2023 Cyanobacteria Monitoring Report for Falmouth Water Stewards, Falmouth, Massachusetts

December 20, 2023

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Table of Contents

Section Name	Page
1. SUMMARY	4
2. BACKGROUND	5
3. METHODS	5
Overview	5
Sampling Locations	6
Water Sampling	7
Field Observations	9
Lab Analysis	9
Interpretation of Results	10
Recommendations for Posting Use Restrictions and Advisories	13
Reporting	13
4. RESULTS	14
Cedar Lake	14
Deep Pond	15
Fresh Pond	16
Jenkins Pond	17
Mares Pond	19
Siders Pond	20
5. CONCLUSIONS	20
6. RECOMMENDATIONS	21
7. ACKNOWLEDGEMENTS	22
8. REFERENCES	23
APPENDICES	
Appendix 1. Resources on Cyanobacteria	26
Appendix 2. APCC's Cyanobacteria Risk Categories	27
Appendix 3. Falmouth Water Stewards ponds Cyanobacteria Risk Comparison	28
Appendix 4. Sampling Locations	30
List of Tables and Figures	
Table 1. Summary of Cyanobacteria Monitoring Results for Cedar Lake, Falmouth	14
Table 2. Summary of Cyanobacteria Monitoring Results for Deep Pond, Falmouth	15
Table 3. Summary of Cyanobacteria Monitoring Results for Fresh Pond, Falmouth	16
Table 4. Summary of Cyanobacteria Monitoring Results for Jenkins Pond, Falmouth	18
Table 5. Summary of Cyanobacteria Monitoring Results for Mares Pond, Falmouth	19

Table 6. Summary of Cyanobacteria Monitoring Results for Siders Pond, Falmouth 20
Figure 1. Sampling Locations for Falmouth Waterway Stewards in 2023 7

2023 Cyanobacteria Monitoring Report for Cedar Lake, Deep Pond, Fresh Pond, Mares Pond, Jenkins Pond, and Siders Pond, Falmouth, Massachusetts

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1. SUMMARY

In 2023, the Association to Preserve Cape Cod (APCC) continued cyanobacteria monitoring in Falmouth for the Falmouth Water Stewards (FWS), following similar monitoring conducted in 2020 through 2022. From June 6 through November 7, 2023, APCC conducted biweekly sampling at six sampling locations (see Appendix 4 for sampling locations). APCC conducted 82 sampling events and collected a total of 82 samples and analyzed samples for cyanobacteria composition and phycocyanin, a cyanobacteria pigment that provides a measure of cyanobacteria biomass.

APCC utilizes a three-level risk characterization system known as "Risk Categories" to describe the results of cyanobacteria monitoring in terms of low, moderate, and high potential risks to human health and pets exposed to harmful cyanobacteria blooms (HCBs). The three Risk Categories are: "Acceptable" (low risk), "Potential for Concern" (moderate risk for humans and pets), and "Use Restriction Warranted" (high risk for humans and pets). In 2022, APCC incorporated complementary microcystin testing from the Barnstable County Department of Health and the Environment Water Quality Lab (County Lab), a state-certified laboratory, and toxin testing continued this year. Samples characterized by APCC as at risk for an exceedance of the Massachusetts Department of Public Health (MDPH) guidelines for microcystin in recreational waters of 8 parts per billion (ppb) were sent to the County Lab for confirmatory testing of microcystin. The County Lab then communicated confirmation of microcystin risks in terms of the state limit to APCC and the town health department.

During the 2023 monitoring season, cyanobacteria levels in Deep and Jenkins reached APCC's "Potential for Concern" Risk Category, but no pond reached the "Use Restrictions Warranted" Risk Category. APCC sent four grab samples from the two sampling locations to the County Lab to be tested for microcystin but none of the samples exceeded the state guideline of 8 ppb. APCC shared all monitoring results with Falmouth Water Stewards, the Town of Falmouth, and the public throughout the season via emailed updates, e-newsletters, frequent updates to our online map (https://apcc.org/cyano), and written reports, including this report. This report should be printed in color, as some sections are color-coded.

2. BACKGROUND

APCC's Cyanobacteria Monitoring Program partners with officials at the town, county, state, and federal levels as well as local pond associations and residents to conduct cyanobacteria monitoring in select Cape Cod ponds. Each season, water samples are collected and processed biweekly and shared with local officials and the general public through reports, emails, and an interactive map of monitoring results provided on our website (https://apcc.org/cyano). Our goals are to raise public awareness of the health and ecological risks posed by harmful cyanobacteria blooms (HCBs), to help inform proper responses to cyanobacteria blooms to protect public health, to monitor priority ponds across the Cape, and to motivate public action to address the causes of HCBs by improving water quality.

Cyanobacteria are an ancient group of photosynthetic microorganisms common in freshwater systems on Cape Cod, in the U.S., and worldwide. Under the right conditions, they can multiply rapidly and form harmful cyanobacteria blooms. According to the Centers for Disease Control and Prevention (CDC), certain common cyanobacteria genera can produce toxins known as cyanotoxins that can be harmful to humans (CDC). HCBs have increased worldwide, including in the U.S., due to nutrient enrichment and rising water temperatures due to climate change. As the occurrence of HCBs increases, so too has the need for cyanobacteria monitoring and awareness of potential health risks increased. Additional resources on cyanobacteria are provided in Appendix 1.

Cape Cod ponds are commonly used for recreation, including swimming, boating, paddle boarding, fishing, as well as for dog walking and swimming. Due to the increasing prevalence of HCBs and the resulting increased threat of public exposure to cyanobacteria and their toxins, MDPH provides guidelines for municipal officials to post and remove advisories at ponds based on established thresholds for cyanobacteria risks in recreational waters (MDPH). Frequent cyanobacteria monitoring of ponds provides fact-based data for resource managers to track cyanobacteria trends in their ponds throughout the season, apply relevant public health criteria, and proactively post and remove recreational advisories. Cyanobacteria monitoring data also provide information on pond health and water quality and help to address data gaps caused by lack of conventional pond water quality monitoring data.

