East Hampton Town Trustees 2017 water quality study, Draft Final Report

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 2017 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, Three-Mile Harbor, Fresh Pond, 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 from 2013 to 2016. During 2017, it was found that most East Hampton Town Trustees waters were of a high quality. Fecal coliform bacteria levels across marine sites were generally low through the spring and summer, with the exception of one date in Three Mile Harbor. The 2013 report to the Trustees indicated that Northwest Creek could be opened to shellfishing and that change was implemented by the NYSDEC in 2014. From 2014 – 2016 some regions of Three Mile Harbor, Northwest Harbor, and Hog Creek that are seasonally closed to shellfishing consistently had levels of fecal coliform bacteria below the levels that require closure. At nearly all marine locations, dissolved oxygen and chlorophyll *a* were at concentrations supportive of fisheries with the exception being within the Head of Three Mile Harbor and Georgica Pond. Harmful algae concentrations were generally low in 2017 with the exception of blooms of the harmful dinoflagellate *Cochlodinium* in Three-Mile Harbor and Accabonac Harbor. In contrast to most marine sites, the two East Hampton Town's freshwater bodies monitored by this study in 2017 displayed multiple water quality impairments. Hook Pond displayed high levels of chlorophyll *a*, but reasonable levels of dissolved oxygen (> 4 mg/L). While Georgica Pond had experienced a series of significant water quality impairments including hypoxia (low oxygen), fish kills, macroalgal blooms, and blue-green algal blooms in prior years, conditions were better in 2017, with the exception of a minor blue green algal bloom in June and an anoxic event and fish

kill following the opening of the ocean inlet in October. For the second time in two years, blue-green algae levels were low in Georgica Pond and an algae harvester was used to reduce nutrient levels suggesting this mitigation approach may help towards improving water quality. Testing of fecal coliform and *Enterococci* bacterial levels in Georgica Pond demonstrated levels occasionally exceed those recommended for swimming and an independent report has indicated that animals, rather than human, are the main source of fecal bacteria to this water body.

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). Since then PSP events 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 March through November of 2015.

Approach

The 2017 sampling season ran from April 10^{th} to November 3rd. Sampling was done on a biweekly basis, with the exceptions of Three Mile Harbor and Georgica Pond, which were sampled weekly. Sampling included eleven marine sites within Napeague Harbor, Accabonac Harbor, Hog Creek, Three-Mile Harbor, and Northwest Creek; and five freshwater sites within Georgica Pond and Hook Pond. Two sites in the brackish Fresh Pond were re-included this year, and sampled as freshwater sites.

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. One Onset HOBO data logger was also deployed at the head of Three-Mile Harbor to continuously record bottom temperature and dissolved oxygen levels over time. Additionally, water was collected at each of these eleven sites and analyzed for chlorophyll *a* and fecal coliform bacteria. Fecal coliform bacteria were quantified according to US EPA monitoring methods (EPA 1978). Water samples were collected onto filters and transferred onto agar plates permissive for the growth of coliforms, 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 water 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 June. The harmful “rust tide” dinoflagellate *Cochlodinium*, known for causing fish kills, was monitored from June through November. 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. *Alexandrium fundyense*, a toxic marine dinoflagellate responsible for paralytic shellfish poisoning, was sampled from April through June. 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 seven freshwater sites (four in Georgica, two in Fresh Pond, and one in Hook Pond) samples were collected for the quantification of chlorophyll *a*, temperature, salinity, and dissolved oxygen as described above. 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 identified using a microscope as described above.

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

Findings

Marine Systems

Fecal Coliform Bacteria

The concentrations of fecal coliform bacteria in 2017 varied slightly from the four-year average, with sites in Three Mile harbor being above average. The average 2017 fecal coliform bacteria concentrations ranged from 1 colony forming units (CFU)/100mL, to 19 CFU/100mL (Fig 1) nearly matching the 2016 range of 0 CFU/100mL to 19 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 the exception of Head of the Harbor, Three-Mile Harbor, with a mean fecal coliform value of 19 CFU/100mL, and reached a singular peak of 328 CFU/100mL on July 24thth (Fig 3). Head of the Harbor was the only site to surpass the 49 CFU/100mL limit, and did so only once. Landing Lane, Accabonac, had elevated levels in 2016, but was below both the average and individual limits in 2017 (Fig 2). Prior studies have generally shown that 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 comparatively higher fecal coliform concentrations in 2017 again showed this trend in Accabonac and Three-Mile Harbors (Fig 2).

Fecal coliform bacteria values measured in this study were compared with NYSDEC shellfish bed statuses. In 2017, measurements at 6 of the sites confirmed the DEC statuses, with five sites being under the limits. Comparing the cumulative measurements from 2015 to 2017, three sites were consistently below threshold. Hog Creek at Isle of Wight (Fig 5), Three-Mile at Hand's Creek (Fig 6), and Northwest Creek (Fig 6) were consistently below the average and individual thresholds for fecal coliform concentration (Fig 4). 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 2014 through 2017 suggests Northwest Creek to be one of the cleanest systems in regards to fecal coliforms (Fig 1 & 2). Similarly, regions in the southern extent of Hog Creek and the region near Hand's Creek have always been below NYSDEC fecal coliform standards but are seasonally closed.

Importantly, the National Shellfish Sanitation Program Guide for the Control of Molluscan Shellfish (2015) requires 30 data points for an official evaluation of water quality to be considered for shellfishing. 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 regard to shellfish sanitation in NY.

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 consequences including hypoxia and acidification, and could be a sign of the development of an algal bloom. The average chlorophyll *a* values for East Hampton's marine systems during the 2017 sampling season ranged from 4µg/L to 10µg/L (Fig 7), values onsistent with the values observed in prior years and near 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 sites averaged below this level. Concentrations at Head of the Harbor, Three-Mile Harbor, passed 20 µg/L on two occasions in July and August (Fig 9).

Regarding harmful algal blooms, 2017 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 2017, *Dinophysis* was not detected in East Hampton's marine waters (Fig 10). *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). In 2016, Accabonac, Three-Mile, and Northwest Creek, which had the most intense blooms. In 2017, concentrations were lower in

Three-Mile, and nearly absent in Northwest Creek, but were higher in Accabonac Harbor. The average *Cochlodinium* densities across all sites ranged from 0 cells/mL to 132 cells/mL in 2017 (Fig 11). Concentrations were higher than in 2015, but lower than they were in 2016 (Fig 12). Individual concentrations surpassed the 300 cell/mL toxicological limit in both Three Mile Harbor with 1,000 cells/mL, and Accabonac Harbor with 529 cells/mL (Fig 13). The peak of the bloom observed at Landing Ln., Accabonac Harbor, occurred August 3rd. Two blooms were observed in Three-Mile Harbor at Head of the Harbor; one on August 3rd at 779 cells/mL, and the other on August 14th at 1,000 cells/mL, with *Cochlodinium* being absent in the week between on August 7th. *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). All of these blooms were earlier than usually, as *Cochlodinium* blooms sometimes do not occur until September. Further, the intensity of *Cochlodinium* blooms obviously differs from year-to-year as is highlighted in Figure 12. These patterns demonstrate that, year-to-year, *Cochlodinium* behaves very differently in East Hampton Town waters, illustrating the importance of long term monitoring of water quality trends. It is notable that while *Cochlodinium* densities were lower in 2015, blooms were intense and more widespread in 2016 and 2017. 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 a shellfish beds closure due to these. In 2013, densities of *Alexandrium* exceeded 100 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 2016, only sites within Three Mile Harbor had observable levels of *Alexandrium*, with a maximum of 48 cells/L (Fig 15). In 2017, *Alexandrium* was absent across all marine sites with the exception of Head of the Harbor, Three-Mile, where it reached a maximum of 70 cells/L (Fig 14). These levels were well-below those known to cause toxicity. Concentrations of *Alexandrium* have been decreasing yearly since the peak bloom in 2013, emphasizing the importance of long term monitoring of water quality to capture such long term trends.

General Water Quality: Salinity & Dissolved Oxygen

Salinity across East Hampton's marine sites was relatively static, mostly staying within 29±1 PSU range and being generally higher at the sites closest to their respective inlets. Hog Creek, Isle of Wight, and Accabonac, Landing Ln., had slightly lower salinity of ~28 PSU (Fig 16). Mean levels of dissolved oxygen from discrete measurements ranged from 3.5 to 9.1 mg/L for marine sites, levels which are generally supportive of fisheries, shellfisheries, and wildlife (>5 mg/L; Fig 18). A continuous dissolved oxygen probe that records every 15 minutes at Head of the Harbor from May through August provided higher resolution data and demonstrated this region experienced periods of low dissolved oxygen throughout much of monitoring period (Fig 18). The site's mean dissolved oxygen level (6.4 mg/L) was above the level ideal for marine life and higher than it was the year before (5.21 mg/L) but the wide variation of dissolved oxygen levels between day and night is evidence of extreme ecosystem metabolism and eutrophication. On most nights during the three-and-a-half-month observation oxygen levels fell below the 3 mg/L and on occasion were anoxic (0 mg/L), indicating conditions unsuitable for all non-bacterial life (Fig 18).

For comparative purposes, NYSDEC's standard for dissolved oxygen for marine water bodies is above 3 mg/L, indicating that this is an impaired water body.

Addressing problems with eutrophication within Three Mile Harbor

During the past four years, Three Mile Harbor has displayed obvious 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 the 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. The Nature Conservancy analysis of nitrogen loading rates for the entire Peconic Estuary, including the Three Mile Harbor watershed indicated that the Three Mile Harbor watershed was has the highest 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 (Lloyd, 2014). 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% (Lloyd, 2014). Across all sites monitored by the Gobler, there has been 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 has also been 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.

As part of NYSDEC's Long Island Nitrogen Action Plan, a 'Subwatersheds' study is being conducted in Suffolk County. While that exercise has thus far affirmed the information above regarding Three Mile Harbor, it has also revealed two pieces of important information about this watershed. First, it has modeled the levels of nitrogen in groundwater surrounding Three Mile Harbor and has depicted a band of extremely high nitrogen (>10 mg/L) in the region surrounding the Head of the Harbor region. In prior reports, the slow flushing rate of the Head of the Harbor was emphasized due to it extreme distance from the Peconic Estuary inlet to Three Mile Harbor and the sand bar that separates the Head of the Harbor from the main basin of this system. Moreover, in prior assessments of Long Island water bodies in general, it has been shown that the combination of slow flushing and heavy nitrogen loads are the precise formula for severe water quality impairment. Hence, after four years of study and data collection, it can be concluded that the Head of the Harbor region is the most eutrophied and impaired marine water body in East Hampton, given Georgica Pond is brackish and not fully marine. As such the Head of the Harbor region is likely most deserved of wastewater remediation, since this is the largest source of nitrogen to this region and since flushing times are unlikely to change in the region.

One final piece of evidence from the LINAP subwatershed study brings good news regarding Three Mile Harbor. Specifically, the groundwater travel times for much of the watershed and specifically the high nitrogen region around Head of the Harbor have travel times are generally rapid. For the whole watershed, 62% of the groundwater drains into Three Mile Harbor is < 10 years and 80% enters in < 25 years. This means that, unlike regions of western Long Island where watershed travel times maybe hundreds of years, these rapid travel times assure that efforts to mitigate wastewater should yield a rapid improvement in water quality in this region.

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, especially around the Head of the Harbor region.

Hook Pond & Fresh Pond

Hook Pond was one of three freshwater bodies studied in 2017 in East Hampton. Chlorophyll *a* concentrations averaged 16 µg/L in 2017, compared to 21 µg/L the year prior, and had a maximum value of 24 µg/L (Fig 24, 25). Hook Pond exceeded the chlorophyll *a* threshold for a eutrophic freshwater body (>8 µg/L) on all dates sampled (Fig 26). Blue-green fluorescence, which serves as an analog for cyanobacterial biomass, had a mean value of 7 µg/L in 2017, compared to an average of 15 µg/L in 2016 (Fig 29, 30). The maximum blue-green fluorescence observed was 12 µg/L, remaining below the NYSDEC safety limit of 20 µg/L. The mean dissolved oxygen level was 11.6 mg/L, and the minimum value was 9.5 mg/L, both well above healthy waterbody levels set by NYSDEC (5 mg/L; Fig 33). However, with only one site, there is 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.

Fresh Pond was formerly a marine sampling site, but was discontinued in 2016 due to its low salinity, unsupportive of marine HABs. The brackish pond was reinstated in 2017 included among the freshwater site. The average Chlorophyll *a* values between the inlet and head of pond were fairly consistent, ranging between 11 and 13 µg/L, with maximum values of 23 and 24 µg/L respectively (Fig24). Chlorophyll a values were at their highest, and above the eutrophic threshold on the first day of sampling on September 5th. Blue-green fluorescence, was very low, with maximum values of 1 and 2 µg/L (Fig 29). Salinity was not measured, but measurements from 2014-15 showed the pond had an average salinity of 10-11 PSU. The mean dissolved oxygen levels were above 8.6 mg/L, and the minimum values were above 7.8 mg/L, at healthy waterbody levels (5 mg/L; Fig 34). Pathogenic bacteria: fecal coliforms and *Enterococci*, were also measured in the pond. Average *Enterococci* values ranged from 22 to 24 CFU/100mL, under the average and individual measurement limits for bathing (Fig 22). Average fecal coliform levels ranged from 139 to 227 CFU/100mL, surpassing the bathing limit of 200 CFU/100mL at the inlet (Fig 19)

Georgica Pond

Fecal Coliform and Enterococci Bacteria

The average fecal coliform values in Georgica Pond ranged from 55 CFU/100mL to 361 CFU/100mL in 2017 (Fig 19). All four sites were well above the average shellfishing safety limit of 14 CFU/100mL, conistent with the NYSDEC shellfishing closure there. Georgica Pond South surpassed the average bathing safety limit of 200 CFU/100mL, as well as the individual date limit of 1,000 CFU/100Ml (Fig 19). Site 15, the kayak launch on Rt. 27 had the highest values in 2016, but had the lowest average and maximum concentrations in 2017 (Fig 20).

Enterococci bacterial levels were also measured as they are a generally more accepted measure for bathing beach evaluation. Average values ranged from 10 CFU/100mL to 31

CFU/100mL, with a maximum value of 49 CFU/100mL being measured at Georgica Pond South (Fig 22). *Enterococci* values surpassed both the average bathing safety limit standard of 35 CFU/100mL, and the individual sample bathing safety limit of 104 CFU/100mL at three sites in 2016, but remained below both limits in 2017 (Fig 23).

Harmful Algae

Georgica Pond had been substantially impaired by algae for the first three years of observation. A total of four stations have been included since 2014 to provide data more representative of the pond as a whole. The greatest chlorophyll *a* values measured in East Hampton Town waters have been consistently sampled in Georgica Pond. Average Chlorophyll *a* values in 2017 ranged from 8 µg/L to 16 µg/L, with the highest mean value measured in southern Georgica, with 16 µg/L (Fig 24). These are significantly lower than the average levels measure in 2016, which ranged from 19 µg/L to 31 µg/L (Fig 25). Sites, with the exception of site 15, still had mean chlorophyll *a* concentrations over 8 µg/L, above the USEPA eutrophic level for freshwater bodies. Sites were over this level when sampling began in early May and declined from there. Values dropped below 8 µg/L for site 15 by August, but persisted across the other three sites for the whole of the sampling season. The highest level of chlorophyll *a* was measured in Georgica Cove on May 8th, with a value of 39 µg/L (Fig 27). For the entire year, chlorophyll a levels were high in May and June, low in July and August, and higher in September and October (Figure 28). While chlorophyll a levels were very low following the opening of the cut in mid-October, they rose again shortly there after and were somewhat elevated in November (Figure 28).

Georgica Pond and Georgica Cove experienced dense blooms of the filamentous macroalga *Cladophora vagabunda*, and subaquatic plant Sago pondweed (*Stuckenia pectinata*) for much of the early summer in 2014, and again in 2015, and was a nuisance for recreational use and shoreline cleanup of the pond. The alga forms thick, bright green mats on the surface which were common in all of the protected creeks and coves of the pond. The alga was also present subsurface and covered much of the bottom of the pond. 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. For 2016 and 2017, mitigation efforts focused on the use of a mechanical algae harvester, which removed these two nuisance species from the surface and subsurface of the pond and surface of the pond remained mostly clear for the whole of the summer, which *Cladophora* growth limited to the shallows very close to shore.

Toxic Cyanobacteria

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 2014 and 2015, but values in 2016 were significantly lower; a trend which continued into 2017. The highest levels in 2017 were seen in southwestern Georgica Pond, with mean blue-green algal fluorescence at 11 µg/L and slightly lower levels within southern Georgica Pond, 10 µg/L (Fig 29). These averages are significantly lower than the years prior, which had decreased from 121 µg/L, to 26 µg/L in 2015 and 2016, respectively (Fig 30). In 2015, 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. In 2017, average values for all four sites sampled remained below 20 μg/L (Fig 29). Talmage Creek along Rt. 27, southwest and southern Georgica each had a single date in early June where blue-green values rose into the twenties, prompting a brief closure of the Pond by NYSDEC (Fig 31). Identification of cyanobacterial cells during the small bloom in 2017 showed *Microcystis* to be present. Toxin samples were taken and analyzed during the minor cyanobacterial bloom where blue-green fluorescence passed 20μg/L. Microcystin was present, but at very low concentration, and below the WHO standard for drinking water of 1 μg/L. Thereafter, levels decreased and remained relatively low through the summer, increased slightly in September, and then declined to low levels through the rest of the sampling year (Fig 32). In summary, blue-green algae levels were low in 2017, despite the very low levels of salinity and closed nature of the Pond through the summer, two conditions that would make the system vulnerable to blue-green algae blooms. The absence of blooms could be attributable to the lack and/or harvest of macroalgae or natural interannual variability.

Salinity & Dissolved Oxygen

Salinity recorded by the telemetry buoy indicated that since the pond remained closed for most of the sampling year, salinity was below 5 PSU, which is supportive of cyanobacterial growth (Orr et al 2004). Upon opening on October 17th, salinity rose sharply to 28 PSU, before declining into the Fall (Fig 32).The average levels of discrete dissolved oxygen measurements ranged from 5.4 to 9.6 mg/L, with the lowest measurement at Rt. 27 (Fig 33). The three other sites were around 9 mg/L, which is safely above the NYSDEC minimum daily average of 5 mg/L to support wildlife (class C waters; http://www.dec.ny.gov/regs/4592.html). The minimum values in 2017 for all sites remained above 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 dissolved oxygen was complemented by the redeployment of the continuously logging telemetry buoy, located in the south end of Georgica Pond, near the southern Georgica (GPS) shore sampling site (Fig 34). For most of the year, oxygen levels were within a healthy range. However, dissolved oxygen concentrations fell to zero following the opening of the inlet and remained at that level for more than two days (Fig 35) perhaps due to tidal exposure of mud flats and/or the possible die-off of aquatic organisms which were observed at that time. These observations are somewhat consistent with prior observations made 2014, 2015, and 2016, although the duration and severity of the low oxygen conditions following the 2017 cut opening exceeded those in prior years. 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 may to be lower and more susceptible to hypoxia.

