Peconic Estuary Partnership 2020 Long-Term Eelgrass (*Zostera marina*) Monitoring Program

Progress Report 21

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

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Executive Summary

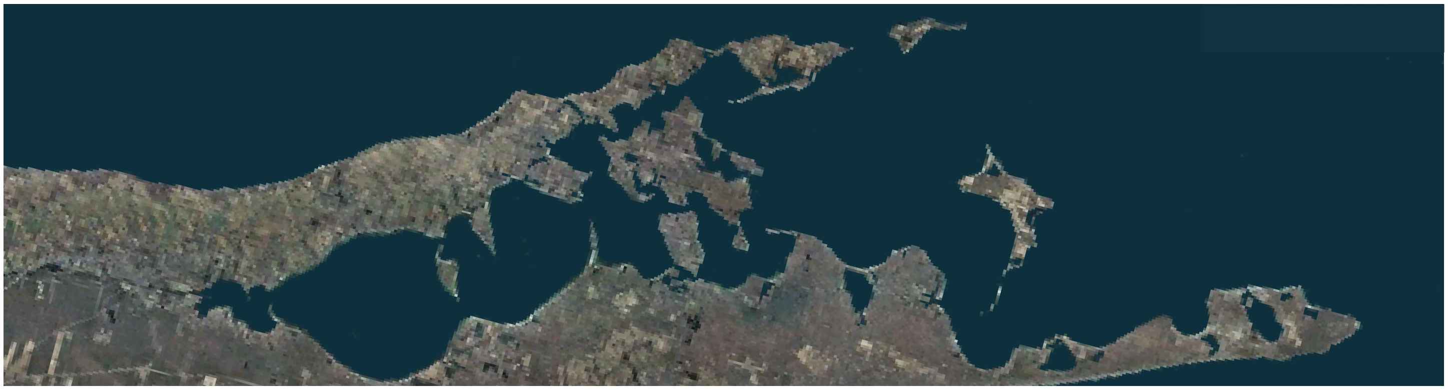
The nine PEP LTEMP sites were surveyed by CCE divers during the summer of 2020. The season started with the installation of light and temperature monitoring stations and deployment of water temperature loggers at all sites in mid-June 2020. Monthly light logger deployments to the stations began in mid-July and finished in late-September 2020. Eelgrass monitoring surveys began in late August and were completed for all sites on 1 September, 2020. In early October all temperature loggers were retrieved for the season. A summary of all of the data collected for the 2020 PEP LTEMP season follows below.

Light availability and water temperature data was collected from all nine LTEMP sites in 2020. Overall, light availability was high throughout the 2020 season for all sites. All sites met or exceeded their minimal Hcomp and Hsat requirements for July and August 2020. For September, five sites (Cedar Point, Orient Point, Coecles Harbor, Fort Pond Bay, and Napeague Bay) did not meet their minimal Hcomp requirements, but all sites satisfied their Hsat goals for the month. The 2020 season was hot and the region was in a drought starting in June and continuing through year's end. Seven sites recorded daily average water temperatures greater than 25°C, with only Orient Point and Fort Pond Bay remaining below this threshold for the season. Three sites experienced at least 30 days with average daily water temperatures above 25°C: Bullhead Bay (73 days), Coecles Harbor (38 days), and Three Mile Harbor (30 days). Bullhead Bay and Three Mile Harbor were the only LTEMP sites recorded daily average temperatures above 27°C, with 35 and 5 days, respectively.

The 2020 monitoring survey was initiated on August 25, 2020 and completed on September 1, 2020. For the 2020 season, only one monitoring site recorded an increase in eelgrass shoot density (Three Mile Harbor) from its 2019 density. Two meadows, Bullhead Bay and Coecles Harbor, recorded a significant decline in shoot density from the previous year. The remaining eelgrass meadows showed no significant changes in eelgrass density from the 2019 season. Macroalgae percent cover was highly variable in 2020 over the nine sites, with five of the nine LTEMP sites recording no significant change in cover from 2019 to 2020, three sites having a significant increase from the 2019 percent covers, and one site experiencing a significant decrease in macroalgae cover from 2019.

LTEMP eelgrass meadow delineations were conducted using aerial imagery flown by New York State in March 2020. The overall quality of the imagery was good and produced accurate maps of the extent of the nine meadows. For 2020, only one meadow, Napeague Harbor, showed a decrease in the extent of the meadow. Coecles Harbor and Three Mile Harbor meadows saw significant increases in acreage, while the remaining LTEMP sites reported slight increases or no significant change from their previous extents.

The 2020 eelgrass monitoring season found that the general health of the meadows in the program was good. While two of the LTEMP meadows, Bullhead Bay and Coecles Harbor, experienced significant reductions in shoot density from their 2019 numbers, these two meadows did record continued expansion of the extent of the meadows from the previous season. The other LTEMP meadows reported no significant changes in shoot densities and only slight increases or no change in areal extent of most of the meadows from 2019 to 2020. Macroalgae cover is down across most of the meadows and divers have reported unusual high water clarity during the 2020 summer, which may be a result of the low rainfall during the ongoing drought. Based on observation made during the 2020 monitoring season, human impacts from boating activities, appear hold the greatest threat to the health and extent of eelgrass meadows, followed by climate change, both higher temperatures and increased storm frequency/intensity. Human impacts to eelgrass meadows in the Peconic Estuary could be addressed with educational outreach and on-the-water signage, similar to programs run in Florida and Gulf states.



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

In 2000, the methodology for the monitoring program was amended to increase the statistical significance

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

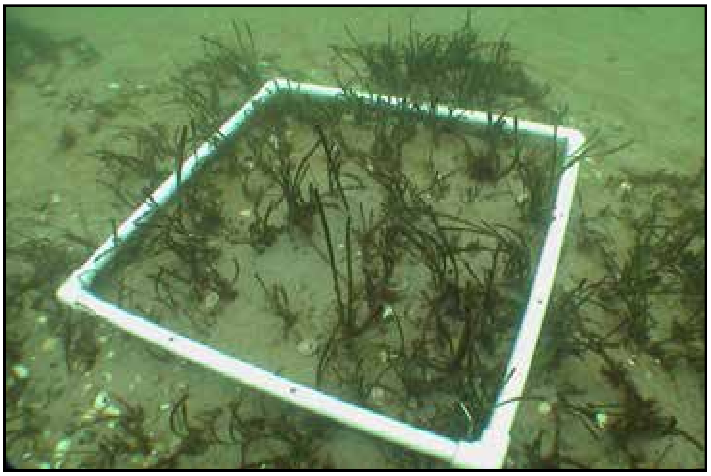


Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

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

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

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

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

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

Water Temperature Monitoring

Water temperature has been increasingly identified as an important environmental parameter to monitor in regard to eelgrass health. High water temperatures (above 25°C/77°F) have been found to reduce the ability of eelgrass to efficiently produce energy that can be used for growth or stored in its rhizomes. Very high water temperatures, greater than 30°C (86°F), may cause the plants to slough above-ground biomass (i.e., blades) and possibly result in mortality of the entire plant. Temperature affects eelgrass by influencing the plants primary production efficiency. This efficiency is typically represented as the ratio of photosynthesis to respiration (P:R) in a plant. Eelgrass, being a temperate water species, has recorded optimal P:R for temperatures ranging from 10-25°C (50-77°F). When temperatures increase above 25°C, the rate of respi-

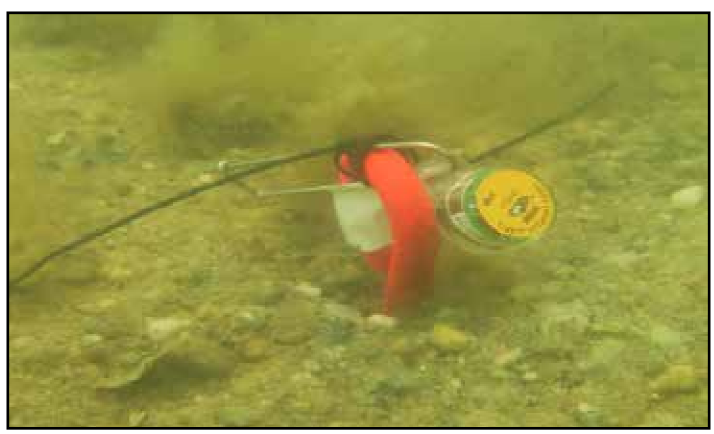


Figure Intro-2. A TidBit v2™ temperature logger attached to a screw anchor, deployed on-site.

ration 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 2020 season, Odyssey PAR loggers were deployed at all active monitoring sites.

Eelgrass Monitoring

The 2020 monitoring began on 25 August and completed on 1 September, 2020. Sampling at each site was distributed among six stations that have been referenced using GPS, with the exception of the Gardiners Bay site, which now supports eight stations. At each of the stations, divers conducted a total of 10 random, replicate counts of eelgrass stem density and macroalgae percent cover in 0.10 m^2 quadrats. Divers also made observations on blade lengths and overall health of plants that they observed. The divers stayed within a 10 meter radius of the GPS station point while conducting the survey. Algae within the quadrats were identified minimally to genus level and if it was epiphytic or non-epiphytic on the eelgrass. Divers were careful not to disturb the eelgrass, so as not to cause plants to be uprooted or otherwise damaged.

Data was statistically analyzed using 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

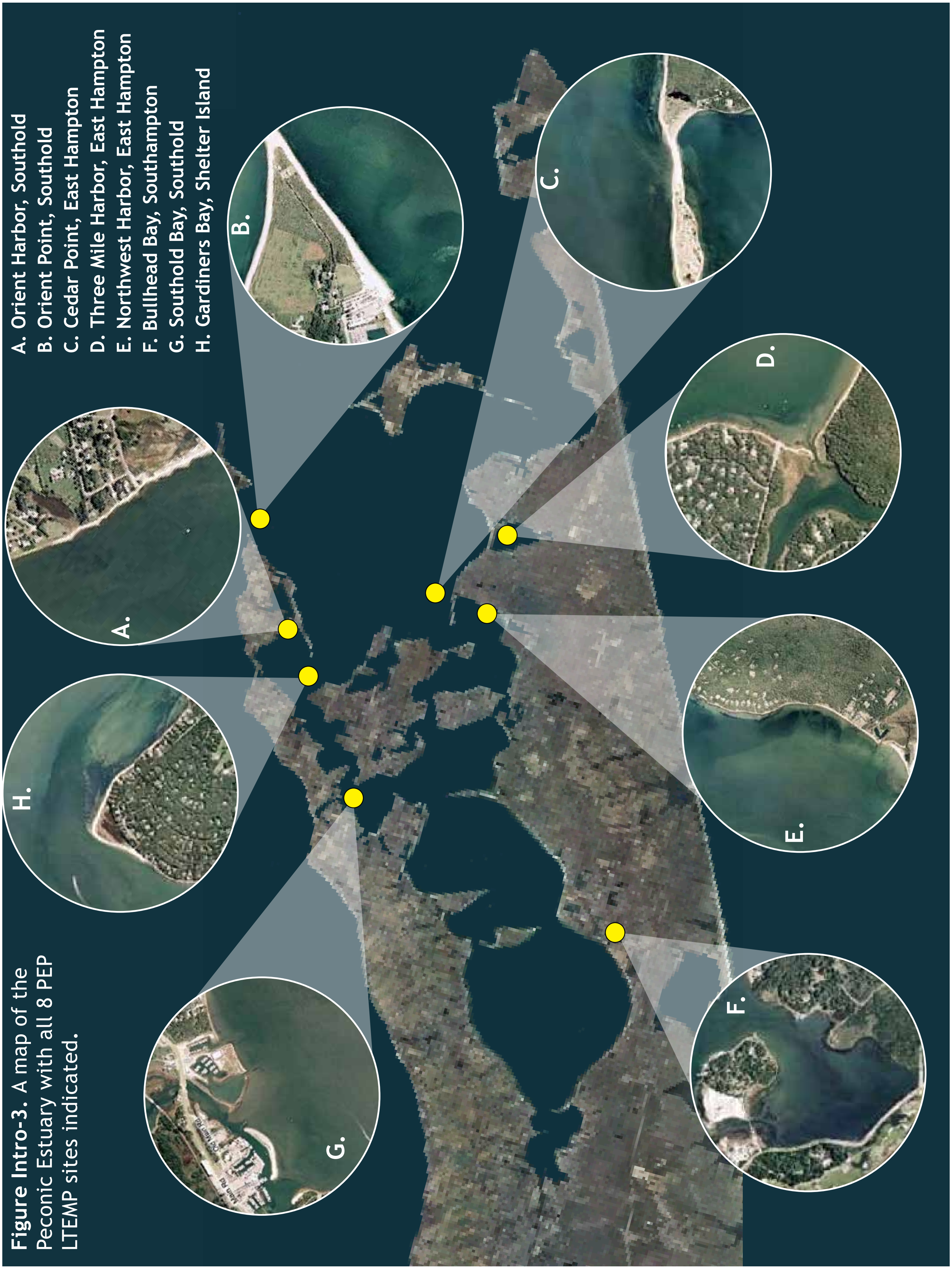


Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

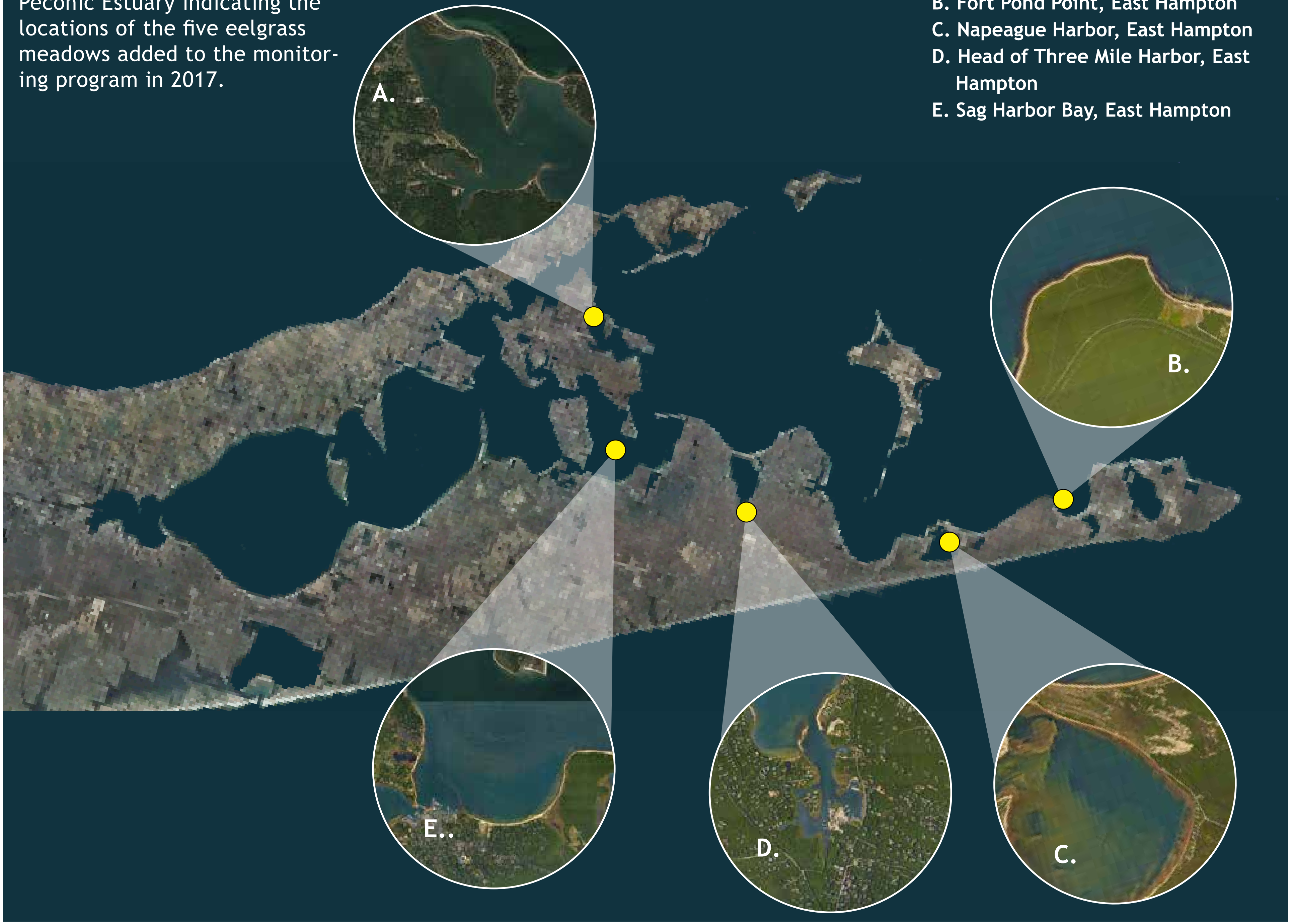


Figure Intro-4. A map of the Peconic Estuary indicating the locations of the five eelgrass meadows added to the monitoring program in 2017.

Introduction and Methods

The 2020 meadow delineations were completed using the New York State Department of Planning aerial photography taken in March 2020. Trend analysis is presented using the results of the eelgrass aerial imagery for when the meadow was added to the LTEMP (2000 would be the earliest), 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 are 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 2020

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 10-day intervals, monthly, for 2020.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	13.8	+1.5	12.8	+4.8	27.8
August	13.2	+0.9	11.7	+3.7	26.5
September	12.4	+0.1	11.0	+3.0	22.8

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, 20, with the average Hcomp and Hsat for each month presented in Table BB-1 above. Due to drought conditions that persisted through the growing season, light availabilty was rarely diminished by cloud cover, providing the Bullhead Bay eelgrass meadow with ample light. The eelgrass meadow experienced surplus light for both Hsat and Hcomp for all three months reported (Table BB-1).

Water temperature loggers were deployed in Bullhead Bay from early June through early October, 2020. The average monthly water temperatures recorded for Bullhead Bay for July-September 2020 are presented in Table BB-1. The Bullhead Bay meadow experienced 73 days with water temperatures exceeding 25°C, with 35 of those days averaging water temperatures above 27°C. This was a significant increase in the number of days over 25°C from 2019, but a slight decrease in the days over 27°C. The high water temperature recorded for Bullhead Bay in 2020 was 30.7°C on 5 July 2020.

Eelgrass Shoot Density

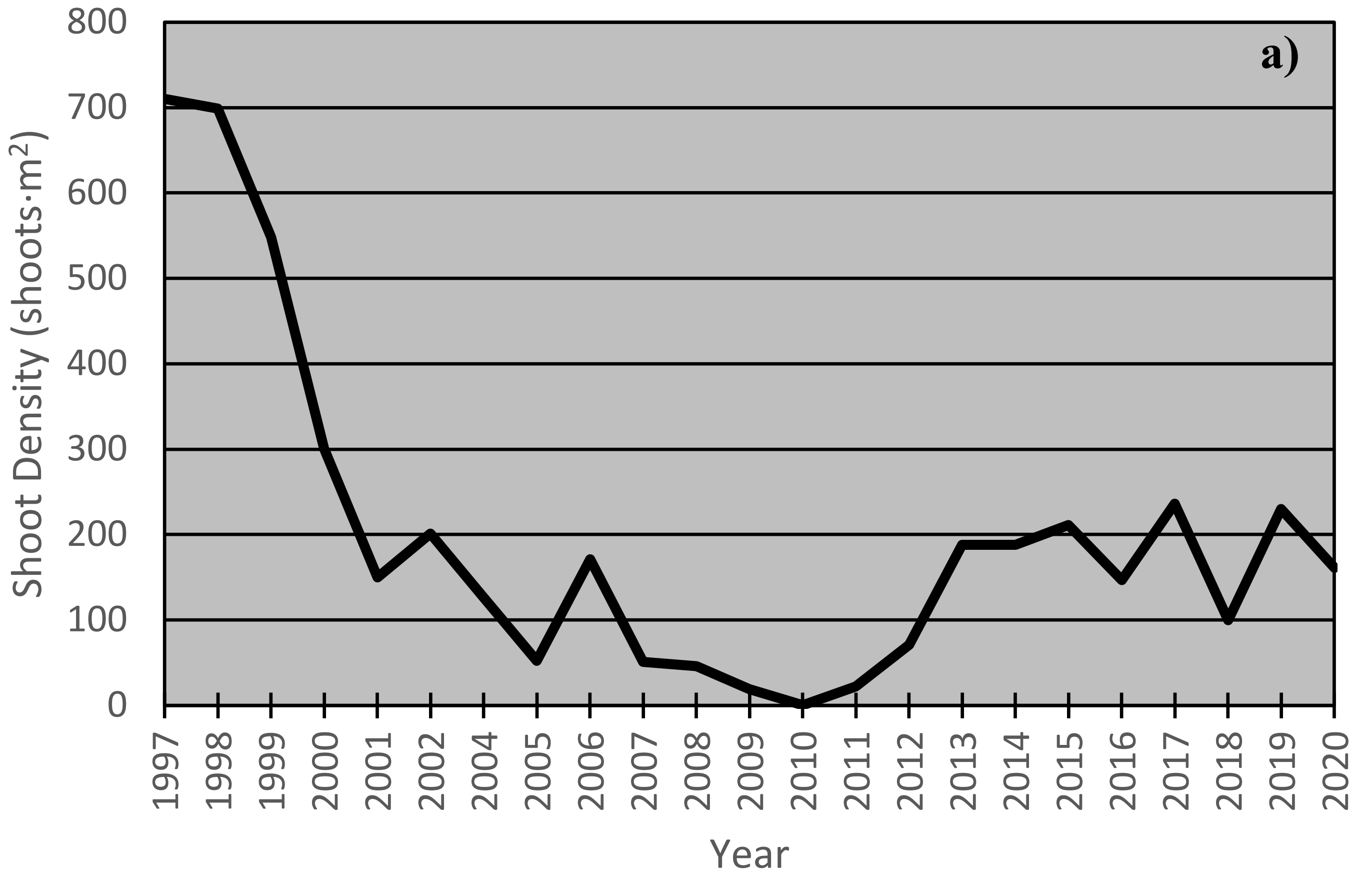
The 2020 eelgrass monitoring visit to Bullhead Bay was conducted on 28 August. Eelgrass shoot density recorded a significant decline from 2019 (Table BB-2; Figure BB-2a). The average shoot density reported for 2020 was 161 shoots·m², compared to 230 shoots·m² for the 2019 season. Even with this decline in overall shoot density, the meadow continues to look healthy and it is continuing to spread into areas in Sebonac Creek where it has been absent since the early 2000s.

