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

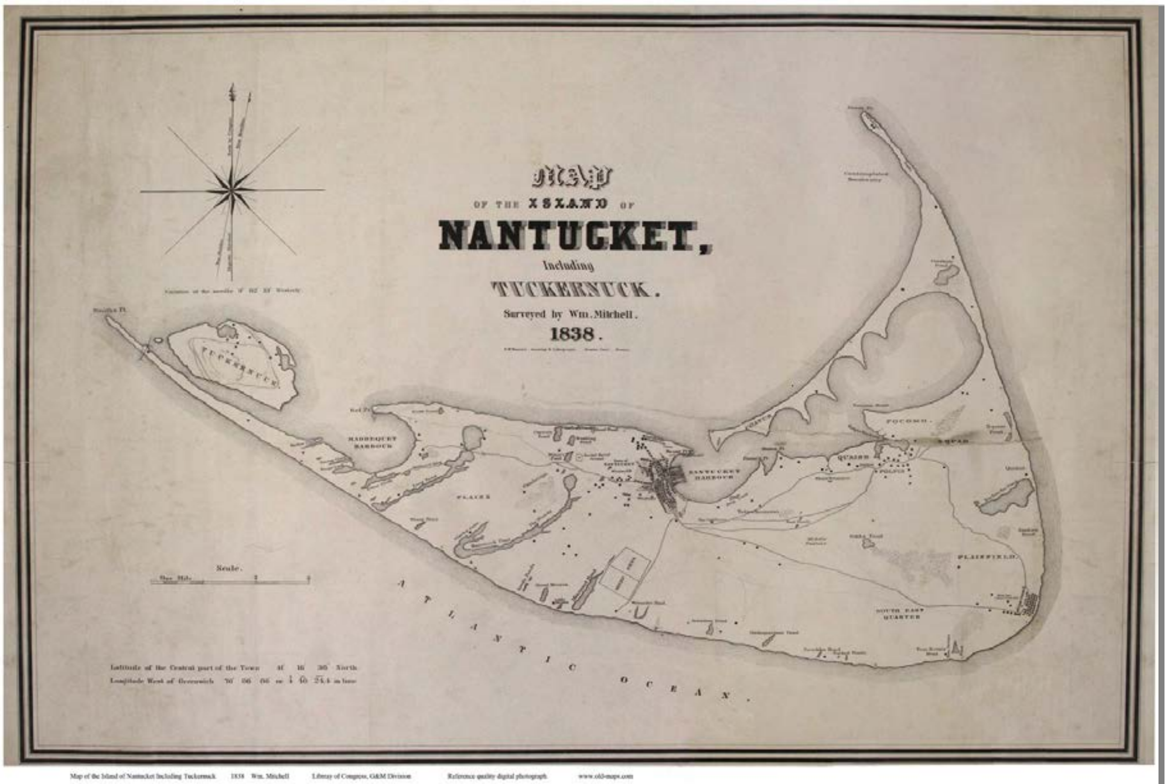

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

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Nantucket Island Ponds and Water Quality

Chapter 1

A Basic Water Quality Primer

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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, 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 $TSI\ (TSIC) = 9.81 * [\ln(Chlorophyll\ a\ average)] + 30.6$
- $Secchi\ disk\ TSI\ (TSIS) = 60 - (14.41 * [\ln(Secchi\ average)])$

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.

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

Table 1-1. Relationships between Trophic Index, chlorophyll, ohosphorus, Secchi depth and Trophic Class.

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

1.7 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 have 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 Water Quality

Chapter 2

Water Quality Sampling Protocol

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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 each 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. Water quality parameters typically sampled on 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*) or oxygen saturation is sampled using the integrated hose technique; the lower zone of different temperature or oxygen saturation is sampled with a horizontal Van Dorn sampler. The collected water samples are transferred to clean, pre-rinsed 500-mL polyethylene (PE) amber sample bottles and stored on ice and in the dark until processed for shipment, usually within 2 hours of collection.

A subsample of the 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 (shown in Attachment 1) accompanies the samples to the analytical lab.

Depending upon conditions observed at each pond, a subsample of raw pond water collected from the epilimnion might be tested for the presence of algal toxins (microcystins). Testing could involve either an Abraxis, LLC Algal Toxin Strip Test for Recreational Water or the sample might be sent to GreenWater Laboratories in Palatka, Florida on certain occasions for microcystin analysis. The strip test was designed to screen for the presence/absence of toxins in pond water and to facilitate appropriate follow-up based upon the results. Since 2013 was the first season that this screening process was used on Nantucket Island ponds, samples of raw pond water also are shipped to GreenWater Laboratories for analysis of microcystins even though the Strip Test may indicate toxin concentrations of 0 ppb or 0-1 ppb for each sample. A 125 PE bottle containing about 100 mL of raw pond water is placed in a small cooler with gel packs and shipped FedEx overnight to the lab.

2.3 Analytical Techniques

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

Table 2-2. The methods and protocols for measurements and sample collection on Nantucket Island ponds.

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:

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

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.

Cyanophyte toxin analysis. At GreenWater Laboratories, samples received for analysis of *microcystin* (MC) are ultra-sonicated to lyse cells and release the toxins. In some cases, a duplicate sample (Lab Fortified Matrix, LFM) was spiked at 1.0 µg/L MCLR, which provided quantitative capability and additional qualitative confirmation. A *microcystin* enzyme linked immunosorbent assay (ELISHA) is utilized for the quantitative and sensitive congener-independent detection of MCs.

2.4 Summary

This chapter provided 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.

2.5 Literature Cited

Nantucket Island Ponds and 2016 Water Quality

Chapter 3

Tom Nevers Pond

3.0 Introduction

Tom Nevers Pond was surveyed by the Nantucket Land Council on two (2) occasions during September 2014, which was reported elsewhere (Sutherland and MacKinnon 2015). This chapter presents a summary and discussion of the physical, chemical and biological data collected from Tom Nevers Pond by Nantucket Land Council staff during 2016 and also compares the 2016 data with the 2014 data.

3.1 Results

Tom Nevers Pond was sampled on May 13th and on August 30st 2016. The maximum water depth recorded was 5.5 feet (1.7 m) on May 13th at the sampling location in the approximate center of the pond; the maximum depth recorded on August 30th was 3.6 feet (1.1 m).

Following the collection of temperature and dissolved oxygen profile data, integrate samples were collected from the surface down to 5 feet on May 13th and 2 feet on August 30th 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 an absence of any visible submerged attached aquatic vegetation during May; there were no additional comments recorded during August 2016.

3.1.1 Physical characteristics

General. Tom Nevers Pond is an irregular shaped body of water with its axis oriented in a northwest-southeast direction (Figure 3-1). 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 or Tom Nevers. The outlet of Tom Nevers Pond at the south end drains toward the Low Beach area and the Atlantic Ocean (Figure 3-1).

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

Temperature. Temperature profile data were collected on both 2016 sampling dates. The May temperature from surface to bottom was isothermal (less than 1^0C variation), and the average temperature was 17.6^0C. The water column still was warming under the influence of rising spring temperatures. By August 30th, the average temperature was 26.6^0C, with a slight 3°C decrease in temperature from surface to bottom.

Since the pond is relatively 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 May 13th 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 Secchi depth transparency measured at Tom Nevers on May 13th was 2.1 feet (0.6 m) while the reading on August 30th was 0.7 feet (0.2 m). Water clarity usually is greater in the spring because the water temperature is rising and conditions still are not ideal for accelerated growth of phytoplankton.

The Secchi depth transparency was recorded as 1.0 feet (0.3 m) on both September 2nd and September 24th 2014. It is common for transparencies to be reduced late in the growing season due to abundance of phytoplankton in the water column (see later in this chapter).

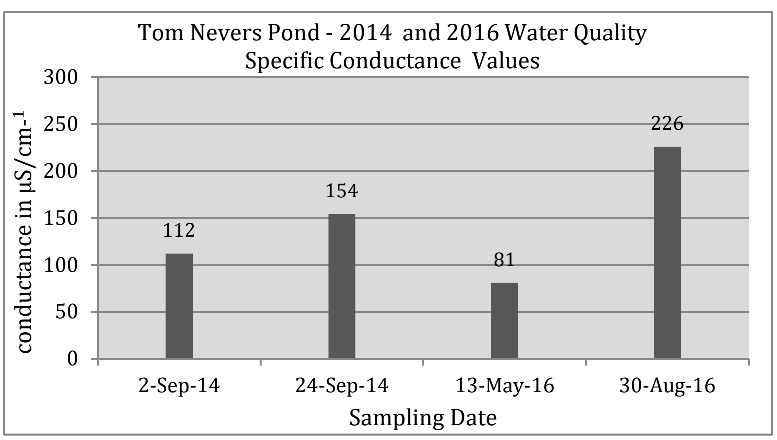
In addition, water color on all 2014 and 2016 sampling dates was listed as 'brown' which is the color of small ponds such as Tom Nevers when there is a strong influence of bog-like vegetation growing around the perimeter of the pond and also draining into the pond from areas upland in the watershed. 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

Specific conductance. The individual conductance values measured at Tom Nevers Pond during 2016 were 81 $\mu S \cdot cm^{-1}$ and 226 $\mu S \cdot cm^{-1}$ on May 13th and August 30th, respectively. Figure 3-2 presents the conductance values measured at Tom Nevers Pond during 2014 (112 $\mu S \cdot cm^{-1}$ on September 2nd; 154 $\mu S \cdot cm^{-1}$ on September 24th) as well as the 2016 values.

The value of 226 $\mu S \cdot cm^{-1}$ recorded on August 30th 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 to the water column which also would raise dissolved ions in the water and, therefore, the conductivity readings.

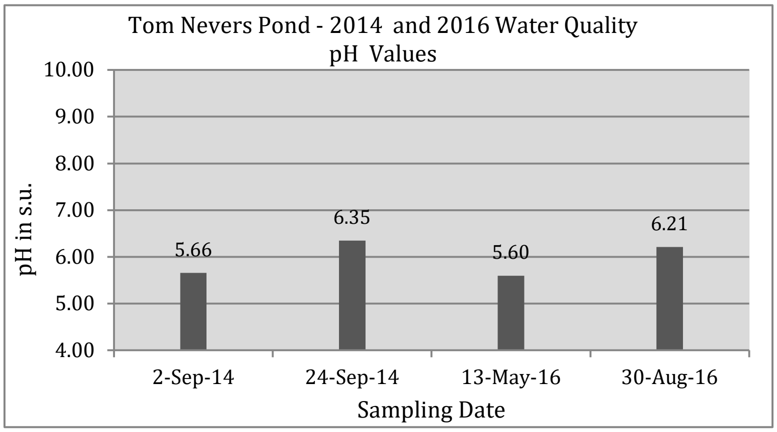
Figure 3-2. Specific conductance measured in Tom Nevers Pond, 2014 and 2016.



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 (5.60 s.u.) on May 13th and then higher (6.21 s.u.) on August 30th. Both values reported from the pond, however, were less than pH 7.00 s.u., which is considered 'neutral' along the pH scale from 0.0-14.0 s.u. The pH values measured in Tom Nevers Pond during 2014 and 2016 are presented in Figure 3-3.

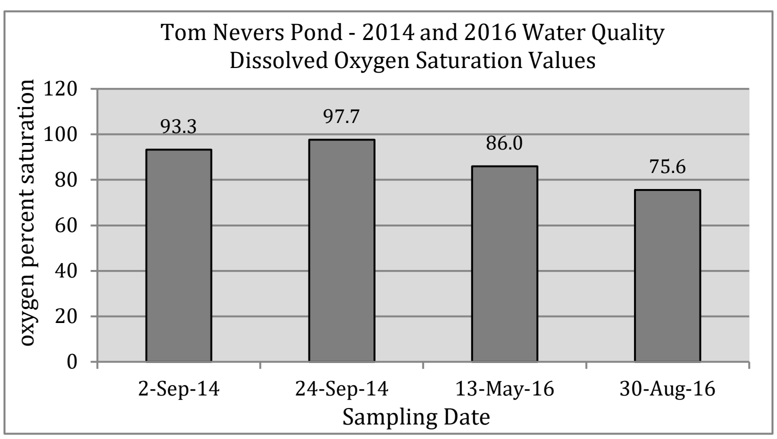
Figure 3-3. pH measured in Tom Nevers Pond, 2014 and 2016.



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 was 86.0 percent on May 13th 2016 and 75.6 percent on August 30th 2016. On both dates, there was a distinct gradient in saturation between the surface and the bottom, which was most pronounced on the latter 2016 sampling date. The 2014 and 2016 oxygen saturation values recorded at Tom Nevers Pond are presented in Figure 3-4.

Figure 3-4. Average dissolved oxygen saturation in Tom Nevers Pond, 2014 and 2016.



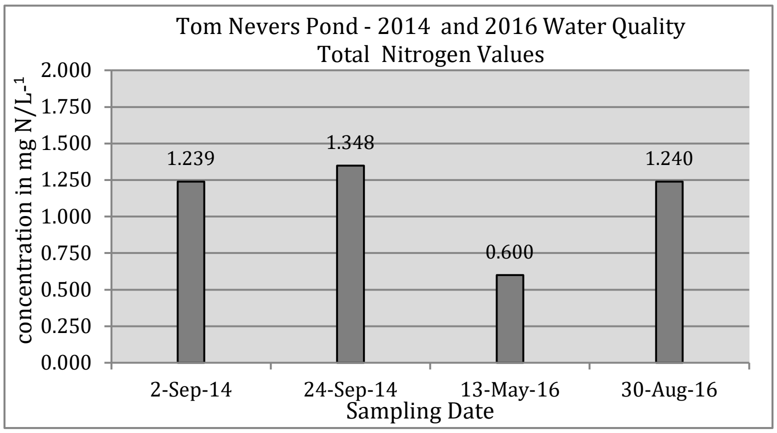
There is nothing particularly noteworthy about the oxygen saturation values measured in Tom Nevers Pond in 2014 and 2016. Gradients in oxygen concentration from surface to the bottom of ponds typically occurs during periods when there are no winds which cause mixing and the calm water exhibits gradients due to decomposition of organic material on the bottom which consumes oxygen and establishes the gradient.

3.1.3 Plant Nutrients

Nitrogen. N**itrate-nitrogen** concentrations measured in Tom Nevers during May and August 2016 were below the detection limit, which also occurred during both September 2014 sampling dates. And while there were measureable levels of **ammonia-nitrogen** on both 2016 sampling dates, the levels were low (0.020 mg $N{\cdot}L^{-1}$ on both dates) and were the same during 2014. 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 was 0.600 mg $N{\cdot}L^{-1}$ on May 13th 2016 and 1.230 mg $N{\cdot}L^{-1}$ on August 30th; the 2014 and 2016 values are shown in Figure 3-5.

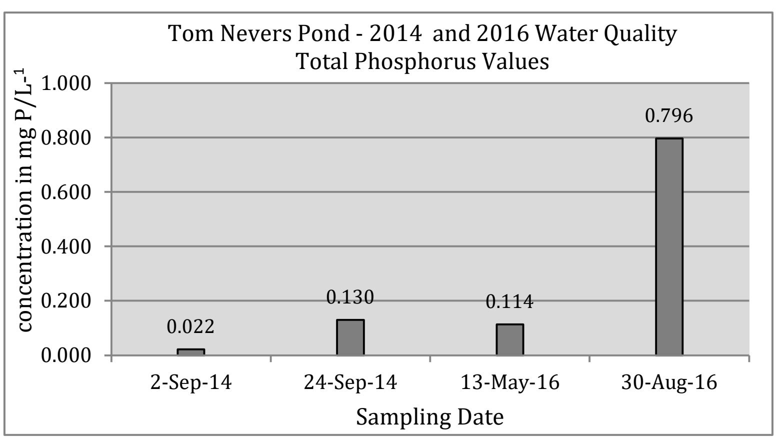
Figure 3-5. Total nitrogen concentrations measured in Tom Nevers Pond, 2014 and 2016.



The low concentrations of **nitrate-** and **ammonia-nitrogen** measured in 2014 and 2016 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 is not unusual because water temperatures in the spring still are warming and below the optimum levels for maximum growth and productivity of phytoplankton.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Tom Nevers during 2016 were 0.114 and 0.796 mg $P{\cdot}L^{-1}$ on May 13th and August 30th, respectively. The May value is in the range of the 2014 **TP** concentrations (0.022 and 0.130 mg $P{\cdot}L^{-1}$ on September 2nd and 24th, respectively) in the pond (Figure 3-6).

Figure 3-6. Total phosphorus concentrations measured in Tom Nevers Pond, 2014 and 2016.



The August 2016 value (0.796 mg $P{\cdot}L^{-1}$) is in the high range of values measured in other Nantucket ponds.

For purposes of comparison, the reader is referred to Chapter 9, Table 9-1 for a summary of **TN** and **TP** values measured in other Nantucket Island ponds by NLC-sponsored projects since 2009.

3.1.4 Phytoplankton

Description of the assemblage. The May 2016 assemblage contained 21 taxa while the August assemblage had 42 taxa; 46 different taxa were identified from both 2016 sampling dates and are listed in Table 3-1.

Table 3.1 Major groups and taxa of phytoplankton identified in Tom Nevers Pond, 2016.

