East Hampton Town Trustees 2015 water quality study, Draft Final Report

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by

Christopher J. Gobler, PhD

Stony Brook University
School *of* Marine and
Atmospheric Sciences

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Executive Summary

This study was undertaken from April through November of 2015 for the East Hampton Town Trustees to assess water quality, harmful algal blooms, and pathogenic bacteria in the marine and freshwater bodies of Accabonac Harbor, Napeague Harbor, Hog Creek, Northwest Creek, Fresh Pond, Three-Mile Harbor, Georgica Pond, and Hook Pond. The study included intensive sampling and focus on Three Mile Harbor and Georgica Pond because of harmful algal blooms and low dissolved oxygen in 2013 and 2014. During 2015, it was found that most East Hampton Town Trustees waters were of a high quality. With the exception of Fresh Pond, fecal coliform bacteria levels across marine sites were low through the spring and summer. The 2013 report to the Trustees indicated that Northwest Creek could be opened to shellfishing and that was implemented by the NYSDEC in 2014. The 2015 data indicates that regions of Three Mile Harbor and Northwest Creek could also be opened to shellfishing. At nearly all marine locations, dissolved oxygen and chlorophyll *a* were at concentrations supportive of fisheries with the exception being some occasions within Hog Creek and the Head of Three Mile Harbor. Harmful algae concentrations were also generally low in 2015. Three-Mile Harbor, which had been beset by blooms of the harmful dinoflagellate, *Cochlodinium*, in years prior, saw very low densities of this species, but did experience a minor bloom of the paralytical shellfish-causing dinoflagellate, *Alexandrium*. In contrast to most marine sites, the two East Hampton Town's freshwater bodies monitored by this study in 2015 displayed multiple water quality impairments. Hook Pond displayed high levels of chlorophyll *a* and blue-green algae, but reasonable levels of dissolved oxygen (> 4 mg/L). Georgica Pond experienced a series of significant water quality impairments including anoxia (no oxygen), fish kills, macroalgal blooms, blue-green algal blooms, and elevated levels of the cyanotoxins, microcystins. These events worsened through the summer (July and

August) and were most problematic during late August and into September. As a result, the pond was closed to shellfishing during late summer and fall of 2015. Combination of multiple technologies permitted a refined examination of the ecological response of this system to exchange with the Atlantic Ocean. Openings of the pond kept algal biomass levels low and in the fall led to the near elimination of blue-green algae while concurrently increasing salinities and dissolved oxygen levels, which could be considered an emergency measure to combat algal blooms in the future. Finally, since levels of harmful algae, fecal coliform, and toxic cyanobacteria varied significantly among locations from 2013 to 2015, continued monitoring of locations will be required to establish a clear base line of conditions across East Hampton Town waters.

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. 2010). 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). 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). 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 fundyense* (> 1,000,000 cells L^{-1}) have led to paralytic shellfish poisoning (PSP)-inducing closures of nearly 10,000 acres of shellfish beds in western Suffolk County during six of the past seven years. In 2008, a second toxic dinoflagellate, *Dinophysis acuminata*, began forming large, annual blooms (> 100,000 cells L^{-1}) that generated the toxins okadaic acid and DTX-1, both of which are the causative agents of diarrhetic shellfish poisoning (DSP). During the past two years, PSP events have spread progressively east to Shinnecock Bay and Sag Harbor. Moreover, 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 ichtyotoxic 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 and b). *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 and 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&B). 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 blooms events (Deborah Barnes, NYSDEC, pers. comm.). However, the precise distribution of *Cochlodinium polykrikoides* blooms in East Hampton Town waters is unknown.

Since 2003, the Gobler lab of Stony Brook University has assessed levels of toxic cyanobacteria and microcystin in more than 30 freshwater systems across Suffolk County. All lakes sampled contained potentially toxic cyanobacteria (typically *Microcystis* sp. or *Anabaena* sp.) and detectable levels of the hepatoxin made by cyanobacteria, microcystin. Fifteen of the lakes had levels of microcystin exceeding levels of 1 µg/L permissible for drinking water according to the World Health Organization (WHO). *Microcystis* is a cyanobacteria that synthesizes a gastrointestinal toxin known as microcystin that is known to inhibit protein phosphorylation. 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.

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 and recreational water limit of 20 µg/L (Chorus and Bartham, 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 and Bartham 1999) and more recently, neurological disorders such as Alzheimer’s disease (Cox *et al.*, 2005).

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 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 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 April through November of 2015.

Approach

The 2015 sampling season ran from April 23rd to November 2nd. Sampling was done on a biweekly basis, with the exceptions of Three Mile Harbor and Georgica Pond, which were sampled weekly. Sampling included twelve marine sites within Napeague Harbor, Fresh Pond, Accabonac Harbor, Hog Creek, Three-Mile Harbor, and Northwest Creek; and five freshwater sites within Georgica Pond and Hook Pond. One additional sampling location was added to Georgica Pond from the 2014 report, and the location of the Hook Pond sampling site was changed to be more representative of the conditions in the main body of the pond.

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 and Fresh Pond were exceptions, with only one site per location, and both located near their inlets. General water quality measurements obtained for each site included salinity, temperature, and dissolved oxygen levels measured with a handheld YSI 556 probe. Two Onset HOBO data loggers were also deployed in Three-Mile Harbor to continuously record temperature and dissolved oxygen levels over time. Additionally, water was collected at each of these twelve sites and analyzed for chlorophyll *a* and fecal coliform bacteria. To quantify fecal coliform bacteria levels, water samples were collected onto filters and transferred onto agar plates permissive for the growth of these bacteria, and incubated at 44.5°C for 24 h. The number of colonies that had grown on the media were then quantified and densities of fecal coliform per 100 mL of seawater were determined. 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, eight 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 three of Three-Mile Harbor sites, and the four Georgica Pond sites for this study were treated as such.

The toxic dinoflagellate *Dinophysis acuminata*, which is responsible for diarrhetic shellfish poisoning (DSP), was sampled for from April into July. The harmful “rust tide” dinoflagellate *Cochlodinium*, known for causing fish kills, was monitored from July through October. In both cases, whole water was collected and preserved with Lugol’s iodine and cells were counted on a Sedgewick-Rafter slide under a microscope. *Alexandruim fundyense*, a toxic marine dinoflagellate responsible for paralytic shellfish poisoning, was sampled from April through May. Samples were filtered through a 20µm sieve, backwashed into a 15mL centrifuge tube, and preserved in formalin and methanol. Cell densities were determined by marking the cells with an oligonucleotide probe, and counting with an epifluorescent microscope, as detailed in Hattenrath et al. (2010).

At the five freshwater sites (four in Georgica and one in Hook Pond) samples were collected for the quantification of chlorophyll *a*, temperature, salinity, and dissolved oxygen as described above. HOBO and YSI data logging water quality probes were deployed in Georgica Pond as well to continuously measure dissolved oxygen, chlorophyll, salinity, temperature, water depth, and blue-green algae. Additionally, each site was sampled for blue-green algae (cyanobacteria), including *Microcystis* and *Anabaena*. Blue-green fluorescence, an analog for cyanobacterial biomass, was measured using a FluoroProbe with live samples. Colonies of these algae were preserved in whole water samples with Lugol's iodine solution, and counted using a microscope as described above.

Several cruises were conducted during the summer and fall in Georgica Pond. Surveys were conducted by kayak to map the extent of the *Cladophora* macroalgae bloom. A series of cruises before and after the October opening of the pond were performed using a vessel equipped with GPS and continuous logging water quality devices. The cruises mapped levels of dissolved oxygen, chlorophyll, salinity, temperature, and blue-green algae across Georgica Pond to specifically understand how the opening of the ocean inlet in Georgica Pond changed these parameters. A telemetry monitoring buoy was placed in southern Georgica Pond and began uploading real-time water quality data to facilitate the understanding of the temporal dynamics of the aforementioned parameters.

Findings

Marine Systems

Fecal Coliform Bacteria

The measured concentrations of fecal coliform bacteria in 2015 were significantly lower than those measured in 2014. The average 2015 fecal coliform bacteria values at sites ranged from 0 colony forming units (CFU)/100mL, to 59 CFU/100mL (Fig 1). That is compared to the 2014 range of 0 CFU/100mL to 146 CFU/100mL (Fig 2). The safe shellfishing standards set by the NYSDEC for fecal coliform bacteria levels are a mean value below 14 CFU/100mL, with 90% of individual values below 49 CFU/100mL. Almost all of the sampled sites in the present study were below these levels, with only one site failing both standards in 2015. In comparison: four sites, across three harbors, failed in 2014. Fresh Pond in Amagansett failed both criteria 2015, as it had in 2014, though its levels were about a third of what they had been the year prior. The mean value of fecal coliform for Fresh Pond in 2015 was 59 CFU/100mL, and reached a peak value of 248 CFU/100mL on June 17 (Fig 3). Individual values surpassed the 49 CFU/100mL limit once on May 7, and observed again June 17 through July 1. The sites at Isle of Wight Rd. in Hog Creek, and Hand's Creek for Three-Mile Harbor each saw concentrations exceed the 49 CFU/100mL in May and August, respectively (Fig 3). These individual values were very high, but do not fail the overall criteria set for shellfishing.

The 2013 study showed that total coliform levels were lower near inlets where the water flushes regularly, and higher in the back of harbors where water residence time is long, which allows the accumulation of land-derived bacteria. The study also determined that coliform bacterial levels generally paralleled temperatures, and thus were highest during summer. The seasonal trend observed for fecal coliforms in 2014 followed that trend. However, spatial relation with regard to inlets was not as clear for fecal coliforms. Fecal coliform levels were at or near 0 CFU/100mL for most sites throughout the sampling season in 2015, and thus did not display clear temporal or spatial trend. The lower levels of fecal coliform bacteria in 2015 were likely associated with the anomalously low rainfall during the late summer months when levels in situ have been highest in the past.

NYSCEC Comparison of Fecal Coliform Data

Fecal coliform bacteria values measured in this study were compared with NYSDEC shellfish bed statuses, and with the recommendations from the 2014 report. Eight of the twelve sites measured in 2014 confirmed the DEC's statuses, and the remaining four sites supported certification of presently uncertified waters (Fig 1, 4). Measurements from 2015 confirmed the DEC statuses for five of the same sites, and supported the 2014 report recommendations. Three seasonally uncertified sites supported by the 2014 report were in turn observed within safe levels in 2015, supportive of certification. These include Sites 6 and 7 in Accabonac, and Site 9 in Hog Creek. Approximately 88 acres of Northwest Creek's northern extent were seasonally opened starting in 2014, between December 15 and March 31 (Fig 6). Measurements from both 2014 and 2015 suggest that Northwest Creek could be opened longer, as it was one of the cleanest systems in regards to fecal coliforms (Fig 1 & 2). These recommendations are based solely on fecal coliform levels, and do not account for other potential sources of contamination and closure.

Harmful Algae: Dinophysis, Cochlodinium, & Alexandrium

All algae contain the pigment chlorophyll *a*, and it is therefore 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 impacts including hypoxia and acidification. The average chlorophyll *a* values for East Hampton's marine systems during the 2015 sampling season ranged from 3µg/L to 8µg/L (Fig 7). This range is consistent with the values observed in 2014, and is within the normal level of 5µg/L for the eastern Peconic Estuary (Fig 8). The USEPA considers 20µg/L of chlorophyll *a* as eutrophic and all site averages were below this level, and only two sites had maximum values that met or exceeded this criteria. Site 1 in Napeague Harbor reached a peak of 20µg/L on October 22, and Site 9 at Hog Creek reached a maximum value of 24µg/L on September 9 (Fig 9). Both sites surpassed the eutrophic level on only one day during the sampling season and were otherwise at low levels.

Regarding harmful algal blooms, 2015 was a mild year in most East Hampton marine systems. Dinoflagellates of the genus *Dinophysis* can cause DSP, a globally significant human health syndrome (Reguera et al., 2012). *Dinophysis* spp. synthesize okadaic acid (OA) and dinophysistoxins (DTXs), the causative toxins of DSP. While DSP is common in regions of Europe, South America and Asia (Reguera et al., 2012), prior to 2008 the US had not experienced a DSP event. However, there have been a series of such outbreaks recently, including in NY (Hattenrath-Lehmann et al., 2013). In 2014, *Dinophysis* had been detected in all six of the sampled harbors and creeks, but the densities were relatively low, with average levels ranging from 7 cells/L to 37 cells/L. Densities were similar in 2015, with averages ranging from 0 cells/L to 39 cells/L (Fig 11). *Dinophysis* was not detected in Hog Creek nor at Hand's Creek in Three Mile Harbor during 2015, unlike the year prior. Similar to 2014, the highest concentration in 2015 was measured in Northwest Creek, which reached a peak value of 98 cells/L. However, this is much lower than the observed maximum of 126 cells/L in 2014 (Fig 12). *Dinophysis* blooms exceeding 10,000 cells/L have the potential to contaminate shellfish. As such, East Hampton waters are far from reaching dangerous levels of this toxic algae.

Cochlodinium is an ichthyotoxic dinoflagellate that has caused fish kills across the globe including some sites on eastern LI (Kudela and Gobler, 2012). *Cochlodinium* was detected at low levels in all seven of the marine systems sampled in 2015, adding Napeague to the list of affected waters. In 2014, average cell counts of *Cochlodinium* ranged from 0 cells/mL to 585 cells/mL (Fig 14). Individual concentrations surpassed the 300 cell/mL toxicological limit in both Accabonac Harbor (998 cells/mL) and Three Mile Harbor (5,220 cells/mL). In 2015, measured cell densities were generally low, with average cell densities ranging from 1 cell/mL to 86 cells/mL (Fig 13). The highest concentrations were detected in Northwest Creek, peaking at 204 cells/mL on September 9. Three sites saw increases from 2014 to 2015; going from an average of 0 cells/mL to 10 cells/mL in Napeague, 9 cells/mL to 30 cells/mL in Hog Creek, and 2 cells/mL to 86 cells/mL in Northwest Creek. *Cochlodinium* blooms in excess of 300 cells/mL have been known to cause mortality in larval fish, which use these estuarine systems as nurseries, and in shellfish (Tang and Gobler 2009). In prior years, *Cochlodinium* blooms initiated in the far western Peconic Estuary and spread eastward. In 2014, *Cochlodinium* blooms on Long Island first emerged in East Hampton Town waters, and may be related to the ability of the organism to form resting cysts; increasing its ability to propagate and spread in areas it has been established (Tang and Gobler 2012). Between 2013 and 2015, *Cochlodinium* has behaved very differently in East Hampton Town waters, illustrating the importance of long term monitoring of water quality trends. It is noteable that while *Cochlodinium* densities were lower in 2015, the organism was more widespread. Given its ability to form cysts (Tang and Gobler 2012), this finding suggests the potential to bloom in more locations in the future.

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 these events. In 2013, densities of *Alexandrium* exceeded 1,000 cells/L, levels known to cause toxicity in shellfish (Anderson 1997), were detected in Three Mile Harbor at Head of the Harbor, representing the most intense *Alexandrium* bloom in East Hampton waters. In 2015, most sampling sites experienced low levels of *Alexandrium* averaging from 1 cell/mL to 5 cells/mL, with a maximum of 7 cells/L or fewer (Fig 15). The exception to this was Three-Mile Harbor at Head of the Harbor (EH 11), which had an average density of 245 cells/L. The maximum observed concentration occurred at this site on May 22, the last day for which it was sampled with a density of 609 cells/L, a level that could make shellfish toxic. Average values were lower across most sites in 2015, although there were increases observed at Napeague, Three-Mile (EH11), and Northwest Creek (Fig 16). The average concentrations at Head of the Harbor more than doubled from 2014, but was lower than the values observed in 2013. Three-Mile Harbor at Head of the Harbor has consistently been the site most impacted by *Alexandrium*. Concentrations of *Alexandrium* were lower in 2014 compared to 2013, and higher in 2014 than 2015, emphasizing the importance of long term monitoring of water quality trends.

General Water Quality: Salinity & Dissolved Oxygen

Salinity across East Hampton's marine sites was relatively static, mostly staying within 29±1 PSU and were generally higher at the sites closest to their respective inlets. Fresh Pond is a brackish system with heavy freshwater influence, and averaged a salinity of 11 PSU. Fresh Pond also had the greatest variation in salinity, dependent on tide, whether the inlet had closed off to the bay, and rainfall (Fig 17).

The mean levels of dissolved oxygen from discrete measurements ranged from 6 to 9 mg/L for marine sites; levels which are supportive of fisheries, shellfisheries, and wildlife (>5 mg/L; Fig 18). Additionally, continuous dissolved oxygen data was recorded for Three Mile Harbor. Two dissolved oxygen probes, one at Head of the Harbor, and one at the Gann Rd. dock, were installed to measure dissolved oxygen at depth from July through August. Data was recorded every 15 minutes to provide better resolution and show diurnal cycles. Dissolved oxygen levels at Gann Rd. were high, and mostly remained above 5 mg/L during the study period (Fig 19). On August

29 and 30, oxygen levels briefly dropped below the hypoxic level of 3 mg/L, and levels remained relatively lower going into September. At Head of the Harbor, the site further from the inlet, and with the most issues related to harmful algal blooms, experienced periods of low dissolved oxygen throughout much of the two months recorded. The site's mean dissolved oxygen levels (4.67 mg/L) were below the level ideal for marine life and lower than Gann Rd. (8.34 mg/L). Dissolved oxygen levels at Head of the Harbor also displayed a wider variation between its high and low values between day and night, evidence of extreme ecosystem metabolism and eutrophication Most nights during the two month observation had oxygen levels fell below the 3 mg/L hypoxia level, and on occasion went anoxic (0 mg/L) on several occasions, indicating conditions unsuitable for benthic life (Fig 19). For comparative purposes, NYSDEC's standard for dissolved oxygen for marine water bodies is above 3 mg/L.

Addressing problems with eutrophication within Three Mile Harbor

During the past three years, Three Mile Harbor has displayed the most clear water quality impairment with low or no oxygen levels during summer and toxic algal blooms caused by *Alexandrium* and *Cochlodinium*. All of these conditions were most problematic within the Head of the Harbor region of Three Mile Harbor. Given that both of these harmful algal blooms have been associated with excessive nitrogen loading (Hattenrath et al 2010; Gobler et al 2012) and given low oxygen conditions are also associated with excessive nitrogen loading, it is important that the nutrient loading conditions be considered in this system. Recently, The Nature Conservancy completed an analysis of nitrogen loading rates for the entire Peconic Estuary, including the Three Mile Harbor watershed (Lloyd, 2014). There are a series of key insights to be yielded from this study. Firstly, the Three Mile Harbor watershed was shown to have the high nitrogen loads in the entire Town of East Hampton in terms of kilograms of nitrogen per year and kilograms of nitrogen per unit area per year (Table 1). Next, the Three Mile Harbor was shown to have a greater proportion of its nitrogen load emanating from wastewater than any other Town of East Hampton with 65% (Table 1). Across all sites monitored during this study, there was a highly significant correlation ($R^2 = 0.93$; $p<0.01$) between the nitrogen loading rate per hectare of watershed and the chlorophyll a level in the receiving water body suggesting excessive nitrogen loading rates are promoting the water quality impairments within Three Mile Harbor. There was also a significant correlation between the percentage of nitrogen load emanating from wastewater and average chlorophyll a levels ($R^2 = 0.87$; $p<0.05$), suggesting that wastewater derived nitrogen may specifically be promoting algal blooms in Three Mile Harbor.

To date, the Town of East Hampton has taken some progressive measures to mitigating nitrogen loading in Three Mile Harbor including the installation of a permeable reactive barrier and the planned construction on a carbon-based injection well. While these measures will be helpful, given that Three Mile Harbor has the largest nitrogen loading rates within the Town, that the large majority of this nitrogen emanates from wastewater, and the significant water quality impairment in this system, it seems clear that this watershed should be a priority location for the upgrading septic tanks and cesspools within the Town of East Hampton.