Macroalgae Cover

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

Year	Mean Density	S.E.
1997	710	+/- 196
1998	620	+/- 112
1999	548	+/- 79
2000	301	+/- 26
2001	150	+/- 18
2002	201	+/- 14
2004	125	+/- 28
2005	52	+/- 11
2006	171	+/- 34
2007	51	+/- 12
2008	46	+/- 9
2009	19	+/- 8
2010	0*	+/- 0
2011	22	+/- 6
2012	71	+/-12
2013	188	+/-20
2014	188	+/-12
2015	211	+/-27
2016	147	+/-25
2017	236	+/-32
2018	100	+/-9
2019	230	+/-19
2020	161	+/-9

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



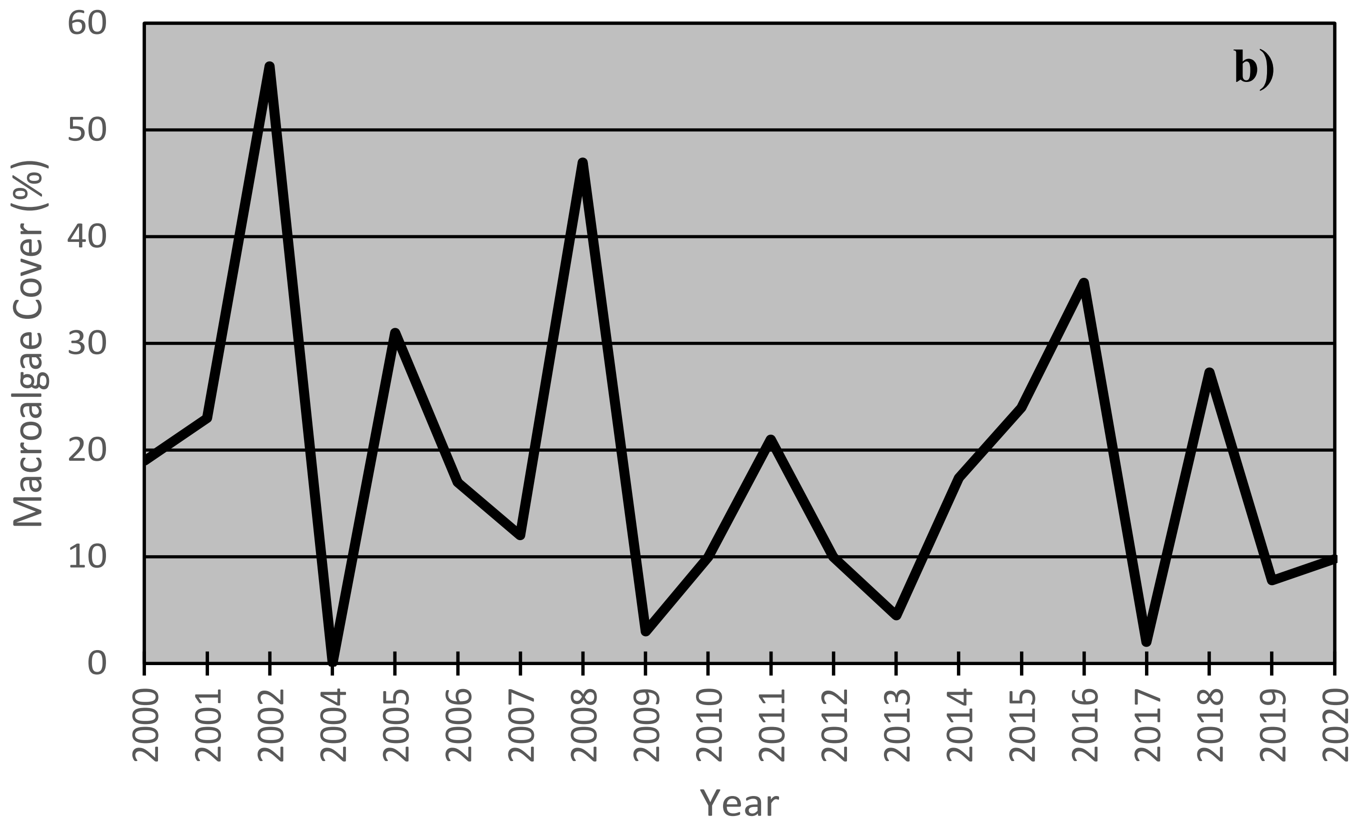


Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

Figure BB-3. The 2020 delineation of the Bullhead Bay eelgrass meadow.

Macroalgae cover in the Bullhead Bay meadow showed a minimal increase in percent cover from 2019 to 2020 (8% to 10%) , respectively (Figure BB-2b). Macroalgal diversity remained low in 2020, with divers recording only five species: *Spyridia filamentosa*, *Gracilaria* sp., *Ulva lactuca*, *Cladophora sericea*, and *Heterosiphonia harveyii*.

Bed Delineation and Areal Extent

Delineation of the Bullhead Bay eelgrass meadow was completed using aerial imagery from New York State Department of Planning aerial photography taken in March 2020. The eelgrass meadow showed only a minor increase in acreage between 2019 and 2020 (Table BB-3). There was continued, observable expansion of the meadow out of Bullhead Bay proper and into Sebonac Creek to the east, that was first noted in 2019. (Figures BB-3 and BB-4f). The eelgrass meadow within in the confines of Bullhead Bay appears to be approaching the limits of its expansion in the bay. Eelgrass has recolonized all of the bay bottom, with the exception of small bare patches, that provide appropriate depth for plants to grow.

Conclusions

Overall, the condition of the eelgrass meadow in Bullhead Bay during the 2020 monitoring was found to be very good. The meadow continues to expand to the east into Sebonac Creek and has filled in most of the habitable bottom within Bullhead Bay. While eelgrass shoot density recorded a significant decline from 2019, the meadow showed a consistent cover of eelgrass with few open patches observed. The decline in shoot density could be the attributed to reduced recruitment of seedlings into the currently stable mature meadow, which will likely rely on vegetative expansion via rhizomes to maintain the meadow unless there are distubance events which open up areas for seedlings. During the visits over the season, few waterfowl were observed at the site, but now that the meadow has expanded to its historical extent, it may attract swans and geese as it represents a significant food source, especially in early summer during seed development.

There is some concern that the drought conditions that extended throughout the summer of 2020 may have resulted in a decrease in the submarine groundwater discharge that has been hypothesized as the main factor allowing eelgrass to survive in Bullhead Bay by mitigating summer high water temperatures, but there was not obvious dieback observed over the 2020 season. Related to high water temperatures, the abundances of colonial tunicates, including Botryllus and Botrylloides, was higher than previously noted in Bullhead

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2020.

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.)
2020	60.1 acres (24.32 hect.)

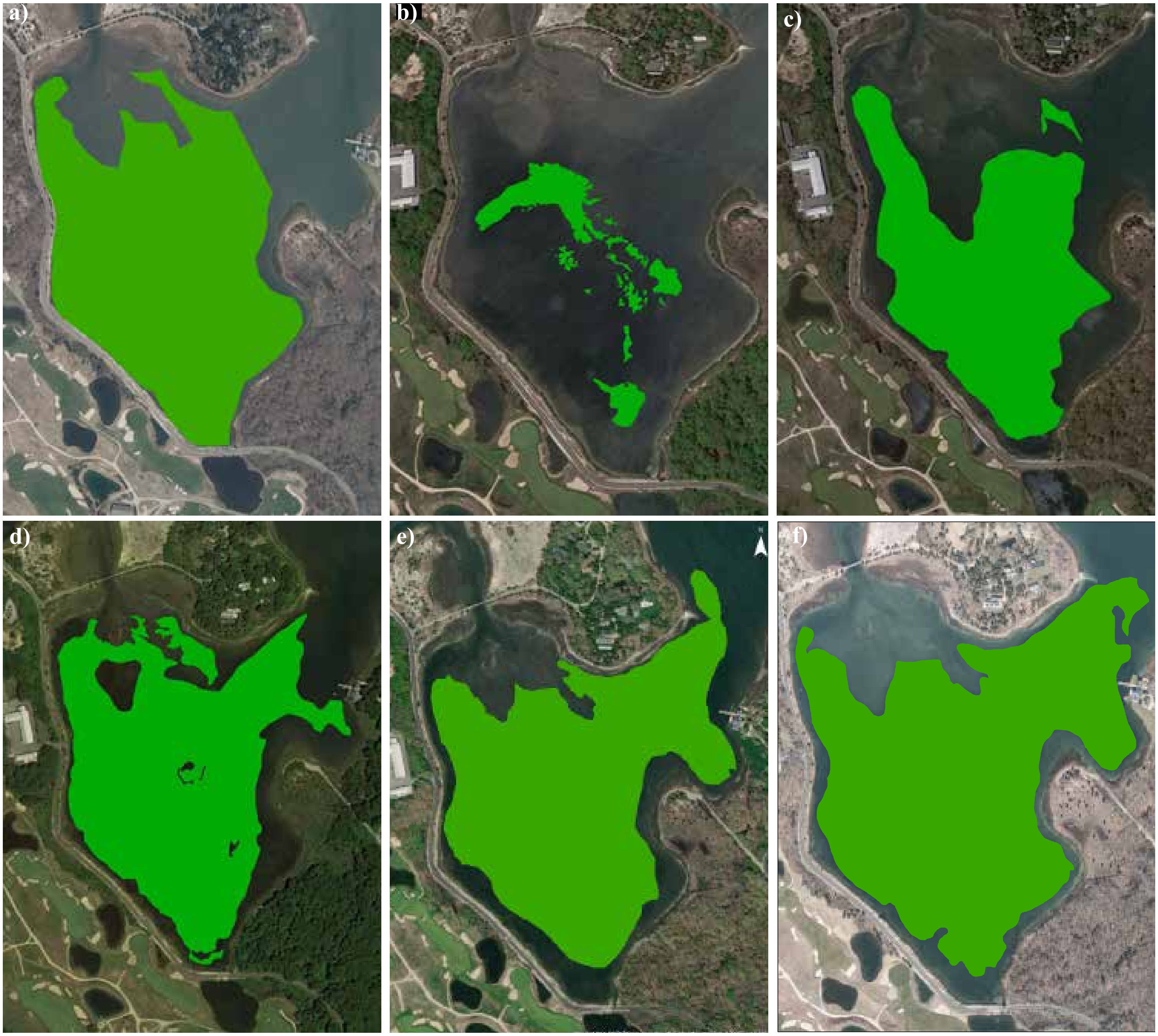


Figure BB-4. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2020. The years represented are a) 2000, b) 2010, c) 2016, d) 2018, e) 2019, and f) 2020.

Bay. Increasing coastal water temperatures favor the growth of tunicates and they may become problematic to eelgrass meadows. These tunicates significantly foul eelgrass shoots and, especially, flower shoots which could result in more frequent sloughing of vegetative blades and possibly a reduction in the production of eelgrass seeds, leading to an increase expenditure of energy by the eelgrass meadow. CCE is involved in a regional survey to assess the potential impact of tunicates on eelgrass populations, having monitored an eelgrass meadow in Moriches Bay for the past several years. CCE is going to request to include the Bullhead Bay eelgrass meadow in the next survey scheduled in 2020, to identify any potential impacts the increasing tunicate population may have on the meadow going forward.

Figure BB-5. a) Colonial tunicates have becoming an increasing fouling problem in the Bullhead Bay eelgrass meadow. The encrusting ascidians create tangles attaching adjacent shoots to one another. b) Since the meadow was declared a sanctuary by Southampton Town, sightings of small clams has increased during the survey.

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 2020

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 10-day intervals, monthly, for 2020.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.5	+2.2	13.1	+5.1	24.1
August	13.1	+0.8	11.8	+3.8	24.7
September	12.3	0	11.0	+3.0	22.5

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

CCE divers deployed a light logger in the Gardiners Bay eelgrass meadow for 10-day deployments, monthly for July-September 2020. The collected light data is summarized in Table GB-1, above. As mentioned in the Bullhead Bay section, 2020 was a drought year and resulted in the Gardiners Bay meadow receiving ample light, as evidenced by the Hcomp and Hsat data reported in Table GB-1. The Gardiners Bay eelgrass meadow experienced surplus light for both Hcomp and Hsat for all months, except for the Hcomp in September 2020, where the meadow received the minimal light required.

Water temperature was monitored at the Gardiners Bay site using an Onset Hobo temperature logger deployed in mid-June, 2020. The average monthly water temperatures for the Gardiners Bay eelgrass meadow are found in Table GB-1. The average monthly water temperatures did not exceed the 25°C threshold for 2020. The 2020 season was warmer than 2019 and recorded 18 days of water temperatures exceeding 25°C, compared to only 1 day over 25°C in 2019. The meadow did not record a day with the average water temperature over 27°C, however the highest recorded water temperature at the site was 27.5°C on 7 August 2020.

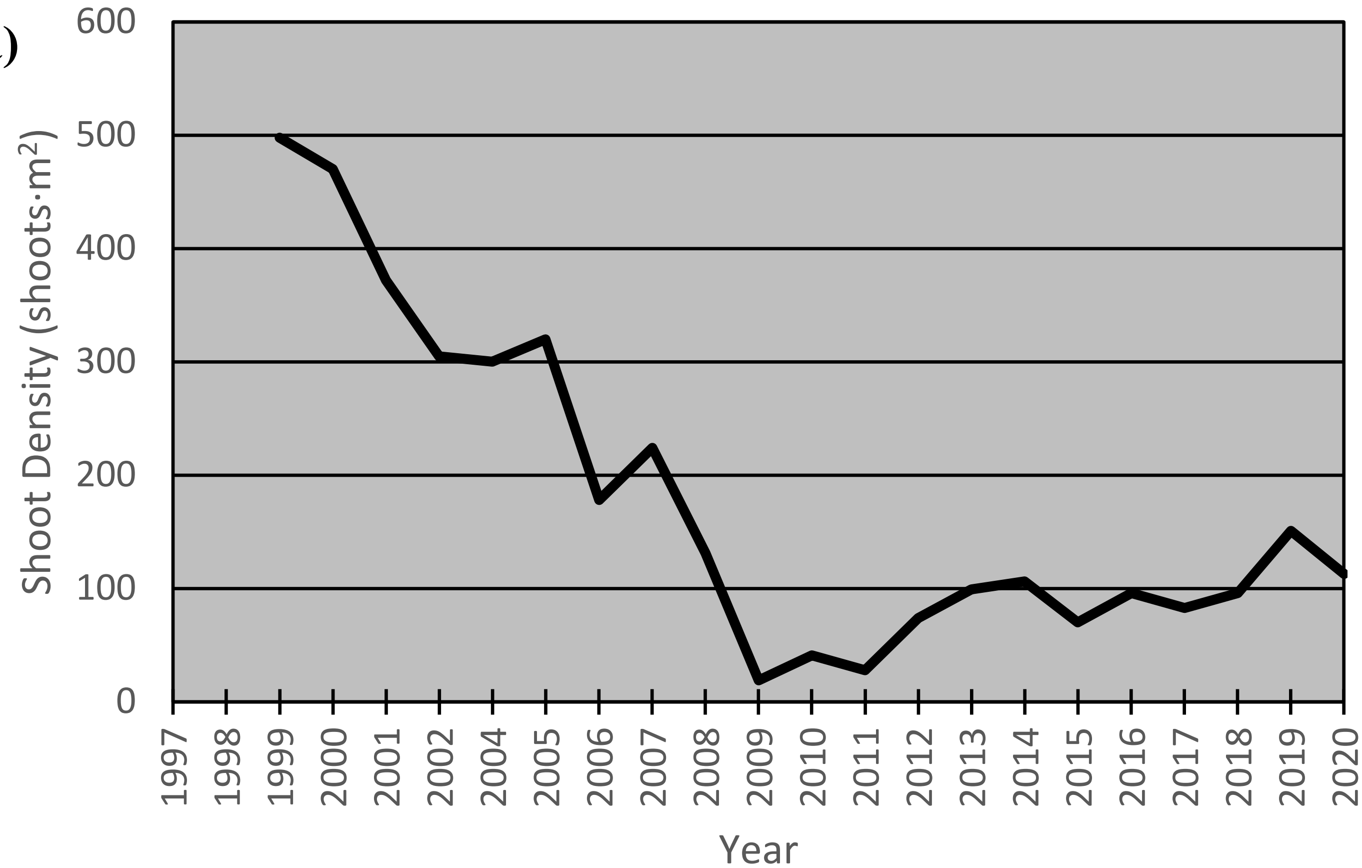
Eelgrass Shoot Density

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2020, 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
2020	113	+/-22

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

a)



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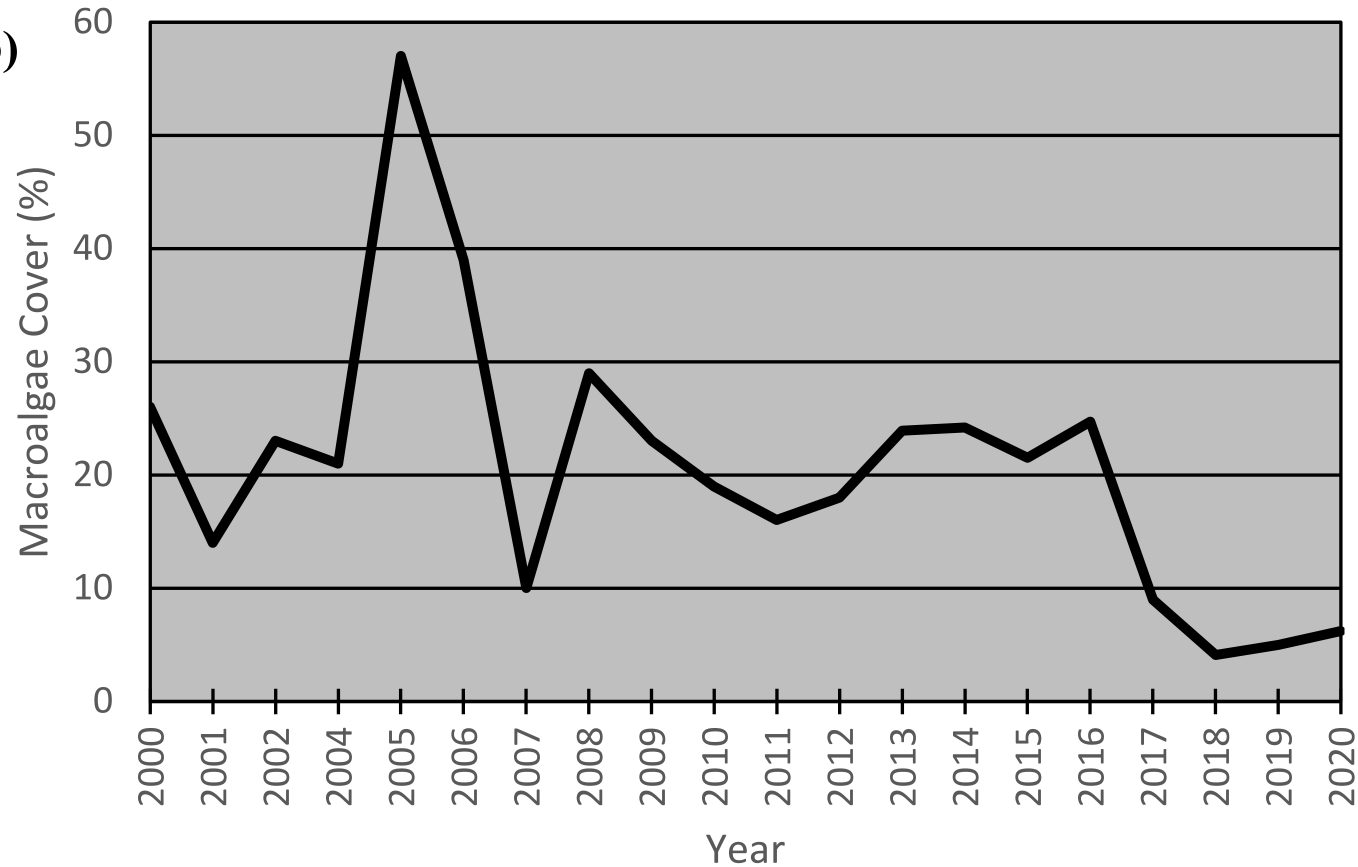


Figure GB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted at the Gardiners Bay site.

Gardiners Bay 2020

Figure GB-3. The 2020 areal delineation of the Gardiners Bay eelgrass meadow on the northeast shore of Shelter Island, NY.

