2020 Cyanobacteria Monitoring Report

Bakers, Cliff, Cobbs, Elbow, Griffiths, Long, Lower Mill, Myricks, Schoolhouse, Sheep, Smalls, Upper Mill and Walkers Ponds, Brewster, MA

Prepared for the Brewster Ponds Coalition (BPC)

By the Association to Preserve Cape Cod (APCC)

February 22, 2021

Background

In 2017, the Brewster Ponds Cyanobacteria Monitoring Program was established. Since then, the program has grown and expanded with the assistance of the Brewster Ponds Coalition (BPC) citizen scientist team. The goals of the program are to improve understanding of cyanobacterial populations in the Brewster ponds with assistance from the Eddy foundation and the Brewster Ponds Coalition, to increase awareness of cyanobacteria blooms throughout the community, and communicate results to help protect public health and safety. Following successful monitoring seasons in 2017, 2018, and 2019, APCC and BPC continued the cyanobacteria monitoring program in 2020 thanks to funding support from the Eddy Foundation. The results of the 2020 monitoring work in the Brewster ponds by APCC and BPC are summarized in this report. All monitoring results were also shared with the BPC community, Brewster town officials, and the public throughout the season.

APCC's Cyanobacteria Monitoring Program Overview

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 to humans and wildlife which may ingest cyanotoxins present in water bodies. Harmful cyanobacteria blooms in freshwater bodies have become more common and 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 pond water quality 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.

Association to Preserve Cape Cod 2
APCC staff and interns interpret monitoring results within a guided 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 and BPC monitored over 40 ponds across Cape Cod, including Bakers, Cliff, Cobbs, Elbow, Griffiths, Long, Lower Mill, Myricks, Schoolhouse, Sheep, Smalls, Upper Mill, and Walkers ponds.

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 Brewster

Ponds this season, samples were collected at the ponds shown in Figure 1 between May and November.

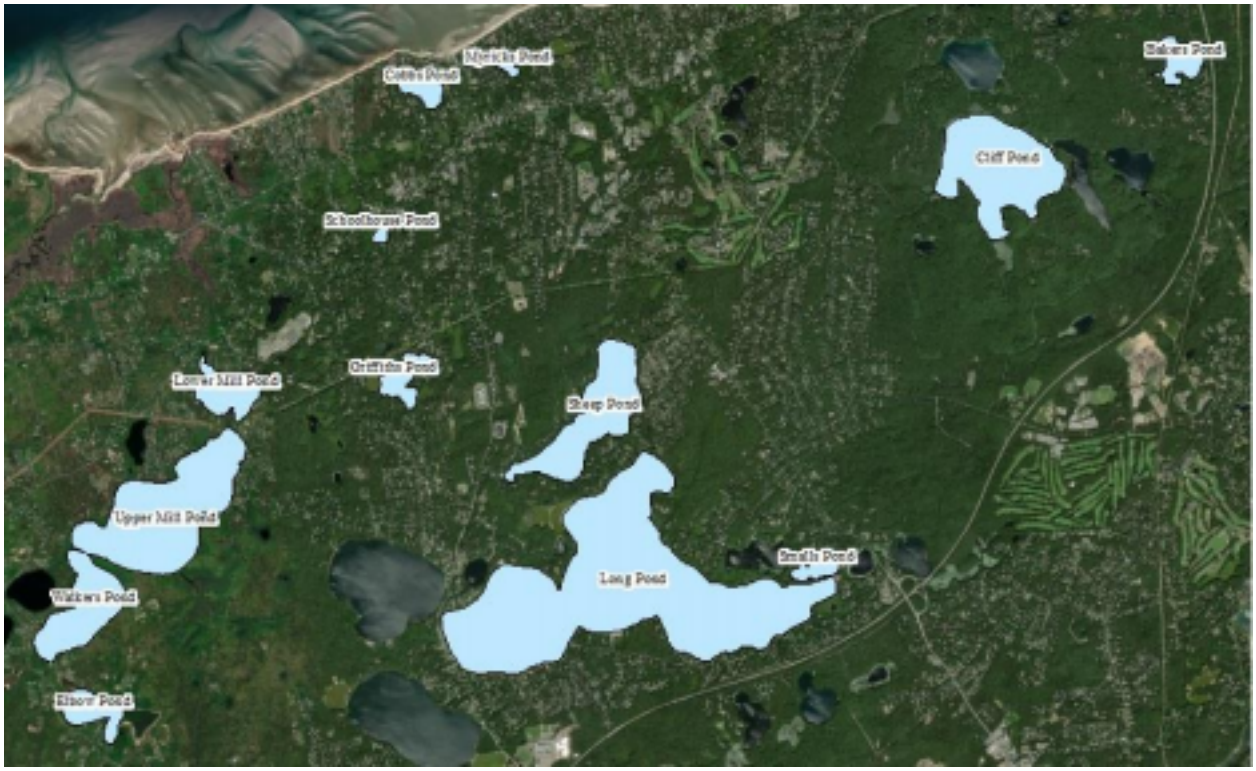

Figure 1. Cyanobacteria sampling stations in 2020.

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 one common cyanotoxin (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. However, no Abraxis cyanotoxin tests were administered in 2020 except for one test at Schoolhouse Pond on August 8, 2020 which failed to confirm microcystin concentrations.

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 as well as 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 3 meters 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 be used to forecast imminent threats due to cyanobacteria blooms. BFC concentrations are typically similar to a potential impending visible cyanobacteria scum accumulation. When these concentrations reach a certain threshold, we are often able to discern that a visible cyanobacteria bloom may have formed in another area of the pond not sampled 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 are taken into account along with APCC's data interpretations when assigning a tier designation. Once a pond reaches APCC's "high" warning tier, APCC will keep the pond in that tier until monitoring results fall 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 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" warning 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" warning tier. On APCC's interactive map of results, the map color is red.

Table 1. APCC Cyanobacteria Monitoring Results 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 < 16 ug/L	PC < 110 ug/L
	Other	PC <160 ug/L	PC < 1,110 ug/L

Results

Bakers Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Baker's Pond over the 12 sampling events this season to be on average 77% *Dolichospermum* spp., 11% *Microcystis* spp., 11% *Woronichinia* spp., and 1% *Aphanizomenon* spp.

