Nantucket Island Ponds and 2019 Water Quality

Capaum Pond, Gibbs Pond, Head of Hummock Pond, Miacomet Pond

A Summary of Physical, Chemical and Biological Monitoring

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March 2020

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TABLE OF CONTENTS

		Page
Chapter 1	A Basic Water Quality Primer	1
	1.0 Introduction	2
	What is "water quality"?	2
	How is water quality measured?	2
	Why are there water quality standards and guidelines?	2
	How do natural processes affect water quality?	2
	What occurs "naturally" in water?	2
	The effect of human activities on water quality	2
	1.1 Water Quality – Physical characteristics	2
	Transparency	2
	1.2 Water Quality – Chemical characteristics	3
	Specific conductance	3
	pH	3
	Dissolved Oxygen concentration/percent saturation	3
	1.3 Water Quality – Plant Nutrients	4
	Nitrogen	4
	Phosphorus	5
	1.4 Water Quality - Biological	5
	1.5 Water Quality – Trophic Status	5
	1.6 Summary	6
	1.7 Literature Cited	7
Chapter 2	Water Quality Sampling Protocol	8
	2.0 Background	9
	2.1 Sampling Protocol	9
	2.2 Methodology	9
	Routine sample collection and processing	9
	2.3 Analytical Techniques	10
	Water column measurements and sample collection	10
	Phytoplankton identification-enumeration	10
	Counting method	10
	Conversion to density (cells/mL^{-1})	11
	Conversion to biovolume (mg^3/mL^{-1})-biomass (mg/m^{-3})	11
	Potentially toxigenic cyanobacteria (PTOX) screen	11
	Cyanotoxin analysis	11
	2.4 Summary	12
	2.5 Literature Cited	12
Chapter 3	Capaum Pond	13
	3.0 Introduction	14
	3.1 Results	14
	3.1.1 Physical characteristics	14
	General	14
	Transparency	15
	Temperature	15
	3.1.2 Chemical characteristics	15
	Specific conductance and Total Dissolved Solids (TDS)	16
	pH	16
	Dissolved oxygen percent saturation	16

TABLE OF CONTENTS (continued)

		Page
Chapter 3	Capaum Pond (continued)	
	3.1.3 Plant nutrients	17
	Nitrogen	17
	Phosphorus	18
	3.1.4 Phytoplankton	18
	Description of the assemblage	19
	Density	20
	Biomass	20
	Dominance	21
	Diversity	23
	Chlorophyll ***a***	23
	3.1.5 Trophic status	24
	3.2 Summary	24
	3.3 Literature Cited	25
Chapter 4	Gibbs Pond	26
	4.0 Introduction	27
	4.1 Results	27
	4.1.1 Physical characteristics	27
	General	27
	Transparency	28
	Temperature	28
	4.1.2 Chemical characteristics	28
	Specific conductance and Total Dissolved Solids (TDS)	29
	pH	30
	Dissolved oxygen percent saturation	30
	4.1.3 Plant nutrients	31
	Nitrogen	31
	Phosphorus	31
	4.1.4 Phytoplankton	32
	Description of the assemblage	32
	Density	33
	Biomass	34
	Dominance	35
	Diversity	36
	Chlorophyll ***a***	36
	4.1.5 Trophic status	37
	4.2 Summary	37
	4.3 Literature Cited	37
Chapter 5	Head of Hummock Pond	38
	5.0 Introduction	39
	5.1 Results	39
	5.1.1 Physical characteristics	39
	General	39
	Transparency	40
	Temperature	40

TABLE OF CONTENTS (continued)

		Page
Chapter 5	Head of Hummock Pond (continued)	
	5.1.2 Chemical characteristics	40
	Specific conductance and Total Dissolved Solids (TDS)	41
	pH	41
	Dissolved oxygen percent saturation	42
	5.1.3 Plant nutrients	42
	Nitrogen	42
	Phosphorus	43
	5.1.4 Phytoplankton	43
	Description of the assemblage	43
	Density	44
	Biomass	45
	Diversity	46
	Chlorophyll ***a***	46
	Dominance	47
	5.1.5 Trophic status	48
	5.2 Summary	48
	5.3 Literature Cited	49
Chapter 6	Miacomet Pond	50
	6.0 Introduction	51
	6.1 Results	51
	6.1.1 Physical characteristics	51
	General	51
	Transparency	52
	Temperature	52
	6.1.2 Chemical characteristics	52
	Specific conductance and Total Dissolved Solids (TDS)	53
	pH	53
	Dissolved oxygen percent saturation	53
	6.1.3 Plant nutrients	53
	Nitrogen	54
	Phosphorus	54
	6.1.4 Phytoplankton	54
	Description of the assemblage	54
	Density	55
	Biomass	56
	Dominance	57
	Diversity	58
	Chlorophyll ***a***	58
	6.1.5 Trophic status	59
	6.2 Summary	59
	6.3 Literature Cited	59
Chapter 7	Cyanophytes, Cyanotoxins and Water Quality Concerns for Nantucket Island Ponds	60
	7.0 Introduction	61
	7.1 Background	61
	7.2 Results	63
	7.2.1 Eurofins Abraxis® Fresh Water Test Strips	63

TABLE OF CONTENTS (continued)

		Page
Chapter 7	Cyanophytes, Cyanotoxins and Water Quality Concerns for Nantucket Island Ponds (continued)	
	7.2.2 Potentially Toxigenic (PTOX) Cyanobacteria Screen	64
	7.2.3 Nantucket Ponds, Cyanophytes and Cyanotoxins in 2019	66
	7.2.3.1 Capaum Pond	66
	Cyanophytes	66
	Cyanophyte toxins	68
	Deployment of the Aerosol Filter Collection Device	69
	7.2.3.2 Gibbs Pond	70
	Cyanophytes	70
	Cyanophyte toxins	72
	Deployment of the Aerosol Filter Collection Device	72
	7.2.3.3 Head of Hummock Pond	72
	Cyanophytes	72
	Cyanophyte toxins	74
	Deployment of the Aerosol Filter Collection Device	74
	7.2.3.4 Miacomet Pond	74
	Cyanophytes	74
	Cyanophyte toxins	76
	Deployment of the Aerosol Filter Collection Device	76
	7.3 Summary	76
	7.4 Literature Cited	77
Chapter 8	Background, 2019 Monitoring Program, Discussion, Summary, Conclusions and Recommendations	79
	8.0 Introduction	80
	8.1 Background	80
	8.2 2019 Water Quality Monitoring Program	80
	8.3 Discussion	80
	Water Quality Parameters	80
	Trophic State	81
	Cyanophytes, Cyanotoxins and Nantucket Island Ponds	83
	8.4 Summary	83
	8.5 Conclusions	84
	8.6 Recommendations	85
	8.7 Literature Cited	85
Attachment #1	Pond Temperature and Dissolved Oxygen Percent Saturation Profiles	

LIST OF TABLES

		Page
Table 1-1	Relationships among Trophic Index, chlorophyll ***a***, phosphorus, Secchi depth, and Trophic Class	6
Table 2-1	Parameters monitored to assess the short-term water quality of Nantucket Island ponds	9
Table 2-2	Physical, chemical and biological parameters included in the study of water quality on Nantucket Island ponds, their collection technique and methodology	10
Table 3-1	Summary of 2019 sampling dates at Capaum Pond	14
Table 3-2	Summary of Capaum Pond integrate and grab sample depths, 2019	14
Table 3-3	Summary of physical data collected from Capaum Pond during 2019	15
Table 3-4	Summary of 2019 chemical characteristics in ***upper*** region of Capaum Pond	15
Table 3-5	Summary of 2019 Capaum Pond phytoplankton community characteristics	19
Table 3-6	Major groups, genera and species of phytoplankton identified in Capaum Pond, 2019	19
Table 3-7	Rank to 2019 phytoplankton dominance in Capaum Pond	22
Table 3-8	Relationships among Trophic Index, chlorophyll ***a***, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996)	24
Table 4-1	Summary of 2019 sampling dates at Gibbs Pond	27
Table 4-2	Summary of Gibbs Pond integrate and grab sample depths, 2019	27
Table 4-3	Summary of 2019 physical data from Gibbs Pond	28
Table 4-4	Summary of 2019 chemical characteristics in ***upper*** region of Gibbs Pond	28
Table 4-5	Major groups, genera and species of 2019 phytoplankton identified in Gibbs Pond	32
Table 4-6	Summary of 2019 Gibbs Pond phytoplankton community characteristics	33
Table 4-7	Rank of 2019 phytoplankton dominance in Gibbs Pond	35
Table 4-8	Relationships among Trophic Index, chlorophyll ***a***, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996)	37
Table 5-1	Summary of 2019 sampling dates at Head of Hummock Pond	39
Table 5-2	Summary of Head of Hummock Pond integrate and grab sample depths, 2019	39
Table 5-3	Summary of 2019 physical data collected from Head of Hummock Pond	40
Table 5-4	Summary of 2019 chemical characteristics in upper region of Head of Hummock Pond	40
Table 5-5	Summary of 2019 Head of Hummock Pond phytoplankton community characteristics	44

LIST OF TABLES (continued)

		Page
Table 5-6	Major groups, genera and species of phytoplankton identified in Head of Hummock Pond, 2019	44
Table 5-7	Ranking of 2019 phytoplankton dominance in Head of Hummock Pond	47
Table 5-8	Relationships among Trophic Index (TI), chlorophyll ***a***, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996)	48
Table 6-1	Summary of 2019 sampling dates at Miacomet Pond	51
Table 6-2	Summary of Miacomet Pond integrate and grab sample depths, 2019	51
Table 6-3	Summary of 2019 physical data collected from Miacomet Pond	52
Table 6-4	Summary of 2019 chemical characteristics in ***upper*** region of Miacomet Pond	52
Table 6-5	Summary of 2019 Miacomet Pond phytoplankton community characteristics	55
Table 6-6	Major groups, genera and species of phytoplankton identified in Miacomet Pond, 2019	55
Table 6-7	Ranking of 2019 phytoplankton dominance in Miacomet Pond	57
Table 6-8	Relationships among Trophic Index (TI), chlorophyll ***a***, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996)	59
Table 7-1	Summary of primary cyanotoxins, health effects and potential toxin-producing Cyanophyte genera (from US EPA 2014)	62
Table 7-2	Summary of 2019 Nantucket pond samples submitted to GreenWater CyanoLab for PTOX testing	65
Table 7-3	A summary of Cyanophyte genera and species (where listed) identified in Nantucket Island ponds, 2019	65
Table 7-4	Cyanophytes identified in Capaum Pond, 2019	66
Table 7-5	Summary of 2019 cyanobacteria toxin results from Capaum Pond	68
Table 7-6	Summary of 2019 Aerosol Filter Collection Device (AFCD) deployments at Capaum Pond	69
Table 7-7	Cyanophytes identified in Gibbs Pond, 2019	70
Table 7-8	Summary of 2019 cyanobacteria toxin results from Gibbs Pond	72
Table 7-9	Cyanophytes identified in Head of Hummock Pond, 2019	72
Table 7-10	Cyanophytes identified in Miacomet Pond, 2019	75
Table 8-1	Summary of Nantucket Island ponds monitored for water quality during 2019	79

LIST OF TABLES (continued)

		Page
Table 8-2	A summary of maximum, minimum and average values for the suite of parameters monitored during 2019 in Capaum, Gibbs, Head of Hummock and Miacomet Ponds	80
Table 8-3	A summary of Trophic Status Indices calculated for total phosphorus, chlorophyll ***a***, and Secchi depth transparency for the Nantucket Island ponds monitored in 2019	81
Table 8-4	Relationship among Trophic Index, chlorophyll ***a***, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996)	81

LIST OF FIGURES

		Page
Figure 3-1	Aerial view of Capaum Pond (from *Google*™ earth)	14
Figure 3-2	Summary of 2019 average concentrations of chemical parameters in Capaum Pond	16
Figure 3-3	Summary of 2019 specific conductance and TDS in *upper* samples from Capaum Pond	16
Figure 3-4	Summary of 2019 pH values measured in Capaum Pond	17
Figure 3-5	Summary of 2019 dissolved oxygen percent saturation in Capaum Pond	17
Figure 3-6	Summary of 2019 total nitrogen concentrations in Capaum Pond	18
Figure 3-7	Summary of 2019 total phosphorus concentrations in Capaum Pond	18
Figure 3-8	Summary of 2019 phytoplankton community density in Capaum Pond	20
Figure 3-9	Density composition of the 2019 phytoplankton community in Capaum Pond	20
Figure 3-10	Summary of 2019 phytoplankton community biomass in Capaum Pond	21
Figure 3-11	Biomass composition of the 2019 phytoplankton community in Capaum Pond	21
Figure 3-12	Phytoplankton community density and biomass diversity in Capaum Pond, 2019	23
Figure 3-13	Summary of 2019 Capaum Pond chlorophyll ***a*** values	23
Figure 4-1	Aerial view of Gibbs Pond (from *Google*™ earth)	27
Figure 4-2	Summary of 2019 average concentrations of chemical parameters in Gibbs Pond	29
Figure 4-3	Summary of 2019 specific conductance and TDS in *upper* samples from Gibbs Pond	29
Figure 4-4	Summary of 2019 pH values measured in Gibbs Pond	30
Figure 4-5	Summary of 2019 dissolved oxygen percent saturation in Gibbs Pond	30
Figure 4-6	Summary of 2019 total nitrogen concentrations in Gibbs Pond	31
Figure 4-7	Summary of 2019 total phosphorus concentrations in Gibbs Pond	31
Figure 4-8	Summary of 2019 soluble reactive phosphorus concentrations in Gibbs Pond	32
Figure 4-9	Summary of 2019 phytoplankton community density in Gibbs Pond	33
Figure 4-10	Density composition of the 2019 phytoplankton community in Gibbs Pond	33
Figure 4-11	Summary of 2019 phytoplankton community biomass in Gibbs Pond	34
Figure 4-12	Biomass composition of the 2019 phytoplankton community in Gibbs Pond	34
Figure 4-13	Phytoplankton community density and biomass diversity in Gibbs Pond, 2019	36

LIST OF FIGURES (continued)

		Page
Figure 4-14	Summary of 2019 Gibbs Pond chlorophyll ***a*** values	36
Figure 5-1	Aerial view of Head of Hummock Pond (from *Google*™ earth)	39
Figure 5-2	Summary of 2019 average concentrations of chemical parameters in Head of Hummock Pond	41
Figure 5-3	Summary of 2019 specific conductance and TDS in *upper* samples from Head of Hummock Pond	41
Figure 5-4	Summary of 2019 pH values measured in Head of Hummock Pond	41
Figure 5-5	Summary of 2019 dissolved oxygen percent saturation in Head of Hummock Pond	42
Figure 5-6	Summary of 2019 total nitrogen concentrations in Head of Hummock Pond	42
Figure 5-7	Summary of 2019 total phosphorus concentrations in Head of Hummock Pond	43
Figure 5-8	Summary of 2019 soluble reactive phosphorus concentrations in Head of Hummock Pond	43
Figure 5-9	Summary of 2019 phytoplankton community density in Head of Hummock Pond	44
Figure 5-10	Density composition of the 2019 phytoplankton community in Head of Hummock Pond	45
Figure 5-11	Summary of 2019 phytoplankton community biomass in Head of Hummock Pond	45
Figure 5-12	Biomass composition of the 2019 phytoplankton community in Head of Hummock Pond	46
Figure 5-13	Phytoplankton community density and biomass diversity in Head of Hummock Pond, 2019	46
Figure 5-14	Summary of 2019 chlorophyll ***a*** values in Head of Hummock Pond	47
Figure 6-1	Aerial view of Miacomet Pond (from *Google*™ earth) showing the 2019 sampling location	51
Figure 6-2	Summary of 2019 average concentrations of chemical parameters in Miacomet Pond	53
Figure 6-3	Summary of 2019 specific conductance and TDS in *upper* samples from Miacomet Pond	53
Figure 6-4	Summary of 2019 total nitrogen concentrations in Miacomet Pond	54
Figure 6-5	Summary of 2019 total and soluble reactive phosphorus concentrations in Miacomet Pond	54
Figure 6-6	Density composition of the phytoplankton community in Miacomet Pond, 2019	55

LIST OF FIGURES (continued)

		Page
Figure 6-7	Density composition of the major groups of phytoplankton in the Miacomet Pond community, 2019	56
Figure 6-8	Summary of 2019 phytoplankton community biomass in Miacomet Pond	56
Figure 6-9	Biomass composition of the major groups of phytoplankton in the Miacomet Pond community, 2019	57
Figure 6-10	Phytoplankton community density and biomass diversity in Miacomet Pond, 2019	58
Figure 6-11	Summary of 2019 chlorophyll ***a*** values in Miacomet Pond	58
Figure 7-1	Capaum Pond shoreline exhibiting a potential HAB on August 26th 2019 (photo credit RJ Turcotte)	63
Figure 7-2	Excerpt from Eurofins Abraxis® strip test for Microcystin showing determination of toxin concentration	64
Figure 7-3	Results of an Eurofins Abraxis strip test for Microcystin on Capaum Pond, September 16th 2019 (photo credit RJ Turcotte)	64
Figure 7-4	Capaum Pond – 2019 cyanophyte and total phytoplankton density	66
Figure 7-5	Capaum Pond – 2019 cyanophyte and total phytoplankton biomass	66
Figure 7-6	Seasonal distribution of cyanophyte genera density in Capaum Pond, 2019	67
Figure 7-7	Seasonal distribution of cyanophyte genera biomass in Capaum Pond, 2019	67
Figure 7-8	Seasonal distribution of cyanotoxins measured in Capaum Pond, 2019	69
Figure 7-9	Gibbs Pond – 2019 cyanophyte and total phytoplankton density	70
Figure 7-10	Gibbs Pond – 2019 cyanophyte and total phytoplankton biomass	71
Figure 7-11	Seasonal distribution of cyanophyte genera density in Gibbs Pond, 2019	71
Figure 7-12	Seasonal distribution of cyanophyte genera biomass in Gibbs Pond, 2019	72
Figure 7-13	Head of Hummock Pond – 2019 cyanophyte and total phytoplankton density	73
Figure 7-14	Head of Hummock Pond – 2019 cyanophyte and total phytoplankton biomass	73
Figure 7-15	Seasonal distribution of cyanophyte genera density in Head of Hummock Pond, 2019	74
Figure 7-16	Seasonal distribution of cyanophyte genera biomass in Head of Hummock Pond, 2019	74
Figure 7-17	Miacomet Pond – 2019 cyanophyte and total phytoplankton density	75
Figure 7-18	Miacomet Pond – 2019 cyanophyte and total phytoplankton biomass	75

LIST OF FIGURES (continued)

		Page
Figure 7-19	Seasonal distribution of cyanophyte genera density in Miacomet Pond, 2019	76
Figure 7-20	Seasonal distribution of cyanophyte genera biomass in Miacomet Pond, 2019	76
Figure 8-1	Summary of Trophic Status Indices calculated for Nantucket Island ponds monitored in 2019	81
Figure 8-2	Seasonal distribution of cyanotoxins measured in Capaum Pond, 2019	82

ACKNOWLEDGEMENTS

Funding for this work was provided by the Nantucket Land Council (NLC), Inc. This was the 11th consecutive year that the NLC has sponsored water quality research on Nantucket Island ponds. By funding these projects, the NLC continues to demonstrate its vision focused on environmental stewardship of the unprotected water resources of Nantucket Island and its desire to advocate for the protection of important features of the Nantucket landscape that are constantly threatened by human encroachment and influence.

The authors would like to thank the Nantucket Conservation Foundation for providing permission to access Capaum Pond and Gibbs Pond for sampling during 2019.

The principal author would like to personally thank the following individuals whose assistance was instrumental in completing the 2019 field work, data analysis and report writing phases of this project: Emily Molden for her continuing the NLC dedication toward the environment and important water quality issues initially fostered by Cormac Collier, RJ Turcotte who has been particularly reliable with critical field sampling of the ponds, often under less than ideal weather conditions, and Michael Kelley and Vince Moriarty (IBM) who conceptualized and then developed a self-contained, field deployable prototype for capturing aerosols of cyanotoxins and/or picocyanobacteria adjacent to Island ponds experiencing harmful algal blooms.

Nantucket Island Ponds and Their Water Quality

Chapter 1

A Basic Water Quality Primer

1.0 Introduction

What is "water quality"? Water quality is a measure of the suitability of water for a particular use based upon certain physical, chemical and biological characteristics. To determine water quality, scientists measure and analyze water characteristics such as temperature, dissolved oxygen, dissolved mineral content, and biological organisms. Selected characteristics are compared with numeric standards and guidelines to determine whether the water is suitable for a particular use.

How is water quality measured? Some aspects of water quality such as temperature, dissolved oxygen, pH and conductance can be determined right in the lake, pond or stream (*in-situ*); other measurements, such as certain chemical constituents, are measured in the laboratory.

Why are there water quality standards and guidelines? Water quality standards and guidelines are established to protect water for specific uses such as drinking, recreation, agricultural irrigation, or the protection of aquatic life. The U.S. Environmental Protection Agency (US EPA) and individual states are responsible for establishing standards for water constituents that are known to pose a human health risk.

How do natural processes affect water quality? Water quality varies from one geographical place to another, with the seasons, with climate and with the types of soils and rocks through which water moves. When water from rain or snow moves over land or through the ground, it may dissolve minerals in rocks and soils and also percolate through organic matter and react with algae and microorganisms, which will change the composition of the water. Water also may transport sand, silt, clay and other materials to streams and rivers, making the water appear cloudy or turbid. When water evaporates from streams, ponds and lakes, the dissolved minerals in the water remain is solution and become more concentrated, which can affect water quality.

What occurs "naturally" in water? Common constituents found dissolved in water include calcium, sodium, bicarbonate and chloride. Water also contains plant nutrients such as nitrogen and phosphorus and certain trace elements such as selenium, chromium and arsenic. The common constituents of water are not considered harmful to human health, although some can affect the taste, smell or clarity of the water. The plant nutrient and trace elements can become harmful to human health or aquatic life if they exceed standards or guidelines.

The effect of human activities on water quality. The water quality of lakes, ponds, streams, rivers and ground water is affected by urban and industrial development, farming, mining practices, combustion of fossil fuels, and other human activities. The most well-known effects of human activities on water quality include nitrogen and phosphorus fertilizers that are applied to crops and lawns, become dissolved in rainwater or snowmelt and are transported to some water body where excess concentrations of these nutrients can encourage excess growth of algae, which cause low dissolved oxygen concentrations and the possibility of fish kills. Other contamination problems can occur as a result of pesticides, herbicides, pharmaceutical products and petroleum products entering water resources.

1.1 Water Quality - Physical characteristics

Transparency. Transparency measures the ease with which light can pass through a substance. In lakes and ponds, transparency usually is measured by the depth of light penetration through the water column. Plants and algae require light to grow and photosynthesize, so their distribution in the water column and on the bottom of the water body is determined by the depth of light penetration and the quality of light at depth. The upper region of the water body that sunlight penetrates is called the *euphotic* zone; the area around the shoreline where depth is shallow enough for plants to receive sunlight transmitted through the water is called the *littoral* zone. The deep area of the lake where plants are not able to grow is the *limnetic* zone.

Water transparency is influenced by the amount of particulate matter in the water. The particulate matter can be algae or sediment from either erosion or wind-based disturbance of the bottom sediment which can suspend material in shallow areas. Some lakes and ponds located in forested regions, such as the Adirondack Mountains of upstate New York, have a dark, stained appearance which is attributed to the leaching of humic and fulvic acids, organic compounds which are constituents of soil and result from the breakdown of vegetation in these geographic areas.

The Secchi disk is the international standardized method for measuring transparency in lakes and ponds and was developed in 1865 by Angelo Secchi. The original disk has undergone several modifications and the current standard for measuring transparency is an 8-inch diameter disk divided into alternating black and white quadrants. The Secchi depth transparency is reached when the reflectance back from the disk equals the intensity of light backscattered from the water. This depth, in meters, divided into 1.7 yields an attenuation coefficient (extinction coefficient) for available light averaged over the Secchi disk depth.

1.2 Water Quality - Chemical characteristics

Specific conductance. The phenomenon of specific conductance is a measure of water's resistance to flow of an electrical current; resistance decreases as ionized salt content of the water increases and promotes the flow of electrical current. Water with a low concentration of major ions, e.g. HCO_3 (bicarbonate), CO_3^{-2} (carbonate), K^+ (potassium), Na^+ (sodium), Ca^{2+} (calcium), Cl^- (chloride), SO_4^{-2} (sulfate) and $Mg^{=2}$ (magnesium) has the greatest resistance to electron flow, while water with a high concentration of ions, e.g. seawater, has less resistance to electron flow.

Total dissolved solids (TDS). **TDS** include inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, sulfates) and some small amounts or organic matter dissolved in water. In general, the total dissolved solids concentration is the sum of the cations ('**+**' charged ions) and anions ('**-**' charged ions). Sodium and particularly chloride ions originating from road salt application in the sub-catchment provide a substantial component of both specific conductance and total dissolved solids and very often it is possible to demonstrate linear relationships among these parameters.

pH. 'pH' is a mathematical transformation of the hydrogen ion [H^+] concentration and expresses the acidic or basic nature of water. The lowercase 'p' in pH refers to 'power' or exponent, and pH is defined as the negative logarithm of the hydrogen ion [H^+] concentration. A change of one (1) pH unit represents a ten-fold (10x) change in the hydrogen ion concentration. Conditions become more acidic as pH decreases, and more basic as pH increases, below and above the mid-point pH level of 7.0, respectively.

Within freshwater and estuarine ecosystems, the pH can fluctuate considerably within daily and seasonal time-frames, and many organisms living within these systems have evolved to tolerate a relatively wide range of environmental pH. Animals and plants can, however, become stressed or even die when exposed to pH extremes or when pH changes rapidly. In addition to the direct effects of pH on aquatic organisms, the hydrogen ion [H^+] concentration affects the aqueous equilibria that involve lake-water constituents such as ammonia, hydrogen sulfide, chlorine and dissolved metals, and can cause pH toxicity.

Carbon dioxide within the aquatic ecosystem is controlled by internal biological activity. All living animals continuously produce carbon dioxide as a by-product of respiration. Algae and plants in lakes and ponds remove carbon dioxide from the water during photosynthesis. The rates of respiration and photosynthesis determine whether there is net addition or removal of carbon dioxide, and whether pH will fall or rise, respectively.

Dissolved oxygen concentration/percent saturation. Oxygen constantly is consumed in lakes and ponds and oxygen consumption results from the respiration of aerobic organisms and from decomposition in the lower waters by organisms (primarily bacteria) that metabolize the organic material settling down from the productive upper levels of the lake or pond.

The two primary mechanisms that replenish oxygen supply are (1) exchange with the atmosphere at the air-water interface, which is particularly effective under windy conditions, and (2) photosynthetic activity of plant material, both phytoplankton and rooted plants, living in the water column.

In general, the maximum concentration of dissolved oxygen that can occur in water is a function of water temperature. Higher concentrations of dissolved oxygen occur in low water temperatures than at high temperature. Dissolved oxygen levels in water often are reported in 'percent saturation' since the calculation corrects for temperature and removes bias from the oxygen concentration readings.

1.3 Water Quality - Plant Nutrients

Nitrogen. Nitrogen is an important nutrient used by phytoplankton and aquatic plants to produce biomass in lakes and ponds. **Total nitrogen (TN)** is a measure of all forms of nitrogen found in water, and consists of organic forms and inorganic forms including nitrate (NO_3^-), nitrite (NO_2^-), ionized ammonia (NH_4), un-ionized ammonia (NH_3^+) and nitrogen gas (N_2). The relationships of these forms of nitrogen is as follows

Total nitrogen (TN) = Organic nitrogen (ON) + Ammonia-nitrogen (NH_3-N) + Nitrate-nitrogen (NO_3-N) + Nitrite (NO_2)

Amino acids and proteins are naturally-occurring organic forms of nitrogen. All forms of nitrogen are harmless to aquatic organisms except un-ionized ammonia and nitrite, which can be toxic to plants and fish. **Nitrite** usually is not a problem in water-bodies since it is readily converted to **nitrate** if enough oxygen is present for oxidation. Bacterial oxidation and reduction of various nitrogen compounds in lake water produces forms of nitrogen that are assimilated by aquatic plants during photosynthesis. There are several forms of nitrogen that are important to the biota of lakes and ponds including inorganic **nitrate** and **ammonia**, and the **organic nitrogen** fraction.

Ammonia-nitrogen, **NH_3-N**, is the first inorganic nitrogen product of organic decomposition by bacteria and is present in lake water primarily as NH_4^+ and NH_4OH. Ammonia is un-ionized and has the formula NH_3; ammonium is ionized and has the formula NH_4^+. The major factor that determines the proportion of ammonia or ammonium in water is pH. The activity of ammonia also is influenced by ionic strength and by temperature. This is important since the un-ionized NH_3 is the form that can be toxic to aquatic organisms, while the ionized NH_4 is harmless to aquatic organisms. The relative proportions of NH_4^+ to NH_4OH in lake water depend primarily upon pH as follows (Hutchinson, 1957):

pH 6	3000:1
pH 7	300:1
pH 8	30:1
pH 9.5	1:1

At pH values ≤7.00, NH_4^+ predominates and is a good source of nitrogen for plants. At higher pH values, NH_4OH can occur in concentrations that are toxic to biological growth.

Nitrate-nitrogen, **NO_3-N**, is produced by the bacterial conversion of organic and inorganic nitrogenous compounds from a reduced state to an oxidized state and is readily assimilated by algae and green plants. Collectively, **nitrate** and **ammonia** provide most of the nitrogen available for assimilation by green plants. **Organic nitrogen** in lake water consists of dissolved and particulate forms, and represents nitrogen contained in the plankton and seston.

Although **total nitrogen (TN)** is an essential nutrient for plants and animals, an excess amount can lead to low levels of dissolved oxygen and negatively alter plant life and organisms. Sources of nitrogen include wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges that contain corrosion inhibitors. The primary sources of nitrogen to Nantucket ponds include fertilizer and failing or improperly maintained septic systems.

Phosphorus. Phosphorus has a major role in biological metabolism and often limits the amount of productivity in lakes and ponds since it is the least abundant of the major structural and nutritional components of the biota such as carbon, hydrogen, nitrogen, etc. Although phosphorus occurs as organic and inorganic forms, more than 90 percent of the phosphorus that occurs in lake water is bound organically with living material or associated with decaying material (Wetzel, 1975).

Most important in lake and pond metabolism is the **total phosphorus** (**TP**) content of unfiltered lake water which contains **particulate phosphorus** (in suspension as particulate matter) and the **dissolved**, or **soluble**, **phosphorus** fraction. Particulate phosphorus can include three forms (1) phosphorus in living organisms (e.g. plankton), (2) mineral phases of rock and soil with absorbed phosphorus, and (3) phosphorus adsorbed onto dead particulate organic matter. The relative importance of each form of phosphorus seems to vary in lakes and ponds, probably as a function of allochthonous material (from outside the system) containing phosphorus, which enters the pond at different times of the year.

A 'typical' body of water would receive significant inputs of phosphorus during periods of high runoff, such as spring snowmelt. In fact, in many north temperate lakes and ponds in the northeastern United States, the period of spring runoff represents about 60-70 percent of the average annual runoff that enters the system from the surrounding watershed (Sutherland et al., 1983).

1.4 Water Quality – Biological

The diversity, composition, dominance and biomass of the planktonic algae reveal the water quality of lakes and ponds. As discussed by Hutchinson (1967), certain algal associations occur repeatedly among lakes with different levels of nutrient enrichment, and the associations are used to characterize trophic status (the degree of eutrophication of a water body). These characterizations are useful since they demonstrate the connection between available nutrient supply and the qualitative and quantitative abundance of algal taxa.

Phytoplankton are single-celled microorganisms that drift in sea water or fresh water and, at times, can grow in colonies large enough to be seen by the human eye. As a group, phytoplankton can be divided into two classes, the algae and the cyanobacteria, and are photosynthetic, which means that they contain the pigment chlorophyll and can utilize sunlight to convert carbon dioxide and water into energy.

World-wide, microscopic phytoplankton living in the oceans and fresh-water lakes and ponds play some of the biggest roles in climate control, oxygen supply and food production, and they form the basis of the aquatic food web. An imbalance of phytoplankton levels, often caused by too many nutrients, can cause blooms in salt and fresh water and lead to an imbalance in other parts of the aquatic food web. Certain species of phytoplankton, especially within the cyanobacteria, can produce harmful toxins which, if ingested by humans can cause neurological and hepatic symptoms.

1.5 Water Quality - Trophic Status

'Trophic' means nutrition or growth. The trophic state of lakes refers to biological production, plant and animal, that occurs in the lake and the level of production is determined by several factors but primarily phosphorus supply to the lake and by the volume and residence time of water in the lake. Many different indicators are used to describe trophic state such as phosphorus, water clarity, chlorophyll, rooted plant growth and dissolved oxygen.

The following trophic categories are used to classify lakes and ponds and provide a basis for comparing water bodies within the same geographical area, or waters not geographically similar:

- Oligotrophic – usually large and deep water bodies with rocky or sandy shorelines, low phosphorus enrichment, limited rooted plant growth, low algal growth and adequate dissolved oxygen throughout the water column.
- Mesotrophic – an intermediate category of productivity with characteristics between the oligotrophic and eutrophic categories.
- Eutrophic – smaller, shallow lakes with organic bottom material, extensive rooted plant growth, low dissolved oxygen in the lower waters, and reduced water transparency from planktonic algal growth.

Lakes and ponds with extreme conditions at either the oligotrophic end of the spectrum or the eutrophic end of the spectrum may be considered hyper-oligotrophic or hyper-eutrophic, respectively.

Carlson's Trophic State Index (TSI) commonly is used to characterize the trophic status (overall health) of a water body (Carlson, 1977). Since they tend to correlate, the three independent variables most often used to calculate the Carlson index include chlorophyll pigments, total phosphorus and Secchi depth. Individual TSI values are calculated from the following equations:

- $Total\ phosphorus\ TSI\ (TSIP) = 14.42 * [\ln(TP\ average)] + 4.15$
- $Chlorophyll$ a $TSI\ (TSIC) = 9.81 * [\ln(Chlorophyll\ a\ average)] + 30.6$
- $Secchi\ disk\ TSI\ (TSIS) = 60 - (14.41 * [\ln(Secchi\ average)])$

The relationships between Trophic Index (TI), chlorophyll (µg L^{-1}), phosphorus (µg L^{-1}), Secchi depth (meters), and Trophic Class (after Carlson, 1996) are as follows:

Table 11. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

Trophic Index	Chlorophyll (µg L^{-1})	TP (µg 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

Of these three variables, chlorophyll probably provides the most accurate index since it is the most accurate predictor of standing crop in the ecosystem. Phosphorus is a more accurate predictor of the summer trophic status of a water body than chlorophyll if the measurements also are made during the winter months, which is not always reasonable. Secchi depth probably is the least accurate predictor but also is the most affordable and easiest measure to obtain since it is a subjective visual determination.

1.6 Summary

This chapter presented the basic elements for understanding the concept of water quality including the physical, chemical and biological information and data usually collected from water resources when some sort of an evaluation is required. This information and the assessment procedure that has been described can be applied to any fresh water or salt water lake or pond but were presented here in the context of the process that has been applied and conducted on Nantucket Island ponds since 2009 when the Nantucket Land Council sponsored water quality investigations on Miacomet and Hummock Ponds.

1.7 Literature Cited

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Nantucket Island Ponds and 2019 Quality

Chapter 2

Water Quality Sampling Protocol

2.0 Background

Water quality sampling generally occurs on Nantucket Island ponds during the ice-free period of the year between April and November. Growth and metabolism in the ponds is highly dependent upon water temperature and the most active growing period in the ponds occurs when the water temperature is 20°C or greater. This is the time when changes in water quality can occur quite rapidly and it is prudent to adjust the frequency of any sampling schedule to detect water quality changes as they occur.

