# East Hampton Town Trustees 2022 water quality study,

# Final Report

by

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## Executive Summary

This study was undertaken from May through October of 2022 for the East Hampton Town Trustees to assess water quality, harmful algal blooms, pathogenic bacteria, and sediments in the marine and freshwater bodies of Accabonac Harbor, Napeague Harbor, Hog Creek, Northwest Creek, Little Northwest Creek, Three-Mile Harbor, Fresh Pond, and Hook Pond. The study also included continuous monitoring and/or surface mapping of Three Mile Harbor, Napeague Harbor, Accabonac Harbor, and Georgica Pond because of harmful algal blooms and/or low dissolved oxygen conditions at these sites in the past. During 2022, most East Hampton Town Trustees waters were often of a high quality. Fecal coliform bacteria levels across marine sites were generally low through the spring and summer, although excursions beyond state standards were observed at multiple sites in Accabonac Harbor and Three-Mile Harbor in patterns were partly consistent with NYSDEC shellfishing recommendations. In addition, levels of *Enterococcus* exceeded levels recommended for swimming by NYSDOH in both systems on occasion in 2022. Microbial source tracking of fecal bacteria found elevated levels of human-derived fecal bacteria near two marinas in Three Mile Harbor but lower levels further away. Fecal bacteria within Accabonac Harbor were primarily derived from birds and their relative importance increased at sites that were more removed from marinas and road-runoff. Dog and small mammal fecal bacteria had a high abundance in Three Mile Harbor, potentially reflective of greater road runoff at the sites sampled and fewer wetlands there. A comparison of sites in the Head of the Harbor revealed a greater abundance of deer and bird derived bacteria at sites less influenced by road run-off and more influenced by forest and streams. While discrete measurements of dissolved oxygen were generally at concentrations supportive of fisheries, continuous measurements of dissolved oxygen in the Head of Three Mile Harbor revealed hypoxic events throughout August. Chlorophyll *a* levels were usually within a healthy range for most sites although 8 of 14 sites displayed levels above guideline values on at least one occasion during late summer or the beginning of fall. Nevertheless, no sites in Accabonac Harbor or Three Mile Harbor experienced bloom levels exceeding the harmful threshold in the summer and fall. Measurements of total nitrogen across all marine sites demonstrated that 6 of the 14 marine locations sampled exceeded the Peconic Estuary Program's recommended value of 0.4 mg N/L, with sites in Hog Creek, Accabonac Harbor, and Three Mile Harbor being above the guidance value. Most of these sites also had elevated levels of

dissolved inorganic N, suggesting strong localized sources of N loading. Novel spatial surveys with an autonomous surface water vehicle revealed the interactive roles of nitrogen loading and tidal exchange in effecting water quality in Three Mile Harbor, Accabonac Harbor, and Napeague Harbor with water quality near inlets being saltier, and lower in chlorophyll and dissolved oxygen compared to regions deeper into each system which had lower salinity, higher chlorophyll *a*, and higher dissolved oxygen. Additionally, sediment survey analysis in Accabonac Harbor revealed that sites closer to the mouth of the Harbor had coarse grained sediment with lower levels of organic matter, whereas regions further into the Harbor, closer to land were more likely to have organically-enriched muds and fine grain sediment. These sites are consistent with the marsh regions in the Harbor having lower energy water flow and finer grain composition.

East Hampton Town's freshwater bodies monitored in 2022 displayed a mix of good and poor water quality. All sites had chlorophyll *a* levels exceeding US EPA guidance levels. Aside from Fresh Pond, Georgica Pond and Forth Pond, Hook Pond and Wainscott Pond each experienced blue-green algae blooms at levels that exceeded the NYSDEC threshold warranting closure of the water bodies for varying periods of time. Wainscott Pond was the most impacted systems, with every sample exceeding bloom levels and mean intensity being nearly an order of magnitude greater than the NYSDEC threshold with the toxin microcystin chronically present but at levels below the EPA guideline for recreation. In contrast to last year, Georgica Pond did not experience intense blue-green algae blooms. Georgica Pond experienced occasional hypoxic events in summer and in fall at the opening of the cut, with these events being more intense than last year. An intensive temporal assessment of Georgica Pond before and after the opening of the cut revealed a dramatic increase in salinity and a decrease in dissolved oxygen and algae associated with the letting of Georgica Pond, but also an increase is dissolved oxygen and algae when the cut re-closed shortly thereafter. Collectively, this study revealed regions of East Hampton with excellent water quality, as well as regions requiring further study, monitoring, and remediation.

## 1. Background

Coastal marine ecosystems are amongst the most ecologically and economically productive areas on the planet, providing an estimated US$20 trillion in annual resources or about 43% of the global ecosystem goods and services (Costanza et al., 1997). Approximately 40% of the world's population lives within 100 km of a coastline, making these regions subject to a suite of anthropogenic stressors including intense nutrient loading (Nixon, 1995; de Jonge et al., 2002; Valiela, 2006). Excessive nutrient loading into coastal ecosystems promotes algal productivity and the subsequent microbial consumption of this organic matter reduces oxygen levels and can promote hypoxia (Cloern, 2001; Heisler et al., 2008). The rapid acceleration of nutrient loading to coastal zones in recent decades has contributed to a significant expansion of algal blooms, some of which can be harmful to ecosystems or the humans who live around those ecosystems.

Globally, the phytoplankton communities of many coastal ecosystems have become increasingly dominated by harmful algal blooms (HABs) and New York's coastal waters are a prime example of this trend. Prior to 2006, algal blooms in NY were well-known for their ability to disrupt coastal ecosystem and fisheries but were never considered a human health threat. Since 2006, blooms of the saxitoxin-producing dinoflagellate *Alexandrium catenatum* have led to paralytic shellfish poisoning (PSP)-inducing closures of thousands of acres of shellfish beds in Suffolk County. In 2008, a second toxic dinoflagellate, *Dinophysis acuminata*, began forming large, annual blooms that generated the toxins okadaic acid and DTX-1, both of which are the causative agents of diarrhetic shellfish poisoning (DSP). During the past decade, moderate levels of *Alexandrium* and *Dinophysis* have recently been detected in East Hampton Town waters. The limited nature of sampling, however, has prohibited definitive conclusions regarding the extent and maximal densities of blooms from being established.

In Suffolk County, blooms of the ichthyotoxic dinoflagellate *Cochlodinium* have occurred every year since 2004 in the Peconic Estuary and Shinnecock Bay and bloom water from these regions has been shown to cause rapid morality in fish, shellfish, and shellfish larvae (Gobler et al., 2008; Tang & Gobler, 2009a; 2009b). *Cochlodinium polykrikoides* forms blooms around the world and the highly lethal effects of these blooms on fish, shellfish, shellfish larvae, zooplankton, and subsequent impacts on fisheries have been well established (Kudela & Gobler, 2012). Studies to date suggest short-lived, labile toxins, similar to reactive oxygen species (ROS), play a central role in the toxicity of *C. polykrikoides* to fish and shellfish (adult, juvenile, and larvae) (Tang & Gobler, 2009a; 2009b). In 2012, these blooms spread into East Hampton Town marine waters. Large populations of bay scallops, that were otherwise abundant prior to the blooms, died following these bloom events (Deborah Barnes, NYSDEC, pers. comm.). However, the precise distribution of *Cochlodinium polykrikoides* blooms in East Hampton Town waters is unknown.

Toxic cyanobacteria blooms represent a serious threat to aquatic ecosystems. Globally, the frequency and intensity of toxic cyanobacteria blooms have increased greatly during the past decade, and have become commonplace in the more freshwater, upper reaches of many US estuaries. Toxin concentrations during many of these blooms often surpass the World Health Organization (WHO) safe drinking water of 1 µg $L^{-1}$ and recreational water limit of 20 µg $L^{-1}$ (Chorus & Bartram, 1999). There are multitudes of examples of sicknesses and deaths associated with chronic, or even sporadic, consumption of water contaminated with cyanotoxins (O'Neil et al., 2012). Cyanotoxin exposure has been linked to mild and potentially fatal medical conditions in humans including gastrointestinal cancers (i.e., liver, colorectal; Chorus & Bartram, 1999) and more recently, neurological disorders such as Alzheimer’s disease (Cox et al., 2005).

Since 2003, the Gobler lab of Stony Brook University has assessed levels of toxic cyanobacteria and microcystin in more than 40 freshwater systems across Suffolk County. Most lakes sampled contain potentially toxic cyanobacteria (typically *Microcystis* spp. or *Anabaena* spp.) and contain detectable levels of the hepatotoxin made by cyanobacteria, microcystin. *Microcystis* is a cyanobacteria that synthesizes a gastrointestinal toxin known as microcystin that is known to inhibit protein phosphorylation. In early September 2012, the NYS Department of Health reported that an autopsy of a dog that died suddenly on the shoreline Georgica Pond revealed *Microcystis*-like cells in its stomach. Although no bloom was obvious in Georgica Pond when it was investigated in late September of 2012, blooms are typically ephemeral, and the most toxic events are typically associated with nearshore, wind accumulated scums, rather than lake water. Historically, the temporal and spatial dynamics of toxic cyanobacteria in Georgica Pond, as well as densities of other harmful algae in East Hampton waters, have not been well-characterized.

A final group of microbes of concern in coastal ecosystems are pathogenic bacteria. Such pathogens can present a hazard to humans recreating in affected waters by infecting the alimentary canal, ears, eyes, nasal cavity, skin, or upper respiratory tract, which can be exposed through immersion or the splashing of water (Thompson et al., 2005). Consumption of contaminated shellfish is one of the most common exposure routes for marine pathogens. Fecal coliform bacteria and *Enterococcus* are the recommended indicator for human pathogens in marine waters, and gastrointestinal symptoms are a frequent health outcome associated with exposure (Thompson et al., 2005). The presence of high levels of fecal coliform bacteria and/or *Enterococcus* may trigger action by a municipal agency to remediate such conditions. One key obstacle to generating a successful remediation plan for high levels of indicator bacteria such as fecal coliform bacteria and/or *Enterococcus* is that the source of the potentially pathogenic bacteria is often unknown. That is, pathogenic, fecal bacteria co-present with fecal coliform bacteria and/or *Enterococcus* may be derived from any animal, including humans and remedial plans for mitigating bacteria from human wastewater will differ radically from plans focused on the mitigation of animal feces. Moreover, mitigation of feces-derived bacteria from birds that live on the waterbody would differ radically from plans to minimize dog or deer feces that might emanate from road run-off.

The objectives of this study were to assess the temporal and spatial dynamics of coliform bacteria, the PSP-causing dinoflagellate *Alexandrium*, the DSP-causing dinoflagellate *Dinophysis*, and the ichthyotoxic dinoflagellate, *Cochlodinium* in East Hampton Town marine waters. It also assesses the dynamics of toxic cyanobacteria and cyanotoxins in East Hampton's major freshwater/brackish bodies. Sampling for general water quality parameters was also included, and sampling proceeded from May through October of 2022 as part of an ongoing, 8-year, monitoring study.

## 2. Approach

### *2.1. Water Quality*

The 2022 sampling season ran from 17-May-2022 through 4-November-2022. Marine sampling was done on a bi-weekly basis, and freshwater sites were sampled weekly. Sampling included sixteen marine sites within Napeague Harbor, Accabonac Harbor, Hog Creek, Three Mile Harbor, Northwest Creek, and Little Northwest Creek (Fig. 1; Table 1); and eight freshwater sites within Fresh Pond, Georgica Pond, Hook Pond, Wainscott Pond, and Fort Pond (Fig. 1; Table 1). Sampling of Fort Pond, Montauk, was performed by the Concerned Citizens of Montauk and delivered to Southampton for processing.

Each marine water body was sampled from two or three individual sites, with at least one located near the water body's inlet to the Peconic estuary, and the others further from the inlet. Northwest Creek was the exception with only one site located near its inlet. General water quality measurements obtained for each site included salinity, temperature, and dissolved oxygen levels measured with a handheld YSI 556 probe. Onset HOBO data loggers were also deployed at the head of Three Mile Harbor, and in Napeague Harbor to continuously record bottom temperature and dissolved oxygen levels over time. Additionally, water was collected from sites and analyzed for chlorophyll *a*, fecal indicator bacteria, and total Nitrogen. Fecal coliform and *Enterococci* bacteria were quantified using Colilert-18 and Enterolert/Quati-tray kits according to manufacturer instructions, yielding most probable number (MPN) in terms of colony forming units (CFU) per 100 mL (IDEXX).

The pigment chlorophyll *a*, which serves as an analog for algal biomass, was measured by filtering whole water through glass fiber filters, extracting the collected pigment from the filter with acetone, and measuring the fluorescence (Parsons et al., 1984). To assess the abundance of harmful algae, nine of these marine sites were sampled more comprehensively with each harbor having at least one such site. These sites were those located furthest from their respective inlets in areas that are more prone to elevated nutrient levels and the proliferation of algae. All of Accabonac Harbor and Three Mile Harbor sites for this study were treated as such.

*Alexandrium fundyense* and *Dinophysis acuminate* are toxic marine dinoflagellates responsible for paralytic shellfish poisoning, and diarrhetic shellfish poisoning (DSP), respectively, and were sampled for during May. The harmful "rust tide" dinoflagellate *Cochlodinium*, known for causing fish kills, was monitored from June through October. In all cases, whole water was collected and preserved with Lugol's iodine and cells were counted on a Sedgewick-Rafter slide under a microscope.

At the seven freshwater sites (three in Georgica, two in Fort Pond, one in Hook, and one in Wainscott Pond), samples were collected for the quantification of chlorophyll *a*, temperature, salinity, and dissolved oxygen as described above. Blue-green algae fluorescence, an analog for cyanobacterial biomass, was measured using a FluoroProbe with live samples. Samples from Fort Pond, Montauk, were delivered to the lab and measured for fluorescence only.

A telemetry monitoring buoy was redeployed in southern Georgica Pond, and uploaded real-time water quality data of temperature, salinity, pH, dissolved oxygen, chlorophyll *a*, and blue-green algae fluorescence. The sensors for chlorophyll *a* and blue-green algae are not as sensitive as the discreet sampling methods, but displayed trends that parallel those measurements.

### *2.2. Indicator bacteria quantification*

During the present study, fecal bacteria contamination was assessed at three sites within Accabonac and Three Mile Harbors, each, and one site each within Hog Creek and Northwest Creek, on selected dates spanning from May to November 2022. On each date, surface water (0.25 m depth) samples were collected in sterile 2 L bottles and transported on ice to the laboratory for further processing within two hours of collection. Triplicate whole water samples were collected for DNA analysis in which samples were well-mixed to ensure even distribution of biomass prior to filtering 25-100 mL onto a 0.2 µm Millipore polycarbonate filter, depending on water turbidity. Samples were immediately frozen in liquid nitrogen and stored at -80°C until further processing. In parallel, sites were additionally sampled for fecal coliform bacteria and *Enterococci* bacteria from May through October, quantified using the IDEXX Enterolert & Quanti-Tray/2000 sampling kits, giving MPN per 100mL.

### 2.3. HYCAT surveys

During September 2022, a HYCAT surface autonomous vehicle (SAV) (Fig. 2) was deployed to Accabonac Harbor and Three Mile Harbor during. The HYCAT SAV was equipped with a YSI EXO2 to provide fine-level spatial resolution of various water quality parameters, including temperature, salinity, dissolved oxygen, pH, and chlorophyll *a*.

### 2.4. Sediment surveys

During the present study, sediment samples were amassed from more than 20 locations around Accabonac Harbor, with concentrated samples near the Louse Point boat launch and near the Accabonac Harbor culvert up north. Samples were weighted and measured to quantify sediment type, the overall thickness of muds, macrophyte abundance and estimated sediment nutrient flux.

## 3. Findings – Marine Systems

### *3.1. General Water Quality: Temperature, Salinity & Dissolved Oxygen*

Average surface temperatures ranged 21.0 – 22.9°C across East Hampton's marine sites, while summertime (27-June-2022 to 20-September-2022) averages ranged 23.2 – 25.2°C (Fig. 3). Overall average and summertime average temperatures across all sites was 21.8 ± 0.6°C and 24.2 ± 0.6°C, respectively. Maximum surface temperatures in East Hampton ranged 24.4 – 30.7°C with an average maximum temperature of 27.1 ± 1.4°C (Fig. 3). Average, summertime average, and maximum salinities in East Hampton ranged 25.0 – 30.7 PSU, 26.2 – 31.0 PSU, and 29.4 – 31.6 PSU, respectively (Fig. 4). Overall average, summertime average, and average maximum salinities were 28.4 ± 1.6 PSU, 29.1 ± 1.4 PSU, and 30.6 ± 0.6 PSU, respectively (Fig. 4). Average dissolved oxygen (DO) concentrations ranged 6.3 – 9.7 mg $L^{-1}$, while summertime average concentrations ranged 5.6 – 9.2 mg $L^{-1}$ (Fig. 5). Overall average and summertime average DO concentrations across all sites was 7.4 ± 1.0 mg $L^{-1}$ and 7.2 ± 1.1 mg $L^{-1}$, respectively. Minimum surface DO concentrations in East Hampton ranged 2.1 – 6.8 mg $L^{-1}$ with an average minimum concentration of 5.0 ± 1.1 mg $L^{-1}$ (Fig. 5). Overall and summertime average DO concentrations were generally above the NYSDEC minimum standard for DO (4.8 mg $L^{-1}$). However, minimum concentrations at sites in Accabonac Harbor (EH 6a, EH7a and EH7b), Hog Creek (EH9), Three Mile Harbor (EH11), Northwest Creek (EH13) and Little Northwest Creek (LNCW1) were below the NYSDEC minimum concentration (Fig. 5).

Surface water temperature and DO were measured continuously in Napeague Harbor and Three Mile Harbor (EH11) during summer 2022. In Napeague Harbor, surface and bottom temperatures were both, on average, 22.1 ± 2.8, and ranged 18.9 – 24.4°C, from the beginning of September to the beginning of October (Fig. 6). During that time, surface and bottom DO concentrations were both, on average, 8.0 ± 0.9mg $L^{-1}$ and ranged 7.2 – 8.0mg $L^{-1}$, respectively (Fig. 7). At no point did surface or bottom DO concentrations decrease below the NYSDEC minimum for DO (4.8 mg $L^{-1}$) (Fig. 7). In Three Mile Harbor, temperature was, on average, 23.9 ± 2.0°C from the end of June until the end of September and ranged 17.3 – 27.1°C (Fig. 8). During that time, DO concentrations were, on average, 3.6 ± 2.5 mg $L^{-1}$ and ranged 0.0 – 8.9 mg $L^{-1}$. Throughout the sampling season, dissolved oxygen concentrations in Three Mile Harbor deviated below the NYSDEC minimum for DO, with all DO levels in September below the NYSDEC DO minimum (Fig. 9).

*3.2. Nitrogen and Eutrophication*

In Napeague Harbor (EH1 and EH2), dissolved inorganic nitrogen (DIN) concentrations were ~0.06 – 0.11 mg N/L from the end of May until the middle of September (Fig. 10). In Hog Creek (EH8 and EH9), concentrations ranged 0.07 – 0.12 µM during the same period of time (Fig. 10). In Northwest Creek (EH13), concentrations ranged 0.06 - 0.08 mg N/L (Fig. 10). In Accabonac Harbor (EH5, EH6a, EH7a, and EH7b), concentrations generally ranged 0.07 – 0.12 mg N/L, with the exception of 20-September-2022 in EH7a (0.13 mg N/L) (Fig. 10). In Three Mile Harbor (EH10, EH10a, EH11a, EH11, and EH12), DIN concentrations generally ranged 0.03 – 0.11 mg N/L, with the exception ofEH11a, where concentrations were 0.17 mg N/L on 11-July-2022 (Fig. 10). In Little Northwest Creek, DIN concentrations ranged 0.03 – 0.09 µM across LNWC1 and LNWC2 (Fig. 10).

In Napeague Harbor, total N concentrations were 0.14 – 0.32 mg N/L on all dates during 2022, which were entirely below the Peconic Estuary total N threshold (0.40 mg N/L) (Fig. 11). In Hog Creek, total N concentrations ranged 0.24 – 0.62 mg N/L throughout 2022. In this region, concentrations exceeded the Peconic Estuary threshold on 17-May-2022 and 11-July-2022 at EH9, in which concentrations were 0.45 and 0.62 mg N/L respectively (Fig. 11). At Northwest Creek, concentrations ranged 0.26 – 0.31 mg N/L throughout 2022 and were entirely below the Peconic Estuary total N threshold (Fig. 11). In Accabonac Harbor, total N concentrations frequently exceeded the Peconic Estuary total N threshold. At EH5, concentrations were 0.21– 0.27 mg N/L throughout 2022. At EH6a, concentrations were 0.32 – 0.51 mg N/L throughout 2022, exceeding the Peconic Estuary total N threshold on 11-July-2023 and 20-September-2022 (Fig. 11). At EH7a, total N concentrations ranged 0.30 – 0.39 mg N/L, exceeding the Peconic Estuary total N threshold on 11-July-2022 (Fig. 11). At EH7b, concentrations exceeded the Peconic Estuary total N threshold on all dates sampled, ranging 0.47 – 0.83 mg N/L (Fig. 11). In Three Mile Harbor, concentrations at EH10 and EH10a ranged 0.13 – 0.28 mg N/L for the entirety of 2022, never once exceeding the Peconic Estuary total N threshold (Fig. 11). At EH11a, concentrations were 0.33 – 0.45 mg N/L for all 2022 dates (Fig. 11). At EH11, concentrations ranged 0.18 – 0.36 mg N/L, never meeting the Peconic Estuary total N threshold in 2022 (Fig. 11). At EH12, total N concentrations were 0.20 – 0.40 mg N/L for all dates (Fig. 11). In Little Northwest Creek, total N concentrations ranged 0.14 – 0.37 mg N/L across LNWC1 and LNWC2 (Fig. 11).

The overall average, summer average, and maximum DIN concentrations at the marine sampling sites were 0.08 ± 0.02, 0.09 ± 0.02, and 0.11 ± 0.02 mg N/L, respectively, and ranged 0.06 – 0.10, 0.05 – 0.14, and 0.07 – 0.17 mg N/L, respectively (Fig. 12). The overall average, summer average, and maximum total N concentrations were 0.31 ± 0.12, 0.31 ± 0.11, and 0.39 ± 0.16 mg N/L, respectively, and ranged 0.17 – 0.62, 0.17 – 0.51, and 0.21 – 0.83 mg N/L, respectively (Fig. 12).

### *3.3. Algae and Harmful Algae; Dinophysis, Cochlodinium, & Alexandrium*

All algae contain the pigment chlorophyll *a* and therefore, is measured as a proxy for total phytoplankton biomass. Moderate levels of algae support productive fisheries and ecosystems, but excessive algal growth can lead to a series of negative ecological consequences, including hypoxia and acidification, and could be a sign of the development of an algal bloom.

Overall average and summertime average chlorophyll *a* concentrations ranged 2.6 – 14.2 µg $L^{-1}$ and 3.6 – 19.4 µg $L^{-1}$, respectively, and averaged 6.9 ± 3.3 µg $L^{-1}$ and 9.1 ± 4.7 µg $L^{-1}$, respectively (Fig. 13). Maximum chlorophyll *a* concentrations were, on average, 21.0 ± 11.2 µg $L^{-1}$ across all sites and ranged 8.1 – 31.8 µg $L^{-1}$. The USEPA considers 20 µg $L^{-1}$ of chlorophyll *a* in marine waters as eutrophic, and all sites were below this level on average. In this season, maximum concentrations in Napeague Harbor (EH1), Accabonac Harbor (EH5, EH6, EH7a, EH7b), Hog Creek (EH9) and Three Mile Harbor (EH11, EH11a) exceeded this level (Fig. 13). For the entirety of May through the end of July, chlorophyll *a* concentrations remained below the USEPA maximum chlorophyll *a* level (Fig. 14). From that point until the end of sampling in the start of October, all sites on all dates, with the exception of Napeague Harbor (EH1; 28.1 µg $L^{-1}$ on 9-September-2022) Accabonac Harbor (EH5; 20.8 µg $L^{-1}$ on 6-October-2022, EH6; 26.4 µg $L^{-1}$ on 8-August-2022, 26.9 µg $L^{-1}$ on 22-August-2022, 31.8 µg $L^{-1}$ on 19-September-2022, EH7a; 25.2 µg $L^{-1}$ on 22-August-2022, EH7b; 22.6 µg $L^{-1}$ 8-August-2022, 27.2 µg $L^{-1}$ on 19-September-2022), Hog Creek (EH9; 49.4 µg $L^{-1}$ on 8-August-2022) and Three Mile Harbor (EH11; 23.9 µg

$L^{-1}$ on 22-October-2022, EH11a; 33.2 µg $L^{-1}$ on 19-September-2022, 32.2 µg $L^{-1}$ on 6-October-2022), had concentrations below the USEPA maximum chlorophyll *a* level (Fig. 14).

*Alexandrium* is a toxic dinoflagellate that synthesizes saxitoxin, which leads to the syndrome of PSP, and can cause illness or death in individuals consuming shellfish containing these toxins (Anderson, 1997). PSP has been occurring annually in New York waters since it first appeared in 2006, with Sag Harbor being the closest region to East Hampton experiencing a shellfish beds closure due to these. In 2013, densities of *Alexandrium* exceeded 1,000 cells $L^{-1}$, levels known to cause toxicity in shellfish (Anderson, 1997). They were detected in Three Mile Harbor at Head of the Harbor (EH11), representing the most intense *Alexandrium* bloom in East Hampton waters at the time resulting in additional sampling times. Nevertheless, in Accabonac Harbor this season, at sites EH5, EH6a, and EH7a, *Alexandrium* concentrations were not present nor detectable between 1-June-2022 and 28-July-2022 (Fig. 15). At Three Mile Harbor, concentrations of *Alexandrium* were detected (Fig. 15). At site EH1l, concentrations peaked to 875 cells $L^{-1}$ on 17-May-2022, just below the *Alexandrium* bloom threshold and quickly decreased to being nondetectable for the rest of the spring and summer (Fig. 15). The alga was not detected at sites EH 10, EH10a, EH11a, nor EH12 (Fig. 15). At all Three Mile Harbor sites during June and July, the alga was either not present or below detected levels (Fig. 15).

*Dinophysis* was present in East Hampton waters during 2022 as well, albeit very sparsely across the surveying season (Fig. 16). In Accabonac Harbor, aside from site EH 7b where algal was present at concentrations of 117 14 cells $L^{-1}$ on 5-May-2022, at all sites, the alga was not detected from the middle of May until the end of July (Fig. 16). In Three Mile Harbor, at sites EH11a and EH12, *Dinophysis* was not detected on any dates (Fig. 16). At site EH10, the alga was present at a concentration of 117 cells $L^{-1}$ on 17-May-2022, 83 cells $L^{-1}$ on 1-June-2022, and 350 cells $L^{-1}$ on 13-June-2022, but was absent on all other dates (Fig. 16). Similarly, EH10a had algal concentrations of 292 cells $L^{-1}$ on 13-June-2022, but not on any other date (Fig. 16). In EH11, *Dinophysis* was the most present, resulting in additional sampling times (Fig. 16). Algal concentrations were initially 42 cells $L^{-1}$ on 11-May-2022 peaking up to 2422 cells $L^{-1}$ on 7-June-2022 (Fig. 16). *Dinophysis* concentrations never exceeded the bloom threshold for *Dinophysis* (10,000 cells $L^{-1}$) during 2022 (Fig. 16).

*Cochlodinium* is an ichthyotoxic dinoflagellate that has caused fish kills across the globe including some sites on eastern Long Island (Kudela & Gobler, 2012). *Cochlodinium* blooms in excess of 300 cells $mL^{-1}$ have been known to cause mortality in larval fish, which use these estuarine systems as nurseries, and in shellfish (Tang & Gobler, 2009a; 2009b). In Accabonac Harbor, *Cochlodinium* concentrations were present in July only at 17 cell $mL^{-1}$ at site EH6a and not detected at any site for the rest of the summer (Fig. 17). In Three Mile Harbor, the alga was detected more frequently, resulting in additional sampling times, peaking at 10 cell $mL^{-1}$ at site EH11 in mid July (Fig. 17). The alga was not detected at site EH10, EH10a, EH11a, nor EH12 (Fig. 17). Concentrations of the alga in Accabonac Harbor and Three Mile Harbor were relatively minute. The distribution and intensity of *Cochlodinium* blooms differ from year-to-year, highlighting the importance of long-term monitoring of water quality trends. It is notable that although *Cochlodinium* does not bloom consistently in each individual location from year to year, over the past eight years, it has spread to and reached harmful densities in four of five harbors. Given its ability to form cysts (Tang & Gobler, 2012), this finding suggests the potential to spread and bloom in more locations in the future.

### *3.4. Fecal Coliform Bacteria and Enterococcus*

Fecal coliform concentrations varied among sites in Accabonac Harbor and Three Mile Harbor during summer and fall 2022. In Accabonac Harbor, concentrations at the EH7a site ranged 54 – >401 colony forming units (CFU) per 100 mL for summer through fall (Fig. 18). At the EH5 and EH7b sites, concentrations ranged <10 – 139 CFU per 100 mL from the beginning of May until the middle of September (Fig. 18). However, in the beginning of October, concentrations were >401 CFU per 100 mL, which exceeds the shellfishing standards for fecal coliform bacteria set by the USFDA National Shellfish Sanitation Program (NSSP) and followed by the NYSDEC (200 CFU per 100 mL) (Fig. 18). At the EH6a site, concentrations were >401 CFU per 100 mL from the beginning of June until the beginning of September and was 233 CFU per 100 mL on 4-October-2022 (Fig. 18). In Three Mile Harbor, concentrations were <401 CFU per 100 mL for EH10 and EH10a on 13-June-2022 and 22-August-2022, respectively (Fig. 18). In Three Mile Harbor, concentrations ranged 0 to 19 CFU per 100 mL (EH10) and <2 to 396 CFU per 100 mL (EH10a) (Fig. 18). Concentrations at EH12 ranged <2 to 17 CFU per 100 mL (Fig. 18). At the

EH11 site, concentrations decreased from ~73 CFU per 100 mL in the beginning of June to ~8 CFU per 100 mL in the beginning of July, were >401 CFU per 100 mL in the beginning of August, decreased to ~11 CFU per 100 mL in the middle of September, and increased to 218 CFU per 100 mL in the middle of October (Fig. 18). At the EH11a site, concentrations were <401 CFU per 100 mL in June and July and ranged 39 – 170 CFU per 100 mL in September and October (Fig. 18). Fecal coliform concentrations exceeded the USFDA and NYSDEC shellfishing standards at the EH11 and EH11a sites frequently throughout summer and fall 2022 (Fig. 18).

Importantly, the National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish (USFDA, 2017) requires 30 data points for an official evaluation of water quality to be considered for shellfishing, which this study now cumulatively exceeds over the past several years. Moreover, it requires highly precise standards (geometric mean & estimated 90th percentile value) for the type of sampling regimen used and method of examining samples (mean probably number vs. filters). The data provided within this report is meant to provide general information on fecal coliform and to assist in guiding future sampling by NYSDEC who have ultimate authority with regards to shellfish sanitation in NY. It should be noted that the Gobler Lab entered the Environmental Laboratory Approval Program (ELAP) of the Wadsworth Center of the NYS Department of Health and had its fecal coliform bacterial levels ELAP certified since 2018.

*Enterococcus* bacteria were also quantified for Accabonac Harbor and Three Mile Harbor sites in 2022; used by the NYSDOH as an environmental standard for bathing beaches. During June 2022, enterococci concentrations exceeded >401 CFU per 100 mL at all Accabonac Harbor sites (except EH5, EH7b), exceeding both the NYSDOH standards for shellfishing (35 CFU per 100 mL) and recreational use (104 CFU per 100 mL) (Fig. 19). At the EH5 site, concentrations exceeded the NYSDOH standard for shellfishing in September (34 CFU per 100 mL) and exceeded both NYSDOH standards in May (189 CFU per 100 mL), June (124 CFU per 100 mL) and October (>400 CFU per 100 mL) (Fig. 19). At the EH6a site, concentrations ranged 32 – >401 CFU per 100 mL from May through September, exceeding both NYSDOH standards, but was 44 CFU per 100 mL in July, 32 CFU per 100 mL in September, and 76 CFU per 100 mL in October (Fig. 19). At the EH7a site, concentrations ranged 22 - >401 CFU per 100 mL from June through September, exceeding the NYSDOH shellfishing standard (Fig. 19). At EH7b, concentrations exceeded NYSDOH enterococci standards for bathing beaches in June (202 CFU per 100 mL) and in

September (133 CFU per 100 mL) and ranged 2 – 202 CFU per 100 mL for May through October (Fig. 19). In Three Mile Harbor, enterococci concentrations varied by site. In EH10, aside from 13-June-2022 (17 CFU per 100 mL), concentrations were below both NYSDOH standards and ranged 0 – 17 CFU per 100 mL for June through October (Fig. 19). At the EH10a site, concentrations ranged <2 – 71 CFU per 100 mL for the entirety of summer and fall 2022. At EH11, concentrations were 177 and >401 CFU per 100 mL (exceeding both NYSDOH standards) during June and October, respectively, and ranged <2 – >401 CFU per 100 mL for May through October, with the higher concentration exceeding the NYSDOH shellfishing standard (Fig. 19). At the EH11a site, concentrations were >401 CFU per 100 mL in October, exceeding both NYSDOH standards and ranged 2 – 71 CFU per 100 ml in May to September, with the higher concentration exceeding the NYSDOH shellfishing standard (Fig. 19). Lastly, at EH12, concentrations were >401 CFU per 100 mL in October, exceeding both NYSDOH standards, and ranged <2 – 71 CFU per 100 mL throughout the summer and fall of 2022 (Fig. 19).

### *3.5 Microbial Source Tracking*

For 2022, microbial source tracking was utilized to assess the relative abundance of four classes of fecal bacteria in Accabonac Harbor and Three Mile Harbor. The use of digital PCR permits the quantification of bacteria specifically emanating from humans, deer, birds, and dogs or small mammals. Within Accabonac Harbor, birds and dogs / small mammals were the biggest source of fecal bacteria (Fig. 19A). As has been the case in prior years, there was a significant abundance of bird-derived fecal bacteria from spring to fall (Fig. 19A). Human bacteria were found in all sites around Accabonac Harbor, a finding consistent with the great human population use of these regions (Fig. 19A). Population use of these regions come in the form of homes and a marina, for example at Shipyard Land and Louse Point, respectively (Fig. 19A). The relative abundance of bird and dog / small mammal fecal bacteria seemed to reflect the amount of expected run-off for each site. The Shipyard Lane site, which received run-off from School Street, Pussy's Pond, and, to a lesser extent, Springs-Fireplace Road, resulted in very high signals from dog and small mammals and bird fecal bacteria (Fig. 19A). In contrast, the site most separated from anthropogenic influences (site 7B), had primarily small mammal fecal bacteria (Fig. 19A).

Microbial source tracking in Three Mile Harbor was also consistent with prior years and reflective of land-use. Compared to Accabonac Harbor, fecal bacteria within Three Mile Harbor were dominated more by dogs and small mammals than birds (Fig. 19A; Fig. 19B), perhaps reflecting the lower abundance of salt marshes within Three Mile Harbor and the greater amount of road run-off within this estuary. Due to a consistent human-derived fecal bacteria signal at the Gann Road site, as second sampling site south of Gann Road was sampled in 2022 to assess the extent to which the human-derived fecal bacteria signal was attenuated. Consistent with the purposeful sampling design, the Gann Road site, which is surrounded by multiple marinas and boat launches, had nearly a quarter of its fecal bacteria emanating from humans, whereas the site due south had a percentage of less than 5%, on averaged (Fig. 19B). A parallel comparison was made within the Head of the Harbor (Fig. 19B). In this case, the human fecal bacteria signal was too small for meaningful comparisons to be made (1-2%)(Fig. 19B). However, there were differences that were seemingly reflective of each site. The site surrounded by roads, parking lots, and marinas had a very large dog and small mammal signal (~65%), whereas the site to the south which was likely more influenced by Tanbark Creek and the surrounding woodlands had only 47% of fecal bacteria from dogs/small mammals, 49% from birds, and 3% from deer (Fig. 19B).

