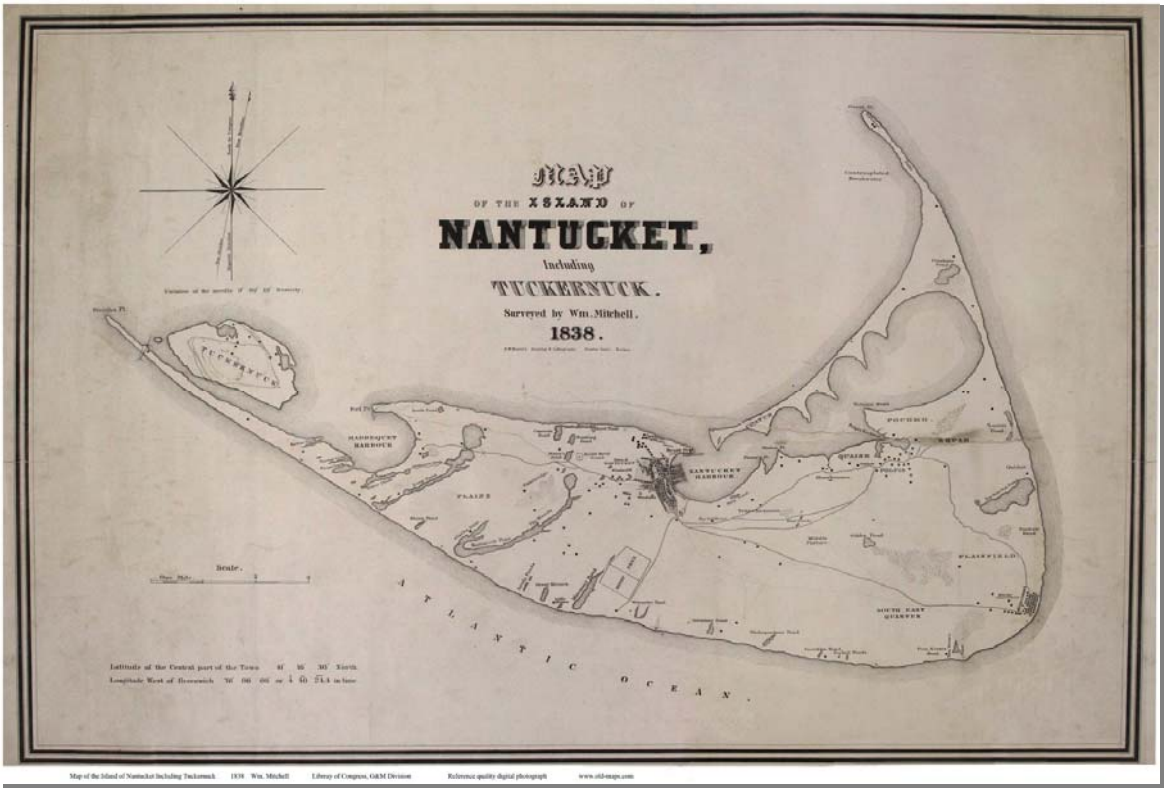
Nantucket Island Ponds and 2017 Water Quality

Gibbs, Head of Hummock, Long, Maxcy, Miacomet, Tom Nevers, and Washing Ponds

A Summary of Physical, Chemical and Biological Monitoring



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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.

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 of nitrogen in a water body 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.

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 - Phytoplankton

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 ***a***, rooted plant growth and dissolved oxygen.

The following trophic categories are used to classify lakes and lakes 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 among Trophic Index (TI), chlorophyll ***a*** (µg·L^{-1}), total phosphorus (µg·L^{-1}), Secchi depth (meters), and Trophic Class (after Carlson 1996) are as follows:

Table 1-1. 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

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.

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Nantucket Island Ponds and Their Water 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, cyanophyte toxins

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 (*epilimnion*) is sampled using the integrated hose technique; the lower zone of different temperature or oxygen concentration 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 epilimnetic 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 levels 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 were placed in a Styrofoam cooler with gel packs and shipped via FedEx (2nd day delivery) to a contract laboratory that is certified to process and analyze the nutrient chemistry analytes and chlorophyll ***a***. A Chain of Custody form accompanies the samples to the analytical 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,	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 protocol used for the microscopic examination of phytoplankton for identification and enumeration is detailed below.

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^{3}mL^{-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.

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

Nantucket Island Ponds and 2017 Water Quality

Chapter 3

Gibbs Pond

3.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Gibbs Pond by the Nantucket Land Council (NLC), Inc. during 2017. The 2016 data collected from Gibbs Pond by NLC staff (Sutherland and Molden, 2017) also are summarized and discussed with regard to the pond's trophic status.

3.1 Results

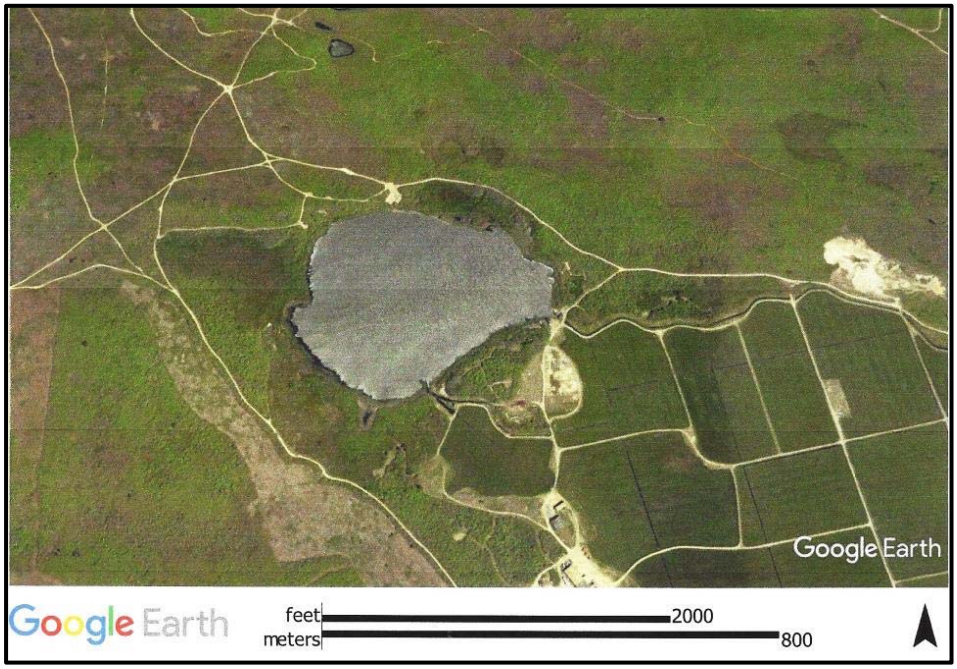
Gibbs Pond was sampled on August 2nd and 29th 2017. The maximum water depth recorded was 12.8 feet (3.9 m) on August 2nd and 13.1 feet (4.0 m) on August 29th at the sampling location in the approximate center of the pond. In 2016, Gibbs Pond was sampled by the NLC on May 13th and August 30th.

Following the collection of Secchi depth transparency, and temperature and dissolved oxygen profile data, integrate samples were collected from the surface down to 6 feet (1.8 m) on August 2nd and 8 feet (2.4 m) on August 29th for the water chemistry and phytoplankton samples. A grab sample for water chemistry also was collected from the 10-foot (3.0 m) depth on August 2nd because the pond exhibited slight thermal stratification with depth; this condition did not exist on August 29th so no additional grab sample was collected. Observations recorded while the pond was being sampled included a notation of an algal bloom during the week prior to the August 2nd sampling date.

3.1.1 Physical characteristics

General. Gibbs Pond is located north of Milestone Road, almost opposite from the intersection with Tom Nevers Road. The pond has a surface area of about 37 acres and a maximum depth of about 16 feet (4.9 m). Figure 3-1 is an aerial view of Gibbs Pond.

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



The pond is used to flood the local cranberry bogs on the Island and there is a single outflow, Phillips Run, which flows into Tom Nevers Pond to the south. The pond receives input from ground water, precipitation and surface runoff from the relatively small surrounding watershed.

Table 3.1 below summarizes the physical data collected from Gibbs Pond during the 2016 and 2017 sampling seasons.

Table 3-1. Summary of physical data from Gibbs Pond, 2016 and 2017.

Gibbs Pond Physical Data, 2016 and 2017		
Sampling Date	Secchi depth (m)	Avg Water Column Temperature (°C)
13-May-16	0.89	15.6
30-Aug-16	0.35	25.7
2016 avg	0.62	20.7
2-Aug-17	0.33	23.4
29-Aug-17	0.38	22.6
2017 avg	0.36	23

Transparency. The 2017 Secchi depth transparency measured at Gibbs Pond was 13 inches (0.33 m) on August 2nd and 15 inches (0.38 m) on August 29th. Both of these readings are extremely low and indicate high productivity (phytoplankton) in the water column which impairs visibility.

Temperature. Temperature profile data were collected during both 2017 sampling excursions. The August 2nd temperature averaged 23.3°C, and there was slight temperature stratification between 6-8 feet of depth. The average temperature of the water column was 22.6°C on August 29th, with essentially no difference in temperature between the surface and the bottom. There is nothing noteworthy about the Gibbs Pond 2017 water temperatures and they are not presented here in graphic form.

3.1.2 Chemical characteristics

Table 3-2 summarizes the 2017 chemical characteristics of Gibbs Pond including the phytoplankton nutrients, phosphorus and nitrogen.

Table 3-2. Summary of chemical data from Gibbs Pond, 2016 and 2017.

	Gibbs Pond Chemical Properties 2016 and 2017								
Sampling Date	Avg DO saturation	TP (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	NO3 + NH4-N (mg/L)	TN (mg/L)	Org N (mg/L)	spC (µS)	pH (s.u.)
13-May-16	97.4	0.217	0.005	0.030	0.035	0.56	0.53	93	6.21
30-Aug-16	89.8	0.478	0.005	0.020	0.025	1.85	1.83	97	8.51
2016 avg	93.6	0.347	0.005	0.025	0.030	1.21	1.18	95	7.36
2-Aug-17	83.6	0.440	0.005	0.005	0.010	1.59	1.58	124	8.42
29-Aug-17	76.0	0.509	0.005	0.030	0.035	1.76	1.73	124	6.75
2017 avg	79.8	0.474	0.005	0.018	0.023	1.68	1.65	124	7.59
all values shown are for the upper regions of the water column highlighted cells = values reported are one-half the lower detection limit									

The table also includes a summary of the 2016 data collected from the pond for comparative purposes later on in this chapter.

Dissolved oxygen percent saturation. Dissolved oxygen is a chemical characteristic of water quality. The average oxygen saturation was 86.3 percent on August 2nd and the water column was supersaturated (>100%) with oxygen down to about the 6-foot (1.8 m) depth; thereafter the saturation dropped rapidly to ~30 percent at the 12-foot depth.

There likely was a period of low, or no, wind prior to August 2nd, which allowed the water column to set up thermally, then resulted in the decreased saturation in the lower region from the decomposition of organic material (e.g., algae) settling into this region.

There was no evidence of decreased oxygen saturation with depth on August 29th, as well as no thermal gradient in the pond. This condition likely was the result of wind-generated mixing of the water in the pond and the low saturation throughout the water column was the result of decomposition exceeding respiration which replenishes oxygen.

Specific conductance. All 2017 conductance values were similar and low which is expected for a pond like Gibbs located on the interior of the Island and sheltered from salt spray (aerosols) and inputs from high ocean water levels. The ***upper*** region integrate sample had a conductance value of 124 $\mu S \cdot cm^{-1}$ on August 2nd; the August 29th value for the ***upper*** sample also was 124 $\mu S \cdot cm^{-1}$. The ***lower*** region value for specific conductance (not shown in Table 3-2) collected on August 2nd was 131$\mu S \cdot cm^{-1}$.

pH. The **upper** region pH was 8.42 s.u. on August 2nd; the ***lower*** region pH on that date (not shown in Table 4.2) was 7.03. The high value (8.42) for the ***upper*** region on August 2nd reflects high productivity from phytoplankton in the water column and a potential imbalance between respiration and photosynthesis. The pH value in the pond on August 29th was 6.75, which is just below neutral pH.

3.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was not detectable in Gibbs Pond on either 2017 sampling date (Table 3-2) which is not unusual since this form of nitrogen is taken up by phytoplankton during the process of photosynthesis. The same condition was observed during both 2016 sampling dates.

Measureable levels of **ammonia-nitrogen** occurred in the water column on both 2017 sampling dates, including 0.005 mg $N \cdot L^{-1}$ in the August 2nd ***upper*** region sample, 0.340 mg $N \cdot L^{-1}$ in the August 2nd sample from the ***lower*** region (not shown in Table 4-2) and 0.030 mg $N \cdot L^{-1}$ measured in the August 29th sample.

Whereas Gibbs Pond exhibited slight temperature and dissolved oxygen stratification on August 2nd, it is not unusual, under these conditions that warm mid-summer conditions would lead to a build-up of **ammonia-nitrogen** in the ***lower*** region of the pond since this is the first nitrogen product from organic decomposition by bacteria of material accumulated near, or on, the pond bottom.

On August 2nd, the **total nitrogen (TN)** concentration in the ***upper*** region of Gibbs Pond was 1.59 mg $N \cdot L^{-1}$, which is a moderate concentration for a pond with high year-round productivity; the ***lower*** region value was 1.35 mg $N \cdot L^{-1}$. By August 29th, the TN concentration was 1.76 mg $N \cdot L^{-1}$ in the pond.

Except on August 2nd when the concentration of ammonia-nitrogen was 0.340 mg $N \cdot L^{-1}$ in the lower region of the Gibbs Pond water column, essentially all (>95 percent) of the nitrogen in the samples collected was comprised of **organic nitrogen** (**ON**) in the form of algae (phytoplankton); see Table 3-2.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Gibbs Pond during 2017 are shown in Table 3-2. On August 2nd, the **TP** concentration was 0.440 mg $P \cdot L^{-1}$, which is elevated and indicative of high productivity. The concentration in the ***lower*** region on August 2nd (not shown in Table 3-2) was 0.424 mg P·L-1.

By August 29th, the TP concentration was 0.509 mg $P \cdot L^{-1}$; no ***lower*** region sample was collected. All of these concentrations are considered elevated and indicate a high level of productivity in the pond, which is substantiated by field observations on both August sampling dates of low Secchi depth transparency.

The reader is referred to Chapter 10 of this report for a comparison of water quality among the 11 Nantucket Island ponds that have been monitored by the NLC since 2009 when there was a cooperative effort with the UMass Field Station to survey Miacomet and Hummock Ponds.

3.1.4 Phytoplankton

Description of the assemblage. There were a total of 40 phytoplankton taxa identified in the August 2nd phytoplankton sample collected from Gibbs Pond and 36 taxa identified in the August 29th sample; 54 different taxa were identified in the pond during 2017 (Table 3-3).

The 2017 phytoplankton community richness in Gibbs Pond was 38 ± 2.8 taxa.

Table 3-3. Major groups and taxa of phytoplankton identified in Gibbs Pond, 2017.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyta)**
Anabaena flos aquae	*Mougeotia* sp.	*Gomphonema* spp.
Aphanizomenon flos aquae	*Oocystis Borgei*	*Gyrosigma* sp.
Chroococcus dispersus	*O. solitaria*	*Navicula* spp.
Dictyosphaerium Ehrenbergianum	*Pediastrum duplex*	*Nitzschia* sp.
Merismopedia glauca	*Pyramimonas tetrarhyncus*	*Planothidium* sp.
Rhabdoderma Gorskii	*Quadrigula lacurstris*	*Stephanodiscus* sp.
Woronichinia naegeliana	*Scenedesmus acuminatus*	*Synedra acus*
Chloromonadophyta	*S. bijuga*	*S. ulna*
Gonyostomum semen	*S. bijuga alternans*	**Chrysophyta (Chrysophyceae)**
Chlorophyta	*S. quadricauda*	*Mallomonas* sp.
Ankistrodesmus falcatus	*Schroederia Judayi*	*Ochromonas* sp.
Closteriopsis longissima	*Selenastrum capriconnutum*	**Euglenophyta**
Closterium sp.	*S. minutum*	*Euglena* spp.
C. gracile	*Sphaerocystis Schroeteri*	*Peranema* sp.
Coelastrum cambricum	*Spirulina* sp.	*Phacus sp.*
Cosmarium spp.	*Staurastrum natator var. crassum*	*Trachelomonas* sp.
Crucigenia rectangularis	*Tetraedron minimum*	**Pyrrhophyta (Cryptophyceae)**
Elakatothrix gelatinosa	**Chrysophyta (Bacillariophyta)**	*Cryptomonas ovata*
Eudorina elegans	*Achnanthes* sp.	*Ceratium hirundinella*
Micractinium pusillum	*Aulocoseria granulata*	*Peridinium cinctum*
Monoraphidium arcuatum	*Cyclotella* sp.	

Table 3-4 presents a summary of the Gibbs Pond phytoplankton community characteristics determined from samples collected during 2016 and 2017.

Table 3-4. Summary of Gibbs Pond phytoplankton community characteristics, 2016 and 2017.

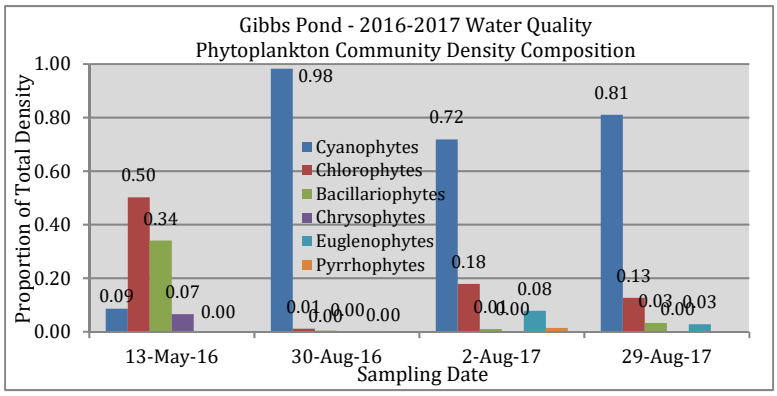
Gibbs Pond Phytoplankton, 2016 and 2017						
Sampling Date	Total Phytoplankton Taxa	Cell Density (cells/mL^{-1})	Cell Biomass (mg/m^3)	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration (µg/L^{-1})
13-May-16	26	5229	2800	1.044	0.924	7.5
30-Aug-16	30	188170	8095	0.165	0.758	216.6
2016 avg	28	96700	5448	0.605	0.841	112.1
2-Aug-17	40	35102	11890	0.901	1.043	66.3
29-Aug-17	36	74603	16150	0.773	0.991	63.5
2017 avg	38	54853	14020	0.837	1.017	64.9

Density. As shown in Table 3-4, phytoplankton community density in Gibbs Pond was 35,102 cells·mL^{-1} on August 2nd and 74,603 cells·mL^{-1} on August 29th; average density was 54,853 cells·mL^{-1} for both sampling dates during 2017.

The 2017 density values indicate a more stable community than was observed during 2016 when the May density was extremely low (5,229 cells·mL^{-1}) following winter and during the spring warming period, followed by 188,170 cells·mL^{-1} during late August when an algal bloom obviously was in progress (which also was substantiated by the chlorophyll a concentration of 216.6 µg·L^{-1} on August 30th).

Figure 3-2 presents the 2016 and 2017 density composition of the Gibbs Pond phytoplankton assemblage for comparative purposes. The May 13th 2016 phytoplankton assemblage was comprised primarily of Chlorophytes (green algae) with 50 percent of the total density and Bacillariophytes (diatoms) with 34 percent of the density; the remainder of the community consisted of Cyanophytes (9 percent) and Chrysophytes (7percent). Euglenophytes and Pyrrhophytes were not identified in the May assemblage. By August 30th 2016, the phytoplankton assemblage had undergone a dramatic change and 98 percent of the community density was comprised of Cyanophytes while the documented bloom was in progress.

Figure 3-2. Density composition of the phytoplankton community in Gibbs Pond, 2016 and 2017.



The 2017 density composition was fairly stable between the 2 sampling dates with the community composition not changing much during the 4-week period. Cyanophytes (Blue-green algae) were dominant and comprised greater than 70 percent of the population on both dates; Chlorophytes were the next dominant group on both dates (Figure 3-2).

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.

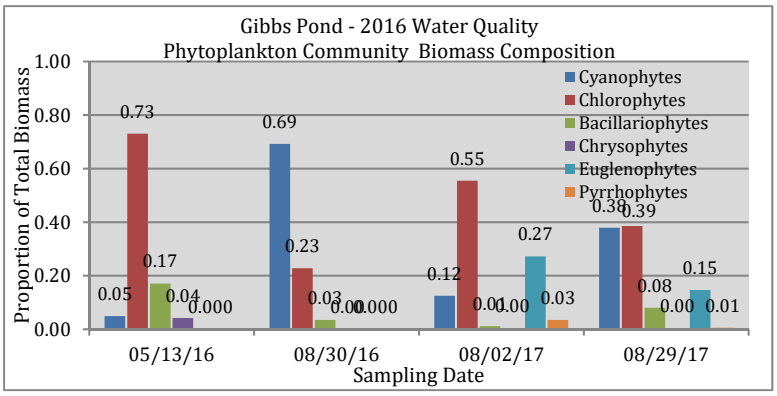
The 2016 and 2017 community biomass values for Gibbs Pond are presented in Table 3-4. Both 2017 biovolumes were greater than the values measured in 2016, and the 2017 values were not that different from each other (11,890 mg/m^3 on August 2nd and 16,150 mg/m^3 on August 29th). The primary culprit in the 2016 'bloom' in Gibbs Pond was *Woronichinia naegeliana*, a Cyanophyte known to produce toxins that are released into the surrounding water column.

Figure 3-2 presents the 2016 and 2017 community biomass composition for Gibbs Pond. The substantial difference between the May and August 2016 composition highlights the unstable nature of the community, while the changes between August 2nd and 29th 2017 are not as dramatic but generally represent shifts in the distribution of biomass among the major phytoplankton groups.

The May 2016 phytoplankton community was comprised primarily of Chlorophytes (73 percent) with lesser amounts of Bacillariophytes (diatoms), Cyanophytes (5 percent) and Chrysophytes (4 percent). By August 30th, the biomass composition of the phytoplankton community had changed dramatically and consisted primarily of Cyanophytes (69 percent) and Chlorophytes (23 percent).

The August 2017 community was more stable when comparing the two (2) sampling dates; the Cyanophytes increased in biomass from 12 percent to 38 percent, while the Chlorophytes decreased in biomass from 55 percent to 39 percent. Most major groups of phytoplankton were represented in the community during 2017, while several major groups (Chrysophytes, Pyrrhophytes) were absent from the community during the 2016 sampling period.

Figure 3-2. Biomass composition of the phytoplankton community in Gibbs Pond, 2016 and 2017.



Dominance. A ranking of phytoplankton taxon dominance in Gibbs Pond during 2016 and 2017 is summarized in Table 3-5.

Table 3-5. Rank of phytoplankton taxa dominance, using biomass, in Gibbs Pond, 2016 and 2017.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
13-May-16	*Sphaerocystis Schroeteri* (Chlorophyte)	1	26
	Staurastrum natator var. *crassum* (Chlorophyte)	2	26
	Cyclotella sp. (Bacillariophyte)	3	15
	Pediastrum duplex (Chlorophyte)	4	10
	Anabaena flos aquae (Cyanophyte)	5	5
30-Aug-16	*Woronichinia naegeliana* (Cyanophyte)	1	52
	Aphanizomenon flos aguae (Cyanophyte)	2	15
	Coelastrum cambricum (Chlorophyte)	3	12
2-Aug-17	*Trachelomonas* sp. (Euglenophyte)	1	26
	Pediastrum duplex (Chlorophyte)	2	18
	Closterium acutum (Chlorophyte)	3	16
	Eudorina elegans (Chlorophyte)	4	6
	Anabaena flos aquae (Cyanophyte)	5	6
29-Aug-17	*Dictyosphaerium Ehrenbergianum* (Cyanophyte)	1	26
	Trachelomonas sp. (Euglenophyte)	2	13
	Pediastrum duplex (Chlorophyte)	3	8
	Gonyostomum semen (Chloromonadophyte)	4	8
	Aphanizomenon flos aquae (Cyanophyte)	5	7
	Closterium gracile (Chlorophyte)	6	5

Taxa are considered community dominants when they comprise at least 5 percent of the total community biomass. There were 5 dominant taxa in the phytoplankton community on May 13th 2016 and 3 dominant taxa in the community on August 30th 2016.

During 2017, there were 5 dominant taxa in the community on August 2nd and 6 dominant taxa on August 29th. Two (2) taxa (*Trachelomonas* sp., *Pediatrum duplex*) were among the dominant forms on both 2017 sampling dates. *Woronichinia naegeliana* was the most dominant species during 2016 and 2017, comprising 52 percent of the community biomass on August 30th 2016 (see Table 3-5).