2.1 Sampling Protocol

Water quality sampling generally occurs at the deepest area of the pond from an anchored boat or kayak. The standardized protocol used when collecting water quality data from any Nantucket Island pond is as follows: (1) depth profiles of temperature and dissolved oxygen (concentration/percent saturation), (2) Secchi depth transparency, (3) the collection of pond water to be analyzed for total phosphorus, a series of nitrogen analytes, chlorophyll ***a***, algal toxins (when warranted), specific conductance, pH and (4) a preserved sample of the phytoplankton community. Table 2.1 summarizes the water quality parameters that typically are sampled on Nantucket Island ponds.

Table 2-1. Parameters monitored to assess the short-term water quality of Nantucket Island ponds.

Physical	
	water temperature
	Secchi depth transparency
	water color
Chemical	
	total phosphorus
	nitrogen series (total nitrogen, ammonia-nitrogen and nitrate-nitrogen)
	pH
	specific conductance
	dissolved oxygen
	total dissolved solids
Biological	
	phytoplankton community response
	- Chlorophyll ***a***, species composition, diversity, relative abundance, biomass
	- Harmful algal blooms including species identification and toxin analysis

2.2 Methodology

This section describes the field procedures that are used to collect samples and the processing that occurs, following sample collection.

Routine sample collection and processing. Sample and data collection occurs at the deepest area in each pond using a boat or kayak anchored at the site. All information is recorded on a field sheet. The total depth of the water column is measured with a weighted Secchi disk attached to a marked line, and then recorded. Latitude-longitude is recorded on all sampling visits using a Garmin GPS 60™ unit.

Secchi depth is measured using a standard 20 cm weighted disk. Measurements are taken on the side of the boat away from direct sunlight in order to avoid surface glare which would interfere with the readings. The disk is lowered into the water column to the depth at which it just disappears, and this depth is noted. The disk then is raised from out of the range of visibility to the depth where it first re-appears, and this depth is noted. The average of the 2 depths is recorded as the Secchi depth transparency on that sampling date.

Vertical profiles of water temperature-dissolved oxygen are measured *in-situ* at 1-foot or 2-foot intervals on each sampling date using a Yellow Springs Instrument (YSI) ProODO™ optical Dissolved Oxygen meter.

Water samples for chemistry, phytoplankton and chlorophyll *a* analyses are collected from the pond following a determination of whether the water column is stratified either thermally or based on oxygen saturation. The upper zone of the water column at similar temperature or dissolved oxygen percent saturation is sampled using the integrated hose technique; the lower zone of different temperature or oxygen percent saturation is sampled with a horizontal Van Dorn sampler. The collected water samples are transferred to clean, pre-rinsed 500-mL polyethylene (PE) amber sample bottles and stored on ice and in the dark until processed for shipment, usually within 2 hours of collection.

A subsample of the ***upper*** region raw water is poured into a 125 mL amber PE bottle for phytoplankton identification and enumeration, preserved with glutaraldehyde solution, labeled with collection information.

A subsample of water collected from the ***upper*** and ***lower*** regions of the water column is analyzed on-site for specific conductance, total dissolved solids, and pH using an Ultrameter II™ (Myron L Company).

The samples collected for nutrient chemistry and chlorophyll ***a*** are prepared for shipment immediately following each pond visit. The 500 mL amber PE bottles are placed in a Styrofoam cooler with gel packs and shipped via FedEx (2nd day delivery) to the Darrin Fresh Water Institute Laboratory in Bolton Landing, New York, a field station affiliated with Rensselaer Polytechnic Institute in Troy, New York. A Chain of Custody form accompanies the samples to the analytical lab.

Depending upon conditions observed at each pond, a subsample of raw pond water collected from the near-shore upper region is tested for the presence of algal toxins (microcystins) using an Eurofins Abraxis®, LLC Algal Toxin Strip Test for Finished Drinking Water. The test was designed to screen for the presence/absence of toxins in pond water and to facilitate appropriate follow-up based upon the results. Since 2013 was the first season that this screening process was used on Nantucket Island ponds, samples of raw pond water also are shipped to GreenWater CyanoLab in Palatka, Florida for a PTOX (potentially toxigenic cyanobacteria) Screen and further cyanotoxin analysis, if warranted. A 125 PE bottle containing about 100 mL of raw pond water is placed in a small cooler with gel packs and shipped FedEx overnight to the lab.

2.3 Analytical Techniques

Water Column Measurements and Sample Collection. The methods and protocol for water column measurements and sample collections on Nantucket Island ponds are summarized below in Table 2.2.

Table 2-2. Physical, chemical and biological parameters included in the study of water quality on Nantucket Island ponds, their collection technique and methodology.

PARAMETER	COLLECTION TECHNIQUE	ANALYTICAL METHODOLOGY
Physical Characteristics (Light, Dissolved Oxygen, Secchi, Temperature)	Vertical profiles at 2-foot intervals (except Secchi) at deep site	Standard Secchi protocol; YSI dissolved oxygen-temperature meter;
Chemical Characteristics (pH, conductivity, NO_3, NH_4, TN, TP)	Integrated epilimnetic sample; hypolimnetic grab sample at least 1 ft above bottom sediment	Ion Chromatograph, Atomic Absorption, Autoanalyzer, Spectrophotometer, pH meter
Biological Characteristics - Phytoplankton	Integrated photic zone sample	chlorophyll a, species identification and enumeration, biomass
Biological Characteristics - Phytoplankton	Integrated photic zone sample	microcystin analysis (if warranted)

The analytical procedures for water chemistry generally are determined by the specific analytical laboratory that receives samples for analysis and are not listed here since no facility has been recommended.

Phytoplankton identification-enumeration. The following protocol is used for the microscopic examination of phytoplankton for identification and enumeration of samples collected from ponds using the integrate hose technique for collection:

Counting method. At least 200 mL of preserved sample is required for this analysis. An inverted microscope is used for phytoplankton counts. The objectives of the inverted microscope are located below a movable stage and the light source comes from above, permitting viewing of organisms that have settled to the bottom of a chamber. A sample is prepared by filling duplicate cylindrical 50 mL Ütermohl settling chambers, which have a thin, clear glass bottom. The samples settle for an appropriate period (1 hour settling time/ mm of column depth, about 3 days). Sedimentation is the preferred method of concentration since it is nondestructive and non-selective. After the settling period, the chamber tower is gently removed with a cover slip, removing all but 1 mL of sample in a small well at the chamber bottom.

The sample is scanned using low magnification to determine the taxa present, and then analyzed at 1000x using oil immersion to accurately count cells below 10-20 μm in size which may be present. For biomass estimates, it also is necessary to have high magnification to measure width, length and depth of a cell. Non-overlapping random fields are examined until at least 100 units of the dominant taxa are counted. The entire chamber floor usually is counted to get a precision level of a least 95%. Results are recorded as number of cells per taxa present, with approximations being used for multicellular (colonial) taxa. Dead cells or empty diatom frustules are not counted.

Conversion to density (cells mL^{-1}). The microscope is calibrated at each magnification using an ocular micrometer placed in the eyepiece of the microscope and a stage micrometer. The number of cells counted for each taxon is determined using the following equation:

$$\# \; of \; cells/mL = \frac{C \; x \; A_s}{V \; x \; A_f x \; F}$$

where, C = number of cells counted (average of two settling chambers)
A_s = area of settling chamber bottom, (mm^2)
V = volume of sample settled (50 mL)
A_f = area of field (determined by the microscope calibration), (mm)
F = number of fields counted

Conversion to biovolume (mg^3 mL^{-1}) - biomass (mg m^{-3}). Phytoplankton data derived on a volume-per-volume basis are more useful than numbers per milliliter (density) since algal cell sizes can differ in various bodies of water or within the same body of water at different times of the year. Average measurements were made from approximately 20 individuals of each taxon for each sampling period. The simplest geometric configuration that best fits the shape of the cell being measured (i.e., sphere, cone, cylinder) is used, and calculations made with corresponding formulas for that shape. The total biomass (um^3mL^{-1}) of any species is calculated by multiplying the average cell volume in cubic micrometers by the number of cells per milliliter. Results are recorded as biomass (mg/m^{-3}) by dividing total biovolume (mg^3/mL^{-1}) by 1,000.

Potentially toxigenic cyanobacteria (PTOX) screen: At GreenWater CyanoLab, one mL aliquots of each non-preserved sample were prepared using Sedgwick Rafter cells. The samples were scanned at 100X for the presence of potentially toxigenic (PTOX) cyanobacteria using a Nikon TE200 Inverted Microscope equipped with phase contrast optics. Higher magnification was used as necessary for identification and micrographs.

Cyanotoxin analysis. At GreenWater Laboratories, samples received for analysis of cyanotoxins are inverted for 60 seconds to mix. A subset from each sample is removed prior to cell lysis for algal identification purposes. Second subsets from each sample are transferred to 15 mL vials. Three freeze-thaw cycles are employed prior to additional sample preparation and subsequent analyses. The specific analytical techniques are as follows:

Enzyme-Linked Immunosorbent Assay (ELISA)

Adda MCs/NODs

A microcystins/nodularins Adda ELISA (Eurofins Abraxis®) was utilized for the quantitative and sensitive congener-independent detection of Adda MCs/NODs (US EPA Method 546 & Ohio EPA DES 701.0). The current method reporting limit is 0.30 ng/mL (ppb) based on kit sensitivity, dilution factors, and initial demonstration of capability.

Liquid chromatography mass spectrometry/mass spectrometry (LC-MS/MS)

ANTX-A

A Waters XSelect HSS T3 2.1 x 150 mm, 3.5-µm column was used in separation with mobile phases (methanol and water) containing acetic acid. The [M+H]+ ion for ANTX-A (*m/z* 166) was fragmented and the product ions (*m/z* 91, 131, 149) were monitored. The [M+H]+ ion for CYN (*m/z* 416) was fragmented and the product ions (*m/z* 194, 274, 336) were monitored. The [M+H]+ ion for the internal standard [15N5]-Cylindrospermopsin (421 *m/z*) was fragmented and the product ion (341 *m/z*) was monitored. The [M+H]+ ion for the internal standard [13C4]-Anatoxin-a (171 *m/z*) was fragmented and the product ion (153 *m/z*) was monitored. The internal standard method was utilized for all quantification

2.4 Summary

This chapter presented the standard protocol currently used when sampling Nantucket Island ponds for water quality. The use of consistent sampling techniques ensures that the most accurate water quality assessments and evaluations are performed even if several different personnel conduct the sampling during the growing season.

2.5 Literature Cited

US EPA Methods are from: US EPA, Methods for Chemical Analysis of Water and Wastes, US EPA-600/4-79-020, Cincinnati, Ohio (Revised March 1983).

Nantucket Island Ponds and 2019 Water Quality

Chapter 3

Capaum Pond

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. (NLC) during 2019.

3.1 Results

Capaum Pond was sampled at about 2-week intervals beginning on July 15th and ending on October 21st for a total of 8 sampling excursions. Table 3-1 below provides a summary of the 2019 sampling dates.

Table 3-1. Summary of 2019 sampling dates at Capaum Pond.

July	August	September	October
15th	12th	9th	7th
29th	26th	19th	21st

The pond always was sampled at about the center which was the deepest region of the water column. Following the collection of temperature and dissolved oxygen profile data on all sampling dates, integrate (***upper***) and grab (***lower***) samples were collected from the pond depths as shown in Table 3-2 below.

Table 3-2. Summary of Capaum Pond integrate and grab sample depths, 2019.

Sampling Date	integrate (*upper*) sample depth	grab (*lower*) sample depth
July 15TH 2019	0-6 feet	na
July 29th 2019	0-4 feet	7 feet
August 12th 2019	0-4 feet	6 feet
August 26th 2019	0-4 feet	na
September 9th 2019	0-4 feet	7 feet
September 19th 2019	0-4 feet	na
October 7th 2019	0-4 feet	na
October 21st 2019	0-4 feet	na

Raw water samples were collected from Capaum Pond for Abraxis test strip analyses on 8 dates including dates not shown above when the pond was checked visually along the shoreline for evidence of HABs. There also was extensive field work conducted on Capaum Pond late in the 2019 season with the cyanotoxin Aerosol Filter Collection Device (ACFD) which will be explained in detail later in this chapter.

3.1.1 Physical characteristics

General. Capaum Pond has an irregular shape with its long axis oriented in a north-south direction as shown in Figure 3-1.

Figure 3-1. Aerial view of Capaum Pond (from *Google*™ earth).

The pond is located along 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 tributaries flowing into the pond and the pond has no outlet. The pond is separated from Nantucket Sound to the north by a high sand berm running parallel to the shoreline.

Table 3-3 summarizes the physical data collected from Capaum Pond including (1) total depth at the sampling station, (2) Secchi depth water transparency and (3) the average water column temperature.

Table 3-3. Summary of physical data collected from Capaum Pond during 2019.

Capaum Pond 2019 Physical Data			
Sampling Date	Total depth (m)	Secchi depth (m)	Avg Water Column Temperature (°C)
July 15th	2.3	0.61	25.6
July 29th	2.1	0.23	25.3
August 12th	2.1	0.33	24.4
August 26th	2.1	0.38	20.9
September 9th	2.4	0.33	19.4
September 19th	2.1	0.56	21.4
October 7th	2.0	0.46	16.9
October 21st	2.1	0.51	13.2

The maximum depth of Capaum Pond during 2019 was 2.4 meters (m), which is 7.8 feet (ft); the minimum depth was 2.0 m which is 6.6 ft. Slight differences in the total depth at the sampling locations during the 2019 season likely were due to slightly different locations for anchoring and sampling.

Transparency. As shown in Table 3-3, the Secchi depth transparency measured at Capaum Pond ranged from a low value of 0.23m (0.75 ft) to a high value of 0.61 m (2 ft) indicating very low light penetration from the pond surface down through the water column. Transparency of the water column is one of the criteria that is used to define water quality and will be discussed later in this chapter.

Field notes indicate that water color on the various 2019 sampling dates was listed as 'cloudy green', 'pale green' or 'green'; these terms generally indicate high algal density or an algal bloom in progress.

Temperature. The shallow nature of Capaum Pond precludes any significant temperature differences between the pond surface and bottom. Temperature differences between the surface and bottom were less than 1ºC on 6 sampling dates and greater than 1ºC on 2 sampling dates. Attachment 1 presents the temperature and dissolved oxygen percent saturation graphs for the ponds sampled during 2019.

3.1.2 Chemical characteristics

Average values for the 2019 chemical properties measured in ***upper*** region water samples collected on each sampling date from Capaum Pond are summarized in Table 3-4.

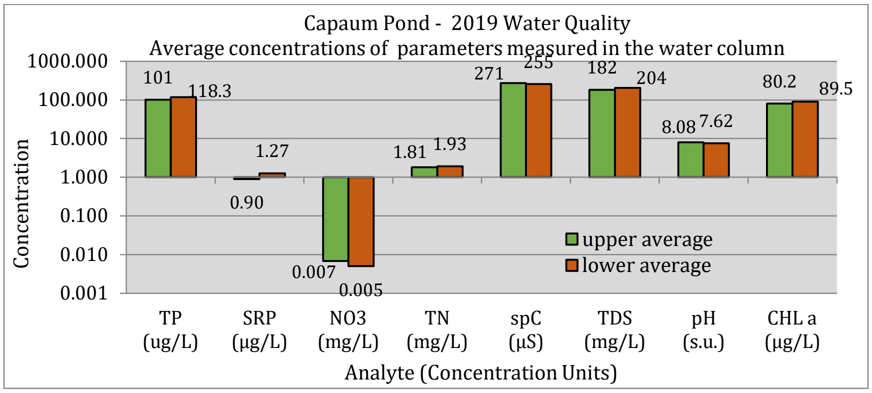
Table 3-4. Summary of 2019 chemical characteristics in *upper* region of Capaum Pond.

	Capaum Pond 2019 Chemical Properties							
Sampling Date	Avg DO % saturation	TP (µg/L)	SRP (µg/L)	TN (mg/L)	NO_3-N (mg/L)	spC (µS/cm)	TDS (ppm)	pH (s.u.)
July 15th	93.0	81.2	1.5	1.58	0.02	252	163	8.40
July 29th	77.7	119	1.6	2.98	0.005	272	176	9.78
August 12th	93.3	125	0.5	2.56	0.005	271	176	8.94
August 26th	108.9	114	1.1	1.61	0.005	271	200	6.55
September 9th	108.6	105	0.5	1.70	0.005	266	177	8.72
September 19th	129.1	87.3	0.5	1.42	0.005	258	171	8.20
October 7th	114.8	76.1	0.5	1.27	0.005	264	177	7.46
October 21st	110.0	97.4	1.0	1.37	0.005	314	217	6.56
2019 average value	107.1	100.6	0.90	1.81	0.005	271	182	8.08

all values shown are for the ***upper*** region of the water column
highlighted cells = values reported are one-half the lower detection limit

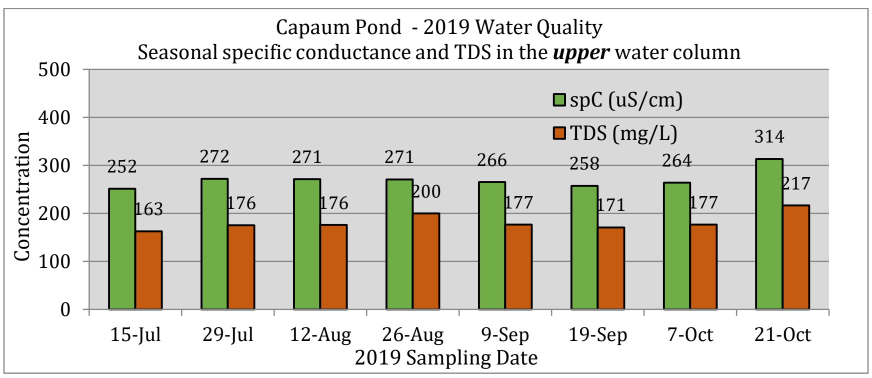
Lower region samples were collected on only 3 of the 8 sampling dates; those data are not summarized in Table 3-1 but are presented below in Figure 3-2 which summarizes the ***upper*** and ***lower*** values for all chemical characteristics collected at Capaum Pond during 2019. The reader should note that the ***y*-axis** in Figure 3-2 is depicted in logarithm scale to best display the wide range of 2019 average analyte values presented in the figure.

Figure 3-2. Summary of 2019 average concentrations of chemical parameters in Capaum Pond.



Specific conductance and Total Dissolved Solids (TDS). The specific conductance and corresponding TDS values measured in the ***upper*** region of Capaum Pond during the 2019 sampling dates are presented in Figure 3-3.

Figure 3-3. Summary of 2019 specific conductance and TDS in *upper* samples from Capaum Pond.



Neither analyte exhibited a wide range of values; specific conductance ranged from 252-314 $\mu S \cdot cm^{-1}$ during the sampling season, while TDS ranged from 163-200 mg/L^{-1}. The relationship between these two analytes in Capaum Pond is defined by the following equation

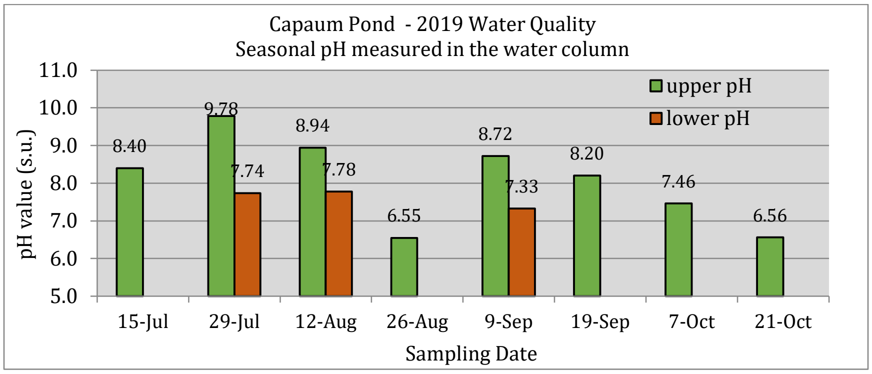
$$\boldsymbol{y = 0.8518x - 48.833},$$

where ***y*** is TDS, ***x*** is the known value of specific conductance and R^2 = 0.8312. The relationship between these two analytes is improved considerably when the values measured on August 26th (see Figure 3-3) are removed from the set of data; when that occurs, the value of R^2 increases to 0.97 and the equation that defines the relationship changes slightly (***y* = 0.8284*x* – 44.562**) .

The relative conductance and TDS values measured in Capaum Pond are considered high within the range of 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 which mixes with the water column periodically and increases levels of both these analytes.

pH. The pH data collected from the ***upper*** and ***lower*** regions of Capaum Pond during the 2019 sampling season are summarized in Figure 3-4. The ***upper*** region pH values ranged from 6.55-9.78 s.u. among the 8 sampling dates, and the average pH value for the ***upper*** region during the entire season was 8.08 s.u.

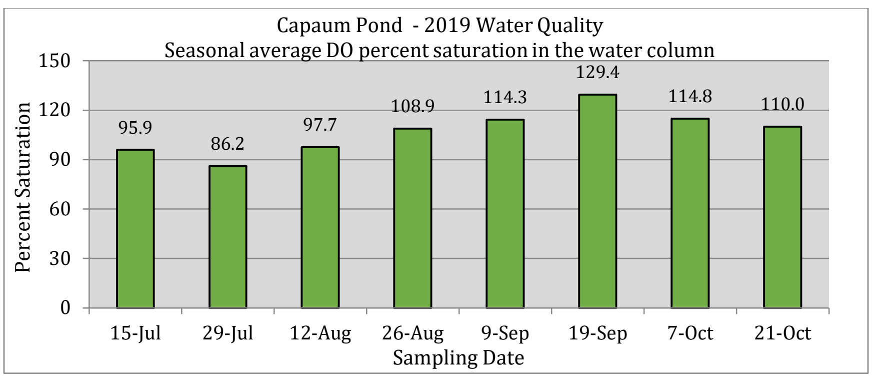
Figure 3-4. Summary of 2019 pH values measured in Capaum Pond.



It is interesting to note the distinct separation of ***upper*** and ***lower*** regions of the water column on the July 29th, August 12th and September 9th sampling dates as demonstrated by the difference of 1 pH unit or greater on these dates, equivalent to a 10-fold difference in pH between the two regions. The high pH values recorded in the ***upper*** region on the three (3) sampling dates reflect a considerable imbalance between pond respiration and photosynthesis which can result when intense algal blooms occur during the growing season. More discussion related to this topic occurs in the chapter section on phytoplankton.

Dissolved oxygen concentration-percent saturation. The 2019 average percent saturation values measured for the water column at Capaum Pond are presented in Figure 3-5.

Figure 3-5. Summary of 2019 dissolved oxygen percent saturation in Capaum Pond.5



The values were near saturation (100 percent) on the first three sampling dates, and then were supersaturated (> 100 percent) on the remaining sampling dates indicating the high level of productivity occurring in the pond throughout the 2019 sampling season.

As discussed briefly for pH in the previous section, there was a gradient of DO percent saturation in Capaum Pond with high concentration in the ***upper*** region of the water column on July 15th, July 29th, August 12th and September 9th and decreasing saturation values in the ***lower*** region on those dates, suggesting a temporary DO stratification of the water column likely as a result of calm (no wind) conditions on the Island. The DO percent saturation graphs are presented in Attachment #1.

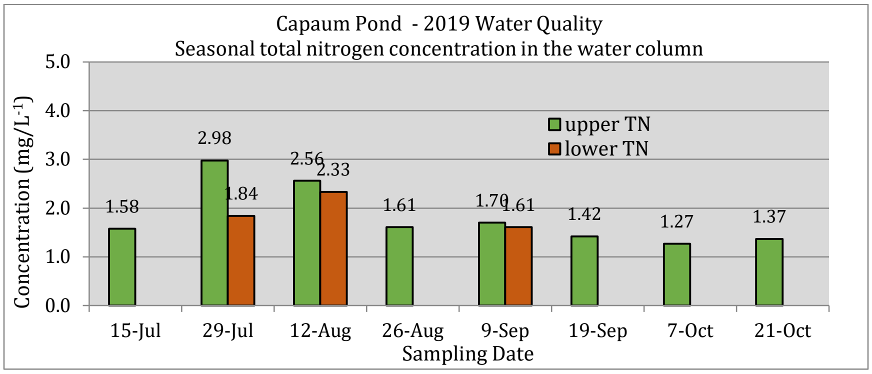
3.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was detected in the water column of Capaum Pond only on the July 15th sampling date (0.02 mg $N \cdot L^{-1}$); otherwise, all of the other nitrate-nitrogen measurements were below detection (0.005 mg $N \cdot L^{-1}$) in both ***upper*** and ***lower*** regions of the pond on all remaining sampling dates.

Although **ammonia-nitrogen** was not one of the 2019 analytes included in the water quality test pattern, previous experience with measuring this form of nitrogen in Nantucket Island ponds had shown that concentrations in the water column always were near or below detection. This phenomenon is not unusual in ponds during the growing season because this form of nitrogen as well as **nitrate-nitrogen** is readily taken up by phytoplankton in the water column for growth and metabolism when available.

The **total nitrogen** (TN) concentrations measured in ***upper*** and ***lower*** regions of Capaum Pond during 2019 are summarized in Figure 3-6.

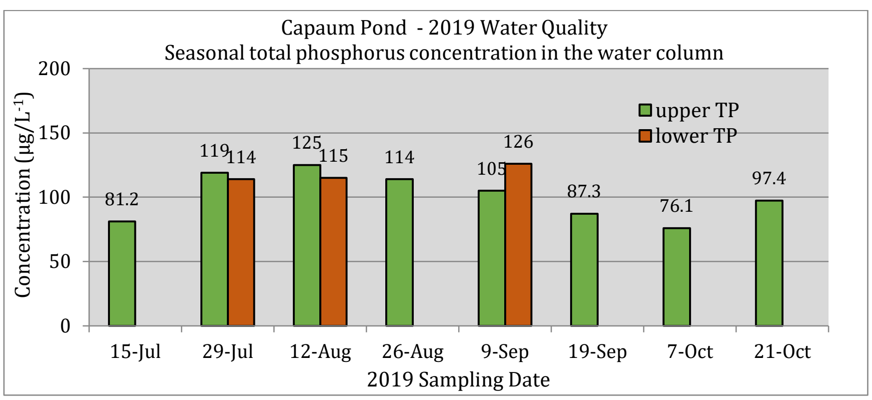
Figure 3-6. Summary of 2019 total nitrogen concentrations in Capaum Pond.



TN values ranged from 1.27-2.98 mg N·L^{-1} across all sampling dates and the average concentration for the season in the ***upper*** region of the pond was 1.83 mg N·L^{-1}. Based upon the very low concentrations of **nitrate-nitrogen** and, presumably, **ammonia-nitrogen**, in the water column**,** essentially all of the **total nitrogen** measured was contained in organic material in the form of phytoplankton and seston (other organisms and non-living particulate matter floating in the water column and possibly re-suspended from the bottom sediment during periods of high wind).

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in ***upper*** and ***lower*** regions of Capaum Pond during 2019 are summarized in Figure 3-7.

Figure 3-7. Summary of 2019 total phosphorus concentrations in Capaum Pond.



As shown in the above figure, the ***upper*** region concentrations ranged from 76-126 µg P·L^{-1} during the 2019 sampling season, while the 2019 average value was 101 µg P·L^{-1} (Table 3-4). The 2019 ***lower*** region TP samples had concentrations slightly less than upper region concentrations on two dates and a concentration higher than the ***upper*** region value on September 9th.

The **soluble reactive phosphorus** (**SRP**) concentrations measured in 2019 samples collected from Capaum Pond were very low throughout the sampling season, ranging from below detection (0.5 µg P·L^{-1}) in the upper region on 4 sampling dates to a high concentration of 1.6 µg P·L^{-1} measured on July 15th. The graph of Capaum Pond SRP values during 2019 is not presented here.

3.1.4 Phytoplankton

Description of the assemblage. Table 3-5 presents a summary of the Capaum Pond phytoplankton community characteristics determined from 8 samples collected during 2019.

Table 3-5. Summary of 2019 Capaum Pond phytoplankton community characteristics.

Gibbs Pond Phytoplankton, 2019						
Sampling Date	Total Taxa	Cell Density (cells/mL^{-1})	Cell Biomass (mg/m^{3})	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration (µg/L^{-1})
July 29^{th}	31	62565	14389	0.346	0.605	201.1
August 12^{th}	37	41615	24903	0.978	0.951	151
August 26^{th}	41	50922	31668	0.899	0.964	69.7
September 9^{th}	44	36246	10075	1.135	1.112	65.4
September 19^{th}	46	83552	11548	0.573	1.194	34.4
October 7^{th}	45	51460	12636	0.826	1.160	26.4
October 21^{st}	55	92805	15135	0.878	1.193	38.0
2019 average	43	59881	17193	0.805	1.026	83.7

The 2019 phytoplankton characteristics in Capaum Pond summarized above will be discussed in the following sections in this chapter.

There were 81 different taxa identified in the 2019 phytoplankton samples collected from Capaum Pond and all six (6) major algal groups, plus the Chloromonadophytes, were represented (Table 3-6). The first 2019 phytoplankton sample collected on July 15^{th} was lost due to bad preservative being added to the sample so there were 7 samples analyzed for 2019.

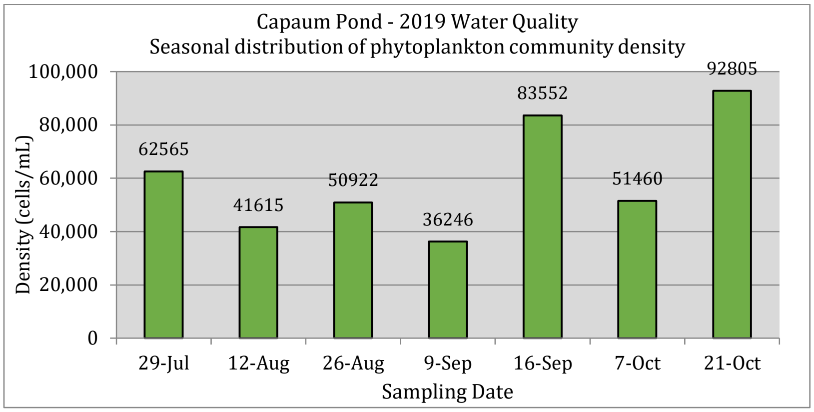
Table 3-6. Major groups, genera and species of phytoplankton identified in Capaum Pond, 2019.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyceae)**
Anabaena flos aquae	*Monoraphidium arcuatum*	*Eunotia* sp.
Aphanizomenon flos aquae	*M. contortum*	*Gomphonema* spp.
Aphanocapsa elachista	*Mougeotia* sp.	*Gyrosigma* sp.
Chroococcus dispersus	*Oocystis Borgei*	*Hippodonta* sp.
C. limneticus	*O. pusilla*	*Navicula* spp.
Gomphosphaeria lacustris compacta	*O. solitaria*	*Neidium* sp.
Merismopedia glauca	*Pediastrum duplex*	*Nitzschia* sp.
Microcystis aeruginosa	*Pyramimonas tetrarhyncus*	*N. longissima*
Planktothrix sp. (filaments)	*Quadrigula lacustris*	*Pinnularia* sp.
Woronichinia Naegeliana	*Scenedesmus abundans*	*Planothdium* sp.
Chloromonadophyta	*S. acuminatus*	*Pleurosigma* sp.
Gonyostomum semen	*S. bijuga*	*Rhoicosphenia curvata*
Chlorophyta	*S. bijuga alternans*	*Stauroneis* sp.
Actinastrum Hantzschii	*S. dimorphus*	*Surirella* sp.
Ankistrodesmus falcatus	*S. quadricauda*	*Synedra acus*
A. fusiformia	*Schroederia Judayi*	*S. ulna*
Characium sp.	*Selenastrum capriconnutum*	**Chrysophyta (Chrysophyceae)**
Closteriopsis longissima	*S. minutum*	*Dinobyron divergens*
Closterium acutum	*S. Westii*	*Mallomonas* sp.
C. gracile	*Sphaerocystis Schroeteri*	*Ochromonas* sp.
Coelastrum cambricum	*Staurastrum natator var. crassum*	**Euglenophyta**
Cosmarium spp.	*Tetraedron minimum*	*Euglena* sp.
Crucigenia quadrata	*Tetrastrum staurogeniaeforme*	*Peranema* sp.
Dictyosphaerium Ehrenbergianum	**Chrysophyta (Bacillariophyceae)**	*Trachelomonas* sp.
Elakatothrix gelatinosa	*Achnanthes* sp.	**Pyrrhophyta (Cryptophyceae)**
Euastrum sp.	*Aulacoseria granulata*	*Cryptomonas erosa*
Eudorina elegans	*Cocconeis* sp.	*C. ovata*
Kirchneriella elongata	*Cyclotella* sp.	*Ceratium hirundinella*
Langerheimia quadriseta	*Cymbella* sp.	*Peridinium cinctum*

The greatest representation of phytoplankton occurred within the Chlorophytes (green algae), where 39 different taxa were identified, followed by the Bacillariophytes with 21 taxa and the Cyanophytes with 10 taxa. The next most abundant groups were the Pyrrhophytes (4 taxa) and Chrysophytes (3 taxa).

Density. Phytoplankton community density in Capaum Pond on the seven (7) 2019 sampling dates is summarized in Figure 3-8.

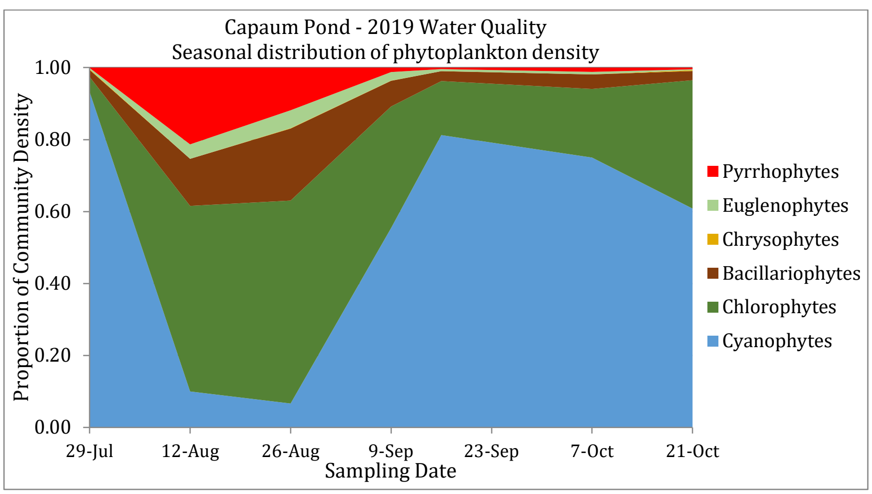
Figure 3-8. Summary of 2019 phytoplankton community density in Capaum Pond.



Density of the community ranged from 36,246 cells·mL^{-1} on September 9th to 92,805 cells·mL^{-1} on October 21st which was the last 2019 sampling date. Overall, density of the phytoplankton community in Capaum Pond was more robust during the latter portion of the sampling season.

The seasonal density composition of the 2019 phytoplankton community in Capaum Pond is shown in Figure 3-9.

Figure 3-9. Density composition of the 2019 phytoplankton community in Capaum Pond.



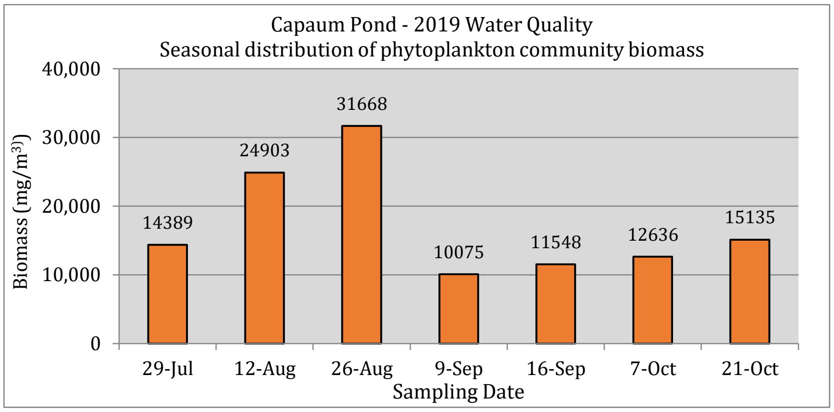
Most of the phytoplankton community density dynamic exhibited during 2019 involved alterations of density dominance early in the season between the Cyanophytes and the Chlorophytes; later on in the season, the Cyanophytes comprised 60 percent or greater of the community, while Chlorophytes were the second most dominant group with 15-~40 percent of the community density (Figure 3-9).