3. METHODS

Overview

APCC's Cyanobacteria Monitoring Program provides scientifically sound data on cyanobacteria community composition, biomass, and estimated toxin concentrations. Our program utilizes the EPA-approved Quality Assurance Project Plan (QAPP) for cyanobacteria monitoring, developed by EPA for the Cyanobacteria Monitoring Collaborative or CMC (CMC QAPP). The CMC QAPP was developed by EPA Region 1 scientists, including Hillary Snook and others, with the goal of encouraging and facilitating widespread monitoring of cyanobacteria. The QAPP is based on methods created by EPA scientists and other cyanobacteria specialists, including Dr. James

Haney at the University of New Hampshire Center for Freshwater Biology and Nancy Leland of Lim-Tex, Inc. The method involves taking concentrated samples of "Bloom Forming Colonies" (BFCs) of cyanobacteria from the pond using a 3-meter student plankton net tow and unconcentrated samples of "Whole Lake Water" (WLW) using a 1-meter integrated tube. Samples are then examined for cyanobacteria composition using microscopy. Cyanobacteria composition is important to document because toxicity varies according to cyanobacteria genus. Samples are also analyzed for phycocyanin concentrations using fluorometry. Phycocyanin is an algal pigment produced by cyanobacteria, different and distinct from chlorophyll, which is produced by algae and plants. Phycocyanin concentrations provide a measure of cyanobacteria biovolume and abundance. The combination of information on composition (obtained through microscopy) and information on cyanobacteria pigment concentrations enables an estimation of risk posed by cyanobacteria at the time of monitoring.

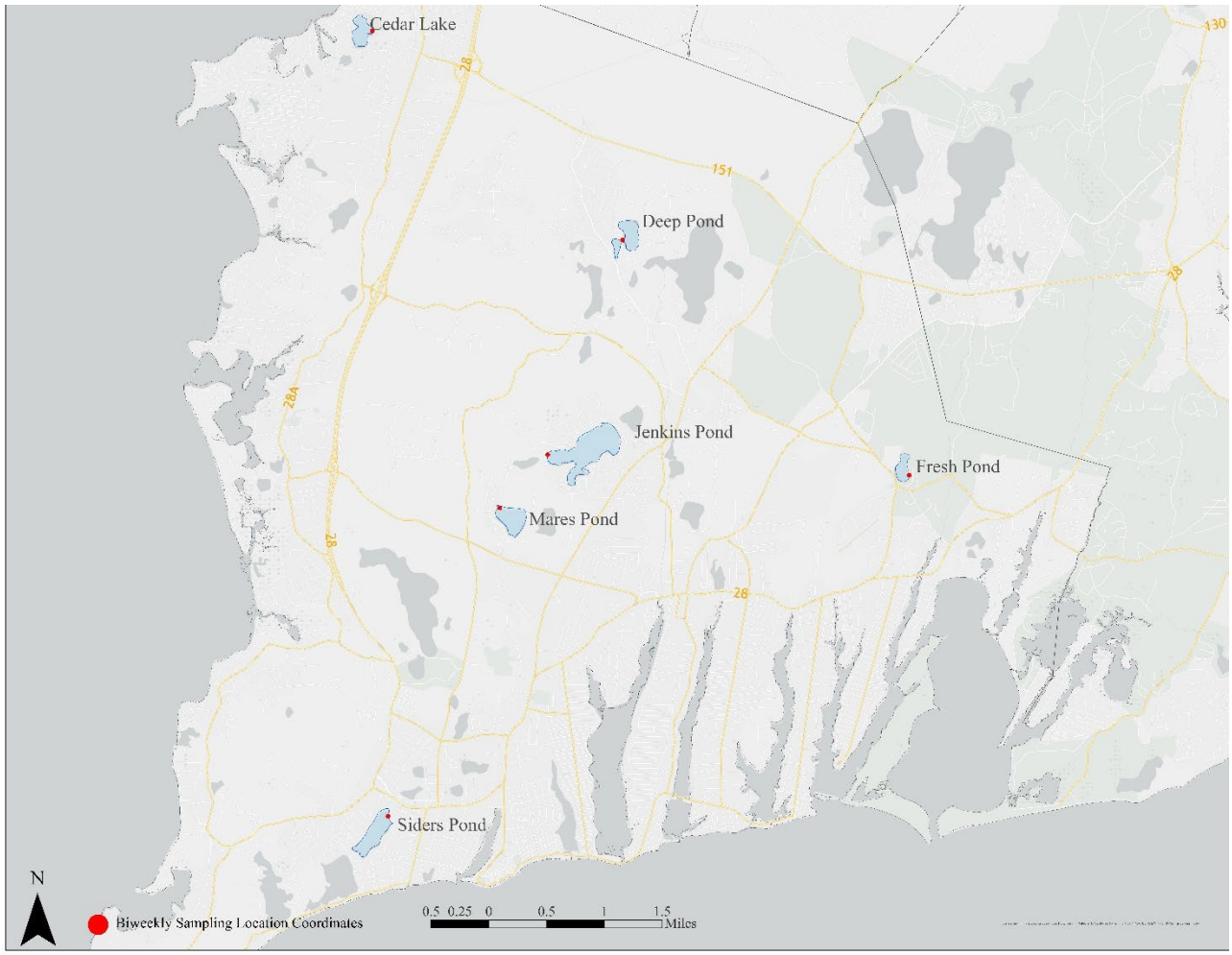
APCC also utilizes the CyanoCasting method developed by Nancy Leland (Leland, 2018), which builds on the methods described in the QAPP by including metrics that allow for the forecasting of potential imminent cyanobacteria blooms and estimates of cyanotoxin (i.e., microcystin) concentrations. The forecasting ability of this method provides valuable advance warnings of potential HCBs to inform proactive responses, such as increased sampling frequency or precautionary advisories of ponds to warn the public of the potential for cyanobacteria blooms. The ability to anticipate potential HCBs and estimate their microcystin concentrations based on frequent monitoring is a unique and valuable feature of APCC's program and stands in contrast to reactive responses involving measurement of cyanobacteria concentrations after a bloom has occurred (Leland et al. 2018, Leland et al 2019).

As a complement to APCC's established monitoring program, the County Lab provides cyanobacteria toxin testing to provide local officials with precise microcystin toxin measurements from ponds pre-screened by APCC as potentially containing cyanobacteria toxin levels of concern. This is the second year that the County Lab has provided this valuable service. The screening process was as follows: At each cyanobacteria sampling event, APCC collected separate water samples for toxin analysis if needed. APCC then analyzed cyanobacteria as described above and used the results to screen each pond. If samples had cyanobacteria results (i.e., risk categories) that indicated a possibility of an exceedance of state microcystin guidelines (i.e., 8 ppb for recreational waters), APCC sent the separate water samples to the County Lab to conduct confirmatory toxin testing of microcystin, one type of cyanobacteria toxin. Toxin test results were then used to determine whether an advisory was warranted. If so, APCC provided a recommendation to the local health official to post an advisory. Local health officials are responsible for deciding whether to post advisories and often rely on consultation with MDPH. To assist with decision-making, APCC conducted follow-up monitoring that included information on when cyanobacteria levels decreased to the point where an advisory, if posted, could be lifted.