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 results of the diversity calculations are presented in Table 3-4. The density and biomass diversity value for each sampling date are quite similar except on August 30th 2016, when the density diversity was 0.165 and the biomass diversity was 0.758.

Cyanophytes. Cyanophytes were identified in all 4 phytoplankton samples collected at Gibbs Pond during 2016 and 2017; there were a total of 8 species identified in the samples as shown in Table 3-6.

Table 3-6. Cyanophyte species identified in Gibbs Pond, 2016.

Species	13-May-16	30-Aug-16	2-Aug-17	29-Aug-2017
*Anabaena flos aquae**	yes (9%)	yes (<1%)	yes (9%)	no
*Aphanizomenon flos aquae**	no	yes (3%)	yes (<1%)	yes (11%)
Gomphosphaeria lacustris compacta	no	yes (1%)	no	no
Chroococcus dispersus	no	no	no	yes (7%)
Dictyosphaerium Ehrenbergianum	no	no	yes (13%)	yes (52%)
Merismopedia glauca	no	yes (1%)	yes (47%)	yes (11%)
Rhabdoderma Gorskii	no	no	yes (<1%)	no
*Woronichinia naegeliana**	no	yes (93%)	yes (3%)	no
'*' = species that are known to produce toxins 'yes' = present; 'no' = absent; (#) = percent of total community composition				

Three of these species, *Anabaena flos aquae*, *Aphanizomenon flos aquae* and *Woronichinia naegeliana* are known to produce algal toxins with a range of effects including liver, nerve, skin and gastrointestinal disorders. While there is no evidence that the genera documented in Gibbs Pond produce any algal toxins, recreational users of the pond should be aware that potentially dangerous Cyanobacteria can be present during the mid-summer periods.

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Gibbs Pond (Table 3-4) were 7.5 $\mu g \cdot L^{-1}$ on May 13th and 216.6 $\mu g \cdot L^{-1}$ on August 30th; the latter value is extremely high and indicative of a major phytoplankton bloom in progress.

During 2017, the chlorophyll ***a*** values were very similar with 66.3 $\mu g \cdot L^{-1}$ measured on August 2nd and 63.5 $\mu g \cdot L^{-1}$ measured on August 29th. Both 2017 values were indicative of high productivity occurring in the pond when the samples were collected.

3.1.5 Trophic Status

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

The reader is referred to Chapter 1 for a more thorough explanation of trophic status and the process of calculating this important indicator of lake and pond productivity.

[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.

Sufficient water quality data were collected from Gibbs Pond during 2017 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 August sampling dates. 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* = 64.9 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (64.9)] + 30.6
TSI = (9.81)(4.17) + 30.6
TSI = 71.54

Total phosphorus
Average total phosphorus = 474.30 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (474.30)] + 4.15
TSI = (14.42)(6.16) + 4.15
TSI = 93.0

Secchi depth
Average Secchi depth = 0.36 m
Secchi TSI = 60 – [14.41*[ln (0.36)]
TSI = 60 – (14.41)(-1.03)
TSI = 74.9

The 2017 TSI values are presented in Table 3-7 with the values calculated for 2016 to evaluate what sorts of trends might be occurring with water quality.

Table 3-7. Trophic State Indices (TSIs) calculated for Gibbs Pond, 2016 and 2017.

Year	Chlorophyll TSI	TP TSI	Secchi TSI
2016	76.9	88.5	66.9
2017	71.5	93.0	74.9

The TSI values presented in the above table should be compared with the criteria presented in Table 3-8 below when evaluating the trophic status of Gibbs Pond.

Table 3-8. 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 2017 water quality parameters were situated within the hyper-eutrophic range which indicates extremely high mid-summer productivity in Gibbs Pond. As shown in Table 3-7, the 2017 TSI value for chlorophyll decreased within the hyper-eutrophic range compared with 2016, while the TSI value for TP increased within the hyper-eutrophic range and the value for Secchi depth shifted from the eutrophic to the hyper-eutrophic range.

The TSI values calculated for Gibbs Pond 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 swimming and other recreational use during the summer months.

3.2 Summary

Based upon the data collected during 2016, 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 2 separate water quality variables that were sampled. 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 sufficient winds 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.

3.3 Literature Cited

Sutherland, J.W. and E. Molden, 2017. *Nantucket Island Ponds and 2016 Water Quality. Tom Nevers, Gibbs, Little Weweeder, Maxcy, Washing and North Head of Long Ponds. A Summary of Physical, Chemical and Biological Monitoring*. Prepared for the Nantucket Land Council, Inc. 90 pp. + attachments.

Nantucket Island Ponds and 2017 Water Quality

Chapter 4

Head of Hummock Pond

4.0 Introduction

Head of Hummock Pond was sampled for water quality by the NLC during July and August 2017. This chapter presents a summary and discussion of the 2017 physical, chemical and biological data collected from the pond by NLC staff.

4.1 Results

When Head of Hummock Pond was sampled on July 25th 2017, the maximum water depth located in the pond was 11.6 feet (3.5 meters) at the sampling location in the approximate center of the pond. Following the collection of temperature and dissolved oxygen profile data, an integrate sample was collected from the surface down to 8.0 feet (2.4 m) of depth for the chemistry and phytoplankton samples. A grab sample was not collected since the pond was so shallow and there was no indication of stratification of the water column with regard to temperature or dissolved oxygen saturation.

On August 29th 2017, the maximum depth found in Head of Hummock Pond was 10.9 feet (3.3 m) and a single integrate sample was collected down to 8.0 feet (2.4 m) for the chemistry and phytoplankton samples

4.1.1 Physical characteristics

General. Head of Hummock Pond is located on the western portion of Nantucket Island, just southeast of the intersection of Madaket Road with Cliff Road. In aerial view, the pond has an inverted pear-shape that is oriented in a north-south direction with the wide portion situated north and the narrow portion on the south (Figure 4-1).

Figure 4-1. 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 the main body of 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, or 6.5 hectares[1]. In order to calculate an approximate volume, if the pond outline is considered as an exaggerated circle, then the radius is 140 m and the rough volume for a bowl (pond in cross-section) can be calculated using the equation for one-half the volume of a sphere as follows:

$$V = \frac{2}{3}\,\pi\,(r^3)$$

Using this equation, the estimated volume of Head of Hummock Pond is 5,772,827 m^3, or 4680 acre-feet. One acre-foot is the volume of water sufficient to cover an acre of surface to a depth of 1 foot. The volume of water contained in Head of Hummock Pond within normal summer water levels would be sufficient to cover 4680 acres of land to a depth of 1 foot.

Table 4-1 presents a summary of the physical characteristics of Head of Hummock Pond collected during July and August 2017.

Table 4-1. Summary of physical data from Head of Hummock Pond, 2017.

Head of Hummock Pond Physical Properties, 2017		
Sampling Date	Secchi depth (m)	Avg Water Column Temperature (°C)
25-Jul-17	0.97	21.5
29-Aug-17	0.76	22.6
2017 avg	0.87	22.1

Transparency. The water clarity in Head of Hummock Pond was poor on both sampling dates, with values of 0.97 and 0.76 m on July 25th and August 29th, respectively (Table 4-1).

Temperature. Temperature profile data were collected on each 2017 sampling trip to Head of Hummock Pond. The average water column temperature on each sampling date is shown in Table 4-1. The water column was isothermal from the surface to the bottom on both sampling dates.

4.1.2 Chemical characteristics

Table 4-2 summarizes the 2017 chemical characteristics of Head of Hummock Pond including the algal nutrients, phosphorus and nitrogen.

Table 4-2. Summary of chemical data from Head of Hummock Pond, 2017.

Sampling Date	Avg DO Saturation	TP (mg/L)	NO3 (mg/L)	NH4 (mg/L)	NO3 + NH4 (mg/L)	TN (mg/L)	Org N (mg/L)	spC (µS)	pH (s.u.)
25-Jul-17	74.5	0.067	0.005	0.040	0.045	0.89	0.85	3941	9.27
29-Aug-17	96.6	0.205	0.005	0.020	0.025	0.98	0.96	3065	8.95
2014 avg	85.6	0.136	0.005	0.030	0.035	0.94	0.91	3503	9.11

Dissolved oxygen percent saturation. The average dissolved oxygen percent saturation value for the Head of Hummock Pond water column on both sampling dates is shown in Table 4-2. The value of 74.5 percent on July 25th is low because of low readings at the 10-foot and 11-foot depths; otherwise, the percent saturation was near 100% throughout the water column.

The value of 96.6 percent from August 29th is low because of a low reading at the 10-foot depth on that sampling date; otherwise, the water column of the pond was supersaturated (>100 percent) with dissolved oxygen on that date.

[1] 1 hectare = 2.47 acres

Specific conductance. The specific conductance levels measured in Head of Hummock Pond during July and August 2017 were high, 3,941 and 3065 $\mu S \cdot cm^{-1}$, respectively, reflecting estuarine conditions and salt water intrusion from the earlier spring opening of Hummock Pond to the Atlantic Ocean. The difference between the 2 readings results from dilution of water in the pond by ground water seepage into the pond and rainfall occurring on the surface of the pond.

pH. Within freshwater and estuarine ecosystems, the pH can fluctuate considerably within daily and seasonal time-frames, and many organisms living in 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 concentration affects the aqueous equilibria that involve pond-water constituents such as ammonia, hydrogen sulfide, chlorine and dissolved metals, and can cause pH toxicity.

Carbon dioxide within the Head of Hummock Pond ecosystem is controlled by internal biological activity. All living animals continuously produce carbon dioxide as a by-product of respiration. On the other hand, algae and plants living and growing in the pond remove carbon dioxide from the water during photosynthesis. The relative rates of respiration and photosynthesis within HHP determine whether there is net addition or removal of carbon dioxide, and whether the pH will fall or rise, respectively.

During 2017, Head of Hummock Pond exhibited high pH values (9.27 s.u. on July 25th and 8.95 s.u. on August 29th; seasonal average = 9.11 s.u.). Based upon the very limited water clarity (low transparency) observed during 2017, most of the biological productivity was occurring in the upper region of the pond.

4.1.3 Plant Nutrients

Nitrogen. The 2017 average **nitrate-nitrogen** concentration in the pond was low (Table 4-2); the concentration averaged 0.005 mg $N \cdot L^{-1}$ in the ***upper*** and ***lower*** regions for the entire season, which is the level of detection for the analytical lab. This condition is not unusual in a pond with high productivity because nitrate-nitrogen is readily taken up by the phytoplankton community for photosynthesis.

Ammonia-nitrogen concentrations were 0.040 and 0.020 mg $N \cdot L^{-1}$ on July 25th and August 29th, respectively. These values are low and not unusual in ponds with high productivity because this form of nitrogen also is available for uptake by the phytoplankton community.

The 2017 **total nitrogen** (TN) measured in Head of Hummock Pond was low when compared with other Nantucket Island ponds that have been surveyed by the NLC. The values were 0.89 and 0.98 mg $N \cdot L^{-1}$ on July 25th and August 29th, respectively, and the average value during 2017 was 0.94 mg $N \cdot L^{-1}$.

Organic nitrogen was not measured directly in collected samples but was calculated by subtracting the ammonia + nitrate concentrations from the TN concentration. The results for the 2017 Head of Hummock Pond data are presented in Table 4-2. On both 2017 sampling dates, > 95 percent of the nitrogen measured in the water column of the pond was in the form of organic nitrogen, which includes the phytoplankton and other organisms (e.g., zooplankton) in the biological community.

Phosphorus. The **total phosphorus** (**TP**) concentration measured in Head of Hummock Pond during 2017 was 0.067 mg $P \cdot L^{-1}$ on July 25th and 0.205 mg $P \cdot L^{-1}$ on August 29th, a 3-fold increase in concentration during about a 1-month period. This high value, along with the condition of reduced transparency in the pond indicates that a phytoplankton bloom was in progress. The 2017 TP values measured in Head of Hummock Pond are indicative of high productivity, even though higher values were measured in other island ponds during 2017.

4.1.4 Phytoplankton

Description of the assemblage. There were 30 taxa identified in the 2017 Head of Hummock Pond phytoplankton samples; all of the major algal groups were represented (Table 4.3).

The number of taxa observed in the pond's phytoplankton community was 20 on July 25th and 24 on August 29th. Community richness averaged 22.0 (±2.8) taxa for the 2017 sampling season.

Table 4-3. Major groups and taxa of phytoplankton identified in Head of Hummock Pond, 2017.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*S. bijuga alternans*	*Planothidium* sp.
Aphanizomenon flos-aquae	*S. quadricauda*	**Chrysophytes (Chrysophyceae)**
Chroococcus disperses	*Schroederia Judayi*	*Ochromonas* sp.
C. limneticus	*Selenastrum capricornutum*	**Euglenophytes**
Microcystis incerta	*Tetraedron minimum*	*Euglena* sp.
Chlorophytes	**Chrysophytes (Bacillariophyceae)**	*Peranema sp.*
Ankistrodesmus falcatus	*Achnanthes* sp.	*Trachelomonas* spp.
Eudorina elegans	*Chaetoceros* sp.	**Pyrrhophytes (Cryptophyceae)**
Oocystis Borgei	*Cocconeis* sp.	*Cryptomonas ovata*
O. solitaria	*Cyclotella* sp.	**Pyrrhophytes (Dinophyceae)**
Pyramimonas tetrarhyncus	*Navicula* spp.	*Ceratium hirundinella*
Scenedesmus acutiformis	*Nitzschia* sp.	*Peridinium cinctum*

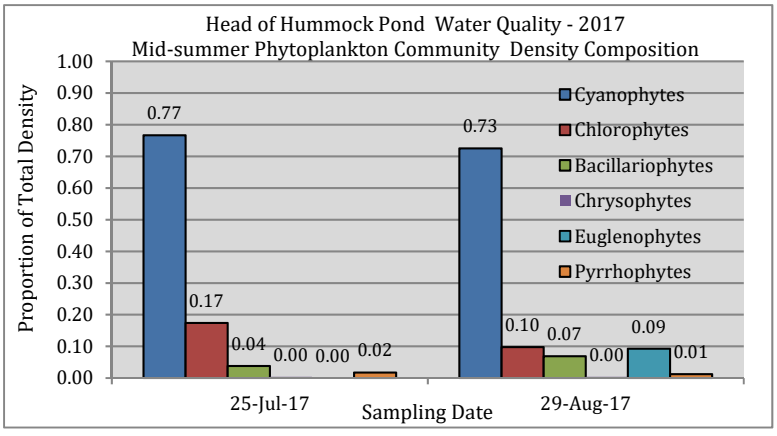
Table 4-4 presents a summary of the 2017 Head of Hummock Pond phytoplankton community characteristics based upon the July and August collections.

Table 4-4. Summary of Head of Hummock Pond phytoplankton community characteristics, 2017.

Head of Hummock Pond Phytoplankotn Community Characteristics, 2017						
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})
25-Jul-17	20	24472	4032	0.864	0.896	21.7
29-Aug-17	24	23718	2939	0.876	0.903	32.3
2017 avg	22	24095	3486	0.870	0.900	27.0

Density. The phytoplankton density during 2017 was moderate with values of 24,472 and 23,718 cells·mL^{-1} measured on July 25th and August 29th, respectively. Figure 4-2 presents the 2017 phytoplankton community cell density composition measured in Head of Hummock Pond.

Figure 4-2. Density composition of the phytoplankton community in Head of Hummock Pond, 2017.



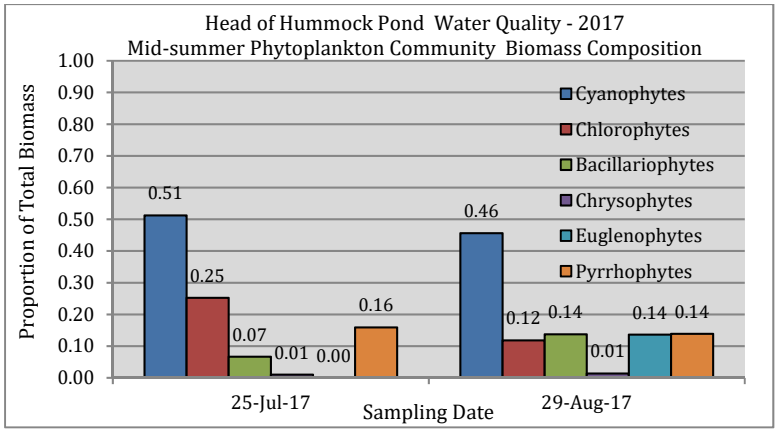
The Cyanophytes comprised 77 and 73 percent of the total phytoplankton community density on July 25th and August 29th, respectively, with lesser amounts of almost all other major groups represented.

The only remaining major phytoplankton groups not represented in the community were the Chrysophytes and Euglenophytes on July 25th and the Chrysophytes on August 29th (see Figure 4-1).

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 that occur in the pond.

During 2017, the phytoplankton community biomass was 4,032 mg·m^{-3} on July 25th and 2,939 mg·m^{-3} on August 29th. Figure 4-3 presents the 2017 biomass composition of the phytoplankton community in Head of Hummock Pond measured in the samples collected on July 25th and August 29th.

Figure 4-3. Biomass composition of the phytoplankton community in Head of Hummock Pond, 2017.



Cyanophytes comprised about 50 percent of the community biomass on both sampling dates and there was good representation among the other major groups except Chrysophytes and Euglenophytes on July 25th and the Chrysophytes on August 29th (also noted above for community density).

Dominance. A ranking of phytoplankton taxa dominance in Head of Hummock Pond during each sampling date in 2017 is summarized in Table 4-5.

Table 4-5. Rank of phytoplankton taxa dominance, using biomass, in Head of Hummock Pond.

Sampling Date	Biomass Rank	Taxon (Major Group)	% of Total Biomass
25-Jul-17	1	*Anabaena flos aquae* (Cyanophyte)	34
	2	*Eudorina elegans* (Chlorophytes)	16
	3	*Aphanizomenon flos aquae* (Cyanophyte)	14
	4	*Pyramimonas tetrarhyncus* (Chlorophyte)	8
	5	*Cryptomonas ovata* (Pyrrhophytes)	8
	6	*Peridinium cinctum* (Pyrrhophyte)	6
29-Aug-17	1	*Anabaena flos aquae* (Cyanophyte)	33
	2	*Chrococcus dispersus* (Cyanophytes)	9
	3	*Cryptomonas ovata* (Pyrrhophytes)	8
	4	*Oocystis Borgei* (Chlorophytes)	7
	5	*Peranema* sp. (Euglenophytes)	7
	6	*Ceratium hirundinella* (Pyrrhophyte)	6
	7	*Trachelomonas* spp. (Euglenophytes)	6
	8	*Nitzschia* sp. (Bacillariophyte)	5

A total of 6 taxa were dominant on July 25th and 8 taxa were dominant on August 29th. The large number of dominant taxa on both dates suggests that diversity of the community was high (discussed below).

The Cyanophyte, *Anabaena flos aquae*, was the leading dominant species in the community on both sampling dates, comprising 34 and 33 percent of the total community on July 25th and August 29th, respectively.

Diversity. Seasonal phytoplankton diversity in Head of Hummock Pond was measured using the Shannon-Wiener function[2] 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.

Density and biomass diversity both were high in HHP during 2017, as shown in Table 4-4. In fact, the density and biomass diversity values were similar on each sampling date.

Cyanophytes. As a major group of phytoplankton, the Cyanophytes were (1) identified in both 2017 samples collected from HHP, (2) density dominants on both sampling dates, and (3) biovolume dominants on both sampling dates. There were five (5) Cyanophyte genera identified in the 2017 phytoplankton samples collected from HHP including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, *Chroococcus dispersus*, *C. limneticus* and *Microcystis incerta*. Table 4-6 summarizes the species of Cyanophytes identified in Head of Hummock Pond during 2017.

Table 4-6. Cyanophyte species identified in Head of Hummock Pond, 2017.

Species	25-Jul-17	29-Aug-17
*Anabaena flos aquae**	yes (34)	yes (33)
*Aphanizomenon flos aquae**	yes (14)	no
Chroococcus dispersus	yes (3)	yes (9)
C. limneticus	no	yes (3)
Microcystis aeruginosa	yes (1)	yes (1)
'yes' = present, 'no' = absent; (#) percent of community total on a sampling date * Species that are known to produce algal toxins		

Anabaena flos aquae, Aphanizomenon flos aquae and *Microcystis incerta* are known to produce toxins (DiTomasi 1994) that can pose a public health issue when present in waters that are used for recreation.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Head of Hummock Pond during 2017 were 21.7 and 32.2 µg L^{-1} on July 25th and August 29th, respectively, for an average of 27.0 µg L^{-1} (Table 4-4).

4.1.5 Trophic Status

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

Sufficient water quality data were collected from HHP during 2017 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 July and August sampling dates. 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:

[2] $H = -\sum_{i=1}^{S} (p_i)\,(log_2)(p_i)$, 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.

Chlorophyll *a*

Average chlorophyll *a* = 27.0 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (27.0)] + 30.6
TSI = (9.81)(2.73) + 30.6
TSI = 62.93

Total phosphorus

Average total phosphorus = 135.5 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (135.5)] + 4.15
TSI = (14.42)(2.27) + 4.15
TSI = 74.94

Secchi depth

Average Secchi depth = 0.86 m
Secchi TSI = 60 – [14.41*[ln (0.86)]
TSI = 60 – (14.41)(-0.147)
TSI = 62.11

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 4-7. 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 TSI of 62.93 calculated for chlorophyll ***a*** was well within the eutrophic range of productivity, while the TSI calculated for total phosphorus (74.94) was within the hyper-eutrophic region. The average 2017 Secchi depth resulted in a calculated TSI value of 62.11 which, although within the eutrophic region, was not as robust a calculator as the other two variables. Regardless of which calculator is used to calculate trophic status, Head of Hummock Pond exhibited poor water quality during the 2017 growing season.

4.2 Summary

Head of Hummock Pond continues to exhibit eutrophic and hyper-eutrophic productivity depending upon which 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 microcystins if blooms are detected.

4.3 Literature Cited

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Nantucket Island Ponds and 2017 Water Quality

Chapter 5

Long Pond

5.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Long Pond by the NLC during 2017. The NLC sampled the North Head of Long Pond during 2016 which is reported elsewhere (Sutherland and MacKinnon 2017).

5.1 Results

Long Pond was sampled on July 25th and August 23rd 2017 at three (3) different locations on each sampling date. The sampling locations are shown in Figure 5-1.

Figure 5-1. Aerial view of Long Pond (from *Google*™ earth) showing 2017 sampling locations.

Table 5-1 summarizes the water depth and depth of sample collection for chemistry and phytoplankton at each sampling location for the July and August sampling dates.

Table 5-1. Summary of sampling properties at Long Pond, 2017.

2017 Long Pond Sampling Properties			
Water Depth (m)	Station s-1	Station s-2	Station s-3
25-Jul-17	1.0	0.81	1.14
23-Aug-17	1.0	1.04	0.91
Sample Depth (m)			
25-Jul-17	0.61	0.30	0.30
23-Aug-17	0.61	0.61	0.61

The pond was so shallow at all sampling locations on both sampling dates that only an integrate sample was collected from the surface down to the depths shown in Table 3-1; no grab samples were collected.

5.1.1 Physical characteristics

General. Long Pond is located at the west end of Nantucket Island, south of Madaket Road, with the pond axis oriented in a southwest to northeast direction. The pond is connected to the North Head of Long

Pond by a causeway that serves as the Madaket Road crossing. The surface area of the pond is ~70 acres and the pond is connected to Madaket Harbor via Hither Creek.

The Town of Nantucket landfill is directly east of the north end of Long Pond (Figure 5-1). The remainder of the east side of the pond is sparsely developed conservation land and with residential development along the northwest side of the pond.

Table 5-2 summarizes the physical properties collected at the three (3) sampling locations on Long Pond during July and August 2017.

Table 5-2. Summary of physical data from Long Pond, 2017.

2017 Long Pond Physical Properties			
Avg. Temperature (°C)	Station s-1	Station s-2	Station s-3
25-Jul-17	20.4	20.4	20.3
23-Aug-17	24.3	24.5	24.1
Secchi Depth (m)			
25-Jul-17	0.76	on bottom	0.53
23-Aug-17	0.71	0.86	0.61

Temperature. Temperature profile data were collected at the 3 sampling stations during both 2017 sampling excursions. The pond is extremely shallow and there was nothing noteworthy about the 2017 temperature data collected.

Transparency. The Secchi depth transparency (Table 5-2) measured at the 3 sampling stations during 2017 always was less than 1.0 m except on July 25th when the Secchi could be seen on the bottom of the pond which was in 2.7 feet (0.81 m) of water.

5.1.2 Chemical characteristics

Specific conductance. All 2017 conductance values were similar and elevated by a factor of 1,000 when compared with other ponds on the Island where there is no exchange of sea water on a regular basis. The readings during the July and August dates are shown in Table 5.3

Table 5-3. Summary of specific conductance data from Long Pond, 2017.