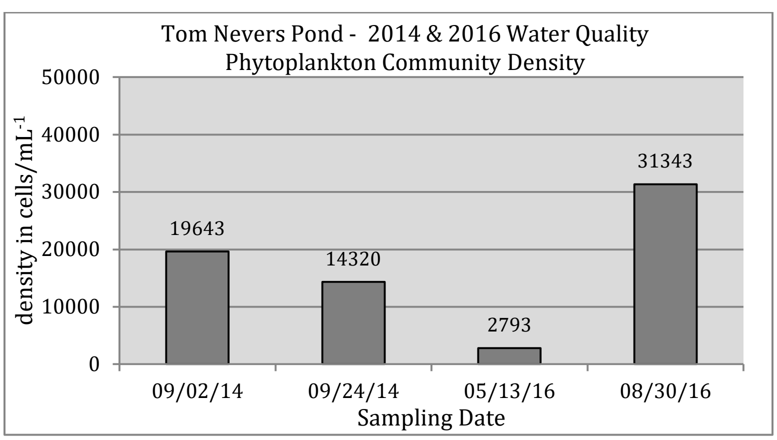
Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Pyramimonas tetrarhyncus*	*Nitzschia* sp.
Anabaenopsis Elenkinii	*Quadrigula lacustris*	*Pinnularia* sp.
Chroococcus dispersus	*Scenedesmus abundans*	*Planothidium* sp.
Gomphosphaeria lacustris compacta	*S. quadricauda*	*Rhoicosphenia curvata*
Merismopedia glauca	*Schroederia Judayi*	*Stephanodiscus* sp.
Chlorophytes	*Selenastrum capricornutum*	*Synedra acus*
Ankistrodesmus falcatus	*Sphaerocystis Schroeteri*	*S. fulgens*
Arthrodesmus sp.	*Spirulina sp.*	*S. ulna*
Closteriopsis longissima	*Staurastrum natator var. crassum*	*Tabellaria floccosa*
Closterium sp.	**Chrysophytes (Bacillariophyceae)**	**Chrysophytes (Chrysophyceae)**
Coelastrum cambricum	*Achnanthes* sp.	*Mallomonas* sp.
Cosmarium spp.	*Aulacoseria granulata*	*Synura uvella*
Monoraphidium arcuatum	*Cyclotella* sp.	**Euglenophytes**
M. contortum	*Cymbella* sp.	*Peranema* sp.
Oocystis Borgei	*Gomphonema* spp.	*Trachelomonas* sp.
O. pusilla	*Gyrosigma* sp.	**Pyrrhophytes (Cryptophyceae)**
O. solitaria	*Navicula* spp.	*Cryptomonas erosa*

The reader is referred to Sutherland and MacKinnon (2015) for a complete listing of the phytoplankton taxa identified in Tom Never Pond during 2014; there were 34 taxa identified on September 2nd 2014 and 26 taxa identified on September 24th 2014.

Community richness was calculated to be 32 (±14.8) taxa for the two sampling periods in 2016 and 30.0 (±5.7) taxa for both 2014 sampling dates.

Density. During 2016, the community density was 2,793 cells·mL^{-1} on May 13th and then increased by 10-fold to 31,343 cells·mL^{-1} by August 30th.

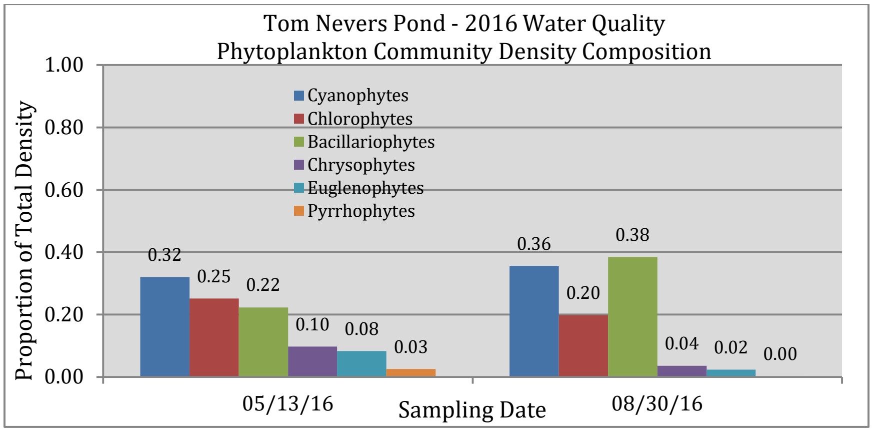
Figure 3-7. Phytoplankton community density in Tom Nevers Pond, 2014 and 2016.



As shown in Figure 3-7, which summarizes the 2014 and 2016 phytoplankton density data, the 2016 values proved to be the low and high values for all four (4) sampling dates on the pond.

All major groups of phytoplankton were represented in the May 13th 2016 assemblage and included Cyanophytes (32 percent), Chlorophytes (25 percent), Bacillariophytes (22 percent), with Chrysophytes (10 percent), Euglenophytes (8 percent) and Pyrrhophytes (3 percent) also present (Figure 3-8).

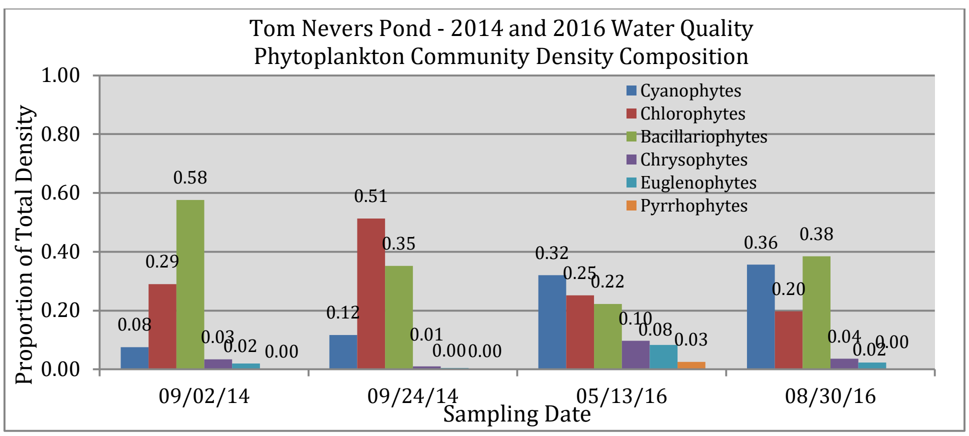
Figure 3-8. Density composition of the phytoplankton community in Tom Nevers Pond, 2016.



As shown above, the same 3 major groups were predominant in the pond during August 2016, although the relative amounts had changed slightly; Bacillariophytes were the dominant group (38 percent), and Pyrrhophytes were not present in the assemblage (0 percent).

As shown in Figure 3-9, a major portion of the September 2014 phytoplankton density was distributed among only 2 major groups, the Chlorophytes (33 percent on the 2nd, 34 percent on the 24th) and the Bacillariophytes (51 percent on the 2nd, 59 percent on the 24th).

Figure 3-9. Density composition of the phytoplankton community in Tom Nevers Pond, 2014 and 2016.



The increased density of the Cyanophytes (Blue-green algae) during 2016 is most noteworthy when comparing the community distributions that were documented in 2014 and 2016; this group averaged about 10 percent of the community in 2014 and 34 percent of the community during 2016. The significance of this change in the community will be discussed below.

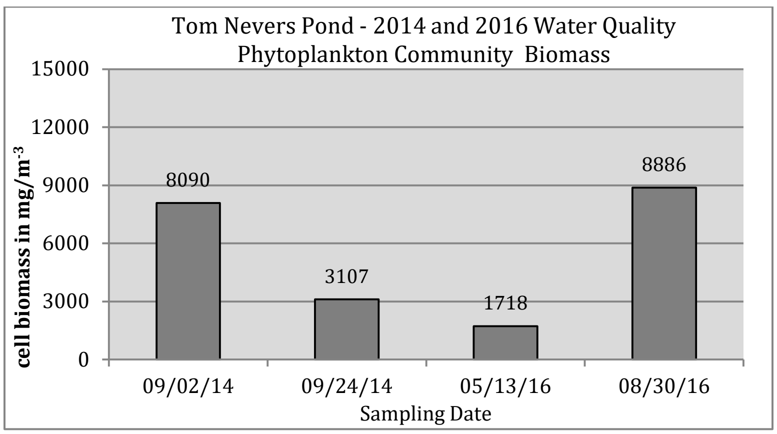
Given the shallow depth of Tom Nevers Pond and the greatly reduced water clarity caused by the 'brown stain' of the water color, the phytoplankton community cell densities measured in Tom Nevers Pond during 2014 and 2016 are considered normal for a pond with these characteristics.

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·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.

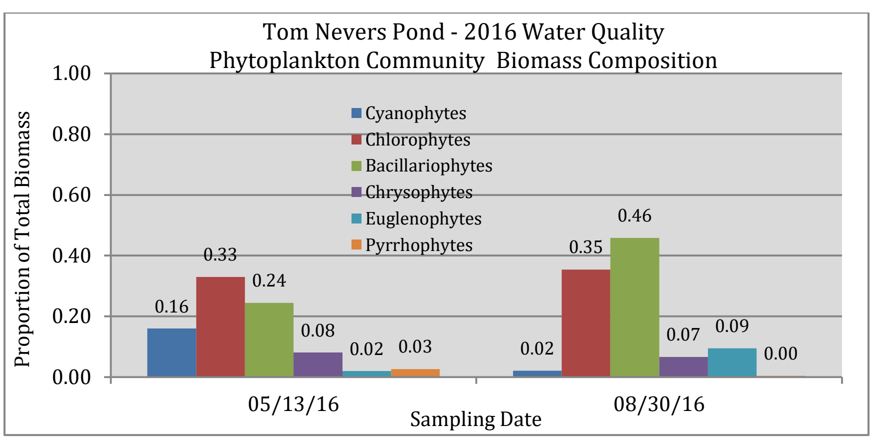
The 2016 phytoplankton community biomass was 1,718 mg·m^{-3} on May 13th and 8,886 mg·m^{-3} on August 30th. These values appear to be consistent with the biomass values recorded during 2014, i.e., 8,090 mg·m^{-3} on September 2nd and 3,107 mg·m^{-3} on September 24th. The 2014 and 2016 values are presented in Figure 3-10.

Figure 3-10. Phytoplankton community biomass in Tom Nevers Pond, 2014 and 2016.



Referring to the 2016 biomass in Figure 3-11, there was a major shift in the community biomass between the spring and late summer composition, especially with regard to the Bacillariophytes (diatoms) that doubled in biomass between the 2 sampling dates.

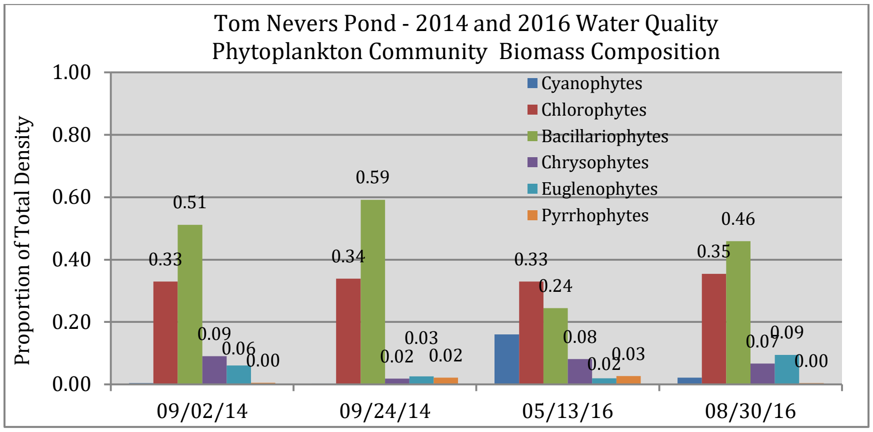
Figure 3-11. Biomass composition of the phytoplankton community in Tom Nevers Pond, 2016.



Other noteworthy changes included a substantial reduction in the Cyanophytes between spring (16 percent) and late summer (2 percent) 2016.

The 2014 and 2016 biomass composition for the Tom Nevers Pond phytoplankton community is presented in Figure 3-12. Particularly noteworthy is the consistency of the Chlorophytes and Bacillariophytes as community dominants during the 2 years where sampling was conducted.

Figure 3-12. Biomass composition of the phytoplankton community in Tom Nevers Pond, 2014 and 2016.



The appearance of Cyanophyte (Blue-green) biomass during 2016 also is noteworthy because this major group was not identified in the 2014 samples collected from the pond.

Dominance. A ranking of phytoplankton taxa dominance in Tom Nevers Pond on both 2016 sampling dates is summarized in Table 3.2. 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 on both sampling dates; 5 of the 6 taxa were biomass dominants on both sampling dates.

Table 3.2 Rank of phytoplankton taxa dominance, using biomass, in Tom Nevers Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*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
8/30/16	*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

The reader is referred to Sutherland and MacKinnon (2015) for a summary of the dominant biomass taxa identified in Tom Nevers Pond during 2014.

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

[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.

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 diversity calculated for Tom Nevers Pond during 2014 and 2016 were very consistent and not that different from a value of 1.0, regardless of whether density or biomass was used in the calculation. The density and biomass diversity values calculated for the pond on the 2014 and 2016 sampling dates are summarized in Table 3-3.

Table 3-3. Phytoplankton community diversity in Tom Nevers Pond, 2014 and 2016.

Tom Nevers Pond Sampling Date	Phyto Density Diversity Value	Phyto Biomass Diversity Value
Sept 2nd 2014	0.989	1.058
Sept 24th 2014	0.858	1.019
May 13th 2016	0.960	1.004
August 30 2016	1.010	1.026

All of these diversity values indicate that, on all sampling dates, the total community was very evenly apportioned and that dominance did not reside with a single, or even a few, taxa.

Cyanophytes. As a major phytoplankton group, Cyanophytes were identified in all 2014 and 2016 samples collected from Tom Nevers Pond. Table 3-4 summarizes the species identified in the 2014 and 2016 samples and their percent of the total phytoplankton community composition when the samples were collected.

Table 3-4. Cyanophyte species identified in 2014 and 2016 samples from Tom Nevers Pond.

Species	Sept 2nd 2014	Sept 24th 2014	May 13th 2016	August 30th 2016
*Anabaena flos aquae**	no	no	yes (32%)	no
*Anabaenopsis Elenkinii**	no	no	no	yes (3%)
Chroococcus dispersus	no	yes (1%)	no	yes (3%)
Gomphosphaeria lacustris compacta	yes (8%)	no	no	yes (5%)
Merismopedia glauca	no	yes (11%)	no	yes (25%)
'yes' = present, 'no' = absent; (##) proportion of community on a sampling date * Species that are known to produce algal toxins				

Of particular concern, however, is the significant increase between 2014 and 2016 in the proportion of the total community represented by Cyanophyte species and the fact that some of these species are recognized as potentially producing algal toxins that can impact the health of animals and humans (Table 3-4).

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Tom Nevers Pond were 2.1 $\mu g \cdot L^{-1}$ on May 13th and 14.0 $\mu g \cdot L^{-1}$ on August 30th; the 2014 chlorophyll ***a*** concentrations were 6.2 $\mu g \cdot L^{-1}$ on September 2nd and 2.1 $\mu g \cdot L^{-1}$ on September 24th. The values measured during 2014 and 2016 indicate a low level of algal productivity in the pond on all occasions except August 30th 2016 when there might have been an algal bloom in progress.

Tom Nevers 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 9, Table 9-1 for a summary of water quality parameters measured by the NLC in all 11 ponds surveyed since 2009.

3.1.5 Trophic Status

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

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

Sufficient water quality data were collected from Tom Nevers Pond during 2016 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 May and August sampling dates. The average values then were substituted into the appropriate equations (Chapter 1) to calculate the TSI values for each variable.

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

Chlorophyll *a*
Average chlorophyll *a* = 8.05 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (8.05)] + 30.6
TSI = (9.81)(2.09) + 30.6
TSI = 51.1

Total phosphorus
Average total phosphorus = 454.9 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (454.9)] + 4.15
TSI = (14.42)(6.12) + 4.15
TSI = 92.4

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 51.1 calculated for chlorophyll ***a*** was just above the threshold of 50 for the mesotrophic region (see Table 3-5 below), while the TSI calculated for total phosphorus (92.4) was well within the hyper-eutrophic region, which has a lower threshold of TI value of 70. The average 2016 Secchi depth (0.43 meters) resulted in a calculated TSI value of 72.2 which also is within the hyper-eutrophic region.

Table 3-5. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

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

Taken at face value, the TSI values calculated for Tom Nevers Pond portray water quality during 2016 that ranges between mesotrophic and hyper-eutrophic conditions, depending upon which independent water quality variable is used as a reference.

There are certain limitations that should be considered, however, when interpreting the 2016 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 basis for using Secchi depth to calculate a TSI value. In addition, the average 2016 TP concentration (454.9 $\mu g/L^{-1}$) used in the calculation was heavily biased by the very high September reading (795.9 $\mu g/L^{-1}$) which could have resulted from a wind event, mixing water from the pond surface to the bottom and re-suspending nutrient material contained in the sediments.

Taking all of the above into consideration, it seems most appropriate to use the TSI value calculated for chlorophyll ***a*** (51.1) as the most accurate indicator of the pond's trophic state during 2016.

3.2 Summary

Tom Nevers Pond can be characterized as a low-to-moderate 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. 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.

3.3 Literature Cited

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 Nantucket Land Council, Inc. 43 pp.

Nantucket Island Ponds and 2016 Water Quality

Chapter 4

Gibbs Pond

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4.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Gibbs Pond by the Nantucket Land Council, Inc. during 2016.

4.1 Results

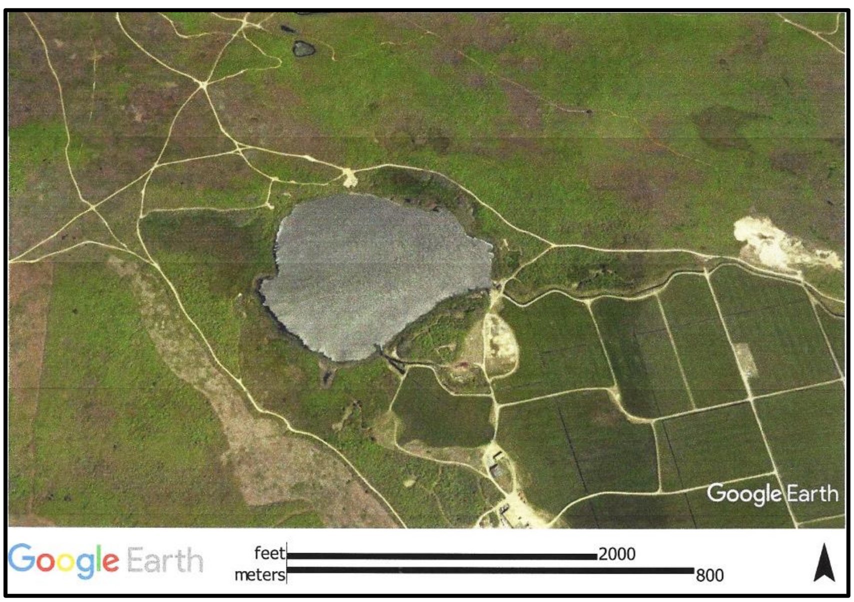
Gibbs Pond was sampled on May 13th and August 30th 2016. The maximum water depth recorded was 14.5 feet (4.4 m) on May 13th and 13.7 feet (4.2 m) on August 30th at the sampling location in the approximate center of the pond.

