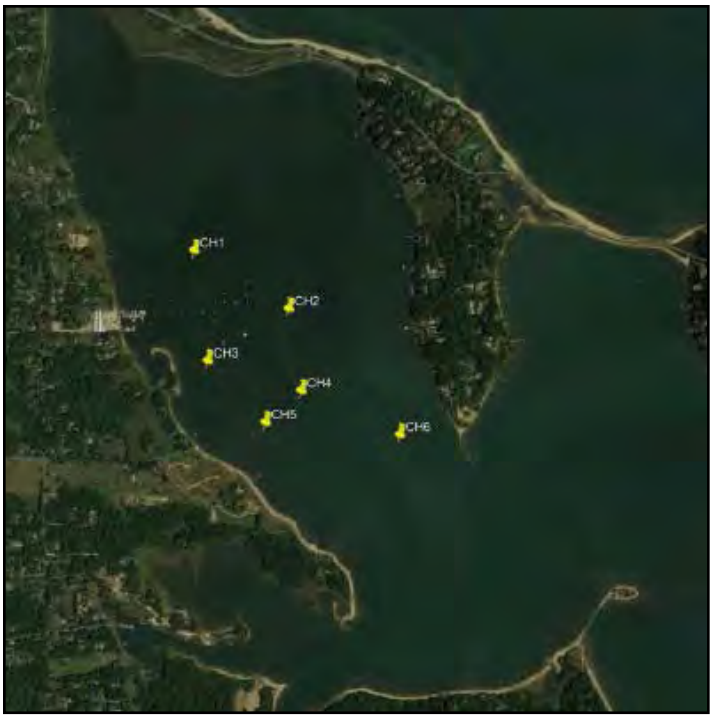


Figure CH-1. An aerial view of the Coecles Harbor monitoring site with monitoring stations indicated by the superimposed numbers.

Light Availability and Temperature

The light and temperature monitoring station in Coecles Harbor was set up in late May 2018, with the Onset HOBO temperature logger deployed at this time. The Odyssey PAR light logger was deployed in for 10-day intervals starting in July and continuing monthly through September. The light data, H_{comp} and H_{sat}, and the average monthly water temperature are presented in Table CH-1.

Light availability in Coecles Harbor varied over the course of the summer of 2018. The meadow received ample light in July with both H_{comp} and H_{sat} running surplus of their minimal daily requirements. August found the meadow slightly deficient in H_{comp} (-0.2

Table CH-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Coecles Harbor over 10-days for September 2018.

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	10.1	+2.1	25.3
August	12.1	-0.2	6.9	-1.1	26.1
September	10.0	-2.3	4.7	-3.3	22.8

hour) and more than 1 hour below the daily average requirement for H_{sat} of 8 hours. September saw a significant deficit in both H_{comp} and H_{sat}, 2.3 and 3.3 hours, respectively.

Water temperatures over the summer of 2018 were found to be high. Both July and August averaged water temperatures greater than 25°C (Table CH-1). The Coecles Harbor meadow experienced a total of 50 days with water temperatures exceeding 25°C and nine days with daily average temperatures greater than 27°C. The highest recorded water temperature for Coecles Harbor in 2018 was 28.9°C, recorded on 10 August.

Eelgrass Shoot Density

The Coecles Harbor eelgrass meadow was visited on 13 September, 2018. The meadow was found to have declined to an average eelgrass shoot density of 41 shoots per m², down from 78 shoots per m² reported for 2017 (Table CH-2). The difference in eelgrass shoot density between the two years is attributed to declines at three stations (1, 4 and 6; Figure CH-1). Two stations (2 and 3) saw increases in shoot density, while station 5 experienced no change between years. There were no obvious causes for the decline at the stations at the time of monitoring, except for station 6, where the harbor bottom had the appearance that it had seen a storm, with eelgrass shoots tattered and seaweed in tangled clumps. Figure CH-3b provides an example of some of the damage reported to the eelgrass.

Table CH-2. The average annual eelgrass shoot density for Coecles Harbor from 2017 to 2018, including standard error.

Year	Mean Density	S.E.
2017	78	+/- 7.5
2018	41	+/- 4.5

Macroalgae Cover

Macroalgae cover in Coecles Harbor continued to be high in 2018. Average percent cover of macroalgae for the meadow was 70% in 2018, virtually unchanged from the percent cover (72%) reported for 2017. The macroalgae community was dominated by the red filamentous seaweed *Spyridia filamentosa* with only one other subordinate species (*Gracilaria* sp.) observed during the monitoring visit.

Bed Delineation and Areal Extent

Google Earth™ imagery taken on 29 June, 2018, was used to delineate the Coecles Harbor eelgrass meadow. Aerial image quality was variable over the meadow resulting in areas of the meadow providing weak eelgrass signatures for delineation. Due to the poor quality of the aerial imagery, only 88.4-acres (Figure CH-2b) were delineated. The 2017 delineations identified 102-acres, using high quality images. The difference between the two years should not be considered lost meadow area, but rather the 2018 delineations should classified as incomplete due to poor image quality.

Conclusions

The 2018 monitoring season was the second year that Coecles Harbor has been included in the eelgrass monitoring program. The 2018 season was found to have been extremely warm, 50 days over 25°C and record high temperature of almost 29°C, and reported a significant decline in eelgrass shoot density from the 2017 season. *Cochlodinium* was observed throughout the harbor during visits in August and September, which could have contributed to the low light availability recorded during those months. High water temperatures and low light availability likely contributed to the majority of the decline in eelgrass shoot density, but the observation at monitoring station 6 of a 'storm-tossed' bottom (there were no significant storms reported during this period), suggests another possible cause, at least locally within the meadow. The

Coecles Harbor 2018

Figure CH-2. The Coecles Harbor eelgrass meadow delineations completed in a) 2017 and b) 2018, for the LTEMP monitoring site.

disturbed bottom at station 6 may have been the result of prop wash from a relatively large boat(s) either traversing the area or docking, repeatedly, at one of the docks located inshore of the monitoring station. The water depth over most of the Coecles Harbor eelgrass meadow is relatively shallow, averaging 5-6 feet deep at low tide, making the meadow susceptible to potential damage from boating activity. The only 'No Wake' areas within the eelgrass meadow is located around the two mooring fields. Other than these areas, boaters are free to run above idle speeds which could result in damage to the meadow in shallow areas.

With only two seasons of monitoring data for Coecles Harbor, a clear picture of the population dynamics of this eelgrass meadow can not be produced. While the decline in eelgrass density in 2018 is concerning, this may be part of cycle within the meadow or a response to an infrequent set of conditions that occurred during this monitoring visit and may not repeat in 2019. The potential impacts of boating traffic through unprotected sections of the meadow should be considered, especially if the type of damage observed at monitoring station 6 is reported again. If this becomes a chronic problem in the meadow, that the possible expansion of the 'No Wake' zones could assist in alleviating this problem.