2017 Long Pond Specific Conductance			
specific conductance (mS/cm)	Station s-1	Station s-2	Station s-3
25-Jul-17	20.4	20.4	20.3
23-Aug-17	24.3	24.5	24.1

The connection between Long Pond and Madaket Harbor, described above, is the reason for the high specific conductance values measured in the pond.

pH. All pH values were circumneutral and very similar at the 3 sampling stations on both 2017 sampling dates (Table 5-4) except station s-1 on July 25th when the pH value was 6.93 s.u.

Table 5-4. Summary of pH data collected from Long Pond, 2017.

2017 Long Pond pH Values			
specific conductance (mS/cm)	Station s-1	Station s-2	Station s-3
25-Jul-17	6.93	7.44	7.61
23-Aug-17	7.50	7.48	7.44

Dissolved oxygen percent saturation. The average 2017 oxygen saturation values for Long Pond are presented in Table 5-5. Values always were less than 100 percent which is expected in a very shallow

pond where the separation between the ***upper*** region where productivity occurs and the ***lower*** region where decomposition occurs is slight.

Table 5-5. Summary of dissolved oxygen saturation data from Long Pond, 2017.

2017 Long Pond Dissolved Oxygen Saturation			
dissolved oxygen % saturation	Station s-1	Station s-2	Station s-3
25-Jul-17	79.3	78.2	66.7
23-Aug-17	85.7	69.5	67.3

In addition, even very light winds moving along the main axis of the pond in a southwest to northeast direction would cause mixing of the water column which also would affect oxygen saturation.

5.1.3 Plant Nutrients

Nitrogen. Table 5-6 presents a summary of concentrations measured for the various forms of nitrogen in Long Pond during 2017.

Nitrate-nitrogen only was detectable at sampling station s-1 on July 25th 2017; otherwise this form of nitrogen was below detection at all stations on both sampling dates. This form of nitrogen is available for uptake by phytoplankton during photosynthesis in the water column so these low values that were measured are not unusual.

Ammonium-nitrogen values in Long Pond during both 2017 sampling dates ranged from 0.005 – 0.040 mg N·L-1 which are low and also not unusual because this form of nitrogen also is available for uptake by phytoplankton during photosynthesis in the water column.

Table 5-6. Summary of nitrogen data from Long Pond, 2017.

2017 Long Pond Nitrogen Data			
nitrate-nitrogen (mg N/L^{-1})	Station s-1	Station s-2	Station s-3
25-Jul-17	0.005	0.020	0.005
23-Aug-17	0.005	0.005	0.005
ammonia-nitrogen (mg N/L^{-1})			
25-Jul-17	0.040	0.040	0.020
23-Aug-17	0.040	0.020	0.005
total nitrogen (mg N/L^{-1})			
25-Jul-17	1.30	1.14	1.21
23-Aug-17	1.52	1.27	1.28
organic nitrogen (mg N/L^{-1})			
25-Jul-17	1.26	1.08	1.19
23-Aug-17	1.48	1.25	1.27
highlighted cells are values reported at one-half the lower detection limit			

Total nitrogen (TN) concentration (Table 5-6) were similar at all stations on all sampling dates and ranged from 1.14 – 1.52 mg N·L^{-1}, values that indicate moderate productivity in the water column.

Organic nitrogen (**ON**) concentrations are summarized in Table 5-6. From these data we can see that more than 95 percent of the nitrogen measured in Long Pond on the 2017 sampling dates was in the form of **ON** which includes the phytoplankton and other organisms found in the water column.

Phosphorus. Table 5-7 presents a summary of the **total phosphorus** (**TP**) values measured in Long Pond on the July 25th and August 23rd sampling dates at the 3 sampling stations.

The **TP** concentrations ranged from 0.102 – 0.190 mg P·L^{-1} and are values that indicate moderate productivity in the Long Pond water column during mid-summer, which also is substantiated by the chlorophyll ***a*** concentrations measured in the pond during 2017 (see below).

Table 5-7. Summary of total phosphorus data from Long Pond, 2017.

2017 Long Pond Total Phosphorus Concentrations			
total phosphorus (mg/L^{-1})	Station s-1	Station s-2	Station s-3
25-Jul-17	0.117	0.105	0.190
23-Aug-17	0.102	0.103	0.155

The reader is referred to Chapter 10 of this report where various water quality parameters are compared among the 11 ponds that have been surveyed by the NLC for water quality since 2009 when Miacomet Pond and Hummock Pond were investigated.

5.1.4 Phytoplankton

Description of the assemblage. A total of 31, 24 and 25 taxa were identified in the July and August 2017 samples collected from Stations s-1, s-2 and s-3, respectively (see Table 5-8 below).

Table 5-8. Major groups and taxa of phytoplankton identified in Long Pond, 2017.

Station s-1

Cyanophyta	**Chrysophyta (Bacillariophyta)**	**Chrysophyta (Bacillariophyta)**
Merismopedia glauca	*Cocconeis* sp.	*Synedra acus*
Oscillatoria sp.	*Cyclotella* sp.	**Chrysophyta (Chrysophyceae)**
Chlorophyta	*Fragilaria crotonensis*	*Mallomonas* sp.
Closterium acutum	*Gomphonema* spp.	*Synura uvella*
Oocystis solitaria	*Gyrosigma* sp.	**Euglenophyta**
Pediastrum duplex	*Hippodonta* sp.	*Euglena* spp.
Pyramimonas tetrarhyncus	*Navicula* spp.	*Peranema* sp.
Schroederia Judayi	*Nitzschia* sp.	*Phacus* sp.
Chrysophyta (Bacillariophyta)	*N. longissima*	**Pyrrhophyta**
Achnanthes sp.	*Pinnularia* sp.	*Cryptomonas erosa*
Amphiprora sp.	*Stephanodiscus* sp.	*C. ovata*
Aulacoseria granulata	*Surirella* sp.	*Peridinium cinctum*

Station s-2

Chlorophyta	**Chrysophyta (Bacillariophyta)**	**Chrysophyta (Chrysophyceae)**
Coelastrum cambricum	*Gyrosigma* sp.	*Ochromonas* sp.
Oocystis Borgei	*Hippodonta* sp.	**Euglenophyta**
Pyramimonas tetrarhyncus	*Navicula* spp.	*Euglena* spp.
Scenedesmus quadricauda	*Nitzschia* sp.	*Peranema* sp.
Chrysophyta (Bacillariophyta)	*N. longissima*	**Pyrrhophyta**
Achnanthes sp.	*Pinnularia* sp.	*Cryptomonas erosa*
Chaetoceros sp.	*Planothidium* sp.	*Peridinium cinctum*
Cocconeis sp.	*Stauroneis* sp.	
Cyclotella sp.	*Synedra acus*	
Gomphonema spp.	*S. ulna*	

Station s-3

Chlorophyta	**Chrysophyta (Bacillariophyta)**	**Chrysophyta (Chrysophyceae)**
Pyramimonas tetrarhyncus	*Gyrosigma* sp.	*Ochromonas* sp.
Chrysophyta (Bacillariophyta)	*Hippodonta* sp.	**Euglenophyta**
Achnanthes sp.	*Navicula* spp.	*Euglena* spp.
Amphiprora sp.	*Nitzschia* sp.	*Peranema* sp.
Aulocoseria granulata	*Pinnularia* sp.	*Phacus* sp.
Chaetoceros sp.	*Planothidium* sp.	**Pyrrhophyta**
Cocconeis sp.	*Rhoicosphenia curvata*	*Cryptomonas erosa*
Cyclotella sp.	*Synedra acus*	*C. ovata*
Gomphonema spp.	*S. fulgens*	*Peridinium cinctum*
	S. ulna	

Community richness for the 2017 phytoplankton samples collected from Long Pond was as follows: 22.0 ± 4.2 taxa at Station s-1, 17.0 ± 8.5 taxa at Station s-2, and 18.5 ± 3.5 taxa at Station s-3.

It is noteworthy that Cyanophytes (Blue-green algae) were identified only at the north station (s-1) during 2017; no Cyanophytes were identified in the other 2017 pond samples.

The 2017 Long Pond phytoplankton community characteristics at the 3 sampling stations are summarized in Table 5-9.

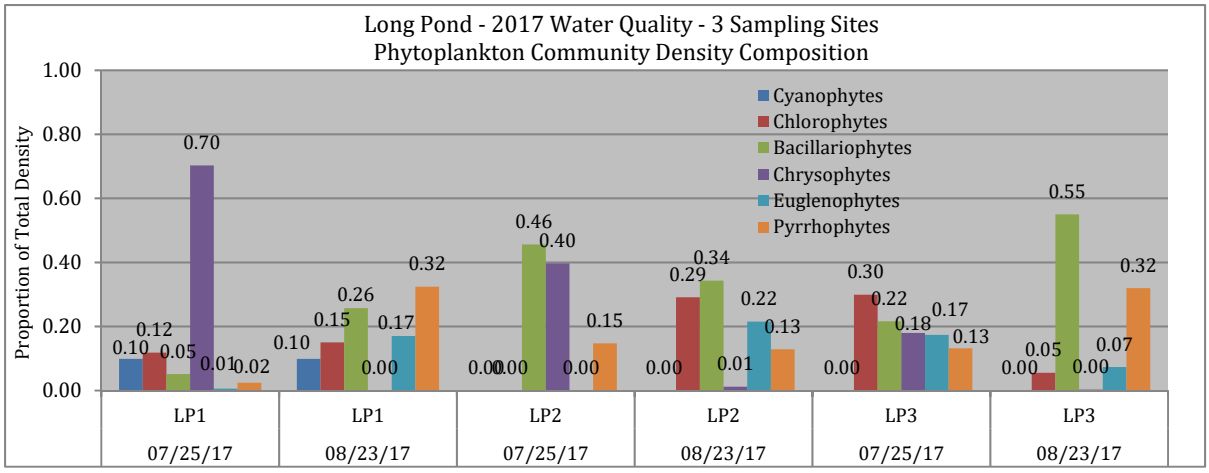
Table 5-9. Summary of Long Pond phytoplankton community characteristics, 2017.

	2017 Long Pond Phytoplankton Community Characteristics						
Station	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})
s1	25-Jul-17	25	9185	5580	0.519	0.549	8.80
	23-Aug-17	19	4546	15367	0.977	0.376	9.80
	2017 avg	22.0	6866	10474	0.750	0.463	9.30
s2	25-Jul-17	11	1222	3503	0.789	0.468	1.70
	23-Aug-17	23	3091	5594	0.940	0.613	5.50
	2017 avg	17.0	2156	4549	0.865	0.541	3.60
s3	25-Jul-17	16	3003	5607	0.897	0.542	12.0
	23-Aug-17	21	3838	11855	0.672	0.257	13.7
	2017 avg	18.5	3421	8731	0.78	0.400	12.9

The average number of taxa was greatest at Station s-1, the northern-most sampling point.

Density. Phytoplankton community density in the pond was greatest at Station s-1 on both sampling dates (Table 5-8), followed by Station s-3 and then Station s-2. All of the 2017 densities at the 3 sampling sites are actually very low and probably because of the high salinity in the pond. The density composition of the 2017 community at the 3 sampling sites is summarized in Figure 5-2 below.

Figure 5-2. Density compositionof the phytoplankton community in Long Pond, 2017.



Stations and sampling dates exhibiting a good representation of major phytoplankton groups in Figure 5-2 generally had a robust density biomass value, e.g., Station s-1 on August 23rd (0.977), Station s-2 on August 23rd (0.940), and Station s-3 on July 25th (0.897). There are no obvious patterns of community density within or among the 3 sampling sites.

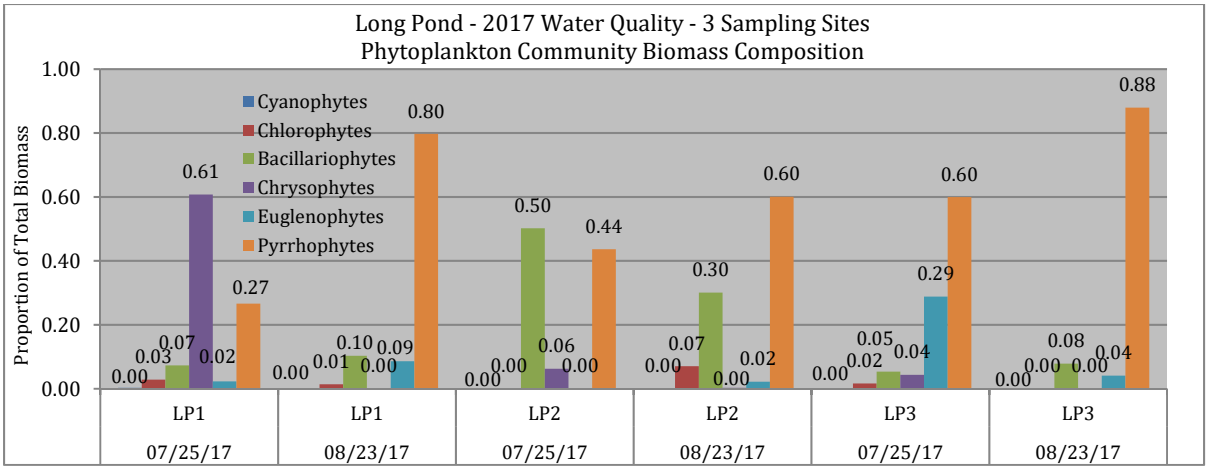
Biomass. Cell biovolume also was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond.

It is quite common for size differences among different taxa of phytoplankton to range over several orders of magnitude. For example, consider the green algae *Crucigenia quadrata* cells (93.3 mg·m^{-3}) and *Closterium* sp. cells (4000.0 mg·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.

As mentioned above for community density, the phytoplankton community biomass measured in Long Pond generally was low during 2017 except at Station s-1 on August 23rd (15,367 mg·m^{-3}) and at Station s-3 on August 23rd (11,855 mg·m^{-3}). This condition also is likely due to the high pond salinity.

The density composition of the 2017 phytoplankton community at the 3 sampling sites is summarized in Figure 5-3 below.

Figure 5-3. 2017 phytoplankton community biomass composition in Long Pond.



The data presented in Table 5-8 for biomass diversity shows a range of low values, from [**H**] = 0.257 to [**H**] = 0.613; these low values are corroborated by the biomass composition shown in Figure 5-3. Among the 3 sampling stations on the 2 sampling dates, the Long Pond community biomass during 2017 at all sampling stations was dominated by only 1 or 2 taxa.

The lowest diversity value ([**H**] = 0.257) occurred at sampling station LP3 on August 23rd when 88 percent of the community was comprised of Pyrrhophytes and the remaining 12 percent of the community was allocated among 2 major groups of phytoplankton.

The highest diversity value ([**H**] = 0.613) occurred at sampling station LP2 on August 23rd when 60 percent of the community biomass was comprised of Pyrrhophytes and the remaining 40 percent of the community biomass was allocated among 4 other major phytoplankton groups (Figure 5-3).

As shown in Figure 5-3, the Pyrrhophytes always were a major portion of the 2017 biomass in Long Pond, as were the Bacillariophytes (diatoms). The next most important groups in the 2017 community structure were the Chrysophytes (LP1-July 25th-61 percent) and the Euglenophytes (LP3-July 25th- 29 percent)(Figure 5-3).

[**Author's Note**]: the Pyrrhophytes are a major group of the algae comprising yellowish-green to golden-brown forms that are mostly unicellular and biflagellate, that form starch, starchy compounds, or oil as food reserves, and that include the dinoflagellates and cryptomonads.

Dominance. A ranking of phytoplankton taxa dominance in Long Pond on the 2017 sampling dates is summarized in Table 5-10 below. There were only 1-4 taxa dominant in the community among the 3 sampling stations and the 2 sampling dates.

Table 5-10. Rank of phytoplankton taxa dominance, using biomass, in Long Pond, 2017.

Station s-1

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
25-Jul-17	*Synura uvella* (Chrysophyte)	1	60
	Peridinium cinctum (Pyrrhophyte)	2	26
23-Aug-17	*Peridinium cinctum* (Pyrrhophyte)	1	80
	Euglena spp. (Euglenophyte)	2	8
	Gyrosigma sp. (Bacillariophyte)	3	7

Station s-2

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
25-Jul-17	*Gyrosigma* sp. (Bacillariophyte)	1	46
	Peridinium cinctum (Pyrrhophyte)	2	40
	Ochromonas sp. (Chrysophyte)	3	6
23-Aug-17	*Peridinium cinctum* (Pyrrhophyte)	1	60
	Gyrosigma sp. (Bacillariophyte)	2	19
	Pinnularia sp. (Bacillariophyte)	3	5
	Coelastrum cambricum (Chlorophyte)	4	5

Station s-3

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
25-Jul-17	*Peridinium cinctum* (Pyrrhophyte)	1	60
	Euglena spp. (Euglenophyte)	2	24
	Phacus sp. (Euglenophyte)	3	6
23-Aug-17	*Peridinium cinctum* (Pyrrhophyte)	1	88

The Pyrrhophyte, *Peridinium cinctum*, always was a dominant form at all sampling stations on both sampling dates (Table 5-9). The next most dominant form was the diatom, *Gyrosigma* sp.

Diversity. Phytoplankton diversity in Long Pond was measured using the Shannon-Weiner function[1] which calculates diversity, **[H]**, using number of taxa and the proportion of individuals distributed among the taxa on each sampling date. An increase in either factor (number of taxa, proportion of individuals) 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 Long Pond was calculated using both density and biomass in the equation. The results of the diversity calculations were presented in Table 5-8 above. There also was some discussion concerning the density and biomass diversity values in the previous section **Density** and **Biomass** above. Density diversity values generally were higher at each sampling station on each sampling date. This was due to the fact that most of the community biomass was confined to 1 or 2 major groups of phytoplankton.

[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.

Cyanophytes. Only two Cyanophyte taxa were identified in Long Pond during 2017, and these two forms only occurred at sampling station s-1. *Merismopedia glauca* and *Oscillatoria* sp. were identified in the July 25th sample and comprised <1 percent of the phytoplankton community biomass, while only *Oscillatoria* sp. was identified on August 23rd and comprised <1 percent of the phytoplankton community biomass.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in the Long Pond at the 3 sampling stations is summarized in Table 5-9 above. Values always were higher at station s-1, followed by s-3 and then s-2. Values at station s-1 and s-3 indicate high (eutrophic) productivity in the water column of the pond, while the station s-2 values are indicative of moderate (mesotrophic) productivity.

5.1.5 Trophic Status

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

Sufficient water quality data were collected from Long Pond during 2017 to calculate the Carlson Trophic State Index (TSI) using chlorophyll ***a***, total phosphorus, and Secchi depth transparency for each sampling station. Average values were calculated for each variable for the May and August sampling dates. The average values then were substituted into equations to calculate the TSI values for each variable.

The stepwise calculations are not shown here because there were 3 sampling stations and 3 sets of calculations would need to be presented. The reader is referred to Chapter 1 for a more thorough explanation of trophic status and the process of calculating this important productivity indicator.

Table 5-11 presents the 2017 Trophic State Indices calculated for Long Pond at the 3 sampling stations.

Table 5-11. Trophic State Indices (TSIs) calculated for Long Pond, 2017.

Station	Chlorophyll TSI	TP TSI	Secchi TSI
s-1	52.5	71.9	64.3
s-2	43.1	71.1	62.2
s-3	55.7	78.4	68.1

The TSI indices calculated for total phosphorus at the 3 sampling stations were all within the hyper-eutrophic range of productivity, while the Secchi depth TSI values were within the eutrophic range. Chlorophyll ***a*** TSI values for stations s-1 and s-3 were indicative of eutrophic productivity while the value for station s-2 (43.1) was within the moderate, or mesotrophic range of productivity.

Table 5-12 shows the relationships among Trophic State Indices and the 3 variables, chlorophyll ***a***, total phosphorus and Secchi depth transparency that are used to interpret the water quality status.

Table 5-12. Relationships among Trophic Index, chlorophyll *a*, total phosphorus, Secchi depth and Trophic Class (after Carlson 1996).

Trophic State Index	Chlorophyll *a* ($\mu g \cdot L^{-1}$)	TP ($\mu g \cdot L^{-1}$)	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

5.2 Summary

Based upon the data collected during 2017, Long Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has high productivity based upon the numerical analysis of 3 separate water quality variables that were sampled. Many of the Island ponds are very similar 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 subject to being released into the water column at various times during the mid-summer growing season when mixing of the water column occurs due to sufficient winds blowing across the Island that generate water currents throughout the pond and physical-chemical conditions are ideal at the water-sediment interface on the pond bottom..

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 E. MacKinnon, 2017. *Nantucket Island Ponds and 2016 Water Quality. Tom Nevers, Gibbs, Little Weweeder, Maxcy, Washing and North Head of Long Ponds. A Summary of Physical, Chemical and Biological Monitoring*. Prepared for the Nantucket Land Council, Inc. 90 pp. + attachments.

Nantucket Island Ponds and 2017 Water Quality

Chapter 6

Maxcy Pond

6.0 Introduction

Maxcy Pond was sampled for water quality by the NLC during August 2017. The pond also was sampled by the NLC during August and September 2014, which was reported elsewhere (Sutherland and MacKinnon 2015), and during May and August 2016, which was reported elsewhere (Sutherland and MacKinnon, 2017). This chapter presents a summary and discussion of the physical, chemical and biological data collected from Maxcy Pond by NLC staff during the period 2014-2017, with emphasis on the 2017 data, and a comparison of all data for the 3 years that water quality sampling occurred.

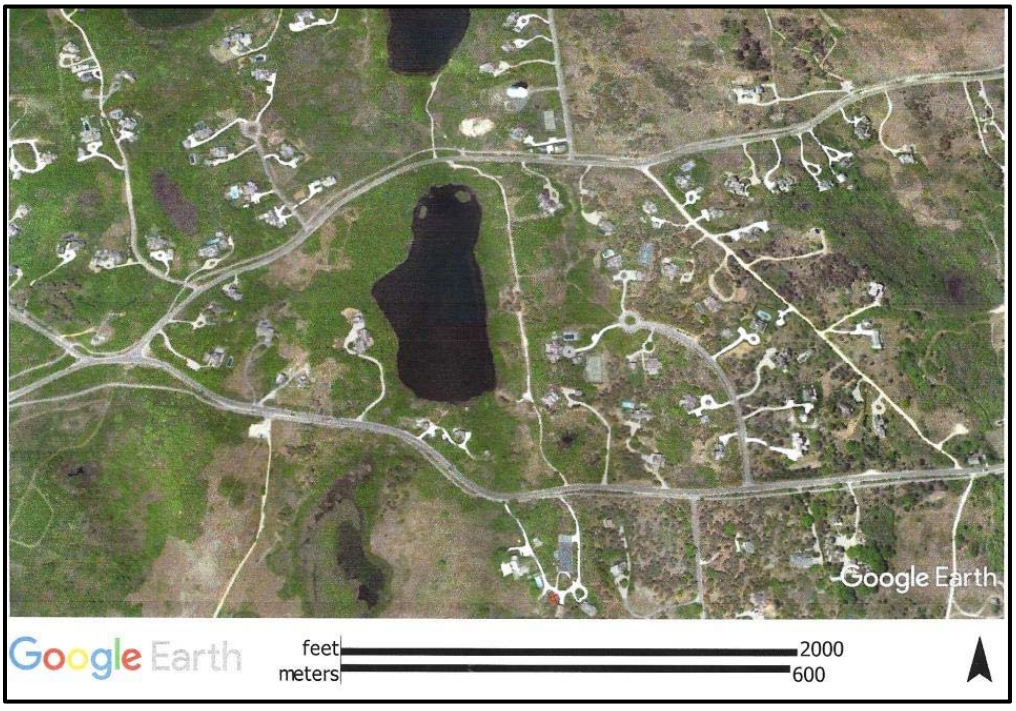
6.1 Results

When Maxcy Pond was sampled on August 1st 2017, the maximum water depth located in the pond was 6.25 feet (1.9 meters) at the sampling location in the approximate center of the pond. Following the collection of temperature and dissolved oxygen profile data, an integrate sample was collected from the surface down to 4 feet (1.2 m) of depth for the chemistry and phytoplankton samples. A grab sample was not collected since the pond was so shallow and there was no indication of stratification of the water column with regard to temperature or dissolved oxygen saturation.

6.1.1 Physical characteristics

General. Maxcy Pond is located on the western portion of Nantucket Island, just east of the intersection of Cliff Road and Madaket Road. The pond has an irregular shape with a bulge along the western shoreline and its axis is oriented in a north-south direction (Figure 6-1). The surface area of the pond is estimated at ~10 acres. There are no permanent streams flowing into the pond, and there is no outlet.

Figure 6-1. Aerial view of Maxcy Pond (from *Google*™ earth).



Maxcy Pond has a total depth of about 5-6 feet and is situated in a basin of low elevation which should provide some protection from winds blowing across the Island.

Table 6-1 presents a summary of the physical characteristics of the pond that were collected during the period 2014-2017 when water quality was sampled.

Table 6-1. Summary of physical data from Maxcy Pond, 2014, 2016, and 2017.

