Peconic Estuary Partnership 2021 Long-Term Eelgrass (*Zostera marina*) Monitoring Program

Progress Report 22

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

Submitted By:
Christopher Pickerell
and
Stephen Schott

Cornell University
Cooperative Extension
of Suffolk County

Executive Summary

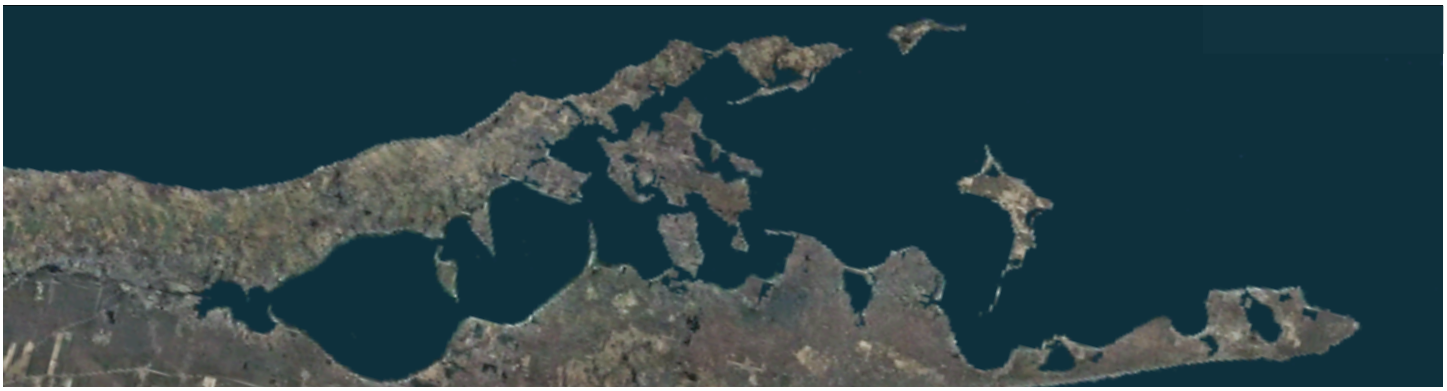
The nine PEP LTEMP sites were surveyed by CCE divers during the summer of 2021. The season started with the installation of light and temperature monitoring stations and deployment of water temperature loggers at all sites in late-May 2021. Monthly light logger deployments to the stations began in mid-July and finished in late-September 2021. Eelgrass monitoring surveys began in late August and were completed for all sites on September 15, 2021, due to weather-related delays. In early October all temperature loggers were retrieved for the season. A summary of all of the data collected for the 2021 PEP LTEMP season follows below.

Light availability and water temperature data was collected from all nine LTEMP sites in 2021. As with the previous season, light availability was high at all sites through 2021. Except for the month of September, all sites met, or exceeded, their light requirements (Hcomp and Hsat). During the September light logger deployment, none of the sites met their Hcomp threshold (12.3 hours). At Orient Point, the light logger was lost during its deployment. The 2021 season proved to be slightly cooler than the previous two seasons. During the 2021 season, seven monitoring 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. Only Bullhead Bay experienced at least 30 days (53 days) with average daily water temperatures above 25°C in 2021. Bullhead Bay was also the only LTEMP site that recorded daily average temperatures above 27°C, with 35 days.

The 2021 monitoring survey was initiated on August 25, 2021 and completed on September 15, 2021. For the 2021 season, two monitoring sites recorded increases in eelgrass shoot density, Cedar Point and Orient Point, from the densities reported in 2020. Four meadows: Bullhead Bay, Three Mile Harbor, Coecles Harbor, and Sag Harbor recorded significant declines in shoot density from the 2020. The remaining eelgrass meadows showed no significant changes in eelgrass density from the 2020 season. As with previous year, macroalgae percent cover was highly variable in 2021 over the nine sites. The majority of sites, six of the nine LTEMP sites, recorded no significant change in cover from 2020 to 2021, with the remaining three sites experiencing a significant decrease in macroalgae cover from 2020.

The 2021 meadow delineations were completed using Google Earth™ imagery from April, 2021. The imagery was good for most sites and produced accurate maps of the extent of the nine meadows. For 2021, two sites showed a decrease in the extent of the meadow based on the imagery, Orient Point and Fort Pond Bay. Three other sites suffered a decline noted at the time of their monitoring visit, Bullhead Bay, Three Mile Harbor, and Coecles Harbor. The remaining sites reported slight increases or no significant change from their previous extents.

The 2021 LTEMP season noted mixed results regarding the overall health of the nine meadows monitered. Four meadows recorded significant declines in shoots density with only two other meadows recording significant increases in density for the season. The almost complete loss of aboveground biomass in Bullhead Bay within a three-week period, was the most profound finding of the 2021 season. The Bullhead Bay meadow had been incredibly healthy for the season leading up to the monitoring visit, so it was a shock to find it gone, with no clear reason, on the day of monitoring. Some of the concern was alleviated during the fall of 2021 visits to Bullhead Bay observed widespread regrowth of shoots. Similar unexpected die-backs were observed in Coecles Harbor and Three Mile Harbor, with again, no clear causes, but regrowth was again evident in the fall. Climate change could be, at least in part, responsible for these events with the region suffering moderate drought conditions, then innundated over a 2-week period with almost 6-inches of rain, which could have lead to stress of the plants in these sites. None of the changes at the remaining LTEMP sites are alarming at this time, but their conditions will be re-evaluated during the 2022 monitoring season.



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

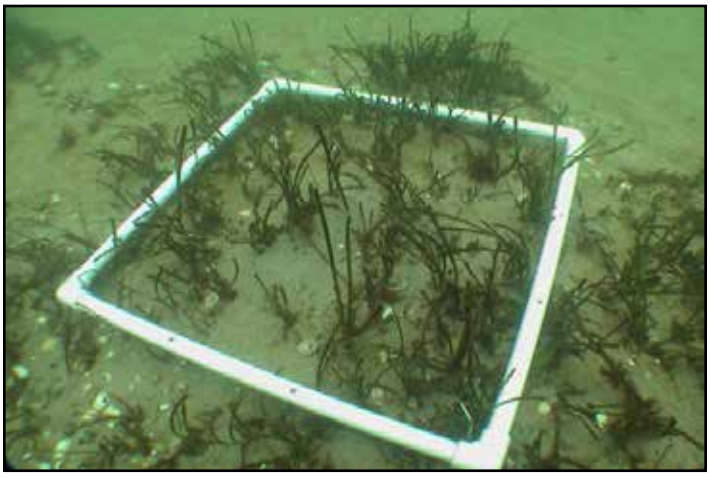


Figure Intro-1. A 0.10 meter^2 PVC quadrat used for eelgrass monitoring.

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 2021 season, Odyssey PAR loggers were deployed at all active monitoring sites.

Eelgrass Monitoring

The 2021 monitoring began on 25 August and completed on 15 September, 2021. 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

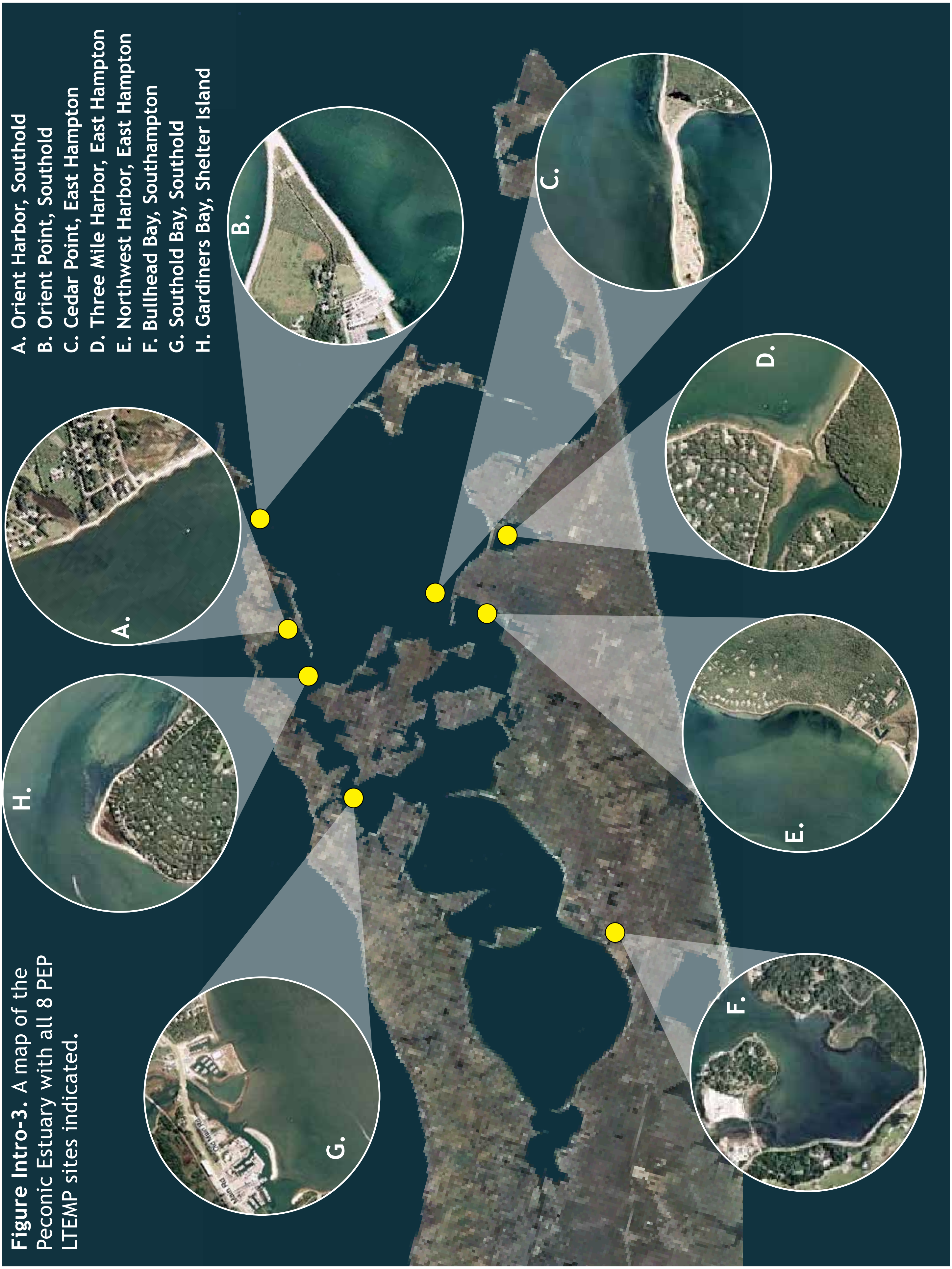


Figure Intro-3. A map of the Peconic Estuary with all 8 PEP LTEMP sites indicated.

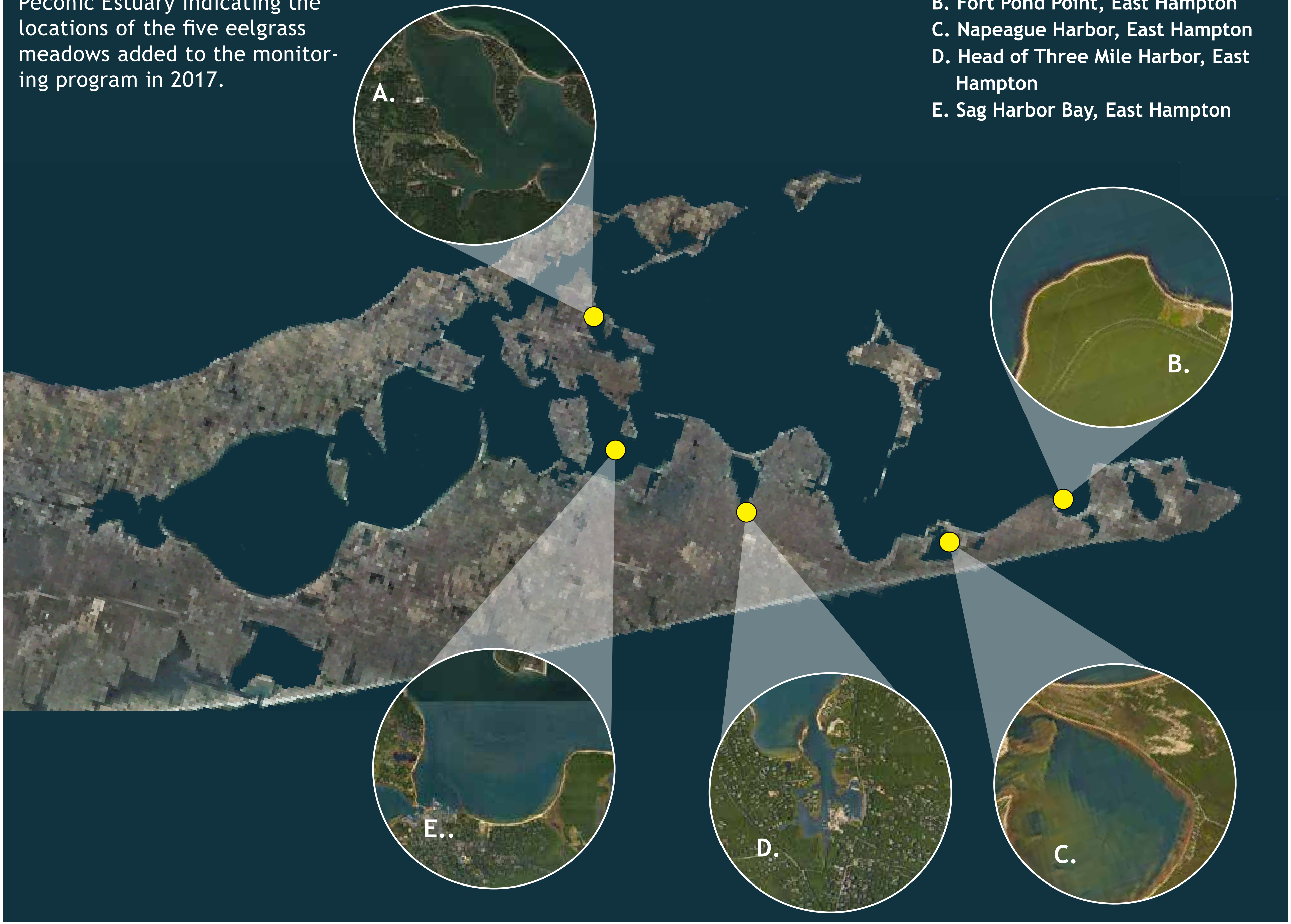


Figure Intro-4. A map of the Peconic Estuary indicating the locations of the five eelgrass meadows added to the monitoring program in 2017.

Introduction and Methods

The 2021 meadow delineations were completed using Google Earth™ imagery from April, 2021. 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 2021

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 2021.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.6	+2.3	13.5	+5.5	26.2
August	13.5	+1.2	12.0	+4.0	26.3
September	12.0	-0.3	10.9	+2.9	23.3

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. Relatively clear and dry weather conditions predominated the 2021 season leading to abundant light reaching the waters surface. This, combined with the exception water clarity observed on several occasions during the seasons in Bullhead Bay resulted in above average light penetration of the water column, resulting in high Hcomp and Hsat values recorded for the meadow (Table BB-1). September was the only month that failed to reach the minimal Hcomp (12.3h), with the meadow falling 0.3 hours short (Table BB-1).

Water temperature loggers were deployed in Bullhead Bay from late May through early October, 2021, with the average monthly water temperatures recorded for Bullhead Bay for July-September 2021 presented in Table BB-1. The 2021 season was cooler than the 2020 season with the Bullhead Bay meadow experienced 57 days with water temperatures exceeding 25°C, compared to 73 days in 2020. The meadow recorded 23 days (vs. 35 days in 2020) with water temperatures averaging above 27°C.

Eelgrass Shoot Density

The 2021 eelgrass monitoring visit to Bullhead Bay was conducted on 7 September. During the boat transit through Sebonac Creek and into Bullhead Bay, it became evident that something was significantly different from the recent visit on 18 August when the light logger was deployed. Water clarity was very poor and eelgrass was not readily observed from the surface.

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
2021	0	+/- 0

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

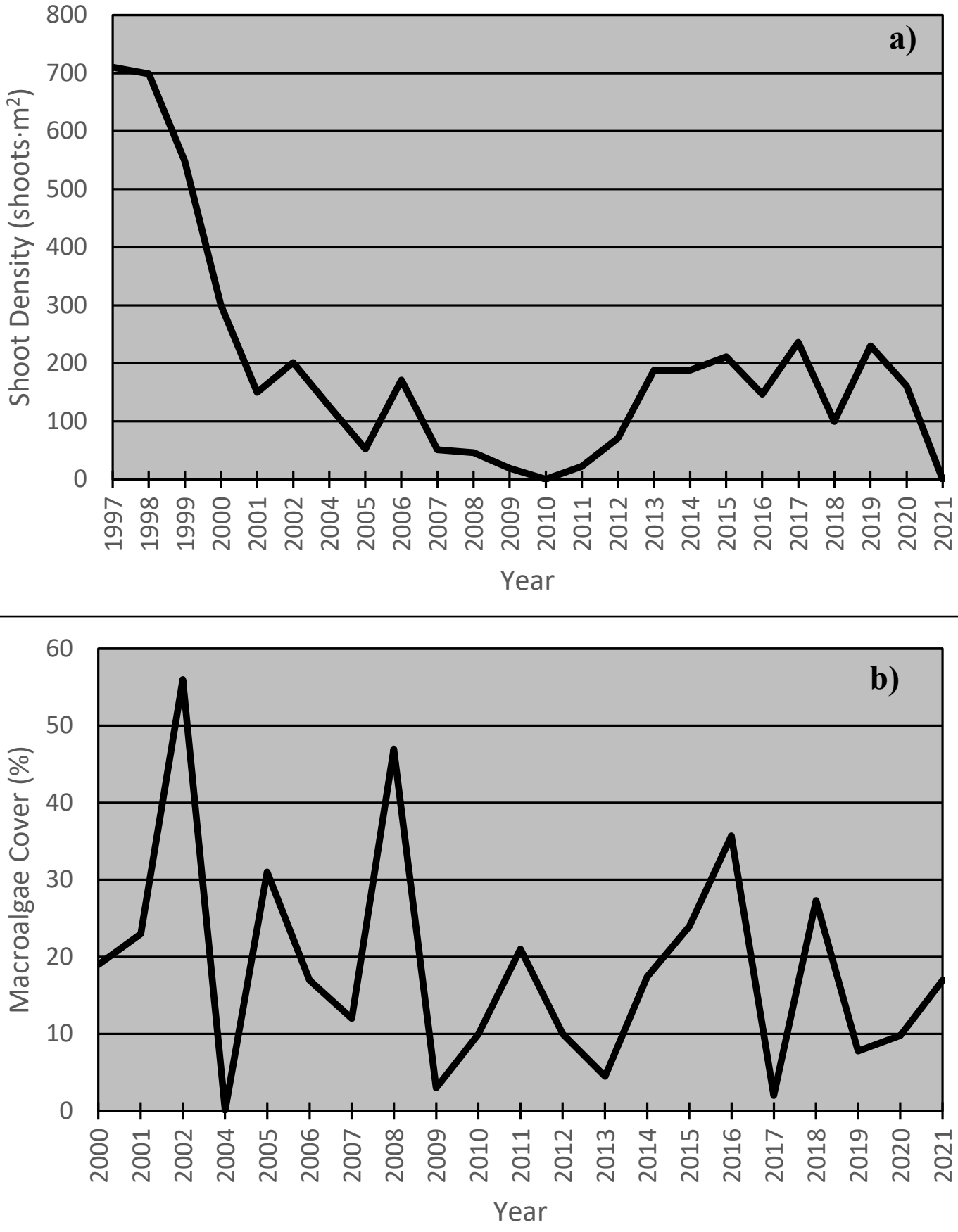


Figure BB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted in Bullhead Bay.

Figure BB-3. The 2021 delineation of the Bullhead Bay eelgrass meadow.

Once in the water, divers found that there were almost no standing eelgrass shoots at any of the monitoring stations. Divers recorded no eelgrass in quadrats at any of the six stations (Table BB-2; Figure BB-2a). The healthy eelgrass meadow observed just 3 weeks before was devastated, with only sporadic, healthy shoots present. Divers' examination of the rhizomes found some to be black and brittle (i.e. dead), but viable shoots were also present, providing some hope that there would be some regeneration of the meadow. Subsequent visits to Bullhead Bay in September to deploy and retrieve the light logger and in October to retrieve the temperature logger observed an increase in eelgrass shoots in parts of the meadow.

Macroalgae Cover

Macroalgae cover in the Bullhead Bay meadow increased from 10% (2020) to 17% (2021) (Figure BB-2b). Only a few species of macroalgae were recorded and included *Spyridia filamentosa*, *Gracilaria* sp., *Ulva lactuca*, *and Codium fragile. Cochlodinium polykrikoides* was observed in small patches throughout the meadow, but the bloom appeared to be of low density.