The Gardiners Bay meadow's monitoring visit was conducted on 25 August, 2020. The eelgrass shoot density declined from the 2019 density (Table GB-2; Figure GB-2a), although the decrease was not found to be statistically significant. While the 2019 eelgrass survey recoreded eelgrass at Stations 4 and 5, no quadrats at these stations recorded eelgrass in 2020. However, eelgrass was observed growing adjacent to these monitoring stations. The 2020 average eelgrass shoot density for Gardiners Bay was 113 shoots·m^2, down from 151 shoots·m^2 in 2019.

Macroalgae Cover

The macroalgae biomass at the Gardiners Bay site remained relatively low in 2020. A slight increase in percent cover of macroalgae was recorded from 5% (2019) to 6.5% (2020) (Figure GB-2b). Macroalgae species that were reported included *Spyridia filamentosa*, *Gracilaria* sp., *Polysiphonia* sp., *Ulva lactuca*, *Codium fragile*, and *Sargassum filipendula*.

Bed Delineation and Areal Extent

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2020.

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.)
2020	20.67 acres (8.37 hect.)

The 2020 meadow delineations were completed using the New York State Department of Planning aerial photography taken in March 2020. The Gardiners Bay eelgrass meadow covered 20.67 acres (Table GB-3; Figure GB-4i), which was a minor, but insignificant increase in the areal extent of the meadow from 2019.

Conclusions

The eelgrass meadow at Gardiners Bay continues to persist at a relatively high shoot density in the close to shore Stations (6-8), but there has also been evidence of recruitment into some of the former offshore areas of the meadow, specifically around Stations 4 and 5. Most of the small patches that have been observed in these offshore areas are likely too small to persist over the winter, but some of the larger patches present the potential for recolonization into the areas that have lost eelgrass at this site. The meadow has maintained a relatively consistent shoot density since 2015, although the overall area of the meadow has only seen stability since 2017.

The eelgrass bioptical model created by Kaitlyn O'Toole and Dr. Brad Petersen (SUNY Stony Brook) suggests that the one of the greater impacts to the Gardiners Bay meadow may be the presence of extensive shoreline hardening at this relatively high wave exposed site. Add to these factors the fragmentation of the meadow by boats traversing the meadow and

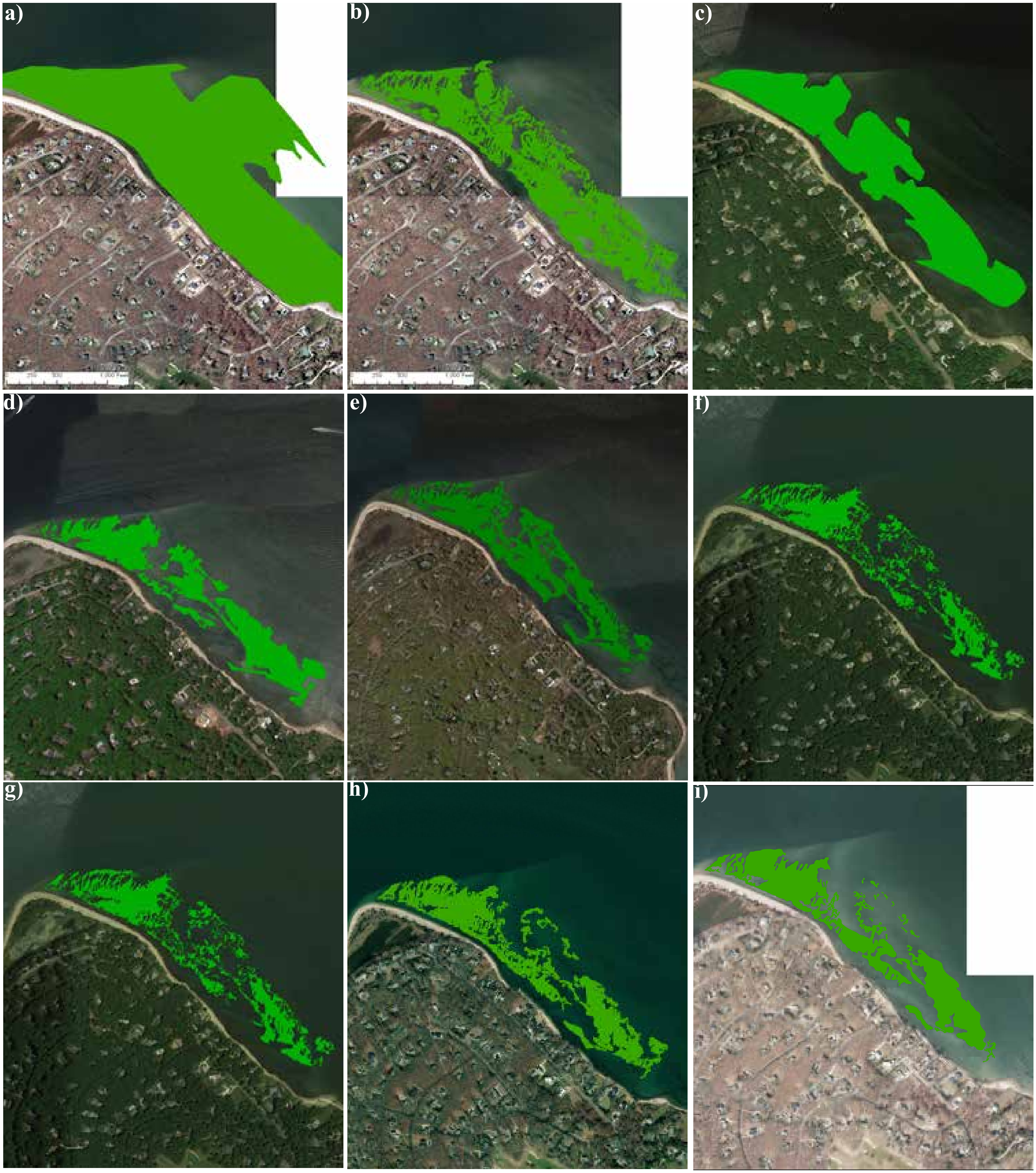


Figure GB-4. A series of aerial delineations of the Gardiners Bay eelgrass from select years from 2000 through 2016. The years represented are a) 2000, b) 2010, c) 2014, d) 2015, e) 2016, f) 2017, g) 2018, h) 2019, and i) 2020.

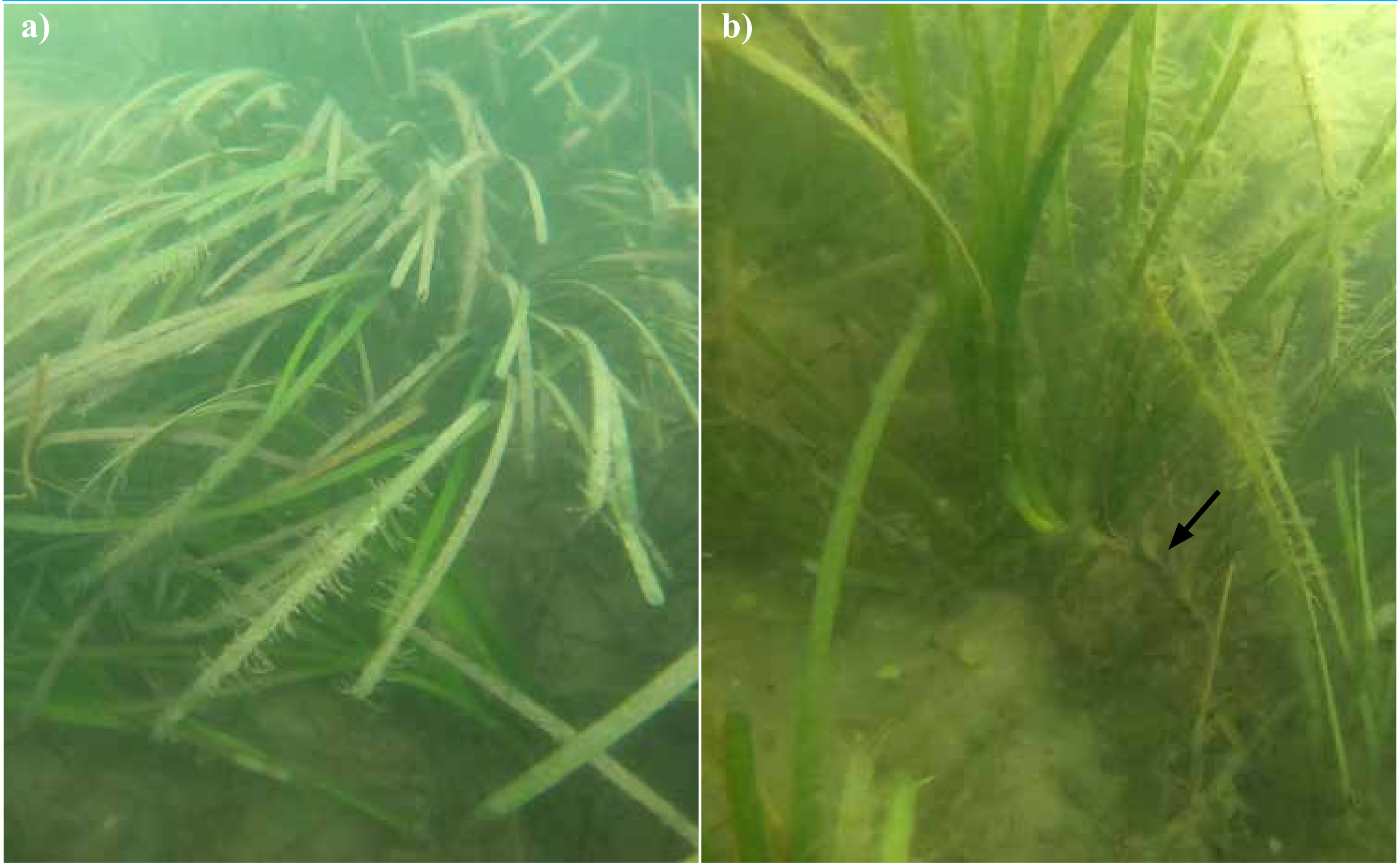


Figure GB-5. Underwater photographs taken by CCE divers while conducting the 2020 eelgrass monitoring at the Gardiners Bay LTEMP site. a) Dense patches of eelgrass were observed growing around station GB7. b) Eelgrass shoots growing out of the sediment due to erosion along the edges of patches was common around station GB8.

the placement of moorings within vegetated areas, we could expect the meadow to maintain its patchy nature.

The observable recruitment of small patches of eelgrass that persist through the summer suggests that condtions in these unvegetated areas can support eelgrass. This suggests that there is a potential for restoration at the site, however, the high currents and wave-exposure at the site would require any attempts be carefully considered to minimize seeds from being swept offsite or adult shoots from being eroded before becoming established.

Three Mile Harbor-2020

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 2020, as was the quadrat survey.

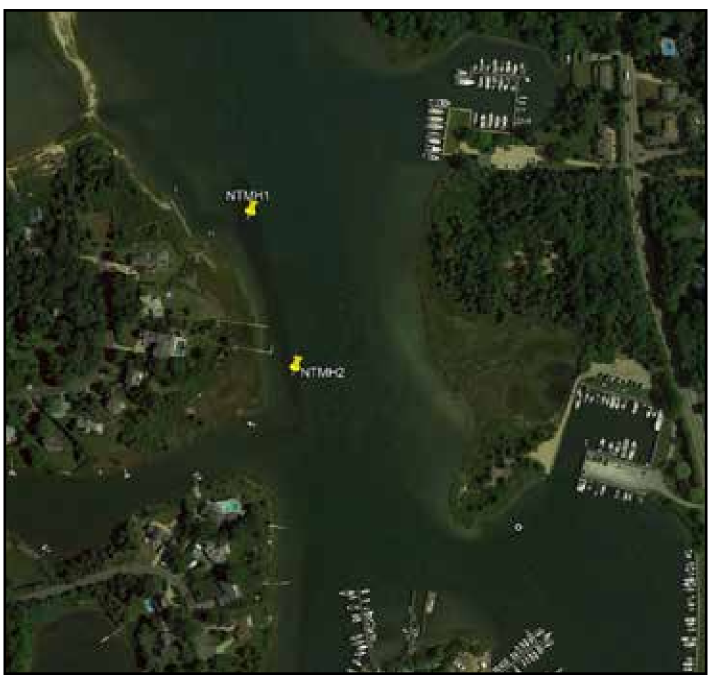


Figure TMH-1. An aerial photograph showing the location of the new Three Mile Harbor eelgrass meadow and its two monitoring stations.

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 2020.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.5	+2.2	13.3	+5.3	24.8
August	13.1	+0.8	12.1	+4.1	25.2
September	ND	ND	ND	ND	22.4

CCE deployed Odyssey PAR loggers 10 days during July, August, and September, 2020 at the meadow at the head of Three Mile Harbor. Average daily Hcomps and Hsats were recorded for the 2020 season and are presented in Table TMH-1. Light conditions for the site provided enough light to the meadow in excess of the basic daily requirement for both Hcomp and Hsat for July and August 2020. The light logger deployed in September malfunctioned and failed to record for the 10-day deployment, so there is no light data for September 2020.

An Onset Hobo water temperature logger was deployed to Three Mile Harbor in mid-June, 2020. Average monthly temperatures recorded for the 2020 season are presented in Table TMH-1. August 2020 was the only month for which the monthly water temperature exceeded 25°C. The Three Mile Harbor meadow experienced 30 days of temperatures greater than 25°C and 5 days of temperatures over 27°C. The highest recorded temperature for 2020 was 29.4°C on 29 July, 2020. Water temperature conditions at the Three Mile Harbor site for 2020 were similar to the conditions reported in 2019.

Eelgrass Shoot Density

Three Mile Harbor was visited on 27 August, 2020. The monitoring survey was conducted at the two stations in the 'new' site at the head of the harbor. The 2020 eelgrass survey reported a significant increase in eelgrass shoot density from 2019 to 2020 (Table TMH-2; Figure TMH-2a), with the shoot density improving from 42 shoots·m^2 (2019) to 90 shoots·m^2 (2020). Eelgrass was recorded at Station 2, whereas no eelgrass was observed at the station in 2019.

Macroalgae Cover

Macroalgae cover at the new Three Mile Harbor site saw a significant increase from 2019 to 2020 (Figure TMH-2b). In 2019, macroalgae cover was 5.3% but increased to 60% in 2020. *Spyridia filamentosa* was the dominant species at both sites with *Polysiphonia* species as the only other species recorded. The increase in macroalgae cover is likely correlated to the

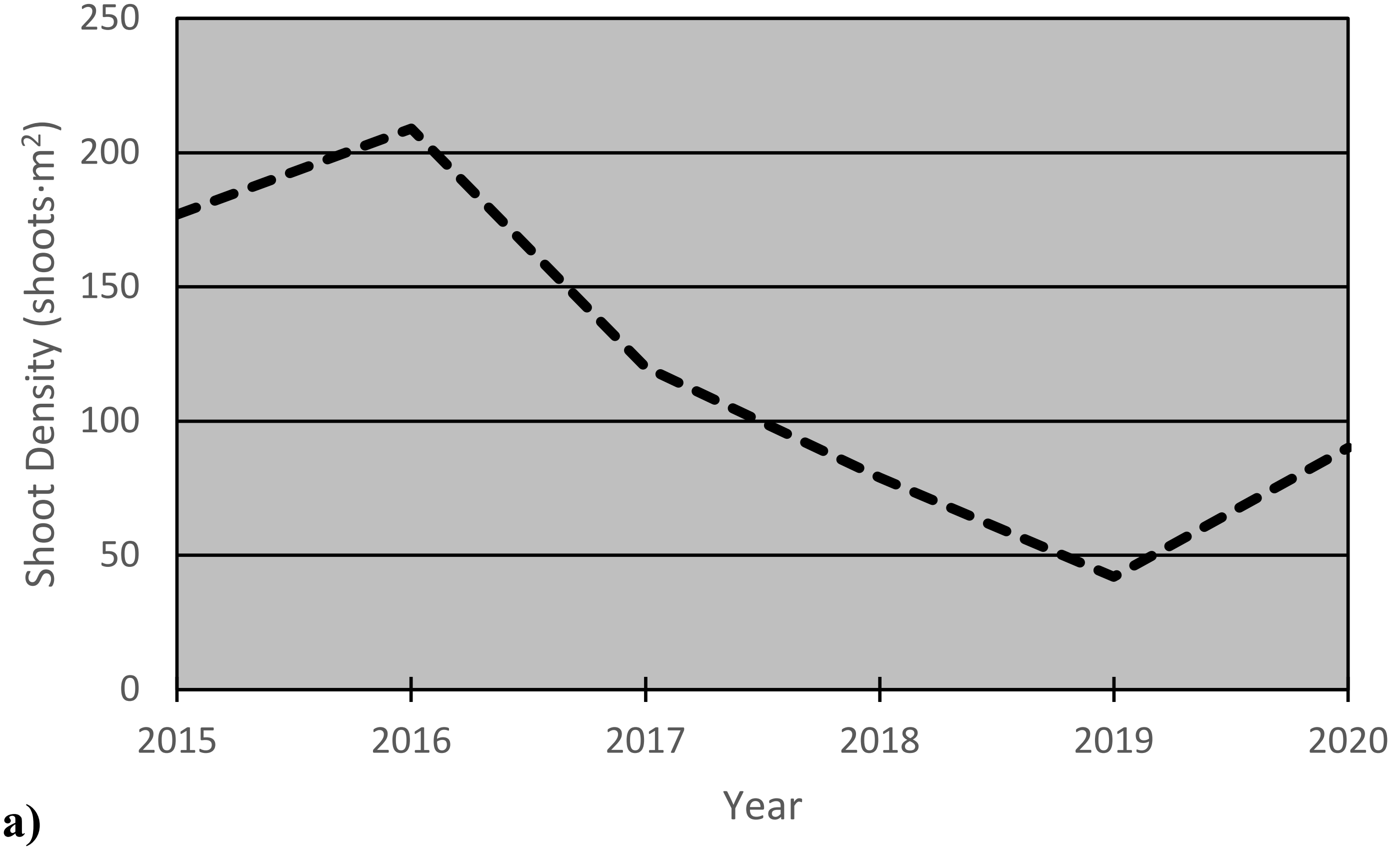
Table TMH-2. The average annual eelgrass shoot density for Three Mile Harbor (new site) from 2015 to 2020, including standard error.

Year	Mean Density	S.E.
2015	177	+/- 17
2016	209	+/- 20
2017	120	+/- 17
2018	79	+/- 20
2019	42	+/- 13
2020	90	+/- 14

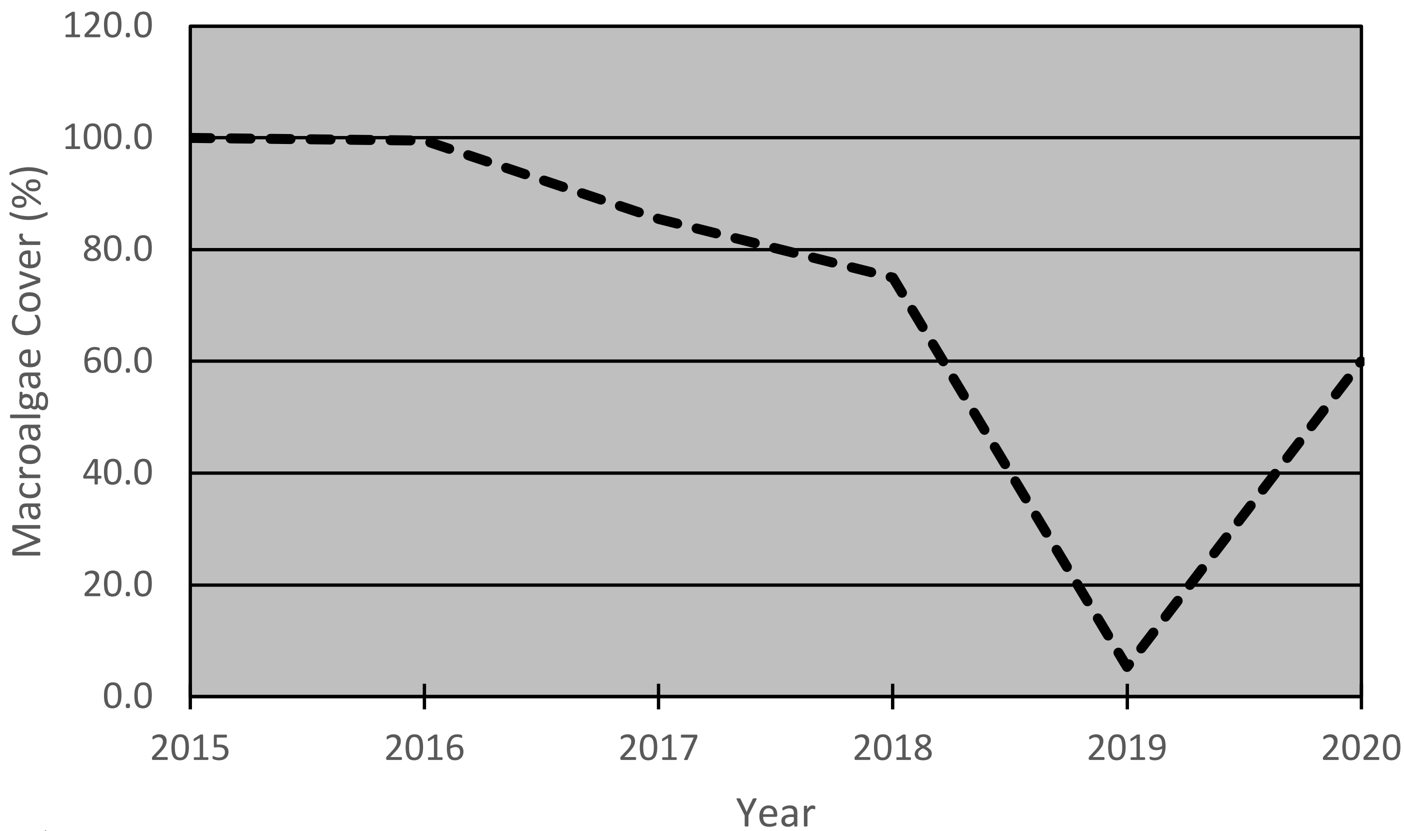
Table TMH-3. The estimated cover of eelgrass in Three Mile Harbor for all years surveyed.