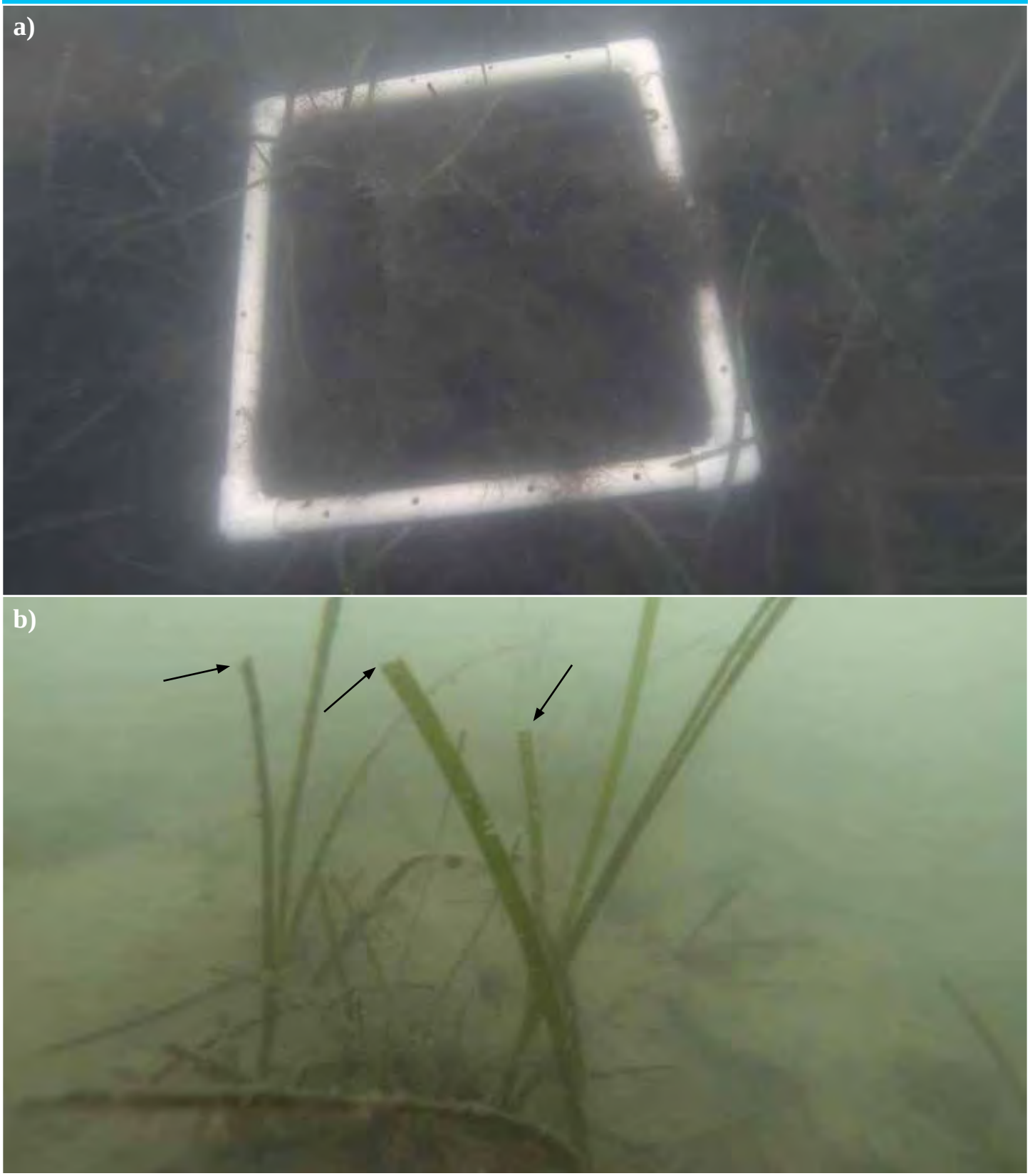
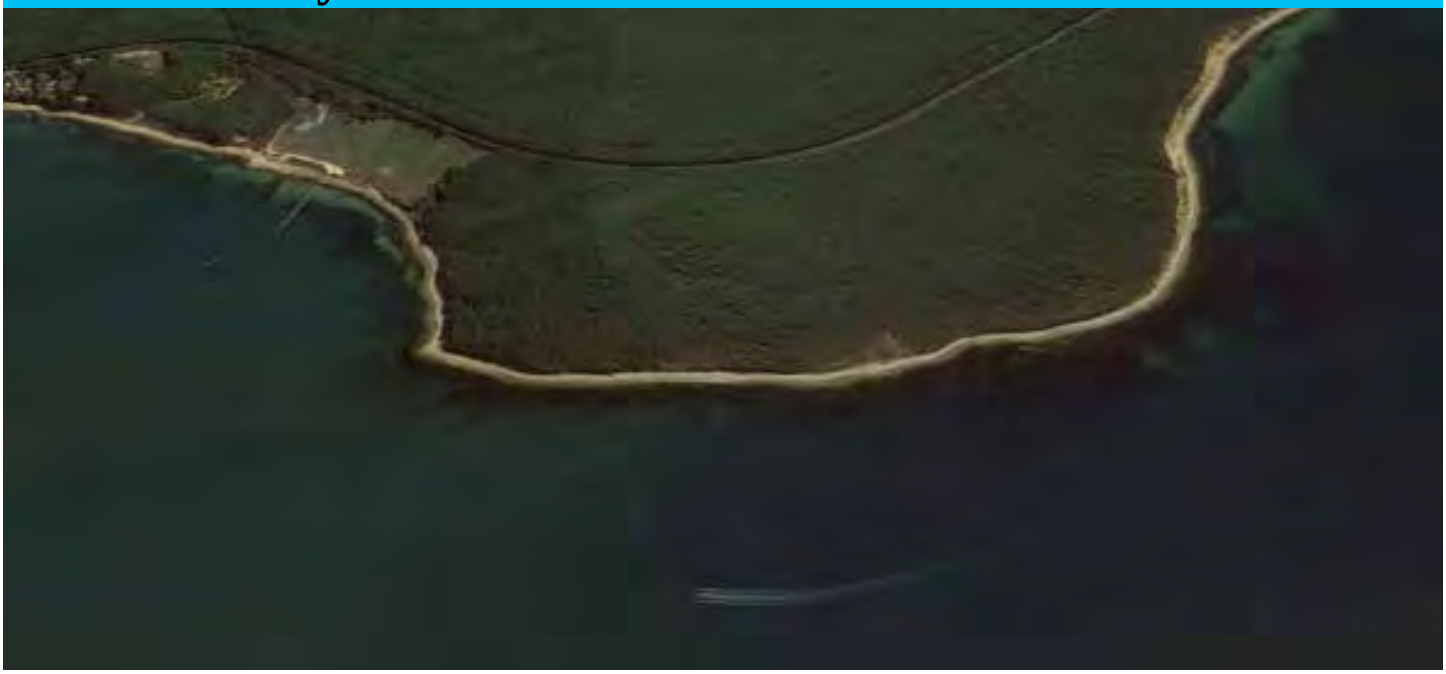


Figure CH3. Underwater photographs taken at a) station 1 with a quadrat illustrating the the high percent cover of *Spyridia filamentosa* and the relatively low density nature of the Coecles Harbor meadow. b) This photograph was taken a station 6 where it appearred as if the meadow had been through a storm. The arrows indicate eelgrass blades that look like they have been cut near their tips, which is commonly observed in meadows after storms or turbulence and often results in the older, weak sections of the blades shearing off.

Fort Pond Bay 2018



Fort Pond Bay is the easternmost eelgrass meadow in the LTEMP. The meadow starts in Fort Pond Bay near the pier at the Edward Vincent Ecker, Sr. County Park, extends north, then west toward Hither Hills State Park (Figure FP-1).

Site Characteristics

The Fort Pond Bay eelgrass meadow extends along more than 1.5 miles of shoreline. The site is divided into a section of open coast, subject to waves generated by winter storms, and a more sheltered section of meadow, protected in the lee of Rocky Point. The open coast eelgrass grows in relative deep water, occupying open spaces in the boulder field. This habit likely provides protection from hydrodynamic forces generated by storms that could erode the meadow. In the sheltered section of the meadow, the eelgrass grows on shallow flats, on sandy bottom. The eelgrass creates large, dense patches with dense rhizome mats that should be able to withstand occasional waves generated from the northeast. As the meadow extends out of the sheltered bay and onto the more exposed northern shore of the South Fork, the meadow occupies deeper water (8-15 feet) and is found in smaller patches growing in open areas of what is essentially a boulder field. This section of the meadow resembles the eelgrass meadow at Cedar Point. Sediment characteristics vary greatly between areas of the meadow. Some sections have a high gravel content (up to 44%), while others are nearly pure sand (more than 90%). However, all sections of the meadow were found to be low in organic content, averaging less than 1% over the six monitoring stations.

Figure FP-1. An aerial view of the Fort Pond Bay monitoring site with monitoring stations indicated by the superimposed numbers.

Light Availability and Temperature

An Odyssey PAR light logger was deployed monthly to Fort Pond Bay for 10-day intervals to record the amount of light available to the eelgrass plants at the site. The logger site was located 100 feet southeast of the old, concrete boat ramp at the site in approximate-

Table FP-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Fort Pond Bay over 10-days for 2018.

