Peconic Estuary Partnership 2019 Long-Term Eelgrass (*Zostera marina*) Monitoring Program

Progress Report 20

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

Submitted By:
Christopher Pickerell
and
Stephen Schott

Cornell University
Cooperative Extension
of Suffolk County

Executive Summary

For the 2019 eelgrass monitoring surveys, nine sites were surveyed by divers from Cornell Cooperative Extension's (CCE) Habitat Restoration Program. Over the course of the 2019 season, temperature loggers were deployed in mid-June and retrieved by early-October, while light loggers were deployed for 10-day intervals monthly from July-September. The monitoring surveys were started on 3 September, 2019 and completed on 20 September, 2019. CCE divers collected data on eelgrass shoot density, macroalgae cover and species diversity, and collected video of each monitoring station for each of the nine eelgrass meadows in the program.

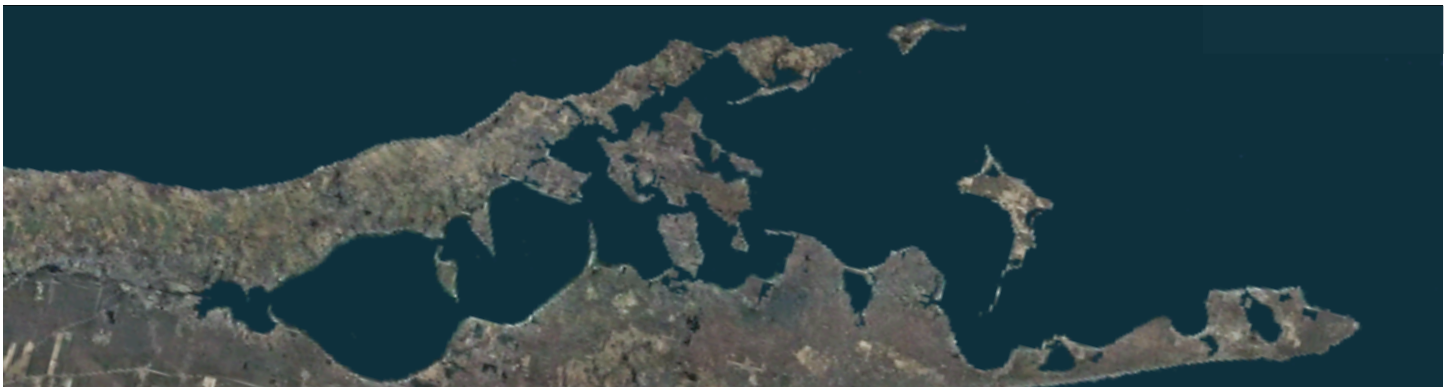
Light availability and water temperature continue to be important gauges of eelgrass health and data for these parameters were collected at all 9 of the current monitoring sites. The light data collected for the 2019 (July-September) found that the light availability to eelgrass was relatively high, based on the Hcomp and Hsat data collected,. For July 2019, eight sites met Hcomp and Hsat requirements, and one site had no data due to a lost light logger. August 2019 found six sites met requirements for both Hcomp and Hsat, while one site did not meet the minimum levels for either parameter, and one site did not meet the requirements for Hsat. During the September deployment, five sites met both Hcomp and Hsat parameters, while three sites failed to meet either parameter, and one site failed its Hcomp, but met its Hsat requirement. The meadows fared better in regards to water temperatures. The 2019 season was cooler that the previous two years. Six sites recorded days with average temperatures $\geq$25°C, while only two sites experienced an average daily temperature above 27°C. The only site that experienced a significant number of days above these two critical levels was Bullhead Bay.

Eelgrass shoot density is the primary parameter of the health of a meadow in the PEP LTEMP. Five monitoring sites recorded an increase in eelgrass shoot density from the 2018 monitoring season (Bullhead Bay, Gardiners Bay, Orient Point, Coecles Harbor, and Napeague Harbor) One site, Cedar Point, was statistically unchanged, while the remaining three sites recorded a decline.

Macroalgae cover within the meadows provides a guage of competition and general water quality at each site. Macroalgae growing within eelgrass meadows and on eelgrass blades compete for nutrients and light. Macroalgae percent cover continued to be highly variable in 2019, both between years and between sites. Six of the LTEMP monitoring sites reported a decline in 2019 from 2018, while three sites saw an increase in macroalgae cover.

The changes in the areal extent of each of the eelgrass populations included in the LTEMP is reported annually, when aerial imagery is available. The delineations of the extent of these meadows allows for a comparison between years and can identify significant changes in each meadow and possibly indicate the cause(s) of that change. The general trend in the Peconic Estuary, since 2000, has been one of shrinking eelgrass meadows. With few exceptions, most meadows have lost acreage over the last 15 years. For the 2019 season, six of the nine monitoring sites showed increases in acreage of eelgrass. Two meadows experienced a decline in acreage, while one meadow's delineation was inconclusive due to poor quality aerial imagery.

The 2019 eelgrass monitoring season provided some optimism for the health of the eelgrass meadows included in the Peconic Estuary long-term eelgrass monitoring program. There were reported gains in eelgrass shoot densities in five meadows, as well as increases in areal extent in six of the meadows and no change in one meadow. Across the Estuary, 2019 supplied eelgrass meadows with sufficient light for growth and the water remained relatively cool, reducing the stress that eelgrass populations have experienced in recent, hotter years. Even the mild winters we have been experiencing are beneficial to the meadows, alleviating instances of ice scour and maintaining water temperature at levels that allow eelgrass seedlings to grow more rapidly.



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 Partnership 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 Partnership'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 labo-

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

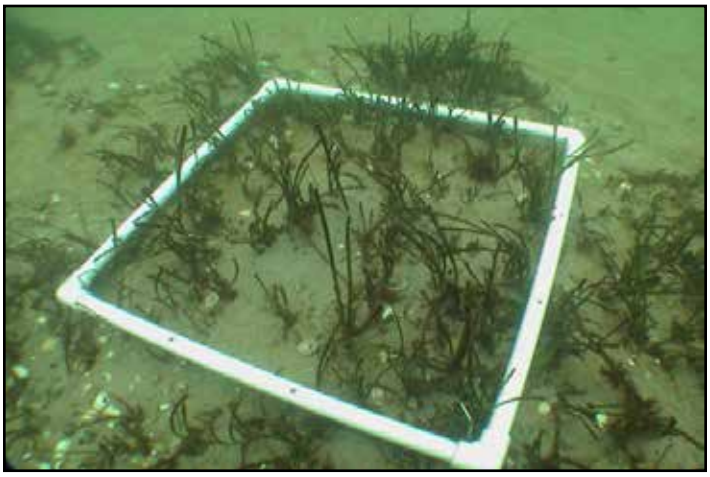


Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

ratory for analysis. The sampling in 1998 and 1999 continued to utilize destructive sampling to collect data, however, sample size was increased to a total of twelve quadrats and there was a decrease in the size of the quadrats to 0.0625 m^2 (12.5 x 12.5 cm).

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

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

blades) and possibly result in mortality of the entire plant. Temperature affects eelgrass by influencing the plants primary production efficiency. This efficiency is typically represented as the ratio of photosynthesis to respiration (P:R) in a plant. Eelgrass, being a temperate water species, has recorded optimal P:R for temperatures ranging from 10-25°C (50-77°F). When temperatures increase above 25°C, the rate of respiration begins to out-pace the rate of photosynthesis, resulting in a net negative production for the plants. However, the imbalance in P:R at high temperatures can be overcome by the eelgrass if the plants receive enough irradiance. Even given unlimited light, water temperatures reaching and exceeding 35°C (95°F) are lethal to eelgrass.

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 Southold Bay and Three Mile Harbor sites (extinct eelgrass meadows) were also included in the survey. The loggers were deployed for 10 days of recording. The logger measured the quantity of PAR at set intervals throughout each day. The loggers were retrieved after 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 2019 season, Odyssey PAR loggers were deployed at all active monitoring sites.

Eelgrass Monitoring

The 2019 monitoring began on 3 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

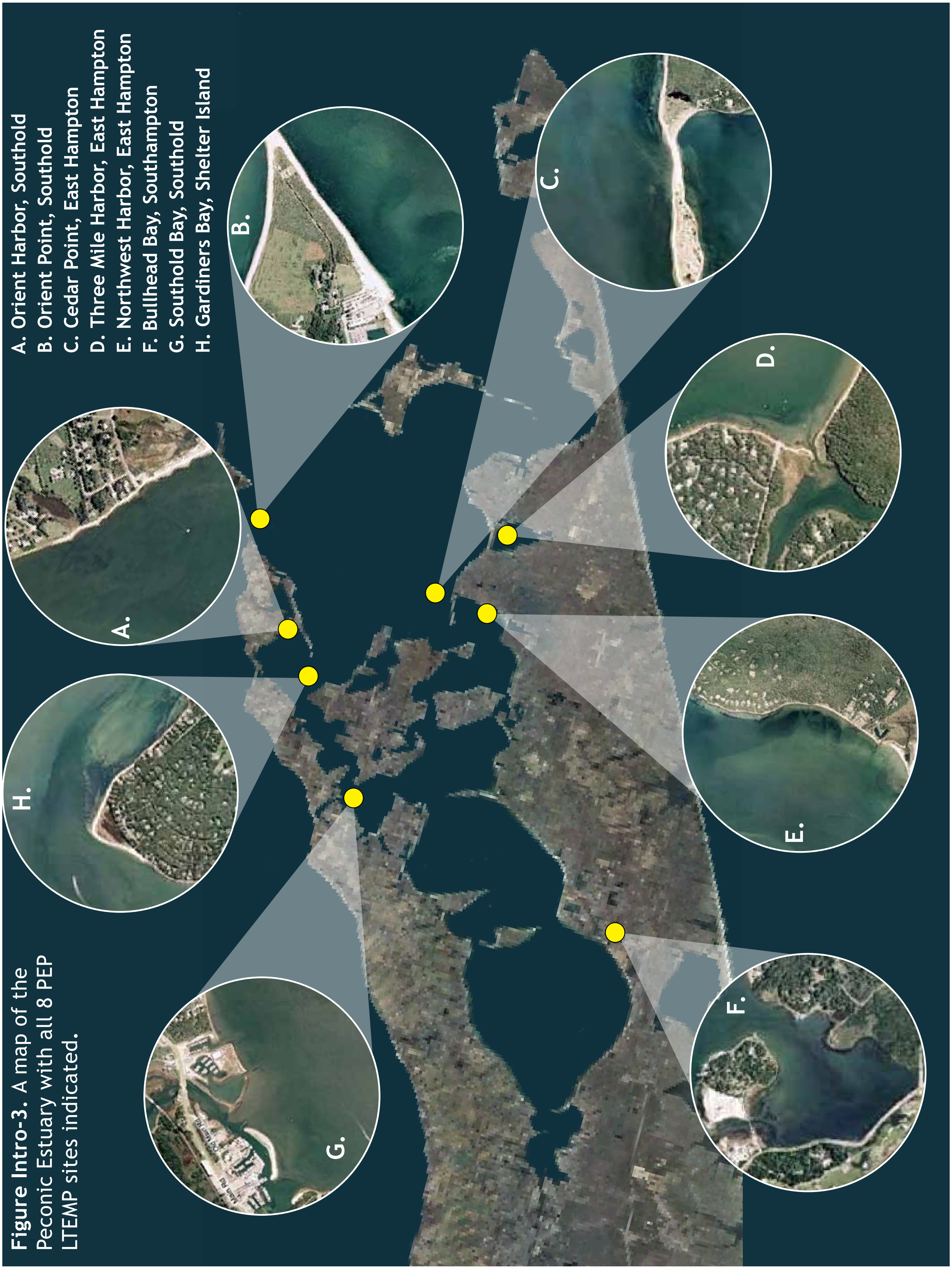


Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

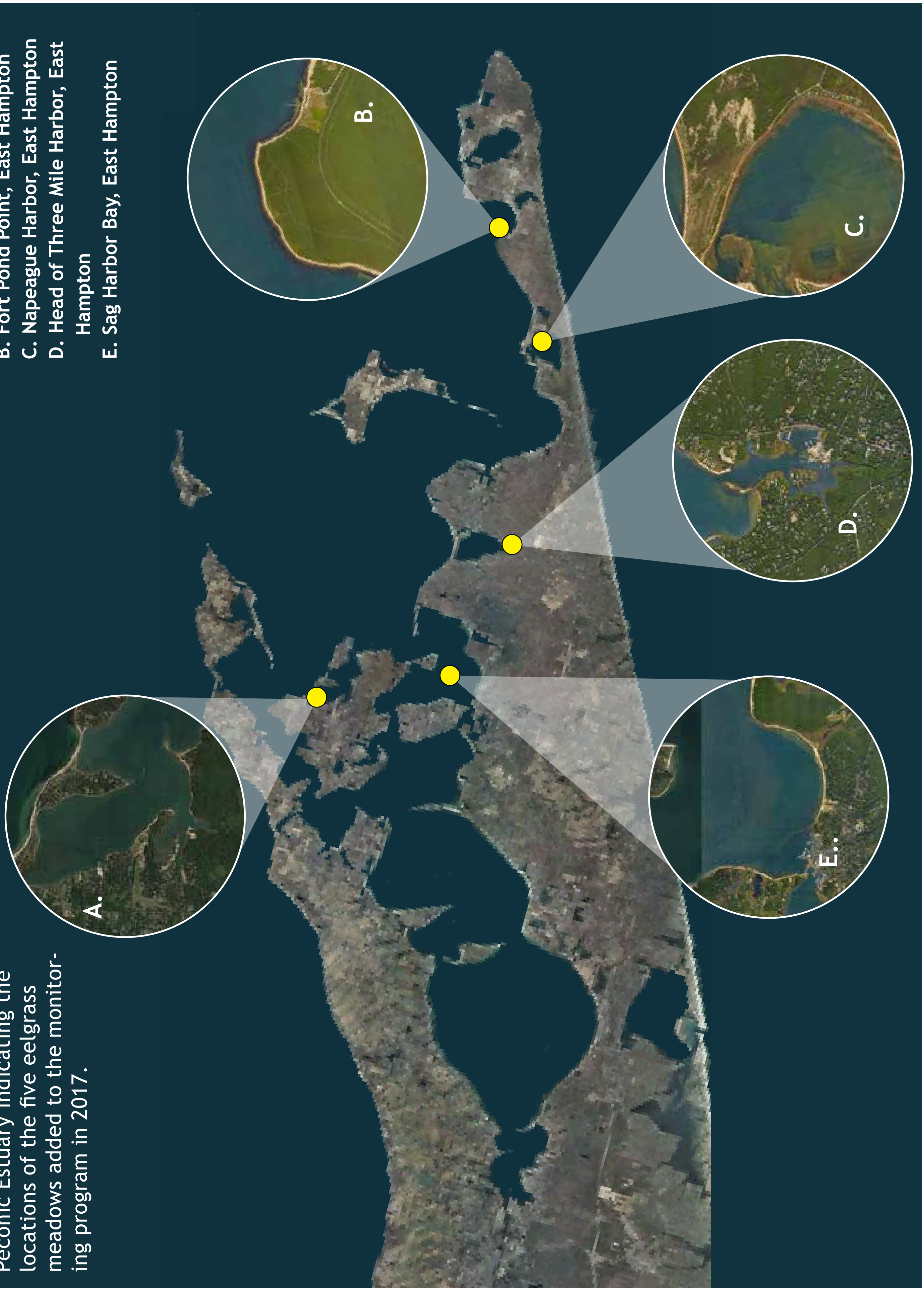


Figure Intro-4. A map of the Peconic Estuary indicating the locations of the five eelgrass meadows added to the monitoring program in 2017.

careful not to disturb the eelgrass, so as not to cause plants to be uprooted or otherwise damaged.

Data was statistically analyzed using the Real Statistics add-on for Excel. The trends, within sites, were analyzed by comparing the current year's data with the data from the previous years.

Bed Delineation and Areal Extent

For the 2019 season, Google™ Earth aerial imagery 19 September, 2019) 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 most recent, previous seasons' delineations. 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 2019

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 2019.

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	13.6	+1.3	10.1	+2.1	28.0
August	13.4	+1.1	9.4	+1.4	26.4
September	12.6	+0.3	8.3	+0.3	22.4

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, 2019, with the average Hcomp and Hsat for each month presented in Table BB-1 above. Similar to conditions reported in 2018, water clarity was good for Bullhead Bay in 2019. The site received surplus in both Hcomp and Hsat (Table BB-1) for all three months. The seasonal shortening of days became evident during the September 2019 recording period.

Water temperature loggers were deployed in Bullhead Bay from early June through early October, 2019. The loggers recorded that the meadow experienced 59 days averaging above 25°C and 43 days above 27°C. The monthly average temperatures for July and August were both above the 25°C threshold (Table BB-1). The highest temperature recorded in 2019 in Bullhead Bay was 30.8°C on 22 July. While not as hot of a season as 2018, the 2019 season was still very warm and saw water temperatures in Bullhead Bay above the optimal range for eelgrass health.

