Nantucket Island Ponds and Their Water Quality

Chapter 3

Capaum Pond - 2015

3.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Capaum Pond by the Nantucket Land Council, Inc. during 2015.

3.1 Results

Capaum Pond was sampled twice during 2015, on July 21st and again on September 8th. The maximum water depth in the pond was 5.5 feet (66 inches) on July 21st at the sampling location in the approximate center of the pond; the sampling depth on September 8th was 4.8 feet (58 inches).

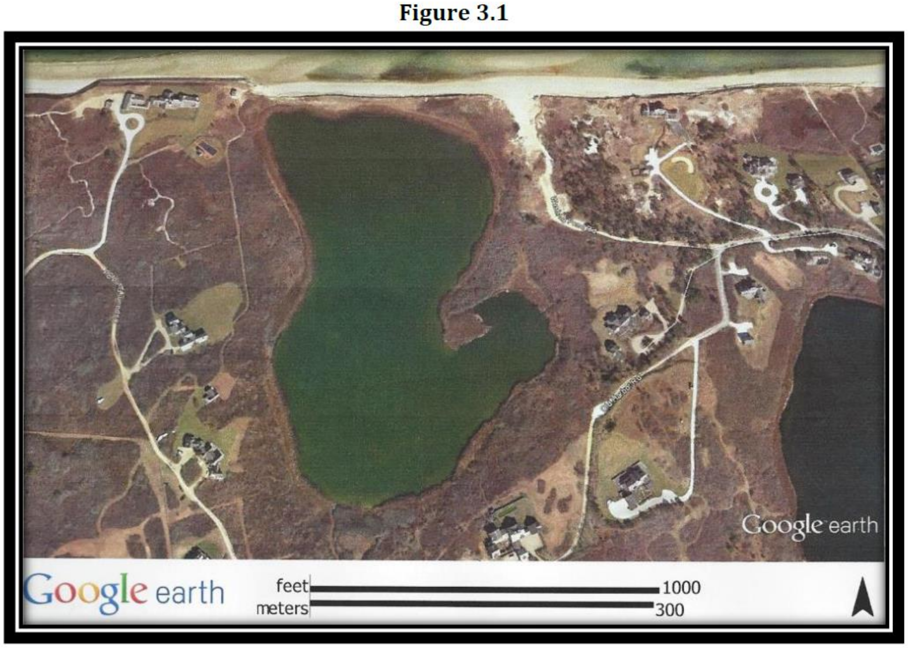
Following the collection of temperature and dissolved oxygen profile data on July 21st, an integrate (*upper*) sample was collected from the surface down to 4 feet of depth for chemistry and phytoplankton analyses; an additional grab (*lower*) sample was collected from the 5-foot depth. On September 8th, the *upper* sample was collected from the surface down to a depth of 3 feet, while the *lower* sample was collected at the 4-foot depth.

A raw water sample was collected for algal toxins on July 21st since observations suggested that an algal bloom was in progress; there also was a follow-up sample collected and submitted on July 28th. The results from these two samples (discussed later in this chapter) prompted subsequent collections of raw water samples for toxin analysis on August 4th and August 13th. Other observations recorded while sampling the pond included: there was an absence of any visible submerged attached aquatic vegetation and the bottom was a dark organic material.

3.1.1 Physical characteristics

General. Capaum Pond has an irregular shape with its long axis oriented north-south (Figure 3.1). The pond is located on the north shore toward the western end of Nantucket Island, ~2,000 feet north of the intersection of Cliff, Madaket and Eel Point Roads. The pond surface area is ~18 acres. There are no streams flowing into the pond and no outlet. The pond is separated from Nantucket Sound by a high sand berm.