Addendum:

The following two reports were based on 2017 sampling in Georgica Pond, were completed for the Friends of Georgia Pond, and are available upon request:

1. "Evaluation of macroalgae and aquatic plant harvesting as a means for improving water quality in Georgica Pond", January 2018

2. "Source tracking of fecal bacteria in Georgica Pond, January 2018

Summaries of these reports will be presented to the Trustees orally in April 2018.

Citations

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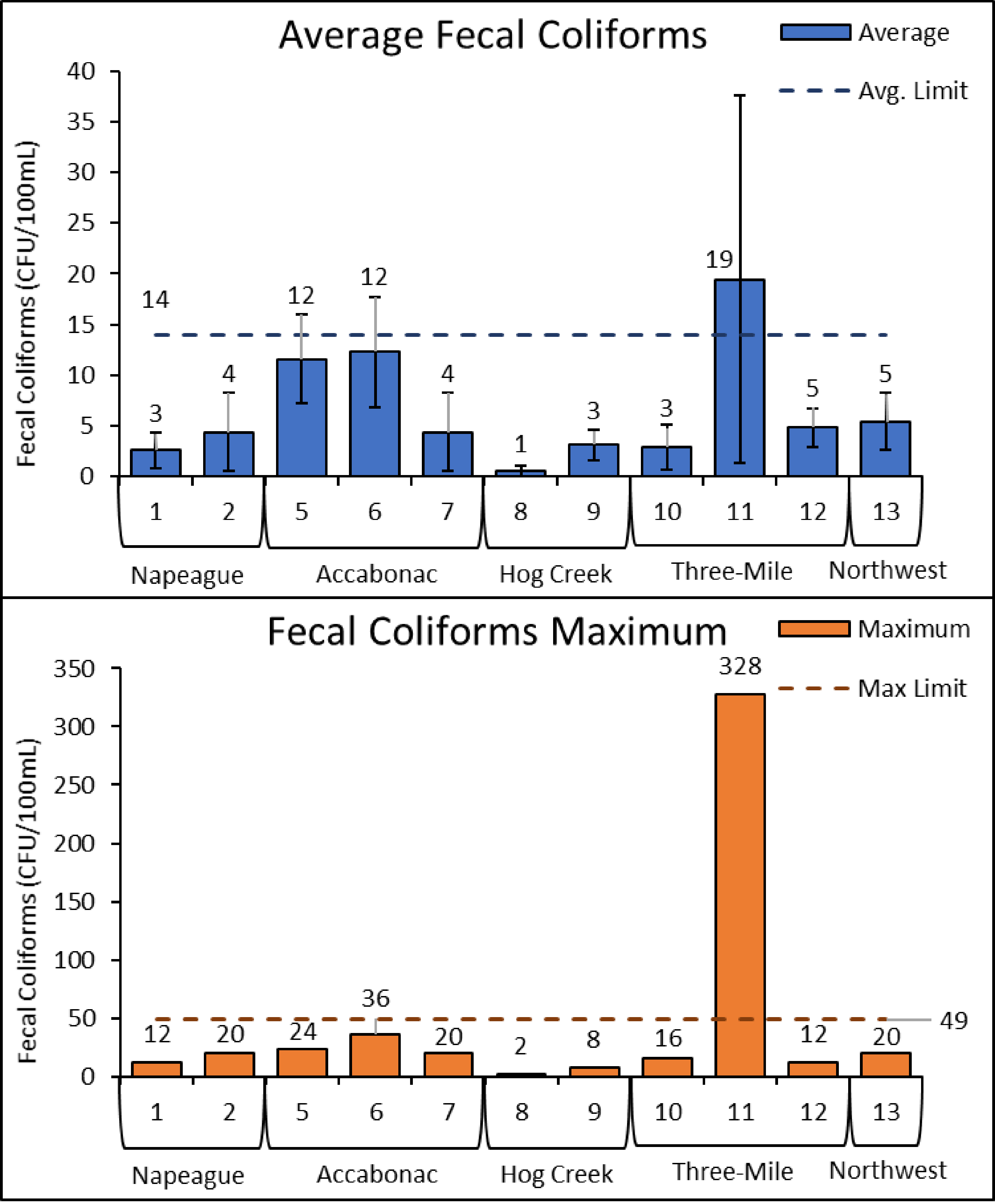

Figure 1: Average and maximum recorded fecal coliform bacteria values for marine sites from March through November of 2017. Error bars show standard error. Dashed lines show shellfishing safety limits.

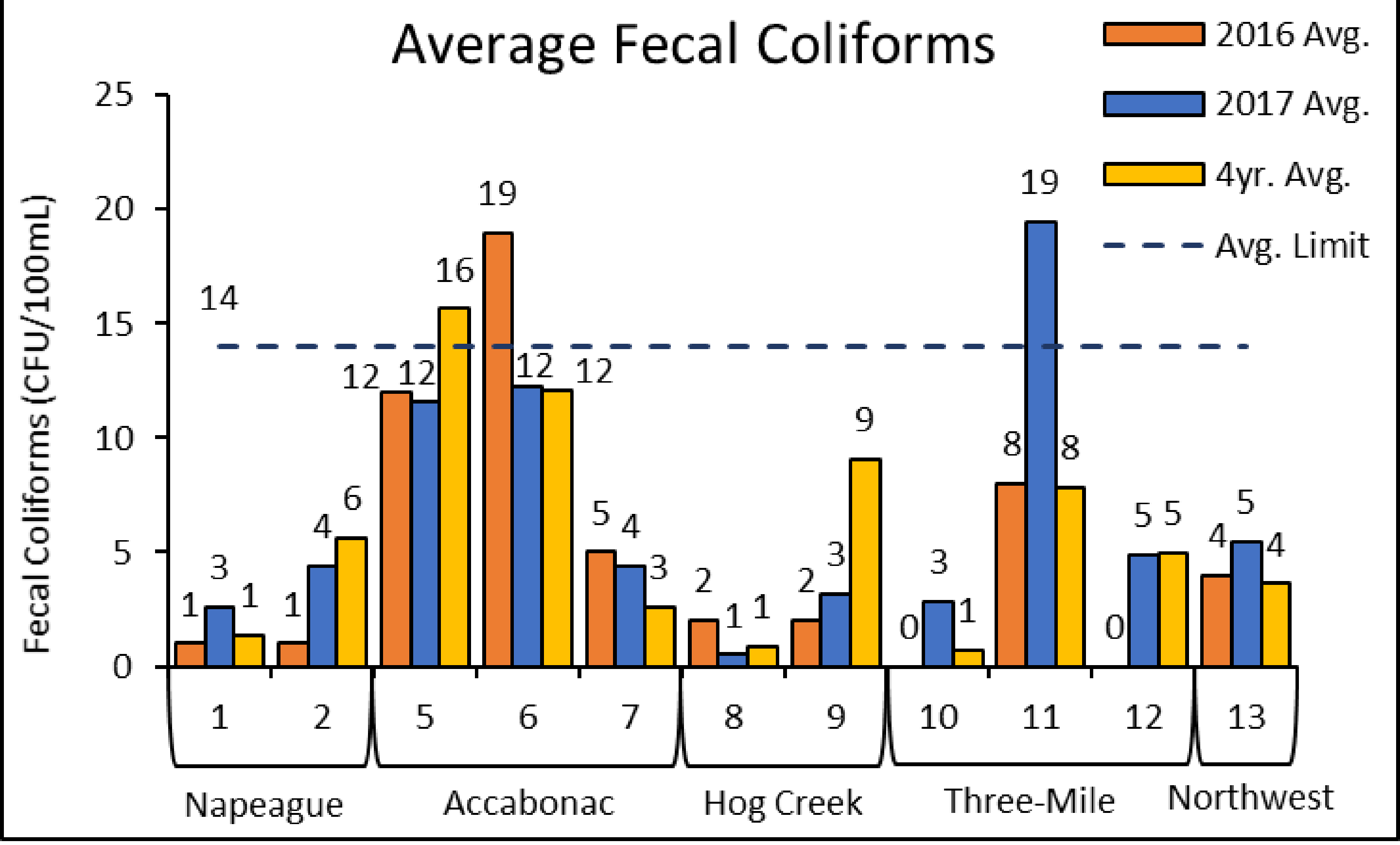

Figure 2: Comparison of average fecal coliform bacteria levels from 2016 and 2017, with running four-year average. Error bars show standard error. Dashed line shows shellfishing safety limit.

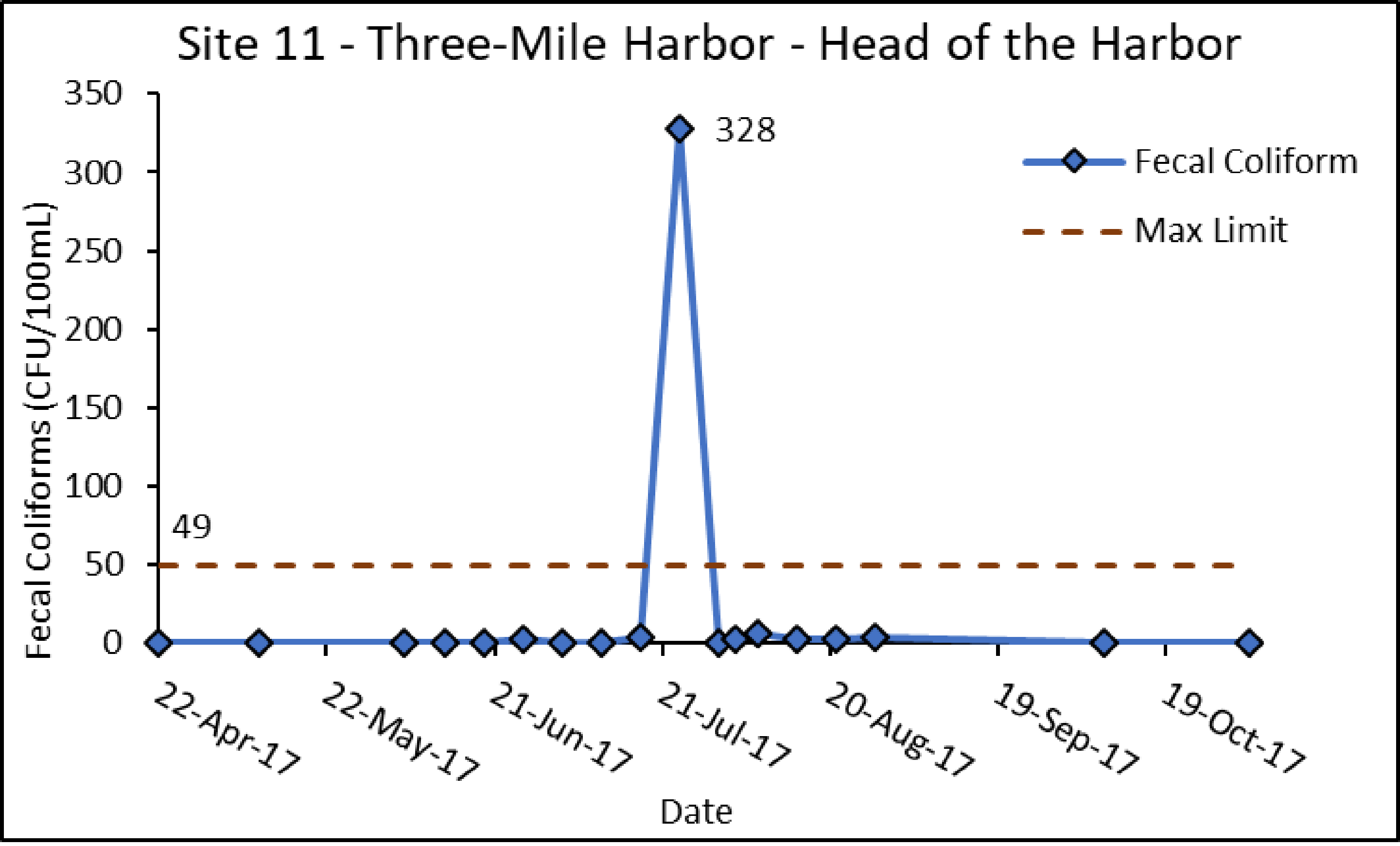

Figure 3: Fecal coliform bacteria concentrations over time from Head of the Harbor, Three-Mile Harbor, which exceeded the average and individual date shell fishing limit.

		2015			2016			2017		
Site #	Site Name	Measure	DEC Status	Comparison	Measure	DEC Status	Comparison	Measure	DEC Status	Comparison
1	Napeague	Below	Open	Confirms	Below	Open	Confirms	Below	Open	Confirms
2	Napeague - Lazy Point	Below	Open	Confirms	Below	Open	Confirms	Below	Open	Confirms
5	Accabonac - Louse Point	Below	Seasonal	Below	Mixed	Seasonal	Confirms	Below	Seasonal	Below
6	Accabonac - Landing Lane	Below	Seasonal	Below	Above	Seasonal	Confirms	Below	Seasonal	Below
7	Accabonac - Gerard Drive	Below	Open	Confirms	Below	Open	Comfirms	Below	Open	Confimrs
8	Hog Creek - Clearwater	Below	Seasonal	Below	Below	Open	Comfirms	Below	Open	Confirms
9	Hog Creek - Isle of Wight	Below	Seasonal	Below	Below	Seasonal	Below	Below	Seasonal	Below
10	Three Mile Harbor - Gann Road	Below	Open	Confirms	Below	Open	Confirms	Below	Open	Confirms
11	Three Mile Harbor - Head of the Harbor	Below	Closed	Below	Mixed	Closed	Confirms	Above	Closed	Confirms
12	Three Mile Harbor - Hand's Creek	Below	Seasonal	Below	Below	Seasonal	Below	Below	Seasonal	Below
13	Northwest Creek	Below	Seasonal	Below	Below	Seasonal	Below	Below	Seasonal	Below

		Cumulative		
Site #	Site Name	Measure	DEC Status	Comparison
1	Napeague	Below	Open	Confirms
2	Napeague - Lazy Point	Below	Open	Confirms
5	Accabonac - Louse Point	Mixed	Seasonal	Confirms
6	Accabonac - Landing Lane	Mixed	Seasonal	Confirms
7	Accabonac - Gerard Drive	Below	Open	Confirms
8	Hog Creek - Clearwater	Below	Open	Comfirms
9	Hog Creek - Isle of Wight	Below	Seasonal	Below
10	Three Mile Harbor - Gann Road	Below	Open	Confirms
11	Three Mile Harbor - Head of the Harbor	Mixed	Closed	Confirms
12	Three Mile Harbor - Hand's Creek	Below	Seasonal	Below
13	Northwest Creek	Below	Seasonal	Below

Figure 4: Comparison of 2015-2017 fecal coliform measurements relative to thresholds, with NYSDEC shellfish bed statuses. Top table shows individual years, and bottom table shows cumulative trends. “Mixed” measurements were below the average threshold, but above the single date limit.

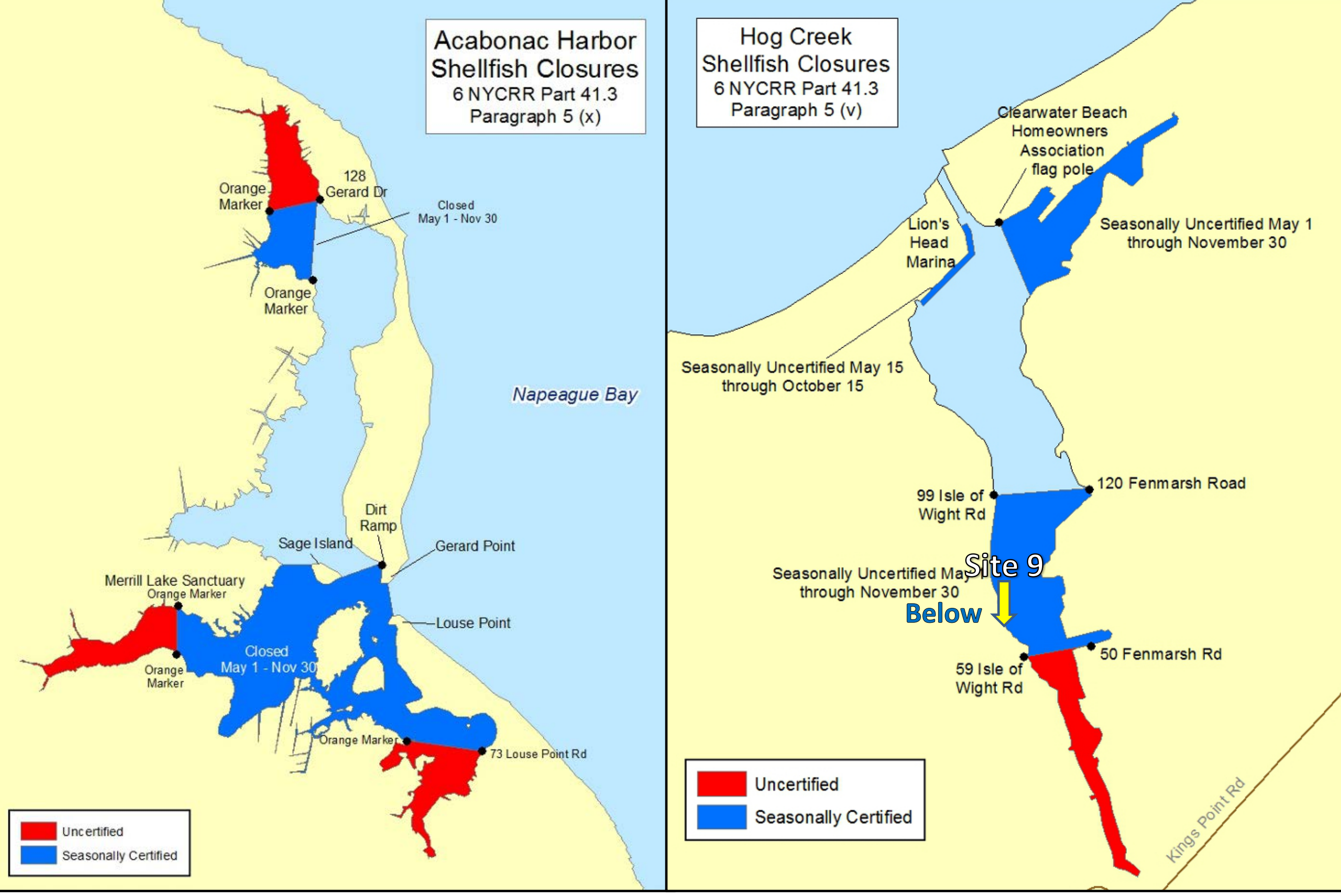

Figure 5: Maps showing 2017 NYSDEC shellfish bed statuses for Accabonac Harbor, and Hog Creek, as well as showing sampling sites. The seasonally closed region in southern Hog Creek has been below all fecal coliform bacterial standards since 2015.