Eelgrass Shoot Density

The Bullhead Bay monitoring visit was conducted on 5 September, 2019. CCE divers recorded eelgrass shoot density averaging above the 2018 average (Table BB-2 and Figure BB-2a). Eelgrass density in the meadow for 2019 averaged 230 shoots·m2, which represents a significant increase over the 2018 season. Overall, observation made during the season found that the meadow has continued to expand and fill in with fewer unvegetated patches and a consistent cover over the entire bay. Due to the near complete coverage of Bullhead Bay with eelgrass, widgeongrass (*Ruppia maritima*) was rarely observed in the meadow after be-

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
2019	230	+/-19

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

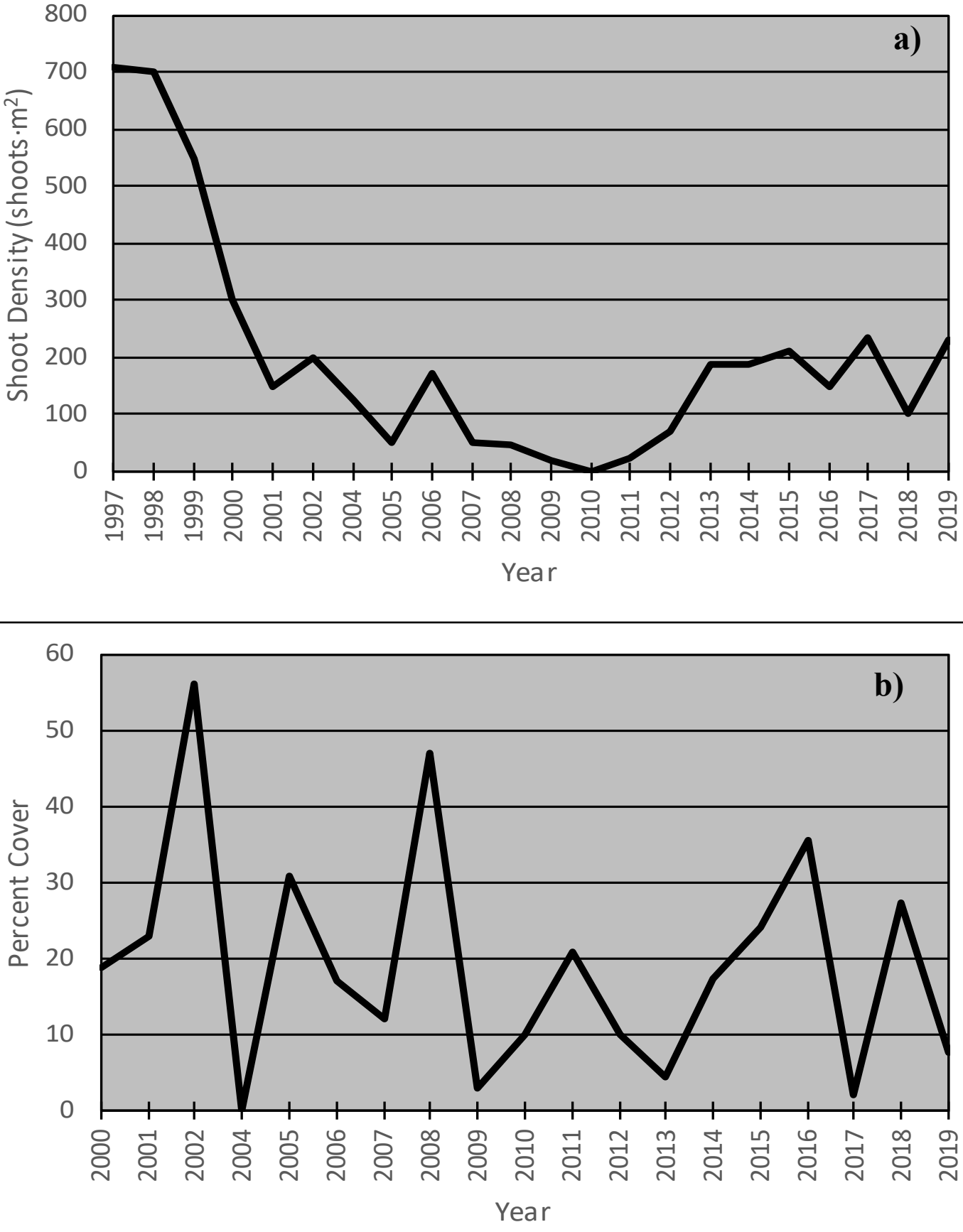


Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

Figure BB-3. The 2019 delineation of the Bullhead Bay eelgrass meadow.

ing prominent when the meadow had been in decline several years ago.

Macroalgae Cover

Macroalgae cover in the Bullhead Bay meadow had shown a significant increase in 2018, but the 2019 survey recorded a decline in the macroalgae community. The 2019 macroalgae cover was 8%, down from 27% the previous season. Macroalgae diversity was minimal in 2019 with only five species observed during monitoring (*Spyrida filamentosa*, *Gracilaria* sp., *Codium fragile*, *Ulva* sp., and *Ceramium* sp.).

Bed Delineation and Areal Extent

Delineation of the Bullhead Bay eelgrass meadow was completed using aerial imagery from Google Earth™ taken on 19 September, 2019. As is noted in Table BB-3, the Bulhead Bay eelgrass meadow has showed continued expansion since 2016. In 2019, the meadow expanded slightly from 2018 (Figures BB-3 and BB-4f). The meadow expanded from just over 56 acres in 2018 to almost 58 acres in 2019 (Table BB), and, as noted above, the density of the meadow increased over 2018.

Conclusions

The Bullhead Bay eelgrass continued to expand in 2019, in both areal extent and shoot density. The scale and speed at which the recovery has taken place in Bullhead Bay provides some optimism for the fate of eelgrass in the Peconic Estuary, as well as lessons that could be useful in restoring eelgrass to other areas with similar conditions within the Estuary.

The potential of submarine groundwater discharge (SGD)to mitigate high summer water temperatures in eelgrass meadows has been discussed in previous reports and some preliminary work has been completed in Bullhead Bay, Napeague Harbor and Three Mile Harbor. More work needs to be undertaken to determine the specific conditions under which SGD can mitigate high water temperatures and support eelgrass survival and growth.

The recovery of Bullhead Bay has highlighted the importance of seeds in the recovery of natural meadows and reinforced their potential in restoration of this species. Eelgrass restoration and management in the Peconic Estuary could benefit from a genetic analysis of the eelgrass population in Bullhead Bay to determine if this population has genetically coded tolerance to high water temperatures, similar to populations found at the southern limits of its range, and if these genes can be introduced to other, extant eelgrass

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2019.

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.)
2019	57.85 acres (23.41 hect.)

Bullhead Bay 2019

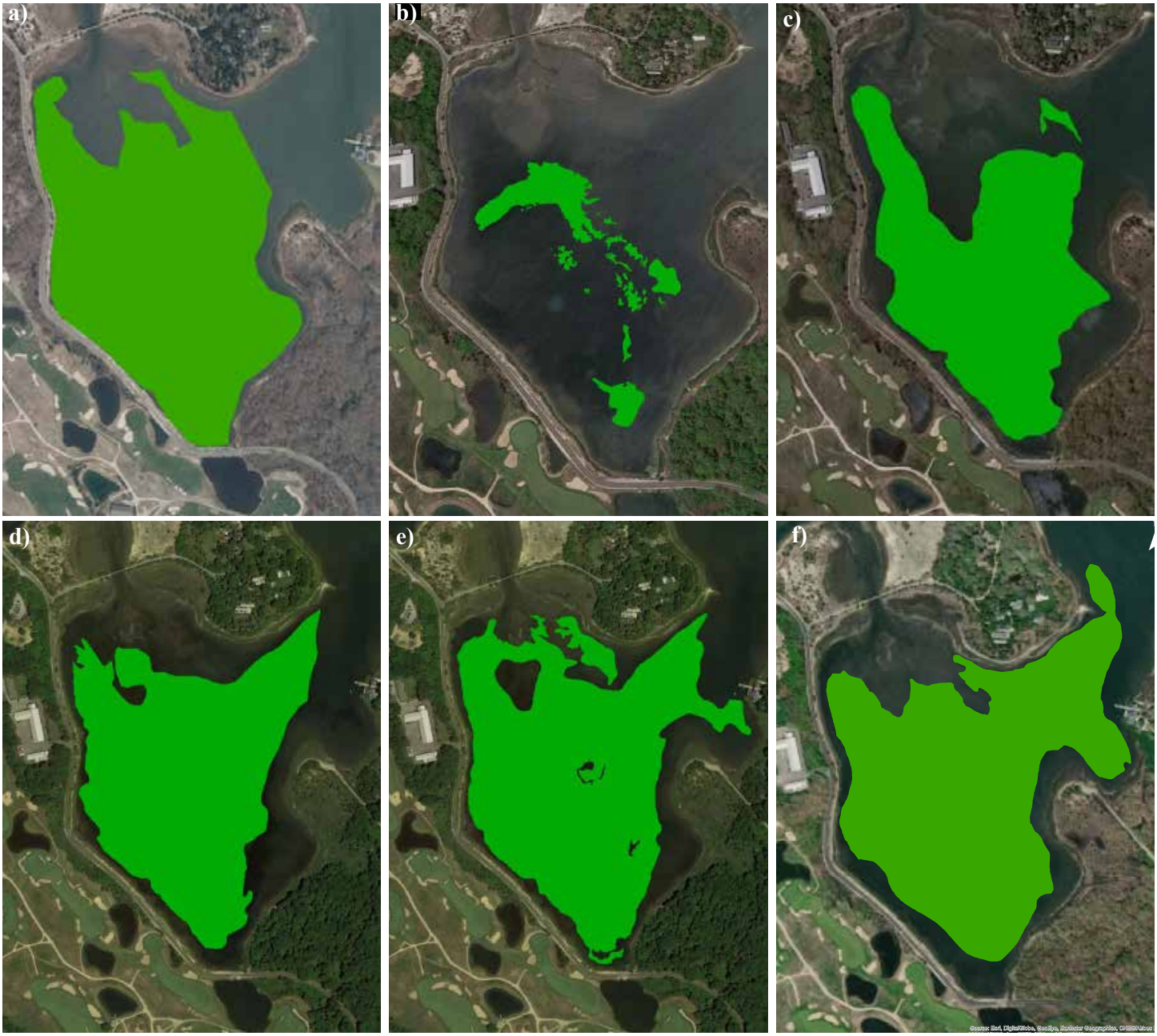


Figure BB-4. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2019. The years represented are a) 2000, b) 2010, c) 2016, d) 2017, e) 2018, and f) 2019.

population to provide a similar tolerance, should that population need to express it in the future.

Looking at more than 20 years of monitoring of the Bullhead Bay eelgrass meadow, a possible trend, or cycle, starts to appear. In 1997, when monitoring started, the meadow was at its peak in density and area. Over the following 13 years, the population declined steadily until 2010, when the meadow reached its lowest point in population density and extent. The years following 2010 have shown a slow, but upward trend in density and expansion. The meadow currently covers a similar area to the 1997 extent, and the density of the meadow is climbing gradually. It will be very interesting going forward to see if this recovery continues and when/if we reach a peak.

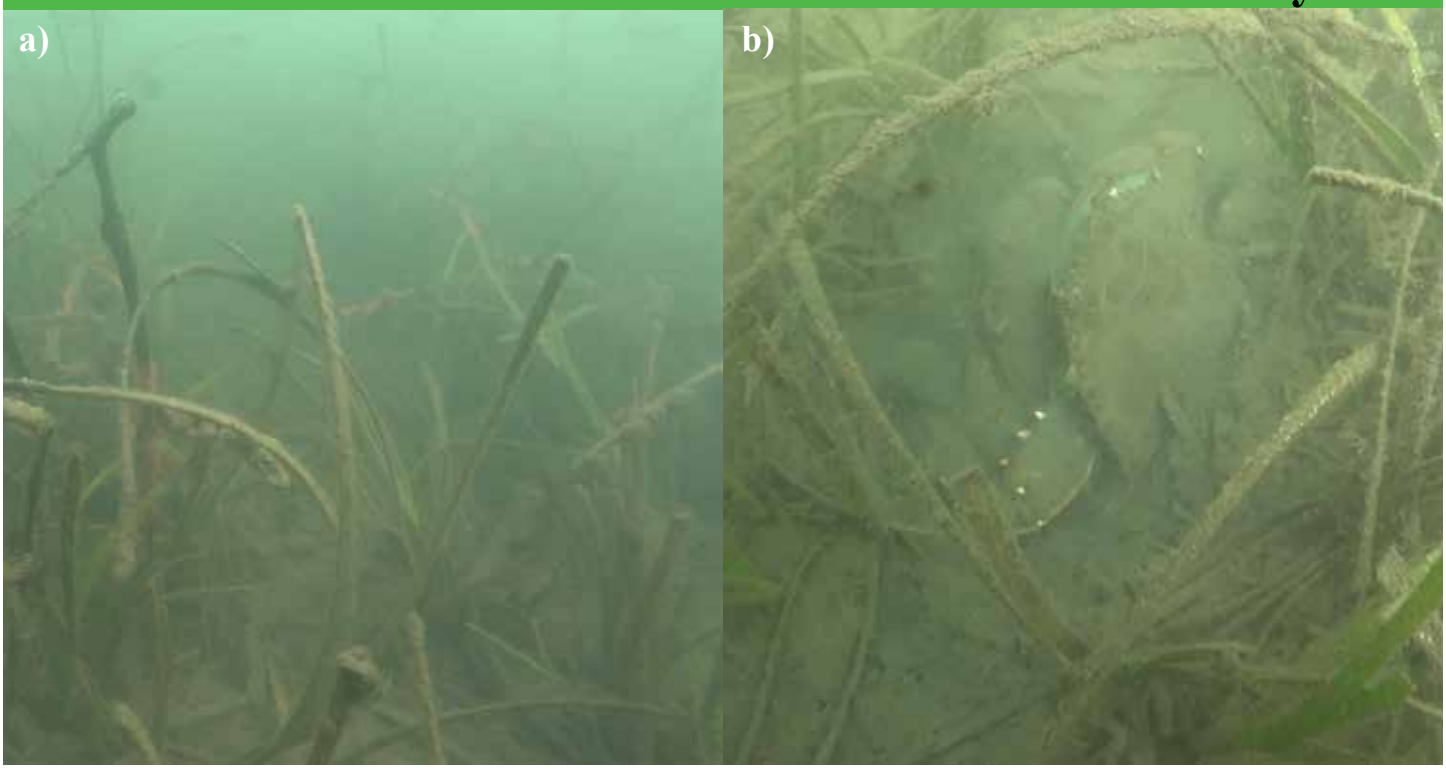


Figure BB-5. a) Non-native tunicates thrive in the warm waters of Bullhead Bay using the eelgrass as a substrate. b) A mating pair of blue crabs sheltered in the eelgrass meadow a Station 4.

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 2019

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 2019.

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	13.1	+0.8	10.1	+2.1	23.6
August	13.2	+0.9	10.0	+2.0	24.1
September	12.7	+0.4	9.5	+1.5	21.6

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 2019 season were conducted for ten-day periods, monthly, from July-September 2019. The collected light data for 2019 is summarized in Table GB-1, above.The Gardiners Bay light loggers showed that the meadow received ample light over all three months. For both Hcomp and Hsat, the site recorded surplus light for all months in 2019. Overall, light conditions should have favored eelgrass growth over the season.

Water temperature was monitored at the Gardiners Bay site using an Onset Hobo temperature logger deployed in mid-June, 2019. The average monthly water temperatures for the Gardiners Bay eelgrass meadow are found in Table GB-1. For 2019, none of the monthly average temperatures reached 25°C and over the season, the site only experience 1 day with water temperatures exceeding the 25°C threshold. Overall the meadow experienced cooler water temperatures in 2019 than the previous two seasons.

Eelgrass Shoot Density

The 2019 LTEMP was conducted on 9 September, 2019 at Gardiners Bay. For the first time in several years, eelgrass was recorded at monitoring stations other than stations 6,7, and 8. Quadrat sampling at station 4 had one quadrat with eelgrass, while station 5 had five of ten quadrats with recorded eelgrass. The average eelgrass shoot density for 2019 was 151

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2019, 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
2019	151	+/-25

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

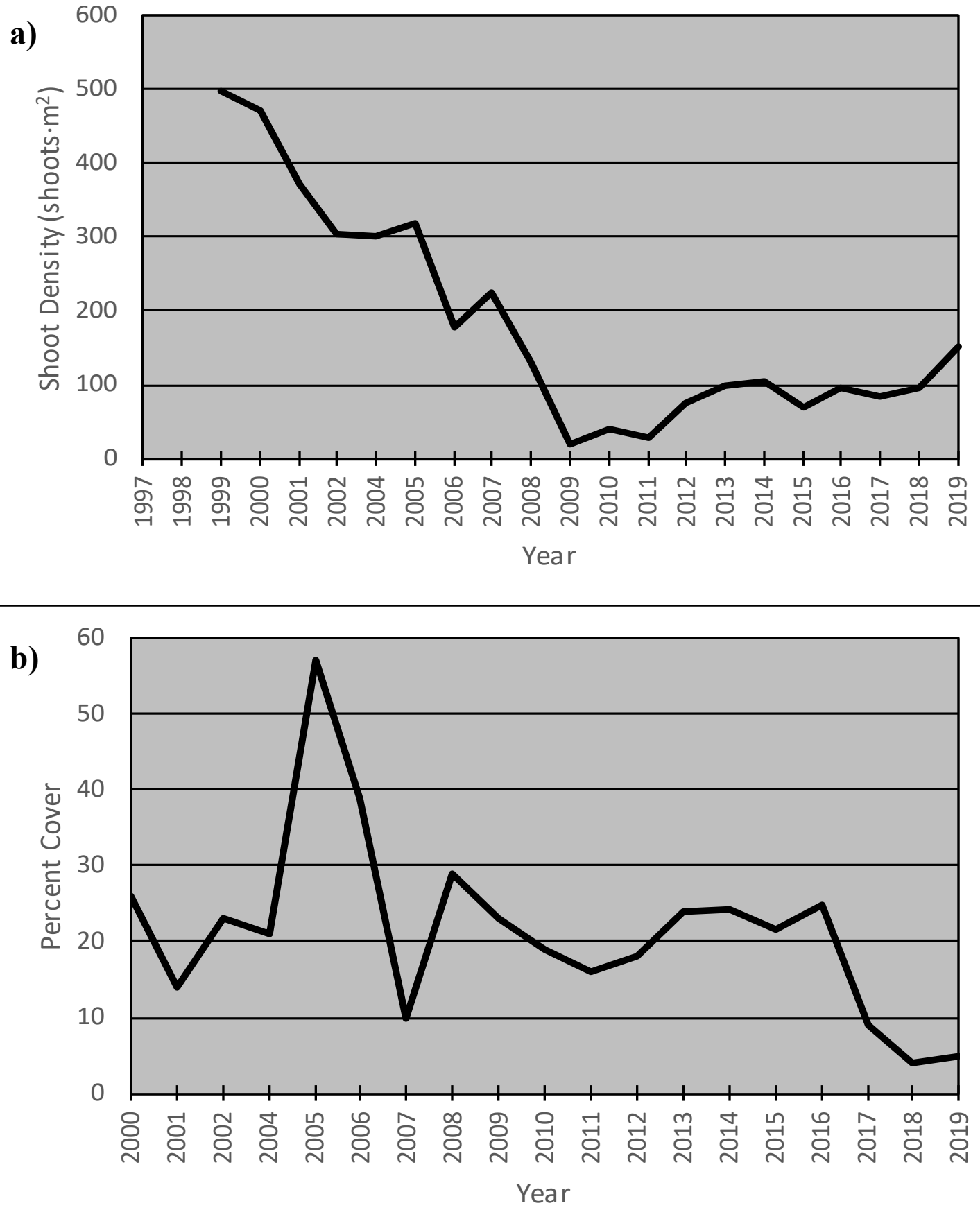


Figure GB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted at the Gardiners Bay site.