Figure 3.1



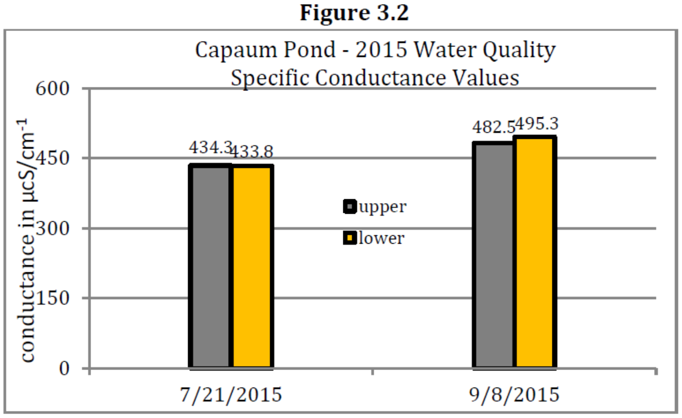
Temperature. Temperature profile data were collected on both 2015 sampling excursions. Due to the pond's shallow depth, there was only 2-3 degrees of temperature fluctuation from surface to bottom on both sampling dates. The average temperature was 25.4°C on July 21st and 25.6°C on September 8th.

Transparency. The Secchi depth transparency measured at Capaum Pond was about 1 foot on both sampling dates, indicating low light penetration from the pond surface down through the water column. The Secchi depth was recorded as 1.2 feet on July 21st and 0.8 feet on September 8th. Water color on both sampling dates was listed as 'cloudy green' which usually is indicative of an algal bloom in progress.

3.1.2 Chemical characteristics

Specific conductance. Figure 3.2 shows the conductivity values measured in the *upper* and *lower* regions of the pond during July and September 2015. The individual values measured on July 21st were 434.3 and 433.8 μS·cm^{-1} in the upper and lower regions, respectively. On September 8th, the *upper* and *lower* values were 482.5 and 495.3 μS·cm^{-1}, respectively.

Figure 3.2

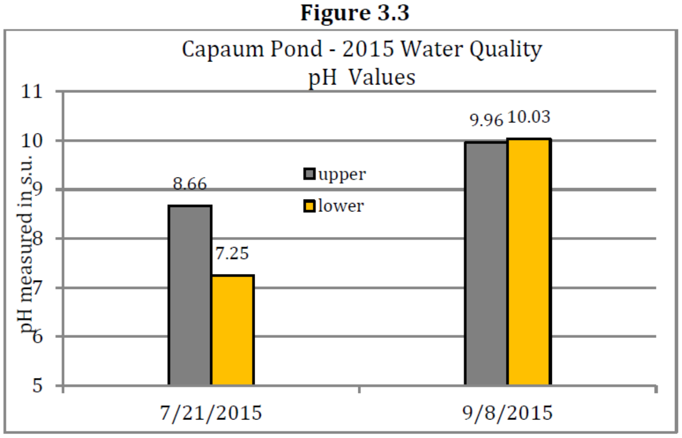


The similarity of the *upper* and *lower* conductance values on both 2015 sampling dates reflects the shallow nature of Capaum Pond and the fact that the water column probably mixes from the surface to the bottom when any substantial wind (> 10 mph) blows across the Island.

The relative conductance values measured in Capaum are considered high within the range of specific conductance values expected from ponds considered to be fresh water and this feature probably is due to the close proximity of the pond to Nantucket Sound and the influence of high winds and salt water spray.

pH. The pH measured in the *upper* and *lower* regions of Capaum Pond on the July and September 2015 sampling dates is shown in Figure 3.3.