Biomass. Cell biovolume also was used to evaluate phytoplankton taxon productivity because 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 large biovolume can make a particular taxon dominant in the phytoplankton community.

Figure 3-10 presents the Capaum Pond phytoplankton community biomass data for the seven (7) sampling dates during 2019.

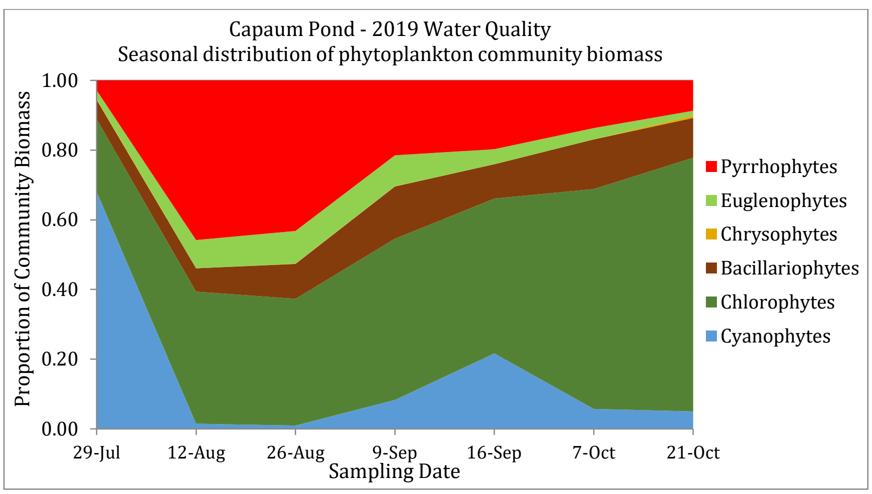
Figure 3-10. Summary of 2019 phytoplankton community biomass in Capaum Pond.



The 2019 phytoplankton community biomass ranged from 10,075 mg·m-3 on September 9th to 31, 668 mg·m-3 on August 26th. As shown in the figure above, the community biomass exhibited consistent increase during the first three sampling dates in 2019; thereafter, the community biomass declined sharply, then showed slight increase from September 9th through the remaining 2019 sampling dates.

Regarding biovolume, the 2019 Capaum Pond phytoplankton community exhibited much different composition characteristics (Figure 3-11) when compared with the community density composition (Figure 3-9).

Figure 3-11. Biomass composition of the 2019 phytoplankton community in Capaum Pond.



Except for the initial sampling date on July 29th when Cyanophytes comprised about 70 percent of the community biomass, the remainder of the season was dominated by Chlorophytes and Pyrrhophytes, and the Cyanophyte biomass was greatly reduced. Pyrrhophytes include fire algae, primarily dinoflagellates, that are marine forms, often associated with 'red' tide.

Dominance. A ranking of 2019 phytoplankton taxa dominance in Capaum Pond is summarized in Table 3-7. Taxa are considered dominant in the community if they comprise at least 5 percent or more of the total phytoplankton biomass.

Table 3-7. Rank of 2019 phytoplankton dominance in Capaum Pond.

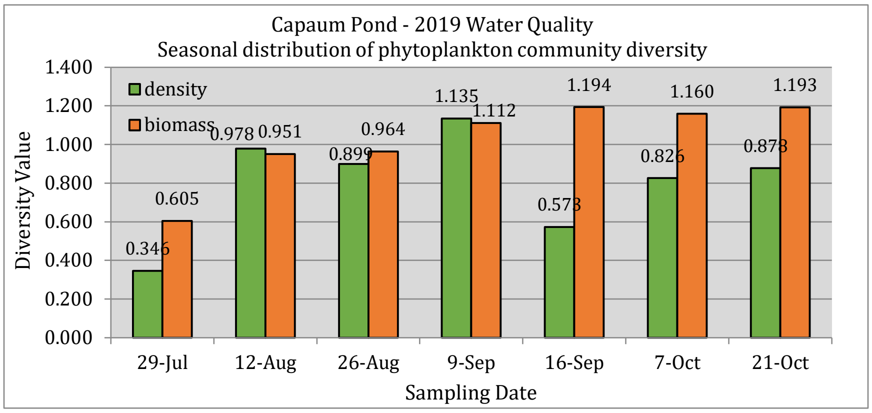
Sampling Date	Genus (species when known) (Major Group)	Density Rank	% of Total Density	Biomass Rank	% of Total Biomass
July 29th	Aphanizomenon flos aquae (Cyanophyte)	1	80.5	1	67.3
	Woronichinia Naegeliana (Cyanophyte)	2	12.8		
	Mougeotia sp. (Chlorophyta)			2	6.2
August 12th	Actinastrum Hantzschii (Chlorophyta)	1	37.0	2	23.4
	Cyclotella sp. (Bacillariophyta)	3	12.0	6	5.4
	Cryptomonas erosa (Pyrrhophyta)	2	19.5	1	31.9
	Closterium acutum ((Chlorophyta)			5	5.5
	Trachelomonas sp. (Euglenophyta)			3	7.4
	Cryptomonas ovata (Pyrrhophyta)			4	6.9
August 26th	Actinastrum Hantzschii (Chlorophyta)	1	42.8	1	26.1
	Cyclotella sp. (Bacillariophyta)	2	19	5	8.2
	Trachelomonas sp. (Euglenophyta)	4	4.9	4	9
	Cryptomonas erosa (Pyrrhophyta)	3	9.8	3	15.4
	Ceratium hirundinella (Pyrrhophyta)			2	21
September 9th	Aphanizomenon flos aquae (Cyanophyte)	4	4.8		
	Aphanocapsa elachista (Cyanophyta)	3	7.4		
	Chroococcus dispersus (Cyanophyta)	2	8.2		
	Woronichinia Naegeliana (Cyanophyte)	1	32.2		
	Actinastrum Hantzschii (Chlorophyta)			3	13
	Coelastrum cambricum (Chlorophyta)			2	13.1
	Aulacoseria granulata (Bacillariophyta)			4	9.4
	Trachelomonas sp. (Euglenophyta)			5	8.8
	Ceratium hirundinella (Pyrrhophyta)			1	17.8
September 16th	Aphanizomenon flos aquae (Cyanophyte)	2	10.4		14.5
	Woronichinia Naegeliana (Cyanophyte)	1	70.9		7.2
	Closterium acutum (Chlorophyta)				7.5
	Staurastrum natator var. crassum (Chlorophyta)				9.3
	Ceratium hirundinella (Pyrrhophyta)				18.7
October 7th	Aphanocapsa elachista (Cyanophyta)	2	21.8		
	Woronichinia Naegeliana (Cyanophyte)	1	49		
	Coelastrum cambricum (Chlorophyta)	3	6.1	1	26.2
	Closterium acutum (Chlorophyta)			6	5.1
	Pediastrum duplex (Chlorophyta)			2	12.5
	Staurastrum natator var. crassum (Chlorophyta)			5	5.7
	Aulacoseria granulata (Bacillariophyta)			4	9.7
	Cryptomonas ovata (Pyrrhophyta)			3	9.9
October 21st	Microcystis aeruginosa (Cyanophyta)	1	29.1		
	Planktothrix sp. (filaments)(Cyanophyta)	2	29.1		
	Dictyosphaerium Ehrenbergianum (Chlorophyta)	3	20	1	19.4
	Scenedesmus bijuga alternans (Chlorophyta)	4	6.2		
	Closterium acutum (Chlorophyta)			3	12.2
	Pediastrum duplex (Chlorophyta)			4	7.8
	Staurastrum natator var. crassum (Chlorophyta)			2	14.7
	Cryptomonas ovata (Pyrrhophyta)			5	6.4

The data summarized in Table 3-7 demonstrate the rapid changes that can occur during a 3-month period within the phytoplankton community with regard to the composition of density- and biomass-dominant taxa. Many of the taxa listed in Table 3-6 above occurred on 1 or 2 occasions during 2019 and were either a density or biomass dominant at that time. Other taxa, such as the Cyanophyte *Aphanizomenon flos aquae*, was observed in the community on 4 sampling dates and was both a density dominant and biomass dominant on multiple occasions when the pond was sampled.

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 diversity index value. Calculated values that approach, or exceed, 1.0 indicate maximum diversity in the distribution of the population.

Diversity was calculated for the 2019 phytoplankton community in Capaum Pond using both density and biovolume for each sampling date; the results of these analyses are shown in Figure 3-12).

Figure 3-12. Phytoplankton community density and biomass diversity in Capaum Pond, 2019.

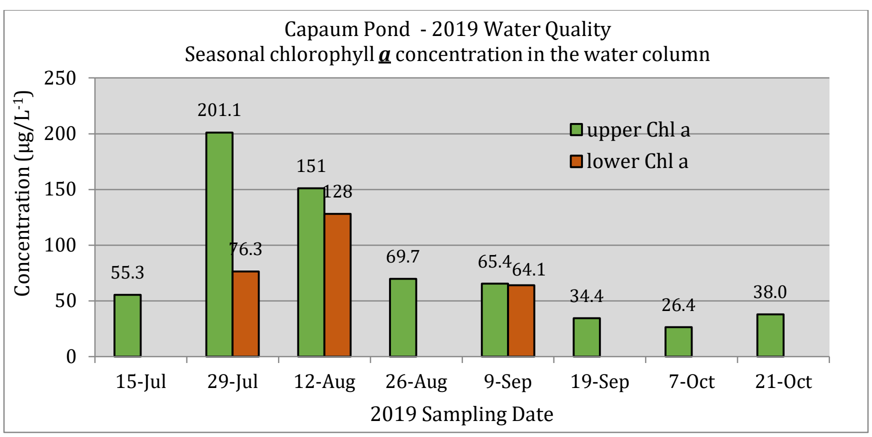


Both density and biomass diversity values were lowest on July 29th; thereafter both diversity values increased and remained near each other until September 16th, when the density diversity value (0.573) declined to about one-half of the biomass diversity value (1.194).

During the remainder of the season, the density diversity value continued to increase while the biomass diversity value remained about the same (Figure 3-12). In other words, the Capaum Pond phytoplankton community was fairly robust during most of the 2019 sampling season with regard to both density and diversity except for the temporary declines mentioned above.

Chlorophyll *a*. The chlorophyll *a* concentrations measured during 2019 are summarized in Figure 3-13.

Figure 3-13. Summary of 2019 Capaum Pond chlorophyll *a* values.



The chlorophyll *a* concentration increased from 55.3 µg $\cdot L^{-1}$ on July 15th to 201.1 µg $\cdot L^{-1}$ on July 29th and thereafter steadily decreased to a concentration around 30 µg $\cdot L^{-1}$ during late September and October. The average concentration in the upper region for the entire sampling season was 80.2 µg $\cdot L^{-1}$.

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[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.

3.1.5 Trophic Status

'Trophic' means nutrition or growth. The trophic state of ponds refers to biological production, plant and animal, which 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 ***a***, 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 productivity.

There were sufficient water quality data collected from Capaum Pond during 2019 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 for each variable for the 2019 sampling season were substituted into the appropriate equations (Chapter 1) used to calculate the TSI values for each variable.

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

Chlorophyll *a*
2019 average chlorophyll ***a*** = 80.16 $\mu g/L^{-1}$
Chlorophyll ***a*** TSI = 9.81*[ln (80.16)] + 30.6
TSI = (9.81)(4.38) + 30.6
TSI = 73.6

Total phosphorus
2019 average total phosphorus = 100.63 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (100.63)] + 4.15
TSI = (14.42)(4.26) + 4.15
TSI = 70.6

Secchi depth
2019 average Secchi depth = 0.43 m
Secchi TSI = 60 – [14.41*[ln (0.43)]
TSI = 60 – (14.41)(-0.8545)
TSI = 72.3

The results of the TSI calculations can be interpreted by comparing the trophic index value with the parameters summarized in Table 3-8. Each water quality indicator (i.e., total 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 of productivity.

Table 3-8. Relationships among Trophic Index, chlorophyll *a*, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996).

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 by humans and animals.

3.2 Summary

Capaum Pond can be characterized as a highly productive body of water that exhibits hyper-eutrophic conditions for the typical parameters used in the assessment of water quality during the growing season. Based upon the composition of the phytoplankton community documented during 2019, 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 as documented by 2019 cyanotoxin samples analyzed from the pond.

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.

Nantucket Island Ponds and 2019 Water Quality

Chapter 4

Gibbs Pond

4.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Gibbs Pond by the NLC during 2019.

4.1 Results

Gibbs Pond was sampled about every 2 weeks commencing on July 15th and ending on October 21st for a total of 8 sampling excursions. Table 4-1 summarizes the 2019 sampling dates on Gibbs Pond.

Table 4-1. Summary of 2019 sampling dates at Gibbs Pond.

July	August	September	October
22nd	5th	3rd	7th
	19th	16th	21st
		30th	

The pond was sampled at about the center which was the deepest area of the water column. Following the collection of temperature and dissolved oxygen profile data on all sampling dates, integrate (***upper***) and grab (***lower***) samples were collected from the pond according to the data provided in Table 4-2.

Table 4-2. Summary of Gibbs Pond integrate and grab sample depths, 2019.

Sampling Date	integrate (*upper*) sample depth	grab (*lower*) sample depth
July 22nd	0-10 feet	16.5 feet
August 5th	0-8 feet	17 feet
August 19th	0-10 feet	15 feet
September 3rd	0-8 feet	16 feet
September 16th	0-10 feet	17.8 feet
September 30th	0-10 feet	na
October 7th	0-8 feet	na
October 21st	0-8 feet	na

Raw water samples were collected from Gibbs Pond on 10 occasions, including dates not shown above, for Eurofins Abraxis® test strip analysis when the pond was checked visually for the presence of HABs along the shoreline. The ACFD unit also was deployed at Gibbs Pond on a single occasion during 2019.

4.1.1 Physical characteristics

General. Gibbs Pond (Figure 4-1) is located about 3 miles from the eastern end of Nantucket, just north of Milestone Road, and almost opposite the intersection with Tom Nevers Road.

Figure 4-1. Aerial view of Gibbs Pond (from *Google*™ earth).

The pond has a surface area of ~37 acres, has an irregular shape and a maximum depth of about 18 feet (5.5 m). There is a single outflow, Phillips Run, which flows into Tom Nevers Pond to the south. Gibbs

Pond receives input from ground water, precipitation and surface runoff from the relatively small surrounding watershed.

Table 4-3 summarizes the physical data collected from Gibbs Pond during the 2019 sampling season.

Table 4-3. Summary of 2019 physical data from Gibbs Pond.

Gibbs Pond 2019 Physical Data			
Sampling Date	Total depth (m)	Secchi depth (m)	Avg Water Column Temperature (°C)
July 22nd	5.2	0.61	26.2
August 5th	5.4	0.41	26.0
August 19th	4.7	0.36	24.5
September 3rd	5.1	0.33	23.2
September 16th	5.4	0.36	20.7
September 30th	5.3	0.33	20.3
October 7th	5.1	0.43	16.8
October 21st	4.8	0.38	13.0

The maximum sampling depth of Gibbs Pond fluctuated during 2019 as a result of slightly different sampling locations and the fact that the pond is used to irrigate the adjacent cranberry bogs which would reduce overall water level.

Transparency. The 2019 Secchi depth transparency at Gibbs Pond ranged from a high of 0.61 m (1.9 feet) on July 22nd to a low of 0.33 m (1.0 feet) on September 3rd and September 30th. Almost all of the water color recorded on the Gibbs Pond field sheets during 2019 was 'brown', indicating that the water column contained humic-tannin material from the adjacent cranberry bogs which impairs visibility.

Temperature. Temperature profile data were collected on all 8 sampling dates during 2019. The highest average temperature of the water column (26.2ºC) occurred on July 22nd and then decreased through the remainder of the season. In addition, there was some slight thermal stratification observed in the pond during the first 2-3 sampling dates which was not apparent thereafter as the water column cooled toward the end of October.

The temperature versus depth profile data collected during 2019 at Gibbs Pond are summarized in graphs presented in Attachment #1.

4.1.2 Chemical characteristics

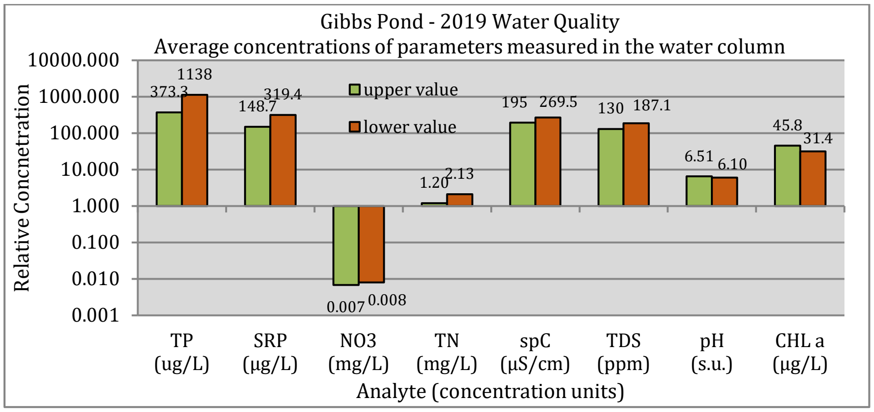
Table 4-2 summarizes the average values for the 2019 chemical characteristics measured at Gibbs Pond including dissolved oxygen, the nutrients phosphorus and nitrogen, and field measurements.

Table 4-4. Summary of 2019 chemical characteristics in *upper* region of Gibbs Pond.

	Capaum Pond 2019 Chemical Properties							
Sampling Date	Avg DO % saturation	TP (µg/L)	SRP (µg/L)	TN (mg/L)	NO_3-N (mg/L)	spC (µS/cm)	TDS (ppm)	pH (s.u.)
July 22nd	65.2	521	209	1.28	0.005	96.5	61.0	6.96
August 5th	72.0	489	299	1.24	0.005	128.3	82.1	7.08
August 19th	70.2	434	198	1.14	0.005	96.4	62.3	6.60
September 3rd	83.2	441	111	1.57	0.005	97.1	62.7	6.94
September 16th	99.0	310	101	1.10	0.005	113.4	74.5	6.80
September 30th	95.9	279	96.4	1.15	0.02	378.3	260	5.70
October 7th	103.0	256	69.4	1.02	0.005	237.3	150.2	6.95
October 21st	104.0	256	106	1.12	0.005	410.7	290.7	5.04
2019 average value	86.6	373.3	148.7	1.20	0.007	194.7	130.4	6.51
all values shown are for the ***upper*** region (epilimnion) of the water column highlighted cells = values reported are one-half the lower detection limit								

Lower region samples were collected from Gibbs Pond on 5 of the 8 sampling dates during 2019; however, those data are not summarized in Table 4-4 but are presented in Figure 4-2 (below) which summarizes the ***upper*** and ***lower*** average values for all 2019 chemical characteristics collected at Gibbs Pond. The ***y-axis*** in Figure 4-2 is depicted in logarithm scale to best display the wide range of 2019 average analyte values presented in the figure.

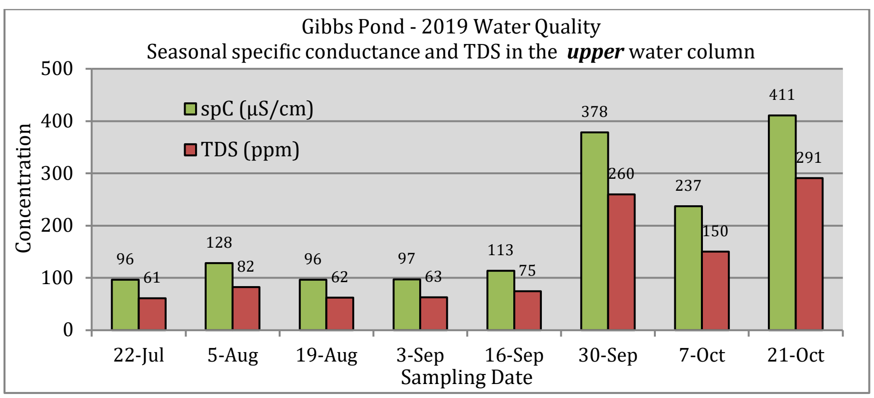
Figure 4-2. Summary of 2019 average concentrations of chemical parameters in Gibbs Pond.



The results for ***lower*** region samples collected at Gibbs Pond during 2019 also are presented in some of the following material in this chapter.

Specific conductance and Total Dissolved Solids (TDS). The distribution of specific conductance and TDS concentrations during the 2019 sampling season at Gibbs Pond is presented in Figure 4-3. The concentrations of both analytes were relatively stable from July 22nd through September 16th (Figure 4-3) and then exhibited substantial concentration increases through the next three sampling dates.

Figure 4-3. Summary of 2019 specific conductance and TDS in *upper* samples from Gibbs Pond.



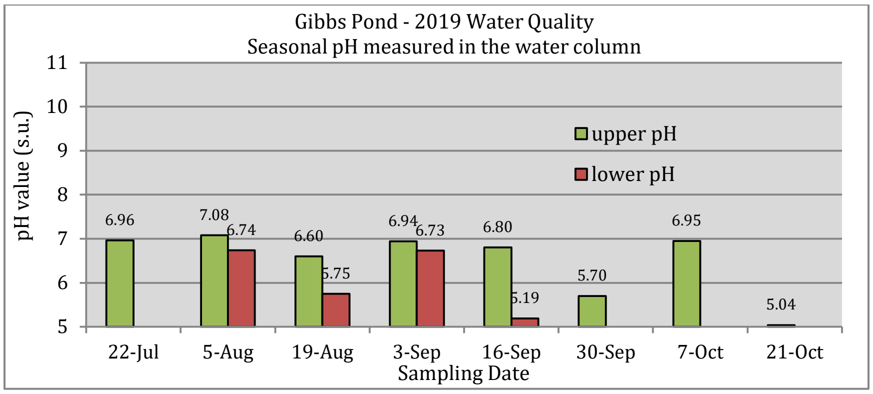
Some of the concentration increase late in the season could be explained by mixing of the ***lower*** region pond water with the ***upper*** region as the water column became isothermal during early fall. The other explanation could be the selective withdrawal of water from the ***upper*** region of the water column for irrigation of the adjacent cranberry bogs which would reduce total depth (as indicated in Table 4-3 from September 16th and beyond) and mixing of the ***lower*** region with higher concentrations would increase the overall concentrations of both analytes.

Although no ***lower*** region water samples were collected from Gibbs Pond beyond the September 16th sampling date to substantiate this possible explanation, the ***lower*** region specific conductance concentration of 692 $\mu S \cdot cm^{-1}$ measured on September 16th versus the ***upper*** region concentration of 113 $\mu S \cdot cm^{-1}$ indicates that ***lower*** region concentrations were substantially higher at that time and possibly remained higher through the end of the season.

The specific conductance and TDS values measured in Gibbs Pond through the September 16th sampling date are considered within the normal range of values expected to occur in ponds that are fresh water. However, the concentrations of these analytes during the remainder of the sampling season are outside this range for fresh water and the pond appears to be too far from either Nantucket Sound (to the north) or the Atlantic Ocean (to the south) to explain the increases in specific conductance and TDS to high winds and salt spray during storm events.

pH. The pH data collected from the ***upper*** and ***lower*** regions of the Gibbs Pond water column during 2019 are presented in Figure 4-4.

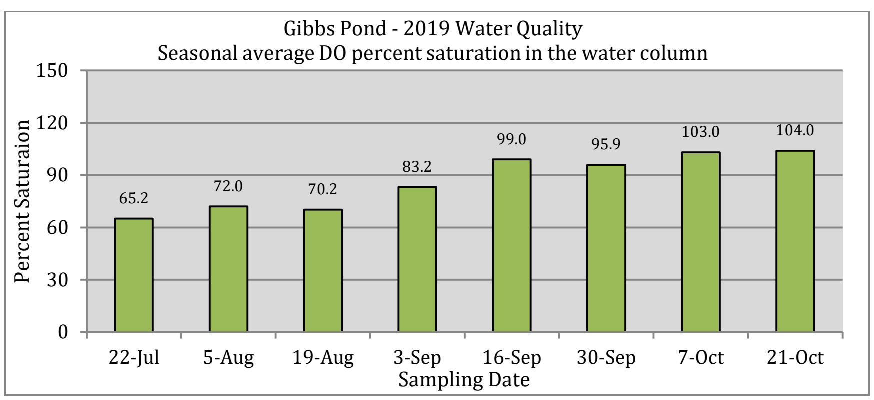
Figure 4-4. Summary of 2019 pH values measured in Gibbs Pond.



The ***upper*** region values ranged from a high value of 7.08 s.u. (August 5th) to a low value of 5.04 s.u. (October 21st) and the average value in the ***upper*** region during 2019 was 6.51 s.u. (Table 4-4). The decreased pH readings near the end of the sampling season could be due to the removal of water from the pond for irrigation and the influx of humic and tannic material form the bogs which would increase acidity of the water column.

Dissolved oxygen percent saturation. Dissolved oxygen is a chemical characteristic of water quality. The 2019 average percent saturation values for dissolved oxygen in the water column of Gibbs Pond are summarized in Figure 4-5.

Figure 4-5. Summary of 2019 dissolved oxygen percent saturation in Gibbs Pond.



The water column values were well below saturation for the first three sampling dates of 2019 and then increased to slightly supersaturated values (>100 percent) by the end of the season. The overall trend of 2019 reflects increased productivity in the ***upper*** region of the water column by the phytoplankton community in the pond.

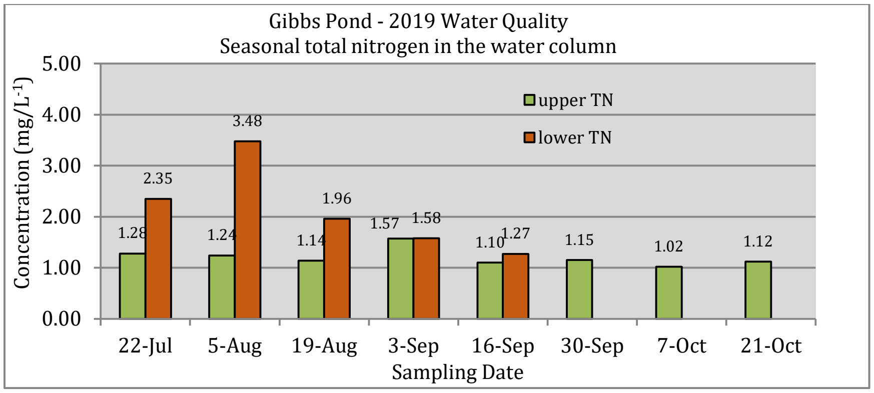
The dissolved oxygen percent saturation data collected during 2019 at Gibbs Pond are summarized in profile graphs presented in Attachment #1.

4.1.3 Plant Nutrients

Nitrogen. **Nitrate-nitrogen** was detected in only a single sample collected from the ***lower*** region of Gibbs Pond on September 16th. The concentration of this sample was 0.02 mg N·L^{-1} which is only slightly above the level of detection 0.01 mg N·L^{-1}. All other samples analyzed for **nitrate-nitrogen** were below detection (Table 4-4) which is not unusual since this form of nitrogen is taken up by phytoplankton during the process of photosynthesis.

Figure 4-6 presents the **total nitrogen** (**TN**) values measured in ***upper*** and ***lower*** region water samples collected from Gibbs Pond during 2019.

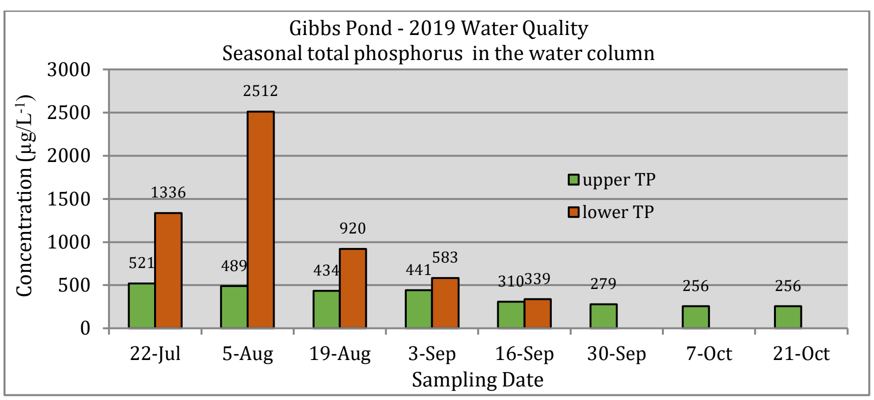
Figure 4-6. Summary of 2019 total nitrogen concentrations measured in Gibbs Pond.



The **TN** concentrations in the ***upper*** region of Gibbs Pond were quite similar throughout the 2019 sampling season, ranging from 1.02 N·L^{-1} to 1.57 N·L^{-1}. The substantially higher **TN** concentrations measured in the ***lower*** region of the pond during the first three sampling dates in 2019 highlight the partial stratification of the water column and the separation of ***upper*** and ***lower*** regions (Figure 4-6), which subsequently broke down as the season progressed.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Gibbs Pond during 2019 are shown in Figure 4-7.

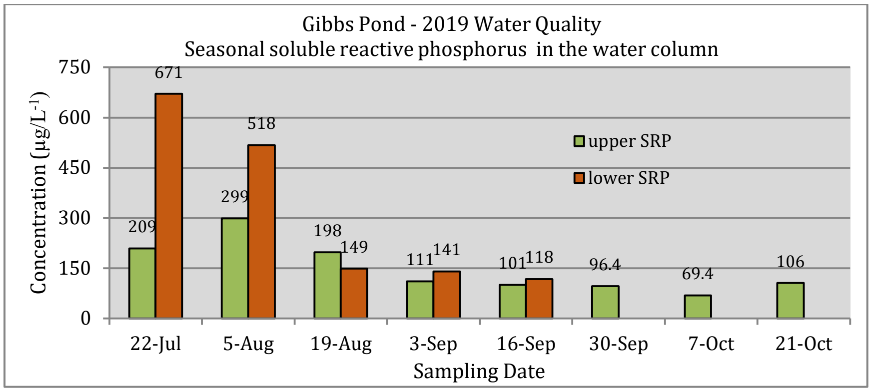
Figure 4-7. Summary of 2019 total phosphorus concentrations measured in Gibbs Pond.



Upper region **TP** concentrations exhibited a high of 521 µg P·L^{-1} on July 22nd, then steadily decreased to 256 µg P·L^{-1} on the last two sampling dates October 7th and 21st) of the season. And, as described for the **TN** concentrations above, the ***lower*** region of Gibbs Pond revealed substantially higher **TP** concentrations during the first three samples dates in 2019, substantiating that the pond was at least partially stratified during this period.

Figure 4-8 summarizes the **soluble reactive phosphorus** (**SRP**) concentrations measured in the ***upper*** and ***lower*** regions of Gibbs Pond during 2019. The **SRP** measured in the ***upper*** region of Gibbs is the highest ever witnessed by this author during 40+ years of monitoring the water quality of lakes and ponds throughout New York State and Nantucket Island.

Figure 4-8. Summary of 2019 soluble reactive phosphorus concentrations in Gibbs Pond.



The even higher **SRP** values in the ***lower*** region of Gibbs Pond during the initial part of 2019 suggest an accumulation of this nutrient due to the settling of material from the ***upper*** region and the inability of any phytoplankton to photosynthesize in the ***lower*** region due to light extinction in the water column.

4.1.4 Phytoplankton

Description of the assemblage. There were a total of 75 phytoplankton genera identified in the nine (9) phytoplankton samples collected from Gibbs Pond during 2019 (Table 4-5).

Table 4-5. Major groups, genera and species of 2019 phytoplankton identified in Gibbs Pond.

Cyanophyta	Chlorophyta	Chrysophyta (Bacillariophyceae)
Anabaena flos aquae	*M. contortum*	*Cyclotella* sp.
Aphanizomenon flos aquae	*Oocystis Borgei*	*Cymbella* sp.
Aphanocapsa elachista	*O. pusilla*	*Eunotia* sp.
Chroococcus dispersus	*O. solitaria*	*Fragilaria crotonensis*
Gomphosphaeria lacustris compacta	*Pediastrum duplex*	*Gomphonema* spp.
Merismopedia glauca	*Pyramimonas tetrarhyncus*	*Gyrosigma* sp.
Planktothrix sp. (filaments)	*Scenedesmus abundans*	*Navicula* spp.
Rhabdoderma Gorskii	*S. acuminatus*	*Nitzschia* sp.
Woronichinia Naegeliana	*S. bijuga*	*N. longissima*
Chlorophyta	*S. bijuga alternans*	*Planothdium* sp.
Actinastrum Hantzschii	*S. dimorphus*	*Pleurosigma* sp.
Ankistrodesmus falcatus	*S. obliquus*	*Stauroneis* sp.
A. fusiformia	*S. quadricauda*	*Synedra acus*
Closteriopsis longissima	*Schroederia Judayi*	*S. ulna*
Closterium acutum	*Selenastrum capriconnutum*	**Chrysophyta (Chrysophyceae)**
C. gracile	*S. minutum*	*Dinobyron divergens*
Coelastrum cambricum	*S. Westii*	*Mallomonas* sp.
Cosmarium spp.	*Sphaerocystis Schroeteri*	*Ochromonas* sp.
Crucigenia quadrata	*Staurastrum natator var. crassum*	**Euglenophyta**
Dictyosphaerium Ehrenbergianum	*Tetraedron minimum*	*Peranema* sp.
Elakatothrix gelatinosa	*Tetrastrum staurogeniaeforme*	*Trachelomonas* sp.
Euastrum sp.	*Xanthidium subhastiferum*	**Pyrrhophyta (Cryptophyceae)**
Eudorina elegans	**Chrysophyta (Bacillariophyceae)**	*Cryptomonas erosa*
Golenkinia radiate	*Achnanthes* sp.	*C. ovata*
Kirchneriella elongate	*Amphora* sp.	*Ceratium hirundinella*
Langerheimia quadriseta	*Aulacoseria granulata*	*Peridinium cinctum*
Monoraphidium arcuatum	*Cocconeis* sp.	

The 2019 phytoplankton community richness in Gibbs Pond was 35 ± 4.8 genera.

Table 4-6 presents a summary of the Gibbs Pond phytoplankton community characteristics determined from the samples collected during 2019.

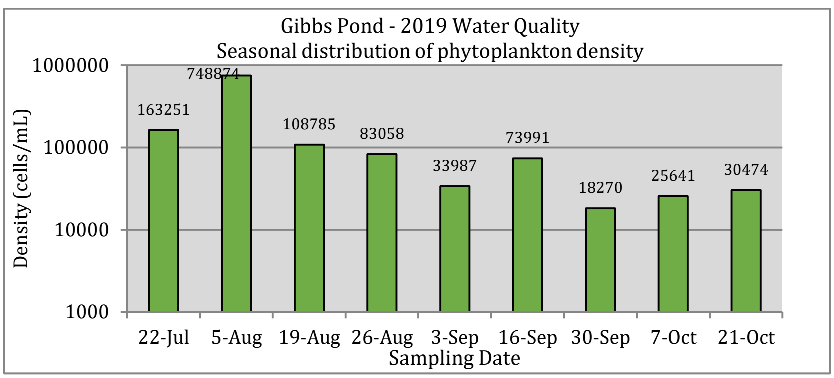
Table 4-6. Summary of 2019 Gibbs Pond phytoplankton community characteristics.