Figure GB-3. The 2019 areal delineation of the Gardiners Bay eelgrass meadow on the northeast shore of Shelter Island, NY.

shoots·m^2, which represents a significant increase from the shoots density in 2018 (Table GB-2; Figure GB-2a).

Macroalgae Cover

The macroalgae percent cover in the Gardiners Bay eelgrass meadow experienced a slight increase in macroalgae cover from 2018 to 2019. The average macroalgae percent cover in 2019 increased to 5% from just over 4% in 2018. While macroalgae species diversity remains relatively high (8 species identified in 2019), the overall biomass at the site is very low.

Bed Delineation and Areal Extent

The 2019 meadow delineations were completed using Google™ Earth imagery taken on 19 September, 2019. Based on these aerial images, a total of 19.6-acres of eelgrass still occupies the Gardiners Bay site (Table GB-3; Figure GB-4h). This represents no significant change between 2019 and the two previous years

Conclusions

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2019.

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.)
2019	19.6 acres (7.93 hect.)

The Gardiners Bay eelgrass meadow remained relatively stable with eelgrass shoot densities showing no significant change over the previous four seasons, but in 2019, the meadow recorded the first significant increase in shoot density since 2007. The meadow's areal extent has also remained relatively stable over the past three monitoring seasons and recruitment of eelgrass was reported at two monitoring stations that hadnt previously supported eelgrass in several years. Water clarity and temperature have maintained levels that are beneficial to eelgrass growth, and the positive changes and stability are likely partially the result of these conditions. If the meadow continues its stability, or shows new gains in the coming monitoring season, it may suggest that the eelgrass meadow has found a new stabile state after the migration of the meadow inshore from its extent at the beginning of the LTEMP program.

There are actions that can be taken to protect this meadow from preventable disturbance events. Moorings at the site could be moved to unvegetated areas reducing the scouring impact on the meadow. Boats continue to travel across the site, well outside the designated navigational channel, and while most of the meadow has migrated inshore far enough to avoid prop scarring from these boats, there are instances when boat travel over extant eelgrass. These events could potentially be avoided through signage placed outside the eelgrass meadow, on posts or buoys, indicating the presence of eelgrass meadows and the need

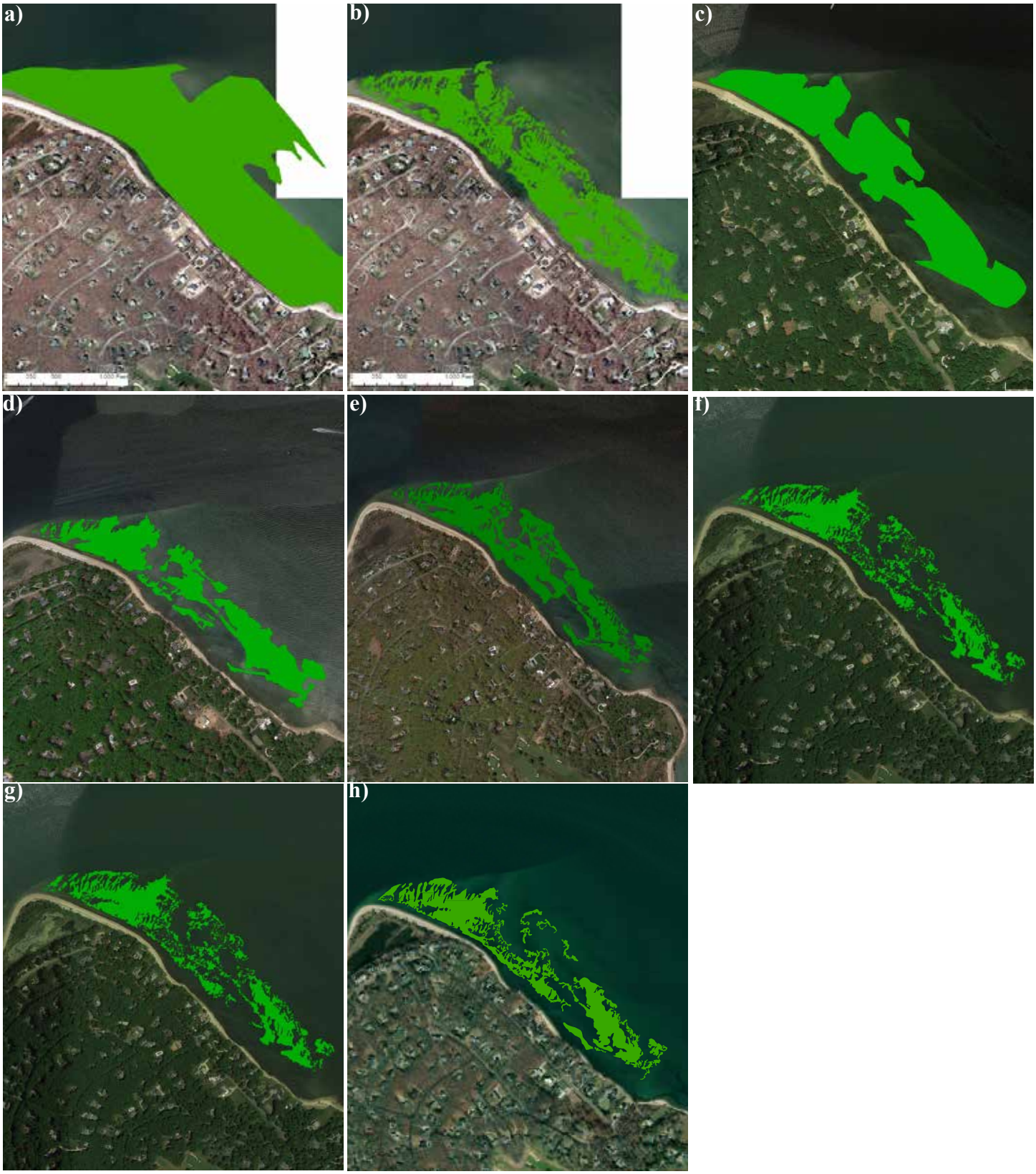


Figure GB-4. A series of aerial delineations of the Gardiners Bay eelgrass from select years from 2000 through 2016. The years represented are a) 2000, b) 2010, c) 2014, d) 2015, e) 2016, f) 2017, g) 2018 and h) 2019.

Figure GB-5. Underwater photographs taken by CCE divers while conducting the 2017 eelgrass monitoring at the Gardiners Bay LTEMP site. a) Due to the higher current at Station 6, the sediment in the eelgrass meadow tends to include shell hash and gravel. b) A juvenile sculpin investigating a quadrat that was cleared for shoot counting at Station 8.

to avoid them. Similar markers are used in Florida and Gulf states to warn boaters out of seagrass meadows. Placement of such markers would require approval from the US Army Corps of Engineers and the US Coast Guard, but it could be worthwhile to explore the possibility of marking eelgrass meadows in the Estuary.

Three Mile Harbor-2019

Following the 2014 Peconic Estuary aerial eelgrass survey, small meadows of eelgrass were identified in the headwaters of Three Mile Harbor, East Hampton. The larger of the meadows was added to the LTEMP program and had two monitoring stations assigned to the meadow (Figure TMH-1). With the retirement of the original Three Mile Harbor LTEMP site (located near Hands Creek), the headwaters meadow is now the only active eelgrass monitoring site in the harbor complex. During the 2014 Peconic Estuary Eelgrass Aerial Survey, three extant eelgrass meadows near the headwaters of Three Mile Harbor were identified (Figure TMH-2). During the 2015 monitoring season, one of these meadows (indicated in Figure TMH-2 within the white oval) had temperature and light loggers deployed to it and ten quadrat counts were completed along its length.The deployment of temperature and light loggers to this meadow were continued in 2016, as was the quadrat survey.

Figure TMH-1. An aerial 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 2019.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	13.9	+1.6	11.2	+3.2	25.3
August	13.7	+1.4	11.0	+3.0	24.9
September	12.0	-0.3	10.1	+2.1	21.9

Odyssey PAR loggers were deployed for 10 days during July, August, and September, 2019 at the meadow at the head of Three Mile Harbor. The average daily Hcomp and Hsat recorded for the 2019 season are presented in Table TMH-1. The meadow received sufficient light to meet its Hcomp requirements for July and August, but fell short of the 12.3 hours for September in 2019. For Hsat, the meadow exceeded its minimum requirement for all three months in 2019, allowing the meadow to produce extra energy to support increased growth or to store as reserves in its rhizomes.

The Onset Hobo water temperature logger was deployed to Three Mile Harbor in mid-June, 2019. The average monthly temperatures are presented in Table TMH-1. For 2019, the water temperature was highest in July with the monthly average of 25.3°C. The month recorded 34 days with an average daily temperature over 25°C, and one day with a daily average temperature over 27°C. This was a similar to the monthly averages reported in 2018, with the difference being that in 2018, August was the warmest month versus July being warmer in 2019.

Eelgrass Shoot Density

Three Mile Harbor was visited on 10 September, 2019 and the monitoring was conducted at the two stations in the 'new' site at the head of the harbor. The meadow reported a significant decline in eelgrass shoot density from 2018 to 2019 (Table TMH-2; Figure TMH-2a). The average shoot density calculated for 2019 was 42 shoots·m^2, down from 79 shoots·m^2 in 2018. During the 2019 monitoring visit, no eelgrass could be found at station 2, which significantly impacted the average shoot density for the site.

Macroalgae Cover

Macroalgae cover at the new Three Mile Harbor site was reported to have significantly decreased from 2018 (Figure TMH-2b). Macroalgae cover was declined to 5.3% in 2019 from 75% in 2018. Macroalgae cover, specifically *Spyridia filamentosa*, was very low at station 1, while station 2 had no macroalgae on the bottom due to the absence of eelgrass to hold the drift macroalgae in this soft-bottom system. The dominant seaweed species at the site continued to be *Spyridia*

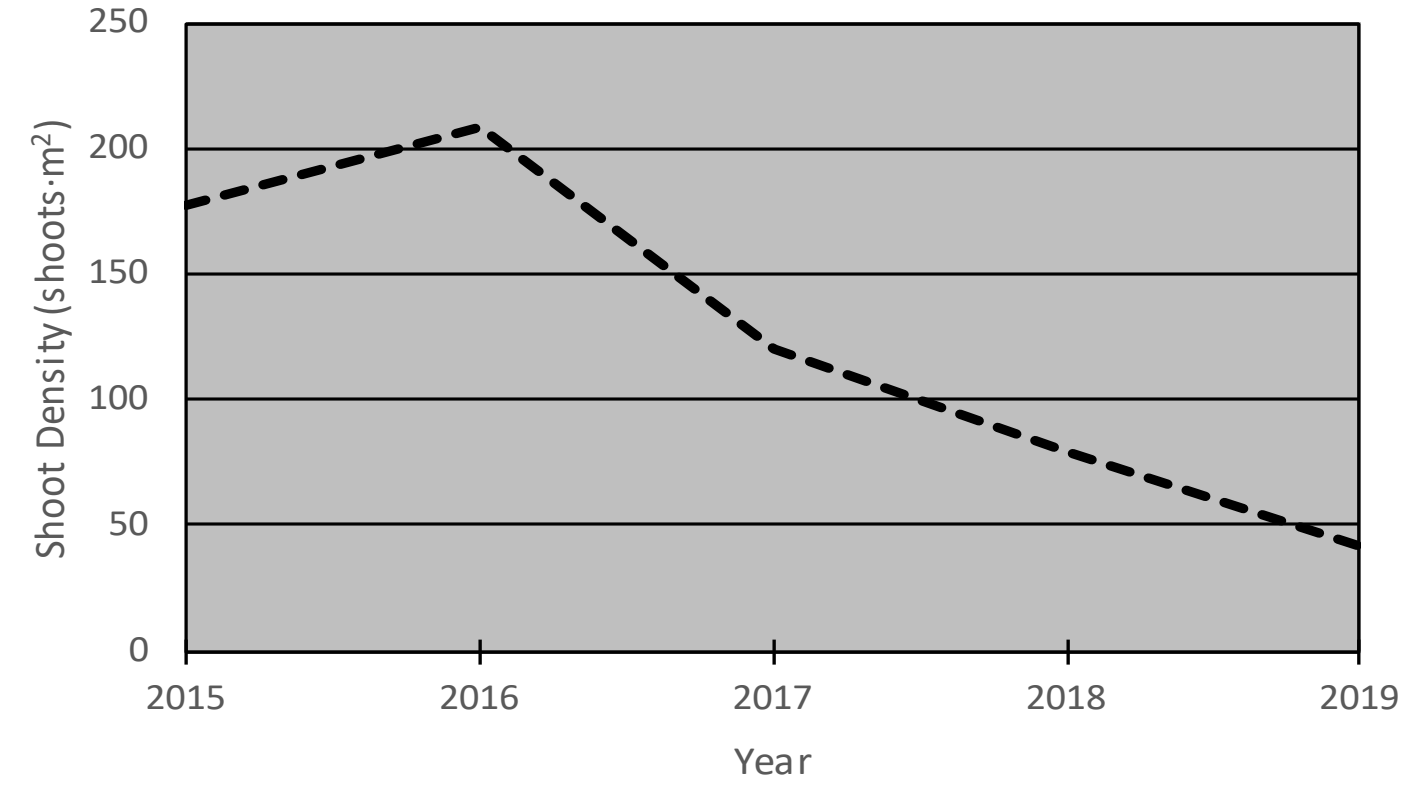
Table TMH-2. The average annual eelgrass shoot density for Three Mile Harbor (new site) from 2015 to 2019, including standard error.

Year	Mean Density	S.E.
2015	177	+/- 17
2016	209	+/- 20
2017	120	+/- 17
2018	79	+/- 20
2019	42	+/- 13

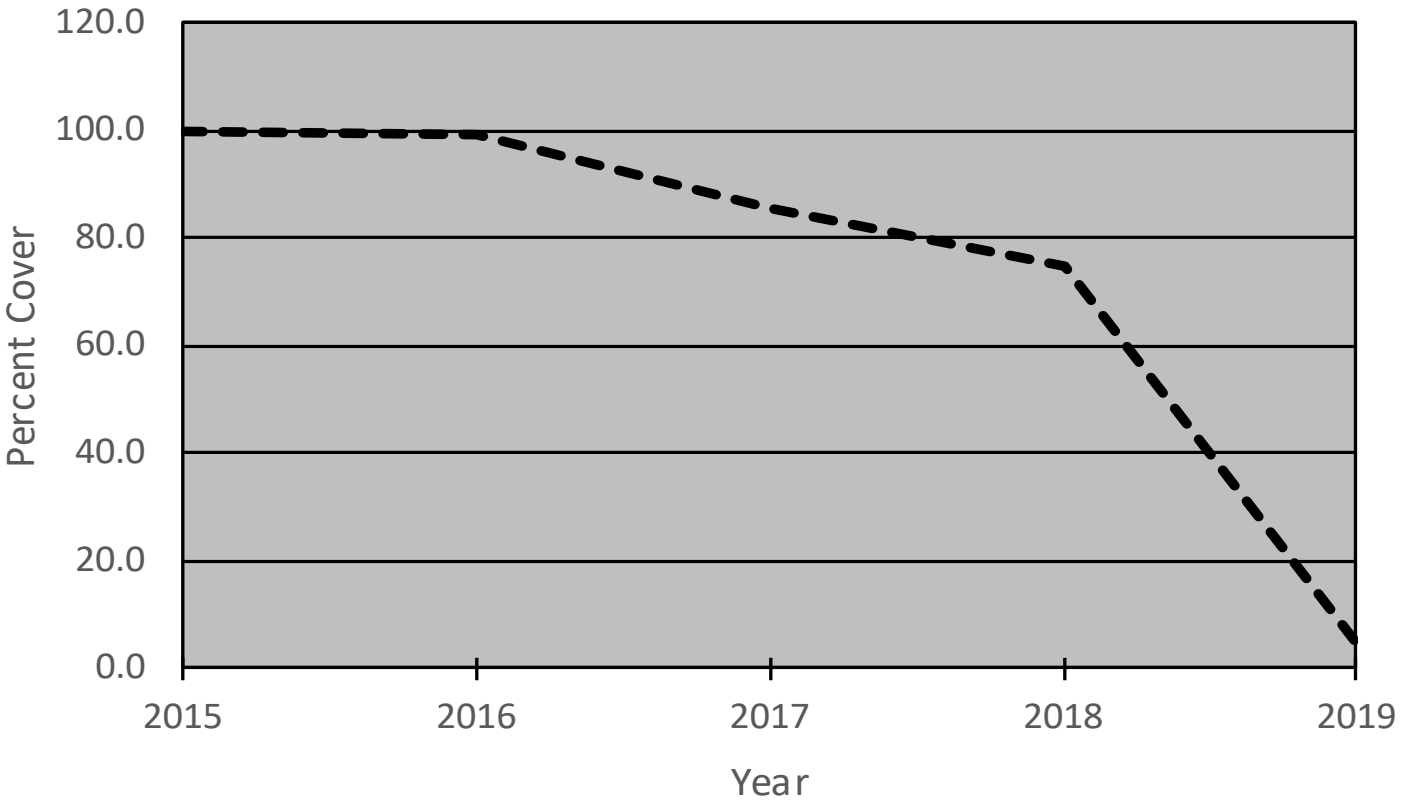
Table TMH-3. The estimated cover of eelgrass in Three Mile Harbor for all years surveyed.

Year	Estimated Area
2014	0.66 acres (0.27 hect.)
2015	0.67 acres (0.27 hect.)
2016	0.68 acres (0.28 hect.)
2017	0.81 acres (0.33 hect.)
2018	0.67 acres (0.27 hect.)
2019	1.4 acres (0.57 hect.)

Three Mile Harbor-2019



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) 2017, c) 2018, and d) 2019 meadow delineations.

filamentosa, although its biomass was significantly reduced from previous years.