*3.6. HYCAT surveys*

In Accabonac Harbor, the HYCAT survey showed that temperature, salinity, DO, and chlorophyll *a* varied by location within the harbor. The lowest temperatures (<20°C) were reported within the western portion of the harbor, while the highest temperatures (~21°C) were to the eastern portion of the harbor. To the north and south of the inlet, temperatures were generally 21.5 – 21.7°C (Fig. 20). The highest measurements of salinity (>31 PSU) occurred in the immediate area north of the inlet and into the northern section of the harbor. Further north, salinity continued >31 PSU. The lowest salinity values (<30.8 PSU) occurred in the areas to the south and west of the inlet (Fig. 21). DO concentrations were highest (>7.8 mg $L^{-1}$) at the west of the inlet and decreased below 7.64 mg $L^{-1}$ in the areas west and north of the inlet (Fig. 22). Chlorophyll *a* concentrations were lowest (<5.0 µg $L^{-1}$) in areas east and west of the harbor. Concentrations increased above 11.0 µg $L^{-1}$ in the areas north of the inlet (Fig. 23).

In Three Mile Harbor, temperatures were lowest (<24.3°C) in the western shore and remained 24.3 – 24.6°C further south on the eastern shore of the harbor. However, temperature gradually increased with increasing distance to the west and south of the eastern shore of the harbor (Fig. 24). Salinity was highest (>31.1 PSU) in the immediate vicinity of the northern channel and remained >31.1 across the entire harbor (Fig. 25). South of the marina, salinity was at its lowest, 30.5 – < 29.9 PSU (Fig. 25). DO concentrations were ~7.4 mg $L^{-1}$ near the northern channel and were lowest (<7.4 mg $L^{-1}$) along the western shore of the harbor and increased further south. With increasing distance from the northern shore, DO concentrations increased above 9.8 mg $L^{-1}$ (Fig. 26). Chlorophyll *a* concentrations were highest (~15.6 µg $L^{-1}$) in south side of the harbor and was variable at all other sampled sections of the harbor, ranging ~1.3 – 10.6 µg $L^{-1}$ (Fig. 27).

In Napeague Harbor, temperatures were highest (>24.8°C) in the southwestern section of the harbor, which is close to the northwestern inlet (Fig. 28). At the north of this section, on the western shore of the harbor, temperatures were lowest (<22.8°C) (Fig. 28). Salinity levels in Napeague Harbor were fairly consistent (31.0 – 31.2 PSU) across the entire harbor (Fig. 29). Dissolved oxygen concentrations were lowest in the southeastern section of the harbor (<7.47 – 7.67 mg $L^{-1}$) and were highest (8.0 – >8.3 mg $L^{-1}$) south of the inlet, on the western shore of the harbor (Fig. 30). Chlorophyll *a* concentrations were fairly low (<3 µg $L^{-1}$) across the entirety of Napeague Harbor (Fig. 31). The highest concentrations were found in the eastern section of the harbor (~2.8 µg $L^{-1}$) but were <1.3 – 2.8 µg $L^{-1}$ across the other sections of the harbor (Fig. 31).

### *3.7 Sediment surveys*

For 2022, sediment surveying was utilized to compare and contrast sediment characteristics in Accabonac Harbor. Measuring % mass through filtration and dry weight measurements allows the quantification of sediment quality, spread and % organic matter. Within Accabonac Harbor, aside from AC3, AC5, AC7 and AC16, the majority of sediment composition consisted between 90 µm - <500 µm (Fig. 33; Fig. 35). Conversely, site AC5 and AC16 had the lowest sediment composition between 90µm - <500µm and had the sediments primarily between 500 µm - <1000 µm and >1000 µm (Fig. 32; Fig. 34). The depth range across these sites ranged 0.0 – 2.0m with sediment makeup from sandy mud to black mud (Table 2; Fig. 38). The amount of organic matter present in Accabonnac Harbor ranged between 0.8-9.9%, with the exception at AC14 and AC20 with the highest organic matter in sediments, 13.9 and 16.6 % organic matter, respectively (Fig. 33). This is consistent with the quality of sediments across sites, where sites with higher % organic matter comprised of mud and black mud with the greatest depths (Fig. 37; Fig. 38). Conversely, sites with the lowest % organic matter had sediment makeup of sandy mud and muddy sand, with minimal depth (Table 2; Fig. 33).

## 4. Findings - Freshwater Systems

### *4.1. General Water Quality: Temperature, Salinity & Dissolved Oxygen*

The overall average temperature across East Hampton's freshwater sites was 22.9 ± 1.0°C and ranged 21.2 – 23.4°C, while summertime average temperature was 26.1 ± 1.8°C and ranged 22.6 – 27.1°C (Fig. 39). Maximum temperature was, on average, 29.6 ± 1.4°C and ranged 27.7 – 31.8°C (Fig. 39). At the buoy in Georgica Pond, temperature was, on average, 20.0 ± 6.3°C and ranged 3.0 – 31.1°C. Temperature did not appear to be affected by the opening of the ocean inlet to the south of Georgica Pond at the beginning of November (Fig. 40). Overall average salinity was 8.1 ± 8.8 PSU and ranged 1.6 – 24.5 PSU, while summertime average salinity was 7.6 ± 9.1 PSU and ranged 0.1 – 24.5 PSU (Fig. 41). Maximum salinity was, on average, 13.3 ± 8.9 PSU and ranged 0.3 – 27.5 PSU (Fig. 41). At the buoy in Georgica Pond, prior to the opening of the ocean inlet to the south of the waterbody, salinity was, on average, 15.3 ± 7.2 PSU and ranged 7.0 – 31.7 PSU (Fig. 42). After the inlet was opened, salinity rapidly increased to 31.1 PSU (Fig. 42). However, the inlet did not stay open long after its initial opening, causing salinity to decrease to 25.2 PSU by the end of November (Fig. 42). Overall average dissolved oxygen (DO) concentrations were 8.1 ± 1.8 mg $L^{-1}$ and ranged 6.2 – 10.4 mg $L^{-1}$, while summertime average concentrations were 8.0 ± 2.0 mg $L^{-1}$ and ranged 5.8 – 10.8 mg $L^{-1}$ (Fig. 43). Minimum DO was, on average, 5.8 ± 2.2 mg $L^{-1}$ and ranged 3.2 – 8.4 mg $L^{-1}$ (Fig. 43). In Fresh Pond (EH4), DO was, on average, 6.3 ± 1.9 mg $L^{-1}$ and ranged 2.9 – 8.8 mg $L^{-1}$, falling below the NYSDEC minimum for DO (4.8 mg $L^{-1}$) on 13-June-2022 (2.87 mg $L^{-1}$ ) and 27-June-2022 (4.2 mg $L^{-1}$)(Fig. 43). In Hook Pond (EH17), DO was, on average, 9.6 ± 1.6 mg $L^{-1}$ and ranged 7.6 – 12.9 mg $L^{-1}$ (Fig. 44). None of the sampled days had DO concentrations that decreased below the NYSDEC minimum for DO, at this site (Fig. 44). In Georgica Pond, DO concentrations were, on average, 6.2 ± 2.0, 7.2 ± 4.1, and 8.8 ± 2.4 mg $L^{-1}$, at EH15, EH16, and EH18, respectively, and ranged 3.2 – 10.1 mg

L$^{-1}$, 3.1 – 22.9 mg L$^{-1}$, and 6.1 – 17.2 mg L$^{-1}$, respectively (Fig. 45). At EH15 and EH16, DO concentrations were below the NYSDEC minimum for DO frequently throughout June, July, and the end of August (Fig. 45). At EH18, DO concentrations were above the NYSDEC minimum for DO for the entirety of 2022 (Fig. 45). In Wainscott Pond, DO concentrations were, on average, 10.4 ± 1.6 mg L$^{-1}$, and ranged 8.3 – 13.7 mg L$^{-1}$, never once falling below the NYSDEC minimum for DO (Fig. 46). At the buoy in Georgica Pond, DO was, on average, 8.5 ± 1.6 mg L$^{-1}$ and ranged 0.3 – 14.0 mg L$^{-1}$, falling below the NYSDEC minimum for DO multiple times at the end of summer through autumn (Fig. 47). The lowest DO at the buoy (0.3 mg L$^{-1}$) occurred at the opening of the ocean inlet but began to increase as the inlet began to close (Fig. 47).

*4.2. Nitrogen and Eutrophication*

At Fresh Pond (EH4), DIN concentrations ranged 0.06– 0.08 mg N/L during 2022, with an overall average and summer average of 0.07 ±0.009 and 0.07 ± 0.009 mg N/L, respectively (Fig. 48). Total N concentrations ranged 0.38 – 0.58 mg N/L during 2022, with concentrations exceeding the Peconic Estuary total N threshold (0.40 mg N/L) for all dates during 2022, with the exception of 20-September-2022. Overall average and summer average total N concentrations were 0.48 ± 0.10 and 0.44 ± 0.08 mg N/L, respectively, both of which were above the Peconic Estuary total N threshold (Fig. 48).

*4.3. Algae and Harmful Algae; Cyanobacteria*

Total algal biomass for freshwater systems was measured using a BBE Moldaenke Fluoroprobe. These values tend to be higher than traditional chlorophyll *a* extraction. The overall average of chlorophyll *a* concentration at freshwater sites in East Hampton was 85.8 ± 101.2 µg L$^{-1}$ and ranged 17.1 – 317.8 µg L$^{-1}$, while summertime average concentration was 85.3 ± 127.1 µg L$^{-1}$ and ranged 14.9 – 397.3 µg L$^{-1}$ (Fig. 49). Maximum chlorophyll *a* concentration was, on average, 311.4 ± 426.7 µg L$^{-1}$ and ranged 40.3 – 1222.6 µg L$^{-1}$ (Fig. 49). The overall average, summertime average, and maximum for chlorophyll *a* at all sites exceeded the USEPA maximum chlorophyll *a* concentration for eutrophic freshwater systems (8 µg L$^{-1}$) (Fig. 49). In Fresh Pond and Hook Pond, average concentrations were 46.1 ± 57.4 µg L$^{-1}$ and 142.0 ± 358.6 µg L$^{-1}$, respectively, and ranged 7.6 – 199.7 µg L$^{-1}$ and 13.4 – 1222.6 µg L$^{-1}$, respectively (Fig. 50). With the exception of 1-June-2022 and 6-October-2022 in Fresh Pond, chlorophyll *a* concentrations at both sites were above the USEPA maximum for chlorophyll *a* in freshwater systems (Fig. 50). In Georgica Pond, chlorophyll *a* concentrations were, on average, 17.1 ± 17.4 μg $L^{-1}$, 52.0 ± 36.1 μg $L^{-1}$, and 47.8 ± 25.6 μg $L^{-1}$ at sites EH15, EH16, and EH18, respectively, and ranged 1.1 – 69.7 μg $L^{-1}$, 17.1 – 120.0 μg $L^{-1}$, and 7.5 – 100.0 μg $L^{-1}$, respectively (Fig. 51). At EH15, concentrations were generally at, just above, or just below the USEPA maximum for chlorophyll *a*, except during September and October, when concentrations frequently exceeded the USEPA maximum (Fig. 51). In EH16, concentrations frequently exceeded the USEPA maximum throughout 2022 (Fig. 51). At EH18, concentrations were generally above the USEPA maximum for the entirety of 2022 (Fig. 51). In Wainscott Pond, concentrations were, on average, 317.8 ± 176.2 μg $L^{-1}$ and ranged 21.4 – 694.9 μg $L^{-1}$, with concentrations on all dates exceeding the USEPA maximum for chlorophyll *a* in freshwater systems (Fig. 52). In Fort Pond, concentrations were, on average, 31.7 ± 7.3 μg $L^{-1}$ and 31.6 ± 5.8 μg $L^{-1}$ for the north and south sites, respectively, and ranged 8.45 – 40.1 μg $L^{-1}$ and 18.8 – 44.0 μg $L^{-1}$, respectively, with concentrations on all dates exceeding the USEPA maximum for chlorophyll *a* in freshwater systems (Fig. 53). Chlorophyll *a* concentrations at the Georgica Pond buoy was, on average, 16.5 ± 24.0 μg $L^{-1}$ and ranged >0.1 – 628.6 μg $L^{-1}$. It should be noted that prior to the opening of the ocean inlet at the waterbody at the start of November, chlorophyll *a* concentrations spiked, often exceeding the USEPA maximum for chlorophyll *a*. Following the opening of the inlet, concentrations increased further, peaking at 628.6 μg $L^{-1}$ in November (Fig. 54).

Toxic cyanobacteria blooms represent a serious threat to aquatic ecosystems and human health. Whereas chlorophyll *a* is an analog for algal biomass, blue-green algal fluorescence serves as an analog specifically for cyanobacterial biomass. The recreational safety limit of 25 μg $L^{-1}$ used by the NYSDEC was surpassed in Georgica Pond, Wainscott Pond, and Fort Pond, in 2022 (Fig. 55). The overall average concentration of blue-green algae across freshwater sites in East Hampton was 28.8 ± 66.8 μg $L^{-1}$ and ranged 0.1 – 193.6 μg $L^{-1}$, while the summertime average was 36.1 ± 90.3 μg $L^{-1}$ and ranged 0.1 – 259.4 μg $L^{-1}$ (Fig. 55). Maximum blue-green algae levels were, on average 76.2 ± 154.9 μg $L^{-1}$ and ranged 0.5 – 455.2 μg $L^{-1}$ (Fig. 55). In Fresh Pond and Hook Pond, blue-green algae levels were, on average, 0.1 ± 0.2 μg $L^{-1}$ and 7.8 ± 22.1 μg $L^{-1}$, respectively, and ranged 0.0 – 0.5 μg $L^{-1}$ and 0.0 – 74.5 μg $L^{-1}$, respectively, never exceeding the NYSDEC bloom threshold for blue-green algae (25 μg $L^{-1}$), with the exception of 3-October-2022 in Hook Pond (Fig. 56). In Georgica Pond, at sites EH15, EH16, and EH18, blue-green algae concentrations were 0.7± 1.0 µg $L^{-1}$, 2.3 ± 3.3 µg $L^{-1}$, and 1.1 ± 1.8 µg $L^{-1}$, respectively, and ranged 0.0 – 4.8 µg $L^{-1}$, 0.0 – 15.5 µg $L^{-1}$, and 0.0 – 6.8 µg $L^{-1}$, respectively (Fig. 57). In EH15, EH16 and EH18, blue-green algae levels never exceeded the NYSDEC bloom threshold (Fig. 57). In Wainscott Pond, blue-green algae levels were, on average, 193.6 ± 138.4 µg $L^{-1}$ and ranged 16.1 – 455.2 µg $L^{-1}$ (Fig. 58). On all dates, besides 12-July-2022 (16.1 µg $L^{-1}$) blue-green algae levels exceeded the NYSDEC bloom threshold at the site (Fig. 58). In Fort Pond, at the north and south sites, blue-green algae levels were, on average, 11.5 ± 7.5 µg $L^{-1}$ and 13.2 ± 8.2 µg $L^{-1}$, respectively, and ranged 0.8 – 25.0 µg $L^{-1}$ and 0 – 27.2 µg $L^{-1}$, respectively (Fig. 59). For both the north site and south site, blue-green algae levels have either met or exceeded the NYSDEC bloom threshold on 17-August-2022 at 25.0 and 27.2 µg $L^{-1}$ respectively (Fig. 59).

Regarding cyanotoxins in freshwater sites, concentrations of microcystin varied by site. Microcystin concentrations were not measured in Fresh Pond or Hook Pond in 2022, as blue-green algae levels never exceeded the bloom threshold (25 µg $L^{-1}$). At both sites, cyanobacteria were not assessed (Table 3). In Georgica Pond site EH15, microcystin concentrations were not detected, nor were bloom-forming cyanobacteria (Table 3). Similarly, at site EH16 in Georgica Pond, both microcystin and other bloom-forming species were not detected (Table 3). At site EH18 in Georgica Pond, microcystin was not present at detectable quantities, nor were any bloom-forming cyanobacteria (Table 3). At no point during 2022 was microcystin present to exceed the USEPA's shoreline (20 ppb) or open water (10 ppb) microcystin threshold in freshwater systems. In Wainscott Pond, microcystin levels were the most elevated of the freshwater sites in East Hampton during 2022 (Fig. 60). Concentrations started at 2.38 ppb on 24-May-2022, dropped to 0.7 ppb by 29-June-2021, and ranged 0.5 – 1.4 ppb throughout July (Fig. 60. During August, concentrations ranged 0.7 – 3.1 ppb and decreased to 0.5 ppb by the end of the month (Fig. 60). During September and October, concentrations never exceeded 0.7 ppb and ranged 0.3 – 0.6 ppb and (Fig. 60). Throughout the entirety of the sampling season, microcystin concentrations never exceeded the USEPA open water threshold for microcystin. At the EH18 site, the most common to the least common cyanobacteria were *Microcystis*, *Aphanizomenon*, *Planktothrix*, *Dolichospermum*, and *Anabaena* (Table 3). In Fort Pond, despite blue-green algae levels meeting and/or exceeding the NYSDEC bloom threshold in August, when microcystin was analyzed, concentrations were nondetectable for microcystin. At the site, *Aphanizomenon* was the only cyanobacteria detected (Table 3).

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**Figures and Tables**

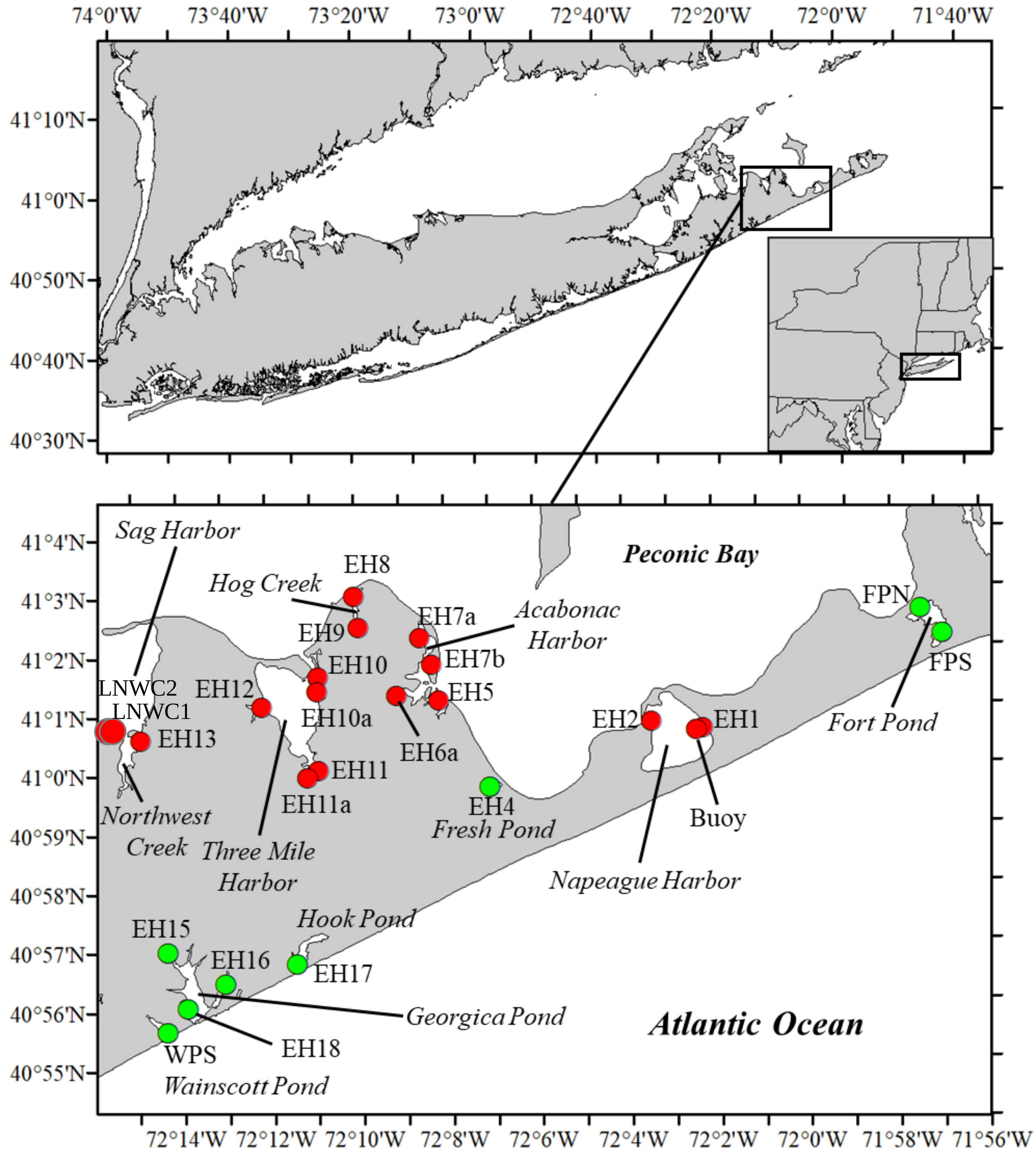



**Figure 1.** Map of the various marine (red dots) and freshwater (green dots) sampling sites in East Hampton, NY during 2022.

**Table 1.** List of the East Hampton sampling sites in 2022, along with their major waterbodies, general locations, and coordinates. Sites shaded in red and green represent marine and freshwater sites, respectively.

| Waterbody | Location | Abbr. | Coordinates |
| --- | --- | --- | --- |
| Napeague Harbor | Napeague Harbor Rd.<br>Lazy Pt.<br>Buoy | EH1<br>EH2 | 41.01079, -72.03769<br>41.01291, -72.05687<br>41.01029, -72.04018 |
| Accabonac Harbor | Louse Pt. Ramp<br>Shipyard Ln.<br>Trustees Trail<br>Gerald Dr. | EH5<br>EH6a<br>EH7a<br>EH7b | 41.01982, -72.13599<br>41.02133, -72.15191<br>41.03760, -72.14284<br>41.03011, -72.13845 |
| Hog Creek | Kings Point Rd.<br>29 Isle of Wight Rd. | EH8<br>EH9 | 41.04956, -72.16711<br>41.04090, -72.16559 |
| Three Mile Harbor | Gann Rd.<br>Squaw Rd.<br>Head of the Harbor<br>Soak Hides Preserve<br>Hands Creek Rd. | EH10<br>EH10a<br>EH11<br>EH11a<br>EH12 | 41.02701, -72.18102<br>41.02289, -72.18149<br>41.00072, -72.18148<br>40.99860, -72.18582<br>41.01880, -72.20211 |
| Northwest Creek<br><br>Little Northwest Creek | NW Landing Rd.<br><br>Harding Terrace<br>Delta | EH13<br><br>LNWC1<br>LNWC2 | 41.00991, -72.24753<br><br>41.001439, -72.270204<br>41.001222, -72.273947 |
| Fresh Pond, Amagansett | Fresh Pond | EH4 | 40.99510, -72.11771 |
| Hook Pond | Hook Pond | EH17 | 40.94619, -72.19077 |
| Georgica Pond | Rt. 27<br>Cove – 112 Apoquogue<br>4 Eel Cove Rd. | EH15<br>EH16<br>EH18 | 40.94999, -72.23915<br>40.94074, -72.21769<br>40.93408, -72.23182 |
| Wainscott Pond | Wainscott Pond, South | WPS | 40.92729, -72.23973 |
| Fort Pond | North<br>South | FPN<br>FPS | 41.04331, -71.95556<br>41.03603, -71.94773 |

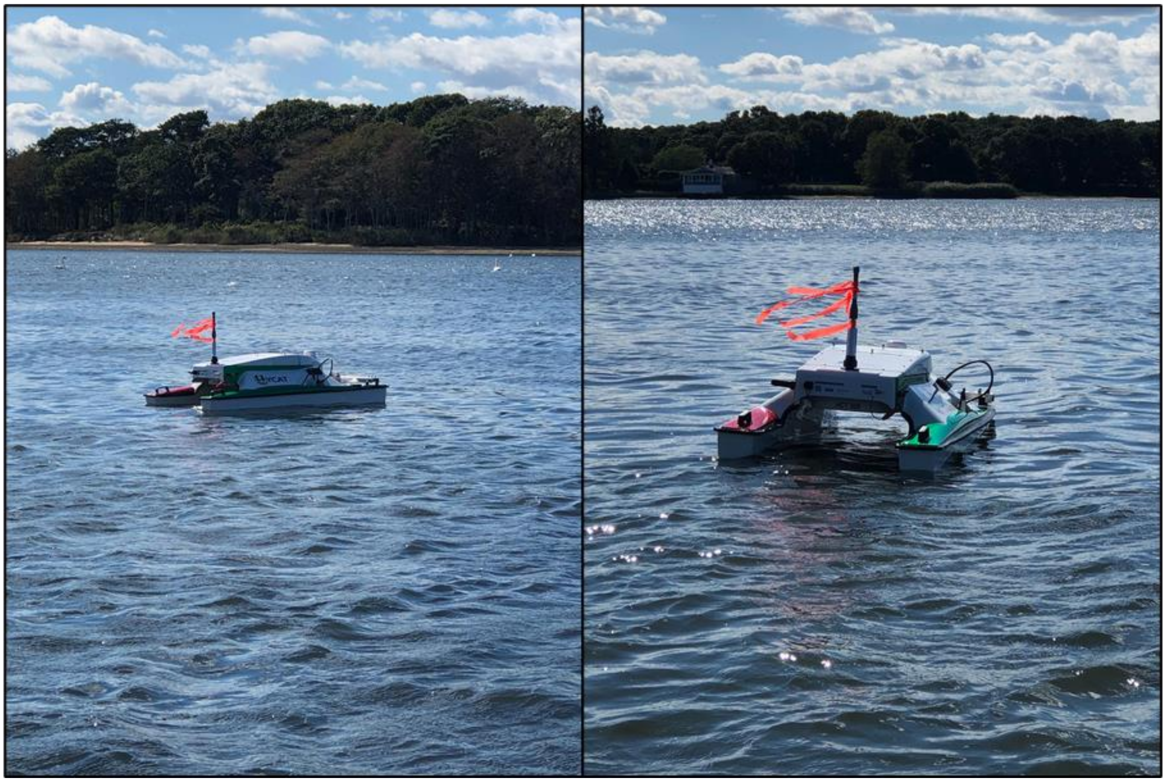


**Figure 2.** Images of the HYCAT autonomous surface vehicle used in surveys of Accabonac Harbor, Napeague Harbor and Three Mile Harbor between August and September 2022.

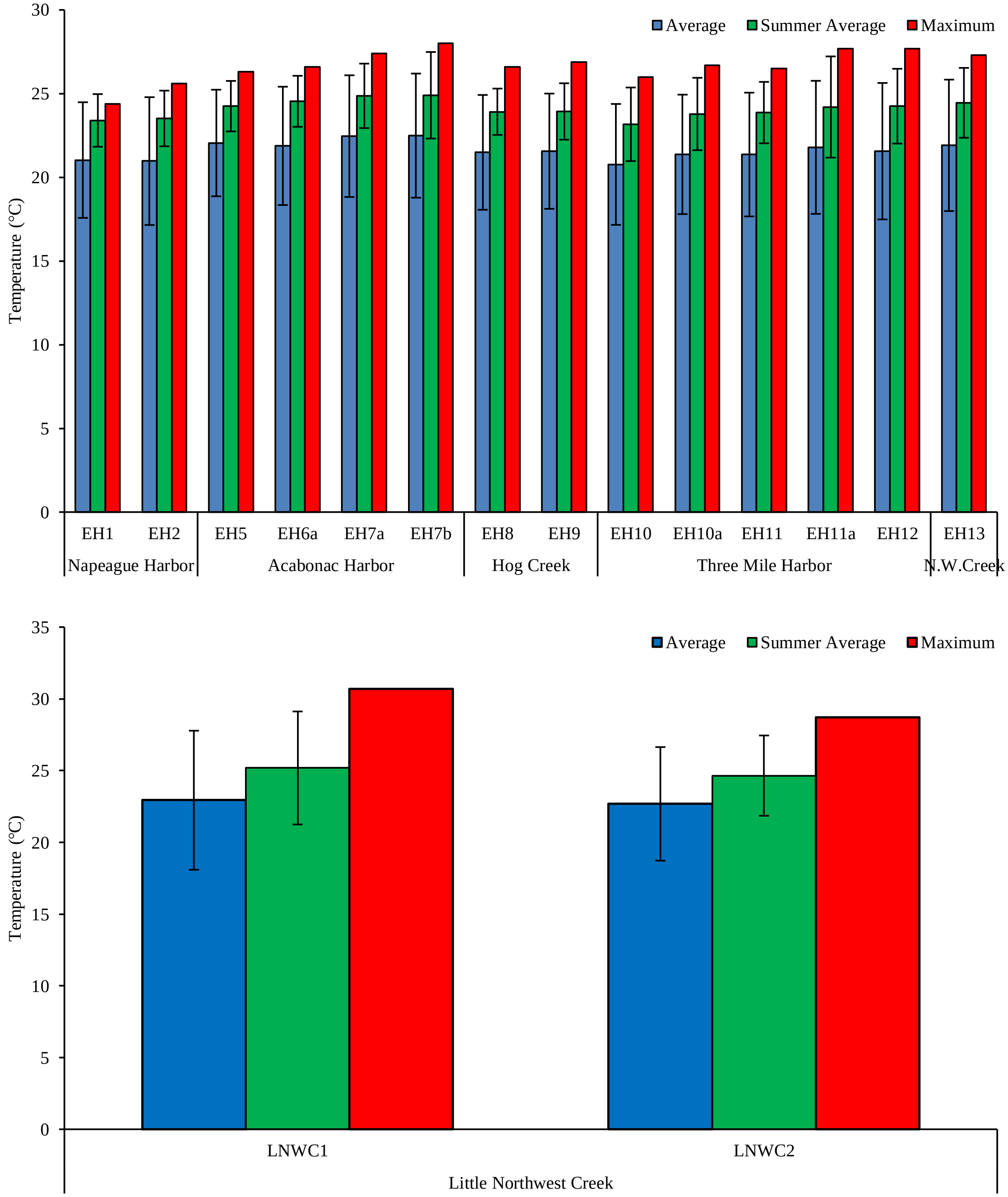



**Figure 3.** Overall average, summer average, and maximum surface water temperatures (°C) at various marine sites in East Hampton during 2022. Error bars represent standard deviation. N.W. Creek = Northwest Creek.

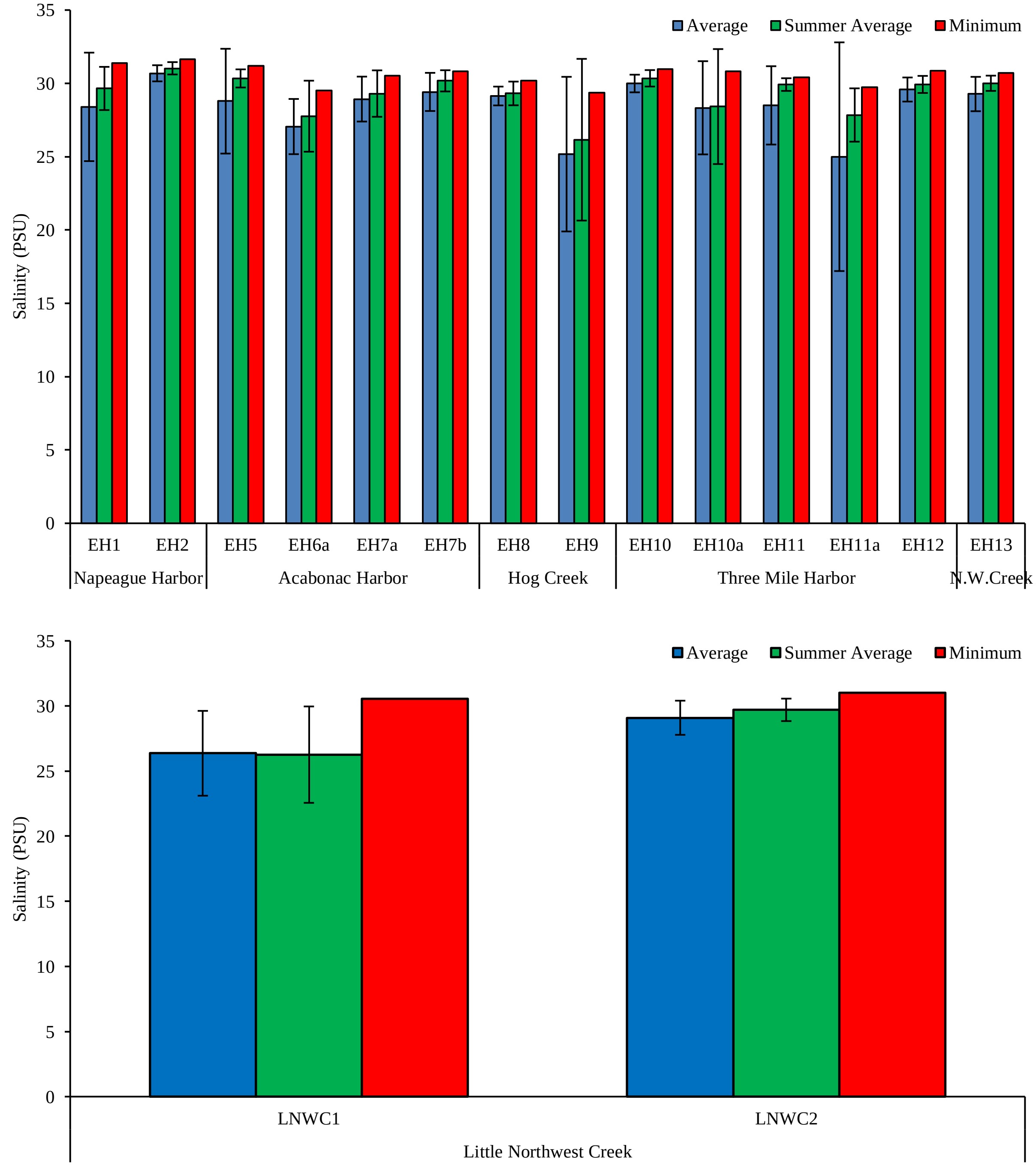



**Figure 4.** Overall average, summer average, and maximum surface water salinities (PSU) at various marine sites in East Hampton during 2022. Error bars represent standard deviation. N.W. Creek = Northwest Creek.