Gibbs Pond Phytoplankton, 2019						
Sampling Date	Total Phytoplankton Taxa	Cell Density (cells/mL^{-1})	Cell Biomass (mg/m^3)	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration (µg/L^{-1})
July 22nd	37	163,251	37,174	0.795	0.615	61.0
August 5th	29	748,874	137,685	0.228	0.190	55.7
August 19th	30	108,785	25,077	0.549	0.763	40.2
August 26th	37	83,058	75,949	0.502	0.791	-
September 3rd	33	33,987	12,310	0.998	0.984	56.1
September 16th	44	73,991	29,146	0.882	1.079	54.2
September 30th	36	18,270	14,031	0.937	0.790	31.4
October 7th	33	25,641	19,531	1.083	0.876	28.7
October 21st	40	30,474	26,886	0.914	0.675	39.1
2019 average	35	172,926	41,977	0.765	0.751	45.8

The 2019 phytoplankton community characteristics in Gibbs Pond summarized above will be discussed in the following sections in this chapter.

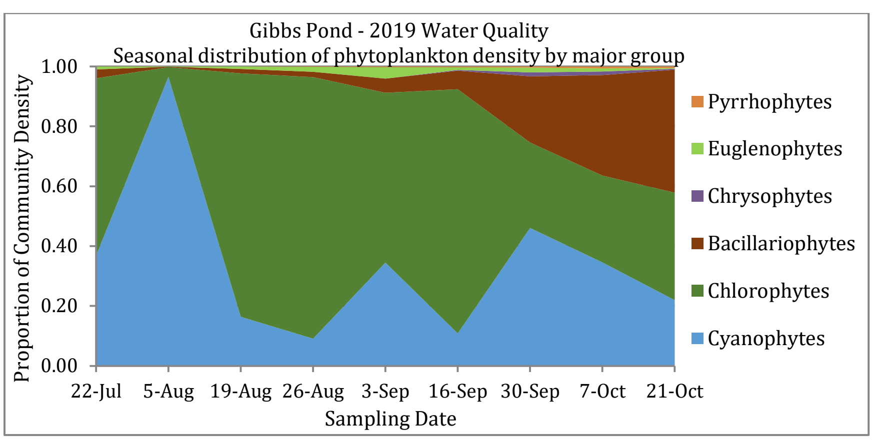
Density. As summarized in Table 4-6 and shown in Figure 4-9, 2019 phytoplankton community density in Gibbs Pond ranged from a high of 748,874 cells·mL^{-1} on August 5th to 18,270 cells·mL^{-1} on September 30th, with an average of 172,926 cells·mL^{-1} for the entire 2019 sampling season.

Figure 4-9. Summary of 2019 phytoplankton community density in Gibbs Pond.



Community density gradually decreased from early in the season toward fall. The seasonal density composition of the 2019 phytoplankton community in Gibbs Pond is shown graphically in Figure 4-10.

Figure 4-10. Density composition of the 2019 phytoplankton community in Gibbs Pond.

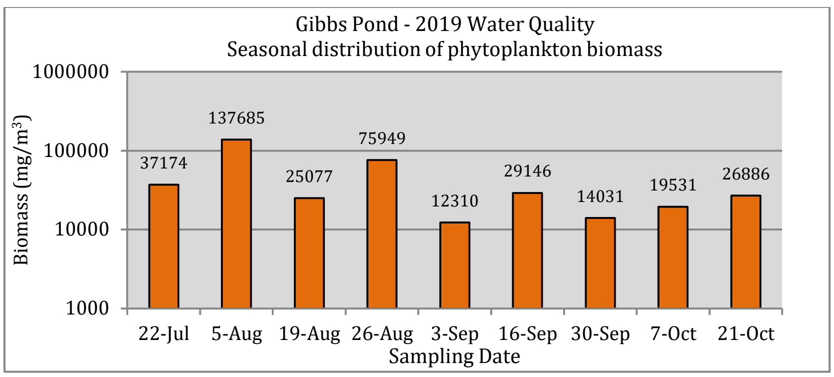


Based upon density, the cyanophytes (blue-green algae) and chlorophytes (green algae) were prominent throughout most of the 2019 sampling season, while the bacillariophytes (diatoms) were more important in the community assemblage near the end of the 2019 sampling season. In many fresh-water ponds, diatoms are dominant early in the season as the water column temperature increases, then decline during mid-summer, and then increase again during fall when temperatures in the water column cool. Other major groups of the phytoplankton were less important during the 2019 season (Figure 4-10).

Biomass. Cell biovolume was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa in the pond. It is quite common for size differences among different taxa to range over several orders of magnitude. For example, consider the green algae *Crucigenia quadrata* cells (93.3 $mg\cdot m^{-3}$) and *Closterium* sp. cells (4000.0 $mg\cdot m^{-3}$). These differences in relative biomass (the size of individual cells) can explain how small numbers of cells with an exceptionally large biovolume can make a particular taxon dominant in the community and have a significant impact on water quality.

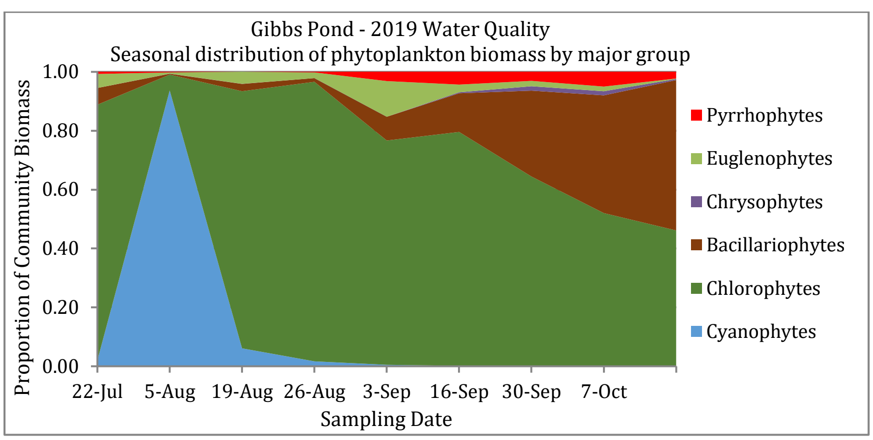
Figure 4-11 presents the Gibbs Pond phytoplankton community biomass data for the nine (9) sampling dates in 2019. There was an order of magnitude change in community biomass during the season with the minimum value of 12,264 mg/m^3 on September 3rd and the maximum value of 137,685 mg/m^3 occurring on August 5th 2019.

Figure 4-11. Summary of 2019 phytoplankton community biomass in Gibbs Pond.



The community biomass exhibited an alteration of low and high values between July 22nd and September 3rd, and then increased slightly thereafter toward the end of the 2019 sampling season. Furthermore, the 2019 biomass (Figure 4-12) presents a much different picture of the Gibbs Pond phytoplankton community when compared with density shown in Figure 4-10.

Figure 4-12. Biomass composition of the 2019 phytoplankton community in Gibbs Pond.



Looking at biomass, the chlorophytes were much more predominant during most of the sampling season, while the cyanophytes were less important and restricted to the August sampling dates. In addition, other groups, such as the euglenophytes and the pyrrhophytes were larger contributors to the overall community when based upon biomass.

Dominance. A ranking of 2019 dominance of phytoplankton genera in Gibbs Pond is summarized in Table 4-7; genera are considered community dominants if they comprise at least 5 percent of the total community density or biomass.

Table 4-7. Rank of 2019 phytoplankton dominance in Gibbs Pond.

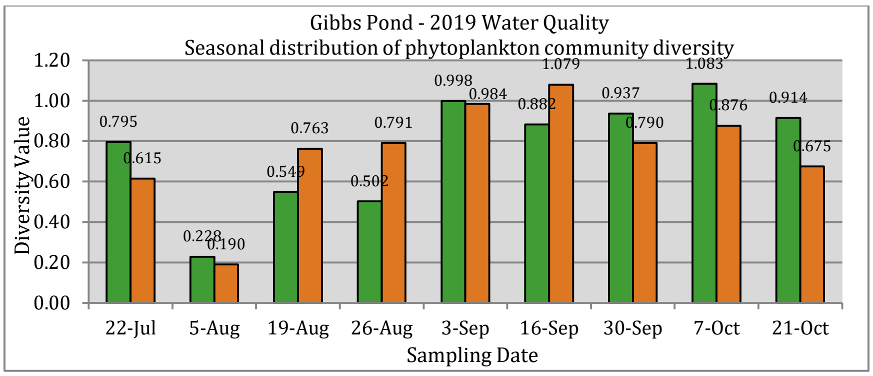
Sampling Date	Genus (and species where known)(Major Group)	Density Rank	% of Total Density	Biomass Rank	% of Total Biomass
July 22nd	*Aphanocapsa elachista* (Cyanophyte)	2	24.7		
	Chroococcus dispersus (Cyanoophyte)	3	7.7		
	Actinastrum Hantzschii (Chlorophyte)	1	41.6	1	69.1
	Dictyosphaerium Ehrenbergianum (Chlorophyte)	3	7.7	2	5.2
	Scenedesmus quadricauda (Chlorophyte)	5	6.7		
August 5th	*Aphanizomenon flos aquae* (Cyanophyte)	1	89.0	1	93.1
August 19th	*Anabaena flos aquae* (Cyanophyte)	2	6.0	4	6.0
	Dictyosphaerium Ehrenbergianum (Chlorophyte)	1	72.0	1	48.2
	Closterium gracile (Chlorophyte)			3	7.5
	Pediastrum duplex (Chlorophyte)			5	5.8
	Staurastrum natator var. *crassum* (Chlorophyte)			2	20.1
August 26th	*Dictyosphaerium Ehrenbergianum* (Chlorophyte)	1	77.0	4	7.3
	Actinastrum Hantzschii (Chlorophyte)			2	17.9
	Ankistrodesmus fusiformis (Chlorophyte)			3	11.8
	Coelastrum cambricum (Chloropyhte)			1	49.6
September 3rd	*Aphanocapsa elachista* (Cyanophyte)	2	21.4		
	Planktothrix sp. (filaments)(Cyanophyte)	4	8.7		
	Ankistrodesmus falcatus (Chlorophyte)	3	13.4	3	9.3
	Dictyosphaerium Ehrenbergianum (Chlorophyte)	1	26.2		
	Scemedesmus quadricauda (Chlorophyte)	5	7.6		
	Closterium gracile (Chlorophyte)			6	4.9
	Coelastrum cambricum (Chloropyhte)			7	4.8
	Pediastrum duplex (Chlorophyte)			4	8.5
	Staurastrum natator var. *crassum* (Chlorophyte)			1	32.8
	Aulacoseria granulata (Bacillariophyte)			5	5.7
	Trachelomonas sp.			2	12.1
September 16th	*Planktothrix* sp. (filaments)(Cyanophyte)	2	6.5		
	Dictyosphaerium Ehrenbergianum (Chlorophyte)	1	54.6	2	21.4
	Pediastrum duplex (Chlorophyte)			4	9.4
	Pediastrum duplex (Chlorophyte)			1	23.5
	Aulacoseria granulata (Bacillariophyte)			3	11.6
September 30th	*Planktothrix* sp. (filaments)(Cyanophyte)	1	42.5		
	Dictyosphaerium Ehrenbergianum (Chlorophyte)	4	5.0		
	Scenedesmus quadricauda (Chlorophyte)	3	9.4		
	Aulacoseria granulata (Bacillariophyte)	2	17.3	2	27.2
	Pediastrum duplex (Chlorophyte)			3	6.9
	Staurastrum natator var. *crassum* (Chlorophyte)			1	44.8
October 7th	*Aphanocapsa elachista* (Cyanophyte)	4	5.6		
	Planktothrix sp. (filaments)(Cyanophyte)	1	24.5		
	Scenedesmus quadricauda (Chlorophyte)	3	9.0		
	Aulacoseria granulata (Bacillariophyte)	2	22.9	1	36.3
	Cyclotella sp. (Bacillariophyte)				
	Closterium gracile (Chlorophyte)			4	6.3
	Pediastrum duplex (Chlorophyte)			3	8.9
	Staurastrum natator var. *crassum* (Chlorophyte)			2	25.9
October 21st	*Planktothrix* sp. (filaments)(Cyanophyte)	2	20.5		
	Scemedesmus quadricauda (Chlorophyte)	3	18.8		
	Aulacoseria granulata (Bacillariophyte)	1	36.3	1	49.5
	Pediastrum duplex (Chlorophyte)			3	6.4
	Staurastrum natator var. *crassum* (Chlorophyte)			2	29.5

The data summarized in Table 4-7 (1) demonstrate the rapid changes that can occur within the phytoplankton community during a 3-month sampling period, and (2) break down the individual phytoplankton groups into the genera that were major participants in the 2019 density and biomass community dynamics. For example, *Aphanocapsa elachista* was a major component of the Cyanophyte community (dominant on 3 of 9 dates), while *Dictyosphaerium Ehrenbergianum* was a major component of the chlorophytes (dominant on 6 of 9 dates). Also interesting is the steady increase in the diatom, *Aulocoseria granulata*, which first appeared in the community on September 3rd (5.7 percent of total biomass) and increased through the end of October to 49.5 percent of the total community biomass.

Diversity. Phytoplankton diversity in Gibbs 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 in Gibbs Pond was calculated using both density and biomass in the equation. The seasonal distributions of the density and biomass diversity are presented in Figure 4-13.

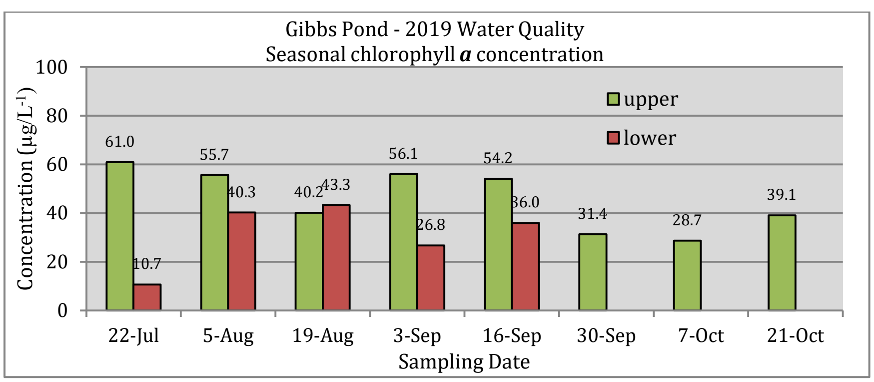
Figure 4-13. Phytoplankton community density and biomass diversity in Gibbs Pond, 2019.



There were community stability issues with regard to both density and biomass diversity on August 5th when both indices reached the lowest point in the season (Figure 3-12). This situation was cause by an almost total dominance on the phytoplankton community by the cyanophyte, *Aphanizomenon flos aquae*, which comprised 89.0 percent and 93.1 percent of the community density and biomass, respectively (also see Table 4-7). Thereafter, both diversity indices increased throughout most of the remainder of the season with density diversity lower in value on some occasions and higher on other occasions.

Chlorophyll <u>*a*</u>. The chlorophyll <u>***a***</u> concentrations measured in Gibbs Pond during 2019 are summarized in Figure 4-18.

Figure 4-18. Summary of 2019 Gibbs Pond chlorophyll <u>*a*</u> values.



Chlorophyll a values ranged from a high of 61.0 µg·L^{-1} on July 22nd to a low value of 28.7 µg P·L^{-1} on October 7th, with an average value for the season of 45.8 µg P·L^{-1} (Table 4-6), which is considered a high

[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.

value for a pond such as Gibbs with low water column transparency caused by humic and tannic compounds in the system.

4.1.5 Trophic Status

Sufficient water quality data were collected from Gibbs Pond during 2019 to calculate the Carlson Trophic State Index (TSI) using chlorophyll ***a***, total phosphorus, and Secchi depth transparency. Average values were calculated for each variable for all 2019 sampling dates. The average values then were substituted into the Carlson equations to calculate the TSI values for each variable. The stepwise calculation and results of the analysis are as follows:

Chlorophyll *a*

2019 average chlorophyll *a* = 45.8 μg/L^{-1}

Chlorophyll *a* TSI = 9.81*[ln (45.8)] + 30.6

TSI = (9.81)(3.82) + 30.6

TSI = 68.07

Total phosphorus

2019 average total phosphorus = 373.3 μg/L^{-1}

Total phosphorus TSI = 14.42*[ln (373.3)] + 4.15

TSI = (14.42)(5.92) + 4.15

TSI = 89.52

Secchi depth

2019 average Secchi depth = 0.40 m

Secchi TSI = 60 – [14.41*[ln (0.40)]

TSI = 60 – (14.41)(-0.92)

TSI = 73.2

The TSI values presented above should be compared with the criteria presented in Table 4-8 below to evaluate the 2019 trophic status of Gibbs Pond.

Table 4-8. Relationships among Trophic Index (TI), chlorophyll *a*, total phosphorus, Secchi depth, and Trophic Class (after Carlson 1996).

Trophic State Index	Chlorophyll *a* (μg·L^{-1})	Total phosphorus (μg·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

The TSI indices for all 3 of the 2019 water quality parameters were situated within either the eutrophic or hyper-eutrophic range, indicating very high mid-summer productivity in Gibbs Pond. The TSI values suggest that certain water quality standards for contact recreation are in question and that further data collection should occur before this pond is considered 'safe' for recreational use during summer months.

4.2 Summary

Based upon the data collected during 2019, Gibbs Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has high productivity characterized as hyper-eutrophic based upon the numerical analysis of 3 separate water quality variables that were monitored. Many Island ponds likely are very similar in productivity to Gibbs Pond due to their extremely shallow nature and the highly enriched organic material contained in the sediments from aquatic vegetation that has decomposed and accumulated in that region. Nutrients such as nitrogen and phosphorus that are trapped in these bottom sediments are released into the water column at various times during the mid-summer growing season when mixing of the water column occurs due to wind of sufficient velocity blowing across the Island that generate water currents throughout the pond and when sufficient physical and chemical properties exist in these lower regions of the pond.

4.3 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.

Nantucket Island Ponds and 2019 Water Quality

Chapter 5

Head of Hummock Pond

5.0 Introduction

Head of Hummock Pond was sampled for water quality by the NLC on six (6) occasions during 2019. This chapter presents a summary and discussion of the 2019 physical, chemical and biological data collected from the pond by NLC staff.

5.1 Results

Head of Hummock Pond was sampled at about 2-week intervals beginning on July 15th and ending on September 24th. The 2019 sampling dates are summarized in Table 5-1.

Table 5-1. Summary of 2019 sampling dates at Head of Hummock Pond.

July	August	September
15th	12th	9th
29th	26th	24th

The pond always was sampled at about the center which is the deepest region of the water column. Following the collection of temperature and dissolved oxygen profile data on all sampling dates, integrate (***upper***) and grab (***lower***) samples were collected from the pond depths as shown in Table 5-2 below.

Table 5-2. Summary of Head of Hummock Pond integrate and grab sample depths, 2019.

Sampling Date	integrate (*upper*) sample depth	grab (*lower*) sample depth
July 15th	0-8 feet	na
July 29th	0-6 feet	10 feet
August 12th	0-6 feet	10 feet
August 26th	0-6 feet	na
September 9th	0-6 feet	10 feet
September 24th	0-6 feet	11 feet

Raw water samples were collected from Capaum Pond for Eurofin Abraxis® test strip analyses on 6 dates including a date not shown above (Table 5-1) when the pond was checked visually along the shoreline for evidence of HABs.

5.1.1 Physical characteristics

General. Head of Hummock Pond is located on the western end of Nantucket Island, just southeast of the intersection of Madaket and Cliff Roads. In aerial view, the pond is an inverted pear-shape oriented in a north-south direction with the wide portion north and the narrow portion south (Figure 5-1).

Figure 5-1. Aerial view of Head of Hummock Pond (from *Google*™ earth)

The outlet for Head of Hummock Pond is at the south end and forms a narrow channel about 3-5 m wide that traverses a wetland for about 250 m before it enters Hummock Pond at the northeast end. At normal summer water levels, Head of Hummock Pond measures about 260 m wide and 340 m long, and occupies a surface area of about 64,000 m^2 (6.5 hectares[1]), or 16 acres

Table 5-3 presents a summary of the physical characteristics of Head of Hummock Pond collected during 2019 including (1) total depth at the sampling station, (2) Secchi depth transparency, and (3) the average water column temperature on the dates the pond was sampled.

Table 5-3. Summary of 2019 physical data collected from Head of Hummock Pond.

Capaum Pond 2019 Physical Data			
Sampling Date	Total depth (m)	Secchi depth (m)	Avg Water Column Temperature (°C)
July 15th	3.7	0.76	24.8
July 29th	3.2	0.76	24.9
August 12th	3.2	0.84	24.6
August 26th	3.3	0.53	22.1
September 9th	3.4	1.02	20.0
September 24th	3.4	0.97	21.1

The maximum depth of Head of Hummock Pond during 2019 was 3.7 meters (m), which is ~12 feet (ft), while the minimum depth was 3.2 m (10.4 ft). Slight differences in water depth at the 2019 sampling locations could be due to differences in water level at the time of sampling as well as different locations for anchoring and sampling in the pond.

Transparency. The 2019 water clarity in Head of Hummock Pond ranged from 0.53 m (1.7 ft) to 1.02 m (3.3 ft) indicating moderate water clarity compared with conditions documented historically (Sutherland 2010). Field notes from the 2019 field sheets indicate that the pond water color most often was listed as 'green'. Clarity of the water column (transparency) is one of the criteria used to define the productivity of a body of water and will be discussed later in this chapter.

Temperature. The greater depth of Head of Hummock Pond compared with other Island ponds provides the opportunity for slight temperature gradients to develop between the pond surface and lower depths. Temperature differences between surface and bottom during 2019 were <1ºC on 2 sampling dates August 26th, September 9th) during 2019 and 5ºC on July 15th.

The temperature profile data for the pond are presented in Attachment #1 at the end of this report.

5.1.2 Chemical characteristics

Table 5-4 summarizes the 2019 chemical characteristics of Head of Hummock Pond measured in water samples collected from the upper region on each sampling date.

Table 5-4. Summary of 2019 chemical characteristics in *upper* region of Head of Hummock Pond.

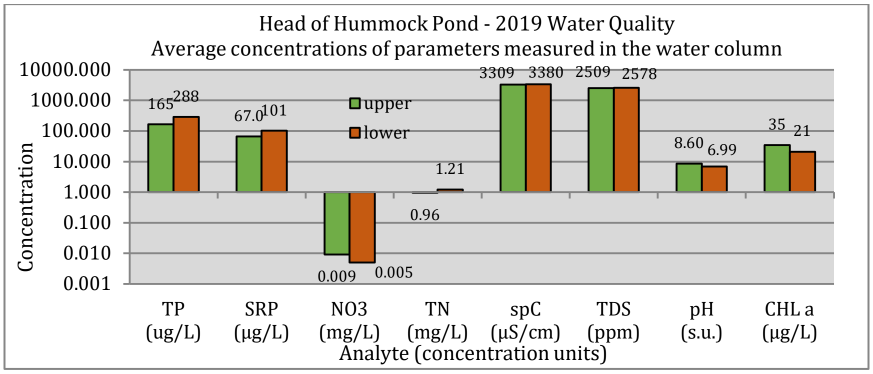
	Capaum Pond 2019 Chemical Properties							
Sampling Date	Avg DO % saturation	TP (µg/L)	SRP (µg/L)	TN (mg/L)	NO_3-N (mg/L)	spC (µS/cm)	TDS (ppm)	pH (s.u.)
July 15th	103.1	87.7	7.3	1.00	0.005	4364	3355	9.05
July 29th	99.0	78.9	3.4	0.99	0.005	3838	2895	9.38
August 12th	97.8	136	47.2	0.89	0.005	3536	2658	8.85
August 26th	102.2	310	135	1.20	0.005	3081	2348	8.10
September 9th	92.6	228	140	0.97	0.03	2645	2008	7.92
September 24th	97.8	147	68.8	0.71	0.005	2388	1790	8.32
2019 average value	98.7	165	67.0	0.96	0.009	3309	2509	8.60
all values shown are for the ***upper*** region (epilimnion) of the water column highlighted cells = values reported are one-half the lower detection limit								

Lower region samples were collected on 4 of the 6 sampling dates; those data are not summarized in Table 5-4 but are presented below in Figure 5-2 which summarizes the ***upper*** and ***lower*** average values for all chemical characteristics collected at Head of Hummock Pond during 2019. The reader should note

[1] 1 hectare = 2.47 acres

that the ***y*-axis** in Figure 5-2 is depicted in logarithm scale to best display the wide range of 2019 average analyte values presented in the figure.

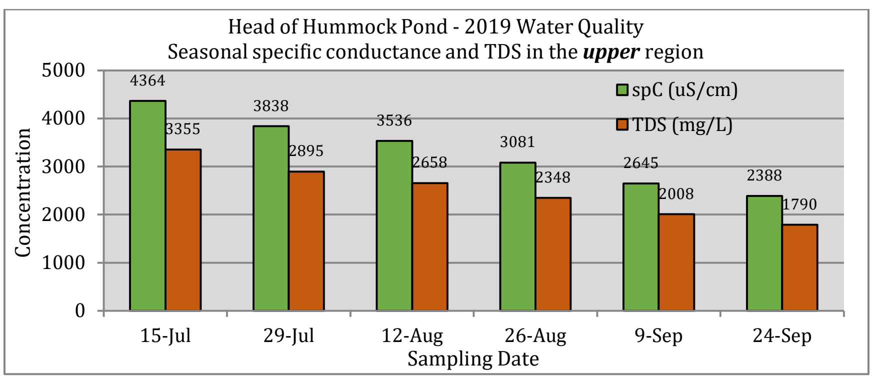
Figure 5-2. Summary of 2019 average concentrations of chemical parameters in Capaum Pond.



There were substantial differences in some analyte concentrations when comparing ***upper*** and ***lower*** region samples, e.g., **total phosphorus** (**TP**) and **soluble reactive phosphorus** (**SRP**) had greater concentrations in the ***lower*** samples, and pH was an order of magnitude greater in the ***upper*** region.

Specific conductance and Total Dissolved Solids (TDS). 2019 **s**pecific conductance and TDS values measured in the ***upper*** region of Head of Hummock Pond are presented in Figure 5-3.

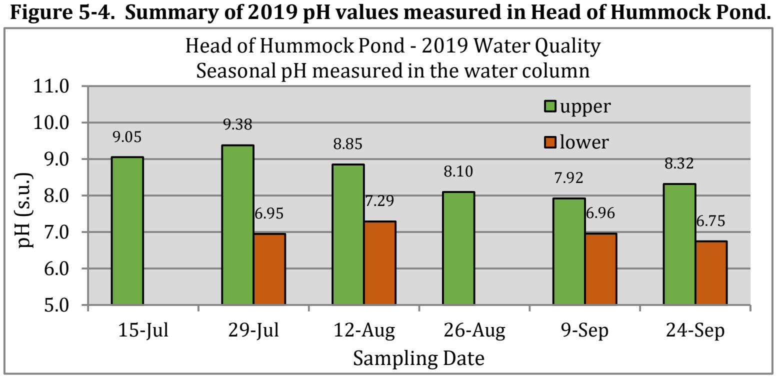
Figure 5-3. Summary of 2019 specific conductance and TDS in *upper* samples from Head of Hummock Pond.



Both analytes exhibited decreasing concentrations during 2019 which is explained as follows: the spring 2019 pond opening (breach) with the Atlantic Ocean significantly raised pond salinity which then decreased as rain and ground water intrusion diluted the pond concentrations of chloride and cations.

pH. The pH data collected from the ***upper*** and ***lower*** regions of Capaum Pond during the 2019 sampling season are summarized in Figure 3-4.

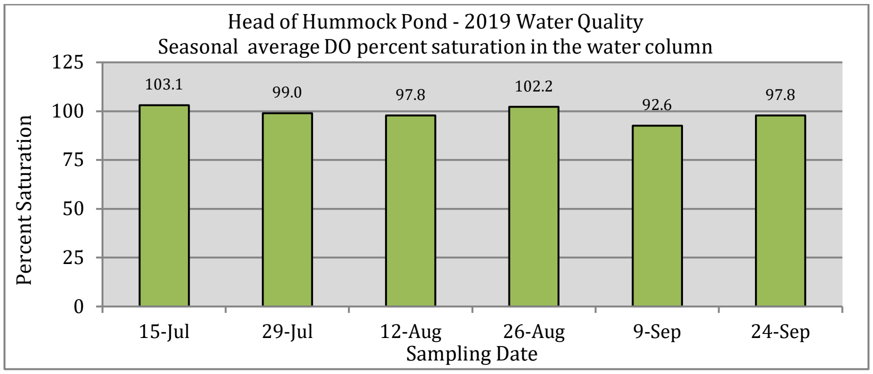
Figure 5-4. Summary of 2019 pH values measured in Head of Hummock Pond.



It is interesting to note the high pH values measured in the ***upper*** region of the pond; two (2) of the 6 readings were above pH 9.0., and the average for 2019 was 8.60 s.u. High pH values in small ponds such as Head of Hummock can indicate an imbalance between respiration and photosynthesis of the phytoplankton community which can result when intense algal blooms are occurring.

Dissolved oxygen percent saturation. The 2019 average dissolved oxygen percent saturation values for the Head of Hummock Pond water column are summarized in Figure 5-5.

Figure 5-5. Summary of 2019 dissolved oxygen percent saturation in Head of Hummock Pond.



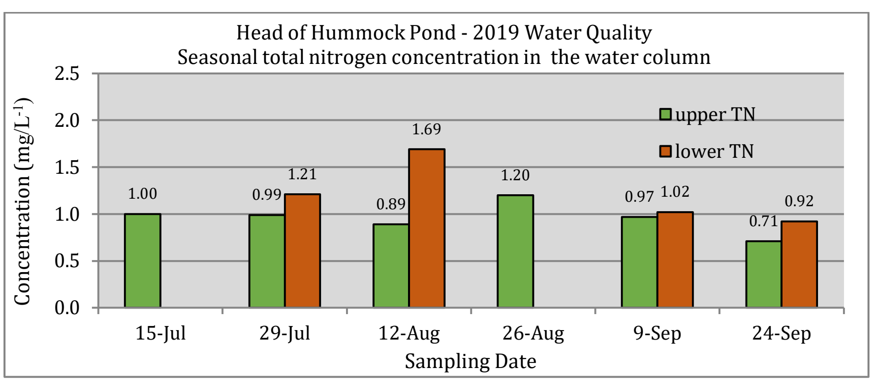
All 2019 values were near or above saturation, indicating that high levels of productivity were occurring in the pond during the entire sampling season. Although not discussed here, there were definite gradients of DO percent saturation exhibited between the upper and lower regions of the pond when profile data were collected, indicating a definite, albeit temporary, separation of these two regions of the water column. The DO percent saturation profiles are presented in Attachment #1 of this report.

5.1.3 Plant nutrients

Nitrogen. Nitrate-nitrogen was detected in the ***upper*** region of the water column on only a single occasion (September 9th) when the concentration was 0.03 mg $N \cdot L^{-1}$, a very low value. Otherwise, all values measured during 2019 were below the lower limit of detection (0.01 mg $N \cdot L^{-1}$). This situation is not uncommon in ponds because this form of nitrogen is readily available for uptake by the primary producers in the water column.

The **total nitrogen** (TN) concentrations measured in ***upper*** and ***lower*** regions of Head of Hummock Pond during 2019 are summarized in Figure 5-6.

Figure 5-6. Summary of 2019 total nitrogen concentrations in Head of Hummock Pond.

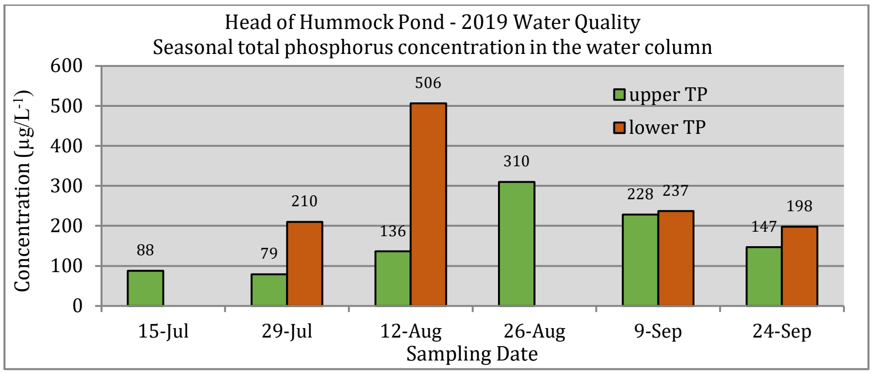


The upper values ranged from 0.71-1.20 mg $N \cdot L^{-1}$ which are considered normal values for a pond such as this one. In addition, the non-detect characteristics of **nitrate-nitrogen** and presumably similar characteristics of **ammonia-nitrogen** (from past studies) means that essentially all of the **TN** in the water column is tied up in organic material, including phytoplankton and seston (other organisms and non-living material in the water column).

As observed with some of the other analytes measured in Head of Hummock Pond, there was a distinct separation of low values in the ***upper*** region and higher values of TN in the ***lower*** region on certain sampling dates.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Head of Hummock Pond during 2019 in the ***upper*** and ***lower*** regions of the pond are summarized in Figure 5-7.

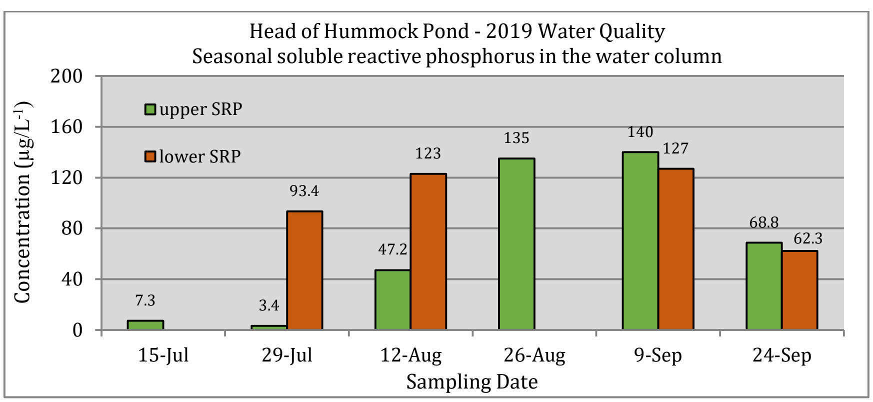
Figure 5-7. Summary of 2019 total phosphorus concentrations in Head of Hummock Pond.



The ***upper*** **TP** concentrations ranged from 79-310 µg P·L^{-1} during the sampling season, and the average value was 165 µg P·L^{-1}. Furthermore, there was a distinct difference between values measured in the ***upper*** and ***lower*** regions on almost all dates when lower region samples were collected, which also was observed for some other analytes measured in the pond during 2019. These concentrations reflect high productivity in the pond during the 2019 sampling season.

A summary of the **soluble reactive phosphorus** (**SRP**) concentrations measured during 2019 are presented in Figure 5-8.

Figure 5-8. Summary of 2019 soluble reactive phosphorus concentrations in Head of Hummock Pond.



The 2019 ***upper*** region **SRP** concentrations ranged from 3.4-140 µg P·L^{-1} and averaged 67.0 µg P·L^{-1} across the entire season. It is most unusual to document that much phosphorus in the water column because this form of the nutrient is readily available and should be consumed by phytoplankton undergoing photosynthesis. A possible explanation for this phenomenon might be low concentrations of available nitrogen acting as the limiting nutrient under these conditions.

5.1.4 Phytoplankton

Description of the assemblage. Table 5-5 summarizes the Head of Hummock Pond phytoplankton community characteristics determined from five (5) samples collected during 2019.

Table 5-5. Summary of 2019 Head of Hummock Pond phytoplankton community characteristics.

Gibbs Pond Phytoplankton, 2019						
Sampling Date	Total Taxa	Cell Density (cells/mL-1)	Cell Biomass (mg/m3)	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration (µg/L-1)
July 29th	24	20079	2452	0.886	0.945	32
August 12th	27	17717	4530	0.937	1.007	30
August 26th	28	22317	6846	0.961	0.911	54
September 9th	23	151686	8735	0.294	0.929	18
September 24th	21	32504	12763	0.887	0.779	10
2019 average	25	48861	7065	0.793	0.914	28.8

These characteristics will be discussed in the following sections.

