North Haven Village 2023 water quality study

Final Report

by

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Executive Summary

This study was undertaken from May through October of 2023 for the North Haven Village Trustees to assess water quality, harmful algal blooms, and pathogenic bacteria in the marine bodies of Fresh Pond, Mashomuck Creek, Ganet Creek, Great Salt Pond, as well as at the Ferry dock on the north shore. While measurements of dissolved oxygen were generally at concentrations supportive of fisheries, Mashomuck Creek was below for most of sampling season. Great Salt Pond fell below this value for dissolved oxygen 3 times from July to September, as well as Fresh Pond which was low in September. Chlorophyll *a* levels exceeded recommended concentrations at Great Salt Pond and Mashomuck Creek from July to October, and Fresh Creek and Polles Creek in July and August, respectively. Measurements of total nitrogen across all marine sites demonstrated that all sample locations except for the ferry site exceeded the USPEA recommended value of 0.4 mg/L, which can lead to harmful algal blooms. Additionally, there was one instance of a harmful algal bloom (HAB) in Fresh Pond of *Cochlodinium polykrikoides* on September 19th, although *Alexandrium* concentration neared bloom threshold of 1000 cells L^{-1} in Polles Creek on May 16th. All sites experienced fecal coliform levels above the NYSDEC recommended level of 14 CFU/100 mL multiple times during the sampling period for long stretches of time. Half of the sites remained below the NYSDOH recommended level of Enterococci at 104 CFU/100 mL with Mashomuck Creek and Great Salt Pond being above on multiple dates and the Ferry site only on July 27th.

In 2022, a preliminary study was conducted for all sites except for the ferry in September and October. Comparatively, the water quality of North Haven Village has gotten worse since then. There were more instances of low dissolved oxygen at more sites in 2023. Additionally, the levels of fecal coliform, enterococci, and Chlorophyll a were higher in 2023. Overall, this study revealed

regions of North Haven waters that of good or fair quality while other regions require further study, monitoring, and possible remediation.

1. Background

Coastal marine ecosystems are amongst the most ecologically and economically productive areas on the planet. They provide an estimated US $20 trillion in annual resources or about 43% of the global ecosystem goods and services (Costanza et al., 1997). Approximately 40% of the world's population lives within 100 km (about 62.14 mi) of a coastline, making these regions subject to anthropogenic stressors such as intense nutrient loading (Nixon, 1995; Valiela, 2006). These nutrients, including nitrogen and phosphorus, are essential in the growth of algal blooms. Therefore, excessive nitrogen loading into coastal ecosystems promotes algal productivity. These nutrients are often being introduced into water through runoff, so when it rains the levels of nutrients can increase. The microbial consumption of the organic matter caused by algal blooms reduces oxygen levels, promoting hypoxia (Cloern, 2001). The rapid acceleration of nutrient loading to coastal zones in recent decades has contributed to a significant expansion of algal blooms. Additionally, certain types of algal blooms can be especially dangerous to coastal ecosystems and humans who live there.

Globally, the phytoplankton communities of many coastal ecosystems have become increasingly dominated by harmful algal blooms (HABs) and New York is 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 a toxic dinoflagellate, *Alexandrium catenella,* have led to paralytic shellfish poisoning (PSP) due to the production of saxitoxin. This induced the closure of thousands of acres of shellfish beds in Suffolk County. In 2008, a second toxic dinoflagellate *Dinophysis acuminata* began forming large annual blooms, generating the toxins okadaic acid and DTX-1. Both toxins are the causative agents of diarrhetic shellfish poisoning (DSP). During the past decade, moderate levels of *A. catenella*

and *D. acuminata* have been detected in waters surrounding North Haven. The lack of sampling in North Haven has prohibited the understanding of risk.

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

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

OBJECTIVES:

1. Monitor water quality across North Haven waters including measurements of temperature, salinity, chlorophyll a, dissolved oxygen, Secchi disk, and harmful algae including A. catenella, D. acuminata, and C. polykrikoides.

2. Quantify nitrogenous nutrients in surface waters. Total levels of nitrogen will be quantified within all marine waters. Concentrations of total nitrogen will be compared to the Peconic Estuary Program's goal of 0.4 mg/L for ecosystem health.

3. Quantify levels of indicator bacteria in North Haven waters. Levels of fecal coliform bacteria and Enterococcus will be quantified in North Haven waters.

4. Provide a final presentation that interprets all findings regarding scientific literature and local, state, and federal regulations.

2. Approach

1. Methods and Approach

The 2023 sampling season ran from May through October. Sampling was performed twice per month with efforts made to sample during wet (within 24 hours of >1" of rainfall) and dry periods and during spring and neap tides. Sampling sites will include Fresh Pond (NHFP), Ganet Creek (NHGC), Polles Creek (NHPC), Great Salt Pond (NHGSP), and Mashomuck Creek (NHMC). In addition, samples were collected from the Shelter Island Sound along the north coast of North Haven (NHFY) as a control, end-member site.

2. Targeted Analyses

General water quality measurements obtained for each site include salinity, temperature, and dissolved oxygen levels measured with a handheld YSI 556 probe calibrated according to the manufacturer's recommendations. A Secchi disk was used to determine water clarity. Additionally, water was collected at each of these sites and analyzed for chlorophyll a. The pigment chlorophyll a, which serves as an analog for algal biomass, was measured by filtering whole water through

glass fiber filters. Chlorophyll a was extracted from the filter with acetone, and then the fluorescence was measured to obtain concentration levels (Parsons et al., 1984).

Levels of harmful algae were quantified by obtaining surface water and preserving it in Lugol's iodine (5% v/v). Samples were then quantified under an inverted microscope. Identification of harmful algae was seasonal with a focus on *A. catenella* in May and June, *D. acuminata* in May, June, and July, and *C. polykrikoides* from July through September. The sites were also sampled for quantification of fecal coliform bacteria and Enterococci bacteria. Enterococci and fecal coliform bacteria were quantified using the IDEXX Enterolert and Colilert, respectively, & Quanti-Tray/2000 sampling kits, giving MPN per 100mL.

3. Findings

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

Surface temperatures ranged from 16.9 to 32.6℃ across North Haven's waters. The seasonal average for surface waters was 24.0 ± 4.0℃, and the summertime mean (June 20th – September 22nd) was 26.3 ± 3.0℃ (Fig. 2 A & B). Maximum temperatures ranged from 27.3 to 32.6℃ and observations peaked between July 20th and August 5th. Surface salinities ranged from 20.0 to 30.8 PSU. The seasonal average was 28.0 ± 1.9 PSU, and summertime average 27.7 ± 2.2 PSU (Fig. 3 A & B). Dissolved oxygen measurements ranged from 1.2 to 11.3 mg L^{-1}, with a mean concentration of 6.5 ± 1.9 mg L^{-1}, and average summertime concentration of 5.8 ± 1.6 mg L^{-1} (Fig. 4 A & B). The NYDEC level of dissolved oxygen supportive of fisheries and other wildlife is 4.8 mg L^{-1}. The only sites that were consistently above this level were in the ferry, Polles Creek, and Ganet Creek. The only site deep enough for use of the Secchi disk was Ganet Creek, which was consistently below the NOAA minimum of 2 meters (Fig. 5).

