2020 Cyanobacteria Monitoring Report
Duck, Dyer, Great, Gull, Higgins and Long Ponds, Wellfleet, MA

Prepared for the Town of Wellfleet (the Town)
By the Association to Preserve Cape Cod (APCC)

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Background

Following a pilot study of cyanobacteria activity in several Wellfleet ponds in 2019, the Wellfleet Ponds Cyanobacteria Monitoring Program was established in 2020. The goals of the program are to improve understanding of cyanobacterial populations in six Wellfleet ponds (Duck, Dyer, Great, Gull, Higgins and Long Ponds), increase awareness of harmful cyanobacteria blooms throughout the community, and communicate results to help protect public health and safety. The 2020 monitoring results detected no visible cyanobacteria blooms during the sampling season and all samples were ranked as low according to our warning tier system indicating no or low concentrations of cyanobacteria detected. Gull Pond experienced a visible cyanobacteria bloom in late November, but this followed the conclusion of the sampling season. The 2020 monitoring results are summarized in this report. All monitoring results were shared with the Town and the public throughout the season.

Overview of APCC's Cyanobacteria Monitoring Program

Harmful cyanobacteria blooms are indicators of nutrient enrichment and warming temperatures due to climate change and are increasing in frequency and severity. Cyanotoxins pose health risks. Increasingly more common, harmful cyanobacteria blooms in freshwater bodies are the subject of numerous reports published by scientists, state and federal agencies, and organizations, some of which are listed here:

- The World Health Organization recognized the public health consequences of cyanobacteria in water in 1999 (WHO 1999).
- The Centers for Disease Control (CDC) call cyanotoxins "among the most powerful natural poisons known" (CDC Fact Sheet on Harmful Algal Blooms). The CDC's Physician Card on Harmful Algal Blooms (HABs) states that swallowing water containing cyanobacteria can damage the central nervous system, liver or kidneys; skin contact can cause allergic dermatitis and conjunctivitis; and inhalation of aerosols containing cyanobacteria or their toxins can cause wheezing, coughing, chest tightness, and shortness of breath.
- New England Interstate Water Pollution Control Commission (NEIWPCC) is an interstate commission that helps the states of the Northeast preserve and advance water

quality. NEIWPCC's webpage states that "the frequency of HAB occurrence is on the rise and cyanobacteria toxicity has been associated with human health impacts including skin rashes, gastrointestinal and respiratory disease, and liver damage. Effects can be even more pronounced (potentially even fatal) in animals ranging from cattle to dogs. HABs have direct implications to the use of recreational waterbodies for contact recreation, the susceptibility of public water supplies to toxins, and the overall degradation of our aquatic resources."

- U.S. Environmental Protection Agency (EPA):
    - "Monitoring and Responding to Cyanobacteria and Cyanotoxins in Recreational Waters." EPA recreational waters
    - EPA Office of Ground Water and Drinking Water webpage. Managing Cyanotoxins in Public Drinking Water Systems. EPA drinking water
    - EPA webpage on nutrient pollution and HABs. EPA and nutrient pollution
- State agencies, including New York (NY), Vermont (VT), Rhode Island (RI), and New Hampshire (NH) have cyanobacteria monitoring programs and provide guidance concerning public health and environmental risks posed by cyanobacteria.
- Commonwealth of Massachusetts:
    - Cyanobacteria webpage: Massachusetts
    - Massachusetts Department of Public Health (MDPH) website on "Guidelines for cyanobacteria in freshwater recreational water bodies." MDPH

Over the course of the last decade, APCC has received input from many pond associations, organizations, and local and regional resource managers on Cape Cod regarding concerns about pond health, pond water quality and the need for data received in a timely manner to inform pond protection measures and ensure public safety. Harmful cyanobacteria blooms are indicators of nutrient enrichment and climate change. Blooms are increasing in frequency and severity and the cyanotoxins they produce pose concerning health risks to people, pets, and wildlife. In response to these concerns and limited data, APCC developed its Cyanobacteria Monitoring Program in 2017 with guidance and input from state and federal agencies and scientists, including the EPA (EPA recreational waters), Massachusetts Department of Public Health (MDPH), and the town of Barnstable's Health Division (Town of Barnstable).

APCC's cyanobacteria monitoring program normally includes training for citizen scientists to collect water samples from shoreline stations. Volunteers then deliver samples to APCC for lab analysis and storage. These citizen scientists provide APCC with highly useful data and help to extend APCC's coverage of cyanobacteria monitoring across the region. In 2020, however, due to the COVID-19 pandemic and the need to limit exposure to volunteers and staff, APCC chose to have staff collect all samples and volunteers were not engaged.

APCC staff and interns interpret the results within a guidance framework that incorporates the most recent scientific information as well as existing state and federal guidance (EPA recreational waters, MDPH). Results are provided to the pond associations and local municipal officials along with recommendations concerning appropriate advisories for the public to minimize or avoid risks due to cyanobacteria exposure. Pond associations typically play a key role in raising awareness of the risks related to cyanobacteria exposure and alerting pond communities of APCC's findings throughout the season.

APCC's Cyanobacteria Monitoring Program provides a webpage with an interactive map where recent monitoring results are posted. Results are interpreted according to cyanobacteria risk levels related to existing local, state and federal guidance concerning people and pet exposure to cyanobacteria blooms (APCC Cyanobacteria). APCC's goals are to raise public awareness of the risks posed by cyanobacteria toxins related to cyanobacteria blooms, and to motivate public action to improve water quality.

In 2020, APCC monitored over 40 ponds across Cape Cod, including Duck, Dyer, Great, Gull, Higgins, and Long ponds. In the 2019 season, APCC monitored 81 ponds and found that 40% exhibited "High" levels of cyanobacteria that warranted the posting of advisories for people and pets to avoid contact with pond water.