There were 45 different genera identified in the 2019 Head of Hummock Pond phytoplankton samples, and all of the major algal groups were represented (Table 5-6). Community richness averaged 25.0 (±2.9) taxa for the 2019 sampling season.

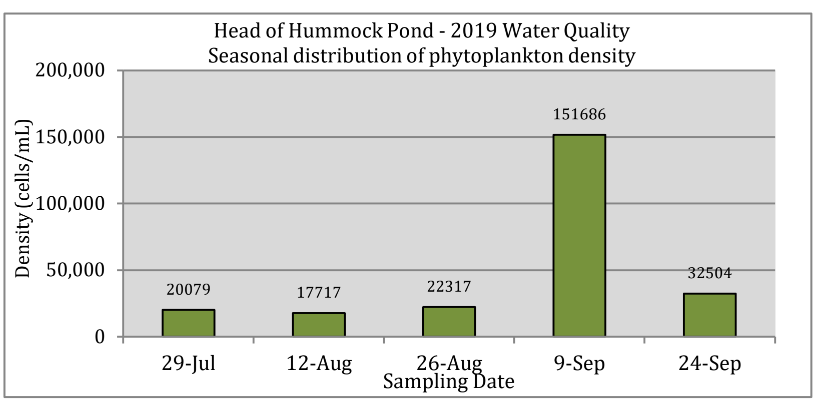
Table 5-6. Major groups, genera and species of phytoplankton identified in Head of Hummock Pond 2019.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyceae)**
Anabaena flos aquae	*S. quadricauda*	*Nitzschia* sp.
Anabaenopsis Elenkinii	*Selenastrum capriconnutum*	*Planothdium* sp.
Aphanizomenon flos aquae	*S. minutum*	*Rhoicosphenia curvata*
Aphanocapsa elachista	*Sphaerocystis Schroeteri*	*Synedra acus*
Chroococcus limneticus	*Tetraedron minimum*	*S. ulna*
Chlorophyta	**Chrysophyta (Bacillariophyceae)**	**Chrysophyta (Chrysophyceae)**
Dictyosphaerium Ehrenbergianum	*Achnanthes* sp.	*Dinobyron divergens*
Elakatothrix gelatinosa	*Amphora* sp.	*Ochromonas* sp.
Eudorina elegans	*Attheya* sp.	**Euglenophyta**
Langerheimia quadriseta	*Cocconeis* sp.	*Peranema* sp.
Monoraphidium contortum	*Cyclotella* sp.	*Trachelomonas* sp.
Oocystis Borgei	*Eunotia* sp.	**Pyrrhophyta (Cryptophyceae)**
O. pusilla	*Fragilaria capucina*	*Cryptomonas erosa*
O. solitaria	*Gomphonema* spp.	*C. ovata*
Pyramimonas tetrarhyncus	*Gyrosigma* sp.	*Ceratium hirundinella*
S. bijuga	*Hippodonta* sp.	*Peridinium cinctum*
S. bijuga alternans	*Navicula* spp.	

The greatest representation within the community occurred within the Chlorophytes (green algae) and Bacillariophytes (diatoms) which each contained 16 genera.

Density. Figure 5-9 presents the phytoplankton community cell density measured in Head of Hummock Pond during 2019.

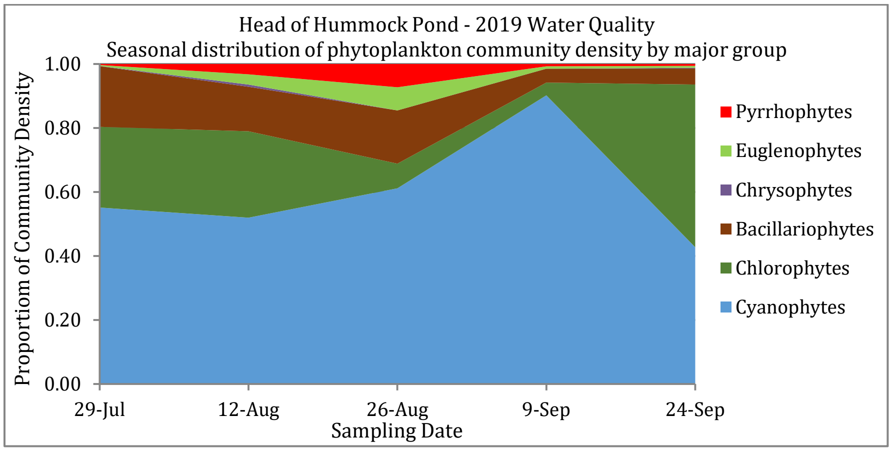
Figure 5-9. Summary of 2019 phytoplankton community density in Head of Hummock Pond.



All densities were in the range of ~18,000-33,000 cells/mL-1 except the density measured on September 9th which was 151,686 cells/mL-1. The low densities throughout most of the 2019 sampling season might be explained by dilution of the phytoplankton community from the spring 2019 breaching of the pond to the Atlantic Ocean.

The seasonal density composition of the 2019 phytoplankotn community in Head of Hummock Pond is summarized in Figure 5-10.

Figure 5-10. Density composition of the 2019 phytoplankton community in Head of Hummock Pond.

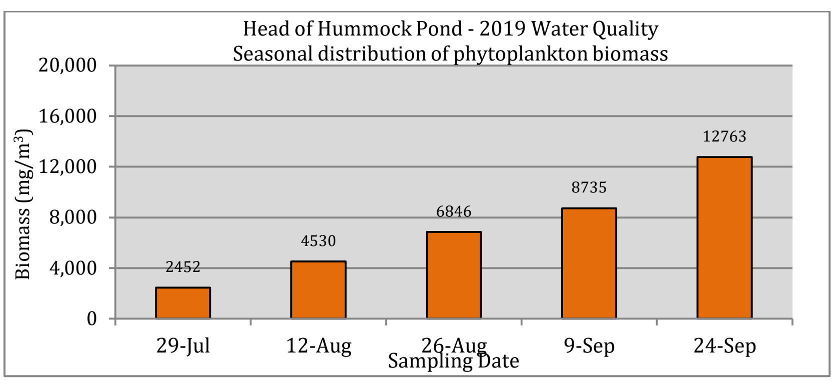


The Cyanophytes always were a major proportion of the community density, ranging from 43 percent to 91 percent across the five sampling dates, and averaging 61 percent for 2019. Chlorophytes averaged 23 percent of the community during 2019 and Bacillariophytes averaged 12 percent. The most dramatic change in the community density composition occurred on September 9th when the Cyanophytes comprised 91 percent of the phytoplankton.

Biomass. Cell biovolume was used to evaluate phytoplankton biomass, or 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.

Figure 5-11 presents the 2019 biomass composition of the phytoplankton community in Head of Hummock Pond measured in the five (5) samples that were collected.

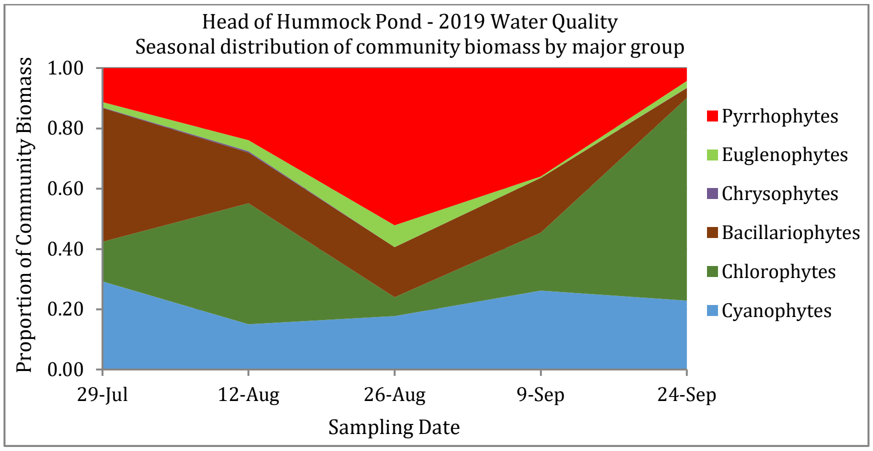
Figure 5-11. Summary of 2019 phytoplankton community biomass in Head of Hummock Pond.



Two items of note from the summary graph above: (1) community biomass steadily increased during the season, and (2) in spite of this increase, all 2019 biomass values for 2019 were extremely low. As mentioned previously, these characteristics of the community could be the result of the spring breach with the Atlantic Ocean which would tend to dilute both the community density and biomass in the pond.

The 2019 Head of Hummock Pond phytoplankton exhibited much different biovolume composition characteristics (Figure 5-12) when compared with the 2019 pond community density composition (Figure 5-10).

Figure 5-12. Biomass composition of the 2019 phytoplankton community in Head of Hummock Pond.

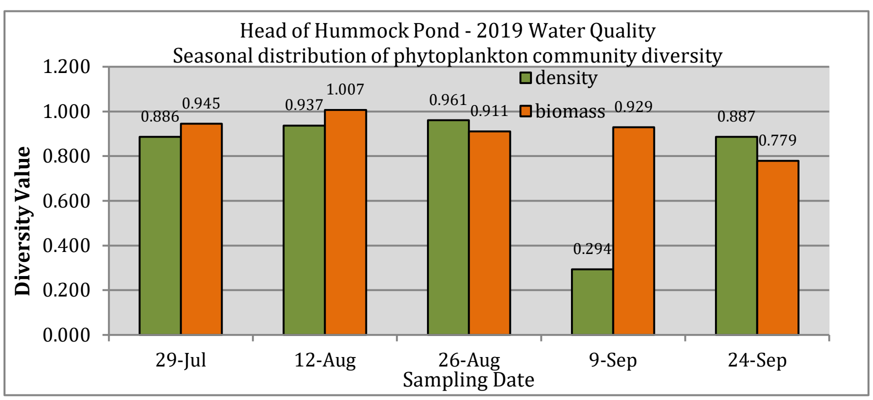


The composition of the Cyanophytes, Chlorophytes, Bacillariophytes and Euglenophytes varied across the five (5) 2019 sampling dates and, for the most part, were secondary in importance to the Pyrrhophytes, which include the fire algae, primarily dinoflagellates, that are marine forms and often associated with the red tide.

The increase and subsequent decrease of the Pyrrhophytes through the 2019 sampling dates is a community feature that reinforces the belief that the spring pond breaching had an important influence on the seasonal composition that followed.

Diversity. Density and biomass diversity values calculated for the Head of Hummock Pond phytoplankton community during 2019 are summarized in Figure 5-13.

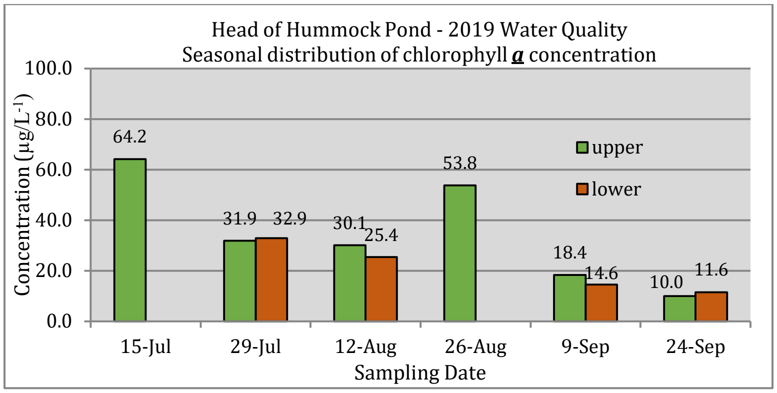
Figure 5-13. Phytoplankton community density and biomass diversity in Head of Hummock Pond, 2019.



Community density and biomass diversity values were high throughout the 2019 season and similar to each other except on September 9th when density diversity was low (0.294) and attributed to the Cyanophytes Aphanocapsa elachista comprising 88 percent of the total community density.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Head of Hummock Pond during 2019 are summarized in Figure 5-14.

Figure 5-14. Summary of 2019 chlorophyll *a* values in Head of Hummock Pond.



The concentrations varied considerably from July 15th through August 26th, thereafter declining through September 24th when the minimum concentration (10.0 µg/L^{-1}). The average concentration for 2019 was 34.7 µg/L^{-1}. Chlorophyll ***a*** is one of the water quality criteria used to evaluate pond productivity, which will be discussed later in this chapter.

Dominance. A ranking of phytoplankton genera dominance in Head of Hummock Pond during each sampling date in 2019 is summarized in Table 5-7.

Table 5-7. Rank of 2019 phytoplankton dominance in Head of Hummock Pond.

Sampling Date	Genus (species when known) (Major Group)	Density Rank	% of Total Density	Biomass Rank	% of Total Biomass
July 29th	Anabaenopsis Elenkinii (Cyanophyte)	6	6.1	5	5.8
	Aphanizomenon flos aquae (Cyanophyte)	2	14.2	2	22.3
	Aphanocapsa elachista (Cyanophyte)	1	34.8		
	Pyramimonas tetrarhyncus (Chlorophyte)	5	7.6	4	6.2
	Selenastrum capricornutum (Chlorophyte)	3	13.8		
	Navicula spp. (Bacillariophyte)	4	11.3	1	32.4
	Nitzschia sp. (Bacillariophyte)	7	4.7	3	7.2
	Cryptomonas ovata (Pyrrhophyte)			3	7.2
August 12th	Anabaena flos aquae (Cyanophyte)	2	13.2	3	11.9
	Aphanocapsa elachista (Cyanophyte)	1	36.3		
	Pyramimonas tetrarhyncus (Chlorophyte)	3	12.0	6	4.7
	Sphaerocystis Schroeteri (Chlorophyte)	4	9.9	1	29.9
	Cyclotella sp. (Bacillariophyte)	5	9.8	4	10.2
	Cryptomonas ovata (Pyrrhophyte)			2	14.9
	Cryptomonas erosa (Pyrrhophyte)			5	7.2
August 26th	Anabaena flos aquae (Cyanophyte)	4	7.6		
	Aphanizomenon flos aquae (Cyanophyte)	2	21.1	2	13.2
	Aphanocapsa elachista (Cyanophyte)	1	33.4		
	Cyclotella sp. (Bacillariophyte)	3	9.7	4	8.4
	Oocystis Borgei (Chlorophyte)			5	5.3
	Cryptomonas erosa (Pyrrhophyte)			3	9.8
	Cryptomonas ovata (Pyrrhophyte)			1	42.0
September 9th	Aphanocapsa elachista (Cyanophyte)	1	87.8	6	6.2
	Chroococcus limneticus (Cyanophyte)			2	19.4
	Oocystis Borgei (Chlorophyte)			4	6.5
	Sphaerocystis Schroeteri (Chlorophyte)			5	6.4
	Navicula spp. (Bacillariophyte)			3	10.2
	Cryptomonas ovata (Pyrrhophyte)			1	34.7
September 24th	Aphanocapsa elachista (Cyanophyte)	3	17.4		
	Chroococcus limneticus (Cyanophyte)	2	20.7	2	29.4
	Eudorina elegans (Chlorophyte)	5	5.7	3	22.9
	Oocystis Borgei (Chlorophyte)	1	29.6	1	39.1
	O. pusilla (Chlorophyte)	4	11.4		

The Cyanophyte, *Aphanocapsa elachista*, was the leading dominant species in the 2019 phytoplankton community density, observed in samples on all five dates and averaging 42 percent of the overall density. Further examination of Table 5-7 also reveals the increasing importance of the Pyrrhophytes in the 2019 community biomass, comprising 7.2 percent of the community on July 22nd (Cryptomonas ovata), 22,1 percent of the community on August 12th (C. ovata, C. erosa) and 51.8 percent of the community on August 26th (C. erosa, C. ovata).

Also apparent from the above summary is the dynamic nature of the community, with constant change in the genera and species that are dominant in the community density and biomass throughout the season.

5.1.5 Trophic Status

Sufficient water quality data were collected from Head of Hummock Pond during 2019 to calculate the Carlson Trophic State Index (TSI) using chlorophyll ***a***, total phosphorus, and Secchi depth transparency. Average values were calculated for each variable for the entire 2019 sampling period. The average values then were substituted into equations to calculate the TSI values for each variable. The stepwise calculation and results of the analysis are as follows:

Chlorophyll *a*
Average chlorophyll ***a*** = 34.7 μg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (34.7)] + 30.6
TSI = (9.81)(3.55) + 30.6
TSI = 65.4

Total phosphorus
Average total phosphorus = 165.0 μg/L^{-1}
Total phosphorus TSI = 14.42*[ln (165.0)] + 4.15
TSI = (14.42)(5.10) + 4.15
TSI = 73.6

Secchi depth
Average Secchi depth = 0.81 m
Secchi TSI = 60 – [14.41*[ln (0.81)]
TSI = 60 – (14.41)(-0.207)
TSI = 63.0

Chlorophyll ***a*** probably yields the most accurate index since it is the most accurate predictor of ecosystem biomass, while phosphorus may be a more accurate predictor of the summer trophic status of a water body than chlorophyll if the measurements also are made during the winter, which was not the case here. Secchi depth probably is the least accurate predictor but is the most affordable and easiest measure to obtain since it is a subjective visual determination.

Table 5-8. Relationships among Trophic Index (TI), chlorophyll *a*, total phosphorus, Secchi depth, and Trophic Class (after Carlson, 1996).

Trophic Index	Chlorophyll *a* (μg L^{-1})	Total Phosphorus(μg 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

The TSIs of 65.4 calculated for chlorophyll ***a*** and 63.0 for Secchi depth were well within the eutrophic range of productivity (Table 5-8), while the TSI calculated for total phosphorus (73.6) was within the Hyper-eutrophic range of productivity. Regardless of which calculator is used to calculate trophic status, Head of Hummock Pond exhibited poor water quality during the 2019 growing season.

5.2 Summary

Head of Hummock Pond continues to exhibit eutrophic and hyper-eutrophic productivity depending upon which 2019 variables are used to calculate the TSI index. This condition has not changed since the 2009 survey conducted on the pond (Sutherland and Oktay 2010). Cyanophyte species that are known to produce toxins are major components of the phytoplankton community. This pond should be monitored for algal blooms during the growing season and possibly tested for cyanotoxins if blooms are detected.

5.3 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.

Sutherland, J.W. and S.D. Oktay. 2010. *Hummock Pond Water Quality. 2009. A Summary of Physical, Chemical and Biological Monitoring*. 78 pp. + appendices.

Nantucket Island Ponds and 2019 Water Quality

Chapter 6

Miacomet Pond

6.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Miacomet Pond by the Nantucket Land Council (NLC) during 2019.

6.1 Results

During 2019, Miacomet Pond was sampled 5 times at about 2-week intervals beginning on July 22nd and ending on September 24th. Table 6-1 summarizes the 2019 sampling dates.

Table 6-1. Summary of 2019 sampling dates on Miacomet Pond.

July	August	September
22nd	5th	3rd
	19th	24th

Following the collection of temperature and dissolved oxygen profile data, integrate (upper) and grab (lower) samples were collected from the pond depths as shown in Table 6-2 below.

Table 6-2. Summary of Maicomet Pond integrate and grab sample depths, 2019.

Sampling Date	integrate (*upper*) sample depth	grab (*lower*) sample depth
July 22nd 2019	0-6 feet	7.5 feet
August 5th 2019	0-4 feet	na
August 19th 2019	0-6 feet	na
September 3rd 2019	0-6 feet	na
September 24th 2019	0-6 feet	na

Raw water samples were collected from Miacomet Pond for a Eurofins Abraxis® test strip analyses on 3 dates including dates not shown above when the pond shoreline was checked visually for evidence of HABs.

6.1.1 Physical characteristics

General. An aerial view of Miacomet Pond and the 2019 sampling location is shown in Figure 6-1.

Figure 6-1. Aerial view of Miacomet Pond (from *Google*™ earth) showing the 2019 sampling location.

Miacomet Pond is located along the south shore of Nantucket Island, just west of the Island wastewater treatment plant. The pond has a reported surface area of 47.3 acres (Conant, 2006) and is oriented along a southwest-northeast axis, having a long, narrow configuration and a total length of ≈1.5 miles (including the narrow channel at the northeast end which extends to Otokomi Road). The south end of the Pond is ≈400 feet wide and tapers to ≈100 feet in width where the Burchell's Pond outlet enters the pond. Beyond this point, the Pond is very constricted, an area appropriately called the Narrows, and tapers to a width of about 10 feet at the extreme northeast end. The Pond has a watershed area of 970.6 acres (Horsley et al., 1990), which yields a drainage basin to lake basin ratio of approximately 20:1. There is no outlet from Miacomet Pond, but the Pond has been breached historically and discharges to the ocean by natural and intentional means, most recently in 2005 (Conant, 2006).

Table 6-3 summarizes the 2019 physical data collected from Miacomet Pond including (1) total depth at the sampling station, (2) Secchi depth water transparency, and (3) average water column temperature.

Table 6-3. Summary of physical data collected from Miacomet Pond during 2019.

Miacomet Pond 2019 Physical Data			
Sampling Date	Total depth (m)	Secchi depth (m)	Avg Water Column Temperature (°C)
July 22nd	2.4	0.61	27.1
August 5th	2.4	1.50	27.6
August 19th	2.4	1.55	26.0
September 3rd	2.2	1.75	24.3
September 24th	2.2	1.55	21.6

The maximum depth of the pond was only slightly different among the 5 sampling dates; some of this depth difference could be due to pond evaporation during the summer and also sampling at a slightly different location.

Transparency. The lowest Secchi depth transparency (0.61 m or 2.0 ft) occurred on the July 22nd sampling date; thereafter, transparency more than doubled for the remainder of the 2019 sampling dates with a maximum water clarity of 1.75 m (5.7 ft) (Table 6-3). Field notes taken when the pond was sampled indicated either 'clear' or 'green' for water color.

Temperature. There never was a distinct thermal gradient exhibited between the surface and the bottom at the sampling station during 2019. The greatest difference between the surface and bottom temperatures occurred on the July 22nd sampling date when the surface temperature was 28.0 °C and the bottom temperature was 25.7 °C.

6.1.2 Chemical characteristics

The chemical characteristics measured at Miacomet Pond during 2019, including specific conductance, pH and dissolved oxygen saturation, are summarized in Table 6-4 and then discussed individually.

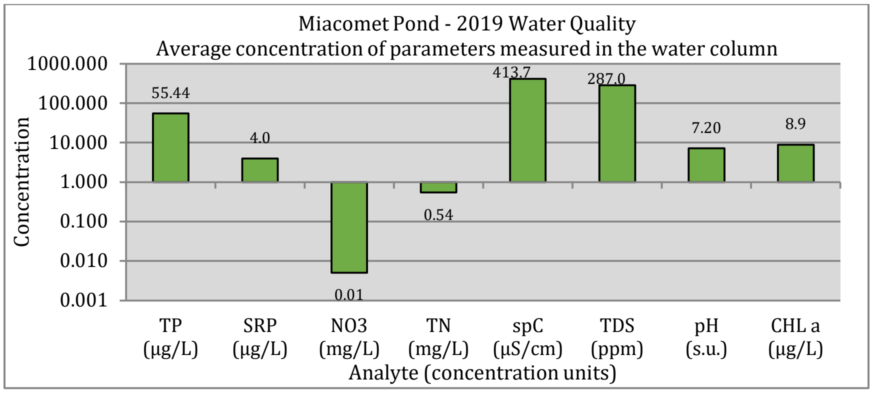
Table 6-4. Summary of 2019 chemical characteristics in *upper* region of Miacomet Pond.

	Capaum Pond 2019 Chemical Properties							
Sampling Date	Avg DO % saturation	TP (μg/L)	SRP (μg/L)	TN (mg/L)	NO_3-N (mg/L)	spC (μS/cm)	TDS (ppm)	pH (s.u.)
July 22nd	99.7	53.7	1.2	0.72	0.005	298	225	7.69
August 5th	110.6	56.9	1.7	0.69	0.005	294	192	7.43
August 19th	103.2	53.5	1.0	0.63	0.005	270	178	7.05
September 3rd	115.3	48.6	0.5	0.62	0.005	256	168	7.78
September 24th	105.1	64.5	15.4	0.06	0.005	952	672	6.06
2019 average value	106.8	55.4	4.0	0.54	0.005	414	287	7.20
all values shown are for the ***upper*** region (epilimnion) of the water column highlighted cells = values reported are one-half the lower detection limit								

The ***lower*** region of the pond was sampled on only one occasion (July 22nd) and those chemistry data are not summarized in Table 7-3.

Figure 6-2 which summarizes the ***upper*** and ***lower*** values for all chemical characteristics collected at Miacomet Pond during 2019.

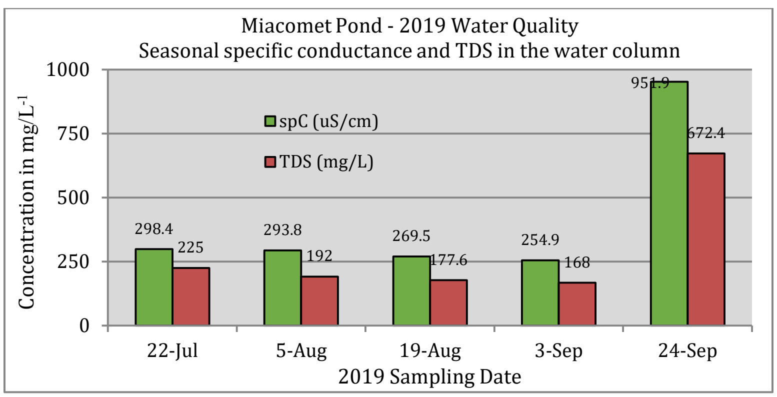
Figure 6-2. Summary of 2019 average concentrations of chemical analytes in Miacomet Pond.



The reader should note that the *y*-axis in Figure 6-2 is depicted in logarithm scale to appropriately display the full range of analyte concentrations.

Specific conductance and Total Dissolved Solids (TDS). The specific conductance and corresponding TDS values measured in the ***upper*** region of the Miacomet Pond water column during the 2019 sampling dates are presented in Figure 6-3.

Figure 6-3. Summary of 2019 specific conductance and TDS in *upper* samples from Miacomet Pond.



In general, 2019 conductance values reveal the influence of the Atlantic Ocean and salt water intrusion into the pond with values early in the season about 2-3 fold higher than conductance expected in truly freshwater systems. The effect of pond proximity to the ocean especially was realized on the last sampling date (September 24th) when an approximate 4-fold increase in conductance to 951.9 µS/cm^{-1} likely caused by high wind and aerosol influence over the barrier beach and perhaps some ocean seepage through the barrier into the pond.

pH. The 2019 pH values for Miacomet Pond are summarized in Table 6-4**.** The values for the first four (4) sampling dates were similar (7.05-7.78) except on September 24th when the pH dropped to 6.06 likely as a result of significant salt water intrusion into the pond. These Miacomet Pond pH concentrations are not displayed graphically.

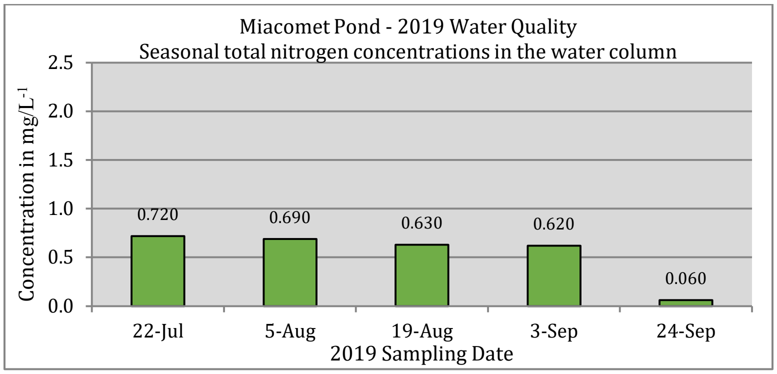
Oxygen concentration and saturation. The average 2019 dissolved oxygen percent saturation values at the Miacomet Pond sampling station are summarized in Table 6-4 but not displayed herein graphically. Dissolved oxygen was just below saturation on the first sampling date (July 22nd) and then slightly supersaturated on the four (4) subsequent sampling dates, indicating good phytoplankton productivity in the pond.

6.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen (**NO_3-N**) concentrations in the pond were below the level of detection on all 2019 sampling dates which is not unusual because this form of nitrogen is readily available for uptake by the primary producers (phytoplankton).

Figure 6-4 summarizes the **total nitrogen** (**TN**) concentrations measured in the pond ***upper*** region samples during 2019.

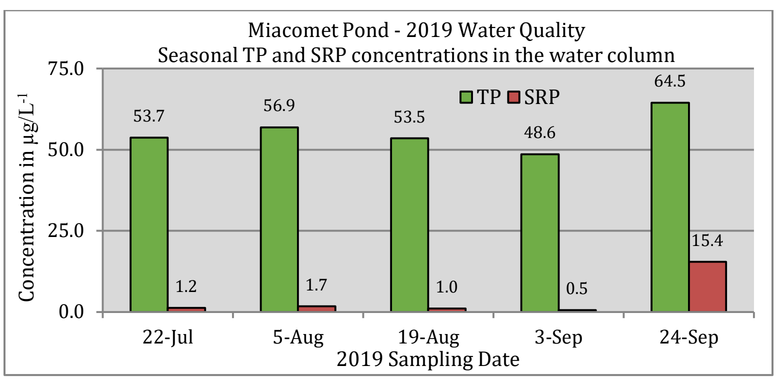
Figure 6-4. Summary of 2019 total nitrogen concentrations in Miacomet Pond.



The concentrations of **TN** in the water column of Miacomet Pond were low (< 1 mg N·L^{-1}) and steadily decreased throughout the season, decreasing by an order of magnitude on the last sampling date (September 24th) to a value of 0.06 mg N·L^{-1}, which is further evidence for a major dilution of water in the pond by some major intrusion of water from the Atlantic Ocean which is located such a short distance across the separating barrier beach.

Phosphorus. The **total phosphorus** (**TP**) and **soluble reactive phosphorus** (**SRP**) concentrations measured in ***upper*** and ***lower*** regions of Capaum Pond during 2019 are summarized in Figure 6-5.

Figure 6-5. Summary of 2019 total and soluble reactive phosphorus concentrations in Miacomet Pond.



TP concentrations were moderate and consistent with little variation throughout the season except for a slight increase on the September 24th sampling date, further evidence of some major wind/water event that affected the pond. **SRP** also was low, decreasing to below detection on September 3rd and then increasing dramatically to 15.4 µg P·L^{-1} on September 24th, likely in response to a major wind event which mixed the water column from surface to bottom and initiated release of **SRP** from anaerobic zone at the sediment-water interface.

6.1.4 Phytoplankton

Description of the assemblage. Table 6-5 presents a summary of the Miacomet Pond phytoplankton community characteristics determined from six (6) samples collected during 2019.

Table 6-5. Summary of 2019 Miacomet Pond phytoplankton community characteristics.

Gibbs Pond Phytoplankton, 2019						
Sampling Date	Total Genera	Cell Density (cells/mL^{-1})	Cell Biomass (mg/m^3)	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration (µg/L^{-1})
July 22nd	34	12,710	12,375	1.179	0.984	14.0
August 5th	36	33,259	21,234	0.671	0.551	14.3
August 19th	23	27,666	4,218	0.619	0.899	3.7
August 26th	30	11,910	5,949	0.823	0.887	-
September 3rd	34	23,635	9,927	0.862	1.008	3.8
September 24th	32	22,658	3,825	0.735	1.097	8.7
2019 average	32	21,973	9,588	0.815	0.904	8.9

The phytoplankton community characteristics summarized above will be discussed individually in the following sections of this chapter.

As summarized in Table 6-6, a total of 64 genera were identified in the 2019 phytoplankton samples collected from Miacomet Pond; 2019 phytoplankton community richness was 31.5 (±4.6) genera.

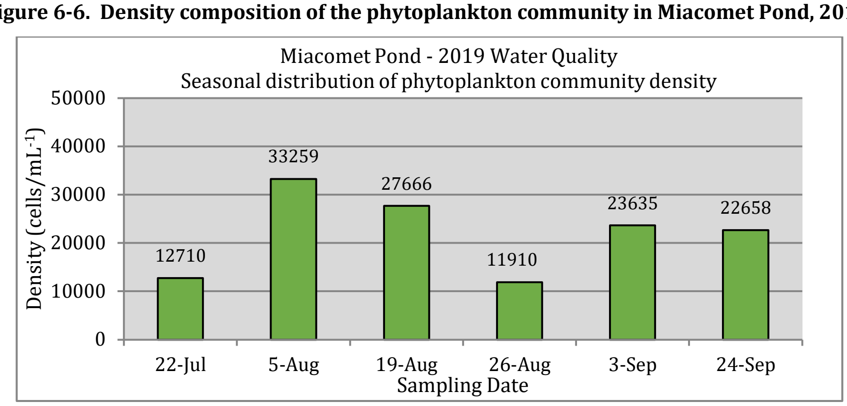
Table 6-6. Major groups and genera of phytoplankton identified in Miacomet Pond, 2019.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyta)**
Anabaena flos aquae	*Pediastrum duplex*	*Nitzschia* sp.
Aphanizomenon flos aquae	*Pyraminonas tetrarhyncus*	*N. longissima*
Aphanocapsa elachista	*Scenedesmus bijuga*	*Pinnularia* sp.
Gomphosphaeria lacustris compacta	*S. bijuga alternans*	*Planothidium* sp.
Merismopedia glauca	*S. quadricauda*	*Stauroneis* sp.
Oscillatoria sp.	*Schroederia Judayi*	*Synedra acus*
Planktothrix sp. (filaments)	*Selenastrum capricornutum*	*S. fulgens*
Woronichinia Naegeliana	*S. minutum*	*S. ulna*
Chlorophyta	*Staurastrum natator* var. *crassum*	**Chrysophyta (Chrysophyceae)**
Ankistrodesmus falcatus	*Tetraedrom minimum*	*Dinobyron divergens*
Closteriopsis longissima	*Xanthidium subhastiferum*	*Mallomonas* sp.
Closterium acutum	**Chrysophyta (Bacillariophyta)**	*Ochromonas* sp.
C. gracile	*Achnanthes* sp.	**Euglenophyta**
Coelastrum cambricum	*Aulacoseria granulata*	*Euglena* sp.
Cosmarium spp.	*Cocconeis* sp.	*Peranema* sp.
Dictyosphaerium Ehrenbergianum	*Cyclotella* sp.	*Trachelomonas* sp.
Gonyostomum semen	*Fragilaria crotonensis*	**Pyrrhophyta (Cryptophyceae)**
Monoraphidium arcuatum	*F. capucina*	*Cryptomonas erosa*
M. contortum	*Gomphonema* spp.	*C. ovata*
Mougeotia sp.	*Gyrosigma* sp.	*Ceratium hirundinella*
Oocystis Borgei	*Hippodonta* sp.	*Peridinium cinctum*
O. pusilla	*Navicula* spp.	
O. solitaria	*Neidium* sp.	

The major phytoplankton groups in the 2019 assemblage included the Chlorophytes (18 genera), Bacillariophytes (17 genera) and Cyanophytes (8 genera).

Density. Phytoplankton cell density in Miacomet Pond ranged from 11,910-33,259 cells·mL^{-1} throughout the 2019 sampling dates (Figure 6-6), and the average density was 21,973 cells·mL^{-1}.