Maxcy Pond Physical Properties, 2014, 2016, 2017		
Sampling Date	Secchi depth (m)	Avg Water Column Temperature (°C)
8/26/2014	on bottom	24.2
9/15/2014	on bottom	20.8
2014 avg	na	22.5
5/19/2016	on bottom	17.2
8/31/2016	on bottom	25.8
2016 avg	na	22.0
8/1/2017	on bottom	25.9

Temperature. Temperature profile data were collected on all sampling excursions to Maxcy Pond, and the temperature profile usually was isothermal from the surface to the bottom. The average temperatures for Maxcy Pond are presented in Table 6-1.

Transparency. The Secchi depth transparency measured at Maxcy Pond was 'on the bottom' on all sampling dates, indicating good water clarity; the pond is too shallow to determine the exact depth of transparency.

6.1.2 Chemical characteristics

Table 6-2 summarizes the 2017 chemical characteristics of Gibbs Pond including the algal nutrients, phosphorus and nitrogen. The table also includes a summary of the 2014 and 2016 data collected from the pond for comparative purposes later on in this chapter.

Table 6-2. Summary of chemical data from Maxcy Pond, 2014, 2016, and 2017.

Sampling Date	Avg DO Saturation	TP (mg/L)	NO3 (mg/L)	NH4 (mg/L)	NO3 + NH4 (mg/L)	TN (mg/L)	Org N (mg/L)	spC (µS)	pH (s.u.)
26-Aug-14	102.2	0.023	0.033	0.010	0.043	0.194	0.151	137	5.05
15-Sep-14	94.1	0.007	0.005	0.004	0.009	0.350	0.341	102	5.22
2014 avg	98.2	0.015	0.019	0.007	0.026	0.272	0.246	120	5.14
19-May-16	97.0	0.023	0.005	0.005	0.010	0.430	0.420	102	5.29
31-Aug-16	102.0	0.037	0.005	0.005	0.010	0.480	0.470	111	6.55
2016 avg	99.5	0.030	0.005	0.005	0.010	0.455	0.445	107	5.92
1-Aug-17	109.6	0.097	0.020	0.005	0.025	0.300	0.275	124	5.76
highlighted cells are values one-half of the lower limit of detection									

Dissolved oxygen percent saturation. The maximum concentration of dissolved oxygen that can occur in water generally 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.

The average dissolved oxygen saturation values for the water column in Maxcy Pond on all sampling dates were either close to saturation (100%) or supersaturated (>100%), which indicates relatively low productivity in the pond and good mixing of the shallow water column.

Specific conductance. All of the conductance values measured at Maxcy Pond during 2014, 2016 and 2017 were within the range of 102-137 $\mu S \cdot cm^{-1}$, which are normal values for a pond fairly well isolated from the ocean, except for wind-driven storms that carry aerosols to the pond. The conductance values

for Gibbs Pond (Chapter 3) and Maxcy Pond are very similar in terms of their relative values, and are within the range of specific conductance values expected in ponds considered to be fresh water.

pH. On all sampling excursions except one (August 31st 2016, pH=6.55 s.u.), the pH measured at Maxcy Pond was well within the acidic range, varying from 5.05-5.76 s.u. (see Table 6-2). Low pH such as measured in Maxcy Pond on 4 of 5 occasions during 2014, 2016 and 2017 is characteristic of waters with low concentrations of dissolved ions and the acidic nature is due, in large part, to the bog-like nature of the vegetation growing along the pond shoreline.

6.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was detectable in Maxcy Pond only on August 26th 2014 (0.033 mg $N \cdot L^{-1}$) and August 1st 2017 (0.020 mg $N \cdot L^{-1}$); otherwise, this plant nutrient was undetectable in the water column (Table 6-2). Low (undetectable) **nitrate-nitro**gen levels is not an unusual phenomenon in fresh-water systems since this form of nitrogen is readily taken up by phytoplankton for metabolism when it is available.

Ammonia-nitrogen was detected in Maxcy Pond chemistry samples collected during 2014, albeit at very low levels, but otherwise was below the limit of detection for all sampling dates thereafter. As with nitrate-nitrogen, low levels of ammonia-nitrogen are not uncommon because this form of nitrogen is available for uptake by phytoplankton.

The **total nitrogen** (**TN**) concentrations measured in Maxcy Pond ranged from 0.194-0.480 mg $N \cdot L^{-1}$ during the 2014, 2016 and 2017 sampling dates, and all values were low when compared with other Nantucket Island ponds. The reader is referred to Chapter 10 of this report where there are several tables that compare the water quality characteristics of the 12 Nantucket Island ponds surveyed by the NLC since 2009.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Maxcy Pond during 2014, 2016 and 2017 ranged from 0.007 – 0.097 mg $P \cdot L^{-1}$ (Table 6.2). The TP concentrations of TP during all 3 years reflect low productivity in the system and this situation is considered normal in dilute waters such as Maxcy Pond. Situations similar to the one in Maxcy Pond occur in the Adirondack Mountain region of New York State where lakes and ponds have been impacted by acid deposition and often exhibit low productivity in the water column (Sutherland et al. 1989).

6.1.4 Phytoplankton

Description of the assemblage. There were 17 taxa identified in the single 2017 phytoplankton sample collected from Maxcy Pond and all major algal groups except Cyanophytes were represented (Table 6-1).

Table 6-3. Major groups and taxa of phytoplankton identified in Maxcy Pond, 2017.

Chloromonadophyta	**Chlorophytes**	**Chrysophytes (Chrysophyceae)**
Gonyostomum semen	*O. pusilla*	*Dinobyron divergens*
Chlorophytes	*O. solitaria*	**Euglenophytes**
Ankistrodesmus falcatus	*Pyramimonas tetrarhyncus*	*Trachelomonas* sp.
Closteriopsis longissima	*Scenedesmus bijuga alternans*	**Pyrrhophytes (Dinophytes)**
Closterium acutum	**Chrysophytes (Bacillariophyceae)**	*Peranema* sp.
C. gracile	*Achnanthes* sp.	
Mougeotia sp.	*Cyclotella* sp.	
Oocystis Borgei	*Navicula* spp.	

The community richness for 2017 was 17.0 taxa.

The description of the 2014 phytoplankton assemblage in Maxcy Pond was presented in Sutherland and MacKinnon (2015), while the description of the 2016 phytoplankton assemblage was presented in Sutherland and MacKinnon (2017).

Table 6-4 presents a summary of the Maxcy Pond phytoplankton community characteristics determined from samples collected during 2014, 2016 and 2017.

Density. The phytoplankton community density in Maxcy Pond always has been below 10,000 cells·mL^{-1} (see Table 6-3), ranging from 2,449 – 9,673 cells·mL^{-1} during 2014, 2016 and 2017. All of the phytoplankton assemblage densities measured in Maxcy Pond are low when compared with other Island ponds that have been surveyed by the NLC during recent years.

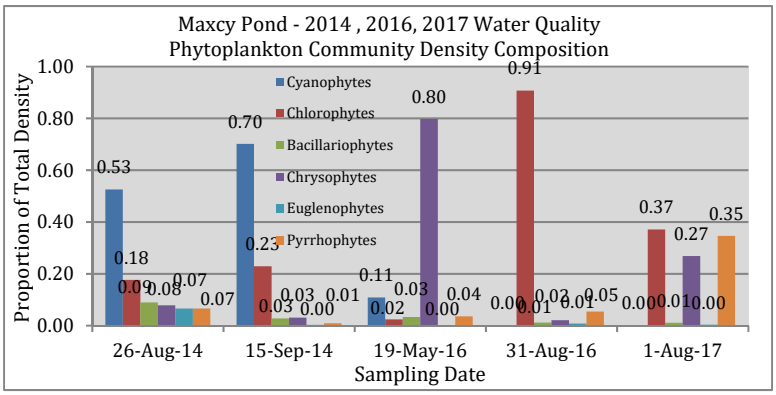
As mentioned previously, Maxcy Pond appears to be a low productivity system that results from acidic conditions and this condition affects the physical, chemical and biological components of the pond.

Table 6-4. Summary of Maxcy Pond phytoplankton community characteristics, 2014, 2016, and 2017.

Maxcy Pond Phytoplankton Characteristics 2014, 2016, and 2017						
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})
26-Aug-14	21	2449	1130	1.058	0.886	2.39
15-Sep-14	16	5894	3560	0.600	0.591	3.11
2014 avg	18.5	4172	2345	0.829	0.739	2.75
19-May-16	16	5114	2265	0.393	0.358	5.70
31-Aug-16	11	9673	14715	0.248	0.310	8.10
2016 avg	13.5	7394	8490	0.321	0.334	6.90
1-Aug-17	17	5085	19545	0.817	0.348	0.57

The density composition of the phytoplankton assemblage in Maxcy Pond during 2014, 2016 and 2017 is shown in Figure 6-2.

Figure 6-2. Density composition of the phytoplankton community in Maxcy Pond, 2014, 2016, 2017.



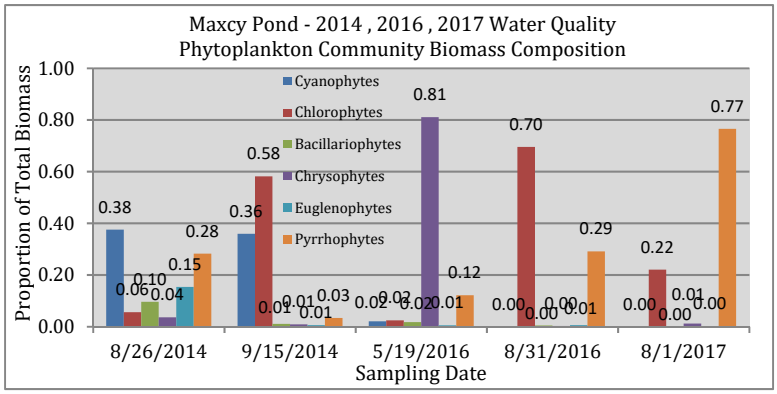
Striking differences in the composition occurred among all 3 years and within certain years (e.g., 2016). The 2014 composition was dominated by Cyanophytes, with lesser amounts of the other major groups. By 2016, Cyanophytes were greatly reduced throughout the entire season, while the Chyrsophytes and Chlorophytes comprised almost the entire community during May and August, respectively.

During 2017, the Chlorophytes, Chrysophytes and Pyrrhophytes shared dominance in the community with the other algal groups either non-existent or exhibiting extremely low numbers (Figure 6-2).

Biomass. Cell biovolume also 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 that occur in the pond. It is quite common for size differences among different types of phytoplankton to range over several orders of magnitude.

The phytoplankton community biomass exhibited by Maxcy Pond during 2014, 2016 and 2017 is presented in Figure 6-3. As shown in the figure, community biomass exhibited trends among the years and within certain years that are similar to the density characteristics described above.

Figure 6-3. Biomass composition of the phytoplankton community in Maxcy Pond, 2014, 2016, 2017.



Cyanophytes dominated the community biomass in August 2014 (38 percent), then transitioning to Chlorophytes (58 percent) and Cyanophytes (36 percent) during September 2014. The 2016 community biomass was dominated by Chrysophytes (81 percent) and Chlorophytes (70 percent) during May and August, respectively, which was the same as the density composition that year (Figure 6-2).

By August 2017, the community biomass closely resembled the biomass composition on August 31st 2016, with Chlorophytes and Pyrrhophytes both dominant, although their position in the community hierarchy had reversed (Figure 6-3). The dominant biomass species in the August 1st 2017 water column was the large cell Pyrrhophyte, *Peridinium cinctum*.

Dominance. Table 6-5 ranks the dominant taxa in the Maxcy Pond phytoplankton community during 2014, 2016 and 2017. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 6-5 Rank of phytoplankton taxa dominance, using biomass, in Maxcy Pond, 2014, 2016, and 2017.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
26-Aug-14	*Anabaena flos aquae* (Cyanophyte)	1	35
	Trachelomonas sp. (Euglenophyte)	2	15
	Peridinium conctum (Pyrrhophyte)	3	15
	Cryptomonas erosa (Pyrrhophyte)	4	13
	Asterionella formosa (Bacillariophyte)	5	6
15-Sep-14	*Mougeotia* sp. (Chlorophyte)	1	47
	Aphanizomenon flos aquae (Cyanophyte)	2	35
	Cosmarium sp. (Chlorophyte)	3	8
19-May-16	*Ochromonas* sp. (Chrysophyte)	1	81
	Peridinium cinctum (Pyrrhophyte)	2	8
	Cryptomonas erosa (Pyhhhophyte)	3	5
31-Aug-16	*Pandorina morum* (Chlorophyte)	1	69
	Peridinium cinctum (Pyrrhophyte)	2	29
1-Aug-17	*Peridinium cinctum* (Pyrrhophyte)	1	77
	Gonyostomum semen (Chloromonadophyte)	2	17

The most obvious trend observed from the data presented in Table 6-5 is the greatly reduced number of taxa that occur as dominants as the community progresses from 2014 through 2016 and then into 2017. That is, there were 5 dominant taxa in August 2014, 3 dominant taxa in September 2014, 3 dominant taxa in May 2016, 2 dominant taxa in late August 2016 and 2 dominant taxa in early August 2017.

Diversity. Phytoplankton diversity in Maxcy 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 Maxcy Pond was calculated using both density and biomass in the equation, with the results of the diversity calculations presented in Table 6-4. The diversity values were very similar on each sampling date during 2014 and 2016, regardless of whether density or biomass was used to evaluate this community characteristic. However, the difference between the 2014 and 2016 diversity values is striking. As described above when discussing density and biomass composition, the Maxcy Pond phytoplankton assemblage was far less diverse during 2016 than during 2014. Another noteworthy occurrence is the difference between the density and diversity values in 2017, with density ([H]=0.817) indicating good diversity and biomass ([H]=0.348) indicating low diversity.

Cyanophytes. As a major phytoplankton group of importance in the aquatic ecosystem, Cyanophytes were identified in samples collected during 2014 and 2016, but not in 2017. Table 6-6 identifies which species were identified on the pond sampling dates and their percent contribution to the community.

Table 6-6. Cyanophyte species identified in Maxcy Pond, 2014, 2016 and 2017.

Species	26-Aug-14	15-Sep-14	19-May-16	31-Aug-16	1-Aug-17
*Anabaena flos aquae**	yes (32)	no	no	no	no
*Anabaenopsis Elenkinii**	yes (9)	yes (3)	no	no	no
*Aphanizomenon flos aquae**	no	yes (67)	yes (3)	no	no
Chroococcus dispersus	yes (2)	no	yes (8)	no	no
Microcystis aeruginosa	yes (10)	no	no	no	no
'yes' = present, 'no' = absent; (##) = percent of community total on a sampling date * Species that are known to produce algal toxins					

A total of 5 Cyanophyte species were identified in Maxcy Pond during 2014 and 2016 including *Anabaena flos aquae*, *Anabaenopsis Elenkinii*, *Aphanizomenon flos aquae*, *Chroococcus dispersus*, and *Microcystis aeruginosa*. Three genera, *Anabaena, Aphanizomenon*, and *Microcystis* are known to produce algal toxins with a range of effects including liver, nerve, skin and gastrointestinal disorders.

While there is no evidence that the phytoplankton genera documented in Maxcy Pond produce any algal toxins, recreational users of the pond should be aware that Cyanophytes (Blue-greens) are possible components of the mid-summer phytoplankton community and that public health and safety factors are a potential concern.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Maxcy Pond during 2014, 2016 and 2017 have ranged from 0.57 – 5.70 $\mu g \cdot L^{-1}$, which are low and indicative of low productivity, thereby confirming earlier comments in this chapter. The concentration of 0.57 $\mu g \cdot L^{-1}$ on August 1st 2017 is the lowest concentration measured in any of the Nantucket Island ponds surveyed by the NLC since 2009.

[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

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

Except for the absence of a valid Secchi depth reading during all 3 years that the pond was sampled, there were sufficient TP and chlorophyll ***a*** data from Maxcy Pond from the 3 years to calculate the Carlson Trophic State Index (TSI) using those 2 variables. The TP and chlorophyll ***a*** values were substituted into equations (see Chapter 1) to calculate the TSI values for each variable. Table 6-7 presents the TSIs calculated for Maxcy Pond for the 3 years that the pond was sampled.

Table 6-7. Trophic State Indices (TSIs) calculated for Maxcy Pond, 2014, 2016, and 2017.

Year	Chlorophyll TSI	TP TSI	Secchi TSI
2014	40.5	43.3	na
2016	49.5	53.2	na
2017	25.1	43.4	na

Table 6-8 summarizes Carlson's Trophic State Index in relation to the 3 independent water quality variables used as predictors and 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* ($\mu g \cdot L^{-1}$)	Total phosphorus ($\mu g \cdot L^{-1}$)	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

Based upon the TSI values calculated using 2014, 2016 and 2017 data, Maxcy Pond moved between mesotrophic and oligotrophic productivity with regard to chlorophyll ***a*** used as the variable for calculation, while total phosphorus in the calculation showed that the pond moved from mesotrophic to eutrophic and then back to mesotrophic productivity.

6.2 Summary

Nantucket has a large number of ponds as compared with the relatively small surface area of the island. And while many of these ponds are used and enjoyed recreationally by Island residents and visitors to the Island, very few of the ponds have any information available concerning water quality until recent surveys were undertaken by the Nantucket Land Council.

During 2014, the NLC embarked on an effort to monitor different Island ponds and collect data so that some base-line record of water quality could be established and used as a reference by subsequent generations of individuals who inherit the Island and its water resources. Evaluating the water quality of Island ponds and becoming proactive to protect some of these threatened resources is a display of good stewardship and the NLC is to be applauded for its effort in this regard.

6.3 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 E. MacKinnon, 2017. *Nantucket Island Ponds and 2016 Water Quality. Tom Nevers, Gibbs, Little Weweeder, Maxcy, Washing and North Head of Long Ponds. A Summary of Physical, Chemical and Biological Monitoring*. Prepared for the Nantucket Land Council, Inc. 90 pp. + attachments.

Sutherland, J.W. and E. MacKinnon. 2015. *Nantucket Island Ponds and Their Water Quality. The 2014 Program – Tom Nevers, Washing and Maxcy Ponds. A Summary of Physical, Chemical and Biological Monitoring*. Prepared for The Natucket Land Council, Inc. 43 pp.

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Nantucket Island Ponds and 2017 Water Quality

Chapter 7

Miacomet Pond

7.0 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 2017.

7.1 Results

Miacomet Pond was sampled on July 26th and August 22nd 2017 at three (3) different locations on each sampling date. An aerial view of the pond and the 2017 sampling locations are shown in Figure 7-1.

Figure 7-1. Aerial view of Miacomet Pond (from *Google*™ earth) showing 2017 sampling locations.

Table 7-1 summarizes the water depth and depth of sample collection for chemistry and phytoplankton at each sampling location in Miacomet Pond for the July and August sampling dates.

Table 7-1. Summary of sampling properties at Miacomet Pond, 2017.

2017 Miacomet Pond Sampling Features			
Water Depth (m)	South site	Mid site	North site
26-Jul-17	2.97	1.60	0.76
22-Aug-17	1.98	1.52	0.69
Sample Depth (m)			
26-Jul-17	2.1	0.9	0.3
22-Aug-17	1.5	1.2	0.3

Only integrate samples were collected for chemistry and phytoplankton analysis at all sampling sites on both sampling dates, either because there was no thermal or dissolved oxygen stratification (south and mid sites) or the water depth was too shallow (north site).

7.1.1 Physical characteristics

General. 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 7-2 summarizes the physical properties collected at the three (3) sampling locations on Miacomet Pond during July and August 2017.

Table 7-2. Summary of physical data from Miacomet Pond, 2017.

2017 Miacomet Pond Physical Properties			
Avg. Temperature (°C)	South site	Mid site	North site
26-Jul-17	21.3	20.9	17.0
22-Aug-17	24.2	24.2	20.5
Secchi Depth (m)			
26-Jul-17	2.18	on bottom	on bottom
22-Aug-17	1.35	on bottom	on bottom

Temperature. There never was a temperature gradient exhibited between the surface and the bottom at any Miacomet Pond sampling station during 2017. However, it was apparent from the average temperature data collected at the stations that cool ground water was infiltrating into the pond at the north sampling site (Table 7-2). On both 2017 sampling dates, the average temperature at this site was considerably cooler than the average temperature at the other 2 sampling sites.

Transparency. Secchi depth transparency could be measured only at the south sampling station; water depth was too shallow at the other sampling stations. The transparency was high (2.18 m) on July 26th and then decreased by about 40 percent on August 22nd (1.35 m).

7.1.2 Chemical characteristics

Specific conductance. The 2017 conductance values for Miacomet Pond are summarized in Table 7-3. The influence of wind, the Atlantic Ocean and ground water dilution on conductance levels was evident during the 2017 season.

Table 7-3. Summary of specific conductance data from Miacomet Pond, 2017.

2017 Miacomet Pond Specific Conductance			
specific conductance (mS/cm)	South site	Mid site	North site
26-Jul-17	659	403	172
22-Aug-17	529	373	157

The primary effect was an increase in Pond conductance values at southern stations through salt water intrusion driven by high wind and aerosol influence over the barrier beach and perhaps some ocean seepage through the barrier. There was a gradient of conductance decreasing from the south to the north station on both 2017 sampling dates.

pH. The 2017 pH values for Miacomet Pond are summarized in Table 7-4**.** The south and mid sites had values above or close to pH 8.0 s.u. on both sampling dates, while the north site was close to neutral pH during July and August.

Table 7-4. Summary of pH data from Miacomet Pond, 2017.

2017 Miacomet Pond pH Values			
specific conductance (mS/cm)	South site	Mid site	North site
26-Jul-17	8.37	7.98	7.41
22-Aug-17	8.65	8.75	7.43

Carbon dioxide within the Miacomet Pond ecosystem is controlled by internal biological activity. All living animals continuously produce carbon dioxide (CO_2) as a by-product of respiration. Algae and plants living and growing in the pond remove carbon dioxide from the water during photosynthesis. The relative rates of respiration and photosynthesis within the pond determine whether there is net addition or removal of carbon dioxide, and whether the pH will fall or rise, respectively. The pH values exhibited at the south and mid sites indicate that respiration (CO_2 addition) is lagging behind photosynthesis (CO_2 removal).

Oxygen concentration and saturation. The average 2017 dissolved oxygen saturation values at the 3 Miacomet Pond sampling stations are presented in Table 7-5.

Table 7-5. Summary of dissolved oxygen saturation data from Miacomet Pond, 2017.

2017 Miacomet Pond Dissolved Oxygen Saturation Values			
DO percent saturation	South site	Mid site	North site
26-Jul-17	92.7	94.7	31.0
22-Aug-17	100.2	100.2	19.9

Dissolved oxygen was either just below or at saturation at the south and mid sites on both 2017 sampling dates. The north sampling station, adjacent to Otokomi Road, exhibited greatly reduced saturation on both dates likely due to the influence of ground water with low oxygen saturation entering the pond at this site.

7.1.3 Plant Nutrients

Nitrogen. Table 7-6 presents a summary of the 2017 nitrogen concentrations measured in Miacomet Pond.

Table 7-6. Summary of nitrogen data from Miacomet Pond, 2017.

2017 Miacomet Pond Nitrogen Data			
nitrate-nitrogen (mg N/L^{-1})	South site	Mid site	North site
26-Jul-17	0.110	0.070	0.380
22-Aug-17	0.170	0.550	0.550
ammonia-nitrogen (mg N/L^{-1})			
26-Jul-17	0.005	0.020	0.050
22-Aug-17	0.010	0.010	0.010
total nitrogen (mg N/L^{-1})			
26-Jul-17	0.460	0.540	0.620
22-Aug-17	0.300	0.640	0.560
organic nitrogen (mg N/L^{-1})			
26-Jul-17	0.345	0.450	0.190
22-Aug-17	0.120	0.080	0.000
highlighted cells are values reported at one-half the lower detection limit			

The concentrations of nitrate in the water column of Miacomet Pond were moderate-to-high during the 2017 and there was a gradient of increasing nitrate concentration in the pond from south to north (Table 7-6). These data provide strong evidence for the contributory nature of the watershed to nitrate loading (reported previously in Sutherland and Oktay 2010) and the fact that the northeast extension of the pond basically is a channel where the groundwater emerges and becomes surface water.

Ammonia-nitrogen values were low in Miacomet Pond during 2017, ranging from below detection (0.005 mg $N \cdot L^{-1}$) to 0.050 mg $N \cdot L^{-1}$. This condition is not unusual because ammonium-nitrogen is a form readily available for uptake by phytoplankton for the photosynthetic process.

The levels of total nitrogen (TN) in Miacomet Pond during 2017 were moderate at all sampling stations on both sampling dates and are below values measured in other Nantucket Island ponds during 2017 as reported in other chapters herein. Furthermore, there was no apparent gradient of TN in the pond as was described for other chemical characteristics.