Hook Pond

Hook Pond was one of two freshwater bodies studied in 2014 and 2015 in East Hampton. The pond was sampled briefly for September and the first week of October. In 2015, a new site was considered and replaced the original site, which was located in a shallow cove. The sites were compared on September 4, and chlorophyll *a*, blue-green fluorescence, and dissolved oxygen levels were shown to be significantly higher. Chlorophyll *a* values averaged 19 µg/L in 2015, compared to 6 µg/L the year prior, and had a maximum value of 32 µg/L (Fig 7, 8). Hook Pond passes the eutrophic level (>8 µg/L) on all dates sampled (Fig 9). Chlorophyll *a* values started at the maximum September 4, and fell over the following two weeks to below 15 µg/L. Blue-green fluorescence, which serves as an analog for cyanobacterial biomass, had a mean value of 30 µg/L in 2015, compared to an average of 2 µg/L in 2014 (Fig 21). This again, is due to the change in sampling location. The maximum blue-green fluorescence observed was 30 µg/L, close to the average for the site, and peaked on September 9 (Fig 21, 23), exceeding the safety limit of 20 µg/L. Unlike Georgica Pond, there appears to be little to no marine influence, with a mean salinity of 0.2 PSU (Fig 17). The mean dissolved oxygen level was 8.84 mg/L, and the minimum value was 7.51 mg/L, both well within healthy levels (Fig 18). The location of the new site allows for observation of the main body of the pond, rather than just the shallow cove observed in previous years. However, with only one site, there is still poor spatial coverage of the pond. Based on the observations in Georgica Pond, great spatial heterogeneity in water quality may exist in that water body.

Georgica Pond

Harmful Algae

Georgica Pond was substantially impaired by algae for most of 2014, and this was again the case in 2015. In 2014 two new sampling locations were added to the pond to provide data more representative of the pond as a whole. In 2015, these stations were used with the addition of one more site located in the south of the pond, east of the cut, and in the region with the highest concentrations of algae. The greatest chlorophyll *a* values measured in East Hampton Town waters were sampled in Georgica Pond in 2014, and again in 2015. The highest mean values for chlorophyll *a* were measured at the new site in southern Georgica Pond (48 µg/L) (Fig 7). All four sites had mean chlorophyll *a* concentrations well over 8 µg/L, above the eutrophic level for freshwater bodies. The sites surpassed this level in late July, and high levels that persisted onward. The highest level of chlorophyll a was measured within southern Georgica Pond (GPS) on August 25, with a value of 112 µg/L (Fig 10). The microalgal bloom began to form in late July, came to a peak August 25, and saw a decline before coming to another peak September 9 at 105 µg/L. After the second peak, concentrations slowly declined, before sharply dropping to a low on October 13, coinciding with the opening of the cut to the ocean. Site 18, which lies west on the same region of the pond reflects a very similar pattern to site GPS. After the drop in concentrations due to the cut, chlorophyll *a* levels rose again. This trend was also true for all sites except for Site 15, where the lowest concentrations occurred. The drop in water level following the cut changes Site 15 to a shallow, groundwater-fed creek whose flow prevents the accumulation of algal biomass. Compared to 2014, mean chlorophyll *a* values in 2015 were lower in southwest Georgica, and in Georgica Cove, but were higher at Rt. 27 (Fig 8).

Georgica Pond and Georgica Cove experienced a dense bloom of the filamentous macroalgae *Cladophora* for much of the early summer in 2014, and again in 2015. Samples of the algae were collected and used for DNA analysis in 2015. The suspected genus was confirmed, and the alga was identified as *Cladophora vagabunda*. The algae forms bright green mats on the surface which, when observed in the field, were several inches thick in places and shaded the water column beneath, causing a general nuisance for recreational use of the pond. The surface mats were common in all of the protected creeks and coves of the pond, especially in the north, and in Georgica Cove (Fig 20), which was almost completely covered at times. The algae was also present subsurface and covered much of the bottom of the pond by mid-July. By late July, coverage of *Cladophora* was greatly diminished, though it persisted along shorelines in low quantities and in Georgica Cove.

Also present in notable quantity was Sago pondweed (*Stuckenia pectinata*). The aquatic plant grew attached to the bottom, and its branching structure provided a hold for the *Cladophora*, aiding the persistence of the mats. Large mats of *Cladophora* grew almost exclusively intertwined with Sago pondweed. Sago pondweed also detaches and washes ashore, forming large mats of its own. The aquatic plant persisted through the rest of the season after *Cladophora* declined, and was the focus of residential removal measures.

Toxic Cyanobacteria: Microcystis & Anabaena

Toxic cyanobacteria blooms represent a serious threat to aquatic ecosystems and human health. Globally, the frequency and intensity of toxic cyanobacteria blooms have increased greatly during the past decade and toxin concentrations during many blooms often surpass the World Health Organization (WHO) safe drinking water and recreational water limit (Chorus and Bartham, 1999).

Whereas chlorophyll *a* is an analog for algal biomass, blue-green algal fluorescence serves as an analog specifically for cyanobacterial biomass. Georgica Pond saw extremely high levels of blue-green algae during both 2014 and 2015. The highest levels in 2015 were seen in southwestern Georgica, with south Georgica having slightly lower levels. Mean fluorescence at Site EH 18 was 121 µg/L and Site GPS saw an average level of 116 µg/L (Fig 21). All four sites in Georgica Pond had averages in excess of 20 µg/L, which the NYSDEC uses to close a lake to recreational use. Levels in Georgica Cove were similar to those observed in the previous year, and southwest

Georgica and the Rt. 27 access both saw increases in their average levels (Fig 22). The maximum blue-green fluorescence observed also occurred in southwestern Georgica on August 25, where it peaked with a value of 445 µg/L (Fig 23), higher also than it was in 2014. Levels at that site rose to over 400 µg/L on August 19th, and persisted above that level until after September 9. The three sites concerning the main body of the pond (EH 15, EH 18, & GPS) saw very similar trends in their fluorescence. The three sites saw their levels rise starting in the first week of August, and reached their peaks in late August and early September. After the opening of the cut, the three sites saw a sharp decrease in blue-green algae levels to near zero values. Georgica Cove, however, behaved differently. The blue-green algae bloom started a month later in the cove, beginning in September, and peaked later in that month. When the pond was opened to the ocean, blue-green fluorescence levels increased in the week following, before it decreased as the others.

Quantification of cyanobacterial cells present during the period from April to November showed three major genera of cyanobacteria present: *Microcystis*, *Anabaena*, and *Aphanizomenon*. *Microcystis* was present for most of the sampling season, though at much lower concentrations than the other two genera; ranging from 4 colonies/mL to 1,980 colonies/mL across sites, with the highest concentrations present in southwestern Georgica (Fig 24). The second most prevalent genus present was *Anabaena*, which was not present for several dates sampled, but rose to a maximum value of 18,680 chains/mL in southwestern Georgica in August. *Anabaena* started to bloom in early August, grew quickly, and came to a peak across all sites on August 13. Concentrations decreased over the next month to near zero values by late September. In 2014 the most prolific cyanobacteria present was *Anabaena*. For 2015 however, *Aphanizomenon* dominated for most of August and September. *Aphanizomenon* was present early in June, and grew steadily at all sites, and it continued to grow as *Anabaena* began to decline. By August 19, *Aphanizomenon* exceeded 10,000 cells/mL at most sites, with concentrations lagging behind in Georgica Cove. Concentrations at all sites surpassed 100,000 cells/mL by September 22, and reached a maximal value of 906,880 cells/mL on September 29th at southwestern Georgica. Following the opening of Georgica Pond to the ocean in October, *Aphanizomenon* counts declined sharply.

Toxin samples were taken and analyzed during the cyanobacterial blooms, on all dates where blue-green fluorescence passed 20µg/L. Microcystin values were mostly at low levels, but it was present for most dates sampled, and across all four sites. Twice for southeast Georgica and once for south Georgica during the month of August, microcystin values were found in excess of the WHO standard for drinking water of 1 µg/L (Fig 25). The highest value recorded in 2015 was 1.35 µg/L; significantly lower than in 2014, when values reached as high as 10.6 µg/L. Additionally, a subset was analyzed for congeners of microcystin: microcystin-LR, microcystin-YR, and microcystin-RR. Microcysin-LR, and -RR were at their observed peak on August 6th, with levels of 8 µg/L and 28 µg/L respectively, and then both declined over the next two weeks to undetectable levels. This peak toxicity coincides with the rise and fall of the early August bloom of *Anabaena* (Fig 24). Microcystin-YR rose as the other toxins declined and ranged from 3-4 µg/L for late August and into September (Fig 25). This congener could be associated with the bloom of *Aphanizomenon* that followed the *Anabaena* bloom (Fig 24). It should be noted that microcystin-LR and -YR have similar toxicities. However, microcystin-RR, which was the highest concentration, is also 10-fold more toxic than the other congeners. Anatoxin-a was also sampled for, but was not found in any detectable amounts.

General Water Quality: Salinity & Dissolved Oxygen

Salinity varied between sites across Georgica Pond. The highest average salinity was measured in southwestern Georgica (EH 18), near the cut to the ocean, and had a mean salinity of 16 PSU, (Fig 17, 26). Southern Georgica was not sampled until after the cut had closed earlier in the year, which accounts for its lower average salinity, but it otherwise has levels similar to EH 18, which is located in the same region of the pond. The average salinity for Georgica Cove was slightly lower, at 11 PSU, and the lowest mean salinity was measured at the Rt. 27 access, with a value of 3 PSU (Fig 17). During the early part of summer, while the cut was open, salinity values were lower in Georgica Cove than in the main body of the pond. Those levels eventually rose after the cut had closed, and became similar to the other sites in the southern extent of the pond (Fig 26). Salinity was near zero at the Rt. 27 access during early summer, when the water level is low and the area becomes a groundwater-fed stream. As water level rose through summer, the freshwater mixed with the brackish water of the pond, and salinities fluctuated in a range of 3 to 6 PSU (Fig 26). After the cut had opened again, the area returned to the shallow creek state.

The average levels of discrete dissolved oxygen measurements ranged from 5 to 10 mg/L, with the lowest measurement in Georgica Cove, and the highest in southwest Georgica (Fig 18). This is above the minimum daily average of 5 mg/L to support wildlife (class C waters; http://www.dec.ny.gov/regs/4592.html). However, the minimum values for EH 15 and EH 16 which were near 0 mg/L, and GPS which had 2 mg/L dissolved oxygen, were all below the 3 mg/L limit that the NYSDEC states oxygen levels should, at no point, fall below to support survival and propagation of fish, shellfish, and wildlife.

Discrete sampling by land of dissolved oxygen was complemented by the implementation of a continuously logging telemetry buoy, located in the south end of Georgica Pond, near the Southern Georgica (GPS) shore sampling site. For most of the year, oxygen levels were within a healthy range. However, oxygen concentrations fell below the hypoxic level of 3 mg/L and went to zero (anoxic) at several points between August and October, when the cyanobacterial blooms were at their highest (Fig 27). It should be noted that the readings of the buoy are taken near-surface in several meters of water. Oxygen levels at or near bottom tend to be lower and more susceptible to hypoxia.

Effects of Opening the Ocean Inlet on Water Quality in Georgica Pond

In 2015, the cut of Georgica Pond was open more frequently than it was closed. The cut was open almost continuously from January through late June. During this time, salinities were high and algae levels were low. While higher salinities tend to discourage the growth of blue-green algae, the rapid inflow of freshwater to Georgica Pond rapidly depressed salinity in Georgica Pond, and were within the level permissive of blue-green algal growth (<15 PSU) by late July at which point a large blue-green algae bloom developed and persisted through October.

Georgica Pond was opened to the Atlantic Ocean via the creation of an inlet on October 8, closed naturally due to storm activity two weeks later, was reopened on October 28, and remained open for the rest of the year. A series of cruises were performed, and a telemetry buoy was installed to monitor conditions resulting from the induction of ocean exchange in the fall. Immediately following the openings of the pond, salinity levels increased in Georgica Pond, evidencing the influx of ocean water which generally has a salinity of 31 PSU. Measurements taken in the south of the pond by the telemetry buoy showed the salinity rose from 8.5 PSU to over 29 PSU in the days following the cut in October (Fig 27). From the closure in June, the gradual decrease in salinity was observed as water levels and freshwater influence slowly increased. The salinity in

Georgica Cove would also change with the openings and closures of the pond, but the response was slower and not of the same magnitude (Fig 26).

Cruise data following the opening of the ocean inlet illustrated the effect of the exchange of seawater across the Pond. This was done in both 2014, and in 2015, with both years showing the same trends, but with different magnitudes of blue-green algae present. Water readily exchanged between the southern and northern regions of Georgica Pond. Georgica Cove however, did not have strong exchange with the main body of the pond, and seemed to have greater freshwater influence. Following the creation of the inlet, salinity in the cove tended to drop instead of increase as the rest of the pond (Fig 29) likely due to the decreased exchange with the Pond proper. Salinity levels did eventually rise in Georgica Cove, but tended to be lower than in the rest of the Pond.

Chlorophyll values at the buoy rose in August, reaching two peaks above 20 µg/L, before slowly declining over the following months (Fig 28). Following the opening of the cut in October, chlorophyll *a* concentrations rose over 20µg/L in the pond. The increase following the creation of the inlet was attributed to a bloom of diatoms and dinoflagellate microalgae that thrived in the brackish system. Importantly, diatoms are generally considered a good food source for aquatic food webs.

Blue-green fluorescence was another parameter measured by the telemetry buoy. Blue-green were not abundant until August, when a large bloom emerged (Fig 28). Between August 23 and September 10, the values were over 20. Importantly, the reading on the buoy were not calibrated to the NYSDEC scale; these readings were over 100 µg/L on that scale. Blue-green algae concentrations fell by over half immediately following the first opening of the cut as water drained from the pond and salinity levels rose (Fig 30). By the end of October, concentrations were at negligible levels following the second opening. These measured values from the buoy closely resembles the trend of the values from the nearby southern Georgica site, but were much lower in concentration.

With particular interest in water circulation in the pond, a bathymetric mapping of Georgica Pond was performed. As observed in discrete and cruise data of salinity in Georgica Cove, salinities immediately drop following the opening of the inlet before eventually matching the rest of the pond (Fig 26, 29). The main factors can be observed in the southern extent of the pond, between the cut and Georgica Cove itself. Afore the inlet, and surrounding the deep hole in southern Georgica Pond is a considerable area of very shallow waters, with depths mostly below 2 feet, and some areas less than 1 foot (Fig 31). When the inlet is opened, the water level drops and these areas become even shallower, with many sandbars becoming exposed. These shallows reduce the ability of water to circulate towards the entrance of Georgica Cove. The second factor influencing the exchange between the two bodies is the entrance of Georgica Cove. There is only a narrow strip of water connecting the two bodies together, and when the inlet is opened, this strip becomes more narrow and shallow. This problem is exacerbated as the prolific growth of the invasive reed *Phragmites* in this region further narrows the entrance. As a result of these two factors, when the inlet is opened and water levels decrease, circulation with the cove is severely reduced. The cove is then recharged from freshwater sources, and its salinity is depressed. After the cut closes itself, the increase in water level can then restore circulation between the two bodies, and salinity in the cove rises to match the rest of the pond.

Use of the ocean inlet for managing water quality in Georgica Pond

The observations made before and following the openings of Georgica Pond in both 2014, and again in 2015, provided important insight and further confirmation regarding the effects on water quality and water levels in this system. In both years, the blue-green algae blooms in the pond ended following the opening of the inlet. The three factors considered as likely contributors toward this rapid occurrence included tidal transport, increased salinities, and lower temperatures. First, the induction of tidal exchange with the ocean facilitates the export of the blue-green algae to the ocean. Next, the higher salinities brought to the pond via the ocean water created salt conditions which were not conducive to blue-green algae which thrive under freshwater and low salinity conditions. *Anabaena* can only tolerate salinities below 15 (Moisander et al 2002) and *Microcystis* thrives at salinities below 10 (Orr et al 2004). Finally, blue-green algae abundances generally parallel temperatures (Paerl and Huisman 2008) and thus these populations were likely to have diminished in November even if the inlet had not opened. Regardless, the first two mechanisms (enhanced tidal exchange and higher salinity) will both occur during any opening of the ocean inlet and thus will discourage blue-green algal blooms. Beyond the mitigation of the blue-green algae, opening of the ocean inlet also likely to improve other Pond attributes such as increased dissolved oxygen.

Further evidence of the role of ocean salinity in discouraging blue-green algae in Georgica Pond came from an experiment conducted in 2015. On August 14th, water was collected from the south end of Georgica Pond this high levels of blue-green algae. This water was diluted by half with filtered Pond water or filtered ocean water, the former leaving the salinity unchanged but the later raising salinity levels from 13 to 21 (Fig 32). After 48 hours, blue-green algae levels in the low salinity waters increased slightly whereas levels in the higher salinity water declined by 40% (Fig 32). This outcome suggests that raising the salinity in Georgica Pond is a means for successfully mitigating blue-green algal blooms.

In a manner that differs from other similar temporarily-open estuaries in the region such as Mecox Bay, Georgica Pond's water levels are highly responsive and dynamic. In 2015, following the closure of the inlet in June, salinity dropped from over 30 PSU to below 15 PSU in only 31 days; levels low enough to support cyanobacteria, which bloomed shortly thereafter (Fig 27, 28). The extent to which the pond water levels recover is likely to be a function of recent rainfall and seasonality. Summer, drought conditions might lead to pond water levels taking a longer amount of time to refill.

When opening the ocean inlet during summer months, one consideration may be the balance of water quality with recreational use of the pond, specifically for boating. The average depth of the pond is only near 1.1 meters, and a drop of 0.5 meters, as observed in 2014 and 2015, greatly reduces the amount of navigable water, and even exposes most of the bottom in the south end (Fig 31). In the future, the Trustees may need to consider the value of improving water quality against water depth / access and other more general ecological considerations such as optimal salinities for desired aquatic life.

A final consideration regarding the opening of the ocean inlet to Georgica Pond is the fate of macroalgae in the pond following the opening of the inlet. The direct effect of the inlet on *Cladophora* macroalgae, which blooms earlier in the summer, is not understood as it dissipates in the fall when the cut has been opened. Given the fact that these algae generally secure themselves the pond bottom, suddenly decreasing the water level in the pond by opening the inlet could expose a significant amount of macroalgae on mud flats that would be left to die, degrade, and rot in some parts of the pond. However, it may thrive in the shallow, warm waters where it has not been exposed. Regardless, the opening of the cut does have clear benefits for reducing microalgal blooms and increasing levels of dissolved oxygen. A more frequent schedule of opening the pond in the spring should keep salinity levels high and thus may discourage the formation of blue-green algal blooms. Moreover, opening Georgica Pond during the summer may discourage the intensification of these events. The impact of summer pond lettings on macroalgae requires further investigation.

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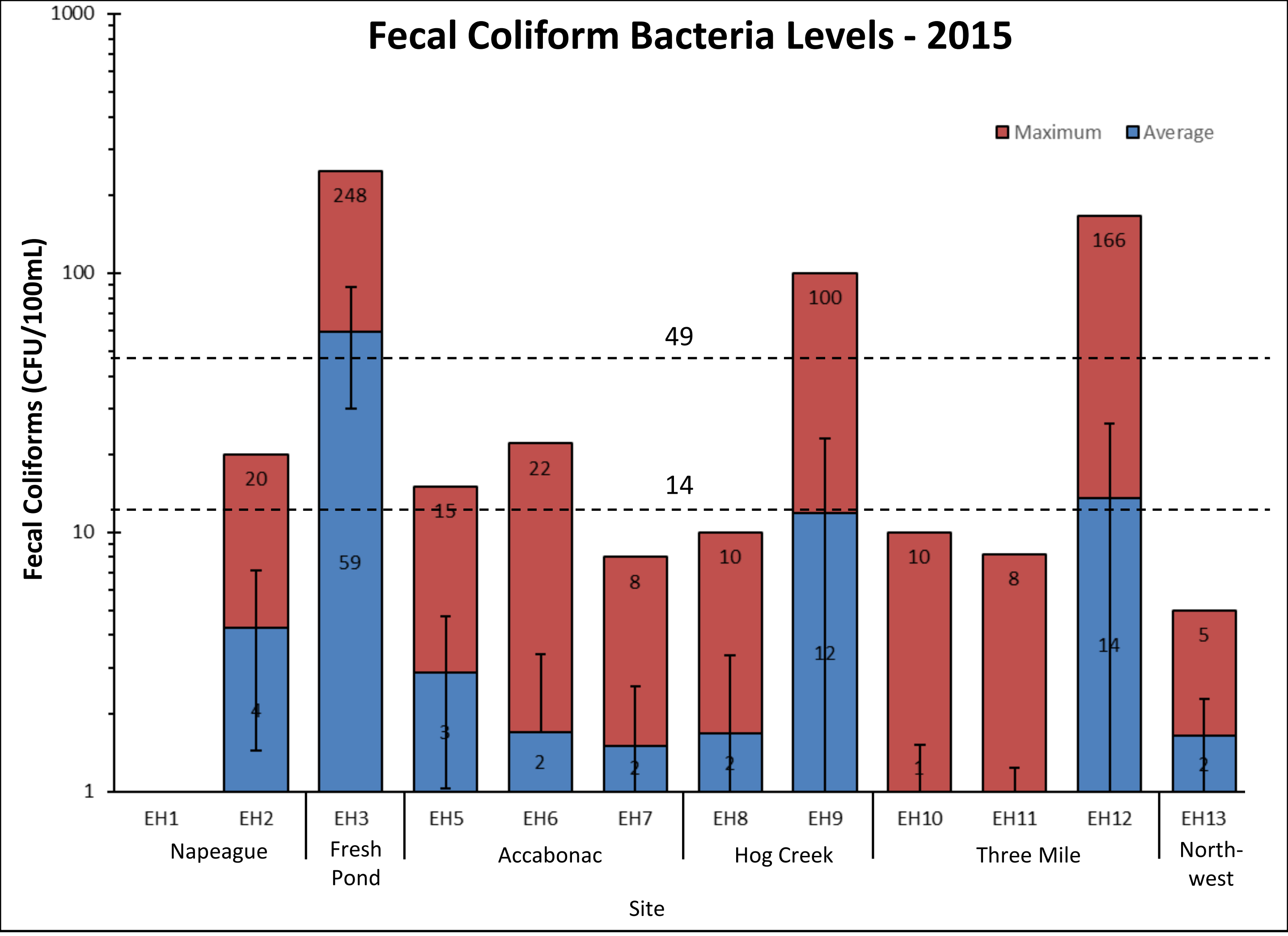


Figure 1: Average and maximum recorded fecal coliform bacteria values from April through October of 2015, shown on a logarithmic scale. Error bars showing Standard Error. Dashed lines represent level standards: 14 cells/100mL for averages, and 49 cells/100mL for individual values.