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	14.5	+2.2	12.8	+4.8	20.6
August	12.5	+0.2	9.7	+1.7	22.9
September	11.8	-0.5	8.2	+0.2	21.4

ly 4 feet of water at mean low tide. Light data was collected monthly from July-September 2018. Table FP-1 includes the average daily Hcomp and Hsat record for the site, by month, collected during the 2018 season. Fort Pond Bay continued to have excellent water clarity during the 2018 season. The only deficit in light availability was reported in September for H_{comp}.

The water temperature data presented in FPB-1 provides the average monthly water temperatures calculated for Fort Pond Bay from logger data for the 2018 season. The meadow did not experience any days with water temperatures reaching, or exceeding 25°C in 2018, however water temperatures were found to be warmer in 2018 than 2017, with a high water temperature of 25.2°C recorded in early August.

Eelgrass Shoot Density

Monitoring in the Fort Pond Bay eelgrass meadow was conducted on 14 September, 2018. The average eelgrass shoot density for the meadow had declined by just over 100 shoots·m^2 to 483 shoots·m^2. The decline in eelgrass density was attributed to increased patchiness at throughout the meadow and fewer small lateral shoots that were prevalent during the 2017 monitoring season.

Macroalgae Cover

Macroalgae cover within the Fort Pond Bay eelgrass meadow increased from 20% (2017) to 26% (2018).

Table FP-2. The average annual eelgrass shoot density for Fort Pond Bay from 2017 to 2018, including standard error.

Year	Mean Density	S.E.
2017	584	±58
2018	483	±49

The macroalgae community was dominated by the brown alga *Sargassum filipendula* attached to hard substrate. A total of 10 species of macroalgae were identified in 2018 and included red and brown seaweed species that are adapted to inhabiting more wave exposed shorelines, including the red alga *Chondrus crispus,* the brown alga *Halosiphon tomentosus*, and the rockweeds *Ascophyllum nodosum* and *Fucus distichus*.

Bed Delineation and Areal Extent

Meadow extent for Fort Pond Bay was delineated using Google Earth™ imagery from 29 June, 2018 and presented in Figure FP-2. Due to the depth range of the meadow and the quality of the aerial images, complete and accurate delineations of the meadow were not possible. The areal extent of the meadow that was delineated covered 14.8-acres for 2018, which would represent a significant loss from the meadow's areal extent reported for 2017 of 35.8-acres if these delineations were complete.

Conclusions

The Fort Pond Bay eelgrass meadow was found to be a large, healthy eelgrass meadow during the 2018 eelgrass monitoring. While the 2018 results found that average eelgrass shoot density had declined by 100 shoots·m^2, the meadow still supports one of the densest eelgrass populations in the LTEMP. Parkland bordering the shoreline along the entire length of the eelgrass meadow minimizes human impact to just two pound nets, which represent a minimal footprint in the meadow. The major impacts to the meadow continue to be wind-driven waves and current at this exposed site, especially during the winter months. Light availability and water temperature were found to be in the optimal range for eelgrass and no doubt are responsible for the areas of meadow that support shoot densities exceeding 1000 shoots·m^2. One potential impact to the eelgrass meadow in 2019 to consider

Figure FP-2. A comparison of Fort Pond Bay eelgrass meadow delineations completed in a) 2017and b) 2018.

is the planned repairs to the fishing pier located at the Edward Vincent Ecker, Sr. County Park. Depending on the scope of the work (e.g. replacing pilings, mooring of a barge), there could be some damage to the meadow near the pier. This will be something that will be looked at in the 2019 monitoring season.

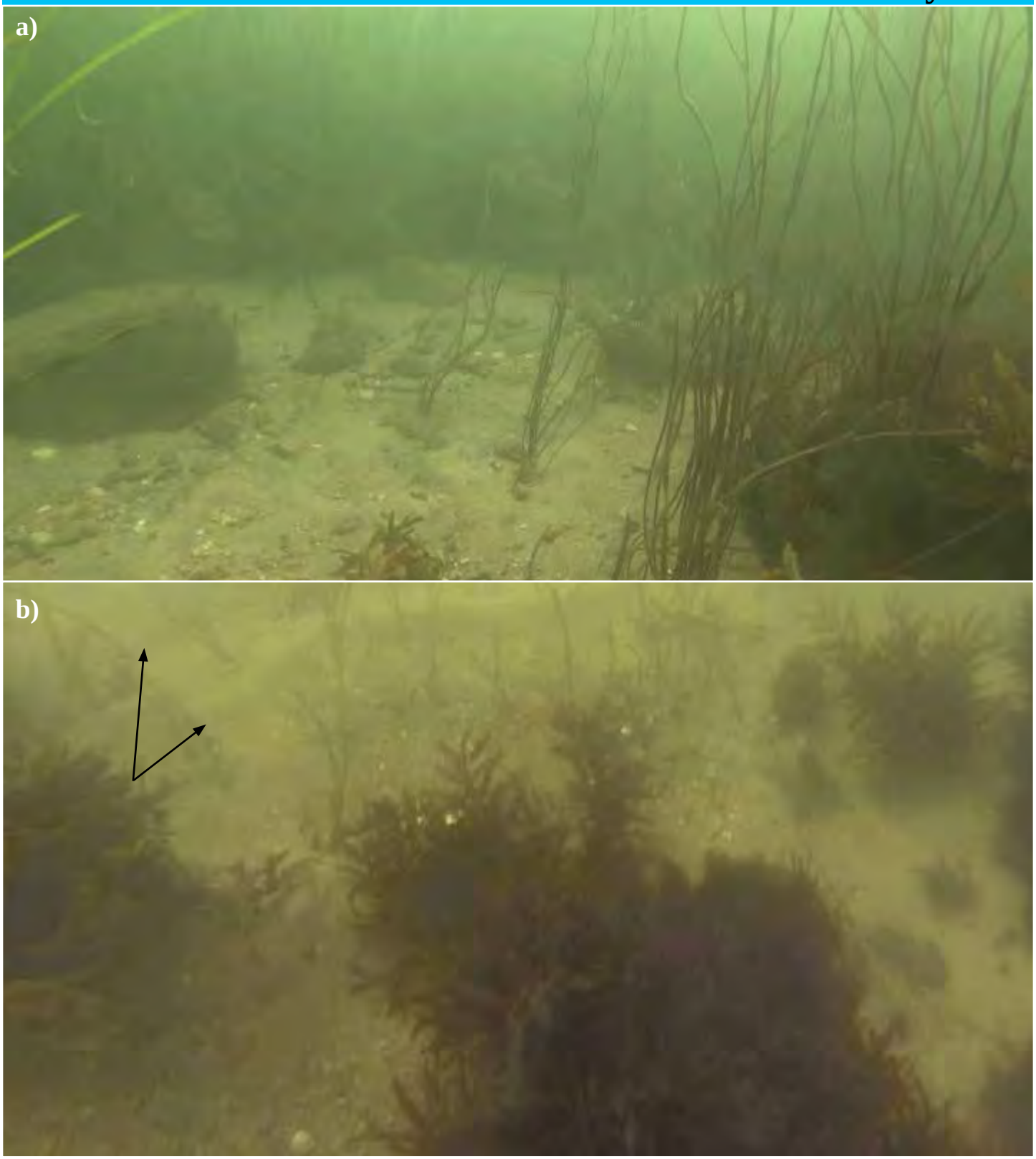
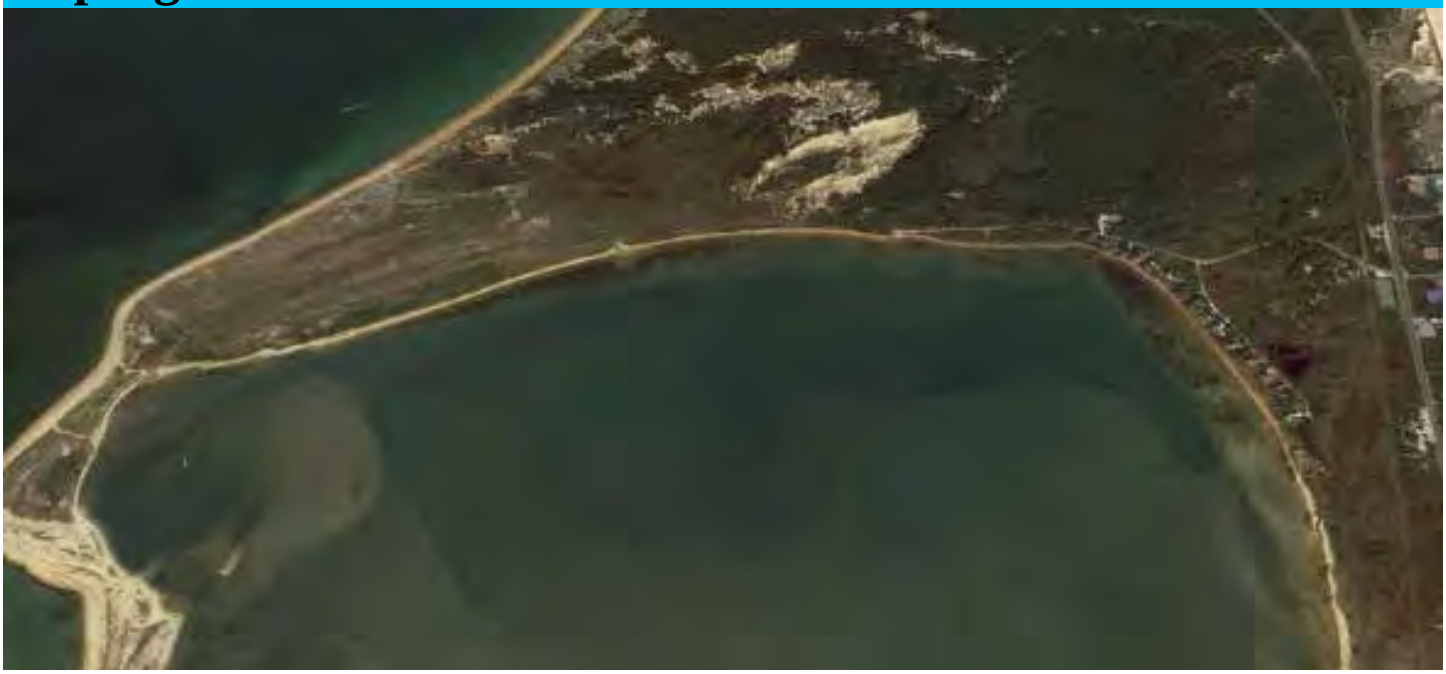