Table 2. Baker's Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent Dominance of Each Genus Identified
5/21/2020	Low	100% *Dolichospermum* spp.
6/2/2020	Moderate	100% *Dolichospermum* spp.
6/12/2020	Low	100% *Dolichospermum* spp.
6/16/2020	Low	100% *Dolichospermum* spp.
6/30/2020	Low	96% *Dolichospermum* spp., 4% *Aphanizomenon* spp.
7/14/2020	Low	100% *Microcystis* spp.
7/28/2020	Low	No Cyanobacteria found on the slide
8/11/2020	Low	No Cyanobacteria found on the slide
8/25/2020	Low	100% *Dolichospermum* spp.
9/8/2020	Low	100% *Dolichospermum* spp.
9/22/2020	Low	100% *Woronichinia* spp.
10/6/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Bakers Pond, the lowest phycocyanin concentration recorded was 0.58 micrograms per liter (ug/L) on July 28, 2020 and the highest phycocyanin concentration recorded was 3,107.34 ug/L on June 2, 2020.

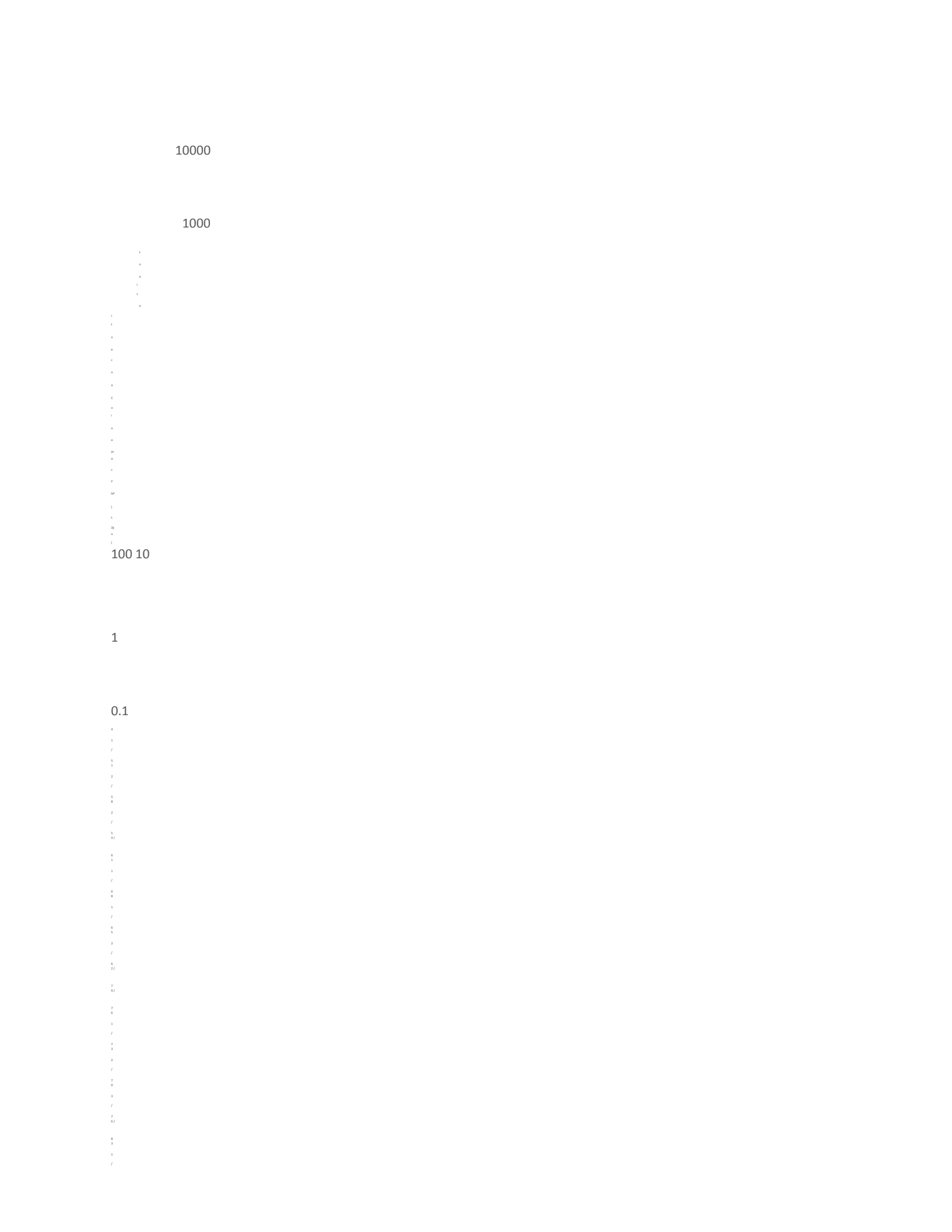
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Figure 2. Bakers Pond Phycocyanin Concentrations in 2020 (*Logarithmic Scale)

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Baker's Pond reached was the "moderate" warning tier on June 2, 2020. A pollen scum was seen on June 2, 2020, and the scum was confirmed to be composed of pollen and not cyanobacteria through an analysis of the scum material under a microscope at the APCC lab.

D. Discussion

During all sampling events, people were observed walking with their dogs along the nature trails. This observation of pond-related activities is relevant because harmful cyanobacteria blooms can cause dogs, children and adults to become ill if pond water is ingested. Bakers Pond generally exhibited a low risk for cyanobacteria exposure over the sampling period albeit with one period when it posed a moderate risk for cyanobacteria exposure. Bakers avoided the "high" warning tier and its only scum formation was evidently pollen related. Pollen scums may sometimes be misinterpreted for cyanobacteria bloom material. However, analysis of the scum on June 2nd revealed the material to be entirely composed of pollen. Bakers Pond's cyanobacteria concentrations, while low, peaked in June and then later in early September. It is common for ponds to experience elevated cyanobacteria concentrations during these periods of pond turnover (Paerl et al., 2001) near spring and fall. In future seasons, it is recommended to keep a closer eye on Baker's Pond during these periods due to the use of it as a popular swimming location.

Cliff Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Cliff Pond over the 20 sampling events this season to be on average 44% *Microcystis* spp., 23%

Dolichospermum spp., and 33% Other.