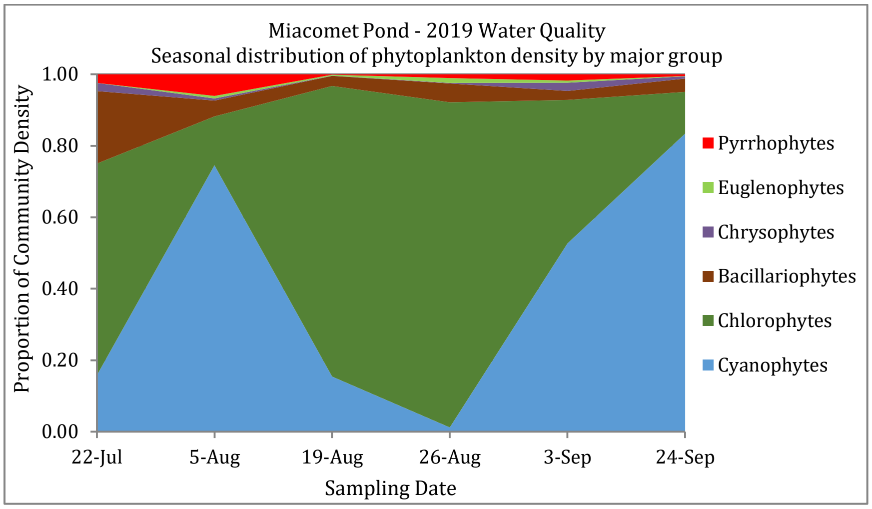
Figure 6-6. Density composition of the phytoplankton community in Miacomet Pond, 2019.



These cell densities are indicative of a moderate level of productivity in the pond which also was reflected by the relatively low chlorophyll a concentrations.

A summary of seasonal distribution of major phytoplankton groups in the density composition of the 2019 community in Miacomet Pond is summarized in Figure 6-7.

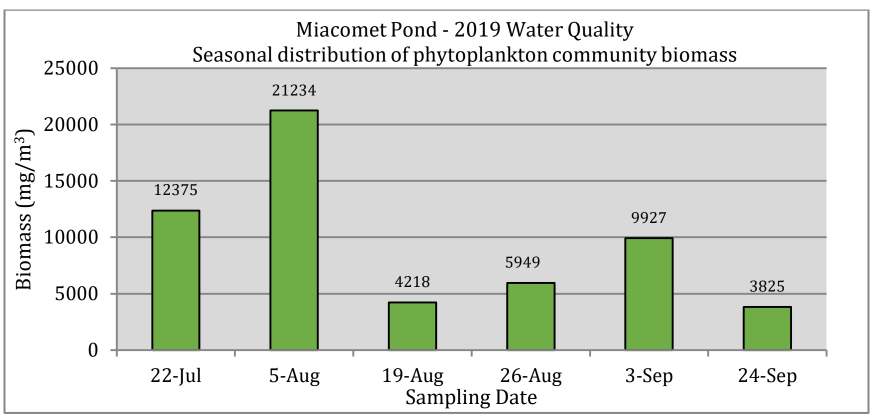
Figure 6-7. Density composition of the major groups of phytoplankton in the Miacomet Pond community, 2019.



Cyanophytes and Chlorophytes were the major density dominants during 2019, exhibiting fluctuations opposite each other as shown in Figure 6-7. The other four (4) major groups of phytoplankton were minor players in the 2019 community density.

Biomass. Biomass ranged from 4,218-21,234 mg/m^3 among the six (6) 2019 sampling dates, and averaged 9,565 mg/m^3. The 2019 biomass composition of the Miacomet phytoplankton community is presented in Figure 6-8.

Figure 6-8. Summary of 2019 phytoplankton community biomass in Miacomet Pond.

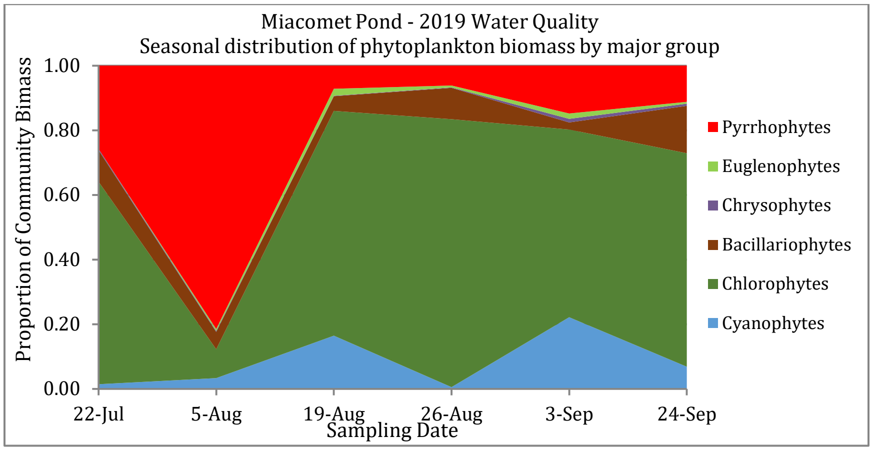


It would appear from these data that some major disruptions occurred in the community during 2019 because of the significant biomass reduction between August 5th (21,234 mg/m^3) and August 19th (4,218 mg/m^3). Thereafter, the community biomass increased steadily from Augsy 19th through September 3rd, and then decreased sharply by the September 24th sampling date.

A summary of seasonal distribution of major phytoplankton groups in the biomass composition of the 2019 community in Miacomet Pond is summarized in Figure 6-9. With regard to biomass, the Cyanophytes are considerably less important in the 2019 phytoplankton community, while the

Chlorophytes retain their importance and the Pyrrhophytes are a major component even though their presence in the community composition was barely visible (Figure 6-7).

Figure 6-9. Biomass composition of the major groups of phytoplankton in the Miacomet Pond community, 2019.



Dominance. Dominant phytoplankton in the 2019 Miacomet Pond community are listed in Table 6-7.

Table 6-7. Rank of 2019 phytoplankton dominance in Miacomet Pond.

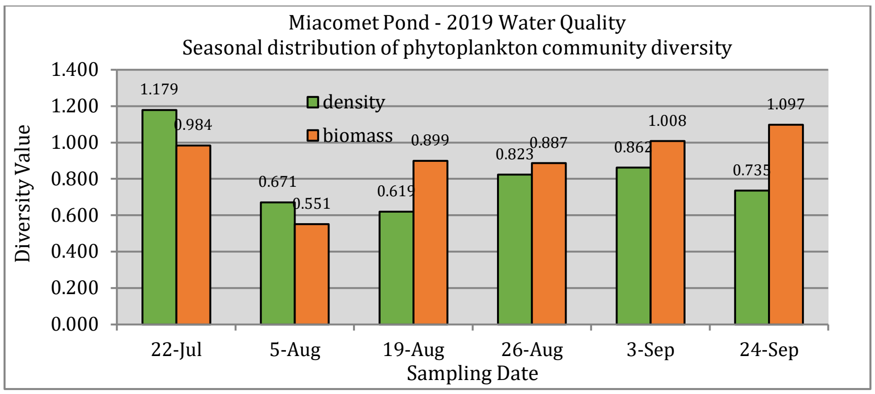
Sampling Date	Genus-species (Major Group)	Density Rank	% of Total Density	Biomass Rank	% of Total Biomass
July 22nd	Anabaena flos aquae (Cyanophyte)	4	5.8		
	Woronichinia Naegeliana (Cyanophyte)	5	5.7		
	Coelastrum cambricum (Chlorophyta)	1	20.4	2	21.9
	Selenastrum capriconnutum (Chlorophyte)	2	16.4		
	Cyclotella sp. (Bacillariophyta)	3	12.6		
	Pediastrum duplex (Chlorophyte)			3	15.1
	Aulacoseria granulata (Bacillariophyte)			4	5.2
	Ceratium hirundinella (Pyrrhophyte)			1	23.2
August 5th	Aphanizomenon flos aquae (Cyanophyte)	2	9.7		
	Aphanocapsa elachista (Cyanophyte)	1	64.8		
	Ceratium hirundinella (Pyrrhophyte)	3	4.6	1	72.8
	Peridinium cinctum (Pyrrhophyte)			2	7.2
August 19th	Aphanizomenon flos aquae (Cyanophyte)	2	12.7	2	16.0
	Coelastrum cambricum (Chlorophyte)	4	4.9	1	33.9
	Scenedesmus bijuga (Chlorophyte)	3	5.9		
	Selenastrum capriconnutum (Chlorophyte)	1	63.6	3	12.9
	Pediastrum duplex (Chlorophyte)			4	11.4
	Ceratium hirundinella (Pyrrhophyte)			5	7.1
August 26th	Coelastrum cambricum (Chlorophyte)	2	19.3	1	40.5
	Monoraphidium arcuatum (Chlorophyte)	4	5.7		
	Scenedesmus bijuga (Chlorophyte)	3	12.4		
	Selenastrum capriconnutum (Chlorophyte)	1	45.9	2	
	Pediastrum duplex (Chlorophyte)				21.7
	Staurastrum natator var. crassum (Chlorophyta)			4	6.0
	Cryptomonas ovata (Pyrrhophyte)			3	6.2
September 3rd	Aphanizomenon flos aquae (Cyanophyte)	1	45.0		48.5
	Gomphosphaeria lacustris compacta (Cyanophyte)	4	5.4		
	Coelastrum cambricum (Chlorophyte)	3	10.9	1	27.3
	Selenastrum capriconnutum (Chlorophyte)	2	18.3		
	Pediastrum duplex (Chlorophyte)			3	10.1
	Staurastrum natator var. crassum (Chlorophyta)			2	14.5
	Cryptomonas ovata (Pyrrhophyte)			5	6.3
	Ceratium hirundinella (Pyrrhophyte)			4	7.2
September 24th	Oscillatoria sp. (Cyanophyte)	1	41.2	6	4.6
	Planktothrix sp. (filaments)(Cyanophyta)	2	34.7		
	Coelastrum cambricum (Chlorophyte)			2	16.3
	Gonyostomum semen			4	8.3
	Pediastrum duplex (Chlorophyta)			1	27.2
	Staurastrum natator var. crassum (Chlorophyta)			3	9.7
	Cryptomonas ovata (Pyrrhophyte)			5	7.1

The data summarized in Table 6-7 demonstrate the rapid changes that occurred during a 2-month period within the phytoplankton community with regard to the composition of density- and biomass-dominant taxa. Many genera occurred on 1 or 2 occasions during 2019 and were either a density or biomass dominant at that time. Other genera, such as the Chlorophyte, *Coelastrum cambricum*, was observed in the community on 5 of 6 sampling dates and was a density and biomass dominant on multiple occasions.

Diversity. Phytoplankton diversity in Miacomet 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 diversity index value. Values that approach 1.0 indicate conditions of maximum diversity in the population distribution.

A summary of 2019 density and biomass diversity values for Miacomet Pond are shown in Figure 6-10.

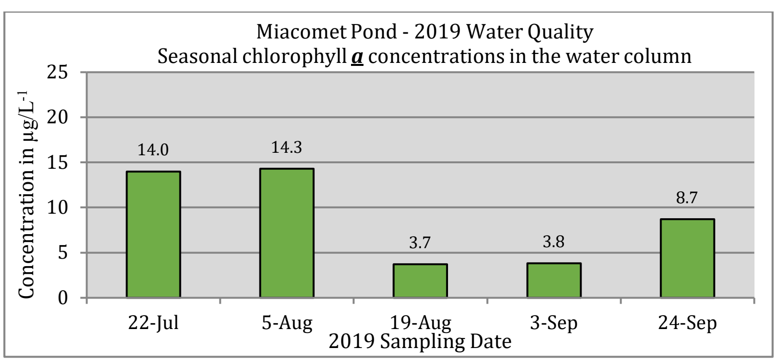
Figure 6-10. Phytoplankton community density and biomass diversity in Miacomet Pond, 2019.



Density and biomass diversity values were in close proximity to each other on all sampling dates except August 19th and September 24th; the lowest diversity value for both parameters occurred on August 5th. Reference to Table 6-7 provides the density and biomass information that caused these community diversity values to be so low, i.e., 64.8 percent of the community density occurred in one species, the Cyanophyte, *Aphanocapsa elachista*, while 72.8 percent of the total community biomass occurred in the Pyrrhophyte, *Ceratium hirundinella*. Overall, however, for the entire 2019 sampling season, density diversity averaged 0.815 while biomass diversity averaged 0.900.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Miacomet Pond during 2019 ranged from 3.7-14.3 $\mu g \cdot L^{-1}$ (Figure 6-11) and the average value for the sampling season was 8.9 $\mu g \cdot L^{-1}$ (Table 6.5).

Figure 6-11. Summary of 2019 chlorophyll *a* values in Miacomet Pond.



Based upon previous Nantucket pond sampling, these chlorophyll ***a*** values indicate low productivity.

[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.

6.1.5 Trophic Status

There were sufficient water quality data, including Secchi depth transparency, total phosphorus and chlorophyll ***a***, collected from Miacomet Pond during 2019 to calculate the Carlson Trophic State Index for all three (3) analytes. The average value for each analyte was substituted into the equations (see Chapter 1) to calculate TSI values. The equations and sequence of calculations are presented below.

Chlorophyll *a*

Average chlorophyll ***a*** = 8.90 µg/L^{-1}

Chlorophyll *a* TSI = 9.81*[ln (8.90)] + 30.6

TSI = (9.81)(2.19) + 30.6

TSI = 52.0

Total phosphorus

Average total phosphorus = 55.4 µg/L^{-1}

Total phosphorus TSI = 14.42*[ln (55.4)] + 4.15

TSI = (14.42)(4.02) + 4.15

TSI = 62.1

Secchi depth

Average Secchi depth = 1.39 m

Secchi TSI = 60 – [14.41*[ln (1.39)]

TSI = 60 – (14.41)(0.331)

TSI = 55.2

Table 6-8 summarizes Carlson's Trophic State Index in relation to the 3 independent water quality variables used as predictors of the trophic classification of lakes and ponds.

Table 6-8. Relationships among Trophic Index (TI) , chlorophyll *a*, total phosphorus, Secchi depth and Trophic Class (after Carlson 1996).

Trophic State Index	Chlorophyll *a* (µg·L^{-1})	Total phosphorus (µg·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

The calculated TSI indices for chlorophyll ***a*,** total phosphorus and Secchi TSI (55.2) placed Miacomet Pond in the lower range of the eutrophic class of productivity.

6.2 Summary

Miacomet Pond exhibits eutrophic productivity based upon the TSI values calculated from the three variables collected during 2019. Miacomet is one of the larger ponds on Nantucket Island and has a sizeable watershed which obviously contributes sufficient nutrients to place the pond within the high productivity bracket. A recent study indicates that phosphorus release from the bottom sediments can provide a significant internal input of this nutrient into the system. Furthermore, the pond has a diverse and healthy representation of Cyanophytes in the phytoplankton community and regular monitoring should be implemented to track the pond for algal blooms and the possible release of toxins which can cause a public safety risk for recreational users of the pond.

6.3 Literature Cited

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Nantucket Island Ponds and 2019 Water Quality

Chapter 7

Cyanophytes, Cyanotoxins and Water Quality Concerns for Nantucket Island Ponds

7.0 Introduction

The major focus of the 2019 water quality monitoring on Nantucket Island was the detection of HABs at the four (4) ponds under investigation. The full scope of this effort included (1) the regular collection of integrated phytoplankton samples from the water column to archive and document the community of each pond, (2) routine weekly observation of the shoreline area of each pond for evidence of HABs, (3) the collection of a water sample for an Eurofins Abraxis® toxin strip test, (4) the analysis of raw water samples for a potentially toxigenic cyanobacteria screen, and based upon these results, (5) the analysis of detectable cyanotoxins present in the water column during conditions suspected to be HABs, and (6) deployment of the Aerosol Filter Collection Device (AFCD) to document transport of aerosolized cyanotoxins and/or airborne pico-cyanobacteria away from the affected pond to adjacent areas where local residents or recreational users could be exposed through contact (inhalation).

Given the importance of Cyanophytes as a biological component in the Nantucket pond ecosystems and its status in the overall 2019 research work-plan, it seemed appropriate to dedicate a chapter of this report to Cyanophytes, cyanotoxins and the findings related to Nantucket Island ponds. Basic information related to the phytoplankton communities of each pond monitored in 2019 was presented in the earlier chapters that summarized the 2019 water quality data. The information presented in this chapter relates specifically to the 2019 Cyanophyte data collected from each pond.

N.B. Author's Note: The terms 'Cyanophyte', 'cyanophyte' and 'cyanobacteria' are used interchangeably within the text of this chapter and throughout the overall report. In general, 'Cyanophyte' and 'Cyanobacteria' both refer to the major group of algae (phytoplankton) historically known as Blue-greens. The use of one term or another merely indicates the author's preference for the material being reported in the text. For example, GreenWater CyanoLab uses the term 'cyanobacteria' exclusively in their testing and reporting, whereas this report author has used 'Cyanophyte' and 'cyanophyte' to either describe the major group of phytoplankton occurring in Nantucket ponds since 2009 when reports first were issued or a particular genera and/or species under discussion in the text.

7.1 Background

As a major group within the phytoplankton, Cyanophytes are ubiquitous, occurring in almost every habitat, and their presence in small numbers in the phytoplankton assemblage of aquatic ecosystems usually is part of a natural process of succession during the growing season. When present in large numbers such as happens in algal 'bloom' conditions, however, Cyanophytes can induce physical, chemical and biological changes in the aquatic environment in which they occur and eventually affect the ecosystem in a negative manner which, over a long period of time, may require some direct remedial action to reverse or overcome.

High concentrations ('blooms') of Cyanophytes in the water column lowers transparency, reducing the depth of the photic zone (area of the water column where incident light is sufficient to allow photosynthesis to occur) and the volume of water (surface area and depth in the pond) that supports other photosynthetic organisms. Many forms of Cyanophytes have internal gas vacuoles that enable them to regulate their depth in the water column to maximize photosynthesis, whereas many of the other forms of phytoplankton have no means of mobility and are subject to the influence of gravity and eventually settle to the bottom.

In addition, high concentrations of Cyanophytes and other algae in the water column result in high rates of cell die-off due to very brief life cycles, thus creating biomass which settles to the bottom and causes oxygen depletion through decomposition of the dead plant material and other organic matter in the bottom sediments. De-oxygenation has a direct negative effect on aquatic organisms in the bottom region of lakes and ponds that depend on oxygen for survival, as well as the indirect effect of toxic gas release and nutrient mobilization into the water column.

In shallow water systems, exhibited by many Nantucket Island ponds, there are regular periods of wind-induced circulation where the ***lower*** region of the water column mixes with the ***upper*** region of the water column, which temporarily reduces overall oxygen saturation and distributes mobilized nutrients throughout the pond for uptake and metabolism by phytoplankton. The release of nutrients into the water column exacerbates the cycle by encouraging increased primary productivity by phytoplankton in an already over-productive and stressed system.

By the time a dense Cyanophyte mat, resembling spilled blue-green paint, is seen floating on the surface of the pond, the cells already have affected the aquatic ecosystem in which they are located and, under certain conditions, can pose health and safety issues for recreational users of the water body. Algal cells floating on the surface and forming a blue-green scum, already have died and lysed, releasing their cell contents into the surrounding environment.

In certain instances, the dead, lysed cells forming a scum on the pond surface are Cyanophytes that produce cyanotoxins and release these toxins (cyanotoxins) when ruptured. The cyanotoxins include neurotoxins (affect the nervous system), hepatotoxins (affect the liver) and dermatoxins (affect the skin). There are several pathways of exposure to cyanobacteria (Cyanophytes) and their toxins including ingestion of drinking water contaminated with cyanotoxins and through direct contact, inhalation and/or ingestion during recreational activities. A wide range of symptoms can occur in humans following acute recreational exposure to HABs and associated toxins including fever, headaches, muscle and joint pain, blisters, stomach cramps, diarrhea, vomiting, mouth ulcers, and allergic reactions.

The body of knowledge surrounding these Cyanophytes and their toxins has grown rapidly, particularly during the past few decades. As of 2008, when a major NATO document (Zaccaroi and Scaravelli, 2008) was released on algal toxins, 46 species of Cyanophytes were identified that produce toxins. In fact, at the time, some researchers believed that it would be prudent to assume any Cyanophyte population has toxic potential in the aquatic ecosystem in which it is located.

Another summary of Cyanophytes and cyanotoxins published by the US Environmental Protection Agency (2014) provided a breakdown of the three (3) primary cyanotoxins (Microcystin-LR, Cylindrospermopsin, Anatoxin-a), the number of known analogues of each toxin, a summary of health effects, and the most common Cyanophyte genera with the potential of producing toxin. The US EPA summary information is presented in Table 7-1.

Table 7-1. Summary of primary cyanotoxins, health effects and potential toxin-producing Cyanophyte genera[1].

<table>
<tr><th>Cyanotoxin</th><th># Known Analogues</th><th>Primary Organ Affected</th><th>Health Effects</th><th>Most common Cyanophyte genera producing toxin[2]</th></tr>
<tr><td>Microcystin-LR</td><td>80~90</td><td>Liver</td><td rowspan="2">Abdominal pain
Vomiting and diarrhea
Liver inflammation and hemorrhage
Acute pneumonia
Acute dermatitis
Kidney damage
Potential tumor growth promotion</td><td>Microcystis
*Dolichospermum
Planktothrix
Anabaenopsis
Aphanizomenon
**Woronichinia</td></tr>
<tr><td>Cylindrospermopsin</td><td>3</td><td>Liver</td><td>Cylindrospermopsis
Aphanizomenon
Dolichospermum
Lyngbya
Rhaphidiopsis
Umezakia</td></tr>
<tr><td>Anatoxin-a group</td><td>2-6</td><td>Nervous system</td><td>Tingling, burning, numbness, drowsiness, incoherent speech, salivation, respiratory paralysis leading to death</td><td>Dolichospermum
Planktothrix
Aphanizomenon
Cylindrospermopsis
Oscillatoria</td></tr>
<tr><td colspan="5">1 table from US EPA 2014.</td></tr>
<tr><td colspan="5">2 not all species of the genera listed produce toxin, listed genera not equally as important in producing toxins</td></tr>
<tr><td colspan="5">* previously the genus Anabaena; ** previously the genus Coelosphaerium</td></tr>
</table>

For some unknown reason, the US EPA cyanotoxin summary information failed to mention *Saxitoxin*, a potent neurotoxin and the substance known as *paralytic shellfish toxin*; used collectively, the term Saxitoxin also refers to the suite of more than 50 structurally related analogues (https://en.wikipedia.org/wiki/Saxitoxin).

The Cyanophyte genera identified so far that are known to produce this toxin include *Dolichospermum*, *Aphanizomenon*, and *Sphaerospermopsis*.

Following review of some scientific literature, it appears that considerable time and world-wide research have occurred since the US EPA cyanotoxin summary was compiled (2014) and it is likely that the list of potential toxin-producing genera has increased since then.

7.2 Results

The results presented in this section and sections beyond relate to the portion of the 2019 work-plan dealing with cyanophytes, cyanotoxins and a summary of findings following the conclusion of the active monitoring effort. The basic information on the phytoplankton communities that occurred in the individual ponds was included in separate chapters earlier in this report.

7.2.1 Eurofins Abraxis® Fresh Water Test Strips

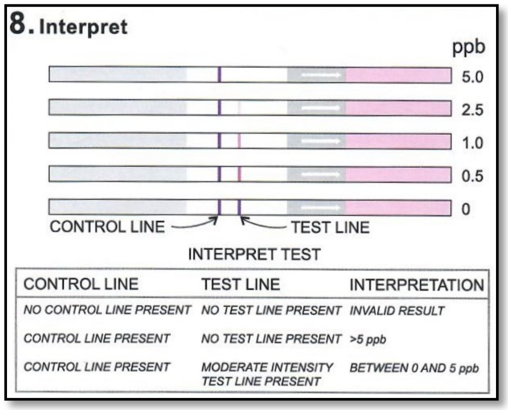
Routine weekly observations were conducted along the shoreline of the four (4) ponds during 2019 to check for potential HABs in progress, determined by the presence of a surface scum resembling spilled blue-green paint (see Figure 7-1).

Figure 7-1. Capaum Pond shoreline exhibiting a potential HAB on August 26th 2019 (photo credit RJ Turcotte).

If observed conditions indicated a possible HAB in progress at a pond, then a water sample was collected and returned to the NLC office for an Eurofins Abraxis® strip test for *Microcystins*, 0-5 ppb, Finished Drinking Water (PN 520017 [20 tests]). According to the manufacturer's literature, if the sample contains toxin over the US EPA health advisory or WHO (World Health Organization) concentration limits (1.0 ng/mL^{-1}), the test will detect the toxin even if there are no visible algal cells in the sample. The only test kit departure as far as use instructions for Nantucket concerned the series of three (3) freeze-thaw cycles to lyse the cells because chloride in the ponds interferes with the lysing material normally used in conjunction with the test strips. The procedure for conducting an algal strip test with the Eurofins Abraxis® kit for *Microcystins* is presented in Attachment #2 at the end of this report.

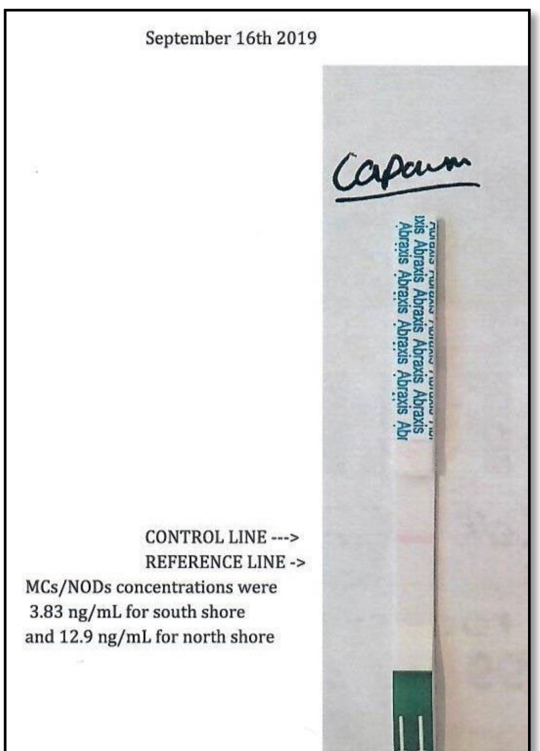
During the 2019 sampling period, a total of 27 different Eurofins Abraxis® strip tests for Microcystins were performed on pond samples including 8 samples from Capaum, 10 samples from Gibbs, 6 samples from Head of Hummock and 3 samples from Miacomet. The interpretation of the algal toxin strip test for presence of toxins is somewhat counterintuitive because the test requires visual comparison of a 'control' line on the strip with a 'test' line on the strip and the intensity of the test line determines the relative concentration of toxin present, with a less intense 'test' line indicating higher concentration and a more intense 'test' line indicating less concentration. Figure 7-2 presents a section from the Eurofins Abraxis® visual instruction for conducting the *Microcystin* strip test.

Figure 7-2. Excerpt from Eurofins Abraxis® strip test for *Microcystin* showing determination of toxin concentration.



As shown in the company literature above, the higher concentrations of toxin are indicated by less intense test lines compared with the control line. Unfortunately, the progression of test line intensities was not always apparent when conducting the Eurofins Abraxis® strip test for *Microcystin* on Nantucket ponds. In most cases, the control line that developed was very faint and the test line appeared to be non-existent (Figure 7-3).

Figure 7-3. Results of an Eurofins Abraxis® strip test for Microcystin on Capaum Pond, September 16th 2019 (photo credit RJ Turcotte).



7.2.2 Potentially Toxigenic (PTOX) Cyanobacteria Screen.

The follow-up to a positive strip test result such as the one shown above usually would prompt sending a cooled raw water sample collected from the subject pond overnight to GreenWater CyanoLab in Palatka, Florida for a Potentially Toxigenic (PTOX) Cyanobacteria Screen. During 2019, GreenWater CyanoLab performed a total of 16 separate PTOX tests on samples received from Nantucket ponds as summarized in Table 7-2.

Table 7-2. Summary of 2019 Nantucket pond samples submitted to GreenWater CyanoLab for PTOX testing.

	Nantucket Island Pond			
2019 Date	Capaum	Gibbs	Head of Hummock	Miacomet
August 5th		X	X	X
August 26th	X	X	X	X
*September 11th	X			
*September 16th	X			
September 24th		X		
September 30th	X			
October 7th	X			
October 21st	X	X		
* 2 samples submitted for PTOX analysis				

The results of the PTOX testing usually were reported back to the Program cooperators within 48-72 hours from the GreenWater CyanoLab receiving the live sample shipment. The results for each raw water sample received were reported as potentially toxin-producing genera (and toxin produced) occurring in the sample. The results would include recommendations for subsequent toxin analysis.

Table 7-3 summarizes the Cyanophyte genera and species identified in Capaum, Gibbs, Head of Hummock and Miacomet Ponds by GreenWater CyanoLab during 2019.

Table 7-3. A summary of Cyanophyte genera and species (where listed) identified in Nantucket Island ponds, 2019.

Genus - species	Capaum	Gibbs	Head of Hummock	Miacomet
* *Anabaena (Dolichospermum) flos aquae*	X	X	X	X
**Anabaenopsis Elenkinii*			X	
**Aphanizomenon flos aquae*	X	X	X	X
Aphanocapsa elachista	X	X	X	X
Chroococcus dispersus	X	X		
C. limneticus	X		X	
Gomphosphaeria lacustris compacta	X	X		X
Merismopedia glauca	X	X		X
**Microcystis aeruginosa*	X			
* *Oscillatoria* sp.				X
**Planktothrix* sp. (filaments)	X	X		X
Rhabdoderma Gorskii		X		
**Woronichinia Naegeliana*	X	X		X
* genera known to potentially produce toxin				

All four (4) ponds were observed to contain several genera of cyanophytes including Capaum and Gibbs Ponds with 9 genera, Head of Hummock Pond with 5 genera, and Miacomet Pond with 8 genera. Each pond also exhibited several Cyanophyte genera known to potentially produce harmful cyanotoxins, including Capaum and Miacomet with 5 genera, 4 genera observed in Gibbs Pond, and 3 genera observed in Head of Hummock Pond.

N.B. Author Note: There were discrepancies in the identification and enumeration of 2019 phytoplankton samples processed by the independent consultant retained by the NLC and the GreenWater CyanoLab with respect to Cyanophyte genera and species of the phytoplankton community in the Nantucket ponds. In general, the GreenWater CyanoLab identified more Cyanophyte genera (and species where possible) and higher densities in the 2019 samples that were submitted to both entities for a quality assurance check.

Having received the individual reports and realizing these differences, there was no attempt to reconcile the issues, nor would it have been possible to do so after the fact, without incurring excessive cost to have all of the 2019 phytoplankton community samples re-analyzed. Therefore, the following material that summarizes the Cyanophyte data collected from the individual Nantucket ponds during 2019 is not always consistent with the Cyanophyte data received from the GreenWater CyanoLab as part of the quality assurance check.

7.2.3 Nantucket Ponds, Cyanophytes and Cyanotoxins in 2019

The following material summarizes 2019 Cyanophyte and related data collected from each of the individual Nantucket Island ponds.

7.2.3.1 Capaum Pond

Cyanophytes. Cyanophytes were identified in all 7 samples collected from Capaum Pond in 2019. A total of 9 different genera and 10 different species were identified; these cyanophytes are summarized in Table 7-4.

Table 7-4. Cyanophytes identified in Capaum Pond, 2019.

Cyanophyte species	
*Anabaena flos aquae**	*Gomphosphaeria lacustris compacta*
*Aphanizomenon flos aquae**	*Merismopedia glauca**
Aphanocapsa elachista	*Microcystis aeruginosa**
Chroococcus dispersus	*Planktothrix* sp.*
C. limneticus	*Woronichinia Naegeliana**
* = genera known to potentially produce toxins	

All of the Cyanophyte genera identified in the table above have been reported to produce algal toxins except *Aphanocapsa* sp., *Chroococcus* spp. and *Gomphosphaeria* sp.

The population dynamics of the Cyanophytes on the seven 2019 sampling dates compared with the density and biomass of the phytoplankton community are illustrated in Figures 7-4 and 7-5, respectively.

Figure 7-4. Capaum Pond – 2019 cyanophyte and total phytoplankton density

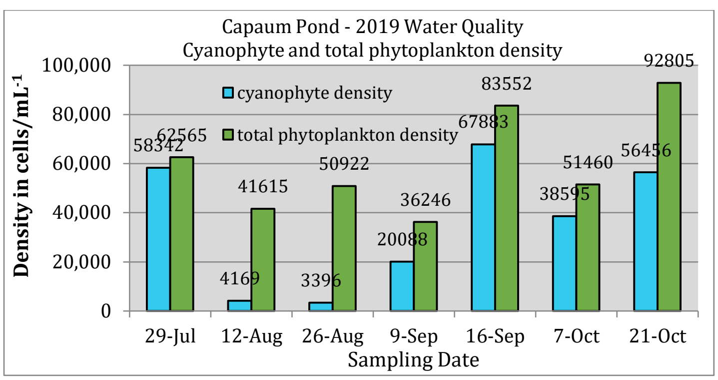
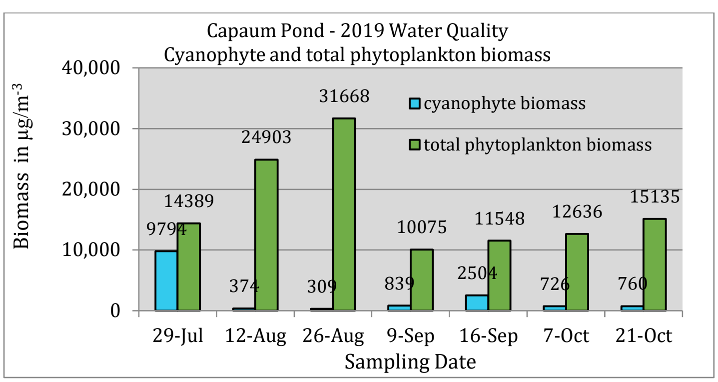


Figure 7-5. Capaum Pond – 2019 cyanophyte and total phytoplankton biomass



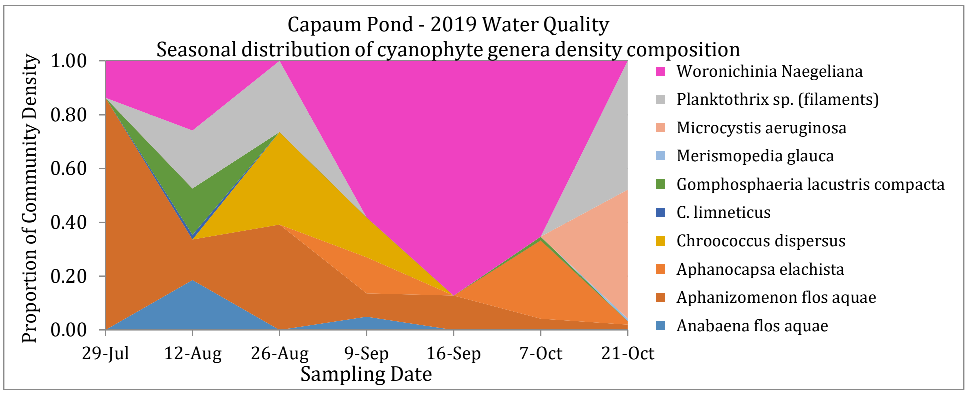
When compared with the total phytoplankton community density in Capaum Pond between late July and late October 2019, the Cyanophytes ranged from about 7 percent of the total community (on August 26th) to over 90 percent of the total community (on July 29th), and averaged about 55 percent of the total community density during the entire sampling period.

The relative importance of Cyanophyte biomass in the 2019 phytoplankton community was in sharp contrast (greatly diminished) to the density, i.e., the Cyanophyte biomass ranged from 68 percent (on July 29th) to 1.0 percent (on August 26th), and the Cyanophyte average for the 2019 sampling season was about 16 percent of the total phytoplankton community biomass.

There were considerable fluctuations of specific genera exhibited within the Cyanophytes among the 7 sampling dates with respect to density and biomass with some genera demonstrating importance throughout the sampling season and other genera being present at various times but not as important in terms of total numbers (density) or biovolume (biomass).

Figure 7-6 summarizes the density distribution of cyanophyte genera during 2019 in Capaum Pond.