Figure FP-3. a) An open patch in the eelgrass meadow at station 5 provides space for *Halosiphon* (hairy sea whip) to grow attached to rocks. b) A small patch of eelgrass, possibly seedlings, growing interspersed with boulders at station 4, a wave-exposed location in the Fort Pond meadow as evidenced by the waves (arrows) in the sand around the eelgrass.

Napeague Harbor 2018



Napeague Harbor is an enclosed embayment located in East Hampton and opens into Napeague Bay. The eelgrass meadow is situated in a shallow band along the east side of the harbor (Figure NAP-1).

Site Characteristics

The Napeague Harbor eelgrass meadow is limited to the eastern shore of the harbor, growing at water depths of less than one foot to four feet at mean low water. The harbor is relatively sheltered with short fetches, preventing the generation of large waves. Due to the shallow nature of the meadow, ice formation in cold winters could impact the meadow by scouring the shallower sections. The sediment over the meadow area is almost uniformly sand, averaging 92% across the meadow. Organic content is low, averaging 0.44%, as would be expected of a sandy site. Napeague Harbor may be unique of all the LTEMP sites in that it has significant, shallow-water groundwater seepage along almost the entire shoreline, and these areas can be identified by the reddish color of the sand bottom.

Figure NAP-1. An aerial view of the Napeague Harbor monitoring site with monitoring stations indicated by the superimposed numbers.

Light Availability and Temperature

Light loggers were deployed monthly, July-September, for 10-day intervals for 2018. The light data was converted to average daily Hcomp and Hsat values presented in Table NAP-1. Water clarity was very high for July and August of 2018 in Napeague Harbor. Both H_{comp} and H_{sat} minimal requirements were exceeded during these months. By September, both parameters were found to be in a deficit for the meadow by just over an hour per day for both parameters.

An Onset HOBO TidBit v2 water temperature logger was deployed to the meadow in early-June 2018 to an area adjacent to monitoring station 4 (Figure NAP-1). The data from the logger was analyzed and average daily and monthly water temperatures were calculated for the site. The monthly average water temperature for August was found to have reached the critical threshold of 25°C temperature, and the meadow ex-

Table NAP-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Napeague Harbor over 10-days for 2018.

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	14.2	+1.9	11.7	+3.7	23.4
August	12.7	+0.4	9.5	+1.5	25.1
September	11.1	-1.2	6.9	-1.1	22.1

perienced 23 days with temperatures averaging above this critical point. The highest temperature recorded in Napeague Harbor was 28.2°C, which occurred in early August.

Eelgrass Shoot Density

The Napeague Harbor eelgrass meadow was monitored on 20 September, 2018. The average eelgrass shoot density calculated for the meadow was 479 shoots·m^2, which was a significant decline from the 2017 eelgrass density of 806 shoots·m^2 (Table NAP-2). This sharp decline in density between years can be accounted for due to the highly patchy nature of monitoring station 6 and fewer small lateral shoots in 2018.

Macroalgae Cover

The macroalgae community in Napeague Harbor changed little between 2017 and 2018. The 2018 average percent cover across the meadow was 26%, versus 20% in 2017. a The dominant species in the meadow was the red, filamentous seaweed, *Spyridia filamentosa*. Secondary species including *Gracilaria* sp., *Codium fragile*, and *Sargassum filipendula* were infrequently observed within the meadow.

Bed Delineation and Areal Extent

The 2017 areal extent of the Napeague Harbor eelgrass meadow was completed using aerial imagery from Google Earth™ taken on 29 June, 2018. Due to the shallow nature of the meadow and the light colored sanding bottom it inhabits, an accurate delineation of the meadow was created (Figure NAP-2). The 2018 delineation identified 13.4 acres of eelgrass confined to the southeast and east shores of the harbor which was a 4.2 acre loss in area from 2017. Much of the loss in bed area occurred at both the northern and southern ends of the meadow. The southern end of the meadow, near station 6 has shown increased fragmentation of the meadow since the 2014 aerial survey, accounting for much of the loss.

Table NAP-2. The average annual eelgrass shoot density for Napeague Harbor from 2017 to 2018, including standard error.

Year	Mean Density	S.E.
2017	806	±63
2018	479	±44

Conclusions

The Napeague Harbor eelgrass meadow was found to have declined significantly from 2017 to 2018. While this drastic decline in eelgrass density in one year is of concern, overall conditions at the site, including light availability and water temperature, support a healthy eelgrass meadow. Human impact on the meadow appears to be low, with recreational clamming in the harbor reduced due to restrictions placed by the Town of East Hampton. There are several boats mooring in the southern section of the meadow that have created unvegetated circles from their mooring chains dragging through the meadow, however these are relatively small and isolated impacts. It is possible that this large change in shoot density is part of the normal cycle in Napeague Harbor's eelgrass meadow, and having only two years of data makes it difficult to create an informed hypothesis.

It should also be considered that aerial photography has shown a progressive fragmentation of the southern end of the meadow, which appears to have continued in 2018, to the point were it was evident at monitoring station 6 by the high number of sampling quadrats that recorded no eelgrass. The cause of this continued fragmentation of the southern end of the meadow is unclear, however, it could be due to climate change and/or human impact that have not yet been observed. Climate change could have a profound effect on the