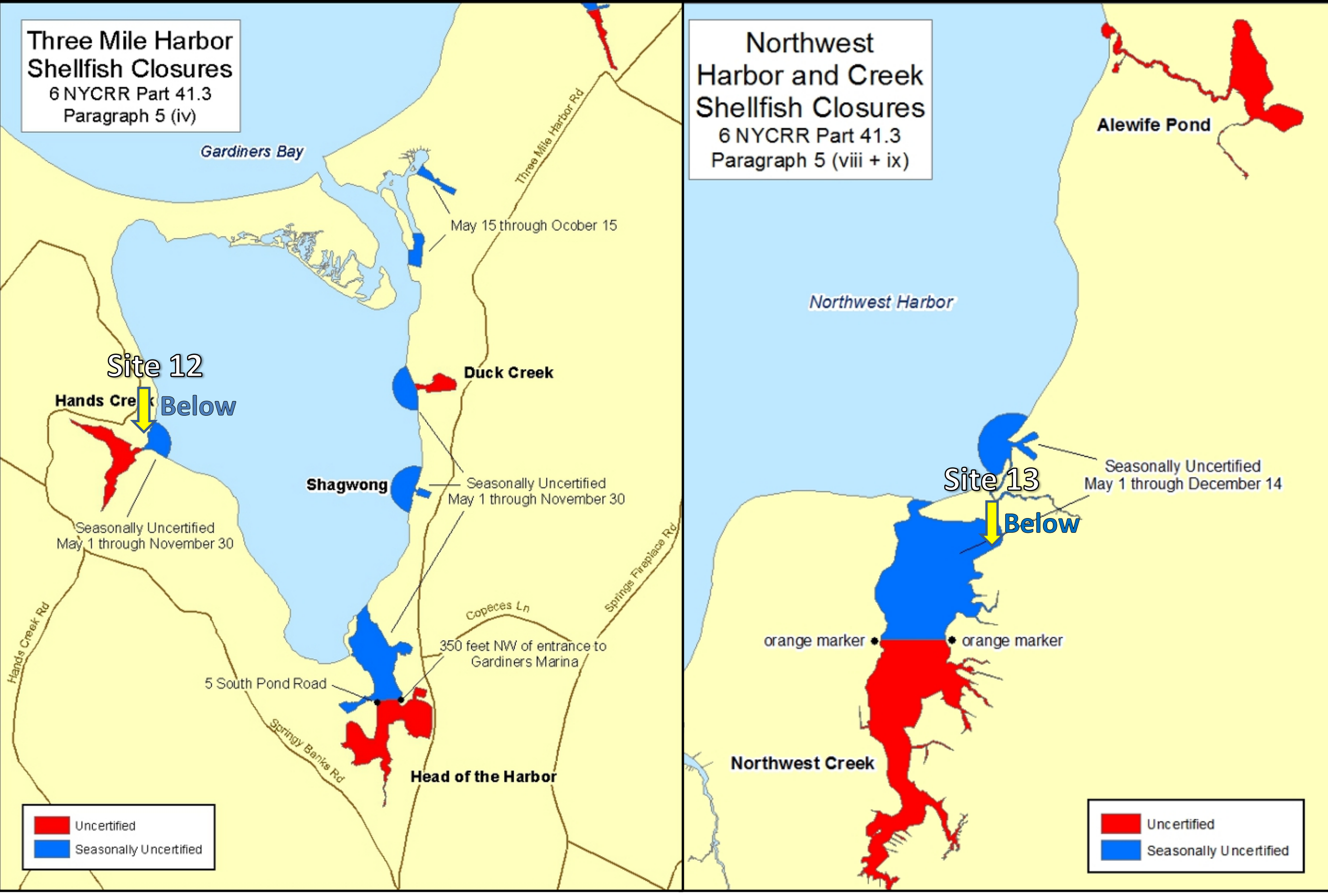

Figure 6: Maps showing 2017 NYSDEC shellfish bed statuses for Three Mile Harbor, and Northwest Creek, as well as showing sampling sites. The seasonally closed region in Northwest Creek and by Hand's Creek has been below all fecal coliform bacterial standards on all dates measured since 2015.

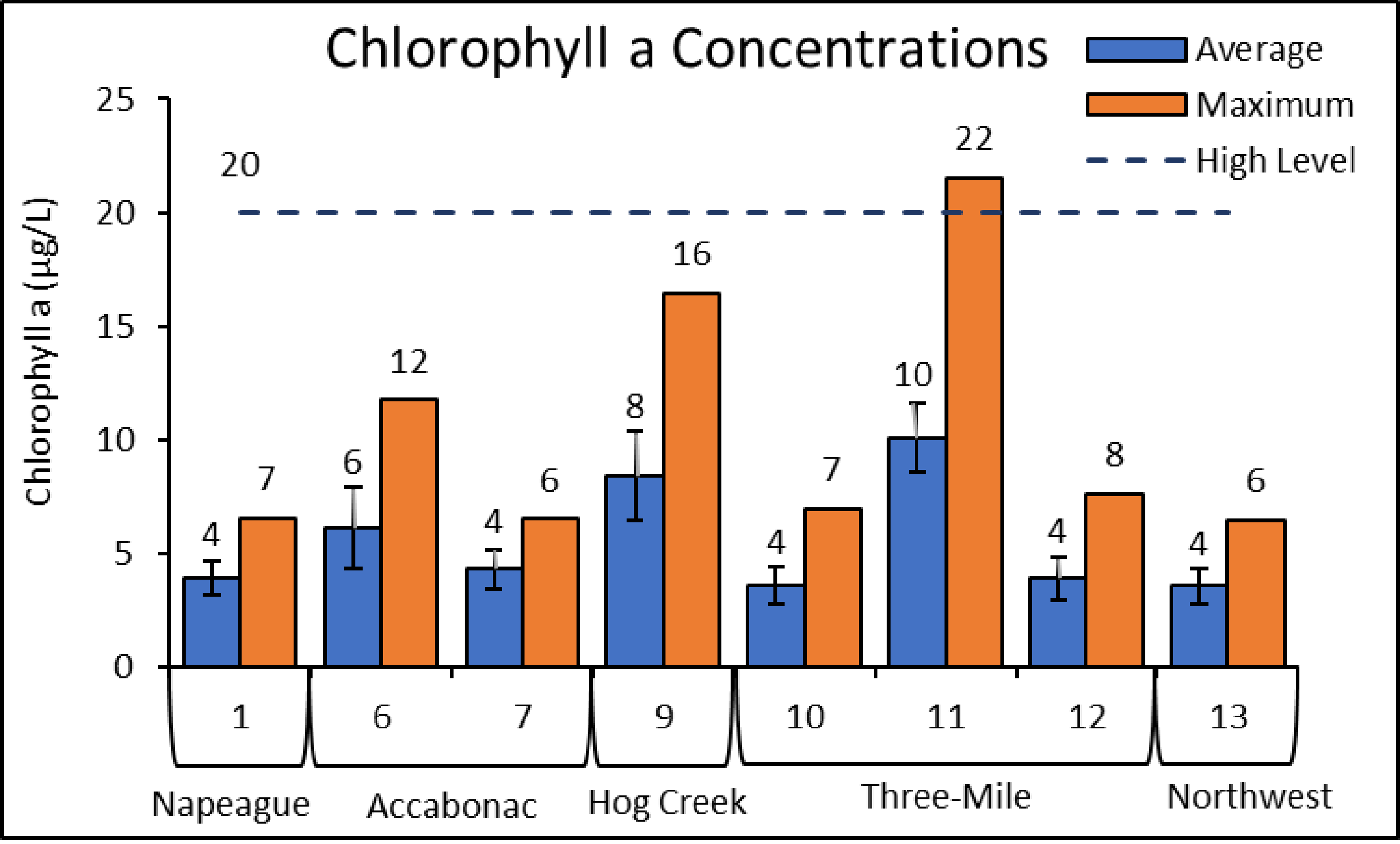

Figure 7: Average and maximum recorded chlorophyll a values for marine sites from April through November of 2017. Error bars show standard error. Dashed line shows high level.

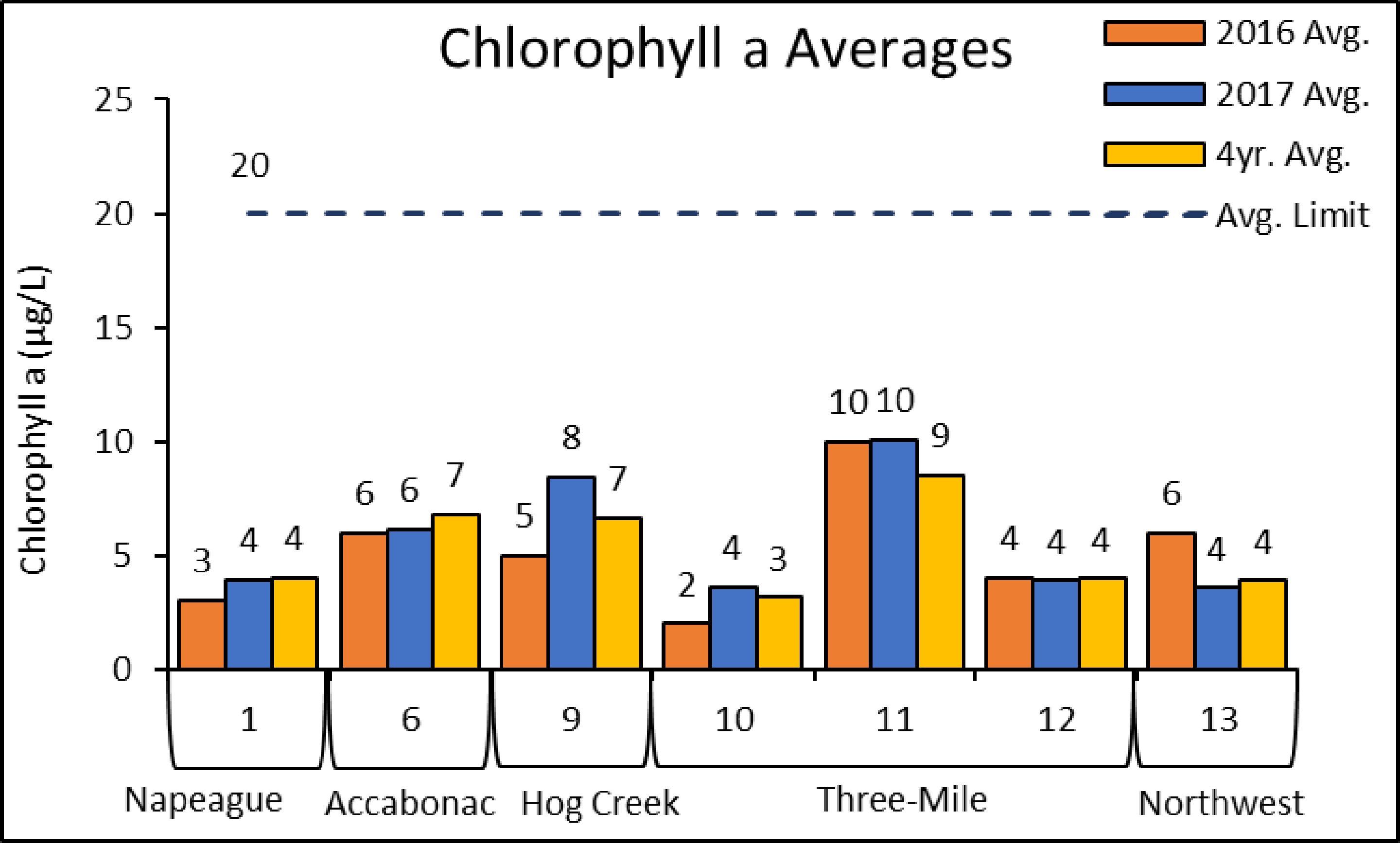

Figure 8: Comparison of average chlorophyll a levels from 2016 and 2017, with running four-year average. Error bars show standard error. Dashed line shows high level of 20 µg/L.

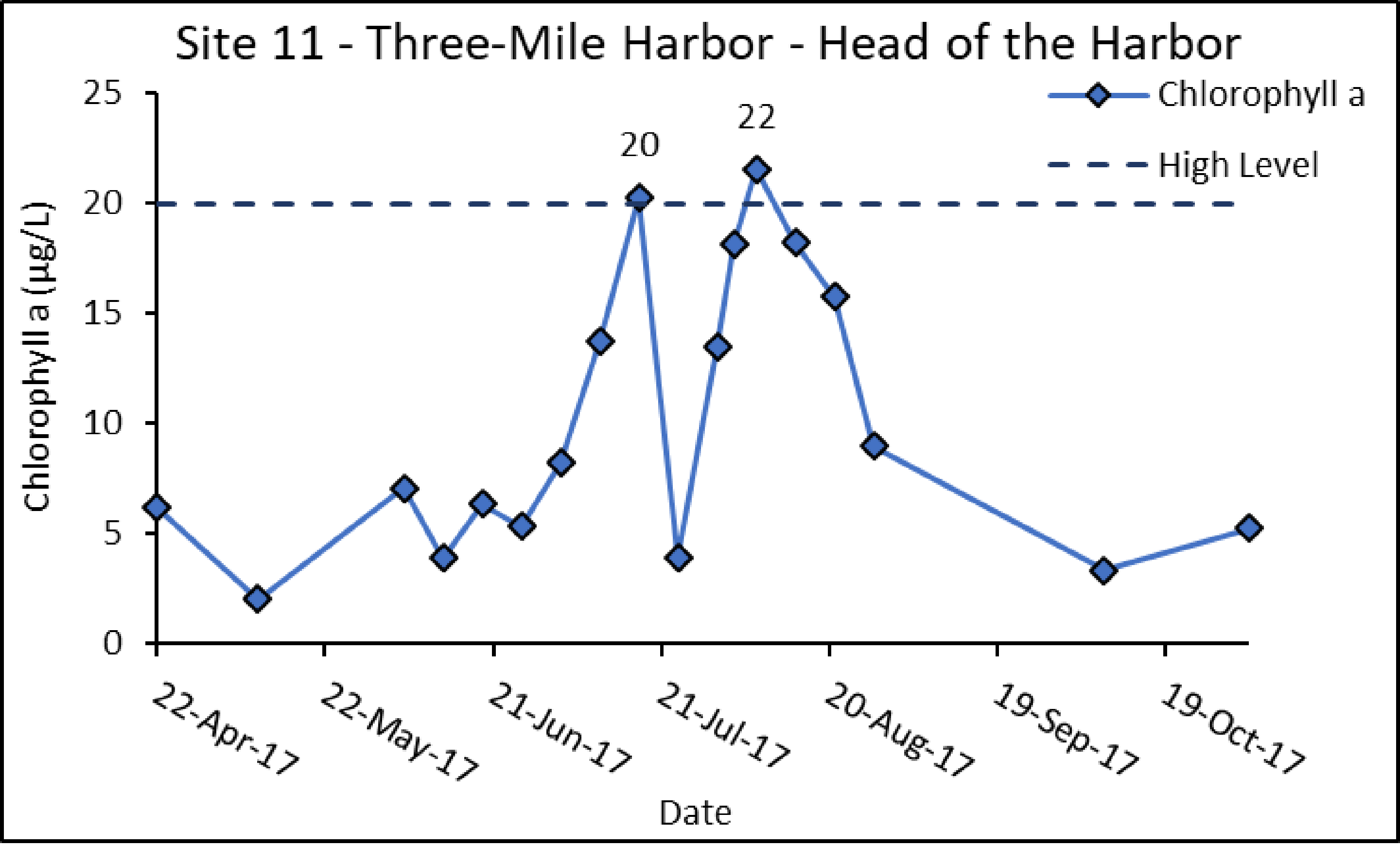

Figure 9: Chlorophyll a levels over time for Head of the Harbor, Three-Mile, which exceeded the high level of 20 µg/L.

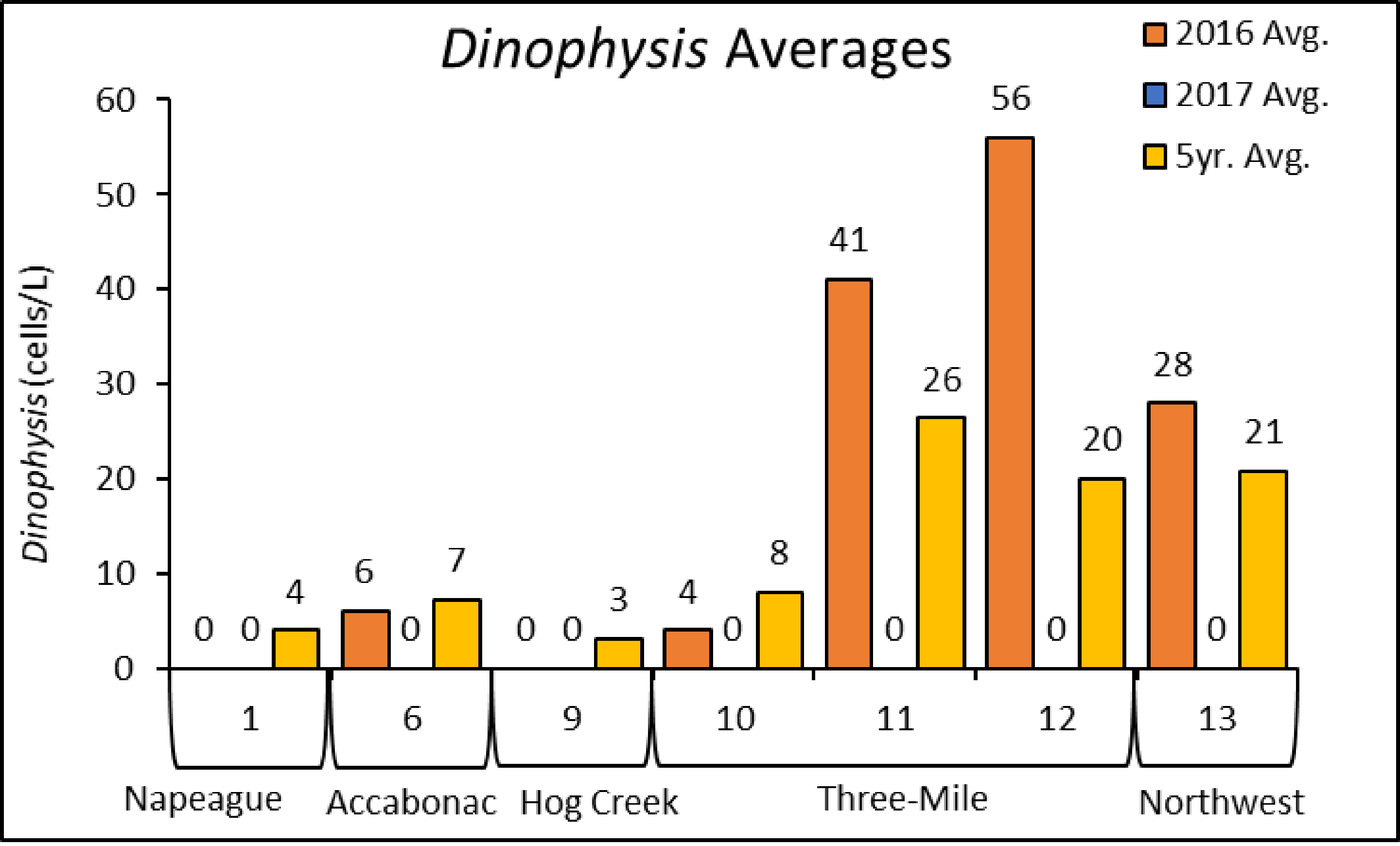

Figure 10: Comparison of average *Dinophysis* concentrations from 2016 and 2017, with the five-year average. Level of concern of 10,000 cells/L not shown within range.