3.2. Nitrogen Concentrations

Nitrogen is one of the necessary nutrients for algae to grow, and if there is not enough nitrogen in the water it can limit the growth of algae. Therefore, the more nutrients we add to the water, the more the algae can grow. The Peconic Estuary total nitrogen threshold is 0.4 mg L^{-1}. For comparison, total nitrogen concentrations at Great Salt Pond exceeded this threshold value throughout the sampling period and was almost 10 times the threshold at its highest concentration

of 3.68 mg N/L on August 8th (Fig. 6 A). Similarly, total nitrogen levels were consistently above the threshold in Mashomuck Creek from May to September with the highest concentration being almost 5 times that of the threshold on May 16th. Total nitrogen concentrations were also elevated in Fresh Pond where concentrations were only below the threshold in June and October. In Polles Creek, total nitrogen levels exceeded the threshold in July, August, and September and in Ganet Creek, total nitrogen levels only exceeded the threshold in August and September. Summer averages of total nitrogen exceeded the threshold at all sites except at the ferry site never reached the threshold value throughout the sampling season (Fig. 6 A & B). Great Salt Pond also had the highest average for chlorophyll a levels and nitrogen, which is consistent with our expectations (Fig. 6 B; Fig. 7 B).

3.3 Algae and Harmful Algae; A. catenella, D. acuminata, & Cochlodinium

All algae contain the pigment chlorophyll *a* and is used 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 such as hypoxia and acidification. The USEPA considers 20 µg L^{-1} of chlorophyll *a* in marine waters as eutrophic, and all sites except for Great Salt Pond were below this level on average, with mean concentrations ranging from 4.8 to 34.0 µg L^{-1} (Fig. 7 A & B). Sites did surpass 20 µg chl *a* L^{-1} on individual dates in all sites except for at the ferry.

A. catenella 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. Although concentrations of *Alexandrium,* remained well below 1000 cells L^{-1} at most sites, Polles Creek came near the bloom threshold at 910 cells/L on 5/16/23 (Fig. 8 A).

Dinoflagellates of the genus *Dinophysis* can cause DSP, a globally significant human health syndrome (Reguera et al., 2012). *Dinophysis* spp. synthesizes okadaic acid (OA) and dinophysistoxins (DTXs), the causative toxins of DSP. *Dinophysis* spp. blooms exceeding 10,000 cells L^{-1} have the potential to contaminate shellfish, and although cells have been detected, concentrations remained well below this level in 2023 (Fig. 8 B).

C. polykrikoides is an ichthyotoxic dinoflagellate that has caused fish mortality across the globe including some sites on eastern Long Island (Kudela and Gobler, 2012). *C. polykrikoides* blooms in excess of 300 cells mL^{-1} have been known to cause mortality in larval fish, which use these estuarine systems as nurseries, and in shellfish (Tang and Gobler 2009). Maximum *C. polykrikoides* cell densities surpassed 300 cells mL^{-1} in Fresh Pond (315 cells mL^{-1}) on September 19th (Fig. 8 C).

3.4. Fecal Coliform

The average concentration of fecal coliform bacteria across all marine sites was 462 colony forming units (CFU) 100 mL^{-1}, ranging from 0 to 4839 CFU 100 mL^{-1} (Fig. 9 & 10 A). The shell fishing standard for fecal coliform bacteria set by the US FDA National Shellfish Sanitation Program (NSSP) and followed by the NYSDEC are mean values below 14 CFU 100 mL^{-1}, with 90% of individual values below 49 CFU 100 mL^{-1}. All sites except for the ferry were above the mean value limit overall, but not for the summer mean. Fecal coliform concentrations that peaked on 6/29, 7/17, 8/8, 8/19, 9/19 all coincided with rainfall in the days leading to/of sampling (Weather Underground, 2023). The only days where all sites exceeded the NYSDEC limit were 7/13, 9/6, and 9/19. Mashomuck Creek was the first site to exceed the recommended levels on 5/16, while all the other sites began to exceed recommended levels 2 weeks later. Mashomuck Creek was also one of the few sites still over the recommended levels in October, as well as Ganet Creek and Great Salt Pond. From June to September, Mashomuck Creek, Ganet Creek, Great Salt Pond, Polles Creek, and Fresh Pond were all over the recommended levels with few exceptions. On 8/8, Fresh Pond dipped below the recommended levels. The site of the Ferry only exceeded the limit on 7/13, 9/6, and 9/19.

3.5. Enterococcus Bacteria

Mean concentration across all sites was 263 CFU 100 mL^{-1}, ranging from 21 to 1,630 CFU 100 mL^{-1}, far more than the NYSDOH bathing standard of <104 CFU 100 mL^{-1} (Fig. 9 B). Averages were over this threshold in Mashomuck Creek and Great Salt Pond. Values were over the safe bathing standard from June through October for Mashomuck Creek, and a maximum in excess of 4,800 CFU 100 mL^{-1}, was reached on July 27th in Great Salt Pond (Fig. 9 B). The ferry

only exceeded the NYSDOH level on 7/27, while Great Salt Pond exceeded this level on 6/1, 7/27, 8/8, 9/6, and 9/19. Like the fecal coliform levels, many of these dates coincide with rainfall. Fresh Pond, Ganet Creek, and Polles Creek never surpassed the NYSDOH standard levels.

4. Conclusions

Management of pathogens in surface waters of North Haven is warranted. For most samples in and around North Haven, fecal coliform bacteria levels exceeded the NYSDEC standard for shellfishing (14 CFU per 100 mL), in 2023. Similarly, for most samples taken in North Haven, Enterococcus levels exceeded the NYSDOH swimming standard (104 CFU per 100 mL). Yet, North Haven's beaches remain open as a bathing beach locale. At the North Haven marine sites, fecal coliform levels were above the NYSDEC shellfishing standard for more than half of the samples, while Enterococcus levels exceeded the NYSDOH swimming standard in around half of samples.

In 2016, Suffolk County adopted Article 19 of the sanitary code which permitted the use of innovative and alternative septic systems. Such systems must reduce total nitrogen levels in septic effluent to less than 19 mg L^{-1} and, to date, five such commercially available systems have been approved for use. Additional systems are in the piloting stage of approval, making the array of choices even larger in the future. For example, the NYS Center for Clean Water Technology at Stony Brook University is piloting Nitrogen Removing Biofilters as onsite septic systems which have been achieving septic effluent of < 10 mg L^{-1} as well as >90% removal of drugs, pharmaceuticals, personal care products, and other organic contaminants. Presently, Suffolk County, the Town of East Hampton Town and the Town of Southampton all have grants available to homeowners to install any of the Article 19-approved low nitrogen septic systems. The cost of a simple installation of the low nitrogen systems is presently ~$25,000, but much more for a complex site. The sum of grants available is often more than the cost of the full installation of the systems, meaning that, in many cases, they can be installed for free. In some cases, however, installation can become more expensive if, for example, major infrastructure or landscaping must be moved or replaced during the installation process.