Sampling Locations

This season, at least 12 samples were collected at each location on a biweekly basis between June 6 and November 7, 2023. Samples were collected in collaboration with FWS at the locations shown in Figure 1.

Figure 1. All Sampling Locations for the FWS in 2023.



Water Sampling

Water samples were collected by APCC staff and interns on a biweekly schedule, between June 6 and November 7, 2023. At each sampling event, three samples were collected from shore, a Whole Lake Water sample collected using a 1-meter tube, a Bloom Forming Colonies sample collected using a 50-micron (um) mesh student plankton net, and a third grab sample for toxin testing (if needed) collected in a glass bottle with a PTFE-lined lid. When cyanobacteria bloom material was found, a sample of the bloom material was taken for additional analysis.

Between June 6, 2023, and November 7, 2023, APCC conducted 12 biweekly sampling events at each location for a total of 72 sampling events. Throughout the season extra off-week samples were taken if there was a concern that an HCB could occur between the scheduled biweekly sampling events. This season there was a total of ten extra samples taken at four ponds. The types of samples collected are described below.

Whole Lake Water (WLW) Sample

The pond water sample that is collected using the 1-meter tube is called the Whole Lake Water (WLW) sample. This is an unconcentrated water sample containing cyanobacteria from the full extent of the 1-meter sampling depth from the pond surface to just above the bottom near shore. This sample is processed by APCC staff to obtain data on cyanobacteria size fractions in the water column. This process is further explained in the "Lab Analysis" section. This sample is not used to forecast future bloom accumulations, as it contains cyanobacteria currently in the water column near shore.

Bloom Forming Colonies (BFC) Sample

The second sample, which is collected using the student plankton net, is called the Bloom Forming Colonies (BFC) sample. This is a concentrated sample of cyanobacteria and algae obtained by towing the student plankton net across a 3-meter cast near the surface. This sample contains larger cyanobacteria colonies which tend to form visible blooms and scums. This sample creates an artificial cyanobacteria accumulation similar to a natural cyanobacteria accumulation that may occur on a pond if the wind condensed cyanobacteria over a distance of three (3) meters into a potentially harmful accumulation near shore. Nearshore accumulations of cyanobacteria are considered to pose a higher risk because this is where children and pets typically interact with the pond.

The concentrations of cyanobacteria in BFC samples can fluctuate dramatically and sudden and steady increases of cyanobacteria concentrations in BFC samples can foreshadow cyanobacteria bloom formation in the near future. Understanding the toxin concentrations of this sample can also provide information on the likelihood of a future microcystin exceedance. This concept is discussed in more detail below.

Toxin Sample

The third sample is a simple grab sample of pond water collected using a 125 milliliter (mL) amber glass bottle with a PTFE-lined cap. This sample is called the toxin sample. When APCC's metrics using cyanobacteria composition and concentration indicate a likelihood that microcystin concentrations may exceed 8 ppb, APCC delivers this sample to the County Lab for analysis of microcystin.

Cyanobacteria Scum Sample

The fourth sample, taken only when needed, is called the scum and may contain cyanobacteria bloom material. Although visual evidence alone of potential cyanobacteria bloom material can be compelling, microscope and fluorometry analysis of the material is needed to confirm whether the material is indeed a cyanobacteria bloom rather than an accumulation of other algae, diatoms, etc. Microscope analysis of the bloom material also provides information on the genus of cyanobacteria making up the bloom, providing an understanding of the types of toxins that may be present. For example, the cyanobacteria genus *Microcystis* is known to produce microcystin

which is a liver toxin, while the genus *Dolichospermum* is known to produce a different toxin called anatoxin, a neurotoxin of concern for which there is not yet an MDPH standard.

Field Observations

APCC staff documented field conditions at each sampling event by completing field data sheets with information on weather, visual appearance of pond surface, water temperature, etc. Photographs were taken of the pond's shoreline at each sampling event, providing documentation of pond appearance and visible conditions and evidence of bloom accumulations.

Lab Analysis

Sample processing

On the same day as sample collection, APCC processed and analyzed samples following our protocol. Triplicate 5 milliliter (mL) subsamples were taken from each of the 3-4 sample types: the WLW sample, the < 50 micron (µm) sample, the BFC sample, and the scum sample when possible cyanobacteria bloom material was discovered. The < 50 µm sample was isolated by filtering the WLW sample through a 50 micron (µm) filter, which resulted in a sample containing only the relatively small colonies of cyanobacteria. Smaller cyanobacteria, known as pico-cyanobacteria in the size range of 0.2 to 2 µm, are also believed to produce cyanotoxins at levels that may be of concern. While APCC's analytical methods do not currently address the pico fraction of cyanobacteria, future work may, if warranted, consider this potential source of cyanotoxins. The WLW and scum samples were processed without further action. The BFC sample was further separated through the use of Zapprs (see EPA QAPP, CMC QAPP).

Microscopy

Using light microscopy, APCC staff and interns counted colonies of cyanobacteria from a 1-mL sample from the BFC sample up to 100 colonies per mL. The information was used to estimate dominance of different cyanobacteria genera. If one genus was found to be the "dominant genus" (defined as 70% of the cyanobacteria community on the slide), then APCC targeted the toxins produced by that genus of cyanobacteria as the toxins of concern for that pond at that time. If a scum sample was taken, APCC also analyzed it under the microscope to inspect genus composition and to confirm whether the scum was indeed composed of cyanobacteria.

Fluorometry to measure phycocyanin pigments

Each triplicate 5 mL sample was frozen and thawed for the purpose of lysing cells to liberate cyanobacteria pigments. Samples were then analyzed for cyanobacteria pigments (phycocyanin) and non-cyanobacteria algal pigments (chlorophyll-a) using a calibrated fluorometer in parts per billion (ppb). APCC uses phycocyanin concentrations in micrograms per liter (ug/L) as an indicator of cyanobacteria biomass rather than cell counts. Understanding cyanobacteria concentrations using fluorometry allows APCC to track cyanobacteria community trends over time. All data were stored on APCC's online server.