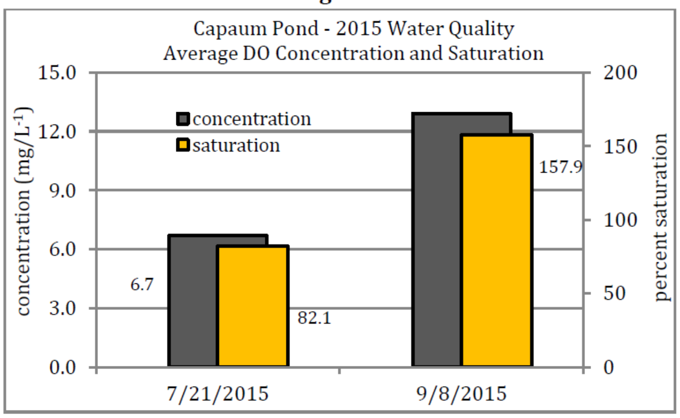
Figure 3.3



The values recorded on July 21st were 8.66 and 7.25 in the *upper* and *lower* regions, respectively, and suggest that a distinct separation of these regions because a difference of 1 pH unit is equivalent to a 10-fold difference in pH. The significantly higher pH values recorded on September 8th, 9.96 in the *upper* region and 10.03 in the *lower* region (average = 10.00) reflect a considerable imbalance between pond respiration and photosynthesis which can result when intense algal blooms occur during the growing season. There will be more discussion related to this topic in the chapter section on phytoplankton.

Dissolved oxygen concentration-percent saturation. The oxygen concentration and saturation patterns in Capaum Pond during July and September 2015 are shown in Figure 3.4.

Figure 3.4



The values shown in Figure 3.4 are average values for the individual readings taken from the surface down to 5 feet on July 21st and down to 4 feet on September 8th.

There was considerable variation in the concentration (Δ=8.44 mg/L-1) and saturation values (Δ=106.3%) measured from the surface to the bottom during the July sampling, and considerably less variation measured during the September sampling date (concentration Δ=1.98 mg/L-1 and saturation Δ=26.4%).

The July dissolved oxygen measurements were typical of a pond with warm water temperatures and moderate productivity. In contrast, the September values for concentration and saturation were elevated, i.e., supersaturated, and indicative of high productivity occurring in the pond, probably from an algal bloom.

3.1.3 Plant Nutrients

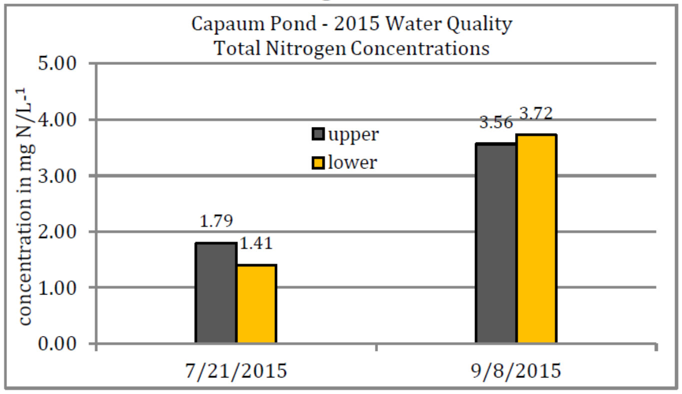
Nitrogen. The July and September concentrations of **nitrate-nitrogen** measured in the *upper* and *lower* regions of Capaum Pond were below the limit of detection on both sampling dates. This phenomenon is not unusual in ponds during the growing season because this form of nitrogen is readily taken up by phytoplankton occurring in the water column when it is available.

The same condition (levels below detection) was observed for **ammonia-nitrogen** in the *upper* region of the pond during both July and September, and in the *lower* region of the pond during September. The only elevated level of ammonia-nitrogen occurred in the *lower* region on September 8th and the value was reported as 0.260 mg N·L-1.

Based upon the low concentrations of **nitrate-nitrogen** and **ammonia-nitrogen** measured in Capaum Pond during 2015, essentially all of the **total nitrogen** measured in the pond was contained in organic material in the form of phytoplankton and seston (other organisms and non-living particulate matter).

The **total nitrogen** (TN) measured in Capaum Pond during July and September 2015 is presented graphically in Figure 3.5. There was no significant difference between the upper and lower concentrations measured on each sampling date; however, there essentially was a doubling in the average TN concentration in the pond between the July (average = 1.60 mg $N \cdot L^{-1}$) and September (3.64 mg $N \cdot L^{-1}$) sampling dates.