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.)
2020	3.1 acres (1.25 hect.)

Three Mile Harbor-2020



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.

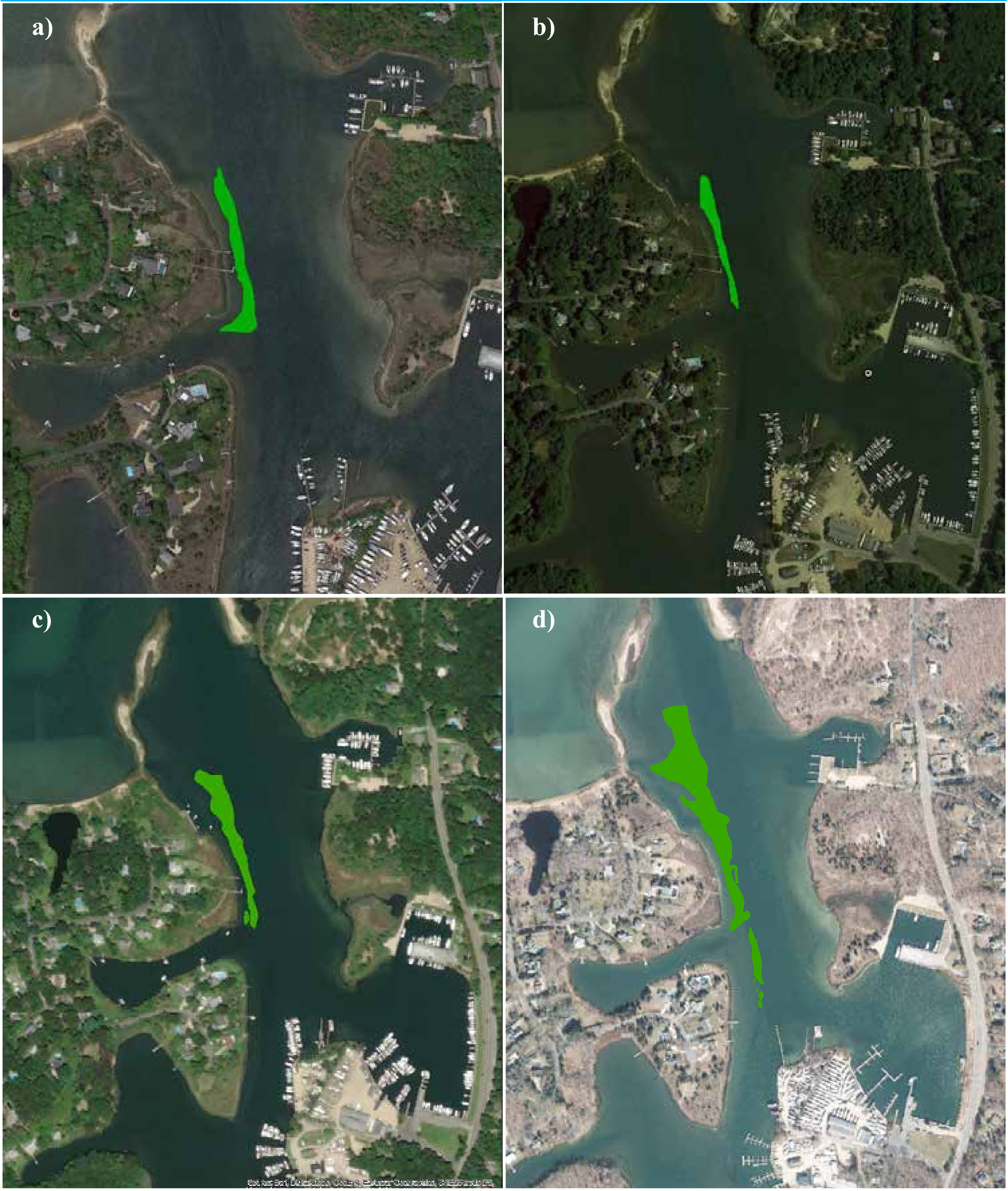


Figure TMH-3. Aerial views of the eelgrass meadow (new Three Mile Harbor) at the head of Three Mile Harbor presenting the a) 2014, b) 2018, c) 2019, and d) 2020 meadow delineations.

increase in eelgrass density at Station 2.

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using the New York State Department of Planning aerial photography taken in March 2020. Figure TMH-3

Figure TMH-4. Underwater photograph of the conditions at station TMH1 in 2020. Turbidity at the site was high and reduced visibility to near 2 feet on the day of the survey.

provides a progression of aerial delineations of the meadow from 2014, 2018, 2019, and 2020. The 2020 areal extent of the bed more than doubled in size over the 2019 meadow, increasing from 1.4 acres to 3.1 acres.(Table TMH-3). The Three Mile Harbor meadow not only recolonized the area lost in 2019, but it showed extensive expansion to the northern part of the meadow. The evidence of expansion to the north in 2019, but the mild 2020 winter may have allowed more expansive recruitment from seed than previously observed at the site.

Conclusions

The 2020 Three Mile Harbor eelgrass survey found that the eelgrass meadow has reversed the decline it had been experiencing from 2018-2019. Both eelgrass shoots density and the areal extent of the eelgrass meadow have more than double over the reported values from the 2019 season. It is possible that the mild winters have increased seedling survival, resulting in an increased rate of recruitment that was observed during the 2020 survey. The restoration potential of eelgrass seeds has been discussed in regards to the recovery of the Bullhead Bay eelgrass meadow, and a similar seed-based recovery is likely at play in Three Mile Harbor. One cause for concern regarding disturbance in this meadow is the mooring of boats along the shore of the northern part of the meadow. Currently, the boats present are moored just inshore of the meadow, but chain-drag could be disturbing the meadows edge. Boats travelling from the channel to their moorings at low tide could be prop dredging, if their motors are not trimmed up.

Cedar Point 2020

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 2020. The light availability was

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 2020.

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	14.4	+2.2	12.9	+4.9	23.0
August	13.1	+0.8	11.6	+3.6	24.0
September	9.0	-3.3	8.2	+0.2	22.0

sufficient for July and August to exceed the minimum standards required for Hcomp and Hsat (Table CP-1). In September 2020, Hcomp ran a deficit of more than 3 hours, but received enough light to produce a minor surplus in Hsat. The deficit in Hcomp could have been the result of the light logger being shaded by drift macroalgae that is prevalent at the site.

The water temperature logger for Cedar Point was deployed mid-June 2020, near monitoring station 3. Water temperatures during the 2020 season were, on average, warmer than those recorded in 2019, with daily average temperatures ranging above 25°C for only 3 days and with a recorded high temperature of 26.3°C on 1 August, 2020.

Eelgrass Shoot Density

The Cedar Point survey visit was conducted on 26 August, 2020. The average eelgrass shoot density for 2020 was found to be 181 shoots·m^2 (Table CP-2; Figure CP-2). The 2020 shoot density represented a decrease of 40 shoots·m^2 from 2019, however this change was not found to be significant. All six monitoring stations supported eelgrass in 2020, similar to the report for 2019.

Macroalgae Cover

The Macroalgae cover in the Cedar Point eelgrass meadow showed an increase from 2019 and 2020. Divers recorded an average macroalgae cover of 33.6%, which is more than double the percent cover of macroalgae for 2019 at 16.7% (Figure CP-2b). As with previous years' surveys, *Sargassum filipendula* remains the primary macroalgae species inhabiting the Cedar Point eelgrass meadow. Divers identified several other common species at the site including: *Spyridia filamentosa*, *Chondrus crispus*,*Heterosiphonia harveyii*, *Halosiphon tomentosus*, *Codium fragile* and *Ulva* species.

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 through 2020, 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
2020	181	+/-24

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for select years from 2000-2020.

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.)
2020	76.6 acres (31.00 hect.)

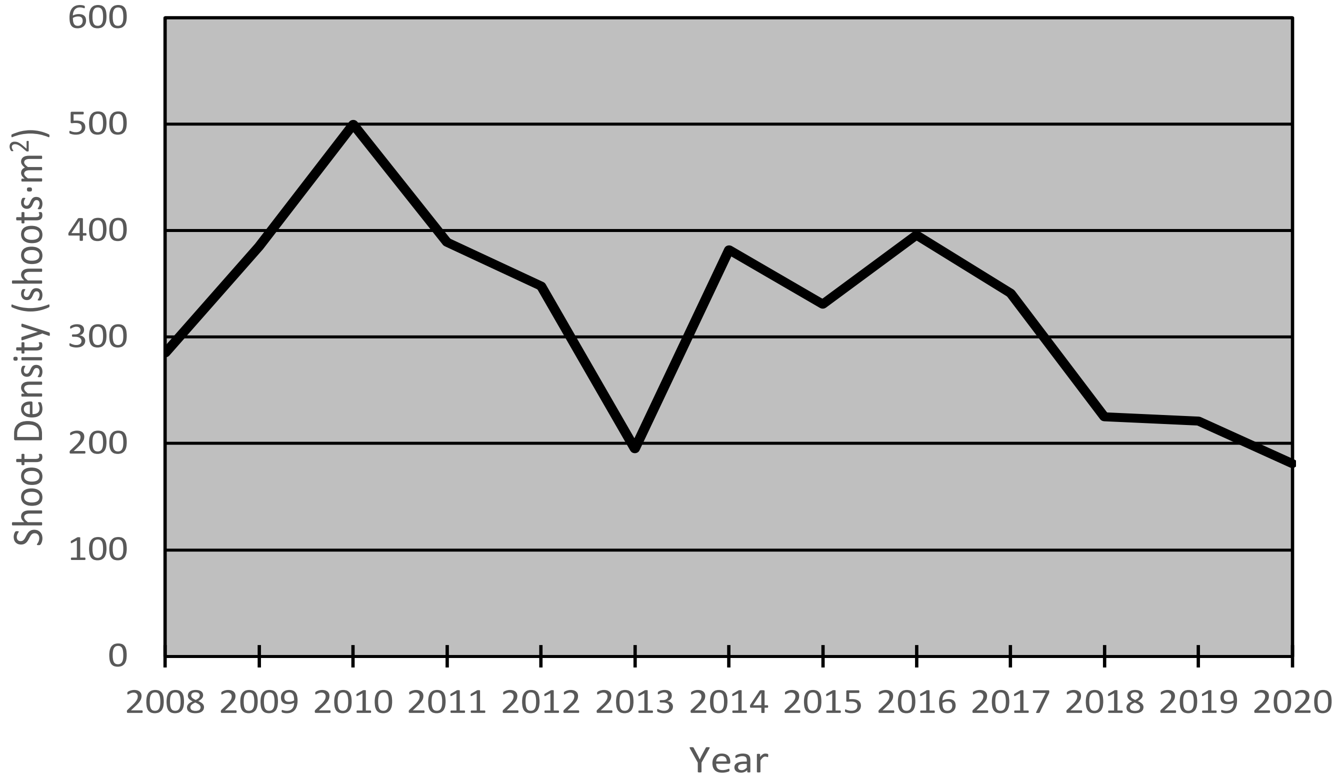


Figure CP-2. The average annual eelgrass shoot density for Cedar Point for 2008-2020.

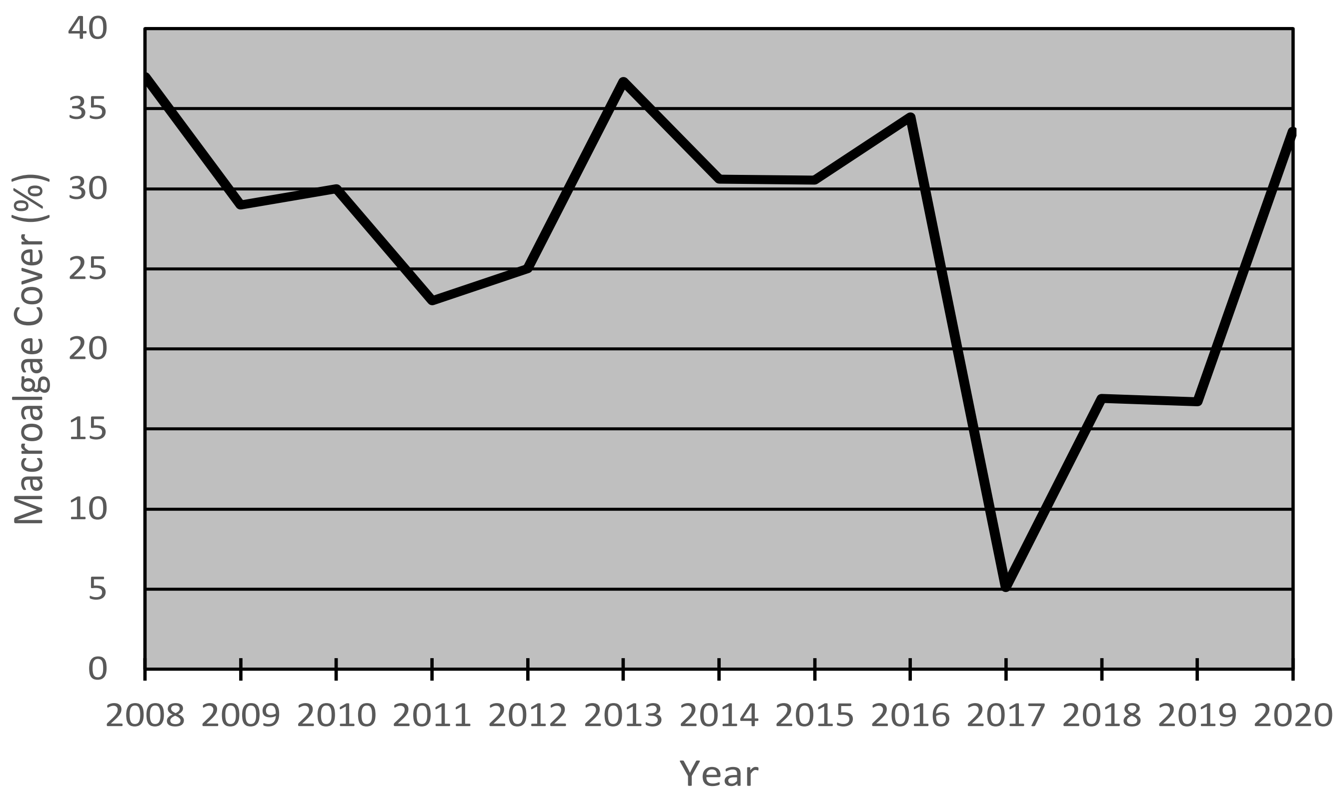


Figure CP-3 Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2020.

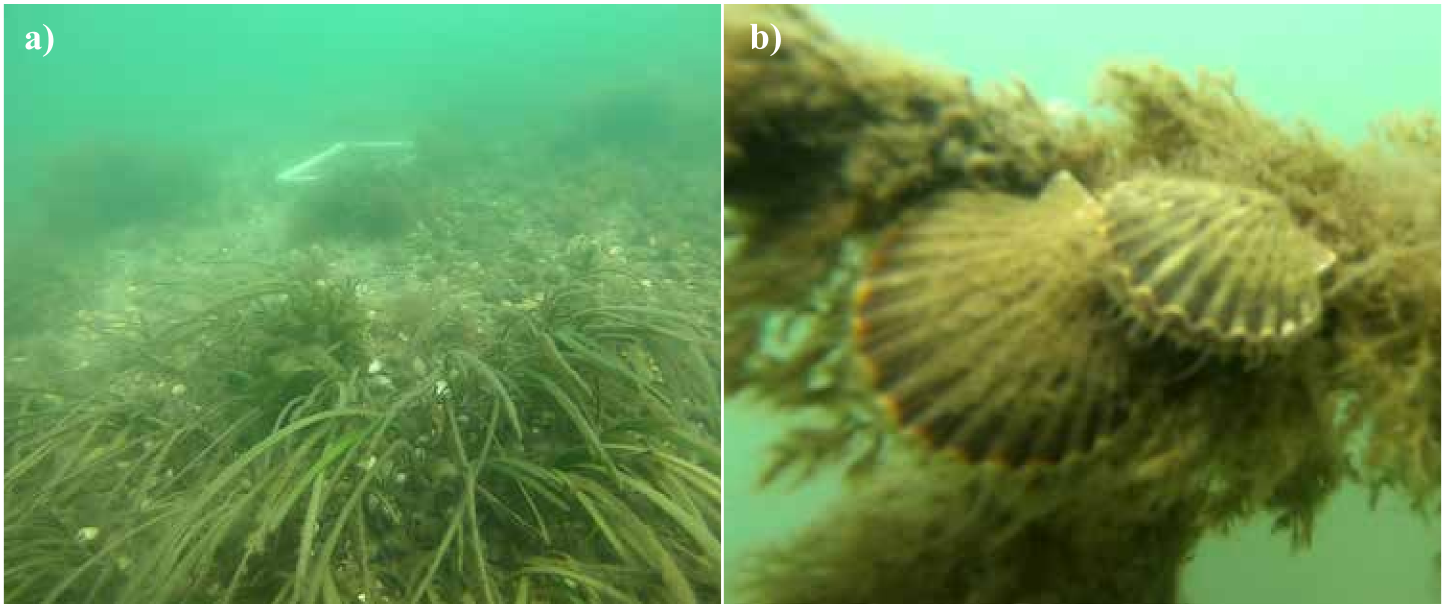


Figure CP-4. a) Conditions at station CP1 showing the patchy nature of the inshore sections of the meadow. b) Bug scallops that attached to a buoy line marking one of SUNY Stony Brook's temperature loggers near station CP5.

the New York State Department of Planning aerial photography taken in March 2020. Based on the aerial images, the meadow increased slightly from its 2019 extent to 76.6 acres in 2020 (Table CP-3; Figure CP-5f). The amount of change is not considered significant and the areal extent of the meadow should be considered as stable between the two years.

Conclusions

The 2020 eelgrass survey at Cedar Point found that the meadow remained stable between since 2018. Eelgrass shoot density hasn't recorded a significant change since the decline from 2017 to 2018, while areal extent of the meadow has shown significant change after the 13 acre loss experienced between 2016 and 2017. Much of the change in the meadow is occurring on the western end where the meadow shoals rapidly causing waves to break along the deep edge of the meadow. The western portions of the meadow have a more gradual slope and supports a higher biomass of Sargassum which may help in diffusing some of the energy. The center of the meadow that had been damaged during Superstorm Sandy has been slow to recover and with the increased frequency and intensity of storms projected for the future, this area my not fully recover, leaving the meadow split into two sections.

a)

b)

c)

Figure CP-5. Delineations of the Cedar Point eelgrass meadow from aerial photographs for a) 2004, b) 2010, c) 2014, d) 2017, e) 2019, and f) 2020 (continued on next page).

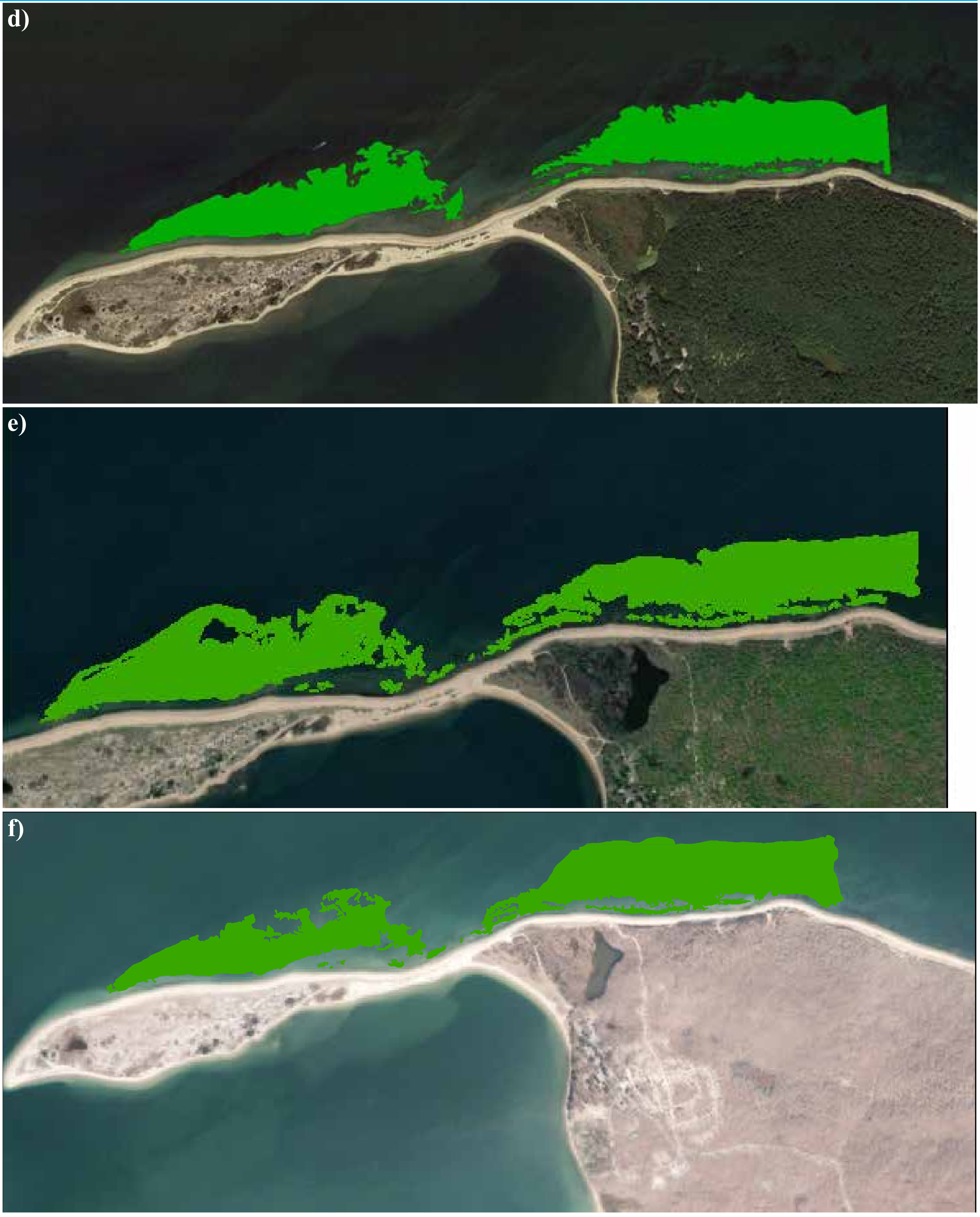


Figure CP-4. Continued.