Beyond the upgrading of septic systems, there are likely opportunities to connect parts of North Haven to the existing sewage treatment plant. The plant is currently discharging very low levels of N to surface waters, on average < 5 mg L^{-1}, which is better than any approved onsite septic system. For regions near the sewage treatment plant, it may be cost effective to hook up homes and facilities to the existing plant. This must be fully investigated, however, as for some parts of Long Island such costs can exceed $50,000 per home and the installation of sewage lines can be disruptive to neighborhoods. Once connected, the installation would create a maintenance-free solution for homeowners although the connection to the sewage treatment plant will represent an additional utility fee. For onsite systems, Suffolk County requires homeowners to purchase operation and maintenance contracts with certified companies who will inspect systems one-to-two times per year to assure systems are functioning properly.

5. Citations

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6. Figures & Tables

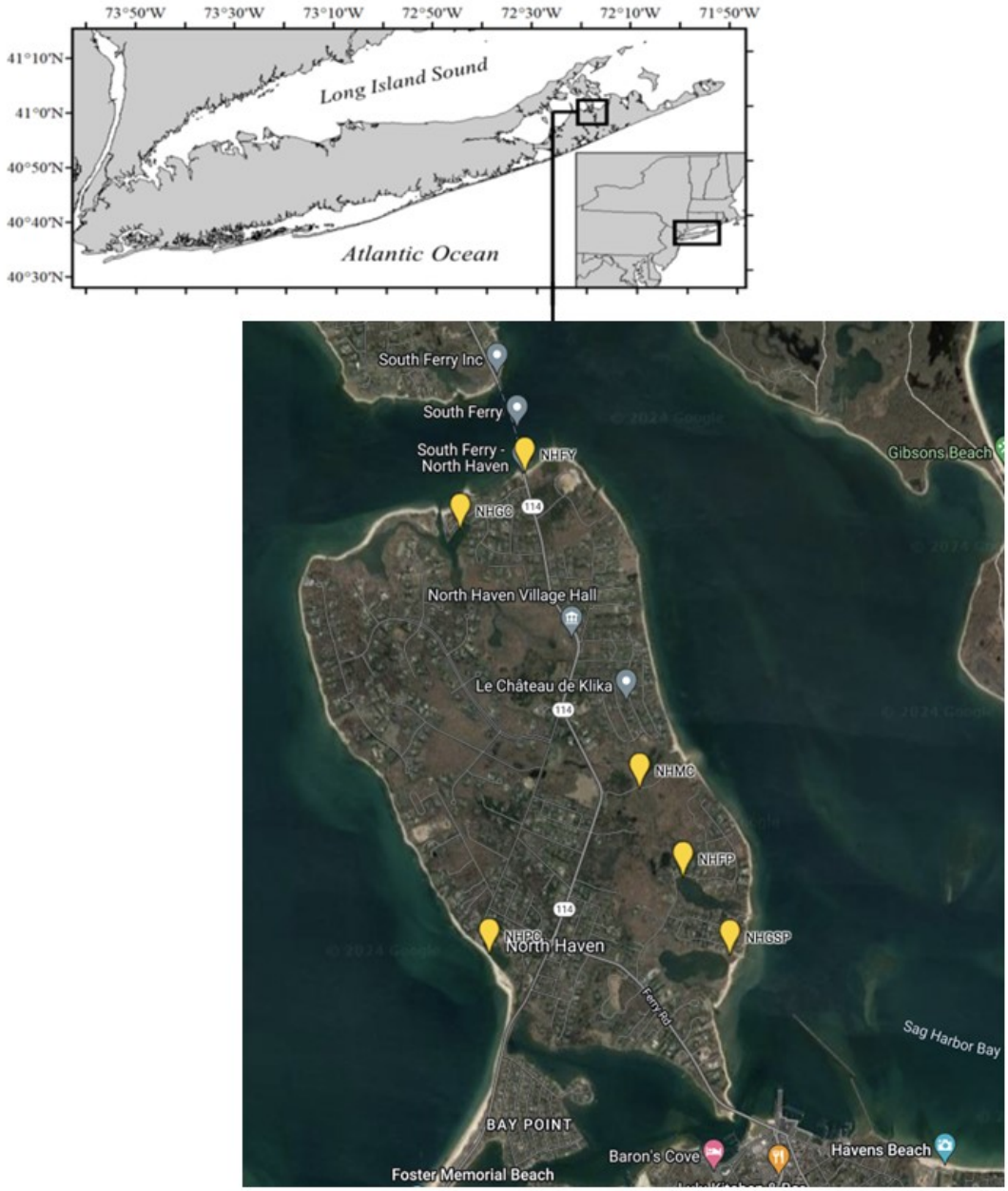

Figure 1. Map of North Haven sample sites during 2023 (indicated with yellow map pins). "NHPC" is Polles Creek, "NHGC" is Ganet Creek, "NHFY" is Ferry, "NHMC" is Mashomuck Creek, "NHFP" is Fresh Pond, and "NHGSP" is Great Salt Pond.