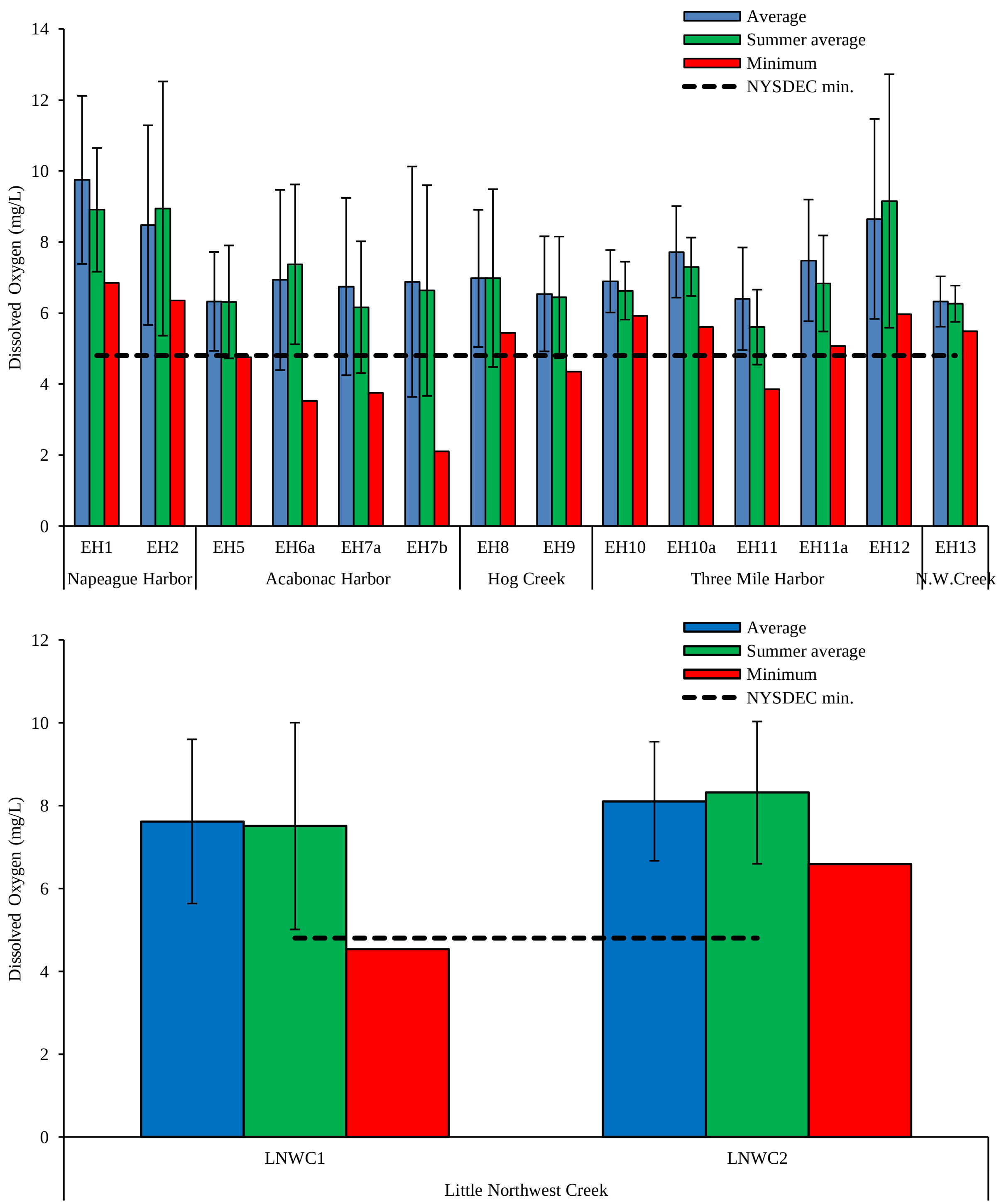



**Figure 5.** Overall average, summer average, and minimum surface water dissolved oxygen concentrations (mg $L^{-1}$) at various marine sites in East Hampton during 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$). Error bars represent standard deviation. N.W. Creek = Northwest Creek.

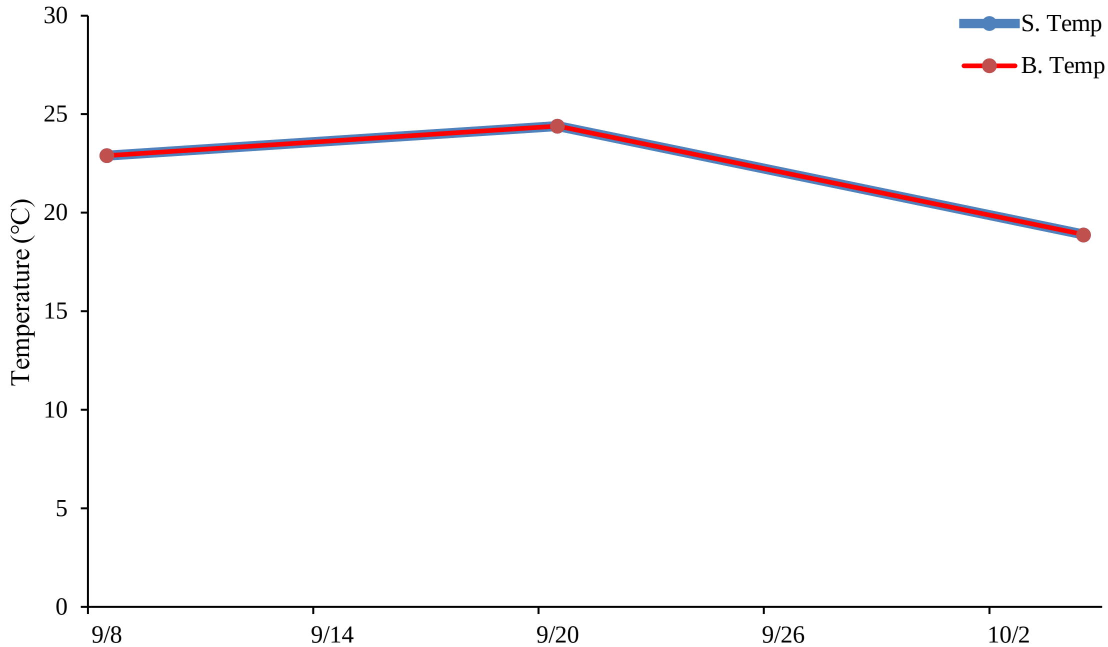



**Figure 6.** Discrete measurements of temperature (°C) in Napeague Harbor between September and October 2022.

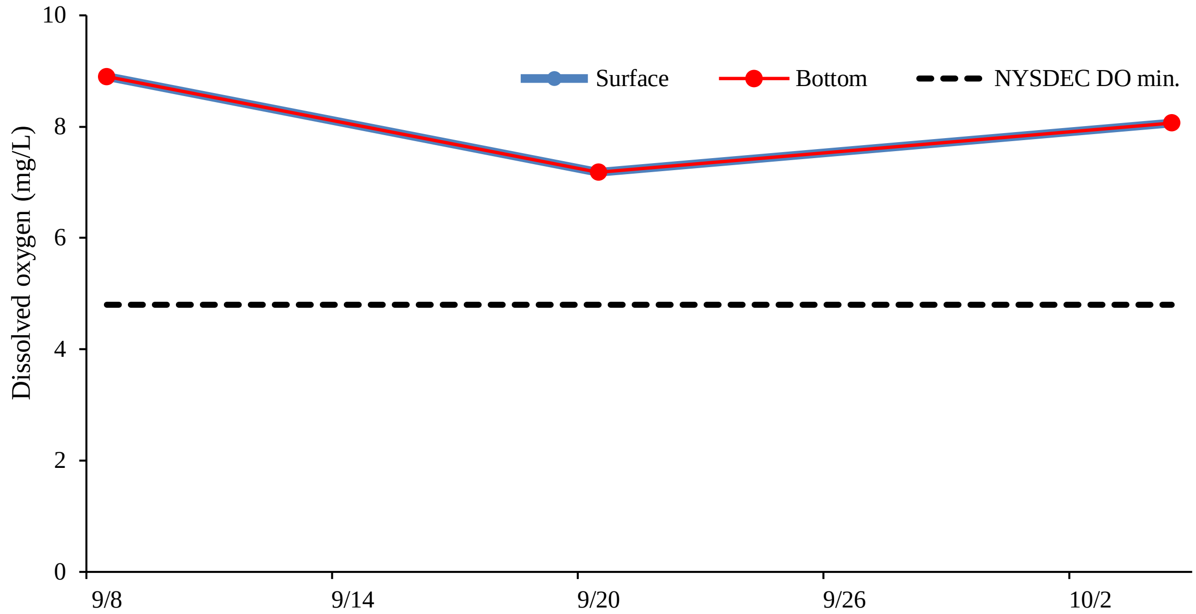



**Figure 7.** Discrete measurements of dissolved oxygen (mg $L^{-1}$) in Napeague Harbor between September and October 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$).

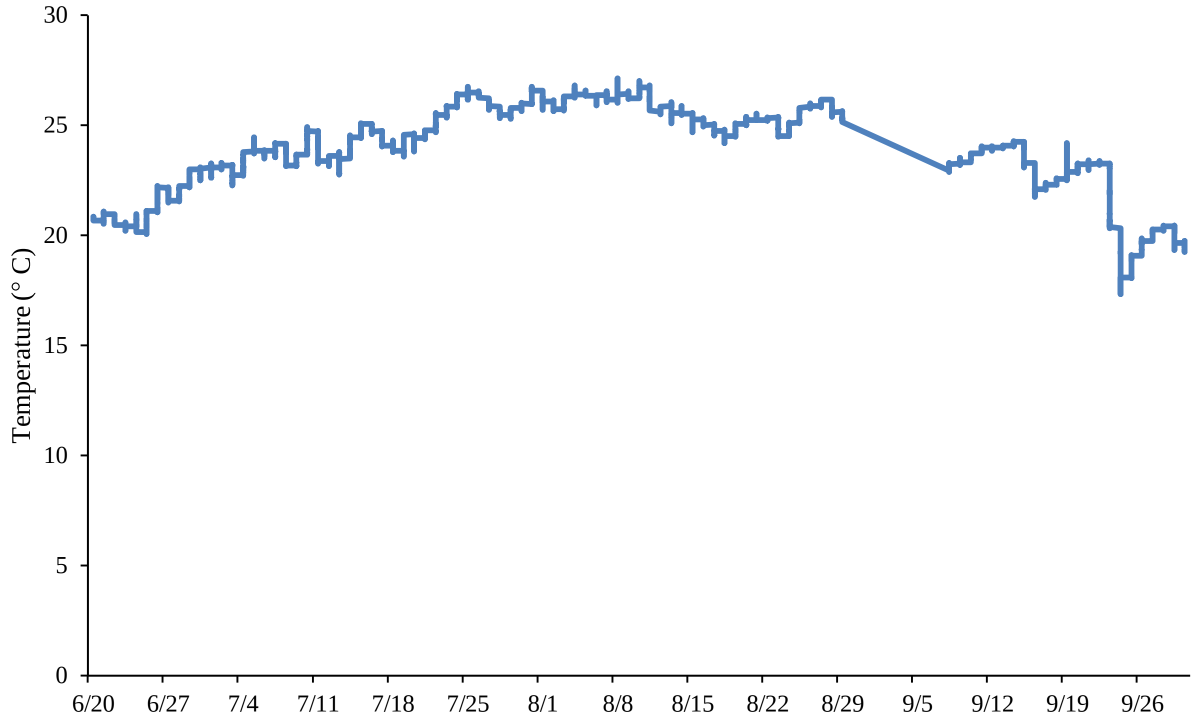



**Figure 8.** Continuous measurements of temperature (°C) in Three Mile Harbor (EH11) during summer 2022.

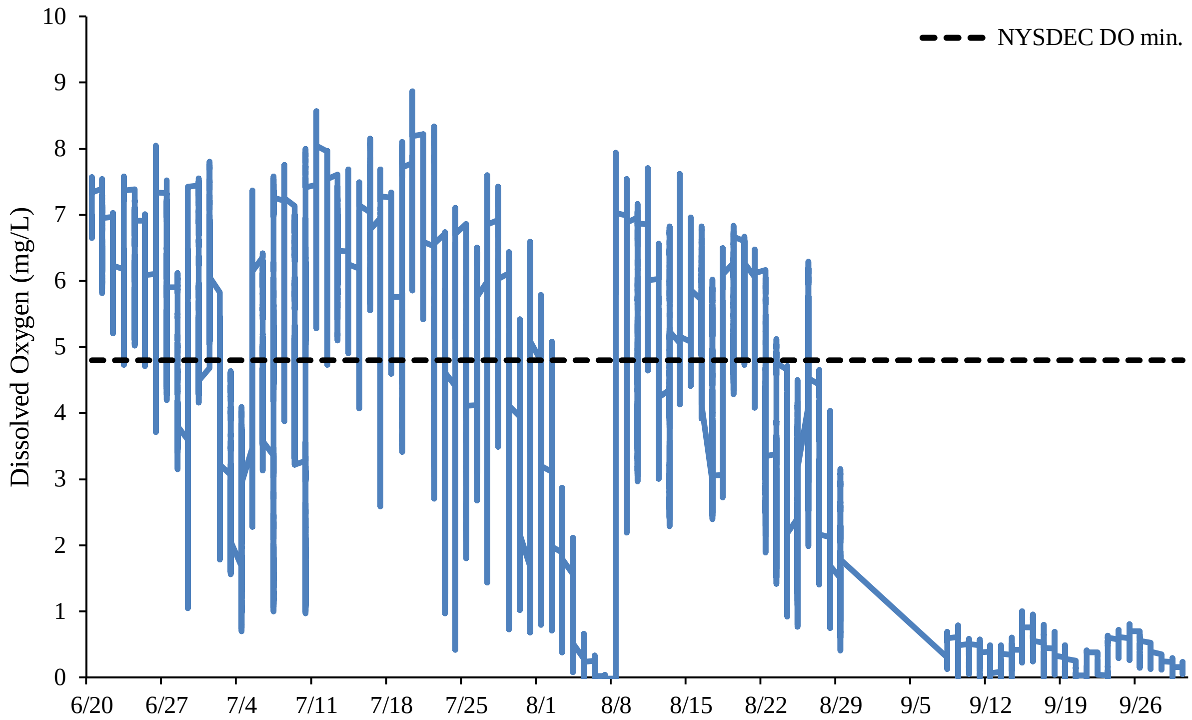



**Figure 9.** Discrete measurements of dissolved oxygen (mg $L^{-1}$) in Three Mile Harbor (EH11) during summer 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$).

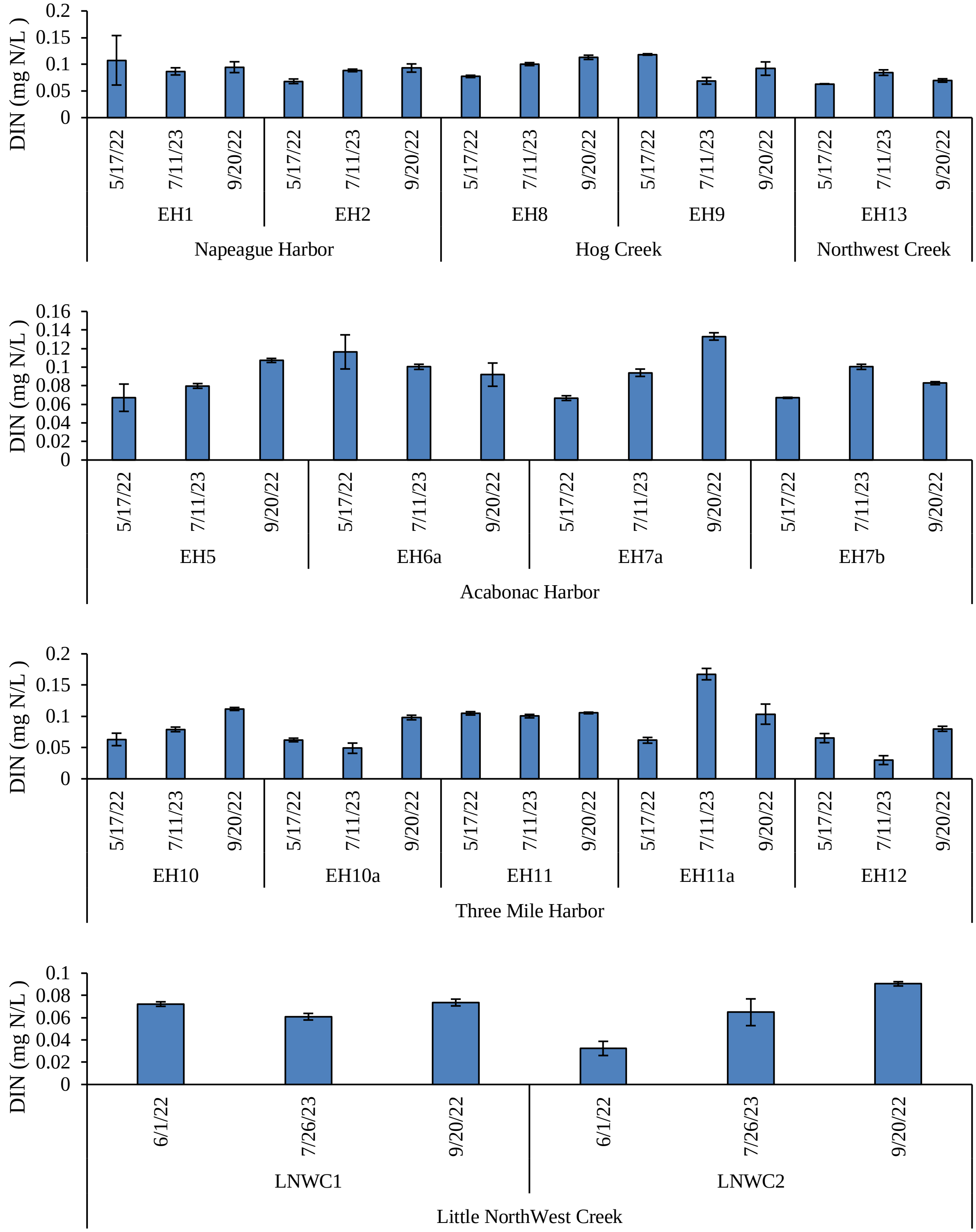



**Figure 10.** Dissolved inorganic nitrogen (DIN) concentrations (µM) at various sites in East Hampton during 2022. Error bars represent standard deviation.

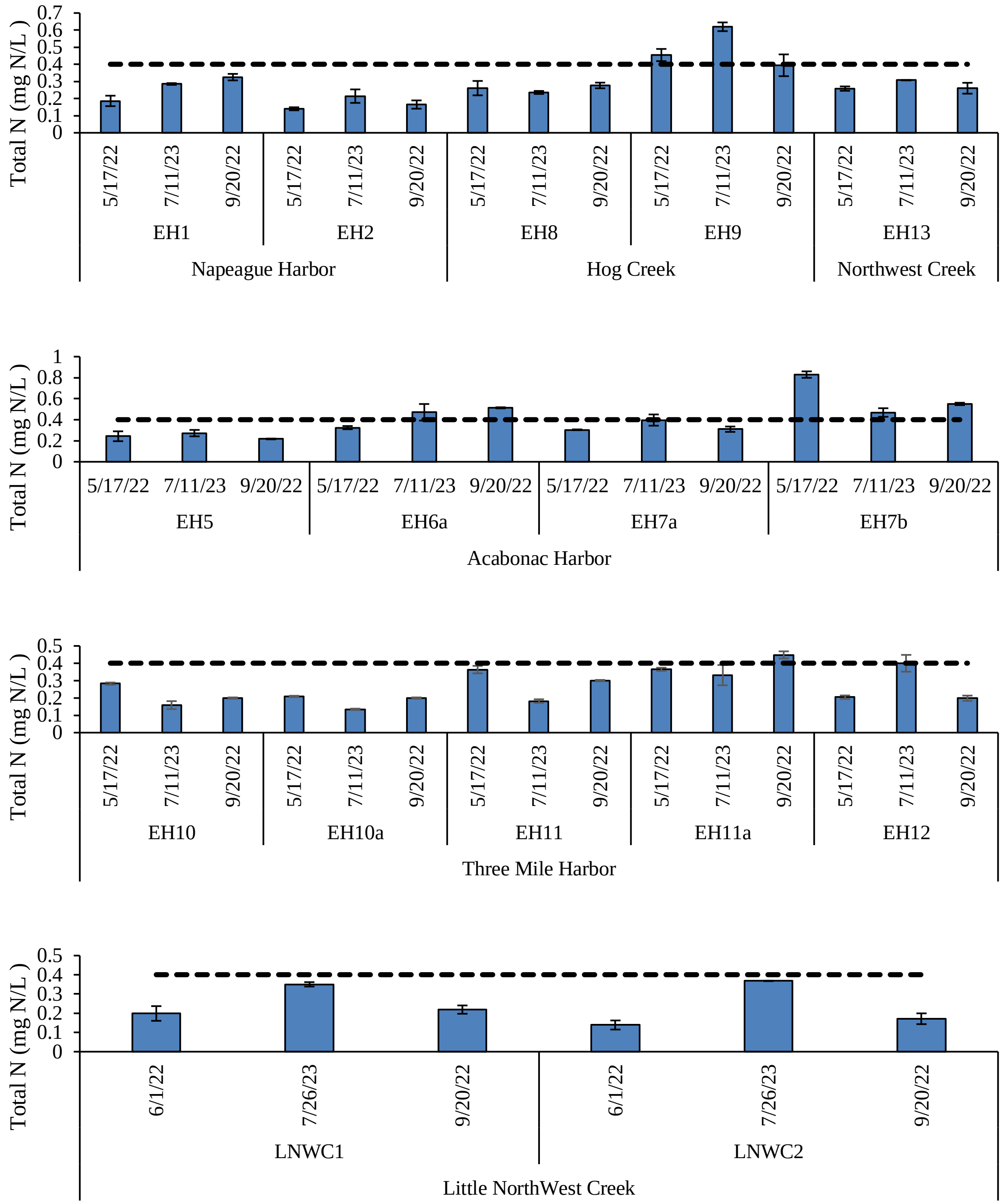



**Figure 11.** Total nitrogen (N) concentrations (µM) at various sites in East Hampton during 2022. Error bars represent standard deviation. The dashed horizontal lines represent the Peconic Estuary threshold for total N (28.6 µM).

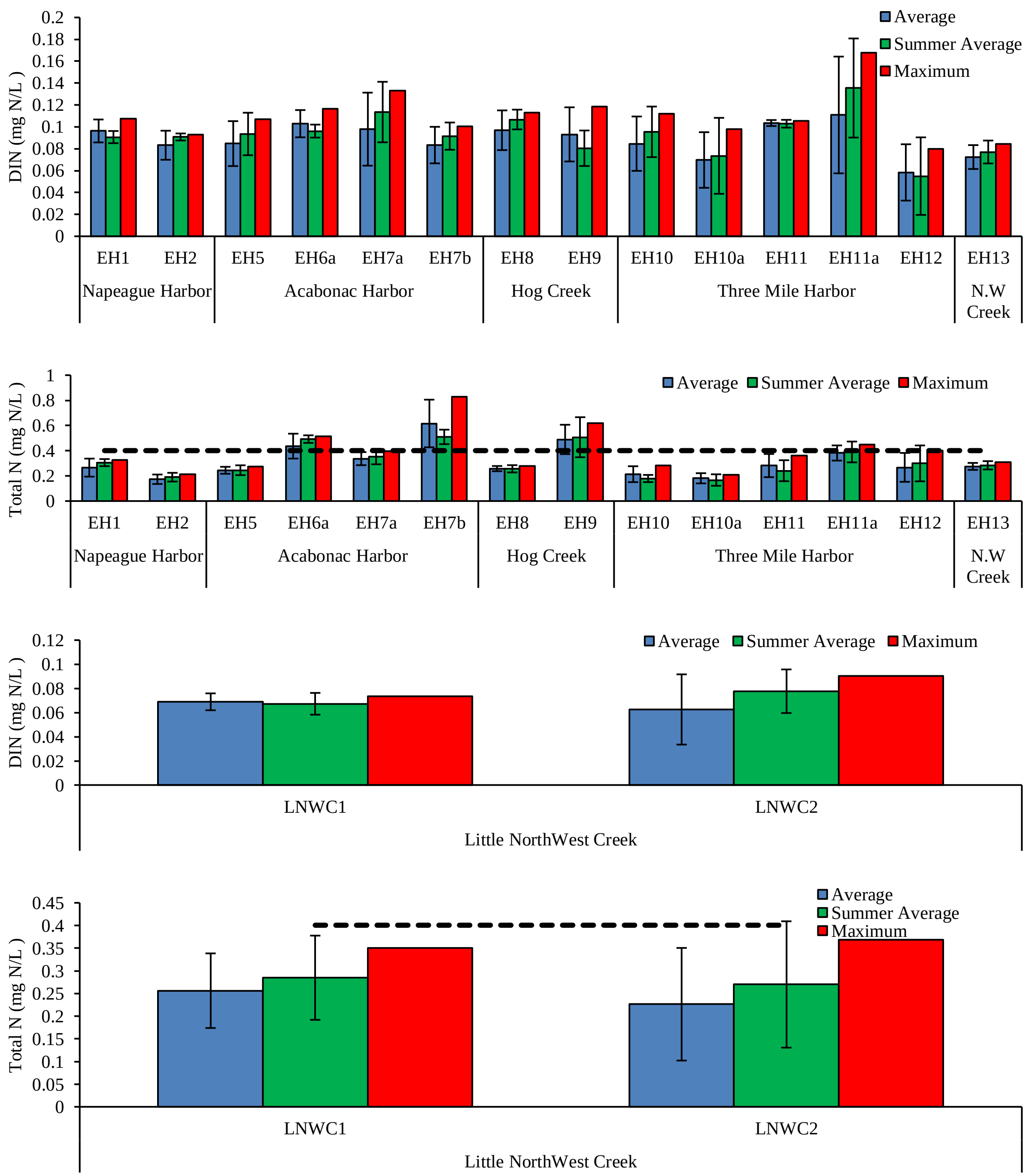



**Figure 12.** Overall average, summer average, and maximum dissolved inorganic nitrogen (DIN), and total nitrogen concentrations at various sites in East Hampton during 2022. The dashed line represents the Peconic Estuary threshold for total nitrogen (0.4 mg $L^{-1}$). Error bars represent standard deviation. N.W. Creek = Northwest Creek.

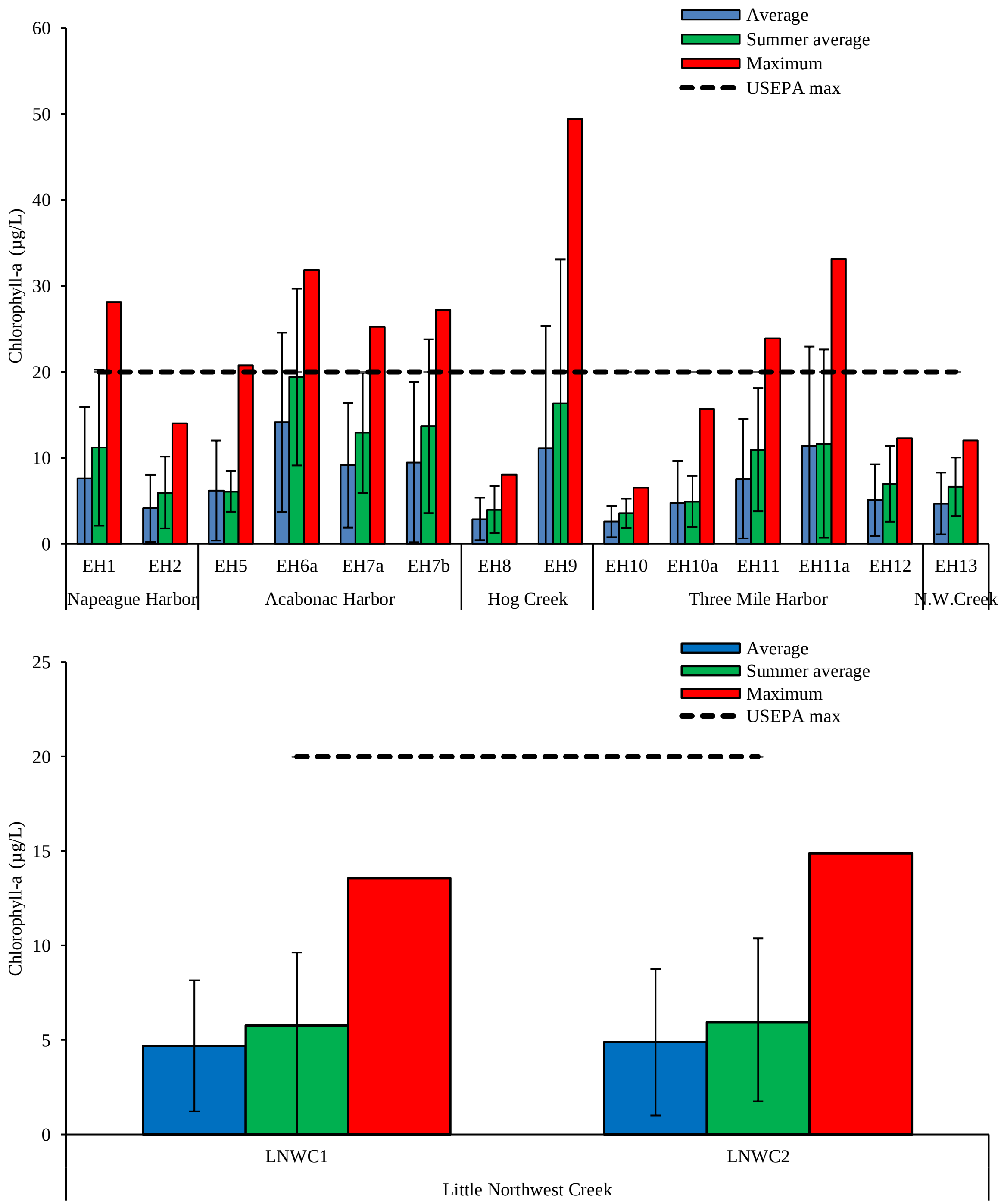



**Figure 13.** Overall average, summer average, and maximum chlorophyll *a* concentration (µg L-1) at various sites in East Hampton during 2022. The dashed line represents the NOAA maximum for chlorophyll *a* (20 µg $L^{-1}$). Error bars represent standard deviation. Nap. Harbor and N.W. Creek = Napeague Harbor and Northwest Creek, respectively.

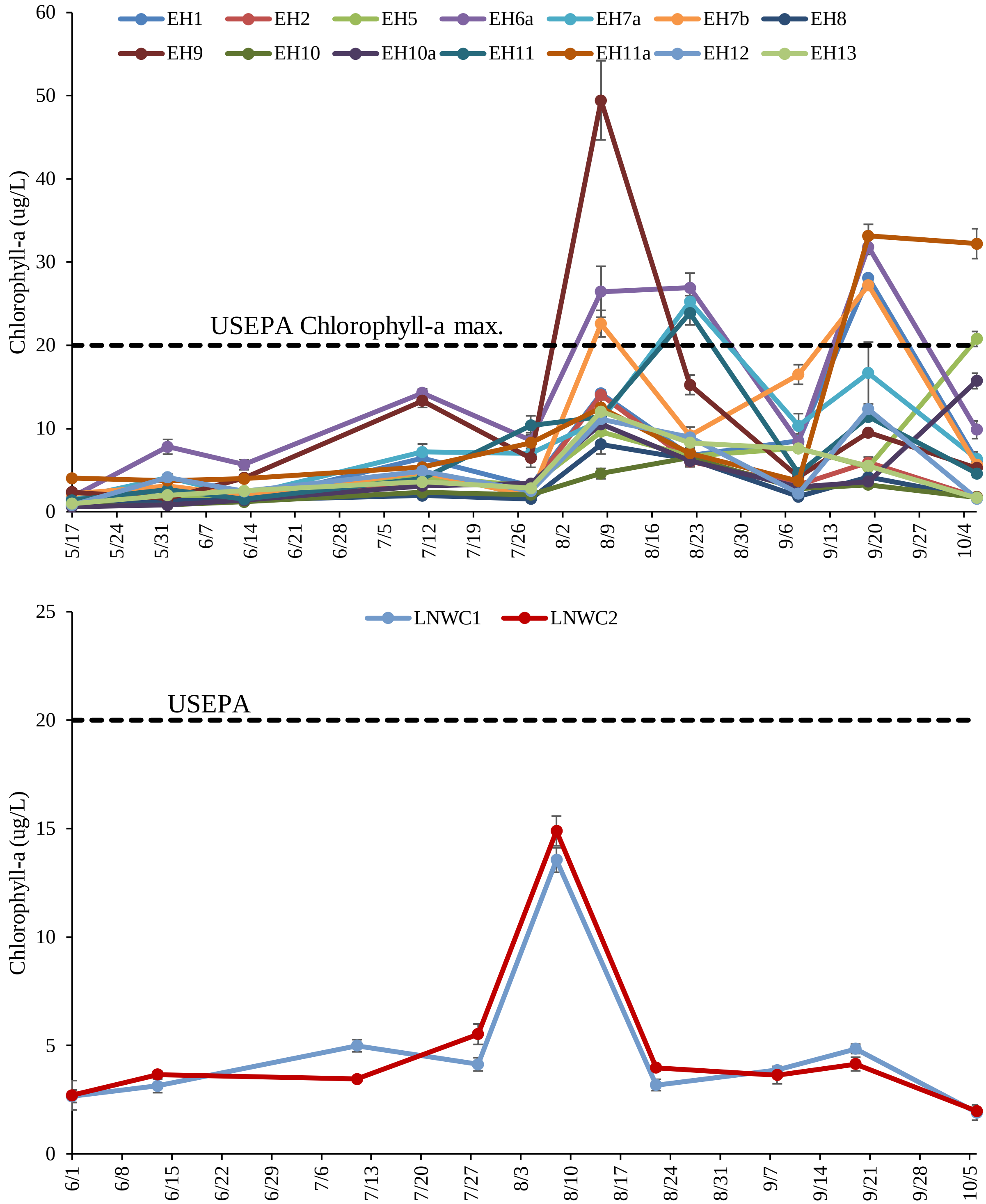
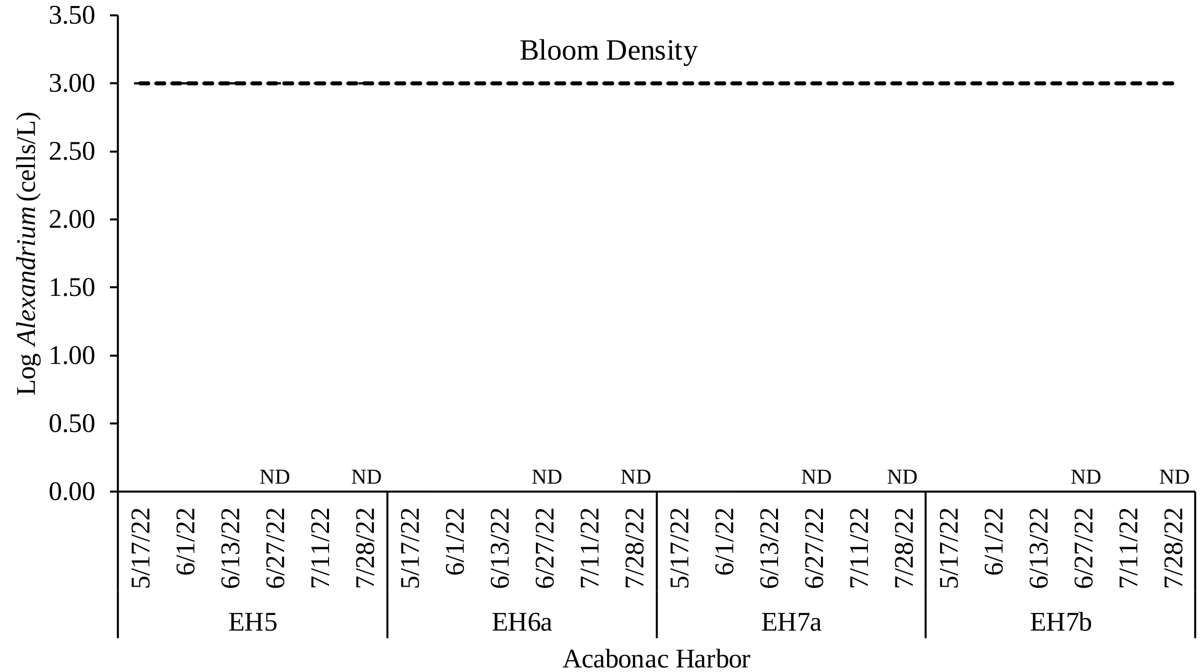



**Figure 14.** Chlorophyll-*a* concentrations (µg $L^{-1}$) at various sites in East Hampton during 2022. The dashed line represents the NOAA maximum for chlorophyll-*a* (20 µg $L^{-1}$). Error bars represent standard deviation.