Microcystin testing by County Lab

At each sampling event, APCC collected extra samples for analysis of microcystin if cyanobacteria risk levels were in the "Use Restriction Warranted" category. To ensure that samples for toxin testing were collected on the same date, time, and place as samples for cyanobacteria monitoring, APCC collected GRAB samples for toxin analysis at the same time and location as our samples for cyanobacteria analyses. Samples for toxin analyses were collected and preserved according to MDPH and EPA protocols (Local Public Health Institute of Massachusetts, Method 546). In the event that APCC's cyanobacteria data indicated the likelihood of a microcystin exceedance, the corresponding GRAB sample(s) were sent to the County Lab for toxin analysis. The County Lab then analyzed the sample for microcystin and then forwarded toxin test results and recommendations of a recreational advisory, when warranted, to local officials and APCC. Toxin test results supplemented APCC's cyanobacteria monitoring data. The simultaneous collection of samples for cyanobacteria and cyanotoxins helped to ensure that cyanotoxin analyses (if warranted) correspond to cyanobacteria monitoring data in terms of time and place. This proactive sampling approach avoids a common pitfall of reactive sampling that can occur when cyanobacteria monitoring data are collected on one date and confirmatory samples are collected several days to a week later when conditions may have changed.

Interpretation of Results

APCC staff interpreted the results within a cyanobacteria risk guidance framework that incorporates the most recent scientific information as well as existing state and federal guidance (EPA recreational waters, MDPH).

Massachusetts Department of Public Health (MDPH) Guidelines for Cyanobacteria

The MDPH cyanobacteria webpage provides guidelines for cyanobacteria in recreational freshwater bodies that are described in italics as follows ("Guidelines for Cyanobacteria at Recreational Freshwater Locations") (MDPH).

[Issuing a Public Health Advisory]
"DPH recommends issuing a public health advisory for HABs at recreational freshwater locations when at least one of the following criteria is met:

1. ***A visible cyanobacteria scum or mat is evident.***
2. ***Total cell count of cyanobacteria exceeds 70,000 cells/mL.***
3. ***Concentration of the toxin microcystin exceeds 8 µg/L (8 ppb); or***
4. ***Concentration of the toxin cylindrospermopsin exceeds 15 µg/L (15 ppb).***

Guideline values are based on US Environmental Protection Agency (US EPA) and World Health Organization (WHO 1999) (WHO 2003) recommendations. When issuing an advisory, signage should be posted at each access point at the waterbody warning against any contact with the water.

Rescinding a Public Health Advisory

Cyanobacteria cells can release cyanotoxins into the water when they die. Therefore, algal toxins may be present when a visible scum or mat is no longer evident. DPH recommends the rescinding of a public health advisory after two successive samples, collected a week apart, demonstrate cell counts or toxin levels below the quantitative guideline values." (MDPH)

Cyanobacteria Risk Categories

APCC interpreted cyanobacteria data using a tiered risk system called "Cyanobacteria Risk Categories." This data interpretation system was created using guidance and feedback from cyanobacteria researchers, Cape Cod health agents, and state guidance. The criteria for the Risk Categories do not include cell counts or cylindrospermopsin (another cyanobacteria toxin), as neither APCC nor the County Lab test for these metrics.

APCC tracked changes in cyanobacteria concentrations between each sampling event. The reason for tracking changes in cyanobacteria concentrations over time is that rapid growth rates, defined here as net daily cyanobacteria growth rates greater than or equal to 0.05 (ud-1), may indicate that a cyanobacteria bloom formation or exceedance of the 8 ppb microcystin level is about to occur. Alternatively, cyanobacteria concentrations may peak and then decrease before a cyanobacteria bloom or microcystin exceedance occurs. APCC recommended weekly testing of ponds where any APCC sample had a confirmed net daily cyanobacteria growth rate greater than or equal to 0.05 (ud-1). Before August 1, 2022, APCC would also place ponds in the "Potential for Concern" category for one week following a growth rate above 0.05 (ud-1). However, following new guidance from program partners, starting on August 1, 2022, APCC stopped recommending a change in risk category based on cyanobacteria growth rate data alone. Instead, if growth rates exceeded 0.05 (ud-1), APCC increased the sampling frequency to one-week intervals in order to catch potential increase in cyanobacteria that might occur.

To assign a Cyanobacteria Risk Category to a pond for a given monitoring period, the most hazardous result among multiple criteria determined the risk category in which the pond was placed. A pond that met even a single criterion in the "Use Restriction Warranted" category was placed in that category. Likewise, a pond that met even a single criterion in the "Potential for Concern" category, but did not meet any criteria in the "Use Restriction Warranted" category, was placed in the "Potential for Concern" category. If a pond met no criteria in the "Use Restriction Warranted" or the "Potential for Concern" categories, that pond was placed in the "Acceptable" category. All descriptions and criteria for these categories are summarized in Appendix 2 and discussed below.

APCC Cyanobacteria Risk Categories

Acceptable
Definition: No concerning cyanobacteria results at the time and place of sampling. To the best of APCC's knowledge and based on our monitoring results, regular recreational usage of the pond is safe with respect to cyanobacteria and toxins. Map color is blue. Formerly the Low Warning Tier.
Recommended Sampling Frequency: Biweekly. In samples containing low levels of cyanobacteria with high growth rates APCC will recommend weekly sampling.

Recommended Action: None.

Potential for Concern

Definition: Monitoring results or the presence of cyanobacteria scum at the time and place of sampling indicates a potential for increased risk for exposure to cyanobacteria toxins approaching but below state standards. Conditions do not yet warrant the posting of a recreational human health advisory according to guidelines from the Massachusetts Department of Public Health (MDPH). While these conditions pose low health risks to adults, risks are higher for children or pets based on lower body mass, particularly if contaminated water is incidentally ingested. Children may inadvertently consume pond water while swimming and pet exposure can result from drinking or ingesting pond water or from grooming after swimming. Map color is yellow. Map color yellow with crosshatching indicates a municipal pet advisory has been issued. Formerly the Moderate Warning Tier[1,2,4].
Recommended Sampling Frequency: Weekly.
Recommended Action:

1. APCC or the town will provide a GRAB sample for toxin analysis to the Barnstable County Water Quality Lab for samples suspected of possibly exceeding the MDPH guidelines for microcystin in recreational waters.
2. The posting of a "Pet Advisory" or similar advisory according to municipal policies and procedures until the pond returns to "Acceptable" status.
3. Sampling should be increased to weekly until all results are once again in the "Acceptable" category.