Orient Point 2020

Orient Point is the eastern tip of the north fork of Long Island. To the south of the point is Gardiners Bay and an eelgrass meadow that was added to the Peconic Estuary Program Long-term Eelgrass Monitoring Program in 2008. The meadow was a large, relatively dense meadow until October of 2006, when, after a week of strong winds out of the east, the meadow suffered extensive losses from the mid-bed to the deep edge. The nearshore area of the meadow saw minimal loss, but the result was that three-quarters of a large, healthy eelgrass meadow was devastated in a short period of time. CCE had established a sentinel site at Orient Point to monitor the recovery of the meadow along three permanent transects, but it was decided around this same time to add two new meadows to the PEP LTEMP to balance the loss of eelgrass at four of the six monitoring meadows and Orient Point was chosen for the opportunity to monitor a meadow in recovery. Figure OP-1 shows the locations of the established monitoring stations within the Orient Point eelgrass meadow.

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

Site Characteristics

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

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

Table OP-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Orient Point over 10-day intervals, monthly, for 2020.

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	12.8	+4.8	21.7
August	13.2	+0.9	12.1	+4.1	23.1
September	12.1	-0.2	10.3	+2.3	21.7

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 loggers were deployed for 10-day periods, once monthly from July-September 2020 in the Orient Point eelgrass meadow. 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 for July and August was in surplus for both Hcomp and Hsat in the Orient Point meadow. September recorded a slight deficit of 0.2 hours for Hcomp, but a more than 2 hour surplus for Hsat. Overall, the seasonal light availability for the meadow was sufficient to meet eelgrass's minimum requirements.

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
2020	91	+/-24

Water temperature was monitored by deploying an Onset Hobo temperature logger in the Orient Point meadow in mid-June 2020. The average monthly water temperatures were calculated from the data collected and presented in Table OP-1. The Orient Point meadow recorded no daily average temperatures exceeding 25°C for 2020. The highest recorded temperature was 26.0°C on 14 August, 2020. The temperatures recorded in 2020 at Orient Point are consistent with the history of the site.

Eelgrass Shoot Density

Eelgrass monitoring at the Orient Point eelgrass meadow was conducted on 26 August, 2020. The average eelgrass shoot density calculated for the meadow was 91 shoots·m^2, down from 128 shoots·m^2 in 2019 (Table OP-2; Figure OP-2). There was no eelgrass recorded at Stations 4 and 6, which has been normal for the past few monitoring seasons, but in addition, no eelgrass was recorded in the quadrats sampled at Station 1, although eelgrass was observed in the vicinity of station.

Macroalgae Cover

The average macoralgae cover for the Orient Point meadow was 24% for the 2020 season (Figure OP-3). This was a significant increase in the cover from the 7.8% reported in 2019. The macroalgae cover reported for 2019 was 7.8%, down from 18% in 2018. Eight species of macroalgae were identified by divers and included *Sargassum filipendula*, as the dominant species on site. Secondary species recorded at the site included two invasive, non-native species, *Codium fragile* and *Grateloupia turuturu*, as well as *Chondrus crispus*, *Agardhiella tikvahiae*, *Spyridia filamentosa*, *Fucus* sp., and *Ulva lactuca* .

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using the New York State Department of Planning aerial

Orient Point 2020

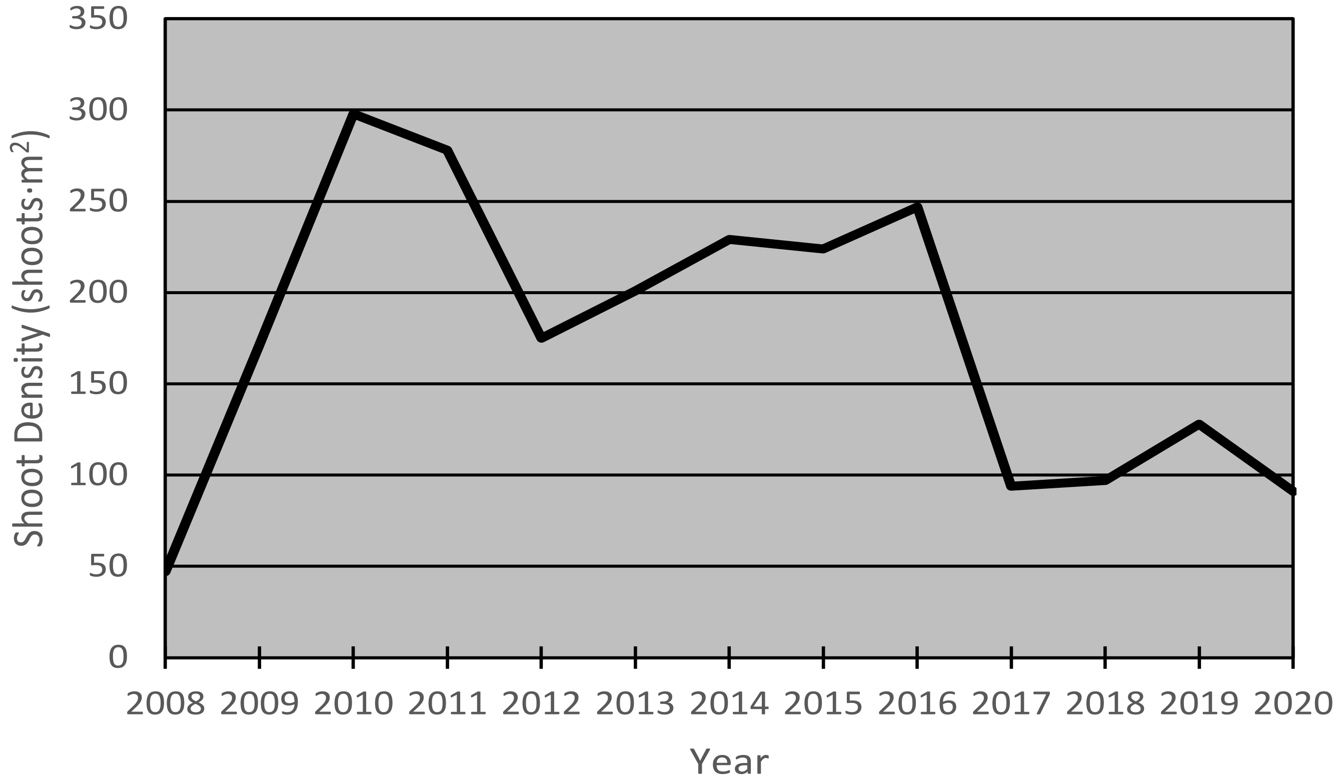


Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2020.

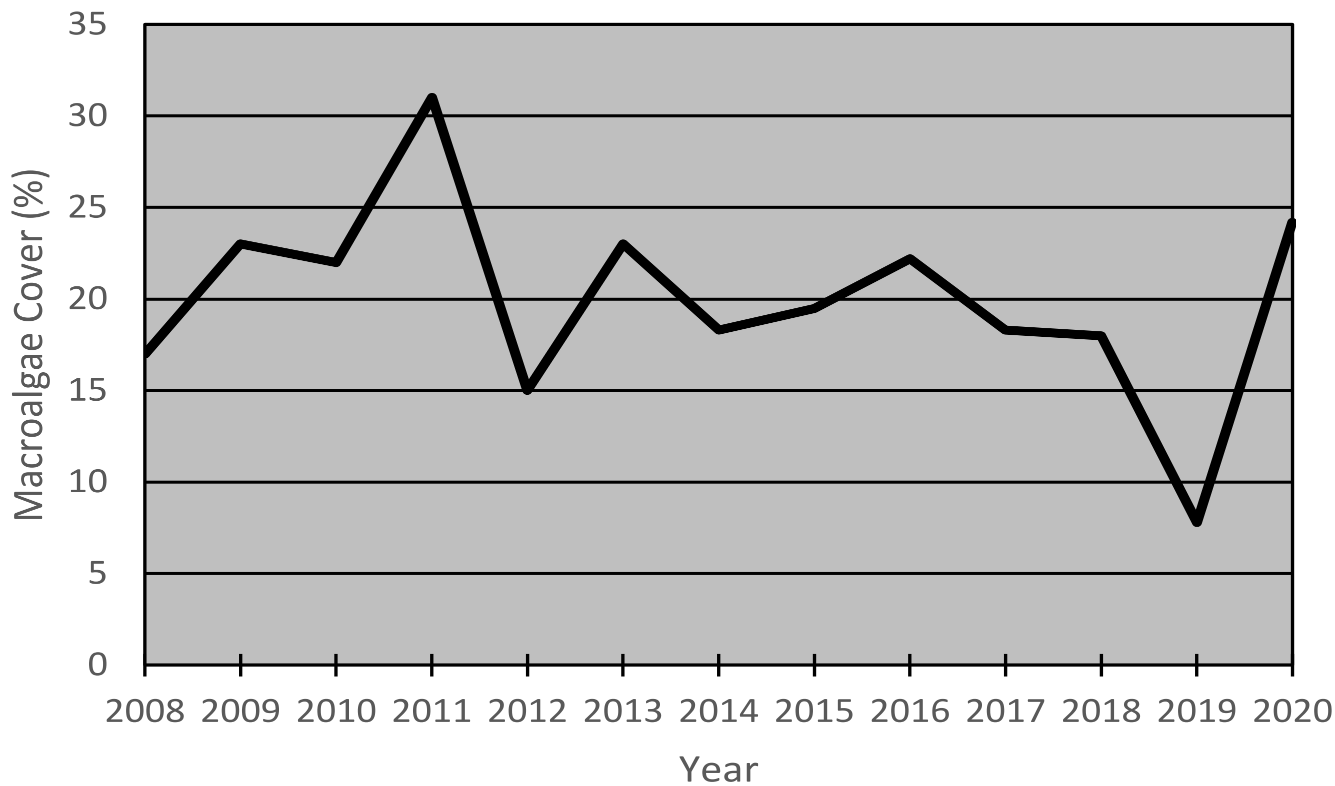


Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2020.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2020.

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.)
2020	16.6 acres (6.72 hect.)

*Area of meadow was significantly underestimated in aerial survey.

photography taken in March 2020. The clarity of the 2020 images were not as good as the imagery from 2019, so the level of detail in the delineation is not as fine for the 2020 meadow extent. The photo-interpretation of the 2020 aerial imagery found the Orient Point eelgrass meadow covered 16.6 acres (Table OP-3; Figure OP-5f). This is a 3.5 acre increase over the 2019 extent, but given the disparity in image quality between the two years, the significance of this increase should be considered conservatively.

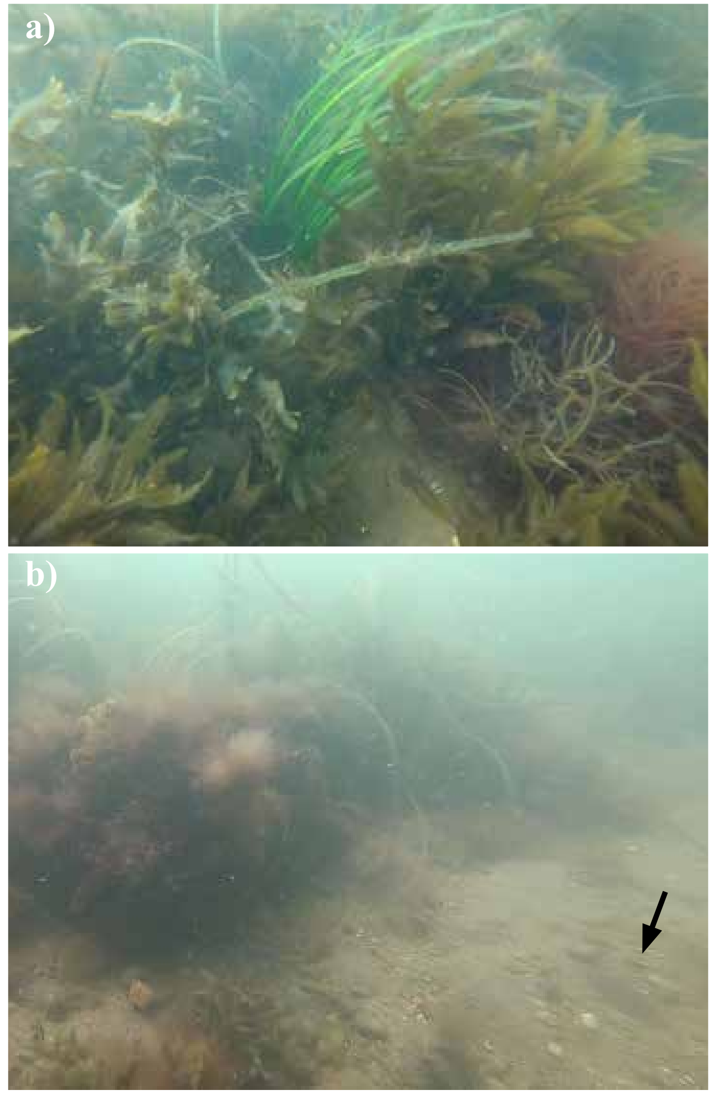


Figure OP-4. Underwater photographs of a) an eelgrass patch growing among seaweed covered boulders near station 1 and b) a juvenile scup/porgy (arrow) foraging in open patch in the meadow near station 5.

Conclusions

The 2020 eelgrass monitoring survey for the Orient Point found that the meadow has continued to maintian a relatively stable shoot density and areal extent. While there was a decline in the average shoot density from 2019 to 2020, the difference was not statistically significant. However, the lack of recorded eelgrass at Station 1 is a significant event. Since 2008, when Orient Point was added to the LTEMP, most of the loss suffered by the meadow has occured along the offshore edge. While the shallow sections of the meadow do suffer from erosion and wave damage, the loss of eelgrass at the inshore Station 1 is more extensive than has previously been observed. The Orient Point meadow has historically been a prolific, seed-producing population, so it will be interesting to see what, if any, recovery is able to occur by the 2021 monitoring visit. The increased frequency and intensity of storms is likely to continue to have the greatest impact on this meadow and may hinder recovery of eelgrass at this site or continue to erode the meadow gradually over time.

Orient Point 2020

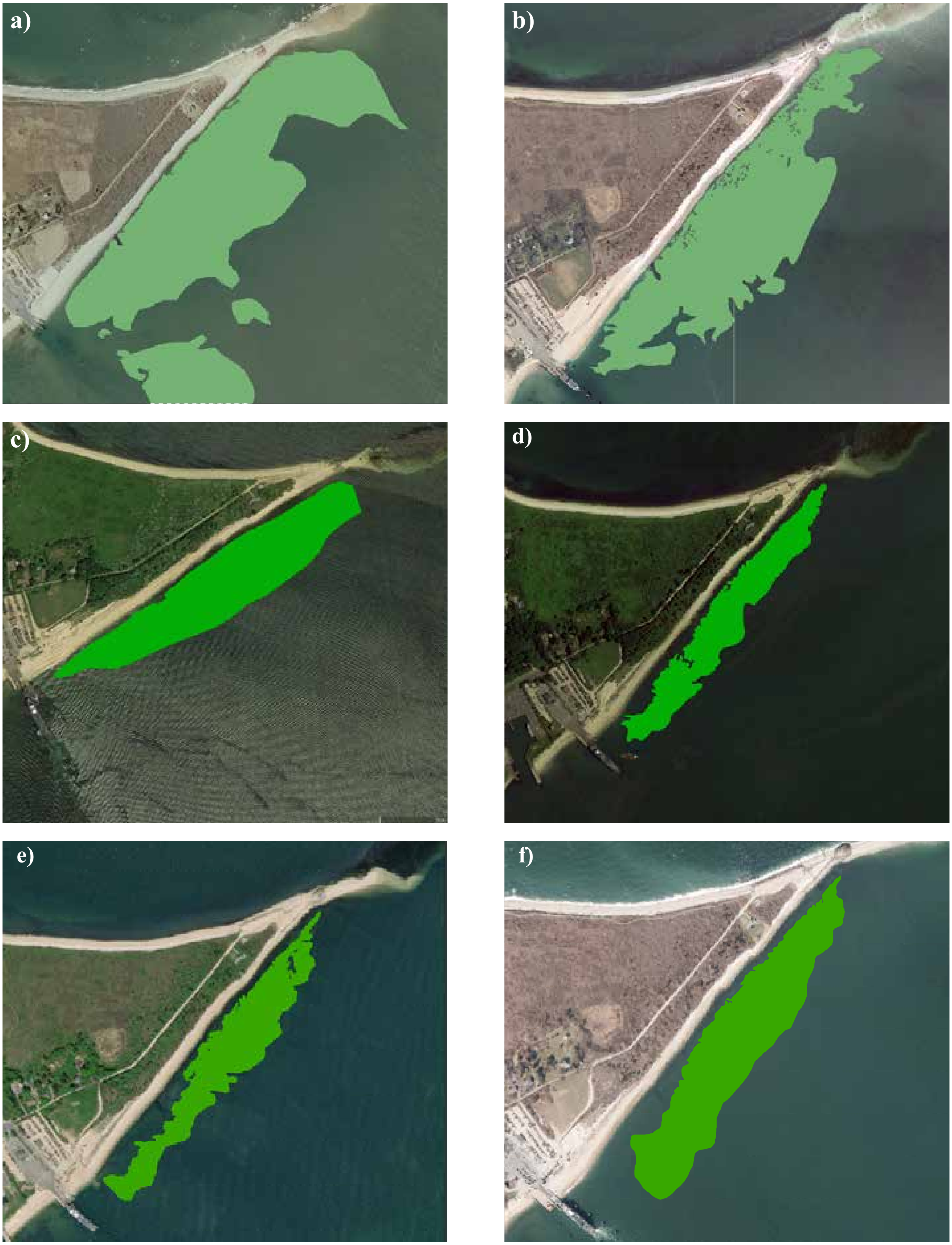


Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2010, c) 2014, d) 2017, e)2019, and f) 2020.

Coecles Harbor 2020

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

An Odyssey PAR light logger was deployed to Coecles Harbor for 10-day intervals, monthly (July-September) for the 2020 season. The average daily Hcomp and Hsat values were calculated from the raw data and presented in Table CH-1. The 2020 drought conditions benefitted several of the other monitoring sites with ample light to support eelgrass, but Coecles Harbor, due to its shallow nature and typically turbid waters did not experience as high of light levels. However, the eelgrass in Coecles Harbor did receive at least the minimal required light to meet Hcomp and Hsat for July and August. In September, Hcomp fell 0.9 hours short of the required 12.3 hours, while Hsat

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-day intervals, monthly, for 2020.

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	25.3
August	12.9	+0.6	11.2	+3.2	25.3
September	11.4	-0.9	9.3	+1.3	22.4

recorded a 1.3 hour surplus.

An Onset HOBO temperature logger was deployed to Coecles Harbor in mid-June 2020. The average monthly water temperatures for July-September 2020 are included in Table CH-1. The Coecles Harbor meadow experienced two months, July and August, in which the monthly average temperatures were greater than 25°C. The meadow recorded 38 days where the daily average temperature exceeded the 25°C threshold, but there were no days for which the daily temperatures reached 27°C. The highest temperature, recorded on 29 July, 2020, reached 27.5°C.

Eelgrass Shoot Density

On 26 August, 2020, the eelgrass survey of Coecles Harbor was completed. The average eelgrass shoot density for 2020 was calculated as 54 shoots·m^2, which was a signficant decline from the 100 shoots·m^2 reported in 2019. The shoot density was observably lower than the previous season, but divers noted that the coverage of eelgrass throughout the meadow was continuous, with minimal patchiness, but at this low density.

Macroalgae Cover

Macroalgae cover in Coecles Harbor remained low for the second straight season in 2019. Macroalgae cover averaged only 14.3%, down slightly from 16% in 2019. CCE divers only identified two species of macroalgae during their survey, *Spyridia filimentosa* and *Gracilaria* species. *Spyridia* constituted almost 99% of the macroalgae biomass observed during the survey for 2020.