Bed Delineation and Areal Extent

The eelgrass meadow for the new Three Mile Harbor

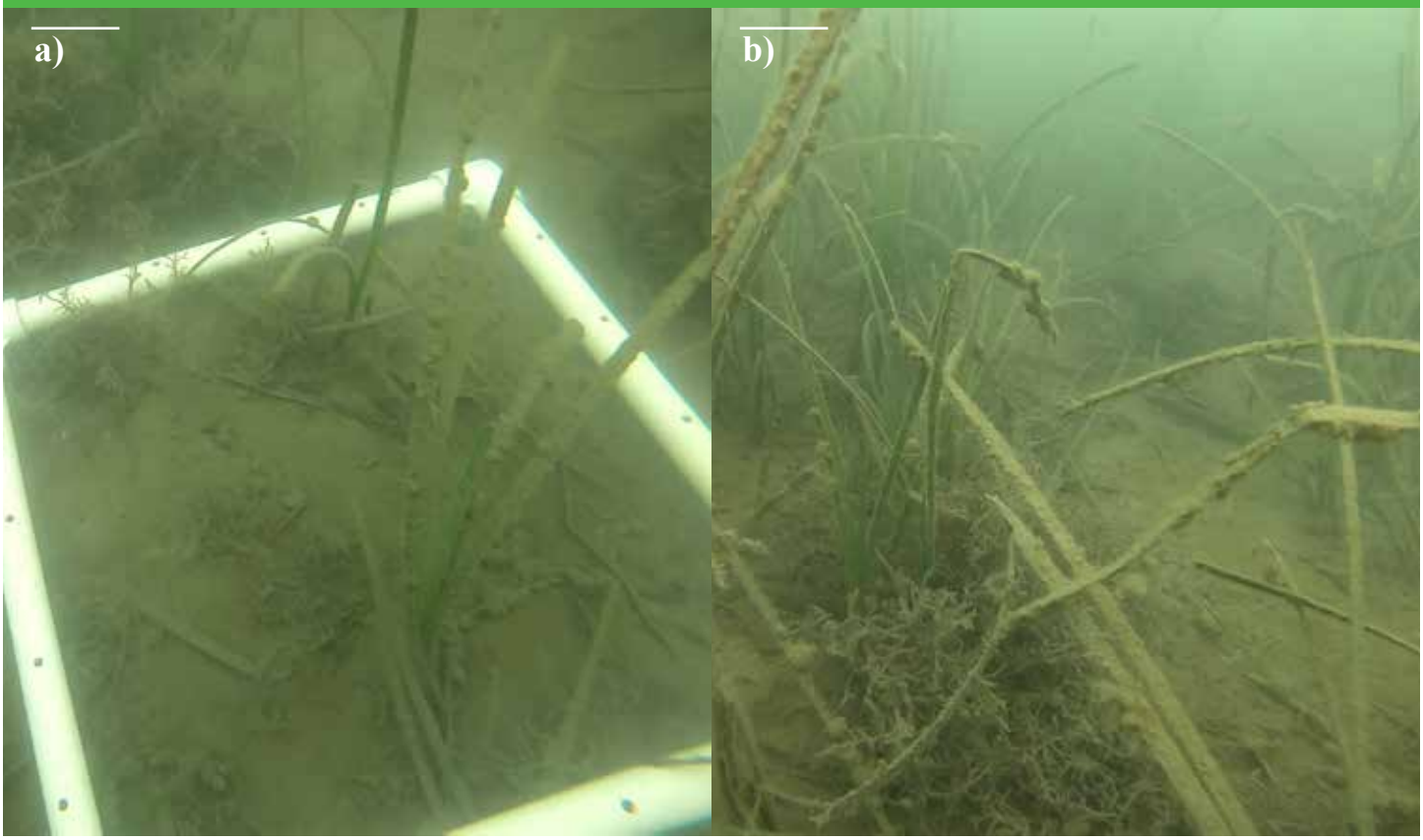


Figure TMH-4. Underwater photographs taken by CCE divers during the 2019 monitoring visit to the Three Mile Harbor eelgrass meadow. a) One of the quadrats sampled at Station 1. b) A photograph illustrating the general condition of the meadow at the site.

site was delineated using Google™ Earth imagery taken on 19 September, 2019. A progression of aerial delineations of the meadow is presented in Figure TMH-3. The 2019 areal extent of the bed in Three Mile Harbor was found to be 1.4-acres, and increase over previous delineations of the site. Based on the 2019 aerial imagery , the bed appears to be expanding to the north, while pulling away from the shore along its southern end (Figure TMH-3d).

Conclusions

The Three Mile Harbor eelgrass bed continued to show the decline the was initially reported in 2018 at station 2. During the 2019 monitoring survey, the diver at station 2 could not find eelgrass within the 10-meter radius of the monitoring station. The nearest eelgrass to the site was observed along the slope of the channel, well outside the area normally monitored (due to safety concerns). No eelgrass at station 2 and a significant decline in shoot density at station 1 resulted in the low density reported for 2019. At the same time that the meadow's shoot density has declined, the meadow has expanded its areal extent, with the meadow extending to the north and moving into the deeper water of the channel. The offshore migration of eelgrass at station 2 could be due to increased boat traffice to the docks along the southern end of the meadow or other anthropogenic factors. While the decrease in shoot density is concerning, the fact that the meadow is actively expanding, suggests that conditions are still supportive of eelgrass growth, however, future site visits in 2020 will prove the health of the meadow.

Cedar Point 2019

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 2019. The light availability in

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 2019. The temperature logger was lost between the July light logger deployment and the August light logger deployment

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.6	+2.3	10.1	+2.1	23.0
August	13.0	+0.7	9.6	+1.6	23.5
September	12.3	0	9.4	+1.4	21.2

the Cedar Point eelgrass meadow was found to meet the minimum standards required for Hcomp and Hsat for all three months sampled. For Hcomp, the site showed a surplus of light for July and August, and met the minimum in September. All three months recorded a surplus in Hsat for 2019, providing the meadow with extra energy that could be used for expansion or building reserves.

A water temperature logger was deployed to the the Cedar Point meadow in mid June 2019, near monitoring station 3. Water temperatures were cooler than those recorded in 2018. The monthly average temperatures remained below 25°C for all three months sampled (Table CP-1). Unlike the 2018, which recorded 15 days ≥ 25°C, 2019 was cooler recording no days averaging at or greater than the threshold. The highest water temperature recorded for 2019 was 26.2°C taken on 22 July.

Eelgrass Shoot Density

The 2019 eelgrass monitoring visit was made on 3 September, 2019. The average eelgrass shoot density for 2019 was reported as 221 shoots·m^2 (Table CP-2; Figure CP-2). This density represents no significant change from the 225 shoots·m^2 reported in 2018.All monitoring stations recorded eelgrass, however stations 2 and 6 reported patchy coverage.

Macroalgae Cover

Macroalgae cover in the Cedar Point eelgrass meadow showed no change between 2018 and 2019. The percent cover of macroalgae for 2019 was 16.7%. *Sargassum filipendula* is the primary macroalgae species inhabiting the Cedar Point eelgrass meadow, growing attach to most hard substrates at the site. Other species recorded at the site included *Spyridia filamentosa*, *Chondrus crispus*, *Halosiphon tomentosus*, *Codium fragile* and *Ulva* species.

Bed Delineation and Areal Extent

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 through 2019, 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
2019	221	+/-33

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for select years from 2000-2019.

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.)
2019	69.8 acres (28.25 hect.)

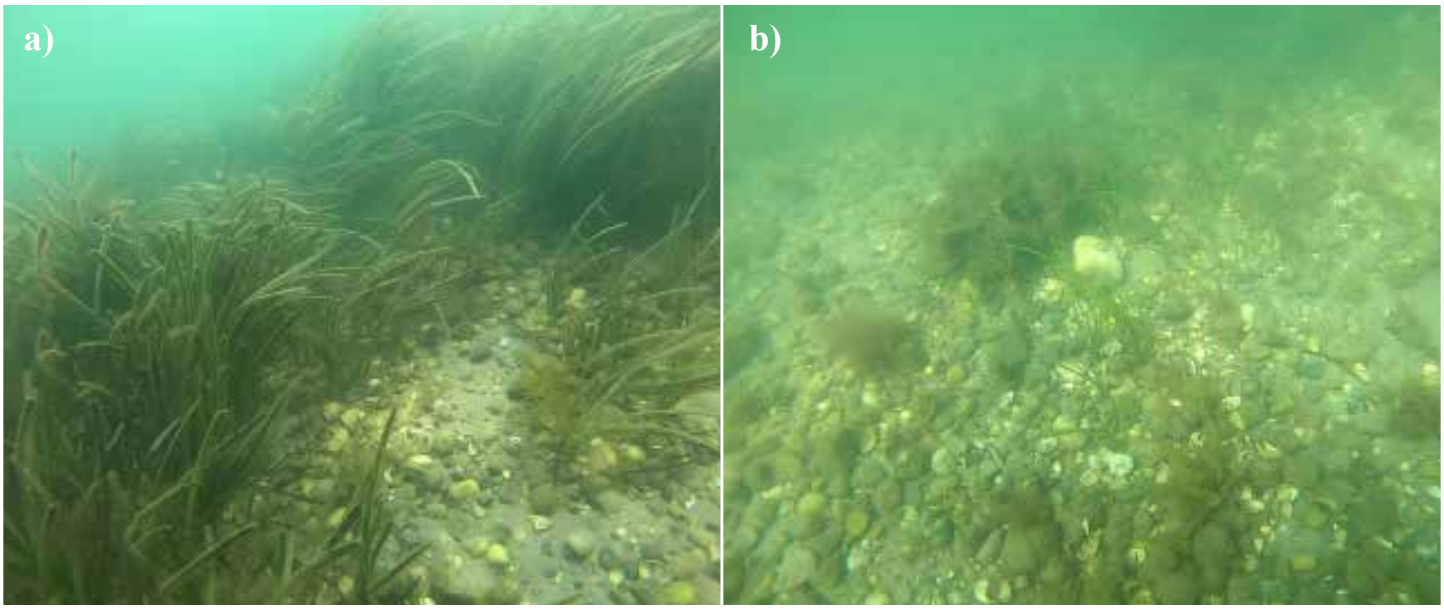


Figure CP-4. a) Conditions at Station 1 where the sediment texture is too fine to allow macroalgae to attach en masse an compete with the eelgrass growing here. b) Clusters of eelgrass seedlings near Station 3 starting to recruit into the area of the meadow that was lost during Superstorm Sandy.

The 2019 delineation of the Cedar Point eelgrass meadow was completed using Google Earth™ imagery taken on 19 September, 2019. The overall quality of the imagery was good and allowed for an accurate assessment of the meadow at this site. Based on the aerial imagery, the meadow declined slightly from its extent in 2018, from 73.6 acres to 69.8 acres (Table CP-3). This change in acreage is within the 10% error attributed to the subjective delineation process, suggesting the overall areal extent of the meadow was relatively unchanged between 2018 and 2019. The most obvious change in the meadow is the regrowth of eelgrass in the middle of the meadow that had been washed out during Superstorm Sandy.

Conclusions

The 2019 LTEMP monitoring found that the Cedar Point eelgrass meadow showed minor changes in shoot density and areal extent from the previous year's survey. Even the macroalgae community showed little change between years. The 2019 seasons reported eelgrass at station 6, which in 2018 had no eelgrass present within 10 meters of the monitoring point, indicating that whatever had caused the loss of eelgrass in that section of the meadow, the eelgrass was recovering. Like the other meadows inhabiting wave exposed shorelines in the Estuary, physical disturbance, specifically waves, is the factor most influecncing the changes at this site. The eelgrass meadow receives adequate light and is not exposed to extreme temperatures, leaving wave-driven sediment movement (erosion and accretion) as the most significant cause of eelgrass loss at the site. The erosional loss of sediment and eelgrass exposes cobble and rock that had been buried under the finer sediments. The availability of the hard substrate results in recruitment of *Sargassum*, which, as it grows, can compete against eelgrass recruiting from seed, preventing immediate recovery of eelgrass to areas of loss. As the *Sargassum* becomes established and spreads, it starts to cause accretion of finer sediments which gradually bury the exposed rocks, changing the area in favor of eelgrass recruitment again. This dynamic in eelgrass-Sargassum systems is based on observations made at Cedar Point and similar meadows, and could use more rigorous scientific evaluation to confirm the theory.

The Cedar Point eelgrass meadow has been slow to recover from the damage suffered in 2012, but while the meadow has had some setbacks, its has been remained fairly stabile over the last few seasons. The exposure to waves at the site makes recruitment by seeds unreliable and slow due to sediment movement and the potential competition from macroalgae, but the meadow has show recovery from the damage resulting from Sandy and should continue to recover, as long as its recovery potential is higher than the rate of loss to wave damage.

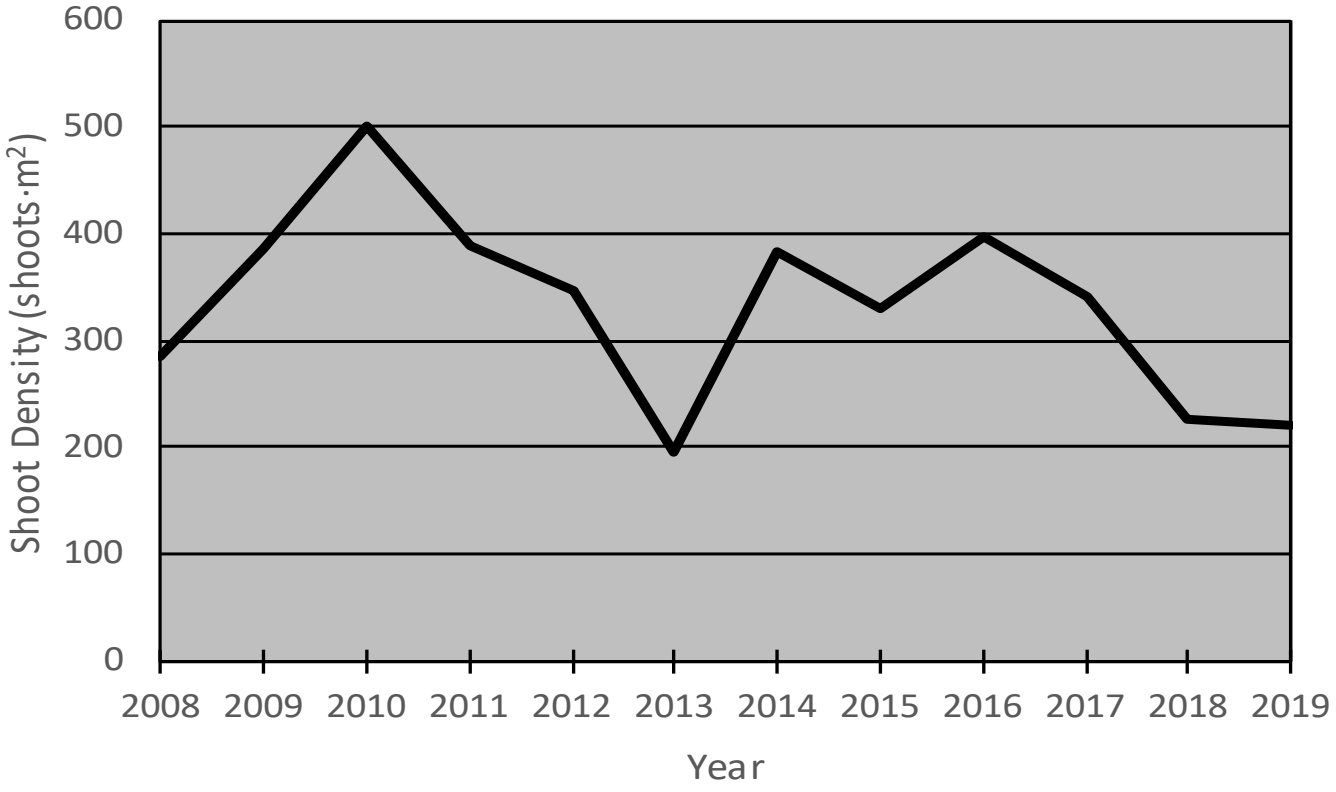


Figure CP-2. The average annual eelgrass shoot density for Cedar Point for 2008-2019.

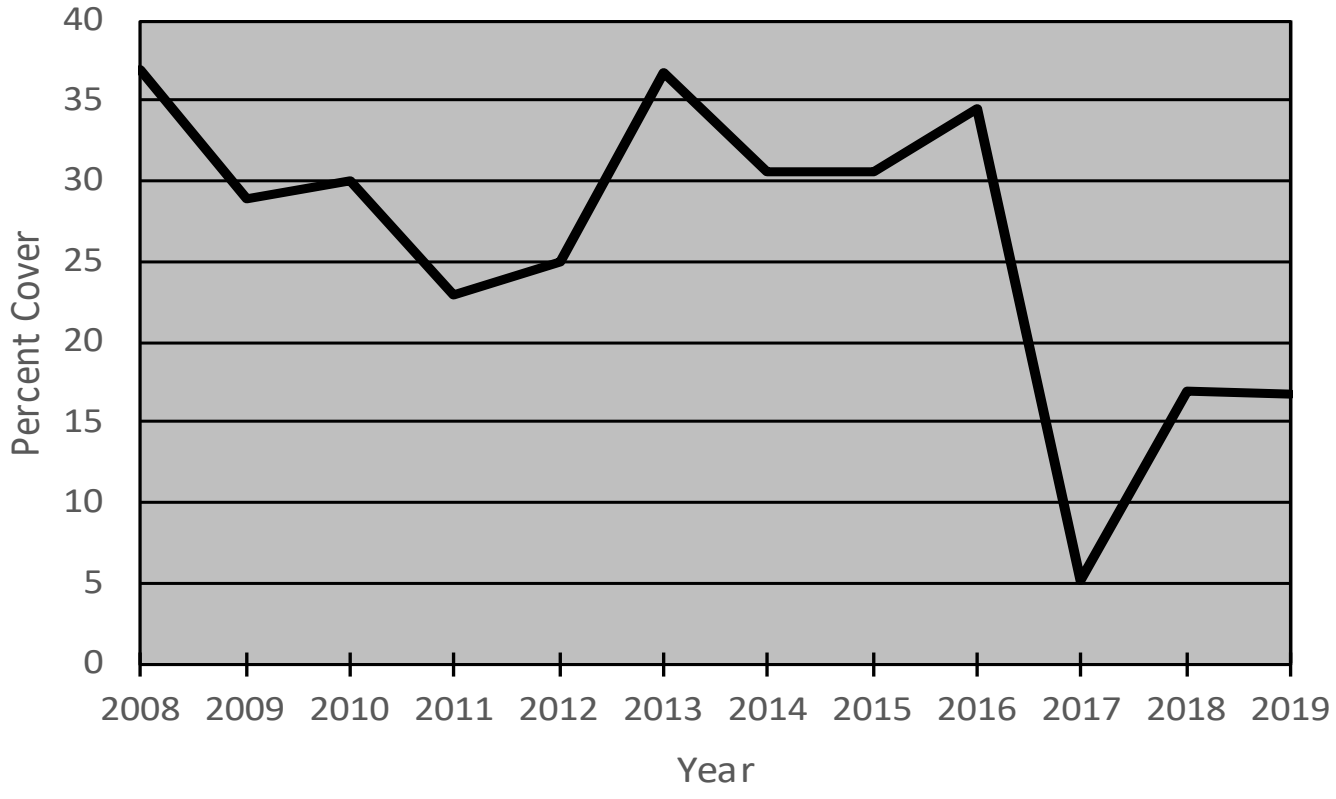


Figure CP-3 Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2019.