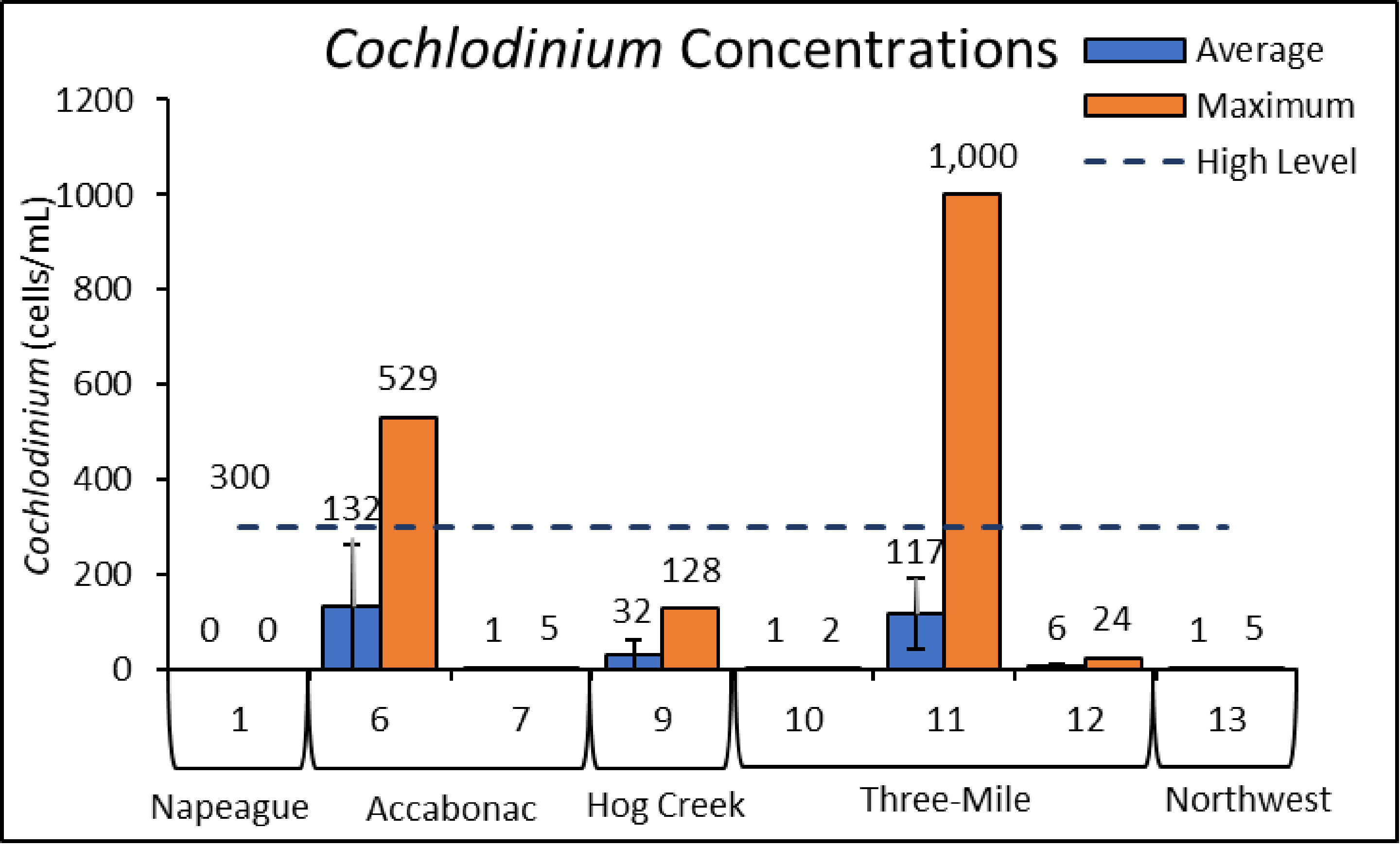

Figure 11: Average and maximum counts of the harmful dinoflagellate *Cochlodinium*. Error bars showing Standard Error. Samples were collected from June into November 2017. Values shown on logarithmic scale.

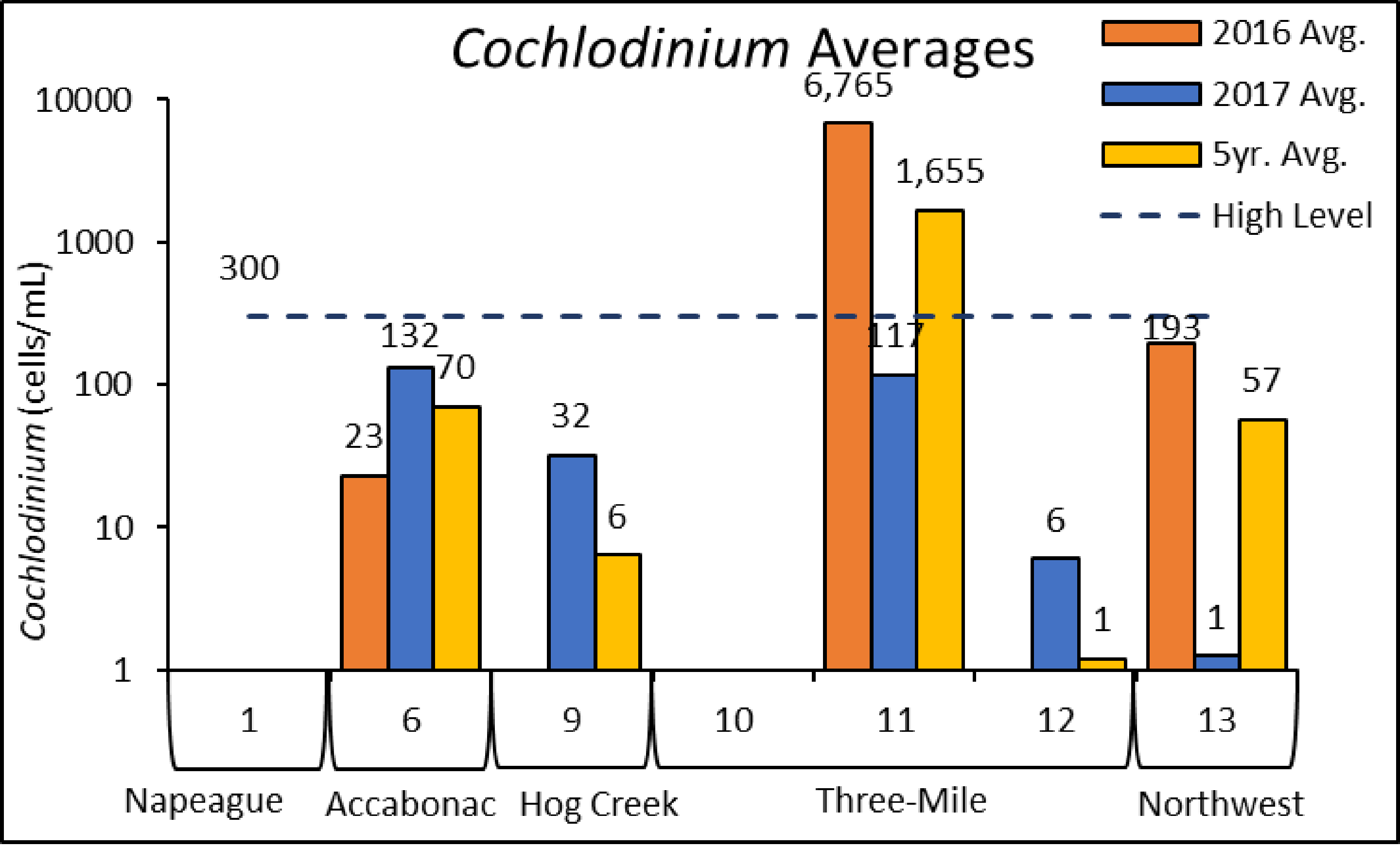

Figure 12: Comparison of average *Cochlodinium* concentrations from 2016 and 2017, with the five-year average. Values shown on logarithmic scale.

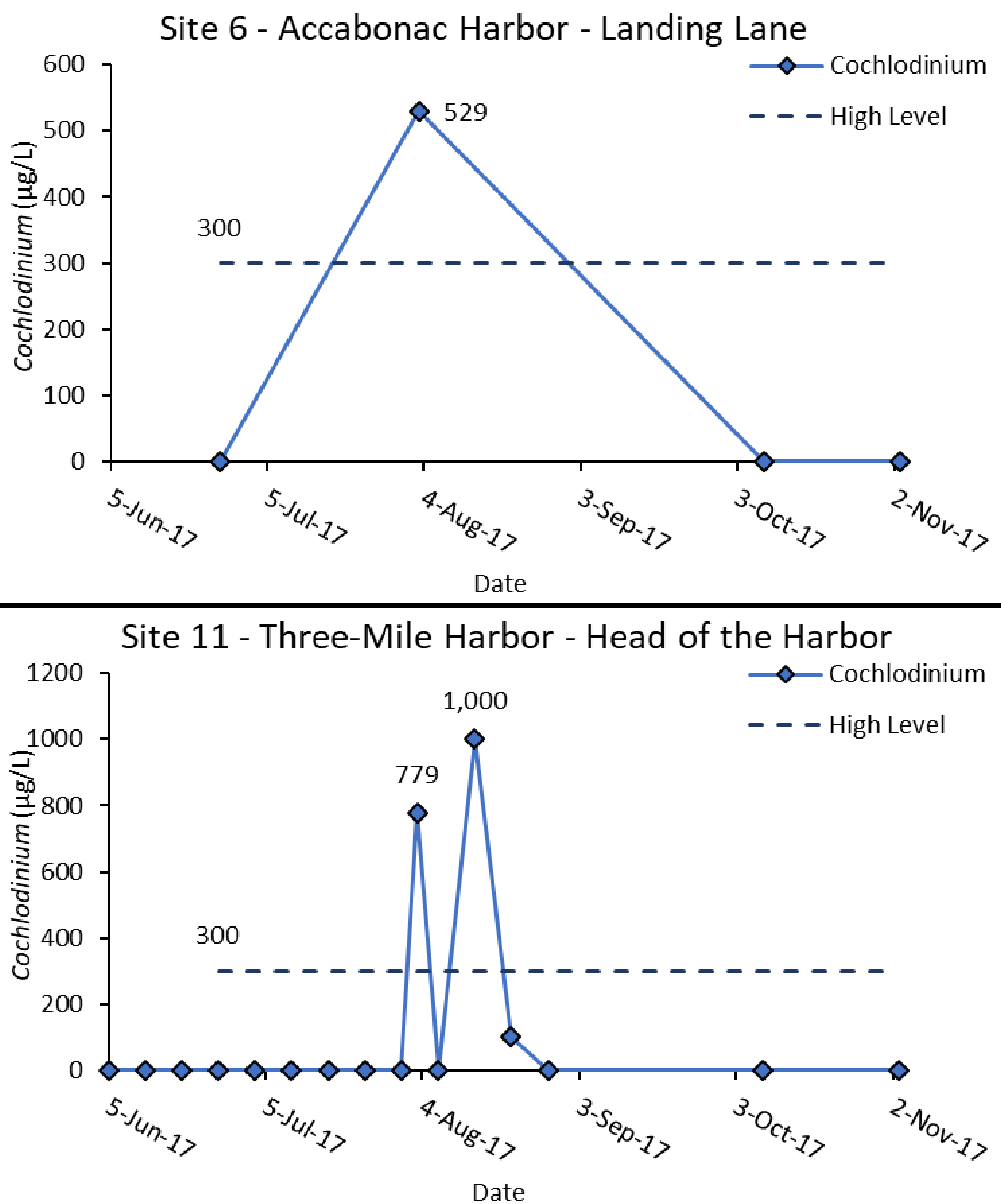

Figure 13: *Cochlodinium* levels over time for two sites that exceeded the level of concern of 300 cells/mL.

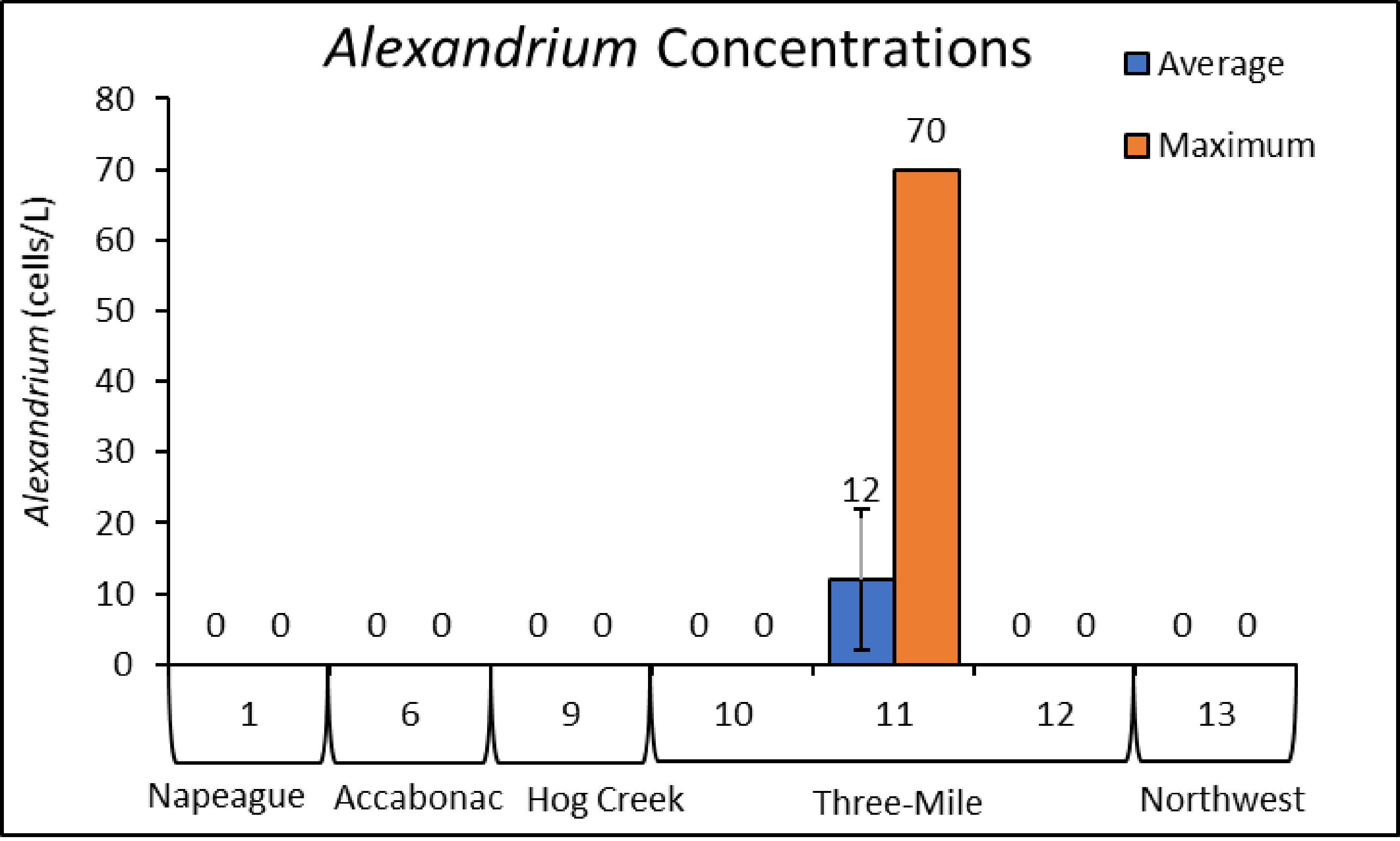

Figure 14: Average and maximum counts of the harmful dinoflagellate *Alexandrium*. Error bars showing Standard Error. Samples were collected from April into June 2017. Level of concern of 100 cells/L not shown within range.

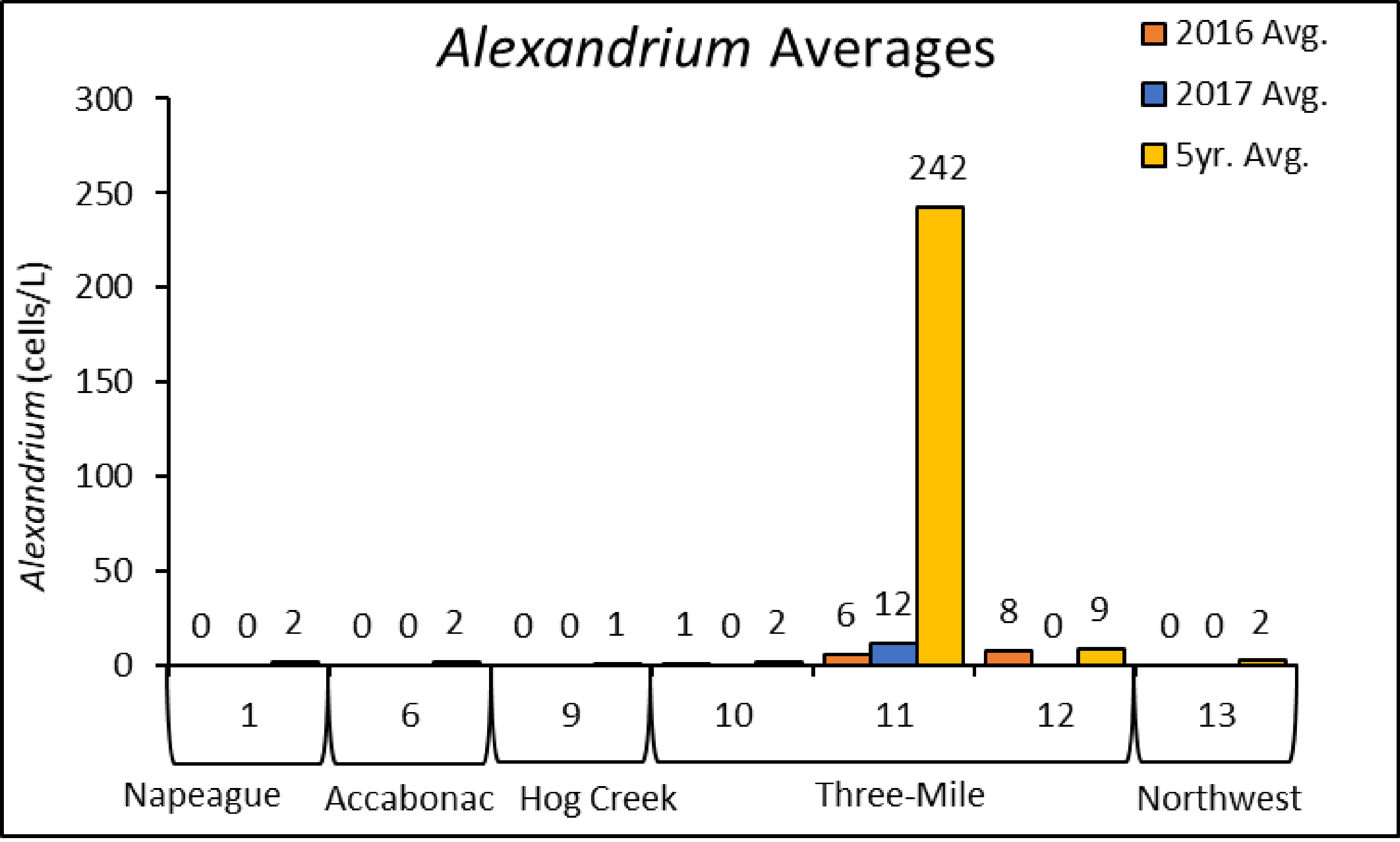

Figure 15: Comparison of average *Alexandrium* concentrations from 2016 and 2017, with the five-year average. Level of concern of 1,000 cells/L not shown within range.