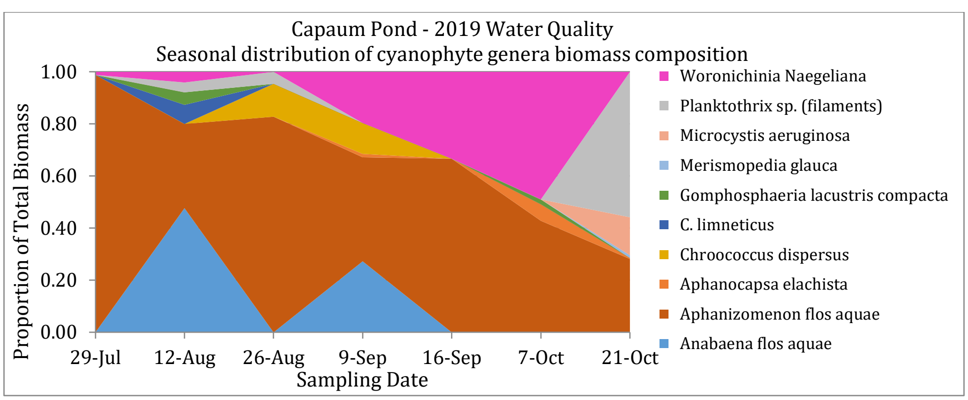
Figure 7-6. Seasonal distribution of cyanophyte genera density in Capaum Pond, 2019.



The dramatic fluctuations of Cyanophyte genera density over time within this major phytoplankton group are emphasized above. Genera such as *Aphanizomenon* and *Woronichinia* were present in the water column throughout most of the sampling season, whereas genera such as *Aphanocapsa*, *Chroococcus* and *Planktothrix* were readily apparent on some sampling dates but exhibited greatly reduced density on other sampling dates to the point of not being evident in Figure 7-6.

Figure 7-7 summarizes the biomass distribution of cyanophyte genera across the 7 sampling dates during 2019 in Capaum Pond.

Figure 7-7. Seasonal distribution of cyanophyte genera biomass in Capaum Pond, 2019.



The 2019 biomass fluctuations within the Cyanophytes were as dynamic as the density fluctuations during the same period. Genera such as *Aphanizomenon* and *Woronichinia* exhibited major biomass importance throughout the 2019 sampling season and maintained dominance within the Cyanophytes as also was demonstrated with respect to density. Other genera, such as *Planktothrix* and *Gomphosphaeria*, were so small in size as to be rendered almost not visible in Figure 3-16, even though the genera were present in the density graph (Figure 7-6).

The fact that major changes within the phytoplankton community can occur within a relatively brief period of time emphasizes the need to sample these island ponds with an appropriate frequency so that major changes in density and biomass are documented to the extent that patterns can be elucidated and described with a sufficient degree of accuracy.

Cyanophyte toxins. During 2019, considerable scientific emphasis was focused on (1) the detection of Cyanophyte toxins in Capaum Pond and (2) whether aerosolization of picocyanobacteria containing toxins or toxins following release from cyanophyte cells is a mechanism of transport away from the pond that can be detected and potentially impact public health through inhalation of transported particles.

As a matter of 2019 field sampling consistency, a raw water sample generally was collected from Capaum Pond on each sampling date and returned to the NLC office where the freeze-thaw process inducing cell lysis occurred, which then was followed by an Eurofins Abraxis® strip test for detection of the toxin *microcystin*. Based upon these strip test results, water samples could be shipped overnight to GreenWater Laboratories in Palatka, Florida for a Potentially Toxigenic (PTOX) Cyanobacteria Screen and then follow-up for specific toxin analyses if warranted by the PTOX Cyanobacteria Screen results.

There were seven occasions during 2019 when raw water samples collected from the pond and shipped overnight to GreenWater CyanoLab warranted toxin analyses including August 26th, September 11th, September 30th, October 7th, and October 21st. The results of the toxin analyses are summarized in Table 7-5.

Table 7-5. Summary of 2019 cyanobacteria toxin results from Capaum Pond.

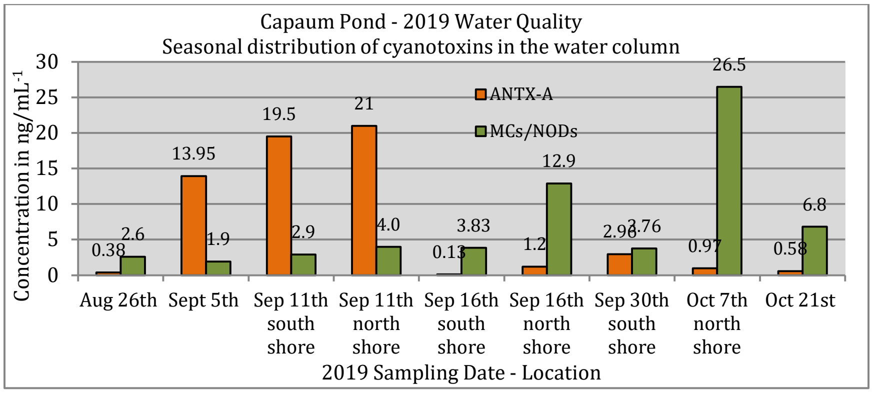
	2019 TOXIN RESULTS				
	ANTX-A	CYN	MCs/NODs	STX/PSTs	
Date	ng/mL	ng/mL	ng/mL	ng/mL	Comments
Aug 26th	0.38	ND	2.6	ND	
Sept 5th	13.95	ND	1.9	ND	
Sep 11th - south shore	19.5	-	2.9	-	south shore water sample
Sep 11th - north shore	21	-	4.0	-	north shore water sample
Sep 16th - south shore	0.13	-	3.83	-	south shore water sample
Sep 16th - north shore	1.2	-	12.9	-	north shore water sample
Sep 30th - south shore	2.96	-	3.76	-	south shore water sample
Oct 7th - north shore	0.97	-	26.5	-	north shore water sample
Oct 21st	0.58	-	6.8	-	
ANTX-A – *Anatoxin-a*; CYN – *Cylindrospermopsin*; MCs/NODs – *Adda Microcystins/Nodularins* STX/PSTs – *Saxitoxin*/Paralytic Shellfish Toxins					

Anatoxin-a, also known as Very Fast Death Factor (VFDF), is a secondary, bucyclic amine alkaloid and cyanotoxin with acute neurotoxicity (https://en.wikipedia.org/wiki/Anatoxin-a). The toxin is produced by at least seven (7) different cyanobacteria genera and symptoms of anatoxin-a exposure include loss of coordination, muscular fasciculations, convulsions and death by respiratory paralysis. Its mode of action is through the nicotinic acetylcholine receptor (nAchR) where it mimics binding of the receptor's natural ligand,

Microcystins, or *cyanoginosins*, are a class of toxins that are cyclic hepatapeptides produced through nonribosomal peptide synthases; Microcystin-LR is the most common of over 50 different microcystins that have been identified (https://en.wikipedia.org/wiki/Microcystin#). Microcystions are hepatotoxic and able to cause serious liver damage. Acute health effects of Microcystin-LR are abdominal pain, vomiting and nausea, diarrhea, headache, blistering around the mouth, and after inhalation, dry cough and pneumonia.

The toxin results summarized in Table 7-5 also are presented in a column chart (Figure 7-89) to display the seasonal distribution of these toxins in Capaum Pond during 2019.

Figure 7-8. Seasonal distribution of cyanotoxins measured in Capaum Pond, 2019.



Anatoxin-a was detected in all 9 samples collected on 7 different dates during 2019. The concentration increased from 0.38 ng/mL^{-1} on August 26th to a high seasonal value of 21 ng/mL^{-1} on September 11th (north shore sample); thereafter, the concentration ranged from 1.13 – 2.96 ng/mL^{-1} through the October 21st sampling date.

Microcystins/nodularins were detected in all 9 samples collected on 7 different dates during the 2019 season (Figure 7-8). Concentrations were <5 ng/mL^{-1} from August 26th through September 11th; thereafter, seasonal high concentrations of 12.9 and 26.5 ng/mL^{-1} occurred on September 16th and October 7th, respectively.

Deployment of the Aerosol Filter Collection Device. In addition to the collection of pond water for the analysis of specific cyanobacterial toxins, there also was considerable effort expended at Capaum Pond during 2019 with deployment of the Aerosol Filter Collection Device (AFCD) units along the pond shoreline, particularly when approaching storms were forecast with sufficient wind blowing across the Island to cause disturbance on the surface of the ponds.

The first AFCD deployment occurred on September 5th; a single device was set up along the south shore of the pond because winds were forecast from the north-northeast direction. Subsequent deployments at Capaum Pond included both AFCD units along the shoreline with location determined by the direction of winds forecast for the particular storm event being monitored. There were a total of five (5) separate storm events monitored at Capaum Pond. The deployment information is summarized in Table 7-6 along with the results from GreenWater Laboratories for the collected filters that were submitted for analysis.

Table 7-6. Summary of 2019 Aerosol Filter Collection Device (AFCD) deployments at Capaum Pond.

Deployment Date	Deployment #	ANTX-A (ng/mL)	MCs/NODs (ng/mL)	Elapsed Time (hrs, min)	Comments
9/5/2019	1	ND	ND	20 hrs, 30 min	mphsouth shore; wind ssw @ 12 mph
9/11/2019	2a	1.00	0.15	15 hrs, 2 min	north shore; wind ssw @ 18 mph; fog
9/11/2019	2b	0.73	0.16	15 hrs, 18 min	north shore; FD; wind ssw @ 18 mph; fog
9/12/2019	3a	ND	0.33	27 hrs, 16 min	south shore; winds wsw @ 5 mph; fog
9/12/2019	3b	ND	ND	27 hrs, 4 min	north shore; winds wsw @ <5 mph; fog
9/14/2019	4a	ND	ND	48 hrs, 51 min	south shore; winds ese @ 14 mph
9/14/2019	4b	ND	ND	49 hrs, 6 min	north shore; winds ese @ 14 mph
10/6/2019	5a	ND	ND	24 hrs, 4 min	north shore; wind ssw @ 4 mph
10/6/2019	5b	ND	ND	24 hrs, 2 min	north shore; FD; wind ssw @ 4 mph
FD = filter duplicate; both AFCD units set up next to each other					

As summarized above, three (3) of the 18 filters submitted for analysis exhibited positive results for Cyanophyte toxins trapped, apparently, as a result of aerosolization; two (2) filters contained *Anatoxin-a* and three (3) filters revealed *Microcystins/Nodularins*. In the case of *Anatoxin-a*, a review of the scientific literature indicates that is the first instance of the cyanotoxin being collected on a filter adjacent to a pond exhibiting a HAB.

And while the results from raw water analyses for toxins (Table 7-5) revealed the presence of *Anatoxin-a* and *Microcystins/Nodularins* in the water column from early September through late October, we do not understand the mechanism of aerosolization of cyanotoxin from ponds exhibiting HABs well enough to explain the limited number of filters with positive results for toxins. The limited number of deployments late in the 2019 season was one critical factor, as was the development of a filter assay protocol by GreenWater CyanoLab for the analysis of both *Anatoxin-a* and *Microcystins/Nodularins* which required almost two months of time and caused a backlog of filters, collected during September and October, to be stored until analyzed.

In spite of the many questions that arose at the end of the 2019 season for aerosol experimentation, there were some valuable insights provided by the detailed metadata that were recorded during AFCD unit deployment and retrieval at Capaum Pond that can inform the upcoming deployments in 2020. For example, the two (2) filters that exhibited *Anatoxin-a* and *Microcystins/Nodularins* were deployed next to each other along the pond shoreline and experienced wind speeds of a least 18 mph at deployment and fog at deployment and retrieval. The presence of fog could be very important and explain a potential mechanism that aids in the transport of aerosols away from the pond.

7.2.3.2 Gibbs Pond.

Cyanophytes. Cyanophytes were identified in all 8 phytoplankton samples collected at Gibbs Pond during 2019; there were a total of 9 genera and 8 species identified in the samples as shown in Table 7-7.

Table 7-7. Cyanophytes identified in Gibbs Pond, 2019.

Cyanophyte species	
**Anabaena flos aquae*	*Merismopedia glauca*
**Aphanizomenon flos aquae*	**Planktothrix* sp. (filaments)
Aphanocapsa elachista	*Rhabdoderma Gorskii*
Chroococcus dispersus	**Woronichinia Naegeliana*
Gomphosphaeria lacustris compacta	
* = genera known to potentially produce toxins	

Anabaena, *Aphanizomenon*, *Planktothrix* and *Woronichinia*, are genera that have the potential to produce toxins including microcystins, saxitoxins, anatoxin-a and cylindrospermopsin.

The Cyanophyte population dynamics on the nine (9) sampling dates with respect to density and biomass of the entire phytoplankton community in Gibbs Pond are shown in Figures 7-9 and 7-10, respectively.

Figure 7-9. Gibbs Pond – 2019 cyanophyte and total phytoplankton density.

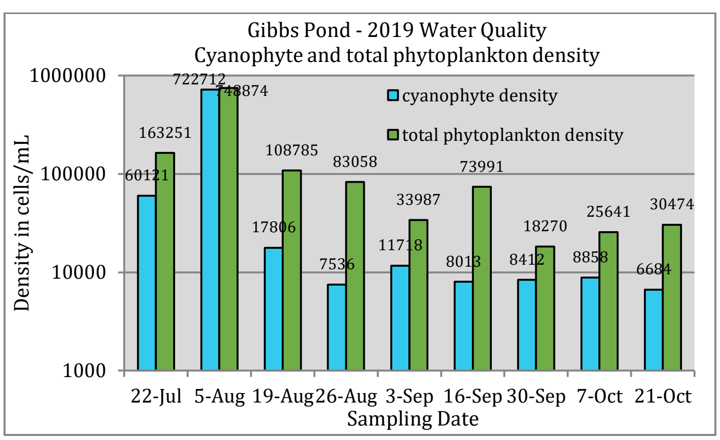
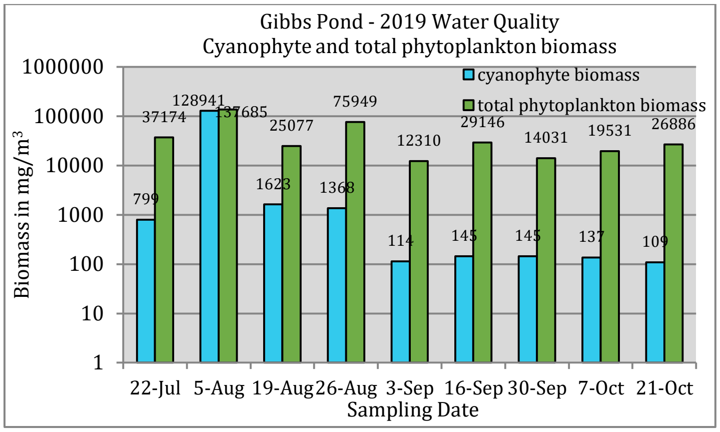


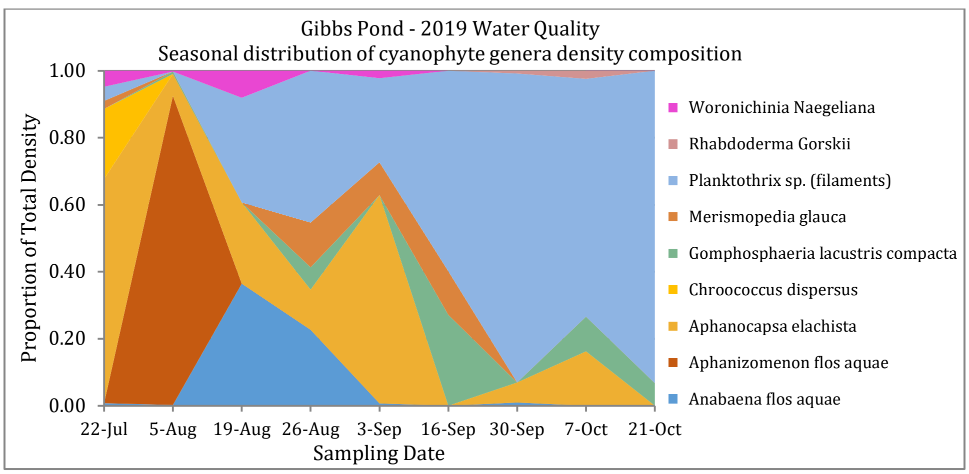
Figure 7-10. Gibbs Pond – 2019 cyanophyte and total phytoplankton biomass.



The 2019 range of Cyanophyte density in the total phytoplankton community ranged from ~10 percent to ~90 percent and averaged 35 percent across the 9 sampling dates. In contrast, the status of Cyanophyte biomass compared with community biomass was greatly diminished, ranging from <1 percent to 94 percent and averaging 12 percent for the 2019 samples that were collected.

Figure 7-11 summarizes the density distribution of Cyanophyte genera during 2019 in Gibbs Pond.

Figure 7-11. Seasonal distribution of cyanophyte genera density in Gibbs Pond, 2019.

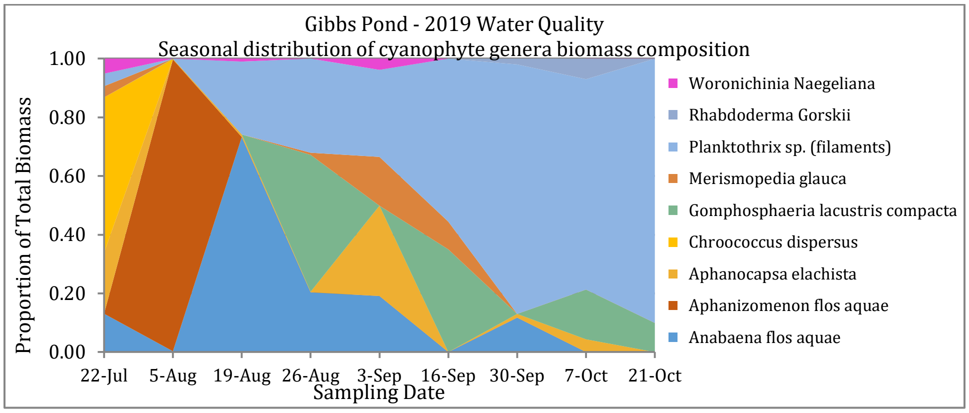


The dramatic fluctuations of different Cyanophyte genera from July through October 2019 are emphasized in this figure. Genera such as *Aphanocapsa* and *Planktothrix* were present throughout most of the season; the density of *Aphanocapsa* remained about the same throughout the period, while *Planktothrix* steadily increased to comprise about 93 percent of the Cyanophyte community by the end of October. Other genera, such as *Anabaena*, *Gomphosphaeria* and *Woronichinia* were present on a majority of sampling dates but were less important in the community based upon density.

Figure 7-12 summarizes the biomass distribution of Cyanophyte genera across the nine sampling dates during 2019 in Gibbs Pond. The 2019 biomass composition of the Cyanophytes also exhibited dynamic fluctuations with major changes in importance of individual genera, such as *Chroococcus*, *Aphanizomenon*, *Anabaena*, and *Gomphosphaeria*, occurring throughout the first half of the season and then *Planktothrix* dominating the Cyanophytes from late August through the end of October. The total biomass dominance of Aphanizomenon on August 5th also is evident from Figure 7-12, while other genera, such as *Merismopedia* and

Woronichinia, were minor components of the Cyanophyte biomass during the entire 2019 period of water quality sampling.

Figure 7-12. Seasonal distribution of cyanophyte genera biomass in Gibbs Pond, 2019.



Cyanophyte toxins. There were four (4) dates during 2019 when raw water samples collected from the pond, lysed and tested using the Abraxis strip test and shipped overnight to GreenWater Laboratories warranted further toxin analyses including August 5th, August 26th, September 24th, and October 21st. The results from the toxin analyses are summarized in Table 7-8.

Table 7-8. Summary of 2019 cyanobacteria toxin results from Capaum Pond.

	TOXIN RESULTS			
	ANTX-A	CYN	MCs/NODs	STX/PSTs
Date	ng/mL	ng/mL	ng/mL	ng/mL
Aug 5th	ND	ND	1.93	ND
Aug 26th	ND	ND	2.8	ND
Sep 24th	ND	ND	1.71	ND
Oct 21st	ND	ND	1.43	ND
ANTX-A – Anatoxin-A CYN – Cylindrospermopsin MCs/NODs – Adda Microcystins/Nodularins STX/PSTs – Saxitoxin/Paralytic Shellfish Toxins				

Microcystins/Nodularins were detected in all 4 samples analyzed by GreenWater Laboratories, albeit the concentrations were low on all occasions.

Deployment of the Aerosol Filter Collection Device. The Aerosol Filter Collection Device (AFCD) was deployed along the north shore of Gibbs Pond on a single occasion, September 5th, and collected the following day. Subsequent analysis of the exposed filter at the GreenWater CyanoLab revealed *non detect* (ND) results for both *Anatoxin-a* and *Microcystins/Nodularins*.

7.2.3.3 Head of Hummock Pond.

Cyanophytes. Cyanophytes were identified in all five (5) samples collected during 2019 from Head of Hummock Pond as summarized in Table 7-9.

Table 7-9. Cyanophytes identified in Head of Hummock Pond, 2019.

Cyanophyte species	
**Anabaena flos aquae*	*Aphanocapsa elachista*
Anabaenopsis Elenkinii	*Chroococcus limneticus*
**Aphanizomenon flos aquae*	
* = genera known to potentially produce toxins	

Anabaena, *Anabaenopsis* and *Aphanizomenon*, are potential toxin-producing genera of Cyanophytes that occurred in Head of Hummock Pond during 2019.

The population dynamics of cyanophytes on the five (5) 2019 sampling dates with respect to density and biomass of the entire phytoplankton community are illustrated in Figures 7-13 and 7-14, respectively.

Figure 7-13. Head of Hummock Pond – 2019 cyanophyte and total phytoplankton density

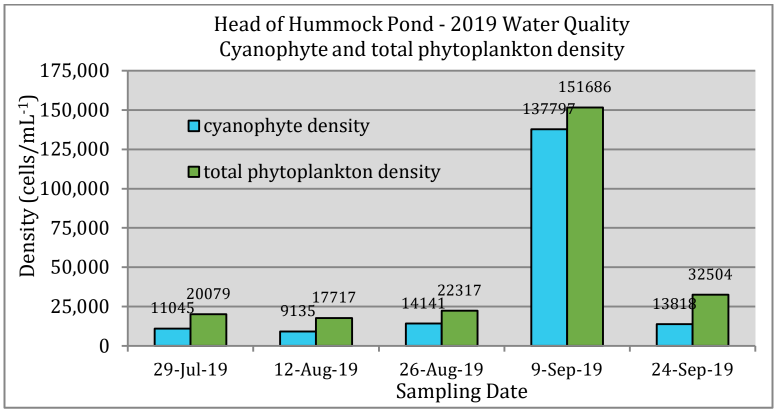
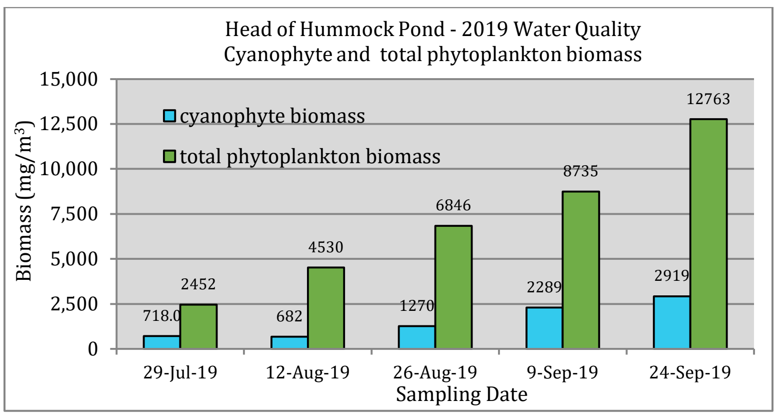


Figure 7-14. Head of Hummock Pond – 2019 Cyanophyte and total phytoplankton biomass



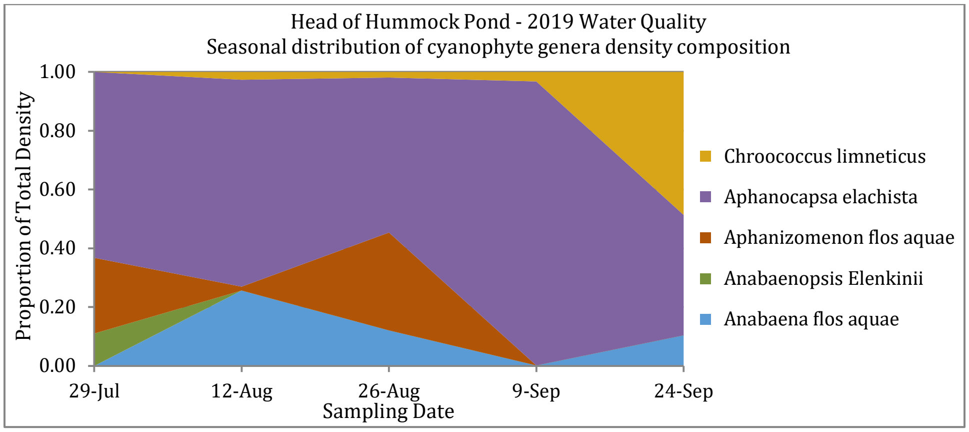
With respect to 2019 total phytoplankton community density in Head of Hummock Pond between the end of July and the end of September, the Cyanophytes ranged from 43 percent of the total community (on September 24th) to 91 percent of the total community (on September 9th), and averaged 61 percent of the total community density. In terms of biomass, the Cyanophytes ranged from 15-29 percent of the 2019 total community and averaged 22 percent for the sampling season.

There were considerable fluctuations of specific Cyanophyte genera exhibited among the 5 sampling dates with respect to density and biomass, with some genera demonstrating importance throughout the sampling season and other genera being present at various times but not as important in terms of total numbers (density) or biovolume (biomass).

Figure 7-15 summarizes density distribution of the 2019 Cyanophyte species in Head of Hummock Pond.

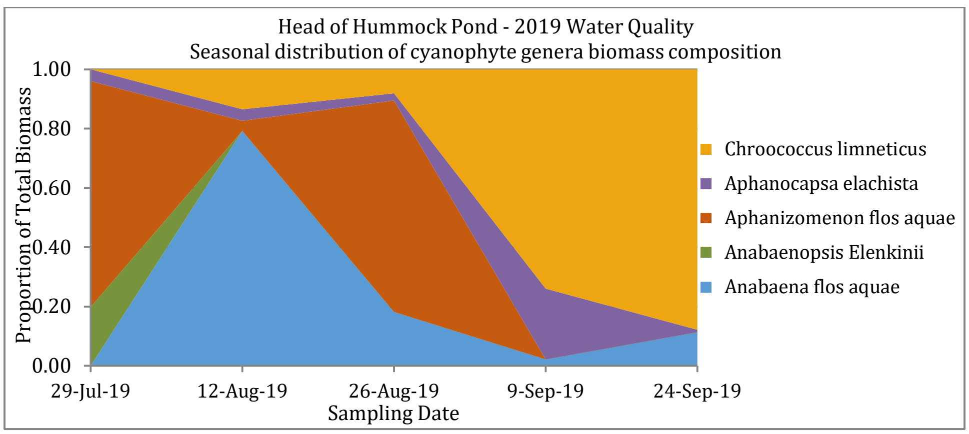
Aphanocapsa elachista was the most dominant Cyanophyte throughout 2019 based upon density, with the other four (4) species fluctuating among sampling dates, and sometimes restricted to only certain portions of the sampling season (*Anabaenopsis Elenkinii*).

Figure 7-15. Seasonal distribution of cyanophyte species density in Head of Hummock Pond, 2019.



Biomass distribution of the Cyanophytes during the 2019 sampling season is summarized in Figure 5-16 and presents a different dynamic for species such as *Aphanocapsa elachista*, which was a major density dominant but only a minor portion of the community biomass.

Figure 7-16. Seasonal distribution of cyanophyte genera biomass in Capaum Pond, 2019.



Conversely, both *Anabaena flos aquae* and *Chroococcus limneticus* exhibited more dominance in the 2019 community biomass than in the community density.

Cyanophyte toxins. There was some limited emphasis directed toward the detection of Cyanophyte toxins in Head of Hummock Pond during 2019 because regular observations failed to reveal any suspicious activity at the pond. Raw water samples were collected from the pond shoreline on six (6) different dates when observations suggested that a HAB might be in progress. Following the recommended freeze-thaw cycle for lysing the algal cells and subsequent test strip reading, 2 samples were sent to GreenWater CyanoLab for a PTOX screen; one sample on August 5th and the other sample on August 26th. The August 5th sample revealed *Cylindrospermopsin* at a concentration of 0.06 ng/mL^{-1}; analyses for other toxins were reported "ND" (non-detect). The August 26th sample did not test positive for any algal toxins.

Deployment of the Aerosol Filter Collection Device. This device was not deployed along the shoreline of Head of Hummock Pond during 2019.

7.2.3.4 Miacomet Pond.

Cyanophytes. Cyanophytes were identified in all five (5) samples collected during 2019 from Miacomet Pond; Table 7-10 is a summary of the 8 different genera that were found in the integrate samples collected from the water column.

Table 7-10. Cyanophytes identified in Miacomet Pond, 2019.

Cyanophyte genera and species	
**Anabaena flos aquae*	*Merismopedia glauca*
**Aphanizomenon flos aquae*	**Oscillatoria* sp.
Aphanocapsa elachista	**Planktothrix* sp. (filaments)
Gomphosphaeria lacustris compacta	**Woronichinia Naegeliana*
* = genera known to potentially produce toxins	

Anabaena, *Aphanizomenon*, *Oscillatoria*, *Planktothrix* and *Woronichinia* are potential toxin-producing genera of Cyanophytes that occurred in Head of Hummock Pond during 2019.

The Cyanophyte population dynamics with respect to density and biomass of the entire phytoplankton community on the six (6) 2019 sampling dates is summarized in Figures 7-17 and 7-18, respectively.

Figure 7-17. Miacomet Pond – 2019 cyanophyte and total phytoplankton density

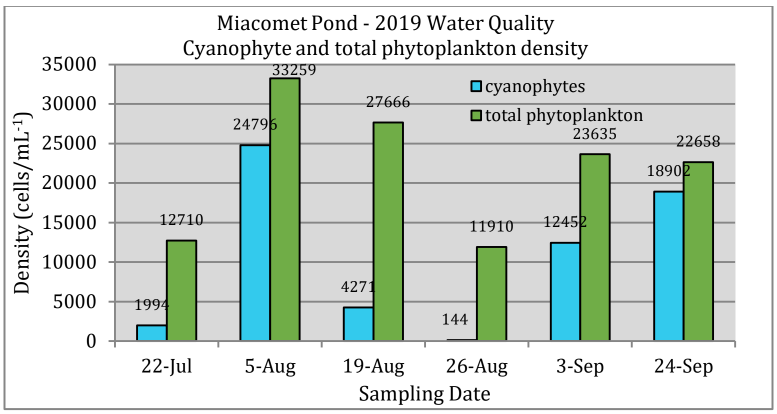
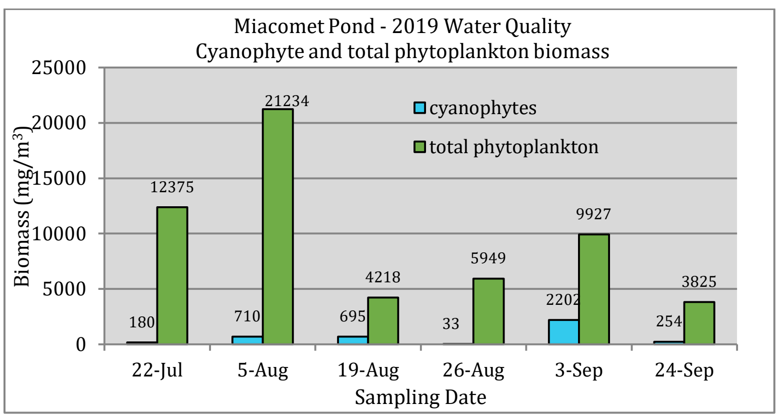


Figure 7-18. Miacomet Pond – 2019 Cyanophytes and total phytoplankton biomass

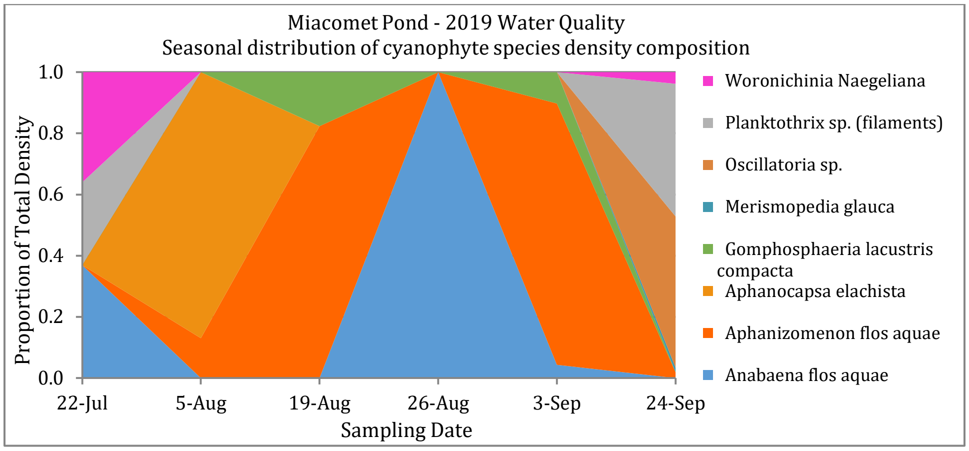


With respect to 2019 density, the Cyanophytes ranged from 1-83 percent of the total phytoplankton community and averaged 40 percent across the 6 sampling dates, with significant fluctuations occurring from one sampling date to the next (Figure 7-17). In terms of 2019 biomass, however, the Cyanophytes, as a group, were much less important in the community, ranging from 1 percent to 22 percent of the total community biomass, and averaging only 9 percent of the total community during the sampling period (Figure 7-18).

Graphical representation of the 2019 density of individual Cyanophyte species across the sampling dates (Figure 7-19) confirms the dynamic fluctuations that occurred within this major group of the phytoplankton.

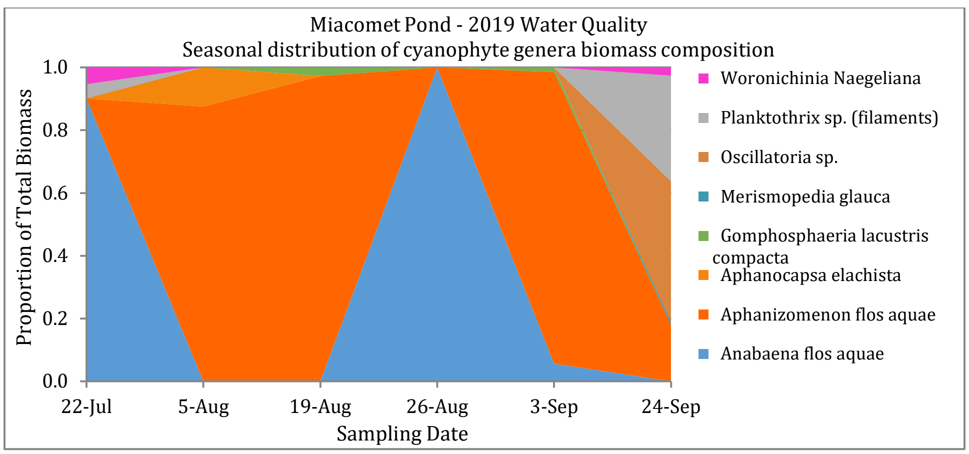
All 8 species are represented in Figure 7-19; however, no single species was observed in the population on every 2019 sampling date; in addition, there were wild fluctuations of presence-absence between individual sampling dates.

Figure 7-19. Seasonal distribution of cyanophyte species density in Miacomet Pond, 2019.



The unstable nature of the Cyanophyte population is not as evident in a graphical representation of individual species biomass (Figure 7-20) because the Cyanophytes, as a major group, were less important in the phytoplankton community biomass as compared with density.

Figure 7-20. Seasonal distribution of cyanophyte species biomass in Miacomet Pond, 2019.



Individual species rise and fall throughout the 2019 season with no one species clearly dominating the water column population in terms of density or biomass for an extended period of time.