Cedar Point 2019

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) 2019 (continued on next page).

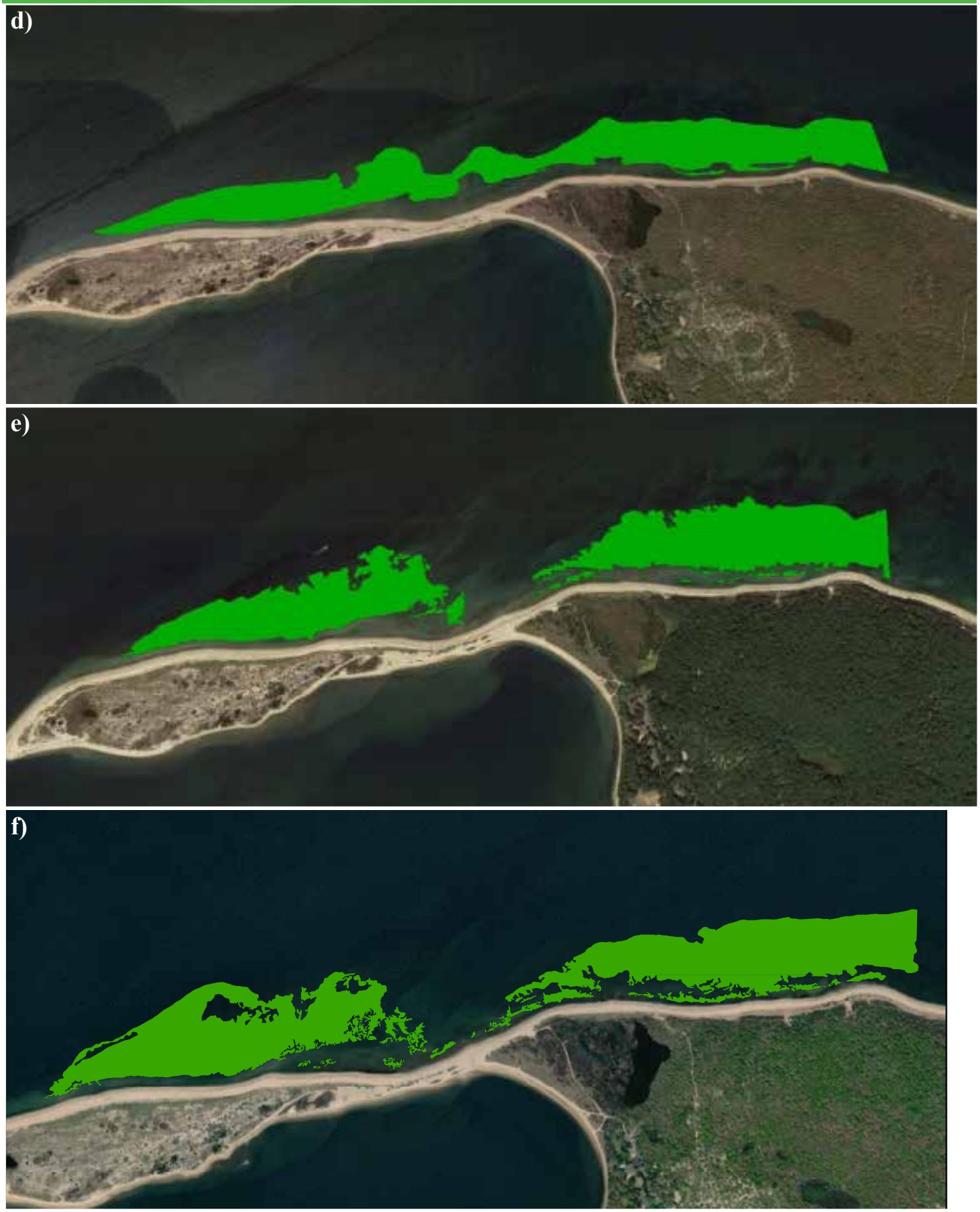


Figure CP-4. Continued.

Orient Point 2019

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 Partnership 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 2019.

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	13.4	+1.1	10.5	+2.5	21.2
August	13.3	+1.0	10.2	+2.2	22.2
September	12.5	+0.2	8.9	+0.9	20.9

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 2019. The daily average Hcomp and Hsat were calculated from this data and daily averages for each month are presented in Table OP-1. Light availability within the Orient Point eelgrass meadow met and exceeded the minimum requirements for Hcomp and Hsat for all three months monitored (Table OP-1). The surplus of light received would have allowed the meadow to meet its minimal daily energy requirements, and provide extra energy for growth and expansion.

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
2019	128	+/-33

Water temperature was monitored by deploying an Onset Hobo temperature logger in the Orient Point meadow in mid-June 2019. The water temperature data was used to calculate average monthly water temperatures (Table OP-1). The Orient Point eelgrass meadow has not shown any issues with high water temperatures in past seasons, and that trend continued in 2019. The meadow experienced no days during the season where average daily water temperatures approached 25°C. The highest water temperature recorded was 24.8°C taken on 26 July, 2019.

Eelgrass Shoot Density

The 2019 Orient Point eelgrass monitoring was conducted on 20 September, 2019. The 2019 elgrass shoot density showed a significant increase from 2018, from 97 shoots·m^2 (2018) to 128 shoots·m^2 in 2019 (Table OP-2; Figure OP-2). As with previous years, monitoring stations (4 and 6) supported no eelgrass.

Macroalgae Cover

Macoralgae cover, in 2019, declined by more than 10% from 2018 (Figure OP-3). The macroalgae cover reported for 2019 was 7.8%, down from 18% in 2018. Macroalgae diversity of the site consisted of 10 species, with the primary species dominating the macroalage community being the brown seaweed, *Sargassum filipendula*. Secondary species recorded at the site included two invasive, non-native species, *Codium fragile* (green) and *Grateloupia turuturu* (red), as well as *Chondrus crispus* (red), *Agardhiella tikvahiae* (red), and five species of the filamentous reds.

Bed Delineation and Areal Extent

The aerial imagery for the 2019 eelgrass delineation at Orient Point was obtained from Google Earth and taken on 19 September 2019. Based on the delineation from the 2019 aerial image, the Orient Point meadow covered 13.1 acres(Table OP-3; Figure OP-5f). This represents an increase of 2.3 acres from the 2018

Orient Point 2019

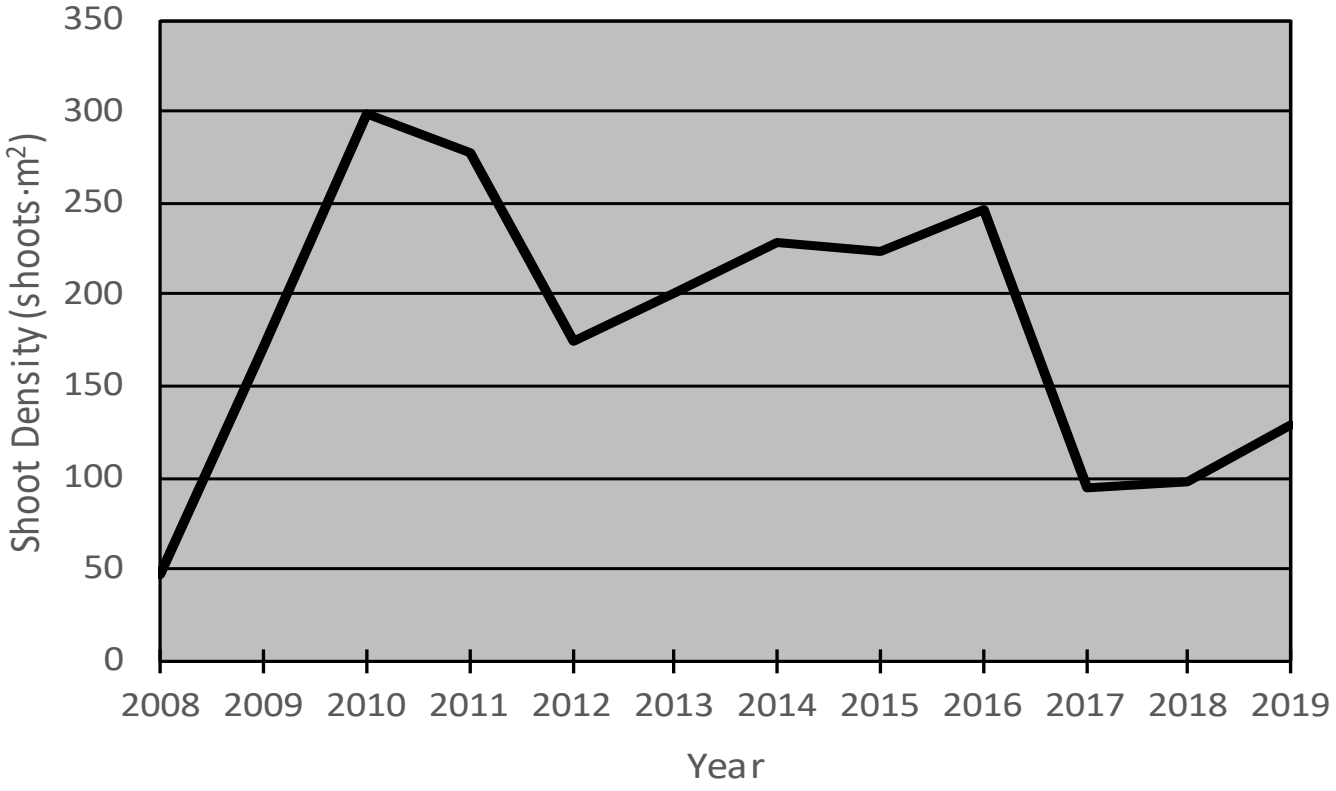


Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2019.

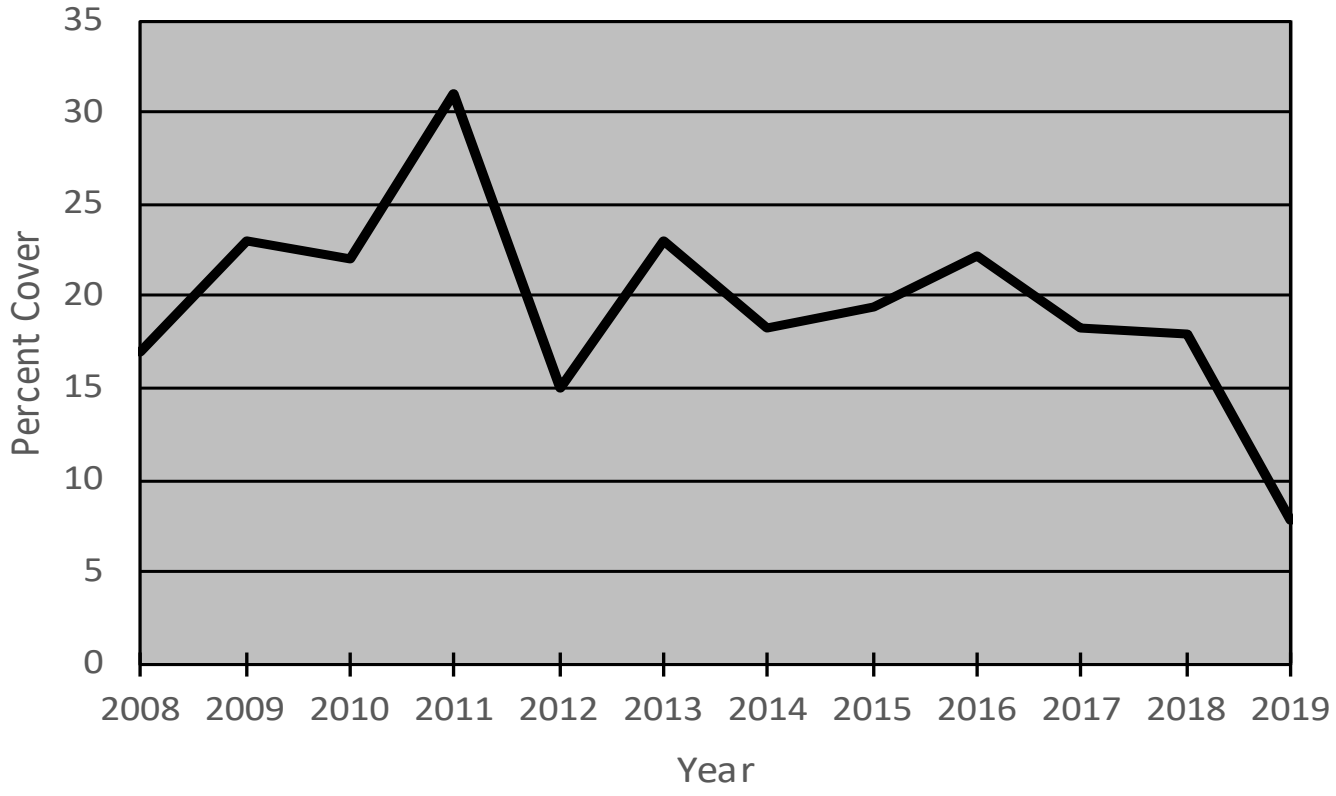


Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2019.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2019.

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.)
2019	13.1 acres (5.30 hect.)

*Area of meadow was significantly underestimated in aerial survey.

delineation of the eelgrass meadow. There has been no significant expansion into offshore areas that were formerly eelgrass meadow, but instead there has been significant growth and expansion in the nearshore areas of the meadow. The growth in the nearshore includes the filling of open patches and the recolonization of unvegetated areas.

Conclusions

The Orient Point eelgrass meadow made some gains in eelgrass shoot density and areal extent in 2019 compared to 2018. The general trend that has been observed in this meadow over the last few years has been the inshore migration of the meadow. This migration has resulted in the coalescing of eelgrass into higher density patches which have been observed to produce large number of flower shoots/seeds. The seeds have been recruiting into unvegetated sandy bottom and, along with vegetative expansion, the nearshore are of Orient Point has become more dense and more continuous.

The only concern with this shift of the meadow into shallower water is what its resilience to increased storm events associated with climate change will be. The meadow took significant damage from Superstorm Sandy, but similar damage could result from lower intensity, but more frequent storms in the future.

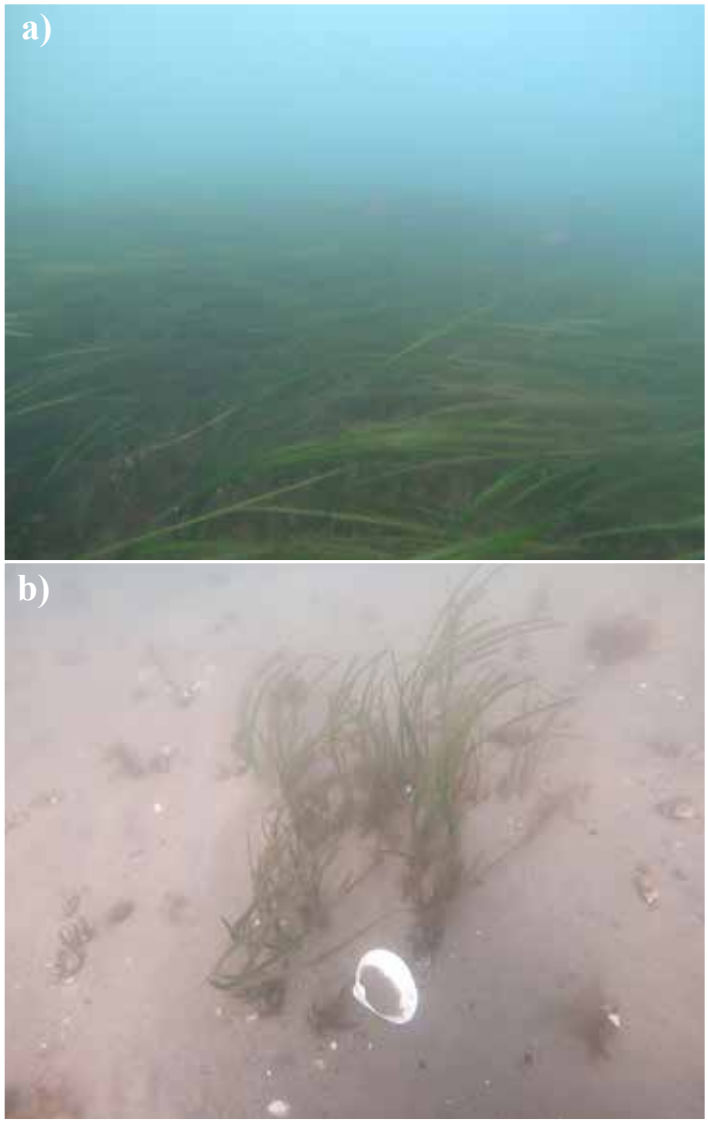


Figure OP-4. Underwater photographs of a) a school of juvenile scup foraging over the nearshore meadow at Station 3. b) One of the small patches of eelgrass that had recruited into an unvegetated area at Station 1.