A simple method for calculating **organic nitrogen** (**ON**) in the water column is to subtract nitrate + ammonia concentrations from the TN concentration. The result of this exercise is presented in Table 7-6. Although some, probably small, portion of the organic nitrogen is in soluble (dissolved) form, the organic nitrogen concentrations are moderate and correspond to moderate concentrations and biomass of phytoplankton in the water column throughout the sampling period, except at the north station near Otokomi Road where the organic portion was either non-existent (0.000 mg N/L^{-1} on August 22nd) or low (0.190 mg N/L^{-1} on July 26th). These data provide additional evidence for the intrusion of nitrate-rich water into the pond near the northeast extension where the channel is narrow and shallow.

Phosphorus. Table 7-7 presents a summary of the **total phosphorus** (**TP**) values measured in Miacomet Pond on the July 26th and August 22nd sampling dates at the 3 sampling stations.

Table 7-7. Summary of total phosphorus data from Miacomet Pond, 2017.

2017 Miacomet Pond Total Phosphorus Concentrations			
total phosphorus (mg/L^{-1})	South site	Mid site	North site
26-Jul-17	0.028	0.035	0.082
22-Aug-17	0.060	0.043	0.028

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

Systems such as Miacomet Pond have different hydrologic cycles and do not receive large inputs of TP via stormwater runoff due to the relatively flat topography of the surrounding watershed, the low relative proportion of impervious structures in the watershed, and the sandy, permeable nature of the soil.

The introduction of TP to Miacomet Pond is primarily through ground water flow and the rate exhibits increases or decreases based upon precipitation cycles. The concentration of TP in the ground water would be a function of land use in the watershed, soil adsorption of TP, and the effectiveness of individual wastewater treatment systems which contribute groundwater discharge to the pond. There also is evidence of Fe-bound phosphorus in the pond sediment that may be released at various times during the summer months (Molden, personal communication).

The concentrations of total phosphorus (TP) in the water column of Miacomet Pond were low, with all values less than 0.100 mg $P \cdot L^{-1}$ during 2017 and there was no south-to-north gradient, nor was there any particular station that exhibited any unusual characteristics.

7.1.4 Phytoplankton

Description of the assemblage. A total of 31, 24 and 25 taxa were identified in the July and August 2017 samples collected from the south, mid and north stations, respectively. Table 7-8 summarizes all of the 68 phytoplankton taxa identified at the 3 sampling stations during 2017.

Table 7-8. Major groups and taxa of phytoplankton identified in Miacomet Pond, 2017.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyta)**
Anabaena flos aquae	*O. pusilla*	*Gyrosigma* sp.
Aphanizomenon flos aquae	*O. solitaria*	*Hippodonta* sp.
Aphanocapsa elachista	*Pandorina morum*	*Hyalotheca* sp.
Chroococcus dispersus	*Pediastrum duplex*	*Navicula* spp.
C. limneticus	*Quadrigula lacustris*	*Nitzschia* sp.
Gomphosphaeria lacustris compacta	*Scenedesmus acutiformis*	*Pinnularia* sp.
Lyngbya sp.	*S. bijuga*	*Planothidium* sp.
Merismopedia glauca	*S. bijuga alternans*	*Rhoicosphenia curvata*
Microcystsis aeruginosa	*S. quadricauda*	*Stauroneis* sp.
Oscillatoria sp.	*Schroederia Judayi*	*Synedra acus*
Rhabdoderma Gorskii	*Selenastrum capriconnutum*	*S. fulgens*
Chlorophyta	*S. minutum*	*S. ulna*
Actinastrum Hantzschii	*Sphaerocystis Schroeteri*	**Chrysophyta (Chrysophyceae)**
Ankistrodesmus falcatus	*Spirulina* sp.	*Mallomonas* sp.
Closteriopsis longissima	*Staurastrum natator* var. *crassum*	*Ochromonas* sp.
Closterium acutum	*Tetraedrom minimum*	**Euglenophyta**
C. gracile	**Chrysophyta (Bacillariophyta)**	*Euglena* sp.
Coelastrum cambricum	*Achnanthes* sp.	*Phacus* sp.
Cosmarium spp.	*Aulacoseria granulata*	*Trachelomonas* sp.
Elakatothrix gelatinosa	*Cocconeis* sp.	**Pyrrhophyta (Cryptophyceae)**
Euastrum sp.	*Cyclotella* sp.	*Cryptomonas erosa*
Eudorina elagans	*Fragilaria crotonensis*	*C. ovata*
Monoraphidium arcuatum	*F. capucina*	*Ceratium hirundinella*
Mougeotia sp.	*Gomphonema* spp.	*Peridinium cinctum*
Oocystis Borgei		

Table 7-9 presents a summary of the 2017 Miacomet Pond phytoplankton community characteristics determined from the samples collected during July and August.

Table 7-9. Summary of Miacomet Pond phytoplankton community characteristics, 2017.

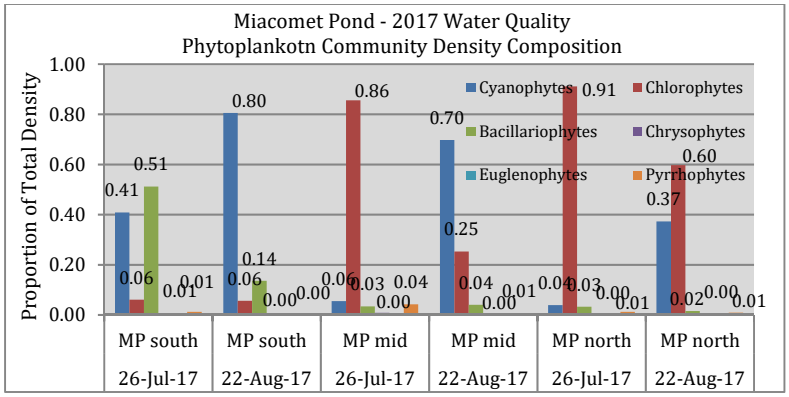
	2017 Miacomet Pond Phytoplankton Community Characteristics						
station	Sampling Date	Total Phytoplankton Taxa	Cell Density (cells/mL^{-1})	Cell Biomass (mg/m^3)	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration ($\mu g/L^{-1}$)
south	26-Jul-17	28	5807	1764	1.079	1.092	5.30
	22-Aug-17	27	41003	4555	0.642	1.134	2.40
	2017 avg	28	23405	3160	0.861	1.113	3.85
mid	26-Jul-17	35	16944	23080	1.079	0.865	8.00
	22-Aug-17	39	34642	12106	0.642	1.094	19.20
	2017 avg	37	25793	17593	0.861	0.980	13.60
north	26-Jul-17	36	34714	28043	1.079	0.418	3.00
	22-Aug-17	37	15607	10064	0.642	0.979	6.40
	2017 avg	37	25161	19054	0.861	0.699	4.70

The south Miacomet station had the lowest number of phytoplankton taxa on both sampling dates and the 2017 average value at this station (28 taxa) was significantly lower than the average value of 37 taxa at the other 2 sampling stations.

Density. Cell density in the Miacomet Pond phytoplankton community ranged about 7-fold during 2017, from 5,807 – 41,003 cells·mL^{-1} as exhibited at the south sampling site (Table 7-9). The other 2 sampling sites exhibited about a 2-fold change in density during 2017, and the average density at all sampling sites was between 23,000 – 26,000 cells·mL^{-1} for the July and August 2017 samples.

The 2017 density composition of the Miacomet phytoplankton community is presented in Figure 7-2.

Figure 7-2. Density composition of the phytoplankton community in Miacomet Pond, 2017.

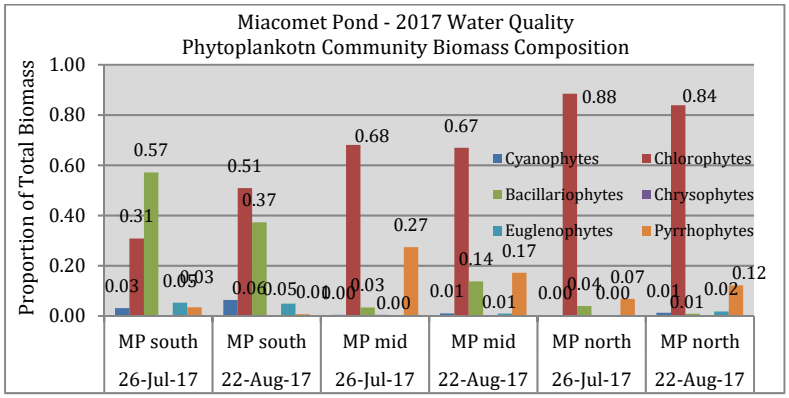


The mid and north stations in the pond exhibited similar composition on both sampling dates and were different from the south station, Chlorophytes were an important component of the south station phytoplankton community which was not the case for the 2 other stations. The importance of the green algae at this site could be linked to a greater tolerance of high salt content in this region of the pond from the influence of the adjacent Atlantic Ocean.

Biomass. Biomass ranged from 1,764 – 28.043 mg/m^3 among the 3 sampling station during July and August and the biomass was reduced considerably at the south sampling station when compared with the other stations on both sampling dates.

The 2017 biomass composition of the Miacomet phytoplankton community is presented in Figure 7-3.

Figure 7-3. Biomass composition of the phytoplankton community in Miacomet Pond, 2017.



In spite of the difference in total biomass between the south station and the mid and north stations, Figure 7-3 shows that the biomass composition at these 3 sampling stations was not that different and that the Chlorophytes and the Bacillariophytes (diatoms) were the primary components of the community on both 2017 sampling dates.

Dominance. Table 6-5 ranks the dominant taxa in the Miacomet Pond phytoplankton community during 2017. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 7-10. Rank of phytoplankton taxa dominance, using biomass, in Miacomet Pond, 2017.

south site

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
25-Jul-17	*Mougeotia* sp. (Chlorophyte)	1	23
	Hyalotheca sp. (Bacillariophyte)	2	16
	Fragilaria crontonensis (Bacillariophyte)	3	15
	Aulocoseria granulata (Bacillariophyte)	4	9
	Cocconeis sp. (Bacillariophyte)	5	6
	Pediastrum duplex (Chorophyte)	6	5
	Euglena sp. (Euglenophyte)	7	5
22-Aug-17	*Coelastrum cambricum* (Chlorophyte)	1	17
	Pediastrum duplex (Chorophyte)	2	16
	Fragilaria crontonensis (Bacillariophyte)	3	10
	Hyalotheca sp. (Bacillariophyte)	4	10
	Pandorina morum (Chlorophyte)	5	8
	Fragilaria capucina (Bacillariophyte)	6	7
	Cocconeis sp. (Bacillariophyte)	7	5

mid site

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
25-Jul-17	*Sphaerocystis Schroeteri* (Chlorophyte)	1	33
	Ceratium hirundinella (Pyrrhophyte)	2	22
	Pediastrum duplex (Chorophyte)	3	16
	Staurastrum natator var. *crassum* (Chlorophyte)	4	9
	Pandorina morum (Chlorophyte)	5	6
	Peridinium cinctum (Pyrrhophyte)	6	5
22-Aug-17	*Eudorina elegans* (Chlorophyte)	1	15
	Coelastrum cambricum (Chlorophyte)	2	12
	Ceratium hirundinella (Pyrrhophyte)	3	12
	Gyrosigma sp. (Bacillariophyte)	4	9
	Pediastrum duplex (Chorophyte)	5	8
	Cosmarium spp. (Chlorophyte)	6	7
	Peridinium cinctum (Pyrrhophyte)	7	5

north site

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
25-Jul-17	*Sphaerocystis Schroeteri* (Chlorophyte)	1	81
	Ceratium hirundinella (Pyrrhophyte)	2	5
22-Aug-17	*Sphaerocystis Schroeteri* (Chlorophyte)	1	29
	Eudorina elegans (Chlorophyte)	2	13
	Ceratium hirundinella (Pyrrhophyte)	3	12
	Cosmarium spp. (Chlorophyte)	4	10
	Staurastrum natator var. *crassum* (Chlorophyte)	5	10
	Cosmarium spp. (Chlorophyte)	6	7

The south sampling site exhibited a predominance of Bacillariophyte (diatom) and Chlorophyte taxa and many of the same forms were present on both sampling dates including *Hyalotheca* sp., *Fragilaria crotonensis*, and *Pediastrum duplex*. The dominant phytoplankton groups in the mid and north sampling

stations were the Chlorophytes and Pyrrhophytes and certain taxa were the major forms at these sites also, i.e., *Sphaerocystis Schroeteri* and *Ceratium hirundinella.*

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

The density and biomass diversity values calculated using the 2017 phytoplankton data from Miacomet Pond are summarized in Table 7-9. In some cases, there was good agreement between the two calculated [H] values at a particular site on a certain sampling date, i.e., south sampling site on July 25th (density [**H**] = 1.079, biomass [**H**]=1.092); however in other cased the diversity values were quite different, i.e., north sampling site on July 25th (density [**H**] =1.079, biomass [**H**]=0.418). These patterns are similar to the differences in community diversity values that have been observed and discussed for other Nantucket Island ponds in previous chapters of this report.

Cyanophytes. A total of 11 Cyanophyte genera were identified from the 2017 samples collected at the 3 sampling stations located on Miacomet Pond, more genera than identified in any other pond during 2017. Furthermore, the distribution and occurrence of these genera as summarized in Table 7-11 below reveals how patchy the components of the phytoplankton community can be within a particular body of water.

Table 7-11. Cyanophyte species identified in Miacomet Pond, 2017.

	south site		mid site		north site	
Species	25-Jul	22-Aug	25-Jul	22-Aug	25-Jul	22-Aug
*Anabaena flos aquae**		yes (<1)				
*Aphanizomenon flos aquae**			yes (3)			
Aphanocapsa elachista		yes (55)				yes (18)
Chroococcus dispersus	yes (16)					yes (18)
C. limneticus					yes (<1)	yes (<1)
Gomphosphaeria lacustris	yes (16)	yes (25)				
*Lyngbya** sp.		yes (<1)				
Merismopedia glauca					yes (2)	
*Microcystis aeruginosa**				yes (65)		
*Oscillatoria** sp.	yes (9)			yes (5)	yes (1)	yes (2)
Rhabdoderma Gorskii			yes (2)		yes (1)	

'yes' = present, 'no' = absent; (##) = percent of community total on a sampling date
* Species that are known to produce algal toxins

On Nantucket Island, the concern about Cyanophytes centers around the ability of certain genera to produce toxins (neurotoxins, hepatotoxins) which are released into the environment and become a public health concern for recreational users of water bodies such as Miacomet Pond, and particularly the southern region of the pond which is separated by a barrier beach from the Atlantic Ocean.

Some sort of on-site testing should be conducted at this pond and other Island ponds that have exhibited genera with toxin-producing capabiltities. There are at least 5 genera of Cyanophytes found in Miacomet Pond that are capable of producing toxins (Table 7-11).

Chlorophyll *a*. The chlorophyll a concentrations measured in Miacome Pond during 2017 are summarized in Table 7-9. The mid sampling station exhibited the greatest average value for 2017, which

[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.

was greatly affected by the high concentration (19.2 µg·L^{-1}) measured on August 22nd. All of the other 2017 values reflect low-to-moderate productivity in the phytoplankton community.

7.1.5 Trophic Status

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

Except for the absence of Secchi depth readings at the mid and north sampling station due to shallow depth, there were sufficient 2017 data for chlorophyll ***a*** and total phosphorus to calculate the Carlson Trophic State Index at all 3 sampling stations along the main axis of the pond. The data were substituted into equations (see Chapter 1) to calculate the TSI values for each variable. Table 7-12 presents the TSIs calculated for Miacomet Pond for 2017.

Table 7-12. Trophic State Indices (TSIs) calculated for Miacomet Pond.

Site	Chlorophyll TSI	TP TSI	Secchi TSI
south	47.0 (M)	52.3 (E)	51.8 (E)
mid	56.2 (E)	57.0 (E)	na
north	45.8 (M)	61.9 (E)	na

Table 7-13 summarizes Carlson's Trophic State Index in relation to the 3 independent water quality variables used as predictors and the trophic classification of lakes and ponds.

Table 7-13. 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 single Secchi TSI (51.8) calculated for the south sampling station places Miacomet Pond in the eutrophic class of productivity, while the chlorophyll ***a*** results generated a mixed response, with the south and north site being mesotrophic and the mid site being eutrophic (based upon the single high reading of 19.20 on August 22nd. The TP TSIs all were in the eutrophic range and probably reflect the most accurate predictor of productivity in Miacomet Pond.

7.2 Summary

Miacomet Pond exhibits eutrophic productivity based upon the TSI from total phosphorus used as the calculating variable. 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 rick for recreational users of the pond.

7.3 Literature Cited

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Nantucket Island Ponds and 2017 Water Quality

Chapter 8

Tom Nevers Pond

8.0 Introduction

The NLC has sampled Tom Nevers Pond on six (6) occasions since 2014, including September 2nd and 24th 2014, May 13th and August 30th 2016, and August 2nd and 22nd 2017. The data collected prior to 2017 have been reported elsewhere (Sutherland and MacKinnon 2015; Sutherland and MacKinnon 2017). This chapter presents a summary and discussion of the physical, chemical and biological data collected from Tom Nevers Pond by NLC staff during 2017 and compares these data with the 2014 and 2016 data.

8.1 Results

Tom Nevers Pond was sampled on August 2nd and 22nd 2017. The maximum water depth recorded was 4.0 feet (1.2 m) on August 2nd and 4.4 feet (1.3 m) on August 22nd at the sampling location in the approximate center of the pond. The greatest water depth measured at the pond was 5.5 feet (1.7 m) on May 13th 2016.

Following the collection of temperature and dissolved oxygen profile data during the August 2017 sampling excursions, integrate samples were collected from the surface down to 3 feet (0.9 m) on both dates for the chemistry and phytoplankton samples. There were no other water samples collected from the pond on either sampling date. Observations recorded while sampling the pond included a red-brown water color on both 2017 sampling dates.

8.1.1 Physical characteristics

General. Tom Nevers Pond is situated along the southeast shore of Nantucket Island, between the farthest extensions of Wanoma Way and Low Beach Road. The pond is an irregular shaped body of water with its axis oriented in a northwest-southeast direction (Figure 8-1).

Figure 8-1. Aerial view of Tom Nevers Pond (from *Google*™ earth)

The surface area of the pond is about 10 acres. A single stream inlet, Phillip's Run, flows into the pond at the north end from Gibbs Pond which is north of Tom Nevers Pond. The outlet of Tom Nevers Pond at the south end drains toward the Low Beach area and the Atlantic Ocean (Figure 8-1).

Table 8-1 summaries the Secchi depth transparency and temperature profile data collected at the pond during 2014, 2016 and 2017.

Table 8-1. Summary of physical data from Tom Nevers Pond, 2014, 2016, and 2017.

Tom Nevers Pond Physical Properties 2014, 2016, 2017		
Sampling Date	Secchi depth (m)	Avg Water Column Temperature (°C)
2-Sep-14	0.30	24.7
24-Sep-14	0.30	19.1
2014 avg	0.30	21.9
13-May-16	0.64	17.6
30-Aug-16	0.21	26.6
2016 avg	0.42	22.1
2-Aug-17	0.23	24.5
22-Aug-17	0.18	25.6
2017 avg	0.20	25.1

Temperature. Temperature profile data were collected on all sampling dates. Due to the shallow nature of Tom Nevers Pond, the temperature from surface to bottom in the pond usually was isothermal. August 30th 2016 was the only sampling date when the pond was slightly stratified and the temperature difference between the surface and the bottom was ~3.0°C.

Since the pond is shallow, it is very susceptible to mixing of the water column when there are extended periods of wind blowing from virtually any direction. This mixing of the water column likely explains the difference between the isothermal condition on most sampling dates and the slight temperature stratification on August 30th when conditions probably were calm and allowed temperature differences to develop between the surface and the bottom.

Transparency. The lowest Secchi depth transparency (0.18 m; 0.75 feet) measured at Tom Nevers was on August 22nd 2017, while the greatest transparency occurred on May 13th 2016. Water clarity usually is greater in the spring because the water temperature is increasing and conditions still are not optimum for phytoplankton growth.

In addition to Secchi depth transparency, water color on all 2014, 2016 and 2017 sampling dates was listed as 'brown' or 'red-brown' which is the color of small ponds such as Tom Nevers when there is a strong influence of bog-like vegetation growing around the perimeter of the pond and also draining into the pond from areas upland in the watershed. In these situations, water color and transparency are strongly influenced by organic humic and fulvic acids leaching into the water from surrounding areas of vegetative growth.

3.1.2 Chemical characteristics

Table 8-2 summarizes the water chemistry characteristics of Tom Nevers Pond based upon the samples collected at the pond during 2014, 2016 and 2017.

Specific conductance. The individual conductance values measured at Tom Nevers Pond during the 3 years that the pond was sampled ranged from 81 – 226 $\mu S \cdot cm^{-1}$; the average conductance value for all

sampling dates was 133 µS·cm^{-1}. Both of the 2017 values were in the low range of conductance, 114 and 110 µS·cm^{-1} on August 2nd and August 22nd, respectively.

The value of 226 µS·cm^{-1} recorded on August 30th 2016 is interesting and higher than expected and could be due to (1) excessive evaporation from the pond which would tend to concentrate the ions dissolved in the water than contribute to conductivity, and/or (2) periods of excessive wind blowing from the south toward the pond which could add significant salt spray (aerosols) to the water column which also would raise dissolved ions in the water and, therefore, the conductivity readings.

Table 8-2. Summary of chemical data from Tom Nevers Pond, 2014, 2016, and 2017.

	Washing Pond Chemical Properties 2014, 2016, 2017								
Sampling Date	Avg DO saturation	TP (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	NO3 + NH4-N (mg/L)	TN (mg/L)	Org N (mg/L)	spC (µS)	pH (s.u.)
2-Sep-14	93.3	0.022	0.005	0.024	0.029	1.239	1.210	112	5.66
24-Sep-14	97.7	0.131	0.005	0.009	0.014	1.348	1.334	154	6.35
2014 avg	95.5	0.076	0.005	0.017	0.021	1.294	1.272	133	6.01
13-May-16	86.0	0.114	0.005	0.020	0.025	0.600	0.576	81	5.60
30-Aug-16	75.6	0.796	0.005	0.020	0.025	1.240	1.216	226	6.21
2016 avg	80.8	0.455	0.005	0.020	0.025	0.920	0.896	153	5.91
2-Aug-17	84.1	0.847	0.010	0.005	0.015	1.120	1.105	114	6.51
22-Aug-17	84.4	0.603	0.170	0.010	0.180	1.100	0.920	110	7.27
2017 avg	84.3	0.725	0.090	0.008	0.098	1.110	1.013	112	6.89
highlighted cells = values shown are ½ the detection limit									

In spite of this single high reading, these conductance values measured at Tom Nevers are within the range of specific conductance values expected from ponds in an estuarine environment considered to be fresh water.

pH. The pH of Tom Nevers Pond was acidic (<6.0 s.u.) on September 2nd 2014 (5.66 s.u.) and May 13th 2016 (5.60 s.u.) and then greater than 6.0 s.u. on all other dates, with the highest reading of 7.27 s.u. occurring on August 22nd 2017.

The pH values below 6.00 documented in Tom Nevers Pond during early September 2014 and mid-May 2016 are very similar to the year-round conditions that occur in small lakes and ponds in the Adirondack Region of New York State where leaching of humic and fulvic acids from the surrounding shorelines and watersheds imparts a dark brown coloration to the water and acid conditions. .

Dissolved oxygen percent saturation. The average oxygen saturation value of the Tom Nevers water column always was less than 100 percent and usually decreased from the surface to the bottom where most of the decomposition of organic material would be occurring. There is nothing particularly noteworthy about the oxygen saturation values measured in Tom Nevers Pond in 2014, 2016 and 2017. Any gradients in oxygen concentration from surface to the bottom of ponds typically occurs during periods when there are no winds which cause mixing and the calm water exhibits gradients due to decomposition of organic material on the bottom which consumes oxygen and establishes the gradient.

8.1.3 Plant Nutrients

Nitrogen. N**itrate-nitrogen** concentrations measured in Tom Nevers Pond were below detection on all sampling dates except during both dates during August 2017 (see Table 8-2) when the concentrations were 0.010 and 0.170 mg N·L^{-1} on the 2nd and 22nd, respectively. And while there were measureable levels of **ammonia-nitrogen** on all sampling dates except August 2nd 2017, the levels were low (average

of 0.015 mg $N \cdot L^{-1}$ on all dates). Low levels of these compounds are expected because these forms of nitrogen are readily taken up by phytoplankton.

The **total nitrogen** (TN) measured in Tom Nevers Pond ranged from 0.600 – 1.348 mg $N \cdot L^{-1}$ among the 6 sampling dates, with an average concentration for all dates of 1.108 mg $N \cdot L^{-1}$.

The low concentrations of **nitrate-** and **ammonia-nitrogen** measured during all years that the pond was sampled indicate that essentially all of the **total nitrogen** measured in Tom Nevers Pond was contained in organic material in the form of phytoplankton and seston (other organisms and non-living particulate matter) in the water column. The low **TN** value measured in May 2016 is not unusual because water temperatures in the spring still are warming and below the optimum levels for maximum growth and productivity of phytoplankton.