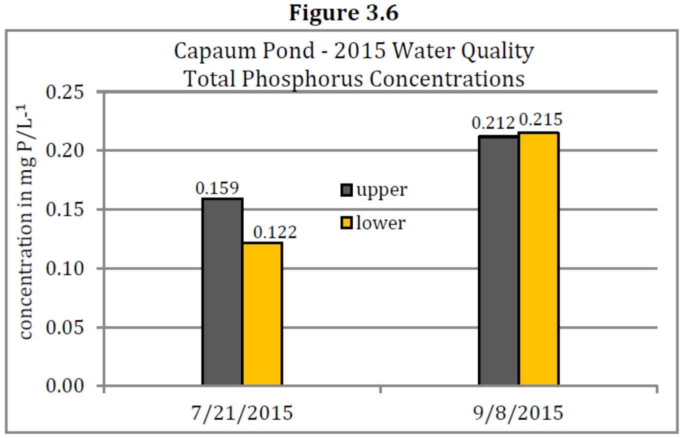
Figure 3.5



The elevated TN concentrations measured in Capaum Pond during July and September 2015 are indicative of phytoplankton blooms occurring in the water column.

Phosphorus. The **total phosphorus (TP)** concentrations measured in Capaum Pond during July and September 2015 are shown in Figure 3.6.

Figure 3.6



As shown in the above figure, there were very minor differences between concentrations measured the upper and lower regions of the pond on each sampling date.

The average concentration in the water column measured on July 21st was 0.141 mg $P \cdot L^{-1}$, and this average increased by the September 8th sampling date to 213.5 mg $P \cdot L^{-1}$. These levels of phosphorus are considered high and reflect the moderate-to-high density of phytoplankton in the water column on both sampling dates.

3.1.4 Phytoplankton

Description of the assemblage. There were 42 different taxa identified in the July and September 2015 phytoplankton samples collected from Capaum Pond and all of the six (6) major algal groups were represented (Table 3.1). As far as the individual sampling dates, there were 30 taxa identified in the July

21st sample and 35 taxa present in the September 8th sample. Community richness for the 2 sampling periods was calculated to be 32.5 (±3.5) taxa.

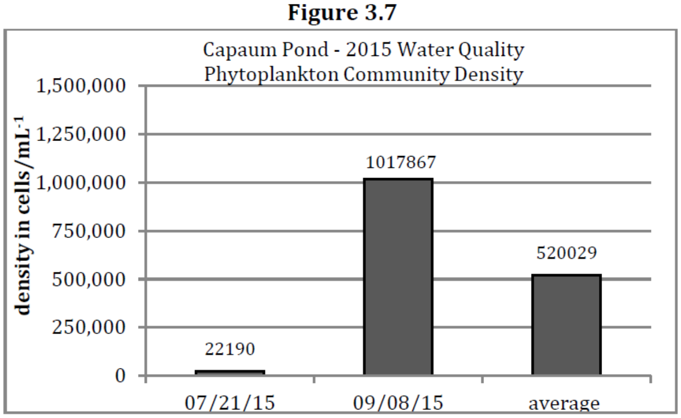
The greatest representation of phytoplankton taxa occurred within the Chlorophytes (green algae), where 20 different taxa were identified. The next most abundant groups were the Bacillariophytes (9 taxa) and Cyanophytes (7 taxa).

Table 3.1

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyceae)**
Anabaena circinalis	O. pusilla	Gomphonema spp.
A. flos aquae	O. solitaria	Navicula spp.
Aphanizomenon flos aquae	Pediastrum duplex	Pinnularia sp.
Chroococcus dispersus	Pyramimonas tetrarhyncus	Planothidium sp.
Gomphosphaeria lacustris compacta	Scenedesmus acuminatus	Stephanodiscus sp.
Microcystis aeruginosa	S. arcuatus	Synedra acus
Woronichinia naegeliana	S. bijuga	**Chrysophyta (Chrysophyceae)**
Chlorophyta	S. quadricauda	Ochromonas sp.
Actinastrum Hantzschii	Schroederia Judayi	**Euglenophyta**
Closteriopsis longissima	Sphaerocystis Schroeteri	Phacus sp.
Coelastrum cambricum	Staurastrum natator var. crassum	Trachelomonas sp.
Cosmarium spp.	Tetraedron minimum	**Pyrrhophyta (Cryptophyceae)**
Eudorina elegans	**Chrysophyta (Bacillariophyceae)**	Cryptomonas erosa
Kirchneriella lunaris	Aulacoseria granulata	C. ovata
Monoraphidium contortum	Cocconeis sp.	Ceratium hirundinella
Oocystis Borgei	Cyclotella sp.	