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) feet on May 13th and 10 feet (3.0 m) on August 30th for the water chemistry and phytoplankton samples. No additional samples were collected on May 13th; however, a grab sample for water chemistry was collected from the 12-foot (3.7 m) depth on August 30th. Observations recorded while the pond was being sampled included an algal 'bloom in progress' on August 30th.

4.1.1 Physical characteristics

General. Gibbs Pond is located north of Milestone Road, about 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 4-1 is an aerial view of Gibbs Pond.

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



The pond is used to flood the cranberry bogs on the Island and there is a single outflow, Phillips Run, that 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.

Temperature. Temperature profile data were collected during both 2016 sampling excursions. The May 13th temperature from surface to bottom varied by about 4.5°C and averaged 15.6°C. On August 30th, the difference between the surface and bottom temperature was 2°C and the average from surface to bottom was 25.7°C. There is nothing particularly noteworthy about the Gibbs Pond water column temperatures and they are not presented here in graphic form.

Transparency. The Secchi depth transparency measured at Gibbs Pond on May 13th was 2.9 feet (0.9 m) and the reading on August 30th was 1.1 feet (0.35 m). Water clarity usually is greater in the spring because the water temperature still is rising from mid-winter lows and conditions in the pond still are not ideal for phytoplankton growth and productivity. Water color observations recorded when the pond was sampled included 'reddish/brown' color on May 13th and 'green' on August 30th when clarity was low.

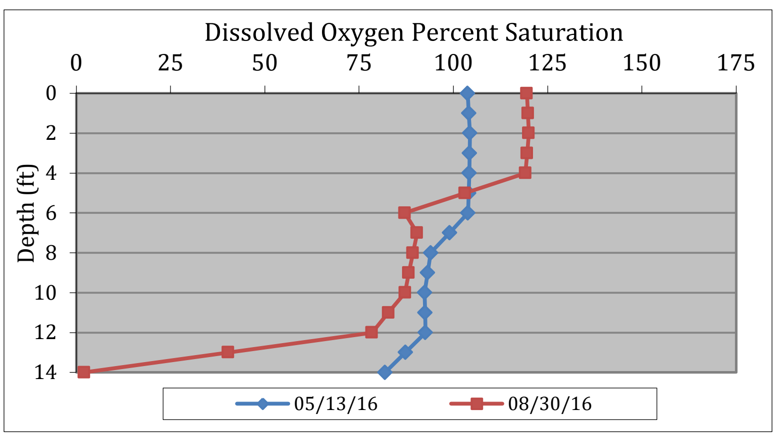
4.1.2 Chemical characteristics

Specific conductance. All 2016 conductance values were similar and noticeably 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 revealed a conductance value of 93 $\mu S \cdot cm^{-1}$ on May 13th, while the August 30th value for the ***upper*** sample was 97 $\mu S \cdot cm^{-1}$. The ***lower*** region value for specific conductance collected on August 30th was 99 $\mu S \cdot cm^{-1}$.

pH. A pH of 6.21 s.u. was recorded for the ***upper*** region of the pond on May 13th. The pH values recorded on August 30th were 8.51 s.u. in the ***upper*** region and 7.73 s.u. in the ***lower*** region. The high value for the ***upper*** region recorded on August 30th reflects high productivity from phytoplankton in the water column and a potential imbalance between respiration and photosynthesis.

Dissolved oxygen percent saturation. The average oxygen saturation values for the Gibbs Pond water column was 97.4 percent on May 13th and 89.8 percent on August 30th. There was a distinct gradient in saturation values with increasing pond depth on both sampling dates; the gradient was most pronounced on August 30th. The depth profiles of oxygen saturation for both 2016 sampling dates are presented in Figure 4-2.

Figure 4-2. Dissolved oxygen saturation values with depth in Gibbs Pond, 2016.



While the location of Gibbs Pond is in an open area, making the pond susceptible to wind, the depth profile of oxygen saturation measured on August 30th suggests that wind conditions had been calm for long enough to allow the water column to stratify with regard to temperature and, particularly, dissolved oxygen as suggested in Figure 4-2.

4.1.3 Plant Nutrients

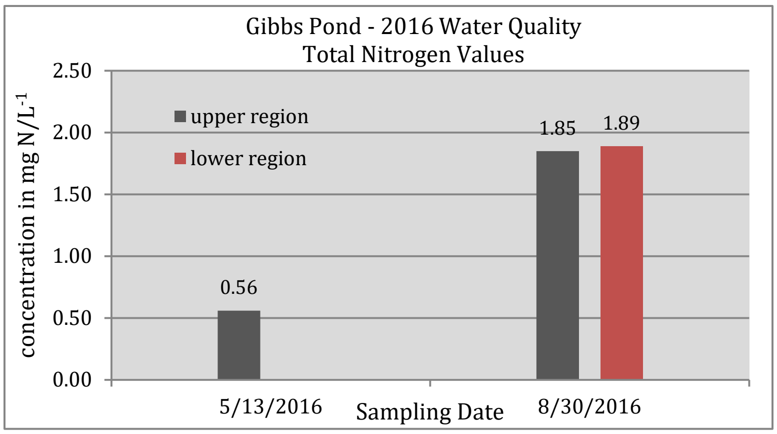
Nitrogen. Nitrate-nitrogen was not detectable in Gibbs Pond on either 2016 sampling date which is not unusual since this form of nitrogen is taken up by phytoplankton during the process of photosynthesis.

Measureable levels of **ammonia-nitrogen** occurred in the water column on both sampling dates, including 0.030 mg N·L^{-1} in the May 13th integrate, 0.020 mg N·L^{-1} in the August 30th sample from the ***upper*** region and 0.120 mg N·L^{-1} measured in the August 30th ***lower*** region sample.

Whereas Gibbs Pond exhibited slight temperature and dissolved oxygen stratification on August 30th, 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 of organic decomposition by bacteria of material accumulated near, or on, the pond bottom.

The 2016 Gibbs Pond **TN** concentrations are summarized in Figure 4-3.

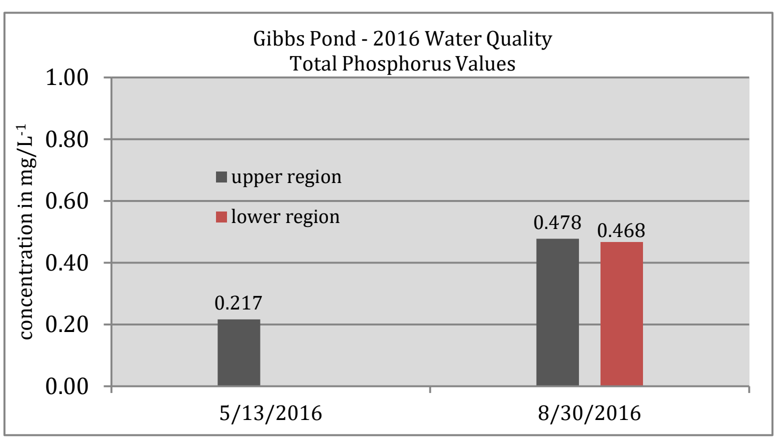
Figure 4-3. Total nitrogen concentrations measured in Gibbs Pond, 2016.



On May 13, the **total nitrogen (TN)** concentration in Gibbs Pond was 0.56 mg N·L^{-1}, which is a reasonable spring value following ice-out and mixing of the water column following winter stagnation. However, by August 30th, the TN concentration had increased to 1.85 and 1.89 mg N·L^{-1} in the ***upper*** and ***lower*** regions, respectively.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Gibbs Pond during 2016 are shown in Figure 4-4.

Figure 4-4. Total phosphorus concentrations measured in Gibbs Pond, 2016.



On May 13th, the **TP** concentration was 0.217 mg P·L^{-1}, which is a high value but not unreasonable considering the possibility of any recent wind-driven mixing of the water column. However, by August 30th, the ***upper*** region TP concentration was 0.478 mg P·L^{-1} and the ***lower*** region concentration was

0.468 mg P·L^{-1}. These concentrations are considered elevated and indicate a high level of productivity in the pond, which is substantiated by the field observation on August 30th of an algal 'bloom in progress'.

The reader is referred to Chapter 9 of this report for a comparison of water quality among the 11 ponds that have been monitored by the NLC since 2009 when there was a cooperative effort with the UMass Filed Station to survey Miacomet and Hummock Ponds.

4.1.4 Phytoplankton

Description of the assemblage. There were 26 phytoplankton taxa identified in the 2016 May community and 30 taxa identified in the August community from Gibbs Pond; 42 taxa were identified in the pond during 2016 (Table 4-1).

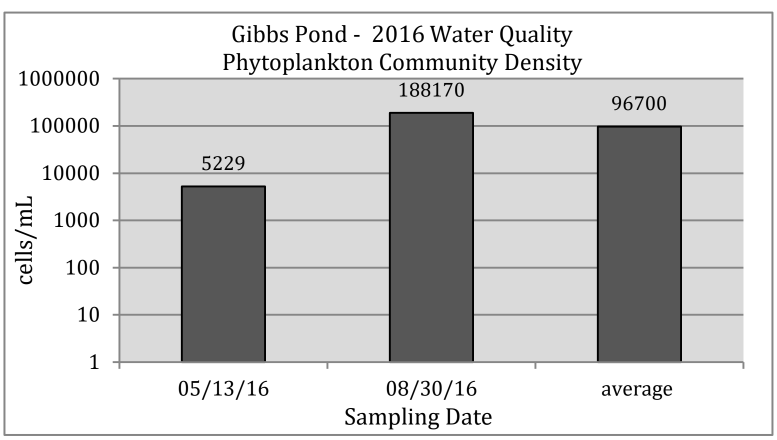
Table 4-1. Major groups and taxa of phytoplankton identified in Gibbs Pond, 2016.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyta)**
Anabaena flos aquae	*Pediastrum duplex*	*Cyclotella* sp
Aphanizomenon flos aquae	*Pyramimonas tetrarhyncus*	*Navicula* spp.
Gomphosphaeria lacustris compacta	*Quadrigula lacurstris*	*Nitzschia* sp.
Merismopedia glauca	*Scenedesmus abundans*	*Planothidium* sp.
Woronichinia naegeliana	*S. arcuatus*	*Stauroneis* sp.
Chlorophyta	*S. Bijuga*	*Stephanodiscus* sp.
Ankistrodesmus falcatus	*S. quadricauda*	*Synedra acus*
Closteriopsis longissima	*S. tetraedon*	**Chrysophyta (Chrysophyceae)**
Closterium sp.	*Sphaerocystis Schroeteri*	*Dinobyron divergens*
C. gracile	*Spirulina* sp.	*Mallomonas* sp.
Coelastrum cambricum	*Staurastrum natator var. crassum*	**Euglenophyta**
Cosmarium spp.	*Tetraedron minimum*	*Peranema* sp.
Monoraphidium arcuatum	**Chrysophyta (Bacillariophyta)**	*Trachelomonas* sp.
M. contortum	*Achnanthese* sp.	**Pyrrhophyta (Cryptophyceae)**
Oocystis Borgei	*Aulocoseria granulata*	*Cryptomonas erosa*
O. solitaria	*Cocconeis* sp.	

Community richness for the 2016 samples was calculated to be 28 ± 2.8 taxa.

Density. Phytoplankton community density in Gibbs Pond was 5,229 cells·mL^{-1} on May 13th and 188,170 cells·mL^{-1} on August 30th; average density was 96,700 cells·mL^{-1} for both dates (Figure 4-5).

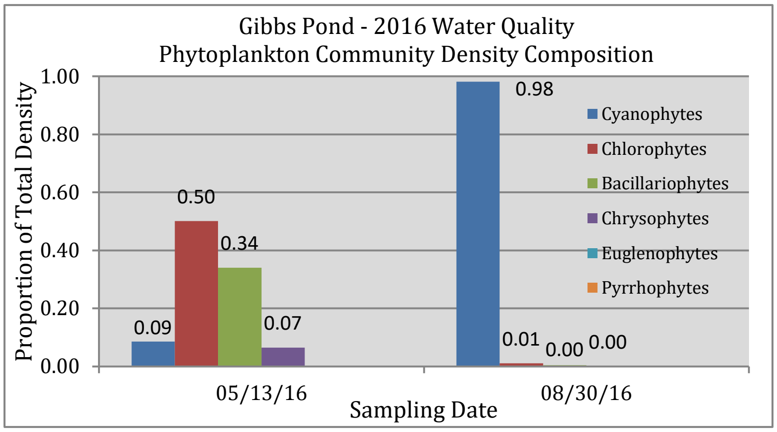
Figure 4-5. Phytoplankton community density in Gibbs Pond, 2016.



The *y*-axis in Figure 4-5 is a logarithm scale which means that each major increment represents a 10-fold increase in cell density. The May 13th density is typical of a spring phytoplankton assemblage when productivity is low and water temperatures in the pond are warming; the August value, however, is extremely high and further evidence that an algal bloom was in progress as was recorded in the field notes on that sampling date.

The May 13th phytoplankton assemblage (Figure 4-6) 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.

Figure 4-6. Density composition of the phytoplankton community in Gibbs Pond, 2016.

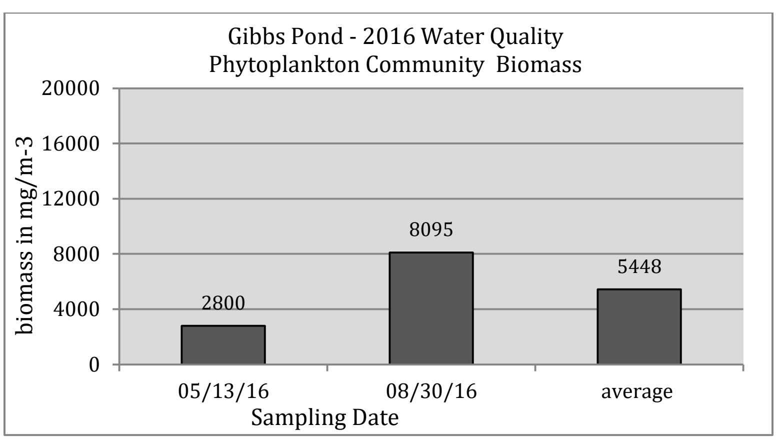


By August 30th, the phytoplankton assemblage had undergone a dramatic change and 98 percent of the community density was comprised of Cyanophytes (Figure 4-6).

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 $mg \cdot m^{-3}$) 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.

The phytoplankton community biomass documented in Gibbs Pond on May 13th and August 30th is presented in Figure 4-7.

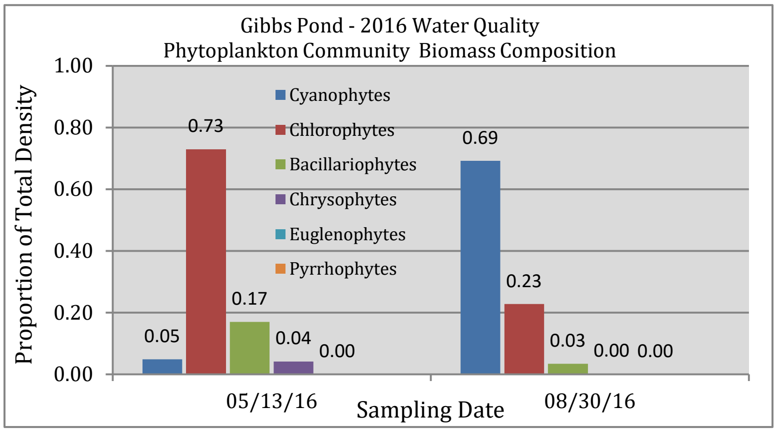
Figure 4-7. Phytoplankton community biomass in Gibbs Pond, 2016.



The biomass in the pond was 2,800 mg·m^{-3} on May 13th and 8,095 mg·m^{-3} on August 30th; an average of 5,448 mg·m^{-3} for both 2016 sampling dates (Figure 4-7).

With respect to community biomass, the May phytoplankton assemblage was comprised primarily of Chlorophytes (73 percent) and Bacillariophytes (17 percent), with lesser amounts of Cyanophytes (5 percent), Chrysophytes (4 percent) and Euglenophytes (<1 percent)(Figure 4-8).

Figure 4-8. Biomass composition of the phytoplankton community in Gibbs Pond, 2016.



By August 30th, the biomass composition of the phytoplankton community had changed dramatically and consisted primarily of Cyanophytes (69 percent) and Chlorophytes (23 percent).

Dominance. A ranking of phytoplankton taxa dominance in Gibbs Pond during 2016 is summarized in Table 4-2.

Table 4-2. Rank of phytoplankton taxa dominance, using biomass, in Gibbs Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*Sphaerocystis Schroeteri* (Chlorophyte)	1	26
	Staurastrum natator var. *crassum* (Chlorophyte)	2	26
	Cyclotella sp. (Bacillariophyte)	3	15
	Pediastrum duplex (Chlorophyta)	4	10
	Anabaena flos aquae (Cyanophyte)	5	5
8/30/16	*Woronichinia naegeliana* (Cyanophyte)	1	52
	Aphanizomenon flos aguae (Cyanophyte)	2	15
	Coelastrum cambricum (Chlorophyte)	3	12

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 and 3 dominant taxa in the community on August 30th (Table 4-2).

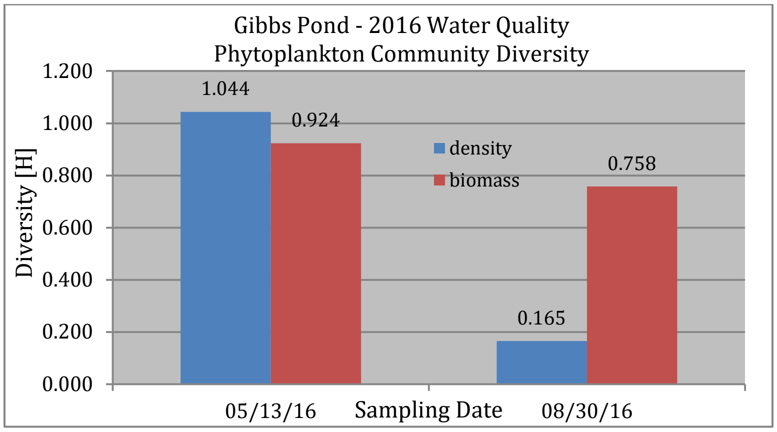
Diversity. Phytoplankton diversity in Gibbs Pond was measured using the Shannon-Wiener function[1] which calculates diversity, **[H]**, using number of taxa and the portion of individuals among the taxa on each sampling date.