Table 3. Cliff Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
6/1/2020	High	83% *Dolichospermum* spp., 17% Other
6/9/2020	High	25% *Dolichospermum* spp., 25% *Microcystis* spp., 50% Other
6/15/2020	High	15% *Microcystis* spp., 5% D*olichospermum* spp., 80% Other
6/22/2020	High	50% *Microcystis* spp., 50% Other
6/29/2020	High	58% *Microcystis* spp., 12% *Dolichospermum* spp., 31% Other
7/7/2020	Low	84% *Microcystis* spp., 2% *Dolichospermum* spp., 14% Other
7/13/2020	Moderate	57% *Microcystis* spp., 14% *Dolichospermum* spp., 29% Other
7/21/2020	Low	68% *Microcystis* spp., 13% *Dolichospermum* spp., 19% Other

7/27/2020	Moderate	42% *Microcystis* spp., 32% *Dolichospermum* spp., 26% Other
8/10/2020	Moderate	23% *Microcystis* spp., 77% Other
8/24/2020	Moderate	86% *Microcystis* spp., 2% *Dolichospermum* spp., 12% Other
9/7/2020	Low	66% *Microcystis* spp., 14% *Dolichospermum* spp., 20% Other
9/21/2020	High	44% *Microcystis* spp., 38% *Dolichospermum* spp., 18% Other
9/28/2020	High	81% *Dolichospermum* spp., 3% *Microcystis* spp., 16% Other
10/5/2020	High	93% *Dolichospermum* spp., 7% Other
10/20/2020	High	60% M*icrocystis* spp., 32% *Dolichospermum* spp., 8% Other
10/27/2020	High	27% *Microcystis* spp., 2% *Dolichospermum* spp., 71% Other
11/4/2020	Moderate	47% *Microcystis* spp., 1% *Dolichospermum spp., 52% Other*

11/11/2020	Low	77% *Microcystis* spp., 13% *Dolichospermum* spp., 10% Other
11/18/2020	Low	44% *Microcystis* spp., 4% *Dolichospermum* spp., 52% Other

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Cliff Pond, the lowest phycocyanin concentration recorded was 14.31 micrograms per liter (ug/L) on November 18, 2020 and the highest phycocyanin concentration recorded was 8,037.19 ug/L on June 1, 2020.

Date

Figure 3. Cliff Pond Phycocyanin Concentrations in 2020 (Logarithmic Scale)

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Cliff Pond reached was the “high” warning tier. Cliff pond was under the “high” warning tier designation from June 1, 2020 to June 29, 2020 and from September 21, 2020 to October 27, 2020. Cliff Pond was listed under the “moderate” warning tier designation on July 13, 2020 and from July 27, 2020 to October 24, 2020. Visible cyanobacteria bloom accumulations were seen on June 9, 2020, June 22, 2020, September 21, 2020, and October 20, 2020, each of which was confirmed by BPC member Chuck Madansky who monitors the pond regularly. Throughout the sampling season the turbidity of the pond remained around 110 cm. A thin cyanobacteria bloom was reported in nearby Little Cliff pond on November 25, 2020 by Chuck Madansky.

D. Discussion

Cliff Pond has a public beach that is popular with swimmers and dog walkers. Cliff Pond exhibited a high risk for cyanobacteria exposure at times over the sampling period with cyanobacteria concentrations often estimated to be near or exceeding state standards. Thin visible cyanobacteria bloom accumulations were common at shore throughout the sampling season. Cliff Pond’s cyanobacteria concentrations peaked in June but remained high for much of the season. Continued monitoring of Cliff and perhaps Little Cliff in future seasons will promote public safety for the many visitors of these two ponds.

Cobbs Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Cobbs Pond over the single sampling event this season to be on average 100% *Woronichinia* spp.

Table 4. Cobbs Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
6/19/2020	Low	100% *Woronichinia* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Cobbs Pond, the phycocyanin concentration recorded was 118.87 micrograms per liter (ug/L) on June 19, 2020.

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

Cobbs Pond was put into the "low" warning tier after the one sampling event of the season.

D. Discussion

Cobbs Pond was only sampled one time over the APCC cyanobacteria sampling season, during which it was found to have low cyanobacteria concentrations. From the sampling location it seemed to be a pond people would use for kayaking, canoeing and paddle boarding. Future monitoring of Cobbs is advised if resources are available to include it.

Elbow Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Elbow Pond over the 21 sampling events this season to be on average 82% *Dolichospermum* spp., 10% *Woronichinia* spp., 7% *Microcystis* spp., and 1% *Coelosphaerium* spp.

Table 5. Elbow Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
5/21/2020	Low	100% *Dolichospermum* spp.
5/29/2020	Low	100% *Dolichospermum* spp.

6/2/2020	Low	100% *Dolichospermum* spp.
6/11/2020	Low	No Cyanobacteria found on the slide
6/16/2020	Low	No Cyanobacteria found on the slide
6/25/2020	Low	No Cyanobacteria found on the slide
6/30/2020	Low	100% *Woronichinia* spp.
7/9/2020	Low	100% *Dolichospermum* spp.
7/14/2020	Low	No Cyanobacteria found on the slide
7/24/2020	Low	No Cyanobacteria found on the slide
7/28/2020	Low	No Cyanobacteria found on the slide
8/6/2020	Low	No Cyanobacteria found on the slide
8/10/2020	Low	No Cyanobacteria found on the slide
8/20/2020	Low	100% *Dolichospermum* spp.
8/24/2020	Low	No Cyanobacteria found on the slide
9/3/2020	Low	92% *Dolichospermum* spp., 8% *Coelosphaerium* spp.
9/8/2020	Low	71% *Microcystis* spp., 29% *Dolichospermum* spp.
9/17/2020	Low	100% *Dolichospermum* spp.
9/22/2020	Low	No Cyanobacteria found on the slide
10/1/2020	Low	100% *Dolichospermum* spp.
10/7/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Elbow Pond, the lowest phycocyanin concentration recorded was 0.1 micrograms per liter (ug/L) on August 10, 2020 and the highest phycocyanin concentration recorded was 515.65 ug/L on June 2, 2020.

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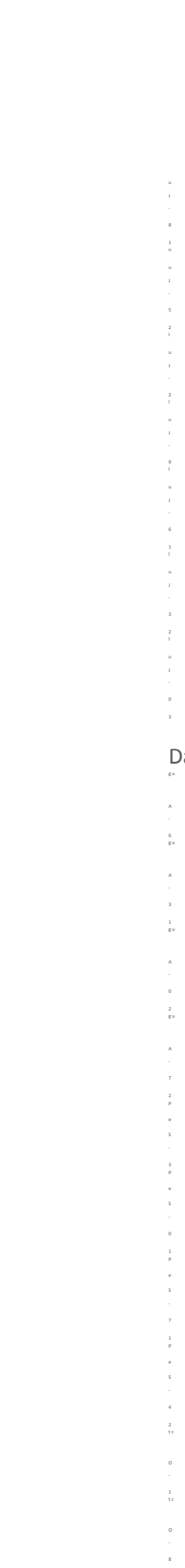

Figure 4. Elbow Pond Phycocyanin Concentrations in 2020 (Logarithmic Scale)

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Elbow Pond reached was the “low” warning tier. Pollen scums were seen on both June 2, 2020 and June 11, 2020 and these was confirmed to be a pollen scums by looking at the samples under the microscope in the APCC lab to see pollen particles were what was creating the visible scum.