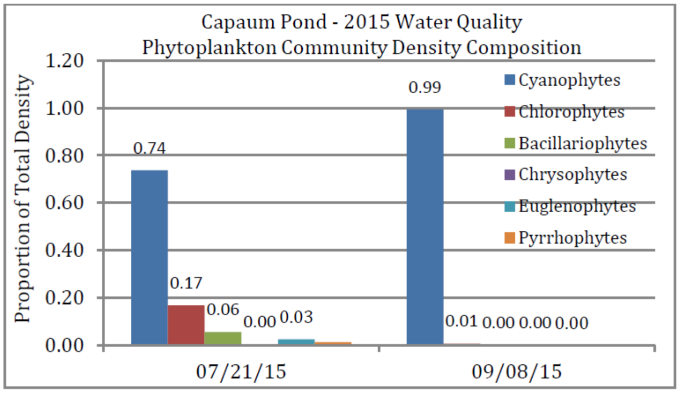
Density. Phytoplankton community density was 22,190 cells·mL^{-1} on July 21st and 1,017,867 cells·mL^{-1} on September 8th, about a 50-fold increase in density between the two sampling dates (Figure 3.7).

Figure 3.7



The July 21st phytoplankton assemblage included primarily Cyanophytes (blue-greens) with 74 percent of the density and the Chlorophytes (green algae) with 17 percent of the community density (Figure 3.8).

Figure 3.8



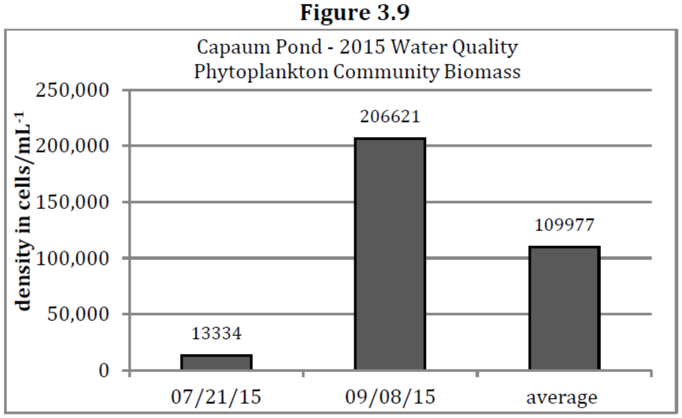
The relative importance of the Cyanophytes increased to 99 percent of the population on September 8th, with the Chlorophytes comprising the remaining 1 percent on this sampling date (Figure 3.8).

Given the shallow depth of Capaum Pond and the greatly reduced water clarity on both sampling dates, the phytoplankton cell density measured during July (22,190 cells·mL^{-1}) is considered to be within the 'normal' range, while the September density (1,017,867 cells·mL^{-1}) represents an explosion in population growth and a serious bloom in progress.

Biomass. Cell biovolume also was used to evaluate phytoplankton taxon productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond. The misleading nature of density as a reliable cell descriptor is evident when reviewing biovolume values and noting the substantial difference between the size of, for example, the green algae *Monoraphidium contortum* cells (30.9 mg·m^{-3}) and *Closterium* sp. cells (4000.0 mg·m^{-3}). The difference in relative biovolume (the size of individual cells) explains how small numbers of cells with a large biovolume can make a particular taxon a dominant member in the phytoplankton community.