Bed Delineation and Areal Extent

The 2021 delineation of the Bullhead Bay eelgrass meadow was completed using aerial imagery from Google Earth™ from April 2021. The imagery, and groundtruthing by CCE, found that the meadow had expanded by just over 5 acres from 2020-2021 (Table BB-3). Expansion of the meadow continues into Sebonac Creek, since first noted in 2019 (Figures BB-3 and BB-4f). Based on the imagery, the meadow in spring of 2021 was almost continuous throughout the delineated areas with on two, small open area of significant size which are located in areas with depths extending beyound 6ft at mean low water. This delineation does not take into account the observed "die-back" in the meadow reported here as aerial images were not available for the period following the monitoring visit. If imagery showing this loss becomes available, the areal extent of the meadow will be adjusted to reflect the observations presented in this report.

Conclusions

The Bullhead Bay eelgrass meadow appeared to be thriving for most of the season, presenting an nearly continuous, dense seagrass meadow that had increased in area since the 2020. Within a three week period at

Table BB-3. Estimated areal coverage of the Bullhead Bay eelgrass meadow for select years from 2000-2021.

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.)
2021	65.5 acres (26.5 hect.)*

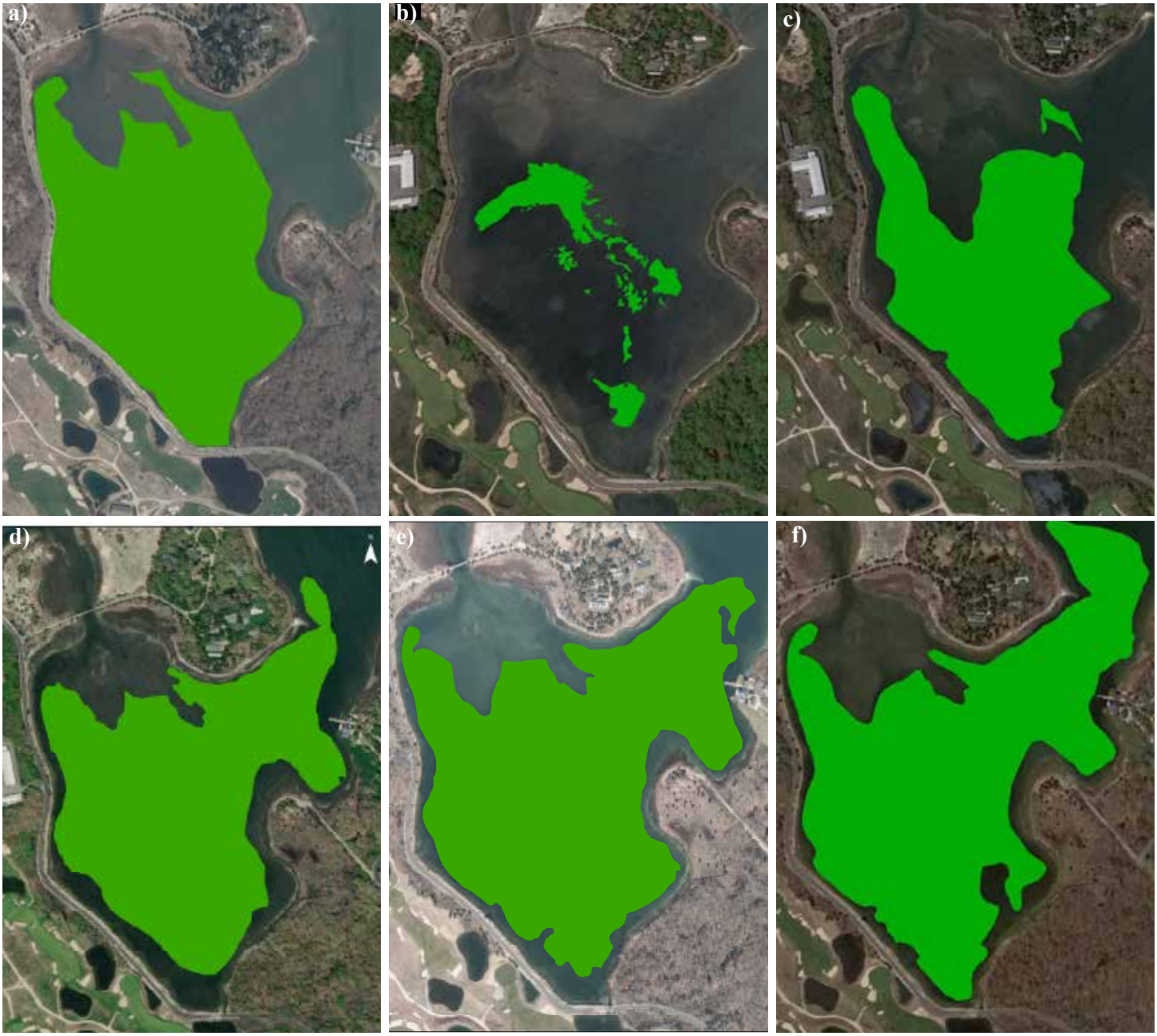


Figure BB-4. A series of aerial delineations of the Bullhead Bay eelgrass from 2000 through 2020. The years represented are a) 2000, b) 2010, c) 2016, d) 2019, e) 2020, and f) 2021.

the end of August and into early September 2021, that all drastically changed. CCE divers were prepared to deploy their quadrats in a large, lush eelgrass meadow, as they had been observing up through mid-August, but instead they found conditions in the meadow that were reminiscent of the 2010 monitoring season when no eelgrass was observed. The only difference between those seasons that lends some hope for a more rapid recovery of the meadow was that the rhizomes examined by divers during the 2021 monitoring visit were still fresh and viable, while in 2010, most were blackened and brittle. Subsequent visits to the site for gear deployment/retrieval did observe increased new growth in areas of the meadow. The cause of this "die-back" event is not clear, but it is likely tied to the extreme rainfall events that occurred in the region in late August into early September, as there was no evidence of a high temperature event that would have produced a similar response in the eelgrass meadow. Rainfall of close to 6-inches was recorded in less than a 2-week period during that time. This amount of rainfall could have resulted in a significant, temporary decline in salinity throughout the meadow, stressing the plants and resulting in the mass sloughing of shoots, but leaving behind healthy rhizomes. CCE does not have equipment deployed that records salinity, so this

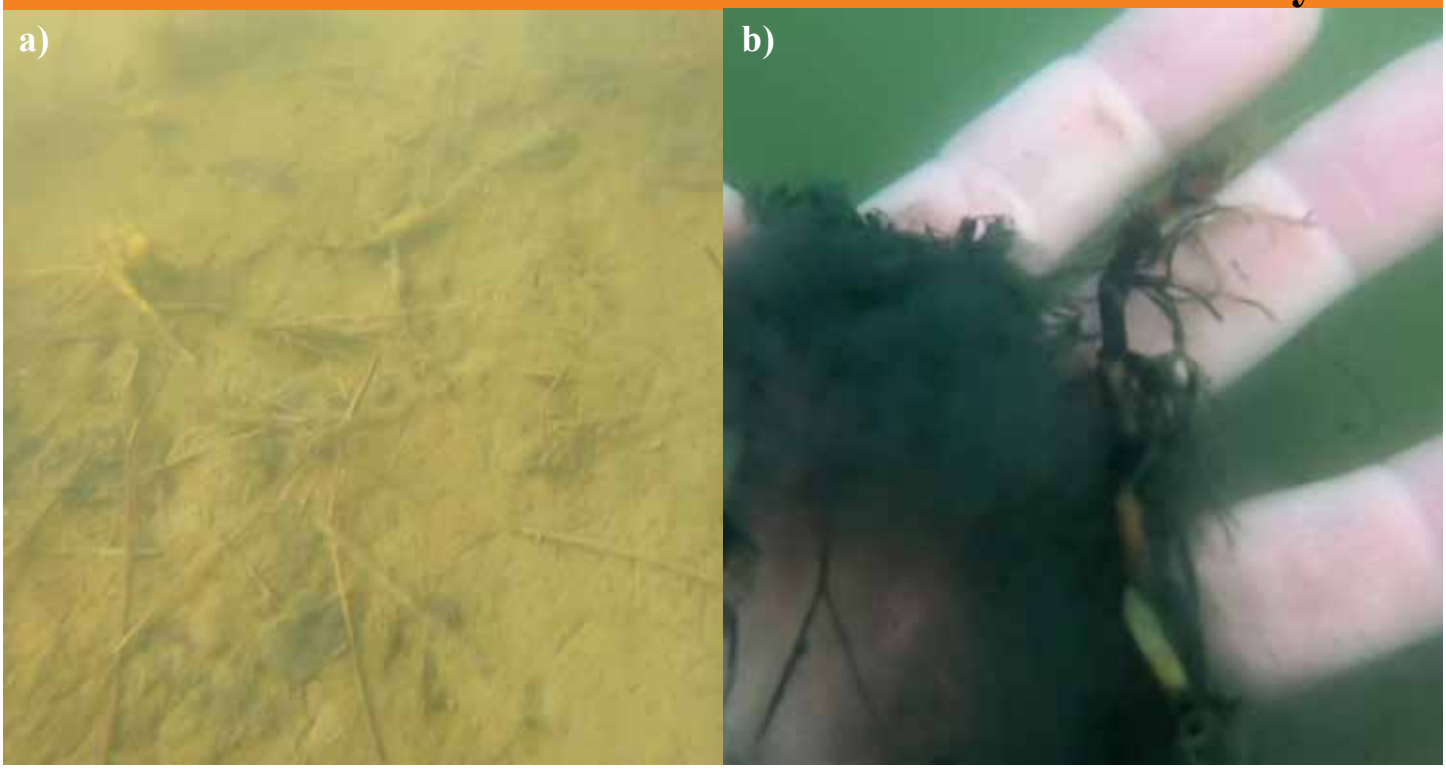


Figure BB-5. a) Remnants of eelgrass flower shoots scattered on the bottom of Bullhead Bay. b) Viable rhizome extracted from the sediment and examined by CCE diver.

hypothesis can not be confirmed, but given the lack of another obvious event that could affect the entire eelgrass meadow in this manner, this is the most likely cause. With the climate continuing to change and the increased frequency of severe weather and storms, this may be the first episode of what may become more common in future seasons. The observed regrowth in subsequent visits during the fall of 2021 provides some optimism that the meadow will recover from this latest impact to the Bullhead Bay eelgrass meadow.

The Gardiners Bay eelgrass monitoring site is located on the east side of Hay Beach Point on Shelter Island. The eelgrass meadow starts near the channel connecting Greenport Harbor to Gardiners Bay in the north and extends southward toward Cornelius Point (Figure GB-1). This site is the most exposed, high-energy eelgrass meadow of the original six monitoring sites. The eelgrass meadow is very patchy and an aerial view of the meadow (Figures GB-1 and GB-4) illustrates the natural appearance of a majority of the meadow.

Figure GB-1. An aerial view of the Gardiners Bay eelgrass meadow with monitoring stations indicated by the superimposed numbers.

Site Characteristics

The Gardiners Bay eelgrass monitoring site is situated in an area of high current and is exposed to significant fetch from the north to the east. This exposure causes the site to be especially influenced by winter storms. The current at this site is also the highest encountered at any of the monitoring sites. The eelgrass meadow is established on relatively shallow, sand flats to the south and west of one of the two main channels that connect Gardiners Bay to the western Peconic Estuary. Both the high wave exposure and high currents at this site have removed most of the finer sediments leaving the majority of the site's sediment as coarse sand to gravel (and shell). Organic content of the Gardiners Bay site's sediments, 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 2021

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 2021.

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July	14.6	+2.3	13.3	+5.3	23.3
August	13.2	+0.9	11.1	+3.1	24.4
September	12.1	-0.2	11.1	+3.1	22.9

periods of time.

Water quality has rarely been a factor in the health of this eelgrass meadow. The flushing that this site experiences is more than adequate to maintain nutrient concentrations at ambient levels for the eastern Estuary. Due to its significant fetch to prevailing winter winds, the turbidity can become high during storms, but suspended solids tend to settle quickly or be flushed shortly afterward. Water clarity also tends to decline with the outgoing tide. Depending on the time of year and/or the tide, drift macroalgae can be transported into the site by the currents and significantly reduce clarity. The effects of storms and macroalgae drift are examples of acute events that are infrequent at this site. Chronic water quality issues would be very rare at this site and would likely involve an Estuary-wide event, like Brown-Tide.

Light Availability and Temperature

A light logger was installed by CCE divers in the Gardiners Bay eelgrass meadow for 10-day deployments, monthly for July-September 2021. Light data collected during the 2021 season is summarized in Table GB-1, above. The Gardiners Bay eelgrass meadow received ample light throughout most of the 2021 season with only the month of September showing of deficit for the minimum required Hcomp (Table GB-1). For most of the season, the eelgrass received surplus light levels, allowing the plants to produce energy that could be stored or used directly to fuel growth and expansion of the meadow.

An Onset Hobo temperature logger was deployed in late-May, 2021 to continuous monitor water temperatures in the Gardiners Bay meadow for the season. The 2021 average monthly water temperatures for the Gardiners Bay eelgrass meadow are found in Table GB-1. The Gardiners Bay eelgrass meadow experienced a cooler season in 2021 than it did in 2020. No monthly average temperature in 2021 exceeded 25°C and the site only recorded 5-days where the daily average water temperture broke the 25°C threshold, compared to 19-days in 2020. Even the maximum water temperature recorded during the 2021 season, 25.6°C, was

Table GB-2. The average annual eelgrass shoot density for Gardiners Bay from 1999 to 2021, 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
2021	98	+/-19

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

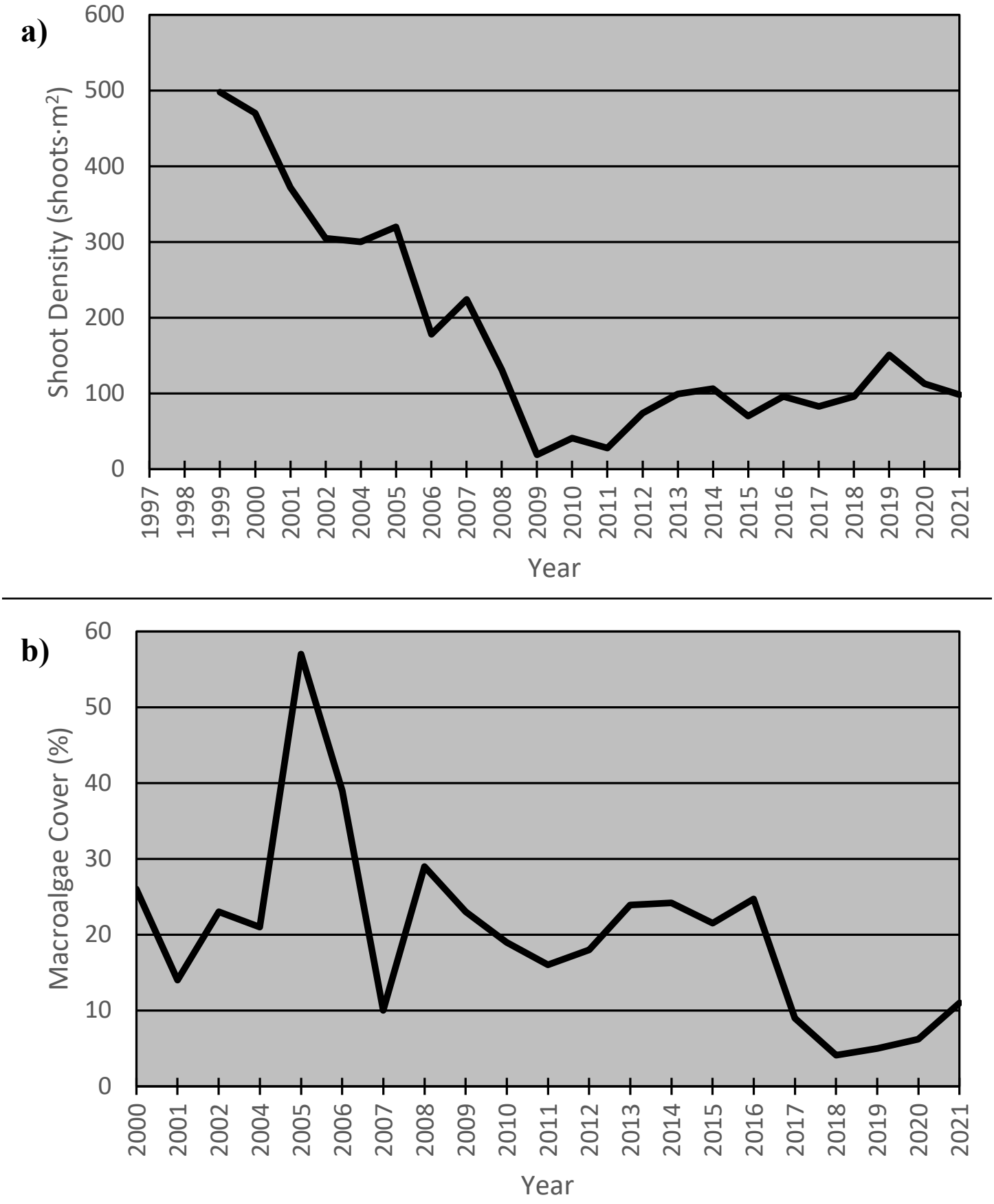


Figure GB-2. Graphs of average a) shoot density and b) macroalgae percent cover trends for all years of the PEP LTEMP conducted at the Gardiners Bay site.

Figure GB-3. The 2021 areal delineation of the Gardiners Bay eelgrass meadow on the northeast shore of Shelter Island, NY.

almost 2°C cooler than the 27.5°C reported for 2020.

Eelgrass Shoot Density

The Gardiners Bay meadow's monitoring visit was conducted on 7 September, 2021. The eelgrass shoot density showed a slight, insignificant decline from the 2020 (Table GB-2; Figure GB-2a), from 119 shoots·m^2 (2020) to 98 shoots·m^2 (2021). In 2020, it was reported that eelgrass was observed growing adjacent to monitoring station 4, but no eelgrass was recorded within the station's sampling. During the 2021 season, it appears that the eelgrass had expanded into monitoring station 4, and the first quadrat with eelgrass was recorded at the station in recent years.

Macroalgae Cover

The macroalgae biomass at the Gardiners Bay site recorded a small, 5% increase, from the 2020 (Figure GB-2b). The 2021 percent cover of 11% follows the low, reported macroalgae cover at this site over the past several seasons. Macroalgae species that were reported included *Spyridia filamentosa*, *Gracilaria* sp., *Sargassum filipendula, Polysiphonia* sp., *Ulva lactuca*, *Codium fragile*, and *Dasya baillouviana*.

Table GB-3. The estimated areal coverage of the Gardiners Bay eelgrass meadow from 2000-2021.

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.)
2021	20.48 acres (8.29 hect.)

Bed Delineation and Areal Extent

The Gardiners Bay eelgrass meadow's 2021 extent was delineated using Google Earth™ imagery taken in April 2021. Based on this imagery, the overall area of the meadow has not changed from its 2020 extent. The 2021 meadow covered 20.48 acres, which represents an insignificant change from the 2020 area (20.67 acres) (Table GB-3; Figure GB-4).

Conclusions

Based on the findings from the 2021 monitoring season, it seems like the Gardiners Bay eelgrass meadow is remaining relatively stable for the parameters reported. Water quality conditions, light and temperature, were found to be within the optimal range for eelgrass, supporting healthy growth which is maintaining the meadow and supporting recruitment in previously unvegetated area along the offshore edge near station 4. The recent series of warm winters have also likely contributed to the overall health of the meadow by extending the active growing season of eelgrass on both ends (spring and fall). The increased frequency of storm/wind events that generate waves that could be damaging to the meadow at this location are a con-

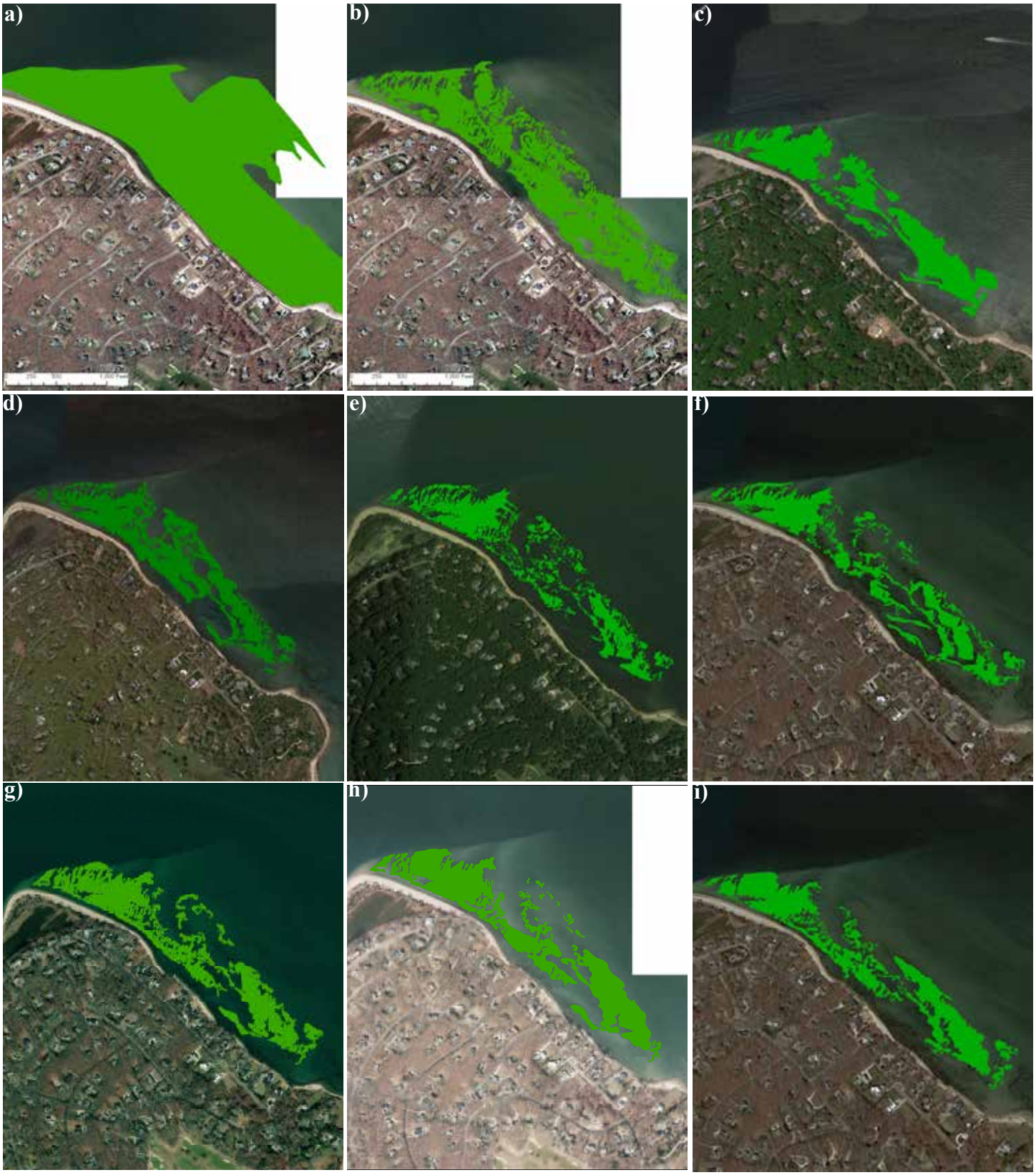


Figure GB-4. A series of aerial delineations of the Gardiners Bay eelgrass from select years from 2000 through 2016. The years represented are a) 2000, b) 2010, c) 2015, d) 2016, e) 2017, f) 2018, g) 2019, h) 2020, and i) 2021.