Use Restriction Warranted

Definition: Monitoring results at the time and place of sampling indicate the pond is unsafe for recreation by humans and pets based on one or more of the following criteria: 1) presence of microcystin at or above state standards (8 ppb microcystin) as described in MDPH guidance, 2) presence of significant cyanobacteria scum layers according to MDPH guidance, 3) a municipal health agent issues a closure for any other reason related to cyanobacteria. Recreational risk to adults is moderate following exposure. Recreational risks are especially high for children and pets following exposure through accidental ingestion of contaminated water. Children may inadvertently consume pond water while swimming and pet exposure can result from ingestion or directly drinking pond water or from grooming after swimming. Due to lower body masses, children and pets are more susceptible to cyanobacteria risks than adults. Map color is red. Map color red with crosshatching indicates a municipal advisory has been issued. Formerly the High Warning Tier[3].
Recommended Sampling Frequency: Weekly.
Recommended Action:

1. APCC or the town will provide a GRAB sample for toxin analysis to the Barnstable County Water Quality Lab for samples suspected of possibly exceeding the MDPH guidelines for microcystin in recreational waters.
2. The town should post a recreational advisory or similar advisory according to municipal policies and procedures and otherwise notify the public to avoid contact and exposure until the pond meets criteria to be reopened or the advisory is lifted by the local health agent.

3. Sampling should be conducted weekly until there are two consecutive weeks when results include no significant cyanobacteria scum and toxin testing of samples contain a microcystin concentration below 8 ppb.

Recommendations for posting Use Restrictions and Advisories

Use restrictions and advisories are issued at the discretion of the municipal health agents. When Use Restriction is Warranted, towns generally issue a Public Health Advisory or when there is a "Potential for Concern," the town of Barnstable generally issues a Pet Advisory. As of now, there is no commonly utilized set of guidelines in use by health agents across the Cape that provides consistency in posting criteria. As a result, members of the public are advised to contact the health agent in their town (see the contact list provided on APCC's website) to determine the official status of the pond in which they are interested. While ponds exceeding MDPH standards as discussed above were marked in red on APCC's map, this coloration does not always mean that a use restriction was issued by the town. APCC updates our list of restricted ponds as we are informed by the respective towns, but APCC does not speak for the towns unless otherwise and explicitly noted on our posting map.

APCC's recommendation for removing a recreational use advisory mirrors the reopening guidance from MDPH. For a microcystin toxin exceedance or cyanobacteria scum, APCC will recommend lifting a recreational use advisory or closure after two consecutive tests a week apart show microcystin concentrations less than 8 ppb and little to no presence of cyanobacteria bloom material, depending on the basis for the original restriction. Health agents are solely responsible for the issuance and removal of recreational use advisories or closures related to water clarity, such as clarity less than 4 feet.

Reporting

Biweekly reports

Results are provided in biweekly reports to local municipal officials and pond associations. Depending on results, reports include recommendations concerning appropriate advisory posting or removal for the public to minimize or avoid risks due to cyanobacteria exposure. During periods of possible harmful cyanobacteria bloom formation requiring weekly sampling, additional reports and updates are sent to officials and pond associations. Pond associations play a key role in raising public awareness of cyanobacteria risks and alerting pond residents of cyanobacteria monitoring results throughout the season.

Interactive map

APCC's cyanobacteria website contains an interactive map where recent monitoring results are posted throughout the season. Updates are submitted on an automated basis at 7 p.m. on the same day as reports of results were emailed to town officials. In some cases, automated map updates are postponed one day if a town official requested additional time to review results before they are posted. The interactive map is located at https://apcc.org/cyano.

Email alerts

APCC provides an email registry signup on our website designed to update interested residents and visitors when harmful cyanobacteria blooms are identified. A quick link to sign up for the Cyanobacteria Alert is on our homepage (https://apcc.org/) and here https://apcc.org/cyano/.

4. RESULTS

Cyanobacteria monitoring results, Risk Categories, and risk communication are described in this section. For each pond, a table is provided to describe results and risk category designations for each sampling event. A complete table of results is provided in Attachment 1 containing all data collected for FWS in 2023. This table is formatted to be printed on an 11"x17" sheet. The full Risk Category criteria are included in Appendix 2. Data interpretation and risk communication to town officials and the public for each sampling event are described in this section as well.

Results for the sampling locations are described below. FWS sampled from six locations in collaboration with APCC. (See appendix 4 for a list of locations.)

Cedar Lake: Behind North Falmouth Library

Durning the 2023 monitoring season, Cedar Lake had no concerning cyanobacteria results at the time and place of each sampling event, resulting in the pond remaining in APCC's "Acceptable" category for the entire season. (Table 1 below).

Table 1. Summary of 2023 cyanobacteria monitoring results for Cedar Lake, Falmouth, MA.

Sampling Date	APCC Current Risk Category	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Current Risk Category Notes
6/6/2023	Acceptable	N/A	6	-
6/20/2023	Acceptable	N/A	28	-
7/6/2023	Acceptable	*Woronichinia* spp.	13	-
7/18/2023	Acceptable	*Woronichinia* spp.	12	-
8/1/2023	Acceptable	*Woronichinia* spp.	6	-
8/15/2023	Acceptable	*Woronichinia* spp.	5	-
8/29/2023	Acceptable	*Woronichinia* spp.	8	-
9/12/2023	Acceptable	*Woronichinia* spp.	16	-

9/26/2023	Acceptable	N/A	13	-
10/10/2023	Acceptable	*Dolichospermum spp.*	4	-
10/24/2023	Acceptable	*Oscillatoria spp.*	4	-
11/7/2023	Acceptable	*Oscillatoria spp.*	2	-

Deep Pond: Pondview Circle neighborhood Beach (Private)

During the 2023 monitoring season, Deep Pond experienced changes in cyanobacteria levels that at different times placed it in APCC's "Acceptable" and "Potential for Concern" Risk Categories (Table 2 below).

On October 10, 2023, Deep Pond was turbid and green with a scum along the shore and elevated growth rates 0.05 (ud-1) causing a Potential for Concern and triggering weekly sampling. On October 16, 2023, an insignificant cyanobacteria scum was observed causing Deep Pond to remain as Potential for Concern until the following week when conditions were acceptable.

During the season, two toxin samples from Deep Pond were sent to the County Lab for microcystin analysis including samples on October 10 and October 16, 2023. The County Lab reported microcystin results were below 8 ppb for these samples.