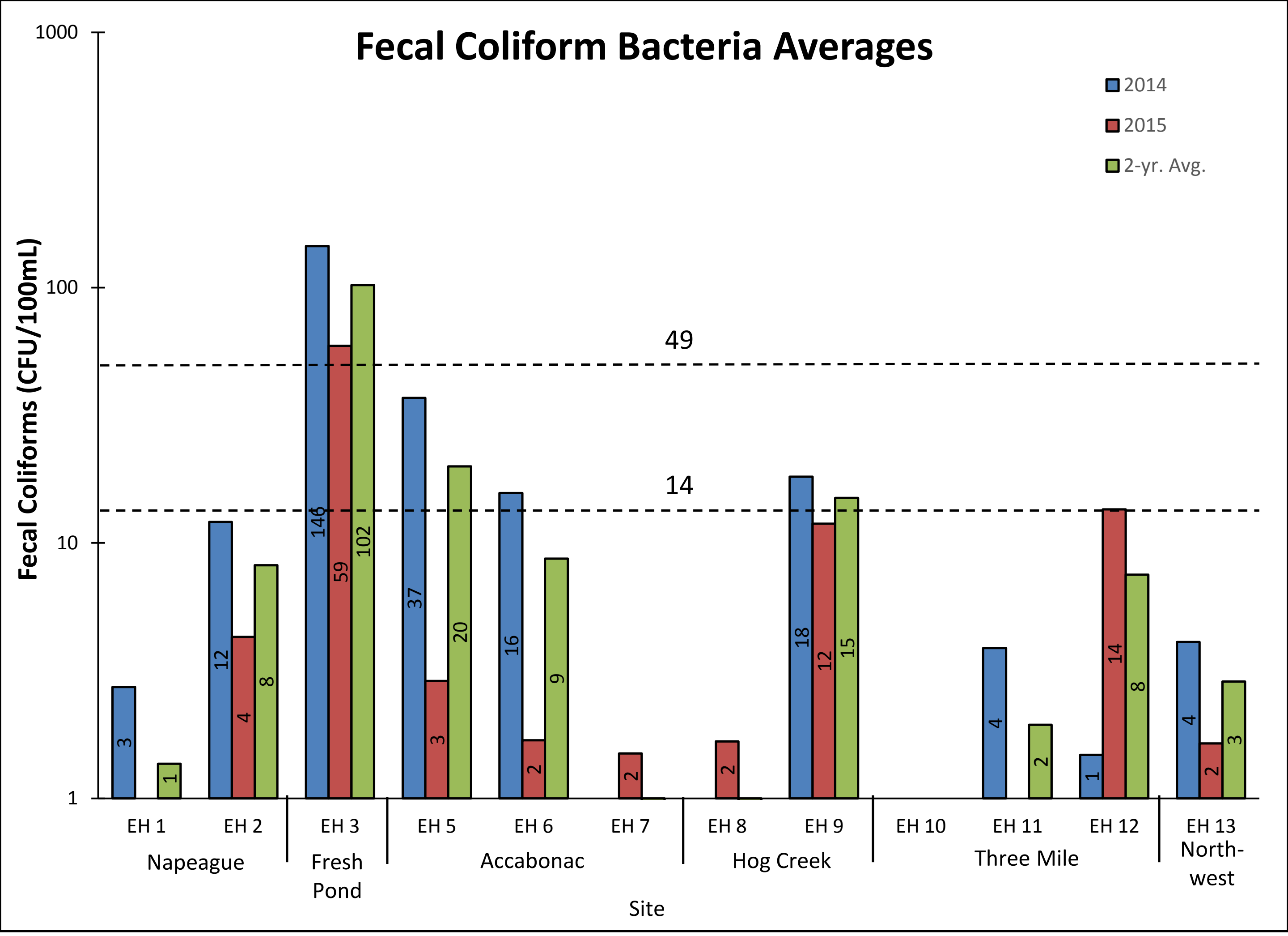


Figure 2: Comparison of average fecal coliform bacteria levels from 2014 and 2015, with the two-year average. Error bars showing Standard Error. Dashed lines represent level standards: 14 cells/100mL for averages, and 49 cells/100mL for individual values.

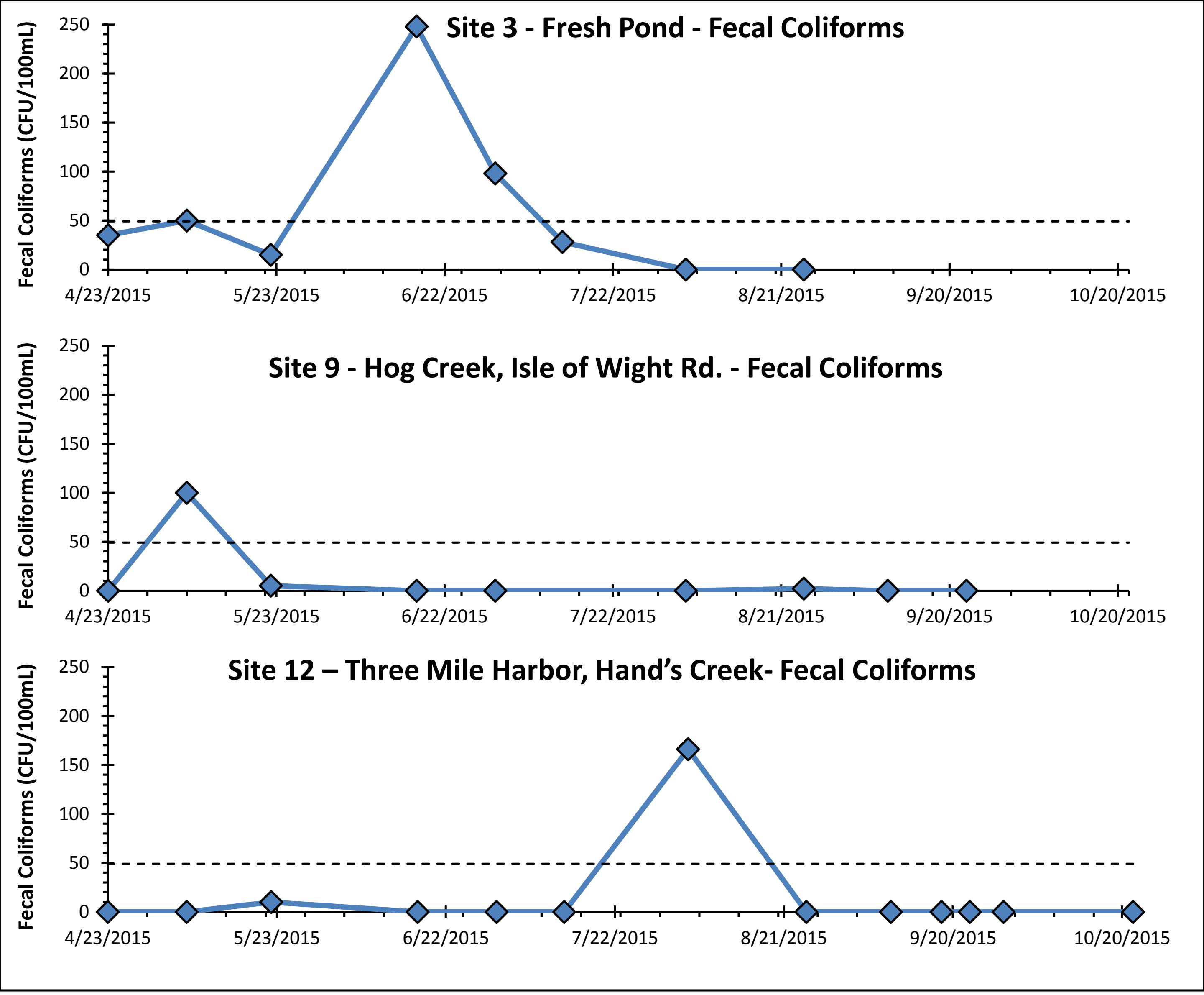


Figure 3: Fecal coliform bacteria levels over time from three sites that passed the 49 cells/100mL limit for an individual date. Fresh Pond, Site 3, was the only site to pass the 14 cells/100mL average limit.

Site #	Site Name	2015 Measure Values	2015 DEC Status	2014 Recommendation	2015 Recommendation
1	Napeague	Under	Open	Open and Confirmed	Open and Confirmed
2	Napeague - Lazy Point	Under	Open	Open and Confirmed	Open and Confirmed
3	Fresh Pond - Outlet	Over	Uncertified	Closed and Confirmed	Closed and Confirmed
5	Accabonac - Louse Point	Under	Seasonally Uncertified	Seasonal and Confirmed	Could be Opened
6	Accabonac - Landing Lane	Under	Seasonally Uncertified	Seasonal and Confirmed	Could be Opened
7	Accabonac - Gerard Drive	Under	Open	Open and Confirmed	Open and Confirmed
8	Hog Creek - Clearwater	Under	Seasonally Uncertified	Could be Opened	Could be Opened
9	Hog Creek - Isle of Wight	Under	Seasonally Uncertified	Seasonal and Confirmed	Could be Opened
10	Three Mile Harbor - Gann Road	Under	Open	Open and Confirmed	Open and Confirmed
11	Three Mile Harbor - Head of the Harbor	Under	Uncertified	Could be Opened	Could be Opened
12	Three Mile Harbor - Hand's Creek	Under	Seasonally Uncertified	Could be Opened	Could be Opened
13	Northwest Creek	Under	Seasonally Uncertified	Could be Opened	Could be Opened

Figure 4: Comparison of measured values against NYSDEC shellfish bed status, and the 2014 report's recommendations. Green text represents new recommendations. Black text confirms the DEC status. Blue text shows where the reports differ from the DEC Status.

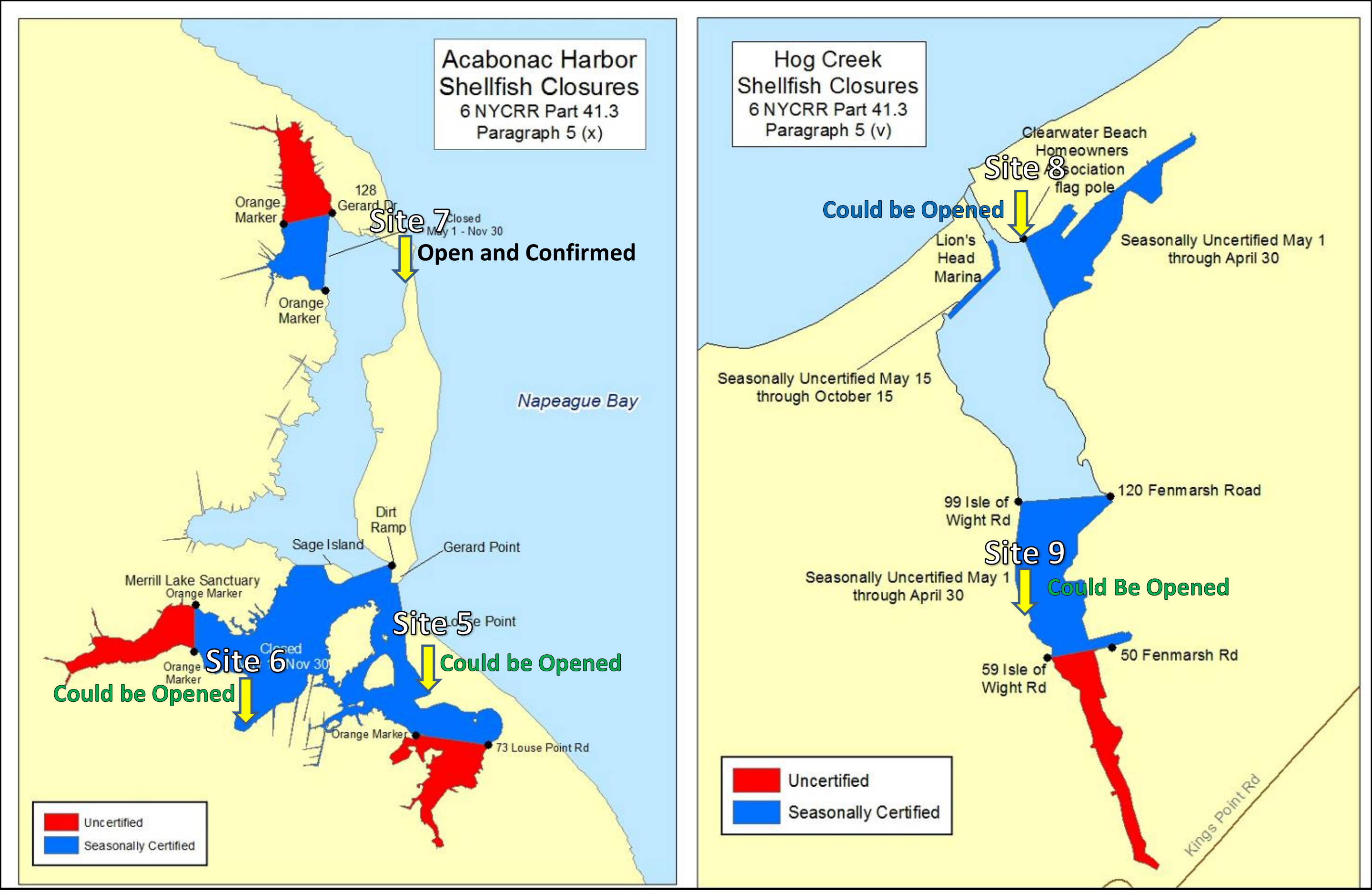


Figure 5: Maps showing 2015 NYSDEC shellfish bed statuses for Accabonac Harbor, and Hog Creek, as well as showing sampling sites.

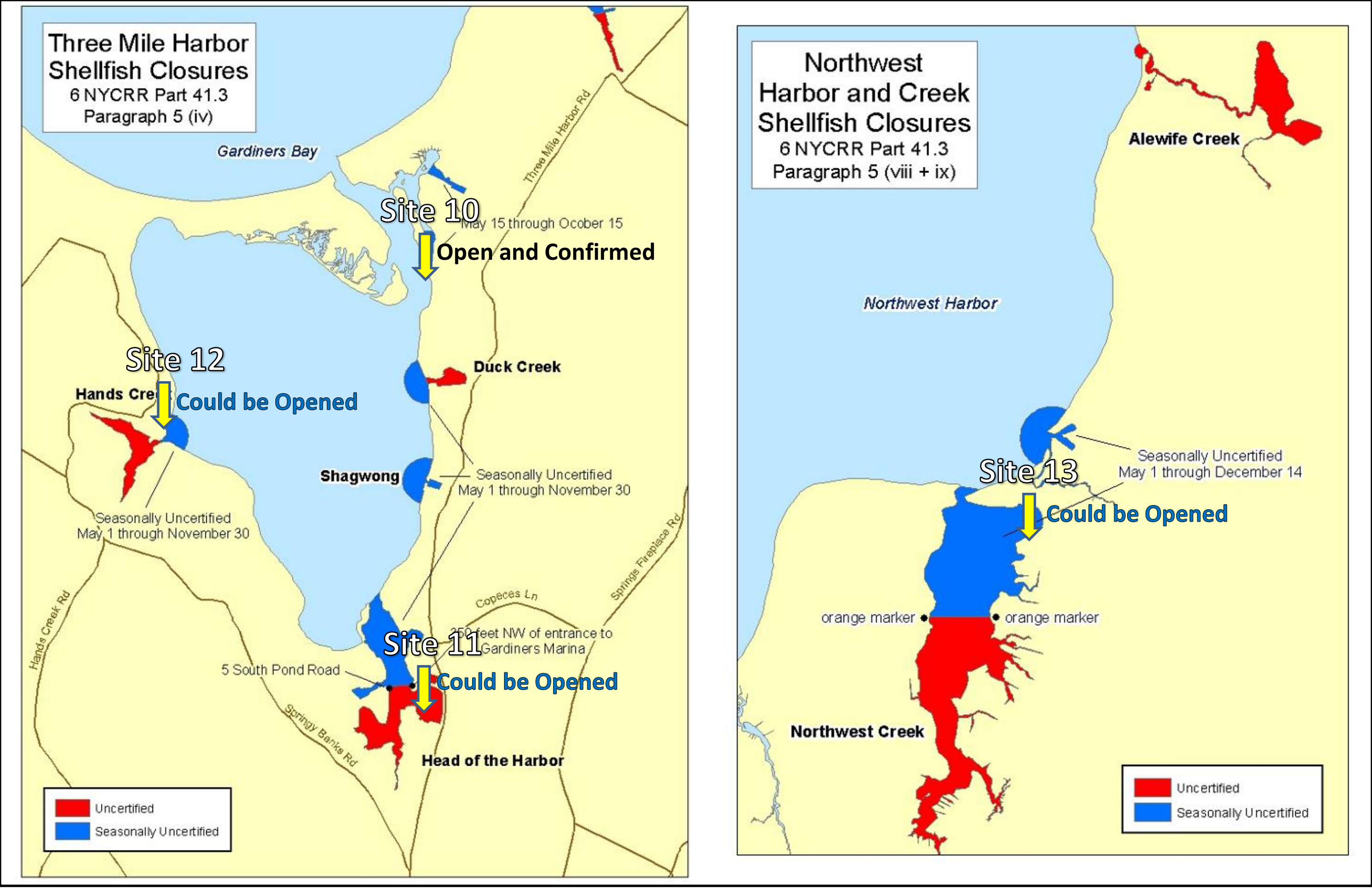


Figure 6: Maps showing 2015 NYSDEC shellfish bed statuses for Three Mile Harbor, and Northwest Creek, as well as showing sampling sites.