D. Discussion

Elbow Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations consistently below the state standards. This pond was sampled from two locations, the shore and the deepest point. Sampling from the deepest point of the pond was performed as part of a separate research project with the University of New Hampshire, but the results were recorded to supplement data taken from the shore station. Pollen scums were common at the pond and may sometimes be misinterpreted for cyanobacteria bloom material. However, analysis of the scum on June 2, 2020 and June 11, 2020 revealed the material to be entirely composed of pollen. Elbow Pond’s cyanobacteria concentrations were generally low and peaked in June.

Griffiths Pond

A. Cyanobacteria Community Composition

Microscopic analysis failed to determine the composition and dominance of cyanobacteria found in the one sampling event at Griffiths Pond due to a lack of cyanobacteria in the sample.

Table 6. Griffiths Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
7/28/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Griffiths Pond, the phycocyanin concentration recorded was 1.92 micrograms per liter (ug/L) on July 28, 2020.

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

Griffith's Pond was put into the "low" warning tier after the one sampling event of the season.

D. Discussion

APCC was asked to sample this pond by a local resident due to reports of fish kills and the surrounding property owners wanted to know if it was cyanobacteria related. APCC advised that they did not think it was cyanobacteria related as the cyanobacteria concentrations were very low and unlikely to have caused the fish kills. When sampling there were many swimmers across the pond from the sampling location.

Long Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Long Pond over the two sampling events this season to be on average 100% *Dolichospermum* spp.

Table 7. Long Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
9/22/2020	Low	100% *Dolichospermum* spp.
10/6/2020	Low	100% *Dolichospermum* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Long Pond, the lowest phycocyanin concentration recorded was 6.53 micrograms per liter (ug/L) on October 6, 2020 and the highest phycocyanin concentration recorded was 23.06 ug/L on September 2, 2020.

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Long Pond reached this season was the "low" warning tier. No visible cyanobacteria blooms were seen here.

D. Discussion

Long Pond was only sampled twice this sampling season, and the cyanobacteria concentrations were low both times. Long Pond is a popular pond for swimming and general recreation. Long Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining below state standards.

Lower Mill Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Lower Mill Pond over the 19 sampling events this season to be on average 98% *Dolichospermum* spp., 1% *Coelosphaerium* spp., and 1% *Microcystis* spp.

Table 8. Lower Mill Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
5/20/2020	Low	99% *Dolichospermum* spp., 1% *Microcystis* spp.
5/29/2020	Low	100% *Dolichospermum* spp.
6/1/2020	Low	100% *Dolichospermum* spp.
6/15/2020	Low	100% *Dolichospermum* spp.
6/29/2020	Low	100% *Dolichospermum* spp.
7/13/2020	Low	100% *Dolichospermum* spp.
7/27/2020	Low	100% *Dolichospermum* spp.
8/3/2020	Low	90% *Dolichospermum* spp., 10% *Microcystis* spp.
8/11/2020	Low	100% *Dolichospermum* spp.
8/25/2020	Low	100% *Dolichospermum* spp.
9/8/2020	Low	100% *Dolichospermum* spp.
9/21/2020	Low	99% *Dolichospermum* spp., 1% *Microcystis* spp.
9/28/2020	High	100% *Dolichospermum* spp.
9/29/2020	High	No sample looked at under the slide (only a scum sample taken)
10/5/2020	High	100% *Dolichospermum* spp.
10/16/2020	High	99% *Dolichospermum* spp., 1% *Microcystis* spp.

10/21/2020	High	100% *Dolichospermum* spp.
10/28/2020	High	99% *Dolichospermum* spp., 1% *Coelosphaerium* spp.
11/4/2020	Moderate	100% *Dolichospermum* spp.
11/11/2020	Moderate	100% *Dolichospermum* spp.
11/18/2020	Low	99% *Dolichospermum* spp., 1% *Microcystis* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Lower Mill Pond, the lowest phycocyanin concentration recorded was 14.17 micrograms per liter (ug/L) on July 13, 2020 and the highest phycocyanin concentration recorded was 2,670.61 ug/L on October 28, 2020.

Date

Figure 5. Lower Mill Pond Phycocyanin Concentrations in 2020 (Logarithmic Scale)

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Lower Mill Pond reached this season was the “high” warning tier. It was in the “high” warning tier from 9/28 to 10/28 with high phycocyanin concentrations and visible bloom accumulations. Lower Mill Pond was also listed in the “moderate” warning tier from November 4, 2020 to November 11, 2020. Visible cyanobacteria scums were seen on

September 28, 2020 and October 21, 2020 that were both confirmed to be composed of cyanobacteria when samples were analyzed under the microscope at the APCC lab. Lower mill Pond was noted to be very turbid or opaque from September 28, 2020 to November 18, 2020. A pollen scum was seen on June 1, 2020 and it was confirmed to be a pollen scum by looking at a sample under the microscope in the APCC lab to see pollen particles were what was creating the visible scum.

D. Discussion

Lower Mill Pond was sampled at a neighborhood beach which is seemingly used for kayaking, paddle boarding, and canoeing. Lower Mill Pond exhibited a high risk for cyanobacteria

exposure at times over the sampling period with cyanobacteria concentrations often estimated to be above state standards. Pollen scums were common and may sometimes be misinterpreted for cyanobacteria bloom material. However, analysis of the pollen scum on June 1st revealed the material to be entirely composed of pollen. Lower Mill Pond's cyanobacteria concentrations peaked in late September and early 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. In future seasons, it is recommended to keep a closer eye on Lower Mill Pond during these periods.

Myrick's Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Myrick's Pond over the two sampling events this season to be on average 100% *Dolichospermum* spp.

Table 9. Myrick's Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
7/20/2020	Low	No Cyanobacteria found on the slide
8/11/2020	Low	100% *Dolichospermum* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Myrick's Pond, the lowest phycocyanin concentration recorded was 28.86 micrograms per liter (ug/L) on August 11, 2020 and the highest phycocyanin concentration recorded was 43.09 ug/L on July 20, 2020.

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Myrick's Pond reached over the sampling events was the "low" warning tier. The pond was quite turbid when sampling took place, although the cause of the turbidity could not be determined.