Figure GB-5. Underwater photographs taken by CCE divers while conducting the 2021 eelgrass monitoring at the Gardiners Bay LTEMP site. a) Bug scallops were abundant throughout the Gardiners Bay site both on open bottom and attached to eelgrass blades b) Northern puffers were constant companions to divers during the monitoring.

cern, but the site providing optimal growth conditions throughout the season (and possibly extended season) may be allowing the meadow to offset the impacts from storm damage.

Human activity in the eelgrass meadow has declined in recent years. Evidence of clamming has been infrequent and the number of boats moored in the meadow has decreased, although the number of moorings has been maintained. As the meadow has migrated inshore over time, there is less interaction with boats prop-dredging through the meadow, however, if there is continued, successful recruitment and expansion along the offshore edge in the future, the issue of boats not maintaining their course in the navigation channel will become an issue for the meadow once again.

CCE is considering attempting restoration test plantings at the site to determine the viability of larger-scale plantings along the offshore edge of the existing meadow. The major factor of concern is the high-current and wave action of the site eroding newly planted eelgrass before it has had time to root securely. Seeding at the site would also pose difficulties caused by currrents washing seeds out of a viable zone of growth or waves over-burying seeds or washing out seedlings. Given that there has been evidence of natural recruitment at the site, restoration is potentially viable, but it will require some consideration before pursuing at a significant scale.

Three Mile Harbor 2021

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 2021.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.6	+2.3	13.7	+5.7	24.0
August	13.1	+1.8	12.2	+4.2	24.9
September	12.2	-0.1	11.1	+3.1	23.0

Odyssey PAR loggers were deployed for 10 days during July, August, and September, 2021 at the meadow at the head of Three Mile Harbor. Table TMH-1 includes the results from those deployments. Overall, the Three Mile Harbor eelgrass meadow received more that its required minimal light levels for both Hcomp and Hsat for 2021, with the only exception being the Hcomp for September when the meadow missed its minimum threshold by 0.1 hours. This shortfall would have a minimal overall effect on the health of the meadow given the results from the rest of the season.

An Onset Hobo water temperature logger was deployed to Three Mile Harbor in late-May, 2021. Average monthly temperatures recorded for the 2021 season are presented in Table TMH-1. While Augusts average temperature approached 25°C, it did not exceed the threshold. The 2021 season was cooler that 2020 with 25 days of temperatures greater than 25°C and no days recorded over 27°C. The maximum water temperature recorded was 26.6°C on 27 August, 2021, almost 3°C cooler than the maximum temperature from 2020.

Table TMH-2. The average annual eelgrass shoot density for Three Mile Harbor (new site) from 2015 to 2021, 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
2021	15	+/- 5

Eelgrass Shoot Density

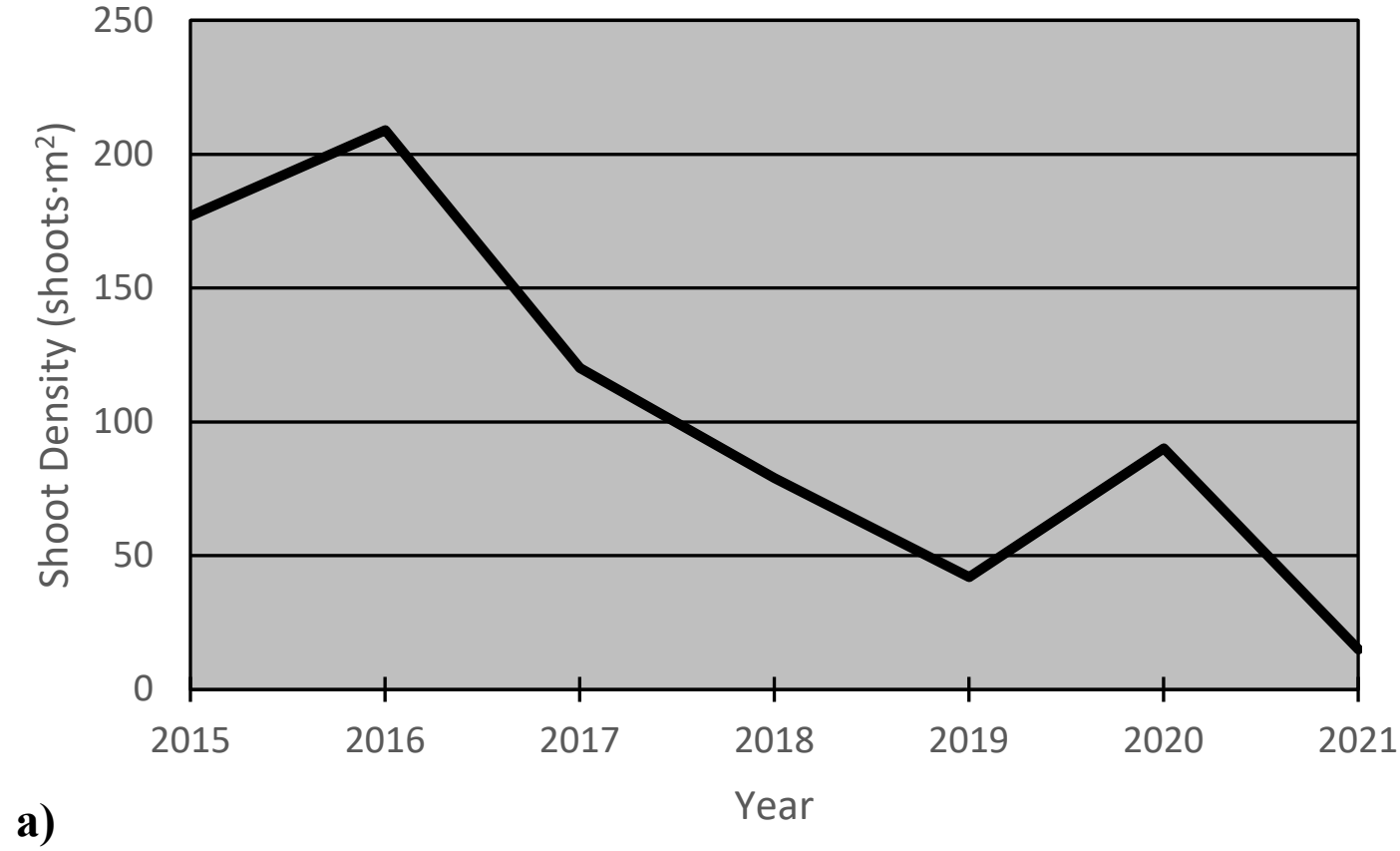
Three Mile Harbor was visited on 26 August, 2021. The monitoring survey was conducted at the two stations in the 'new' site at the head of the harbor. The 2021 monitoring visit recorded a significant decline in the eelgrass shoot density from 90 shoots·m^2 (2020) to only 15 shoots·m^2 (2020), on average (Table TMH-2; Figure TMH-2a). Eelgrass was only observed in station 1. The diver monitoring station 2 noted clusters of upright, but dead eelgrass shoots and seemly healthy rhizomes throughout the monitoring site.

Macroalgae Cover

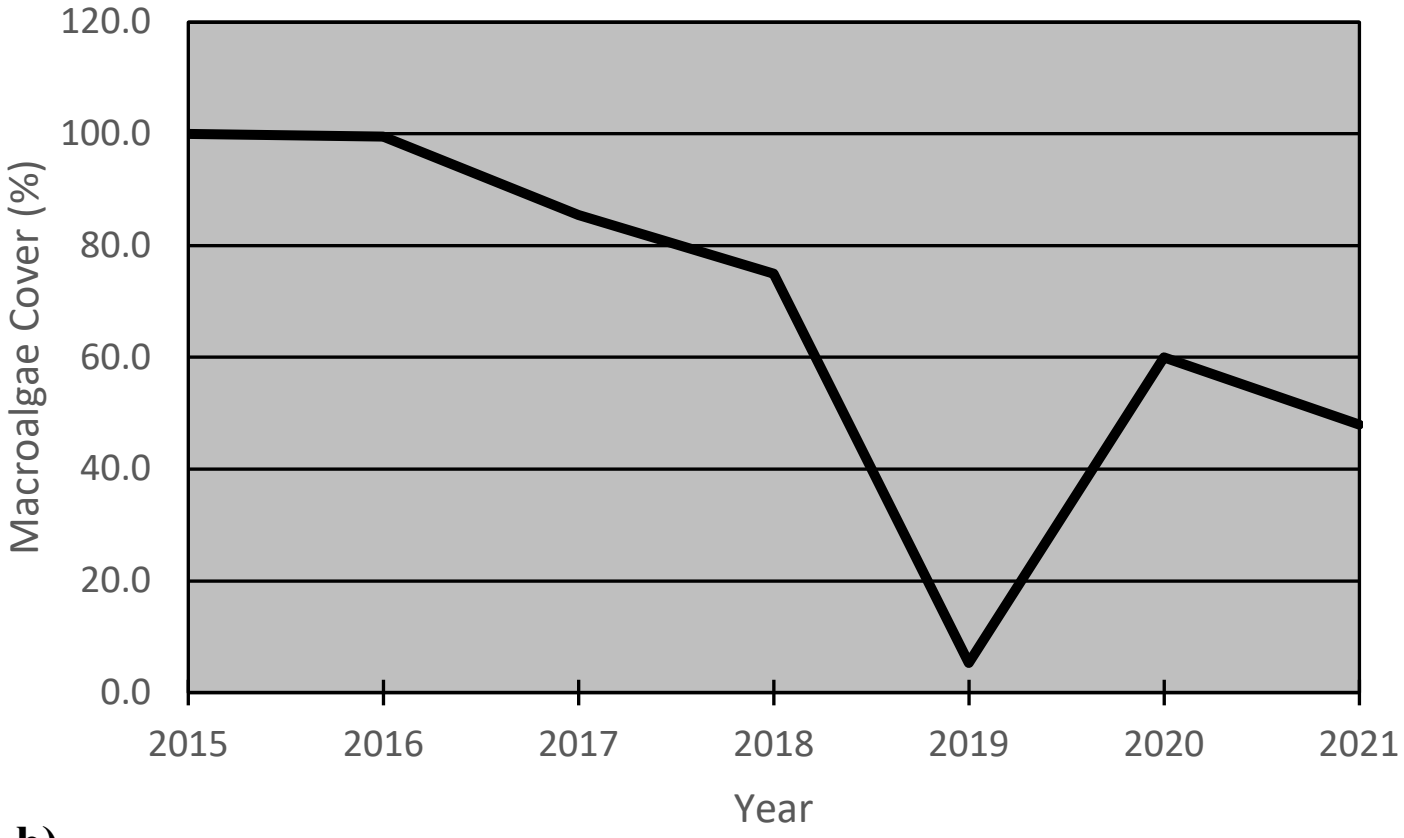
Table TMH-3. The estimated cover of eelgrass in Three Mile Harbor for all years surveyed.

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.)
2021	3.74 acres (1.51 hect.)*

*Meadow extend at time of monitoring was significantly smaller.



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) 2019, c) 2020, and d) 2021 meadow delineations.

Macroalgae cover declined from 2020 to 2021 at the new Three Mile Harbor site (Figure TMH-2b). The 2021 macroalgae cover was recorded as 48%, a 12% decline from 2020. *Spyridia filamentosa* was a monoculture across both stations, with other species only present outside of the monitoring stations in shallower

Figure TMH-4. A small cluster of eelgrass shoots occupying one of the rare areas of the meadow not overgrown by *Spyridia*.

water.

Bed Delineation and Areal Extent

The 2021 meadow delineations used Google Earth™ imagery captured in April 2021. As the imagery was captured in early spring 2021, it, unfortunately, does not reflect the extent of the meadow at the time of the monitoring visit. The loss of eelgrass in the southern meadow (Figure TMH-3d) was not accounted for but the total acreage was marked by an asterisk (Table TMH-2) explaining that the total did not represent the meadow extent at the time of monitoring. Based on the delineations, and not adjusted for the loss of eelgrass noted during monitoring, the meadow had expanded by almost 0.75-acres in the spring 2021 compared to 2020. This was the second year of delineations in which the meadow had shown expansion.

Conclusions

CCE visits each of the meadows at least twice monthly from July-September while deploying/retrieving light loggers to the monitoring sites. While a diver is only in the water briefly at this time, observations of the meadow are made from above water as the boat navigates the meadow toward the logger site. During the 2021 season, it was observed that the northern eelgrass meadow was unusually dense compared to previous years and that eelgrass was evident growing further north along the shore than had been noted previously. Until the day of the monitoring visit, the decline in the Three Mile Harbor meadows was not apparent. There had been a significant rainfall event on 23 August of over an inch, but this was unlikely to have resulted in a significant salinity change like that hypothesized for Bullhead Bay. The temperature data shows that the meadow was experiencing a late season water temperature spike leading up to the monitoring visit. This elevation in temperature, along with other unidentified factors, could have resulted in sloughing of eelgrass shoots, resulting in the significant decline of shoot density. This response by eelgrass to stressors, such as elevated water temperatures, is common in southern populations (e.g., Chesapeake Bay) and this may become a more common event in local meadows as climate continues to change. Follow-up monitoring in 2022 of the site will determine if there was any long-term damage done to the meadow.

Cedar Point 2021

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 2021 at Cedar Point, East Hamp-

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 2021.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.6	+2.3	13.4	+5.4	22.5
August	12.4	+0.1	10.3	+2.3	23.8
September	12.1	-0.1	10.9	+2.9	22.6

ton. As has been the trend with previous monitoring sites discussed above, the Cedar Point eelgrass meadow received sufficient light to meet its Hcomp and Hsat needs for July and August 2021 (Table CP-1). In September 2021, Hcomp ran a deficit of 0.1 hours, but received enough light to produce a surplus in Hsat (+2.9 hours) (Table CP-1).

The water temperature logger for Cedar Point was deployed late-May 2021, near monitoring station 3. Water temperatures during the 2021season were, on average, about the same as those recorded in 2020, with daily average temperatures ranging above 25°C for only 3 days, but with a recorded high temperature of 25.3°C (27 August, 2021), a degree cooler than 2020's high temperature.

Eelgrass Shoot Density

The Cedar Point monitoring visit was conducted on 28 September, 2021. The average eelgrass shoot density for 2021 was found to have increased signficantly from 2020 with a density of 252 shoots·m^2 (Table CP-2; Figure CP-2). The density recorded for 2021 represents a recovery of the meadow from the decline it experienced from 2019 to the 2020 monitoring visits.

Macroalgae Cover

Macroalgae cover in the Cedar Point eelgrass meadow was reported at its second lowest percent cover at 11% in 2021 (Figure CP-3). This represents a more than 20% decrease from the percent cover in reported for the 2020 season at Cedar Point. *Sargassum filipendula* remains the primary macroalgae species inhabiting the Cedar Point eelgrass meadow, occupying the coarser gravel-cobble sediments and boulders, where eelgrass dominates the open, sandy sediments. Other species of note included other rockweed (*Fucus*) species, S*pyridia filamentosa*, *Chondrus crispus*, *Halosiphon tomentosus*, *Codium fragile* and *Ulva* species.

Table CP-2. The annual average eelgrass shoot density for Cedar Point for 2008 through 2021, 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
2021	252	+/-27

Table CP-3. The estimated cover of the eelgrass meadow at Cedar Point for select years from 2000-2021.

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.)
2021	81.0 acres (32.78 hect.)

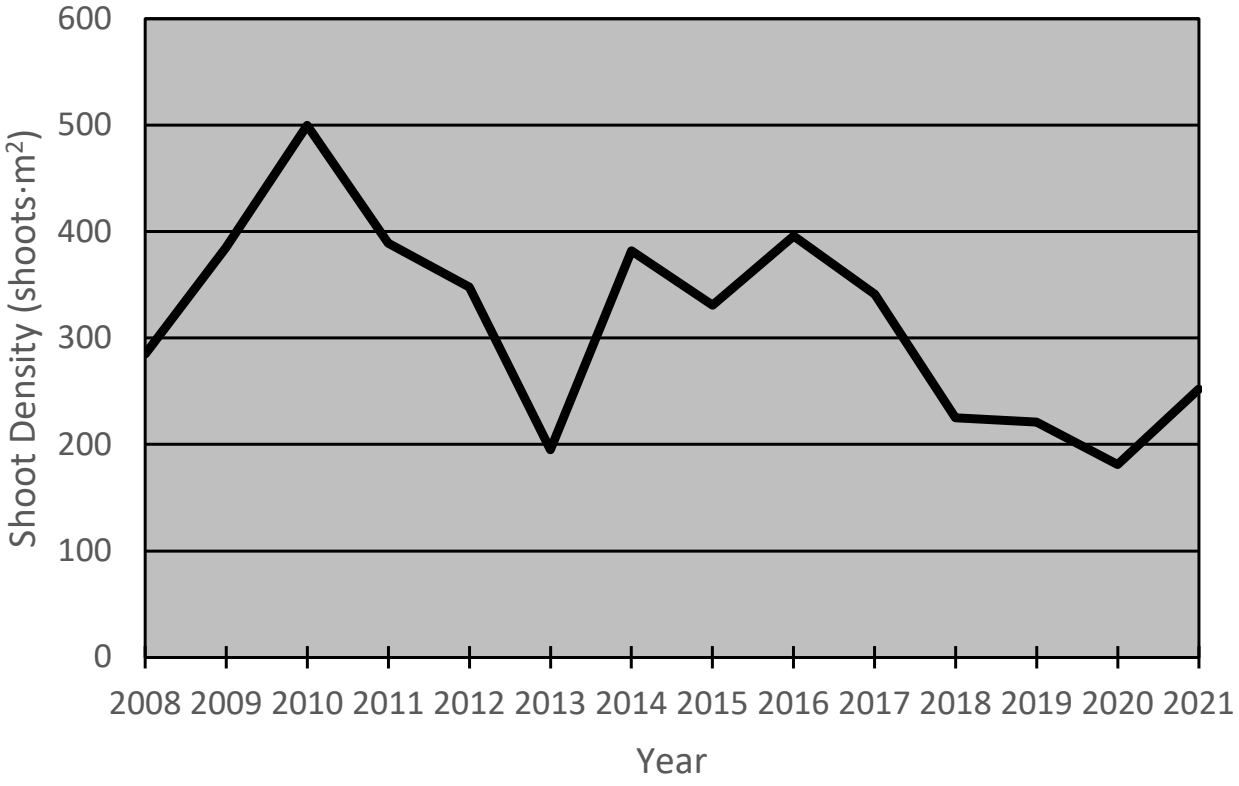


Figure CP-2. The average annual eelgrass shoot density for Cedar Point for 2008-2021.