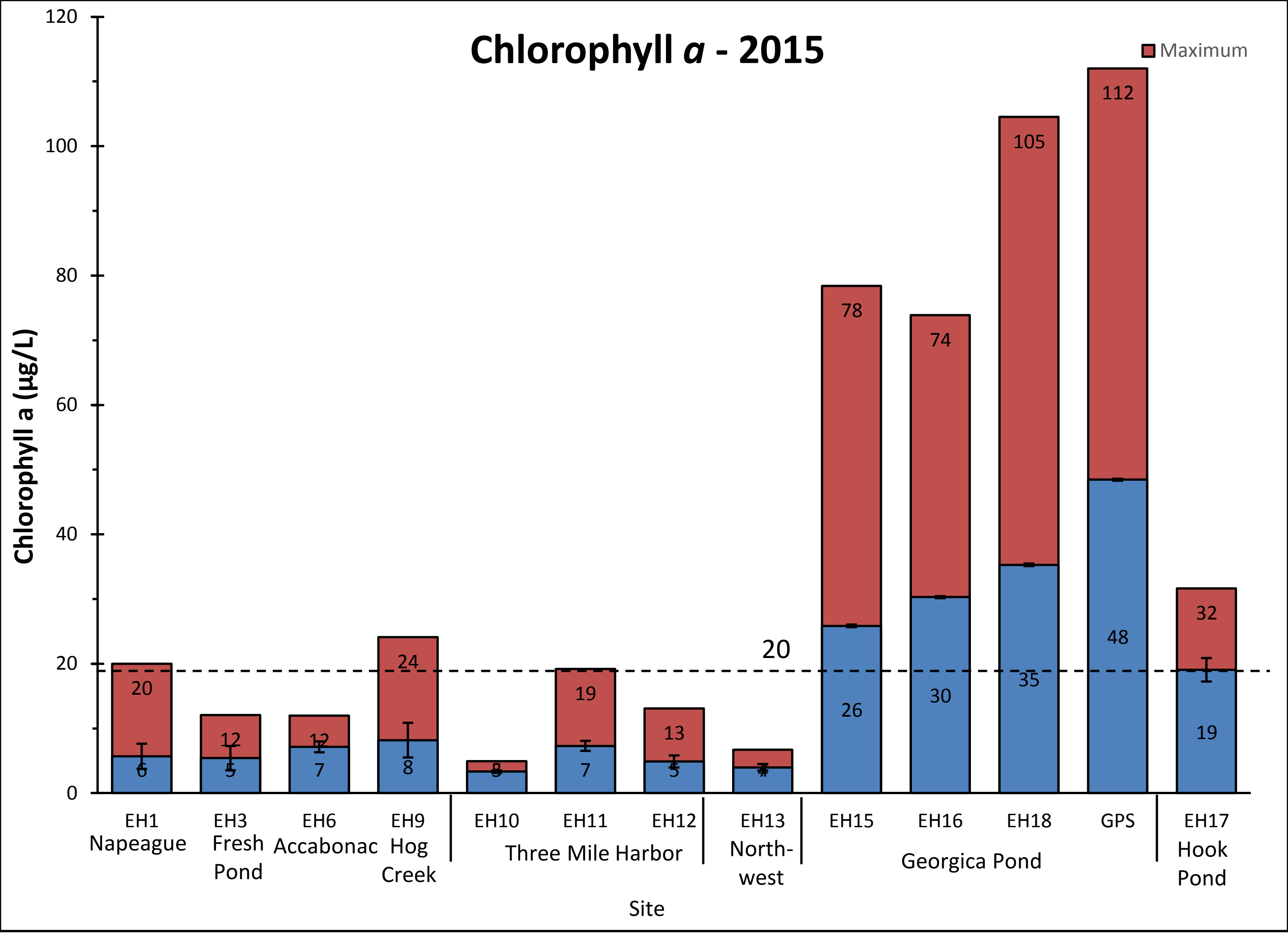


Figure 7: Average and maximum measured values of chlorophyll *a* across all marine and freshwater sites, from April through November of 2015. Error bars showing Standard Error. The dashed line represent a high level standard of 20µg/L.

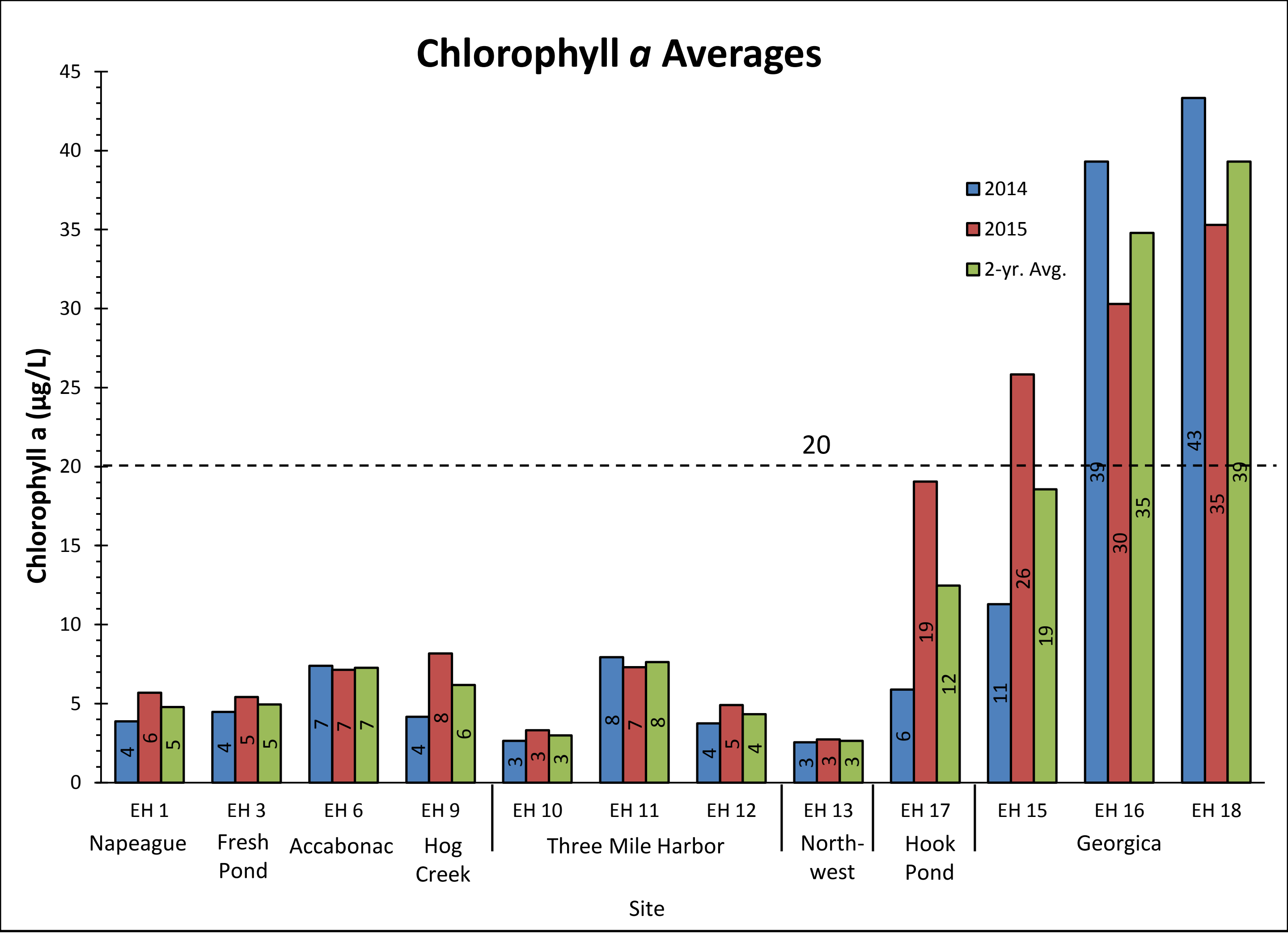


Figure 8: Comparison of average chlorophyll *a* levels from 2014 and 2015, with the two-year average. Error bars showing Standard Error. Dashed lines represents the high level standard of 20 µg/L.

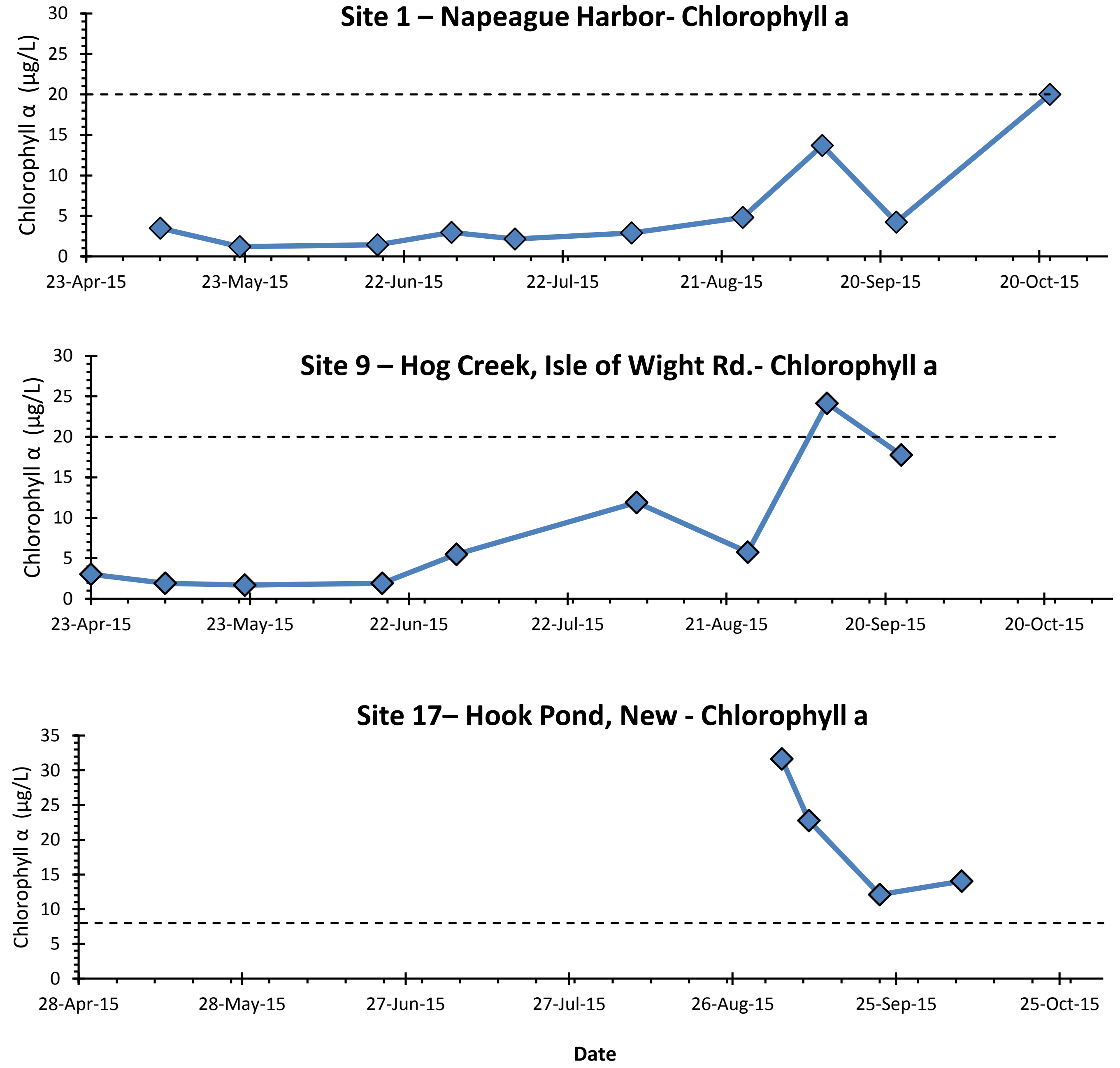
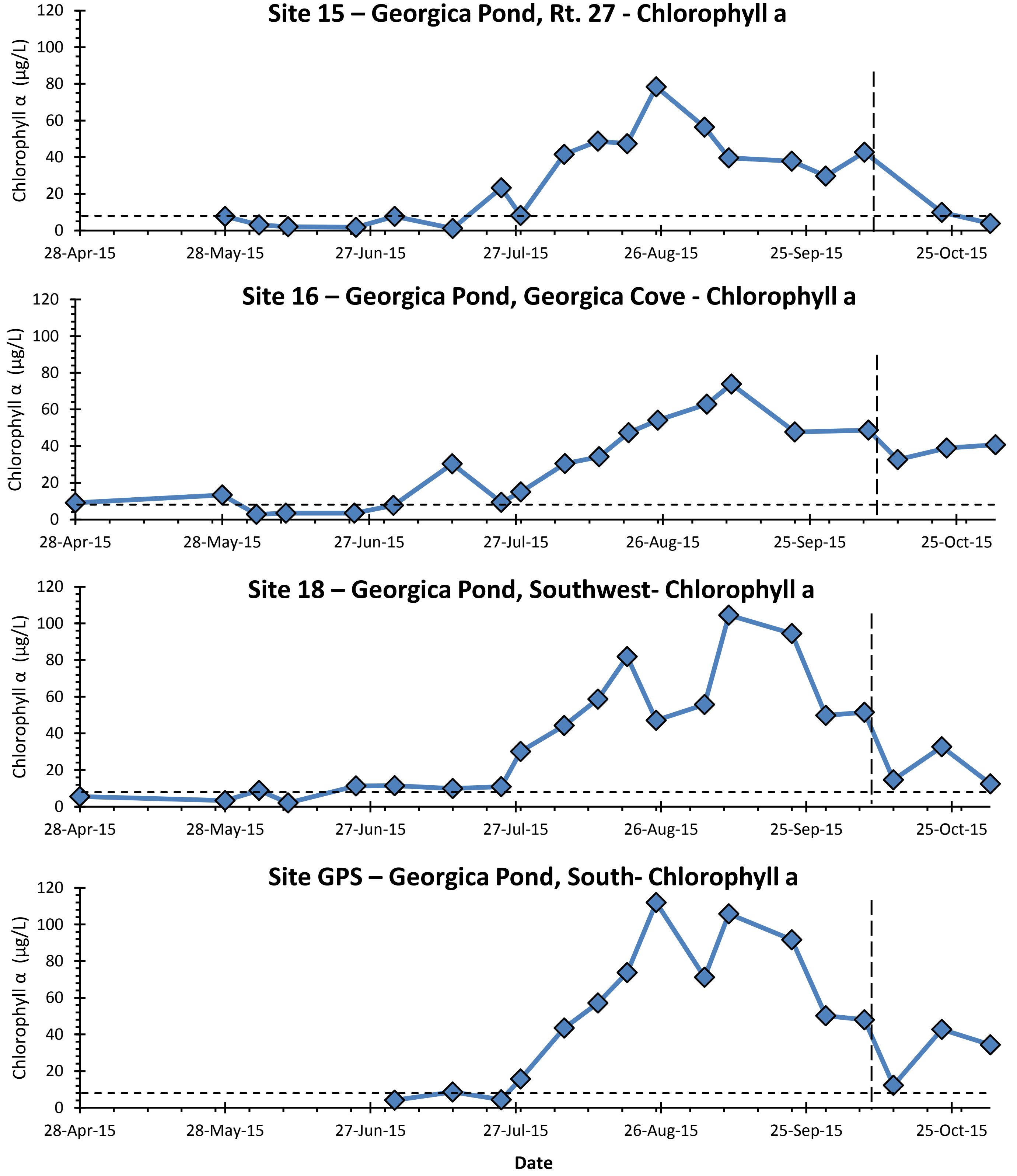


Figure 9: Measured *chlorophyll a* values over time for two marine sites, which passed the standard of 20 µg/L, Hook Pond, which passed the freshwater standard of 8 µg/L.


Site 15 – Georgica Pond, Rt. 27 - Chlorophyll a

Site 16 – Georgica Pond, Georgica Cove - Chlorophyll a

Site 18 – Georgica Pond, Southwest- Chlorophyll a

Site GPS – Georgica Pond, South- Chlorophyll a

Figure 10: Measured *chlorophyll a* values over time for all Georgica Pond sites. Dashed line shows the standard of 8 µg/L.

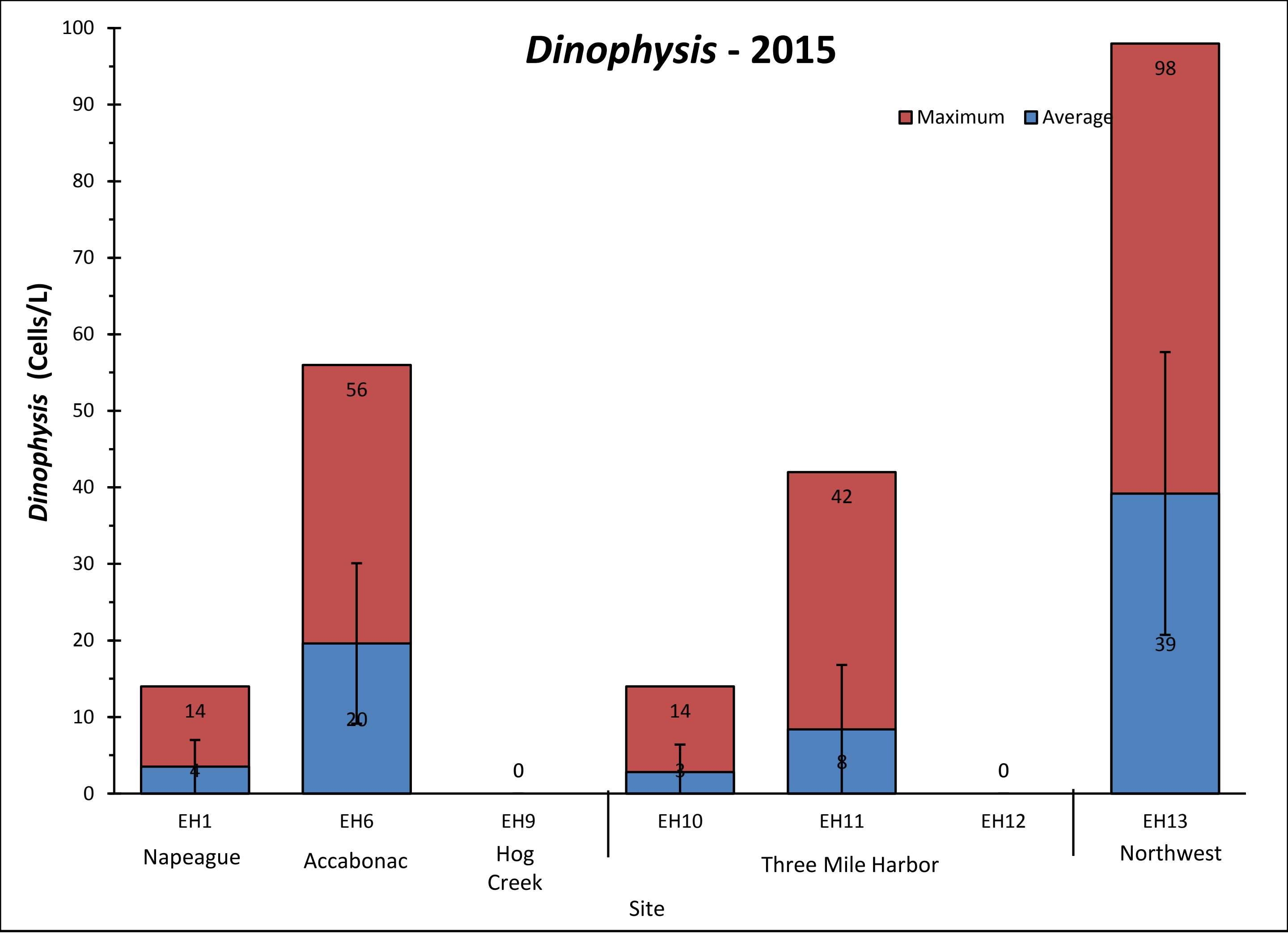


Figure 11: Average and maximum counts of the harmful dinoflagellate *Dinophysis*. Error bars showing Standard Error. Samples were collected from April and into July 2015. Level of concern of 10,000 cells/L not shown within range.