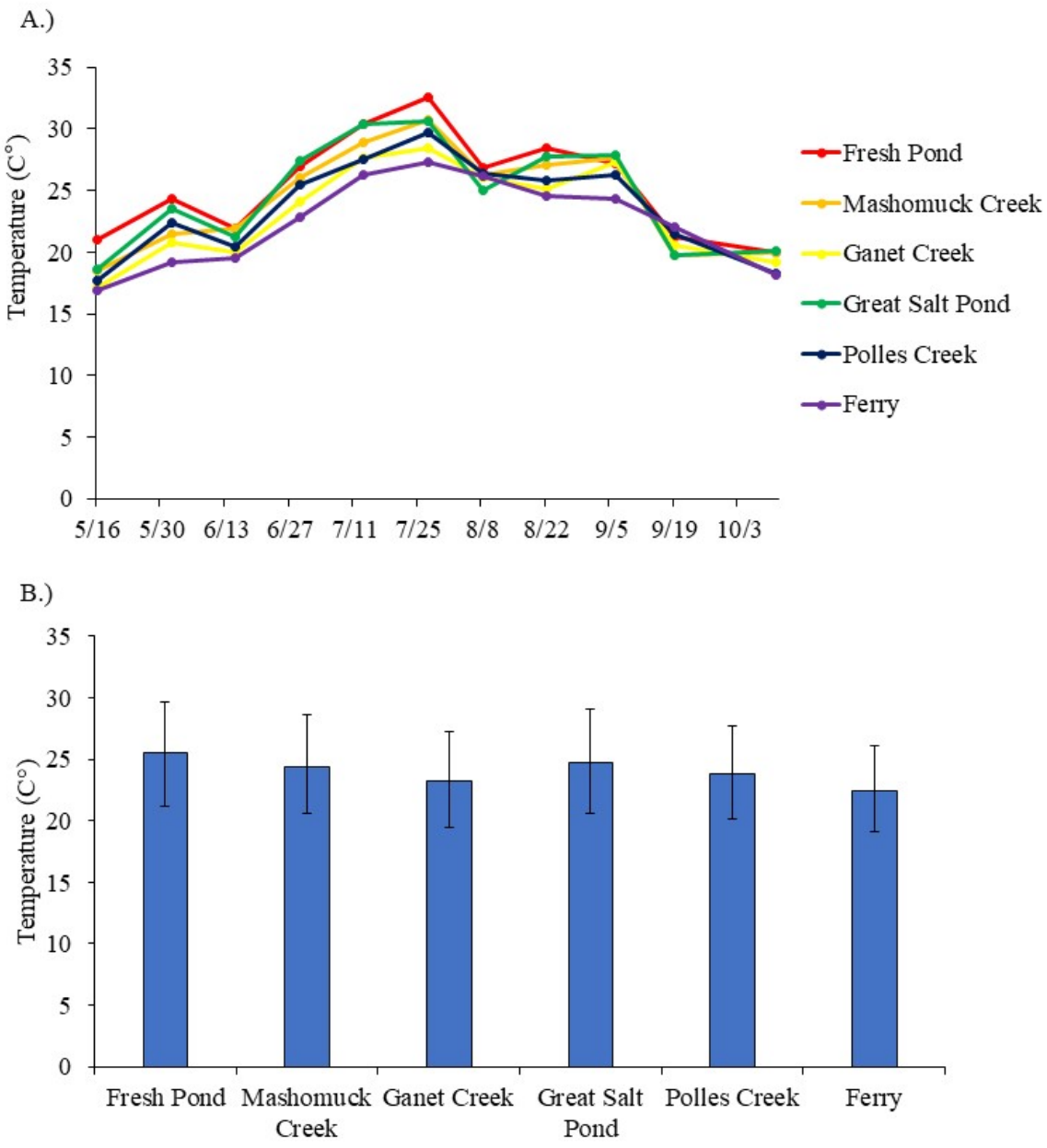

Figure 2. Temperature levels shown in a time series (A) and averages of sites in a bar graph (B) of North Haven in 2023. Standard deviation bars show 1 standard deviation specific to each site.

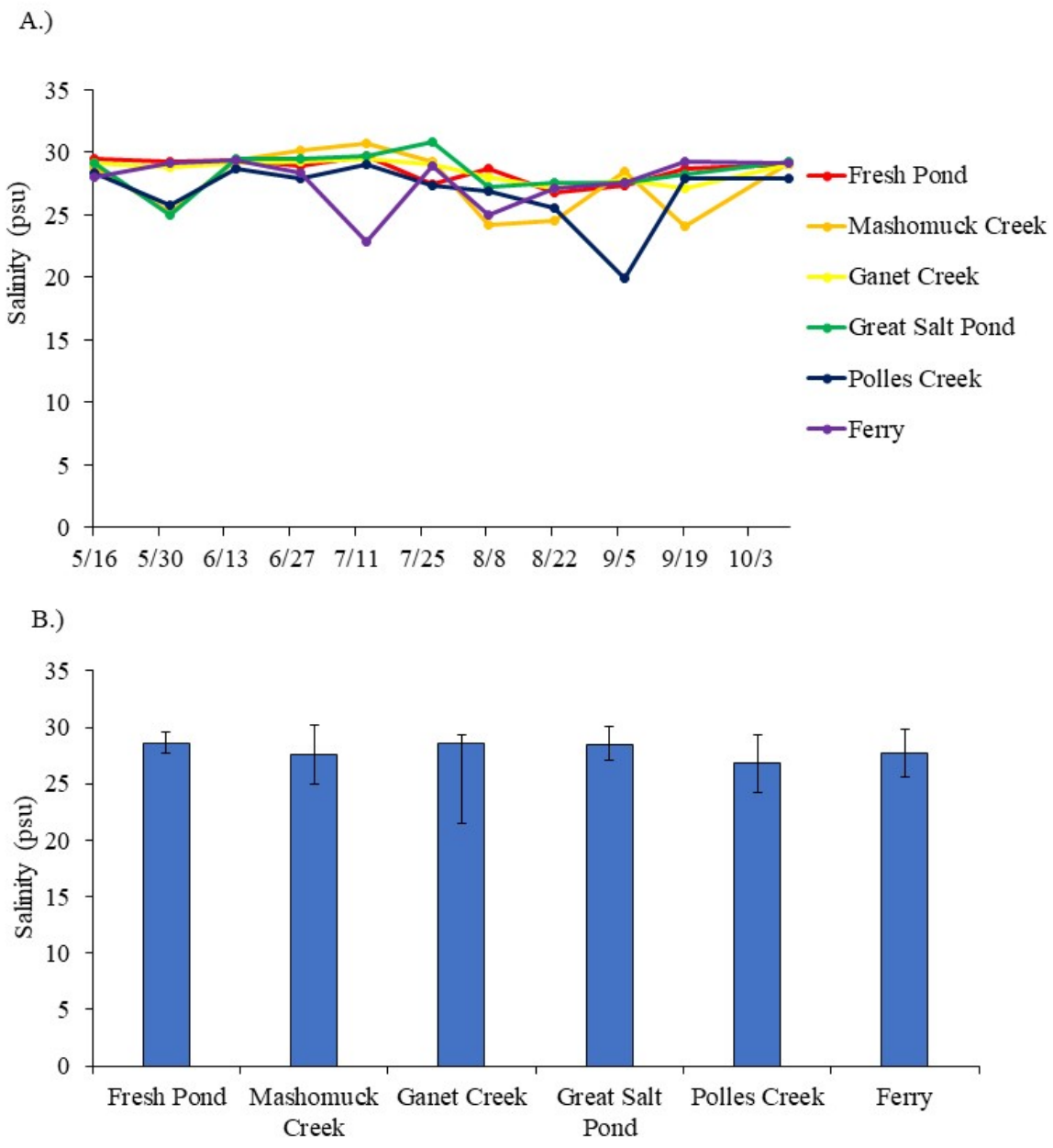

Figure 3. Salinity levels shown in a time series (A) and averages of sites in a bar graph (B) of North Haven in 2023. Standard deviation bars show 1 standard deviation specific to each site.