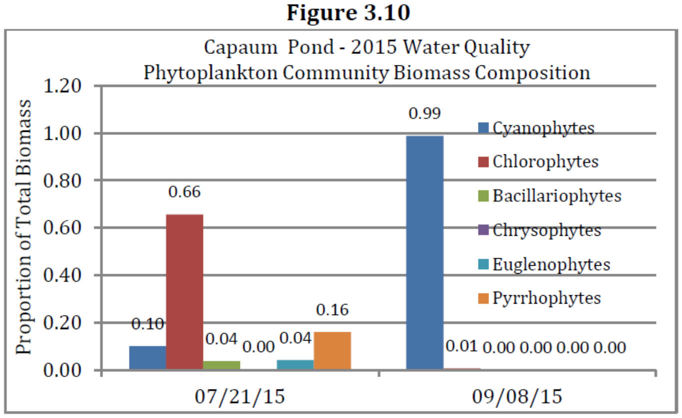
The phytoplankton community biomass was 13,334 mg·m^{-3} on July 21st and 206,621 mg·m^{-3} on September 8th, a 15-fold increase from the July value to the September value (Figure 3.9).

Figure 3.9



With regard to biovolume, the July 21st phytoplankton assemblage in Capaum Pond included primarily the Chlorophytes (66 percent of the community) and then the Pyrrhophytes (fire algae, primarily dinoflagellates that are marine forms, 'red' tide) with 16 percent of the community biovolume (Figure 3.10).

Figure 3.10



On September 8th, the Cyanophytes comprised 99 percent of the community biovolume and the Chlorophytes made up the remaining 1 percent.

Dominance. A ranking of phytoplankton taxa dominance in Capaum Pond is summarized in Table 3.2 for the July-September sampling dates. Taxa are considered dominant in the community if they comprise at least 5 percent of the total biomass. There were 5 dominant taxa in the phytoplankton community on July 21st and only one dominant taxon on September 8th (Table 3.2). As discussed above, green algae comprised the major portion of the phytoplankton community biomass during July while essentially all of the community biomass on September 8th was the Cyanophyte, *Aphanizomenon flos aquae* (97 percent).

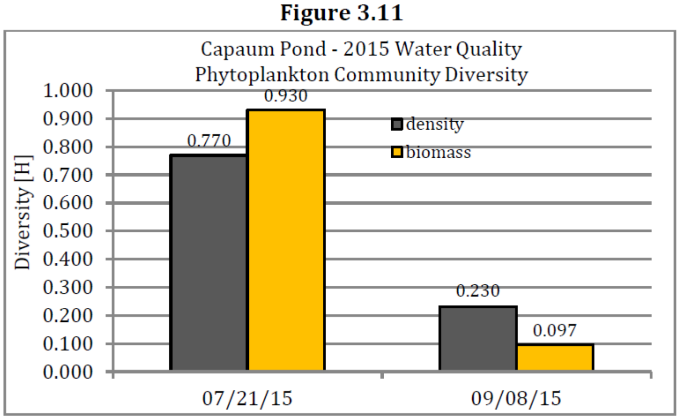
Table 3.2

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
7/21/15	*Staurastrum natator* var. *crassum* (Chlorophyte)	1	40
	Ceratium hirundinella (Pyrrhophyte)	2	15
	Pediastrum duplex (Chlorophyte)	3	9
	Anabaena flos aquae (Cyanophyte)	4	8
	Cosmarium spp. (Chlorophyte)	5	6
9/8/15	*Aphanizomenon flos aquae* (Cyanophyte)	1	97

Diversity. Phytoplankton diversity in Capaum Pond was measured using the Shannon-Wiener function[1] which calculates diversity, **[H]**, using number of taxa and the portion of individuals among the taxa on each sampling date. An increase in either factor will increase the value of the diversity index. Calculated values that approach 1.0 indicate conditions of maximum diversity in the distribution of the population.

Diversity was calculated for Capaum Pond using both density and biovolume for the July and September sampling dates. The results of these analyses are shown in Figure 3.11.

Figure 3.11



Both versions of the diversity calculation shown in Figure 3.11 emphasize the dramatic change that occurred in the phytoplankton between July and August when the fairly diverse community changed to a community dominated by a single Blue-green algal species.