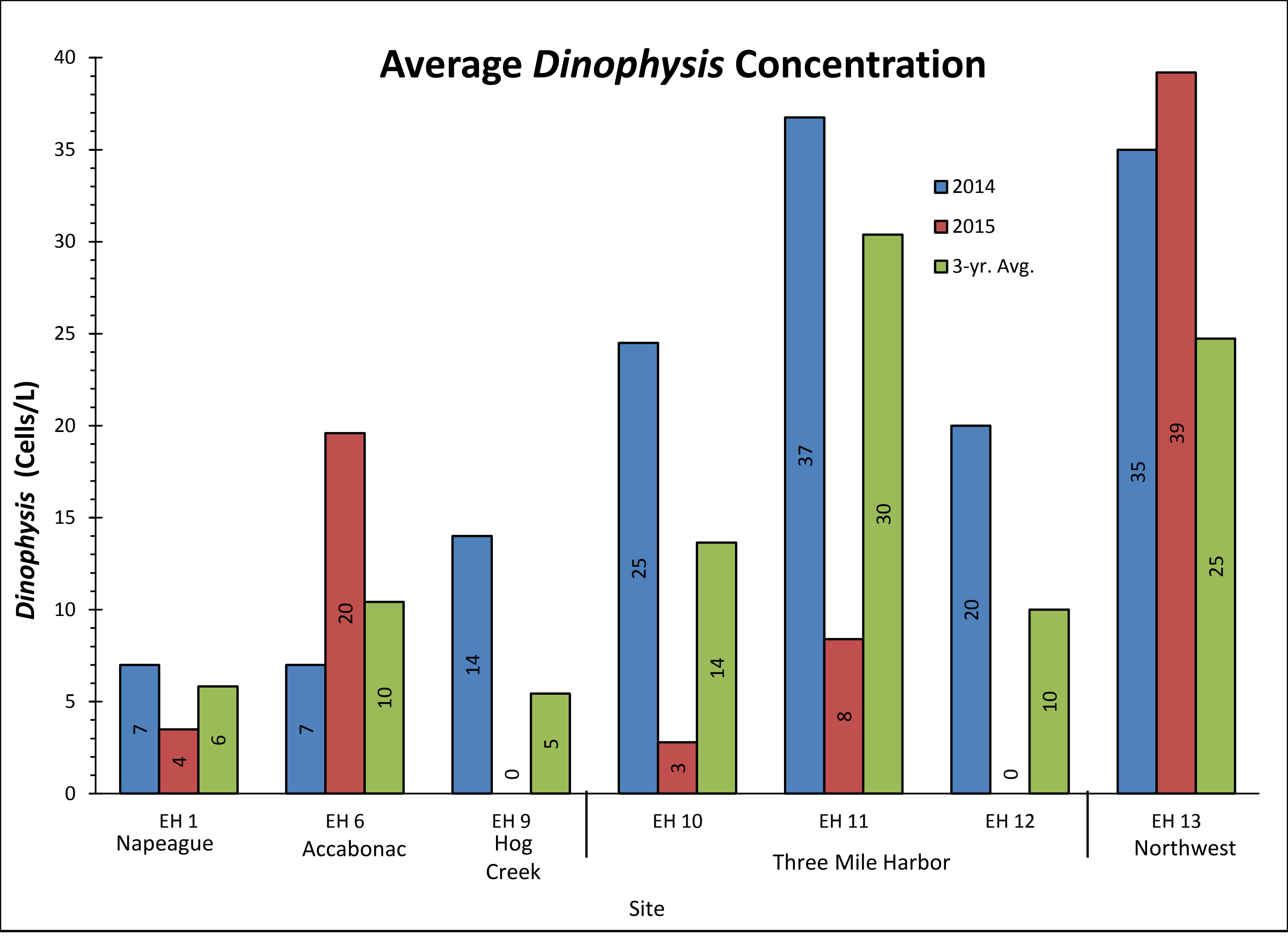


Figure 12: Comparison of average Dinophysis concentrations from 2014 and 2015, with the three-year average. Level of concern of 10,000 cells/L not shown within range.

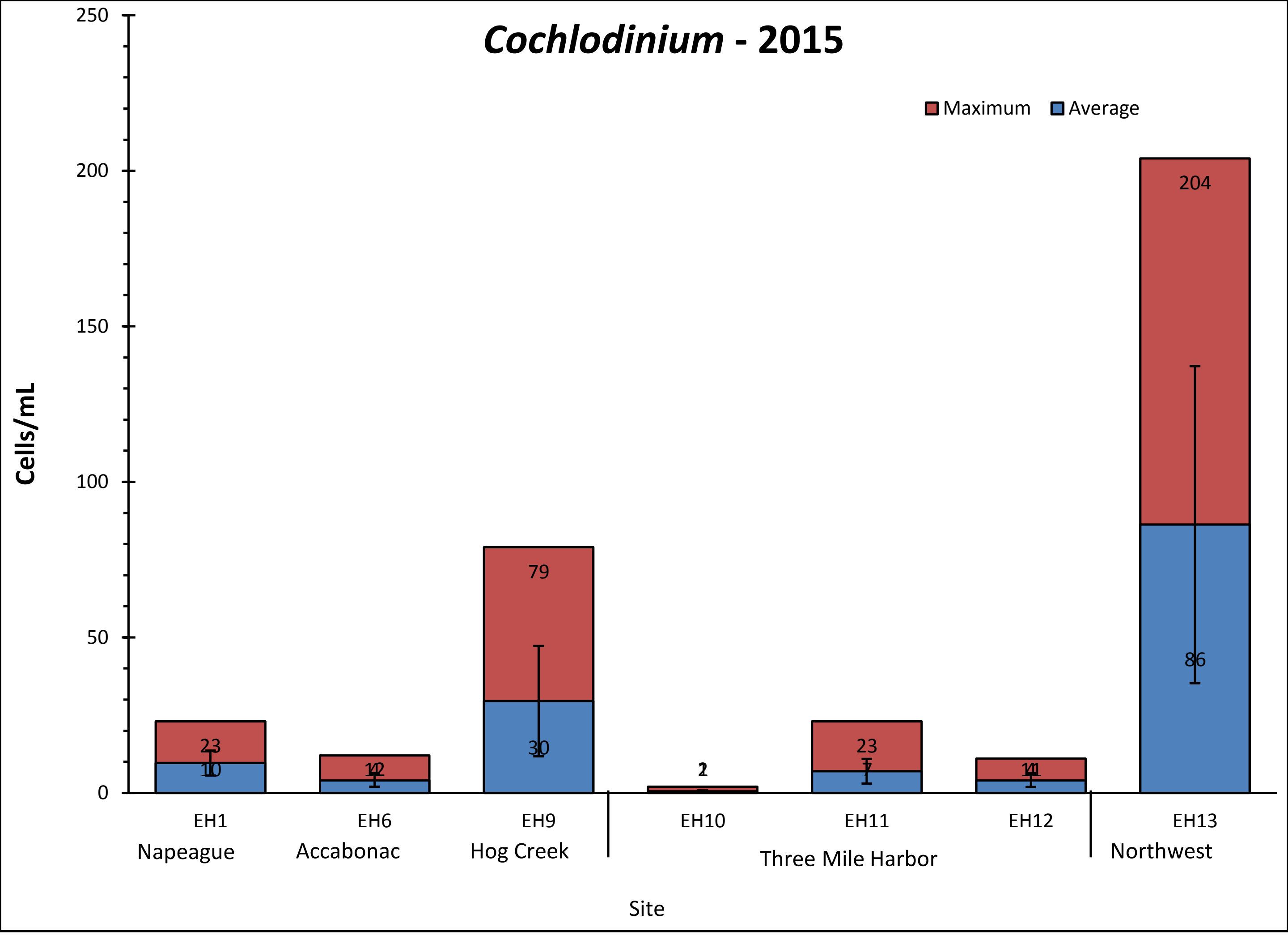


Figure 13: Average and maximum values of *Cochlodinium* across marine sites from August into October 2015. Error bars showing Standard Error. Level of concern of 500 cells/mL not shown within range.

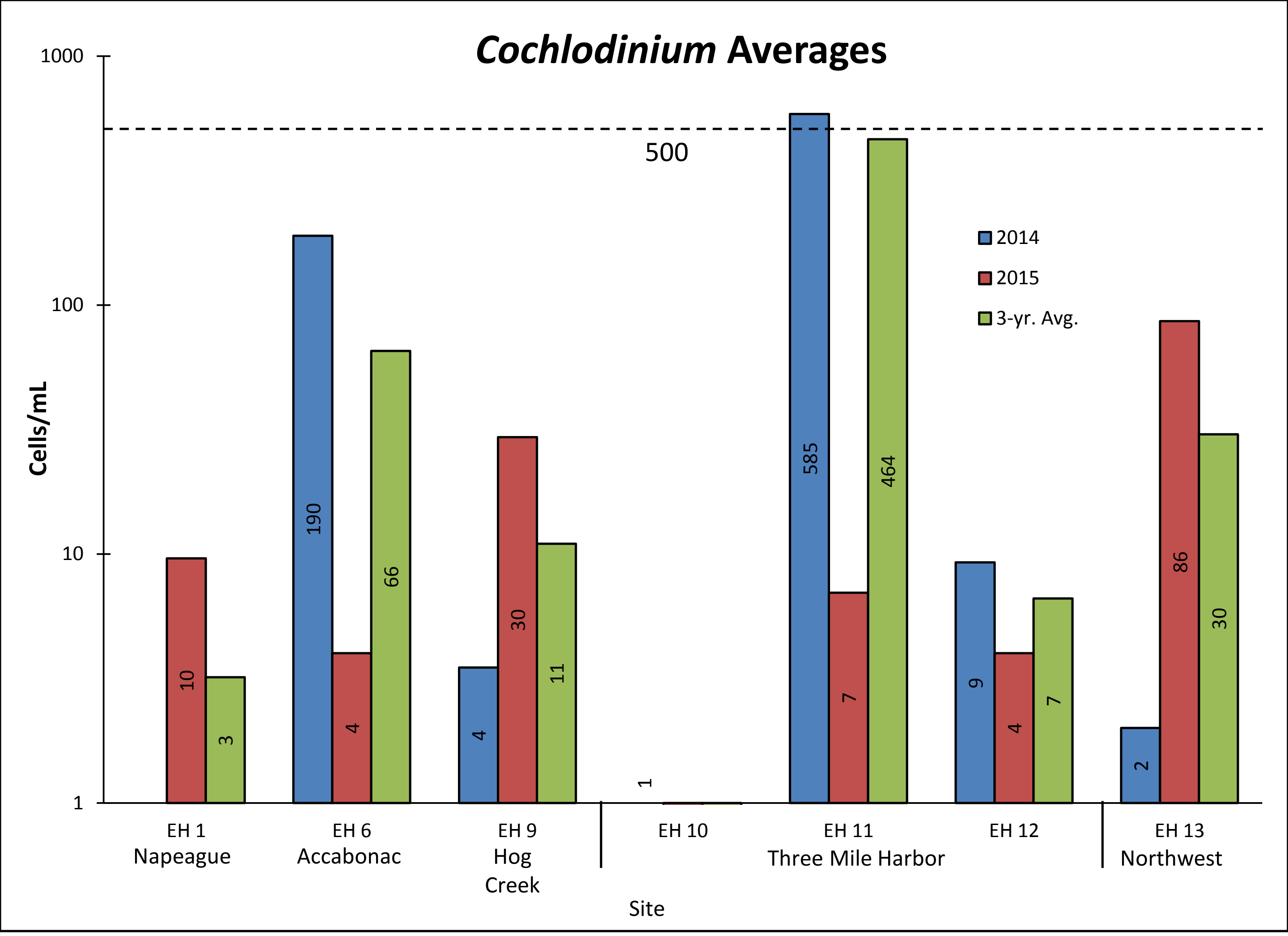


Figure 14: Comparison of average *Cochlodinium* concentrations from 2014 and 2015, with the three-year average. Dashed line shows level standard of 500 cells/mL.

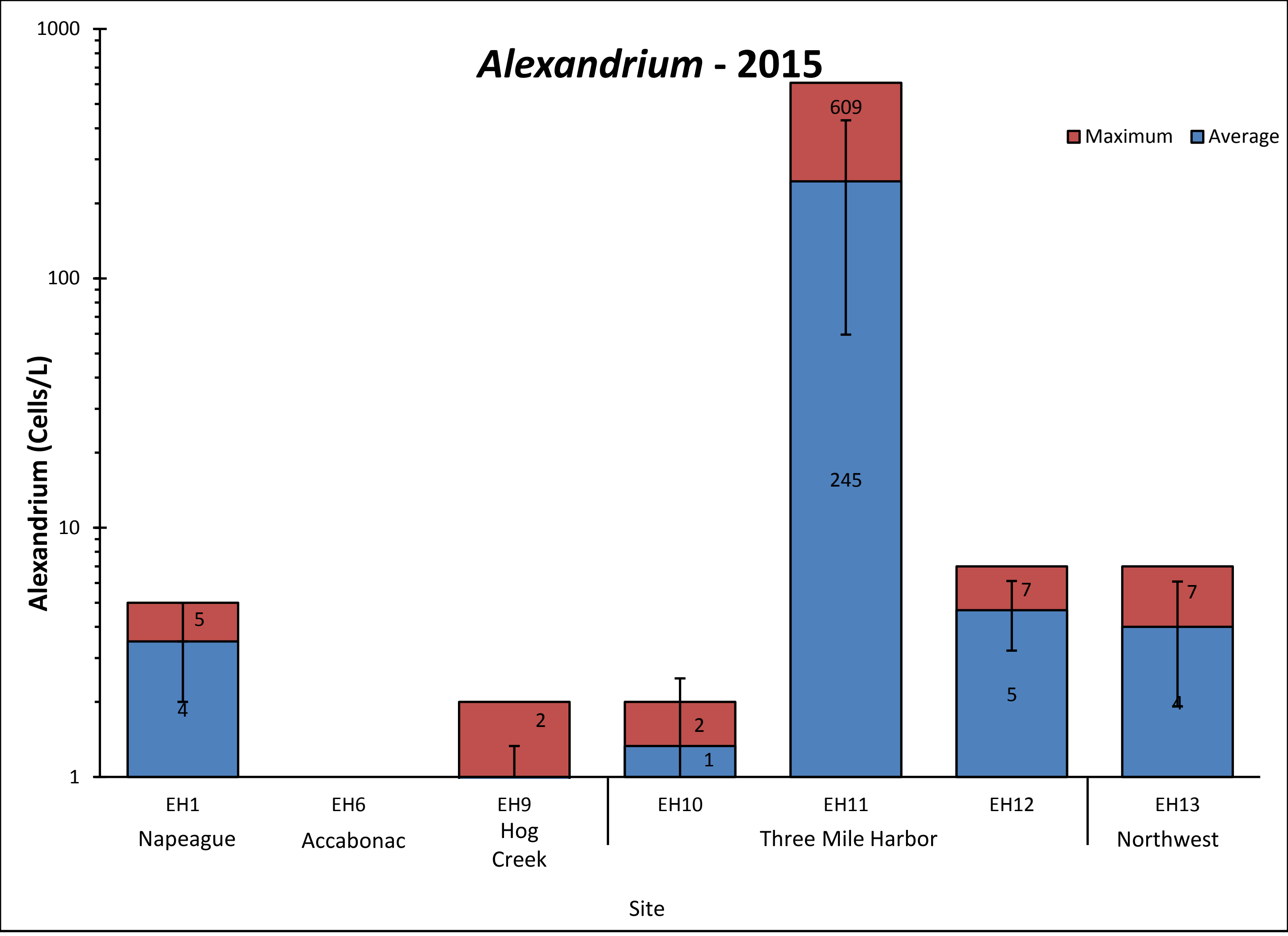


Figure 15: Average and maximum values for *Alexandrium,* from April into May 2015. Error bars showing Standard Error. Level of concern of 1,000 cells/L not shown within range.

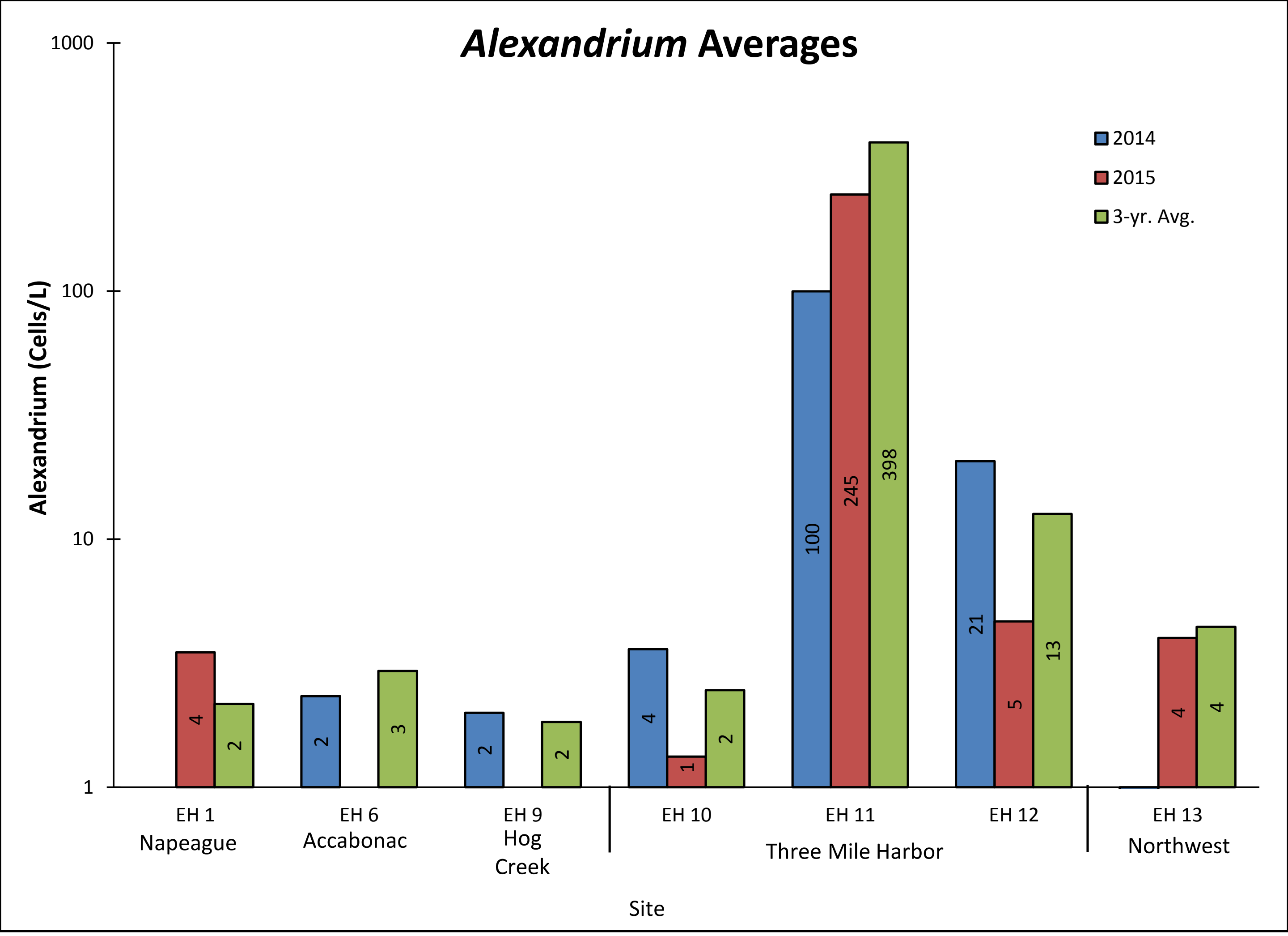


Figure 16: Comparison of average *Alexandrium* concentrations from 2014 and 2015, with the three-year average. Level of concern of 1,000 cells/L not shown within range.

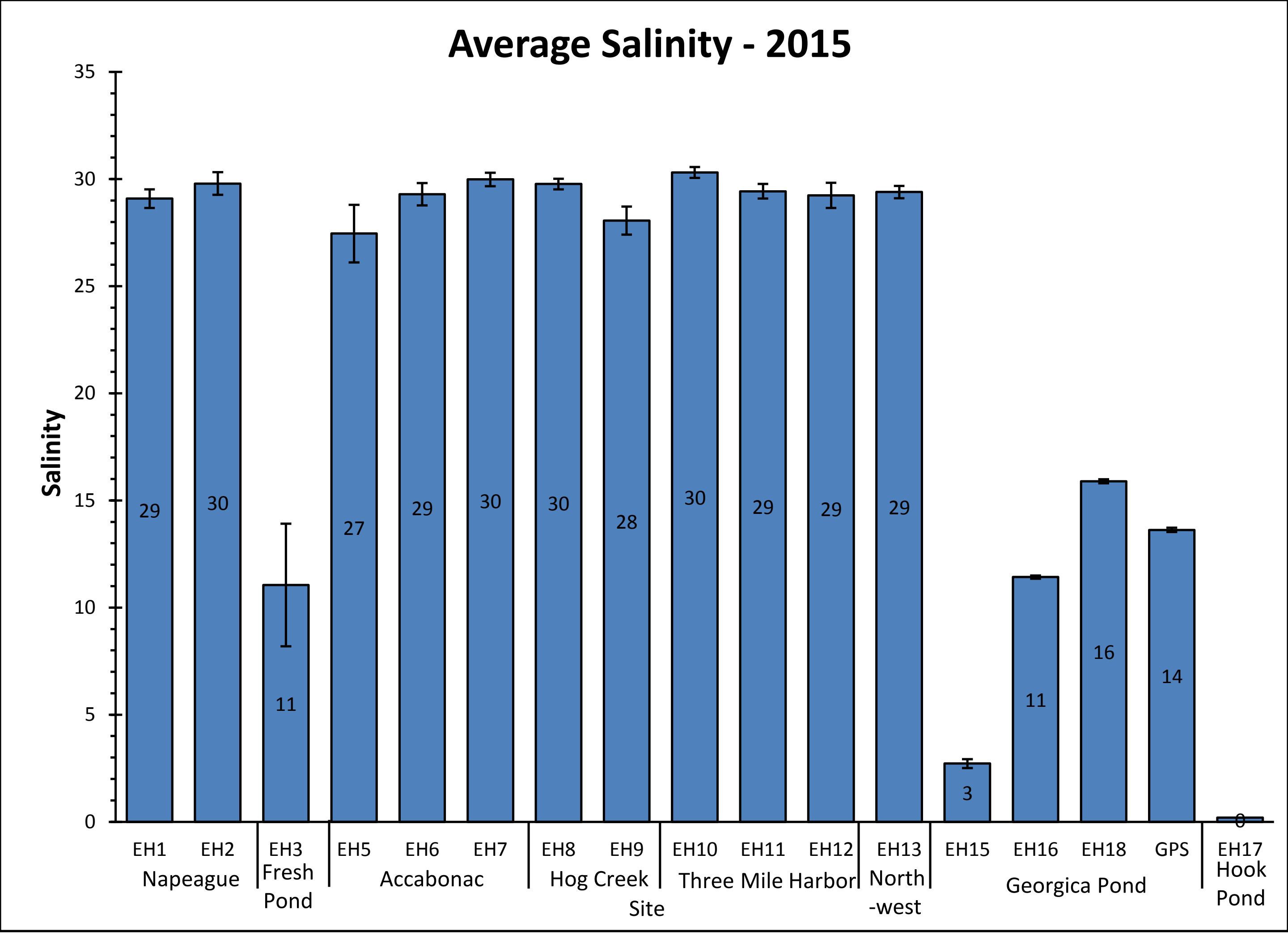


Figure 17: Average salinities across all marine and freshwater sites, from April through November 2015. Error bars showing Standard Error.