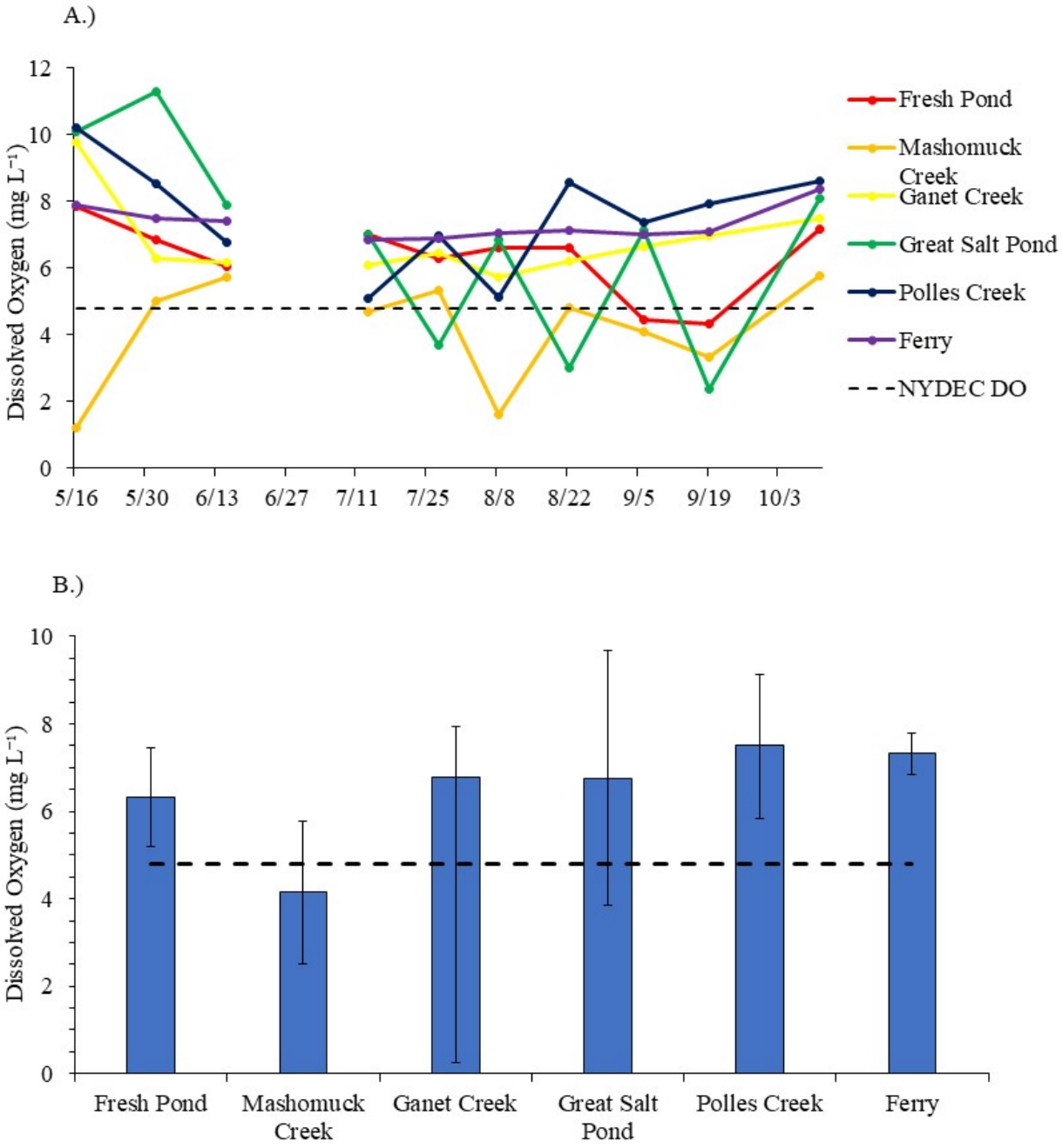

Figure 4. Dissolved Oxygen measurements in a time series (A) and averages taken across sites (B) in North Haven 2023. (*Data was unable to be collected for dates between June 13th and July 11th).* The NYDEC dissolved oxygen recommendation of 4.8 mg L -1 indicated by the dotted line. Standard deviation bars show 1 standard deviation specific to each site.

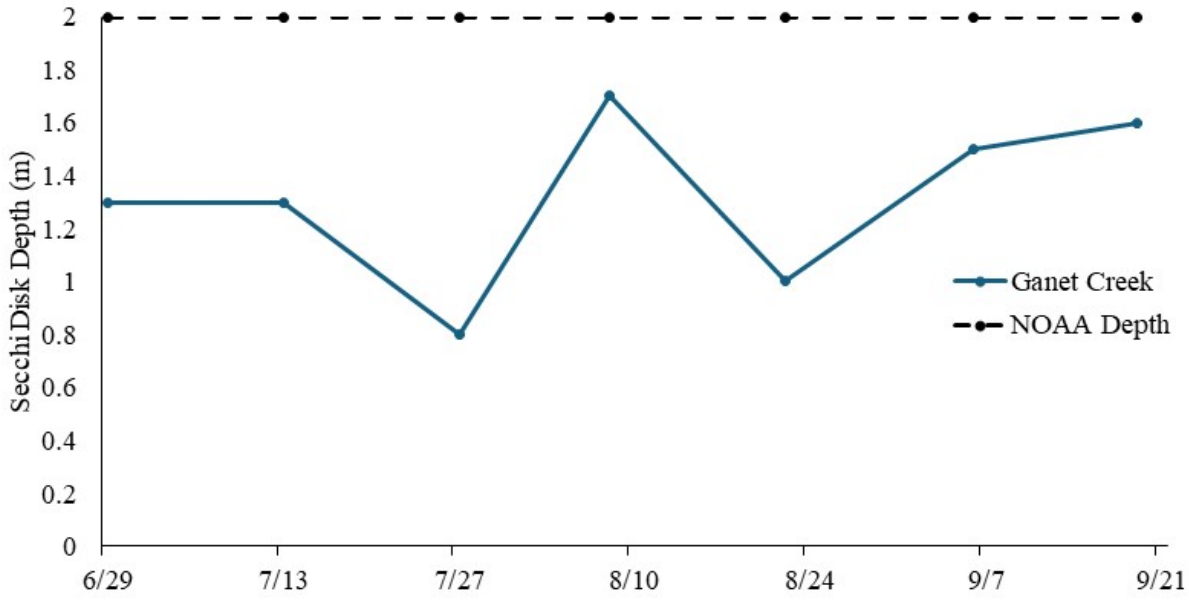

Figure 5. Secchi disk depths (m) across Ganet Creek in North Haven during 2023. Dotted line represents the Secchi disk depth standard of 2.0 meters; Secchi disk depth standard set by NOAA. *All other sampling locations (i.e. Fresh Pond, Mashomuck Creek, Polles Creek, Great Salt Pond, Ferry) had Secchi disk depths consistent at level of the 0.5 meters (not shown in this figure).*