Cyanophytes. As a major phytoplankton group, Cyanophytes were identified in the July and September sampling dates on Capaum Pond. There were 3 different species identified on July 21st and 6 different species identified on September 8th. As shown in Table 3.3, 7 species were identified in the pond.

Table 3.3

Cyanophyta	
Anabaena circinalis	*Gomphosphaeria lacustris compacta*
A. flos aquae	*Microcystis aeruginosa*
Aphanizomenon flos aquae	*Woronichinia naegeliana*
Chroococcus dispersus	

[1] $H = -\sum_{i=1}^{s} (p_i)(log_2)(p_i)$, in units of information per individual per unit volume or area, where p_i is the proportion of the total samples belonging to the *i*th species and S is the number of species.

All of the Cyanophyte species identified in the table above have been shown to produce algal toxins except *Chroococcus dispersus* and *Gomphosphaeria lacustris compacta.*

Algal toxins. Four (4) raw water samples were collected from Capaum Pond during 2015 and shipped to GreenWater Laboratories to be analyzed for algal toxins. Water quality conditions observed at the pond on July 21st indicated that a bloom was in progress and prompted the collection of the first sample for algal toxins. Results from the analysis of this first sample encouraged the subsequent collections. Table 3.4 presents a summary of the results received from the toxin analyses.

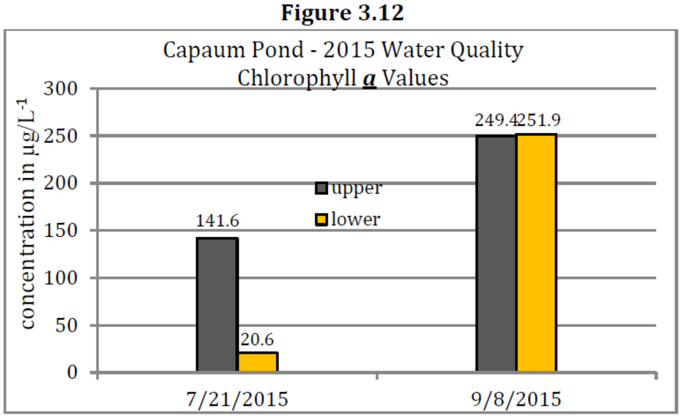
Table 3.4

	Levels of Toxin (in µg/L)				
2015 Sampling Date	**Microcystins**	**Anatoxin-a**	**Cylindrospermopsin**	**Saxitoxin**	**Status**
July 21st	1.76				Moderate
July 28th	1.29*	ND	ND	0.11**	*Moderate, **Minimal
August 4th	0.87*	ND	ND	0.10**	*Low, **Minimal
August 13th	1.41*	ND	ND	0.08**	*Moderate, **Low
Level of detection (µg/L)	0.15	0.05	0.10	0.05	
ND = not detected above the LOD/LOQ					
Guidelines for interpretation of results. For samples which are *non-detects* – the highest possible risk category is listed.					
0.0-0.2 µg/L (little to no risk from blue-green algal toxins: Minimal Risk)					
0.2-1.0 µg/L (toxin detected but below World Health Organization (WHO) drinking water guidelines: Low Risk)					
1.0-10.0 µg/L (toxin levels above the WHO drinking water guidelines but generally below WHO limits for recreational use: Moderate Risk)					
10-20 µg/L (toxin levels are significant and approach WHO limits for recreational contact: High Risk)					
>20 µg/L (toxin levels exceed WHO guidelines for recreational contact. Users should avoid contact and be extremely careful to wash off pets)					

MC was detected in samples submitted from July 21st and July 28th. The dominant genera identified in the July 28th sample prompted GreenWater Lab to recommend additional analyses be performed on the sample for anatoxin-a, cylindrospermopsin, and saxitoxin. The presence of saxitoxin in the July 28th motivated the collection of the subsequent samples that were submitted for toxin analysis. Based upon the collective toxin analyses performed in 2015, contact recreation in Capaum Pond should be discouraged and the pond probably should be posted to advise visitors to the area of the potential adverse health effects.