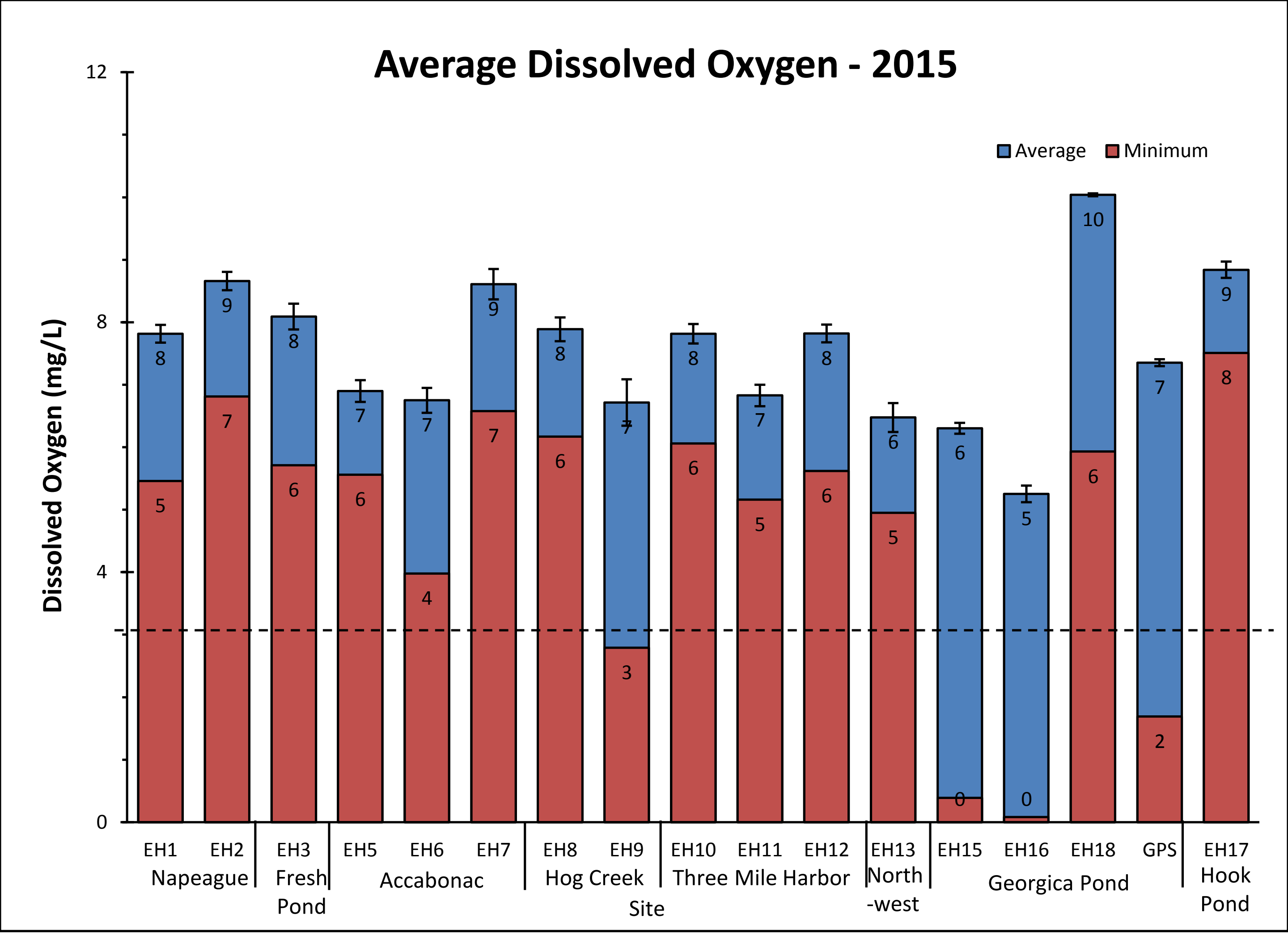


Figure 18: Mean and minimum dissolved oxygen values across all marine and freshwater sites for 2015. Error bars showing Standard Error. Dashed line at 3mg/L shows limit for hypoxic waters.

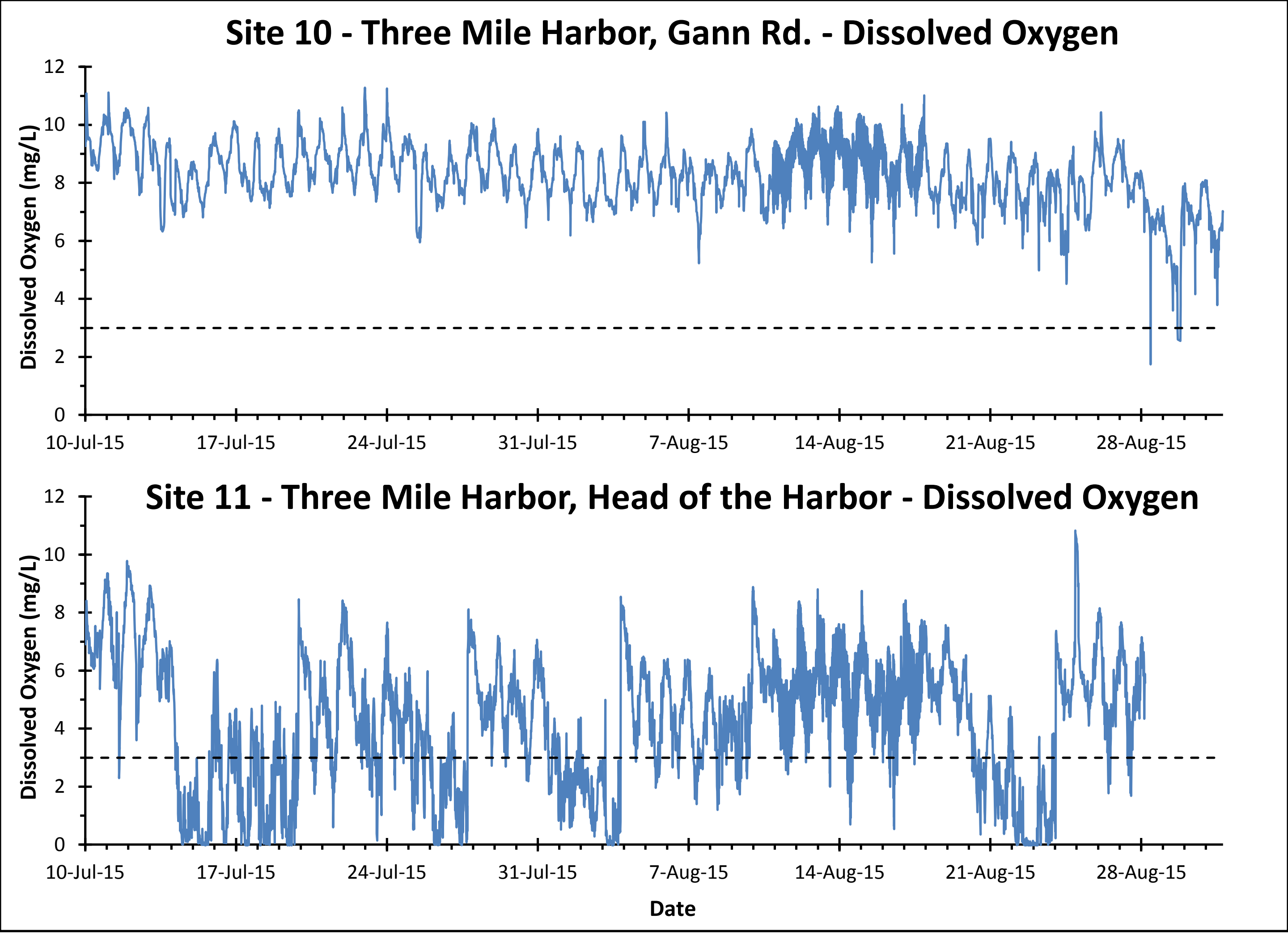


Figure 19: Time series of dissolved oxygen levels at depth from Gann Rd., and Head of the Harbor. HOBO data loggers were deployed between July 10th and September 1st, and recorded values every 15 minutes. Dashed line at 3 mg/L shows hypoxic level.

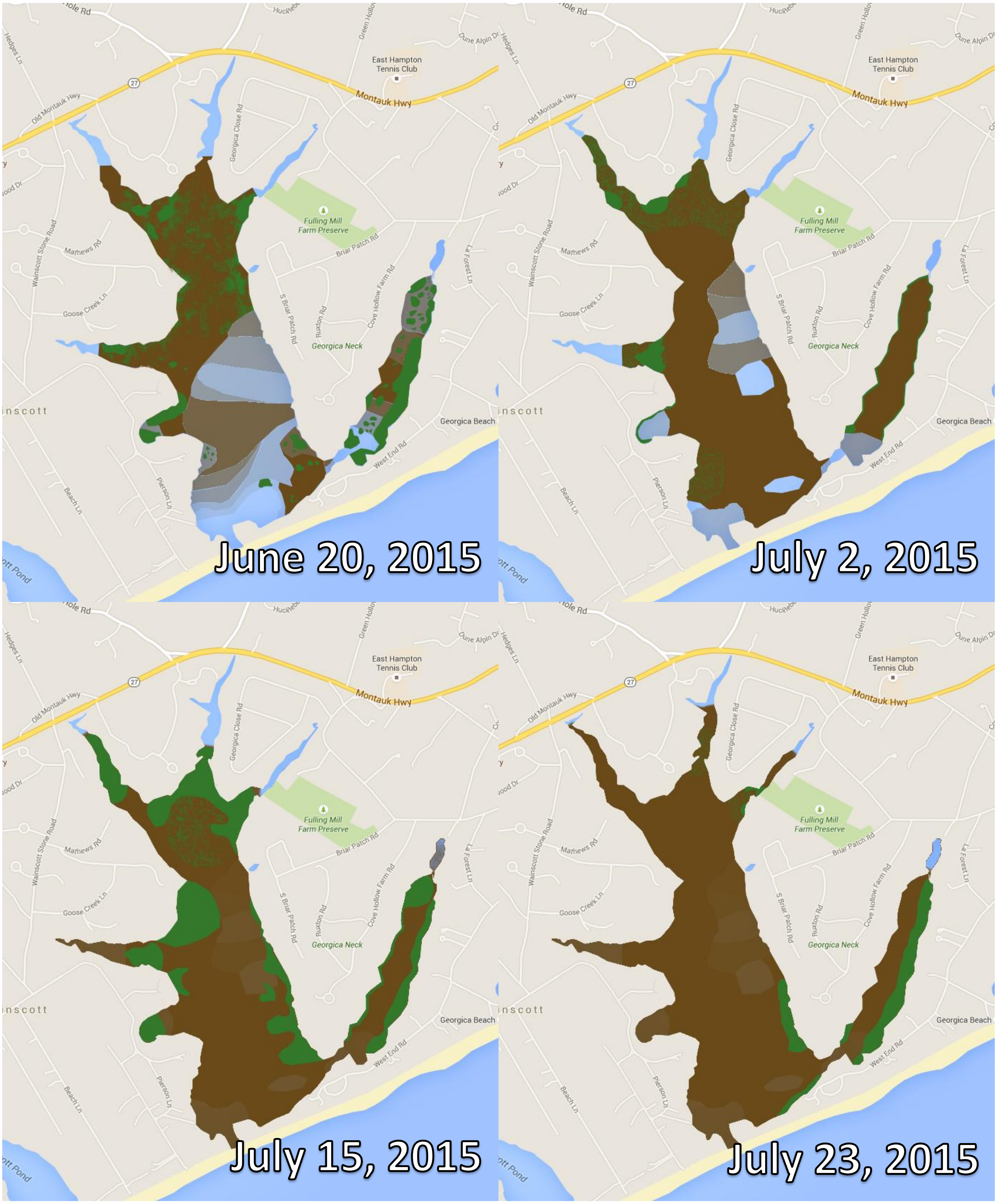


Figure 20: Maps showing extent of *Cladophora* macroalgal bloom from four surveys in June and July 2015. Green shows areas where the alga floated on the surface in patches or thick mats. Brown shows bottom coverage of the alga, with higher opacity representing percent coverage.

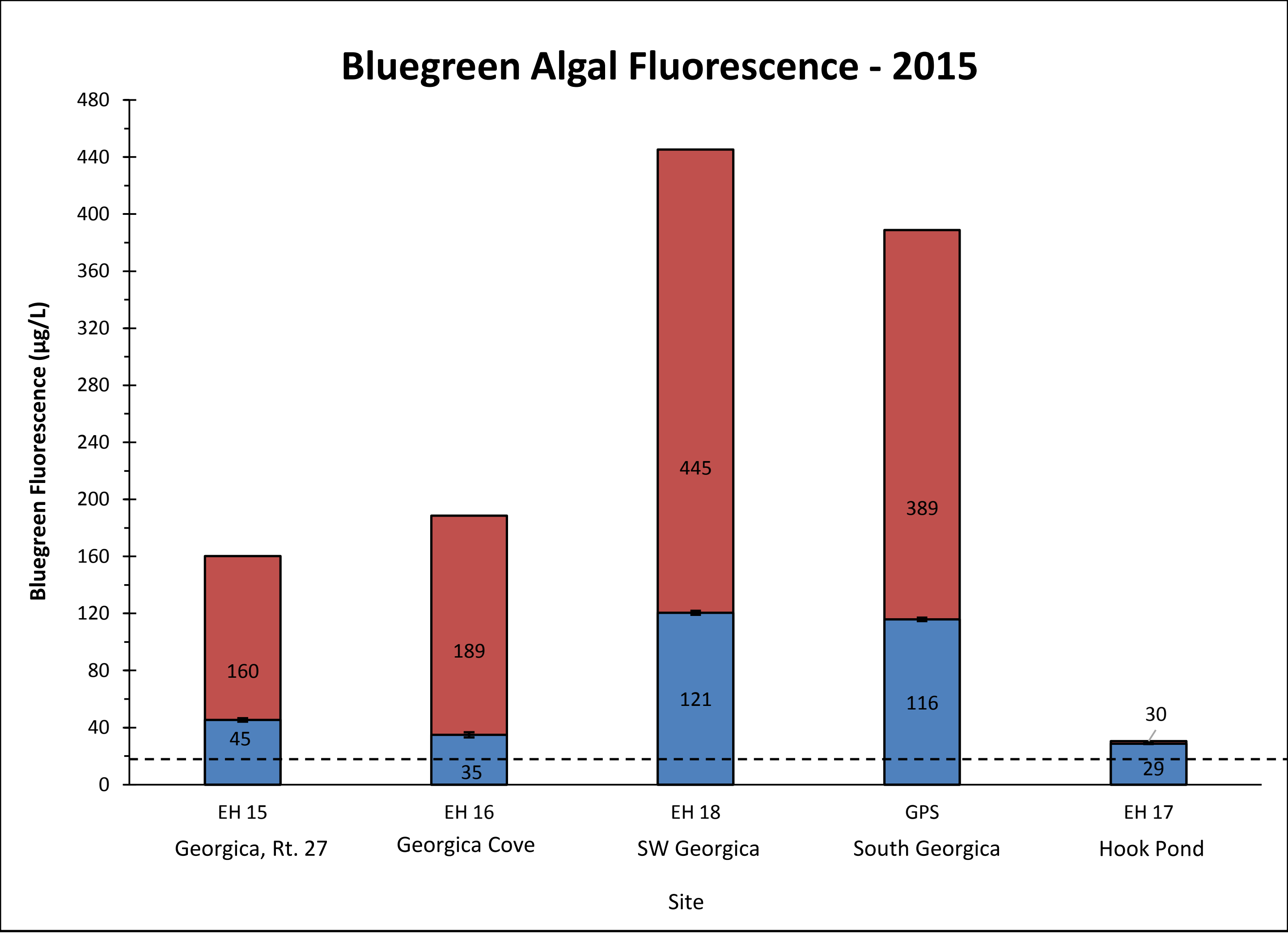


Figure 21: Average and maximum levels of bluegreen fluorescence, measured across the freshwater sites of Hook Pond and Georgica Pond from May through November 2015. Error bars showing Standard Error. Dashed line shows 20 µg/L.