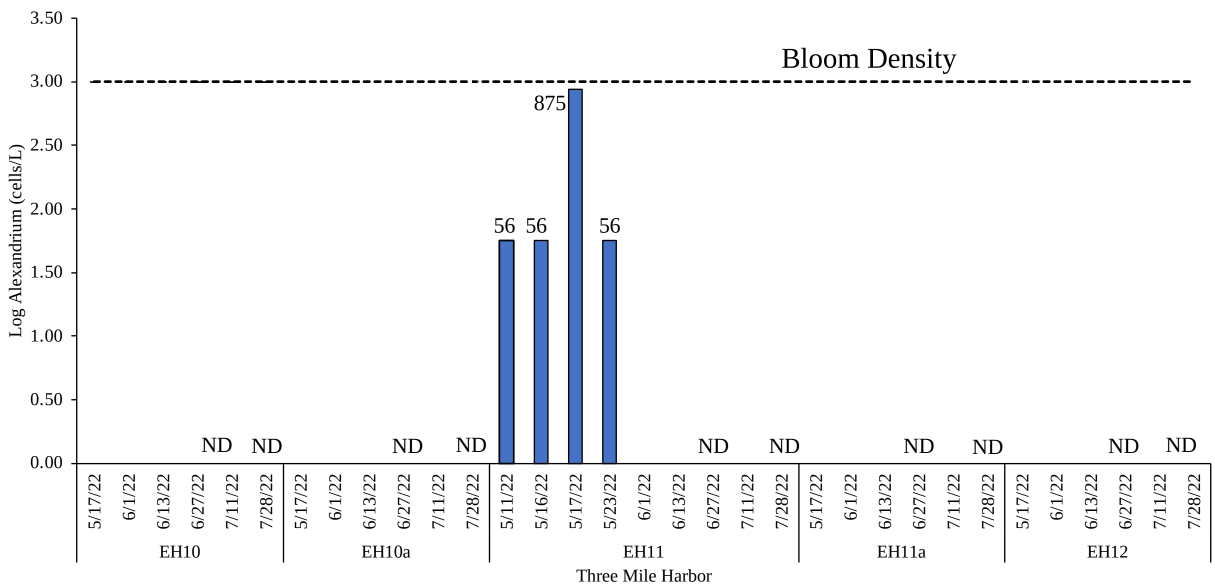
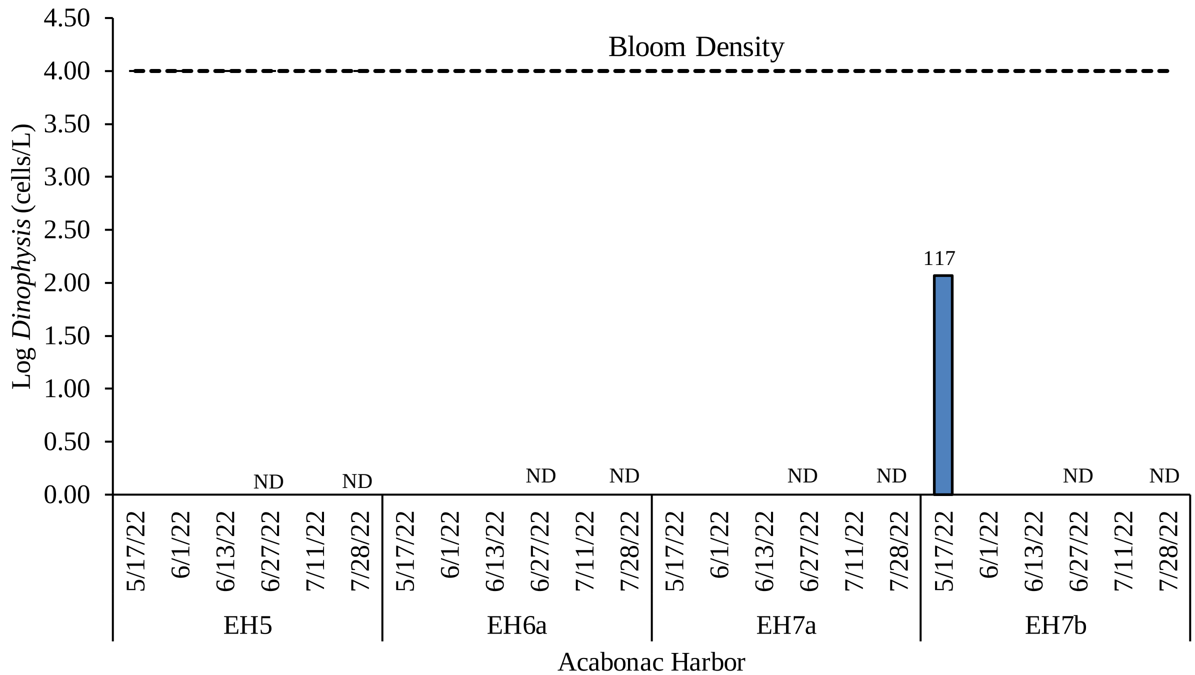




**Figure 15.** Concentrations of *Alexandrium* (cells $L^{-1}$) at Accabonac Harbor and Three Mile Harbor during 2022. The dashed lines represent bloom thresholds for *Alexandrium* (1,000 cells $L^{-1}$). ND = No data collected for the date.



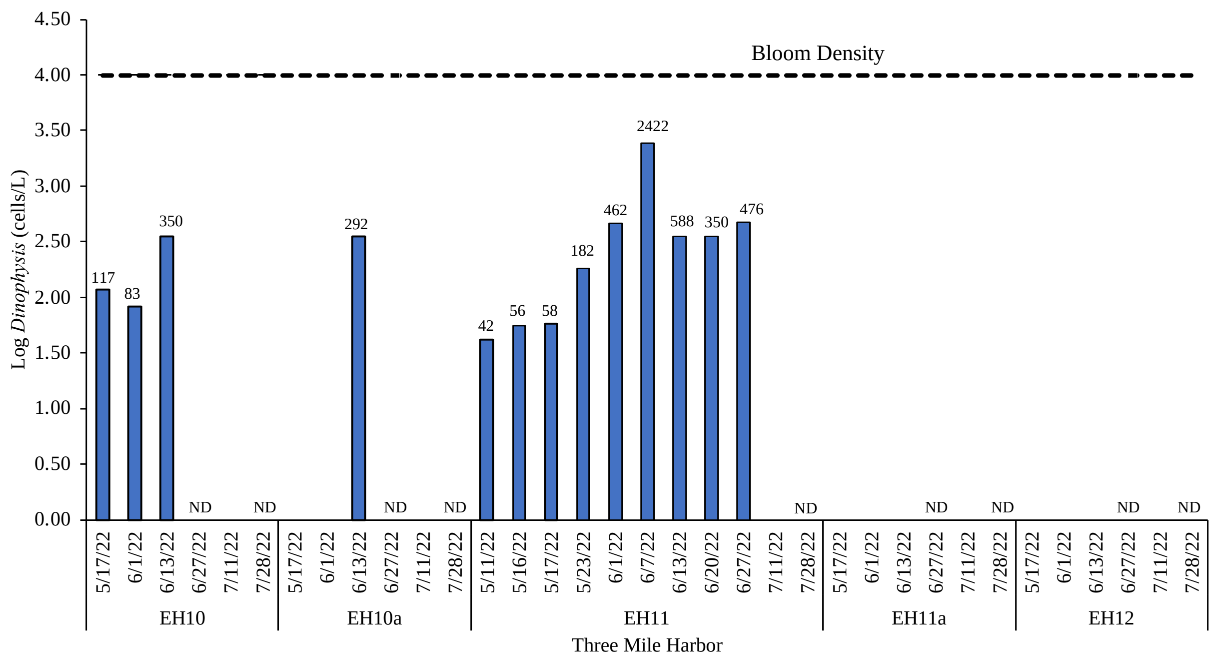
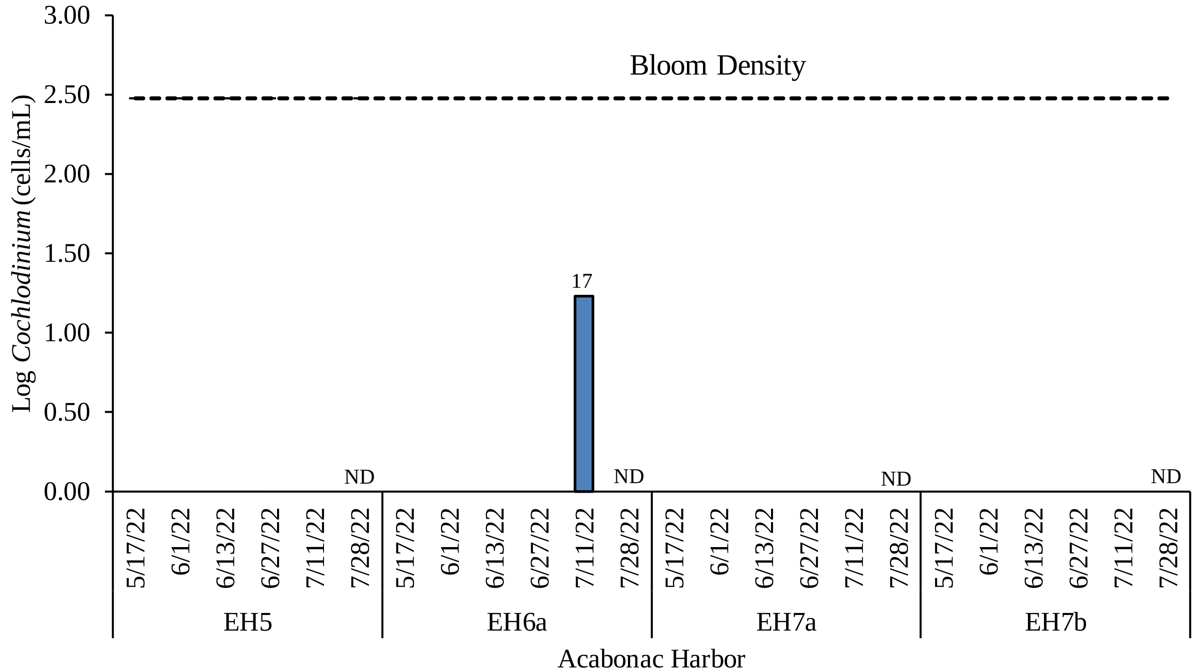




**Figure 16.** Concentrations of *Dinophysis* (cells $L^{-1}$) at Accabonac Harbor and Three Mile Harbor during 2022. The dashed lines represent bloom thresholds for *Dinophysis* (10,000 cells $L^{-1}$). ND = No data collected for the date.



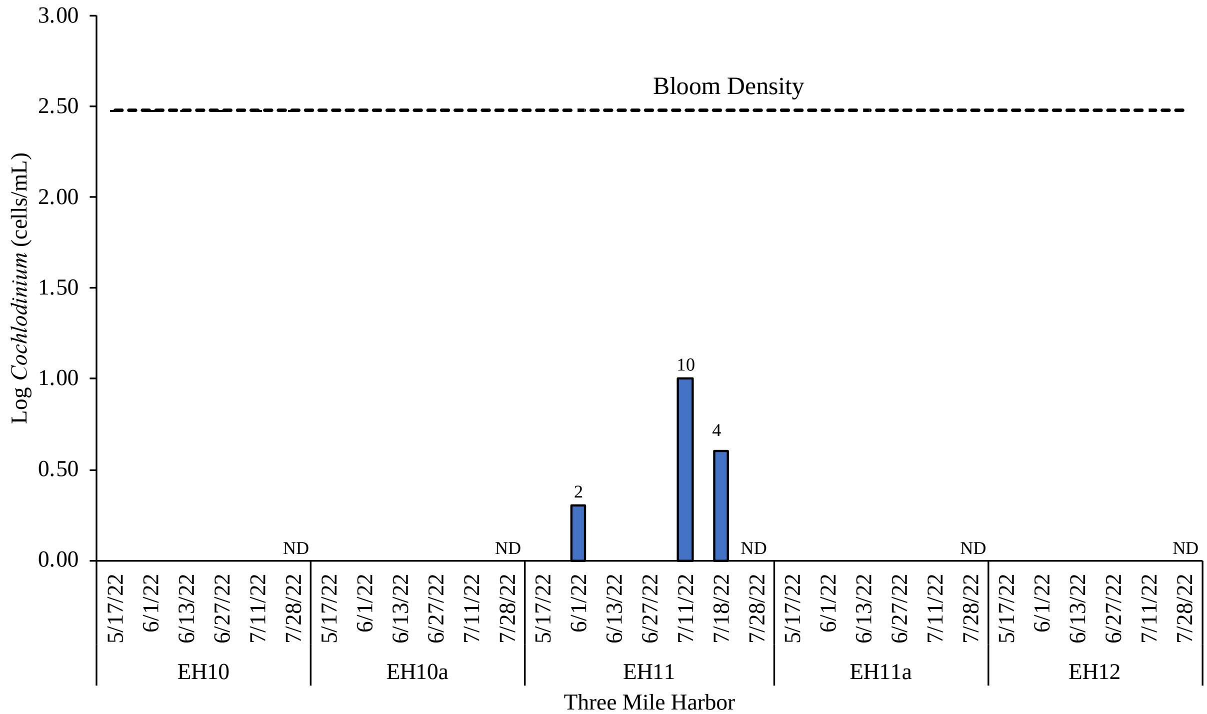




**Figure 17.** Concentrations of *Cochlodinium* (cells $mL^{-1}$) at Accabonac Harbor and Three Mile Harbor during 2022. The dashed lines represent bloom thresholds for *Cochlodinium* (300 cells $mL^{-1}$). ND = No data collected for the date.

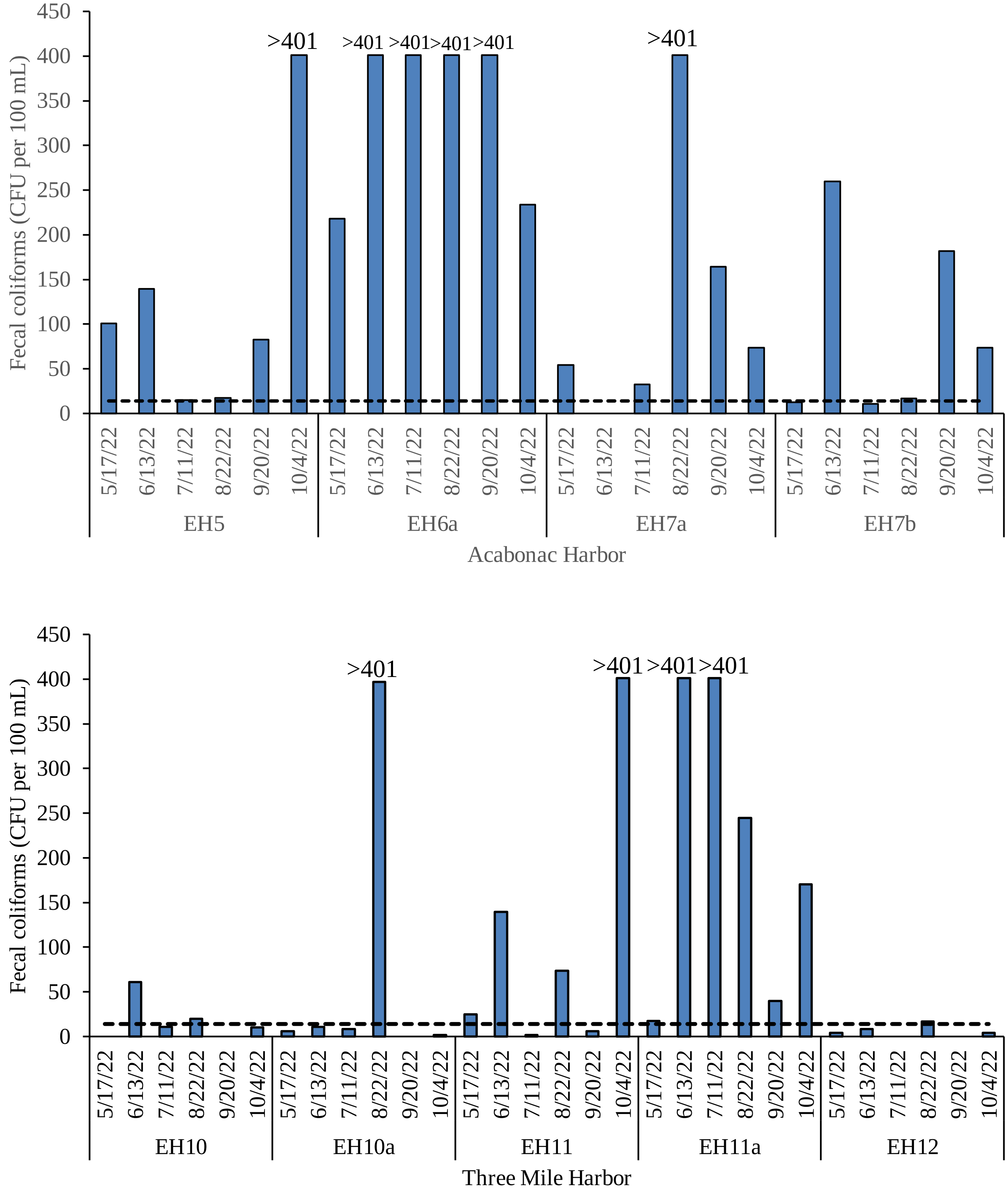



**Figure 18.** Fecal coliform levels (CFU per 100 mL) at various sites in Accabonac Harbor and Three Mile Harbor during 2022. The dashed lines are the NYSDOH maximum fecal coliform levels for shellfishing (14 CFU per 100 $mL^{-1}$).

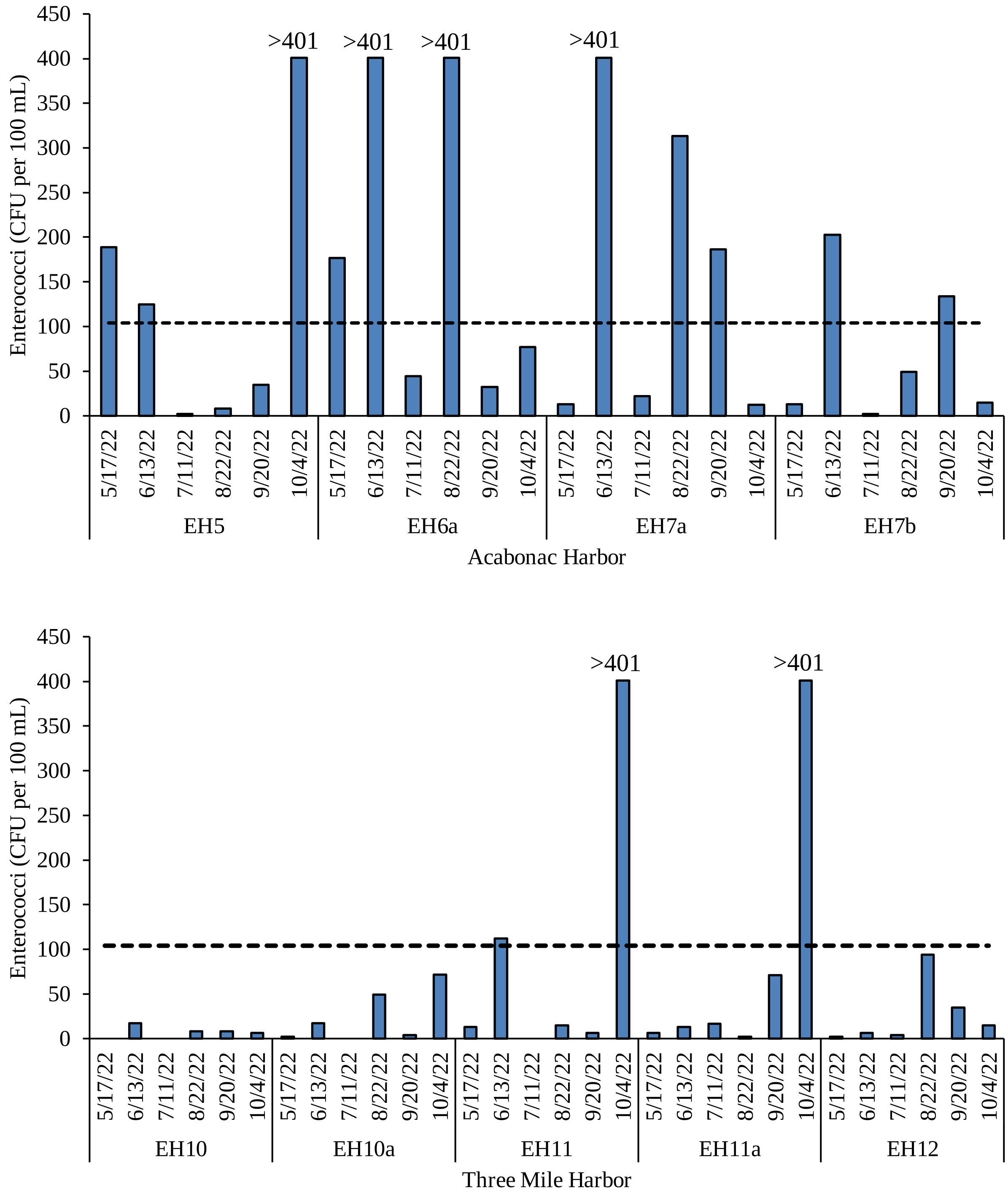



**Figure 19.** Enterococci levels (CFU per 100 mL) at various sites in Accabonac Harbor and Three Mile Harbor during 2022. The dashed lines are the NYSDOH maximum enterococci levels for recreational use (104 CFU per 100 $mL^{-1}$).

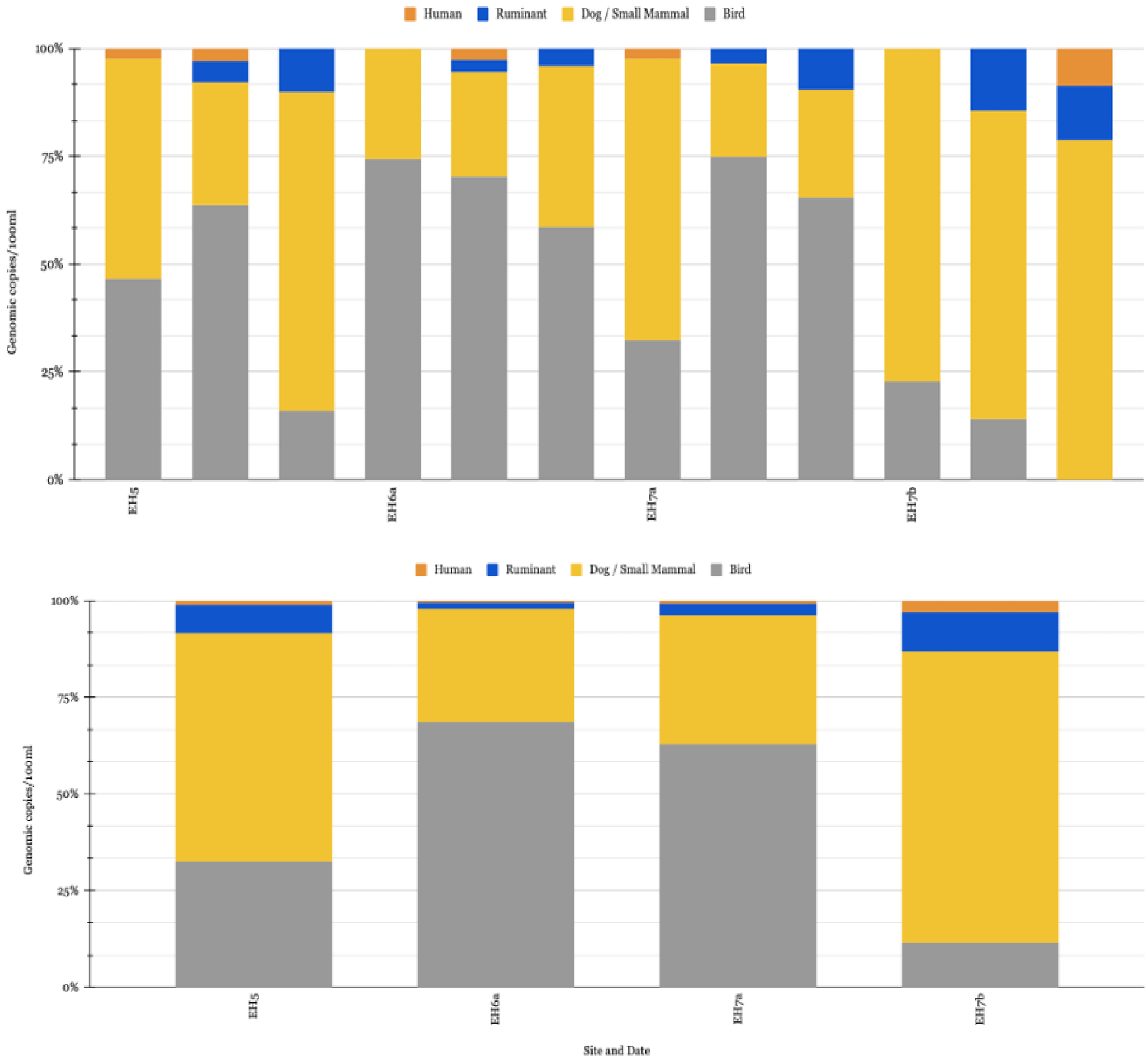



**Figure 19A.** Relative abundance of four classes of fecal bacteria (human, bird, deer, dog/small mammal) in Accabonac Harbor by date (above; June 13, Aug 22, Oct 4) and on average (below).

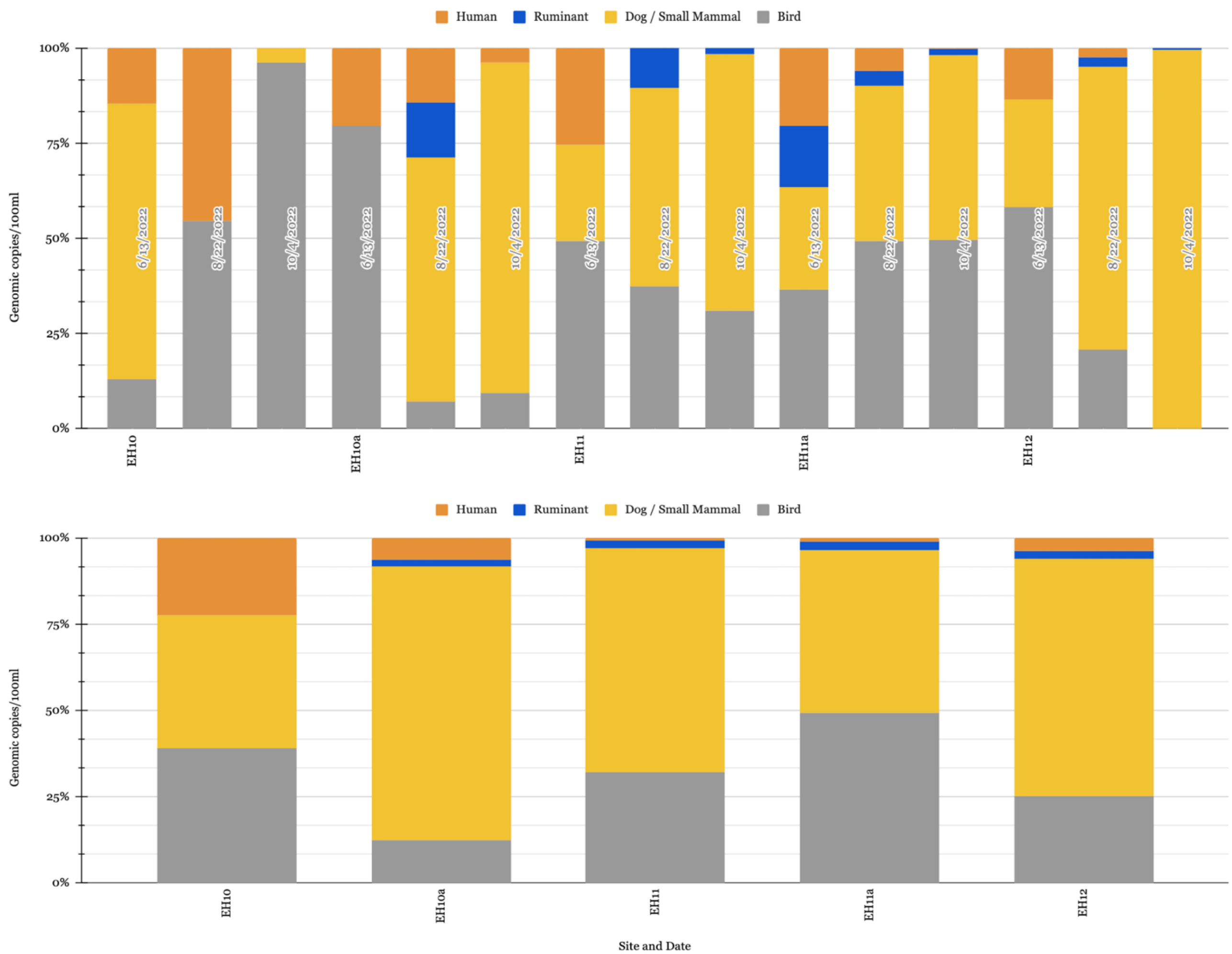



**Figure 19B.** Relative abundance of four classes of fecal bacteria (human, bird, deer, dog/small mammal) in Three Mile Harbor by date (above; June 13, Aug 22, Oct 4) and on average (below).

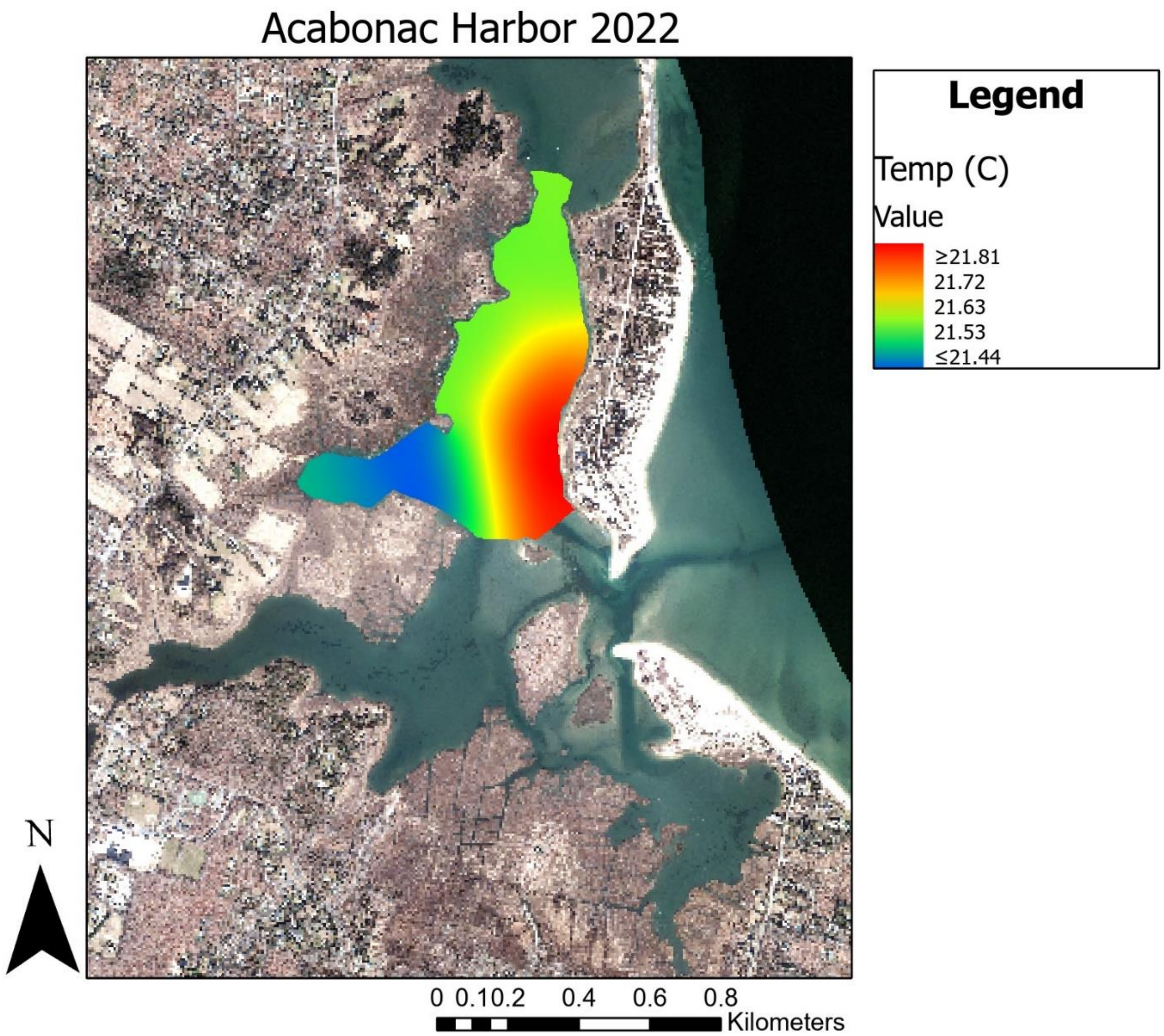



**Figure 20.** Temperature (°C) measurements taken across Acabonac Harbor during September 2022 by the HYCAT autonomous surface vehicle.