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using the New York State Department of Planning aerial photography taken in March 2020. The aerial image quality was very clear for delineating eelgrass and the meadow was found to have expanded to 163.9 acres in 2020 (Table CH-3; Figure CH-2d). Observations made by CCE personnel over the course of the season identified the presence of eelgrass within several of the newly delineated areas for 2020. This expansion is a signficant increase over the 2019 extent of the meadow, but such a large increase between years had also occurred from 2018-2019.

Conclusions

After a 2019 monitoring season that reported the condition of the meadow to have improved over the 2017 and 2018 seasons, the 2020 eelgrass survey reported

Table CH-2. The average annual eelgrass shoot density for Coecles Harbor from 2017 to 2020, including standard error.

Year	Mean Density	S.E.
2017	78	+/-8
2018	41	+/-5
2019	100	+/-6
2020	54	+/-4

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.)
2020	163.9 acres (66.32 hect.)

Coecles Harbor 2020

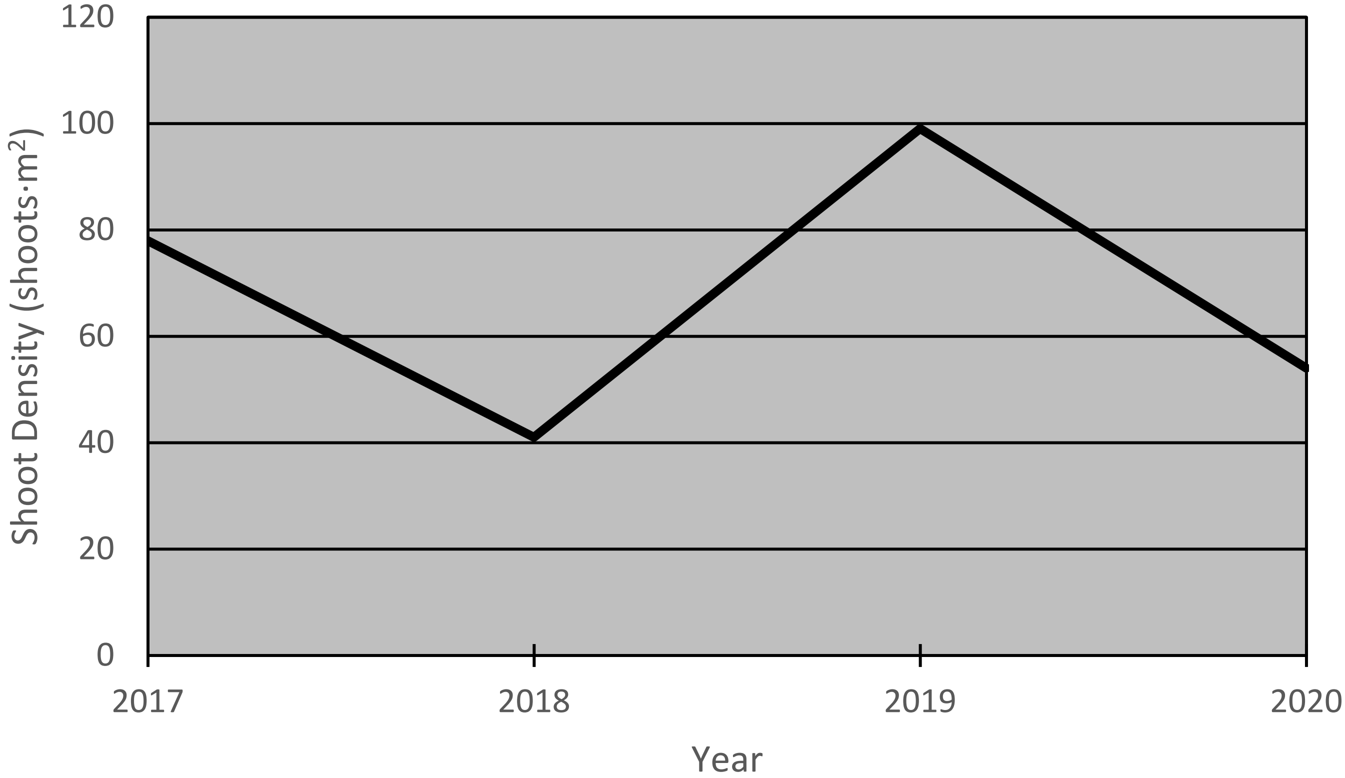


Figure CH-2. Graph of the annual mean eelgrass shoot density for Coecles Harbor from 2017-2020.

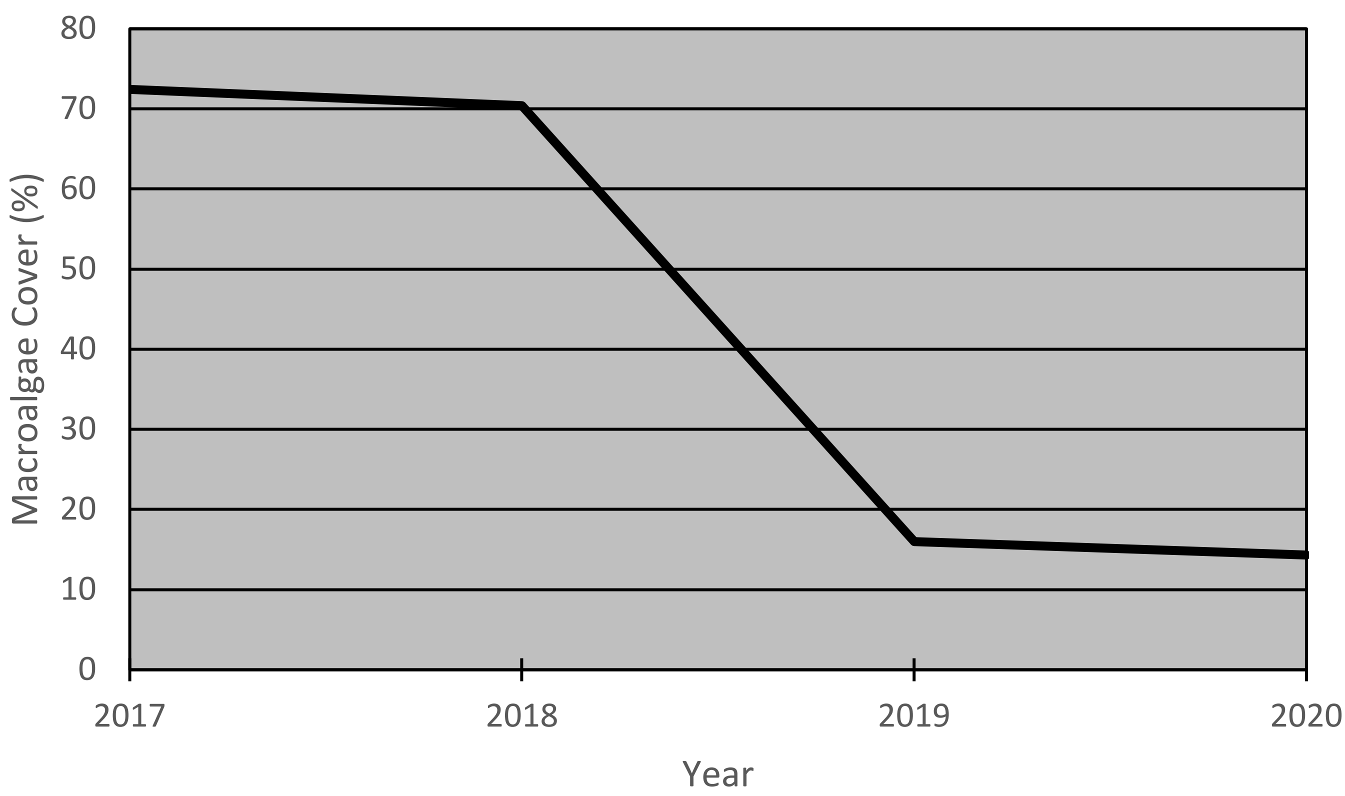


Figure CH-3. The annual mean macroalgae percent cover for Coecles Harbor from 2017-2020.

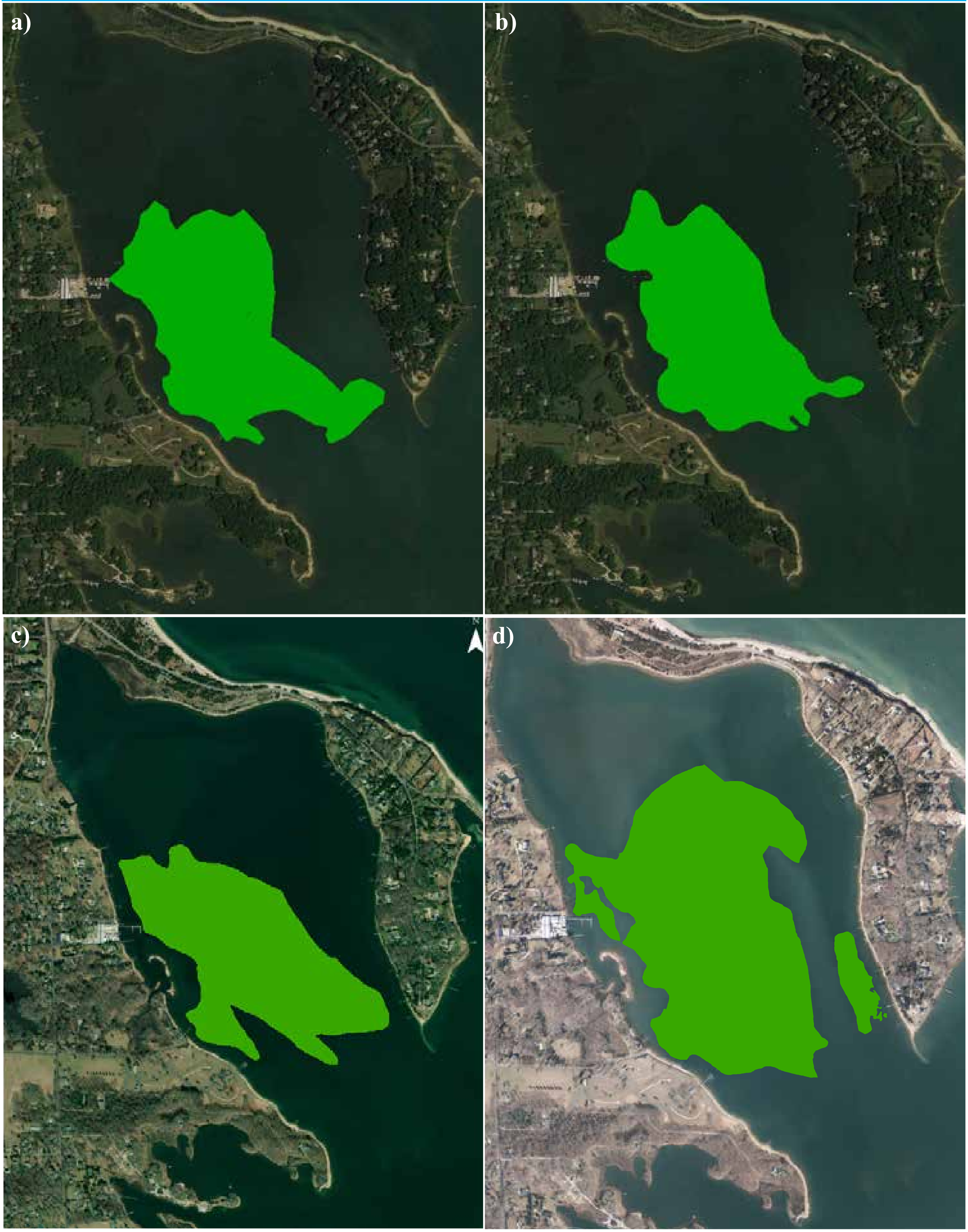


Figure CH-4. The Coecles Harbor eelgrass meadow delineations completed in a) 2014, b) 2017, c) 2019 and d)2020 for the LTEMP monitoring site.

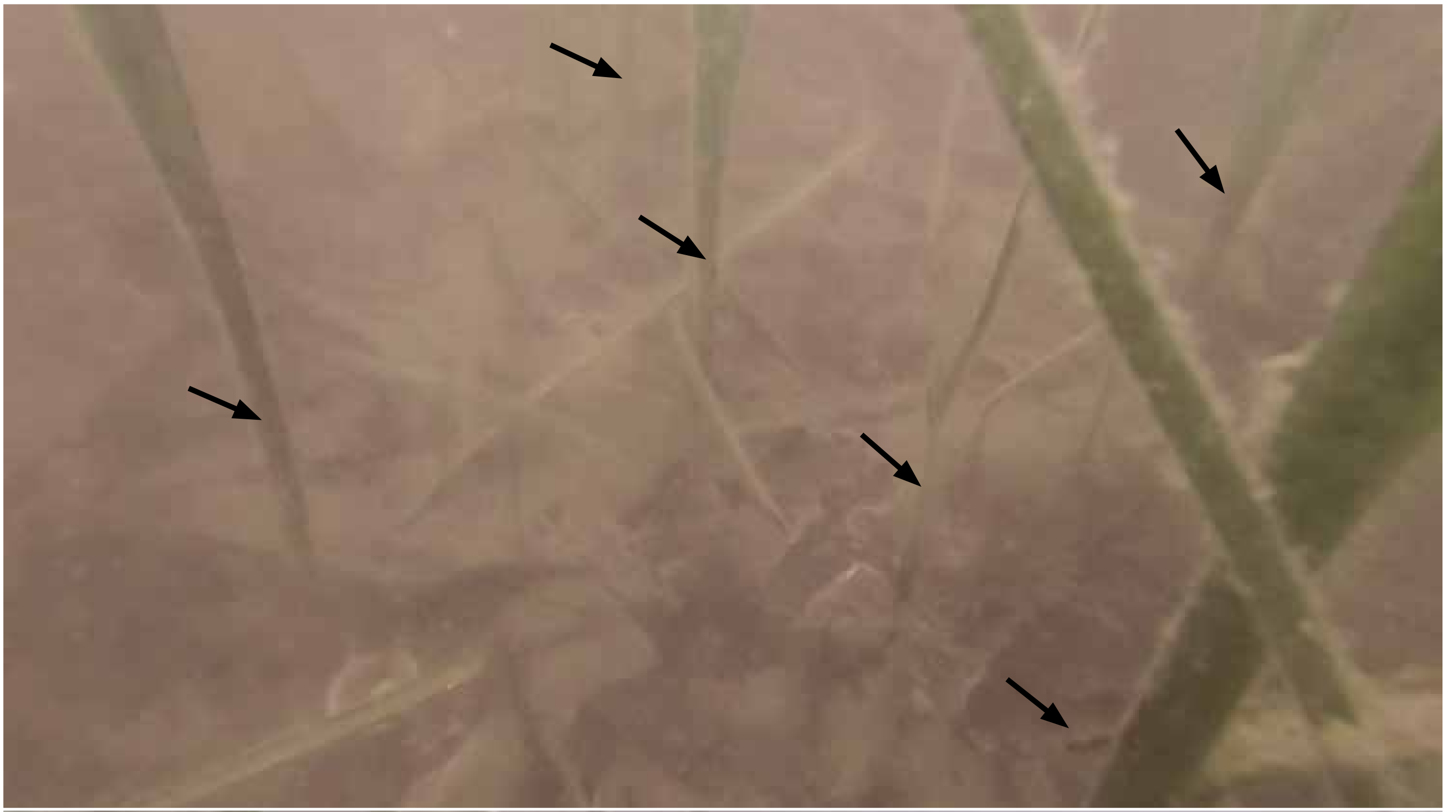


Figure CH-5. Photographs showing the observed conditions at a) station CH1 with the large spacing between shoots (indicated by the arrows) that was seen throughout meadow and b) station CH5 where a spent eelgrass flower shoot (arrow) has persisted more than two months after dropping its seeds..

a significant decline in the average shoot density in the Coecles Harbor meadow. Although the 2020 was almost half of the 2019 shoot density, displayed a consistent cover over the bottom throughout the meadow. There were few open patches observed or patches of obviously higher density; the meadow had an uncharacteristicly uniform look that has not been noted before in an LTEMP meadow. The photograph in Figure CH-5b is representative this uniformity across the meadow. Given this consistency across the meadow, it adds uncertainty as to whether the decrease in shoot density is a response to some negative condition or, conversely, ajust the natural state of the meadow under optimal conditions, especially give that the meadow showed further expansion in areal extent from 2019. The four seasons of survey data and observations in the Coecles Harbor eelgrass meadow have yet to provide a clear picture of what could be considered the normal state of this meadow. The other noteworthy finding from 2020 was the more than 40 acre increase in the size of the meadow. This "new" expansion could represent a true change in the area of the meadow from 2019-2020, or it could be an artifact of the differences in imagery quality between years allowing for more eelgrass signatures to be identified in 2020. Likely, the reason for such a great change in a short period of time is a combination of both factors.

Fort Pond Bay 2020

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, monthly, July through September for the 2020 season. Due to tampering with the logger station in its location southeast of the pier during 2019, the logger station was moved

Fort Pond Bay 2020

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-day intervals, monthly, for 2020.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.5	+2.2	13.3	+5.3	20.8
August	13.1	+0.8	11.5	+3.5	22.1
September	12.1	-0.2	10.8	+2.8	21.1

to the north side of the pier where it would be less accessible to the public. The monthly light data was analyzed and Table FP-1 includes the average daily Hcomp and Hsat values that were recorded at the Fort Pond site in 2020. The Fort Pond meadow recorded surplus hours of both Hcomp and Hsat for July and August, but September was mixed with the site falling short of the minimum Hcomp by 0.2 hours and Hsat with a 2.8 hour surplus.

An Onset Hobo temperature logger was deployed mid-June, 2020 to Fort Pond. Due to its location at the far eastern extent of the Peconic Estuary, high water temperatures would not be expected for this eelgrass meadow. The monthly average water temperatures presented in Table FP-1 show that the meadow did not approach the 25°C threshold that is of concern at other LTEMP sites. For the 2020 season, no daily average temperature exceeded 25°C, and the highest temperature recorded was 24.1°C, reported on 13 August, 2020.

Eelgrass Shoot Density

Monitoring in the Fort Pond Bay eelgrass meadow was conducted on 27 August, 2020. The average eelgrass shoot density calculated for the Fort Pond Bay meadow was 297 shoots·m^2 (Table FP-2; Figure FP-2).

Table FP-2. The average annual eelgrass shoot density for Fort Pond Bay from 2017-2020, including standard error.

Year	Mean Density	S.E.
2017	584	±58
2018	483	±49
2019	348	±43
2020	297	±34

The decrease in shoot density was not statistically significant, however it is a large enough of a decline to bear watching.

Macroalgae Cover

The average macroalgae cover for Fort Pond's 2020 eelgrass survey was 36%. The reported increase over the 2019 macroalgae cover was minor and found to be not significant. As the site includes extensive boulder fields, there is abundant hard structure supporting the growth of macroalgae. *Sargassum filipendula* is the dominant seaweed in this meadow, heavily colonizing rock surfaces from the shallow subtidal to depths approaching 15 feet. Other species common in the meadow included *Halosiphonia*, *Fucus*, *Ascophyllum*, *Chondrus*, *Polysiphonia*, *Grateloupia* (non-native), *Dasysiphonia* (non-native), and *Polysiphonia* species. A total of 12 species of macroalgae were identified during the 2020 survey at Fort Pond.

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using the New York State Department of Planning aerial photography taken in March 2020. The aerial imagery

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.)*
2020	48.19 acres (19.50 hect.)

*Aerial imagery quality prevented complete delineation of meadow.

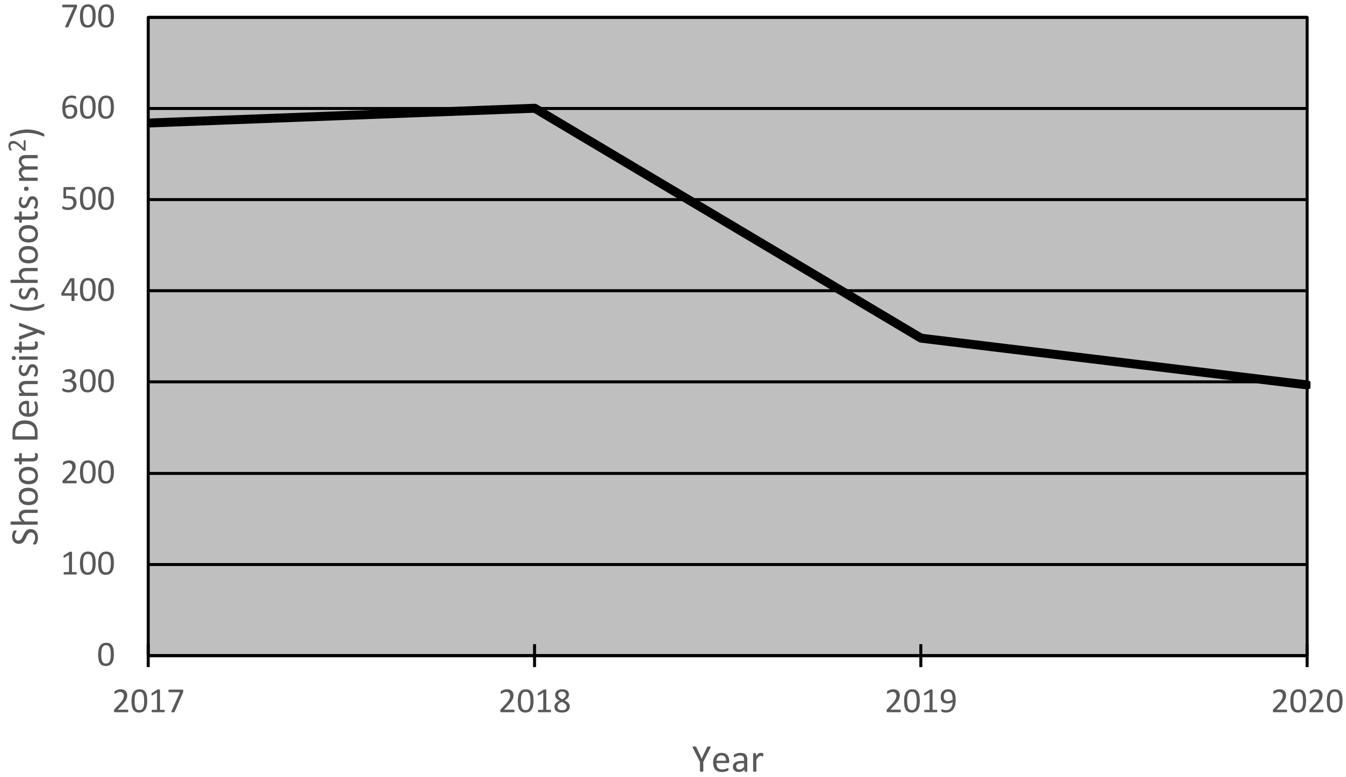


Figure FP-2. Graph of the annual mean eelgrass shoot density for Fort Pond Bay from 2017-2020.