D. Discussion

Myricks Pond was only sampled twice this sampling season, both after reports potential cyanobacteria bloom material. Cyanobacteria bloom material was found in Myrick's during the previous sampling season, so a possible cyanobacteria bloom formation was not surprising. However, during both sampling events the cyanobacteria concentrations were low and the visible scum material that was reported was not composed of cyanobacteria. Perhaps the bloom material had disappeared before APCC was able to sample the pond or other forms of algae or phytoplankton created accumulations that looked like visible cyanobacteria bloom accumulations. Myrick's Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining below state standards.

Schoolhouse Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Schoolhouse Pond over the 7 sampling events this season to be on average 57% *Woronichinia* spp., *35% Dolichospermum* spp., 6% *Coelosphaerium* spp. and 2% *Microcystis* spp.

Table 10. Schoolhouse Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
8/25/2020	Moderate	100% *Woronichinia* spp.
9/3/2020	Moderate	81% *Dolichospermum* spp., 11% *Microcystis* spp., 8% *Woronichinia* spp.
9/8/2020	High	98% *Dolichospermum* spp., 1% *Woronichinia* spp., 1% *Coelosphaerium* spp.
9/14/2020	High	62% *Woronichinia* spp., 28% *Coelosphaerium* spp., 10% *Dolichospermum* spp.
9/22/2020	High	100% *Woronichinia* spp.
9/28/2020	Low	55% *Dolichospermum* spp., 34% *Woronichinia* spp,, 11% *Coelosphaerium* spp.
10/6/2020	Low	95% *Woronichinia* spp., 5% *Microcystis* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Schoolhouse Pond, the lowest phycocyanin concentration recorded was 12.82 micrograms per liter (ug/L) on October 6, 2020 and the highest phycocyanin concentration recorded was 5,994.60 ug/L on September 8, 2020.

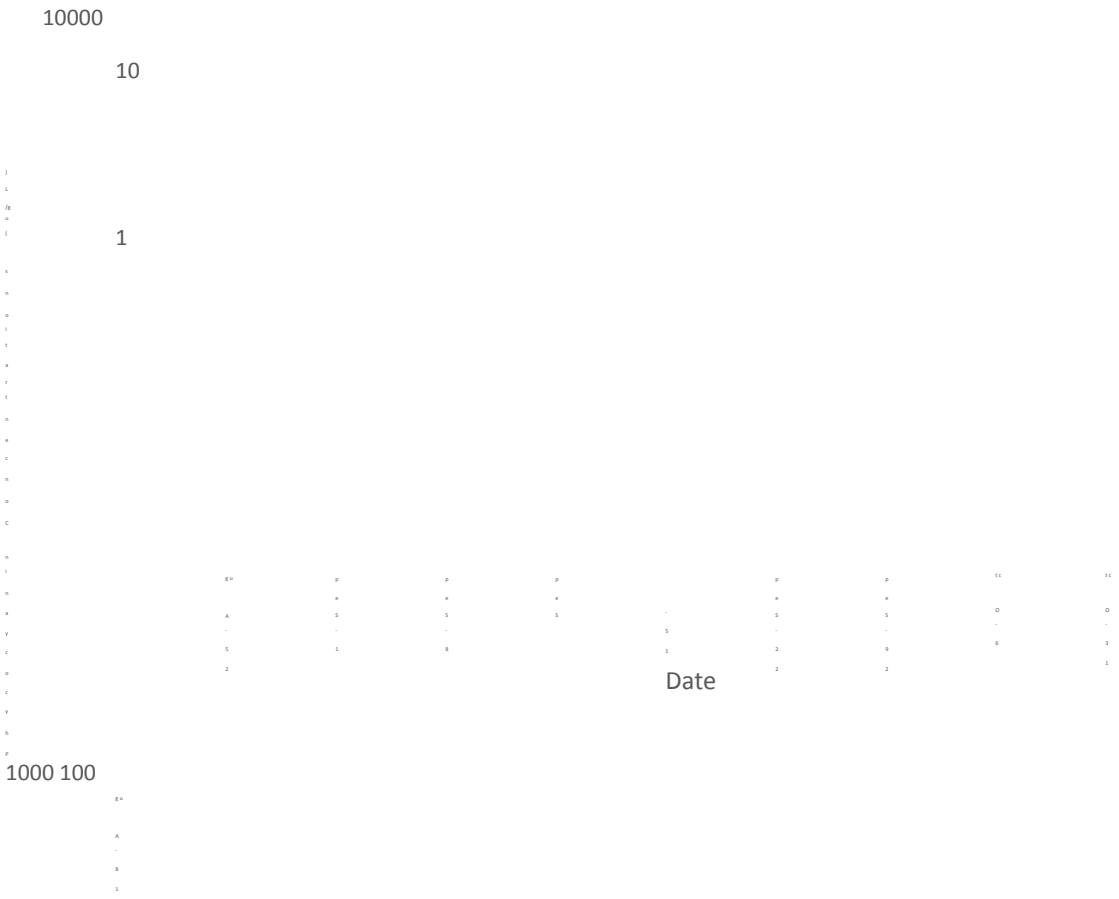

Figure 6. Schoolhouse Pond Phycocyanin Concentrations in 2020 (Logarithmic Scale)

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

Schoolhouse Pond started being sampled because there was a large visible cyanobacteria bloom reported and confirmed by APCC staff from August 25, 2020 September 14, 2020. Samples of this scum were taken to the APCC lab and confirmed to be cyanobacteria. The highest warning tier Schoolhouse Pond reached over the sampling season was the “high” warning tier from September 8, 2020 to September 22, 2020. It also was listed in the “moderate” warning tier from

October 25, 2020 to September 3, 2020.

D. Discussion

Schoolhouse Pond was only sampled in the latter half of the sampling season, starting in late August when a large cyanobacteria scum was reported to APCC. High cyanobacteria concentrations were found in Schoolhouse pond along with visible cyanobacteria bloom accumulations mixed in with a gelatinous material that could have been bryozoans (small

invertebrates). Schoolhouse Pond has a dock where fishermen have been observed. Schoolhouse exhibited a high risk for cyanobacteria exposure at times over the sampling period with cyanobacteria concentrations creating bloom conditions that in our estimations met the state standards for cyanobacteria bloom material.

Sheep Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Sheep Pond over the 12 sampling events this season to be on average 100% *Dolichospermum* spp.