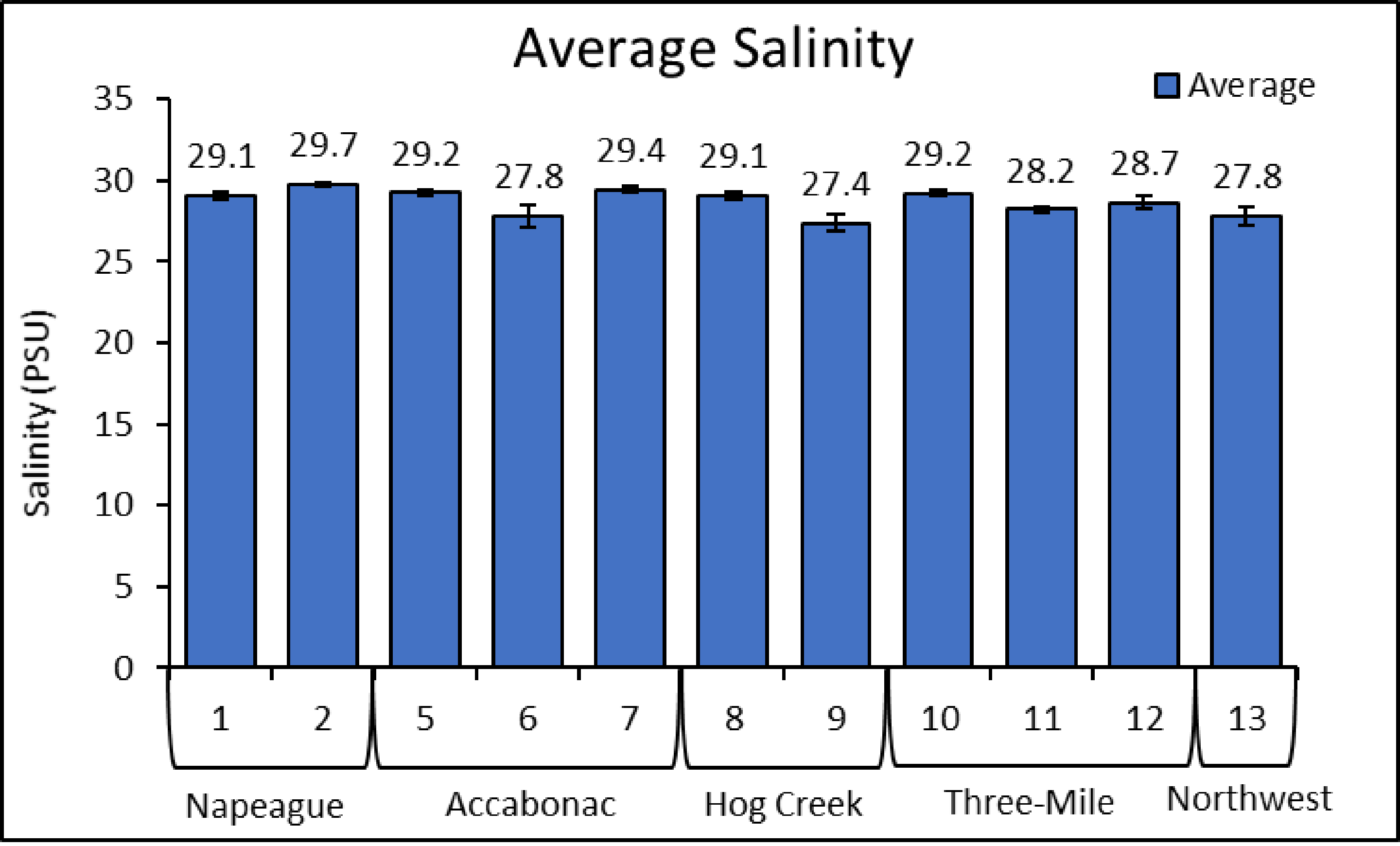

Figure 16: Average salinity values for marine sites from April through November of 2017. Error bars show standard error.

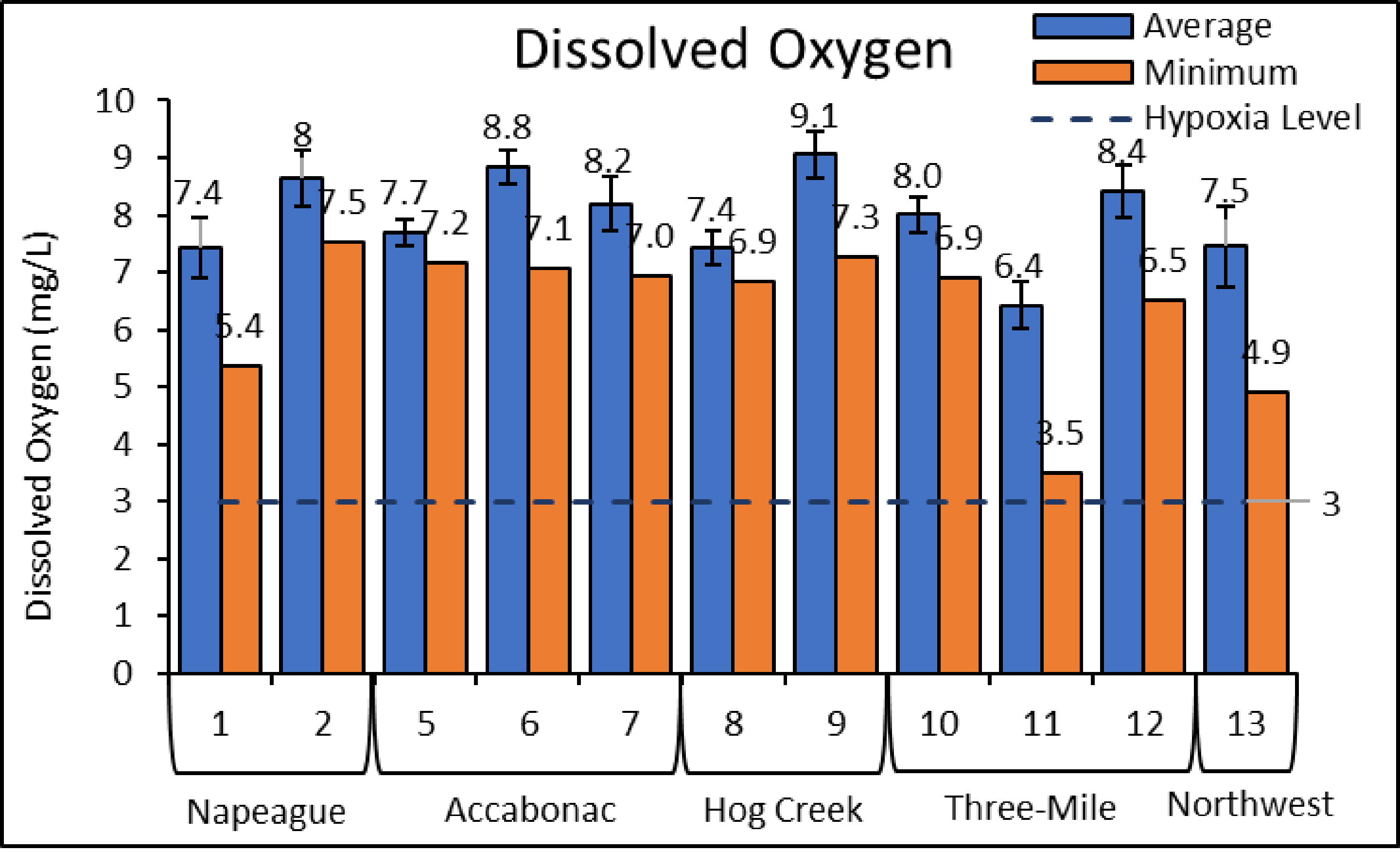

Figure 17: Average and minimum recorded dissolved oxygen values for marine sites from April through November of 2017. Error bars show standard error. Dashed line shows hypoxia threshold.

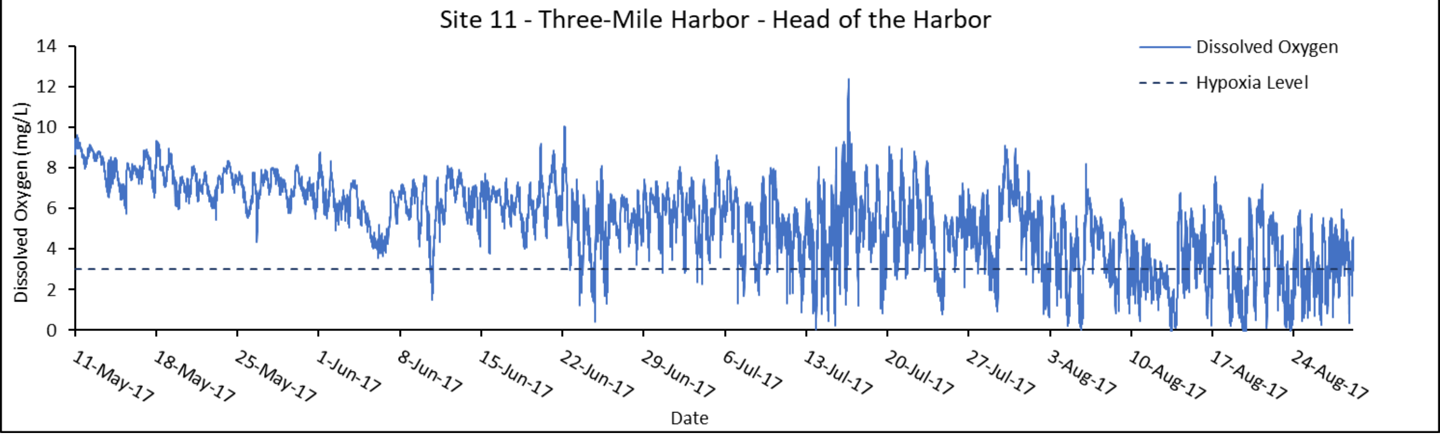

Figure 18 : Time series HOBO data of dissolved oxygen levels at depth from Head of the Harbor, Three-Mile. Dashed line shows hypoxic level for low oxygen.

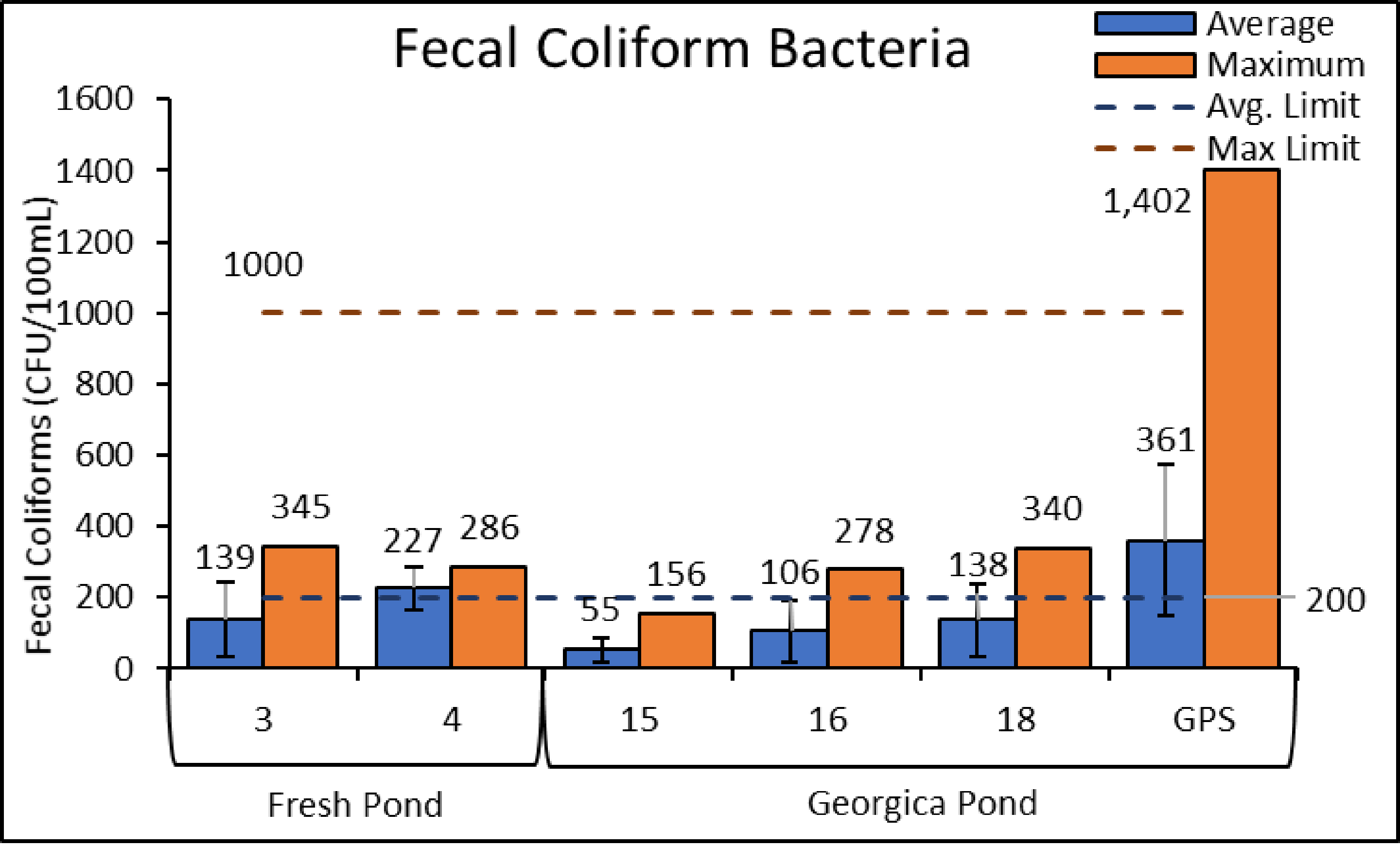

Figure 19: Average and maximum recorded fecal coliform bacteria values for freshwater sites, Fresh Pond and Georgica, from May through November of 2017. Error bars show standard error. Dashed lines show bathing safety limits.

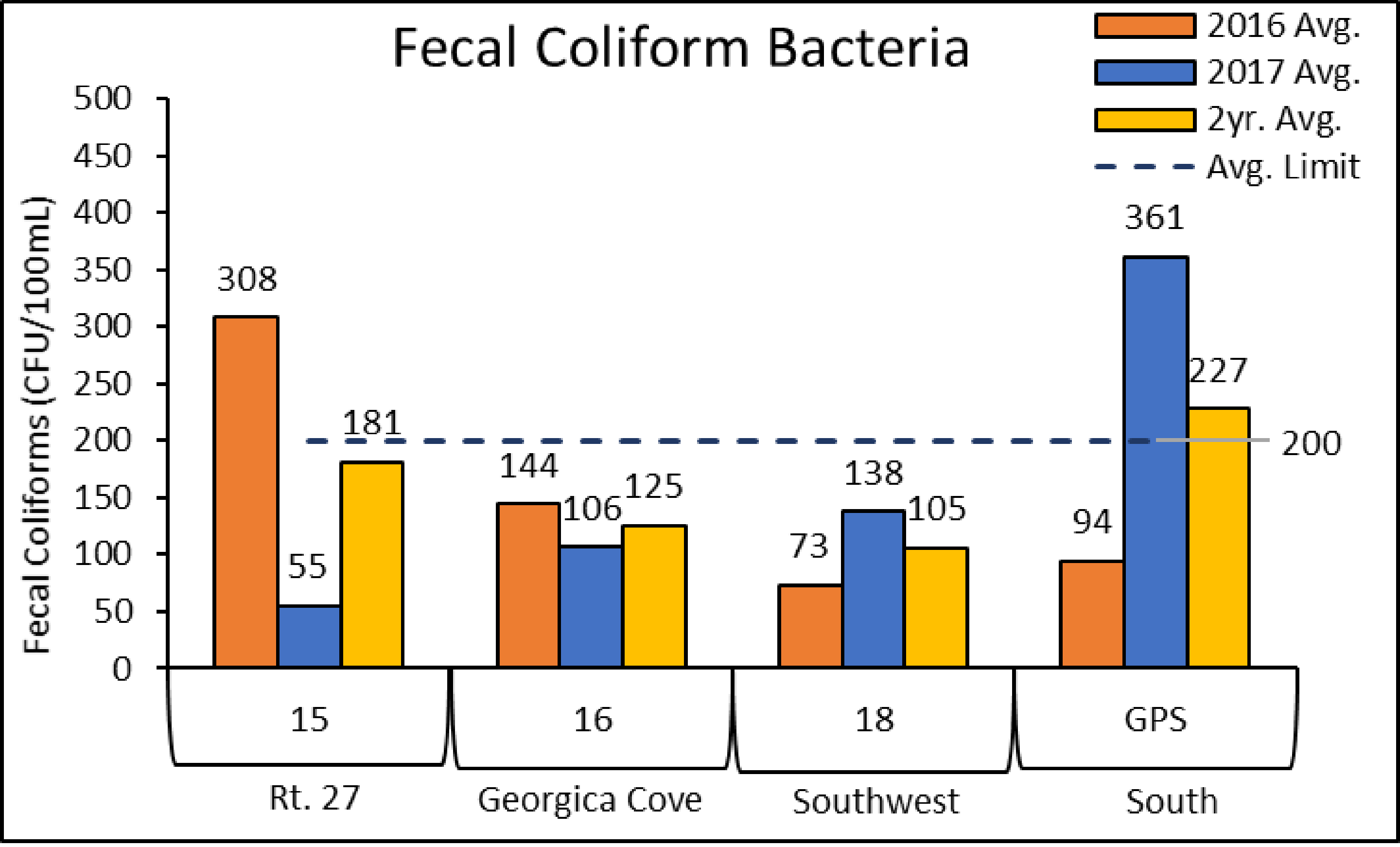

Figure 20: Comparison of average fecal coliform bacteria levels from 2016 and 2017, with two-year average. Error bars show standard error. Dashed line shows bathing safety limits.