APCC collaborates with many local, regional, state and federal partners, including organizations, homeowners associations, pond associations, water quality committees, municipal staff from Cape Cod and Martha's Vineyard towns, and state and federal agencies and organizations. Partners include the town of Barnstable, Cape Cod towns, Massachusetts Department of Public Health, Massachusetts Department of Environmental Protection, the U.S. EPA, Massachusetts Bays National Estuary Partnership, Massachusetts Division of Marine Fisheries, Barnstable County Department of Health and the Environment, with funding from Massachusetts Environmental Trust, Cape Cod Healthcare, private foundation grants, and dues and donations from APCC members.

Methods

APCC's Cyanobacteria Monitoring Program uses an EPA-approved monitoring protocol developed and published by the U.S. Environmental Protection Agency for the Cyanobacteria Monitoring Collaborative (CMC 2017) and published scientific articles (Leland and Haney, 2018; Leland, Haney, Conte, Malkus-Benjamin and Horsley, 2019). The protocol utilizes a combination of field observations, microscopy and fluorometry to analyze samples from freshwater lakes and ponds for cyanobacteria and cyanobacteria pigments. The data collected includes photographs and field observations, digital microscopy to identify composition (type of cyanobacteria present) and dominance, and concentrations of phycocyanin and chlorophyll pigments indicative of the amounts of cyanobacteria vs. general algae and phytoplankton, respectively. APCC tracks changes in cyanobacterial composition, dominance and abundance on a biweekly basis from June to October.

At this sampling frequency, APCC is often able to forecast when cyanobacteria blooms may be forming or when toxin concentrations may be approaching harmful levels. These signs instruct APCC to increase the frequency of testing and to inform town officials to be aware of potential threats and to plan for proactive management actions to protect public safety. In the Wellfleet ponds this season, samples were collected at the locations designated in Figure 1 between June and October.

Figure 1. Cyanobacteria sampling stations in 2020.

To estimate cyanotoxin levels, measured phycocyanin concentrations in samples are compared to published relationships between concentrations of phycocyanin in whole lake water and bloom-forming colonies and cyanotoxin concentrations (Leland and Haney, 2018; Leland, Haney, Conte, Malkus-Benjamin and Horsley, 2019). Cyanotoxin analysis is conducted for specific instances by our scientific collaborators at the University of New Hampshire and Lim-Tek, Inc. When possible, APCC also conducts tests for microcystin using Abraxis cyanotoxin test strip kits. These tests are rather costly and APCC is always seeking appropriate funding for cyanotoxin testing. Increased availability of cyanotoxin data to supplement our data can be a useful measure to determine more exact risk levels. In Wellfleet no Abraxis cyanotoxin tests were conducted in 2020.

In contrast to measuring cyanobacteria using cell counts, which is one of the methods listed by the Massachusetts Department of Public Health (MDPH), APCC's method is less costly, offers a faster turn-around time for results, and is often useful for predicting cyanobacteria bloom formation. APCC's method of using both microscopy to determine dominance along with fluorometry of phycocyanin also reveals expected genus-specific toxicity which is not found

through basic cell counts. Cyanobacteria pigment data and other collected data also support research efforts that will expand our understanding about the health of the ponds.

To interpret the results based on the dominant cyanobacteria genus in the sample and concentration of phycocyanin (PC) pigment, measured in micrograms per liter (ug/L) to estimate cyanotoxin levels, the threshold *s* in Table 1 are used. These phycocyanin values correspond to expected microcystin concentrations and each threshold denotes a regulatory standard for microcystin or the expectation of a cyanobacteria bloom formation. WLW stands for Whole Lake Water and denotes unconcentrated samples taken near shore with an integrated tube. The cyanobacteria concentrations in this sample reveal what was found in the water at moment of sample collection. BFC stands for Bloom-Forming Colonies and denotes samples taken with student plankton net towed over 3m near shore. The cyanobacteria concentrations in this sample reveal cyanobacteria growth and activity much more clearly than the WLW samples. BFC samples can describe exponential growth of cyanobacteria to predict blooms and can inform APCC staff of imminent cyanobacteria threats. BFC concentrations are typically similar to a potential impending visible cyanobacteria scum accumulation. When these concentrations reach a certain threshold, APCC can tell that a visible cyanobacteria bloom may have formed at some section of the pond not visible to APCC at the time of sampling or that a bloom likely recently formed or will form in the near future. BFC is APCC's preferred metric for cyanobacteria concentrations due to this forecasting ability, although WLW data is useful as well. As continued understanding of cyanobacteria risks emerge, APCC will update these tiers, as necessary.

Along with phycocyanin data, a visible cyanobacteria scum line or bloom formation may trigger a "high" warning tier designation. Exponential growth rates are also taken into account when assigning a warning tier. Finally, town advisory postings for cyanobacteria supersede APCC's data interpretations. Once a pond reaches APCC's "high" warning tier, APCC will keep the pond in that tier until it has found readings below the criteria for the tier over two consecutive sampling events taken a week apart. This protocol is taken from the Massachusetts Department of Public Health (MDPH). When relating the findings, as interpreted by this protocol, to town officials, pond associations and the public, APCC uses the following descriptions:

Low indicates general safety for recreational activities according to our data. Assignment of results to this level indicates that monitoring data indicate no or low concentrations of cyanobacteria detected. To the best of our knowledge at the time and location of sample collection, regular recreational usage of the pond is safe with respect to cyanobacteria and toxins. On APCC's interactive map of results, the map color is blue.