Table 2. Summary of 2023 cyanobacteria monitoring results for Deep Pond, Falmouth, MA.

Sampling Date	APCC Current Risk Category	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Current Risk Category Notes
6/6/2023	Acceptable	*Dolichospermum* spp.	225	-
6/20/2023	Acceptable	N/A	6	-
7/6/2023	Acceptable	*Microcystis* spp.	15	-
7/18/2023	Acceptable	*Microcystis* spp.	22	-
8/1/2023	Acceptable	*Microcystis* spp.	10	-
8/15/2023	Acceptable	*Microcystis* spp.	14	-
8/29/2023	Acceptable	*Microcystis* spp.	130	-
9/6/2023	Acceptable	*Microcystis* spp.	111	-
9/12/2023	Acceptable	*Microcystis* spp.	56	-
9/26/2023	Acceptable	*Microcystis* spp.	5	-

10/10/2023	Potential for Concern	*Microcystis spp.*	33	Scum, turbidity and high growth rates were observed. Microcystin result: Non-detect
10/16/2023	Potential for Concern	*Microcystis spp.*	299	Insignificant cyanobacteria scum was observed. Microcystin result: Non-detect
10/24/2023	Acceptable	*Microcystis spp.*	8	-
11/7/2023	Acceptable	Mixed	31	-

Fresh Pond: From Surrey Lane

Durning the 2023 monitoring season, Fresh Pond had no concerning cyanobacteria results at the time and place of each sampling event, resulting the pond remaining in APCC's "Acceptable" category for the entire season. (Table 3 below).

On June 20, August 29, and October 10, 2023, Fresh Pond experienced elevated net daily cyanobacteria growth rates > 0.05 (ud-1). APCC recommended weekly sampling following the elevated growth rate on June 20, August 29, and October 10, 2023.

Table 3. Summary of 2023 cyanobacteria monitoring results for Fresh Pond, Falmouth, MA.

Sampling Date	APCC Current Risk Category	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Current Risk Category Notes
6/6/2023	Acceptable	*Dolichospermum* spp.	6	-
6/20/2023	Acceptable	*Dolichospermum* spp.	500	-
6/29/2023	Acceptable	*Dolichospermum* spp.	361	-
7/6/2023	Acceptable	*Woronichinia* spp.	4	-
7/18/2023	Acceptable	*Microcystis* spp.	6	-
8/1/2023	Acceptable	*Microcystis* spp.	3	-
8/15/2023	Acceptable	*Microcystis* spp.	29	-

8/29/2023	Acceptable	*Microcystis* spp.	92	-
9/6/2023	Acceptable	Mixed	13	-
9/12/2023	Acceptable	Mixed	7	-
9/26/2023	Acceptable	*Oscillatoria* spp.	12	-
10/10/2023	Acceptable	Mixed	25	-
10/16/2023	Acceptable	N/A	7	-
10/24/2023	Acceptable	N/A	4	-
11/7/2023	Acceptable	*Dolichospermum spp.*	14	-

Jenkins Pond: Pinecrest Beach Drive (Private)

During the 2023 monitoring season, Jenkins Pond experienced changes in cyanobacteria levels that at different times placed it in APCC's "Acceptable" and "Potential for Concern" Risk Categories (Table 4 below).

On July 6, 2023, Jenkins Pond, a thin green layer along shore was confirmed to be cyanobacteria, changing the risk category to Potential for Concern and initiating weekly sampling. A toxin sample was sent to the County Lab with the result of 0.73 ppb. On July 18, 2023, Jenkins Pond returned to Acceptable condition.

On October 10, 2023, Jenkins Pond experienced elevated net daily cyanobacteria growth rates > 0.05 (ud-1) and on October 12 cyanobacteria scum was confirmed, photos were sent to the MDPH and determined to be insignificant. APCC recommended weekly sampling following the elevated growth rate on October 10, 2023.

On October 24, 2023, Jenkins Pond experienced elevated net daily cyanobacteria growth rates > 0.05 (ud-1). APCC recommended weekly sampling following the elevated growth rate on October 24, 2023.

During the season, two toxin samples from Jenkins Pond were sent to the County Lab for microcystin analysis including samples on July 6 and October 12, 2023. The County Lab reported microcystin results were below 8 ppb for these samples.

Table 4. Summary of 2023 cyanobacteria monitoring results for Jenkins Pond, Falmouth, MA.

Sampling Date	APCC Current Risk Category	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Current Risk Category Notes
6/6/2023	Acceptable	Mixed	18	-
6/20/2023	Acceptable	*Microcystis* spp.	52	-
7/6/2023	Potential for Concern	*Microcystis* spp.	926	Insignificant cyanobacteria scum observed. Microcystin result: 0.73 ppb
7/13/2023	Potential for Concern	*Microcystis* spp.	84	Insignificant cyanobacteria scum observed.
7/18/2023	Acceptable	*Microcystis* spp.	38	-
8/1/2023	Acceptable	*Microcystis* spp.	15	-
8/15/2023	Acceptable	*Microcystis* spp.	12	-
8/29/2023	Acceptable	*Microcystis* spp.	10	-
9/12/2023	Acceptable	*Microcystis* spp.	13	-
9/26/2023	Acceptable	*Microcystis* spp.	55	-
10/10/2023	Acceptable	Mixed	18	-
10/12/2023	Potential for Concern	Mixed	58	Insignificant cyanobacteria scum observed. Microcystin result: Non-detect
10/16/2023	Acceptable	Mixed	24	-
10/24/2023	Acceptable	Mixed	55	-
11/7/2023	Acceptable	Mixed	118.7	-

Mares Pond: Neighborhood Beach off Pattee Road (Private)

Durning the 2023 monitoring season, Mares Pond had no concerning cyanobacteria results at the time and place of each sampling event, resulting in the pond remaining in APCC's "Acceptable" category for the entire season. (Table 5 below).

On August 15 and October 10, 2023, Mares Pond experienced elevated net daily cyanobacteria growth rates > 0.05 (ud-1). APCC recommended weekly sampling following the elevated growth rate on August 25 and October 10, 2023.

Table 5. Summary of 2023 cyanobacteria monitoring results for Mares Pond, Falmouth, MA.