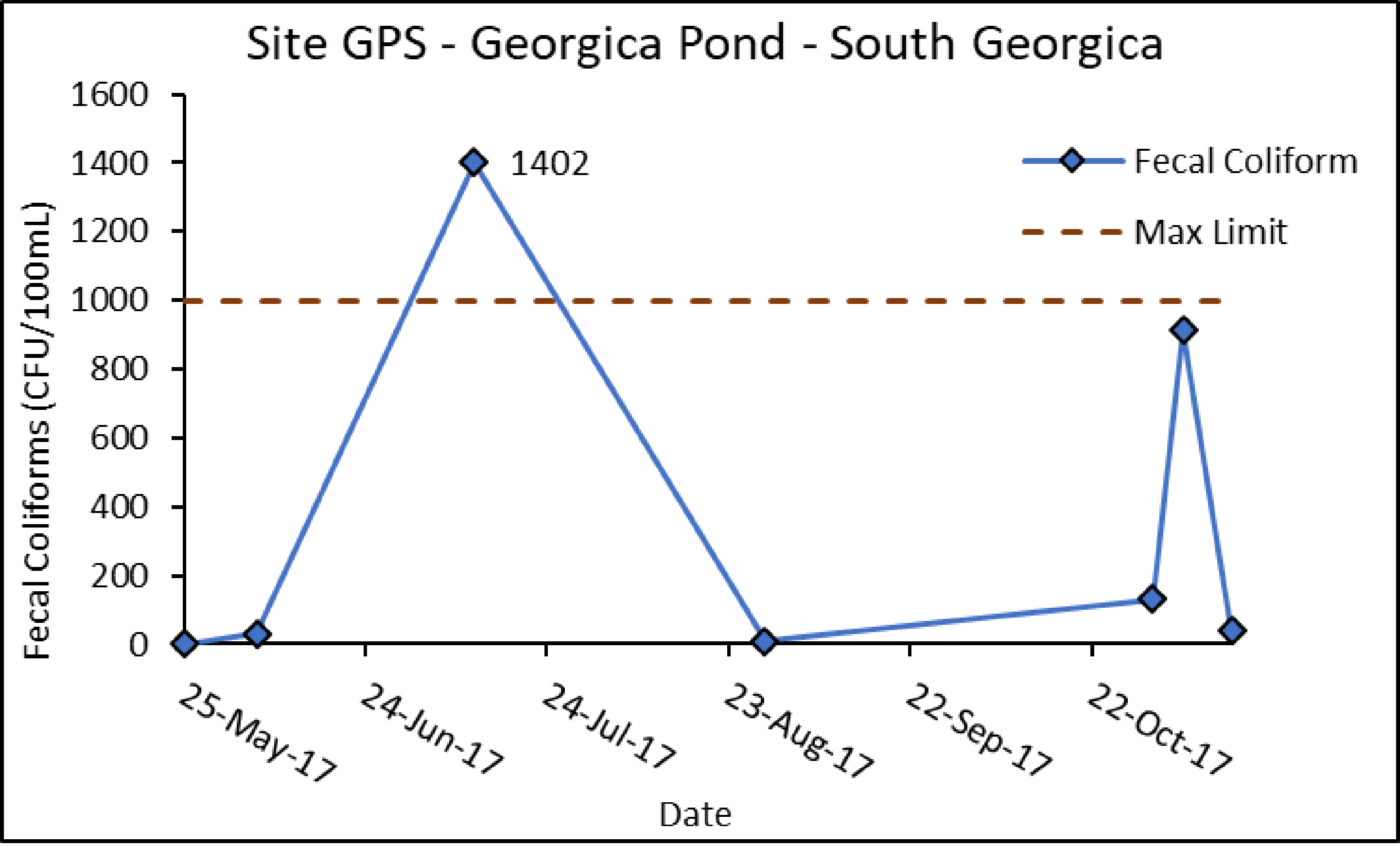

Figure 21: Fecal coliform bacteria levels over time from Georgica pond at in Southern Georgica Pond, which exceeded the average and individual date limits for bathing. Single date threshold not shown.

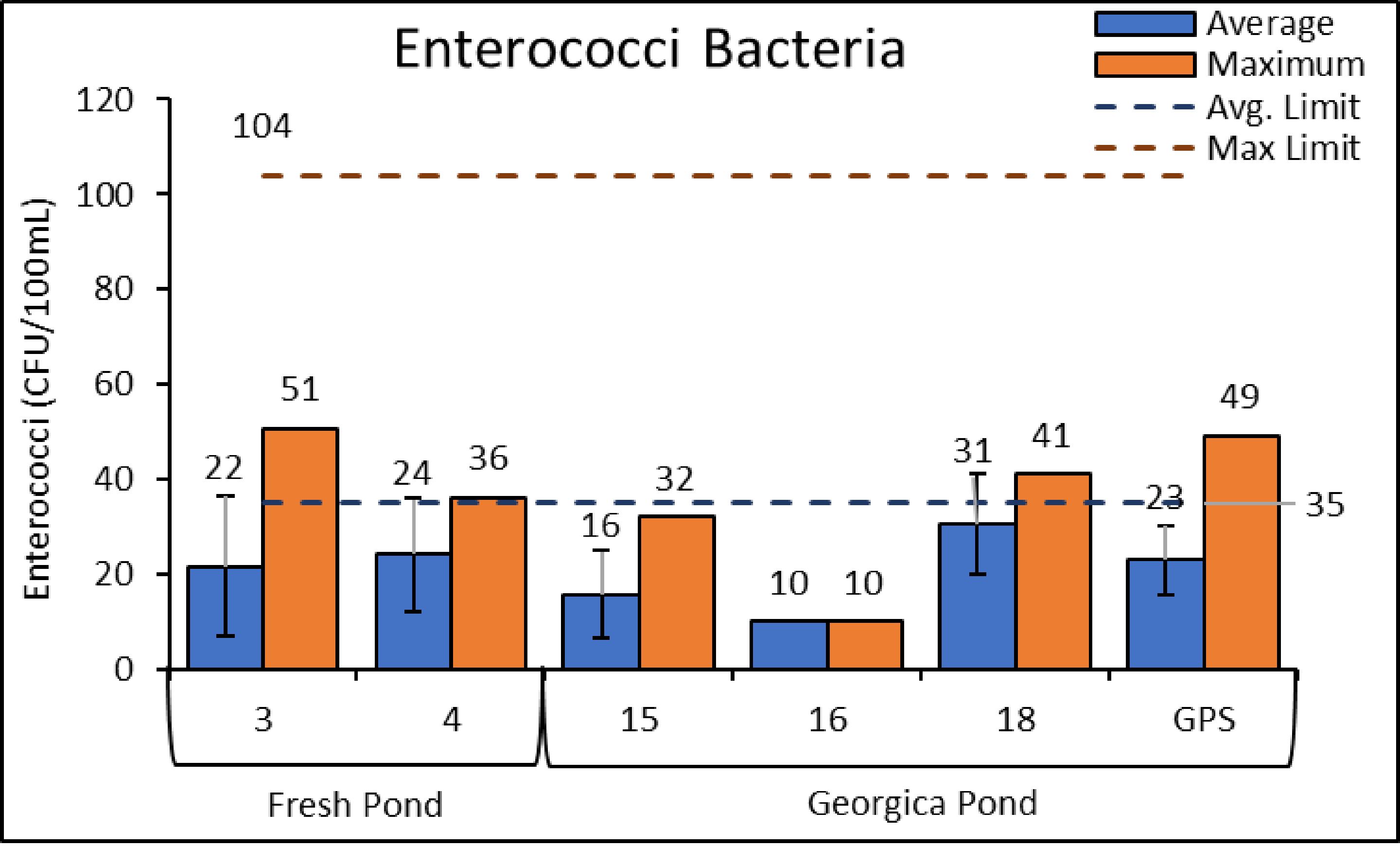

Figure 22: Average and maximum recorded enterococci bacteria values for Georgica Pond sites from May through November of 2017. Error bars show standard error. Dashed lines show bathing safety limits.

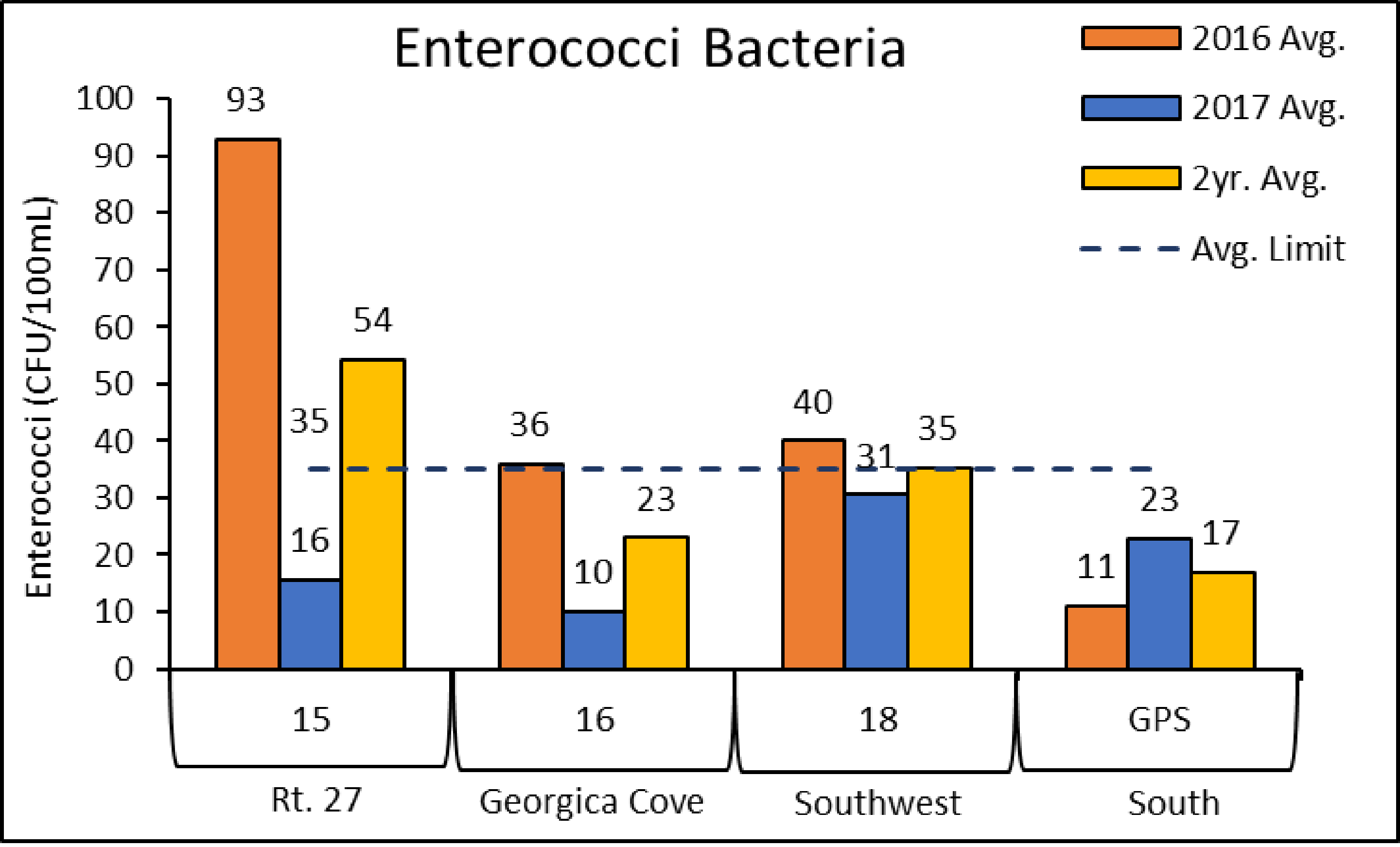

Figure 23: Comparison of average *Enterococci* bacteria levels from 2016 and 2017, with two-year average. Error bars show standard error. Dashed line shows bathing safety limits.

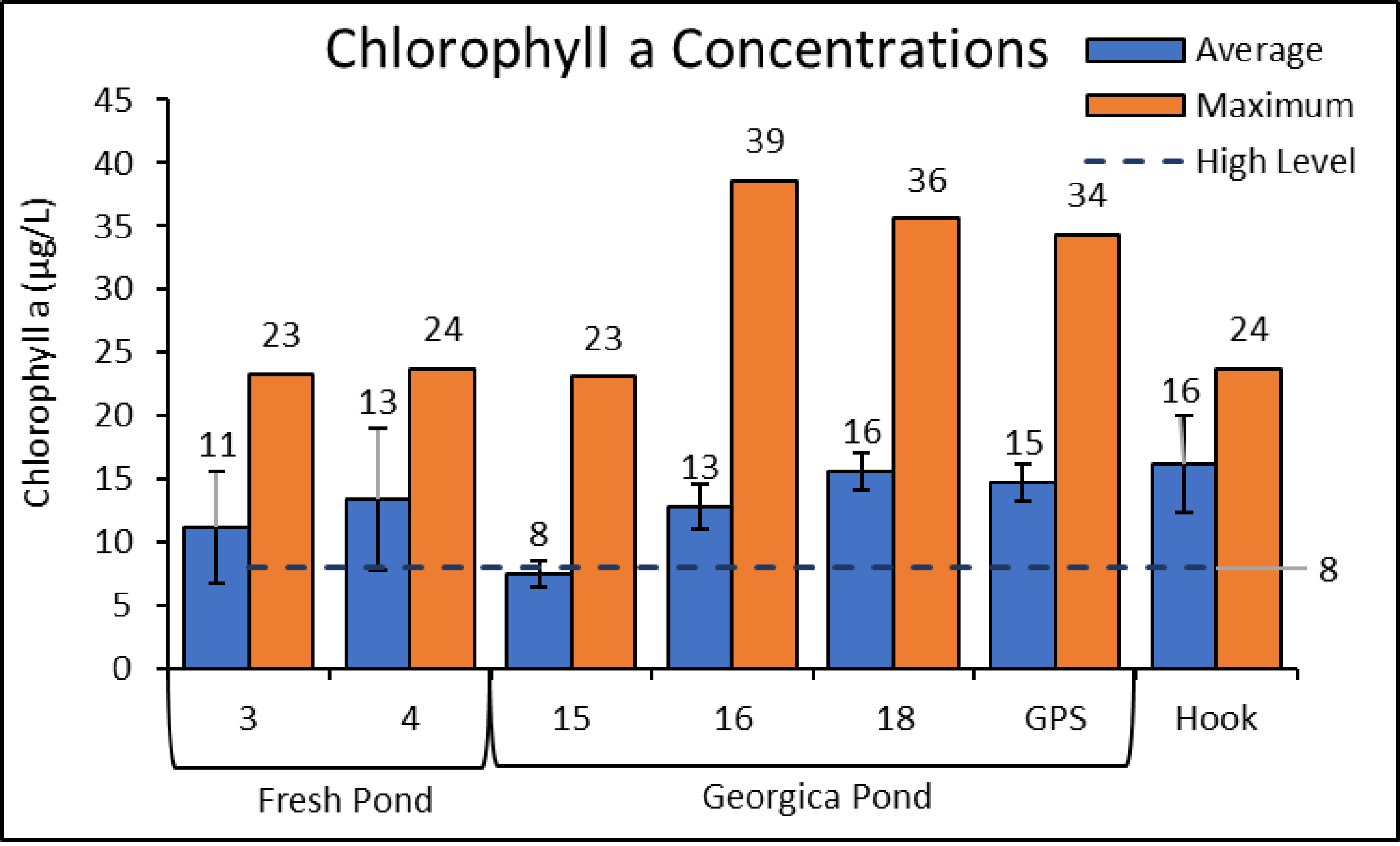

Figure 24: Average and maximum recorded chlorophyll a values for freshwater sites from May through November of 2017. Error bars show standard error. Dashed line shows high level of 8 µg/L.

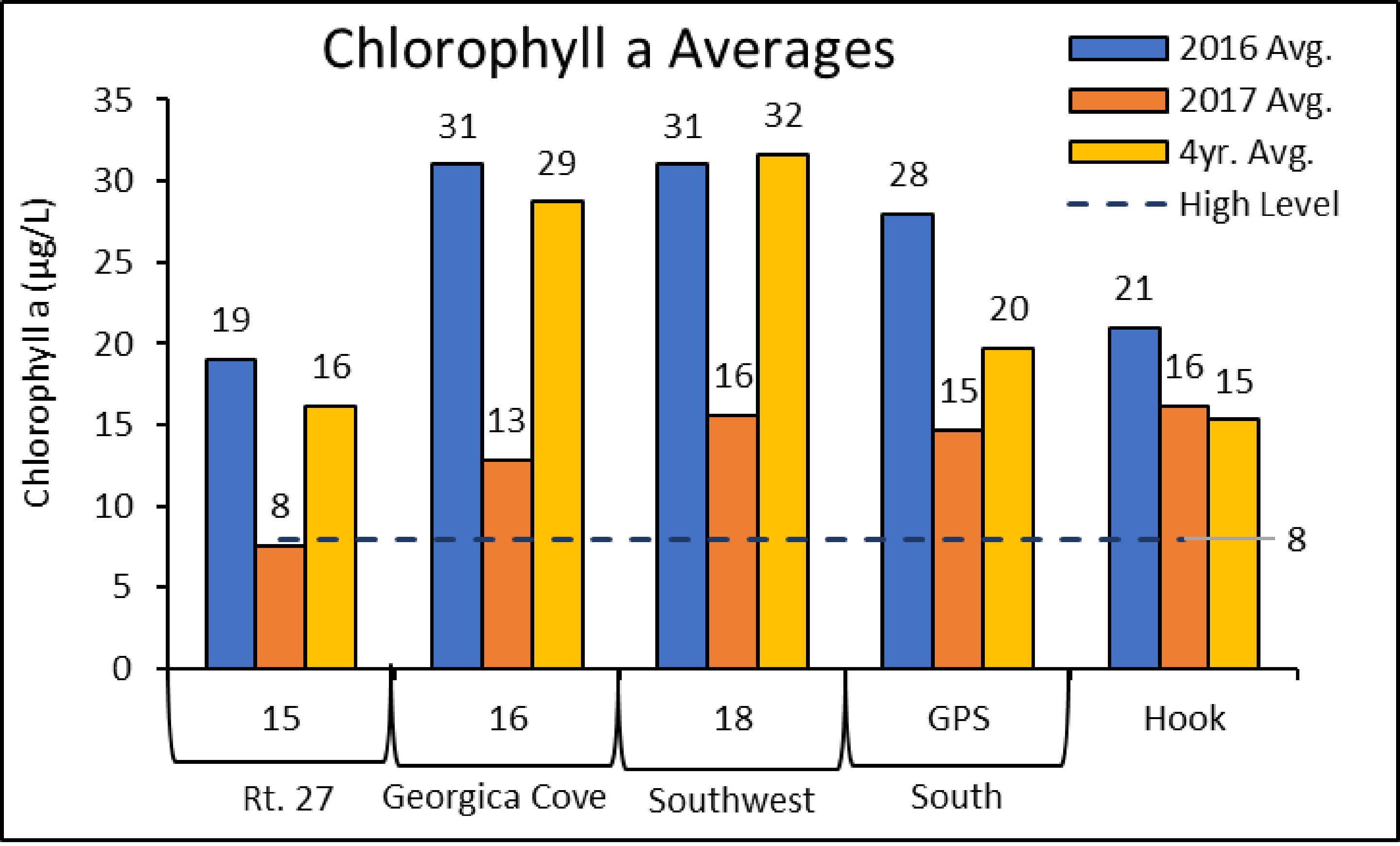

Figure 25: Comparison of average chlorophyll a levels from 2016 and 2017, with running four-year average. Error bars show standard error. Dashed line shows high level of 8 µg/L.