Moderate indicates the cyanobacteria concentrations in the pond are particularly dangerous to children or pets if ingested and is very similar to the town of Barnstable's "Pet Advisory" level. Assignment of results to this level indicates that monitoring data indicate moderately high levels of cyanobacteria concentrations detected. While these conditions pose low to minimal health risks to adults, they can be dangerous for children or pets if water is ingested accidentally or incidentally during recreational activities. Pet exposure can be from drinking water or grooming after swimming. Due to lower body masses, children and pets are more susceptible to impacts at lower concentrations than adults. This tier is consistent with the town of Barnstable's "Pet Advisory." If a town official declares a Pet Advisory for a pond at a given time, APCC will

designate the pond in the Moderate tier. On APCC's interactive map of results, the map color is yellow.

High indicates that APCC found that either toxin levels approached state standards for recreation or that a visible cyanobacteria scum was present; each poses a considerable risk for human and pet interactions with the pond. This tier is between the town of Barnstable's "Warning" and "Closure" tiers. Assignment of results to this level indicates that monitoring data indicate high levels of cyanobacteria concentrations were detected. Health risk to adults is high and is especially dangerous for children and pets when ingested. APCC found cyanobacteria concentrations near or exceeding state recreational standards with potential for exponential growth rates of cyanobacteria. Any accidental consumption of pond water is considered dangerous and interacting with the pond in general carries risk for adverse health effects. If a town official declares a Warning or Closure for a pond at a given time, APCC will designate the pond in the High tier. On APCC's interactive map of results, the map color is red.

Table 1. APCC Cyanobacteria Monitoring Results Table with Map Colors

Warning Tier	Dominant Genus	WLW	BFC
High	*Microcystis* spp.	PC > 110 ug/L	PC > 390 ug/L
	Other	PC > 1,100 ug/L	PC > 3,900 ug/L
Moderate	*Microcystis* spp.	16 ug/L < PC < 110 ug/L	110 ug/L < PC < 390 ug/L
	Other	160 ug/L < PC < 1,100 ug/L	1,110 ug/L< PC < 3,900 ug/L
Low	*Microcystis* spp.	PC < 16ug/L	PC < 110ug/L
	Other	PC < 160ug/L	PC < 1,110 ug/L

Results

Duck Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Duck Pond was 83% *Woronichinia* species (spp.), and 17% *Coelosphaerium* spp.

Table 2. Cyanobacteria Genera Dominance in Duck Pond

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/9/2020	Low	No Cyanobacteria found on the slide
6/23/2020	Low	No Cyanobacteria found on the slide
7/7/2020	Low	No Cyanobacteria found on the slide
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	No Cyanobacteria found on the slide
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	No Cyanobacteria found on the slide
9/15/2020	Low	No Cyanobacteria found on the slide
9/29/2020	Low	83% *Woronichinia* spp., 17% *Coelosphaerium* spp.
10/14/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Duck Pond, the lowest phycocyanin concentration recorded was 1.22 micrograms per liter (ug/L) on June 23rd and the highest phycocyanin concentration recorded was of 16.61 ug/L on September 29th.

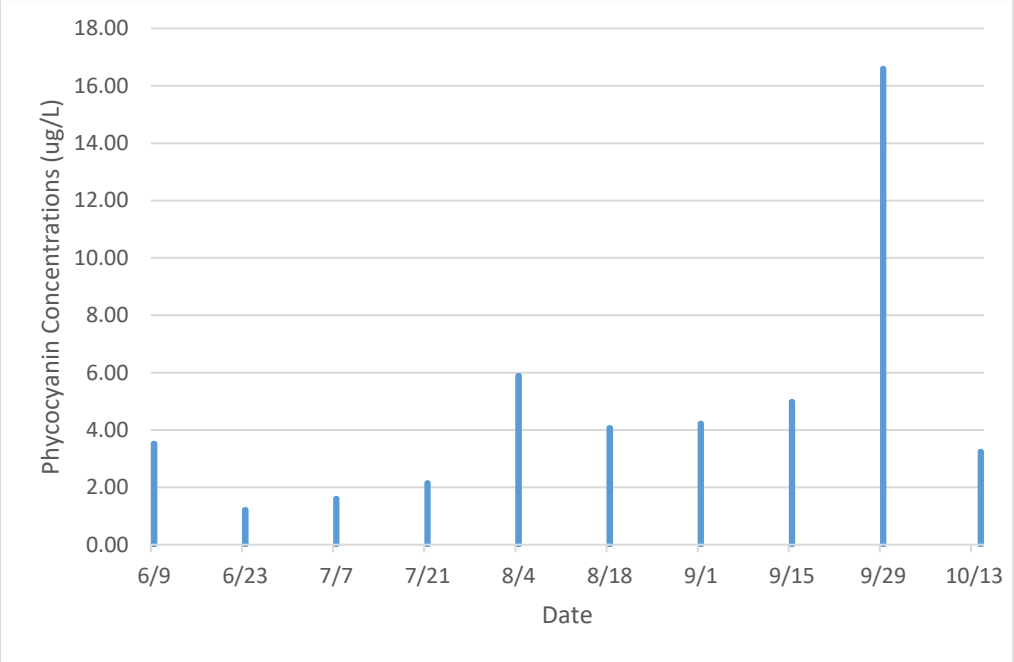

Figure 2. Phycocyanin Concentrations in Duck Pond in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Duck Pond reached was the low warning tier. There were no visible blooms. There was a light pollen scum seen on June 9th but no cyanobacteria were found during sampling.

D. Discussion

Duck Pond exhibited a low risk for cyanobacteria exposure over the entire sampling period with cyanobacteria concentrations remaining well below state standards. APCC staff were only able to document colonies of cyanobacteria for one sampling event. In the network of ponds APCC tests, it is rare for a pond to contain such trace concentrations of cyanobacteria. Due to this small sample size, APCC's recorded seasonal averages for cyanobacteria composition and dominance in Duck Pond may not accurately represent its true seasonal ratios of cyanobacteria genera. Duck also was found to have great clarity in its water column.