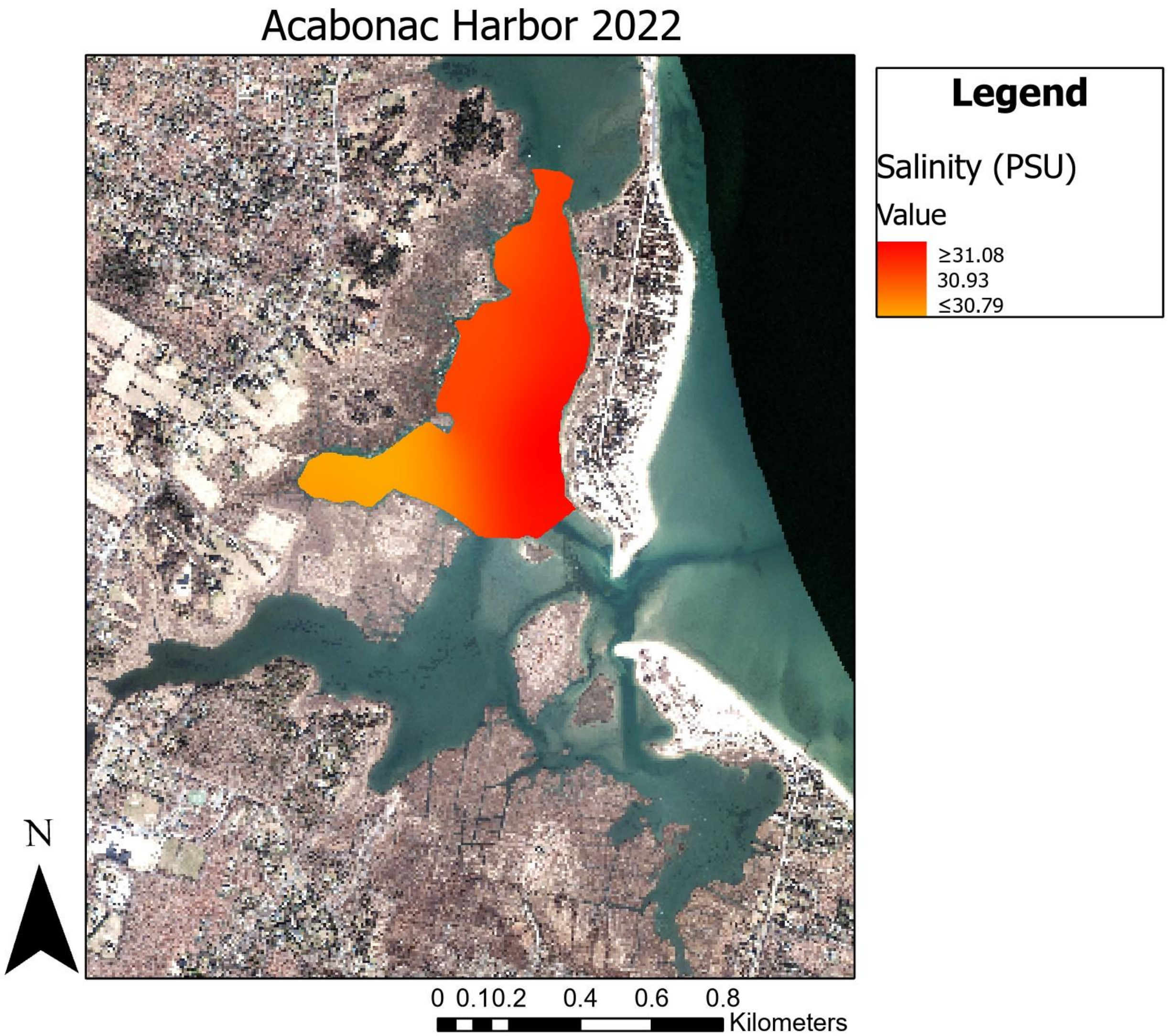



**Figure 21.** Salinity (PSU) measurements taken across Acabonac Harbor during September 2022 by the HYCAT autonomous surface vehicle.

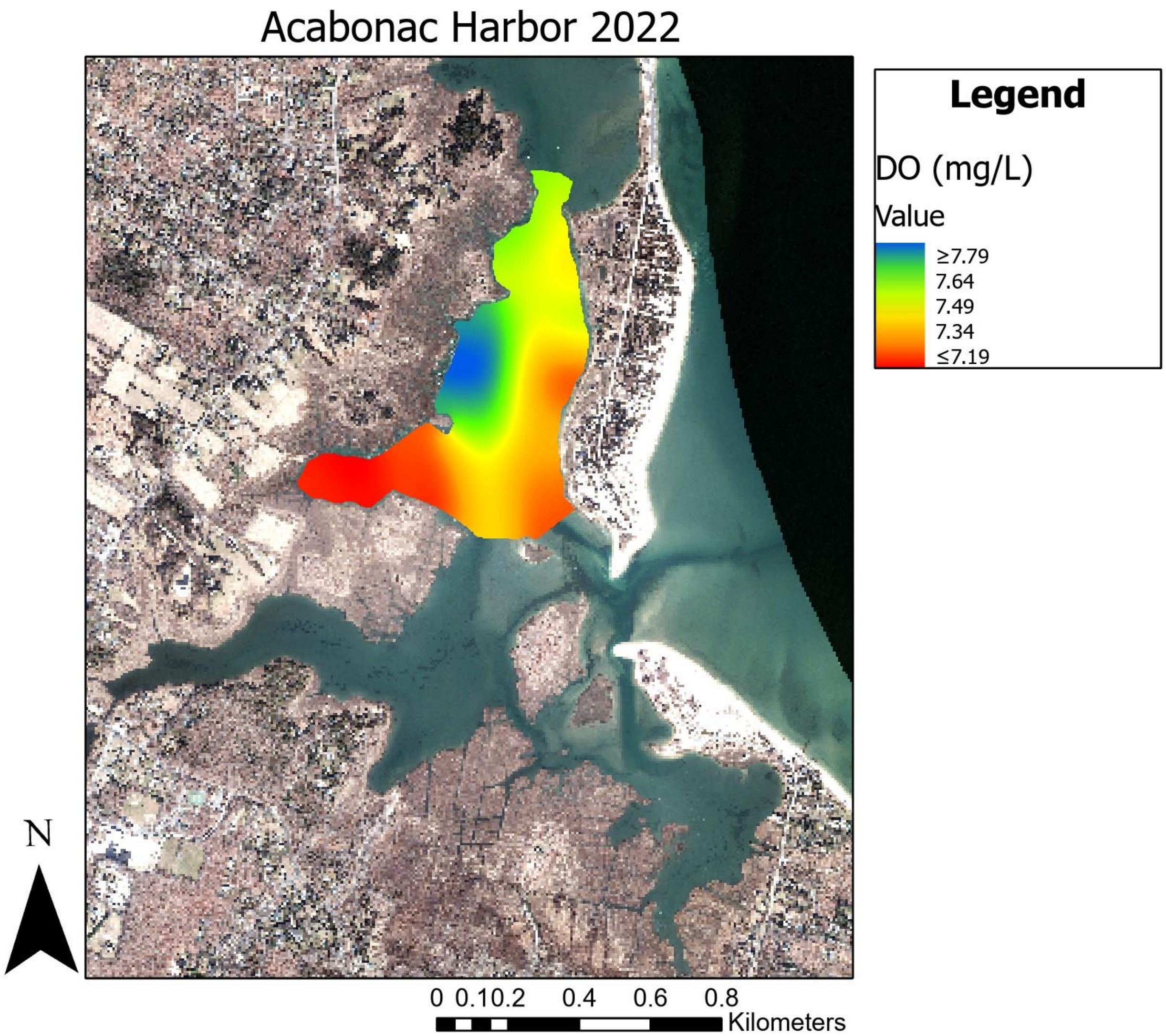



**Figure 22.** Dissolved oxygen (mg $L^{-1}$) measurements taken across Acabonac Harbor during September 2022 by the HYCAT autonomous surface vehicle.

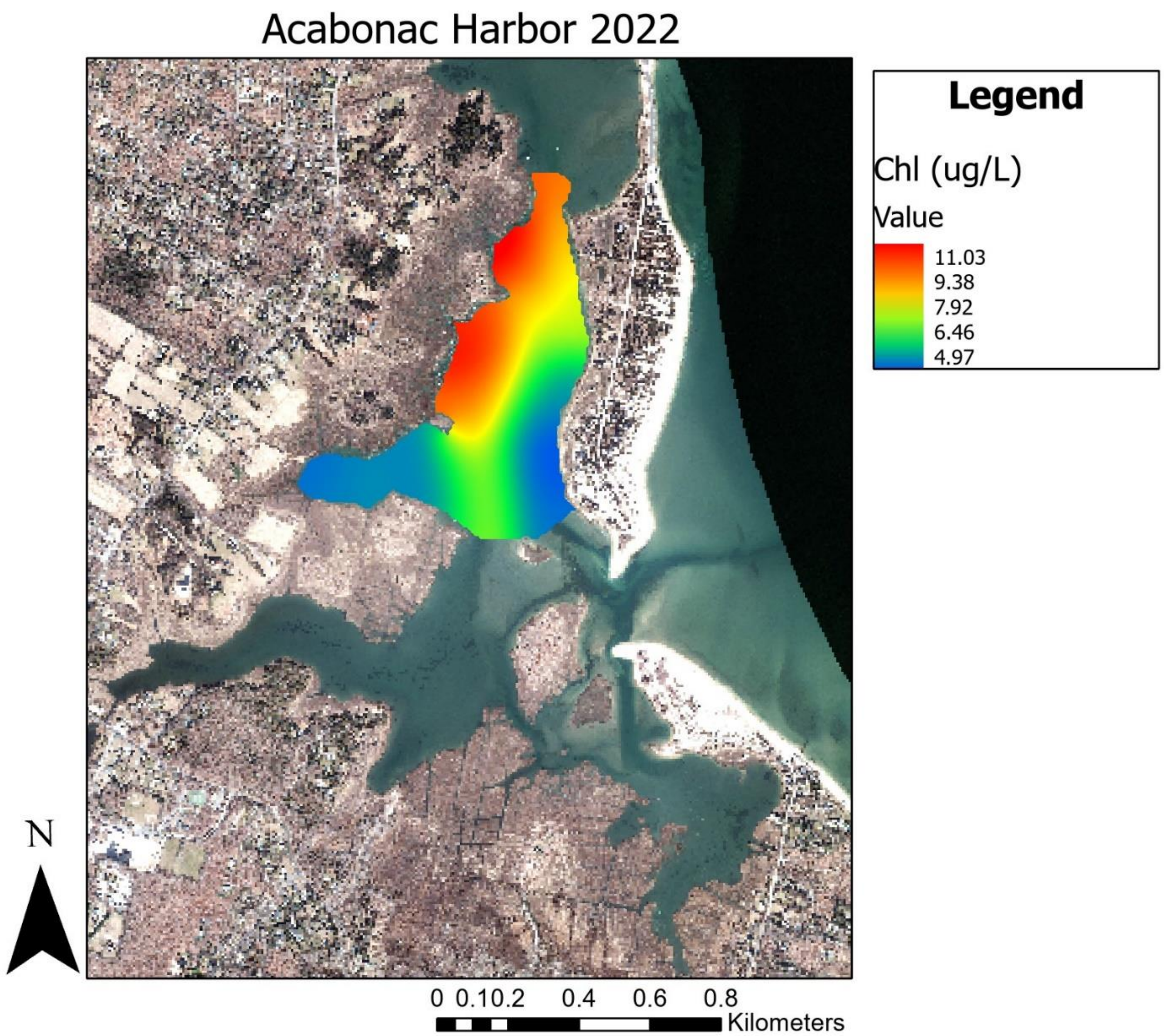



**Figure 23.** Chlorophyll *a* (µg $L^{-1}$) measurements taken across Acabonac Harbor during September 2022 by the HYCAT autonomous surface vehicle.

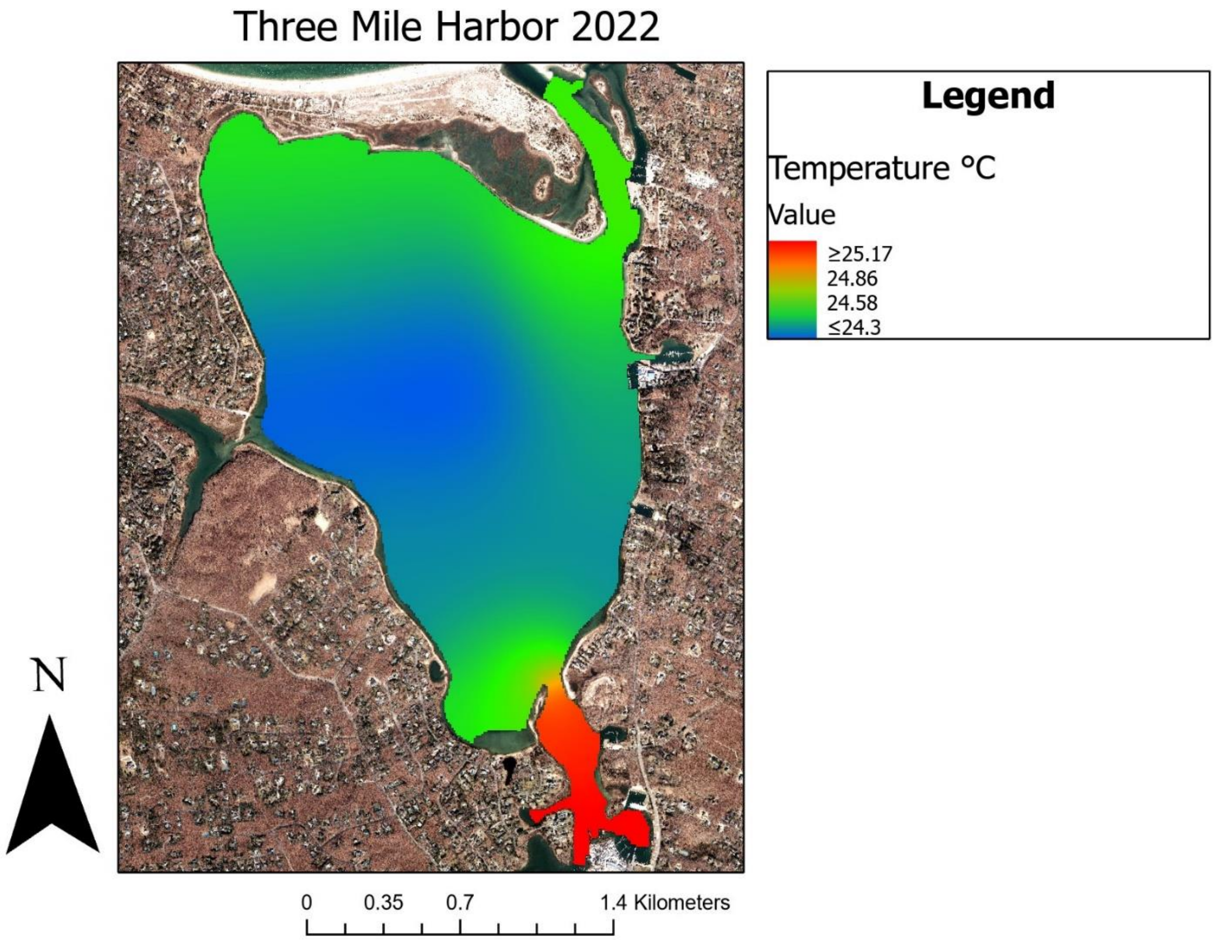



**Figure 24.** Temperature (°C) measurements taken across Three Mile Harbor during September 2022 by the HYCAT autonomous surface vehicle.

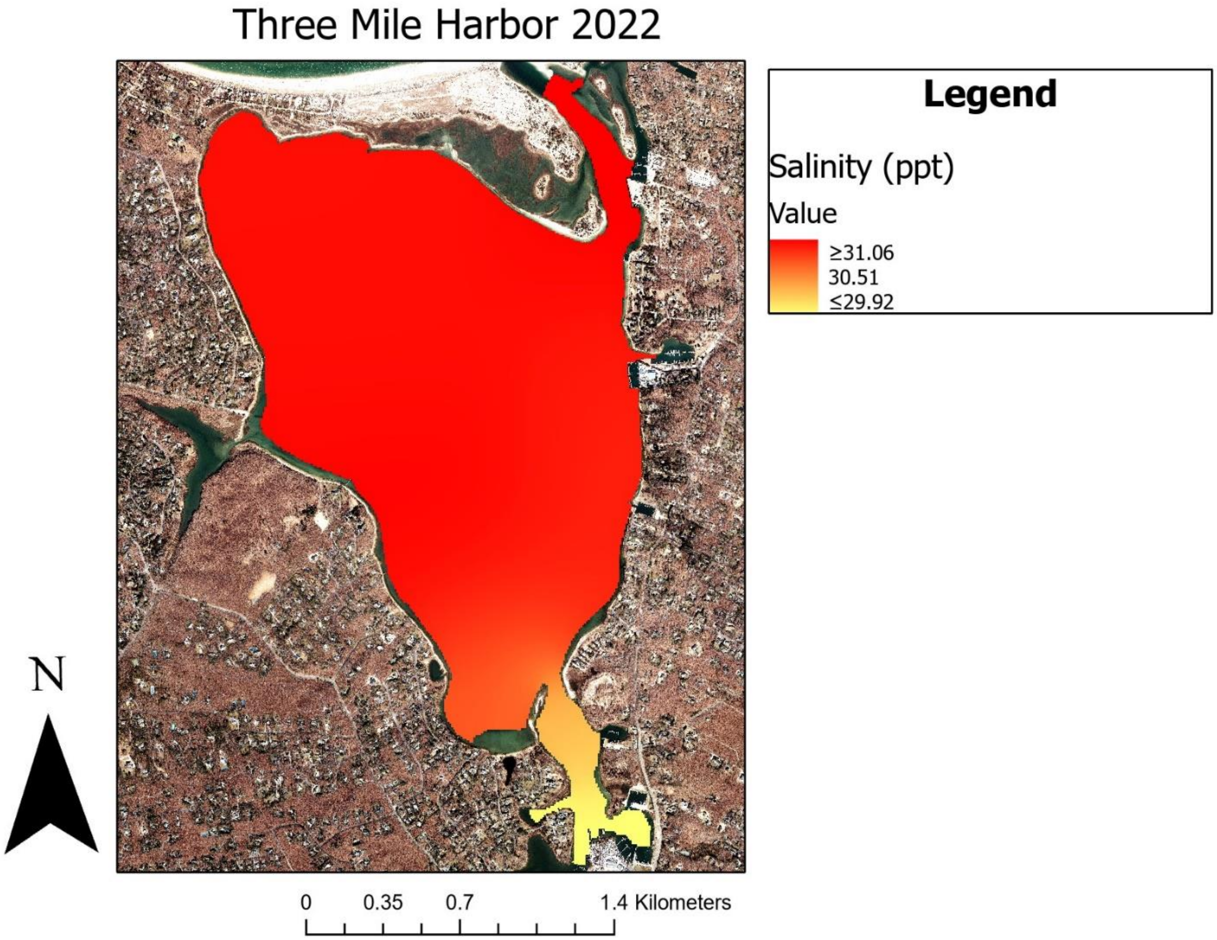



**Figure 25.** Salinity (PSU) measurements taken across Three Mile Harbor during September 2022 by the HYCAT autonomous surface vehicle.

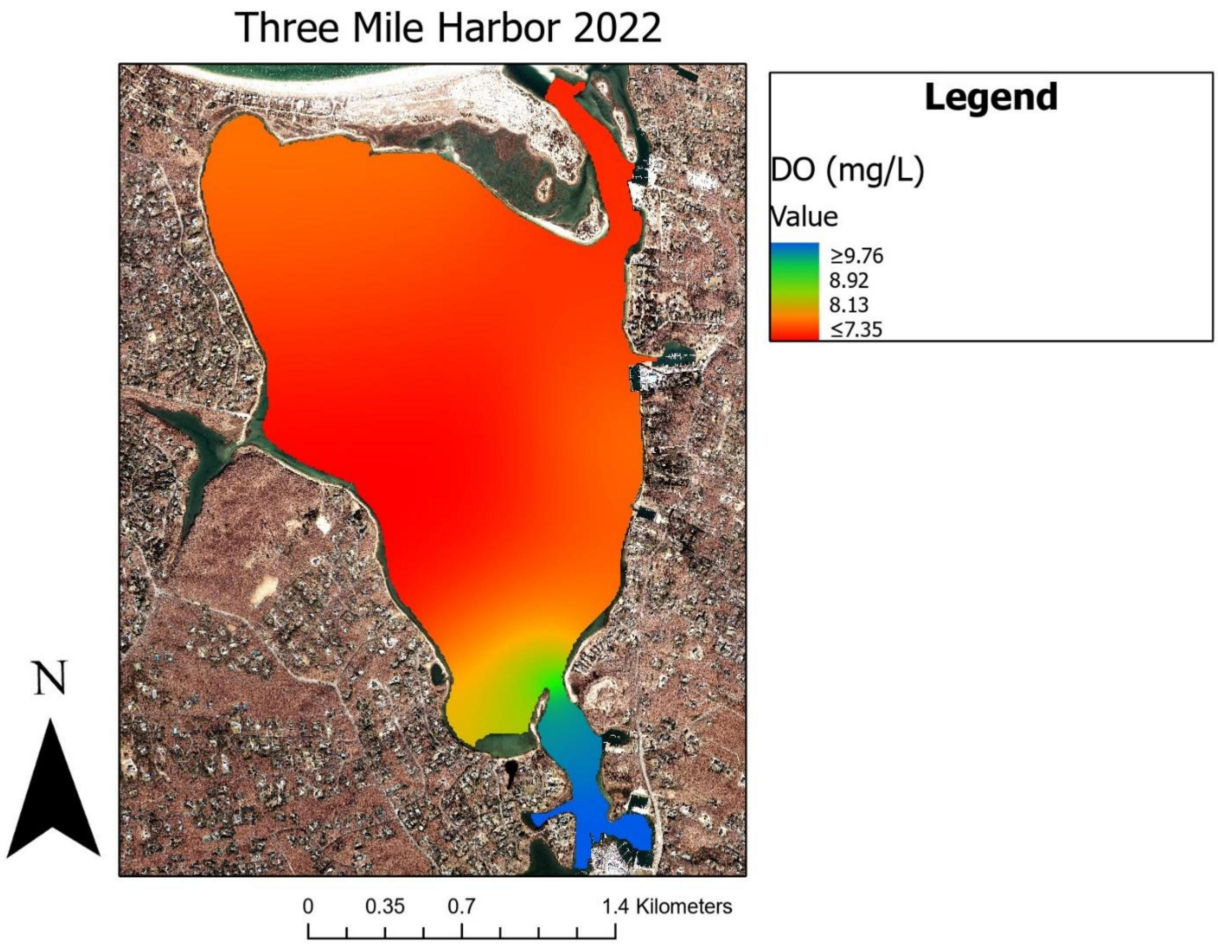



**Figure 26.** Dissolved oxygen (mg $L^{-1}$) measurements taken across Three Mile Harbor during September 2022 by the HYCAT autonomous surface vehicle.

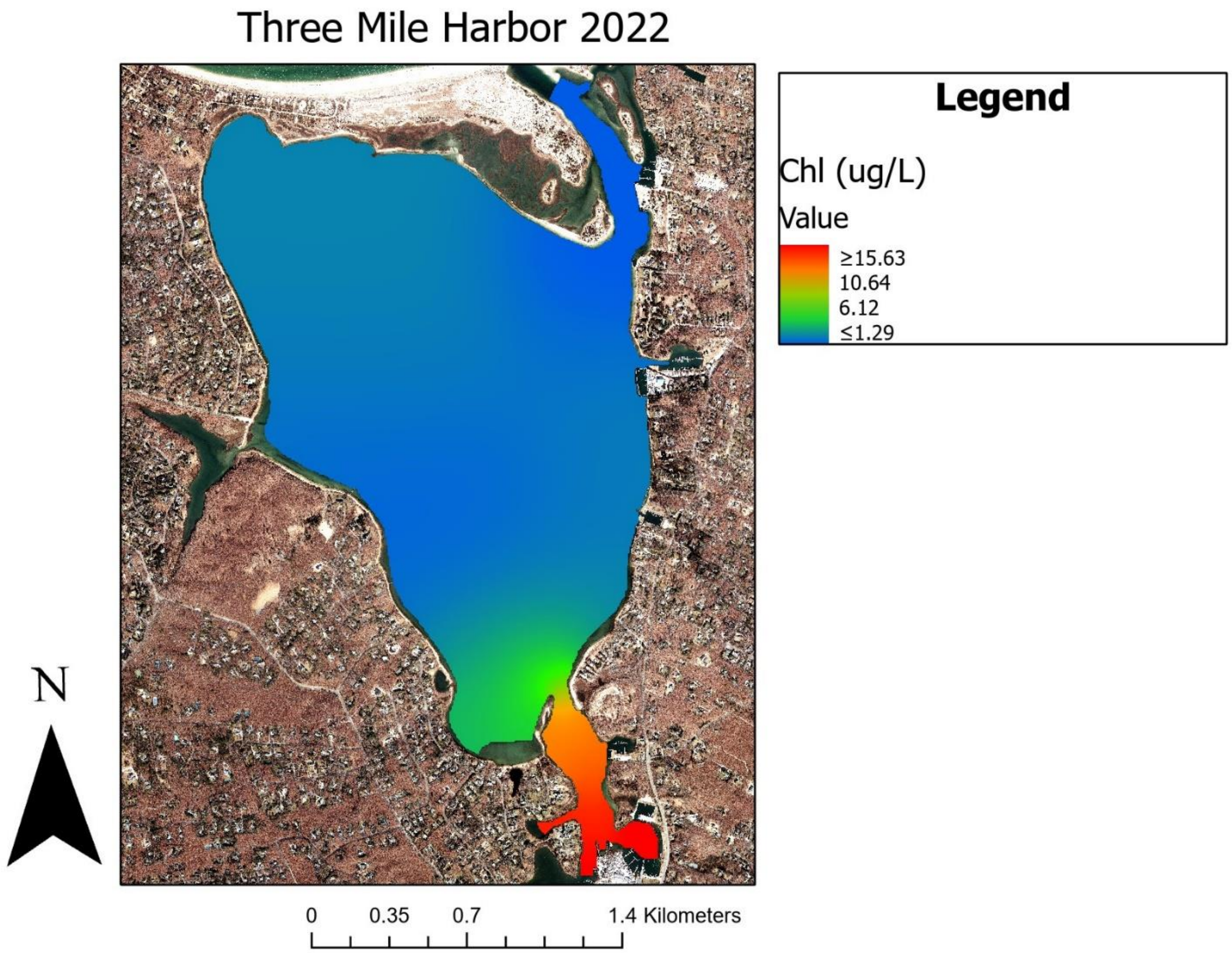



**Figure 27.** Chlorophyll *a* (µg $L^{-1}$) measurements taken across Three Mile Harbor during September 2022 by the HYCAT autonomous surface vehicle.

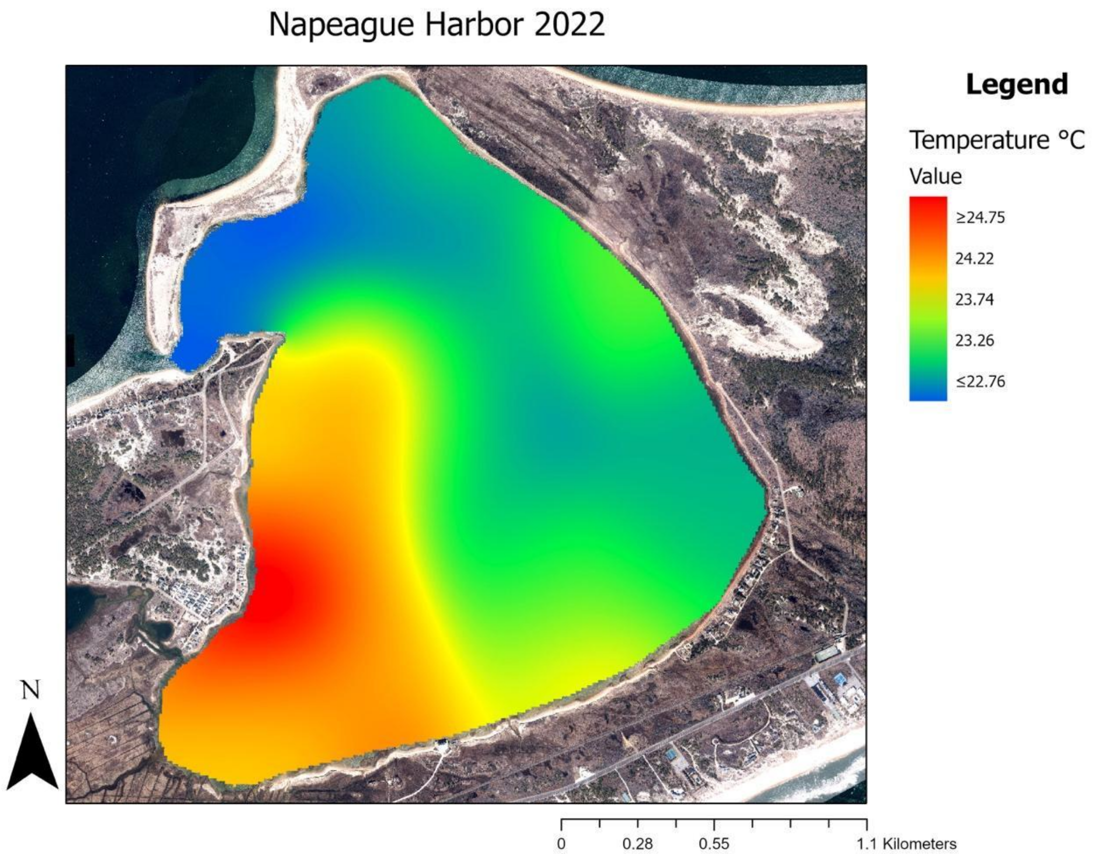



**Figure 28.** Temperature (°C) measurements taken across Napeague Harbor during August 18, 2022, by the HYCAT autonomous surface vehicle.

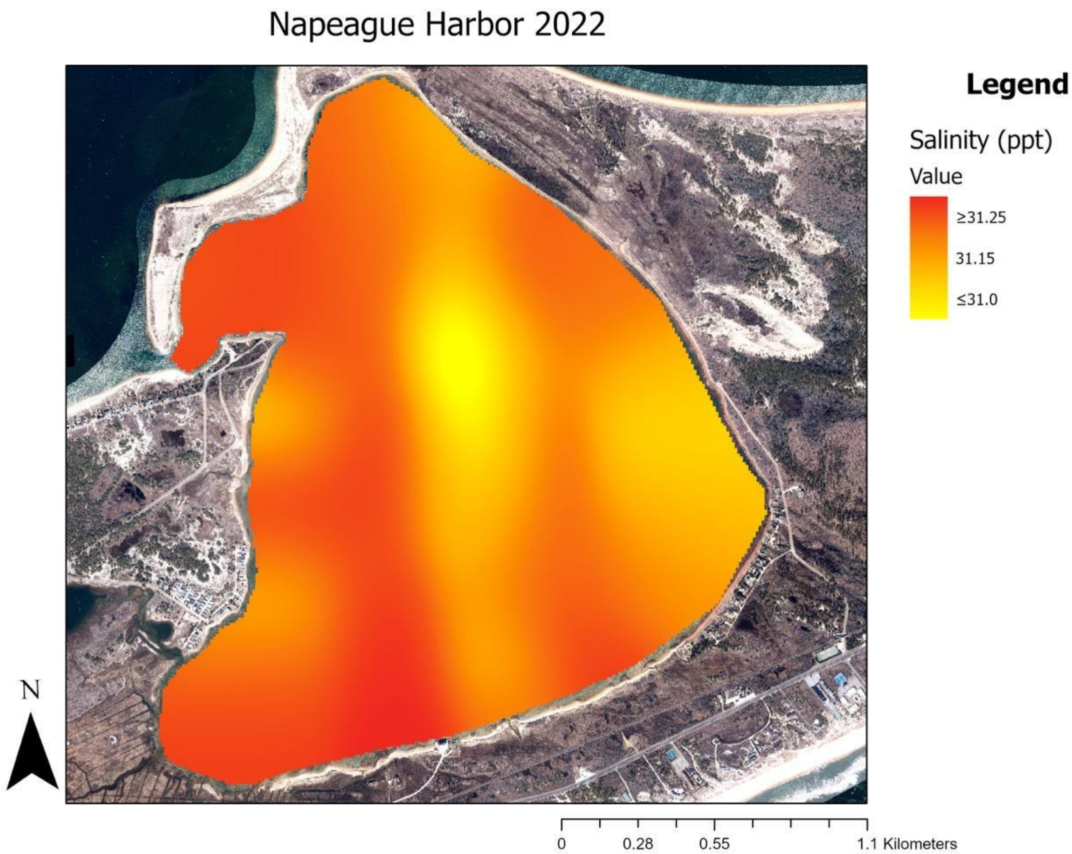



**Figure 29.** Salinity (ppt) measurements taken across Napeague Harbor during August 18, 2022, by the HYCAT autonomous surface vehicle.

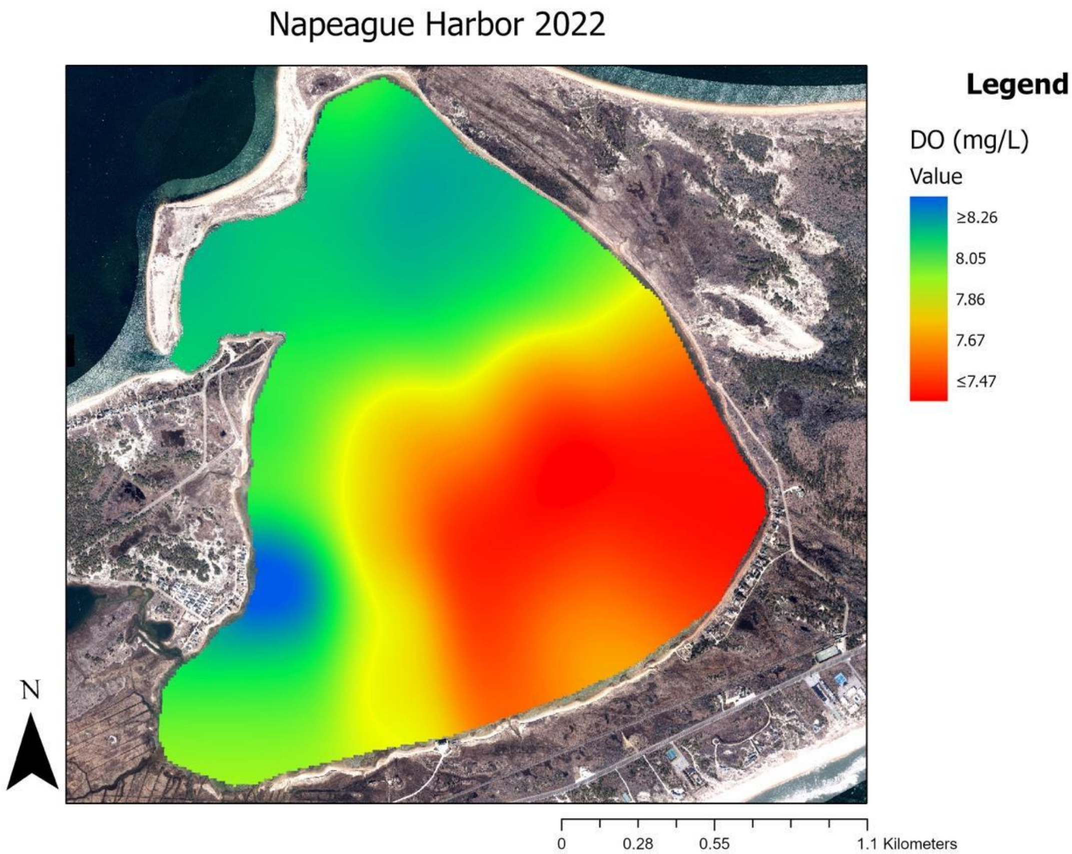



**Figure 30.** Dissolved oxygen (mg $L^{-1}$) measurements taken across Napeague Harbor during August 18, 2022, by the HYCAT autonomous surface vehicle.