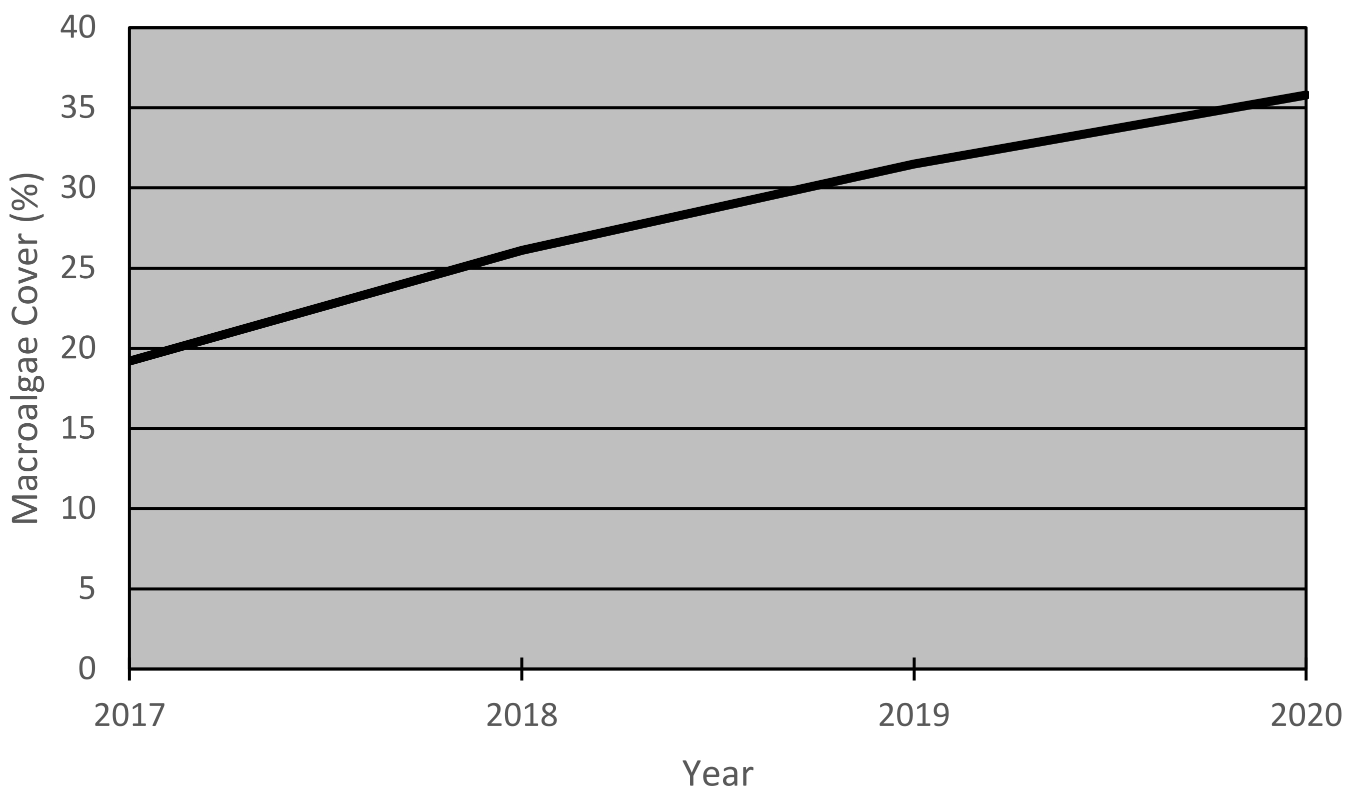


Figure FP-3. The annual mean macroalgae percent cover for Fort Pond Bay from 2017-2020.

Fort Pond Bay 2020

Figure FP-4. A comparison of Fort Pond Bay eelgrass meadow delineations completed in a) 2014, b) 2019 and c) 2020.

for 2020 provided a clear view of most of the meadow, however, the aerial images were confined close to shore resulting in a small section of the offshore edge of the eelgrass meadow being cut off. Compared to the

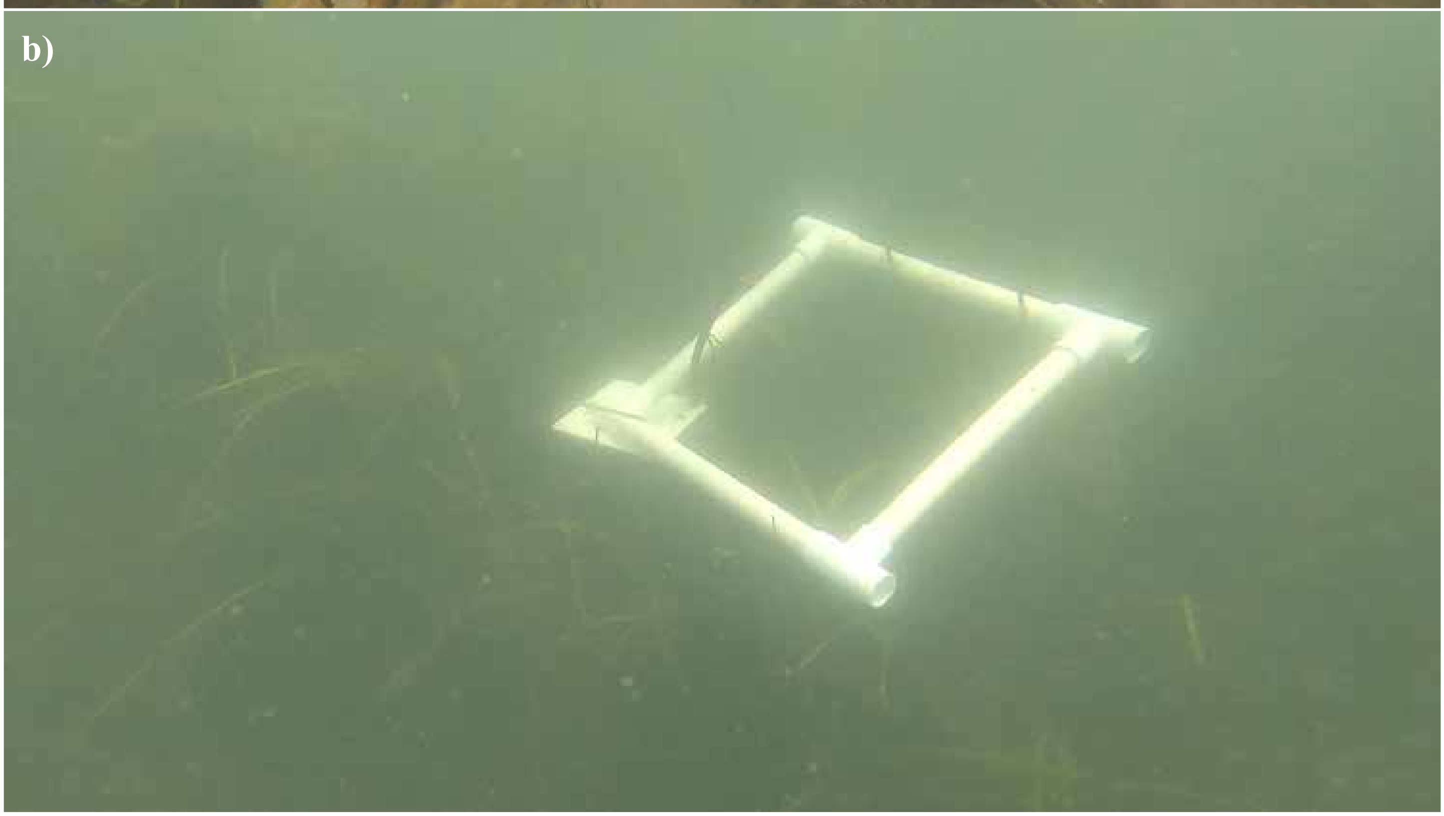


Figure FP-5. Underwater photographs taken during the course of completing the 2020 monitoring at the Fort Pond Bay eelgrass meadow. a) A juvenile sea bass stays close to the eelgrass meadow for protection from predators. b) A randomly tossed PVC quadrat sinks into the eelgrass meadow near station FP-4.

two previous seasons' aerial imagery (2018 and 2019) with waves and sun glint obscuring the western half of the Fort Pond meadow, the 2020 imagery provided a more complete view of the site. The Fort Pond eelgrass meadow covered 48.2 acres in 2020 (Table FP-3; Figure FP-4c). This represents a significant increase from the 35.8 acres delineated in 2017 and a minor increase from 42 acres reported from the 2014 Peconic

Estuary Eelgrass Survey.

Conclusions

The 2020 eelgrass monitoring survey for the Fort Pond found the eelgrass meadow to be healthy and thriving. Shoot density showed a decline from 2019, but the change was not significant. Light and water temperature in the meadow were reported within the optimal range for eelgrass and the increase in the extent of the meadow over its 2014 and 2017 delineated areas suggest that this eelgrass population is thriving. Divers did note that open, eroded patches seemed to be more common along the western portions of the meadow, where it has a greater northerly exposed to winter storms, but none of the patches were found to be extensive. With climate change, the impacts of storms on the meadow may increase, but compared to the stresses faced by other eelgrass meadows in the program, the Fort Pond meadow is one of the healthiest in the LTEMP.

Napeague Harbor 2020

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

Odyssey PAR light loggers were deployed monthly (July-September) for 10-day periods for the 2020 season. The light data was converted to average daily Hcomp and Hsat values presented in Table NAP-1. Light availability in the Napeague meadow was high in July and August for both Hcomp and Hsat, although Hcomp for August received a small surplus (+0.7 hours) of light. September typically sees a decline in available light due to decreasing daylength and seasonal weather patterns. For September 2020, Hcomp ran a -0.3 hour deficit but produced a 2.5 hour surplus.

The Onset HOBO TidBit v2 water temperature logger was deployed to the meadow in mid-June 2020. Average monthly water temperature are recorded in Table NAP-1. None of the three months reported an average temperature over 25°C for 2020. Over the 2020 season, the meadow recorded only 16 days with

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-day intervals, monthly, for 2020.

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	14.4	+2.1	12.9	+4.9	23.9
August	13.0	+0.7	11.4	+3.4	24.2
September	12.0	-0.3	10.6	+2.6	21.5

water temperatures over 25 days. The highest temperature recorded for the site was 28.1°C on 21 July, 2020. Considering the shallow depth at which the eelgrass meadow grows in Napeague Harbor, higher water temperatures should be expected, however significant groundwater discharge has been documented in the meadow and likely moderates the water temperature over the meadow.

Eelgrass Shoot Density

CCE personnel conducted the 2020 eelgrass survey in Napeague Harbor 1 September. The average eelgrass shoot density reported for 2020 was 554 shoots·m^2, which was a slight decrease from the 560 shoots·m^2 reported in 2019 (Table NAP-2; Figure NAP-2). The highest shoot density reported for 2020 was 1,310 shoots·m^2 in Station 2

Macroalgae Cover

The 2020 macroalgae cover in Napeague Harbor decreased to half of the percent cover reported in 2019 for the meadow. Macroalgae cover was 16% (Figure NAP-3) and consisted primarily of the red seaweed Spyridia filamentosa, but included Spermothamnion, Gracilaria, Codium and Ulva.

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using the New York State Department of Planning aerial photography taken in March 2020. Delineation of the Napeague Harbor eelgrass meadow identified 13.9 acres of eelgrass at the site (Table NAP-3; NAP-4d). The 2020 acreage is down 1.6 acres from the 15.5 acres delineated in 2019. Much of this decline was identified in the northern extent of the meadow where the meadow has split into two sections, as well as the continued expansion of unvegetated patches in the southern end of the meadow (Figure NAP-4d)

Conclusions

The Napeague Harbor eelgrass meadow was found to be in good health in 2020. Shoot density and areal extent of the meadow was stable between 2019 and 2020 with only slight changes in these parameters. Light and temperature parameters for the meadow continue A few points of concern were noted during the 2020 survey. First, the expansion of unvegetated patches in the southern end of the meadow have observably increased in size. The mooring of boats within this area of the meadow has been identified as a negative impact in previous LTEMP reports, and winter storms may be contributing to the expansion of the open

Table NAP-2. The average annual eelgrass shoot density for Napeague Harbor from 2017 to 2020, including standard error.

Year	Mean Density	S.E.
2017	806	+/-63
2018	479	+/-44
2019	560	+/-44
2020	554	+/-50

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.)
2020	13.9 acres (5.63 hect.)

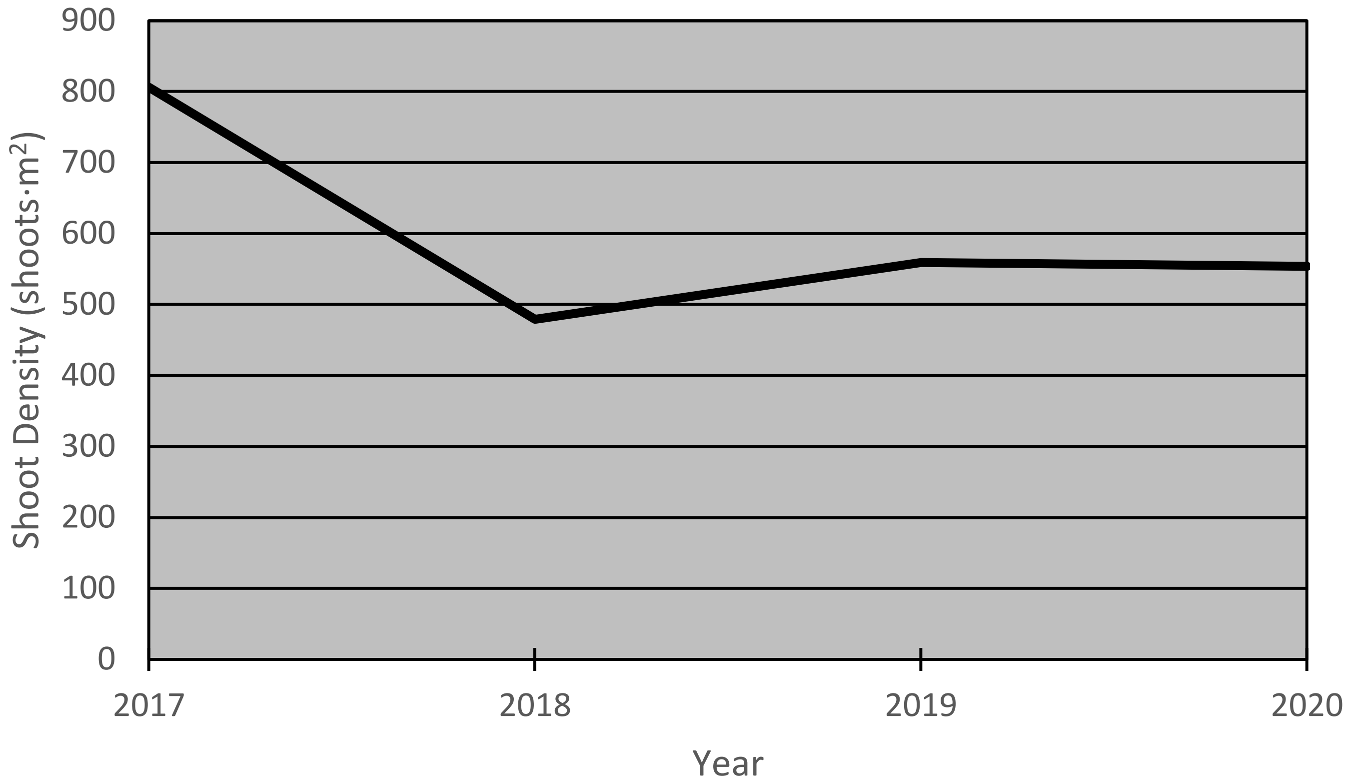


Figure NAP-2. Graph of the annual mean eelgrass shoot density for Fort Pond Bay from 2017-2020.

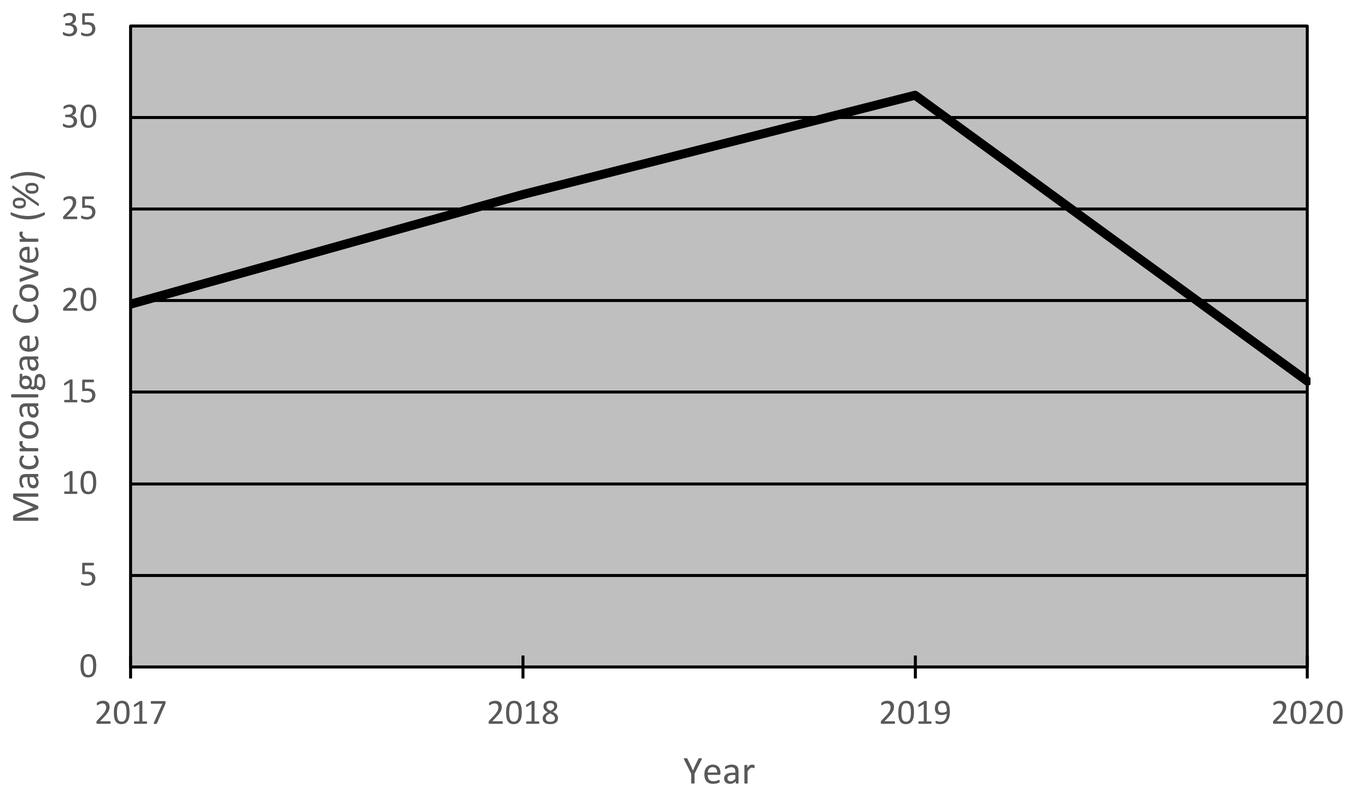


Figure NAP-3. The annual mean macroalgae percent cover for Fort Pond Bay from 2017-2020.

Figure NAP-4. A comparison of Napeague Harbor eelgrass meadow delineations completed in a) 2014, b) 2017 c) 2019, and d) 2020.