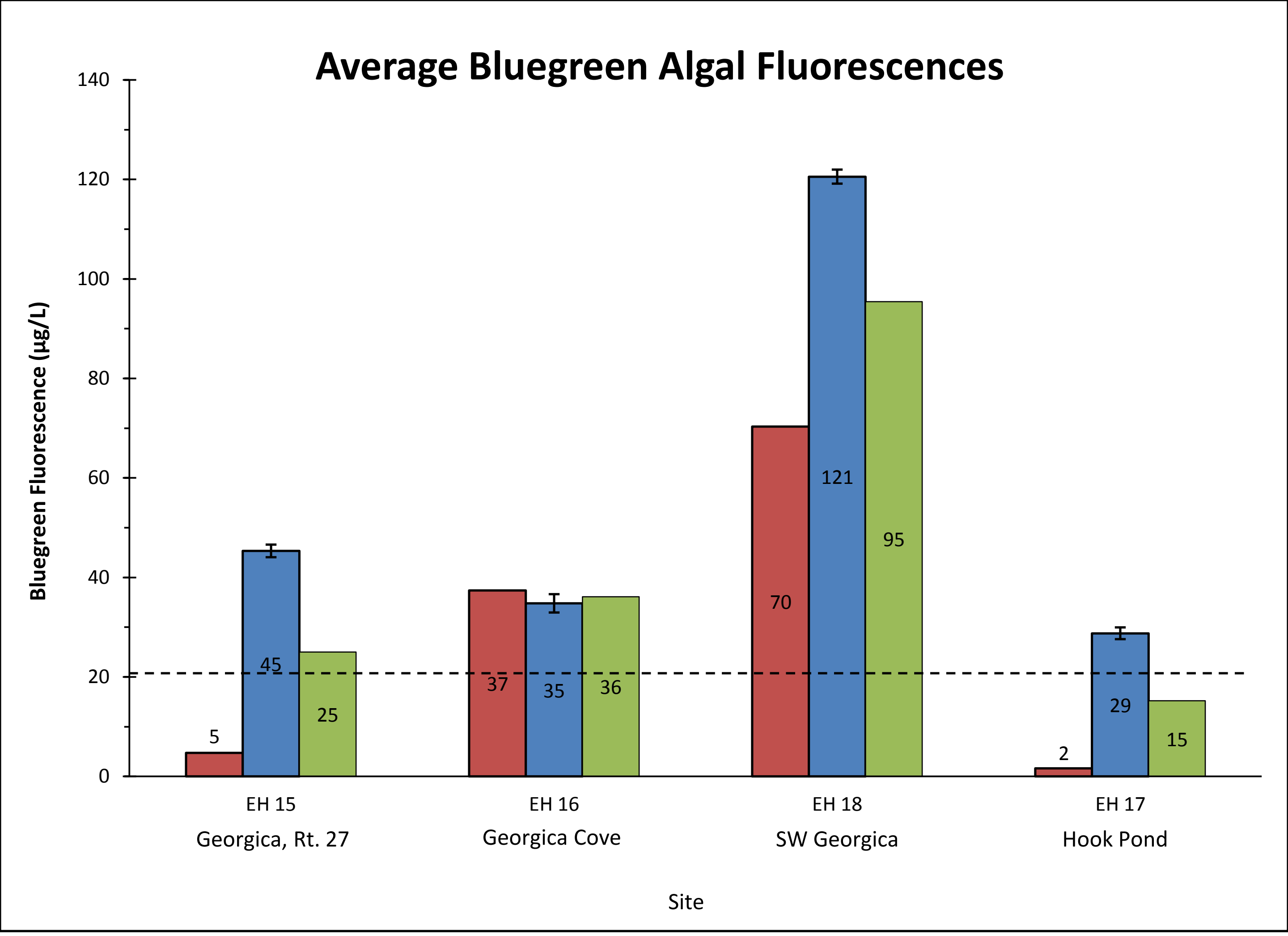
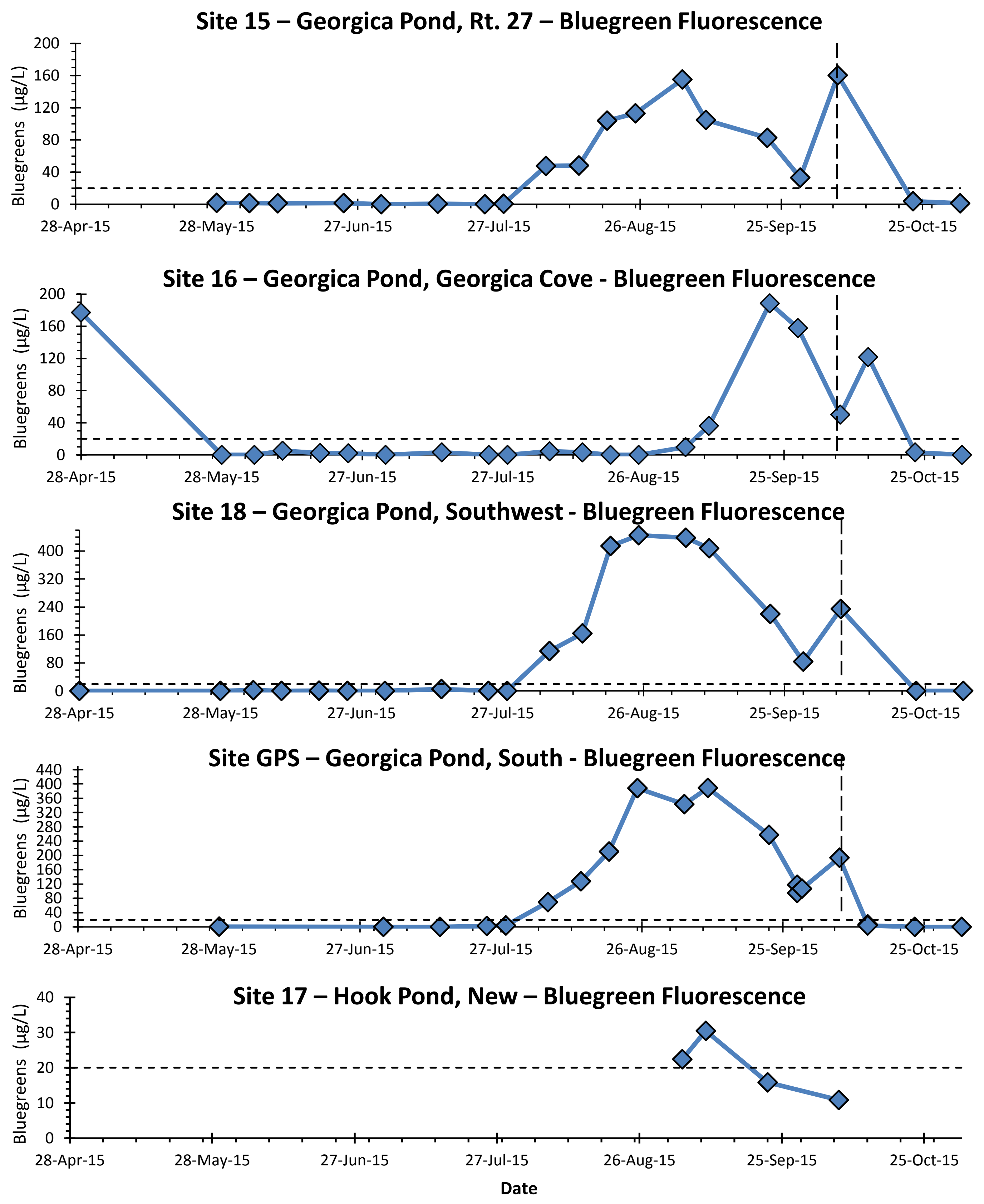


Figure 22: Comparison of average bluegreen fluorescence from 2014 and 2015, with two-year average. Error bars showing Standard Error. Dashed line shows 20 µg/L.



Site 15 – Georgica Pond, Rt. 27 – Bluegreen Fluorescence

Site 16 – Georgica Pond, Georgica Cove - Bluegreen Fluorescence

Site 18 – Georgica Pond, Southwest - Bluegreen Fluorescence

Site GPS – Georgica Pond, South - Bluegreen Fluorescence

Site 17 – Hook Pond, New – Bluegreen Fluorescence

Figure 23: Individual bluegreen fluorescence values over time for Georgica and Hook Pond sites. These sites exceeded 20 µg/L, which is represented by the horizontal dashed line. Dashed vertical line shows when the cut at Georgica Pond was opened.

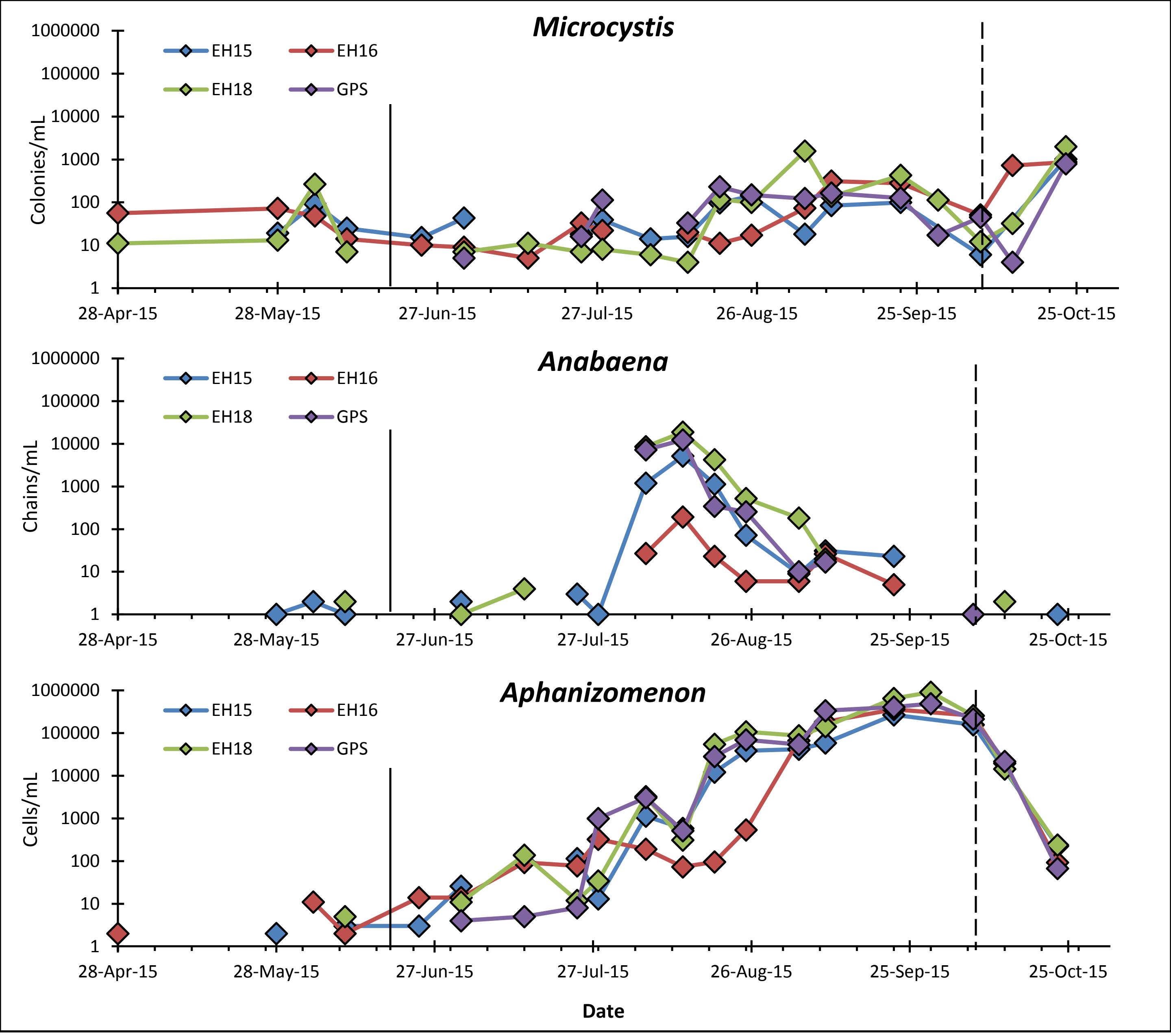


Figure 24: Individual counts of cyanobacteria in Georgica Pond. Dashed vertical line shows when the cut at Georgica Pond was opened. Solid vertical shows closure of the cut.

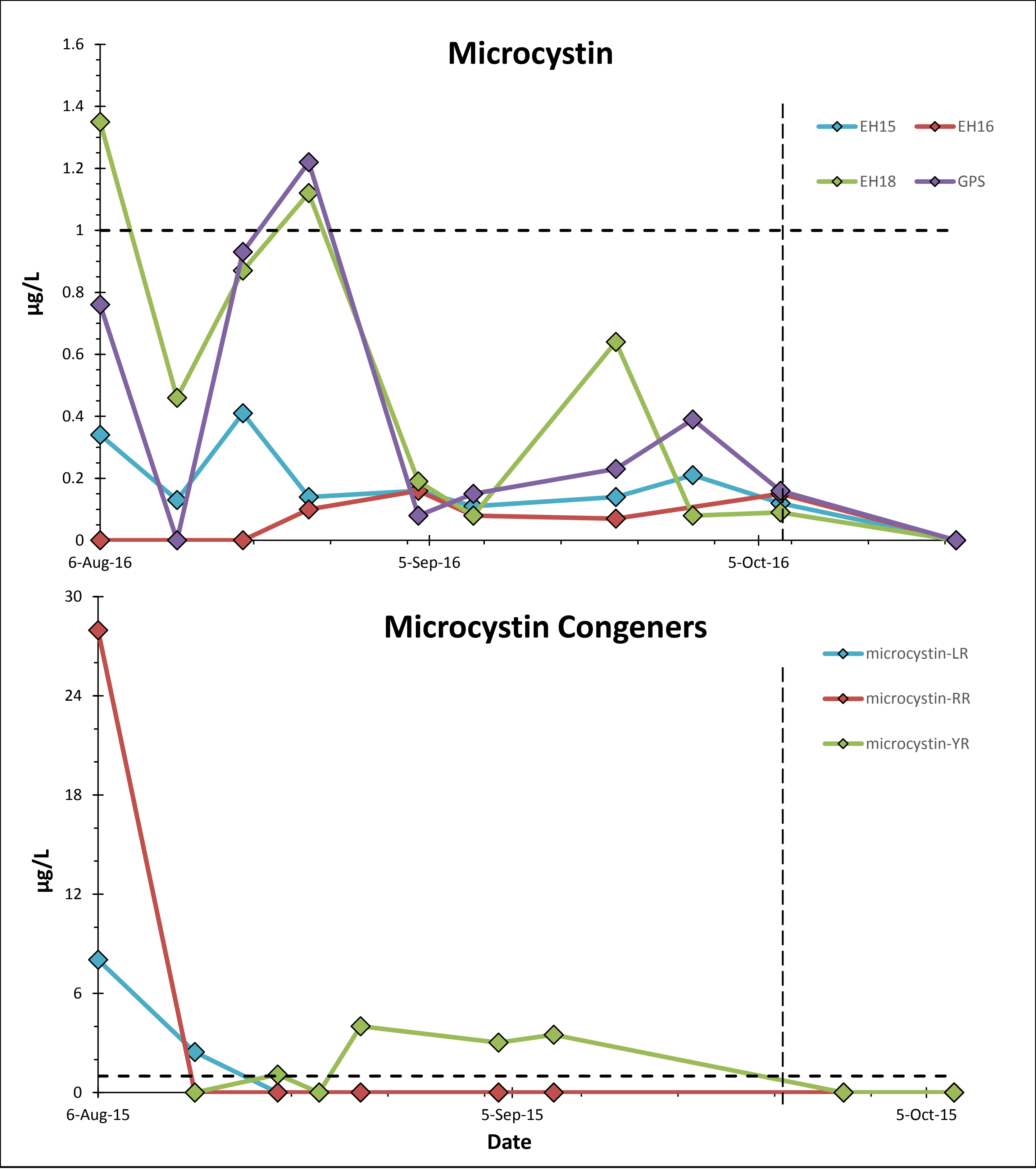


Figure 25: Toxin concentrations of microcystin and its congeners, from sites in Georgica Pond. Horizontal dashed line on the toxin plot shows WHO microcysin standard for drinking water of 1 µg/L. Dashed vertical line shows when the cut at Georgica Pond was opened.

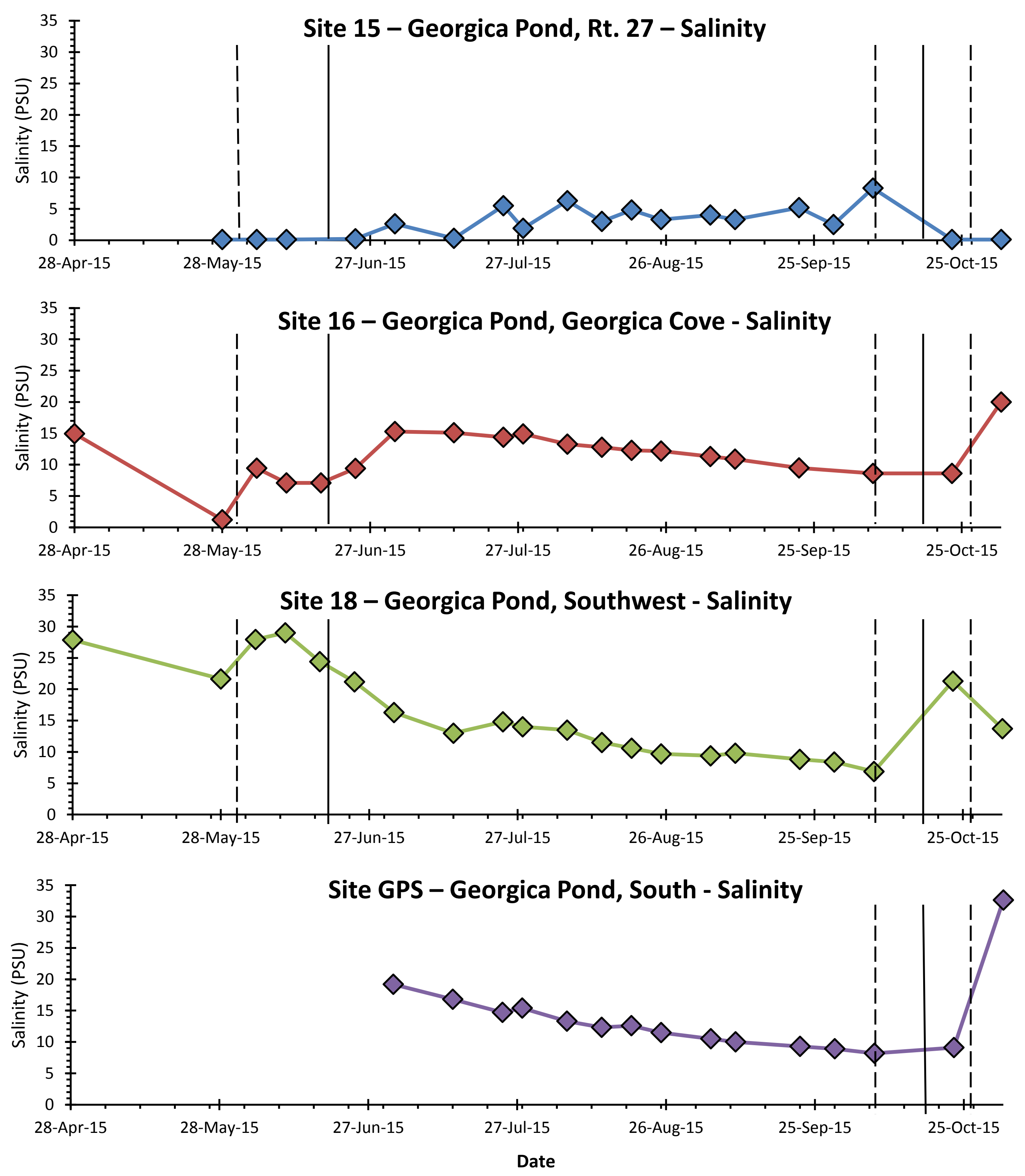
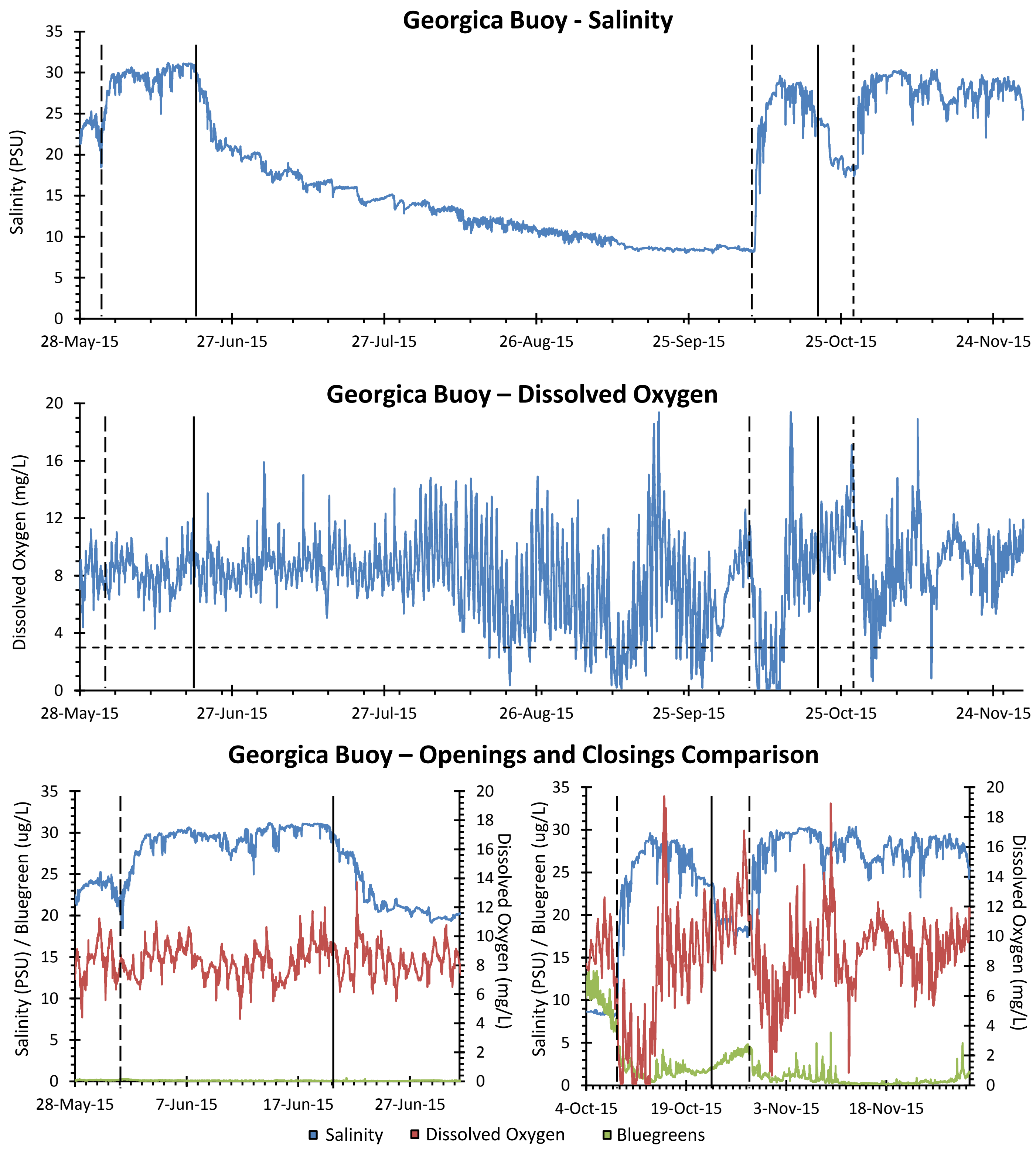


Figure 26: Time series of salinity data for Georgica Pond's three sites. Dashed vertical lines show when the pond was opened to the ocean, and solid vertical line shows when it closed.