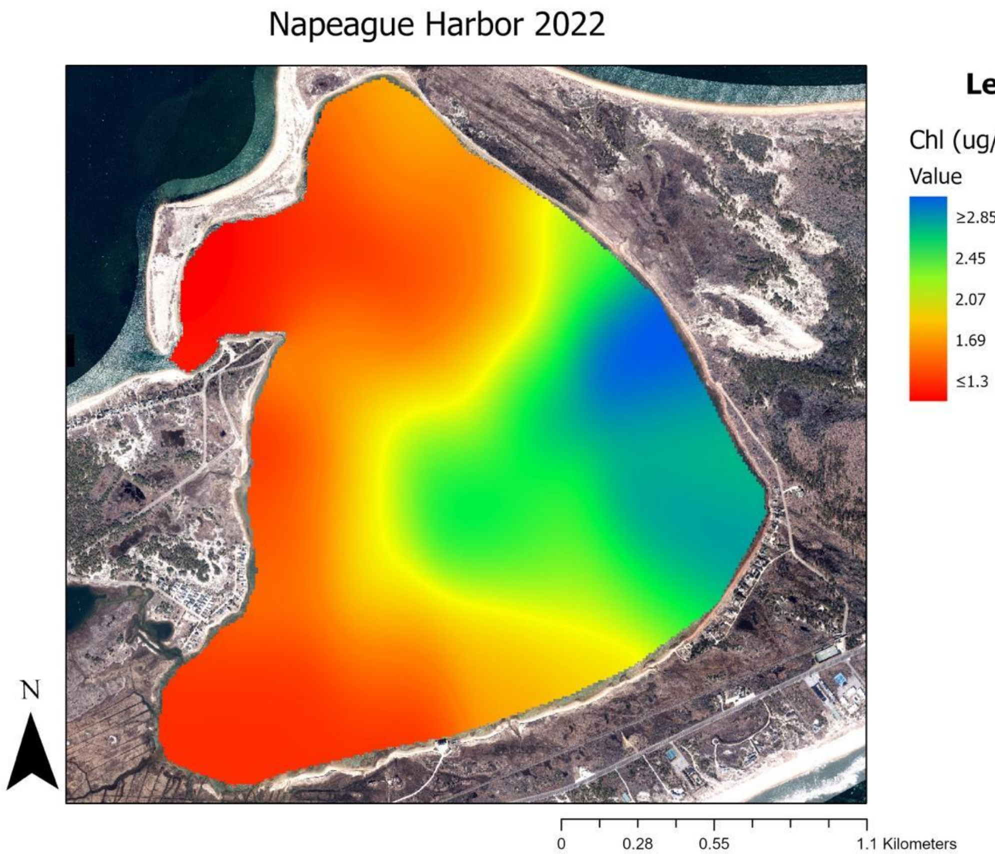



**Figure 31.** Chlorophyll *a* (µg $L^{-1}$) measurements taken across Napeague Harbor during August 18, 2022, by the HYCAT autonomous surface vehicle.

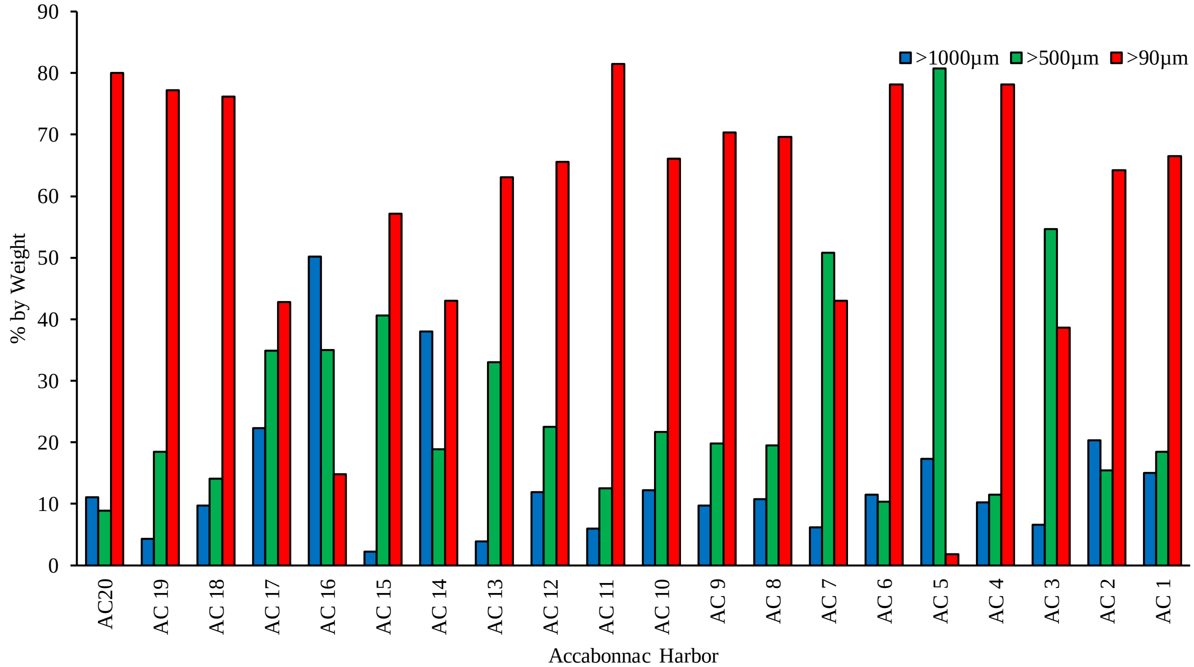



**Figure 32.** Overall sediment composition in % by weight at various sites in Accabonac Harbor during 2022.

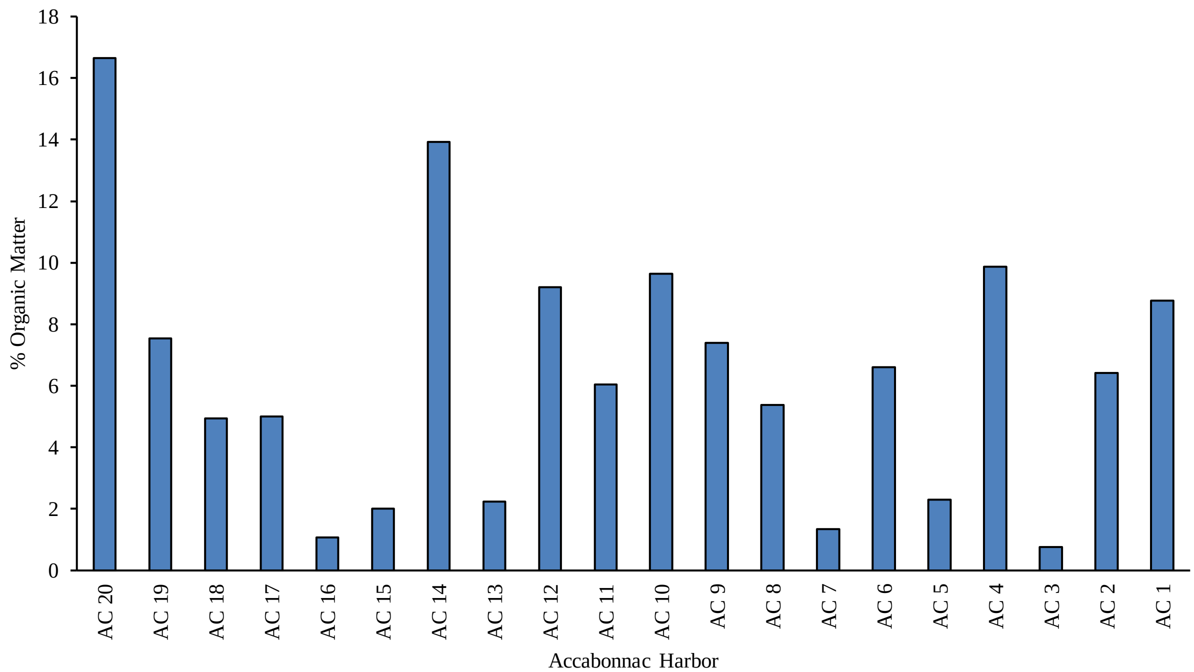



**Figure 33.** Overall organic sediment composition in % by organic matter at various sites in Accabonac Harbor during 2022.

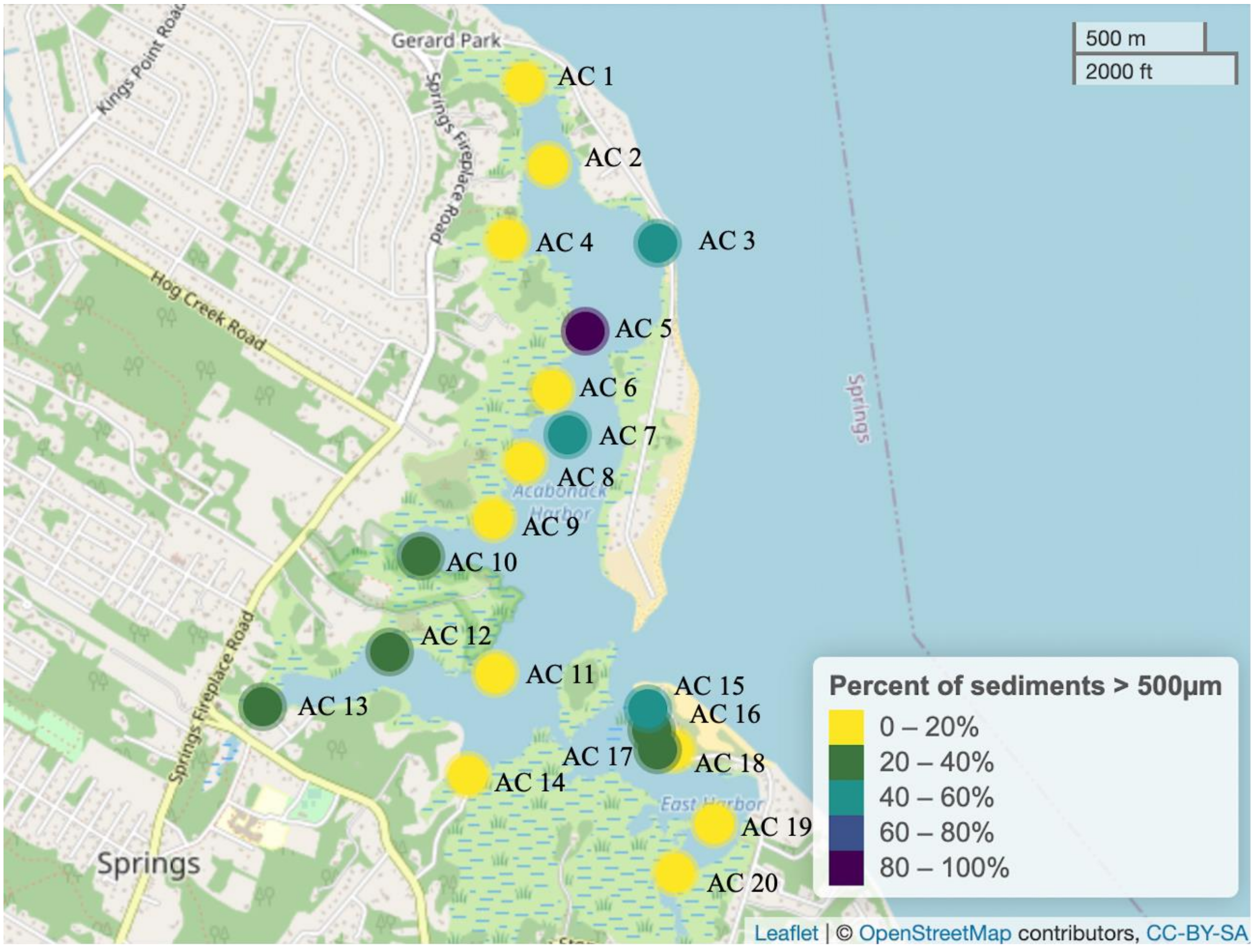



**Figure 34.** Percent of sediments > 500µm measurements taken in 2022 across multiple sites in Accabonac Harbor.

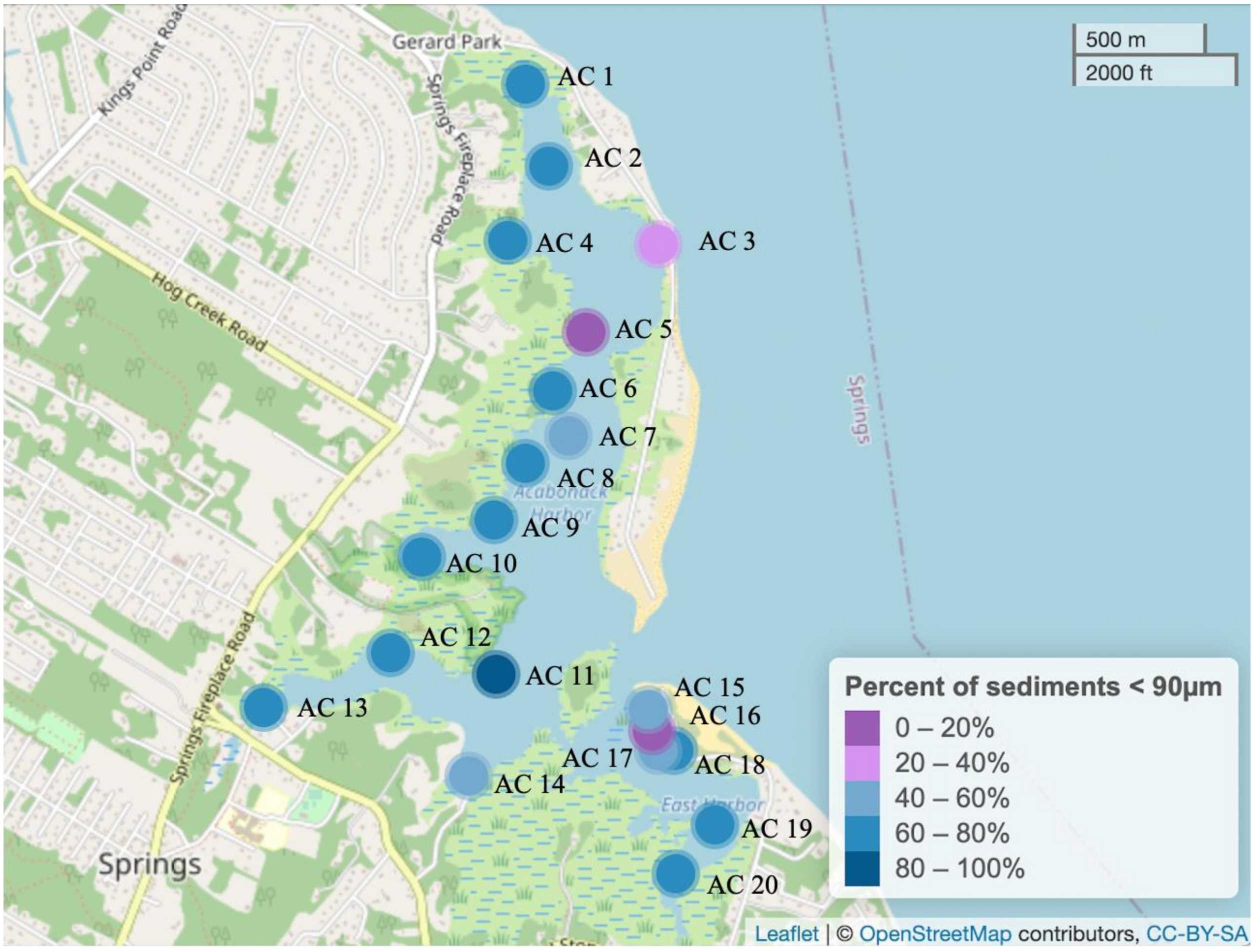



**Figure 35.** Percent of sediments < 90µm measurements taken in 2022 across multiple sites in Accabonac Harbor.

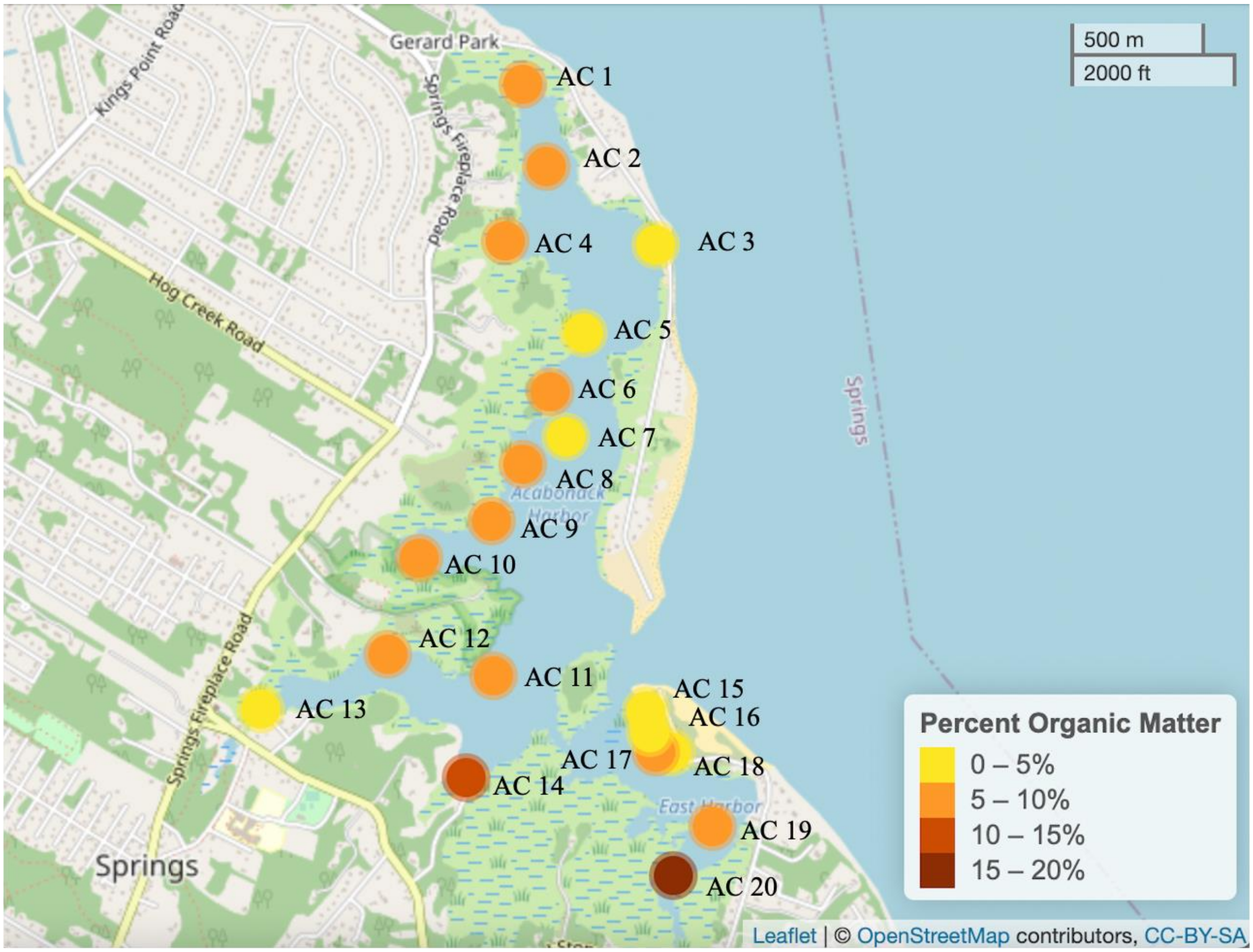



**Figure 36.** Percent of organic matter measurements taken in 2022 across multiple sites in Accabonac Harbor.

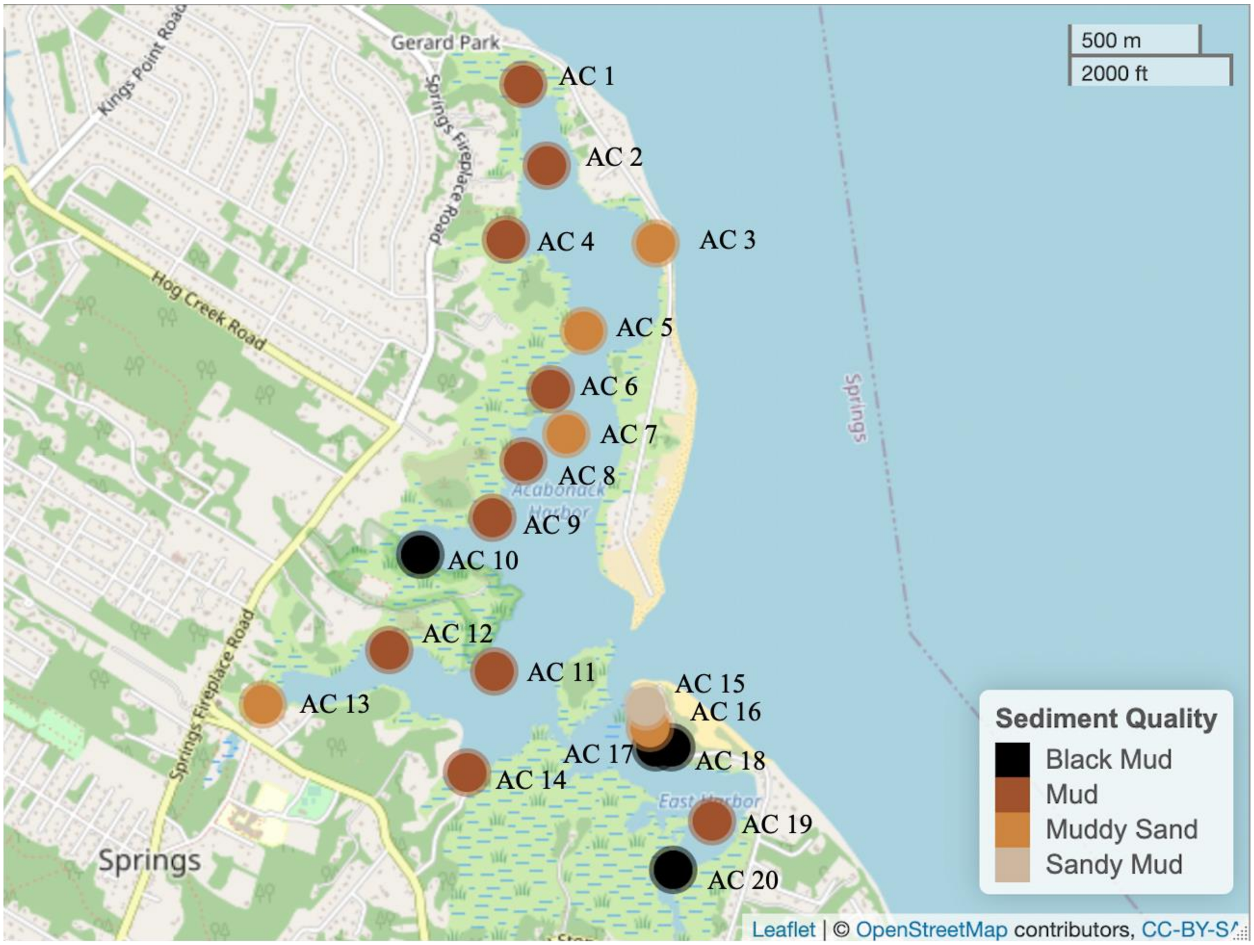



**Figure 37.** Sediment Quality measurements taken in 2022 across multiple sites in Accabonac Harbor.

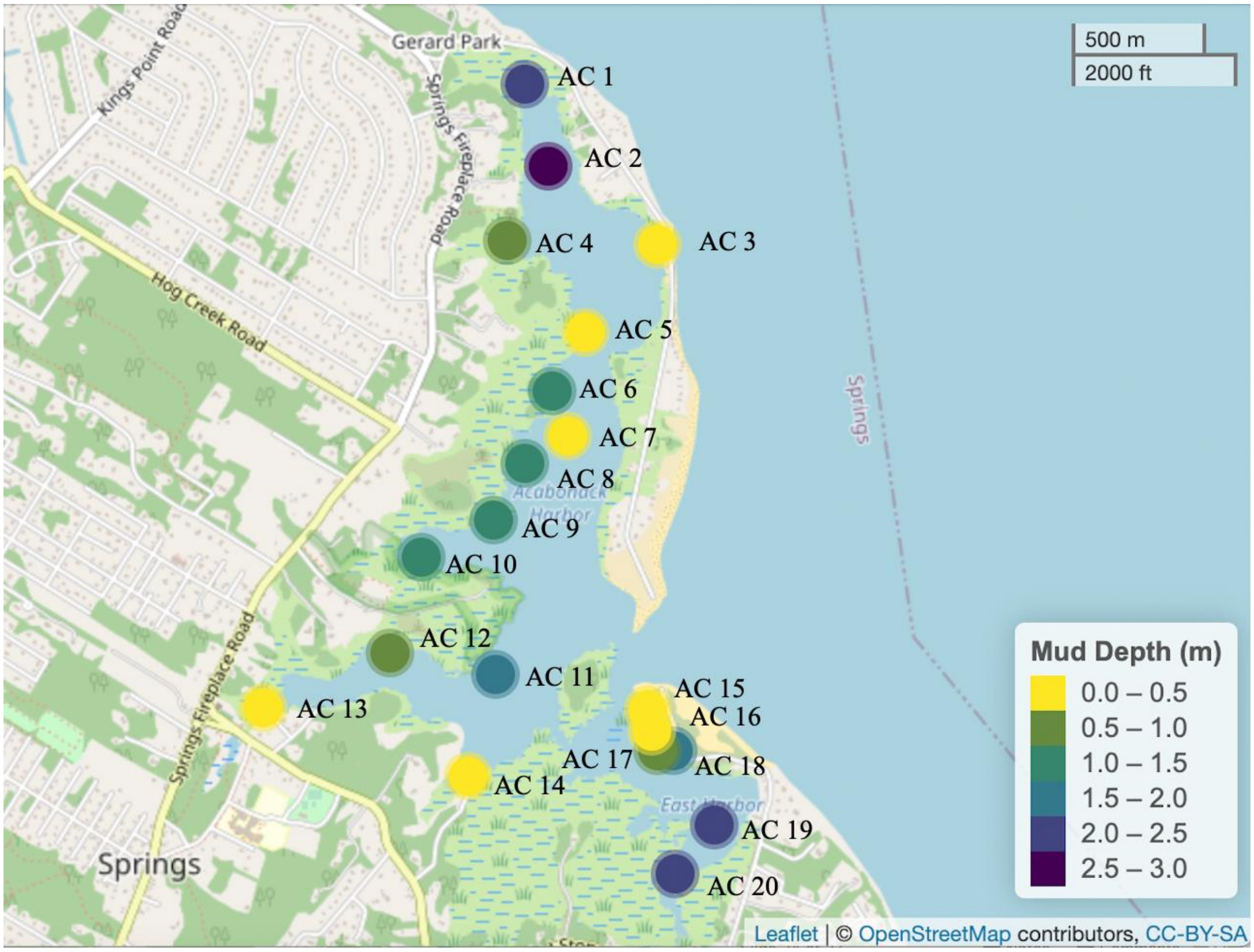



**Figure 38A.** Mud depth (m) measurements taken in 2022 across multiple sites in Accabonac Harbor.

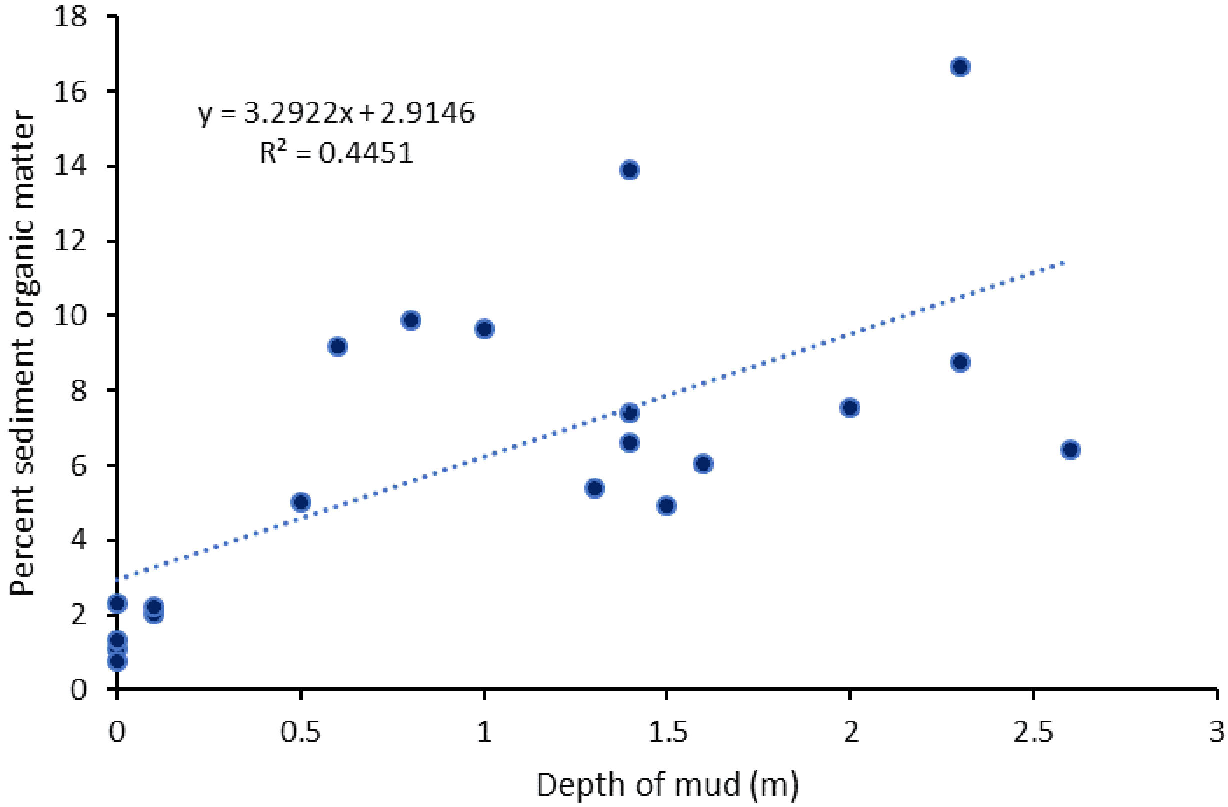



**Figure 38B.** Percent sediment of organic matter over the depth of mud (m) in 2022 across Accabonac Harbor.

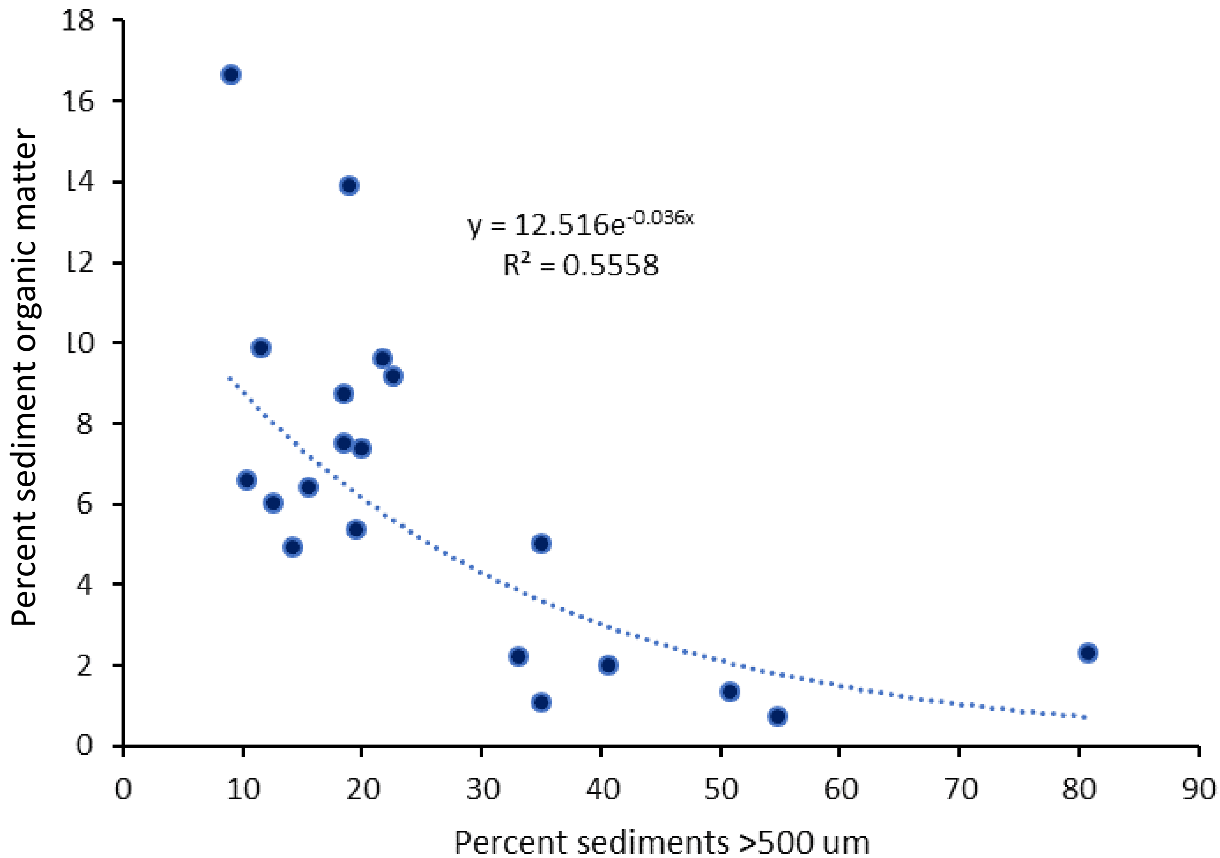



**Figure 38C.** Percent sediment of organic matter over the percent sediments > 500 um in 2022 across Accabonac Harbor.

**Table 2.** List of sites in Accabonac in 2022, measuring sediment depth (m) and sediment quality.

| Location | Site | Depth (meters) | Sediment Quality |
|---|---|---|---|
| Accabonac Harbor | AC 1 | 2.3 | Mud |
| | AC 2 | 2.6 | Mud |
| | AC 3 | 0.0 | Muddy Sand |
| | AC 4 | 0.8 | Mud |
| | AC 5 | 0.0 | Muddy Sand |
| | AC 6 | 1.4 | Mud |
| | AC 7 | 0.0 | Muddy Sand |
| | AC 8 | 1.3 | Mud |
| | AC 9 | 1.4 | Mud |
| | AC 10 | 1.0 | Black Mud |
| | AC 11 | 1.6 | Mud |
| | AC 12 | 0.6 | Mud |
| | AC 13 | 0.1 | Muddy Sand |
| | AC 14 | 0.4 | Mud |
| | AC 15 | 0.1 | Sandy Mud |
| | AC 16 | 0.0 | Muddy Sand |
| | AC 17 | 0.5 | Black Mud |
| | AC 18 | 1.5 | Black Mud |
| | AC 19 | 2.0 | Mud |
| | AC 20 | 2.0 | Black Mud |

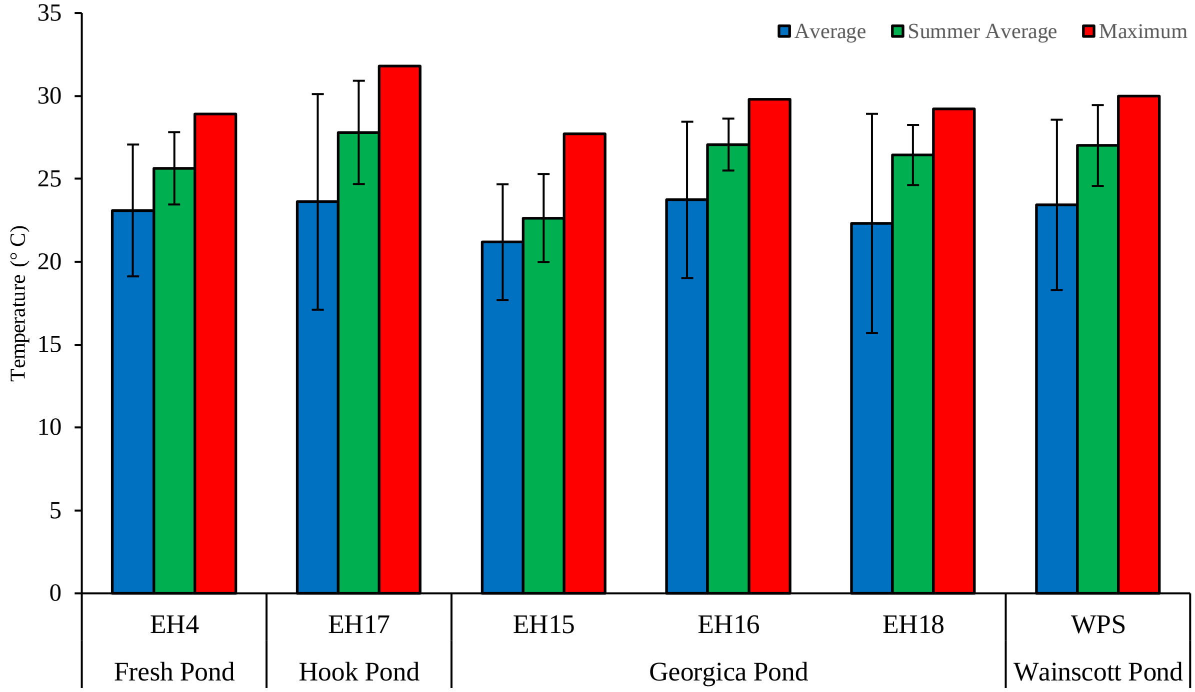



**Figure 39.** Overall average, summer average, and maximum surface water temperatures (°C) at freshwater sites in East Hampton during 2022. Error bars represent standard deviation.