Dyer Pond

A. Cyanobacteria Community Composition

The composition and dominance were not determined as microscopic analysis revealed that no cyanobacteria were found in Dyer Pond over the 10 sampling events this season.

Table 3. Cyanobacteria Genera Dominance in Dyer Pond

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/9/2020	Low	No Cyanobacteria found on the slide
6/23/2020	Low	No Cyanobacteria found on the slide
7/7/2020	Low	No Cyanobacteria found on the slide
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	No Cyanobacteria found on the slide
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	No Cyanobacteria found on the slide
9/15/2020	Low	No Cyanobacteria found on the slide
9/29/2020	Low	No Cyanobacteria found on the slide
10/14/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Dyer Pond, the lowest phycocyanin concentration recorded was 1.04 micrograms per liter (ug/L) on September 15th and the highest phycocyanin concentration recorded was 14.81 ug/L on June 9th.

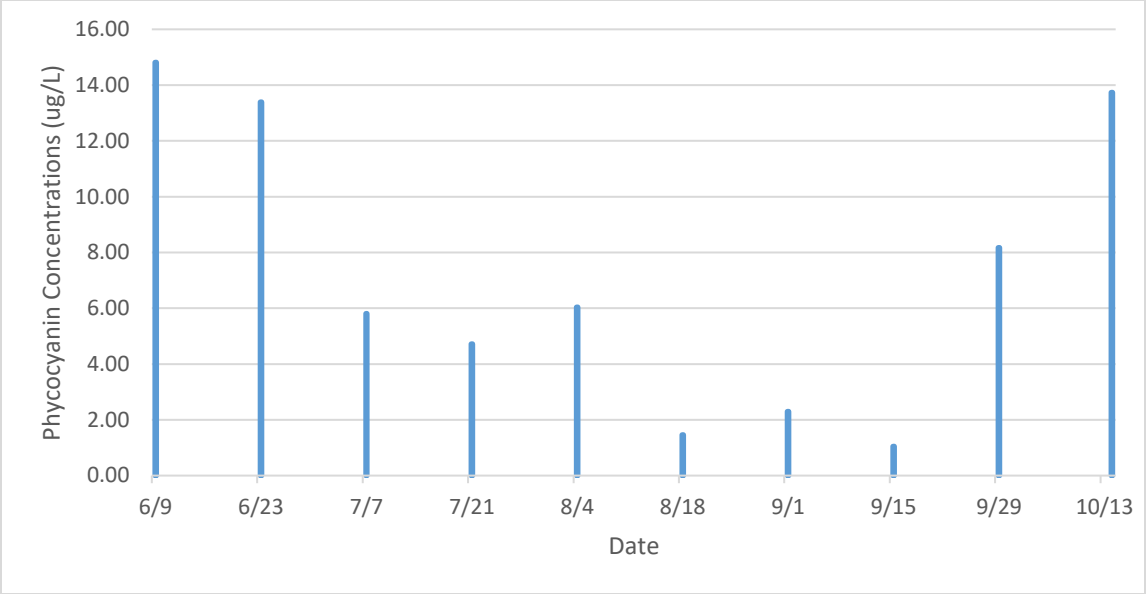

Figure 3. Phycocyanin Concentrations in Dyer Pond in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Dyer Pond reached was the low warning tier. There were no visible blooms. There was a pollen scum seen on June 9th but no cyanobacteria were found during sampling.

D. Discussion

Dyer Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining well below state standards. Similar to Duck, it is rare for APCC staff to find such low concentrations of cyanobacteria in a pond over the course of a season. Dyer Pond's cyanobacteria concentrations, while very low, peaked in June and October. It is common for ponds to experience elevated cyanobacteria concentrations during these periods of pond turnover (Paerl et al,. 2001) in spring and fall. Tadpoles and bass were often seen during sampling and people were observed swimming and fishing in Dyer Pond.

Great Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Great Pond was 93% *Dolichospermum* spp., and 7% *Woronichinia* spp.

Table 4. Cyanobacteria Genera Dominance in Great Pond

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/9/2020	Low	No Cyanobacteria found on the slide
6/23/2020	Low	100% *Dolichospermum* spp.
7/7/2020	Low	100% *Dolichospermum* spp.
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	100% *Dolichospermum* spp.
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	No Cyanobacteria found on the slide
9/15/2020	Low	100% *Dolichospermum* spp.
9/29/2020	Low	67% *Dolichospermum* spp., 33% *Woronichinia* spp.
10/13/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Great Pond, the lowest phycocyanin concentration recorded was 1.53 micrograms per liter (ug/L) on August 4th and the highest phycocyanin concentration recorded was 80.28 ug/L on September 15th.