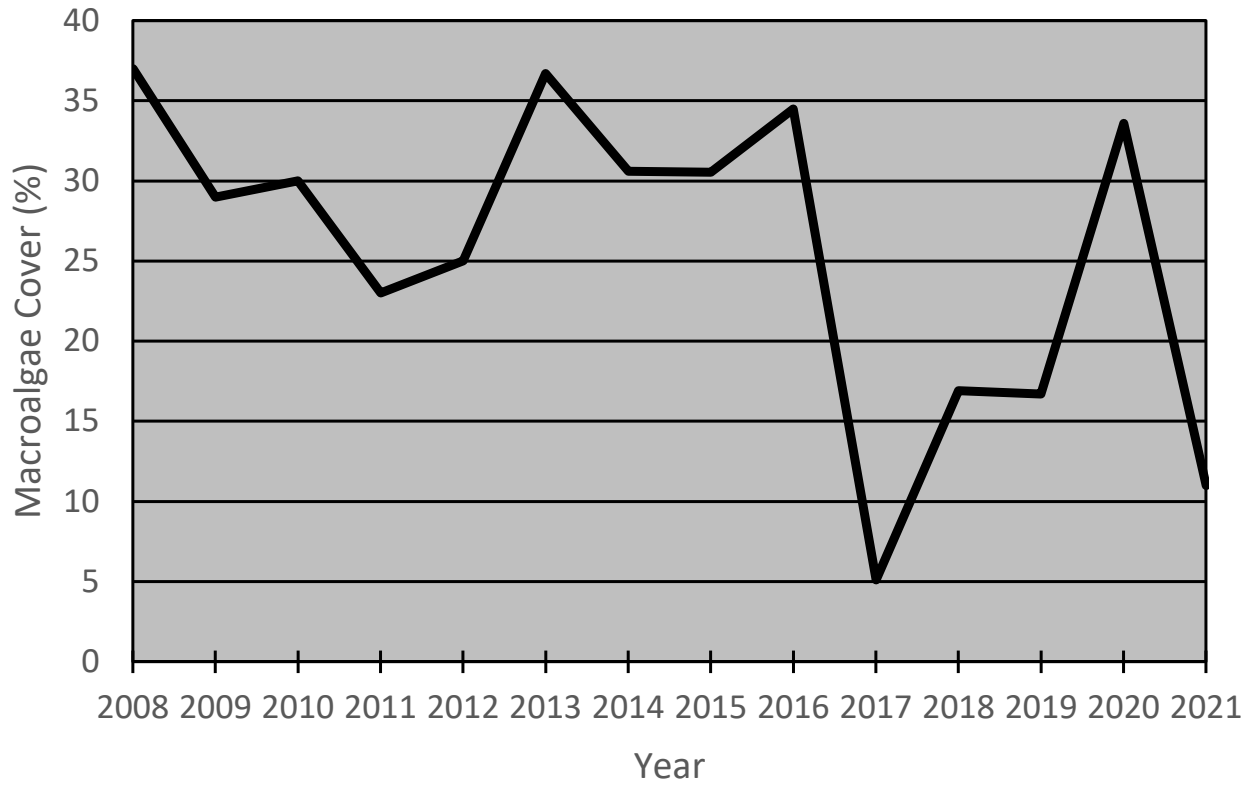


Figure CP-3 Annual mean macroalgae cover for Cedar Point, East Hampton from 2008 to 2021.

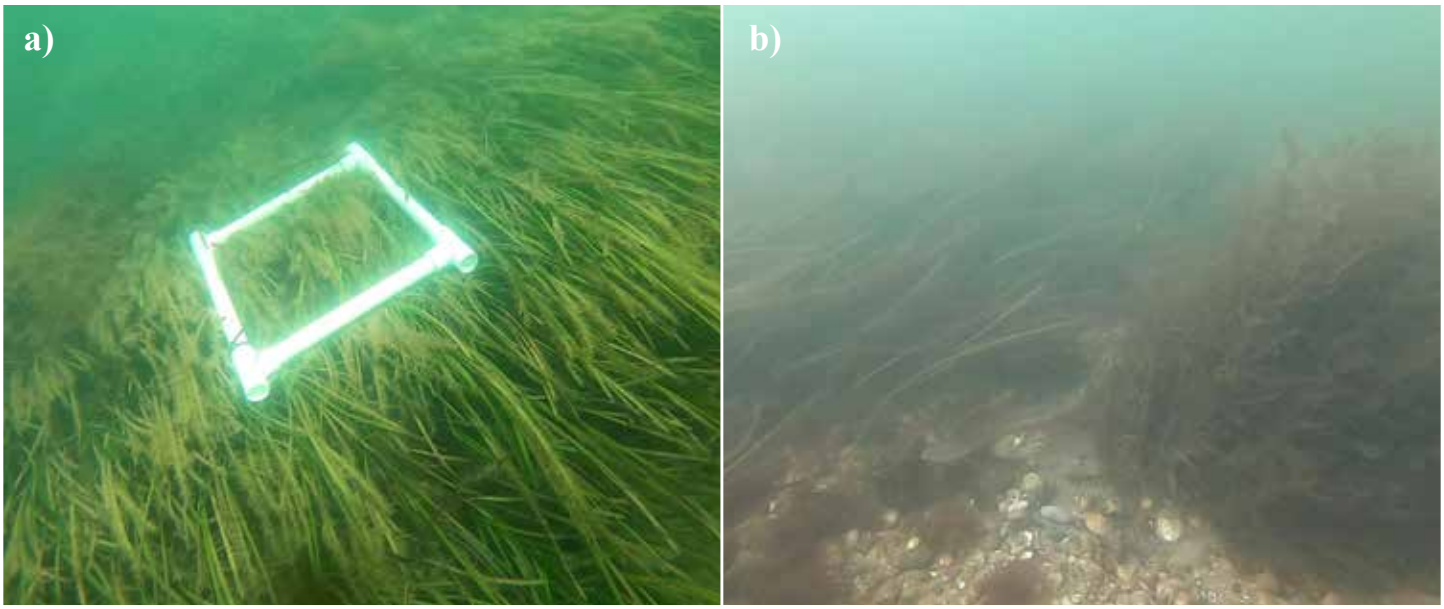


Figure CP-4. a) Quadrat laying on a dense patch of eelgrass waiting to be counted by a diver at station CP2. b) Transition from eelgrass patch to open-bottom, *Sargassum* bed near station CP6.

Bed Delineation and Areal Extent

The 2021 meadow delineations for Cedar Point were completed using Google Earth™ imagery from April, 2021. The delineations of the Cedar Point eelgrass meadow resulted in 81-acres of eelgrass consisting of two large, highly-patchy beds, with small groups of eelgrass patches along the inshore edge (Table CP-3; Figure CP-4f). The extent of the Cedar Point meadow did not change significantly from 2020, however the overall nature of the meadow has become patchier.

Conclusions

The Cedar Point eelgrass meadow is a relatively healthy meadow based on shoot density and areal extent trends from the collective monitoring data for the site. However, the meadow has become observably more patchy, with increased evidence of significant erosion within the meadow since 2012. The meadow used to consist of large, continuous patches of moderately dense eelgrass, but those large patches have slowly broken apart in the past 10-years. Increased storm frequency and intensity in recent years have subjected this site to long durations under heavy wave energy. This increase in wave exposure to a higher level may have changed how eelgrass is able to inhabit the site. This new, patchy habit at Cedar Point, may represent the 'new normal' for this, and similar sites as the climate continues to change. Eelgrass can survive in relatively high wave exposed sites, but these populations are definitely shaped by the conditions they live under, and the Cedar Point eelgrass meadow may represent a new, developing model under severe conditions.

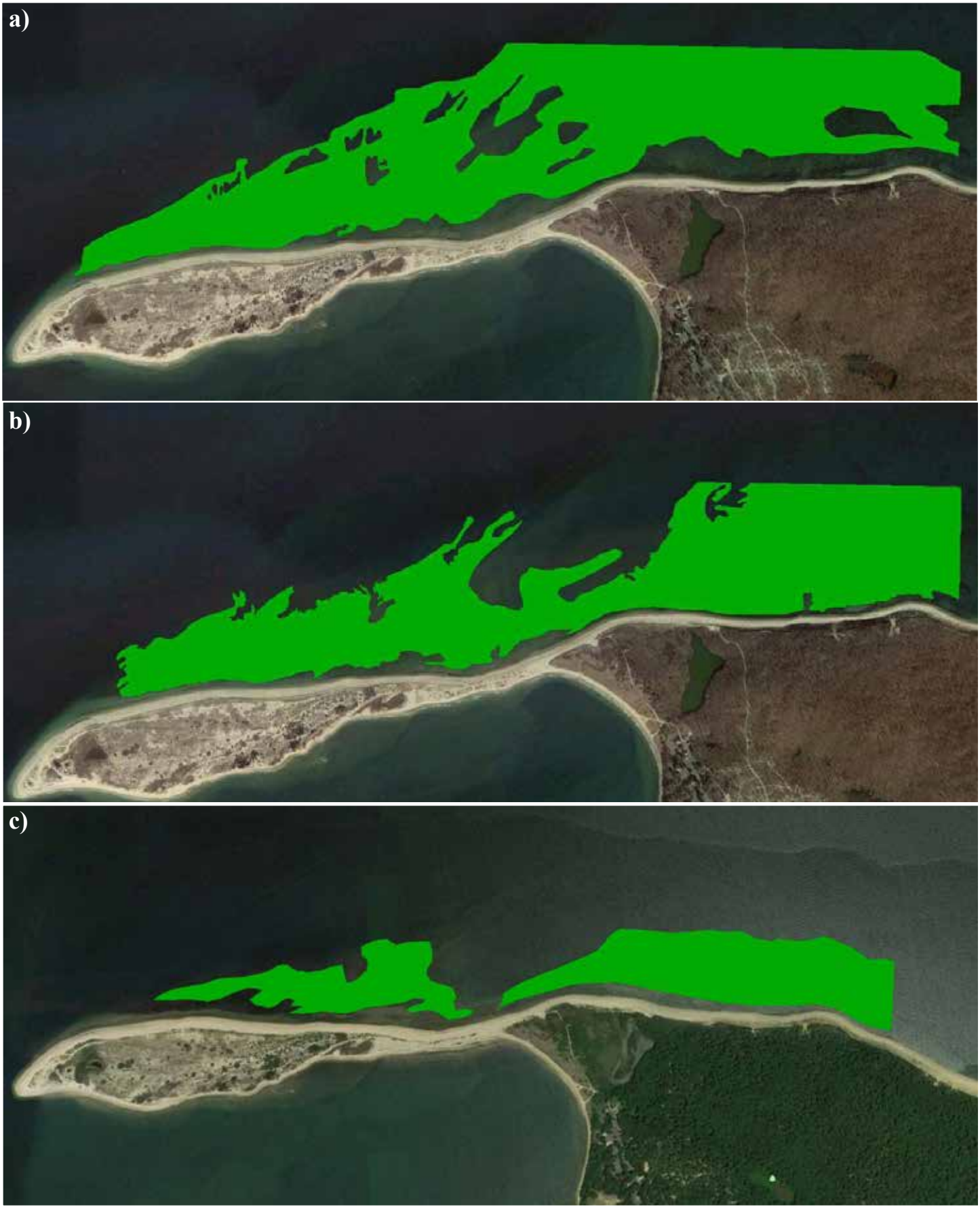


Figure CP-5. Delineations of the Cedar Point eelgrass meadow from aerial photographs for a) 2004, b) 2010, c) 2014, d) 2019, e) 2020, and f) 2021 (continued on next page).

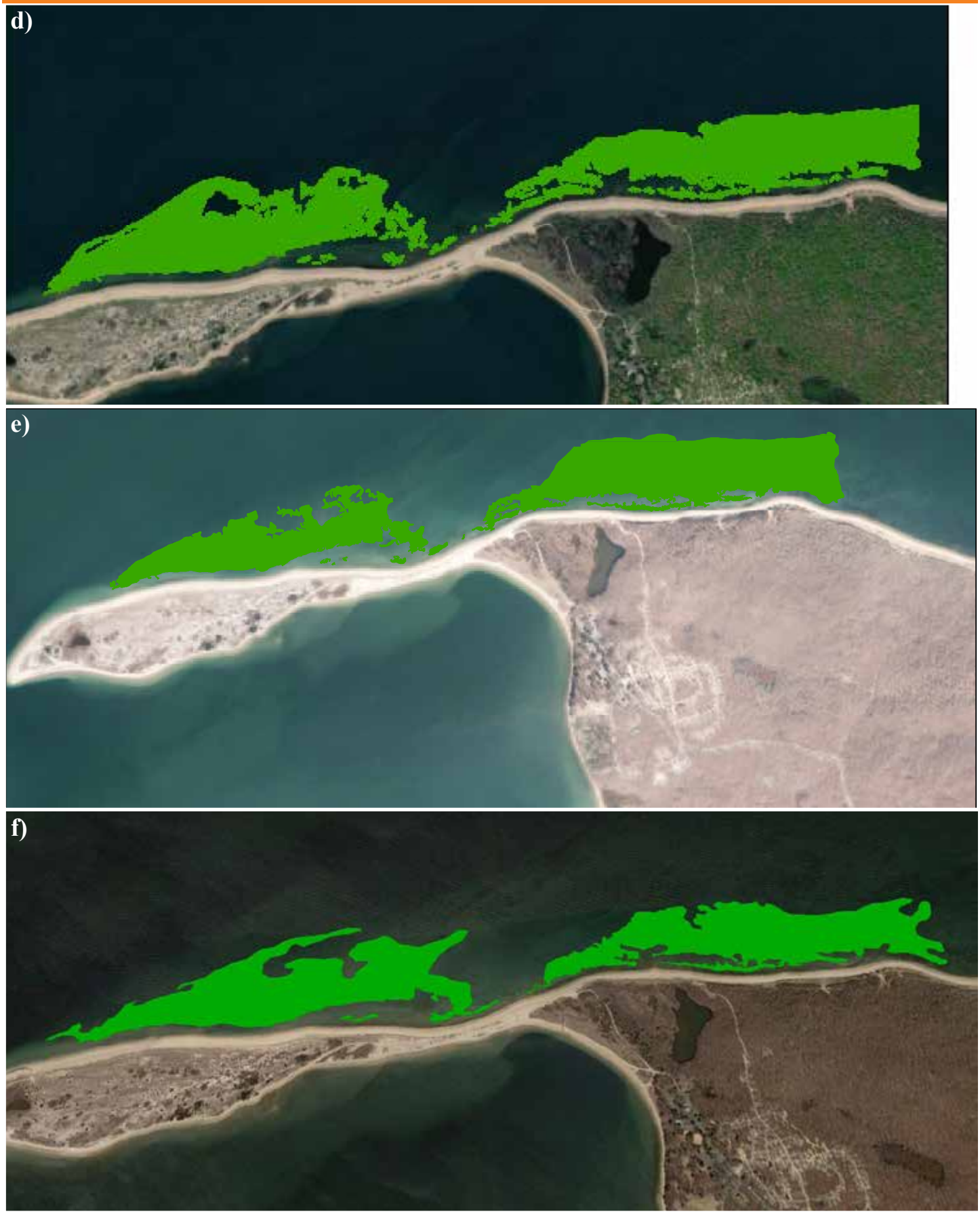


Figure CP-4. Continued.

Orient Point 2021

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 2021. There is no light data for September due to the loss of the light logger prior to retrieval.

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	14.8	+2.5	13.7	+5.7	21.0
August	12.7	+0.4	10.7	+2.7	22.6
September	ND	ND	ND	ND	22.3

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

The Orient Point light logger was deployed for 10-day periods, once monthly from July-September 2021. Light availability for both July and August exceeded the minimum threshold for both Hcomp and Hsat in the Orient Point meadow (Table OP-1). During the attempted retrieval of the light logger after its September 2021 deployment period, the diver could not locate the logger. It is assumed that the logger was hooked by a fisherman as the adjacent temperature logger had multiple hooks and line wrapped around the helical anchor to which it was attached. Based on the trends from previous years at this site, it can be infered that while the hours of Hcomp and Hsat were lower for September, they were likely close to meeting the minimum requirements of eelgrass.

Water temperature was monitored by deploying an Onset Hobo temperature logger in the Orient Point meadow in late-May 2021. The Orient Point eelgrass meadow had never had an issue with high water temperatures, due to its location in the estuary, and that trend continued in 2021. Table OP-1 presents the monthly average temperatures for July-September for the meadow and all months remained well below the 25°C threshold for 2021. The site experienced no daily average water temperatures above 25°C, and recorded a high temperature of only 23.8°C on 27 August, 2021.

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
2021	146	+/-25

Eelgrass Shoot Density

The Orient Point eelgrass meadow monitoring was conducted on 25 August, 2021. The average eelgrass shoot density calculated for the meadow was 146 shoots·m^2, which was up from 91 shoots·m^2 in 2020 (Table OP-2; Figure OP-2). As with the 2020 season, there was no eelgrass recorded at Stations 4 and 6, the norm with the meadow retreating inshore over time. In 2020, there was also no eelgrass recorded in Station 1, but in 2021, the eelgrass was showing recovery in this area with divers recording densities in quadrats at the station.

Macroalgae Cover

The average macoralgae cover for the Orient Point meadow remained relatively stable between the 2020 and 2021 monitoring seasons (Figure OP-3). Macroalgae cover experiences only a 2.2% decline from the previous season (Figure OP-3). down from 18% in 2018. Divers identified seven species of macroalgae with *Sargassum filipendula*as the dominant species on

Orient Point 2021

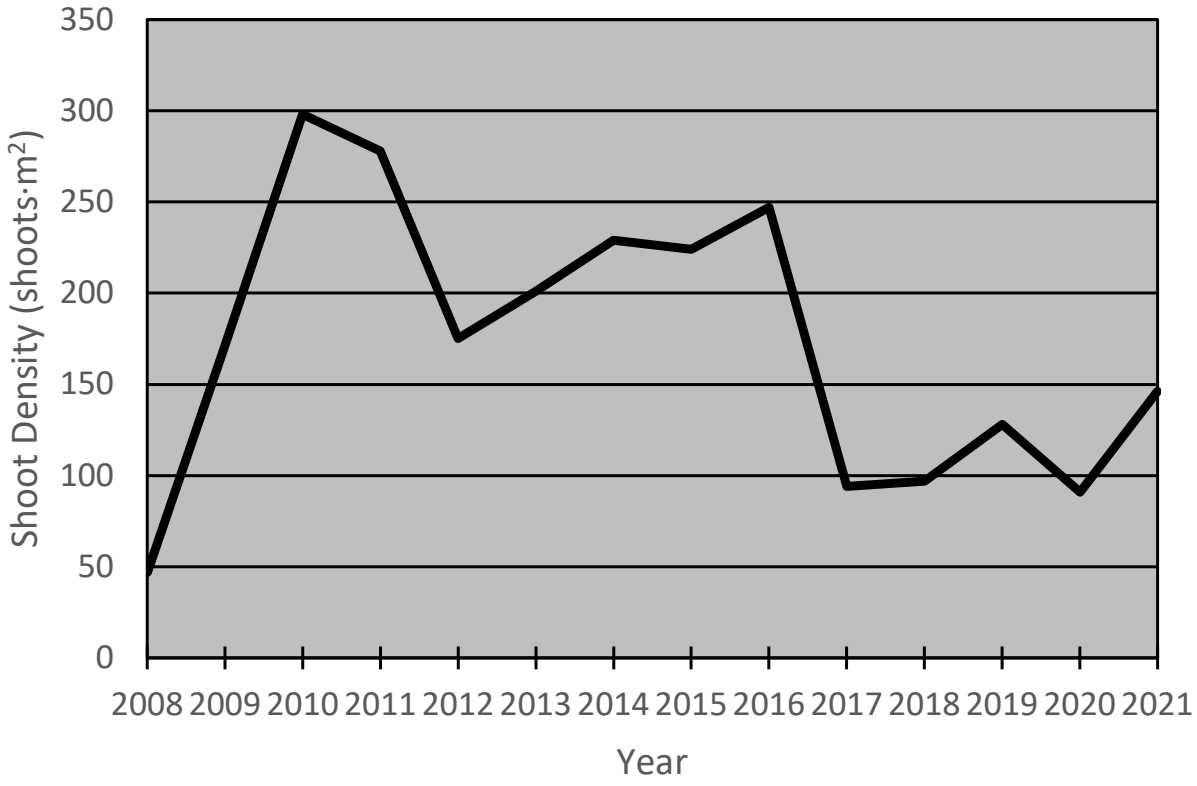


Figure OP-2. Graph of the annual mean eelgrass shoot density for Orient Point from 2008-2021.