A comparison of the TN and organic nitrogen (Org N) values summarized in Table 8-2 reveals that greater than 95 percent of the nitrogen measured in Tom Nevers Pond is comprised of organic nitrogen.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Tom Nevers during 2017 were the highest measured during the 3 years that the pond has been sampled (Table 8-2); the values were 0.847 and 0.603 mg $P \cdot L^{-1}$ on August 2nd and August 22nd, respectively. These values for TP represent some of the highest values measured in Nantucket Island ponds since the NLC began monitoring water quality during 2009.

For purposes of comparison, the reader is referred to Chapter 10, Table 10-1 for a summary of **TN** and **TP** values measured in other Nantucket Island ponds by NLC-sponsored surveys since 2009.

8.1.4 Phytoplankton

Description of the assemblage. Table 8-3 presents a summary of the phytoplankton taxa that were identified in the 2017 phytoplankton samples collected from Tom Nevers Pond. The August 2nd assemblage contained 19 taxa while the August 22nd assemblage had 28 taxa; 31 different taxa were identified from both 2017 sampling dates.

Table 8-3. Major groups and taxa of phytoplankton identified in Tom Nevers Pond, 2017.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Chroococcus dispersus	*Pediastrum duplex*	*N. longissima*
Dictyosphaerium Ehrenbergianum	*Pyramimonas tetrarhyncus*	*Surirella* sp.
Chlorophytes	*Scenedesmus bijuga*	*Synedra acus*
Ankistrodesmus falcatus	*S. bijuga alternans*	**Chrysophytes (Chrysophyceae)**
Arthrodesmus fuellebornei	*S. quadricauda*	*Mallomonas* sp.
C. longissima	*Schroederia Judayi*	*Ochromonas* sp.
C. acutum	*Selenastrum capricornutum*	**Euglenophytes**
C. gracile	*S. minutum*	*Peranema* sp.
Crucigenia rectangularis	*Spirulina sp.*	*Trachelomonas* sp.
Elakatothrix gelatinosa	*Staurastrum natator var. crassum*	**Pyrrhophytes (Cryptophyceae)**
Monoraphidium arcuatum	**Chrysophytes (Bacillariophyceae)**	*Cryptomonas ovata*
M. contortum	*Cyclotella* sp.	
	Navicula spp.	

The reader is referred to Sutherland and MacKinnon (2015) for a complete listing of the phytoplankton taxa identified in Tom Nevers Pond during 2014; there were 34 taxa identified on September 2nd 2014 and 26 taxa identified on September 24th 2014.

The reader also is referred to Sutherland and MacKinnon (2017) for a complete listing of the phytoplankton taxa identified in Tom Nevers Pond during 2016; there were 21 taxa identified on May 13th 2016 and 42 taxa identified on August 30th 2016.

Community richness was calculated for the 3 years that Tom Nevers Pond has been sampled for water quality and the richness was as follows: 30.0 ± 5.7 taxa in 2014, 31.5 ±14.8 taxa in 2016, and 23.5 ± 6.4 taxa in 2017.

Table 8-4 presents a summary of the Tom Nevers Pond phytoplankton community characteristics determined from samples collected during 2014, 2016 and 2017.

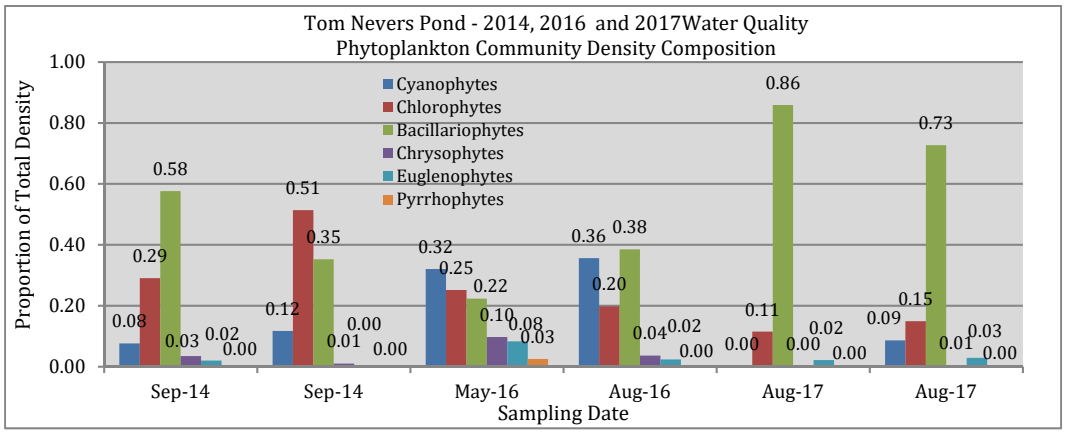
Table 8-4. Summary of Tom Nevers Pond phytoplankton community characteristics, 2014, 2016, and 2017.

Tom Nevers Pond Phytoplankton Community Characteristics 2014, 2016, 2017						
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})
2-Sep-14	34	19,643	8,090	0.989	1.058	6.23
24-Sep-14	26	14,320	3,107	0.858	1.019	2.12
2014 avg	30	16,982	5,599	0.924	1.039	4.18
13-May-16	21	2,793	7,718	0.960	1.004	2.10
30-Aug-16	42	31,343	8,886	1.010	1.026	14.0
2016 avg	32	17,068	5,302	0.985	1.015	8.05
2-Aug-17	19	22,149	6,661	0.444	0.376	11.70
22-Aug-17	28	23,610	8,444	0.687	0.767	7.50
2017 Avg	24	22,880	7,553	0.566	0.572	9.60

Density. Community density ranged from 2,793 -31,343 cells·mL^{-1} during the 3 years that the pond has been monitored, about a 15-fold difference in the number of organisms in the water column. The lowest density occurred on May 13th 2016, which is expected because the pond was warming up following the previous winter and water temperature was not yet ideal for good phytoplankton productivity.

The density composition of the phytoplankton community in 2014, 2016 and 2017 is shown in Figure 8-2. There were some notable changes in the community composition during these 3 years.

Figure 8-2. Density composition of the phytoplankton community in Tom Nevers Pond, 2014, 2016, and 2017.



The pond exhibited considerable fluctuation during 2014, 2016 and 2017 with respect to the major groups of phytoplankton that were dominant in the community. During 2014, the Chlorophytes and

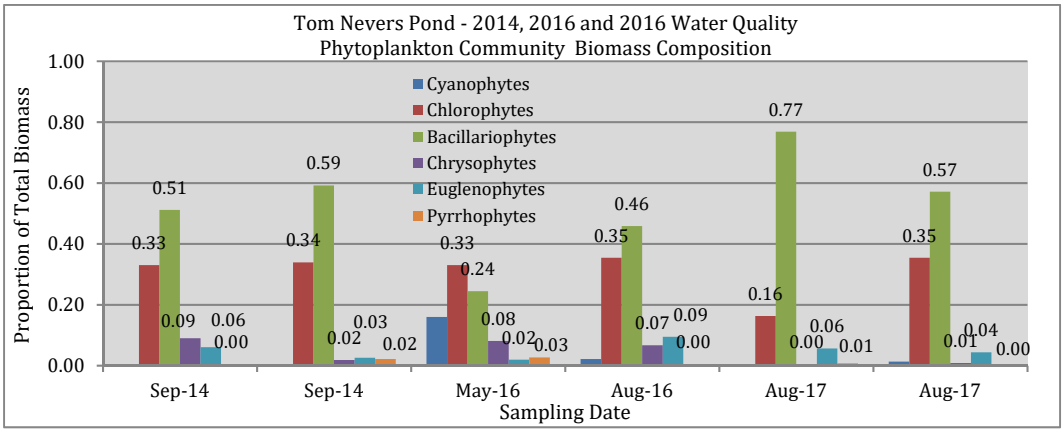
Bacillariophytes were the major dominant groups, although their roles in the community interchanged between the two September sampling dates (see Figure 8-2). During May 2016, all of the major groups were represented in the community, and 2016 also is noteworthy because it was the only year when Cyanophytes were community dominants. By 2017, the Chlorophytes comprised over 85 percent of the community on both sampling dates, with the other groups less important on both sampling dates.

Biomass. Cell biovolume also 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 that can occur in the pond.

The difference in using density as the only community descriptor is evident when reviewing cell biomass values and noting the substantial difference between the size of, for example, 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.

As shown in Figure 8-3, the biomass compositions in Tom Nevers Pond during 2014, 2016 and 2017 were similar in that the Bacillariophytes and Chlorophytes always were the major dominant groups in the community, and in that order. The Bacillariophytes ranged from 24 – 77 percent of the total phytoplankton community during 2014, 2016 and 2017, while the Chlorophytes ranged from 16 – 35 percent of the community during the same period.

Figure 8-3. Biomass composition of the phytoplankton community in Tom Nevers Pond, 2014, 2016,2017.



Dominance. A ranking of phytoplankton taxa dominance in Tom Nevers Pond during the sampling dates in 2014, 2016 and 2017 is summarized in Table 8-5. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

There were 6 dominant taxa in the phytoplankton community during 2014 and 2016 and then only 3 dominant taxa on both sampling dates during 2017. The Bacillariophyte, *Cyclotella* sp., was a biomass dominant on all 6 sampling dates; the Chlorophyte, *Staurastrum natator* var. *crassum* occurred as a biomass dominant on 4 of the 6 sampling dates; the Bacillariophyte, *Synedra acus*, was a density dominant on 3 of the 6 sampling dates.

Diversity. Phytoplankton diversity in Tom Nevers 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.

The density and biomass diversity values calculated for Tom Nevers Pond were similar on each sampling date (see Table 8-4). Overall diversity in the pond was high (0.858 or greater) except during 2017 when the Bacillariophtyes and Chlorophytes combined to comprise 93 percent of the community on August 2nd and 92 percent of the community on August 22nd.

Table 8-5. Rank of phytoplankton taxa dominance, using biomass, in Tom Nevers Pond, 2014, 2016, 2017.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
2-Sep-14	*Synedra acus* (Bacillariophyte)	1	30
	Cyclotella sp. (Bacillariophyte)	2	12
	Closterium sp. (Chlorophyte)	3	10
	Staurastrum natator var. *crassum* (Chlorophyte)	4	9
	Asterionella formosa (Bacillariophyte)	5	7
	Scenedesmus bijuga (Chlorophyte)	6	5
24-Sep-14	*Cyclotella* sp. (Bacillariophyte)	1	22
	Synedra acus (Bacillariophyte)	2	21
	Asterionella formosa (Bacillariophyte)	3	13
	Kirchneriella lunaris (Chlorophyte)	4	11
	Closterium sp. (Chlorophyte)	5	8
	Staurastrum natator var. *crassum* (Chlorophyte)	6	6
13-May-16	*Staurastrum natator* var. *crassum* (Chlorophyte)	1	23
	Sphaerocystis Schroeteri (Chlorophyte)	2	18
	Anabaena flos-aquae (Cyanophyte)	3	16
	Tabellaria flocccosa (Bacillariophyte)	4	11
	Synura uvella (Chrysophyte)	5	7
	Cyclotella sp. (Bacillariophyte)	6	6
30-Aug-16	*Cyclotella* sp. (Bacillariophyte)	1	31
	Sphaerocystis Schroeteri (Chlorophyte)	2	13
	Trachelomonas sp. (Euglenophyte)	3	9
	Staurastrum natator var. *crassum* (Chlorophyte)	4	8
	Tabellaria flocccosa (Bacillariophyte)	5	7
	Synura uvella (Chrysophyte)	6	7
2-Aug-17	*Cyclotella* sp. (Bacillariophyte)	1	75
	Pediastrum duplex (Bacillariophyte)	2	11
	Trachelomonas sp. (Euglenophyte)	3	5
22-Aug-17	*Cyclotella* sp. (Bacillariophyte)	1	49
	Pediastrum duplex (Bacillariophyte)	2	22
	Synedra acus (Bacillariophyte)	3	7

Cyanophytes. As a major phytoplankton group, Cyanophytes were identified in 5 of the 6 phytoplankton samples collected from Tom Nevers Pond. Table 8-6 summarizes the species identified in the 2014, 2016 and 2017 samples and their percent of the total phytoplankton community composition.

The Cyanophytes were most prevalent during 2016 when they comprised 32 percent of the community on May 13th and 36 percent of the community on August 30th. Of particular note is the decrease in Cyanophyte presence in the community between 2016 and 2017; no species were identified in the August

[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.

2nd sample and only 2 species comprising 8 percent of the community composition were identified in the August 22nd sample.

Table 8-6. Cyanophyte species identified in Tom Nevers Pond, 2014, 2016, and 2017.

Species	2-Sep-14	24-Sep-14	13-May-16	30-Aug-16	2-Aug-17	22-Aug-17
*Anabaena flos aquae**	no	no	yes (32)	no	no	no
*Anabaenopsis Elenkinii**	no	no	no	yes (3)	no	no
Chroococcus dispersus	no	yes (1)	no	yes (3)	no	yes (6)
Dictyosphaerium Ehrenbergianum	no	no	no	no	no	yes (2)
Gomphosphaeria lacustris compacta	yes (8)	no	no	yes (5)	no	no
Merismopedia glauca	no	yes (11)	no	yes (25)	no	no
'yes' = present, 'no' = absent; (##) percent of community on a sampling date * Species that are known to produce algal toxins						

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Tom Nevers Pond during 2014, 2016 and 2017 ranged from 2.10 – 14.00 $\mu g \cdot L^{-1}$ and averaged 7.28 $\mu g \cdot L^{-1}$ (Table 8-4). Tom Nevers Pond chlorophyll ***a*** levels are within the low range of values when compared with other Nantucket Island Ponds surveyed since 2009. The reader is referred to Chapter 10, Table 10-1 for a summary of water quality parameters measured by the NLC in all 11 ponds surveyed since 2009.

8.1.5 Trophic Status

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

Sufficient water quality data were collected from Tom Nevers Pond during 2017 to calculate the Carlson Trophic State Index (TSI) using all three variables (chlorophyll ***a***, total phosphorus, Secchi depth transparency). Average values were calculated for each variable for the August sampling dates. The average values then were substituted into the appropriate 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* = 9.60 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (9.60)] + 30.6
TSI = (9.81)(2.26) + 30.6
TSI = 52.8

Total phosphorus
Average total phosphorus = 724.9 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (724.9)] + 4.15
TSI = (14.42)(6.59) + 4.15
TSI = 99.1

Secchi depth
Average Secchi depth = 0.43 m
Secchi TSI = 60 – [14.41*[ln (0.43)]
TSI = 60 – (14.41)(-0.84)
TSI = 72.2

The TSI of 52.8 calculated for chlorophyll ***a*** was just above the threshold of 50 for the mesotrophic region (see Table 8-7 below), while the TSI calculated for total phosphorus (99.1) was within the upper range of the hyper-eutrophic region, which has a lower threshold of TI value of 70. The average 2017 Secchi depth (0.43 m) resulted in a calculated TSI value of 72.2 which also is within the hyper-eutrophic region.

Table 8-7. Relationships among Trophic Index (TI), chlorophyll *a*, total phosphorus, Secchi depth and Trophic Class (after Carlson 1996).

Trophic Index (TI)	Chlorophyll *a* ($\mu g \cdot L^{-1}$)	Total phosphorus ($\mu g \cdot L^{-1}$)	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 values calculated for Tom Nevers Pond portray poor water quality during 2017 that ranges between mesotrophic and hyper-eutrophic conditions, depending upon which variable is used in the calculation.

There are certain limitations that should be considered, however, when interpreting the 2017 TSI numbers calculated for Tom Nevers Pond. For example, the extremely low transparency measured at the pond (0.4 m average value) was the result of organic material (humic and fulvic acids) in the water and not the result of algal productivity (density and/or biomass) which is the routine basis for using Secchi depth to calculate a TSI value.

The collective TSI values calculated for Tom Nevers Pond since 2014 are summarized in Table 8-8 below

Table 8-8. Trophic State Indices (TSIs) calculated for Tom Nevers Pond, 2014, 2016, and 2017.

Year	Chlorophyll TSI	TP TSI	Secchi TSI
2014	44.6	66.6	77.3
2016	51.1	92.4	72.2
2017	52.8	99.1	72.2

Taking all of the above calculations into consideration, there has been a trend of increasing productivity in Tom Nevers Pond since 2014, specifically with regard to chlorophyll ***a*** and total phosphorus, i.e., the TSI values of both variables have increased since 2014. The Secchi TSI has been the most consistent TSI variable, and always has indicated hyper-eutrophic productivity based upon the influence of organic material either suspended or dissolved in the pond water column.

8.2 Summary

Tom Nevers Pond can be characterized as a moderate-to-high productivity dystrophic body of water that is strongly influenced by drainage from surrounding areas that contain bog-like vegetation and give the pond water its characteristic 'stained' appearance. It also receives drainage from Gibbs Pond to the north. There are many small lakes and ponds in the Adirondack Mountain region of New York State that have similar water quality characteristics (Sutherland 1989). Aside from the limited transparency of the water, the other primary characteristic of dystrophic waters includes low pH which also is from the influence of the surrounding vegetation. Based upon the limited depth of light penetration in the water column, only certain taxa of phytoplankton can adapt to the restrictive conditions in these waters and the taxa that are present must be situated just below the water surface to receive the optimum amount of incident radiation in order to successfully photosynthesize.

8.3 Literature Cited

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Nantucket Island Ponds and 2017 Water Quality

Chapter 9

Washing Pond

9.0 Introduction

Washing Pond was sampled by the NLC during August and September 2014 (Sutherland and MacKinnon, 2015), and during May and August 2016 (Sutherland and MacKinnon, 2017). This chapter presents a summary and discussion of the physical, chemical and biological data collected from Washing Pond by Nantucket Land Council staff during 2017 and also compares these data with the 2014 and 2016 data.

9.1 Results

Washing Pond was sampled on July 26th and August 29th 2017. The maximum water depth located in the pond was 14.5 feet (4.4 m) on July 26th at a sampling location in the approximate center of the pond; the maximum water depth located on August 29th was 13.8 (4.2 m).

Following the collection of temperature and dissolved oxygen profile data on July 26th, an integrate sample was collected from the surface down to 10 feet (3.0 m) of depth for the chemistry and phytoplankton samples; no grab sample was collected from the ***lower*** region of the pond. The depth of collection on August 29th was 0-8 feet (2.4 m); no grab sample was collected from the ***lower*** region of the water column.

9.1.1 Physical characteristics

General. Washing Pond is located on the western portion of Nantucket Island, just about due north of Maxcy Pond. The pond is rectangular in shape with a middle bulge giving it the appearance of an ellipse with its main axis oriented in a north-south direction (Figure 9-1). The surface area of the pond is about 8 acres. There are no permanent streams flowing into the pond, and there is no outlet.

Figure 9-1. Aerial view of Washing Pond (from *Google*™ Earth)

Washing Pond has a total depth of 14-16 feet and is situated in a basin of low elevation which should provide some limited protection from wind blowing across the Island and mixing of the water column even though it is in close proximity to the Atlantic Ocean.

Table 9-1 summarizes the physical data collected from Washing Pond during the 2014, 2016 and 2017 sampling seasons.

Table 9-1. Summary of physical data from Washing Pond, 2014, 2016, and 2017.

Washing Pond Physical Properties 2014, 2016, 2017		
Sampling Date	Secchi depth (m)	Avg Water Column Temperature (°C)
26-Aug-14	1.9	24.0
15-Sep-14	1.5	21.6
2014 avg	1.7	22.8
19-May-16	3.5	16.5
31-Aug-16	1.3	25.5
2016 avg	2.4	21.0
26-Jul-17	1.5	22.9
29-Aug-17	1.4	23.6
2017 avg	1.5	23.3

Temperature. Temperature profile data were collected on all sampling excursions to Washing Pond. An examination of these data indicated that there were only very slight temperature differences between the surface of the pond and the ***lower*** region near the bottom, usually in the range of 1-2°C.

Transparency. With the exception of the May 19th 2016 value of 3.5 m, all of the Secchi depths recorded at Washing Pond have been similar, ranging between 1.3 – 1.9 m of depth. In almost all cases, 'water color' recorded on the field sheet was 'green' or green-brown' indicating algae in the water column that affect transparency and suggest moderate productivity. Water color on May 19th 2016 was recorded as 'clear', which accounts for the high Secchi depth recorded and indicates that no algal bloom in progress.

9.1.2 Chemical characteristics

Table 9-2 summarizes the chemical characteristics of Washing Pond, including the algal nutrients, phosphorus and nitrogen, based upon the water samples collected during 2014, 2016 and 2017.

Table 9-2. Summary of chemical data from Washing Pond, 2014, 2016, and 2017.

	Washing Pond Chemical Properties 2014, 2016, 2017								
Sampling Date	Avg DO saturation	TP (mg/L)	NO3-N (mg/L)	NH4-N (mg/L)	NO3 + NH4-N (mg/L)	TN (mg/L)	Org N (mg/L)	spC (µS)	pH (s.u.)
26-Aug-14	91.7	0.051	0.028	0.021	0.049	0.584	0.535	154	6.81
15-Sep-14	92.6	0.035	0.005	0.200	0.205	0.671	0.466	156	6.67
2014 avg	92.2	0.043	0.017	0.111	0.127	0.628	0.501	155	6.74
19-May-16	84.0	0.020	0.005	0.005	0.010	0.400	0.390	134	5.99
31-Aug-16	81.6	0.049	0.005	0.005	0.010	0.610	0.600	148	7.53
2016 avg	82.8	0.035	0.005	0.005	0.010	0.505	0.495	141	6.76
26-Jul-17	79.8	0.037	0.050	0.040	0.090	0.610	0.520	143	7.36
29-Aug-17	93.9	0.039	0.005	0.005	0.010	0.530	0.520	144	8.37
2017 avg	86.8	0.038	0.028	0.023	0.050	0.570	0.520	144	7.87

indicates that ***upper*** and ***lower*** region samples were collected; all values listed are for the ***upper*** regions only
highlighted cells = values listed are one-half the lower detection limit

Lower region chemistry samples were collected on 3 sampling dates; the remaining sampling excursions collected only integrate samples from the ***upper*** region for chemistry. In all cases, the difference in the ***upper*** and ***lower*** region values was very small; the results presented for a sampling date include the value for the integrate (***upper*** region) sample only.

Specific conductance. The conductance values from Washing Pond ranged from 134 – 156 $\mu S \cdot cm^{-1}$ which are values characteristic of fresh-water systems; several other ponds on Nantucket Island exhibited a similar range in values including Gibbs and Maxcy Ponds. All values collected from Washing Pond during 2014 and 2016 essentially are the same and within the range expected in ponds considered to be fresh water with some minimal influence from aerosol salt spray from the Atlantic Ocean.

pH. The pH values from Washing Pond ranged from 5.99 – 8.37 s.u. The value of 8.37 s.u. is the only noteworthy value, and probably is the result of high productivity in the system during later August 2017.

Dissolved oxygen percent saturation. The maximum concentration of dissolved oxygen that can occur in water, in general, is a function of water temperature. Higher concentrations of dissolved oxygen occur in lower water temperatures than at higher 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.

The average oxygen saturation in Maxcy Pond ranged from 79.8 – 93.9 percent and examination of the profile data revealed a general decrease in percent saturation with increasing depth in the water column, which is typical of freshwater systems where maximum productivity occurs in the upper region of the pond and decomposition and oxygen consumption occurs in the lower region. In addition, Maxcy Pond is sheltered from the wind which would render the water column less susceptible to wind-driven mixing. There was only one sampling date (August 26th 2014) when the surface of the pond was supersaturated (>100 percent) with oxygen; on all other sampling dates, the surface was below saturation and saturation declined with water depth indicating relatively high productivity. The percent saturation conditions on May 19th 2016 suggest that the pond was in the process of mixing throughout the water column.

9.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen usually was not detected in chemistry samples collected from the pond; out of 9 samples collected for chemistry from the ***upper*** and ***lower*** regions during 2014, 2016 and 2017, nitrate-nitrogen was detected in only 3 samples. This situation is not unusual because nitrate-nitrogen is readily available for uptake by phytoplankton in the pond for productivity.

Ammonia-nitrogen was detectable in 5 of 9 samples collected from the water column of Washing Pond; however, concentrations generally were low (<0.100 mg $N \cdot L^{-1}$), with only a single high value of 0.200 mg $N \cdot L^{-1}$ measured on September 15th 2014. Ammonia-nitrogen is the first product of the decomposition of organic material (phytoplankton) in the water column, so it is not unusual that concentrations would be detectable if breakdown exceeds uptake, especially if the detectable concentrations of ammonia-nitrogen occur in levels of the water column where light conditions are not ideal for phytoplankton productivity.

The **total nitrogen** (**TN**) concentrations measured in Washing Pond during 2014, 2016, and 2017 ranged from 0.400 – 1.149 mg $N \cdot L^{-1}$ (the ***lower*** region value on August 26th 2014 not shown in Table 9-2). Almost all of the TN values within the range were ~0.600 mg $N \cdot L^{-1}$.