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.

[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.

Diversity in Gibbs Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Figure 4-9. The data shown below highlight the importance of considering both density and biomass when considering phytoplankton community characteristics in a particular body of water.

Figure 4-9. Phytoplankton community diversity in Gibbs Pond, 2016.



Using density as the primary variable, diversity [H] values calculated for Gibbs Pond were 1.044 and 0.165 in May and August 2016, respectively. With biomass, the diversity values were 0.924 during May and 0.758 during August. Regardless of which variable is used to calculate diversity, the most noteworthy feature is the dramatic difference between using density or biomass to calculate the August 2016 community metric.

Cyanophytes. Cyanophytes were identified in both the May and August samples collected in Gibbs Pond during 2016 (Table 4-3). There were 5 taxa identified including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, *Gomphosphaeria lacustris compacta*, *Merismopedia glauca* and *Woronichinia naegeliana*.

Table 4-3. Cyanophyte species identified in Gibbs Pond, 2016.

Species	May 13th 2016	August 30th 2016
*Anabaena flos aquae**	yes (9%)	yes (<1%)
*Aphanizomenon flos aquae**	no	yes (3%)
Gomphosphaeria lacustris compacta	no	yes (1%)
Merismopedia glauca	no	yes (1%)
*Woronichinia naegeliana**	no	yes (93%)

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 chlorophyll ***a*** concentrations measured in Gibbs Pond 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.

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.

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 Gibbs Pond during 2016 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 May 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* = 112.05 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (112.05)] + 30.6
TSI = (9.81)(4.72) + 30.6
TSI = 76.9

Total phosphorus
Average total phosphorus = 347.15 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (347.15)] + 4.15
TSI = (14.42)(5.85) + 4.15
TSI = 88.5

Secchi depth
Average Secchi depth = 0.62 m
Secchi TSI = 60 – [14.41*[ln (0.62)]
TSI = 60 – (14.41)(-0.48)
TSI = 66.9

The TSI indices calculated for chlorophyll ***a*** and total phosphorus were situated well within the 'hyper-eutrophic' range of values, while Secchi depth transparency was well within the 'eutrophic' range, as shown by comparing the TSI values calculated above with the information in Table 4-4 below.

Table 4-4. Trophic State Indices calculated for 2016 water quality data measured in Gibbs Pond.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 Gibbs Pond suggest that certain water quality standards for contact recreation are in question and that further investigation should occur with regard to this pond being used for swimming during the summer months.

4.2 Summary

Based upon the data collected during 2016, Gibbs Pond exhibits water quality similar to certain 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 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.

4.3 Literature Cited

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Nantucket Island Ponds and 2016 Water Quality

Chapter 5

Little Weweeder Pond

5.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Little Weweeder Pond by Nantucket Land Council staff during 2016.

5.1 Results

Little Weweeder Pond was sampled on May 13th and August 30th 2016. The maximum water depth located in the pond was 4.6 feet (1.4 m) on May 13th at the sampling location in the approximate center of the pond. The maximum water depth located on August 30th was 3.9 feet (1.2 m).

Following the collection of temperature and dissolved oxygen profile data on May 13th, an integrate sample was collected from the surface down to 4 feet of depth for the chemistry and phytoplankton samples. A grab sample was not collected due to the shallow pond depth.

The depth of integrate sample collection on August 30th was from 0-3 feet of depth and there was no grab sample collected on this sampling date either.

5.1.1 Physical characteristics

General. Little Weweeder Pond is located along the south shore of Nantucket Island, at the end of Folger Avenue and about 0.7 mile east of Miacomet Pond. The pond has an elongated shape with a slight indentation along the western shoreline (Figure 5-1).

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

The surface area of the pond is estimated at about 9,200 ft^2, or about 0.21 acres. There are no permanent streams flowing into the pond, and there is a connection between Little Weweeder and a larger pond to the south through a culvert beneath the road.

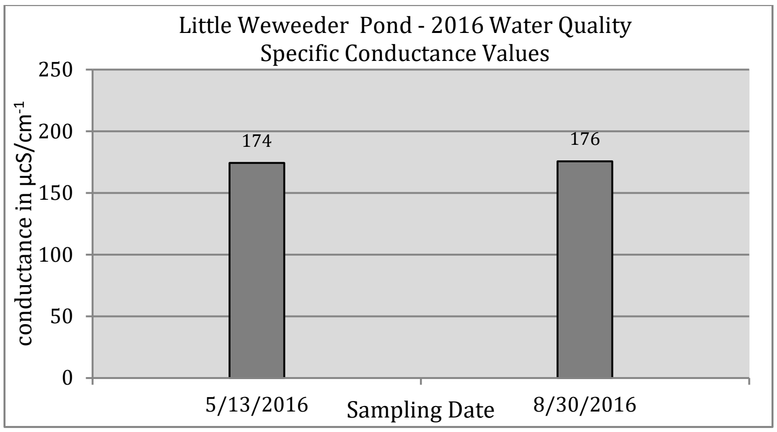
Temperature. Temperature profile data were collected on both 2016 sampling excursions to Little Weweeder Pond. The temperature collected on both sampling dates essentially was isothermal from the surface to the bottom with only slight differences observed; the average temperature of the water column was 17.5°C on May13th and 24.5°C on August 30th.

Transparency. The Secchi depth transparency measured at Little Weweeder Pond on May 13th was 4.0 feet (1.2 m) and could not be determined on August 30th due to vegetation growing on the bottom which obscured visibility of the disc. In addition, the water color was noted as 'clear' on both sampling dates by NLC staff sampling the pond.

5.1.2 Chemical characteristics

Specific conductance. Figure 5-2 presents the specific conductance values measured at Little Weweeder Pond on May 13th and August 30th 2016.

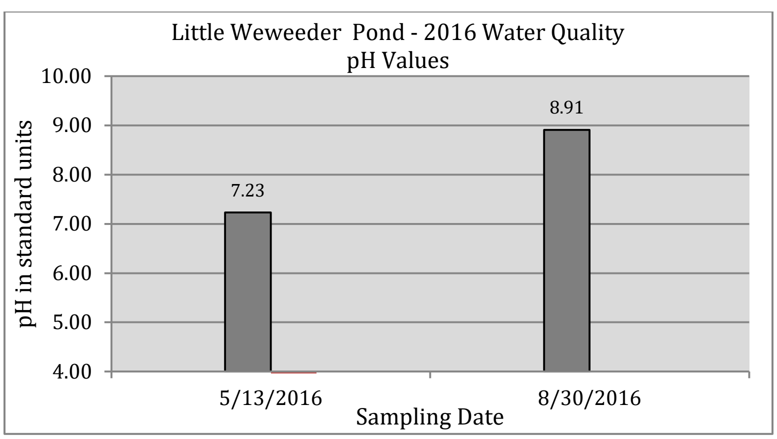
Figure 5-2. Specific conductance measured in Little Weweeder Pond, 2016.



The results for the 2 integrate samples essentially were the same; 174 and 176 $\mu S \cdot cm^{-1}$ on May 13th and August 30th, respectively. These values are within the range expected for a small freshwater pond located in this area that is subject to the influence of salt spray from the Atlantic Ocean.

pH. As shown in Figure 5-3, Little Weweeder Pond had a neutral pH (7.23 s.u.) on May 13th, and an elevated pH (8.91 s.u.) on August 30th.

Figure 5-3. pH measured in Little Weweeder Pond, 2016.



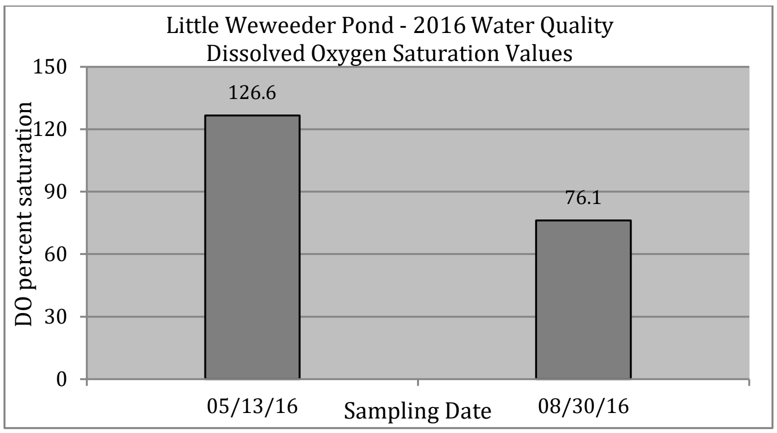
The high value recorded on August 30th reflects high productivity from phytoplankton in the water column and a potential imbalance between respiration and photosynthesis.

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 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 dissolved oxygen saturation values measured in Little Weweeder Pond during May and August 2016 are shown in Figure 5-4.

Figure 5-4. Dissolved oxygen saturation values measured in Little Weweeder Pond, 2016.



The percent saturation value of 126.6 percent recorded on May 13th (126.6) indicates a supersaturated condition in the water column which occurs when any combination or all of the following occur: (1) water temperatures are low, (2) there is mixing in the pond, and (3) phytoplankton respiration is occurring (and replenishing oxygen) at a greater rate than photosynthesis (which consumes CO_2) which occurs slower at lower temperatures.

5.1.3 Plant Nutrients

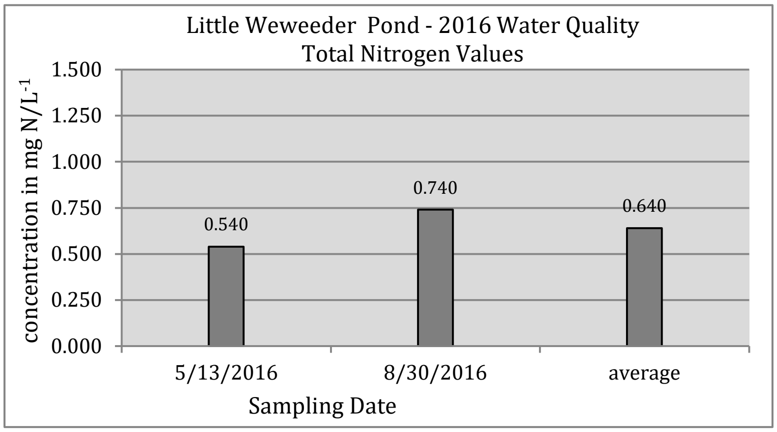
Nitrogen. **Nitrate-nitrogen** was not detectable in Little Weweeder Pond on either May 13th or August 30th; i.e., concentrations were 0.005 $N \cdot L^{-1}$, which is not an unusual phenomenon in fresh-water systems since this form of nitrogen is readily taken up by phytoplankton for metabolism when it does become available in the water column.

Although there were measureable levels of **ammonia-nitrogen** in the water column on both 2016 sampling dates, the levels were low, which also is not unusual since this form of nitrogen also is available for uptake by phytoplankton. The levels of **ammonia-nitrogen** measured in Little Weweeder Pond were 0.020 mg $N \cdot L^{-1}$ on both May 13th and August 30th.

The **TN** concentrations measured in the pond were 0.540 mg $N \cdot L^{-1}$ on May 13th and 0.750 mg $N \cdot L^{-1}$ on August 30th, an average of 0.640 mg $N \cdot L^{-1}$ for both sampling dates (Figure 5-5). Based upon the undetectable and very low **nitrate-** and **ammonia-nitrogen** concentrations, respectively, measured in Gibbs Pond during 2016, about 95 percent of the 2016 **TN** concentrations were was tied up as organic nitrogen (phytoplankton and other seston) in the water column.

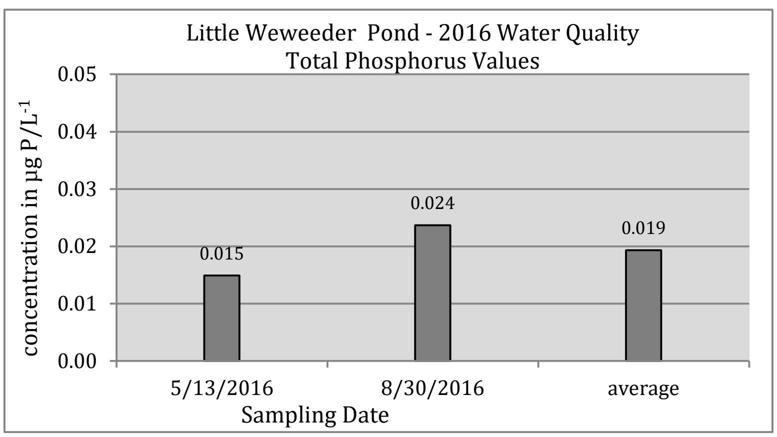
The 2016 **TN** concentrations measured in Gibbs Pond are moderate concentrations when compared with other Nantucket Island ponds that have been surveyed by the NLC since 2009. The reader is referred to Chapter 9 of this report for a summary and comparison of these water quality parameters.

Figure 5-5. Total nitrogen concentrations measured in Little Weweeder Pond, 2016.



Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Little Weweeder Pond during May and August 2016 are shown in Figure 5-6. On May 13th, the **TP** concentration was 0.015 mg P·L^{-1} in the water column and by August 30th, the TP concentration had increased to 0.024 mg P·L^{-1}. The average value for the 2016 season was 0.019 mg P·L^{-1}.

Figure 5-6. Total phosphorus concentrations measured in Little Weweeder Pond, 2016.



The concentrations of TP measured in Little Weweeder Pond reflect low productivity in the system and this situation is considered normal in dilute systems such as Little Weweeder Pond.

As a comparison to Little Weweeder Pond, average **TP** levels documented in other Nantucket Island ponds during 2016 were 0.266 mg P·L^{-1} in *Tom Nevers Pond* and 0.039 mg P·L^{-1} in *Washing Pond*.

5.1.4 Phytoplankton

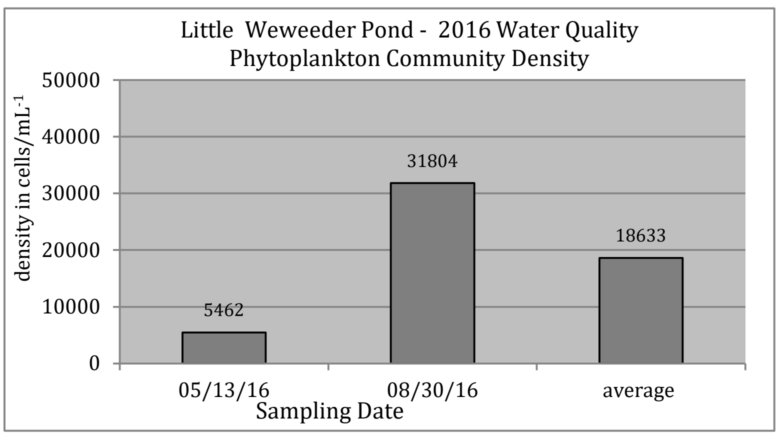
Description of the assemblage. There were 35 taxa identified in the 2016 phytoplankton samples collected from Little Weweeder Pond and all of the major algal groups were represented (Table 5-1). A total of 18 taxa were identified in the May 13th sample and 29 taxa were identified in the August 30th sample. The community richness calculated for the 2016 sampling dates was 23.5 (±7.8) taxa.

Table 5-1. Major groups and taxa of phytoplankton identified in Little Weweeder Pond, 2016.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Oocystis pusilla*	*Gomphonema* spp.
Aphanizomenon flos aquae	*O. solitaria*	*Navicula* spp.
Chroococcus limneticus	*Pandorina morum*	*Nitzschia* sp.
Woronichinia naegeliana	*Pediastrum duplex*	*Rhoicosphenia curvata*
Chlorophytes	*Pyramimonas tetrarhyncus*	*Stauroneis* sp.
Ankistrodesmus falcatus	*Quadrigula lacustris*	*Synedra acus*
Arthrodesmus sp.	*Scenedesmus arcuatus*	*Tabellaria floccosa*
Closteriopsis longissima	*S. bijuga*	**Euglenophytes**
Closterium sp.	*Sphaerocystis Schroeteri*	*Peranema* sp.
C. gracile	**Chrysophytes (Bacillariophyceae)**	*Trachelomonas* sp.
Coelastrum cambricum	*Achnanthes* sp.	**Pyrrhophytes (Dinophytes)**
Cosmarium spp.	*Cyclotella* sp.	*Peridinium cinctum*
Mougeotia sp.	*Cymbella* sp.	*Cryptomonas erosa*

Density. The phytoplankton community density in Little Weweeder Pond was 5,462cells·mL^{-1} on May 13th and 31,804 cells·mL^{-1} on August 30th; the average density was 18,633 cells·mL^{-1} for both 2016 sampling dates (Figure 5-7). The phytoplankton densities measured in Little Weweeder Pond during 2016 are low when compared with other Island ponds that have been monitored by the NLC during recent years.

Figure 5-7. Phytoplankton community density in Little Weweeder Pond, 2016.

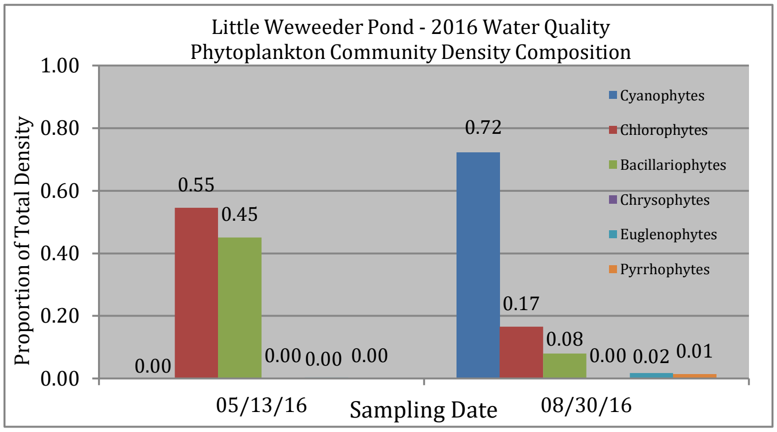


The May 13th phytoplankton assemblage in Little Weweeder Pond was comprised entirely of Chlorophytes (green algae) with 55 percent of the community density and Bacillariophytes (diatoms) with 45 percent of the community density (Figure 5-8). All other major groups of phytoplankton were absent from the community during the spring of 2016.