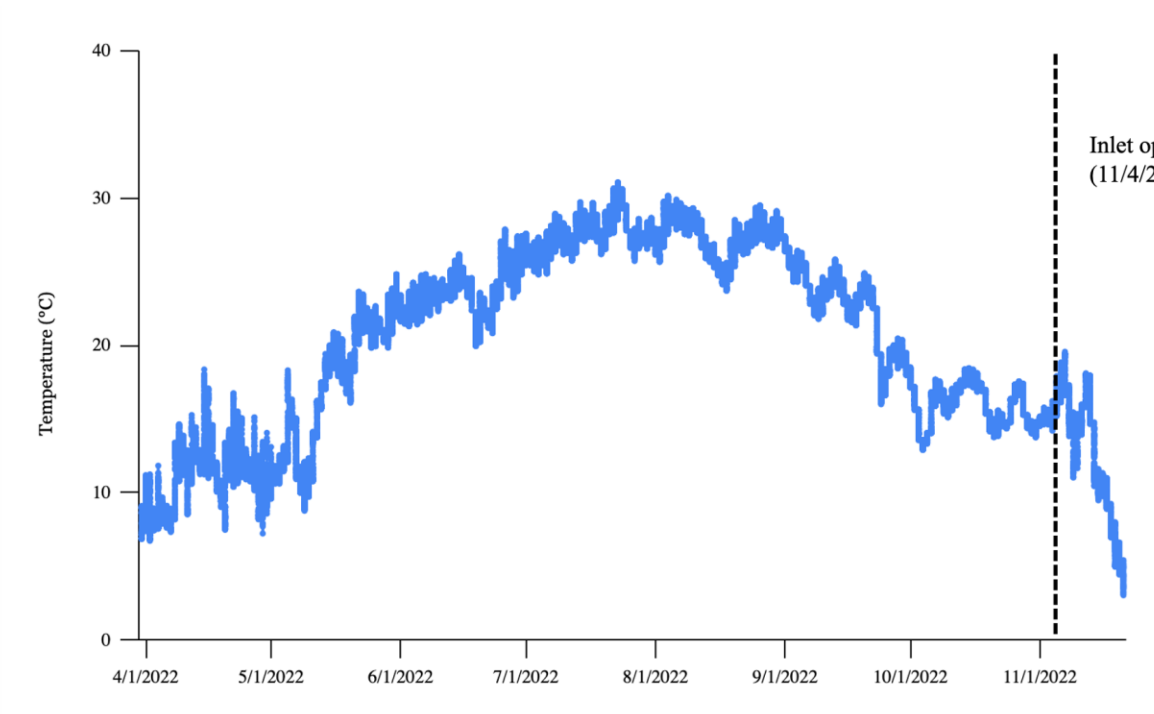



**Figure 40.** Continuous surface water temperatures (°C) at the buoy in Georgica Pond during 2022. The vertical dashed line represents when the ocean inlet in the south of Georgica Pond was opened on 4-November-2022.

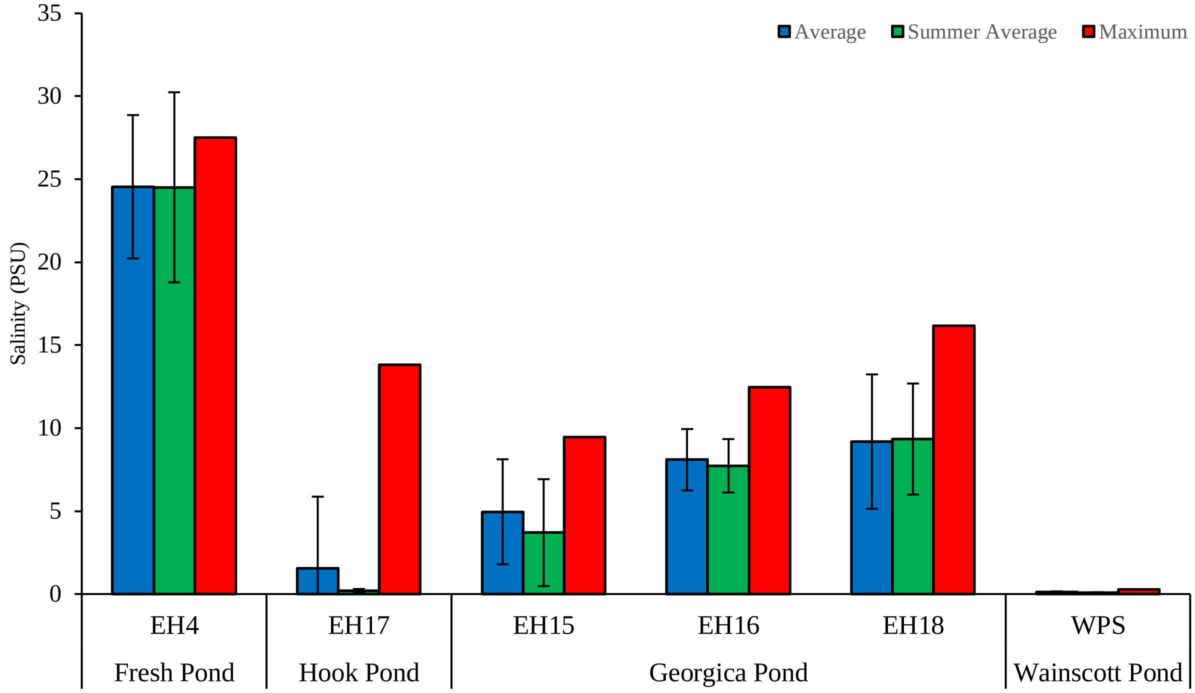



**Figure 41.** Overall average, summer average, and maximum surface water salinities (PSU) at freshwater sites in East Hampton during 2022. Error bars represent standard deviation.

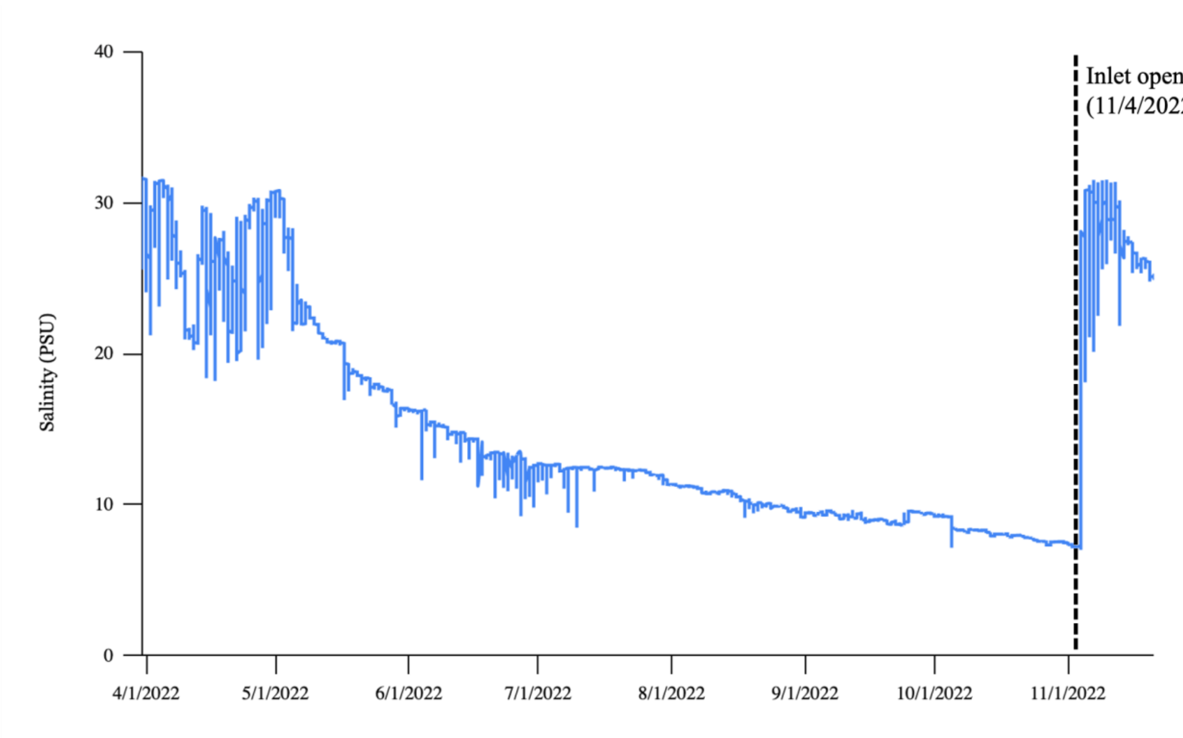



**Figure 42.** Continuous surface water salinity (PSU) at the buoy in Georgica Pond during 2022. The vertical dashed line represents when the ocean inlet in the south of Georgica Pond was opened on 4-November-2022.

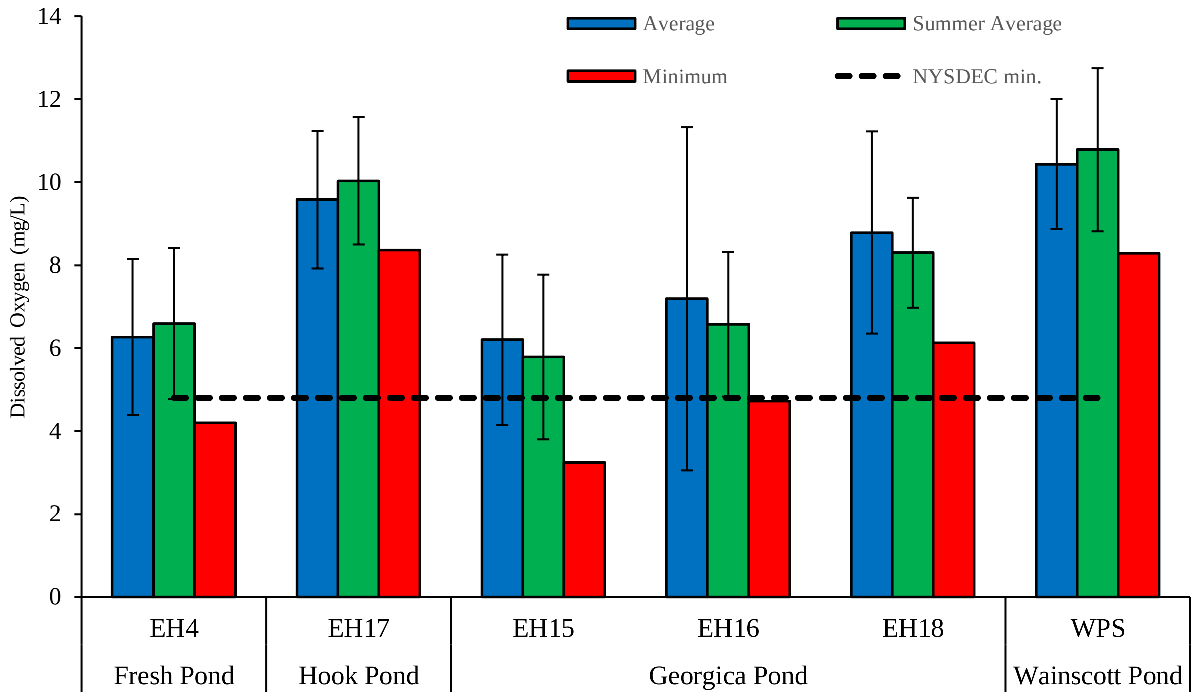



**Figure 43.** Overall average, summer average, and minimum surface water dissolved oxygen concentrations (mg $L^{-1}$) at freshwater sites in East Hampton during 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$). Error bars represent standard deviation.

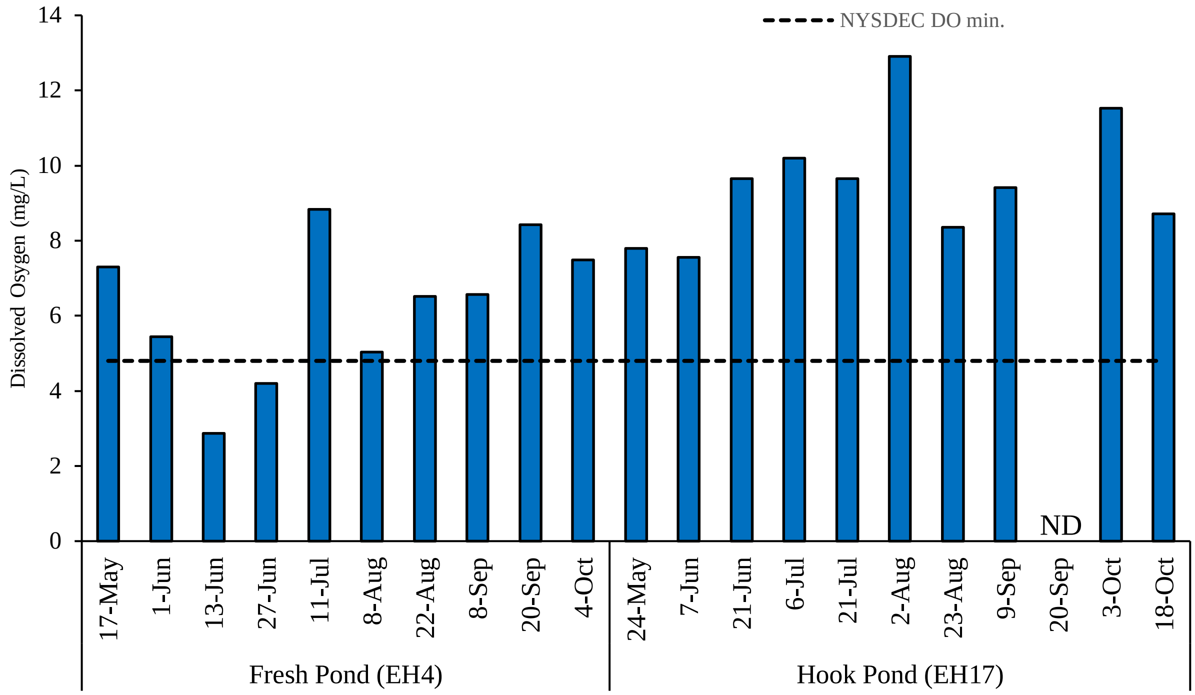
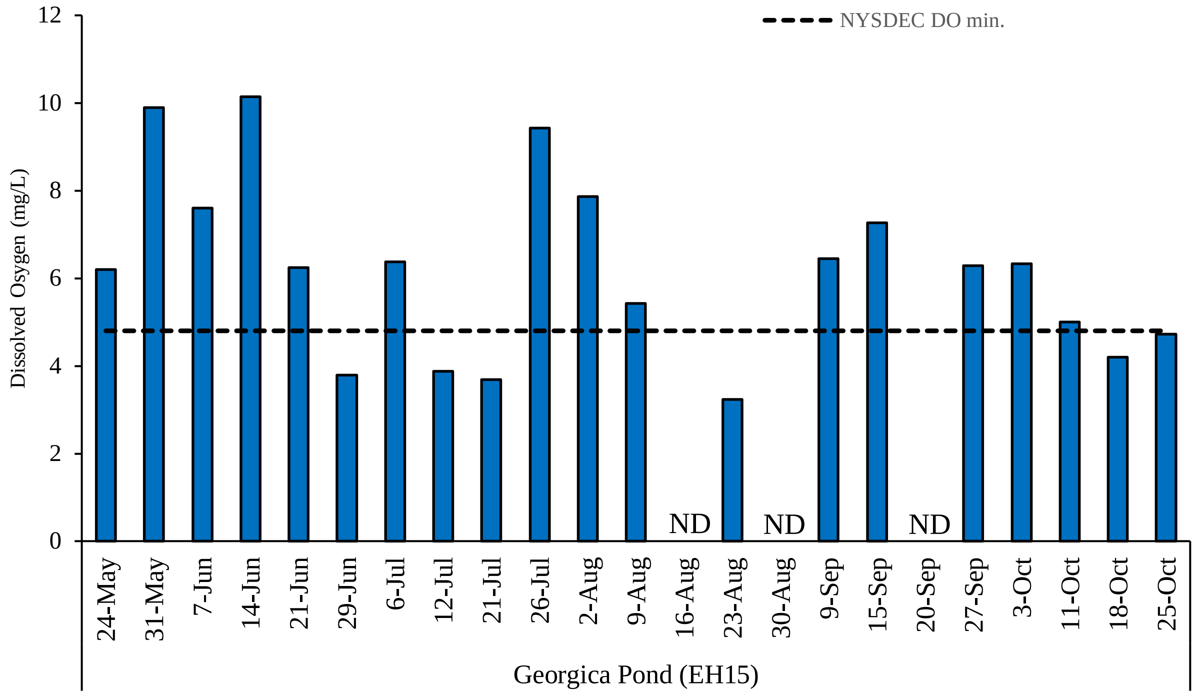
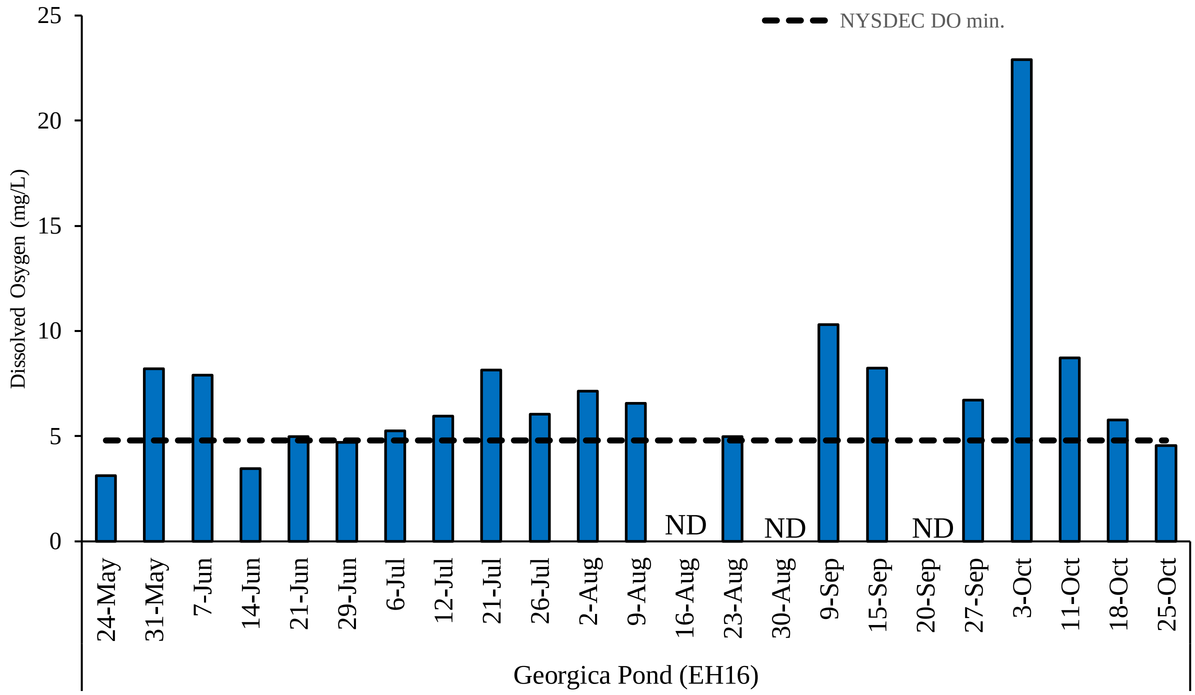



**Figure 44.** Surface water dissolved oxygen concentrations (mg $L^{-1}$) at Fresh Pond (EH4) and Hook Pond (EH17) during 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$). ND = No data collected for the date.


NYSDEC DO min.
Dissolved Osygen (mg/L)
0
2
4
6
8
10
12
ND
ND
ND
24-May
31-May
7-Jun
14-Jun
21-Jun
29-Jun
6-Jul
12-Jul
21-Jul
26-Jul
2-Aug
9-Aug
16-Aug
23-Aug
30-Aug
9-Sep
15-Sep
20-Sep
27-Sep
3-Oct
11-Oct
18-Oct
25-Oct
Georgica Pond (EH15)


NYSDEC DO min.
Dissolved Osygen (mg/L)
0
5
10
15
20
25
ND
ND
ND
24-May
31-May
7-Jun
14-Jun
21-Jun
29-Jun
6-Jul
12-Jul
21-Jul
26-Jul
2-Aug
9-Aug
16-Aug
23-Aug
30-Aug
9-Sep
15-Sep
20-Sep
27-Sep
3-Oct
11-Oct
18-Oct
25-Oct
Georgica Pond (EH16)

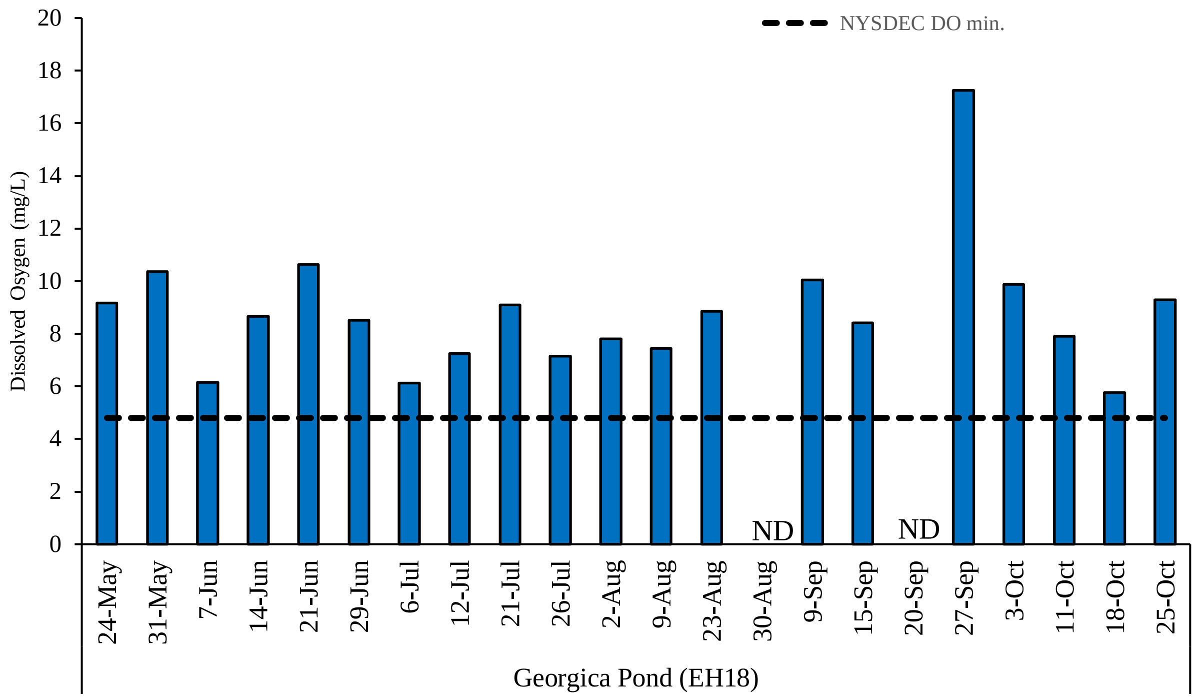



**Figure 45.** Surface water dissolved oxygen concentrations (mg $L^{-1}$) at various sites in Georgica Pond during 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$). ND = No data collected for the date.

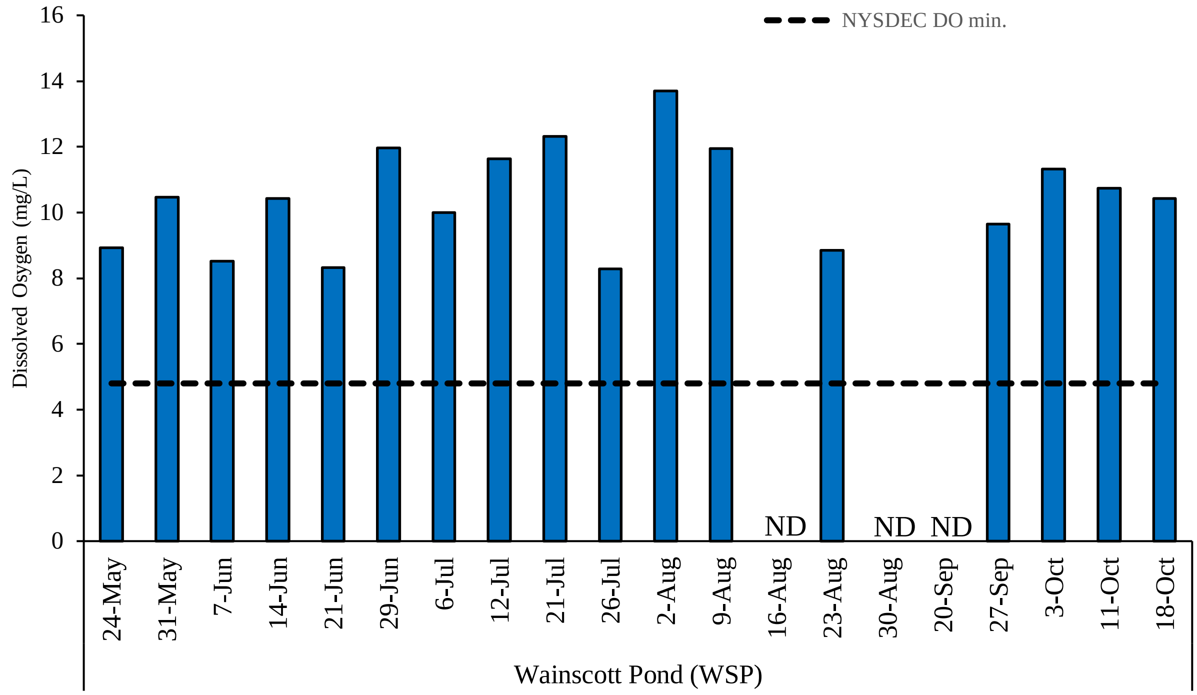



**Figure 46.** Surface water dissolved oxygen concentrations (mg $L^{-1}$) in Wainscott Pond during 2022. The dashed line represents the NYSDEC minimum for dissolved oxygen (4.8 mg $L^{-1}$). ND = No data collected for the date.

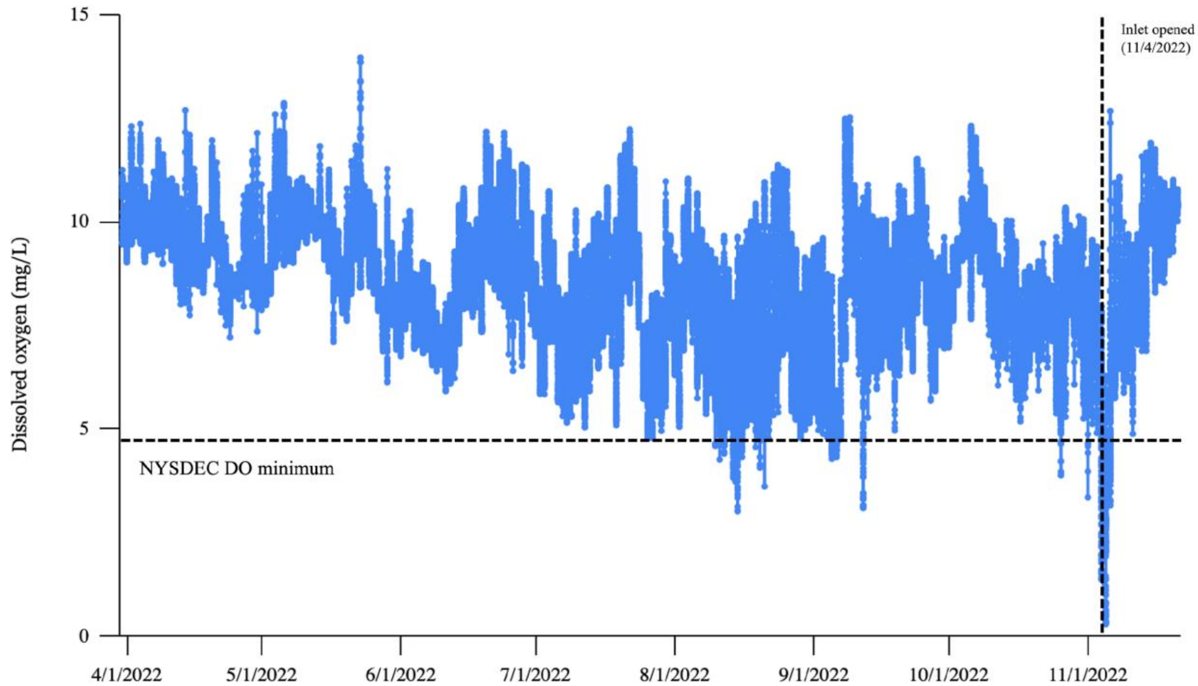



**Figure 47.** Continuous surface water dissolved oxygen (mg $L^{-1}$) at the buoy in Georgica Pond during 2022. The vertical dashed line represents when the ocean inlet in the south of Georgica Pond was opened on 4-November-2022. The horizontal dashed line represents the NYSDEC DO minimum (4.8 mg $L^{-1}$).

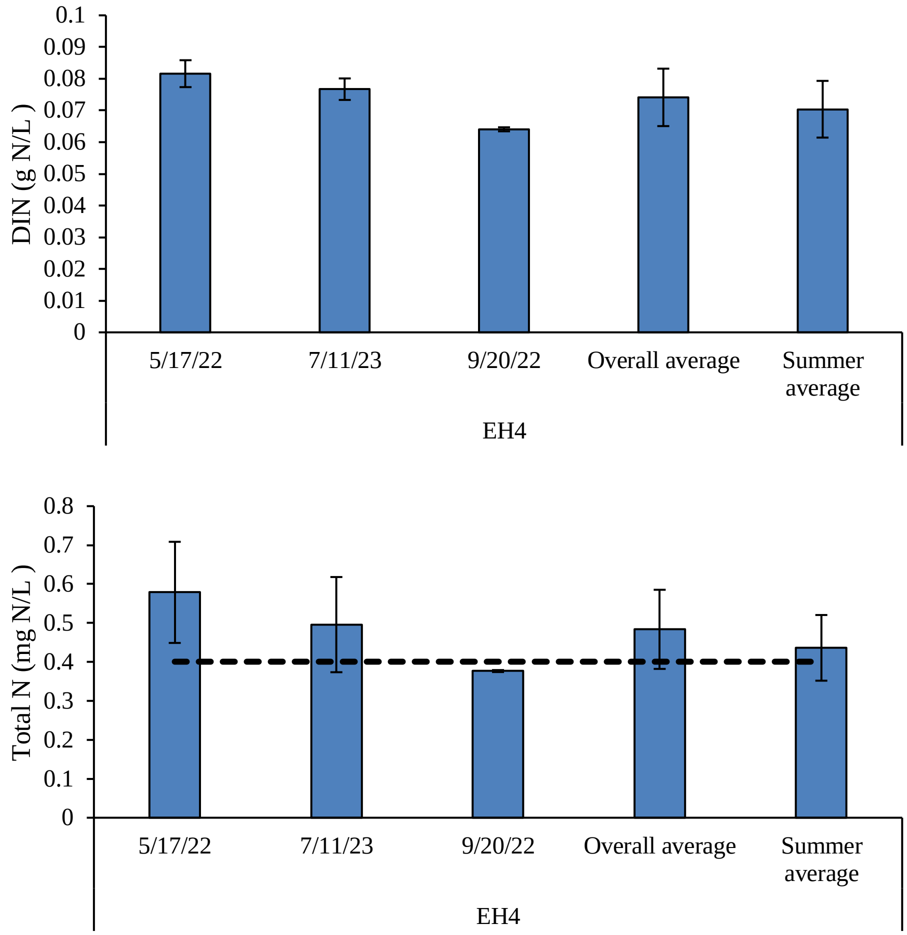



**Figure 48.** Dissolved inorganic nitrogen (DIN), and total N, at Fresh Pond (EH4) during 2022. The dashed line represents the Peconic Estuary total N threshold (28.6 µM). Error bars represent standard deviation.

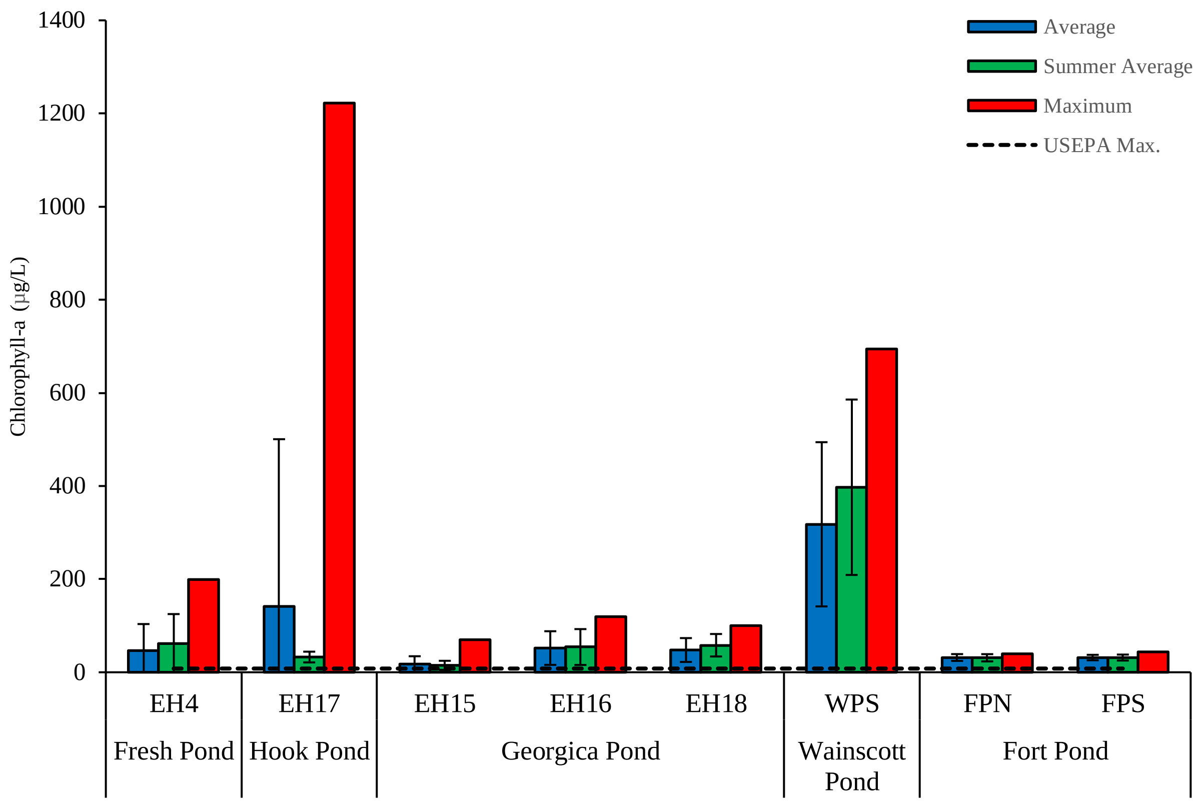



**Figure 49.** Overall average, summer average, and minimum chlorophyll *a* concentration (µg L-1) at freshwater sites in East Hampton during 2022. The dashed line represents the USEPA maximum for chlorophyll *a* in freshwater systems (8 µg $L^{-1}$). Error bars represent standard deviation.