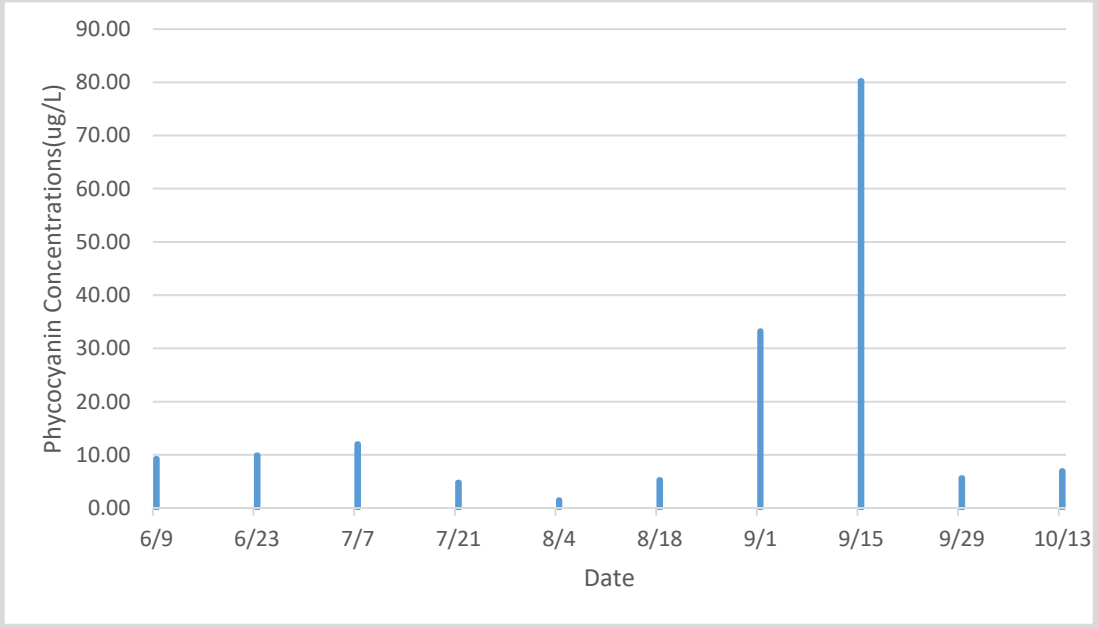

Figure 4. Phycocyanin Concentrations in Great Pond in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Great Pond reached was the low warning tier. There were no visible blooms. There was a pollen scum seen on June 9th but no cyanobacteria were found during sampling.

D. Discussion

Great Pond has a public beach that is popular with swimmers. During all of our sampling events, many people were observed swimming. Great Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining well below state standards. Pollen scums may sometimes be misinterpreted for cyanobacteria bloom material. However, analysis of the scum on June 9th revealed the material to be entirely composed of pollen. Great Pond's cyanobacteria concentrations, while low, peaked in September. It is common for ponds to experience elevated cyanobacteria concentrations during these periods of pond turnover (Paerl et al,. 2001) in spring and fall. In future seasons, it is recommended to keep a closer eye on Great Pond during these periods due to the use of it as a popular swimming location.

Gull Pond – Location 1 (Public Landing)

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Gull Pond at location 1 was 100% *Dolichospermum* spp.

Table 5. Cyanobacteria Genera Dominance at Gull Pond, Location 1

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/9/2020	Low	100% *Dolichospermum* spp.
6/23/2020	Low	100% *Dolichospermum* spp.
7/7/2020	Low	100% *Dolichospermum* spp.
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	No Cyanobacteria found on the slide
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	No Cyanobacteria found on the slide
9/15/2020	Low	No Cyanobacteria found on the slide
9/29/2020	Low	No Cyanobacteria found on the slide
10/13/2020	Low	100% *Dolichospermum* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Gull Pond at sampling location 1 (public landing), the lowest phycocyanin concentration recorded was 0.77 micrograms per liter (ug/L) on July 7th and the highest phycocyanin concentration recorded was 332.77 ug/L on June 9th.

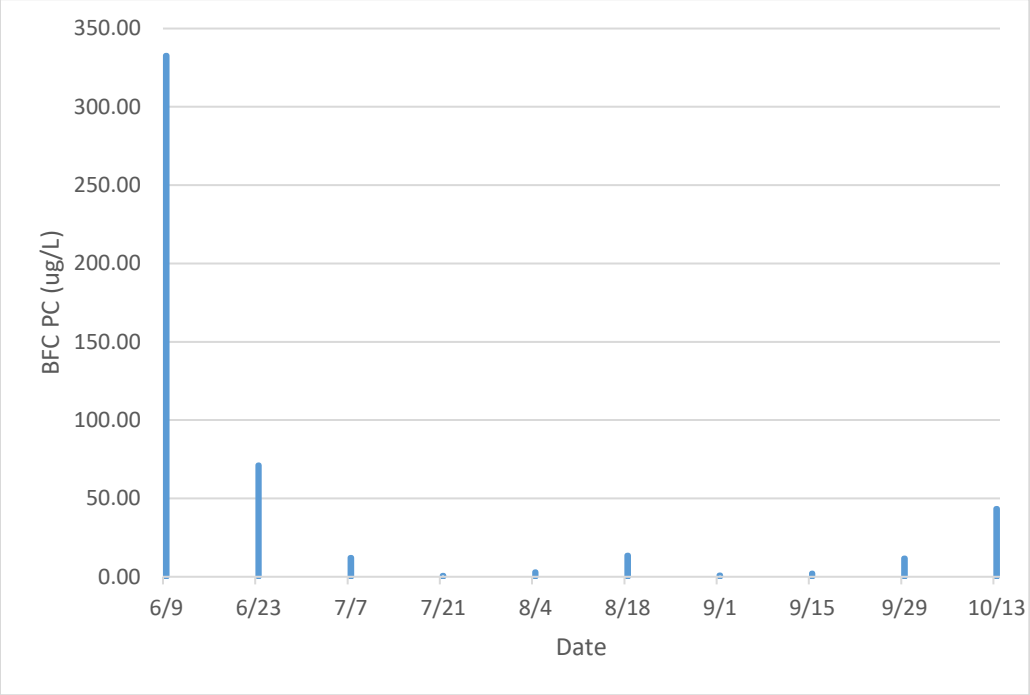

Figure 5. Phycocyanin Concentrations at Gull Pond Location 1 in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Gull Pond at location 1 reached was the low warning tier. There were no visible blooms.