On August 30th, there had been a major shift in the community composition (Figure 5-8) with Cyanophytes (Blue-green algae) the major phytoplankton group comprising 72 percent of the community density. At that time, Chlorophytes were 17 percent of the community, followed by the diatoms (8 percent), Euglenophytes (2 percent), and Pyrrhophytes (1 percent).

When small ponds exhibit major shifts in community composition similar to the situation observed in Little Weweeder Pond during 2016, it is not clear whether the changes are due to instability in the community that is exhibited from one year to the next, or a seasonal succession that occurs every year with a major shift in community structure as the pond progresses through its annual cycle. This is why several years of water quality data should be collected from a pond before any evaluations are performed to categorize the status and dynamics of productivity.

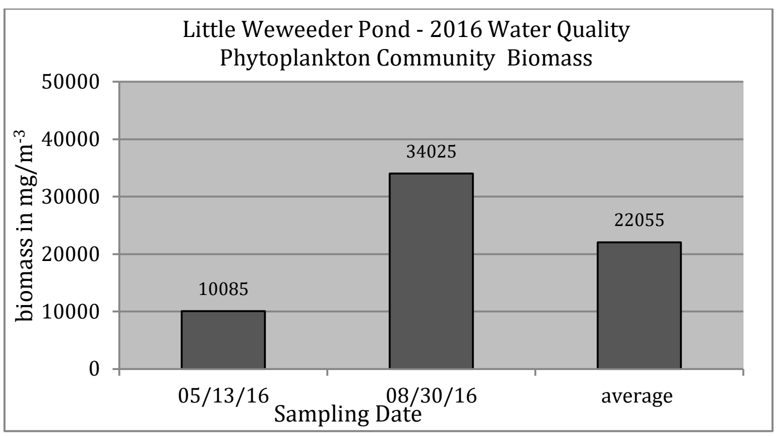
Figure 5-8. Density composition of the phytoplankton community in Little Weweeder Pond, 2016.



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 to observe size differences among different types of phytoplankton of several orders of magnitude.

The 2016 phytoplankton community biomass documented in Little Weweeder Pond on May 13th and August 30th is presented in Figure 5-9.

Figure 5-9. Phytoplankton community biomass in Little Weweeder Pond, 2016.

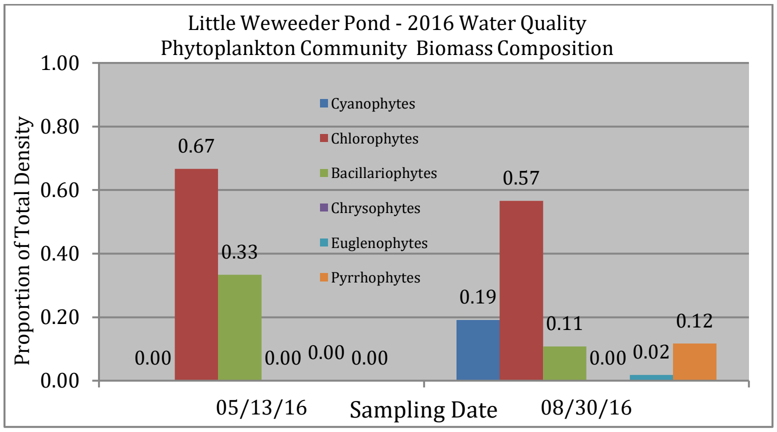


Biomass was 10,085 mg·m^{-3} on May 13th and then tripled to 34,025 mg·m^{-3} on August 30th; the average biomass of the 2016 sampling dates was 22,055 mg·m^{-3} (Figure 5-9).

The May 13th biomass assemblage in Little Weweeder Pond was similar to the density of the assemblage discussed above, with Chlorophytes and Bacillariophytes making up the entire community with 67 percent and 33 percent, respectively (Figure 5-10).

By August 30th, however, Chlorophytes (57 percent) still maintained a major portion of the community, while the Cyanophytes (19 percent) were considerably less important in terms of biomass (Figure 5-10). The August 30th biomass assemblage also included Bacillariophytes (11 percent), Euglenophytes (2 percent) and Pyrrhophytes (12 percent).

Figure 5-10. Biomass composition of the phytoplankton community in Little Weweeder Pond, 2016.



Dominance. A ranking of phytoplankton taxa dominance in Little Weweeder Pond on the 2016 sampling dates is summarized in Table 5-2. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 5-2. Rank of phytoplankton taxa dominance, using biomass, in Little Weweeder Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*Closterium* sp. (Chlorophyte)	1	57
	Tabellaria floccosa (Bacillariophyte)	2	25
	Stauroneis sp. (Bacillariophyte)	3	5
8/30/16	*Staurastrum natator* var. *crissum* (Chlorophyte)	1	48
	Anabaena flos aquae (Cyanophyte)	2	19
	Peridinium cinctum (Pyrrhophyte)	3	12
	Tabellaria floccosa (Bacillariophyte)	4	10

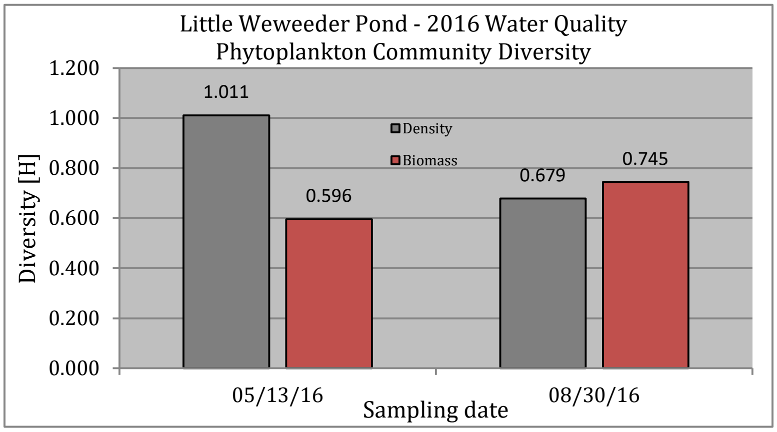
There were 3 dominant taxa in the phytoplankton community on May 13th and 4 dominant taxa in the community on August 30th (Table 5-2). As discussed above, the green algae and diatoms comprised a major portion of the community in May, and in late summer (August 30th), the greens, and Blue-greens were the major components of the community.

Diversity. Phytoplankton diversity in Little Weweeder 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 Little Weweeder Pond was calculated using both the community density and biomass in the equation. The results are presented in Figure 5-11, and highlight the differences that can occur when either density or biomass is used to perform the calculation. For example, the diversity [H] calculated using density was 1.011 on May 13th, whereas the diversity calculated using biomass on that date was 0.596. By August 30th, in contrast, the diversity [H] for both community parameters was similar with density at 0.679 and biomass at 0.745. The argument concerning which phytoplankton community variable is most important is purely philosophical in nature and has no impact other than to define the instantaneous community conditions from 2 different perspectives.

[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.

Figure 5-11. Phytoplankton community diversity in Little Weweeder Pond, 2016.



Cyanophytes. As a major phytoplankton group of aquatic ecosystem importance, the Cyanophytes were identified only in the August 2016 phytoplankton samples collected from Little Weweeder Pond. There were 4 species present on that date, including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, *Chroococcus imneticus* and *Wornichinia naegeliana*.

Three of these Cyanophyte genera, including *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 Little Weweeder Pond produce any algal toxins, recreational users of the pond should be aware that Cyanophytes (Blue-greens) are potential components of the summer phytoplankton community.

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Little Weweeder Pond were 23.4 $\mu g \cdot L^{-1}$ on May 13th and 16.7 $\mu g \cdot L^{-1}$ on August 30th, indicating a moderate level of algal productivity in the pond on both occasions. The average chlorophyll ***a*** concentration for both 2016 sampling dates was 20.05 $\mu g \cdot L^{-1}$.

In comparison to Little Weweeder Pond, chlorophyll ***a*** levels measured in Nantucket Island ponds during 2016 included an average of 6.1 $\mu g \cdot L^{-1}$ in *Tom Nevers Pond* during May and August and an average of 10.6 $\mu g \cdot L^{-1}$ in *Washing Pond* during May and August.

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.

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

There were sufficient TP and chlorophyll ***a*** data from Little Weweeder Pond during 2016 to calculate the Carlson Trophic State Index (TSI) using those 2 variables. Average values were calculated for chlorophyll ***a*** and total phosphorus 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 calculation and results of the analysis are as follows:

Chlorophyll *a*
Average chlorophyll *a* = 20.05 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (20.05)] + 30.6
TSI = (9.81)(3.00) + 30.6
TSI = 60.0

Total phosphorus
Average total phosphorus = 19.30 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (19.30)] + 4.15
TSI = (14.42)(2.96) + 4.15
TSI = 46.8

Table 5-3 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 5-3. Relationships among Trophic Index, chlorophyll *a*, total phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 value calculated for chlorophyll ***a*** (60.0) using the 2016 data, Little Weweeder Pond was well within the eutrophic region of productivity. With regard to total phosphorus, however, the pond was within the mesotrophic range of productivity during 2016.

5.2 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. During 2014, the Nantucket Land Council 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.

5.3 Literature Cited

Nantucket Island Ponds and 2016 Water Quality

Chapter 6

Maxcy Pond

6.0 Introduction

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

6.1 Results

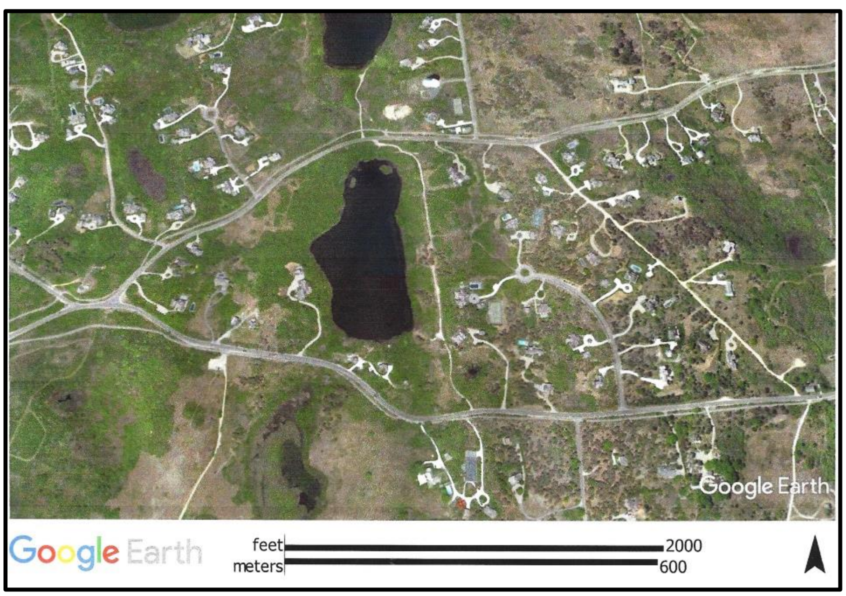
Maxcy Pond was sampled on May 19th and August 31st 2016. The maximum water depth located in the pond was 6.2 feet (1.9 meters) on May 19th at the sampling location in the approximate center of the pond. The maximum water depth located on August 31st was 5.0 feet (1.5 meters).

Following the collection of temperature and dissolved oxygen profile data on May 19th, an integrate sample was collected from the surface down to 4 feet of depth for the chemistry and phytoplankton samples. A grab sample was not collected since the pond was so shallow. The depth of integrate sample collection on August 31st also was from 0-4 feet of depth and there was no grab sample collected on this sampling date either.

6.1.1 Physical characteristics

General. Maxcy Pond has an irregular shape with a bulge along the western shoreline and its axis is oriented in a north-south direction (Figure 3.1). The surface area of the pond is estimated at about 10 acres. There are no permanent streams flowing into the pond, and there is no outlet located along the shoreline.

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.

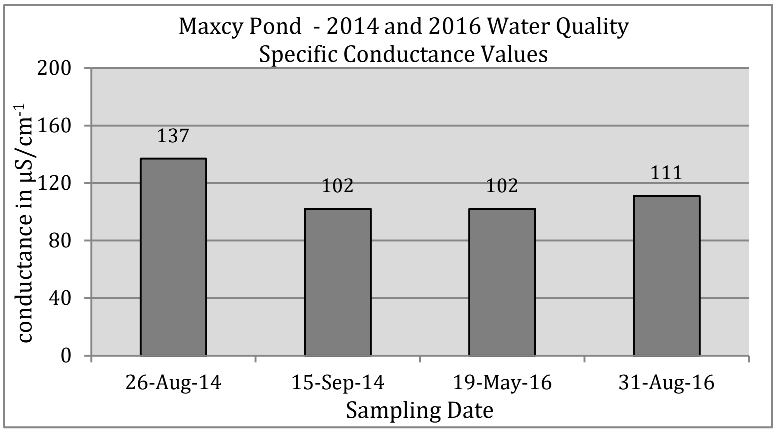
Temperature. Temperature profile data were collected on both 2016 sampling excursions to Maxcy Pond, and the temperature collected on both occasions essentially was isothermal from the surface to the bottom; the average temperature of the water column was 17.1°C on May 19th and 25.8 °C on August 31st.

Transparency. The Secchi depth transparency measured at Maxcy Pond was 'on the bottom' on both sampling dates which means that the pond had exceptional clarity and was not deep enough to measure the actual Secchi depth transparency. In addition, the water color was noted as 'clear' on both sampling dates by NLC staff sampling the pond.

6.1.2 Chemical characteristics

Specific conductance. The specific conductance measured at Maxcy Pond on May 19th was 102 $\mu S \cdot cm^{-1}$, while the value for the integrate sample collected on August 31st was 111 $\mu S \cdot cm^{-1}$. Figure 6-2 presents the specific conductance values measured at Maxcy Pond during 2014 and 2016.

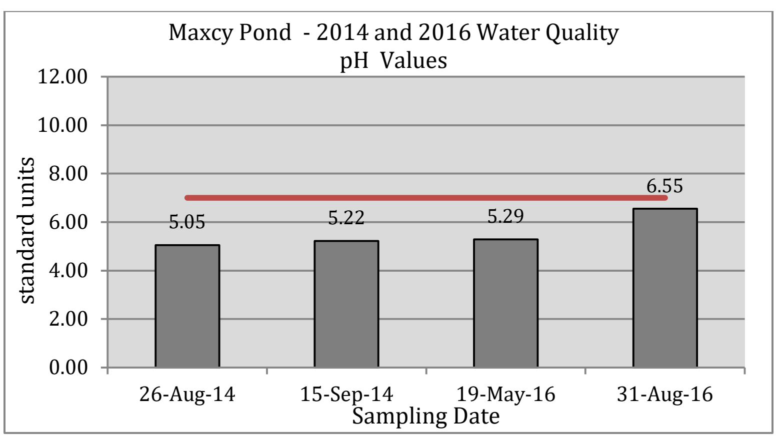
Figure 6-2 Specific conductance measured in Maxcy Pond, 2014 and 2016.



The results for the 2 years that Maxcy Pond has been sampled are low, but are within the range of specific conductance values expected in ponds considered to be fresh water.

pH. The pH measured at Maxcy Pond on May 19th was acidic at 5.29 s.u., and the value measured on August 31st was 6.55 s.u. All pH values measured at Maxcy Pond during 2014 and 2016 are shown in Figure 6-3.

Figure 6-3. pH measured in Maxcy Pond, 2014 and 2016.



The horizontal 'red' line shown on Figure 6-3 indicates the region along the pH scale that is considered 'neutral'. Low pH such as measured in Maxcy Pond on 3 of 4 occasions 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.

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 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 dissolved oxygen saturation values in Maxcy Pond during May and August 2016 were essentially the same from the surface of the pond down to the bottom and were not noteworthy for any particular reason. The data collected on May 19th revealed an average oxygen saturation value of 97.0 percent, while the average value measured on August 31st was 85.9 percent. Lower saturation would be expected during the height of mid-summer, and particularly during periods of low, or no, wind because organic matter settling toward the pond bottom would start to decompose and consume oxygen in the process.

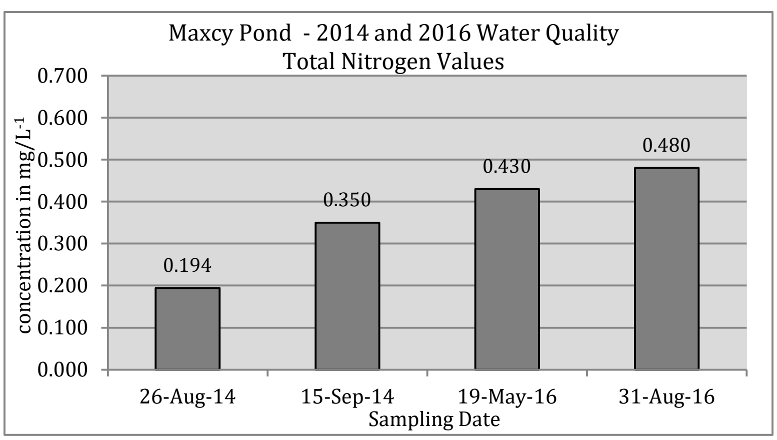
6.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was not detectable in Maxcy Pond on either 2016 sampling date. 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 in the water column. During 2014, there was nitrate-nitrogen present at 0.033 mg $N{\cdot}L^{-1}$ on August 26th, but the value was below detection (0.005 mg $N{\cdot}L^{-1}$) on September 15th.

There was no measureable **ammonia-nitrogen** in the water column on either 2016 sampling date. During 2014, the ammonia-nitrogen concentration was 0.010 mg $N{\cdot}L^{-1}$ on August 26th and below detection (0.005 mg $N{\cdot}L^{-1}$) on September 15th. As with nitrate-nitrogen, low levels of ammonia-nitrogen are not uncommon because this form of nitrogen is available for uptake by phytoplankton.

The 2016 **total nitrogen** (**TN**) concentrations measured in Maxcy Pond on May 19th and August 31st were 0.430 mg $N{\cdot}L^{-1}$ and 0.480 mg $N{\cdot}L^{-1}$, respectively, and were the highest concentrations recorded in the pond during the 2 years (2014 and 2016) that the pond was sampled (Figure 6-4).