All TN concentrations measured in Washing Pond during 2014, 2016 and 2017 are within the range expected in a body of water that exhibits moderate productivity, except perhaps the value of 1.149 mg N/L^{-1} which occurred on August 26th 2014 and could be an outlier. Based upon the dissolved oxygen profile collected on that date, it would appear that the pond experienced a calm period (with little or no wind) which allowed a saturation gradient to develop with low dissolved oxygen levels near the bottom of the pond. These conditions could promote the internal loading of nitrogen from the bottom sediments

into the *lower* water column and could explain the substantial ***upper*** and ***lower*** concentration differences of TN on that date.

The **TN** concentrations measured in Washing Pond during 2014, 2016, and 2017 are similar to **TN** values measured in other Nantucket Island ponds during previous NLC surveys which began during 2009. The reader is referred to Chapter 10 of this report for a comparison of water quality parameters for the suite of 11 Island ponds that have been surveyed during the past 9 years.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Washing Pond during 2014, 2016 and 2017 ranged from 0.020 – 0.052 mg $P \cdot L^{-1}$ (see Table 7-2). All of the TP values are within the range of concentrations for a body of water with moderate productivity.

9.1.4 Phytoplankton

Description of the assemblage. A total of 35 taxa were identified in the 2017 phytoplankton samples collected from Washing Pond and all of the major groups were represented in these samples (Table 9-3).

Table 9-3. Major groups and taxa of phytoplankton identified in Washing Pond, 2017.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Chrysophyceae)**
Chroococcus dispersus	*Quadrigula lacustris*	*Dinobyron divergens*
Dictyosphaerium Ehrenbergianum	*Sphaerocystis Schroeteri*	*Mallomonas* sp.
Microcystis aeruginosa	*Staurastrum natator* var. *crassum*	*Ochromonas* sp.
Woronichinia naegeliana	*Tetraedron minimum*	**Euglenophytes**
Chloromonadophyta	**Chrysophytes (Bacillariophyceae)**	*Euglena* spp.
Gonyostomum semen	*Achnanthes* sp.	*Peranema* sp.
Chlorophytes	*Aulacoseria granulata*	*Phacus* sp.
Arthrodesmus fuellebornei	*Cocconeis* sp.	*Trachelomonas* sp.
Closterium acutum	*Cyclotella* sp.	**Pyrrhophytes (Cryptophytes)**
Crucigenia rectangularis	*Fragilaria crotonensis*	*Cryptomonas ovata*
Elakatothrix gelatinosa	*Navicula* spp.	**Pyrrhophytes (Dinophytes)**
Eudorina elegans	*Planothidium* sp.	*Ceratium hirundinella*
Oocystis Borgei	*Stauroneis* sp.	*Peridinium cinctum*
Pyramimonas tetrarhyncus	*Synedra acus*	

There were 30 taxa identified in the pond's phytoplankton community on July 26th and 22 taxa identified in the community on August 29th; 2017 community richness was calculated to be 26.0 (±5.7) taxa.

Table 9-4 presents a summary of the Washing Pond phytoplankton community characteristics determined from samples collected during 2014, 2016 and 2017.

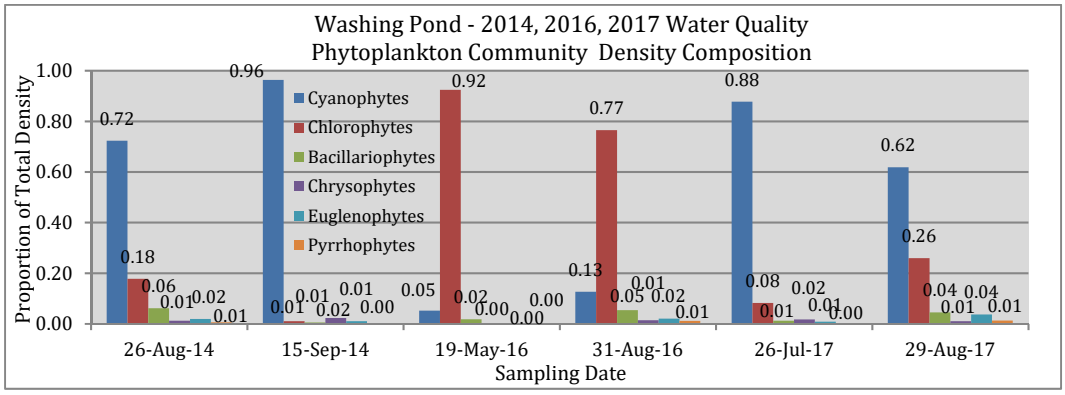
Table 9-4. Summary of Washing Pond phytoplankton community characteristics, 2014, 2016, and 2017.

Washing Pond Phytoplankotn Community Characteristics, 2014, 2016, 2017						
Sampling Date	Total Phytoplankton Taxa	Cell Density (cells/mL^{-1})	Cell Biomass (mg/m^3)	Density Diversity [H]	Biomass Diversity [H]	Chl ***a*** Concentration ($\mu g/L^{-1}$)
26-Aug-14	37	40680	16734	0.871	0.892	5.02
15-Sep-14	28	102174	6003	0.181	0.963	10.86
2014 avg	32.5	71427	11369	0.526	0.957	7.94
19-May-16	24	39373	7597	0.301	0.777	2.1
31-Aug-16	27	25003	20785	0.628	0.619	24.6
2016 avg	25.5	32188	14191	0.465	0.698	13.4
25-Jul-17	30	27465	7274	0.729	0.970	11.1
29-Aug-17	22	10079	6511	0.773	0.627	14.6
2017 Avg	26	18772	6893	0.751	0.799	12.9

Density. The density of phytoplankton in Washing Pond ranged from 10,079 – 102,174 cells·mL^{-1}, a 10-fold difference in the number of individuals. The average cell density from data collected on the 6 sampling dates was 40, 796 cells·mL^{-1}. The September 15th 2014 density is extremely high (102,174 cells·mL^{-1}) when compared with the other density values and there likely was a bloom in progress in the pond at that time.

The density composition of the phytoplankton community in 2014, 2016 and 2017 is shown in Figure 9-2. There were some notable changes in the community composition during these 3 years.

Figure 9-2. Density composition of the phytoplankton community in Washing Pond, 2014, 2016, and 2017.

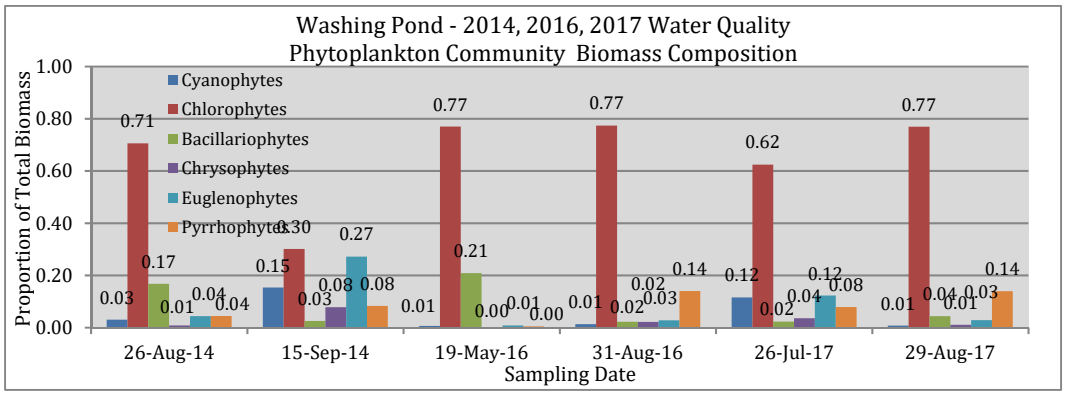


Cyanophytes were the dominant group on both 2014 sampling dates, exhibiting 72 and 96 percent of the community on August 26th and September 15th, respectively, while Chlorophytes dominated the community on both 2016 dates, with 92 and 77 percent of the community density on May 19th and August 31st, respectively. Then in 2017, density dominance reverted back to the Cyanophytes, with 88 and 62 percent of the total community density on July 25th and August 29th, respectively.

Data such as these from Washing Pond emphasize the importance of monitoring a body of water for several years instead of just one year when some interpretation of water quality is desired because some of the pond characteristics can change from year-to-year as exhibited by the phytoplankton community in Washing Pond.

Biomass. As shown in Figure 9-3, the biomass compositions in Washing Pond during 2014, 2016 and 2017 were similar in that the Chlorophytes always were the major dominant group in the community, with proportions ranging from 30 -77 percent.

Figure 9-3. Biomass composition of the phytoplankton community in Washing Pond, 2014, 2016, and 2017.



The phytoplankton community biomass in Washing Pond ranged from 6,003 – 20,785 mg/m^{-3} on the 6 sampling dates during 2014, 2016 and 2017 (Table 9-4), while the average biomass from all sampling dates was 10,817 mg/m^{-3}.

Based upon biomass, Chlorophytes clearly are the most important community group in Washing Pond during the 3 years that the pond was sampled.

Dominance. The ranking of phytoplankton taxa dominance in Washing Pond on the 2014, 2016 and 2017 sampling dates is summarized in Table 9-5. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 9-5. Rank of phytoplankton taxa dominance, using biomass, in Washing Pond, 2014, 2016, and 2017.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
8/26/14	*Staurastrum natator* var. *crassum* (Chlorophyte)	1	47
	Aulacoseria granulata (Chlorophyte)	2	14
	Closterium sp. (Chlorophyte)	3	6
	Gonyostomum semen (Chloromonadophyte)	4	6
9/15/14	*Staurastrum natator* var. *crassum* (Chlorophyte)	1	30
	Trachelomonas sp. (Chrysophyte)	2	16
	Phacus sp. (Chrysophyte)	3	11
	Aphanizomenon flos aquae (Cyanophyte)	4	11
	Coelastrum cambricum (Chlorophyte)	5	6
	Microcystis aeruginosa (Cyanophyte)	6	5
5/19/16	*Closterium acutum* (Chlorophyte)	1	40
	Volvox aureus (Chlorophyte)	2	22
	Tabellaria floccosa (Bacillariophyte)	3	18
	Staurastrum natator var. *crassum* (Chlorophyte)	4	5
8/31/16	*Sphaerocystis Schroeteri* (Chlorophyte)	1	64
	Ceratium hirundinella (Pyrrhophyte)	2	14
	Eudorina elegans (Chlorophyte0	3	6
7/25/17	*Gonyostomum semen* (Chloromonadophyte)	1	38
	Eudorina elegans (Chlorophyte)	2	16
	Dictyosphaerium Ehrenbergianum (Cyanophyte)	3	6
	Staurastrum natator var. *crassum* (Chlorophyte)	4	6
	Ceratium hirundinella (Pyrrhophyte)	5	6
	Phacus sp. (Euglenophyte)	6	5
8/29/17	*Gonyostomum semen* (Chloromonadophyte)	1	57
	Sphaerocystis Schroeteri (Chlorophyte)	2	11
	Ceratium hirundinella (Pyrrhophyte)	3	11

The number of dominant taxa in the pond ranged from 3 – 6 on the 6 sampling dates and, in general, very few taxa occurred more than once or twice as dominants in all of the samples that were analyzed.

Diversity. Phytoplankton diversity in Washing 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 Washing Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Table 9-3. All of the density and biomass diversity values calculated for each sampling date are quite similar with the exception of September 15th 2014 when the density diversity was 0.181 and the biomass diversity was 0.963, and May 19th 2016 when the density diversity was 0.301 and the biomass value was 0.628.

[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.

The September 15th 2014 density values are dissimilar because 96 percent of the community was comprised of Cyanophytes; the biomass diversity adjusted for this density dominance because the Cyanophyte species, *Microcystis aeruginosa*, that comprised 92 percent of the community was extremely small sized and comprised only 5 percent of the community biomass. The same situation was true for the May 19th 2016 discrepancy (0.301 vs 0.628), i.e., *Volvox aureus* was 87 percent of the density but only 22 percent of the community biomass.

Cyanophytes. As a major phytoplankton group, the Cyanophytes have been identified in all 6 phytoplankton samples collected from Washing Pond. A summary of the species identified to date is presented in Table 9-6. Viewing the data in the table, it is apparent that the Cyanophytes have become less important in the community as sampling progressed from 2014 through 2016 and 2017. This is encouraging because four (4) Cyanophyte genera including *Anabaena*, *Aphanizomenon*, *Microcystsis* and *Woronichinia* are known to produce toxins with a range of effects including liver, nerve, skin and gastrointestinal disorders.

Table 9-6. Cyanophyte species identified in Washing Pond, 2014, 2016, and 2017.

Species	26-Aug-14	15-Sep-14	19-May-16	31-Aug-16	25-Jul-17	29-Aug-17
*Anabaena flos aquae**	no	no	no	yes (3)	no	no
*Aphanizomenon flos aquae**	yes (2)	yes (2)	no	no	no	no
Chroococcus dispersus	yes (1)	no	no	yes (2)	yes (1)	no
C. limneticus	yes (<1)	no	no	no	no	no
Dictyosphaerium Ehrenbergianum	no	no	no	no	yes (6)	no
Gomphosphaeria lacustris compacta	yes (8)	no	yes (<1)	no	no	no
*Microcystis aeruginosa**	yes (49)	yes (92)	no	no	yes (<1)	yes (<1)
*Woronichinia naegeliana**	yes (11)	yes (2)	yes (5)	yes (8)	yes (<1)	yes (<1)
'yes' = present, 'no' = absent; (##) proportion of community on a sampling date * Species that are known to produce algal toxins						

While there is no evidence that the genera documented in Washing Pond produced any algal toxins, recreational users of the pond should be aware that Cyanophytes can be present during the mid-summer periods and pose a potential public health and safety issue.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Washing Pond during 2014, 2016 and 2017 have ranged from 2.1 $\mu g \cdot L^{-1}$ on May 19th 2016 to 24.6 $\mu g \cdot L^{-1}$ on August 31st 2016. The May 19th value is low and indicative of a freshwater pond with low productivity in the early spring while water column temperatures are warming. The August value is high and may be indicative of a bloom in the pond which would explain the low Secchi depth reading of 1.3 m.

9.1.5 Trophic Status

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

Sufficient water quality data were collected from Washing Pond during 2016 to calculate the Carlson Trophic State Index (TSI) using all three variables. Average values were calculated for each variable (chlorophyll ***a***, total phosphorus, Secchi depth) for the July and August sampling dates. 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* = 12.85 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (12.85)] + 30.6
TSI = (9.81)(2.55) + 30.6
TSI = 55.65

Total phosphorus
Average total phosphorus = 38.2 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (38.2)] + 4.15
TSI = (14.42)(3.64) + 4.15
TSI = 56.7

Secchi depth
Average Secchi depth = 1.45 m
Secchi TSI = 60 – [14.41*[ln (1.45)]
TSI = 60 – (14.41)(0.37)
TSI = 54.6

The TSI calculated for chlorophyll ***a*** (55.65) was within the eutrophic range of productivity (Table 9-7), which also was the case for the TSI calculated for total phosphorus (56.7). The average 2017 Secchi depth (1.45 m) resulted in a calculated TSI value of 47.4, and also placed the pond in the low range of eutrophic productivity.

Table 9-7. 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})	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

If we compare the TSI values calculated during 2014, 2016 and 2017, we see that there have been slight negative and positive changes in water quality of Washing Pond among the 3 years sampled (Table 9-8).

Table 9-8. Trophic State Indices (TSIs) calculated for Washing Pond, 2014, 2016, and 2017.

Year	Chlorophyll TSI	TP TSI	Secchi TSI
2014	50.9	58.5	52.6
2016	56.0	55.2	47.4
2017	55.7	56.7	54.6

The chlorophyll ***a*** TSI increased between 2014 and 2016 (50.9 to 56.0), while the TP and Secchi TSIs decreased (58.5 to 55.2; 52.6 to 47,4, respectively, indicating slight improvements in water quality. Then, the chlorophyll ***a*** TSI decreased (56.0 to 55.7) between 2016 and 2017, while both TP and Secchi TSIs increased, from 55.2 to 56.7 and from 47.4 to 54.6, respectively, between 2016 and 2017.

9.2 Summary

Based upon all of the data collected during 2014, 2016 and 2017, Washing Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has high productivity which is characterized as eutrophic and based upon the numerical analysis of 3 separate water quality variables that were sampled. Many of the Island ponds probably are very similar due to their extremely shallow nature and the highly enriched organic material contained in the sediments from aquatic vegetation that has decomposed in that region. Nutrients such as nitrogen and phosphorus that are trapped in these bottom sediments are subject to being released into the water column at various times

during the mid-summer growing season when decomposition of organic matter occurs on the pond bottom followed by mixing of the water column when the pond surface is exposed to sustained winds blowing across the Island.

9.3 Literature Cited

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Nantucket Island Ponds

Chapter 10

Summary of Water Quality in Nantucket Island Ponds Surveyed

By the Nantucket Land Council, Inc. since 2009

10.0 Introduction

This chapter provides a brief water quality summary of Nantucket Island ponds that have been monitored by the Nantucket Land Council (NLC) Inc. since 2009 when Miacomet and Hummock Ponds were surveyed cooperatively by the NLC and the UMass Field Station. During the 8-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

The purpose of this data summary is to provide information that will document water quality of important Island ponds through time so that reasonable and prudent decisions can be made by policy makers and administrators regarding public health and safety because many of these ponds are used for contact recreation.

10.1 Background

Water Quality Parameters. All of the parameters that are measured on a pond have certain value in assessing the overall water quality. This process should become clear when reading through the various chapters in this report that describe the 2017 water quality of ponds that were monitored by the NLC. As a means of highlighting all of the water quality data collected by the NLC since 2009, Table 9-1 provides a summary of maximum, minimum and average values for the suite of parameters that have been monitored during the past 9 years on the 11 Nantucket Island Ponds surveyed to date.

Trophic Status. It has come to the attention of the NLC that many of the estuarine and fresh water ponds on Nantucket exhibit extremely high productivity with regard to the primary criteria that commonly are used to evaluate trophic status. Trophic status was described in Chapter 1 and also in the individual pond chapters in this report. The evaluation criteria include total phosphorus, chlorophyll ***a***, and Secchi depth transparency.

While one year of water quality data usually is not considered sufficient to characterize a lake or pond with respect to productivity, this currently is the situation for certain Nantucket ponds that have been added to the sampling regime during recent years. Having some water quality data to analyze is better than not having any data, and evaluations for individual ponds always can be updated when more data become available.

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 values can give 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 all of the trophic status data collected by the NLC since 2009, Table 9-2 provides a summary of Trophic Status Indices calculated for total phosphorus, chlorophyll ***a*** and Secchi depth transparency for 11 Nantucket Island ponds when sufficient data were available to perform the calculations.

Cyanophyte Populations. The problem with certain Cyanophyte species occurring in Nantucket Island ponds has been discussed in the series of water quality reports issued by the NLC since 2009.

As a 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 as occur in algal 'bloom' conditions, however, Cyanophytes can induce physical, chemical and biological changes in the aquatic environment in which they occur and eventually cause negative changes to the ecosystem which may require some direct remedial action to reverse or overcome.

The body of knowledge surrounding these organisms and their toxins is growing rapidly. 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. Some researchers believe that it would be prudent to assume any cyanophyte population can have toxic potential in the aquatic ecosystem in which it is located.

High concentrations ('blooms') of Cyanophytes in the water column lowers transparency, reducing the depth of the photic zone (area where incident light is sufficient to allow photosynthesis to occur) and the volume of water (area of the pond) that supports other photosynthetic organisms. In addition, high concentrations of Cyanophytes and other algae in the water column result in high rates of cell die-off which settle to the bottom and causes oxygen depletion through decomposition of dead plant material.

De-oxygenation has a direct negative effect on aquatic organisms in the bottom region 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 mixing 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 metabolism by phytoplankton. The release of nutrients into the water exacerbates the cycle by encouraging increased primary productivity 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 some instances, the dead, lysed cells are Cyanophytes that produce cyanotoxins and release these toxins when ruptured. In addition to being toxic and dangerous to animals, such as cattle, dogs and cats, cyanotoxins also should be considered a public safety risk to the extent that contact or consumption by humans breathing air down-wind of the pond which contains toxin spores borne as aerosols from the scum concentrated at the surface of the pond should be avoided.

The State of Massachusetts surface water quality standards (314 CMR 4.00) do not specifically address algae; however, the Department of Public Health has developed a Frequently Asked Questions (FAQs) sheet concerning health impacts of *Microcystsis* and *Anabaena* blooms in waterbodies throughout the state. A copy of the sheet is provided in Attachment #1. It is interesting that *Aphanizomenon* is not included on this listing because it is a known producer of toxins and is one of the genera identified in Nantucket Island ponds since water quality surveys began in 2009.

In addition to the above material, the MA Department of Public Health (MDPH) has created '*Guidelines for Cyanobacteria in Freshwater Recreational Water Bodies in Massachusetts*'. This document contains a literature review of the phenomenon and MDPH recommendations. A copy of the document is in Attachment #2.

Table 9-3 summarizes the various species of Cyanophytes that have been identified in Nantucket ponds since 2009 and indicates which species are known to pose public health and safety issues with regard to contact recreation. There has been some limited monitoring of algal toxins in Nantucket ponds during previous years and algal toxins have been identified on certain occasions; however, there are insufficient data to claim that the populations of Cyanophytes that characterize Nantucket water quality pose a definite health threat for recreational users of the ponds.

10.2 Literature Cited

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.

Table 10-1. A summary of maximum, minimum and average values for the suite of parameters monitored during the past nine years on 11 Nantucket Island ponds surveyed by The Nantucket Land Council, Inc.. Values highlighted are one-half the lower detection limit.

Nantucket Island Ponds	Secchi (m)	Chl *a* (µg/L)	DO (% sat)	NO3-N (mg/L)	NH4-N (mg/L)	TN (mg/L)	TP (µg/L)	TDS (mg/L)	spC (µS/cm)	pH (s.u.)
Miacomet Pond*										
minimum value	1.22	2.4	83.2	0.011	0.005	0.208	19.5	99	153	6.75
maximum value	2.57	42.8	100.6	0.170	0.057	0.986	289.0	1514	2040	8.17
average value	1.94	16.6	93.1	0.061	0.022	0.555	63.5	639	890	7.65
year monitored: 2009, 2017										
Hummock Pond										
minimum value	0.56	2.4	80.8	0.005	0.005	0.66	35.3	2785	3545	6.64
maximum value	1.68	98.0	105.3	1.010	0.195	2.20	133.2	32120	31350	8.67
average value	1.2	18.8	95.8	0.155	0.040	1.081	78.4	9956	11117	7.63
year monitored: 2009, 2012										
Head of Hummock Pond*										
minimum value	0.18	2.1	37.6	0.005	0.005	0.69	73.3	410	600	6.28
maximum value	2.03	187.5	110.8	0.639	1.160	3.47	828.8	10430	12180	10.19
average value	0.76	50.1	85.3	0.045	0.209	1.45	288.4	3245	4067	7.99
year monitored: 2009, 2010, 2011, 2012, 2013, 2017										
Maxcy Pond										
minimum value	na	0.57	94.1	0.005	0.004	0.194	7.0	65	102	5.05
maximum value	na	8.1	109.6	0.033	0.010	0.480	97.0	88	137	6.55
average value	na	4.04	101.0	0.014	0.006	0.351	37.4	75	115	5.57
year monitored: 2014, 2016, 2017										
Tom Nevers Pond										
minimum value	0.18	2.1	75.6	0.005	0.009	0.600	21.6	52	81	5.60
maximum value	0.64	14.0	97.7	0.170	0.024	1.348	847.0	245	226	7.27
average value	0.31	7.28	86.9	0.033	0.015	1.108	419	101	133	6.27
year monitored: 2014, 2016, 2017										
Washing Pond										
minimum value	1.3	2.1	84.0	0.005	0.005	0.400	19.9	85	134	5.99
maximum value	3.5	24.6	93.9	0.028	0.200	0.671	51.5	98	156	8.37
average value	1.8	11.4	87.3	0.016	0.046	0.568	38.7	93	147	7.12
year monitored: 2014, 2016, 2017										

* results for ponds with more than 1 sampling location are reported for the location with the deepest water depth

Table 10-1 (continued).