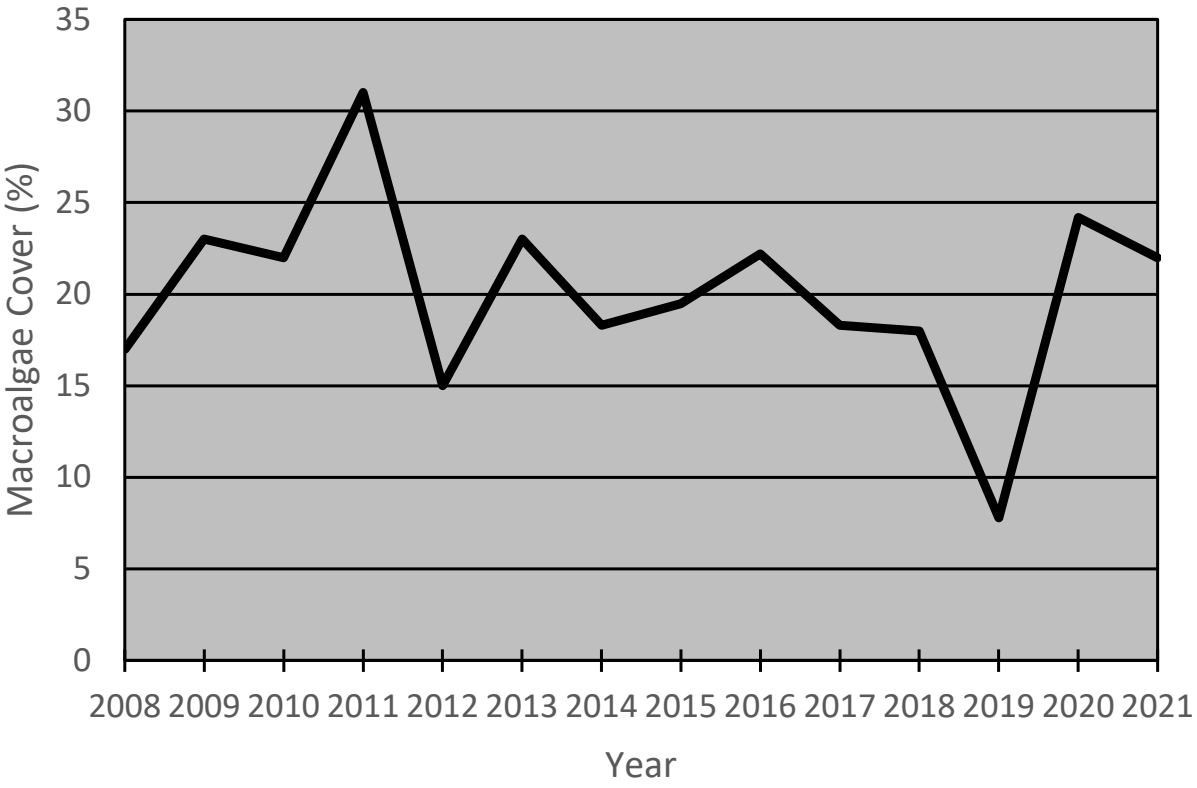


Figure OP-3. The annual mean macroalgae percent cover for Orient Point from 2008-2021.

Table OP-3. Trend analysis of the estimated area of the Orient Point meadow as determined from aerial photographs from 2000 to 2021.

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.)
2021	12.87 acres (5.21 hect.)

*Area of meadow was significantly underestimated in aerial survey.

site. Secondary species recorded at the site included two invasive, non-native species, *Codium fragile* and *Grateloupia turuturu*, as well as *Chondrus crispus*, *Spyridia filamentosa*, *Fucus* sp., and *Ulva lactuca* .

Bed Delineation and Areal Extent

Google Earth™ imagery taken in April 2021 was used to delineate the Orient Point eelgrass meadow. The meadow appears to have split into two sections (Figure OP-5f) and sections of its offshore edge have retreated inshore from 2020. The meadow appears to have lost almost 4-acres from 2020 to 2021, but it is more likely that the poor quality of the 2020 image resulted in an overestimation of the meadow, which the much clearer 2021 imagery was able to decern. The 12.87-acres delineated from the 2021 imagery is comparable to the 13.1-acres delineated in 2019 (Table CP-3).

Conclusions

Overall, the condition of the Orient Point eelgrass meadow was found to be good in 2021. The area of the meadow has remained stable since 2017, as has the eelgrass shoot density. The site has always been susceptible to wave erosion, but since Superstorm Sandy,

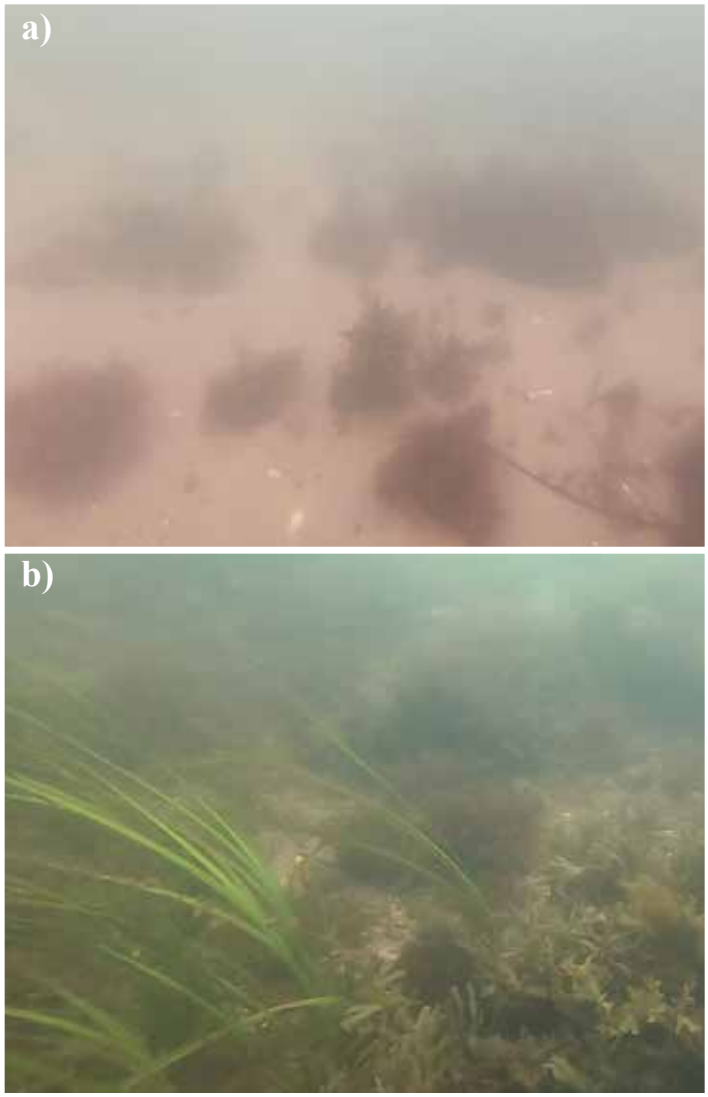


Figure OP-4. a) Photograph showing the accumulation of fine sediment at station OP1 as a result of shoreline erosion. b) Intermingling of eelgrass and macroalgae near station 5.

the frequency and extent of erosion along the edges of the meadow appear to have increased, especially on the inshore edge of the meadow. The shoreline along the meadow had sustained significant damage after Sandy and a rock revetment was placed just above MHW along the north end of the meadow to maintain the upland (parking area). Additionally, the only residence at the point has completed construction to reinforce/expand their seawall. Both of these structures used to be above normal MHW, but with shoreline erosion, they are immersed at high tides and reflect wave energy into the inshore areas of the eelgrass meadow, which could account for the erosion observed in the meadow at these locations. Further along the shore to the southwest (toward the ferry terminal), frequent wave events coupled with higher than aver-

age tides has resulted in large amounts of sediment being washed into the nearshore. This is especially evident in the area of the meadow around monitoring Station 1, where eelgrass has been lost over the last two seasons. The bottom characteristics around this monitoring station have become more fine-grained with fewer exposed boulders suggesting that sediment has been building and may have buried the eelgrass that once covered this area of the meadow. Given time, eelgrass may recruit back into these area, however it will likely be a slow process given the dynamic nature of the site.

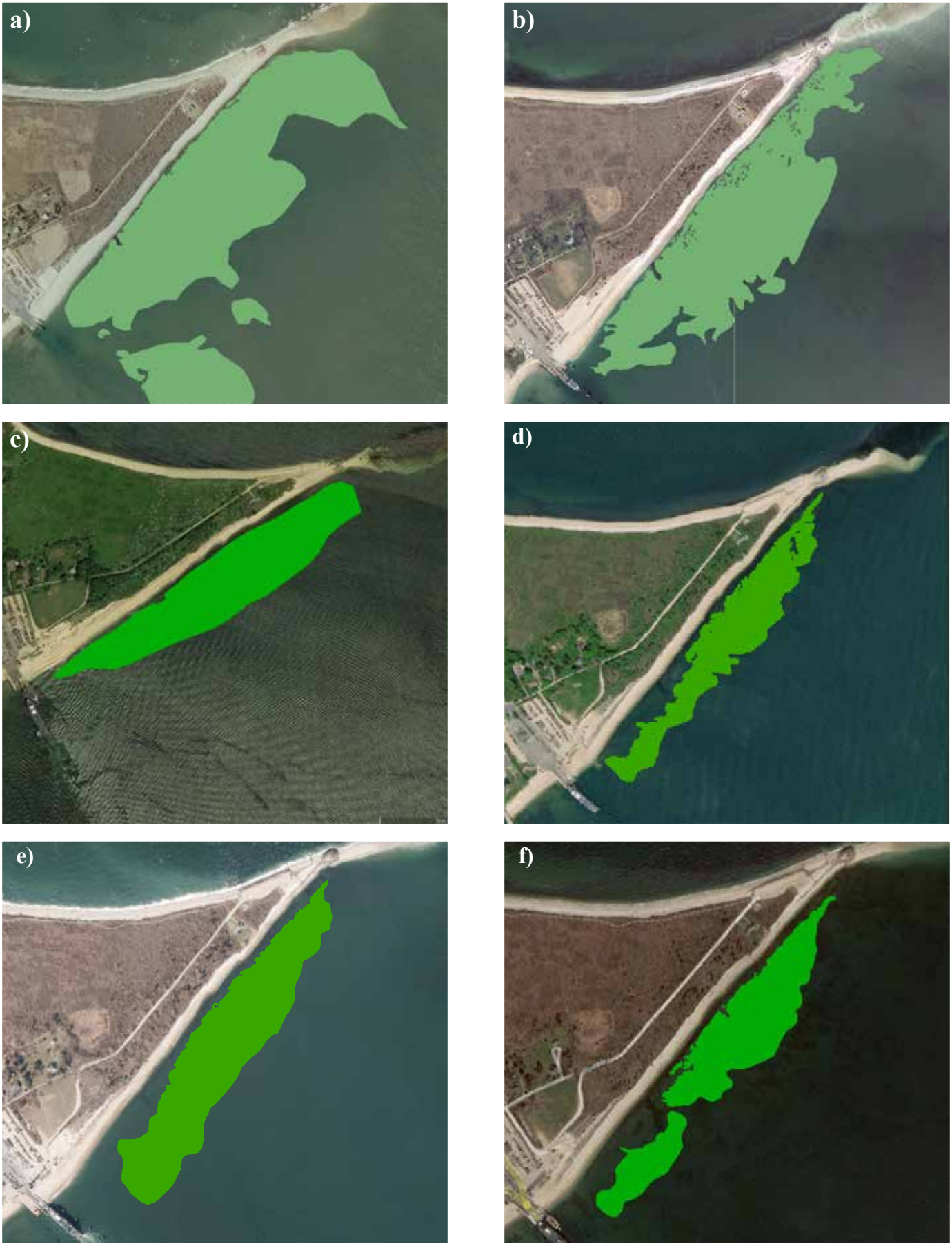


Figure OP-5. Delineations of the Orient Point, Southold, NY eelgrass meadow from aerial imagery for a) 2004, b) 2010, c) 2014, d) 2019, e)2020, and f) 2021.

Coecles Harbor 2021

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 2021 season. Table CH-1 presents the daily average Hcomp and Hsat for the sampled period. Water clarity in Coecles Harbor does not tend to be as high as other eelgrass monitoring sites in the Peconic Estuary. Its shallow depth and fine-sediment bottom, which is easily stirred-up, contribute to its typical murky appearance. Despite less than clear waters, the meadow still receives enough sunlight to support eelgrass growth throughout the harbor. Table The meadow received enough light to meet it minimum requirements for all months except for Septem-

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 2021.

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	12.3	+4.3	24.3
August	12.8	+0.5	11.7	+3.7	25.2
September	11.4	-0.9	8.9	+0.9	22.9

ber 2021, where Hcomp was at a 0.9 hour deficit.

An Onset HOBO temperature logger was deployed to Coecles Harbor in late-May 2021. The average monthly water temperatures for July-September 2021 are included in Table CH-1. The eelgrass meadow experienced only one month in which the monthly average temperatures were greater than 25°C, August (Table CH-1). The Coecles Harbor meadow recorded 28 days with the daily average temperature exceeding the 25°C threshold, but there were no days for which the daily temperatures reached 27°C. The highest temperature, recorded was 26.7°C on 27 August, 2021.

Eelgrass Shoot Density

The monitoring visit to Coecles Harbor was conducted on 8 September, 2021. The average eelgrass shoot density for 2021 declined from the previous season to 25 shoots·m^2, which represents the second continuos year in which the meadow recorded a signficant decline (Table CH-2; Figure CH-2). For the first time since monitoring this meadow, a station recorded no eelgrass in any quadrat. Monitoring Station 1 had no viable eelgrass present, and almost no macroalgae, but the diver found the rhizomes to be intact and appearing viable, similar to the situations in other, similar monitoring sites.

Table CH-2. The average annual eelgrass shoot density for Coecles Harbor from 2017 to 2021, including standard error.

Year	Mean Density	S.E.
2017	78	+/-8
2018	41	+/-5
2019	100	+/-6
2020	54	+/-4
2021	25	+/-4

Macroalgae Cover

Macroalgae cover in Coecles Harbor increased slightly in 2021 from the previous season (Figure CH-3). Macroalgae cover averaged 20% for 2021, compared to 14% in 2020. CCE divers only identified three species of macroalgae during their survey: *Spyridia filimentosa , Ulva lactuca* and *Gracilaria* species. *Spyridia* remained the most common species within the eelgrass meadow.

Bed Delineation and Areal Extent

The 2021 meadow delineations were completed using Google Earth™ imagery from April, 2021. As noted above for other meadows, the imagery available for the 2021 season was taken several months prior to the monitoring visit and does represent the extent of the meadow at the time of the monitoring visit, consider-

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.)
2021	175 acres (70.82 hect.)*

*Meadow extend at time of monitoring was smaller than delineated from April 2021 imagery.

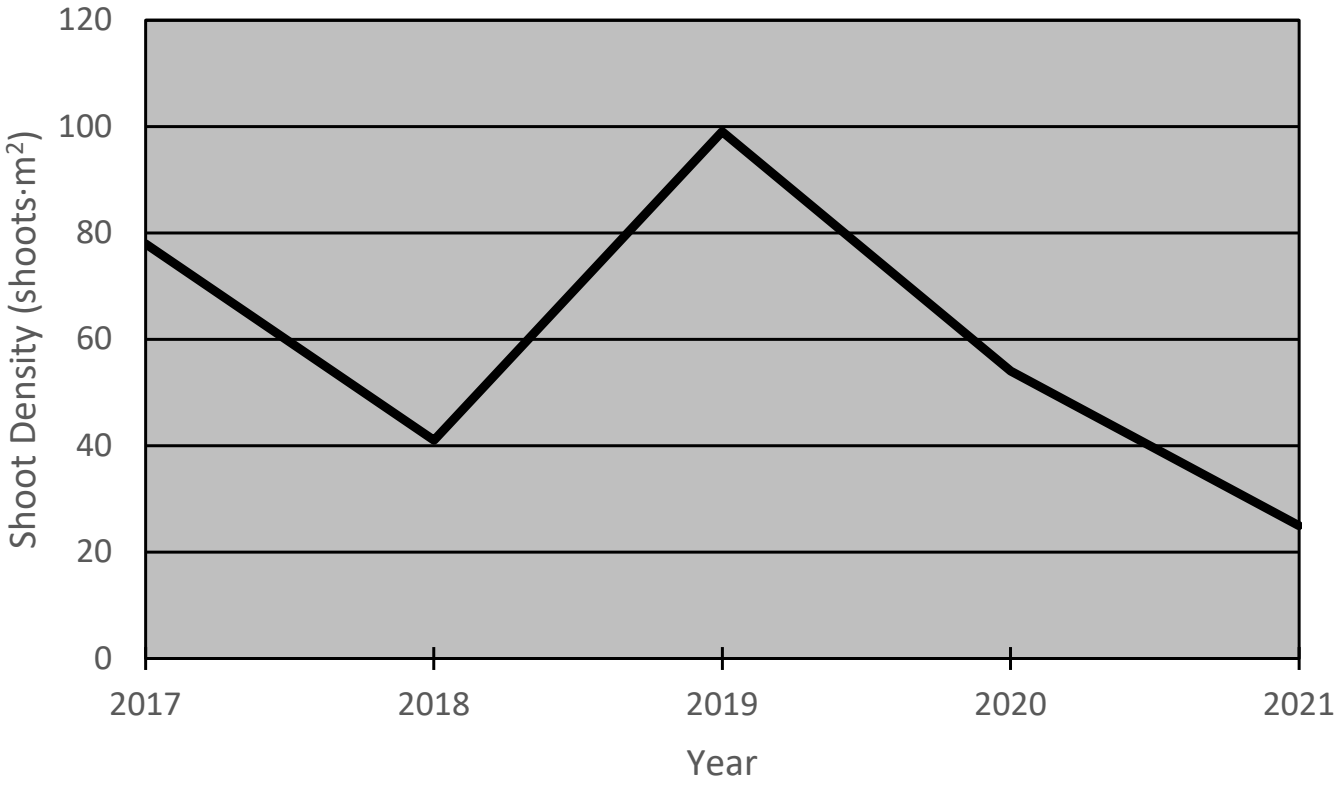


Figure CH-2. Graph of the annual mean eelgrass shoot density for Coecles Harbor from 2017-2021.

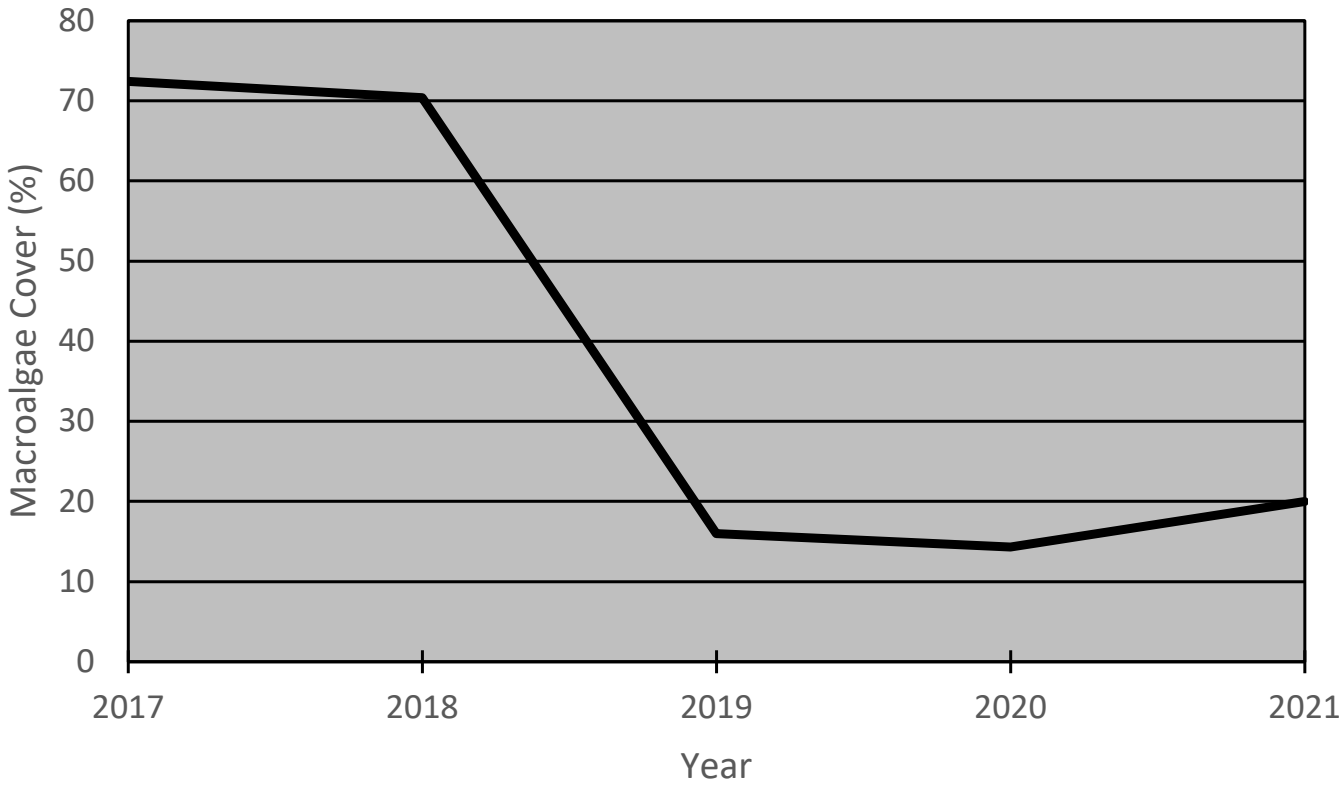


Figure CH-3. The annual mean macroalgae percent cover for Coecles Harbor from 2017-2021.