Currently, the Orient Point meadow is not adversely impacted by high water temperature or low light availability which may contributing to the nearshore expansion of the meadow, even in the face of the frequent storm-generated waves.

As resilience of the nearshore meadow to wave damage is in question, it might be beneficial for a survey of the reproductive potential of the meadow to be conducted. This would include, but not be limited to quantifying seed production and recruitnment in the Orient Point meadow. Information collected from this type of study could be applied to other meadows to determine their resilience and recovery potential.

Orient Point 2019

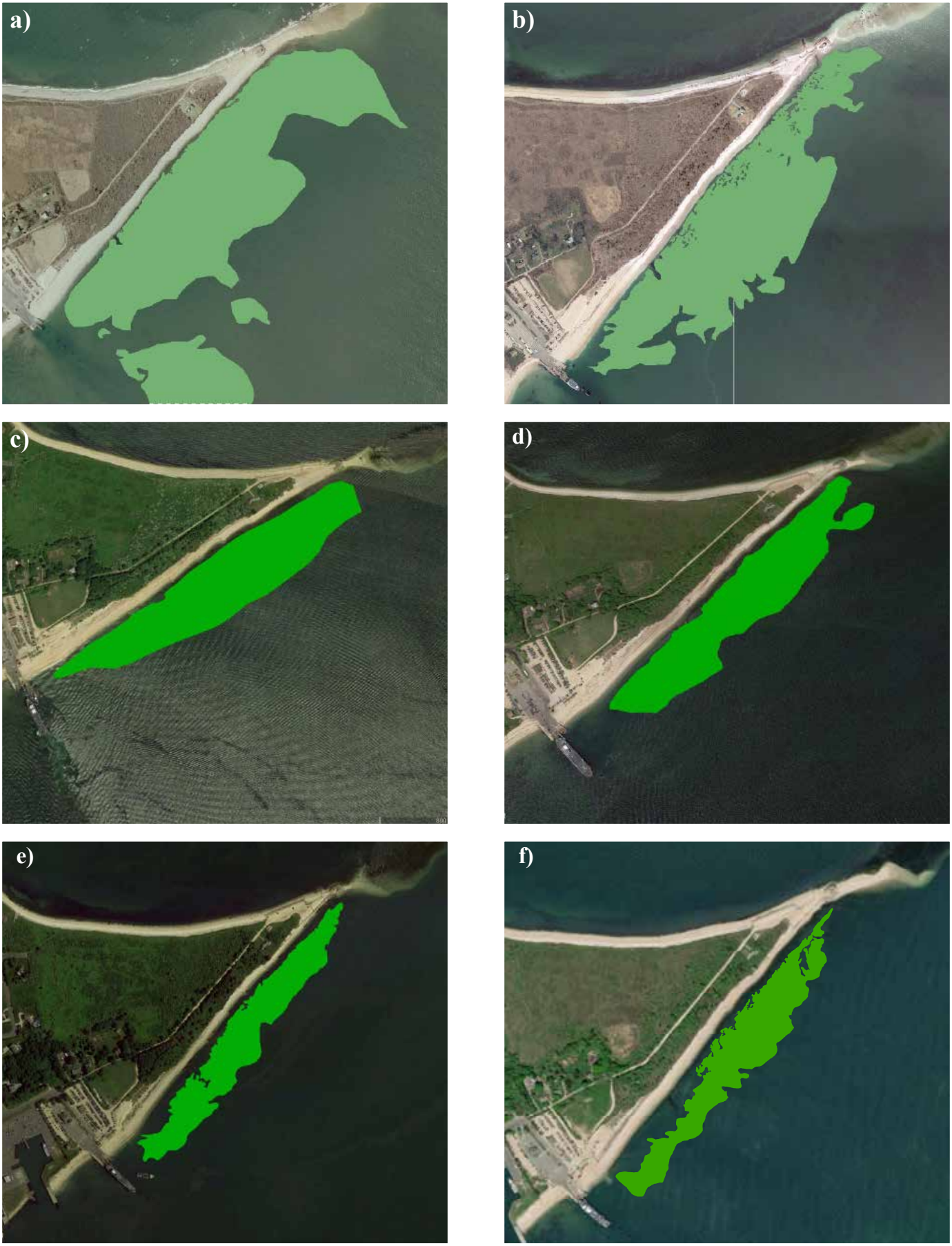


Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2010, c) 2014, d) 2015, e)2017, and f) 2019.

Coecles Harbor 2019

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 *Margalefidinium 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

A PAR light logger was deployed monthly, July-September, for 10-day intervals for 2019. The light data was converted to average daily Hcomp and Hsat values presented in Table CH-1. The Coecles Harbor eelgrass meadow met the Hcomp and Hsat requirements for eelgrass for July and August, but experienced a deficit of light for September in 2019. Compared to the light data from 2018, the meadow received more light in 2019. The surplus of Hsat is especially important to eelgrass as it provides energy to grow and expand.

An Onset HOBO temperature logger was deployed to Coecles Harbor in mid-June 2019. The average

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 2019.

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	9.9	+1.9	25.2
August	12.5	+0.2	9.3	+1.3	24.8
September	10.0	-2.3	7.9	-0.1	21.6

monthly water temperatures for July-September 2019 are included in Table CH-1. July 2019 was the only month where the average water temperature exceeded the 25°C threshold, although August was not far below that limit. In total, the Coecles Harbor eelgrass meadow experienced 36 days with water temperature averaging above 25°C, with the highest water temperature recorded at 27.1°C on July 14, 2019. Compared to the 2018 season, 2019 was cooler, experiencing 14 fewer days at temperatures above 25°C.

Eelgrass Shoot Density

The Coecles Harbor eelgrass meadow was visited on 9 September, 2019. From the first year of monitoring in Coecles Harbor, the meadow has been characterized by its overall large size, but low shoot density. The average eelgrass shoot density for 2019 more than doubled the 2018 density at 100 shoots·m^2. The 2019 density is the highest recorded at the site since monitoring began in 2017.

Macroalgae Cover

Macroalgae cover in Coecles Harbor has been high across the meadow in the previous two monitoring seasons. The 2019 macroalgae cover decline dramatically to 16%, down from 72% and 70% in 2017 and 2018, respectively. The macroalgae community in 2019 consisted almost completely of the red, filamentous seaweed, *Spyridia filamentosa*, with CCE divers observing few other species in the meadow.

Bed Delineation and Areal Extent

Google Earth™ imagery taken on 19 September, 2019, was used to delineate the Coecles Harbor eelgrass meadow. The aerial image quality was very clear for delineating eelgrass and the meadow was found to cover almost 120 acres in 2019 (Table CH-3; Figure CH-2c). This is an increase over the 2017 extent of the meadow and was close to the acreage delineated in the 2014 PE Eelgrass Aerial Survey.

Conclusions

Based on the findings of the 2019 eelgrass monitoring survey for Coecles Harbor, the meadow has shown improvements in eelgrass shoot density and areal extent over previous years. With 2019 being only the third year of monitoring at the site, it is difficult to make a determination on whether, with its low eelgrass shoot density, the Coecles Harbor eelgrass meadow is a meadow in distress, or if the low density is the natural state of this meadow. It has been remarkable the consistency in density across this large meadow each year. Continued monitoring of the site will provide a more clear picture of the nature and dynamics of this meadow.

Table CH-2. The average annual eelgrass shoot density for Coecles Harbor from 2017 to 2019, including standard error.

Year	Mean Density	S.E.
2017	78	+/-8
2018	41	+/-5
2019	100	+/-6

Table CH-3. The estimated cover of eelgrass in Coecles Harbor for all years surveyed.

Year	Estimated Area
2017	102 acres (41.28 hect.)
2018	88.2 acres (35.69 hect.)
2019	119.8 acres (48.48 hect.)

Coecles Harbor 2019

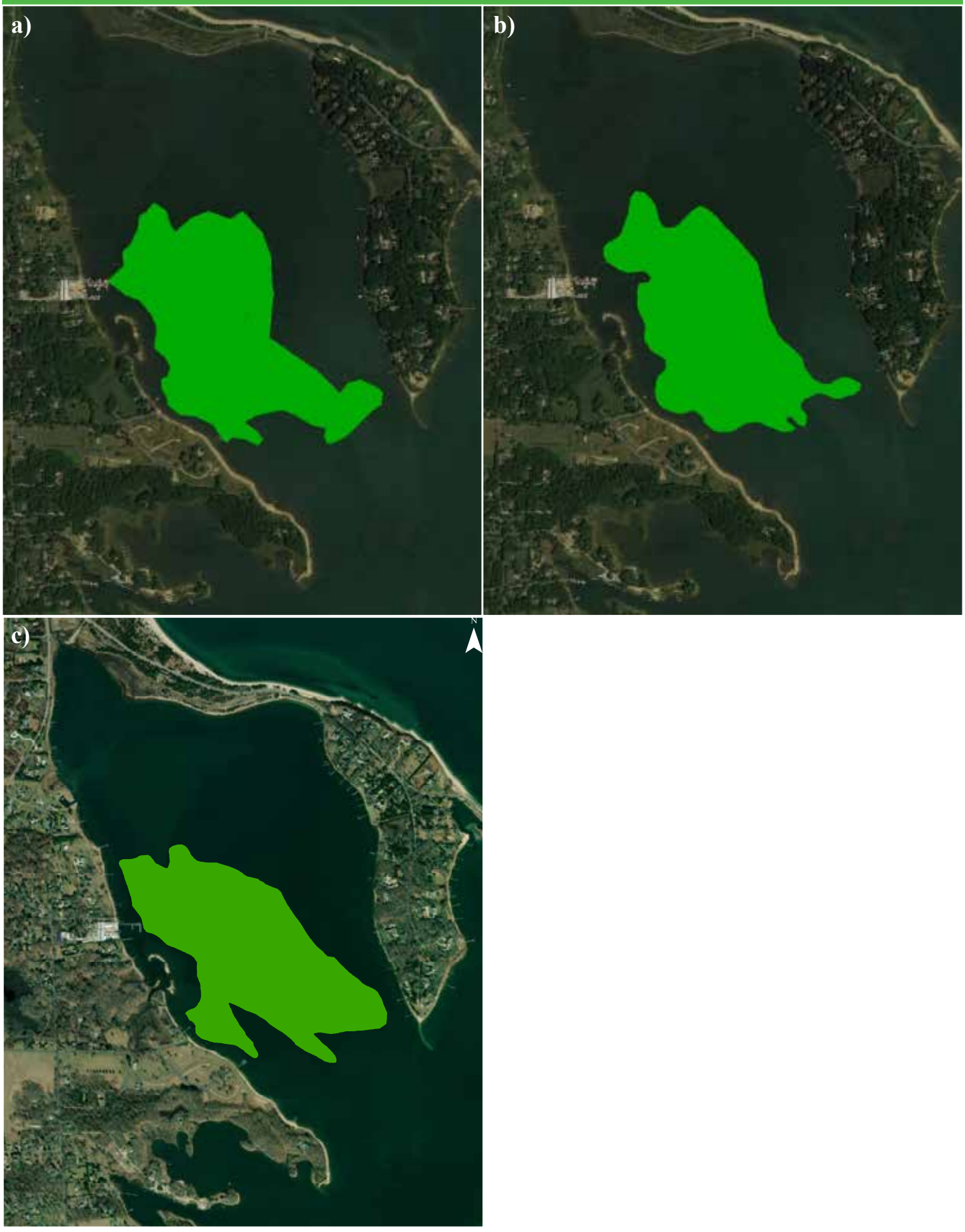


Figure CH-2. The Coecles Harbor eelgrass meadow delineations completed in a) 2014, b) 2017 and c) 2019 for the LTEMP monitoring site.

Figure CH3. Photographs showing the observed conditions at a) station 2 and b) station 5 during the Coecles Harbor eelgrass monitoring visit in 2019.

The Coecles Harbor eelgrass meadow includes two mooring fields within its borders, on public and one private. It would be useful in managing this eelgrass meadow to evaluate the impacts the mooring fields have on overall health of this eelgrass population. Ideally, the use of conservation moorings would be

promoted in both fields, but there has been resistance from the private marina as the liability for unproven moorings is too high if they should fail.

Coecles Harbor may also be a candidate for a submarine groundwater discharge survey (SGD). Multiple local sources have suggested that there is SGD in the near shore areas of Coecles Harbor and in some locations, it may coincide with eelgrass. Locating and measuring the SGD in this meadow may not be feasible, given its large area, but information may exist that could assist in targeting locations in the Coecles Harbor meadow.

Fort Pond Bay 2019

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 FPB-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-

Fort Pond Bay 2019

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 2019.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	ND	ND	ND	ND	ND
August	13.6	+1.3	10.9	+2.9	ND
September	12.8	+0.5	8.6	+0.6	20.4

ly 4 feet of water at mean low tide. Light data was collected monthly from July-September 2019. Table FP-1 includes the average daily Hcomp and Hsat record for the site, by month. The light logger was lost (possibly taken) during the July deployment, so there is no light data for that month. The data for August and September 2019 found that the site received a surplus of light over these months for both Hcomp and Hsat.

The water temperature data presented in FP-1 provides the average monthly water temperature calculated for only the month of September for 2019 in Fort Pond Bay. The temperature logger, and the screw anchor it was attached to, were removed from the site sometime in mid-August. A replacement was deployed on August 30, 2019 to record the rest of the season's temperatures. Given the loss of the temperature logger with the data for the hottest period of the summer, July-August, there is no certainty that the site never experienced water temperatures exceeding 25°C. However, given the site's location in the Estuary, and data from the previous seasons, it is unlikely that water temperatures exceeded the optimal range for eelgrass during the 2019 season.

Eelgrass Shoot Density

Monitoring in the Fort Pond Bay eelgrass meadow was conducted on 10 September, 2019. The average eelgrass shoot density for the Fort Pond Bay meadow was 348 shoots·m^2 (Table FP-2). This was a signficant decline from the 2018 shoot density of 483 shoots·m^2. The lower average shoot density was, in part, due to the increased patchiness at monitoring stations 1-3.

Table FP-2. The average annual eelgrass shoot density for Fort Pond Bay from 2017-2019, including standard error.

Year	Mean Density	S.E.
2017	584	±58
2018	483	±49
2019	348	±43

Macroalgae Cover

Macroalgae cover within the Fort Pond Bay eelgrass meadow averaged 32% for 2019. As mention previously, the macroalgae community at the site primarily consists of specimens attached to the abundant hard substrate (i.e. rock)found throughout the meadow. There was minimal drift macroalgae observed in the meadow, likely due to the exposure to waves that most of the site experiences. Macroalgae diversity at the site was lower that past seasons's with only 10 species identified during monitoring. The macroalgae community continues to be composed primarily of the brown rockweed *Sargassum filipendula*, with common subordinate species expected of a cool, rocky shore, including the red alga *Chondrus crispus,* the brown alga *Halosiphon tomentosus*, and the rockweed *Ascophyllum nodosum*.

Bed Delineation and Areal Extent

Meadow extent for Fort Pond Bay was delineated

Table FP-3. The estimated area of eelgrass at the Fort Pond for all years surveyed.

Year	Estimated Area
2017	35.8 acres (14.49 hect.)
2018	14.8 acres (5.99 hect.)*
2019	21.2 acres (8.58 hect.)*

*Aerial imagery quality prevented complete delineation of meadow.

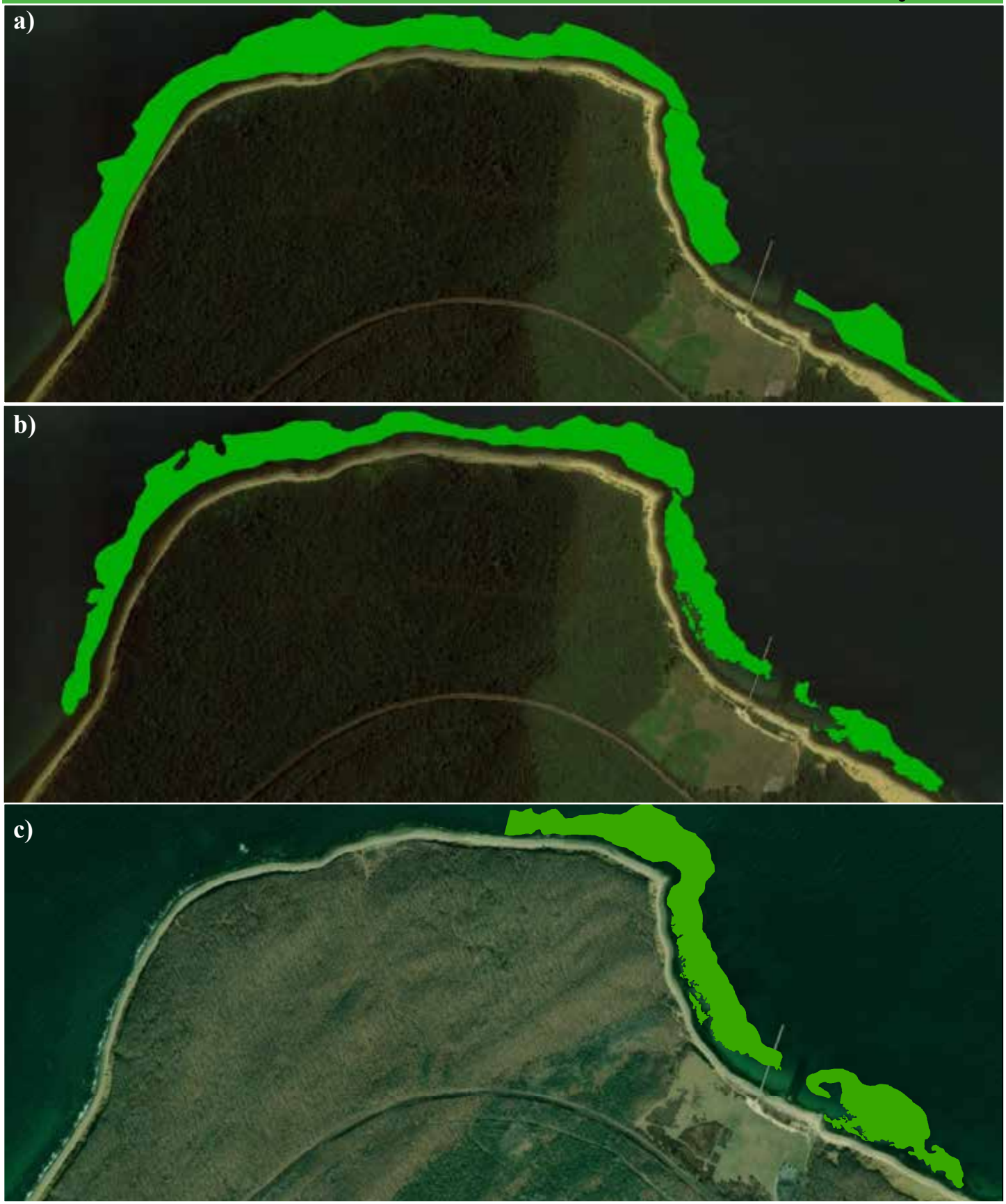


Figure FP-2. A comparison of Fort Pond Bay eelgrass meadow delineations completed in a) 2014, b) 2017 and c) 2019.