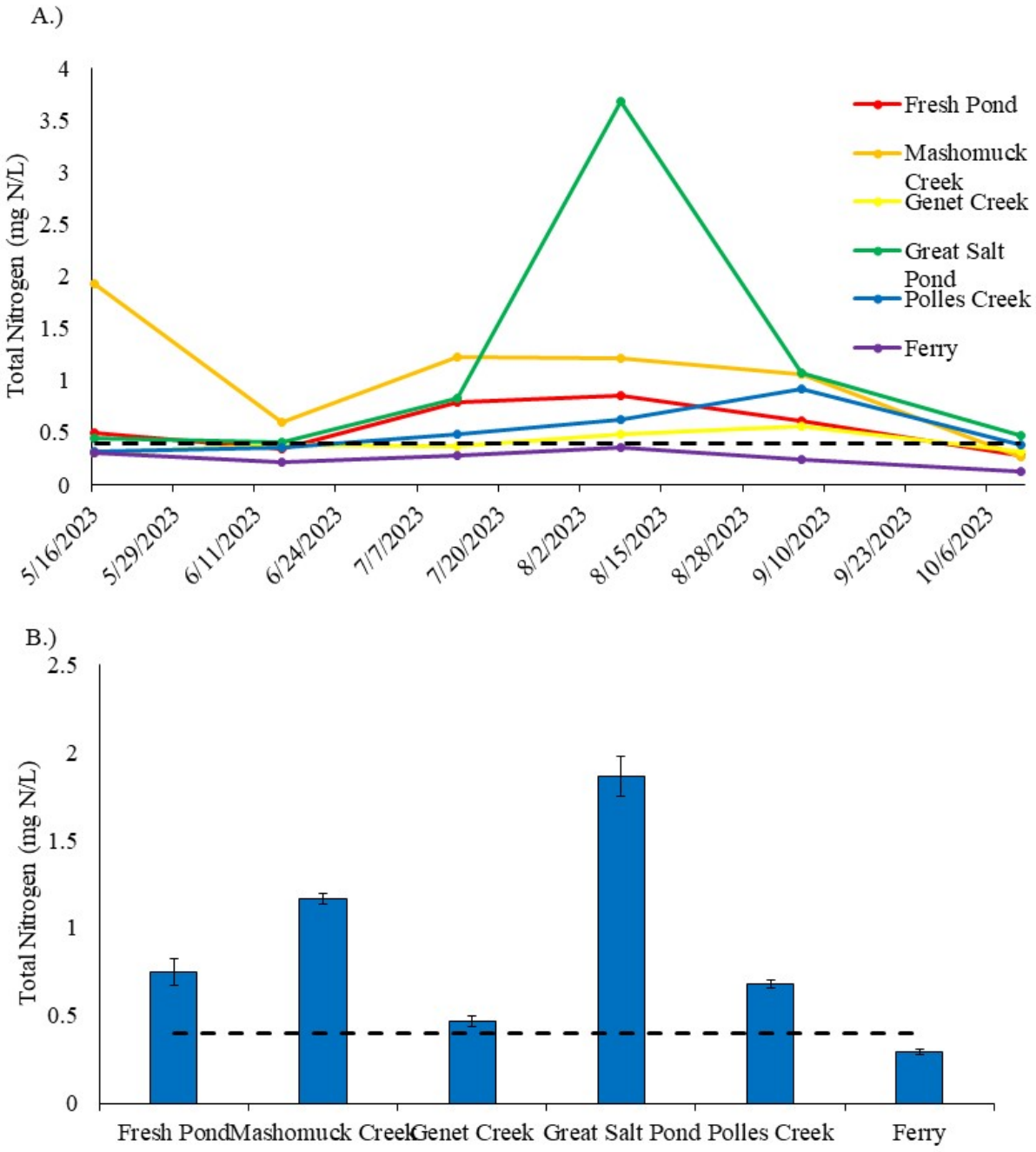

Figure 6. A.) Time-series, and B.) Summer average of total nitrogen levels (mg N/L) at North Haven marine sites during 2023. Columns represent averages ± standard deviation. The USEPA recommends levels of total nitrogen be under 0.4 mg L^{-1}, indicated by the dotted line.