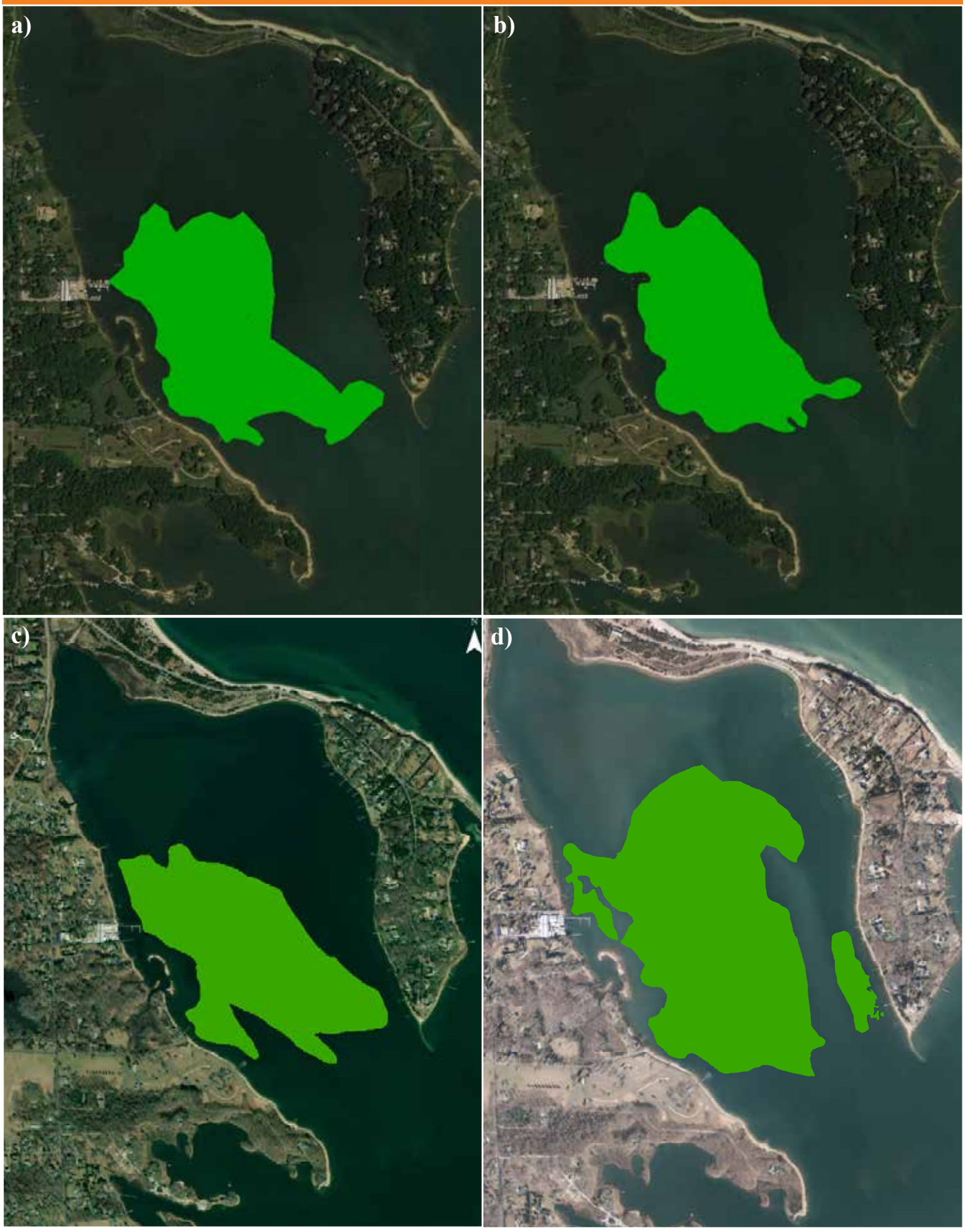


Figure CH-4. The Coecles Harbor eelgrass meadow delineations completed in a) 2014, b) 2017, c) 2019 and d)2020 for the LTEMP monitoring site.

Figure CH-5. Photographs showing the observed conditions at a) station CH1 showing the dead shoots and no live standing eelgrass at the site, contrasted by b) station CH6 where live eelgrass shoots were prevalent throughout the monitoring station.

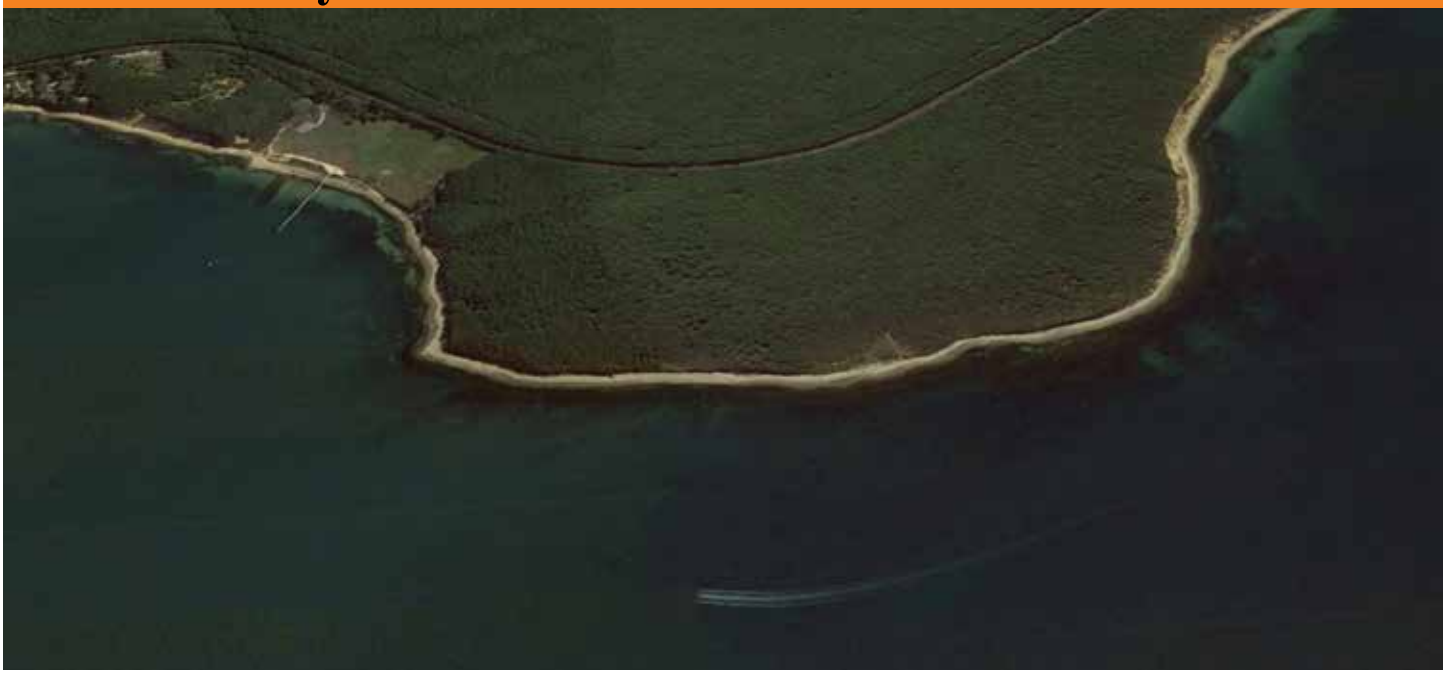
ing that monitoring Station 1 had no eelgrass present. Considering the delineation from the imagery, and comparing it to the imagery from 2020, the Coecles Harbor eelgrass meadow showed a increase in area in

2021. With the increase in area of the meadow from 2020 to 2021 being only 11-acres, the change is nominal and suggests that the meadow remained stable between these two years.

Conclusions

The Coecles Harbor eelgrass meadow has maintained itself as a large, low-density eelgrass meadow since its inclusion in the PEPLTEMP in 2017, and the 2021 monitoring data continues to support that characterization. However, the 2021 data has shown that the meadow was being impacted by some factor(s) that resulted in the loss of eelgrass at one monitoring station. Given the overall size of the meadow, its relative low-density, and the typical poor water clarity throughout this area of Coecles Harbor, it is hard to determine if the decline at Station 1 is a localized event, or if this was happening in other locations throughout the meadow in 2021. With the small long-term dataset available for the Coecles Harbor eelgrass meadow, it has shown past trends where the eelgrass density in the meadow has drastically declined, then rebounded the following year. There should be some optimism that there were still, what appeared to be, viable eelgrass rhizomes at Station 1 which could regrow new shoots once whatever stressor caused the initial loss of aboveground biomass has passed. Follow-up monitoring during 2022 will determine if this was a temporary decline or a long-term trend in Coecles Harbor.

Fort Pond Bay 2021



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 2021 season. The logger station had been moved in 2020 to the north side of the pier where it would be less accessible to the public due

Fort Pond Bay 2021

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 2021.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.6	+2.3	13.6	+5.6	20.3
August	12.3	0	10.4	+2.4	21.9
September	12.1	-0.2	10.9	+2.9	21.7

to repeated vandalism of loggers. Table FP-1 includes the average daily Hcomp and Hsat values that were recorded at the Fort Pond site in 2021. The Fort Pond meadow recorded surplus hours of Hsat for all months sample. For Hcomp, the site received more than the minimal hours required for July, met the threshold requirement for August and ran a 0.2 hour deficit for September.

An Onset Hobo temperature logger was deployed late-May, 2021 to Fort Pond at the new location north of the pier. Fort Pond Bay is the furthest eastern eelgrass meadow monitored for the LTEMP, and water temperature at the site do not approach the 25°C threshold, as is evident by the monthly average water temperatures presented in Table FP-1, above. The Fort Pond meadow experienced no day during 2021 where daily average water temperature exceeded 25°C, and the maximum water temperature recorded at the site was 23.6°C.

Eelgrass Shoot Density

Eelgrass monitoring in Fort Pond Bay was conducted on 15 September, 2021. The average eelgrass shoot density for the Fort Pond Bay meadow in 2021 was 351 shoots·m^2 (Table FP-2; Figure FP-2). This represents a significant increase in shoot density from the 2020 season.

Table FP-2. The average annual eelgrass shoot density for Fort Pond Bay from 2017-2021, including standard error.

Year	Mean Density	S.E.
2017	584	±58
2018	483	±49
2019	348	±43
2020	297	±34
2021	351	±36

Macroalgae Cover

The Fort Pond Bay site supports a large macroalgae community due to the availability of hard substrate (i.e. boulders) interspersed throughout the meadow. Macroalgae cover was 35% for 2021, which was unchanged from the macroalgae cover reported for the 2020 season. The primary macroalgae species at the site is *Sargassum filipendula*. Other species reported for the meadow 2021 included *Halosiphonia*, *Fucus*, *Ascophyllum*, *Chondrus*, *Grateloupia* (non-native), *Dasysiphonia* (non-native), *Cladostephus*, and *Polysiphonia* species. A total of 10 species of macroalgae were identified during the 2021 survey at Fort Pond.

Bed Delineation and Areal Extent

The 2021 delineation of the Fort Pond Bay eelgrass meadow was completed using aerial imagery from

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.)
2021	42.91 acres (17.37 hect.)

*Aerial imagery quality prevented complete delineation of meadow.

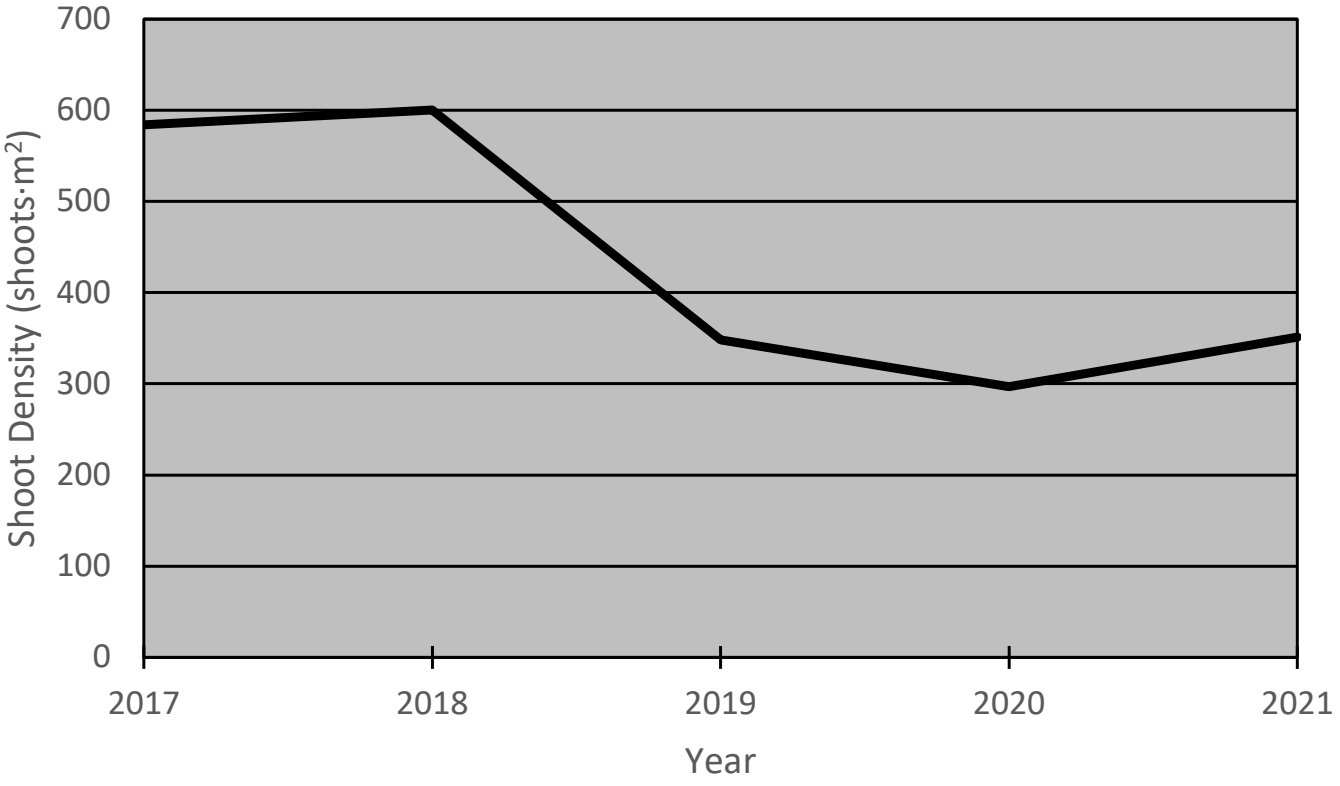


Figure FP-2. Graph of the annual mean eelgrass shoot density for Fort Pond Bay from 2017-2021.

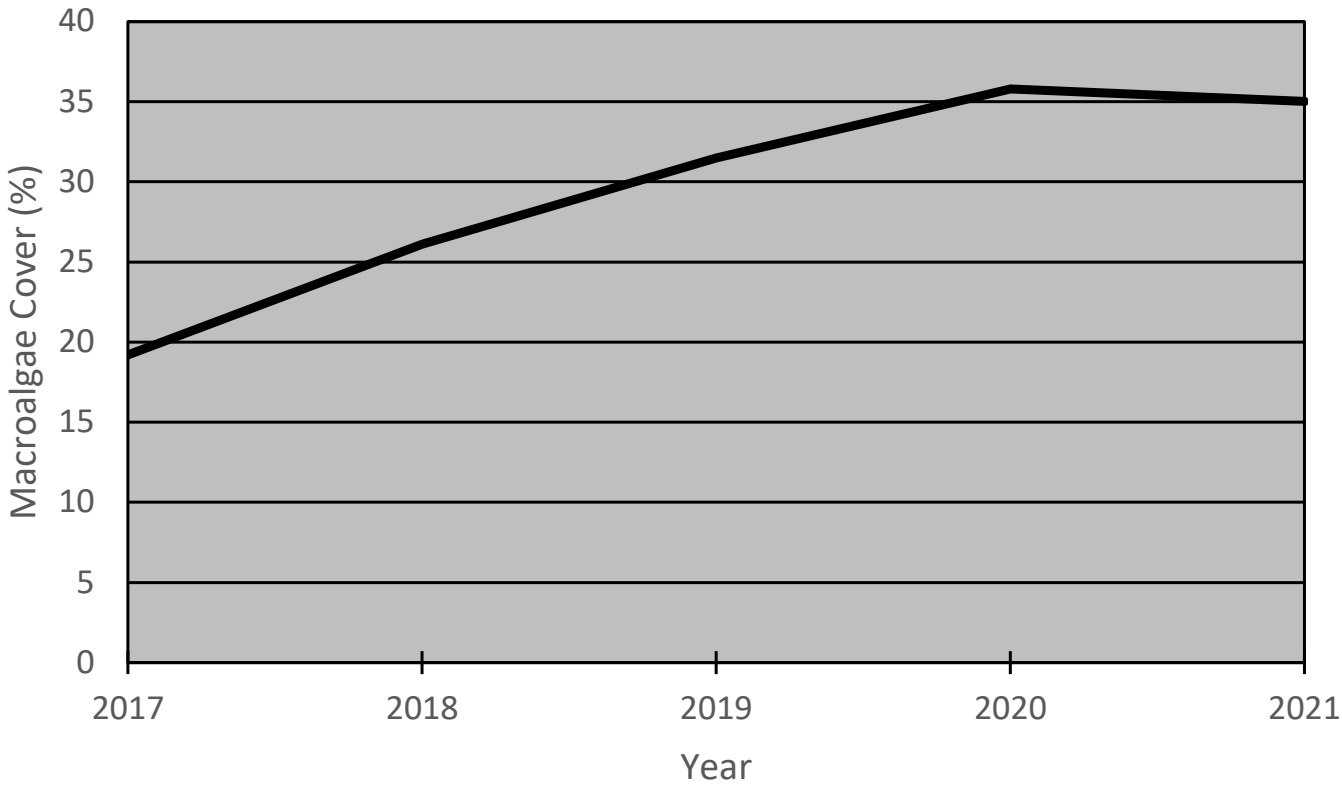


Figure FP-3. The annual mean macroalgae percent cover for Fort Pond Bay from 2017-2021.

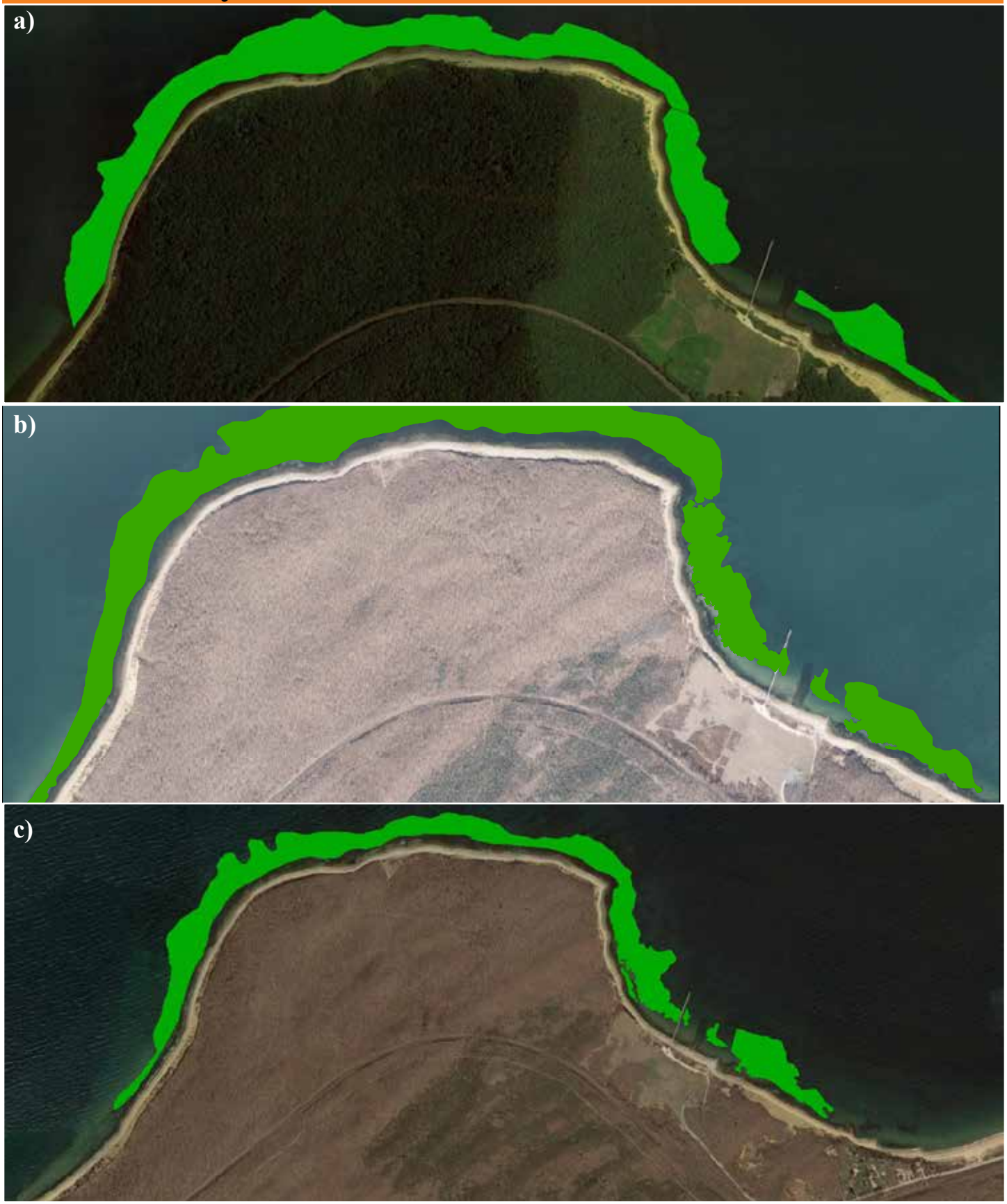


Figure FP-4. A comparison of Fort Pond Bay eelgrass meadow delineations completed in a) 2014, b) 2020 and c) 2021.