Table 11. Sheep Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
5/21/2020	Low	100% *Dolichospermum* spp.
6/2/2020	Low	100% *Dolichospermum* spp.
6/16/2020	Low	100% *Dolichospermum* spp.
6/30/2020	Low	No Cyanobacteria found on the slide
7/14/2020	Low	No Cyanobacteria found on the slide
7/28/2020	Low	No Cyanobacteria found on the slide
8/11/2020	Low	No Cyanobacteria found on the slide
8/24/2020	Low	100% *Dolichospermum* spp.
9/8/2020	Moderate	100% *Dolichospermum* spp.

9/11/2020	Low	100% *Dolichospermum* spp.
9/22/2020	Low	100% *Dolichospermum* spp.
10/6/2020	Low	No Cyanobacteria found on the slide

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Sheep Pond, the lowest phycocyanin concentration recorded was 1.29 micrograms per liter (ug/L) on July 28, 2020 and the highest phycocyanin concentration recorded was 1,260.90 ug/L on September 8, 2020.

10000 1000 100

10

1

Date

Figure 7. Sheep Pond Phycocyanin Concentrations in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier that Sheep Pond reached over the sampling season was the "moderate" warning tier on September 8, 2020. A visible cyanobacteria scum was reported on September 10, 2020 but the bloom material was not present when APCC staff sampled the pond the following day. A pollen scum was seen on June 2, 2020. this was confirmed to be a pollen scum by looking at a sample under the microscope in the APCC lab to see pollen particles were what was creating the visible scum.

D. Discussion

Sheep Pond was sampled at a public beach that is a popular swimming location for people and their pets. Swimmers were seen most times the pond was sampled. Sheep Pond exhibited a low risk for cyanobacteria exposure over the sampling period, albeit one period when the risk was moderate, with cyanobacteria concentrations remaining below state standards. Pollen scums may sometimes be misinterpreted for cyanobacteria bloom material. However, analysis of the scum on June 2nd revealed the material to be entirely composed of pollen. Sheep Pond's cyanobacteria

concentrations 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 Sheep Pond during these

periods due to the use of it as a popular swimming location.

Smalls Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Smalls Pond over the 1 sampling event this season to be on average 100% *Woronichinia* spp.

Table 12. Smalls Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
8/10/2020	Low	100% *Woronichinia* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Smalls Pond, the phycocyanin concentration recorded was 0.1 micrograms per liter (ug/L) on August 10, 2020.

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

Smalls Pond was put in the “low” warning tier after the one sampling event of the

season. D. Discussion

Smalls Pond was only sampled once during the sampling season following reports of a possible cyanobacteria bloom, but it had low concentrations of cyanobacteria present. Smalls Pond is connected to a public beach for Long Pond, so it has potential to have people or pets swimming in its vicinity. Smalls Pond exhibited a low risk for cyanobacteria exposure for the sampling period with cyanobacteria concentrations remaining below state standards.

Upper Mill Pond

A. Cyanobacteria Community Composition

Microscopic analysis revealed the composition and dominance of cyanobacteria found in Upper Mill Pond over the 12 sampling events this season to be on average 94% *Dolichospermum* spp. 5% *Microcystis* spp. and 1% *Woronichinia* spp.

Table 13. Upper Mill Pond Cyanobacteria Genera Dominance

Sampling Date	APCC Map Warning Tier	Percent dominance of each genus identified
5/20/2020	Low	100% *Dolichospermum* spp.
6/1/2020	Low	86% *Dolichospermum* spp., 14% *Microcystis* spp.
6/15/2020	Low	86% *Dolichospermum* spp., 14% *Microcystis* spp.
6/26/2020	Low	100% *Dolichospermum* spp.
6/29/2020	Low	79% *Dolichospermum* spp., 14% *Microcystis* spp,, 7% *Woronichinia* spp.
7/13/2020	Low	84% *Dolichospermum* spp., 16% *Microcystis* spp.
7/27/2020	Low	100% *Dolichospermum* spp.
8/11/2020	Low	100% *Dolichospermum* spp.
8/24/2020	Low	100% *Dolichospermum* spp.
9/8/2020	Low	99% *Dolichospermum* spp., 1% *Woronichinia* spp.
9/21/2020	Low	99% *Dolichospermum* spp., 1% *Woronichinia* spp.
10/5/2020	Low	92% *Dolichospermum* spp., 8% *Woronichinia* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Upper Mill Pond, the lowest phycocyanin concentration recorded was 2.52 micrograms per liter (ug/L) on May 20, 2020 and the highest phycocyanin concentration recorded was 262.10 ug/L on June 26, 2020.

1000 100

10

1

Date

Figure 8. Upper Mill Pond Phycocyanin Concentrations in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Upper Mill Pond reached over the sampling season was the “low” Warning Tier. There was a visible cyanobacteria scum reported by a local resident on June 26, 2020 in the passageway between Upper Mill Pond and Walkers Pond. The following day APCC staff did not observe a visible cyanobacteria scum in this area and therefore could not confirm the 6/26/20 observation.

D. Discussion

Upper Mill Pond was sampled at a public beach that has a swimming location. Upper Mill Pond exhibited a low risk for cyanobacteria exposure over the sampling period with cyanobacteria concentrations remaining below state standards. Upper Mill Pond’s cyanobacteria concentrations peaked in June.

Walkers Pond

A. Cyanobacteria Community Composition

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Microscopic analysis revealed the composition and dominance of cyanobacteria found in Walkers Pond over the 21 sampling events this season to be on average 55% *Dolichospermum* spp., 31% *Woronichinia* spp., 10% *Microcystis* spp., 3% *Coelosphaerium* spp., and 1% *Aphanocapasa* spp.