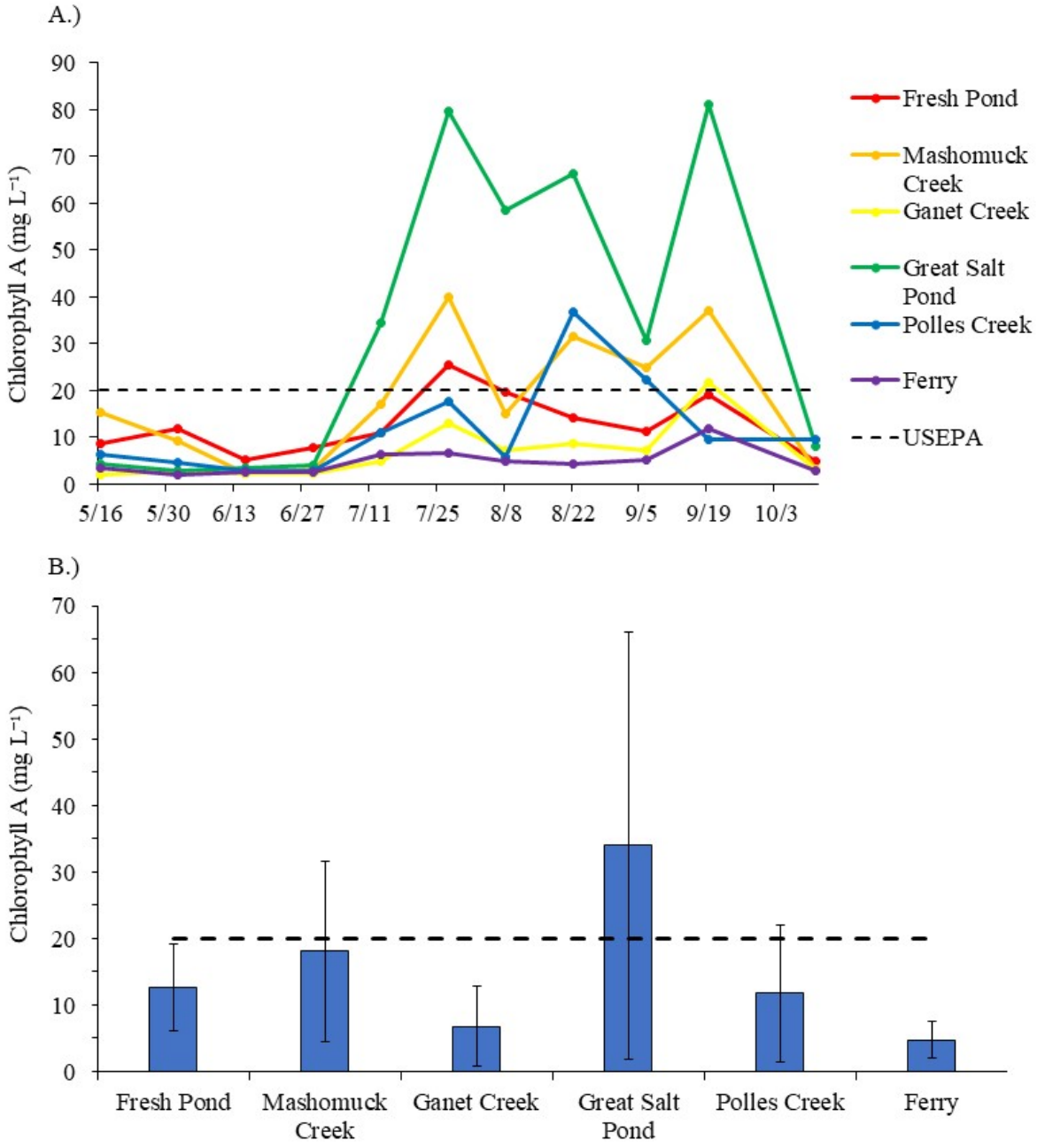

Figure 7. Chlorophyll-a levels measured in a time series (A) and averaged by site in a bar graph (B) in North Haven 2023. The USEPA recommends levels of chlorophyll a be under 20 mg L^{-1}, indicated by the dotted line.

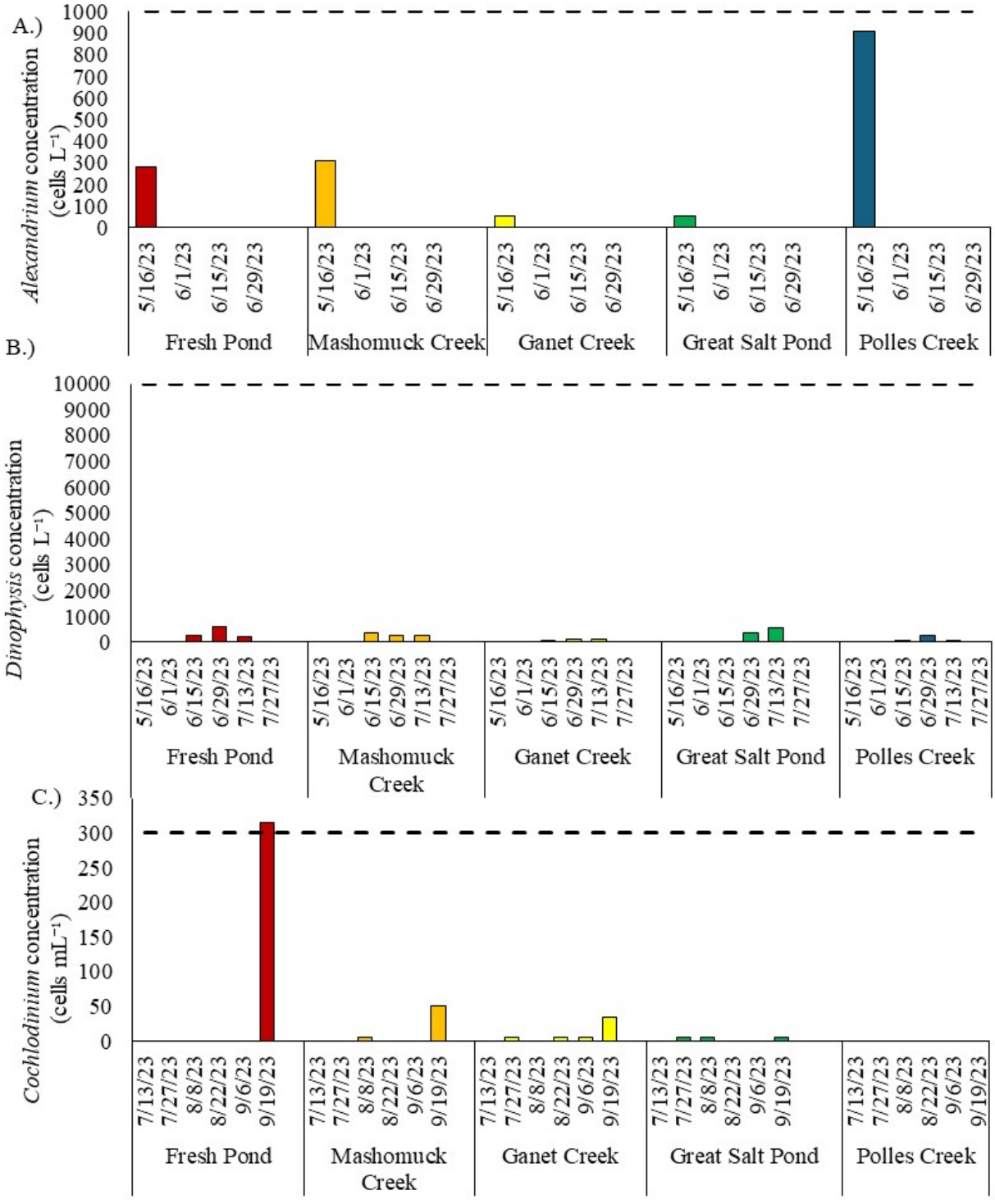

Figure 8. Concentrations of A.) *Alexandrium* (cells L^{-1}) B.) *Dinophysis* (cells L^{-1}) and C.) *Cochlodinium* (cells mL^{-1}) across marine sites in North Haven during 2023. The dashed lines represent respective bloom thresholds: 1000 cells mL^{-1} for *Alexandrium,* 10,000 cells cells L^{-1} for *Dinophysis*, ans 300 cells mL^{-1} for *Cochlodinium*