Google Earth™ from April 2021. The 2021 delineated eelgrass meadow covered 42.91-acres (Table FP-3) along almost 2 miles of shoreline (Figure FP-4c). While this extent is slightly lower than the 2020

Figure FP-5. Underwater photographs taken during the course of completing the 2021 monitoring at the Fort Pond Bay eelgrass meadow. a) A juvenile scup forage along the protective edge of an eelgrass patch. b) The open coast section of the meadow near station FP-4 with eelgrass filling in between seaweed-covered boulders.

meadow extent, it represents no significant change between the years.

Conclusions

The Fort Pond Bay site presents one of the healthiest and most vibrant eelgrass meadows in the LTEMP. The meadow experiences little impact from water quality issues or human activity. The meadow is

located on the open coast and is subjected to frequent storm and wind-driven waves, but the its integration into the near-shore boulder fields provides moderate protection, and increased the habitat complexity of the site. Due to this meadow's location, it is expected that it should see impact from storms on a regular basis, however, conditions support the meadow's ability to regenerate storm damage and maintain the integrity of the meadow.

Napeague Harbor 2021

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 2021 season to the Napeague Harbor eelgrass meadow. The light data was converted to the average daily Hcomp and Hsat values presented in Table NAP-1. The Napeague meadow experienced a surplus Hcomp for July and August 2021, but ran a small deficit of 0.6 hours for September. The eelgrass experienced a surplus of Hsat for all months surveyed (Table NAP-1).

The Onset HOBO TidBit v2 water temperature logger was deployed to the meadow in late-May 2021. Average monthly water temperature are recorded in Table NAP-1. The Napeague meadow did not record an average monthly temperature over 25°C for 2021. The 2021 season recorded cooler temperatures for the season compared to 2020 with only 5 days with water temperatures over 25°C. The highest temperature

Table NAP-1. H_{comp}, H_{sat} and temperature data calculated from the deployment of Odyssey PAR loggers and TidBit temperature loggers in Napeague Harbor over 10-day intervals, monthly, for 2021.

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	13.4	+5.4	23.0
August	12.9	+0.6	11.4	+3.4	24.0
September	11.7	-0.6	10.7	+2.7	22.1

recorded for the site in 2021 was 25.7°C on 27 August, almost 2.5°C cooler than 2020's high temperature.

Eelgrass Shoot Density

The 2021 eelgrass monitoring visit to Napeague Harbor took place on 15 September. The average eelgrass shoot density reported for 2021 was 484 shoots·m^2, which was a decrease from the 554 shoots·m^2 reported in 2020 (Table NAP-2; Figure NAP-2), but does not represent a significant change. The highest shoot density reported for 2021 was 1,140 shoots·m^2 at Station 4.

Macroalgae Cover

Macroalgae cover in Napeague Harbor saw significant decline from 2020 to 2021 (Figure NAP-3). the average percent cover for 2021 was 2%, down from 16% the season before. Macroalgae observed within the eelgrass meadow included *Spyridia filamentosa* and *Gracilaria* species, but *Codium fragile* was observed on cobble and shell on unvegetated bottom.

Bed Delineation and Areal Extent

The 2021 meadow delineations for Napeague Harbor were completed using Google Earth™ imagery from April, 2021. The 2021 delineation of the Napeague Harbor eelgrass meadow is presented in Figure NAP-4d and identified 15.38-acres of eelgrass at the site (Table NAP-3). The almost 1.5-acre change in the meadow from 2020 to 2021 was due to recovery lost area within the section of the meadow along the northeast shore of the harbor (Figure NAP-4d). The decline in the southern section of the eelgrass meadow is illustrated by the increase patchiness evident in the time series in Figure NAP-4.

Conclusions

Napeague Harbor continues to maintain a healthy eelgrass population. There is evidence of new eelgrass recruitment to areas along the eastern shoreline which, barring impact from physical damage (e.g., storms or human activity) may reestablish eelgrass in areas that had been lost years ago. The area of concern for the Napeague meadow is at its southern extent. This section of the meadow is in direct contact with human activities that are likely impacting the structure of the meadow. There are several boat moorings located within the eelgrass meadow which cause localized, physical disturbances. In addition to the damage moor-

Table NAP-2. The average annual eelgrass shoot density for Napeague Harbor from 2017 to 2021, including standard error.

Year	Mean Density	S.E.
2017	806	+/-63
2018	479	+/-44
2019	560	+/-44
2020	554	+/-50
2021	484	+/-39

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.)
2021	15.38 acres (6.22 hect.)

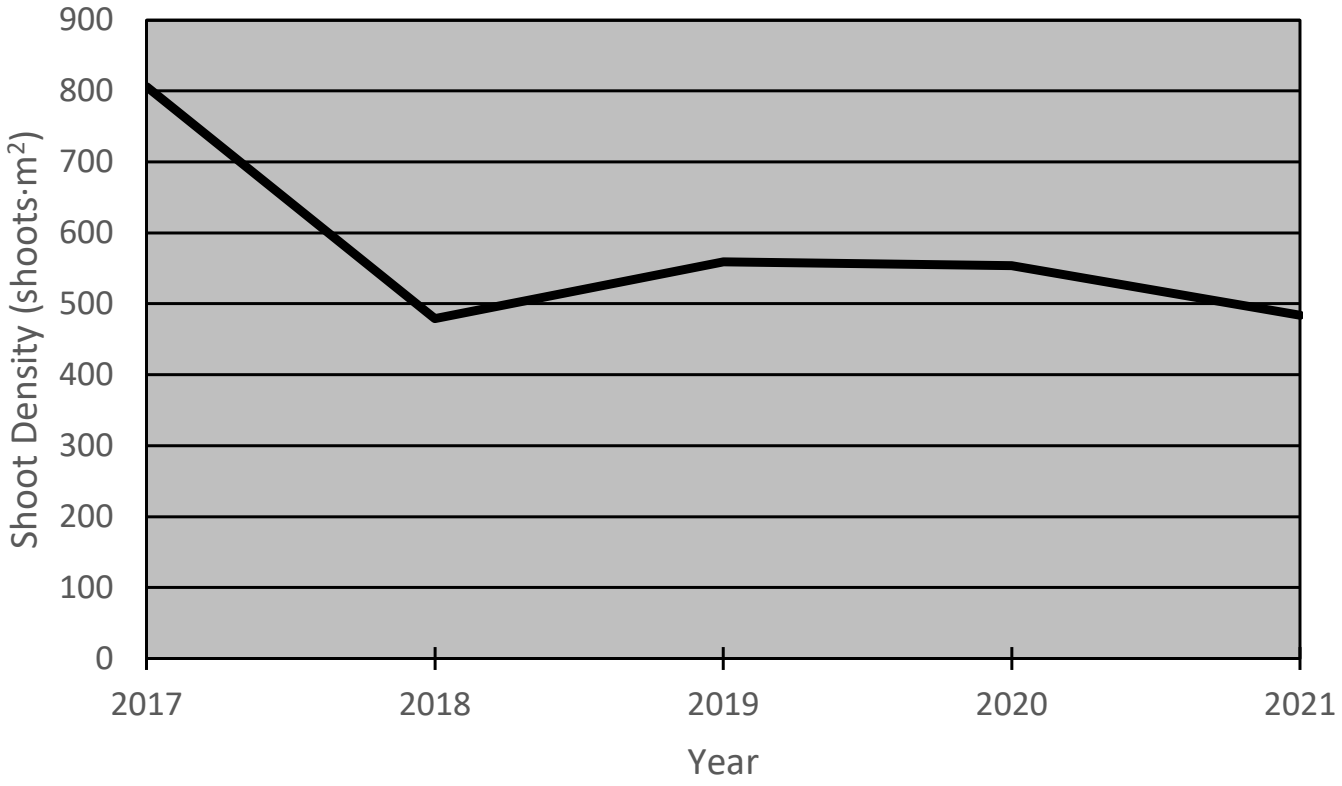


Figure NAP-2. Graph of the annual mean eelgrass shoot density for Fort Pond Bay from 2017-2021.

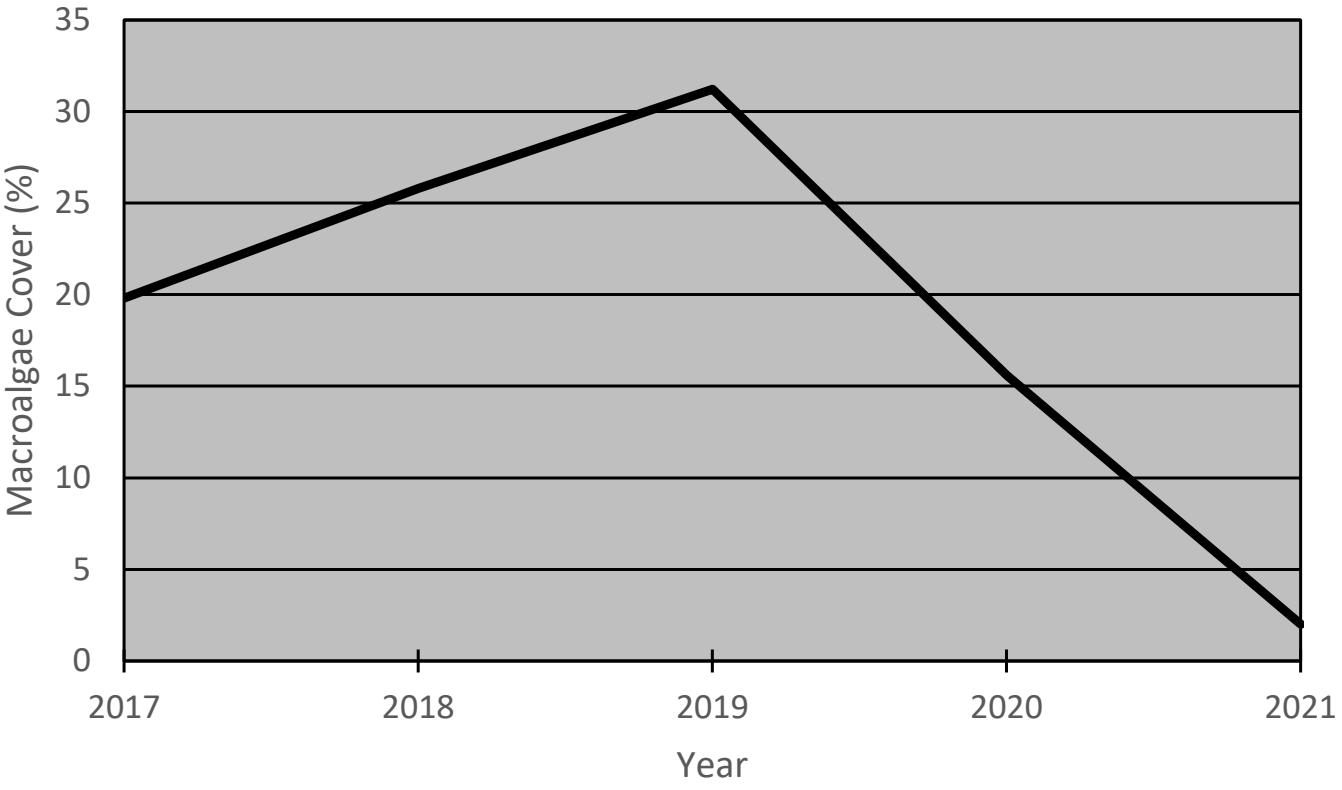


Figure NAP-3. The annual mean macroalgae percent cover for Fort Pond Bay from 2017-2021.

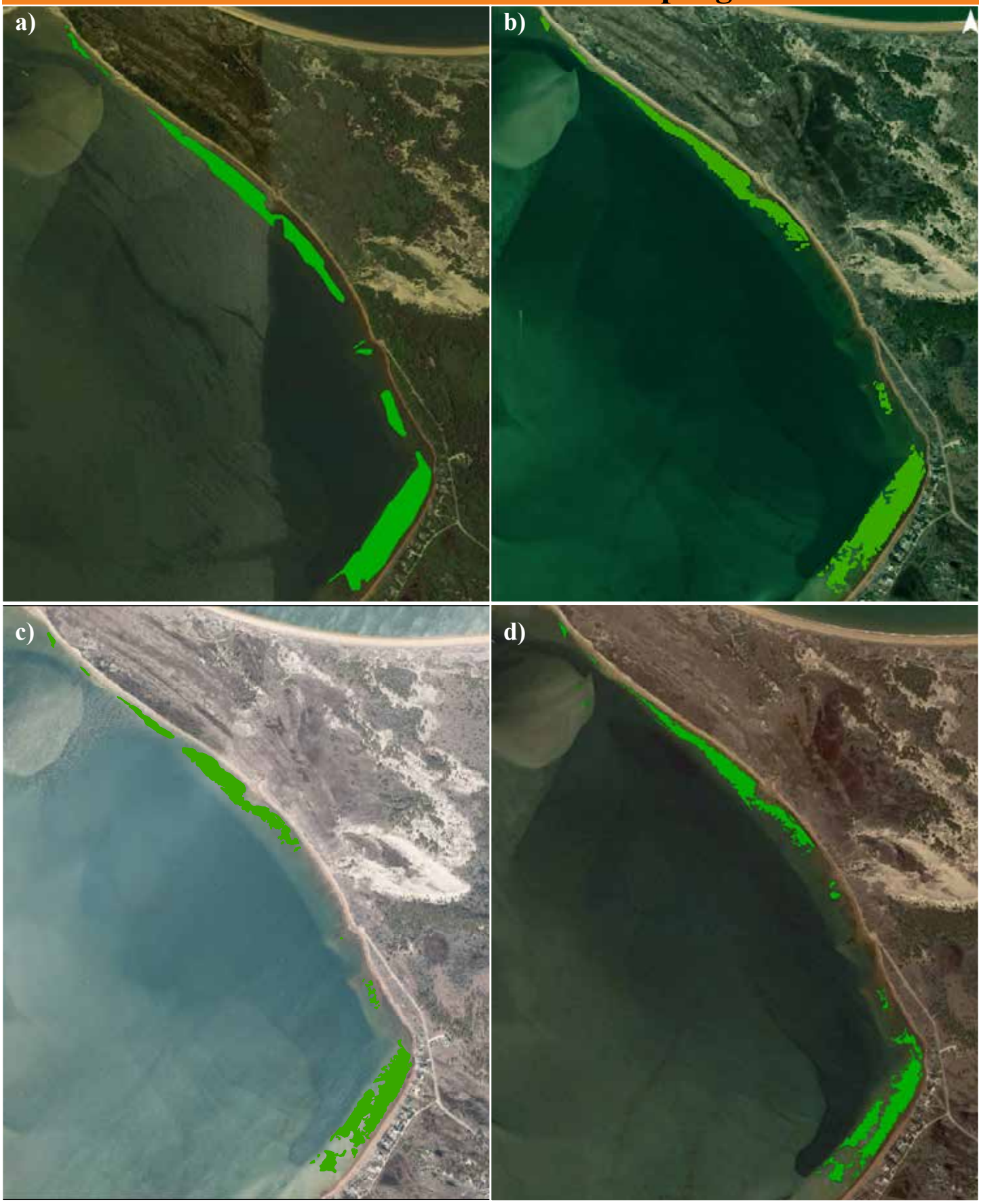


Figure NAP-4. A comparison of Napeague Harbor eelgrass meadow delineations completed in a) 2014, b) 2019, c) 2020, and d) 2021.

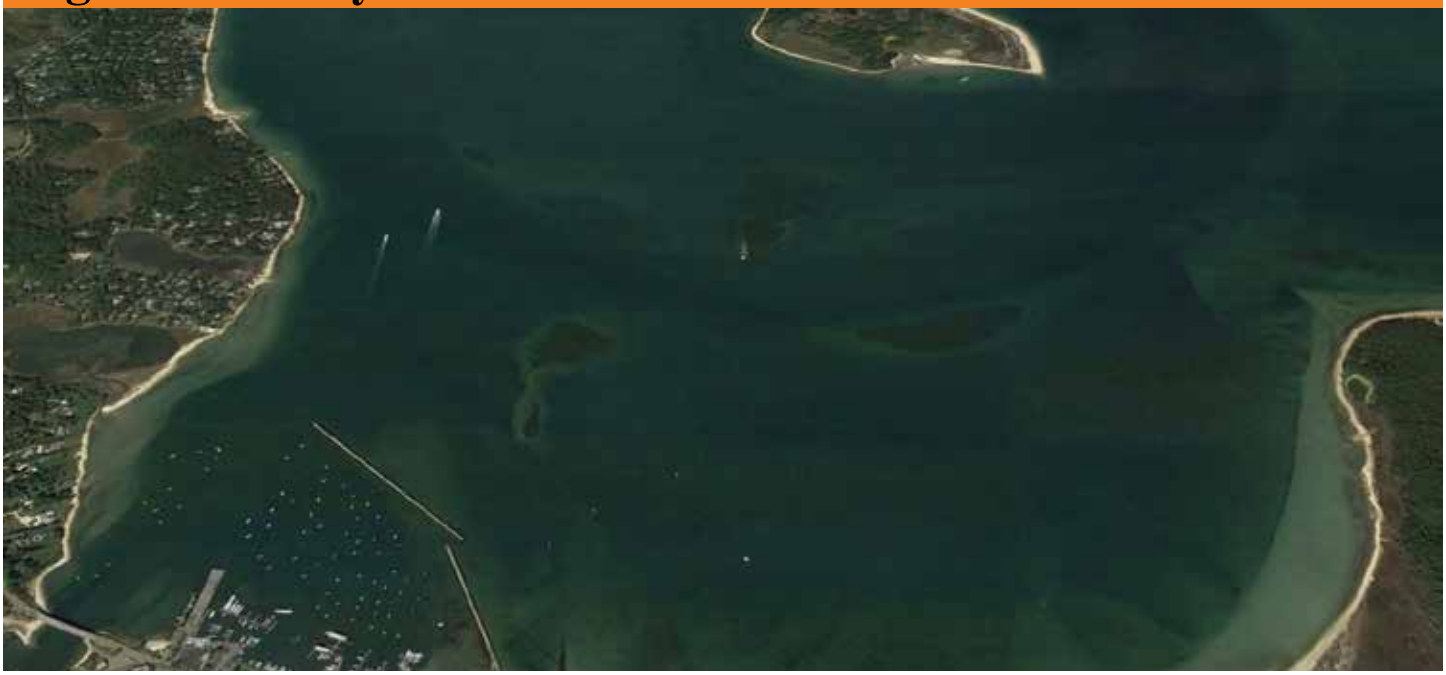
Figure NAP-5. a) A horseshoe crab shed near station NH-2. b) A diver sorts through a quadrat counting eelgrass shoots at station NH-4.

ing create, boats are traversing this area and disturbing the bottom as they motor in shallow water, uprooting eelgrass by their propwash. This is a situation that would need to be addressed at a local level and require minimal change for the residence, but it could have significant benefits for the meadow.

Another observation from the 2021 monitoring visit that bears some attention was the presence, along the northern section of the meadow, of erosional edges

within the shallow meadow. These edges were reminiscent of the erosional edges that can be found in the Cedar and Orient Point meadows on open coasts. The erosional edges could have been remnants of recent clamming activity or digging by foraging crabs/horseshoe crabs, or they could be from increased wave exposure along this section of the shoreline due to changing weather patterns. Divers will be looking for evidence of these erosional edges during the 2022 monitoring visit, as this is something that bears watching.

Sag Harbor Bay 2021



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

An Odyssey PAR light logger was deployed adjacent to the SH2 (Figure SH-1) monitoring station monthly, from July-September 2021. The results from the 2021 season 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, except during September, when Hcomp missed the 12.3 hour threshold by 0.3 hours. This trend was similar across monitoring sites for 2021.

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 2021.

Month	Ave. Daily H_{comp} (h)	Net Daily H_{comp} (h)	Ave. Daily H_{sat} (h)	Net Daily H_{sat} (h)	Ave. Monthly Temperature (°C)
July	14.6	+2.3	13.4	+5.4	23.6
August	13.4	+1.1	12.0	+4.0	24.6
September	12.0	-0.3	10.9	+2.9	23.0

The water temperature trend for the Sag Harbor Bay eelgrass meadow was found to be cooler than the previous years in 2021. The monthly average water temperatures presented in Table SH-1, show that the site remained below 25°C for July-September, 2021. Sag Harbor Bay only recorded 11 days of daily average temperatures over 25°C, 14 fewer days than in 2020. The highest water temperature recorded for the site was 25.9°C on 27 August, 2021.

Eelgrass Shoot Density

Eelgrass monitoring for Sag Harbor Bay was conducted on 9 September, 2021. The combined average eelgrass shoot density for all three eelgrass beds was 197 shoot·m² (Table SH-2), which represents a significant decrease in eelgrass density from 2020. For each of the three individual eelgrass beds comprising the site, an average shoot density was calculated for each. For Bed1, the 2021 shoot density was 247 shoot·m², which was a significant decline from the 343 shoot·m² reported in 2020. Bed2 experienced a minor decrease in shoot density from 2020 to 2021. The 2020 density was 144 shoot·m², while the 2021 density was 124 shoot·m². The final bed, Bed3 reported no significant change between 2020 (255 shoot·m²) and 2021 (222 shoot·m²).