Cyanophyte toxins. Raw water samples were collected from the Miacomet Pond shoreline on four (4) occasions when observations indicated that a HAB might be occurring. A sample collected on June 23rd was sent to GreenWater CyanoLab for a PTOX analysis and subsequent toxin follow-up determined that 0.38 ng/mL of *Adda Microcystins/Nodularins* were present at the time the sample was collected from the pond; the analysis also revealed ND (non-detect) results for *Anatoxin-a* and *Saxitoxin*.

Deployment of the Aerosol Filter Collection Device. This device was not deployed along the shoreline of Miacomet Pond during 2019.

7.3 Summary

The major focus of the 2019 water quality monitoring on Nantucket Island was the detection of HABs at Capaum, Gibbs, Head of Hummock and Miacomet Ponds. The full scope of this effort included (1) the regular collection of integrated phytoplankton samples from the water column to archive and document the community of each pond, (2) routine weekly observation of the shoreline area of each pond for evidence of HABs, (3) the collection of a water sample for an Eurofins Abraxis® toxin strip test, (4) the analysis of raw water samples for a potentially toxigenic cyanobacteria screen, and based upon these results, (5) the analysis of detectable cyanotoxins present in the water column during conditions suspected to be HABs, and (6) deployment of the Aerosol Filter Collection Device (AFCD) to document transport of aerosolized cyanotoxins and/or airborne pico-cyanobacteria away from the affected pond to adjacent areas where local residents or recreational users could be exposed through contact (inhalation).

Based upon the 2019 results described in this chapter, there should be no doubt that cyanophytes and cyanotoxins are a potential water quality and public health threat on Nantucket Island at least during the growing season of each year which is the time when the Island is most populated from tourism. And even though we still do not understand the exact mechanism whereby spores or particles of algal toxins and picocyanobacteria are released from the surface of ponds experiencing a HAB into the atmosphere for transport as aerosols, there was some minimal but very basic evidence collected during 2019 by the AFCDs that proved transport does occur away from the pond surfaces.

In spite of the material presented above, the presence of potentially cyantoxin producing genera or species in a Nantucket pond does not mean that toxins are being produced. That is why the present study used the Eurofins Abraxis® strip test to evaluate the presence of toxins, usually followed by submission of water samples to GreenWater CyanoLab for analysis. The dedication of the NLC during the past decade with regard to water quality monitoring and efforts specifically related to identifying HABs and cyanotoxins highlights the fact that different Nantucket ponds contain dramatically different populations of cyanobacteria and, as a result, different cyanotoxins and concentrations of toxins among these ponds.

The interested reader is referred to the following US Environmental Protection Agency (US EPA) link for more information related to the federal standards for cyanobacteria and cyanotoxins in drinking water and recreational waters: **https://www.epa.gov/cyanohabs**

There will be further discussion concerning cyanophytes, cyanotoxins and Nantucket Island ponds in the next chapter of this report.

7.4 Literature Cited

https://en.wikipedia.org/wiki/Anatoxin-a

https://en.wikipedia.org/wiki/Microcystin#)

https://en.wikipedia.org/wiki/Saxitoxin).

United States Environmental Protection Agency. 2014. Cyanobacteria and Cyanotoxins: Information on Drinking Water Systems. Office of Water; EPA-810F11001. 11 pp. + Frequently Asked Questions.

Zaccaroi, A. and D. Scaravelli. 2008. Toxicity of Fresh Water Algal Toxins to Humans and Animals. Pp. 46-90. In: *Algal toxins: Nature, Occurrence, Effect and Detection*. Edited by Valtere Evangelista, Laura Barsanti, Anna Maria Frassanito, Vincenzo Passarelli, and Paolo Gualtieri. NATO Science for Peace and Security Series A: Chemistry and Biology. Springer, P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

Nantucket Island Ponds and 2019 Water Quality

Chapter 8

Background, 2019 Monitoring Program, Discussion, Summary, Conclusions and Recommendations

8.0 Introduction

This chapter provides (1) a summary of the 2019 water quality monitoring program, (2) a brief summary and discussion of the results, and (3) some basic conclusions and recommendations for future considerations of pond monitoring and water quality management so that reasonable and prudent decisions can be made by scientists, property owners, policy makers and administrators regarding public health and safety because many of these ponds are used for contact recreation.

8.1 Background

The Nantucket Land Council (NLC) Inc. became involved in water quality monitoring of Nantucket Island ponds during 2009 when Miacomet and Hummock Ponds were surveyed as part of a cooperative effort sponsored by the NLC and the UMass Field Station. During the 10-year period since 2009, the NLC has sponsored the water quality survey of 12 different ponds on the Island; in some cases, these ponds have been surveyed during multiple years. A summary of the ponds surveyed and the years the surveys were conducted is summarized most recently in Sutherland and Molden (2019).

8.2 2019 Water Quality Monitoring Program. Beginning on July 15th, the NLC conducted a total of 27 sampling excursions on four (4) Island ponds including Capaum, Gibbs, Head of Hummock and Miacomet; sampling concluded on October 21st. Table 8-1 summarizes the 2019 sampling schedule for the Island ponds that were sampled.

Table 8-1. Summary of Nantucket Island ponds monitored for water quality during 2019.

Date	Capaum	Gibbs	Head of Hummock	Miacomet
July 15th	X		X	
July 22nd		X (2)		X (2)
July 29th	X (2)		X (2)	
August 5th		X (2)		X
August 12th	X (2)		X (2)	
August 19th		X (2)		X
August 26th	X		X	
September 3rd		X (2)		X
September 9th	X (2)		X (2)	
September 16th		X (2)		
September 19th	X			
September 24th			X (2)	X
September 30th		X		
October 7th	X	X		
October 21st	X	X		
# excursions	8	8	6	5
# chem samples	11	13	10	6
X (2) = pond sampled; samples collected from *upper* and *lower* levels				

The field protocols for water quality sampling have been described earlier in this report (Chapter 2) and these protocols are followed strictly on each pond that is monitored.

8.3 Discussion

Water Quality Parameters. All of the parameters (analytes) that are measured on a pond have certain value in assessing overall water quality, which should become clear when reading through the various pond chapters in this report and previous reports that describe the water quality of ponds that have been monitored by the NLC. In an effort to highlight all of the water quality data collected by the NLC during 2019, Table 8-2 provides a summary of *maximum*, *minimum* and *average* values for the suite of analytes that were monitored in each of the 4 ponds, including physical, chemical and biological data.

Table 8-2. A summary of maximum, minimum and average values for the suite of parameters monitored during 2019 in Capaum, Gibbs, Head of Hummock and Miacomet Ponds.

Nantucket Ponds	Secchi (m)	Chl ***a*** (µg/L)	DO (% sat)	NO3-N (mg/L)	TN (mg/L	TP (µg/L)	SRP (µg/L)	TDS (mg/L)	spC (µS/cm)	pH (s.u.)
Capaum Pond										
minimum value	0.23	26.4	86.2	0.005	1.27	76.1	0.50	163	252	6.55
maximum value	0.61	201.1	129.4	0.02	2.98	126	1.6	217	314	9.78
average value	0.43	80.2	107.1	0.007	1.81	101	0.90	182	271	8.08
Gibbs Pond										
minimum value	0.33	28.7	65.2	0.005	1.02	256	69.4	61	96	5.04
maximum value	0.61	61.0	104.0	0.02	1.57	521	299	291	411	7.08
average value	0.40	45.8	86.6	0.007	1.20	373.3	148.7	130	195	6.51
Head of Hummock										
minimum value	0.53	10.0	92.6	0.005	0.71	78.9	3.4	1790	2388	7.92
maximum value	1.02	64.2	103.1	0.03	1.20	310	140	3355	4364	9.38
average value	0.81	34.7	98.7	0.009	0.96	165	67.0	2509	3309	8.60
Miacomet Pond										
minimum value	0.61	3.7	99.7	0.005	0.06	48.6	0.50	168	255	6.06
maximum value	1.75	14.3	110.6	0.005	0.72	64.5	15.4	672	952	7.78
average value	1.39	8.9	106.8	0.005	0.54	55.4	4.0	287	414	7.20

Values highlighted are one-half the lower detection limit.

Each of the four (4) ponds monitored during 2019 had certain characteristics that distinguished that pond from the others included in the program. For example,

- Capaum Pond exhibited the highest average chlorophyll ***a*** concentration (80.2 µg/L^{-1}) and the lowest average soluble reactive phosphorus (SRP)concentration (0.90 µg/L^{-1}),
- Gibbs Pond exhibited the lowest average Secchi depth transparency (0.40 m) and the highest average total phosphorus (TP) (373.3 µg/L^{-1}) and average SRP (148.7 µg/L^{-1}) concentrations,
- Head of Hummock Pond had the highest average specific conductance (3309 µS/cm @ 25ºC), TDS (2509 mg/L^{-1}) and pH (8.60 s.u.) values, and
- Miacomet Pond exhibited the highest Secchi depth transparency (1.39 m) and the lowest concentrations of several analytes including chlorophyll ***a*** (8.9 µg/L^{-1}), total nitrogen (TN)(0.54 mg/L^{-1}), and TP (55.4 µg/L^{-1}).

Ponds such as these monitored during 2019 are very dynamic in nature and subject to great influence by both autochthonous (within the system) and allochthonous (outside the system) factors to the extent that a comparison of these waters at another time in the future could likely reveal much different results than the 2019 results summarized above.

Trophic State. In simplest terms, '*trophic state*' is the total weight of living biological material (biomass) in a water body at a specific time and location (Carlson and Simpson 1996), with the understanding that the time and location specific measurements can be grouped to achieve estimations of trophic state at the level of the individual lake or pond under investigation. Trophic state is the biological response to external driving factors such as nutrients, season of the year, and climate, as well as internal factors such as temperature, mixing of the water column, etc.

Using the information presented above for *trophic state*, the *trophic state index* developed by Carlson (1977) uses algal biomass as the basis for the water body classification. Three (3) variables, including chlorophyll a, total phosphorus and Secchi depth transparency are used, independently, to estimate algal biomass. Carlson's technique of classification is different than the earlier typological system developed by Naumann (1929) because the index reflects a continuum of states and not just a single state.

Total phosphorus and chlorophyll ***a*** data are the most objective criteria used to evaluate water quality in a pond because these values are measured by a laboratory using standard analytical techniques and the data can provide a relative comparison of water quality among ponds of similar size and/or geographic location.

Secchi depth is a subjective measurement recorded by an individual and may differ from the transparency reading obtained by another individual even though both readings are collected at the same location and under the same conditions. In contrast to the analytical criteria used to assess water quality, Secchi depth transparency is the least expensive parameter to measure.

As a means of comparing the trophic status data collected by the NLC during 2019, Table 8-3 provides a summary of Trophic Status Indices calculated for total phosphorus, chlorophyll ***a*** and Secchi depth transparency for the four (4) ponds that were monitored.

Table 8-3. A summary of Trophic Status Indices calculated for total phosphorus, chlorophyll *a* and Secchi depth transparency for the Nantucket Island ponds monitored in 2019.

	2019 Trophic Status Indices and Trophic Status		
Pond	Total phosphorus (TP)	Chlorophyll *a* (Chl *a*)	Secchi Depth (SD)
Capaum	70.6 (HE)	73.6 (HE)	72.3 (HE)
Gibbs	89.5 (HE)	68.1 (E)	73.2 (HE)
Head of Hummock	73.6 (HE)	65.4 (E)	63.0 (E)
Miacomet	62.1 (E)	52.0 (E)	55.2 (E)
E = eutrophic status, HE = hyper-eutrophic status			

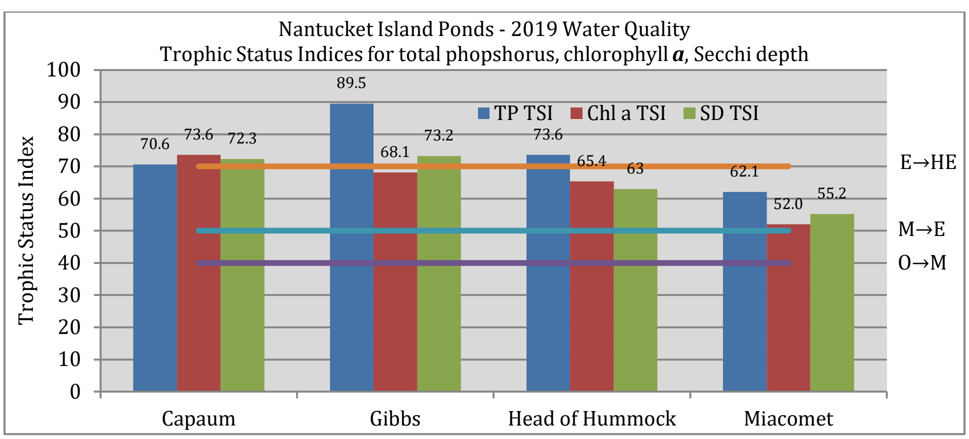
Trophic Status Indices calculated from the equations for TP, chlorophyll ***a***, and Secchi depth for each pond are referred to Table 8-4 to interpret the trophic class that defines the productivity for the calculated index value.

Table 8-4. Relationships among Trophic Index, chlorophyll *a*, total phosphorus, Secchi depth and Trophic Class (after Carlson, 1996).

Trophic Index	Chlorophyll (µg L^{-1})	TP (µg 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

The summary of Trophic Status Indices calculated for all four (4) ponds are graphically summarized in Figure 8-1 so that the ponds can be compared with one another.

Figure 8-1. Summary of Trophic Status Indices calculated for Nantucket Island ponds monitored in 2019.



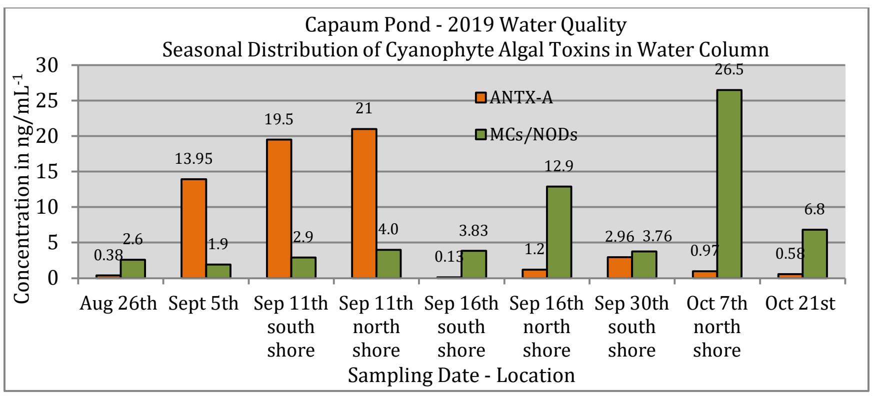
One year of water quality data is not considered sufficient to characterize a lake or pond with respect to productivity; however, the current exercise was carried out in an effort to compare the ponds that were monitored during 2019. Continued monitoring of these ponds over a longer period of time will strengthen the individual water quality data-base for each pond and provide important information about changes in water quality and trends that might be occurring with regard to the various analytes that are important in evaluating pond productivity.

Cyanophytes, Cyanotoxins and Nantucket Island Ponds. Although there still is considerable research to be conducted in this area, the consequences of cyanophytes-cyanotoxins and their potential effects on water quality and public health on Nantucket Island are real and need to be addressed in the future so that year-round and seasonal residents are made aware of the situation and can act accordingly.

The 2019 water quality results collected from Capaum Pond are a Case Study of the issue and provide considerable evidence that the problem with cyanophytes-cyanotoxins on Nantucket Island must be addressed. This particular body of water, approximately 18 acres in size, exhibited a single and extended HAB which was detected on August 26th and continued through October 21st. During this 2-month period, there were 9 different sampling excursions conducted for cyanotoxins and detectable levels of *Anatoxin-a* and *Microcystins/Nodularins* were reported in each of the 9 samples.

As summarized in Figure 8-1, *Anatoxin-a* dominated during the first part of the period, with concentrations ranging from 0.38-21.0 ng/L^{-1}, and averaging 13.7 ng/L^{-1} between August 26th and September 11th. *Microcystins/Nodularins* predominated during the second part, ranging from 3.76-26.5 ng/L^{-1}, and averaging 10.8 ng/L^{-1} between September 16th and October 21st.

Figure 8-1. Seasonal distribution of cyanotoxins measured in Capaum Pond, 2019.



The following guidelines for exposure to algal toxins were adopted by the World Health Organization (WHO) several decades ago (1999) and there is no evidence of any update since that time despite the world-wide increase in HAB reports and research efforts associated with HABs:

- 0.0-0.2 ng/L (little to no risk from Blue-green algal toxins: *Minimal Risk*)
- 0.2-1.0 ng/L (toxin detected but below WHO drinking water guidelines: *Low Risk*)
- 1.0-10.0 ng/L (toxin levels above WHO drinking water guidelines but below WHO limits for recreational use: *Moderate Risk*)
- 10-20 ng/L (toxin levels significant and approach WHO limits for recreational contact: *High Risk*)
- >20 ng/L (*toxin levels exceed WHO guidelines for recreational contact; users should avoid contact and be extremely careful to wash off pets*)

Using these WHO guidelines to interpret the 2019 cyanotoxin results from Capaum Pond (Figure 8-1) from late August through late October clearly highlights the existence of major blocks of time when any contact with water in the pond provided *Moderate-to-High Risk* and other periods when all contact with pond water should be avoided due to extremely high cyanotoxin concentrations.

8.4 Summary

2019 was a very productive year in terms of water quality and HABs sampling and related aerosol collection of algal toxins on Nantucket Island in spite of a late start during the growing season. Beginning on July 15th, the Nantucket Land Council conducted a total of 27 sampling excursions on four (4) Island ponds including Capaum, Gibbs, Head of Hummock and Miacomet; sampling concluded on October 21st. On September 5th, two (2) prototype aerosol filter collectors were delivered to the Island; the collectors were deployed that day at Gibbs and Capaum Ponds. Subsequently, the two (2) aerosol collectors were re-deployed on 4 separate occasions at Capaum Pond.

Highlights of the 2019 sampling season compiled from field sampling sheets, related notes and laboratory results are as follows:

- 41 chemistry samples were submitted to the Darrin Fresh Water Institute for analysis; 27 samples collected from the ***upper*** region using the integrated hose technique and 14 samples collected from the ***lower*** region using a van Dorn bottle,
- 41 phytoplankton samples were collected using the integrated hose technique and submitted to Jill Scaglione for identification and enumeration,
- 27 pond surface water samples were collected for Eurofins Abraxis® strip tests and processed back in the NLC office following a series of 3 freeze-thaw procedures to lyse the algal cells in the sample,
- 16 pond surface water samples were submitted to GreenWater CyanoLab in Palatka Florida for a Potentially Toxigenic (PTOX) Cyanobacteria Screen for suspected incidents of suspicious blooms occurring on Island ponds,
- 26 samples were submitted to GreenWater CyanoLab for toxin analysis; 10 of the 26 samples were pond surface water; 16 of the 26 samples were filters collected during various deployments either at Gibbs Pond or Capaum Pond,
- 15 of the 16 pond surface water samples submitted to GreenWater CyanoLab exhibited positive results for algal toxins; 2 of the 10 filters submitted for analysis exhibited positive results for *Anatoxin-a*; 3 of the 10 filters exhibited positive results for *Adda Microcystins/Nodularins*,
- All 9 surface water samples collected at Capaum Pond and submitted for toxin analysis exhibited positive results beginning on August 26th and continuing through October 21st when the last sample was collected; 8 of the 9 surface water samples collected at Capaum Pond exhibited positive results for *Anatoxin-a*; 9 of the 9 samples exhibited positive results for *Adda Microcystins/Nodularins*,
- All 4 surface water samples collected at Gibbs Pond and submitted for toxin analysis exhibited positive results for *Adda Microcystins/Nodularins* beginning on August 26th and continuing through October 21st when the last sample was collected,
- 1 of 2 surface water samples collected from Head of Hummock Pond and submitted for toxin analysis exhibited positive results for the cyanotoxin *Cylindrospermopsin*,
- A single surface water sample collected from Miacomet Pond and submitted for toxin analysis exhibited positive results for *Adda Microcystins/Nodularins*.

The 2019 cyanotoxin results received from GreenWater CyanoLab for the Nantucket Island ponds that were monitored were presented previously in Chapter 8 of this report.

8.5 Conclusions

The following conclusions are presented after careful consideration of the 2019 water quality data collected from Capaum, Gibbs, Head of Hummock and Miacomet Ponds:

(1) All four (4) ponds exhibited high levels of trophy (productivity, nutrient enrichment) during 2019 regardless of which index (total phosphorus, chlorophyll ***a***, Secchi depth transparency) was used for the evaluation; the 2019 order of the four (4) ponds in decreasing levels of productivity (increasing water quality) was as follows: Capaum>Gibbs>Head of Hummock>Miacomet.

(2) Determination of pond productivity using only one year of water quality data is not sufficient to characterize a pond because subtle changes from year-to-year can influence the status of pond water quality within the trophic gradient.

(3) Ponds such as the ones that were monitored during 2019 are very dynamic in nature and subject to great influence by both autochthonous (within the system) and allochthonous (outside the system)

factors to the extent that a comparison of these waters in the future could likely reveal different results than the 2019 results summarized above.

(4) Nantucket Island ponds experience harmful algal blooms (HABs) at various times during the growing season and as a result due diligence is required on the local level to monitor conditions and, if necessary, post advisories to make recreational users of the ponds aware of potential public health concerns due to exposure to dangerous cyanotoxins in the water.

8.6 Recommendations

Environmental stewardship of Nantucket Island ponds falls under various jurisdictions including the Town of Nantucket, the Nantucket Conservation Foundation, and the Nantucket Island Land Bank, with other organizations such as the Nantucket Land Council advocating for the planning, protection and preservation of Island resources which include the ponds and associated water quality. The following recommendations are presented after careful consideration of the 2019 water quality data collected from Capaum, Gibbs, Head of Hummock and Miacomet Ponds and previous water quality data collected by Sutherland and Molden (see 2019 report) during the past decade:

(1) Certain Nantucket Island ponds require attention directed toward several water quality issues that have been manifested for most of the past decade, including considerable nutrient enrichment and extended blooms of cyanobacteria that potentially produce toxins and pose a public health threat. All of the ponds investigated during 2019 (Capaum, Gibbs, Head of Hummock, Miacomet) have been subject to previous water quality investigations by the Nantucket Land Council and should receive monitoring attention in the future.

(2) A list of Island ponds should be identified and monitored on a weekly basis for evidence of HABs along the pond shoreline during the 2020 growing season between June 1st and October 15th. This effort should be coordinated by the Town of Nantucket and involve other organization including the Nantucket Conservation Foundation, the Nantucket Island Land Bank and the Nantucket Land Council. Each organization would agree to visit the same selected ponds on the same day each week. Visits to each pond would include observations along the shoreline for evidence of a HAB in progress; if something suspicious is observed, the field person would take a photograph and then put on a pair of disposable gloves and collect a raw water sample which will be delivered to the Nantucket Land Council for an Eurofins Abraxis® strip test for the cyanotoxins *Anatoxin-a* and *Adda Microcystins/Nodularins*. The results of the cyanotoxin strip test will determine whether the collected raw water samples are sent overnight to GreenWater CyanoLab for further analysis.

(3) The list of Nantucket ponds that should be monitored regularly for HABs during the 2020 growing season include Capaum, Clark's Cove, Gibbs, Head of Hummock, Hummock, Long Pond (several possible locations determined by previous prevailing winds), Maxcy, Miacomet, North Head (Long Pond), Sesachacha, Tom Nevers, and Washing. The Nantucket Land Council will be responsible for monitoring Capaum, Gibbs and Head of Hummock Pond during 2020.

(4) Based upon the water quality results from 2019, Capaum and Gibbs Ponds should receive regular bi-weekly water quality monitoring during 2020. The result of HABs reconnaissance during 2020 will determine which additional ponds should receive regular water quality monitoring in future years.

8.7 Literature Cited

Sutherland, J.W., and E. Molden. July 2019. *Nantucket Island Ponds and 2018 Water Quality. Capaum Pond. A Summary of Physical, Chemical and Biological Monitoring.* Prepared for the Nantucket Land Council, Inc., 6 Ash Lane, Nantucket MA 02554. 32 pp. + attachments.

Zaccaroi, A. and D. Scaravelli. 2008. Toxicity of Fresh Water Algal Toxins to Humans and Animals. Pp. 46-90. In: *Algal toxins: Nature, Occurrence, Effect and Detection*. Edited by Valtere Evangelista, Laura Barsanti, Anna Maria Frassanito, Vincenzo Passarelli, and Paolo Gualtieri. NATO Science for Peace and Security Series A: Chemistry and Biology. Springer, P.O. Box 17, 3300 AA Dordrecht, The Netherlands.

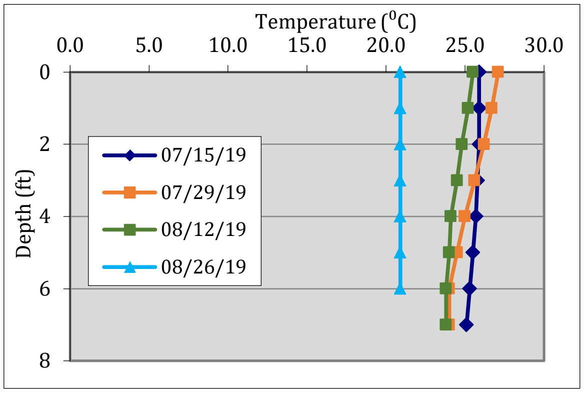
Nantucket Island Ponds and 2019 Water Quality

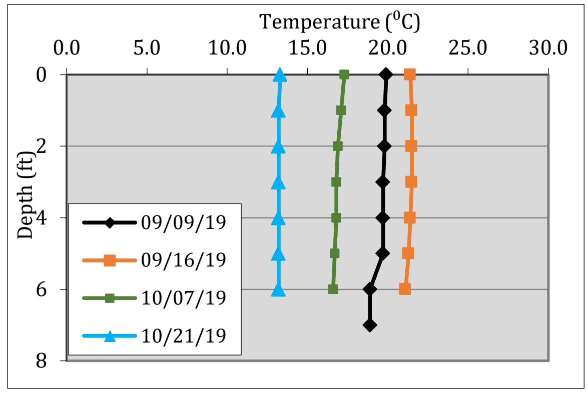
Attachment #1

Pond Temperature and Dissolved Oxygen Percent Saturation Profiles

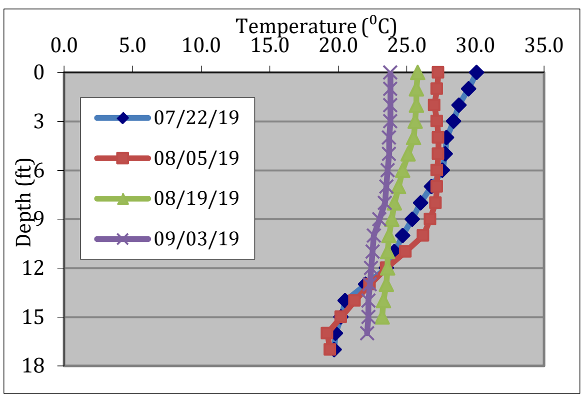
2019 Temperature Profile Data

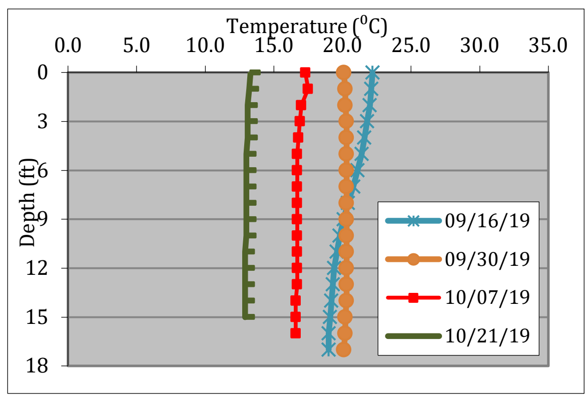
Capaum Pond



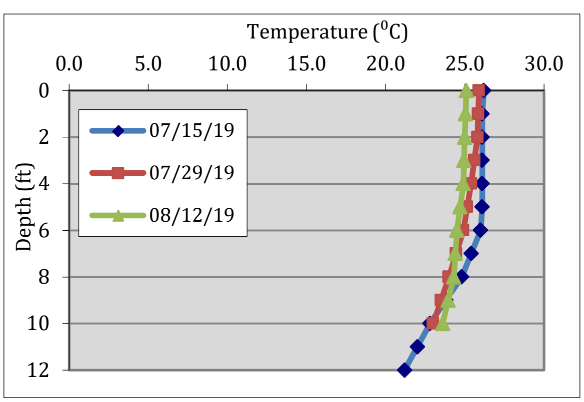


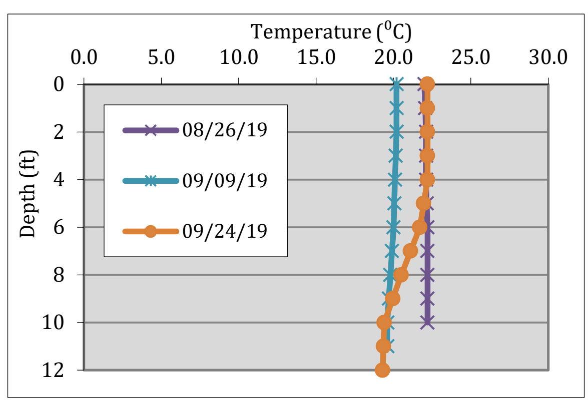
Gibbs Pond





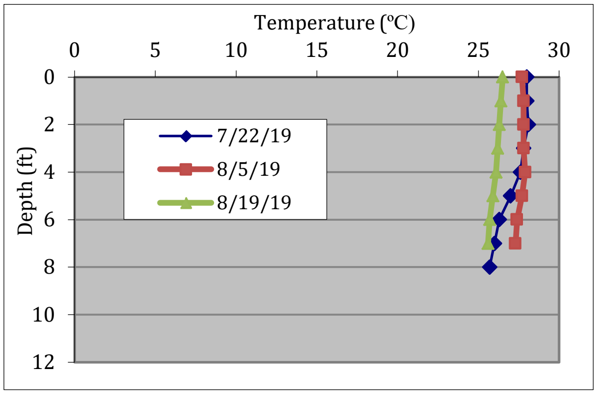
Head of Hummock Pond

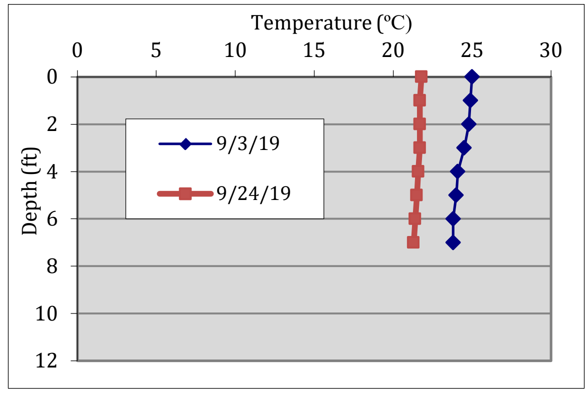




2019 Temperature Profile Data (continued)

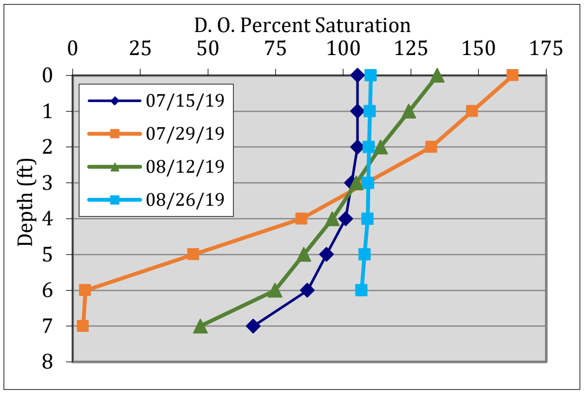
Miacomet Pond

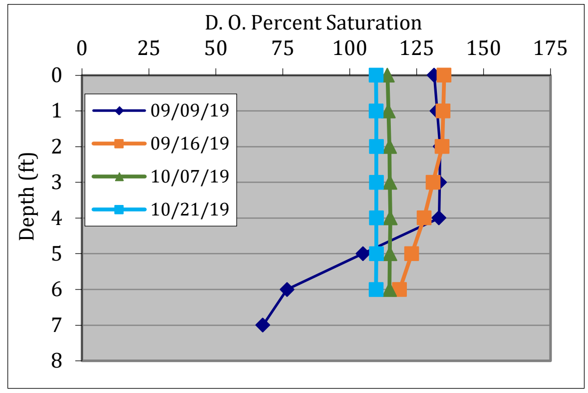




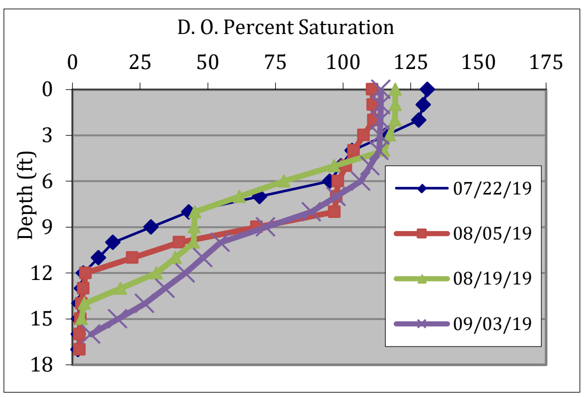
2019 Dissolved Oxygen Percent Saturation Profile Data

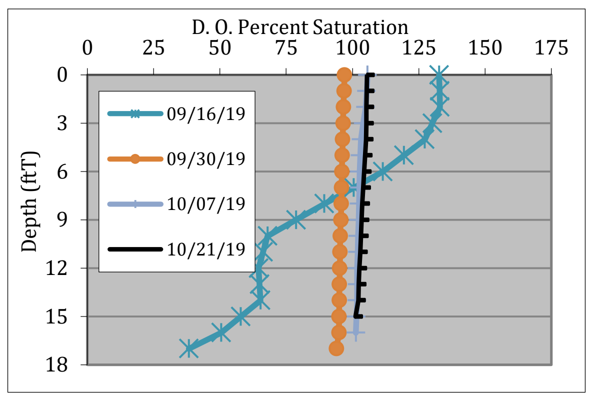
Capaum Pond



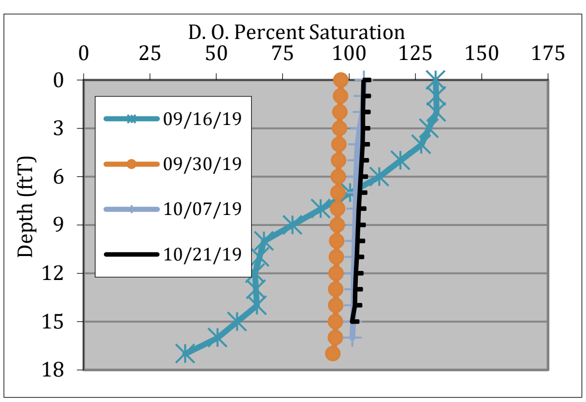


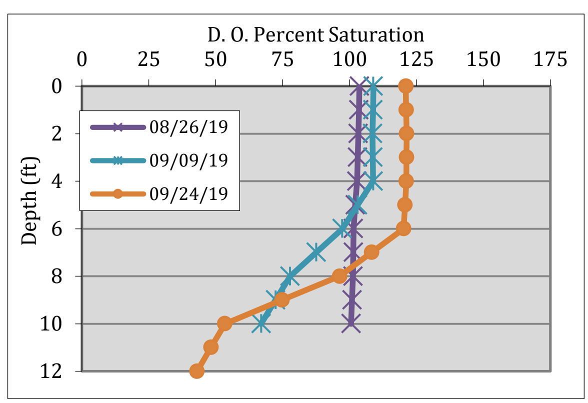
Gibbs Pond





Head of Hummock Pond





2019 Dissolved Oxygen Percent Saturation Profile Data

Miacomet Pond