Figure NAP-5. a) A blue crab foraging for food in the eelgrass meadow near station NH-1. b) Boats moored in the eelgrass meadow near station NH-5 at the southern end of Napeague Harbor.

patches created by the moorings. This may be an issue that could be addressed by the Town of East Hampton where moorings would not be allowed within eelgrass meadows. The second concern is the splitting of the meadow in the northern end of the harbor. This section of meadow has been continuous for as far back as CCE could find in aerial imagery. In 2019, CCE personnel had to abandon monitoring in this section of the meadow when the wind came up and generated greater than 2 foot waves, reducing visibility with stirred up sediment. While periods of wave action are not an uncommon occurrence at the site, it is possible that due to an increase in frequency of these events, coupled with the extremely shallow depth of the meadow in this area, wave exposure has increased and is becoming more of an impact on the eelgrass meadow than it had been in the past. If the split persist into next season, or worsens, restoration could be a consideration for revegetating this section of the meadow. The groundwater seepage survey conducted by Ron Paulsen included sampling sites in this area and there was significant seepage recorded, which would benefit potential restoration efforts.

Sag Harbor Bay 2020

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). The three individual eelgrass beds are referred to as Beds1-3 with Bed1 including stations SH1 and SH2, Bed2 containing SH3 and SH4, and Bed3 consisting of SH5 and SH6.

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

Site Characteristics

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

As in previous years, the Odyssey PAR light logger was deployed adjacent to the SH2 (Figure SH-1) monitoring station monthly, from July-September 2020. 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. The Sag Harbor eelgrass meadows received sufficient light throughout the monitoring period to meet or provide a surplus for both Hcomp and Hsat. The 2020 season coincided with a drought in the region, which could account for the high light levels.

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-day intervals, monthly, for 2020.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.3	+2.0	12.7	+4.7	24.4
August	13.1	+0.8	11.7	+3.7	24.9
September	12.3	0.0	10.9	+2.9	22.6

Sag Harbor Bay water temperatures for 2020 were found to be warmer, on average, than 2019. For 2020, monthly average water temperatures remained below 25°C for all three months (Table SH-1). Sag Harbor Bay did record 24 days of daily average temperatures over 25°C, which is eight more days than reported for 2019. The highest water temperature recorded for the site was 27.2°C on 30 July, 2020. While increase in temperauters from 2019 is notable, at this time, high water temperature is not a primary concern for the eelgrass meadows in Sag Harbor.

Eelgrass Shoot Density

Eelgrass monitoring for Sag Harbor Bay was conducted on 28 August, 2020. The combined average eelgrass shoot density for all three eelgrass beds was 247 shoot·m² (Table SH-2). This small increase in shoot density from 2019 does not represent a significant change for the meadows. Each of the three individual eelgrass beds at the site had an average shoot density calculated for them and the 2020 average was compared to the 2019 average. For Bed1, the 2020 survey found a significant increase in shoot density. In 2019, the average shoot density for Bed1 was 196 shoot·m² with the 2020 season reporting a density of 343 shoot·m², representing a significant increase between years. Bed2 experienced a significant decline from 2019 (233 shoot·m²) to 2020 (144 shoot·m²). Bed3 reported no significant change between 2019 (240 shoot·m²) and 2020 (255 shoot·m²).

Table SH-2. The average annual eelgrass shoot density for Sag Harbor from 2017 to 2020, including standard error.

Year	Mean Density	S.E.
2017	249	+/-16
2018	331	+/-25
2019	223	+/-15
2020	247	+/-17

Macroalgae Cover

Macroalgae cover within the Sag Harbor eelgrass meadow remained low for 2020 and only showed a slight increase over the 5% cover reported for 2019. The average macroalgae percent cover for 2020 was 8% (Figure SH 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. The individual eelgrass beds at within Sag Harbor Bay support varying biomass and species. Bed1, with its boulders and gravel bottom support large macroalgae species like *Sargassum* and *Codium* and have the highest percent cover of all of the beds (14% for 2020). Beds2 and 3 have lower macroalgae cover (8% and 1%, respectively) and included smaller species including *Spyridia filimentosa*, *Polysiphonia* sp., and *Agardhiella*.

Bed Delineation and Areal Extent

The 2020 meadow delineations were completed using

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.)
2020	48.0 acres (19.42 hect.)

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

Sag Harbor Bay 2020

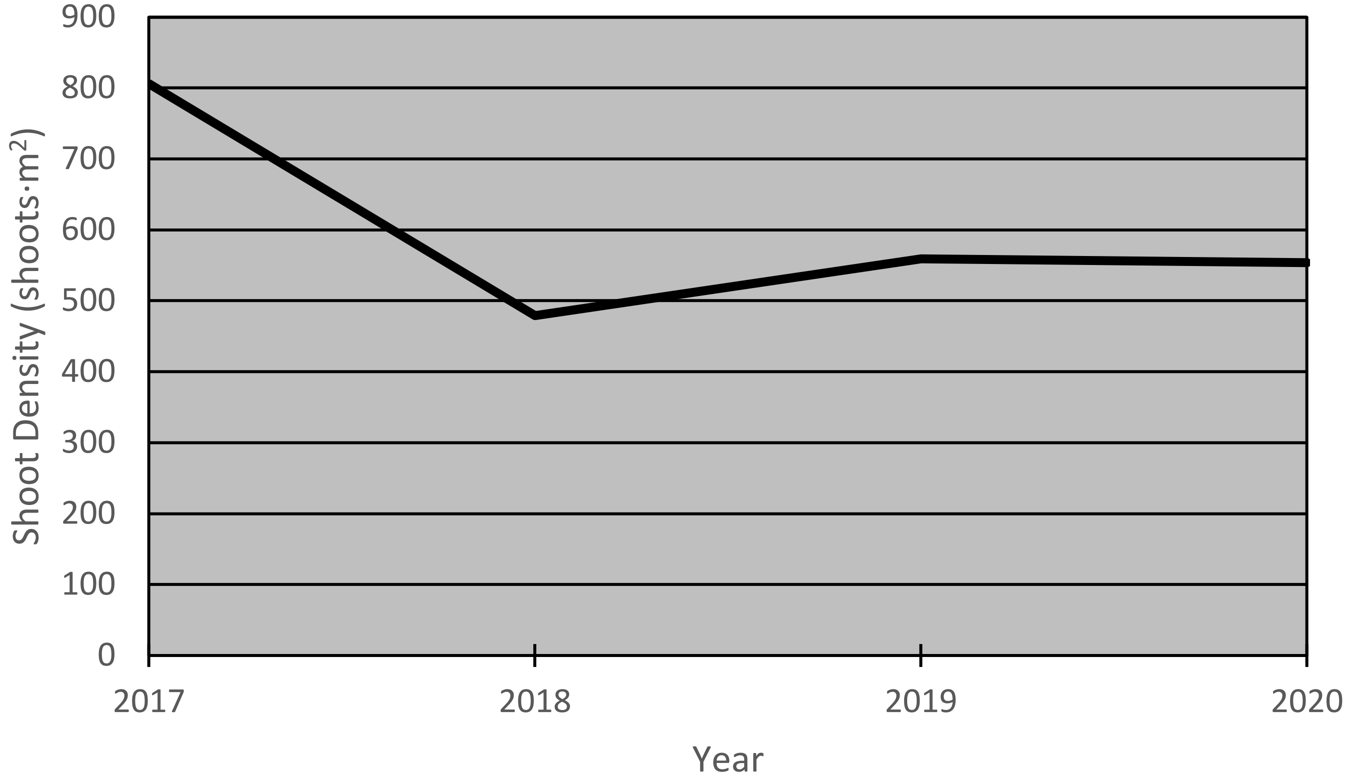


Figure SH-2. Graph of the annual mean eelgrass shoot density for Fort Pond Bay from 2017-2020.

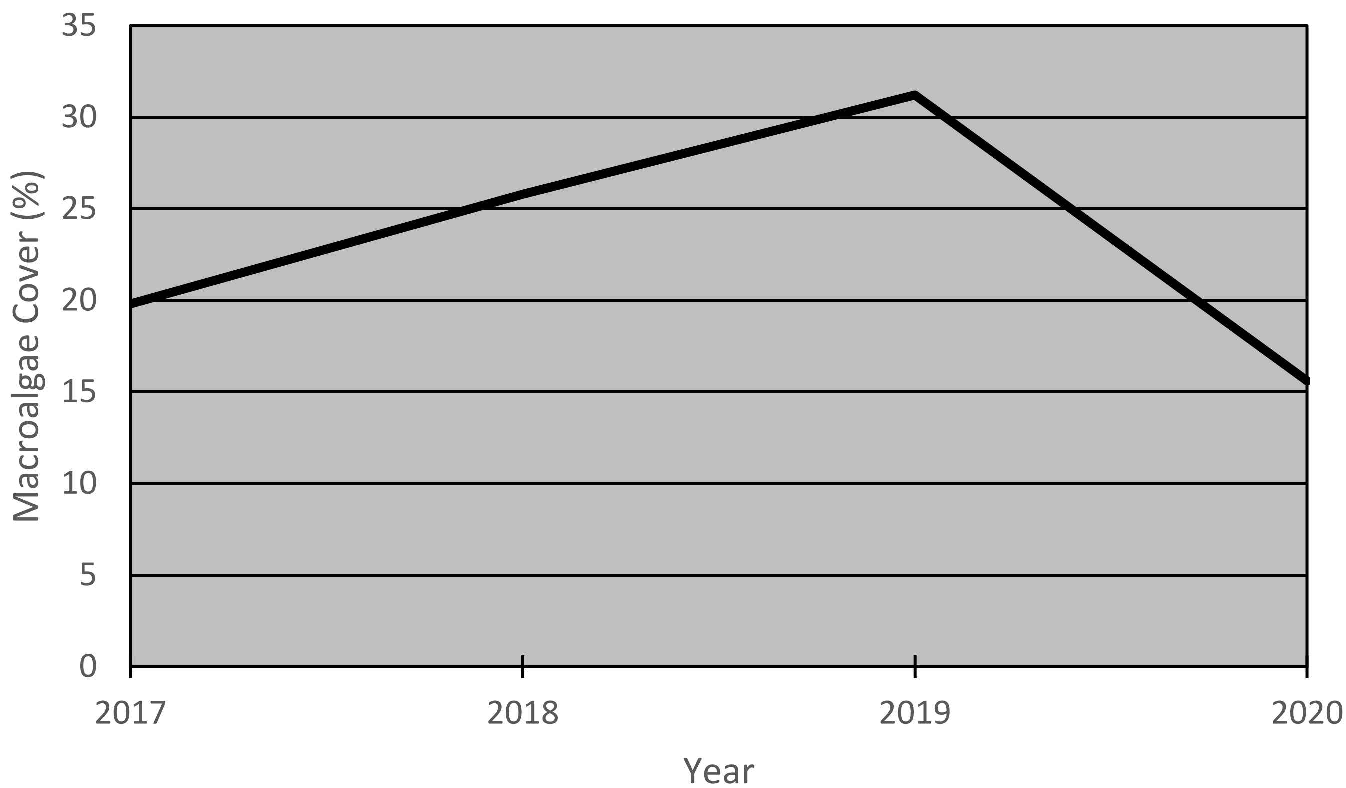


Figure SH-3. The annual mean macroalgae percent cover for Fort Pond Bay from 2017-2020.

Figure SH-4. Comparison of delineations between a) 2014, b) 2017, c) 2019 and d) 2020 for the Sag Harbor Bay eelgrass meadow complex.

the New York State Department of Planning aerial photography taken in March 2020. Based on the imagery, the three eelgrass beds making up the Sag Harbor Bay site covered a total of 48 acres (Table SH-3; Figure SH-4). While this a more than 10 acre increase from the 2019 delineations, there is no significant difference between 2017, the first year the meadow was delineated for the LTEMP, and the 2020 meadow extent. Aerial imagery quality can influence accurate eelgrass delineation, and in 2018, some of the

Figure SH-5. a) An adult scallop found in the meadow at station SH-2 during the survey. b) CCE diver aquires a “friend” while conducting a quadrat count. Northern puffers are regularly attracted to the monitoring activities hoping for a free meal.

imagery coverage of the site was so poor in quality, that it prevented complete, accurate delineation of the meadow (as noted in Table SH-3). While the imagery available for 2019 seemed to be of a quality that would produce a relative accurate delineation of the meadow, it appears, compared to 2020, that it did not produce an accurate mapping. Further, there is only a six month differrence in the date on which the aerial images were taken (September 2019 and March 2020), which would not be enough time, especially given the slow growth of eelgrass over winter, for the meadow to have recovered 10 acres. That leaves the comparison between 2017 and 2020 which shows the meadows have changed relatively little over the four years the site has been monitored.

Conclusions

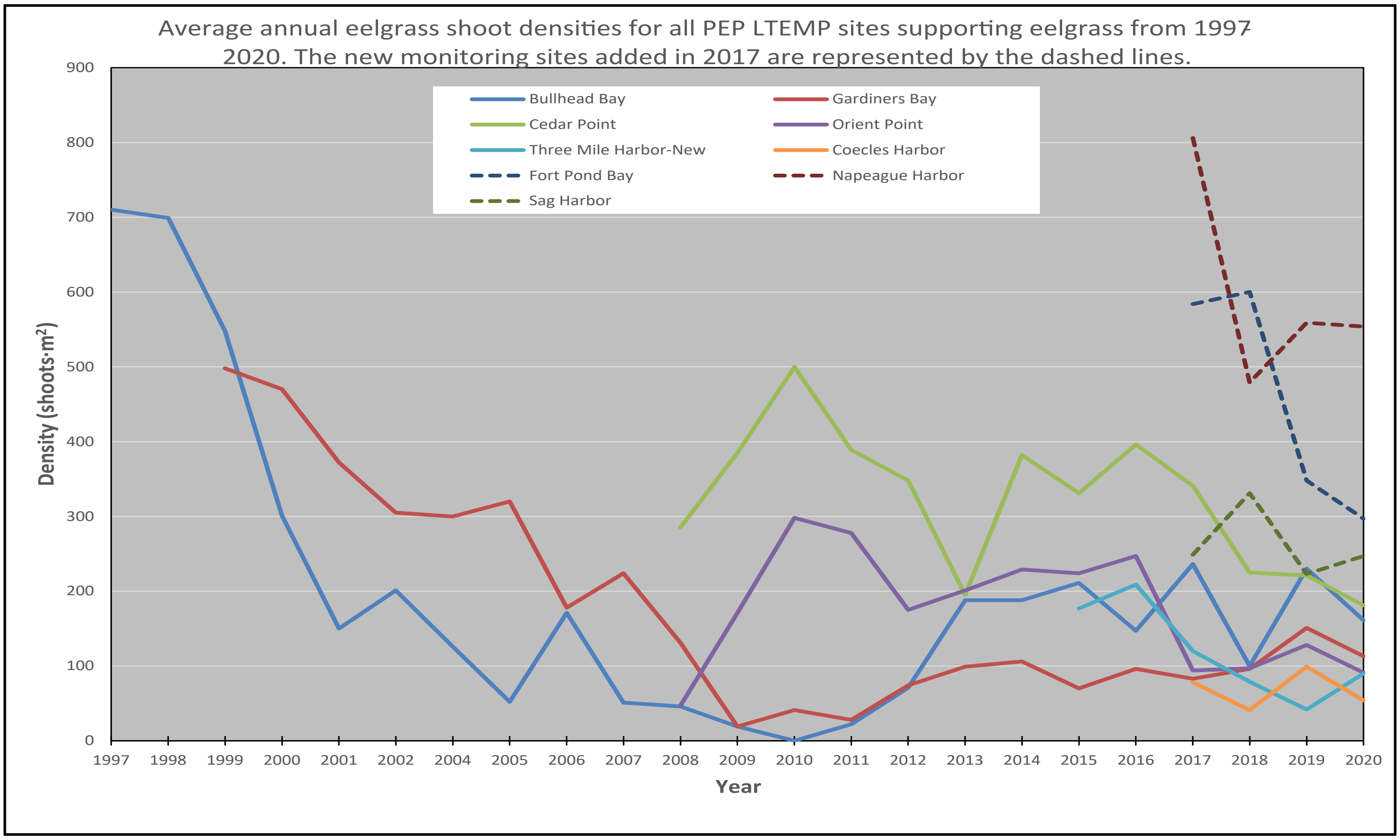
The Sag Harbor Bay eelgrass meadow complex has remained relatively stable over the four years it has been included in the monitoring program. The 2018 season showed some modest increases in shoot density and macroalgae cover, but there has been no significant changes in density and macroalgae cover for the remaining three monitoring seasons. The extent of the meadow has remained stable, as well, when comparing the 2017 and 2020 delineations, the two best imagery sets. The eelgrass population appears to be healthy and the environmental conditions in Sag Harbor Bay continue to be within tolerances for eelgrass. CCE has had success over the last several years with restoration plantings along the southern edge of eelgrass Bed2. Restoration plantings have shown low mortality rates, and transplant growth and spread has been the highest observed for restoration work in the Peconic Estuary. The site is included in CCE's restoration schedule for at least the next two years, at which time, the success of the restoration work should be obvious in aerial imagery.

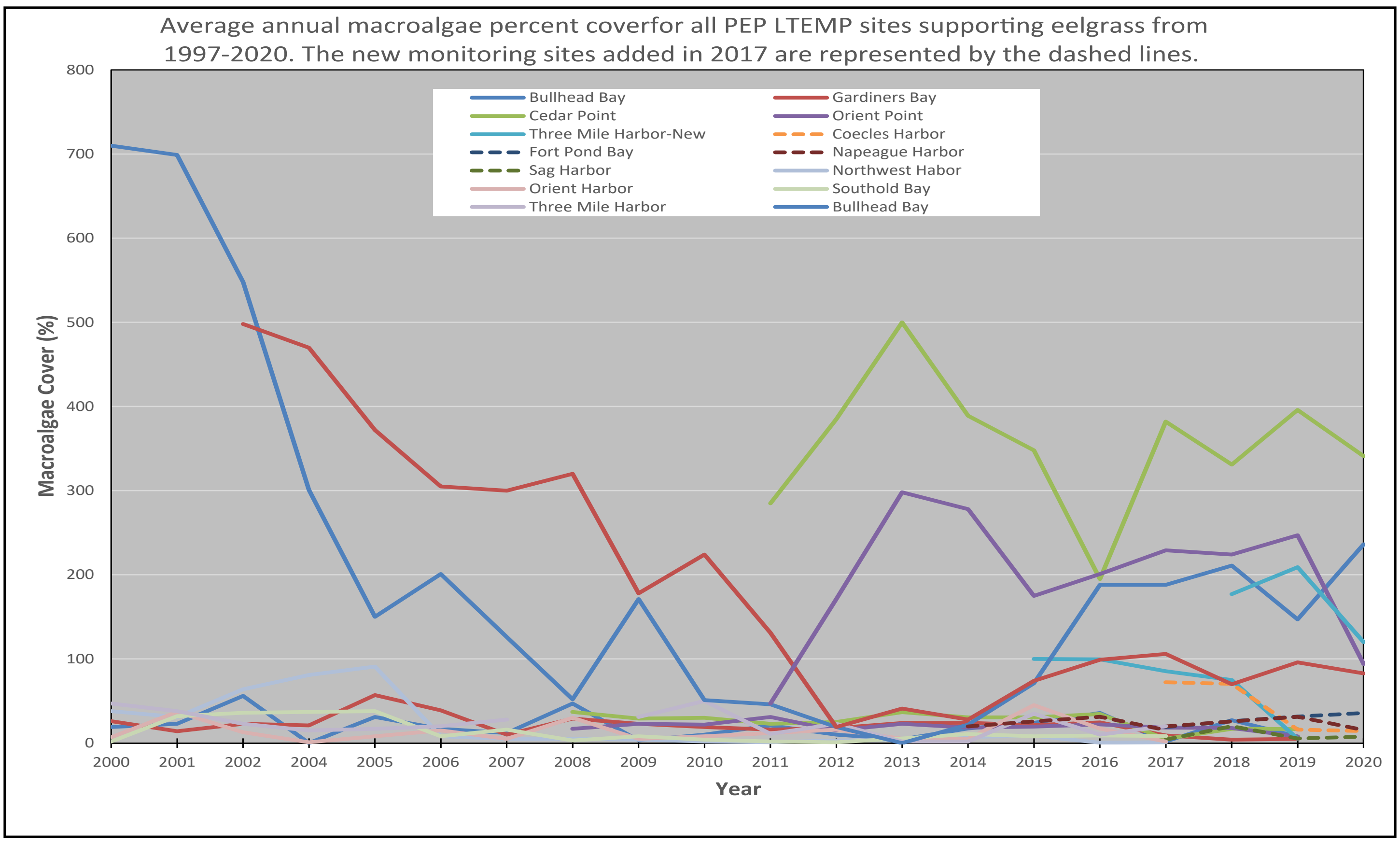
The Seagrass Bio-Optical Model for the Peconic Estuary, developed by Kaitlyn O'Toole and Brad Petersen (SUNY Stony Brook) identified several areas for eelgrass restoration within Sag Harbor Bay. Some of these sites were investigated by CCE for their restoration potential previously, but with little success. However, a few of the locations have been added to the list of eelgrass test sites and eelgrass restoration plantings should be completed within the next two years.

The main impacts to the eelgrass beds within Sag Harbor Bay continue to be human activity revolving around boating. The increase in the number and size of large vessels transitting the area or anchoring/mooring could result in increased erosion due to large wakes, increased incident of anchoring in the eelgrass meadows, particularly Bed2, or grounding incidents for the shallow meadows. Considerations for the protection of the Sag Harbor Bay meadows could include marking/posting eelgrass meadow locations, setting a reduced speed zone in the areas of the harbor that wakes would impact the meadows, providing educational pamphlets that could be distributed by harbormaster/dockmaster in Sag Harbor identifying the importance and locations of local meadows, and responsible navigation around these areas.

Appendix

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





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