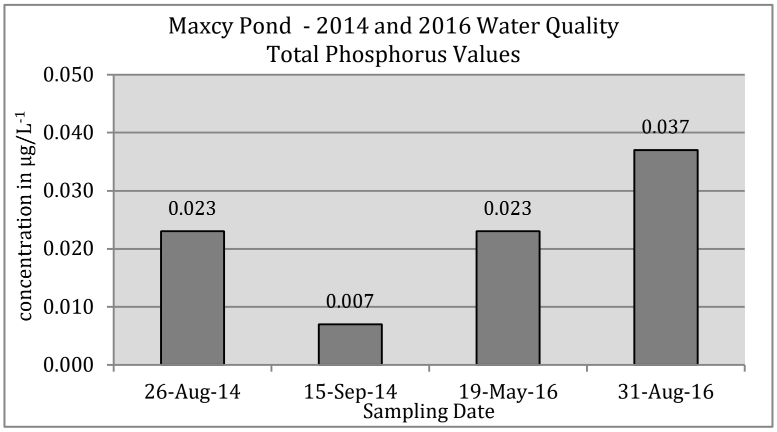
Figure 6-4. Total nitrogen concentrations measured in Maxcy Pond, 2014 and 2016.



The **TN** concentrations measured in the pond during 2014 were 0.194 mg $N{\cdot}L^{-1}$ on August 26th and 0.350 mg $N{\cdot}L^{-1}$ on September 15th, and are low concentrations when compared with other Nantucket Island ponds. The reader is referred to Chapter 9 of this report where there are several tables that compare the water quality characteristics of the 11 Nantucket Island ponds surveyed by the NLC since 2009.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Maxcy Pond during 2016 were 0.023 mg P·L^{-1} on May 19th and 0.037 mg P·L^{-1} on August 31st. As shown in Figure 6-5, the 2016 concentrations are similar to the range of concentrations measured during 2014.

Figure 6-5. Total phosphorus concentrations measured in Maxcy Pond, 2014 and 2016.



The concentrations of TP measured in Maxcy Pond during 2014 and 2016 reflect low productivity in the system and this situation is considered normal in dilute waters such as Maxcy Pond. Situations similar to this one occur in the Adirondack Mountain region of New York State where lakes and ponds have been impacted by acid deposition and often reflect low productivity in the water column.

6.1.4 Phytoplankton

Description of the assemblage. There were 23 taxa identified in the 2016 phytoplankton samples collected from Maxcy Pond and all of the major algal groups were represented in the samples (Table 6-1).

Table 6-1. Major groups and taxa of phytoplankton identified in Maxcy Pond, 2016.

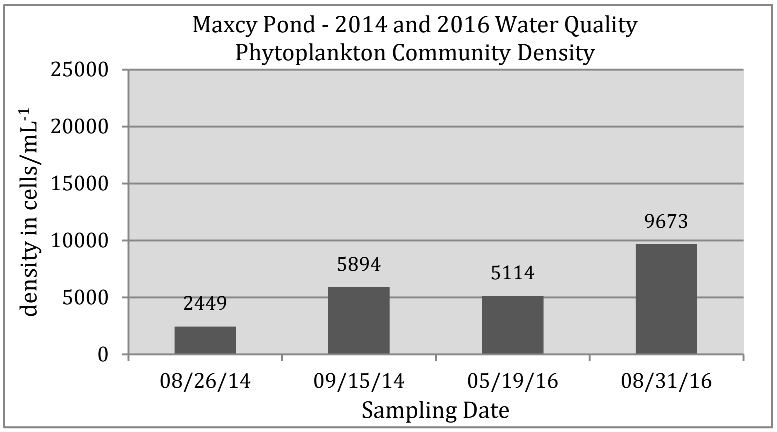
Cyanophytes	**Chrysophytes (Bacillariophyceae)**	**Chrysophytes (Chrysophyceae)**
Anabaena flos aquae	*Achnanthes* sp.	*Dinobyron divergens*
Chroococcus dispersus	*Cyclotella* sp.	*Ochromonas* sp.
Chlorophytes	*Cymbella* sp.	**Euglenophytes**
Ankistrodesmus falcatus	*Navicula* spp.	*Euglena* sp.
Closterium spp.	*Planothidium* sp.	*Peranema* sp.
Oocystis solitaria	*Rhoicosphenia curvata*	*Trachelomonas* sp.
Pandorina morum	*Stephanodiscus* sp.	**Pyrrhophytes (Cryptophytes)**
Scenedesmus bijuga	*Synedra acus*	*Cryptomonas erosa*
Tetraedron minimum		**Pyrrhophytes (Dinophytes)**
		Peridinium cinctum

There were 16 taxa identified in the pond's phytoplankton community on May 19th and 11 taxa on August 31st; community richness calculated for the 2016 sampling periods was 13.5 (±3.5) taxa.

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

Density. The 2016 phytoplankton community density in Maxcy Pond was 5,114 cells·mL^{-1} on May 19th and 9,673 cells·mL^{-1} on August 31st. The densities for 2014 and 2016 are shown in Figure 6-6. All of these 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.

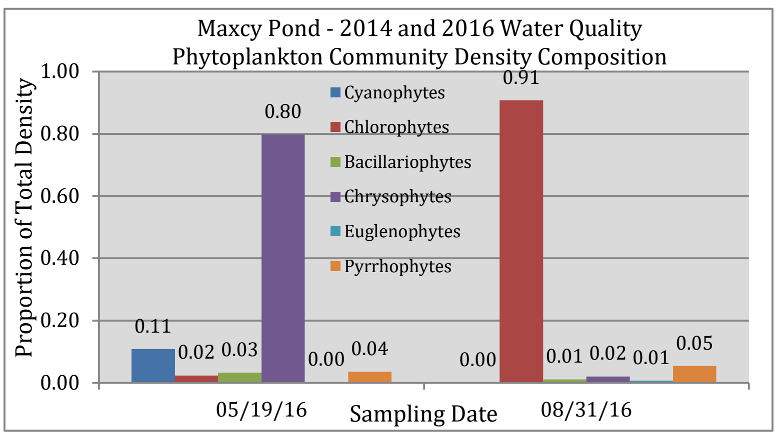
Figure 6-6. Phytoplankton community density in Maxcy Pond, 2014 and 2016.



The density composition of the 2016 phytoplankton assemblage in Maxcy Pond exhibited marked changes between the spring (May 19th) and late summer (August 31st) sampling periods (Figure 6-7).

The 2016 spring assemblage contained primarily Chrysophytes (80 percent), also known as 'golden' algae that have flagella, with lesser amounts of Cyanophytes (11 percent), Pyrrhophytes (4 percent), Bacillariophytes (3 percent), and Chlorophytes (2 percent).

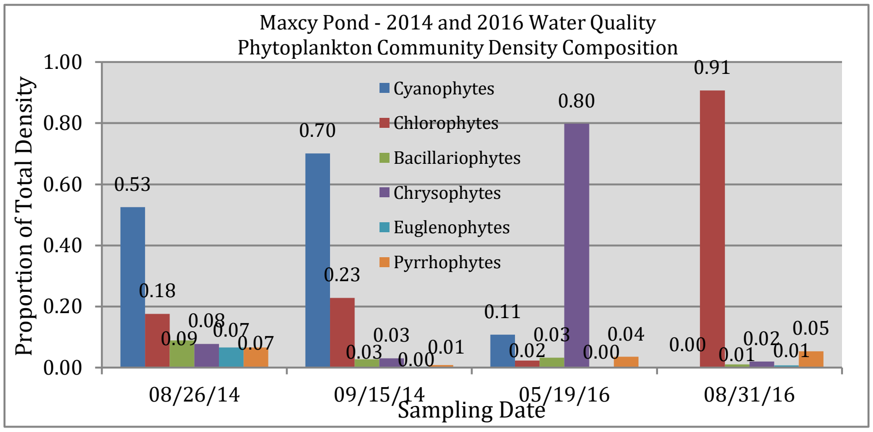
Figure 6-7. Density composition of the phytoplankton community in Maxcy Pond, 2016.



By August 31st, Chlorophytes comprised 91 percent of the phytoplankton community, with lesser amounts of Pyrrhophytes (5 percent), Chrysophytes (2 percent), Bacillariophytes (1 percent) and Euglenophytes (1 percent). There were no Cyanophytes (Blue-green algae) detected in the August assemblage.

The contrast between the community density composition in the 2014 and 2016 Maxcy Pond phytoplankton assemblages is immediately evident in Figure 6-8. During 2014, the major groups were Cyanophytes and Chlorophytes, with smaller contributions from the other major groups. During 2016, the Chrysophytes and Chlorophytes were principal components of the community assemblage, with smaller contributions from the other algal groups.

Figure 6-8. Density composition of the phytoplankton community in Maxcy Pond, 2014 and 2016.

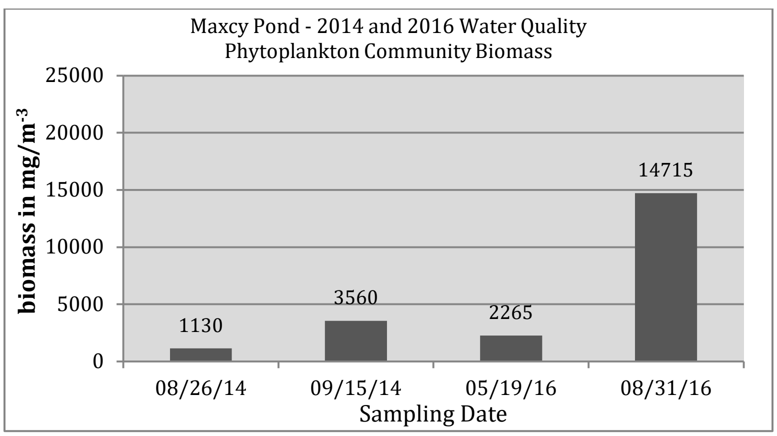


Biomass. Cell biovolume also was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond. It is quite common for size differences among different types of phytoplankton to range over several orders of magnitude.

The May 19th phytoplankton community biomass was low at 2,265 mg·m^{-3} and then increased about 7-fold to 14,715 mg·m^{-3} on August 31st.

When compared with the 2014 measured biomass values (Figure 6-9), the August 2016 concentration was the highest recorded for the pond during the 2 years of water quality survey.

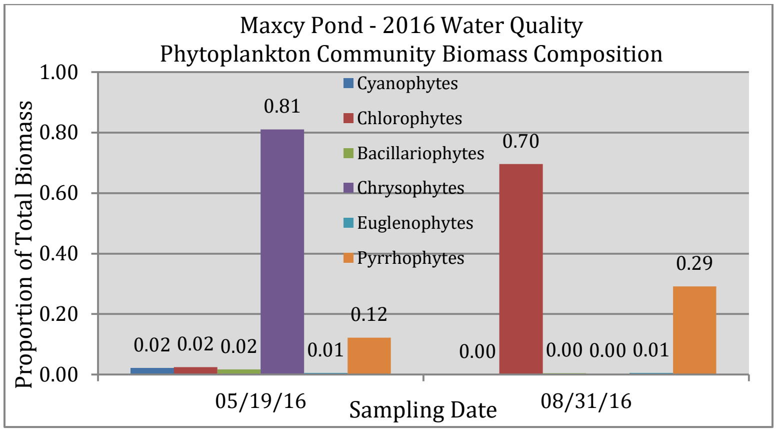
Figure 6-9. Phytoplankton community biomass in Maxcy Pond, 2014 and 2016.



The biomass composition of the 2016 phytoplankton community assemblage in Maxcy Pond (Figure 6-10) was very similar to the 2016 density composition described above, i.e., Chrysophytes dominated the community in May (81 percent) and Chlorophytes dominated the community in August (70 percent).

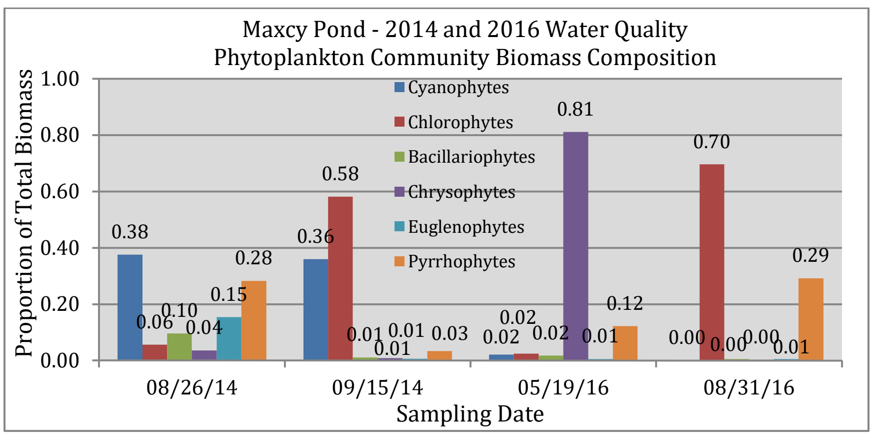
Another noteworthy change in the biomass composition during 2016 was the sizeable increase in Pyrrhophytes from 12 percent of the community composition in May to 29 percent of the community composition in August.

Figure 6-10. Biomass composition of the phytoplankton community in Maxcy Pond, 2016.



The 2014 and 2016 biomass composition of the Maxcy Pond phytoplankton communities is presented in Figure 6-11. From these data, it is evident that the communities were very different in composition. There do not appear to be any similarities between the two assemblages.

Figure 6-11. Biomass composition of the phytoplankton community in Maxcy Pond, 2014 and 2016.



Dominance. A ranking of phytoplankton taxa dominance in Maxcy Pond on the 2016 sampling dates is summarized in Table 6-2. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 6-2 Rank of phytoplankton taxa dominance, using biomass, in Maxcy Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/19/16	*Ochromonas* sp. (Chrysophyte)	1	81
	Peridinium cinctum (Pyrrhophyte)	2	8
	Cryptomonas erosa (Pyhhhophyte)	3	5
8/31/16	*Pandorina morum* (Chlorophyte)	1	69
	Peridinium cinctum (Pyrrhophyte)	2	29

There were 3 dominant taxa in the phytoplankton community on May 19th and 2 dominant taxa in the community on August 31st (Table 6-2). As discussed above, the Chrysophytes dominated the community in May and, in August, the Chlorophytes and Pyrrhophytes were the major components of the community.

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. The results of the diversity calculations are presented in Table 6-3.

Table 6-3. Phytoplankton community diversity in Maxcy Pond, 2014 and 2016.

Maxcy Pond Sampling Date	Phyto Density Diversity Value	Phyto Biomass Diversity Value
Aug 26th 2014	1.058	0.83
Sept 15th 2014	0.886	0.740
May 19th 2016	0.393	0.320
August 31st 2016	0.358	0.330

The diversity calculations were very similar on each sampling date, regardless of whether density or biomass was used to evaluate this community characteristic (Table 3-3). 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. Any time there is a big decrease in community diversity, it means that a greater proportion of the community resides with fewer individuals instead of more individuals.

Cyanophytes. As a major phytoplankton group of aquatic ecosystem importance, the Cyanophytes were identified in certain samples collected during 2014 and 2016; Table 6-4 identifies which species were identified on the various 2014 and 2016 sampling dates and their percent contribution to the community.

Table 6-4. Cyanophyte species identified in Maxcy Pond, 2014 and 2016.

Species	Aug 26th 2014	Sept 15th 2014	May 19th 2016	August 31th 2016
*Anabaena flos aquae**	yes (32%)	no	no	no
*Anabaenopsis Elenkinii**	yes (9%)	yes (3%)	no	no
*Aphanizomenon flos aquae**	no	yes (67%)	yes (3%)	no
Chroococcus dispersus	yes (2%)	no	yes (8%)	no
Microcystis aeruginosa	yes (10%)	no	no	no
'yes' = present, 'no' = absent; (##) proportion of community 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 of these 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.

[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.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Maxcy Pond were 5.70 $\mu g \cdot L^{-1}$ on May 19th and 8.10 $\mu g \cdot L^{-1}$ on August 31st, indicating a low–to-moderate level of algal productivity in the pond on both occasions. The 2014 chlorophyll a levels in Maxcy Pond were even lower, 2.39 $\mu g \cdot L^{-1}$ on August 26th and 3.11 $\mu g \cdot L^{-1}$ on September 15th.

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 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 a valid Secchi depth reading on either sampling date, there were sufficient TP and chlorophyll ***a*** data from Maxcy Pond during 2016 to calculate the Carlson Trophic State Index (TSI) using those 2 variables. Average values were calculated for chlorophyll ***a*** and total phosphorus 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 calculation and results of the analysis are as follows:

Chlorophyll *a*
Average chlorophyll *a* = 6.90 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (6.90)] + 30.6
TSI = (9.81)(1.932) + 30.6
TSI = 49.5

Total phosphorus
Average total phosphorus = 29.95 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (29.95)] + 4.15
TSI = (14.42)(3.400) + 4.15
TSI = 52.3

Table 6-5 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 6-5. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 the 2016 data, Maxcy Pond was at the high end of the mesotrophic range of productivity based upon the 2016 chlorophyll a values measured. The slight increase in 2016 TP values detected in Maxcy Pond between 2014 and 2016 placed the pond at the low end of the eutrophic range of productivity during the current round of sampling.

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

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 2016 Water Quality

Chapter 7

Washing Pond

7.0 Introduction

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

7.1 Results

Washing Pond was sampled on May 19th and August 31st 2016. The maximum water depth located in the pond was 14.5 feet (4.4 m) on May 19th at a sampling location in the approximate center of the pond; the maximum water depth located on August 31st was 15.3 feet (4.7 m).

Following the collection of temperature and dissolved oxygen profile data on May 19th, an integrate sample was collected from the surface down to 10 feet of depth for the chemistry and phytoplankton samples; a grab sample was collected at the 13-foot depth for water chemistry. The depth of collection on August 31st was 0-6 feet for the integrate sample; no grab sample was collected from the deeper portion of the water column.

7.1.1 Physical characteristics

General. Washing Pond is rectangular in shape with a middle bugle giving it the appearance of an ellipse with its axis oriented in a north-south direction (Figure 7-1). The surface area of the pond is about 8 acres. There are no permanent streams flowing into the pond, and there is no outlet located along the shoreline.

Figure 7-1. 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.