D. Discussion

Although APCC's cyanobacteria monitoring season ended in mid-October, a cyanobacteria bloom was reported in late November by Sophia Fox of the National Park Service. This is the second straight year that Gull has experienced a cyanobacteria bloom event although fortunately this time it happened late in the fall. Including this fall bloom and the elevated cyanobacteria concentrations found in early June, Gull experienced its highest cyanobacteria concentrations around times of pond turnover. It is common for ponds to experience elevated cyanobacteria concentrations during these periods (Paerl et al,. 2001) in spring and fall. In future seasons, it is recommended to keep a closer eye on Gull Pond during these times due to the presence and use of the pond by swimmers and boaters.

Gull Pond – Location 2 (North side near Higgins)

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Gull Pond at location 2 was 99% *Dolichospermum* spp., and less than 1% *Woronichinia* spp.

Table 6. Cyanobacteria Genera Dominance at Gull Pond Location 2

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/23/2020	Low	100% *Dolichospermum* spp.
7/7/2020	Low	100% *Dolichospermum* spp.
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	No Cyanobacteria found on the slide
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	100% *Dolichospermum* spp.
9/15/2020	Low	No Cyanobacteria found on the slide
9/29/2020	Low	99% *Dolichospermum* spp., 1% *Woronichinia* spp.
10/14/2020	Low	100% *Dolichospermum* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Gull Pond at sampling location 2, the lowest phycocyanin concentration recorded was 0.73 micrograms per liter (ug/L) on July 21st and the highest phycocyanin concentration recorded was 357.12 ug/L on June 23rd.

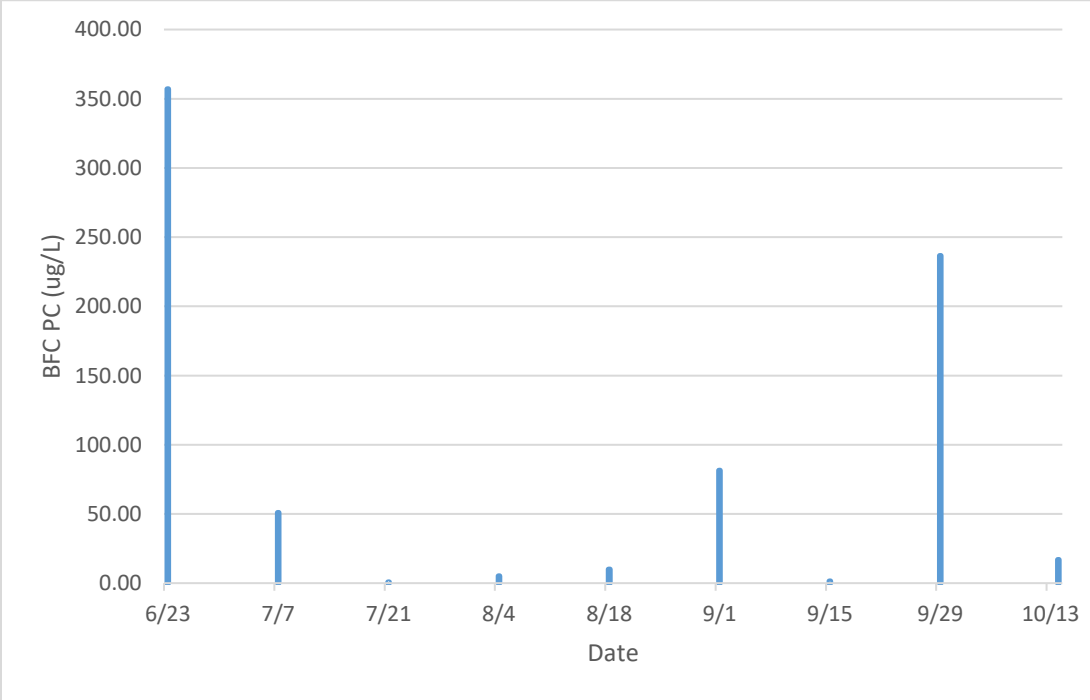

Figure 6. Phycocyanin Concentrations at Gull Pond Location 2 in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Gull Pond location 2 reached was the low warning tier. There were no visible blooms.

D. Discussion

Gull Pond, as noted above, experienced a cyanobacteria bloom in late November, reported by Sophia Fox of the National Park Service. This is the second consecutive year that Gull Pond has experienced a cyanobacteria bloom event, although this time it happened late in the fall. Including this fall bloom and the elevated cyanobacteria concentrations found in early June, Gull Pond experienced its highest cyanobacteria concentrations around times of pond turnover. It is common for ponds to experience elevated cyanobacteria concentrations during these periods (Paerl et al,. 2001) in spring and fall. In future seasons, we recommend keeping a closer eye on Gull Pond during these times due to the presence and use of the pond by swimmers and boaters. Additionally, the only time results differed from Gull's two locations was in late September when Location 2 experienced elevated concentrations of cyanobacteria whereas Location 1 avoided such conditions. Monitoring the two locations will add to our understanding of the dynamics and distribution of cyanobacteria concentrations in Gull Pond.

Higgins Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria in Higgins Pond was 96% *Dolichospermum* spp., and 4% *Aphanizomenon* spp.

Table 7. Cyanobacteria Genera Dominance in Higgins Pond

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/9/2020	Low	100% *Dolichospermum* spp.
6/23/2020	Low	100% *Dolichospermum* spp.
7/7/2020	Low	100% *Dolichospermum* spp.
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	No Cyanobacteria found on the slide
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	75% *Dolichospermum* spp., 25% *Aphanizomenon* spp.
9/15/2020	Low	No Cyanobacteria found on the slide
9/29/2020	Low	100% *Dolichospermum* spp.
10/14/2020	Low	100% *Dolichospermum* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Higgins Pond, the lowest phycocyanin concentration recorded was 1.45 micrograms per liter (ug/L) on August 4th and the highest phycocyanin concentration recorded was 90.99 ug/L on June 23rd.