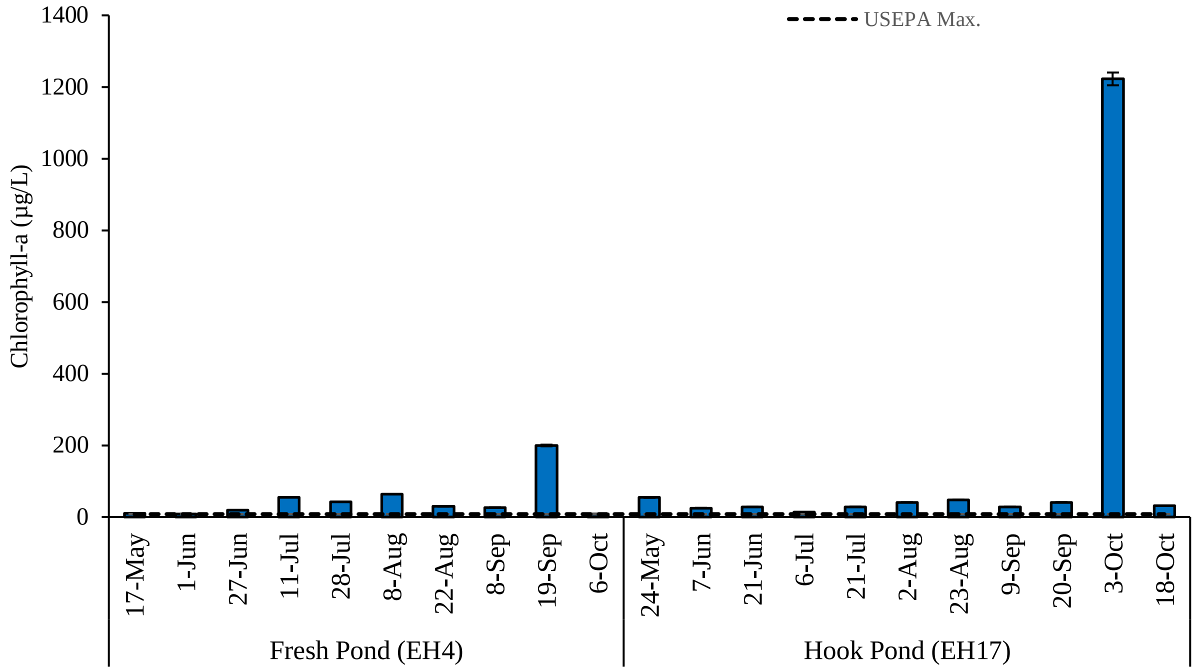



**Figure 50.** Chlorophyll *a* concentrations (µg $L^{-1}$) in Fresh Pond (EH4) and Hook Pond (EH17) during 2022. The dashed line represents the USEPA maximum for chlorophyll *a* in freshwater systems (8 µg $L^{-1}$). Error bars represent standard deviation.

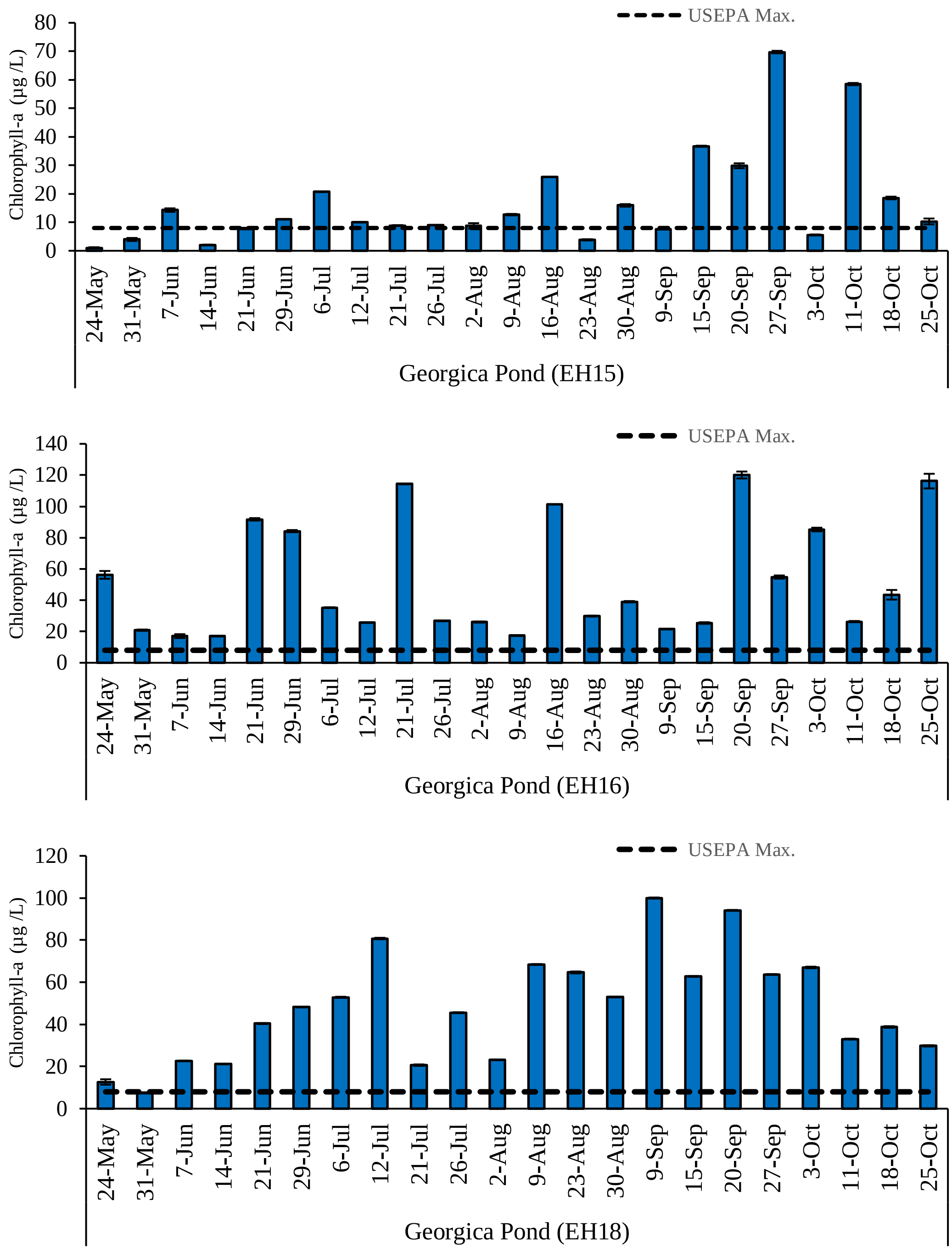



**Figure 51.** Chlorophyll *a* concentrations (µg $L^{-1}$) at various sites in Georgica Pond during 2022. The dashed line represents the USEPA maximum for chlorophyll *a* in freshwater systems (8 µg $L^{-1}$). Error bars represent standard deviation.

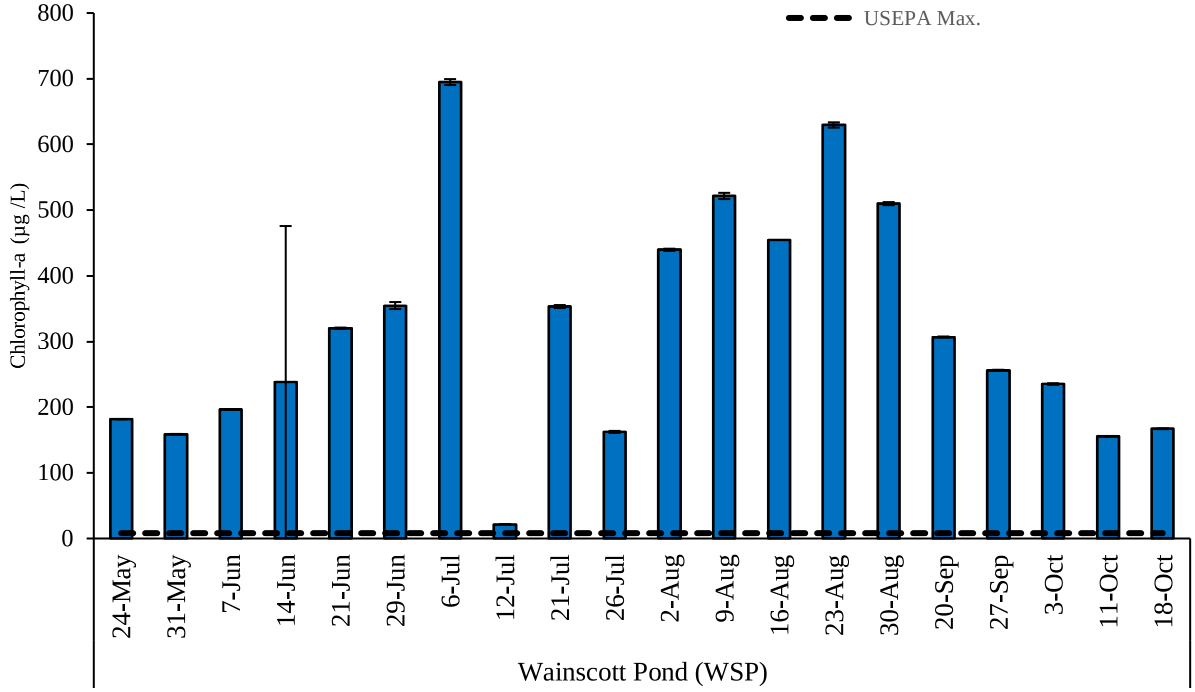



**Figure 52.** Chlorophyll *a* concentrations (µg $L^{-1}$) in Wainscott Pond during 2022. The dashed line represents the USEPA maximum for chlorophyll *a* in freshwater systems (8 µg $L^{-1}$). Error bars represent standard deviation.

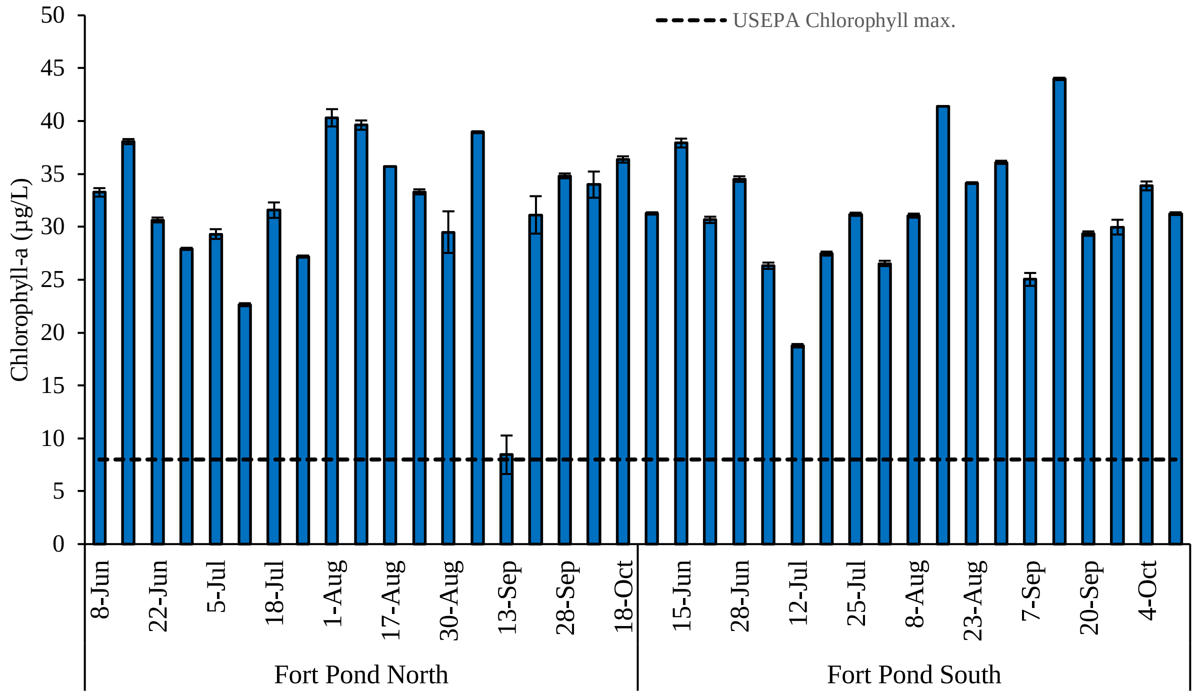



**Figure 53.** Chlorophyll *a* concentrations (µg $L^{-1}$) at the northern and southern sites in Fort Pond during 2022. The dashed line represents the USEPA maximum for chlorophyll *a* in freshwater systems (8 µg $L^{-1}$). Error bars represent standard deviation.

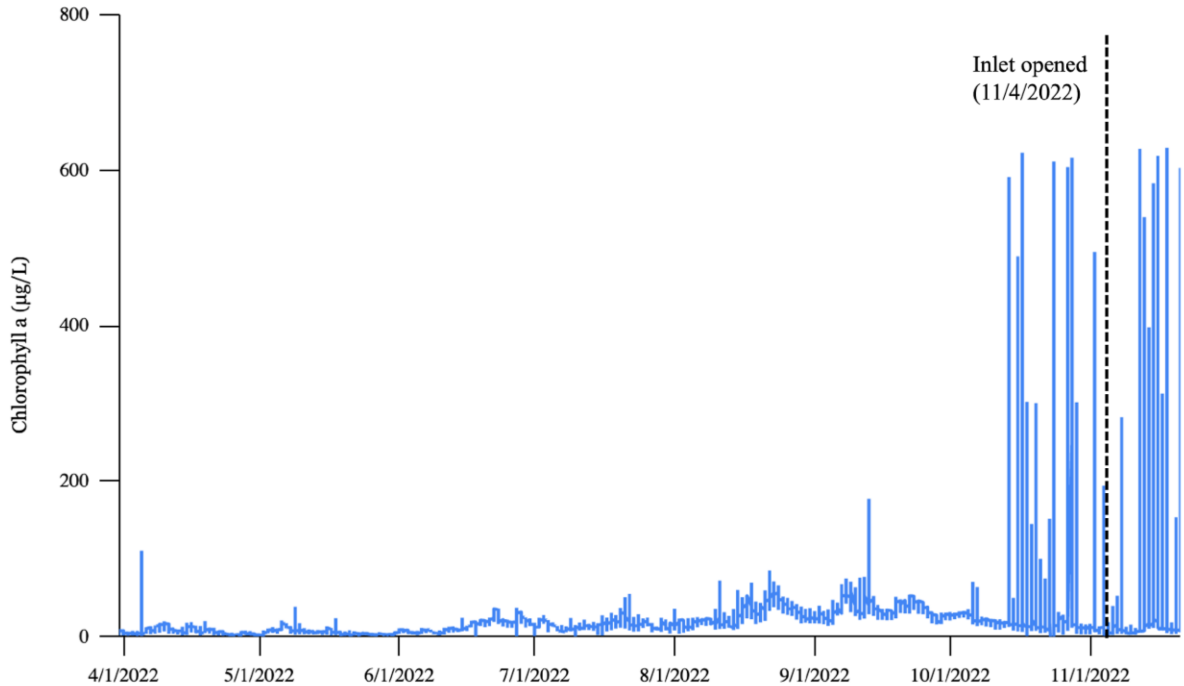



**Figure 54.** Continuous chlorophyll *a* (µg $L^{-1}$) at the buoy in Georgica Pond during 2022. The vertical dashed line represents when the ocean inlet in the south of Georgica Pond was opened on 4-November-2022.

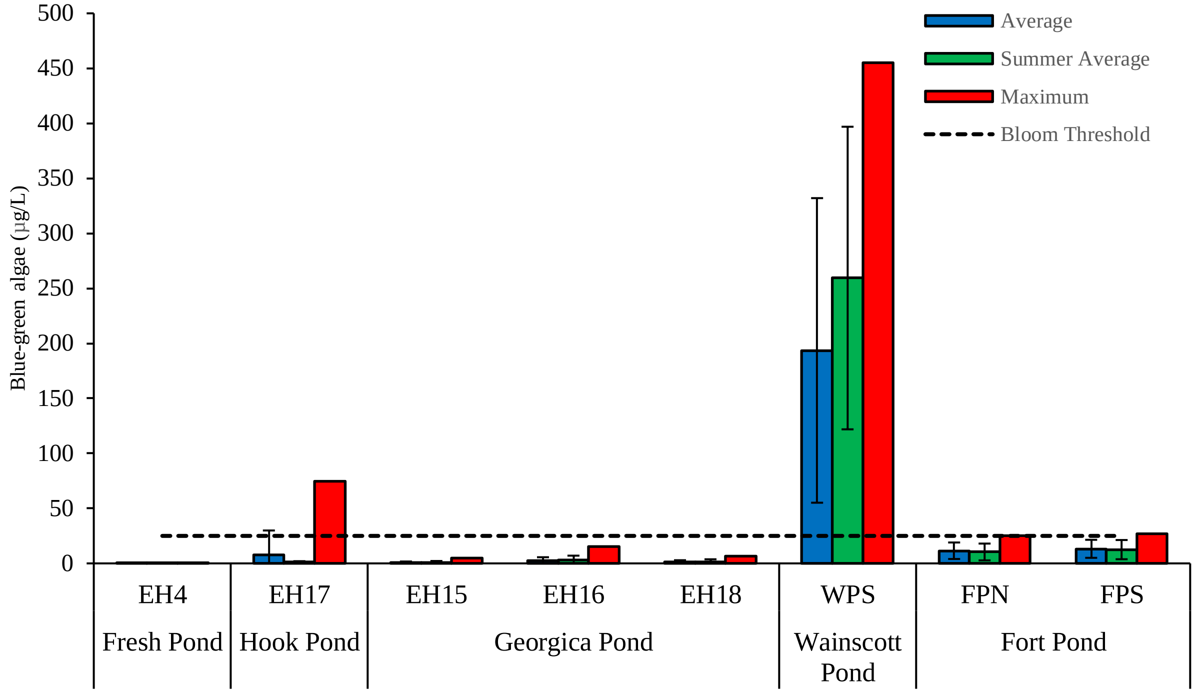



**Figure 55.** Overall average, summer average, and minimum blude-green algae concentrations (µg $L^{-1}$) at freshwater sites in East Hampton during 2022. The dashed line represents the NYSDEC bloom threshold for blue-green algae (25 µg $L^{-1}$). Error bars represent standard deviation.

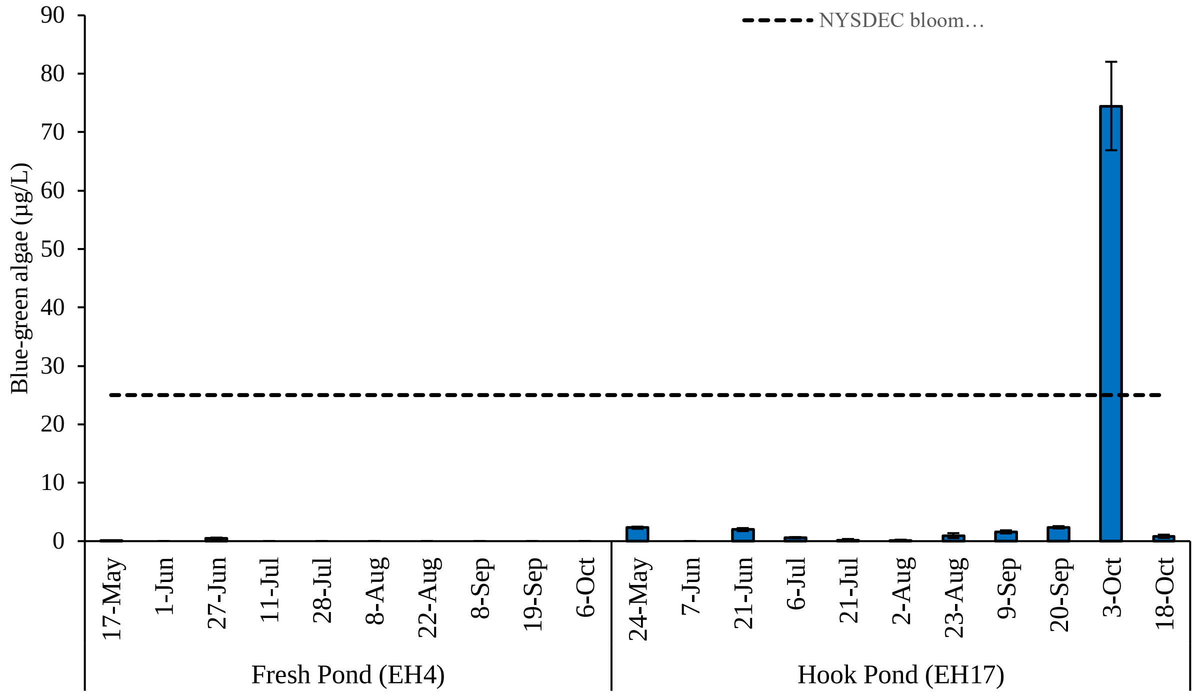



**Figure 56.** Blue-green algae concentrations (µg $L^{-1}$) in Fresh Pond (EH4) and Hook Pond (EH17) during 2022. The dashed line represents the NYSDEC bloom threshold for blue-green algae (25 µg $L^{-1}$). Error bars represent standard deviation.

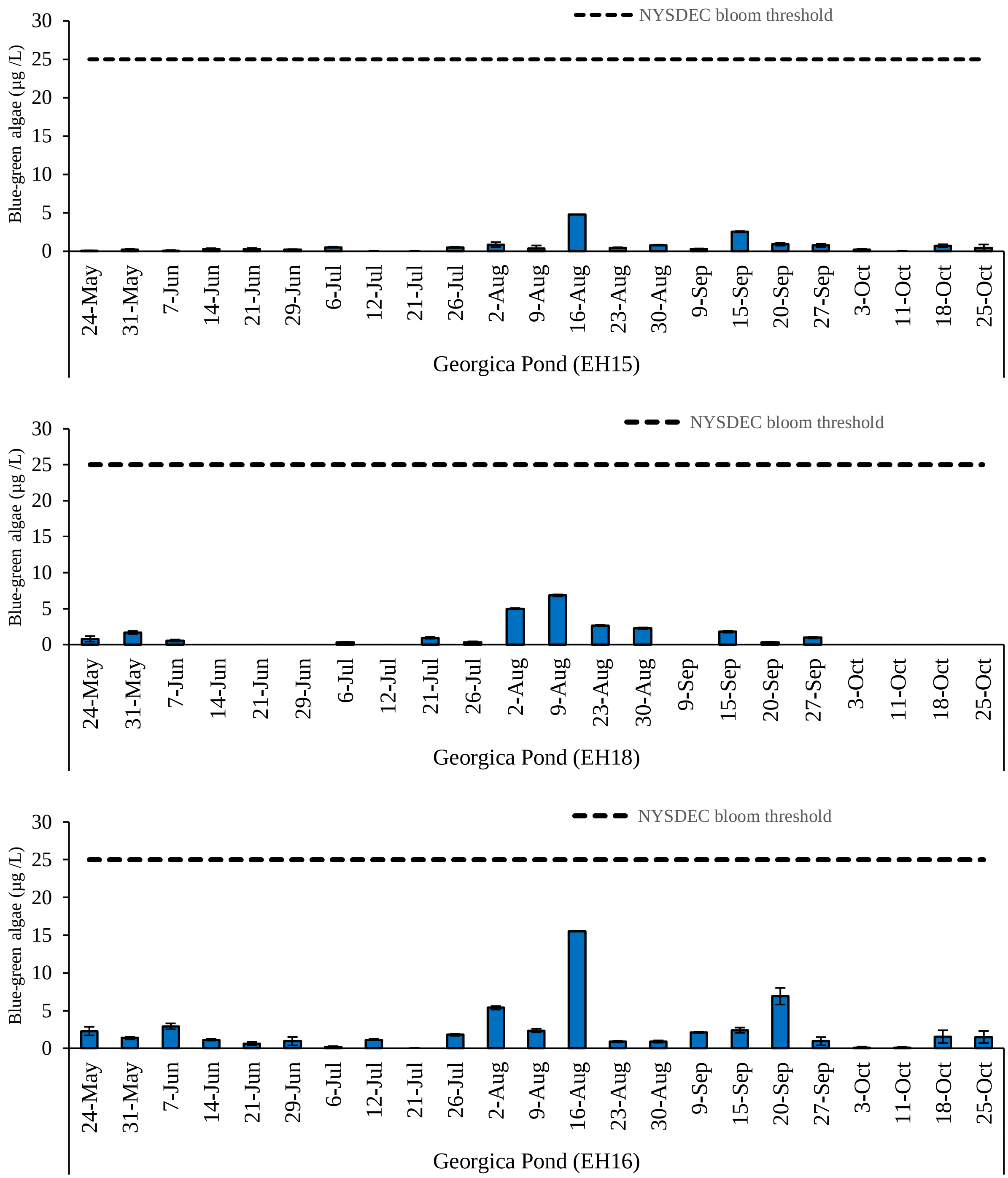



**Figure 57.** Blue-green algae concentrations (µg $L^{-1}$) at various sites in Georgica Pond during 2022. The dashed line represents the NYSDEC bloom threshold for blue-green algae (25 µg $L^{-1}$). Error bars represent standard deviation.

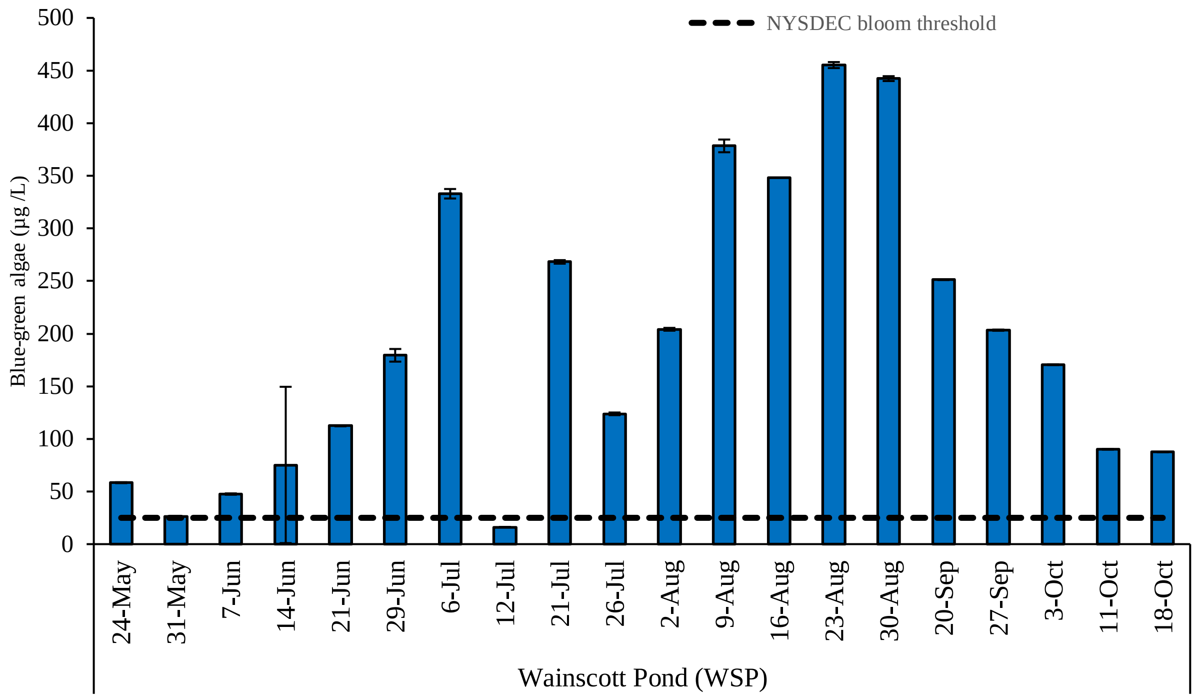



**Figure 58.** Blue-green algae concentrations (µg $L^{-1}$) in Wainscott Pond during 2022. The dashed line represents the NYSDEC bloom threshold for blue-green algae (25 µg $L^{-1}$). Error bars represent standard deviation. Error bars represent standard deviation.

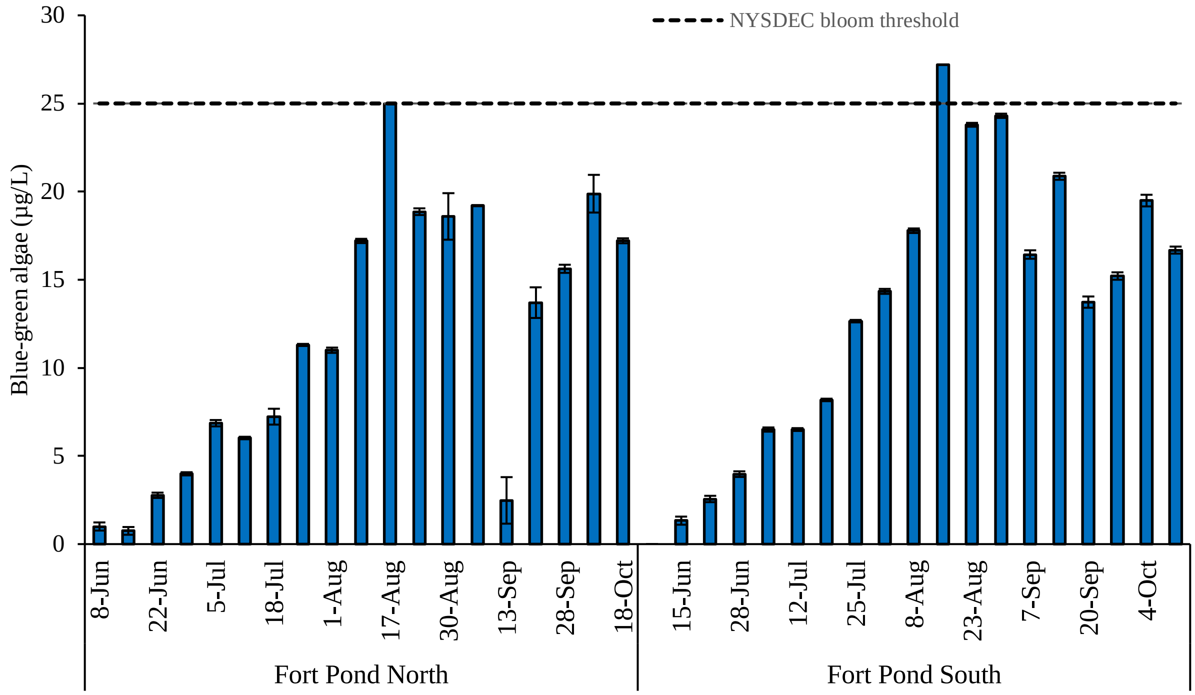



**Figure 59.** Blue-green algae concentrations (µg $L^{-1}$) at the northern and southern sites in Fort Pond during 2022. The dashed line represents the NYSDEC bloom threshold for blue-green algae (25 µg $L^{-1}$). Error bars represent standard deviation.

**Table 3.** List of cyanobacteria detected at each of the freshwater East Hampton sites in 2022, from most common to least common genera.

| Location | Site | Cyanobacteria (most to least common) |
|---|---|---|
| Fresh Pond | EH4 | Not detected |
| Hook Pond | EH17 | *Planktothrix* |
| Georgica Pond | EH15 | Not Detected |
| | EH16 | Not Detected |
| | EH18 | Not Detected |
| Wainscott Pond | WPS | *Microcystis, Aphanizomenon, Planktothrix, Dolichospermum, Anabaena* |
| Fort Pond | North | *Aphanizomenon, Planktothrix, Dolichospermum* |
| | South | *Aphanizomenon, Planktothrix, Dolichospermum* |

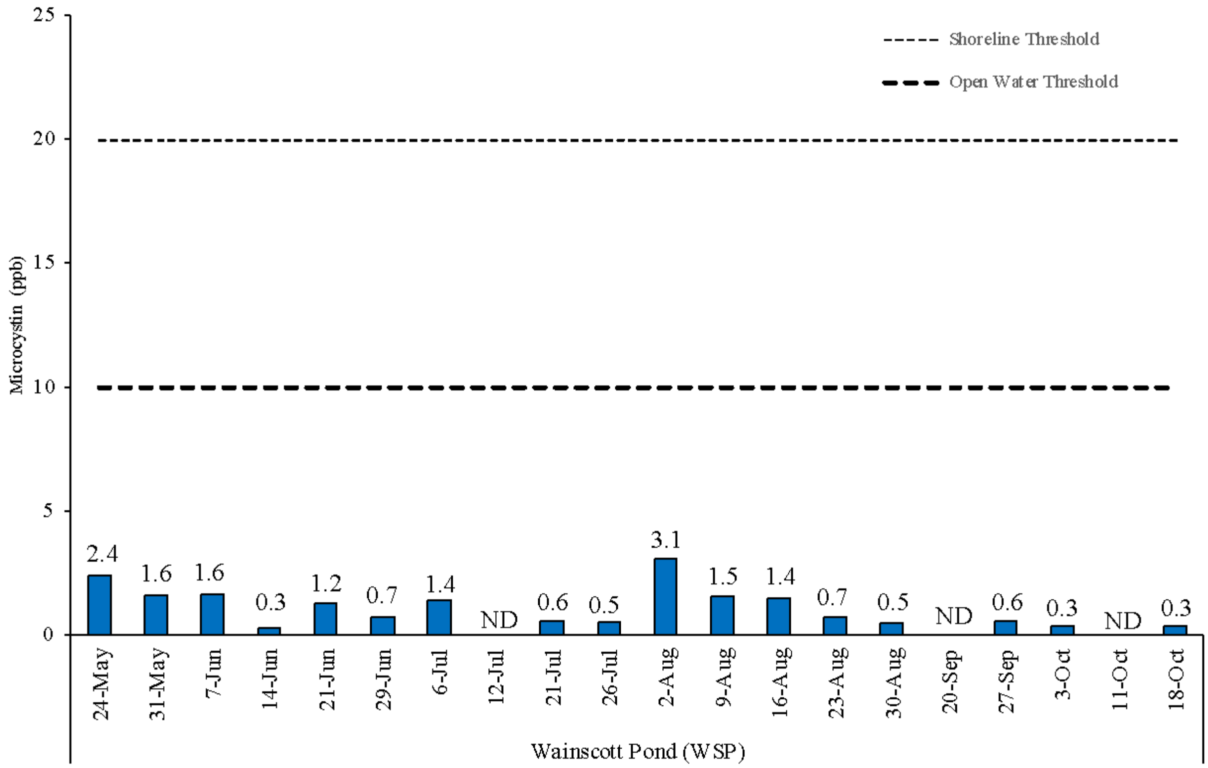



**Figure 60.** Microcystin concentrations (ppb) at Wainscott Pond during 2022. ND = Non-Detectable