Nantucket Island Ponds	Secchi (m)	Chl *a* (µg/L)	DO (% sat)	NO3-N (mg/L)	NH4-N (mg/L)	TN (mg/L)	TP (µg/L)	TDS (mg/L)	spC (µS/cm)	pH (s.u.)
Capaum Pond										
minimum value	0.25	141	82.1	0.005	0.030	1.79	158.8	286	434	8.66
maximum value	0.36	249	157.9	0.005	0.030	3.56	211.7	320	483	9.96
average value	0.30	196	120	0.005	0.030	2.68	185.3	303	458	9.31
year monitored: 2015										
Pest House Pond										
minimum value	na	1.8		0.005	0.030	1.36	31.2			
maximum value	na	28.0		0.005	0.470	2.69	99.7			
average value	na	14.9	95.2[1]	0.005	0.250	2.03	65.5	27960[1]	28390[1]	8.79[1]
year monitored: 2015										
Gibbs Pond										
minimum value	0.33	7.5	76.0	0.005	0.020	0.56	216.7	60	93	6.21
maximum value	0.89	216.6	97.4	0.005	0.030	1.85	508.6	79	124	8.51
average value	0.49	88.5	87.4	0.005	0.021	1.44	410.7	70	109	7.47
year monitored: 2016, 2017										
Little Weweeder Pond										
minimum value	1.1	16.7	84.2	0.005	0.020	0.540	14.9	112.5	174	7.23
maximum value	1.2	23.4	126.6	0.005	0.020	0.740	23.7	112.7	176	8.91
average value	1.2	20.1	105.4	0.005	0.020	0.640	19.3	112.6	175	8.07
year monitored: 2016										
North Head Long Pond										
minimum value	0.66	3.8	93.8	0.005	0.005	1.00	56.9	12630	14270	6.65
maximum value	0.85	7.8	95.4	0.005	0.030	1.44	70.5	22060	23180	6.83
average value	0.76	5.8	94.6	0.005	0.018	1.22	63.7	17345	18725	6.74
year monitored: 2016										
Long Pond*										
minimum value	0.71	8.8	79.3	0.005	0.040	1.30	116.7	27680	28450	6.93
maximum value	0.76	9.8	85.7	0.005	0.040	1.52	102.1	34410	33600	7.50
average value	0.74	9.3	82.5	0.005	0.040	1.41	109.4	31045	31025	7.22
year monitored: 2017										

[1] results are for a single sample collected at the pond outflow culvert
* results for ponds with more than 1 sampling location are reported for the location with the deepest water depth

Table 10-2. A summary of Trophic Status Indices calculated for total phosphorus, chlorophyll ***a*** and Secchi depth transparency for 11 Nantucket Island ponds since 2009, when sufficient data were available to perform the calculations.

YEAR OF WATER QUALITY SURVEY																										
	2009			2010			2011			2012			2013			2014			2015			2016			2017		
POND	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**	**TP**	**CH**	**SD**
Miacomet	E	E	E																						E	M	E
Hummock	E	E	E							E	E	E															
Head Hummock	HE	E	E	HE	HE	E	HE	E	E	HE	E	E	HE	E	E										HE	E	E
Maxcy																M	M	na				M	E	na	M	0	
Tom Nevers																E	M	HE				HE	E	HE	HE	E	HE
Washing																E	E	E				E	E	M	E	E	E
Capaum																			HE	HE	HE						
Pest House																			E	E	na						
Gibbs																						HE	HE	E	HE	HE	HE
Little Weweeder																						M	E	E			
North Head Long																						E	M	E			
Long																									HE	E	E

TP = total phosphorus; CH = chlorophyll ***a***; SD = Secchi depth transparency
E = eutrophic status, HE = hyper-eutrophic status, M = mesotrophic status, O = Oligotrophic status; na = insufficient data for calculation

Table 10-3. A summary of Cyanophyte species that have been identified in Nantucket Island ponds since 2009.

	Pond Name											
SPECIES	Miacomet	Hummock	Head of Hummock	Maxcy	Tom Nevers	Washing	Capaum	Pest House	Gibbs	Little Weweeder	North Head Long	Long
Anabaena circinalis							**2015**					
Anabaena flos aquae	**2009, 2017**	**2009, 2012**	**2009, 2011, 2012, 2013, 2014, 2015, 2017**	**2014**	**2016**	**2016**	**2015**	**2015**	**2016, 2017**	**2016**		
Anabaena spiroides	**2009**	**2009**	**2009, 2010, 2011**									
Anabaenopsis Elenkinii			**2010, 2014**	**2014**	**2016**							
Aphanocapsa elachista	**2017**		**2010, 2011, 2013**									
Aphanizomenon flos aquae	**2009, 2017**		**2013, 2015, 2017**	**2014, 2016**		**2014**	**2015**	**2015**	**2016, 2017**	**2016**		
Chroococcus dispersus	**2017**	**2012**	**2012, 2013, 2014, 2015, 2017**	**2014, 2016**	**2014, 2016,**	**2014, 2016, 2017**	**2015**		**2017**			
C. limneticus	**2009, 2017**	**2009, 2012**	**2009, 2011, 2012, 2014, 2015, 2017**			**2014**				**2016**		
C. turgidus			**2011**									
Coelosphaerium Naegelianum	**2009**		**2009, 2012**									
Dictyosphaerium Ehrenbergianum					**2017**	**2017**			**2017**			
Gloeocapsa rupestris			**2010, 2011**									
Gomphosphaeria lacustris compacta	**2017**		**2014, 2015**		**2014, 2016**	**2014, 2016**	**2015**		**2016**			
Lyngbya sp.	**2017**		**2015**									
Merismopedia glauca	**2017**	**2012, 2013**			**2014, 2016**				**2016, 2017**			**2017**
Merismopedia punctata	**2009**	**2009**										
Microcystis aeruginosa	**2009, 2017**	**2009**	**2009, 2014, 2015, 2017**	**2014**		**2014, 2017**	**2015**					
Microcystis incerta		**2012**	**2009, 2010, 2011, 2012, 2013**									
Oscillatoria sp.	**2017**							**2015**				**2017**
Rhabdoderma Gorskii									**2017**			
Woronichinia naegeliana	**2017**					**2014, 2016, 2017**	**2015**		**2016, 2017**	**2016**		

Attachment 1

MA Department of Public Health

Microcystis and *Anabaena* Algae Blooms:

Frequently Asked Questions Concerning Health Impacts

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Microcystis and *Anabaena* Algae Blooms: Frequently Asked Questions Concerning Health Impacts

Q: What is *Anabaena*? What is *Microcystis*?

A: *Anabaena* and *Microcystis* are types of cyanobacteria (commonly known as blue-green algae) that grow naturally in many waterbodies. Under certain conditions (such as warm weather and an abundance of nutrients in the water) the algae may undergo an explosive type of growth that results in dense, floating mats of algae. This is commonly referred to as an "algae bloom."

Q: Can exposure to *Anabaena* and *Microcystis* cause health effects?

A: Yes. *Anabaena* and *Microcystis* are different from most other types of algae because they can produce toxins. There are two ways to be exposed to these toxins. During a bloom, the toxins are contained within the algae cells. If these cells are ingested, they break open in the stomach and the toxins are released. Alternatively, after an algae bloom ends and the algae die, the toxins are released into the water where they can be directly ingested. The toxins can be potentially harmful to people and animals.

Q: What types of health concerns are associated with exposure to toxins from *Anabaena* and *Microcystis*?

A: Health concerns vary depending on the type of exposure (e.g., contact, ingestion) and the concentrations of toxins present. *Microcystis* produces the toxin microcystin. *Anabaena* may produce a few different toxins, including anatoxin and microcystin. Ingestion of small amounts of toxin can cause gastrointestinal distress. If elevated levels of the algal toxin anatoxin are

present in the water and ingested, serious neurological damage can result. Symptoms of anatoxin poisoning include numb lips, tingling fingers and toes, and dizziness. If elevated levels of the algal toxin microcystin are present in the water and ingested, serious liver damage can result.

Symptoms of microcystin poisoning include abdominal pain, diarrhea, and vomiting. Contact with high levels of *Anabaena* and *Microcystis* has also been found to contribute to eye, ear, and skin irritation.

Q: How can I reduce my risk of health effects associated with exposure to *Anabaena* and *Microcystis*?

A: Do not come into contact with water near an algae bloom or any algal scum onshore. This also applies to pets.

Q: How long do blooms last?

A: It depends on several factors, most importantly the weather. Since algae benefit from warm, sunny weather, as the days get shorter and cooler, the algae die off. Any rainfall will help to circulate the water and break up the bloom. In addition, over time, algae may deplete the nutrients in the water so they are unable to grow further. As algae die off, they may release toxins into the water. Thus, it is important to refrain from recreating in the area of a bloom for two weeks after it has ended.

Q: If I have had contact with an algae bloom, what should I do?

A: For questions related to health concerns, contact your health care provider, local board of health, or the Massachusetts Department of Public Health, Bureau of Environmental Health at (617) 624-5757.

Attachment 2

MA Department of Public Health

Guidelines for Cyanobacteria in Freshwater

Recreational Water Bodies in Massachusetts

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MDPH GUIDELINES FOR CYANOBACTERIA IN FRESHWATER RECREATIONAL WATER BODIES IN MASSACHUSETTS

INTRODUCTION AND BACKGROUND

This document outlines a protocol for evaluating potential health concerns related to the presence of cyanobacteria (blue-green algae) in Massachusetts recreational freshwater bodies. Blooms can form when cyanobacteria, which are bacteria that grow in water, multiply quickly and form "scums" or "mats" on the surface of the water. Blooms can occur at any time but most often occur in late summer or early fall. The most common types of cyanobacteria that bloom are *Microcystis* and *Anabaena*. Certain strains of *Microcystis* and *Anabaena* manufacture toxins called microcystin and anatoxin, respectively, and these toxins can produce adverse health effects. Toxins are released from intact cyanobacteria cells when they die in the waterbody or when they are ingested by animals or humans. Once ingested, the digestive juices destroy their cell wall (lyse the cell) and the toxin is released into the gastrointestinal tract.

The scientific literature on health effects resulting from exposures to cyanobacteria-related toxins associated with blooms is developing, with the most widely cited guidance published by the World Health Organization (WHO) in 2003 (WHO 2003). This document reviews the WHO guidance as well as the current scientific literature for the purpose of updating current MDPH guidance with respect to responding to suspected or actual cyanobacteria blooms in Massachusetts recreational freshwater bodies.

REVIEW OF LITERATURE

Cyanobacteria, under the right conditions, can multiply quickly and pose a health risk to those coming into contact with the water. This ability to multiply quickly makes monitoring their numbers important. Because the health risk rises with the cell counts, the goal of any monitoring plan is to be able to take action before levels are reached that pose health risks.

This section reviews the current literature in order to make recommendations related to the presence of cyanobacteria in a recreational water body. There are three measures on which action can be taken:

1. Observation of visible scum or mat layer
2. Total cell count of cyanobacteria (units of total cells/mL water)
3. Concentration of cyanobacteria toxin (e.g., microcystin) (units of µg toxin/L of water)

These three measures will be evaluated based on a literature review of current studies on a) cell counts and health effects, b) cyanobacteria toxin levels and health effects, and c) correlations between cell counts and toxin levels.

Literature on Cell Counts and Health Effects

A prospective cohort study of 852 people was conducted in Australia in 1995 (Pilotto et al. 1997). Participants were interviewed at five freshwater bodies that had a history of cyanobacteria blooms. Information on their health and recreational water-related activities was collected. Follow-up interviews were held two and seven days later and noted any specific health symptoms, such as diarrhea, rashes, and eye or ear irritations. The responses from the interviews were compared with cyanobacteria counts from water samples collected at the freshwater bodies on the day the participants were first interviewed. No significant difference in reported health symptoms was found at two days following exposure. However, the authors reported that exposed individuals had an elevated odds ratio for symptoms seven days following exposure to the following:

- > 5,000 cyanobacteria cells/mL for over an hour
- Bathing in water with 5,000-20,000 cyanobacteria cells/mL
- > 80,000 cyanobacteria cells/mL

The odds ratio is based upon all symptoms reported. Thus, the cell counts or exposure period were not correlated with one specific symptom, but the odds of developing one of the seven symptoms the study examined.

This study forms the basis of the WHO guidance related to cell counts of 20,000/mL. At this level, the WHO recommends that there should be notification to inform individuals about possible health risks associated with contacting the water. WHO chose the level of 20,000 and not 5,000 because they noted that the reported effects at 5,000 were mild and not reported by a large number of people (WHO 2003).

More recent studies have used different methods to evaluate health effects from cyanobacteria, but the methods used cannot be translated to estimates of cell counts or toxin levels, hence are of limited use for purposes of developing guidelines. However, they do provide additional evidence that exposure to cyanobacteria can result in health effects, particularly dermal irritant effects.

A prospective cohort study found increased reporting of respiratory symptoms and of any symptom (respiratory, gastro-intestinal illness, ear, eye, dermal, or fever) at three days following exposure to cyanobacteria cell surface area > 12 mm^2/mL (Stewart et al. 2006b). The Stewart study chose to use cell surface area instead of cell counts, which prevents direct comparison of the thresholds found in the two studies.

Microcystins and World Health Organization Guidance

The WHO recommended a drinking water guideline of 1 part per billion (ppb) microcystin, the toxin produced by certain strains of the cyanobacteria, *Microcystis*. The study forming the basis of the WHO drinking water guideline was a 13-week oral gavage mice study with microcystin (Fawell et al 1994). Based on liver histopathology and serum enzyme changes, a no-observed adverse effect level (NOAEL) of 40 µg/kg body weight/day was derived. WHO applied an uncertainty factor of 1,000 to derive a Tolerable Daily Intake (TDI) level of 0.04 ug/kg/day. [A TDI is the estimated amount of a substance that can be consumed daily over a lifetime without an appreciable health risk (WHO 2006).] WHO then applied standard exposure assumptions (e.g., a 70 kg adult drinks 2 liters of water a day) to derive a drinking water guideline of 1 ppb.

Although WHO discussed other animal studies, the above study was deemed to be the most conservative study on which to base a microcystin guideline. No other studies were available in the literature that would affect the use of the mice study as a basis for the microcystin guideline.

In order to assess health concerns related to microcystin (generally cell-bound) in recreational waters (as opposed to drinking water), WHO applied conservation exposure assumptions related to recreational water use. Specifically, WHO assumed an adult, weighing 60 kg, consumes 100 mL of water while swimming or wading, while a child, weighing 15 kg, may consume 250 mL of water during the same activities. If microcystin is present in the cyanobacteria and water (after lysing the cells) at a concentration of 1 ppb (or 1 µg/L), the total exposure to an adult would be nearly equal to the TDI while for a child, it would be about 10 times the TDI. Individuals with certain existing health conditions (i.e., liver ailments) could be at greater risk. Given the conservative assumptions used in deriving the TDI and exposure estimates for recreational water activities, WHO suggested that an appropriate guideline for microcystin in recreational waters could be 20 ppb.

Other Health Effects Studies

Two studies have examined the effects of individuals wearing skin patches containing cyanobacteria. One study involved placing dermal patches containing either whole or lysed cells at varying concentrations. This study found that approximately 20% of individuals had dermal reactions to the patches, whether they contained whole or lysed cells and independent of the cell count. The dermal reactions were reportedly all mild. The authors concluded that some percentage of the healthy population is susceptible to skin reactions from cyanobacteria (Pilotto et al. 2004). The second study involved placing dermal patches containing cyanobacteria and cyanobacteria toxins on volunteers. This study found that only one of 39 participants had a dermal reaction, and this reaction was to a non-toxin producing cyanobacteria (Stewart et al. 2006c).

Literature on Correlation Between Cell Counts and Toxin Levels

The available literature suggests there is some correlation between cyanobacteria cell counts and the toxin concentration in the water, but this correlation is uncertain. For example, the cells can begin to die, and as they die, they release the toxin. Thus, although the cell count may show a decreasing amount of cells, the toxin concentration in the water may actually increase for a period of time. In addition, it is difficult to select sampling locations as the cells and the toxins may not be equally distributed within a bloom.

Data available from Lake Champlain in Vermont show levels of microcystin greater than 20 ppb were generally found in waters with cell counts over 100,000 (Watzin et al. 2005). The WHO concluded that *Microcystis*-dominated algal blooms with 100,000 cells/mL may contain 20 ppb of toxin (WHO 2003). Thus, it is reasonable to assume, based on currently available data, that cell counts of 100,000 or more may have toxin levels of 20 ppb or more. The WHO recommended that at cell counts of 100,000 cyanobacteria cells/mL or greater, swimming should be discouraged and on-site advisory signs should be posted. This advisory also reflects concern that counts could rise rapidly, along with the associated toxin health risks. Based on the 1997 Pilotto et al. study, the WHO estimated that cell counts of approximately 20,000 could result in toxin concentrations in water ranging from about 2-4 ppb (WHO 2003).

MDPH RECOMMENDATIONS

The following paragraphs provide MDPH recommendations for cyanobacteria and toxin guidelines to prevent acute exposure to elevated levels of these substances in recreational waters. Dense blooms and scums can contain millions of cells/mL and toxin levels in the parts per million. They can form near embankments and in areas suitable for swimming and other forms of recreation. They can also move around in the water body and grow quickly, making management of them difficult (Watzin et al. 2005, WHO 1999, 2003). Exposure to high levels of cells and toxins is dangerous and the more serious published reports of acute health effects from cyanobacteria typically involves exposure to dense blooms and scums (Behm 2003, Hitzfeld et al. 2000, WHO 1999, 2003). The proposed guidelines are designed to allow preventive action to be taken prior to exposure, thereby mitigating possible health concerns.

Guideline for Cyanobacteria Toxin (Microcystin) in Recreational Water

MDPH recommends adoption of the WHO TDI of 0.04 µg/kg/day of microcystin. In order to estimate a recreational water body concentration that would result in exposures at or below the TDI, the following assumptions were made:

Adult

Weight:	70 kg
Intake:	0.05 L water/hour
Duration:	1 hour/day

Child

Weight:	35 kg
Intake:	0.1 L water/hour
Duration:	1 hour/day

These assumptions are taken from U.S. EPA guidance (1997; 1989). The average 10-year old child weighs approximately 35 kg and an average adult weighs approximately 70 kg. This average weight of a 10-year old child is also similar to the average weight of all children between the ages of 1-18 years old (EPA 1997). The intake rate is based on guidance from EPA on surface water ingestion while swimming (EPA 1989). For children, the intake rate was doubled to 100 ml, which is approximately seven tablespoons of water. According to EPA, non-competitive (recreational) swimmers consume more water than competitive swimmers (EPA 2003). Children playing in the water consume more water than those swimming for exercise. For exposure assessments of adults in swimming pools, EPA has created a model that assumes they consume either 0.0125 or 0.025 L/hr (EPA 2003). However, since this assessment is for cyanobacteria in freshwater bodies, and water from freshwater bodies is less distasteful to ingest than pool water, these lower intake rates for adults were not used. The duration of time spent in the water was estimated to be one hour per day, seven days a week during a 13-week season. The WHO TDI was based on a 13-week mice study. Thirteen weeks is approximately the length of the summer bathing season in Massachusetts.

To calculate a water concentration of microcystin that would result in a total dose of 0.04 µg microcystin/kg body weight/day (the TDI), the following equation is used:

Guideline Concentration = (weight) x (TDI) / (intake) x (duration)

Using the stated assumptions, the results indicate that a guideline based on adult exposure would be 56 µg microcystin per liter water, or 56 ppb. For a child, the guideline would be 14 ppb. Hence, to be most conservative, MDPH recommends the toxin guideline be 14 ppb.

Guidelines for Cyanobacteria Cell Counts

The available literature and the equation noted above suggest that at approximately 20,000 cells/mL, associated toxin levels may range between 2-4 ppb, while at 100,000 cells/mL, associated toxin levels may be approximately 20 ppb. If we assume a linear relationship between cyanobacteria cell counts and associated toxin levels (data are sparse in this area), a cell count of 70,000 cells/mL would correspond to a toxin level of approximately 14 ppb. This is also the concentration derived using the equation. Thus, to be protective and reduce potential exposures to levels at which there is a greater likelihood of health effects, MDPH recommends that at a cell count of 70,000 cells/mL, individuals should be advised to refrain from coming into contact with the affected water.

Recommendations for Monitoring or Advisory Posting

MDPH believes that the current literature supports the use of a cell count guideline of 70,000 cells/mL in order to prevent adverse health effects from exposure opportunities to cyanobacteria and related toxins during algal blooms. MDPH also recognizes that it is generally more feasible to monitor using cell count methods rather than toxin analytical methods. We do offer the following general guidance related to monitoring potential cyanobacteria problems with the stated goal of preventing health effects before cyanobacteria or toxins reach levels of concern or higher:

1. If a visible cyanobacteria scum or mat is evident, MDPH recommends an immediate posting by the local health department, state agency, or relevant authority to advise against contact with the water body.
2. If the cell count exceeds 50,000 cells/mL, toxin testing of lysed cells should be done to ensure that guideline of 14 ppb is not exceeded. The lysing should consist of three freeze and thaw cycles.
3. If either the cell count exceeds 70,000 cells/mL or the toxin level of lysed cells meets or exceeds 14 ppb, post an advisory against contact with the water. The lysing should consist of three freeze and thaw cycles.
4. Because cyanobacteria can multiply extremely rapidly, frequency of follow-up testing may depend in part on weather conditions, e.g., predicted hot, dry, and calm conditions, all of which promote rapid cyanobacteria generation, may suggest more frequent testing than weekly.
5. Since decreasing cell counts indicate cell die-off and lysing cells release toxins, algal toxin concentrations in the water may rise for a period of time after cell counts decrease. Many factors (e.g., wind, rain, temperature) can effect the progression of die-off, which supports a measured approach for lifting an advisory similar to that of Oregon and Australia: advisories may be lifted after two successive and representative sampling rounds one week apart demonstrate cell counts or toxin levels below those at which an advisory would be posted.

Signage should be posted at (all) water body entry points and should include the following: date of the posting, contact information for the posting authority, language (to be provided or reviewed by MDPH) advising against contact with the water, and a recommendation that pets accidentally entering the water be rinsed.

This proposed protocol does not pertain to the toxin anatoxin, which is produced by several species of cyanobacteria. There is no guidance in the literature for responding to detections of anatoxin. Thus, if anatoxin is detected, MDPH will evaluate such situations episodically, using supplemental information such as cyanobacteria counts, exposure scenarios (popular swimming site, for instance), and upcoming weather forecasts. The cyanobacteria *Anabaena*, which produces anatoxin, would be included in any cell counts of cyanobacteria. Therefore, there is some mechanism for managing the risk it poses.

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Appendix: Guidelines from Other Health Organizations

California State Water Resources Control Board

At cell counts greater than 40,000 cell/mL of *Microcystis* and *Planktothrix* or at cell counts greater than 100,000 cells/mL of potentially toxic cyanobacteria (e.g., *Anabaena* and *Microcystis*), the Board's draft guidelines recommend that a beach be closed. The 40,000 cells/mL value was derived using a risk assessment approach based on child's recreational exposure to the toxin (CSWRCB 2006). This approach is not described further in the Board's draft guidance document. The 100,000 cells/mL value appears to be taken from the WHO guidance.

California Department of Health Services

At cell counts greater than 20,000 cells/mL, the Department's draft guidance recommends that a beach be closed. No supporting information is given. However, it is likely that this number is taken from the WHO guidance, which advises notifying bathers of the presence of cyanobacteria at this cell count.

Vermont

At cell counts greater than 4,000 cells/mL, Vermont recommends that the water be tested for toxins. This threshold is based upon the results from 6 years of research in Lake Champlain and other waterbodies in the state. They have found that the toxin levels do not approach their guideline of 6 ppb of toxin until the cell counts are higher than 4,000 cells/mL (Watzin et al. 2003, 2005, and Stone and Bress 2007). This low threshold enables them to monitor developing situations and minimize potential exposure to elevated levels of toxin.

The Vermont guidance level of 6 ppb of toxin is based upon the same study that the WHO used to generate their provisional guideline for drinking water consumption. The study was conducted in 1994, and involved administering the cyanobacteria toxin microcystin orally to mice. Based upon liver histopathology and serum enzyme level changes, and adding an uncertainty factor of 1,000, the WHO generated a TDI (Tolerable Daily Intake) of 0.04 ug/kg/day. This TDI is a level of the toxin that should be safe to consume daily over a lifetime. Assuming that an adult weight 60 kg and drinks 2 liters of water per day, using this TDI, the WHO derived a drinking water guideline of 1 ppb of microcystin in water.

Vermont took the TDI that the WHO had generated, and using different assumptions about body weight and water consumption, generated a guideline for recreational exposure to the cyanobacteria toxin. They assumed an exposure scenario where a child, weighing 15 kg, ingests 100 mL of beach water per day (EPA guidance). Based on this scenario, Vermont calculated a recreational water guideline of 6 ppb.

The World Health Organization

The WHO does not recommend a cell count at which to test for the toxin. The lowest WHO cell count guideline is 20,000 cells/mL, and that is due to health concerns based on irritative or allergenic effects of cyanobacteria described in a study by Pilotto et al (1997 cited in WHO 2003). At this level, the WHO recommends that officials "post on-site risk advisory signs" and "inform relevant authorities". The Pilotto study is one of the two studies upon which Australia bases its 5,000 cells/mL guidance described above.

Australia

At toxin levels greater than 10 ppb, Australia recommends that a beach be closed. This concentration is based on a LOAEL derived from a pig study by Falconer et al (1994 cited WHO 1999; also discussed in Kuiper-Goodman et al. 1999 as cited Australian Guideline 2005). In this study, pigs consumed drinking water that contained microcystin. Based upon general liver damage (observed from histopathology and serum enzyme level changes), a LOAEL of 100 ug/kg/day was derived. Australia then added an uncertainty factor of 5,000 and assuming a child weighing 15 kg consume 100 mL of water for 2 weeks, generated a recreational water guideline of 10 ppb.

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