using Google Earth™ imagery from 19 September, 2019. Unfortunately, the image quality for the western half of the site was not conducive to delineating eelgrass due to waves and sun glint. Only 21.2 acres

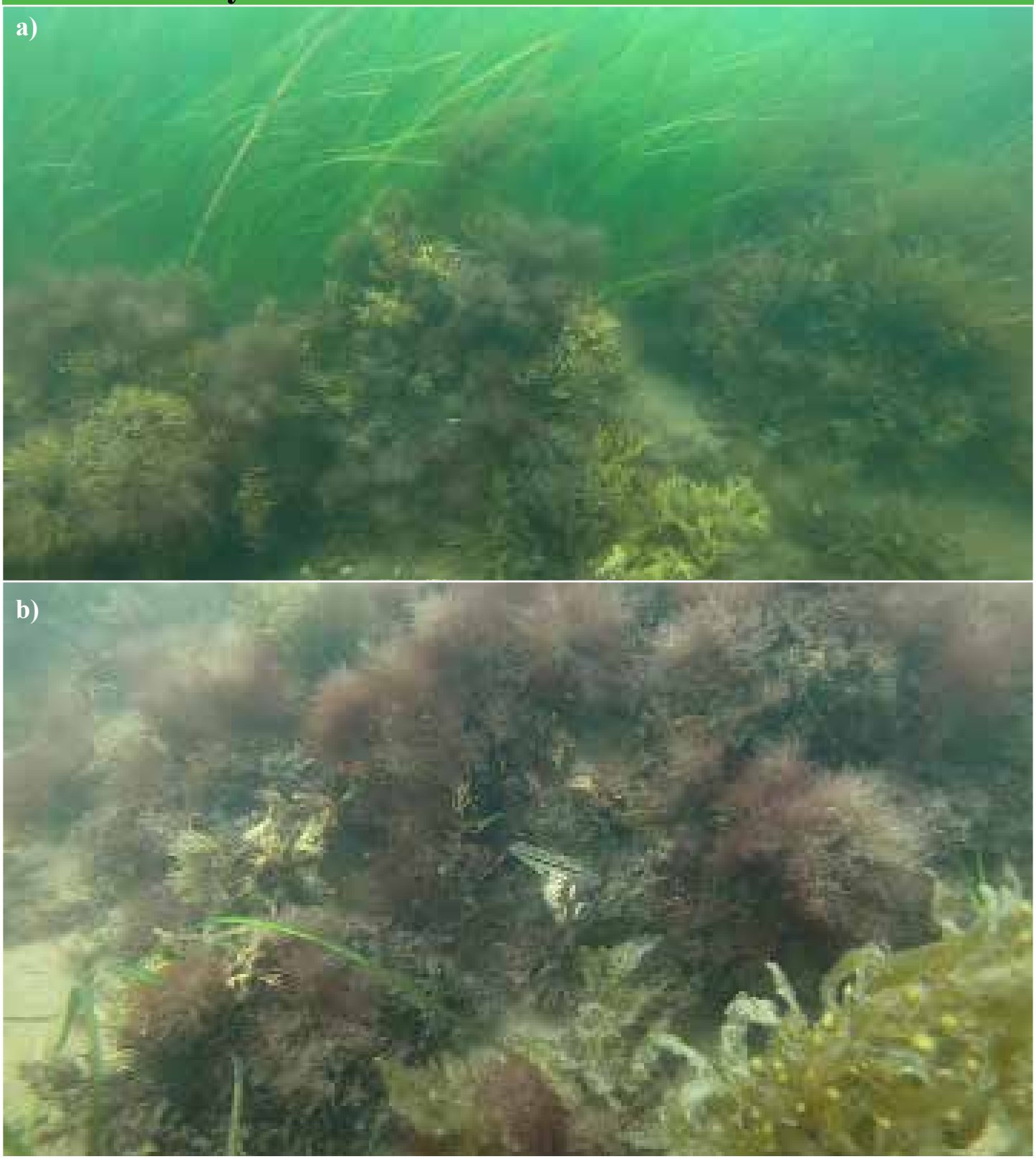


Figure FP-3. Underwater photographs taken during the course of completing the 2019 monitoring at the Fort Pond Bay eelgrass meadow. a) Dense patches of eelgrass growing in the shallower inshore area at Station 2. b) A black seabass juvenile takes advantage of the mixed eelgrass-seaweed covered boulder habitat at Station 4.

of eelgrass were delineated for the site for 2019 (Table FP-3). The delineated map of the meadow is presented in Figure FP-2c, and the sharp edge of the delineation on the western end indicates the change of the image quality for the site. Due to the incomplete delineation for 2019, it is not possible to estimate the overall change in areal extent in meadow from previous years.

Conclusions

The 2019 monitoring season found that the Fort Pond Bay eelgrass meadow continues to be healthy. The light and temperature data for the site were incomplete due to tampering/theft of light logger in July and the temperature logger in August, but based on past data, and the location of the meadow in the Estuary, it is unlikely that either of these parameters exceeded their optimal range during 2019. Wave exposure is more of an impact on this meadow than light or water temperature. The observed increased patchiness and eroded edges in the meadow on its western end (stations 1-3) and the eastern end (station 6) is a testament to the wave forces the meadow experiences.

Napeague Harbor 2019

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 entire bay is sheltered with little fetch allowing 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 2019. The light data was converted to average daily Hcomp and Hsat values presented in Table NAP-1. For July and August 2019, the meadow exceeded its Hcomp requirement of 12.3 hours, providing a small surplus those months. September recorded the meadow with a 1.5 hour deficit for Hcomp. The Hsat had a 1.5 hour surplus in July, but ran deficits in August (-1.7 hours) and September (-2.0 hours).

An Onset HOBO TidBit v2 water temperature logger was deployed to the meadow in mid-June 2019 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 temperatures (Table NAP-1) remained below the 25°C temperature

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 2019.

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	13.2	+0.9	9.5	+1.5	24.2
August	12.8	+0.5	6.3	-1.7	23.8
September	10.8	-1.5	6.0	-2.0	21.1

threshold for the season, however, the meadow did experience 13 days at temperature ≥ 25°C, with a high temperature of 28.5 recorded on 21 July, 2019. The 2019 season saw fewer days above 25°C than 2018 (23 days ≥ 25°C).

Eelgrass Shoot Density

The Napeague Harbor eelgrass meadow was initiated on 11 September, 2019, but due to high westerly winds, waves had reduced visibility to zero at monitoring stations 1 and 2, so they were revisited on 17 September to complete the sampling. The average eelgrass shoot density for 2019 was 560 shoots·m^2, a significant increase from 2018 (Table NAP-2). The Napeague Harbor meadow continues to support the highest density eelgrass in the monitoring program with the highest quadrat count for 2019 recorded at 1,240 shoots·m^2.

Macroalgae Cover

The macroalgae community in Napeague Harbor recorded a slight increase in percent cover in 2019. The average percent cover across the meadow was 31%, with only five species were reported. The red, filamentous seaweed, *Spyridia filamentosa*, continues to be the most common species in the meadow. Other species identified in the meadow included *Gracilaria* species, *Spermothamnion repens*, *Codium fragile* and *Sargassum filipendula*.

Bed Delineation and Areal Extent

The 2019 areal extent of the Napeague Harbor eelgrass meadow was completed using aerial imagery from Google Earth™ taken on 19 September, 2019. 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-2c). The 2019 delineation identified 15.5 acres of eelgrass along the eastern shore of Napeague Harbor. This represents a slight increase in area from 2018.

Conclusions

The Napeague Harbor eelgrass meadow countines to be a healthy eelgrass meadow. As stated in previous reports, it is believed that groundwater discharge withing the meadow help to mitigate higher water temperatures that could otherwise become problematic for eelgrass in this system. Besides the potential threat that high summer water temperatures present to the Napeague Harbor eelgrass meadow, anthropogenic activities are an ongoing threat to to sections of the meadow. The most obvious activity impacting the southern end of the meadow is the placement of moorings within the meadow in shallow water. Scouring from mooring chains is readily observable, as is prop scars from boats transitting to their moorings. The

Table NAP-2. The average annual eelgrass shoot density for Napeague Harbor from 2017 to 2019, including standard error.

Year	Mean Density	S.E.
2017	806	±63
2018	479	±44
2019	560	±44

Table NAP-3. The estimated cover of eelgrass in Napeague Harbor for all years surveyed.

Year	Estimated Area
2017	17.6 acres (7.12 hect.)
2018	13.4 acres (5.42 hect.)
2019	15.5 acres (6.27 hect.)

Napeague Harbor 2019

Figure NAP-2. A comparison of Napeague Harbor eelgrass meadow delineations completed in a) 2014, b) 2017 and c) 2019.

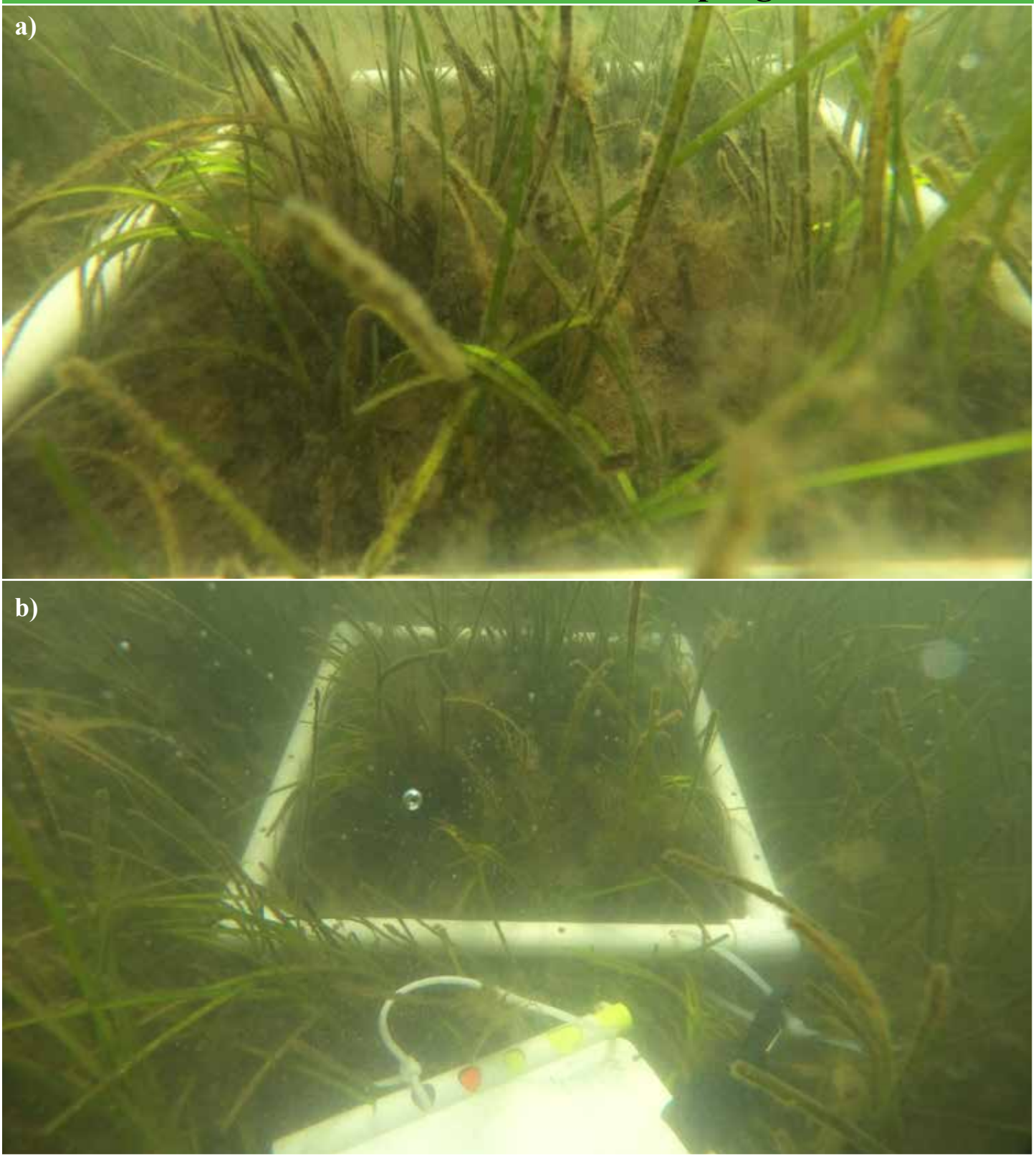


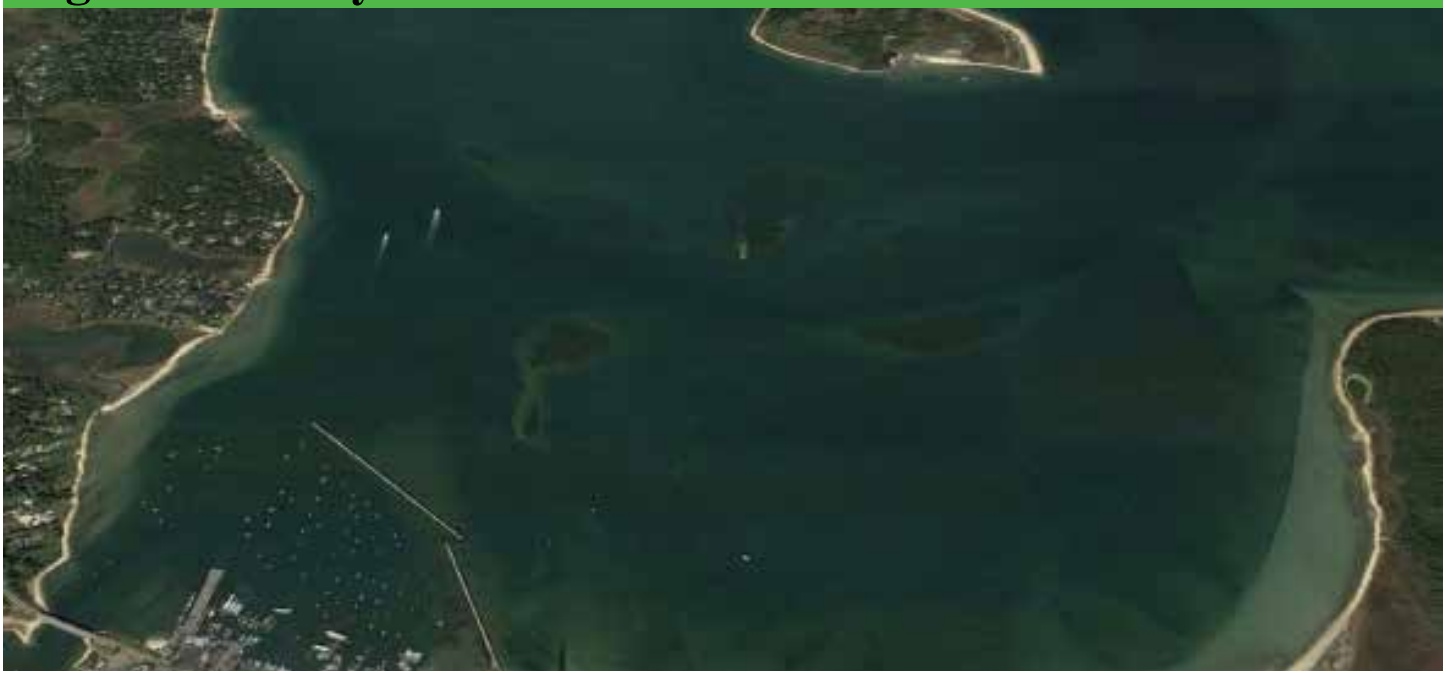
Figure NAP-3. Photographs taken by CCE divers during the 2019 eelgrass monitoring visit to Napeague Harbor. a) A quadrat dropped in the eelgrass meadow at Station 3 and b) a quadrat ready to have eelgrass shoot density counted at Station 5.

second impact on the meadow are continued instances of recreational clamming observed in the meadow. On two occassions, individuals clamming in areas with eelgrass were documented by CCE staff in 2019. Given that CCE staff visit the site a limited number of times each season, recreational clamming could be oc-

curing more frequently and causing measurable damage to the meadow. In both the case of moorings and recreational clamming, actions to mitigate/regulate these activities in the eelgrass meadow would need to be taken by the Town of East Hampton. If moorings were required to be placed outside of eelgrass meadows, this would alleviate the scouring by mooring chains and the prop scars by boats transiting shallow meadows to their anchorage. Recreational clamming is discouraged in the eelgrass meadows in Napeague Harbor, and the meadows were declared a sanctuary in the early 2000s, although it is not clear if clamming activities in the eelgrass meadows are prohibitted or how they are enforced. Signage along the eastern shore could help to reduce instances of clamming in the meadow. In most cases, it is likely ignorance that leads people to clam in the eeelgrass meadow.

Future study that should be undertaken in Napeague Harbor concerns the influence of submarine groundwater discharge's (SGD) role in mitigating high water temperatures in eelgrass meadows. Expanding upon the preliminary work conducted by Ron Paulsen in 2017 would provide more information on the influence of SGD on the successful growth of eelgrass. Work on SGD in Napeague Harbor and Bullhead Bay could provide data that would allow for a model to be developed that may be able to identify areas within the Peconic Estuary that could be suitable for restoration attempts due to the presence of SGD.

Sag Harbor Bay 2019



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 disctinct 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.