Georgica Buoy - Salinity

Georgica Buoy – Dissolved Oxygen

Georgica Buoy – Openings and Closings Comparison

Figure 27: Salinity and dissolved oxygen data from the Georgica Pond Telemetry Buoy. Vertical dashed lines show opening of cut to ocean, solid vertical lines show when the cut closed.

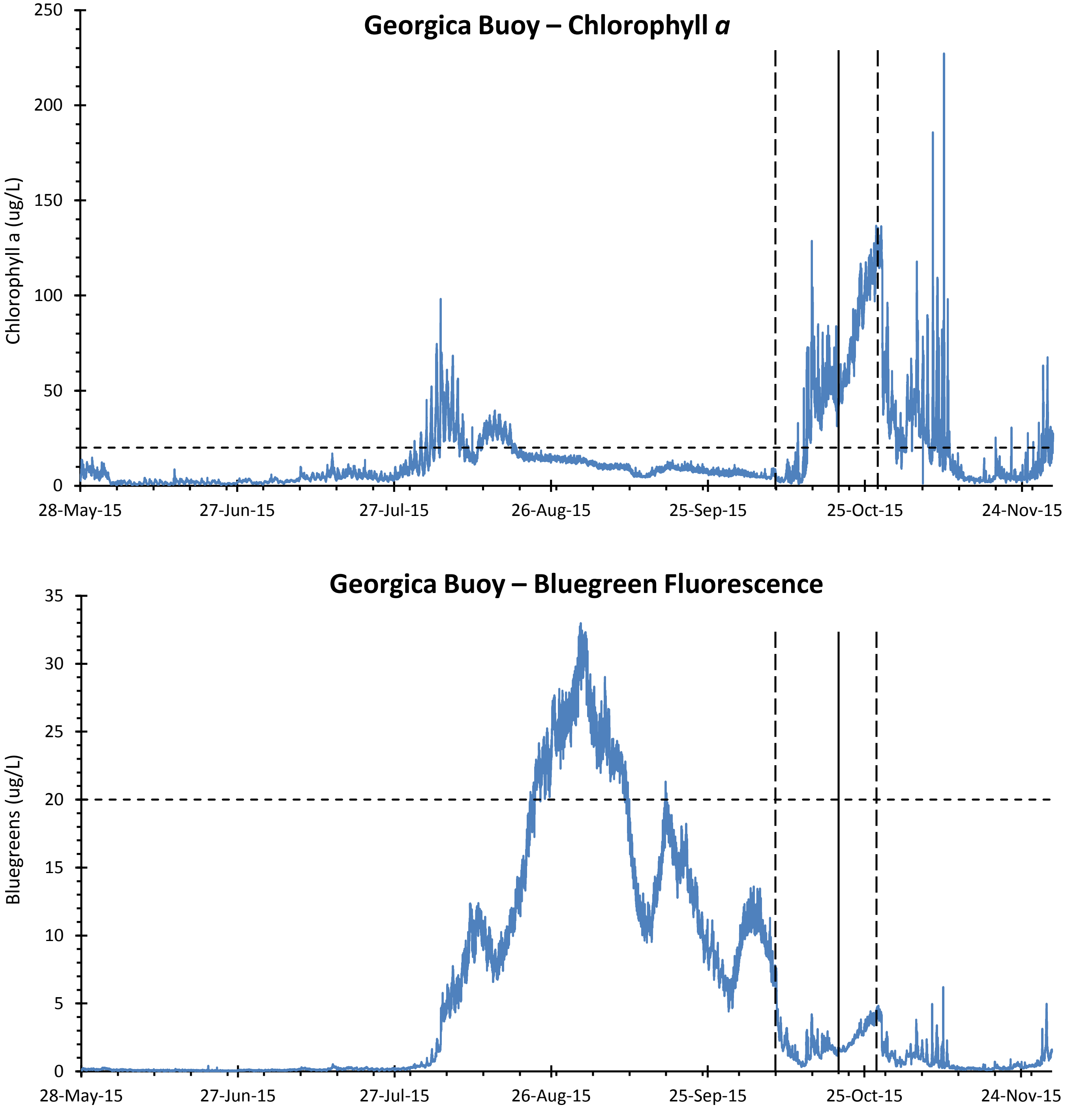
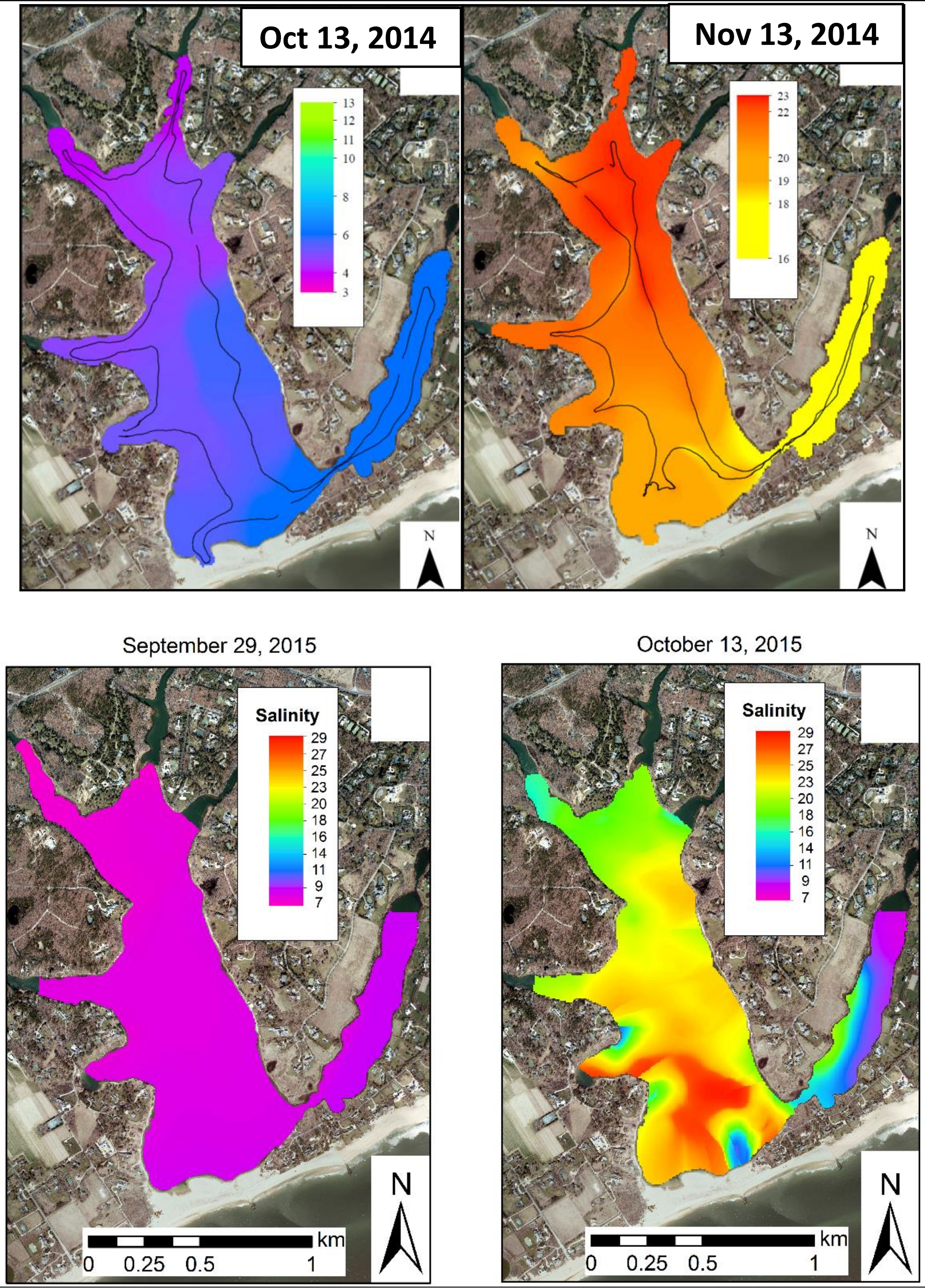


Figure 28: Chlorophyll a and bluegreen fluorescence from the Georgica Pond Telemetry Buoy. Horizontal dashed line shows 20 µg/L. Vertical dashed lines show opening of cut to ocean, solid vertical lines show when the cut closed.


Oct 13, 2014

Nov 13, 2014

September 29, 2015

October 13, 2015

Figure 29: Salinity data from cruises in 2014 and 2015, before and after the opening of the cut.

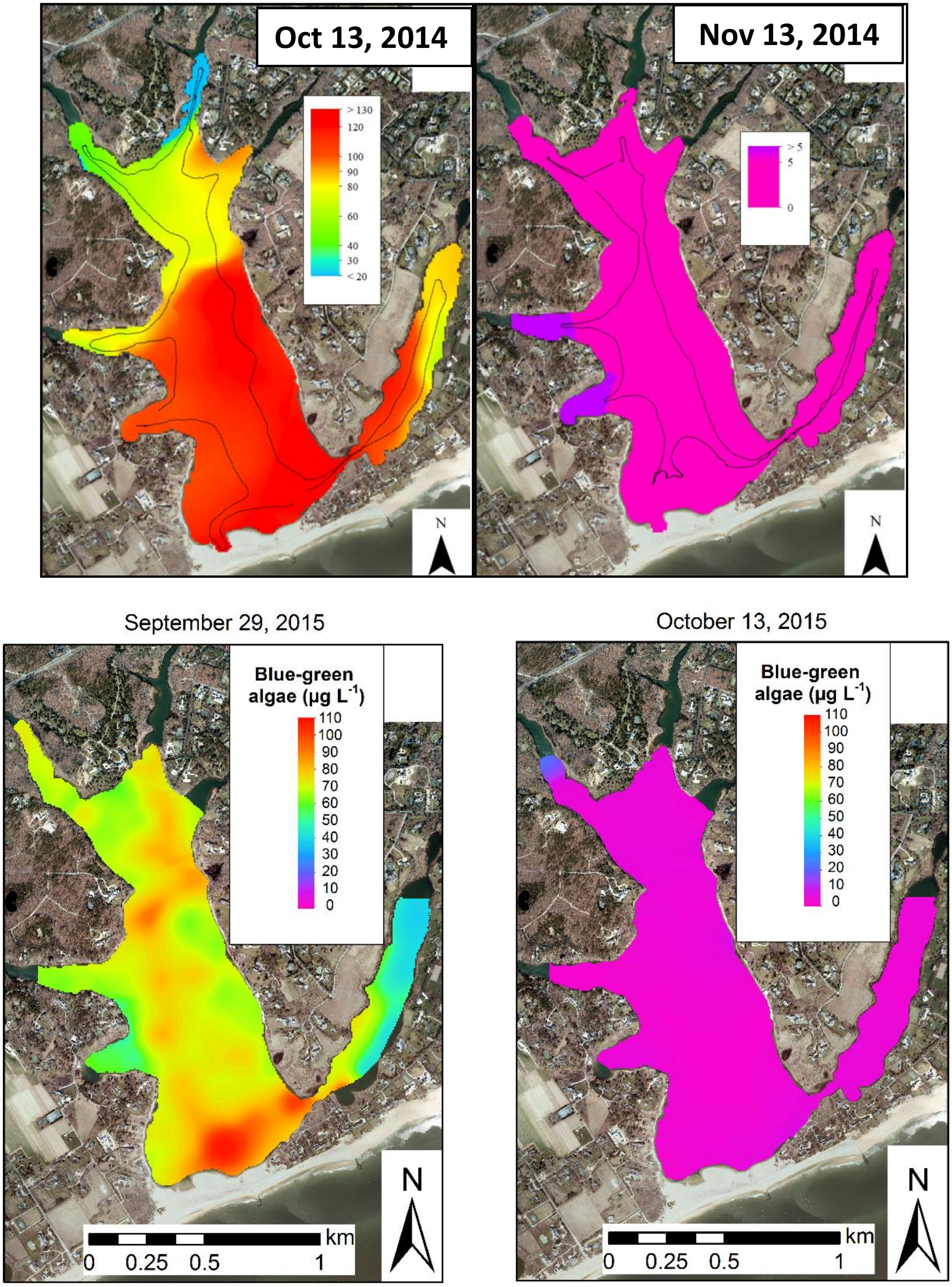


Figure 30: Blue green algal fluorescence data from cruises in 2014 and 2015, before and after the opening of the cut.

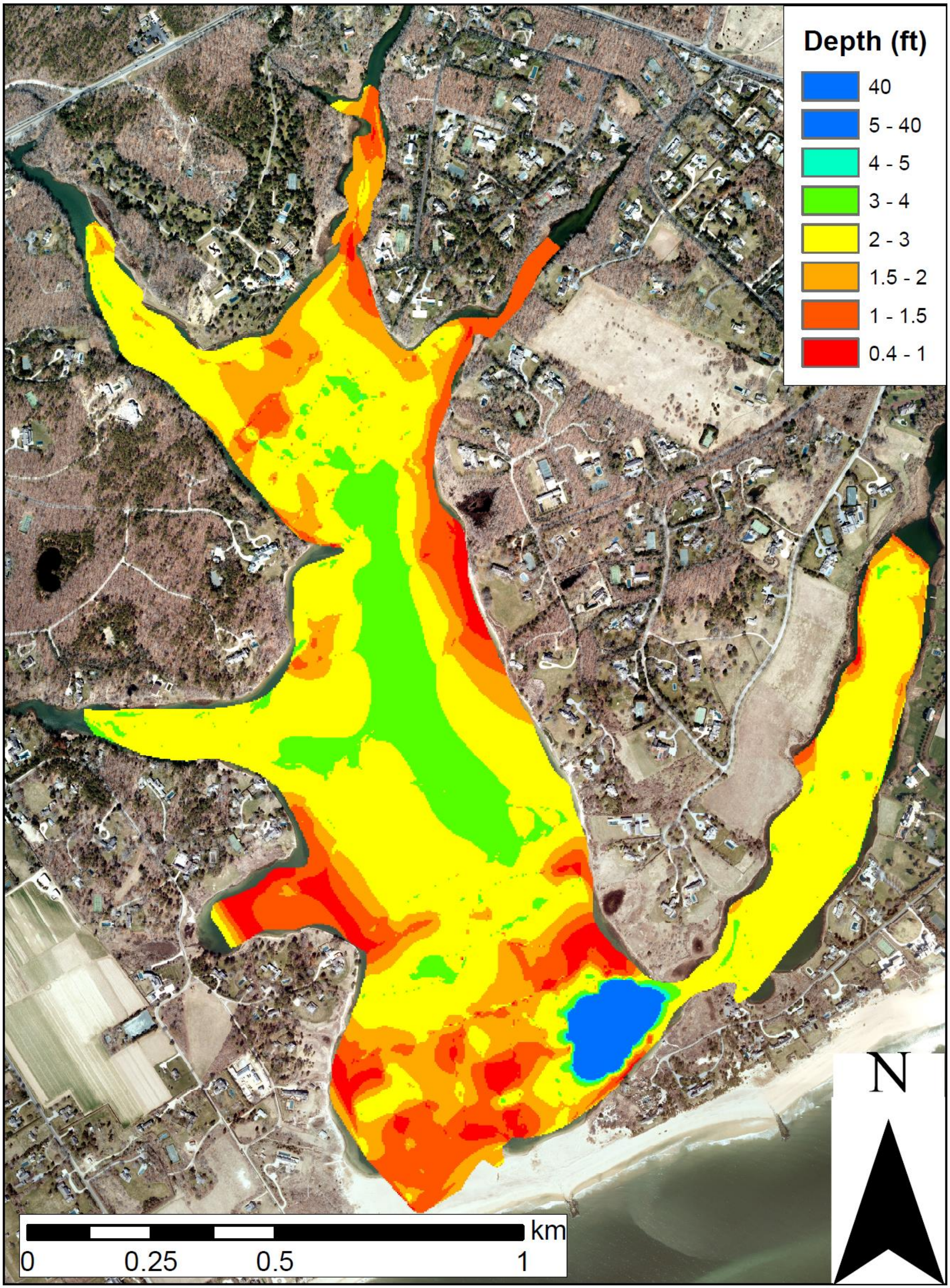


Figure 31: Bathymetry map of Georgica Pond, showing relative depth in feet.

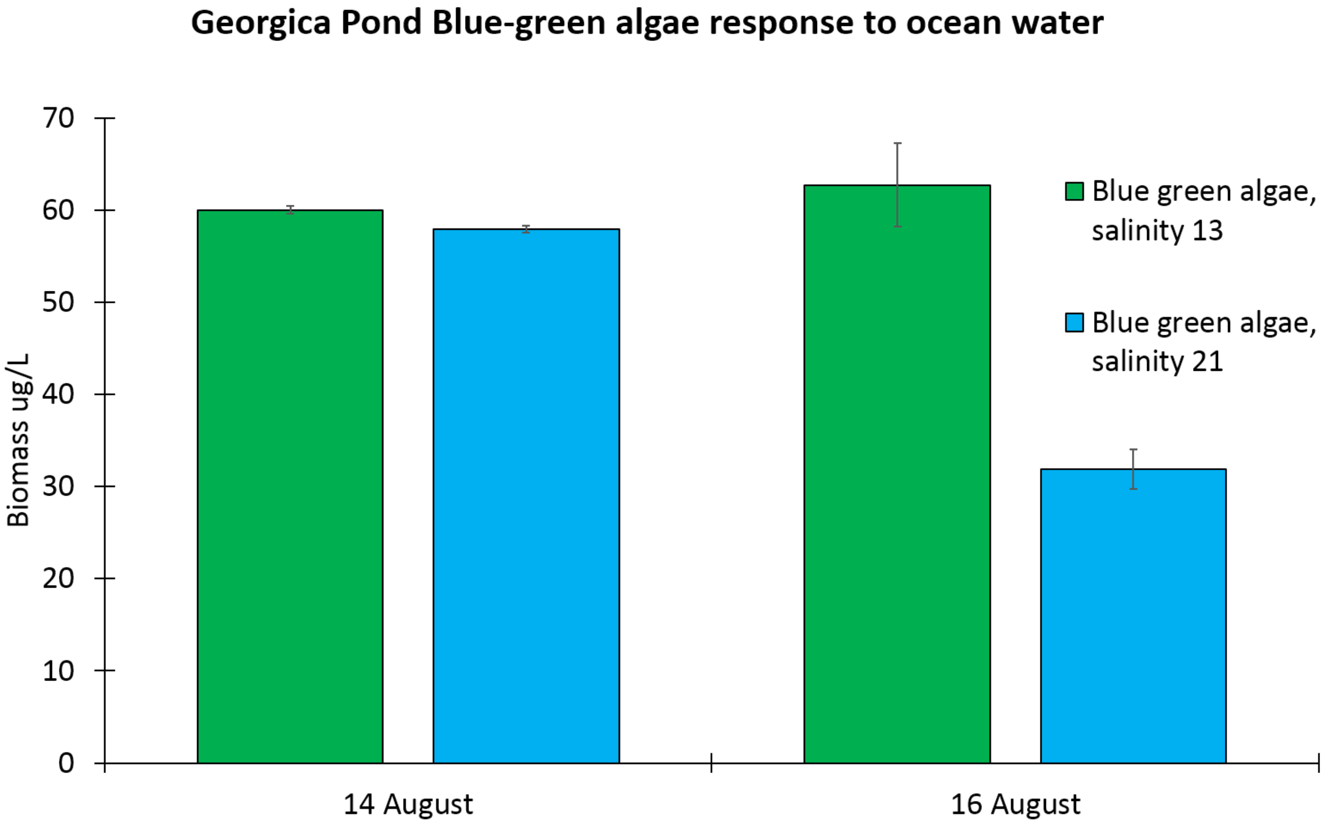


Figure 32. Effect of ocean and pond water on the levels of blue-green algae in Georgica Pond, August 2015.

Table 1. Nitrogen loading rates and sources for multiple water bodies in East Hampton Town.

Site	Nitrogen load kg/yr/ha	Nitrogen load kg/yr	Percent from Wastewater	Percent from Fertilizer	Percent from Atmosphere
Northwest Harbor	3.4	9500	44	10	41
Three Mile Harbor	6.1	16600	65	11	25
Accabonac Harbor	4.5	9300	60	9	31
Napeague, west	1.8	696	30	3	67
Napeague, east	1.6	279	16	2	82
Ammagansett	3.7	4602	37	6	39
Lake Montauk	5.1	4927	52	8	29
Montauk Point	1.5	1028	6	1	93