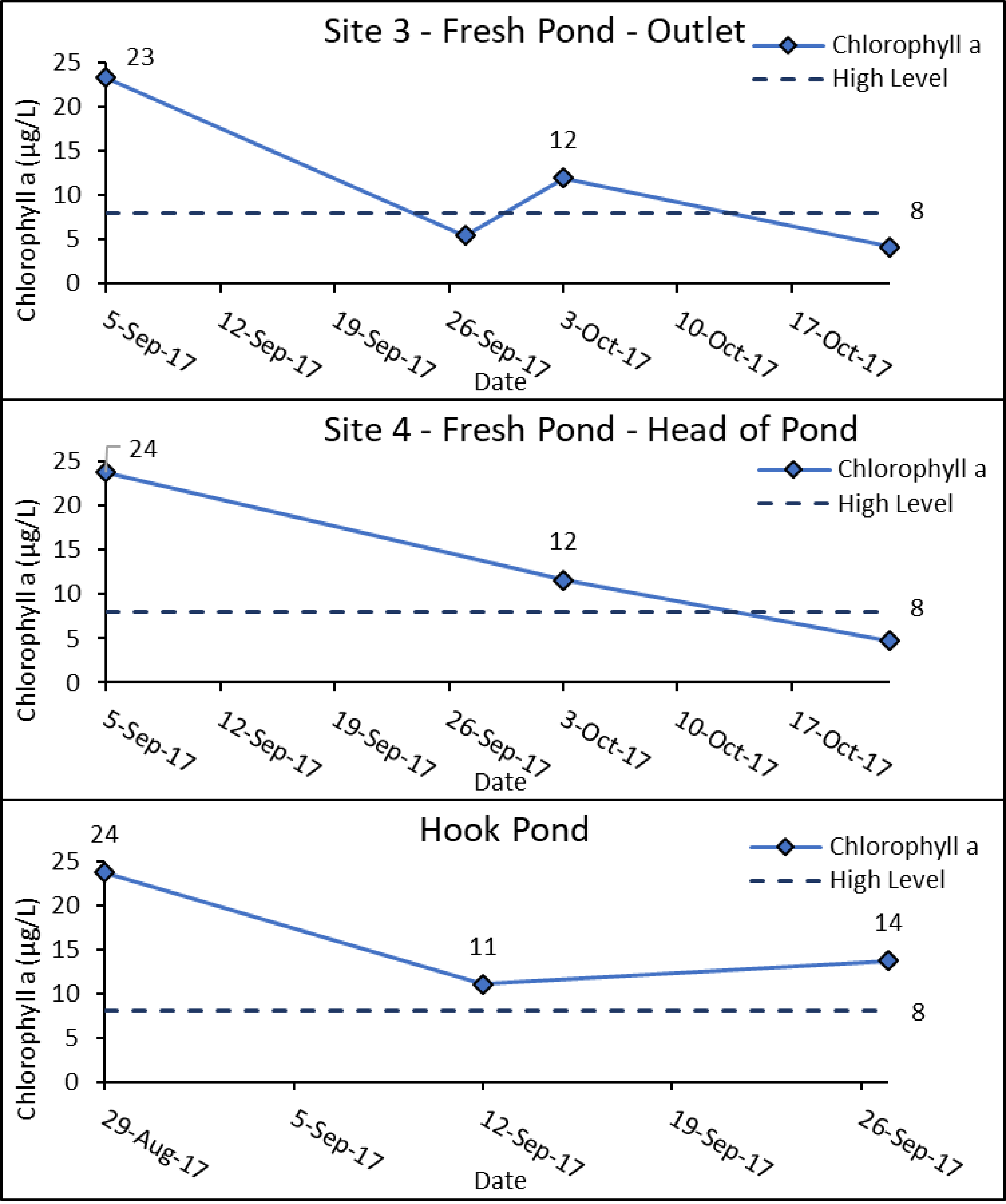

Figure 26: Chlorophyll a levels over time for sites which exceeded the high level of 8 µg/L.

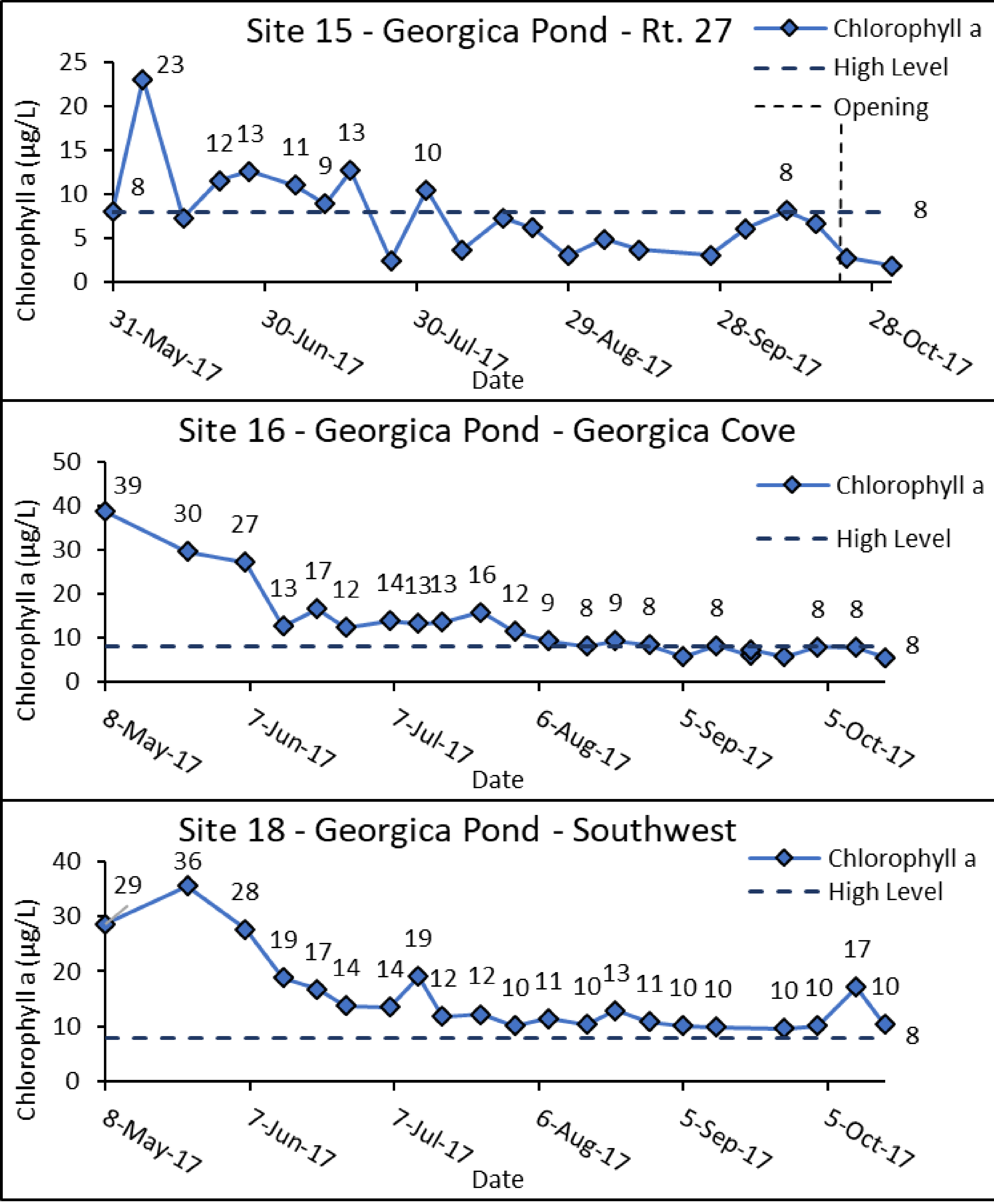

Figure 27: Chlorophyll a levels over time for sites which exceeded the high level of 8 µg/L. Vertical dashed line shows opening of the inlet.

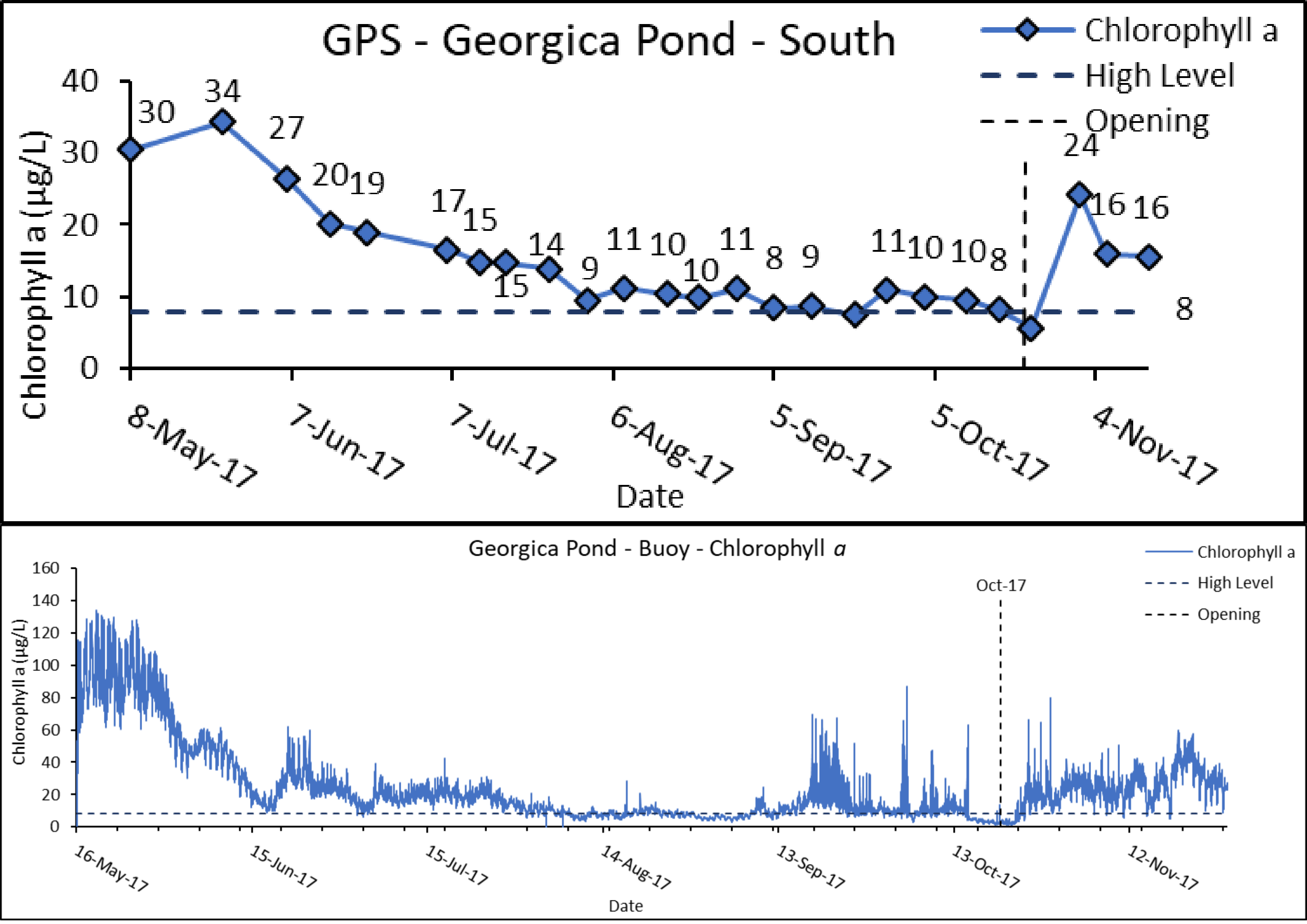

Figure 28: Chlorophyll a levels over time for sites which exceeded the high level. As well as continuous telemetry buoy data. Vertical dashed line shows opening of the inlet.

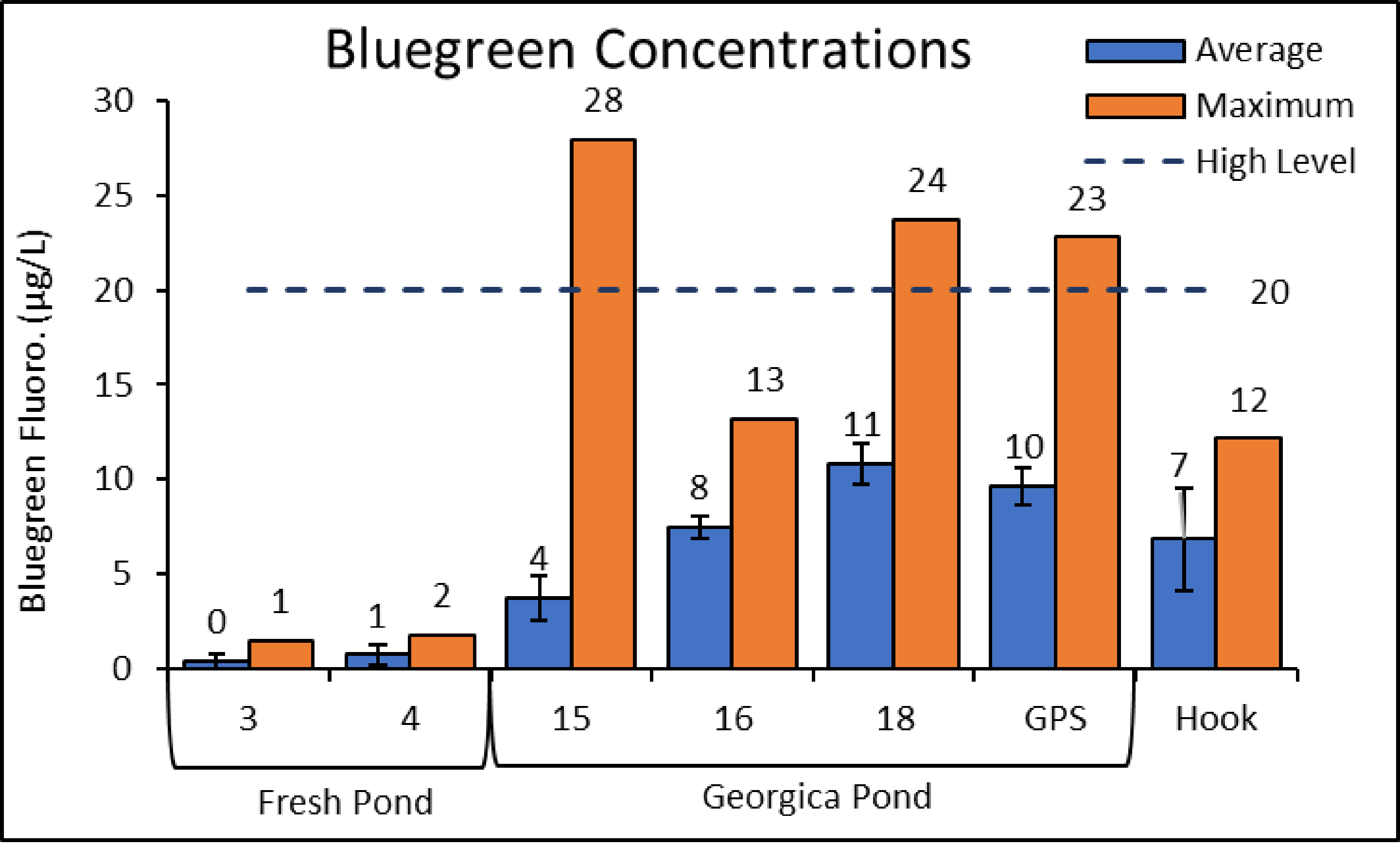

Figure 29: Average and maximum recorded bluegreen fluorescence values from May through November of 2017. Error bars show standard error. Dashed line shows high level of 20 µg/L.