Table 14. Walkers Pond Cyanobacteria Genera Dominance

Sample Date	APCC Map Warning Tier	Percent dominance of each genus identified
5/20/2020	Low	98% *Dolichospermum* spp., 2% *Microcystis* spp.
6/1/2020	Moderate	92% *Dolichospermum* spp., 8% *Microcystis* spp.
6/5/2020	Low	86% *Microcystis* spp., 14% *Dolichospermum* spp.
6/15/2020	Low	36% *Microcystis* spp., 59% *Dolichospermum* spp., 1% *Woronichinia* spp.
6/26/2020	High	80% *Dolichospermum* spp., 16% *Microcystis* spp., 4% *Woronichinia* spp.
6/29/2020	High	51% *Woronichinia* spp., 32% *Dolichospermum* spp., 23% *Microcystis* spp.
7/6/2020	High	67% *Woronichinia* spp., 19% *Dolichospermum* spp., 8% *Microcystis* spp., 6% *Aphanocapsa* spp.
7/10/2020	Low	74% *Woronichinia* spp., 25% *Dolichospermum* spp., 1% *Microcystis* spp.
7/13/2020	Low	62% *Woronichinia* spp., 36% *Dolichospermum* spp., 2% *Microcystis* spp.
7/20/2020	Low	86% *Dolichospermum* spp., 13% *Woronichinia* spp., 1% *Microcystis* spp.
7/27/2020	Moderate	88% *Dolichospermum* spp., 12% *Woronichinia* spp.
7/31/2020	High	89% *Dolichospermum* spp., 11% *Woronichinia* spp.
8/3/2020	High	91% *Dolichospermum* spp., 8% *Woronichinia* spp.,

		1% *Microcystis* spp.
8/11/2020	Low	96% *Woronichinia* spp., 2% *Dolichospermum* spp., 2% *Microcystis* spp.
8/25/2020	Low	95% *Woronichinia* spp., 5% *Dolichospermum* spp.
9/8/2020	Low	72% *Woronichinia* spp., 20% *Microcystis* spp., 8% *Dolichospermum* spp.
9/21/2020	Low	38% *Woronichinia* spp., 28% *Coelosphaerium* spp., 23% *Dolichospermum* spp., 2% *Microcystis* spp.
10/5/2020	Low	80% *Dolichospermum* spp., 10% *Coelosphaerium* spp., 7% *Woronichinia* spp., 3% *Microcystis* spp.
10/22/2020	Low	80% *Dolichospermum* spp., 10% *Coelosphaerium* spp., 7% *Woronichinia* spp., 3% *Microcystis* spp.
10/28/2020	High	70% *Dolichospermum* spp., 18% *Coelosphaerium* spp., 12% *Woronichinia* spp.
11/4/2020	Low	80% *Dolichospermum* spp., 12% *Woronichinia* spp., 8% *Coelosphaerium* spp.

B. Cyanobacteria Abundance based on Phycocyanin Pigment Concentrations

In Walkers Pond, the lowest phycocyanin concentration recorded was 85.96 micrograms per liter (ug/L) on June 5, 2020 and the highest phycocyanin concentration recorded was 6,457.91 ug/L on October 22, 2020.

1000 100

10

1

Date

Figure 9. Walkers Pond Phycocyanin Concentrations in 2020

C. Warnings, Advisories and APCC Cyanobacteria Map Levels

The highest warning tier Walkers Pond reached was the “high” warning tier. Walkers Pond was listed in the “high” warning tier from June 26, 2020 to July 6, 2020 and July 31, 2020 to August 3, 2020 with high phycocyanin concentrations and visible cyanobacteria bloom accumulations. Walkers Pond was also listed under the “moderate” warning tier on June 1, 2020 and July 27, 2020. Visible cyanobacteria bloom accumulations were seen on June 26, 2020, June 29, 2020, August 3, 2020, and October 22, 2020. These were all confirmed to be composed of cyanobacteria when a sample was taken back to the APCC lab. There was a visible cyanobacteria

scum reported on June 26, 2020 in the passageway between Upper Mill Pond and Walkers Pond, but it was not confirmed to be a cyanobacteria scum by APCC staff as it was not found the next

day. The sand at the shore of the pond was stained green on August 11, 2020 but it wasn't possible to sample the material to confirm if this was cyanobacteria or not. Throughout the sampling season the pond was very turbid. The lowest measured portable Secchi depth reading was 17 cm on August 25, 2020. A pollen scum was seen on both June 1, 2020 and June 5, 2020 and these were confirmed to be pollen scums by microscopy.

D. Discussion

Walkers Pond was sampled at a public beach where residents often spend time kayaking, paddle boarding, fishing, and canoeing. Walkers Pond exhibited a high risk for cyanobacteria exposure often throughout the sampling period with cyanobacteria concentrations remaining above state standards. Pollen scums may sometimes be misinterpreted for cyanobacteria bloom material. However, analysis of the scum on June 1, 2020 and June 5, 2020 revealed the material to be entirely composed of pollen. Walkers Pond's cyanobacteria concentrations peaked in June, July and October. The season long conditions of high cyanobacteria accumulations in Walkers is concerning and continued robust monitoring is recommended.

Conclusions

The fourth season of the Brewster Ponds Cyanobacteria Monitoring Program was a success. The collaborative efforts between BPC, APCC, and the town of Brewster's Health Department resulted in a tremendous amount of data collected, consistent lines of communication, and increased awareness of cyanobacteria behavior in Brewster ponds. This year APCC provided BPC with a comprehensive weekly report, documenting results, trends, and interpretations of data in an improved format over what was provided the year before. As in previous years, the interactive cyanobacteria map found on APCC's website served as a means to communicate findings with the public and BPC members to gain awareness and an understanding of the issue (APCC Cyanobacteria).

To incorporate information from evolving scientific consensus, APCC adjusted the warning tiers for the Interactive Map in 2020. APCC produced a document explaining the need for these adjustments and it was shared and discussed with BPC members Marty Burke and Chuck Madansky. For remaining inquiries, APCC maintained a consistent line of communication with BPC through Marty, through frequent calls, and sought to ensure complete transparency between the two parties.

Overall, the Brewster ponds had a range of cyanobacteria risk in the 2020 season. Ponds that experienced cyanobacteria concentrations during the season that warranted being placed in the "high" warning tier included Cliff, Lower Mill, Schoolhouse, and Walkers ponds. By APCC's

analysis, the other ponds exhibited only low or moderate 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.

Recommendations

Continued yearly monitoring will continue to provide greater understanding of the cyanobacteria community in each of the Brewster ponds. More years of data will allow us to draw better predictions year over year as the past few years helped us to predict when to monitor some ponds more closely. 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 understanding of the cyanobacteria trends of Brewster's ponds.

APCC plans to perform a pilot study of a different cyanotoxin, anatoxin-a, in the 2021 season. Anatoxin-a is a neurotoxin produced by *Dolichospermum* spp., a common cyanobacteria genus detected in 2020 in Bakers, Cliff, Elbow, Long, Lower Mill, Myrick's, Schoolhouse, Seymour, Sheep, Upper Mill and Walkers 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. Select Brewster ponds will be included in this study.