Napeague Harbor 2018

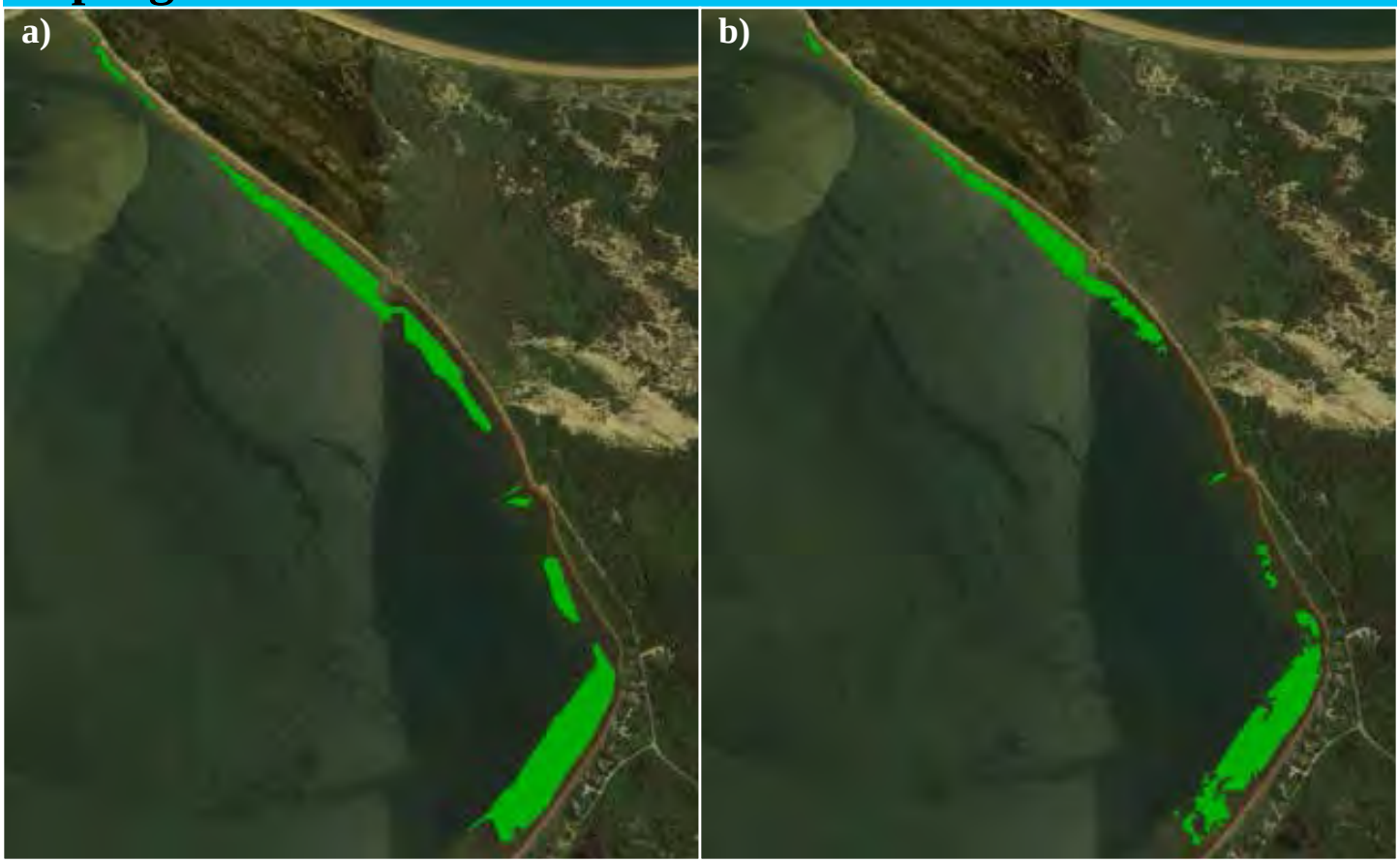


Figure NAP-2. A comparison of Napeague Harbor eelgrass meadow delineations completed in a) 2017 and b) 2018.

eelgrass in Napeague Harbor, given the shallow nature of the meadow and its distance from the mouth of the harbor in regards to impacts from high water temperature. Based on a submarine groundwater discharge (SGD) survey conducted in Napeague Harbor in 2017, the presence of eelgrass is correlated to areas with strong SGD. It is believed that the Napeague Harbor eelgrass meadow benefits from the same SGD temperature-mitigating effects as Bullhead Bay. The southern end of the eelgrass meadow had low SGD signal which could correspond to a reduced ability of groundwater to mitigate higher temperatures. With climate change, increased frequency and duration of drought could cause areas of normally low SGD to experience a further reduction in discharge, causing the eelgrass to loss this temperature-mitigating buffer, resulting in eelgrass decline. If the degradation of the southern end of the meadow is due to low SGD, the extent of the loss should not expand, as areas with high SGD were identified in the meadow adjacent to the fragmenting area. The 2019 monitoring season may provide some insight into how the meadow is trending.

Napeague Harbor, like Bullhead Bay, presents another example of an eelgrass meadow that is likely benefitting from SGD and represents a good opportunity to conduct surveys and experiment to determine what aspects of SGD may be promoting eelgrass growth in these enclosed embayments.

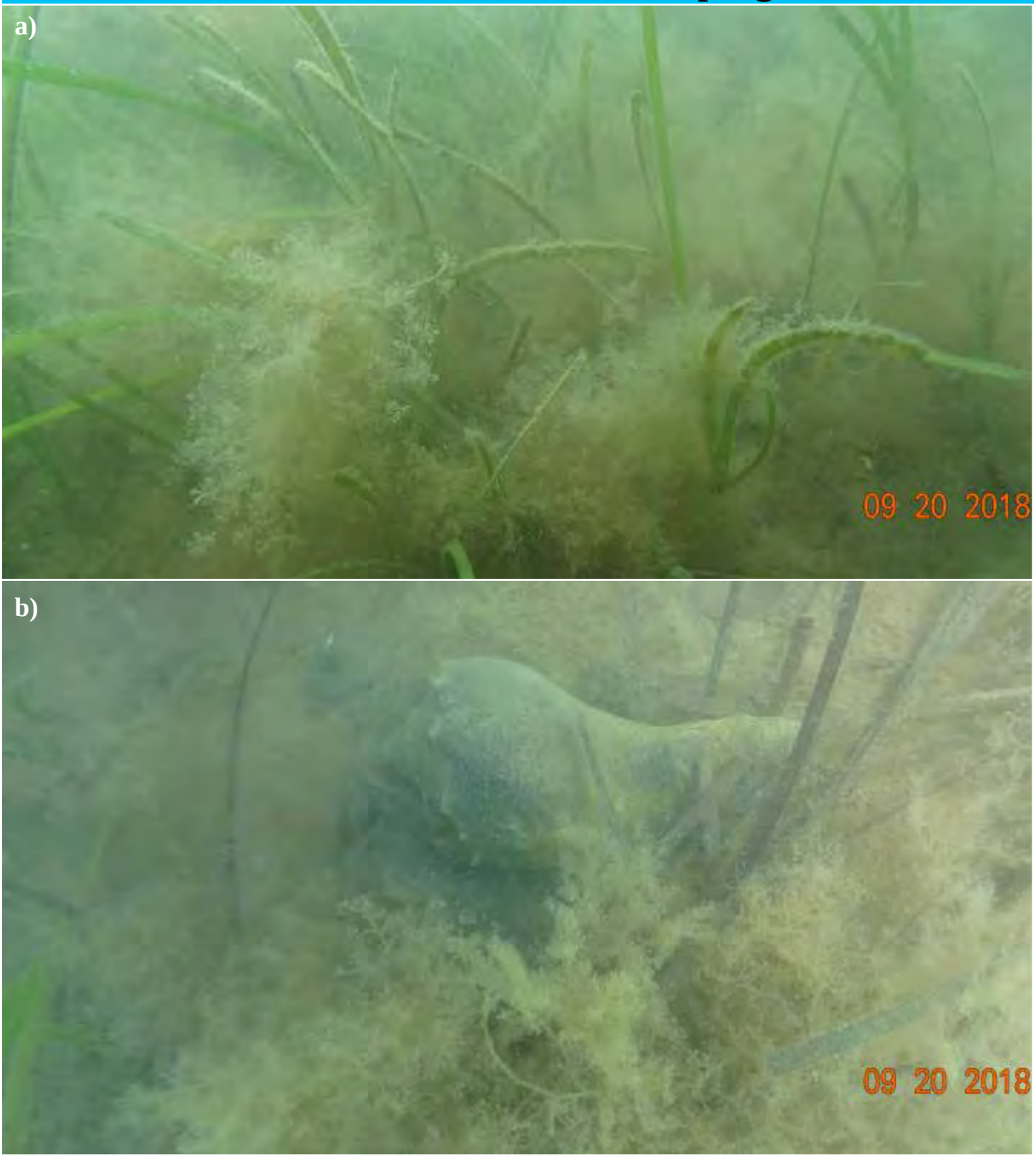
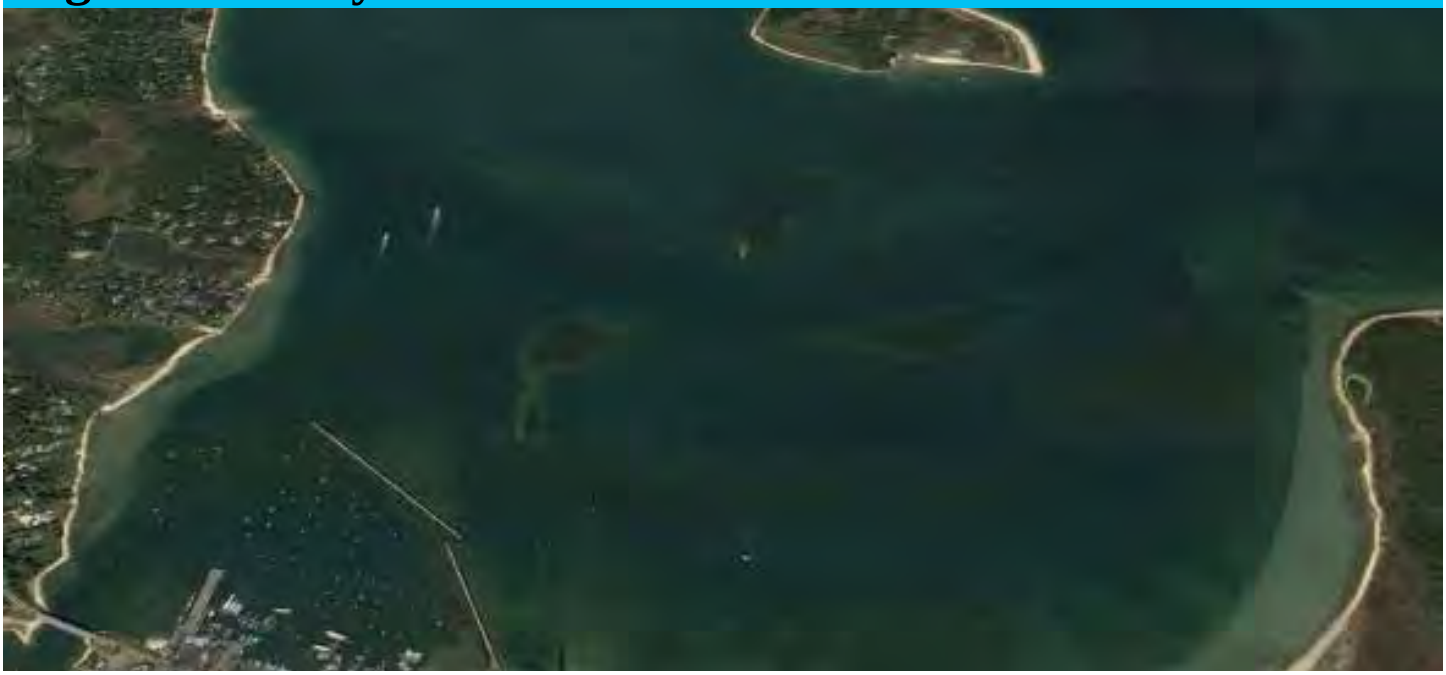