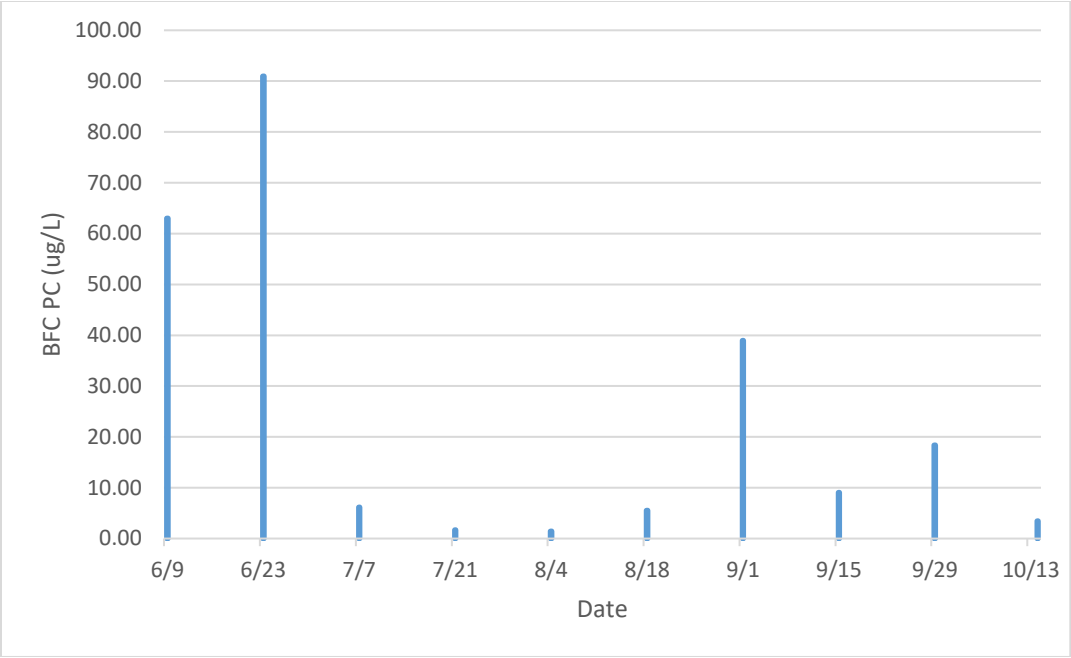

Figure 7. Phycocyanin Concentrations in Higgins Pond in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Higgins Pond reached was the low warning tier. There were no visible blooms. There was also a pollen scum seen on June 9th and a brown scum seen on the water's edge on June 23rd but APCC's analysis of the material confirmed these scums were not composed of cyanobacteria.

D. Discussion

Higgins Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining well below state standards. People were observed walking on a path along the pond and using kayaks and canoes on the pond. Higgins Pond's cyanobacteria concentrations, while low, peaked in June. It is common for ponds to experience elevated cyanobacteria concentrations during these periods of pond turnover (Paerl et al,. 2001)

in spring and fall. In future seasons, we recommend keeping a closer eye on Higgins Pond during these periods due to this observed pattern and use of the pond by boaters and walkers.

Long Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria in Long Pond was 50% *Aphanizomenon* spp., 25% *Dolichospermum* spp., and 25% *Microcystis* spp.

Table 8. Cyanobacteria Genera Dominance in Long Pond

Sampling Date	APCC Map Warning Tier	Percent Dominance of each genus identified
6/9/2020	Low	No Cyanobacteria found on the slide
6/23/2020	Low	100% *Aphanizomenon* spp.
7/7/2020	Low	100% *Aphanizomenon* spp.
7/21/2020	Low	No Cyanobacteria found on the slide
8/4/2020	Low	No Cyanobacteria found on the slide
8/18/2020	Low	No Cyanobacteria found on the slide
9/1/2020	Low	No Cyanobacteria found on the slide
9/15/2020	Low	100% *Microcystis* spp.
9/29/2020	Low	100% *Dolichospermum* spp.
10/13/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Long Pond, the lowest phycocyanin concentration recorded was 0.30 micrograms per liter (ug/L) on June 9thth and the highest phycocyanin concentration recorded was 14.65 ug/L on August 18th.