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 Brewster. 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 Bakers, Cliff, Elbow, Lower Mill, Schoolhouse, Seymour, Upper Mill, and Walkers Ponds 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 nutrient loading, 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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Literature Cited

Publications

Gensemer, Robert W. & Playle, Richard C.. 1999. The Bioavailability and Toxicity of Aluminum in Aquatic Environments. Critical Reviews in Environmental Science and Technology, 29:4, 315-450. https://www.tandfonline.com/doi/abs/10.1080/10643389991259245

Gobler, C.J., Burkholder, J.M., Davis, T.W., Harke, M.J., Johengen, T., Stow, C.A., and Van de Waal, D.B. 2016. The dual role of nitrogen supply in controlling the growth and toxicity of cyanobacterial blooms. Harmful Algae. 54: 87-97. https://pubmed.ncbi.nlm.nih.gov/28073483/

Han. J, Bong-seok, J., Noriko, F., and Ho-Dong, P. 2013. The effect of alum coagulation for in lake treatment of toxic *Microcystis* spp. and other cyanobacteria related organisms in microcosm

experiments. Ecotoxicology and Environmental Safety. 96: 17-23
https://www.researchgate.net/publication/249647068_The_effect_of_alum_coagulation_for_in_lake_treatment_of_toxic_*Microcystis*_spp._and_other_cyanobacteria_related_organisms_in_microcosm_experiments

Leland, N.J. and Haney, J.F. .2018. Alternative Methods for Analysis of Cyanobacterial Populations in Drinking Water Supplies: Fluorometric and Toxicological Applications Using

Phycocyanin. Journal of Water Resource and Protection, 10, 740-761.
https://www.scirp.org/journal/PaperInformation.aspx?paperID=86671

Leland, N.J., Haney, J.F., Conte, K., Malkus-Benjamin, K. and Horsley, B. 2019. Evaluation of Size Structure in Freshwater Cyanobacterial Populations: Methods to Quantify Risk Associated with Changes in Biomass and Microcystin Concentrations. Journal of Water Resource and Protection, 11, 810-829. https://www.scirp.org/journal/paperinformation.aspx?paperid=93424

Nogaro, G., Burgin, A.J., Schoepfer, V.A., Konkler, M.J., Bowman, K.L., and Hammerschmidt, C.R. 2013. Aluminum sulfate (alum) application interactions with coupled metal and nutrient cycling in a hypereutrophic lake ecosystem. Environmental Pollution, 176: 267- 274.
https://pubmed.ncbi.nlm.nih.gov/23454589/

Paerl, H.W., Fulton, Roland S., Moisander, Pia H., Dyble, Julianne 2001. Harmful Fresh Water Algal Blooms with an Emphasis on Cyanobacteria. The Scientific World. 76-113.
https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/petitioners_exhibit/dwr/DWR-734.pdf

Paerl, H.W., Havens, K.E., Hall, N.S., Otten, T.G., Zhu, M., Xu, H., Zhu, G., and Qin, B. 2019. Mitigating a qglobal expansion of toxic cyanobacterial blooms: confounding effects and challenges posed by climate change. Marine & Freshwater Research. Published online March 26, 2019. http://paerllab.web.unc.edu/files/2020/06/Paerl-and-Barnard-2020-Harmful-Algae.pdf

Paerl, H.W., Xu, H., McCarthy, M.J., Zhu, G., Qin, B., Li, Y., Gardner, W.S. 2010. Controlling harmful cyanobacteria blooms in a hyper-eutrophic lake (Lake Taihu, China): The need for a dual nutrient (N&P) management strategy. Water Research. 45, 5: 1973-1983. https://pubmed.ncbi.nlm.nih.gov/20934736/

Agencies and Organizations

Association to Preserve Cape Cod (APCC) webpage on Cyanobacteria Monitoring Program at:
https://apcc.org/our-work/science/community-science/cyanobacteria/

Centers for Disease Control (CDC). Facts about Harmful Algal Blooms for Health Care Professionals. Posted at: https://www.cdc.gov/habs/materials/factsheet-cyanobacterial-habs.html

Centers for Disease Control (CDC). Physician Reference card for cyanobacteria. Posted at: https://www.cdc.gov/habs/pdf/habsphysician_card.pdf

Commonwealth of Massachusetts webpage on cyanobacteria: https://www.mass.gov/guides/cyanobacterial-harmful-algal-blooms-cyanohabs-water

Cyanobacteria Monitoring Collaborative Program (CMC). 2017. Quality Assurance Program Plan (QAPP) for the Cyanobacteria Monitoring Collaborative Program. Rev: 0, April 26, 2017: Posted at: https://cyanos.org/wp-content/uploads/2017/04/cmc_qapp_final.pdf

Environmental Protection Agency (EPA), webpage on Harmful Algal Blooms, at https://www.epa.gov/nutrientpollution/harmful-algal-blooms Hyperlink: EPA and nutrient pollution EPA website on “Monitoring and Responding to Cyanobacteria and Cyanotoxins in Recreational Waters”. https://www.epa.gov/cyanohabs/monitoring-and-responding cyanobacteria-andcyanotoxins-recreational-waters Hyperlink: EPA recreational waters EPA Office of Ground Water and Drinking Water webpage. Managing Cyanotoxins in Public Drinking Water Systems. https://www.epa.gov/ground-water-and-drinking water/managingcyanotoxins-public-drinking-water-systems

Massachusetts Department of Public Health (MDPH) website on “Guidelines for cyanobacteria in freshwater recreational water bodies”. https://www.mass.gov/info-details/guidelines forcyanobacteria-in-freshwater-recreational-water-bodies

New England Interstate Water Pollution Control Commission (NEIWPCC), webpage on Harmful Algal Blooms, at https://neiwpcc.org/our-programs/wetlands-aquatic-species/habs/

New Hampshire state issues cyanobacteria advisories and alerts, at https://www.des.nh.gov/news-and-media/state-issues-cyanobacteria-advisories-and-alerts-new hampshire

New York State Department of Health, Harmful algal bloom program. Website: https://www.health.ny.gov/environmental/water/drinking/bluegreenalgae/

Rhode Island Department of Health website on harmful algal blooms, at https://health.ri.gov/healthrisks/harmfulalgaeblooms/

State of the Waters: Cape Cod 2020. Action Plan for Homeowners/Business Owners. Posted at: https://capecodwaters.org/action-plan/#ponds-hom

Town of Barnstable Health Division. Beach Status and Water Quality. Posted at: https://town.barnstable.ma.us/Departments/healthdivision/Health_Notices/Beach-Status---Water Quality.pdf

World Health Organization. 1999. Toxic cyanobacteria in water: a guide to their public health consequences, monitoring and management. https://www.who.int/water_sanitation_health/resourcesquality/toxcyanbegin.pdf