Figure NAP-3. a) Sections of the meadow support an abundant growth of the red macroalga *Spyridia filamentosa.* b) A knobbed whelk forages for a meal in within the eelgrass meadow.

Sag Harbor Bay 2018



Sag Harbor Bay is an open bay surrounded by North Haven (Southampton Town) to the west, Mashamock (Shelter Island) to the north and Barcelona Point (East Hampton) to the east. The eelgrass meadow monitored at this site is actually a group of distinct eelgrass beds within the bay. The LTEMP monitors three of these beds with 6 monitoring stations divided among the beds (Figure SH-1).

Site Characteristics

Figure SH-1. An aerial view of the Sag Harbor Bay monitoring site with monitoring stations indicated by the superimposed numbers.

The Sag Harbor eelgrass meadow complex consists of at least five individual meadows over 0.5 acres in size. The meadows are all subjected to moderate current velocities during changing tides and can be subjected to significant wave actions during the winter months with prevailing winds out of the north-northwest. The sediment in all the meadows primarily consists of sand, averaging 83% across the meadow, although station SH1 had a higher constituent of gravel-sized sediment at 22% and a sand component of 57%. The overall organic content for the site was less than 1% (0.66%) which may be due to tidal current washing organic materials out of the meadows.

Because the Sag Harbor eelgrass meadow consists of multiple eelgrass beds, the beds are numbered and identified by the monitoring stations located within them. The individual beds are identified as Bed1 (stations SH1 and SH2), Bed2 (stations SH3 and SH4) and Bed3 (stations SH5 and SH6).

Light Availability and Temperature

An Odyssey PAR light logger was deployed adjacent to the SH2 monitoring station monthly, from July-September 2018. The loggers collected 10 days of light data per deployment and the results are summarized in Table SH-1 in terms of H_{comp} and H_{sat}. Light availability within the Sag Harbor eelgrass meadow was mixed over the season. For July and August, the meadow received a surplus of light for both H_{comp} and H_{sat}. The September light data recorded minor deficits in both parameters, which were likely the result of the

Table SH-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Sag Harbor Bay over 10-days for 2018.

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	11.6	+3.6	23.9
August	12.6	+0.3	9.1	+1.1	25.5
September	11.6	-0.7	7.8	-0.2	23.0

seasonal decrease in daylength and sun angle.

Water temperatures in 2018 were found to have been higher than those recorded in 2017. Daily average temperatures for Sag Harbor Bay surpassed 25°C on 35 days in 2018. The highest individual temperature recorded was 27.6°C on 9 August, 2018.

Eelgrass Shoot Density

Monitoring of the eelgrass meadow in Sag Harbor Bay was completed on 7 September, 2018. The combined eelgrass shoot density averaged 331 shoot·m² (Table SH-2). This was a significant increase over the 2017 shoot density. Average shoot densities were also calculated for each of the three beds monitored. Bed1 had a density of 396 shoot·m². Bed2 had an average density of 246 shoot·m², and Bed3 had a shoot density of 346 shoot·m².

Macroalgae Cover

Macroalgae cover within the Sag Harbor eelgrass increased in 2018 from the previous year. The average percent cover for 2018 was 20%, an increase of 16% from 2017. Comparison of the macroalgae cover between the three beds in Sag Harbor found that Beds 1 and 2 did not differ at 11% each, but Bed3 had a significantly higher percent cover at 36%. The individual beds supported different macroalgae species based on their bottom type. Bed1 with a coarse sediment and boulders was dominated by *Sargassum filipendula* and *Codium fragile*, while Bed2 was nearly a monoculture of *Spyridia filamentosa* tangled in the eelgrass blades or attached to small shell and gravel on the predominantly sand bottom. Bed3 has a bottom with a high percentage of shell which provided substrate for *Codium fragile* and *Ulva* species.

Table SH-2. The average annual eelgrass shoot density for Sag Harbor from 2017 to 2018, including standard error.

Year	Mean Density	S.E.
2017	249	±16
2018	331	±25

Bed Delineation and Areal Extent

The aerial delineations of the meadow's extent was completed using Google Earth™ imagery flown on 29 June, 2018. The quality of the aerial images for 2018 were poor for the Sag Harbor area and only 12.7-acres were delineated. All of Bed2 was obscured by the poor water clarity in the imagery, as was more than half of Bed1 and a majority of Bed3, based on the 2017 delineations. Due to this issue of suboptimal aerial imagery, the findings for changes in aerial extent between 2017 and 2018 are inconclusive.

Conclusions

The eelgrass beds that make up the Sag Harbor eelgrass monitoring site were found to be in good condition during the 2018 monitoring visit. Light data suggested that the meadow was receiving ample light for most of the growing season. Water temperature data, however, found that the meadow was subjected to higher water temperature for a higher number of days in 2018 than the previous season. As a whole, eelgrass shoot density increased from 2017 to 2018. Looking at the individual statistics for each bed, a more than 200 shoot·m² increase in Bed1 accounted for a majority of the increase between the two years. There were no statistical differences between years for the other two eelgrass beds. Macroalgae cover for the site experienced an average increase in 16% from 2017 to 2018. In contrast to the eelgrass density, this increase was seen across all three eelgrass beds, not just one.