Light Availability and Temperature

An Odyssey PAR light logger was deployed adjacent to the SH2 monitoring station monthly, from July-September 2019. The loggers collected 10 days of light data per deployment and the results are summarized in Table SH-1 in terms of Hcomp and Hsat. Light conditions at Sag Harbor during the 2019 season were mixed, in terms of providing optimal conditons for eelgrass growth. July 2019 found the meadow receiving surplus for both Hcomp and Hsat, while it ran a deficit for August and September. While the deficits were not large, compared to previous years, they still have the potential to impact the overall productivity and health of the meadow.

Water temperatures for 2019 in Sag Harbor Bay were found to be moderate, with average monthly temperatures reported below 25°C for all three months (Table

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 2019.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.1	+1.8	9.9	+1.9	24.4
August	11.3	-1.0	6.1	-1.9	24.4
September	10.2	-2.1	7.8	-0.2	21.6

SH-1). While the monthly average temperatures did not exceed 25°C, the site did record 16 days on which the daily average water temperature was above this threshold. The highest water temperature recorded for the site was 26.7°C on 31 July, 2019.

Eelgrass Shoot Density

The Sag Harbor Bay eelgrass meadow was monitored on 5 September, 2019. The meadow averaged 223 shoot·m² for the season, which is a significant dcline from the 331 shoot·m² recorded in 2018 (Table SH-2). Analysis of the quadrat counts for each of the three individual beds that make up the site found that the decline in shoot density was focused in Bed1 and Bed3, while Bed2 showed no significant change from 2018. Shoot density in Bed1 declined from 396 shoot·m² (2018) to 196 shoot·m² (2019). Bed3 experienced a change from 346 shoot·m² in 2018 to 240 shoot·m² for 2019.

Macroalgae Cover

Macroalgae cover within the Sag Harbor eelgrass meadow was low in 2019, with only a 5% cover reported for the meadow. This percent cover does not include the epiphytic algae that grow heavily on the older eelgrass blades in all of the beds at this site. Analysis of the individual beds within the site found that Bed1 had significantly higher macroalgae cover than the other two beds. Overall, the site had significantly lower cover compared to 2018 with a decrease in percent cover of 15%.The 2019 percent macroalgae cover was reported as 10%, 3%, and 3% for Beds 1-3, respectively. Species composition between the three beds remains distinct, primarily due to the substrate present in each bed. Bed1, characterized by abundant gravel and rock was dominated by *Sargassum filipendula* and *Codium fragile*. Bed2 has a sandy sediment which supported the filamentous red algae, including *Spyridia filamentosa* and *Neosiphonia harveyi*, as drift and epiphytes on the eelgrass blades. Bed3 was predominantly colonized by *Codium fragile* attached shells covering the bottom.

Bed Delineation and Areal Extent

The aerial delineations of the meadow's extent was completed using Google Earth™ imagery flown on 19 September, 2019. The meadow covered 37.6 acres in 2019, representing a loss of almost 12.5 acres from the 2017 acreage (Table SH-3). The loss in acreage was confined to Bed1 and Bed3, while Bed2 remained relatively unchanged (Figure SH-2). It should be noted that at least a portion of the change in areal extent between 2017 and 2019 could be due to the quality of the aerial imagery and the subjective judgement of the

Table SH-2. The average annual eelgrass shoot density for Sag Harbor from 2017 to 2019, including standard error.

Year	Mean Density	S.E.
2017	249	±16
2018	331	±25
2019	223	±15

Table SH-3. The estimated cover of eelgrass in Sag Harbor for all years surveyed.

Year	Estimated Area
2017	50.3 acres (20.36 hect.)
2018	12.7 acres (5.14 hect.)*
2019	37.6 acres (15.22 hect.)

*Aerial image quality for this meadow was poor, resulting in anincomplete delineation of the meadow

Sag Harbor Bay 2019

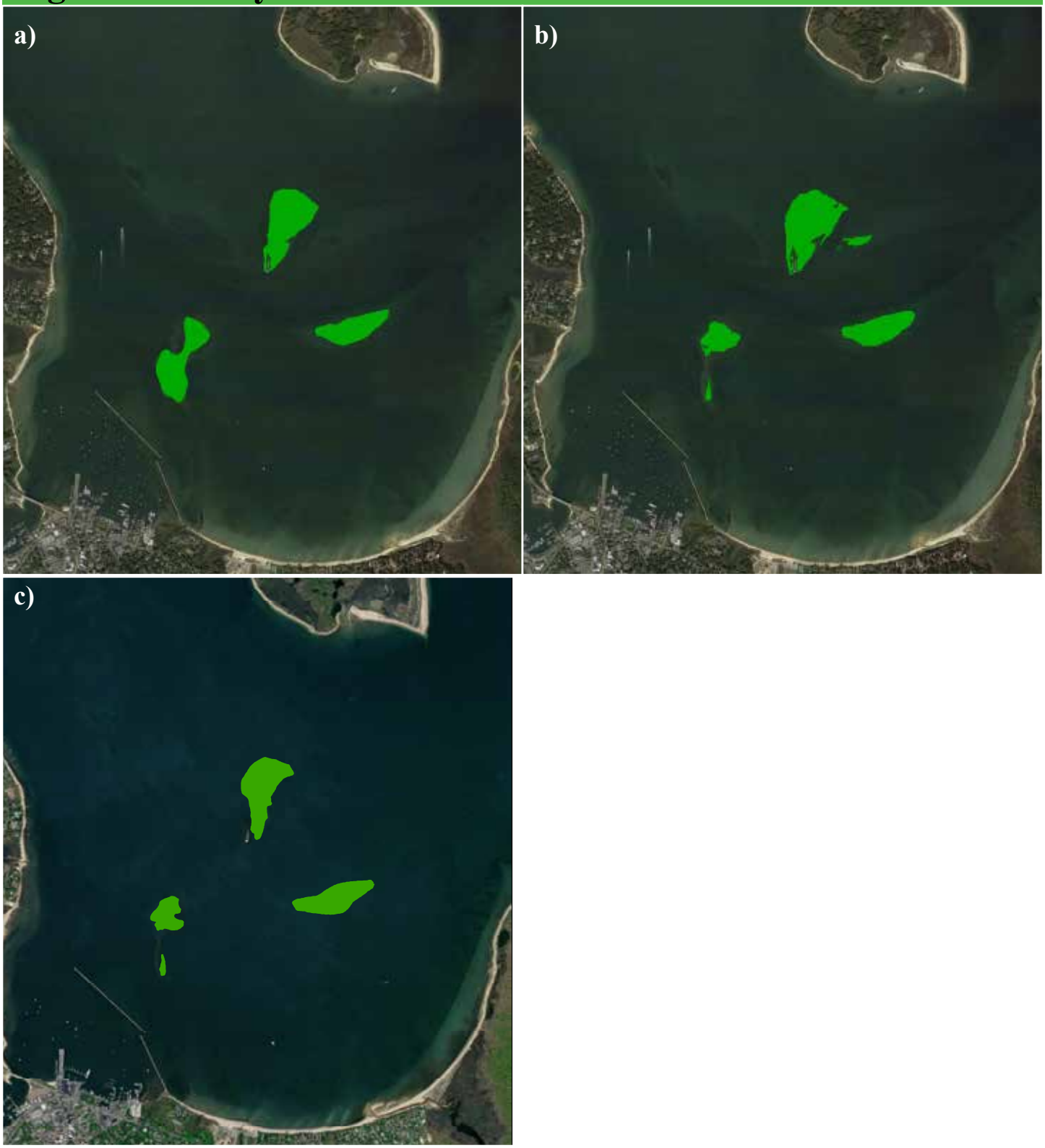


Figure SH-2. Comparison of delineations between a) 2014, b) 2017 and c) 2019 for the Sag Harbor Bay eelgrass meadow complex.

delineator.

Conclusions

The 2019 monitoring results found that the meadow has experienced a signficant decline in shoot density, macroalgae cover and acreage from 2018 (2017 for acreage) levels. Light availability declined over the season, with July recording surplus for both Hcomp and Hsat, but running deficits for August and Septem-

Figure SH-3. a). Heavily epiphytized eelgrass blades growing at Station 2. The epiphyte load is high on the older blades, with the younger blades remaining relatively clean. b) Two chowder clams that were washed out of the sediment at Station 5, presumably by wave action as the bottom at the sstation showed relatively deep sand waves.

ber. Water temperature averaged below 25°C for the season and only recorded 16 days with average temperatures exceeding this threshold. In all, conditions recorded at the site were not optimal throughout the

season, but could not account entirely for the decline reported. Delineating the areal extent of eelgrass meadows is a subjective process, and as such has an inherent error atributed to it. Given good quality aerial imagery, one could expect as much as 10% of the change in areal extent between years to be due to subjectivity, but the changes between 2017 and 2019 exceed that level, indicating a real loss of area in Beds 1 and 3, which is evident in Figure SH-2.

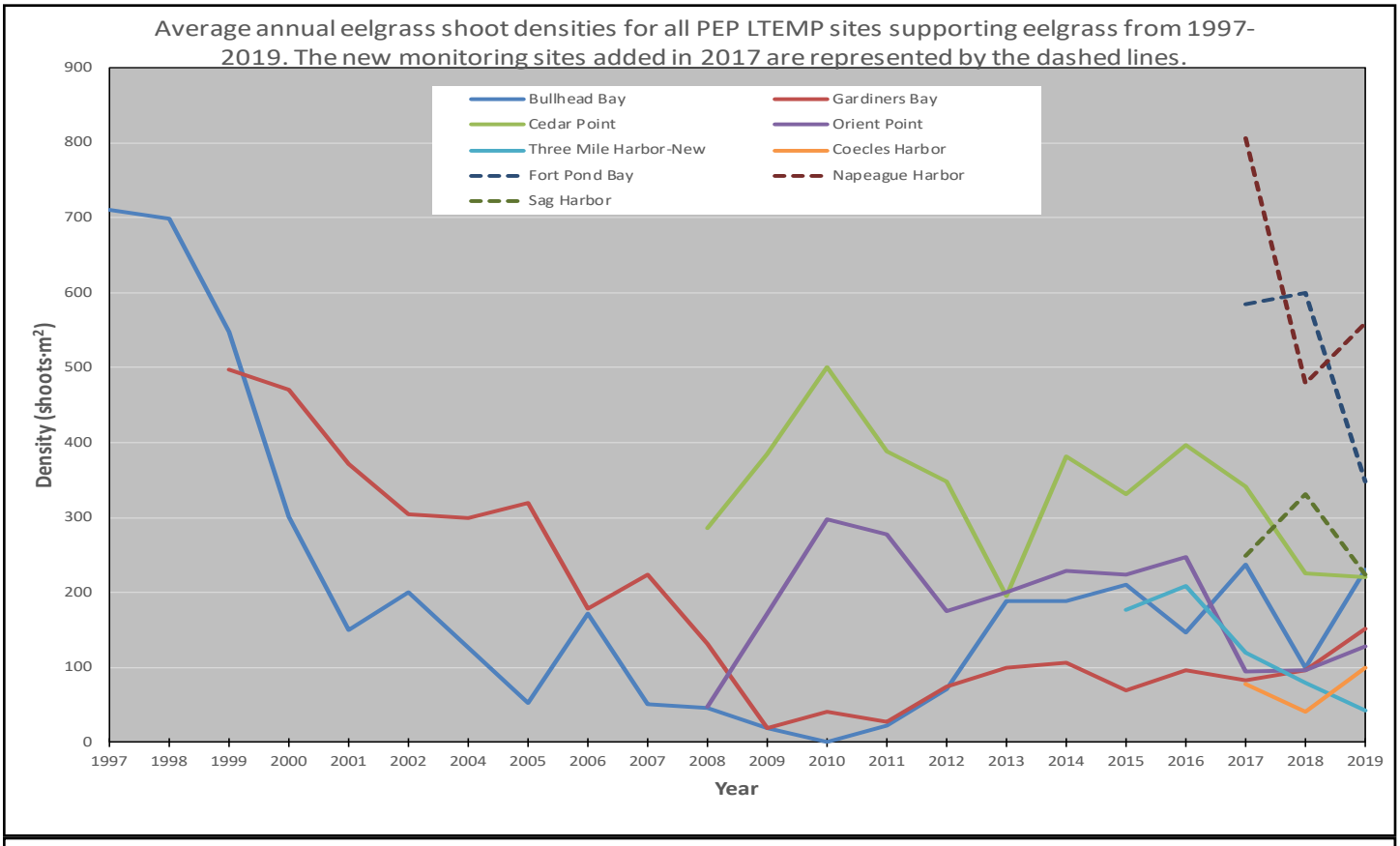
The Sag Harbor Bay eelgrass monitoring site consists of three distinct eelgrass bed (Beds 1-3). Two of these beds have accounted for all of the change in 2019. Beds 1 and 3 both experienced significant declines in eelgrass shoot density and areal cover, while Bed2 has remained consistent. The changes in Beds 1 and 3 may be due to the relatively shallow depth making these beds more susceptible to storm, and boat, generated waves. Both of these meadows average only 3-4 feet below mean low water and, with the bay being relatively open, are impacted by waves more than the deeper (6-7 feet below MLW) Bed2. Boat traffic, especially larger vessels, has increased in the area and these boat-generated waves can be very large when they break over the shallow eelgrass meadows. Large, boat-generated waves have been observed, and experienced in-water, by CCE staff at the site. Wave-eroded edges have become more common in Bed1 and sand waves at Bed3 have been observed. Wave-generated erosion, coupled with less than optimal light conditions could be responsible for a large part of the eelgrass loss reported in these beds.

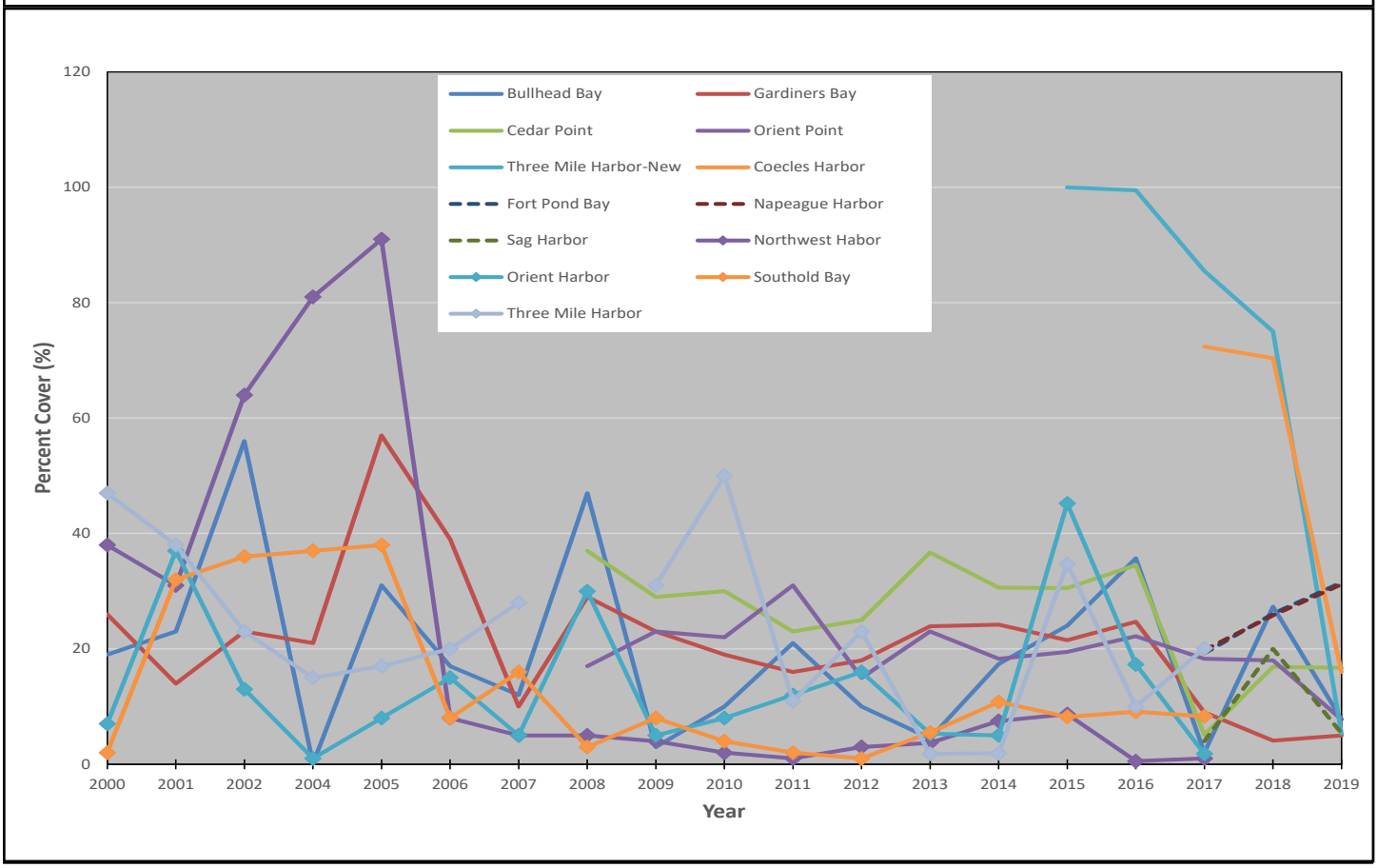
It should also be noted that Bed2 is an active CCE restoration site. For the past 5 years, CCE has been actively planting eelgrass adjacent to the southern edge of the bed in an effort to enhance the existing meadow. During this period, CCE has planted an average of 5,000 eelgrass shoots per year using the burlap disk method. The plantings have proved to be successful, with high survival rates in transplants and measured spread outside of their original transplant areas. The active restoration in this bed could be helping to mitigate any shrinkage in areal extent the bed may be experiencing, allowing it to maintain area between years while the other two beds have shown decline. Eelgrass plantings will continue at the site into 2020 and likely beyond as funding has been secured to continue work at the site.

The Sag Harbor Bay eelgrass monitoring site has only been in the program for three seasons. Although there was a significant decline reported for several measured parameters between 2018 and 2019, the 2019 season only differed from the 2017 season in areal extent. The dataset is too small to make any long-term predictions on how this meadow will trend in the future, as the changes reported by the program over the last three seasons may reflect the normal dynamic nature of the site, however, the success, to date, of the eelgrass plantings at Bed2 suggest that the overall conditions in Sag Harbor Bay support the health and growth of eelgrass at the site.

Appendix

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





References

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

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

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

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

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