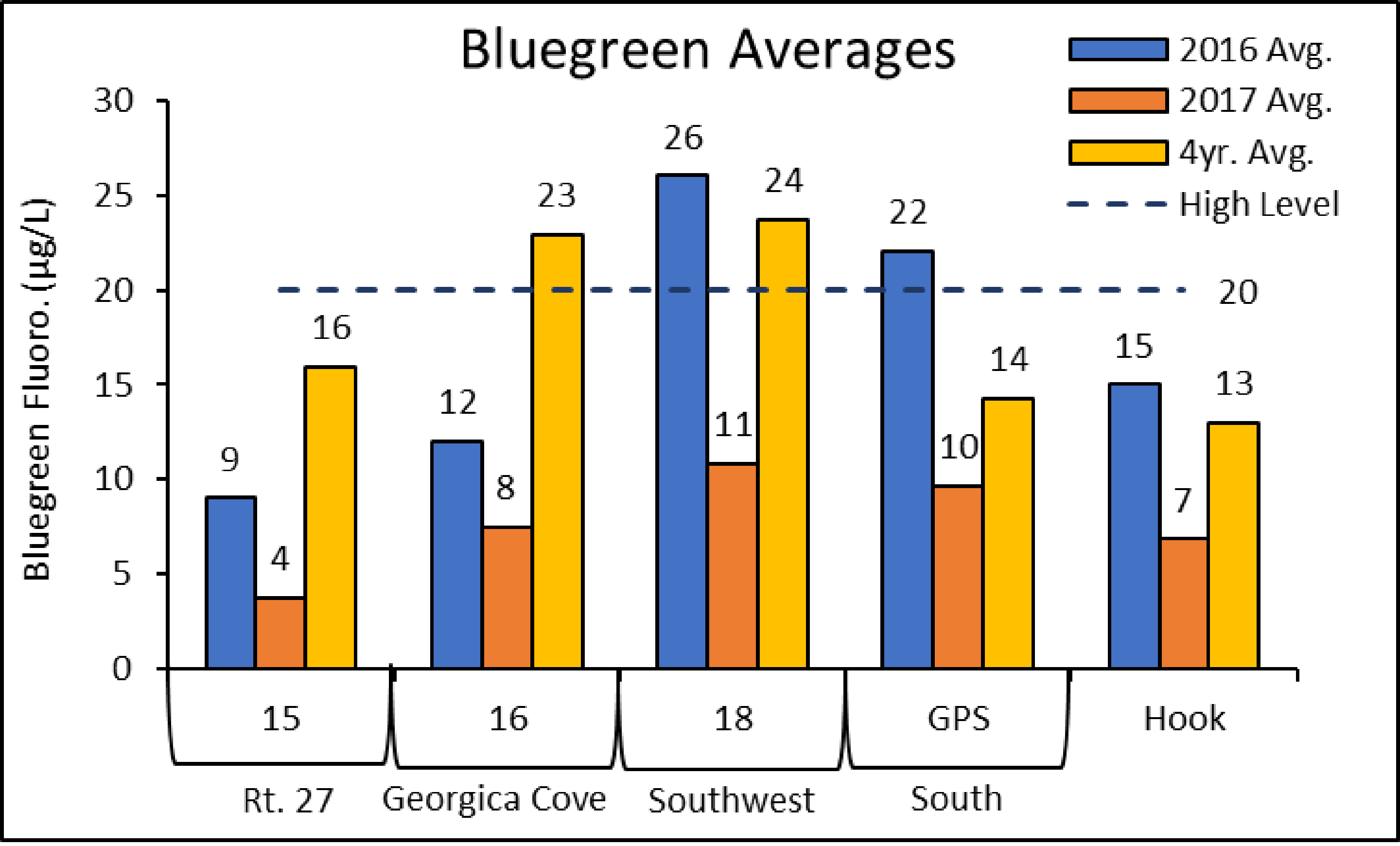

Figure 30: Comparison of average bluegreen fluorescence levels from 2016 and 2017, with running four-year average. Error bars show standard error. Dashed line shows high level 20 µg/L.

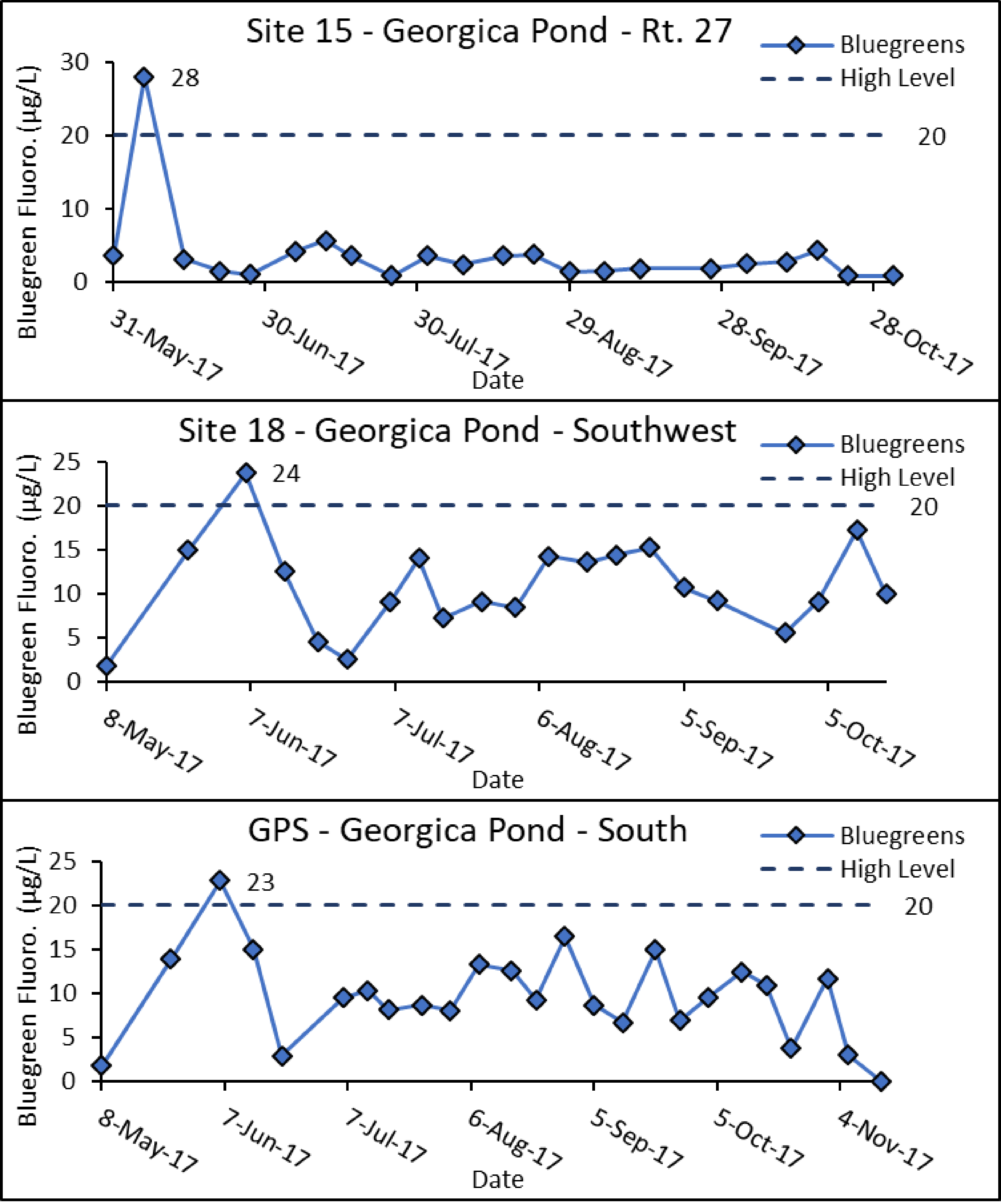

Figure 31: Bluegreen fluorescence levels over time for sites exceeding the high level of concern. Vertical dashed line shows opening of the inlet.

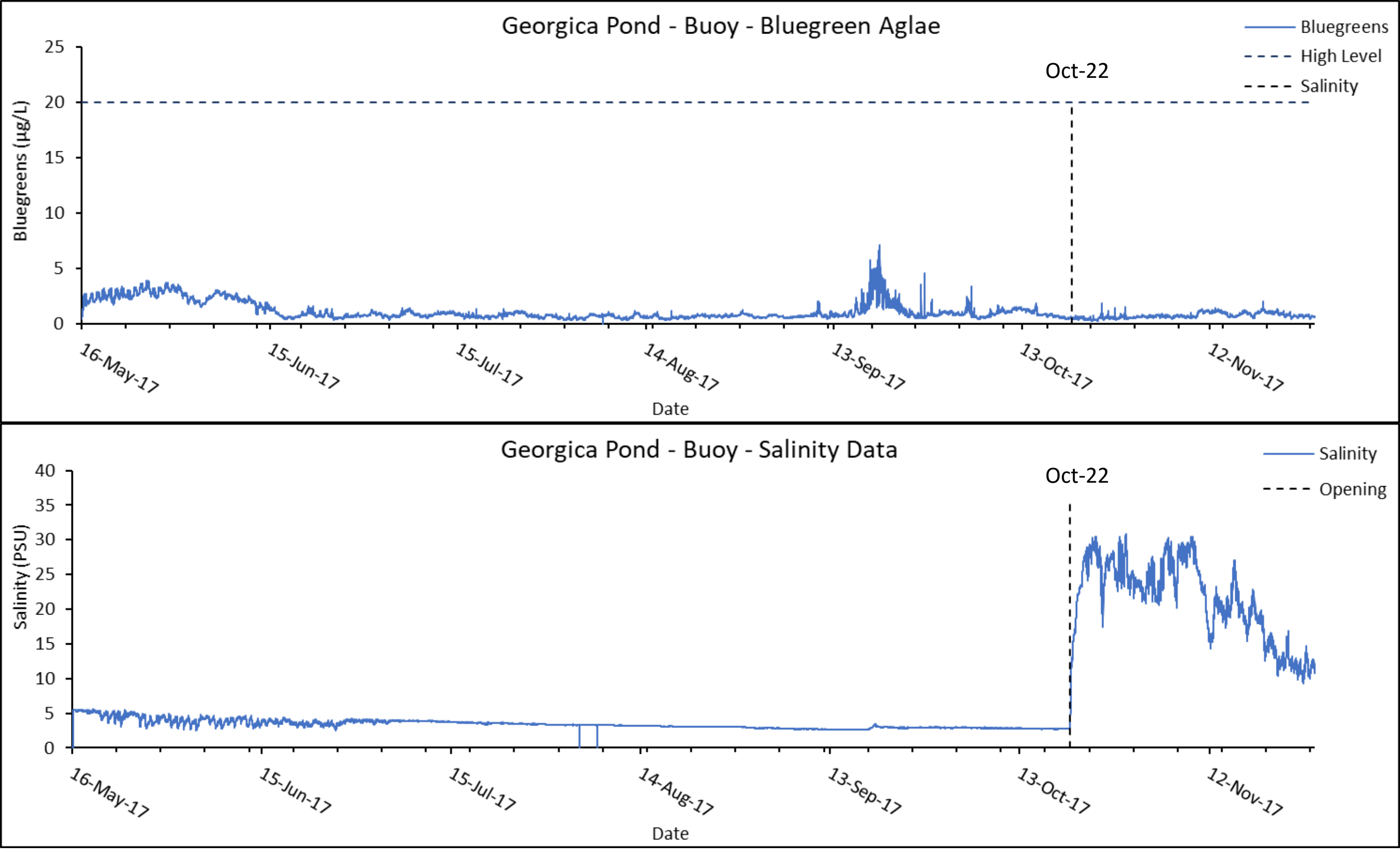

Figure 32: Continuous telemetry buoy data for bluegreen fluorescence and salinity. Vertical dashed line shows opening of the inlet.

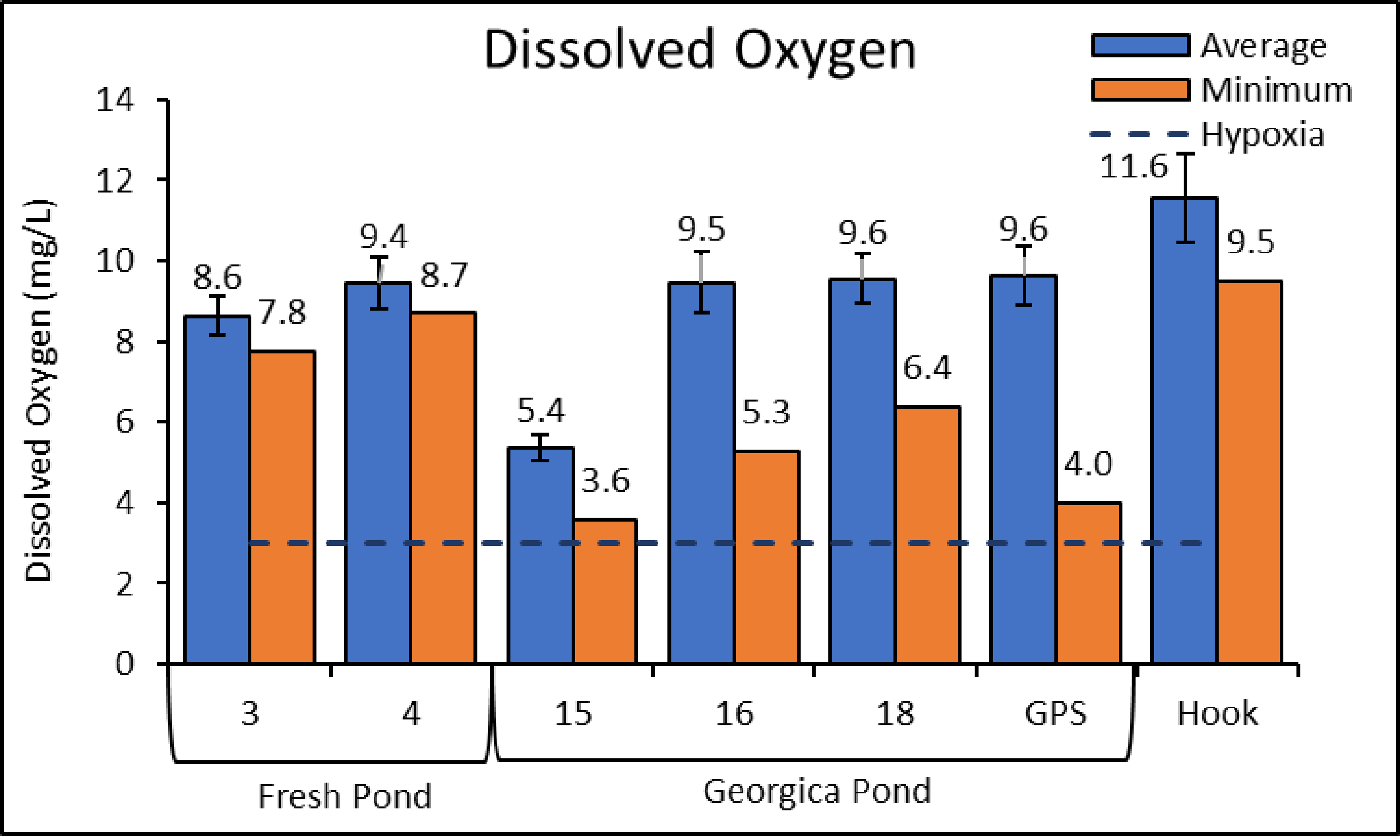

Figure 33: Average and minimum recorded dissolved oxygen values for freshwater sites from May through November of 2017. Error bars show standard error. Dashed line shows hypoxia threshold.

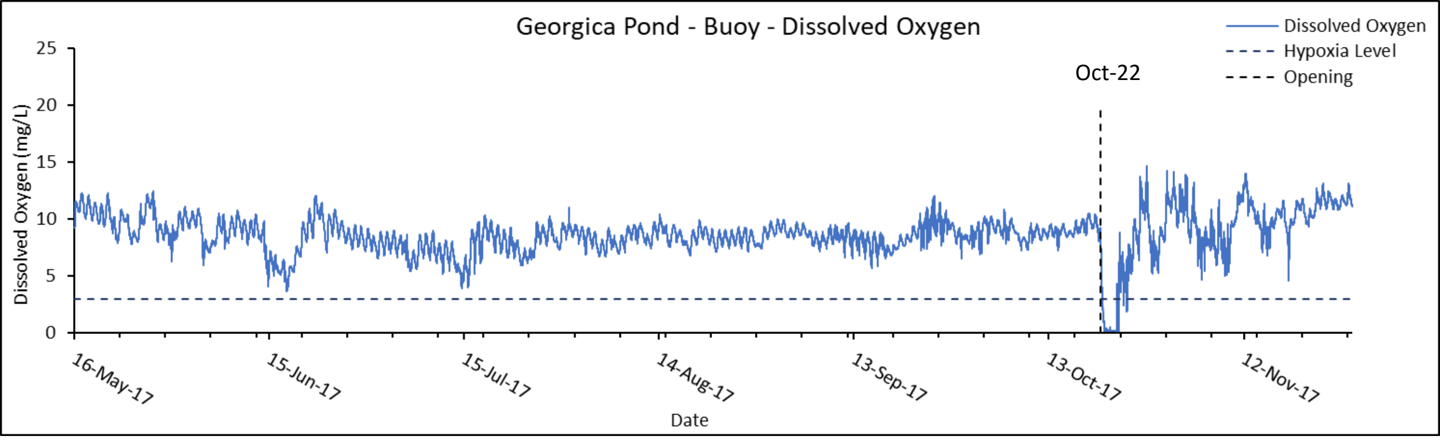

Figure 34: Continuous telemetry buoy data for dissolved oxygen. Vertical dashed line shows opening of the inlet. Horizontal dashed line shows hypoxia threshold of 3 mg/L.

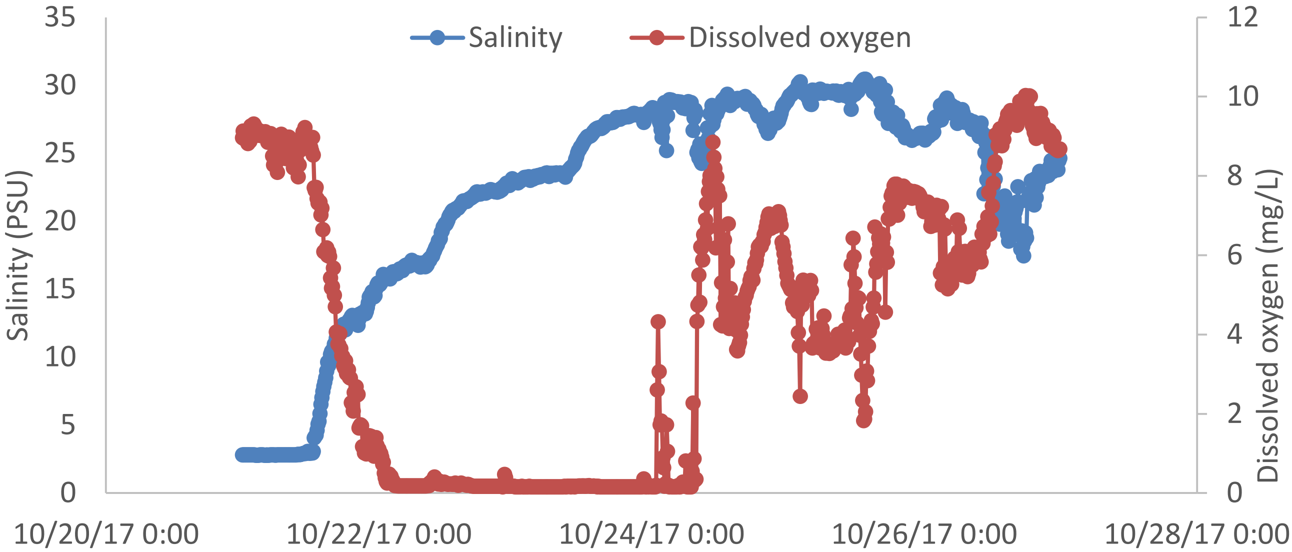

Figure 35: Continuous telemetry buoy data for dissolved oxygen and salinity following the opening of the cut with the 48 h anoxia event highlighted.