The Sag Harbor eelgrass monitoring site is one of the more interesting sites in the monitoring program. It consists of three distinct eelgrass beds that are all

Sag Harbor Bay 2018

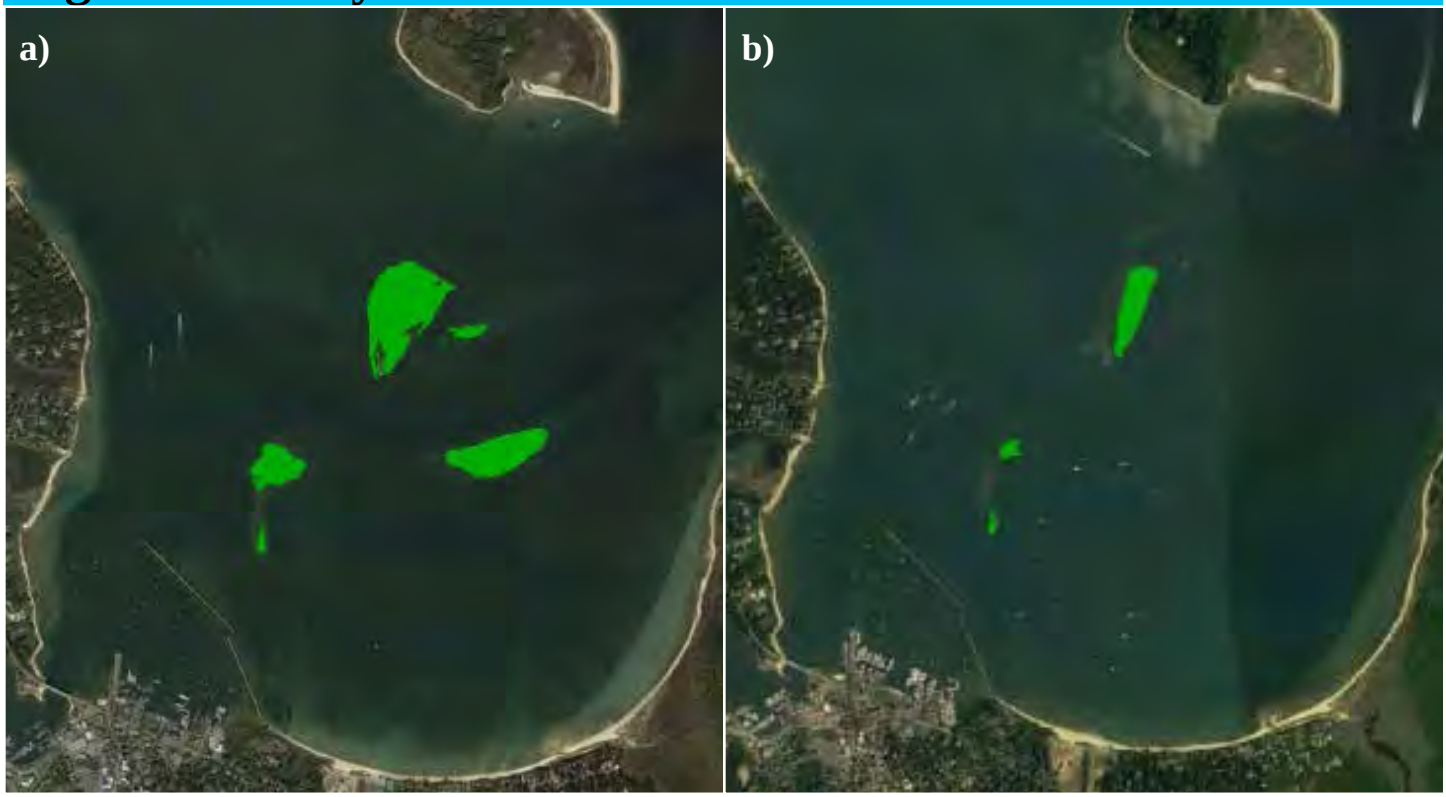


Figure SH-2. Comparison of delineations between a) 2017 and b) 2018 for the Sag Harbor Bay eelgrass meadow complex.

different from one another in terms of bottom type, hydrodynamics, plant morphology and their corresponding macroalgae community. Even though the site includes three distinct eelgrass beds, due to their proximity to one another, they share the same water quality and weather. Changes in one bed with no corresponding changes in the others would suggest a localized impact that could be linked to a characteristics specific to that eelgrass bed. Unfortunately, two years of data collection is not sufficient to begin to tease out trends or links between bed characteristics and responses to differing environmental conditions or disturbances. This meadow complex provides the opportunity to do some investigation into the unique characteristics of each bed and if they respond differently to the same environmental changes.