Sampling Date	APCC Current Risk Category	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Current Risk Category Notes
6/6/2023	Acceptable	*Dolichospermum* spp.	41	-
6/20/2023	Acceptable	Mixed	31	-
7/6/2023	Acceptable	N/A	1	-
7/18/2023	Acceptable	Mixed	2	-
8/1/2023	Acceptable	*Dolichospermum* spp.	43	-
8/15/2023	Acceptable	*Dolichospermum* spp.	110	-
8/25/2023	Acceptable	*Dolichospermum* spp.	232	-
8/29/2023	Acceptable	*Dolichospermum* spp.	198	-
9/12/2023	Acceptable	*Dolichospermum* spp.	59	-
9/26/2023	Acceptable	*Dolichospermum* spp.	13	-
10/10/2023	Acceptable	*Dolichospermum spp.*	44	-
10/16/2023	Acceptable	*Dolichospermum spp.*	5	-
10/24/2023	Acceptable	N/A	33	-
11/7/2023	Acceptable	*Dolichospermum spp.*	131	-

Siders Pond: Residence off Town Hall Square, Falmouth (Private)

Durning the 2023 monitoring season, Siders Pond had no concerning cyanobacteria results at the time and place of each sampling event, resulting in the pond remaining in APCC's "Acceptable" category for the entire season. (Table 6 below).

Table 6. Summary of 2023 cyanobacteria monitoring results for Siders Pond, Falmouth, MA.

Sampling Date	APCC Current Risk Category	Dominant Genus	Bloom Forming Colonies Phycocyanin (ug/L)	Current Risk Category Notes
6/6/2023	Acceptable	*Woronichinia* spp.	4	-
6/20/2023	Acceptable	N/A	5	-
7/6/2023	Acceptable	N/A	19	-
7/18/2023	Acceptable	*Woronichinia* spp.	6	-
8/1/2023	Acceptable	N/A	25	-
8/15/2023	Acceptable	N/A	36	-
8/29/2023	Acceptable	N/A	0	-
9/13/2023	Acceptable	N/A	18	-
9/26/2023	Acceptable	N/A	9	-
10/10/2023	Acceptable	N/A	15	-
10/24/2023	Acceptable	N/A	15	-
11/7/2023	Acceptable	*Woronichinia* spp.	5	-

5. CONCLUSIONS

In 2023, six ponds were monitored in Falmouth by FWS and APCC (see Appendix 4 for sampling locations). APCC's 2023 cyanobacteria monitoring program collected and analyzed 72 samples and documented field conditions on each of the scheduled 72 sampling dates throughout the season as well as an additional ten based on higher growth rates or higher warning categories. APCC sent four grab samples from the two sampling locations to the County Lab to be tested for microcystin but none of the samples exceeded the state guideline of 8 ppb.

Deep Pond and Jenkins Pond reached APCC's "Potential for Concern" due to moderate levels of cyanobacteria, but no pond reached the "Use Restrictions Warranted" Risk Category. Unlike in

years past, Mares Pond received recreational advisories in late May or early June. For a comparison of interpreted cyanobacteria risks in 2023 compared to previous seasons, see Appendix 3.

In the previous three years of monitoring, APCC's monitoring data and the presence of cyanobacteria scums was used to estimate cyanobacteria risk. In 2023, the County Lab's capability to conduct microcystin analyses provided the town health department and APCC with direct measurements of toxin, increasing understanding of current toxin risks.

All results were promptly shared with the Falmouth Water Stewards and the Town of Falmouth via biweekly reports and then entered into the APCC Interactive Map following the completion of sample analysis (https://apcc.org/cyano).

6. RECOMMENDATIONS

Based on the results from the 2023 monitoring season and previous monitoring work, APCC provides the following recommendations:

Recommendation 1: Continue the sampling season to include late season monitoring**.** Many ponds in APCC's cyanobacteria monitoring program experience their highest cyanobacteria concentrations in the spring and the fall. Additional late season monitoring could shed light on potential bloom conditions outside of the typical June to Labor Day monitoring season performed in Cedar Lake, Deep Pond, Fresh Pond, Mares Pond, Jenkins Pond, and Siders Pond this 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.

Recommendation 2: Continue yearly cyanobacteria monitoring. Monitoring over multiple years for full seasons would provide greater understanding of the cyanobacteria community in Cedar Lake, Deep Pond, Fresh Pond, Mares Pond, Jenkins Pond, and Siders Pond. More seasons of data will allow us to draw better predictions year after year. Continued monitoring will also allow for the ability 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 restoration.

Recommendation 3: Reduce nutrient loading to freshwater ponds. Algal blooms and cyanobacteria blooms in ponds are associated with nutrient loading to ponds. Furthermore, there is mounting evidence that nitrogen as well as phosphorus is involved in stimulating algal blooms in freshwater ponds. Residents living adjacent to ponds and within the pond watershed should reduce sources of nutrient pollution flowing from their properties towards the pond. Excess fertilizer use, septic systems around ponds, poor stormwater management infrastructure, and a lack of adequate vegetation buffers exacerbate nutrient loading of ponds. Reducing or eliminating fertilizer use, maintaining septic systems or upgrading to better wastewater management systems that remove more nutrients, treating stormwater runoff before it enters

wetlands or ponds, and planting vegetated buffers where none exist will help to protect pond water quality.

Recommendation 4: Recognize that scientific understanding of the causes of HCBs continues to evolve. 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). Residents and officials should understand that there may be many factors that cause HCBs on Cape Cod. Continued monitoring of cyanobacteria and water quality will lead to increased understanding and awareness, a safer public, and hopefully improved health of our freshwater ponds.

Recommendation 5: Consider carefully before planning or undertaking pond restoration and protection options. If a pond is impacted by HCBs, here are some steps to consider:

- Identify the important uses and desirable features of the pond and surrounding areas.
- Consider the natural evolution of a pond over time, from open water to vegetated marsh to wet meadow.
- Identify potential causes of HCBs (e.g., excess nutrients, warming, etc.).
- Identify potential actions to promote pond health and reduce HCBs.
    - For a comprehensive list of actions that residents, municipalities, and state agencies can take to promote pond health, visit APCC's State of the Waters: Cape Cod website (State of the Waters) , specifically, the Action Plan for ponds.
    - Under the Freshwater Initiative, the Cape Cod Commission is developing a Pond Restoration Technologies matrix to identify potential methods for pond protection and restoration. Each pond is unique, and restoration technology that works for one pond may not work well for another.
- Develop a comprehensive plan for pond protection and restoration that addresses the causes as well as the symptoms of impaired pond health. Treating a single problem without considering the effects on other pond resources can potentially cause problems. Planning for pond protection should be done to address not only short-term solutions but also medium-term and long-term solutions.
- Develop a watershed management plan and continue to engage residents around the pond and within the watershed about best land care practices, pond ecology, etc.