Chlorophyll *a*. The chlorophyll *a* concentrations measured in Capaum Pond during 2015 are shown in Figure 3.12. There was a distinct separation of *upper* and *lower* regions of the pond on July 21st with respect to chlorophyll *a* as shown by the difference in the relative values, i.e., 141.6 µg P·L^{-1} versus 20.6 µmg P·L^{-1}, respectively.

Figure 3.12



This is another example of the separation of *upper* and *lower* regions of the pond on this sampling date, and the low chlorophyll reading in the *lower* region suggests that most of the phytoplankton community is located in the *upper* region where the light penetration is more suitable for photosynthesis.

The most interesting observation related to the mid-summer chlorophyll ***a*** in the pond was the pronounced increase in concentration by September 8th, when an average of 250 mg $P \cdot L^{-1}$ was measured in the water column, almost twice the concentration in late July.

These data support other pond measurements that the September phytoplankton density had increased to over 1 million cells per mL and that an intense bloom was occurring in the pond.

3.1.5 Trophic Status

'Trophic' means nutrition or growth. The trophic state of ponds refers to biological production, plant and animal, that occurs in the pond and the level of production is determined by several factors but primarily phosphorus supply to the pond and by the volume and residence time of water in the pond. Different indicators are used to describe trophic state such as phosphorus, water clarity, chlorophyll, rooted plant growth and dissolved oxygen. The reader is referred to Chapter 1 for a more thorough explanation of trophic status and the process of calculating this important indicator of lake and pond productivity.

There were sufficient water quality data collected from Capaum Pond during 2015 to calculate the Carlson Trophic State Index (TSI) using the three most common variables for evaluation (chlorophyll ***a***, total phosphorus, Secchi depth transparency). Average values were calculated for each variable for the July and September sampling dates. The average values then were substituted into the appropriate equations (Chapter 1) to calculate the TSI values for each variable.

The stepwise calculation and results of the analysis are as follows:

Chlorophyll *a*
Average mid-summer chlorophyll *a* = 165.9 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (165.9)] + 30.6
TSI = (9.81)(5.11) + 30.6
TSI = 80.7

Total phosphorus
Average mid-summer total phosphorus = 176.8 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (176.8)] + 4.15
TSI = (14.42)(5.18) + 4.15
TSI = 78.8

Secchi depth
Average mid-summer Secchi depth = 0.30 m
Secchi TSI = 60 – [14.41*[ln (0.30)]
TSI = 60 – (14.41)(-1.19)
TSI = 77.3

The results of the TSI calculations can be interpreted by comparing the average value and the trophic index value with the parameters summarized in Table 3.4. Each water quality indicator (i.e., phosphorus, Secchi depth and chlorophyll a) measured in Capaum Pond resulted in a trophic index that was within the range 70-100, which denotes a hyper-eutrophic condition.

Table 3.4

Trophic Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth (m)	Trophic Class
< 30 - 40	0.0 – 2.6	0.0 - 12	> 8 - 4	Oligotrophic
40 - 50	2.6 – 7.3	12 - 24	4 - 2	Mesotrophic
50 - 70	7.3 - 56	24 - 96	2 – 0.5	Eutrophic
70 – 100+	56 – 155+	96 – 384+	0.5 - <0.25	Hyper-eutrophic

Taken at face value along with the results from the assessment of the phytoplankton community, and algal toxins, the TSI values calculated for Capaum Pond portray a highly degraded water quality where any sort of contact recreation should be avoided.

3.2 Summary

Capaum Pond can be characterized as a highly productive body of water that exhibits hyper-eutrophic conditions for the usual parameters used in the assessment of water quality during the growing season. Based upon the composition of the phytoplankton community documented during 2015, recreational use of this pond should be avoided because a variety of Cyanophyte species occur in the pond that are known to produce harmful algal toxins.

3.3 Literature Cited

Carlson, R. E. and J. Simpson. 1996. A Coordinator's Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Carlson, R. E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22(2): 361-369.