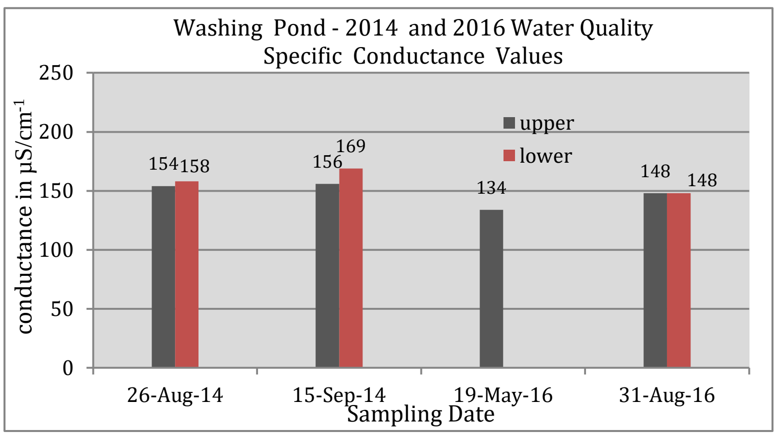
Temperature. Temperature profile data were collected on both 2016 sampling excursions to Washing Pond. The profile data essentially were isothermal on both occasions with only about 1°C difference between the surface and bottom temperatures. The average temperature of the pond was 16.5°C on May 19th and 25.5°C on August 31st.

Transparency. The 2016 Secchi depth transparency measured at Washing Pond was 3.5 m on May 19th and 1.3 m on August 31st. Water color on May 19th was recorded as 'clear', which accounts for the high Secchi depth recorded and indicates that there was no algal bloom in progress. Water color was recorded as 'clear-green brown' on May 19th which could be an indication of an algal bloom in progress and explains the lower transparency reading.

7.1.2 Chemical characteristics

Specific conductance. The 2016 specific conductance values measured in Washing Pond were 134 $\mu S \cdot cm^{-1}$ in the ***upper*** region on May 19th and 148 $\mu S \cdot cm^{-1}$ in the ***upper*** region on August 31st. There was sufficient oxygen percent stratification on August 31st to collect a ***lower*** region sample and conductance was the same as the ***upper*** region sample on that date, 148 $\mu S \cdot cm^{-1}$. Figure 7-2 presents the conductance values measured at Washing Pond during 2014 and 2016 when the pond was monitored.

Figure 7-2. Specific conductance measured in Washing Pond, 2014 and 2016.



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. There is nothing noteworthy to report concerning the pH values collected from Washing Pond during 2016 when the upper region of the pond exhibited a pH of 5.99 s.u. on May 19th and the measured values for the upper and lower regions were 7.53 s.u. and 7.14 s.u. on August 31st, respectively. In addition, all of the 2014 pH values essentially were within the range of 6.00 to 7.00 and none of these values indicate anything unusual occurring in the pond.

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 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.

On May 19th, oxygen saturation values decreased from 96.0 percent at the surface down to 90.7 percent at 14 feet; subsequently, the values dropped to 0.2 percent at 15 feet and 1.3 percent at 16 feet. The August 31st profile showed a more gradual decline through the water column on August 31st, with about 93 percent saturation at the pond surface, then a gradual decrease to 76.2 percent at 13 feet and 2.6 percent at 14 feet.

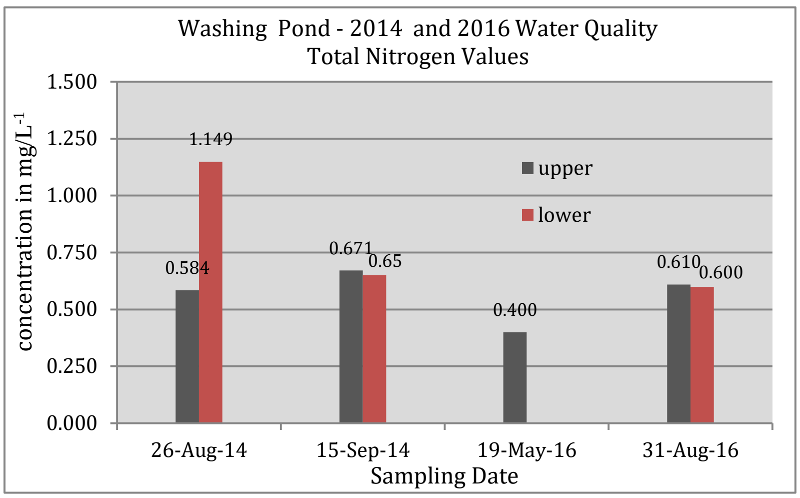
The conditions on May 19th suggest that the pond was in the process of mixing throughout the water column while there was little or no wind to promote mixing of the water column on August 31st which explains the gradual decrease of percent saturation with depth. Calm conditions can result in an oxygen saturation deficit in the lower regions due to the decomposition of organic matter in this region.

7.1.3 Plant Nutrients

Nitrogen. **Nitrate-nitrogen** was not detected on either 2016 date in samples collected from the *upper* and *lower* regions of the pond. The same situation was observed for **ammonia nitrogen** in the water column on both 2016 sampling dates. While both of these nutrients were measured in low (detectable) concentrations in Washing Pond during 2014, none of the measurements were noteworthy for any particular reason.

The **total nitrogen** (**TN**) measured in Washing Pond during 2016 was 0.400 mg N/L^{-1} in the integrate sample collected on May 19th and 0.610 and 0.590 mg N/L^{-1} in samples collected from the upper and lower regions of the pond on August 31st. The 2014 and 2016 **TN** concentrations are shown in Figure 7-3.

Figure 7-3. Total nitrogen concentrations measured in Washing Pond, 2014 and 2016.



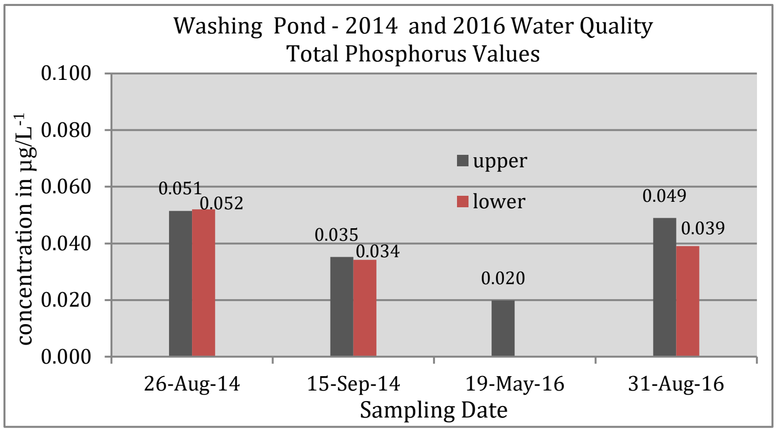
All of the TN concentrations measured in Washing Pond during 2014 and 2016 are within the range expected in a body of water that exhibits moderate productivity, except perhaps the value of 1.050 mg N/L^{-1} which occurred on August 26th 2014 and could be an outlier. Based upon the dissolved oxygen profile 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.

However, the total phosphorus (**TP**) data collected from Washing Pond on August 26th (see below) do not support the same internal loading scenario described here for **TN**, perhaps because **TP** generally is less available in fresh water lakes and ponds and would be more readily taken up by phytoplankton when available in the water column.

The **TN** concentrations measured in Washing Pond during 2014 and 2016 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 9 of this report for a comparison of water quality paramters for the suite of 11 Island ponds that have been surveyed during the past 8 years.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Washing Pond during 2016 were 0.020 µg P·L^{-1} on May 19th in the *upper* region and 0.039 and 0.049 µg P·L^{-1} on August 31st in the *upper* and *lower* region, respectively. The collective TP values for 2014 and 2016 are shown in Figure 7-4.

Figure 7-4. Total phosphorus concentrations measured in Washing Pond, 2014 and 2016.



The TP value of 0.020 µg P·L^{-1} measured on May 19th was the lowest value recorded in the pond during the 2 years of data collection. All of the TP values are within the range of concentrations for a body of water with moderate productivity.

7.1.4 Phytoplankton

Description of the assemblage. A total of 38 taxa were identified in the 2016 phytoplankton samples collected from Washing Pond and all of the major groups were represented in samples collected from Washing Pond and all of the major algal groups were represented in the samples (Table 7-1).

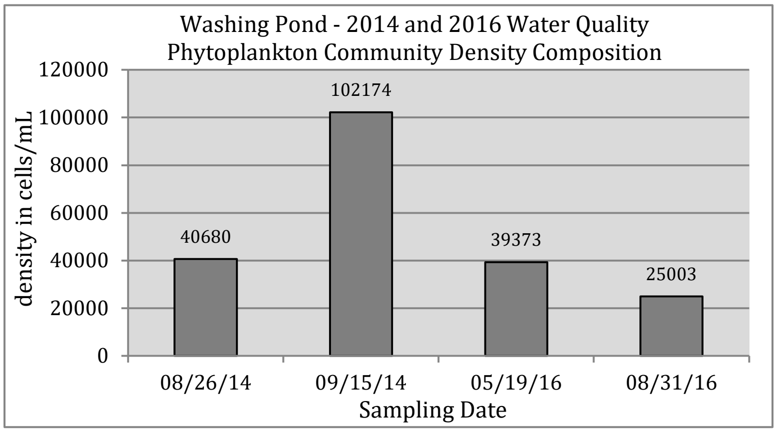
Table 7-1. Major groups and taxa of phytoplankton identified in Washing Pond, 2016.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Schroederia Judayi*	*Planothidium* sp.
Chroococcus dispersus	*S. tetraedon*	*Rhoicosphenia curvata*
Gomphosphaeria lacustris compacta	*Selanastrum capricornutum*	*Stephanodiscus* sp.
Woronichinia naegeliana	*S. minutum*	*Synedra acus*
Chlorophytes	*Sphaerocystis Schroeteri*	*Tabellaria floccosa*
Ankistrodesmus falcatus	*Staurastrum natator* var. *crassum*	**Chrysophytes (Chrysophyceae)**
Closterium acutum	*Tetraedron minimum*	*Dinobyron divergens*
Closterium gracile	*Volvex aureus*	*Mallomonas* sp.
Eudorina elegans	**Chrysophytes (Bacillariophyceae)**	**Euglenophytes**
Mougeotia sp.	*Aulacoseria granulata*	*Trachelomonas* sp.
Oocystis Borgei	*Asterionella formosa*	**Pyrrhophytes (Cryptophytes)**
O. pusilla	*Cocconeis* sp.	*Cryptomonas ovata*
Pandorina morum	*Cyclotella* sp.	**Pyrrhophytes (Dinophytes)**
Quadrigula lacustris	*Gyrosigma* sp.	*Ceratium hirundinella*
Scenedesmus quadricauda	*Navicula* spp.	

There were 24 taxa identified in the pond's phytoplankton community on May 19th and 27 taxa identified in the community on August 31st; 2016 community richness was calculated to be 25.5 (±2.1) taxa.

Density. Community density in Washing Pond was 39,373 cells·mL^{-1} on May 19th and 25,003 cells·mL^{-1} on August 31st 2016. The 2014 and 2016 community densities are shown in Figure 7-5.

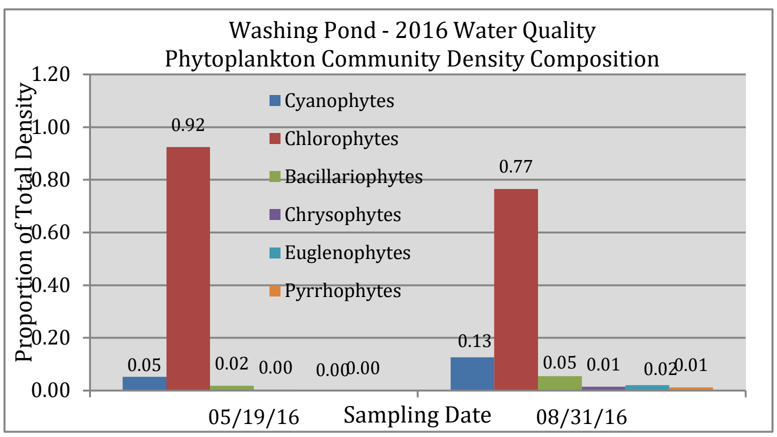
Figure 7-5. Phytoplankton community density in Washing Pond, 2014 and 2016.



The September 15th 2014 density is extremely high when compared with the other density values and there likely was a bloom in progress in the pond at that time.

The May and August density composition of the pond phytoplankton community were almost identical (Figure 7-6), with Chlorophytes the dominant group (92 percent and 77 percent, respectively) followed by Cyanophytes (Blue-greens) as the next largest group with 5 percent in May and 13 percent in August.

Figure 7-6. Density composition of the phytoplankton community in Washing Pond, 2016.

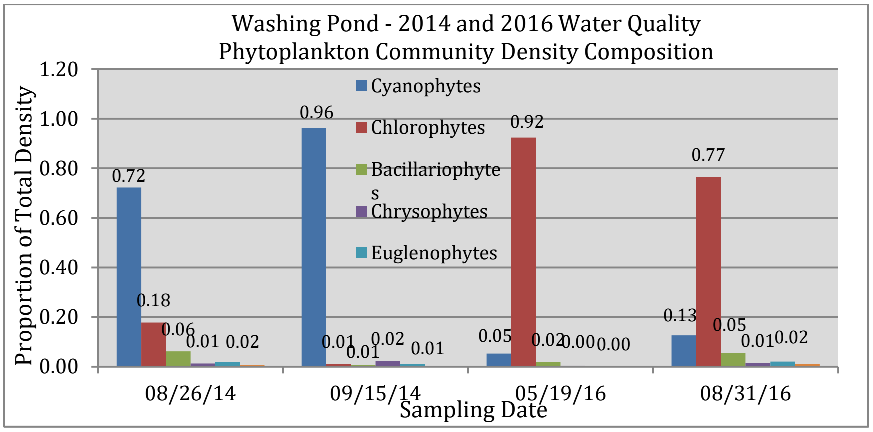


The diatoms (Bacillariophytes) were the only other major phytoplankton group present in May, while the August assemblage was represented by all 6 major groups,

The density composition of the phytoplankton community in 2014 and 2016 is shown in Figure 7-7. There was a dramatic change in the community structure when viewing the relative composition during these 2 years.

Cyanophytes were the dominant group during both 2014 sampling dates, exhibiting 72 percent and 96 percent of the community on August 26th and September 15th, respectively, and Chlorophytes dominated the community during both dates in 2016.

Figure 7-7. Density composition of the phytoplankton community in Washing Pond, 2014 and 2016.

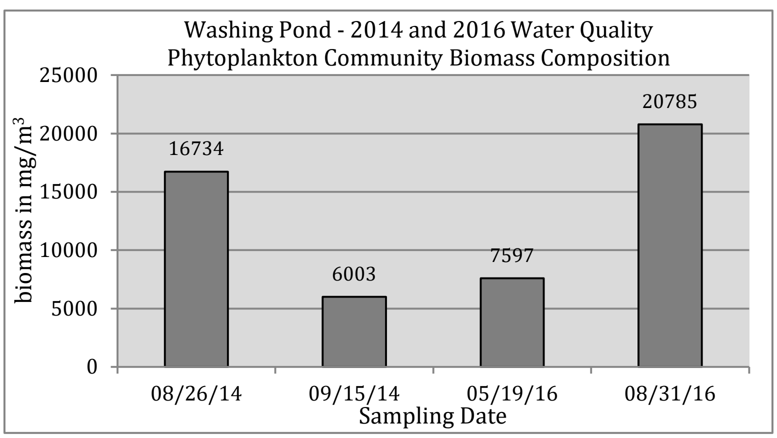


Data such as these from Washing Pond emphasize the importance of monitoring a body of water for several years instead of just one year when some interpretation of water quality is desired because some of the pond characteristics can change as exhibited by the phytoplankton community in Washing Pond.

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 documented in Washing Pond during May and August 2016 was measured at 7,597 mg/m^{-3} and 20,785 mg/m^{-3}, respectively, and averaged 14,191 mg/m^{-3}. These values are similar to the 2014 biomass values which are summarized in Figure 7-8 along with the 2016 data.

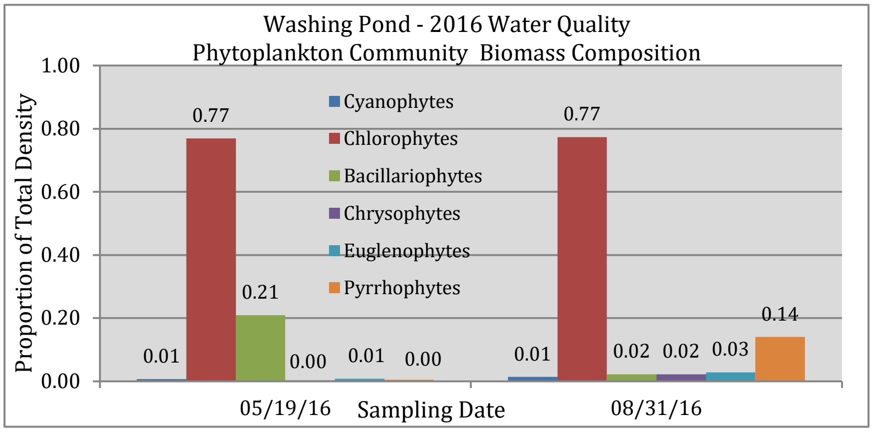
Figure 7-8. Phytoplankton community biomass in Washing Pond, 2014 and 2016.



The biomass in Washing Pond was 16,734 mg·m^{-3} on August 26th 2014 and 6003 mg·m^{-3} on September 15th 2014, and averaged 11,369 mg·m^{-3} for both 2014 sampling dates (Figure 7-8).

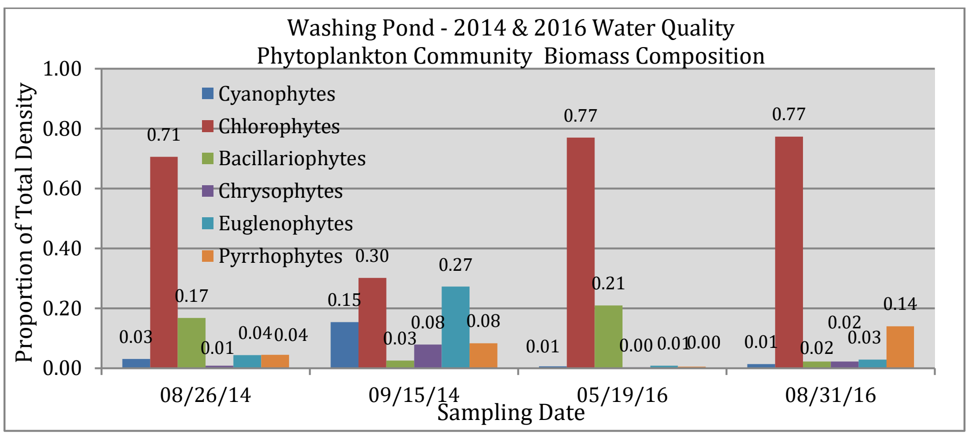
As shown in Figure 7-9, the May and August 2016 phytoplankton community compositions were very similar, with Chlorophytes comprising 77 percent of the total biomass on both dates. The Bacillariophytes (diatoms) were the next most important group on May 19th (21 percent) and Pyrrhophytes held that second ranking position on August 31st (14 percent).