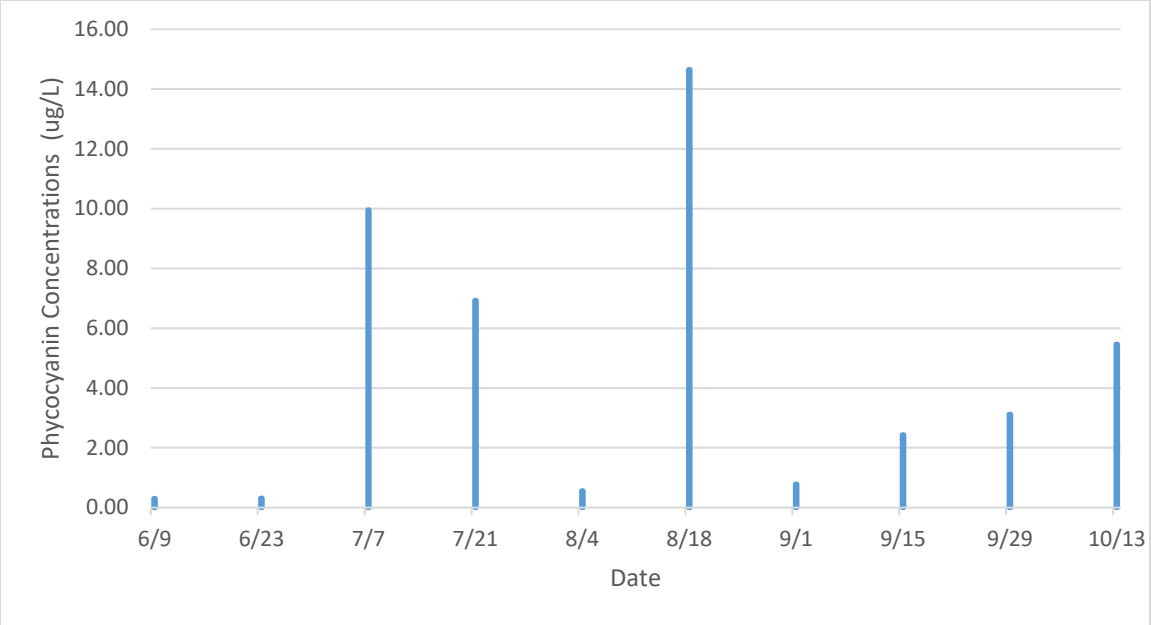

Figure 8. Phycocyanin Concentrations in Long Pond in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Long Pond reached was the low warning tier. There were no visible blooms. There was a pollen scum seen on June 9th but no cyanobacteria were found during sampling.

D. Discussion

Long Pond has a sandy beach popular with swimmers and people were also observed walking their dogs on the beach. Long Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining well below state standards with no clear seasonal peaks. In future seasons, we recommend continuing to sample at Long Pond due to the use of the pond by swimmers and dog walkers, and observation of *Microcystis* spp. in one of the samples.

Conclusions

This first full season of cyanobacteria monitoring by APCC in Wellfleet ponds was a success in terms of collecting and analyzing samples and documenting results on every intended date throughout the season. The monitoring data provide a baseline for cyanobacteria trends in Wellfleet ponds over the extent of a season. All results throughout the season were posted promptly to the APCC Interactive Map following the completion of sample analysis (APCC Cyanobacteria).

Overall, the Wellfleet ponds fared well for low cyanobacteria risk in the 2020 season as only Gull Pond experienced a potentially harmful cyanobacteria bloom. By APCC's analysis, the

other five ponds exuded low risks for cyanobacteria hazards for the entirety of the sampling season. However, with so many ponds experiencing their highest cyanobacteria concentrations in the spring and the fall, more early and late season monitoring could shed light on potential bloom conditions outside of the typical June to October monitoring season. Although residents may interact with these ponds less during these times, there are still dangers posed to pets who may consume or swim in these waters while on walks during colder months.

Recommendations

Monitoring over multiple years would provide greater understanding of the cyanobacteria community in each of the Wellfleet ponds. More seasons of data will allow us to draw better predictions year over year. Continued monitoring will also allow us to track degradation in the ponds as increased occurrence of harmful cyanobacteria blooms point to larger issues of pond impairment. Monitoring efforts will shed light on the ponds most in need of protection and possibly rehabilitation. Monitoring in the early and late season will also lead to an increased understand of the cyanobacteria trends of Wellfleet's ponds.

APCC hopes to perform pilot studies of a different cyanotoxin, anatoxin-a, in 2021. Anatoxin-a is a neurotoxin produced by *Dolichospermum* spp., a common cyanobacteria genus detected in 2020 in Great, Gull, Higgins and Long Ponds. The occurrence of anatoxin-a in natural water bodies has not been adequately researched, and more data could help to characterize the risk potential from this neurotoxin.

To promote improved pond health, residents surrounding vulnerable pond ecosystems should take action to reduce potential nutrient pollution flowing from their property. Excess fertilizer use, improper management of septic systems, poor stormwater management infrastructure, and a lack of adequate vegetation buffers are all examples of behavior that serve to exacerbate the nutrient loading of the ponds in Wellfleet. For a complete list of actions residents can take to promote pond health, please visit APCC's Recommended Actions for Ponds page, a part of the State of the Waters: Cape Cod project (State of the Waters).

In general, APCC does not support the use of aluminum sulfate (alum) treatments to alleviate phosphorus loading and cyanobacteria blooms. While these treatments often produce desired results in the short term, they only provide temporary relief from one factor (phosphorus) contributing to the increasing issue of excessive cyanobacteria growth, and they raise significant concern among environmentalists for a variety of reasons. Recent research has found that alum treatments can produce "unintended ecological consequences," including increasing dissolved aluminum and sulfate in lake water, altering important nitrogen cycling processes, and affecting benthic communities (Nogaro et al., 2013). Negative side-effects of dissolved forms of aluminum may harm certain invertebrates and are known to be toxic to fish (Gensemer and Playle, 1999). A third paper on this topic concluded that alum treatment should not be used to treat cyanobacteria HABs due to unintended effects, including microcystin toxin release and reduced activity of beneficial cyanobacteria-lysing and microcystin-degrading bacteria (Han et al., 2013).

Furthermore, there is growing evidence that management of nitrogen in addition to phosphorus is important in controlling cyanobacteria blooms. Nitrogen loading has been found to promote

blooms of certain non-nitrogen fixing genera of cyanobacteria including *Microcystis* spp. (Paerl et al. 2010), which was present in Long Pond this season. *Microcystis* spp. have been found to dominate waters with low phosphorus concentrations and nitrogen loading may "selectively promote the abundance of *Microcystis* spp." (Gobler et al. 2016).

In addition to managing nutrients, changing climate conditions, including the currently warming atmosphere and altered rainfall patterns, are believed to play a significant role in the increasing frequency and intensity of harmful cyanobacteria blooms (Paerl et al., 2019).

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