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Appendix 1. Resources on Cyanobacteria

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[1]) Microsoft Word - toxcyanbegin.doc (who.int).
- The Centers for Disease Control (CDC) call cyanotoxins "among the most powerful natural poisons known" (NCEH Cyanobacteria Blooms Fact Sheet (cdc.gov)). The habsphysician_card.pdf (cdc.gov) 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 (Harmful Algal Blooms • 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." (Monitoring and Responding to Cyanobacteria and Cyanotoxins in Recreational Waters | US EPA)
    - EPA Office of Ground Water and Drinking Water webpage. Managing Cyanotoxins in Public Drinking Water Systems. (Managing Cyanotoxins in Public Drinking Water Systems | US EPA)
    - EPA webpage on nutrient pollution and HABs. (Harmful Algal Blooms | US EPA)
    - EPA webpage on Cyanobacteria HABs. (Cyanobacteria Harmful Algal Blooms (CyanoHABS) in Water Bodies)
- State agencies, including New York (Harmful Blue-Green Algae Blooms (ny.gov)), Rhode Island (Cyanobacteria (Blue-Green Algae) | Rhode Island Department of Environmental Management), and New Hampshire (NHDES Fact Sheet: Potential Dangers of Cyanobacteria in New Hampshire Waters) have cyanobacteria monitoring programs and provide guidance concerning public health and environmental risks posed by cyanobacteria.
- Commonwealth of Massachusetts:
    - Cyanobacteria webpage: (Cyanobacterial Harmful Algal Blooms (CyanoHABs) & Water | Mass.gov)
    - Massachusetts Department of Public Health (MDPH) website on "Guidelines for cyanobacteria in freshwater recreational water bodies." (Guidelines for Cyanobacteria at Recreational Freshwater Locations | Mass.gov)

Appendix 2. APCC's Cyanobacteria Risk Categories.

APCC 2022 Cyanobacteria Risk Categories Revised 7/26/2022				
Criteria		**APCC Acceptable**	**APCC Potential for Concern**	**APCC Use Restriction Warranted**
Microcystin	Potential microcystin calculated by APCC based on measurement of phycocyanin in Bloom Forming Colony samples.	Potential microcystin calculated at low levels that do not warrant additional toxin testing[2,4].	Potential microcystin is elevated to a point where an exceedance is deemed possible and confirmatory toxin testing warranted[2,4].	
	Measured microcystin by Barnstable County Water Quality Lab.	Less than 4 ppb microcystin measured in GRAB sample.	Between 4 and 8 ppb microcystin measured in GRAB sample.	Greater than 8 ppb microcystin measured in GRAB sample[3].
Cyanobacteria Blooms and Scums	Cyanobacteria bloom material reported and confirmed by APCC.	None present at the time and place of sample collection.	A cyanobacteria scum or bloom is present but is deemed to be insignificant by the Massachusetts Department of Public Health and the town's health agent.	A cyanobacteria scum or bloom is present and is deemed to be significant by the Massachusetts Department of Public Health or the town's health agent[3].
Notes	To interpret cyanobacteria data using this table, the most hazardous result determines the category the pond is placed in from right to left. A pond that meets even a single criterion in the "Use Restriction Warranted" column will be placed in that category. Likewise, a pond that meets even a single criterion in the "APCC Potential for Concern" category but does not meet any criteria in the "APCC Use Restriction Warranted" category, will be placed in the "APCC Potential for Concern" category. If a pond meets no criteria in the "APCC Use Restriction Warranted" or the "APCC Potential for Concern" category, that pond is placed in the "APCC Acceptable" category. [2] Developed with recommendations from Nancy Leland of Lim-Tex Inc. and affiliated with the University of New Hampshire Center for Freshwater Biology. [3] Criteria attributed to MDPH. [4] Predictive cyanobacteria metrics that project and estimate risks, rather than reactive cyanobacteria metrics that measure risk after a bloom has occurred.			

Appendix 3. Cedar Lake, Deep Pond, Fresh Pond, Jenkins Pond, Mares Pond, Siders Pond Cyanobacteria Risk Comparison.

As of 2023, APCC has completed four seasons of cyanobacteria monitoring for the FWS. The table below details APCC's communication of cyanobacteria risk for Cedar Lake, Deep Pond, Fresh Pond, Jenkins Pond, Mares Pond, and Siders Pond in each season. Red indicates a "Use Restriction Warranted" or "High Warning Tier" designation and yellow indicates a "Potential for Concern" or "Moderate Warning Tier" designation, and blue indicates an "Acceptable" or "Low Warning Tier" designation. See the 2020 and 2021 APCC reports for FWS and the Town of Falmouth for more information on findings and risk communication in these sampling seasons.

Cedar Lake 2020-2023 Cyanobacteria Risk Comparison												
	June		July		August		September		October		November	
Year	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-30th
2020												
2021												
2022												
2023												

Deep Pond 2020-2023 Cyanobacteria Risk Comparison												
	June		July		August		September		October		November	
Year	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-30th
2020												
2021												
2022												
2023												

Fresh Pond 2021-2023 Cyanobacteria Risk Comparison												
	June		July		August		September		October		November	
Year	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-30th
2021												

2022												
2023												

Jenkins Pond 2020-2023 Cyanobacteria Risk Comparison												
	June		July		August		September		October		November	
Year	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-30th
2020												
2021												
2022												
2023												

Mares Pond 2020-2023 Cyanobacteria Risk Comparison												
	June		July		August		September		October		November	
Year	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-30th
2020												
2021												
2022												
2023												

Siders Pond 2021-2023 Cyanobacteria Risk Comparison												
	June		July		August		September		October		November	
Year	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-31st	1st-15th	16th-30th	1st-15th	16th-31st	1st-15th	16th-30th
2021												
2022												
2023												

Appendix 4. Sampling Locations

- Cedar Lake: Behind North Falmouth Library
- Deep Pond: Pondview Circle neighborhood Beach (Private)
- Fresh Pond: From Surrey Lane (Private)
- Jenkins Pond: Pinecrest Beach Drive (Private)
- Mares Pond: Neighborhood Beach off Pattee Road (Private)
- Siders Pond: Residence off Town Hall Square, Falmouth (Private)