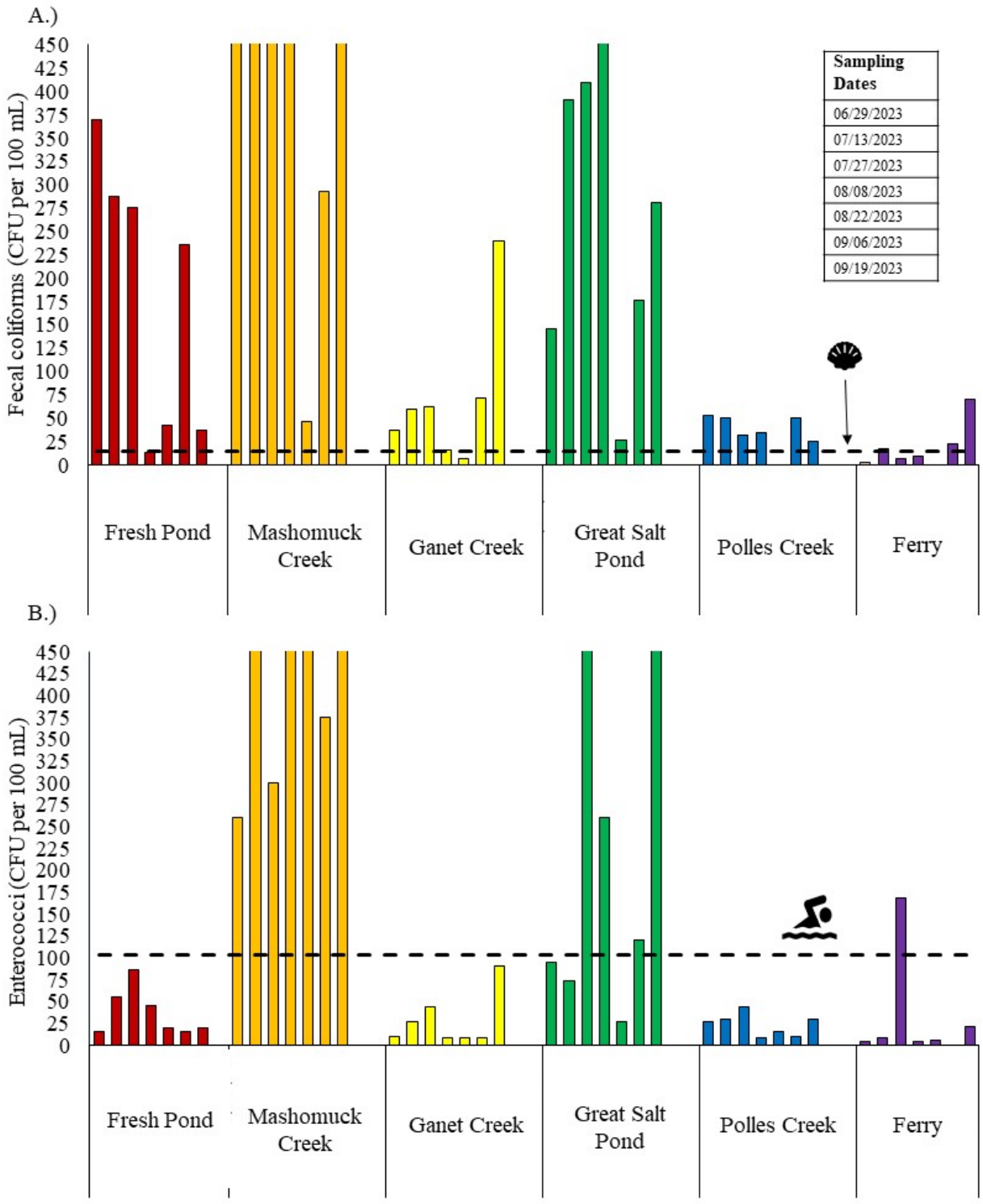

Figure 9. Time-series of A.) fecal coliform and B.) enterococci concentrations (CFU per 100 mL) across marine sites in North Haven in Summer 2023.

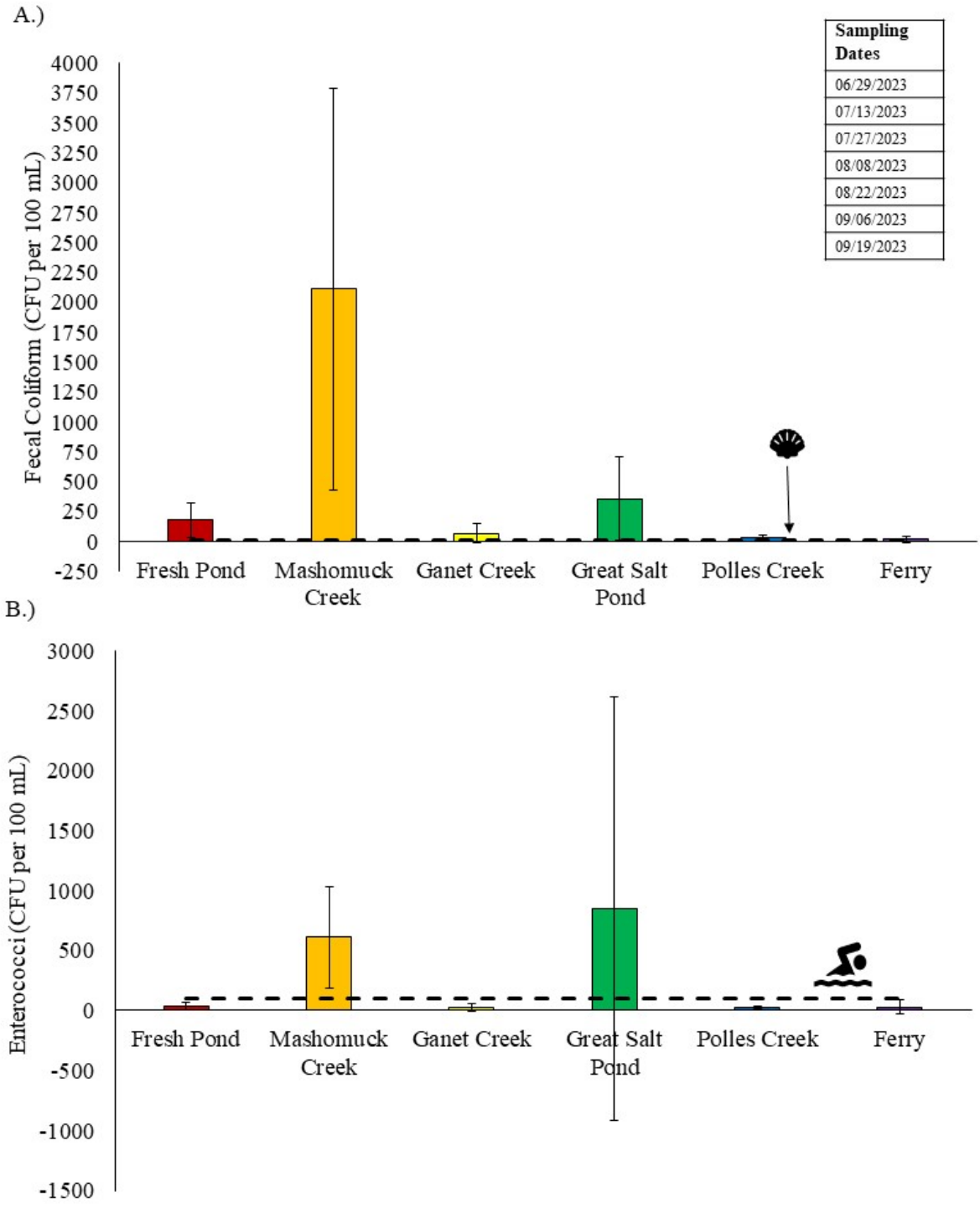

Figure 10. Total averages of A.) fecal coliform and B.) enterococci concentrations (CFU per 100 mL) across marine sites in North Haven, from June to September 2023. Columns represent averages ± standard deviation.