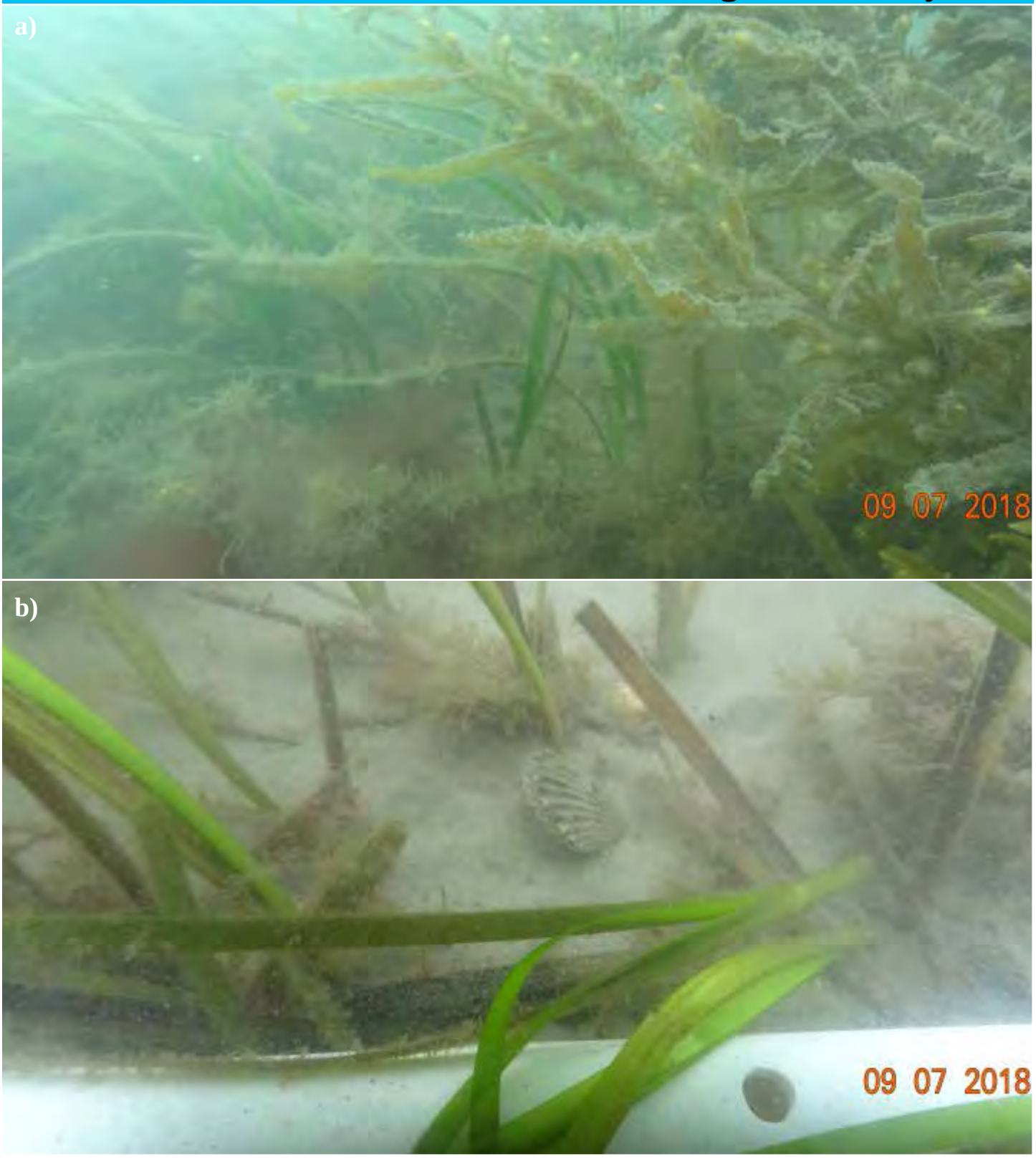
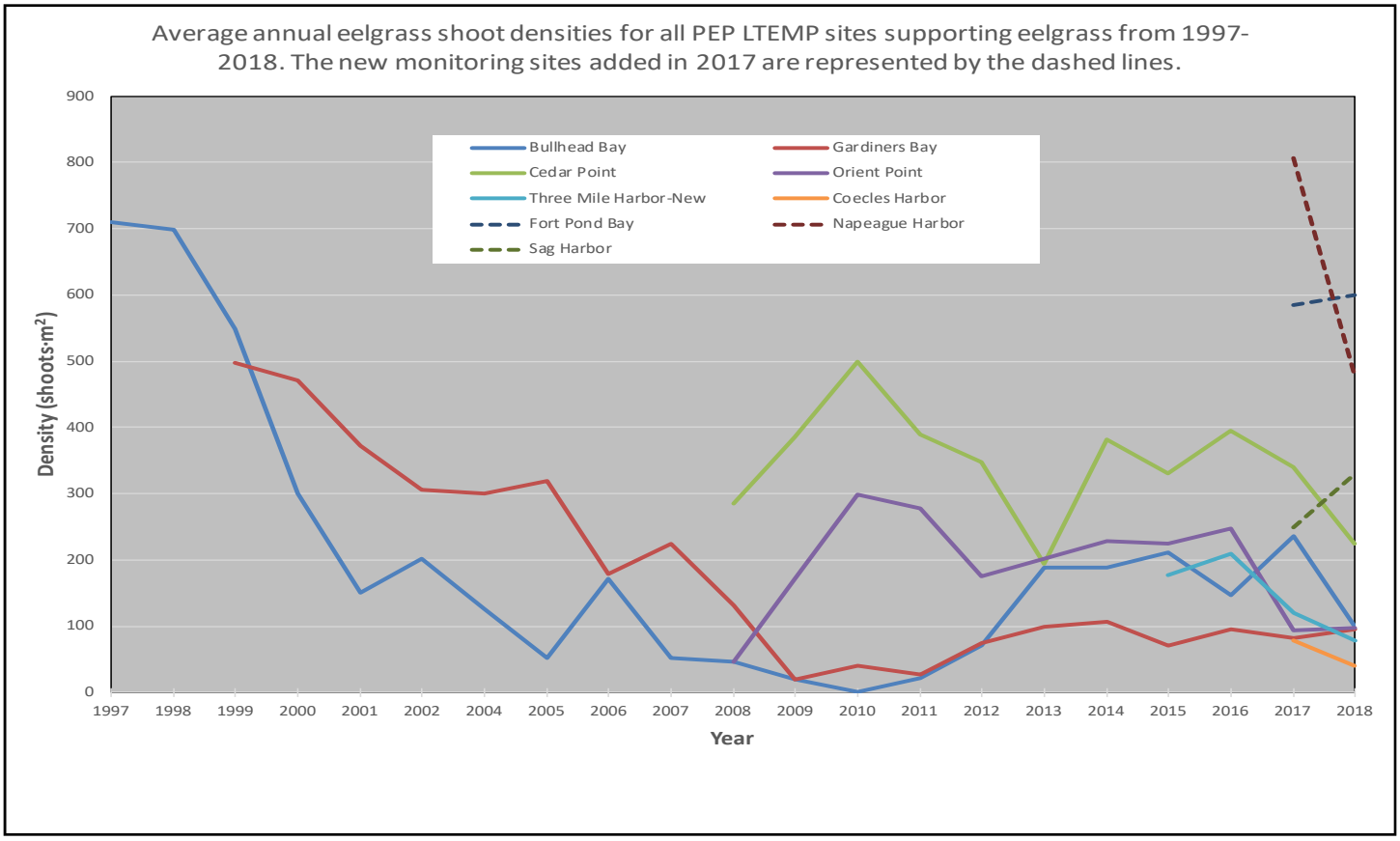
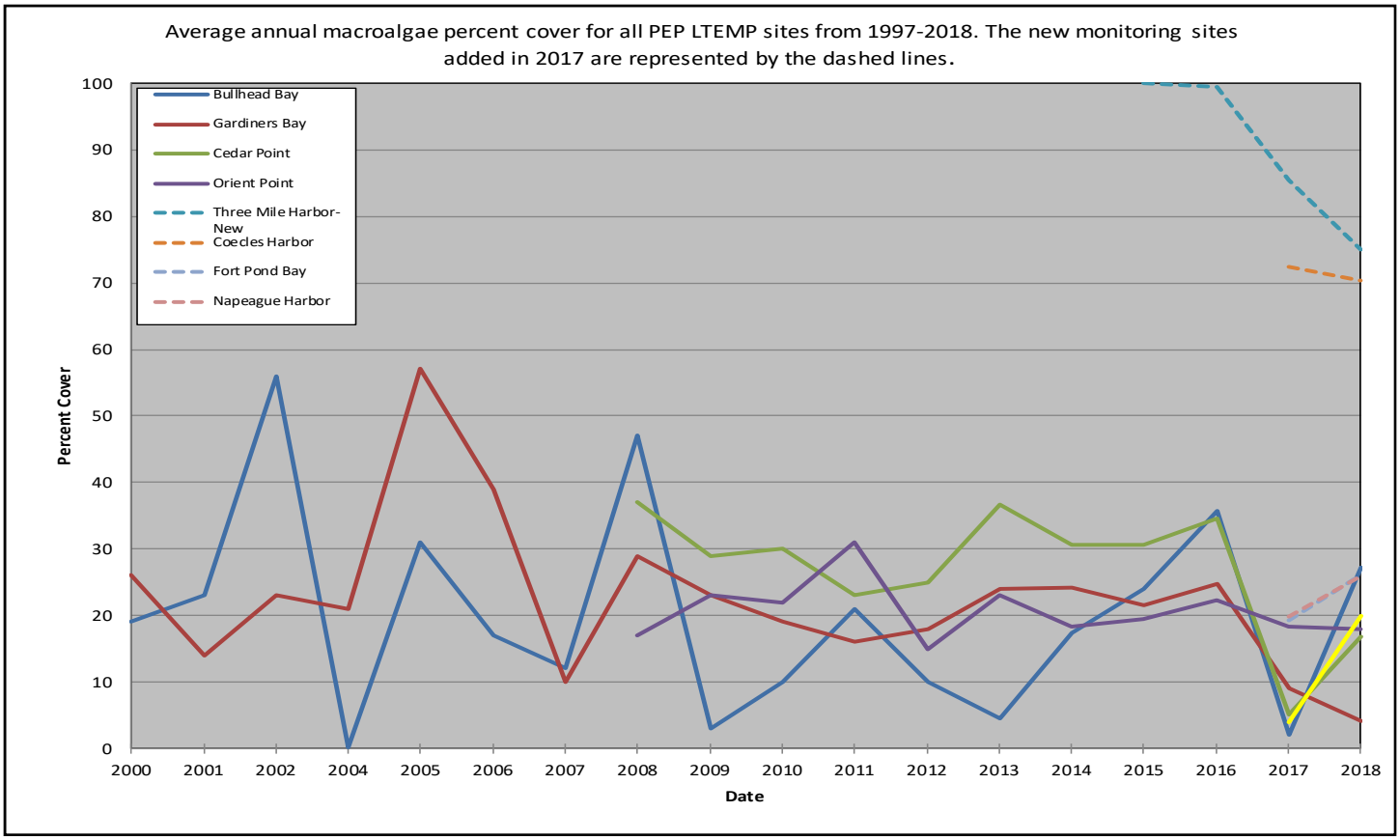


Figure SH-3. a). Eelgrass at station 6 (Bed 3) growing interspersed with *Sargassum*. b) A "bug" bay scallop attached to a section of exposed eelgrass rhizome at station 4 (Bed 2).

Appendix

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





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