Table SH-2. The average annual eelgrass shoot density for Sag Harbor from 2017 to 2021, including standard error.

Year	Mean Density	S.E.
2017	249	+/-16
2018	331	+/-25
2019	223	+/-15
2020	247	+/-17
2021	197	+/-12

Macroalgae Cover

Macroalgae cover experienced a slight decline from 2020 to 2021 within the Sag Harbor eelgrass meadow. The macroalgae cover was 4% in 2021, down from 8% in 2020 (Figure SH-3).Bed1 and Bed3 recorded average macroalgae cover of 3% for 2021, with Bed2 having the highest macroalgae cover at 7%. Larger macroalgae species like *Sargassum* and *Codium* wehere more common in Bed1 with its abundant boulders, while Bed2 and Bed3 supported smaller species like *Gracilaria, Spyridia,* and filamentous species.

Bed Delineation and Areal Extent

The 2021 meadow delineations for Sag Harbor were completed using Google Earth™ imagery from April, 2021. The three eelgrass beds making up the Sag Harbor Bay site covered a total of 50.12 acres (Table SH-3; Figure SH-4). This represents an insignificant change from the 2020 meadow extent. Good image quality in the 2021 imagery allowed for the delinea-

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.)
2021	50.12 acres (20.28 hect.)

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

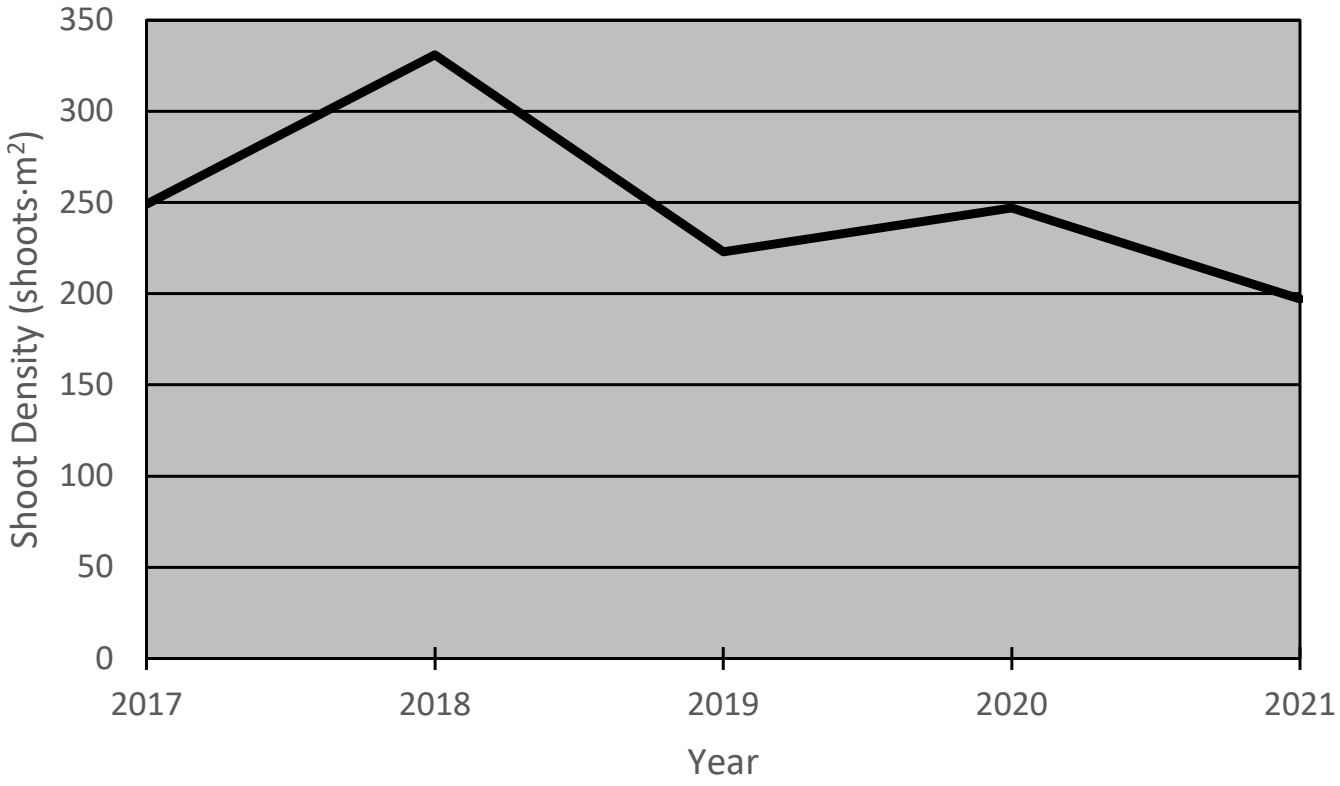


Figure SH-2. Graph of the annual mean eelgrass shoot density for Fort Pond Bay from 2017-2021.

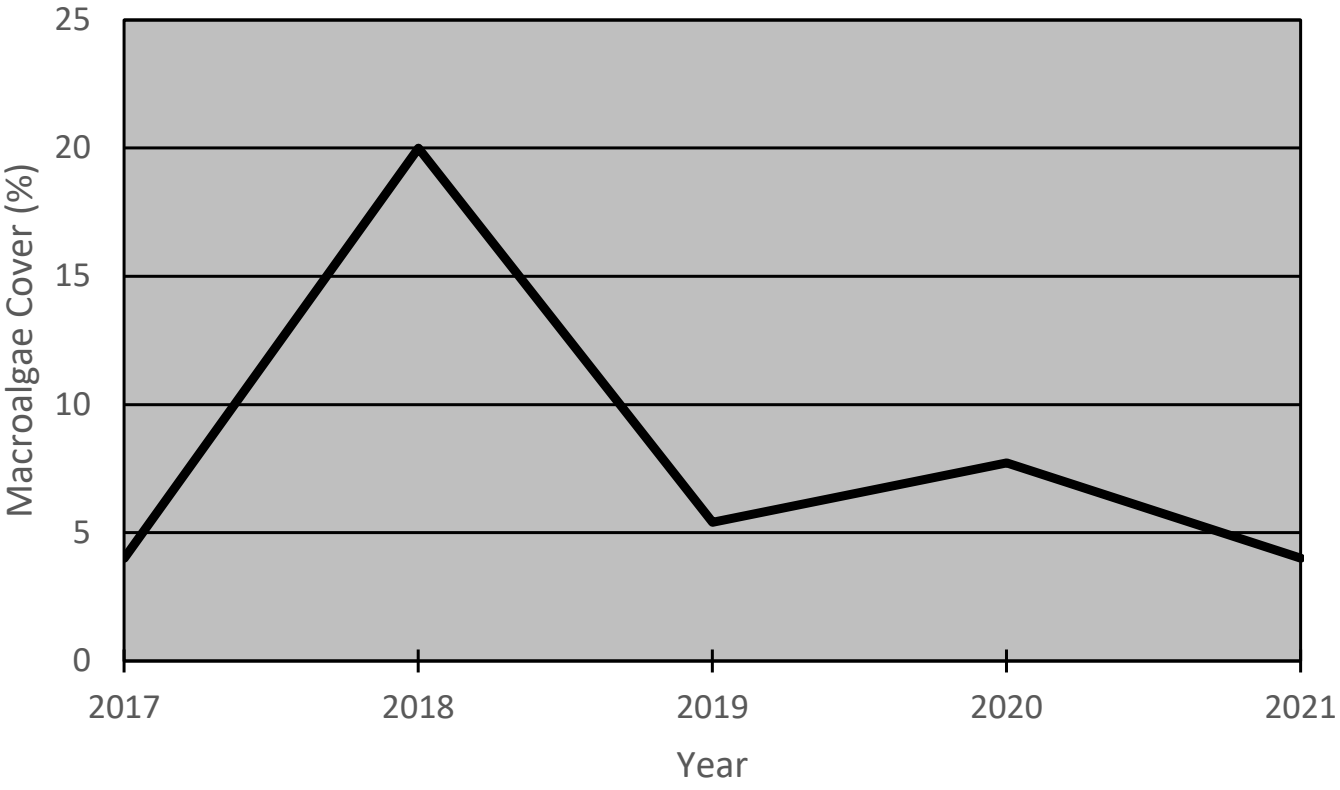


Figure SH-3. The annual mean macroalgae percent cover for Fort Pond Bay from 2017-2021.

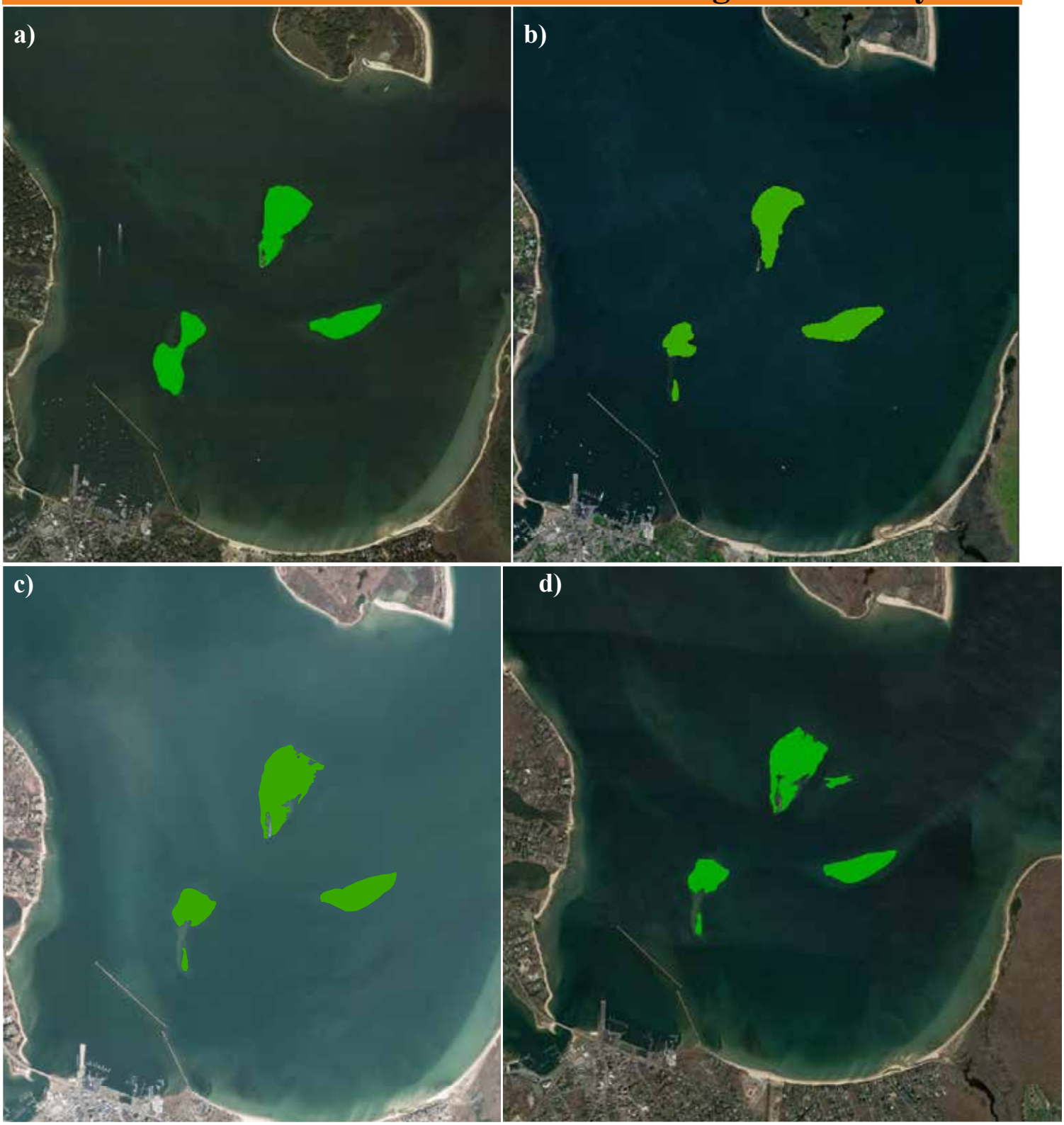


Figure SH-4. Comparison of delineations between a) 2014, b) 2019, c) 2020 and d) 2021 for the Sag Harbor Bay eelgrass meadow complex.

tion of the small bed adjacent to Bed1 which was not identified in 2019 or 2020 imagery.

Conclusions

Conditions within the Sag Harbor Bay complex continued to support healthy eelgrass meadows in 2021. While there was an overall significant decline in eelgrass shoot density for the site, the loss was almost completely confined to Bed1 where there was

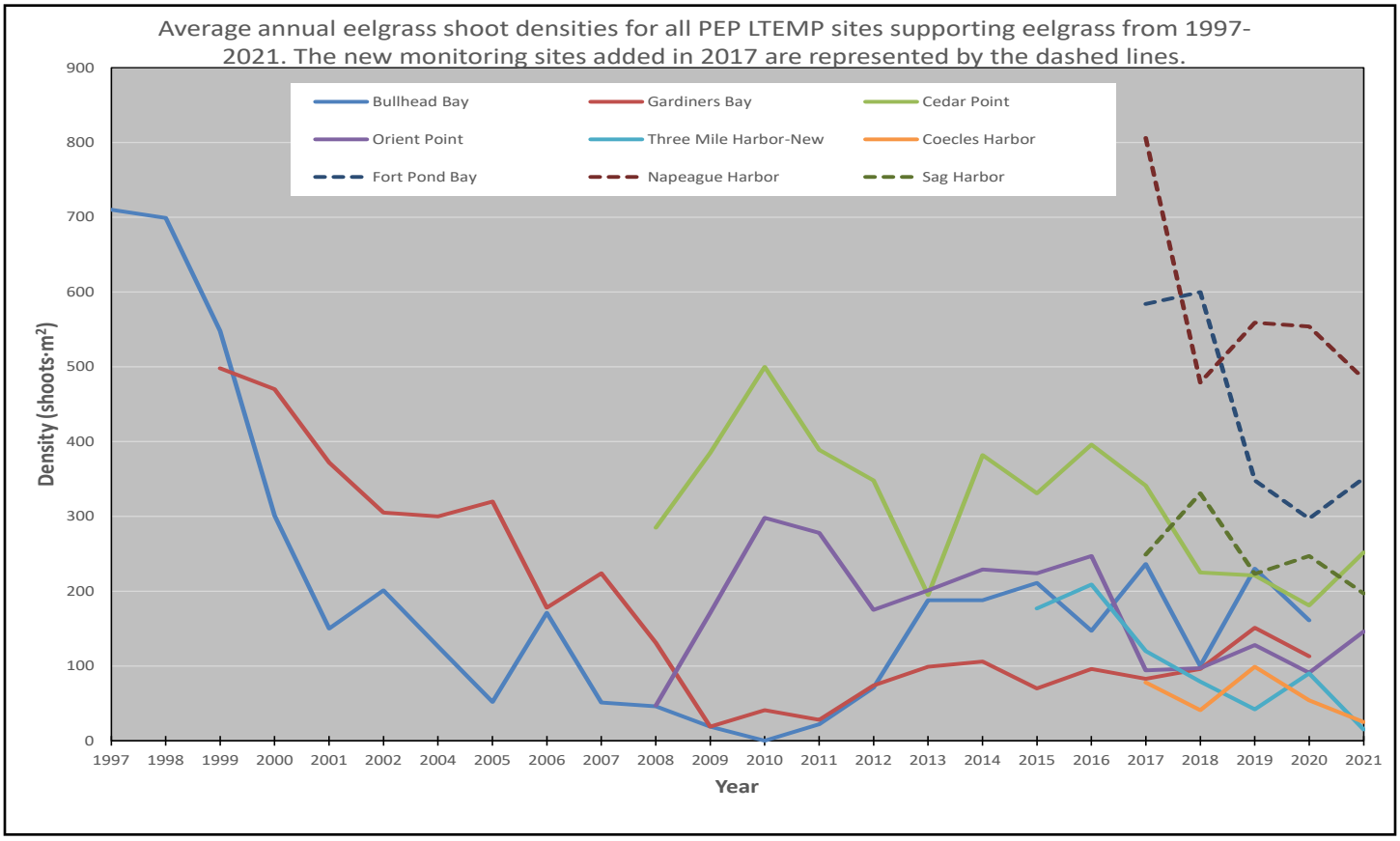
Figure SH-5. a) A bug scallop discovered in a quadrat while monitoring at station SH2. b) Diver discovers a feather blenny has claimed and old clam shell for a home within the Sag Harbor eelgrass meadow.

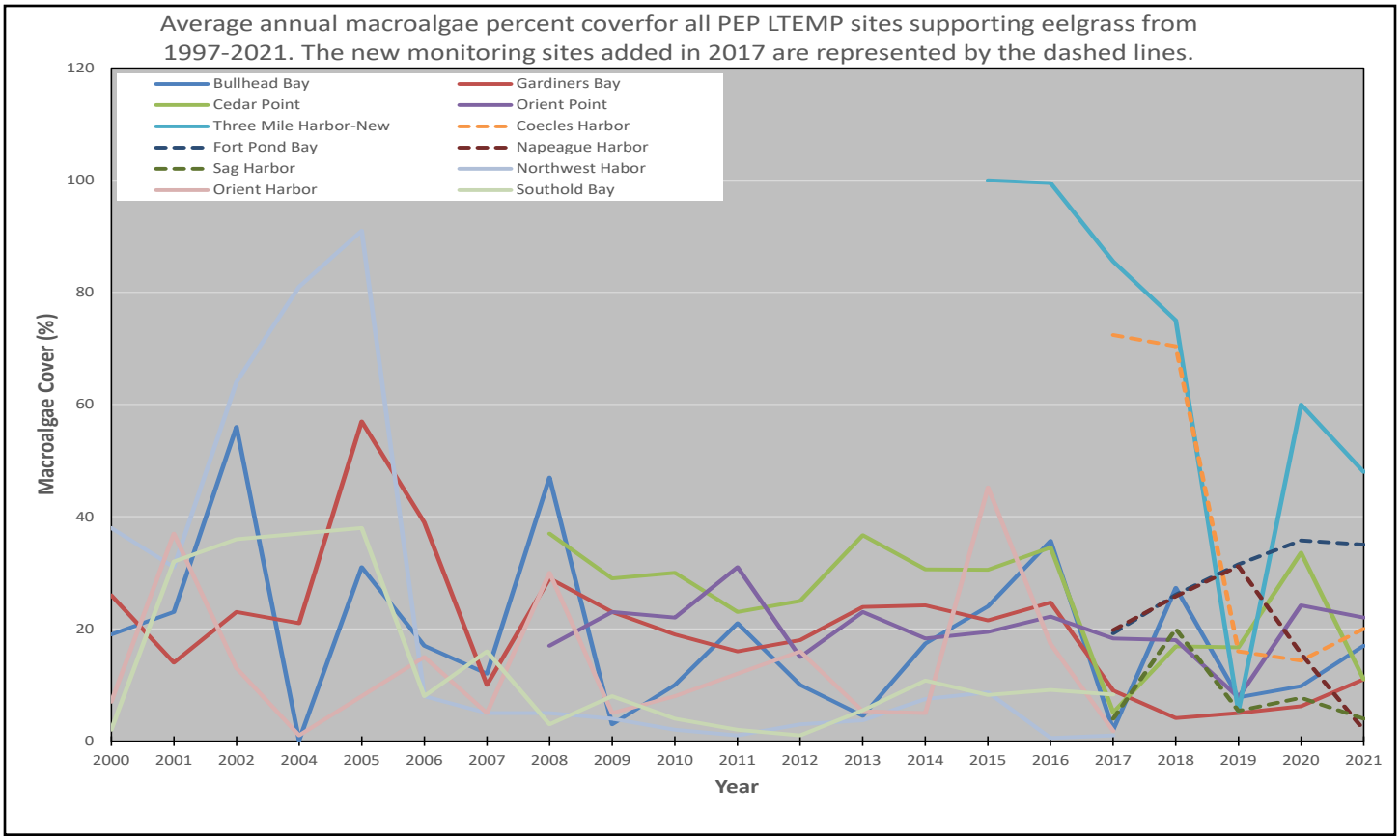
an observable increase in erosion around the boulders throughout this bed's extent. Bed2 and Bed3 showed no significant change between 2020 and 2021, and the restoration planting area that CCE has been expanding over the past few years just south of Bed2 has showed minimal mortality of the transplanted eelgrass and significant natural expansion of the plantings in the 2 year old planting area. CCE plans to continue to expand the plantings near Bed2 to enhance this natural eelgrass bed.

CCE was approached by civic groups from Sag Harbor for recommendations on how the existing eelgrass could be protected and preserved. The location of the meadows in Sag Harbor Bay were provided to the groups, with the idea that they would be incorporated into any plans for the expansion of the mooring field in Sag Harbor, and also made available to the public to direct vessels away from anchoring in eelgrass. There has not been an update from the groups on how this effort has proceeded, but an inquiry will be made this fall to check on progress.

Appendix

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





References

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

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

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

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

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