Figure 7-9. Biomass composition of the phytoplankton community in Washing Pond, 2016.



The community biomass values measured in Washing Pond during 2014 and 2016 are presented in Figure 7-10 and show the differences that can occur when interpreting community structure using density or biomass.

Figure 7-10. Biomass composition of the phytoplankton community in Washing Pond, 2014 and 2016.



Based upon biomass, Chlorophytes clearly are the most important community group in Washing Pond during 2014 and 2016; September 15 2014 was the only time that Chlorophytes (30 percent) shared community dominance with another group, the Euglenophytes (27 percent).

Referring back to Figure 7-7 which presents density composition in Washing Pond during 2014 and 2016, we see that Cyanophyes were the density dominants and the Chlorophytes were greatly reduced in terms of community importance.

Dominance. A ranking of phytoplankton taxa dominance in Washing Pond on the 2016 sampling dates is summarized in Table 7-2. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

There were 4 dominant taxa in the phytoplankton community on May 19th and 3 dominant taxa in the community on August 31st (Table 7-2). As discussed above, the green algae (Chlorophytes) comprised a major portion of the community on both 2016 sampling dates.

The reader is referred to Sutherland and MacKinnon (2015) for a summary of the dominant biomass taxa identified in Washing Pond during 2014.

Table 7-2. Rank of phytoplankton taxa dominance, using biomass, in Washing Pond during 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/19/16	*Closteriumacutum* (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

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 7-3.

Table 7-3. Phytoplankotn community diversity in Washing Pond, 2014 and 2016.

Washing Pond Sampling Date	Phyto Density Diversity Value	Phyto Biomass Diversity Value
Aug 26th 2014	0.871	0.892
Sept 15th 2014	0.181	0.963
May 19th 2016	0.301	0.777
August 31st 2016	0.628	0.619

As discussed above with regard to the comparison between density and biomass, the choice of variable can greatly affect the character of the community because of extremely large size (biomass) differences among different species of phytoplankton, whereas numbers of individuals (density) is a relative variable.

For example, on September 15th 2014, diversity based upon biomass was high, with a value of 0.963 (1.00 is the highest diversity value), which suggests a balance in size among the community taxa. In contrast, diversity based upon density on that date was 0.181, which indicates that most of the community density resided with a single species, which was the case (*Microcystis aeruginosa*, 92 percent).

Cyanophytes. As a major phytoplankton group, the Cyanophytes were identified in both the May and August 2016 samples collected in Washing Pond. A total of 4 taxa were identified during 2016 and are listed in Table 7-4 along with the species of Cyanophytes identified in the 2014 samples collected from Washing Pond.

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.

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

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

Table 7-4. Cyanophyte species identified in Washing Pond, 2014 and 2016.

Species	Aug 26th 2014	Sept 15th 2014	May 19th 2016	August 31th 2016
*Anabaena flos aquae**	no	no	no	yes (3%)
Aphanizomenon flos aquae	yes (2%)	yes (2%)	no	no
Chroococcus dispersus	yes (1%)	no	no	yes (2%)
C. limneticus	yes (<1%)	no	no	no
Gomphosphaeria lacustris compacta	yes (8%)	no	yes (<1%)	no
Microcystis aeruginosa	yes (49%)	yes (92%)	no	no
*Woronichinia naegeliana**	yes (11%)	yes (2%)	yes (5%)	yes (8%)
'yes' = present, 'no' = absent; (##) proportion of community on a sampling date * Species that are known to produce algal toxins				

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Washing Pond were 2.1 $\mu g \cdot L^{-1}$ on May 19th and 24.6 $\mu g \cdot L^{-1}$ on August 31st. 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. The 2014 chlorophyll ***a*** readings were 5.0 and 10.9 $\mu g \cdot L^{-1}$ on August 26th and September 15th, respectively.

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.

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 May 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* = 13.35 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (13.35)] + 30.6
TSI = (9.81)(2.59) + 30.6
TSI = 56.0

Total phosphorus
Average total phosphorus = 34.45 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (34.45)] + 4.15
TSI = (14.42)(3.54) + 4.15
TSI = 55.2

Secchi depth
Average Secchi depth = 2.40 m
Secchi TSI = 60 – [14.41*[ln (2.40)]
TSI = 60 – (14.41)(0.88)
TSI = 47.4

The TSI of 56.0 calculated for chlorophyll ***a*** was within the eutrophic range of productivity (see Table 7-5), which also was the case for the TSI calculated for total phosphorus (55.2). The average 2016 Secchi depth (2.4 m) resulted in a calculated TSI value of 47.4, at the high end of the mesotrophic range of productivity.

Table 7-5. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 and 2016, we see that there was a slight change in water quality of Washing Pond between those 2 years (Table 7-6).

Table 7-6. Trophic State Indices (TSIs) calculated for Washing Pond in 2014 and 2016.

Year	Chlorophyll TSI	TP TSI	Secchi TSI
2014	50.9	58.5	52.6
2016	56.0	55.2	47.4

The chlorophyll ***a*** TSI increased between the 2 years (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

7.2 Summary

Based upon the data collected during 2016, 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 whenthe pond surface is exposed to sustained winds blowing across the Island.

7.3 Literature Cited

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 Nantucket Land Council, Inc. 43 pp.

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Nantucket Island Ponds and 2016 Water Quality

Chapter 8

North Head of Long Pond

8.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from the North Head of Long Pond by the Nantucket Land Council, Inc. during 2016.

8.1 Results

North Head of Long Pond was sampled on May 13th and August 31th 2016. The maximum water depth recorded was 4.7 feet (1.4 m) on May 13th and 4.6 feet (1.4 m) on August 31st at the sampling location in the approximate center of the pond.

Following the collection of Secchi depth transparency, and temperature and dissolved oxygen profile data, integrate samples were collected from the surface down to 4 feet on May 13th and 3 feet on August 31st for the water chemistry and phytoplankton samples. No additional water samples were collected on either sampling date. Observations recorded while the pond was being sampled included a lack of attached (rooted) vegetation growing on the bottom of the pond.

8.1.1 Physical characteristics

General. North Head of Long Pond is located in an area known as Dionis, north of Madaket Road and south of Eel Point Road, adjacent to the Town of Nantucket landfill. The pond is separated from the main body of Long Pond by a causeway which serves as the Madaket Road crossing (Figure 8-1). The surface area of the pond is about 42 acres and the maximum depth is 4-5 feet at the center of the pond.

Figure 8-1. Aerial view of North Head of Long Pond (from *Google*™ earth).

Much of the pond is surrounded by property owned by the Linda Loring Nature Foundation, and permanently protected with a Conservation Restriction held by the Nantucket Land Council. The pond receives input from ground water, precipitation and surface runoff from the relatively small surrounding watershed. The main body of Long Pond is connected to Hither Creek via the Madaket Ditch which may affect salinity.

Temperature. Temperature profile data were collected during both 2016 sampling excursions. The May 13th temperature was isothermal from surface to bottom at 17.4°C. On August 31st, there was a slight variation in temperature of the water column and the average temperature was 24.6°C.

Transparency. The Secchi depth transparency measured at the North Head of Long Pond on May 13th was 2.2 feet (0.7 m) and the reading on August 31st was 2.8 feet (0.9 m). Water color observations recorded when the pond was sampled were 'clear > brown' on August 31st.

8.1.2 Chemical characteristics

Specific conductance. All 2016 conductance values were similar and noticeably high 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 reading on May 13th was 14.3 mS/cm^{-1} and the reading on August 31st was 23.2 mS/cm^{-1}.

pH. pH values were 6.65 s.u. on May 13th and 6.83 s.u. on August 31st; there is nothing noteworthy about the pH values recorded at the North Head of Long Pond during 2016.

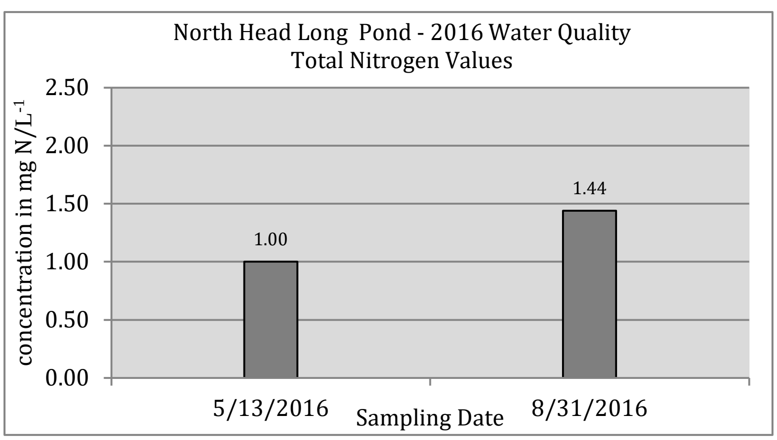
Dissolved oxygen percent saturation. The average oxygen saturation values for the pond were 95.4 percent on May 13th and 76.4 percent on August 31st. There was a slight percent saturation gradient with increasing water depth on the latter date which suggests that the pond experienced a period when wind was not blowing by a sufficient amount to mix the pond from surface to bottom that allowed the gradient to develop.

8.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was not detectable in the pond on either 2016 sampling date which is not unusual since this form of nitrogen is taken up by phytoplankton during the process of photosynthesis. There was only a slight amount (0.030 mg $N \cdot L^{-1}$) of **ammonia-nitrogen** measured on May 13th and no detectable amount of **ammonia-nitrogen** on August 31st; this compound also is taken up by phytoplankton in the water column for productivity during the growing season.

On May 13, the **total nitrogen (TN)** concentration (Figure 8-2) measured in the pond was 1.00 mg $N \cdot L^{-1}$, which is a reasonable spring value when water temperatures are rising and productivity is increasing in the pond. By August 31st, the **TN** value had increased to 1.44 mg $N \cdot L^{-1}$ which is a value indicative of moderate productivity in this pond.

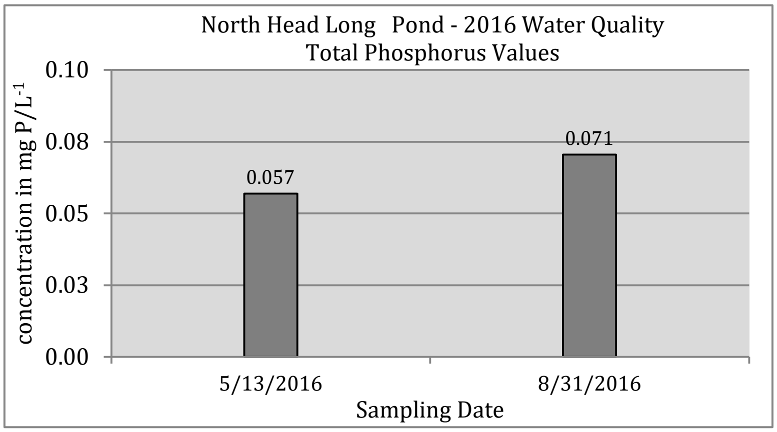
Figure 8-2. Total nitrogen concentrations measured in North Head of Long Pond, 2016.



Based upon the low **nitrate-nitrogen** and **ammonia-nitrogen** values recorded, virtually all of the nitrogen measured in North Head of Long Pond during 2016 was tied up in organic material, i.e., phytoplankton and other organisms in the water column.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in North Head of Long Pond were 0.057 mg $P \cdot L^{-1}$ and 0.071 mg $P \cdot L^{-1}$ on May 13th and August 31st, respectively (Figure 8-3).

Figure 8-3. Total phosphorus concentrations measured in North Head of Long Pond, 2016.



These **TP** concentrations are slightly elevated and indicate a moderate level of productivity in the pond, which also is substantiated by the chlorophyll ***a*** concentrations measured during 2016 (see below).

The reader is referred to Chapter 9 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.

8.1.4 Phytoplankton

Description of the assemblage. A total of 23 taxa were identified in the 2016 May and August phytoplankton samples collected from North Head of Long Pond (Table 8-1).

Table 8-1. Major groups and taxa of phytoplankton identified in Noth Head Long Pond, 2016.

Chlorophyta	**Chrysophyta (Bacillariophyta)**	**Chrysophyta (Bacillariophyta)**
Monoraphidium arcuatum	*Cocconeis* sp.	*Synedra acus*
Pediastrum duplex	*Cyclotella* sp	*S. ulna*
Pyramimonas tetrarhyncus	*Cymbella* sp.	*Tabellaria floccosa*
Scenedesmus bijuga	*Gomphonema* sp.	**Chrysophyta (Chrysophyceae)**
Schroederia Judayi	*Navicula* spp.	*Ochromonas* sp.
Chrysophyta (Bacillariophyta)	*Nitzschia* sp.	**Euglenophyta**
Achnanthese sp.	*Planothidium* sp.	*Peranema* sp.
Amphora sp.	*Stephanodiscus* sp.	*Trachelomonas* sp.
Aulocoseria granulata		

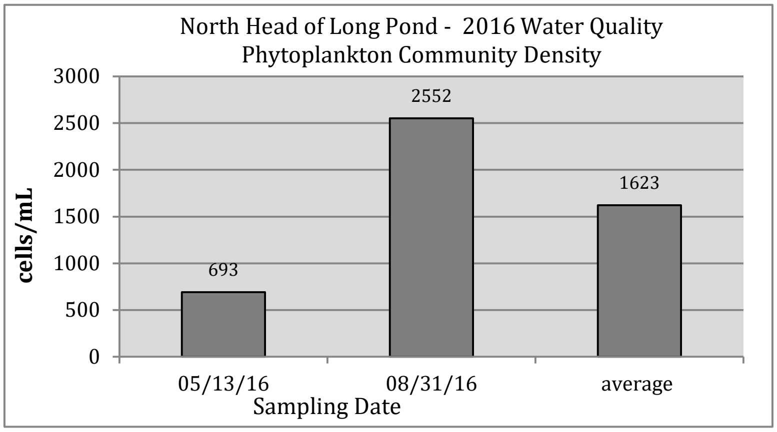
These data are noteworthy; this is the smallest assemblage of phytoplankton recorded for Nantucket island ponds since NLC surveys were first conducted starting in 2009. There were 14 taxa in the May assemblage and 16 taxa in the August assemblage.

Community richness for the 2016 phytoplankton samples collected from North Head of Long Pond was calculated to be 15.0 ± 1.4 taxa.

Also noteworthy is the observation that there were no Cyanophytes (Blue-green algae) observed in either of the 2016 phytoplankton samples collected from the pond.

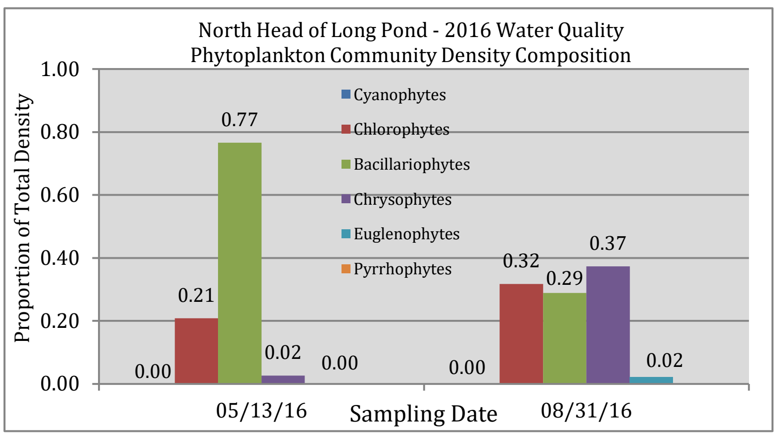
Density. Phytoplankton community density in the pond was 693 cells$\cdot mL^{-1}$ on May 13th and 2,552 cells$\cdot mL^{-1}$ on August 31st (Figure 8-4). Both of these recorded densities are low and indicate of a relatively diminished phytoplankton community in this body of water.

Figure 8-4. Phytoplankton community density in North Head of Long Pond, 2016.



The May 13th phytoplankton assemblage (Figure 8-5) was comprised primarily of Bacillariophytes (diatoms) with 77 percent of the total density and Chlorophytes (green algae) with 21 percent of the density; the remainder of the community consisted of Chrysophytes (2 percent). Cyanophytes, Euglenophytes and Pyrrhophytes were not identified in the May assemblage.

Figure 8-5. Density composition of the phytoplankton community in North Head of Long Pond, 2016.



By August 31st, the phytoplankton assemblage had become more diversified. There were about equal proportions of Chlorophytes (32 percent), Bacillariophytes (29 percent) and Chrysophytes (37 percent) in the community, with Euglenophytes (2 percent) the only other major group represented (Figure 8-5).

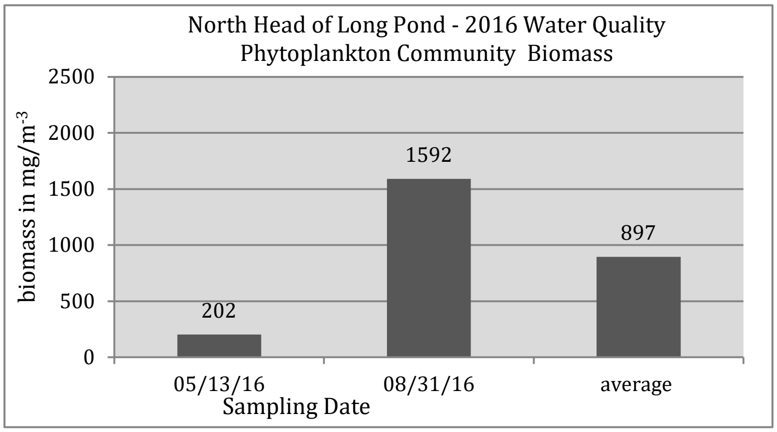
Biomass. Cell biovolume also was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond.

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 was mentioned above with regard to community density, the phytoplankton community biomass measured in North Head of Long Pond during 2016 also was low, with 202 mg·m^{-3} and 1,592 mg·m^{-3} measured May 13th and August 31st, respectively; the average 2016 community biomass was 897 mg·m^{-3}

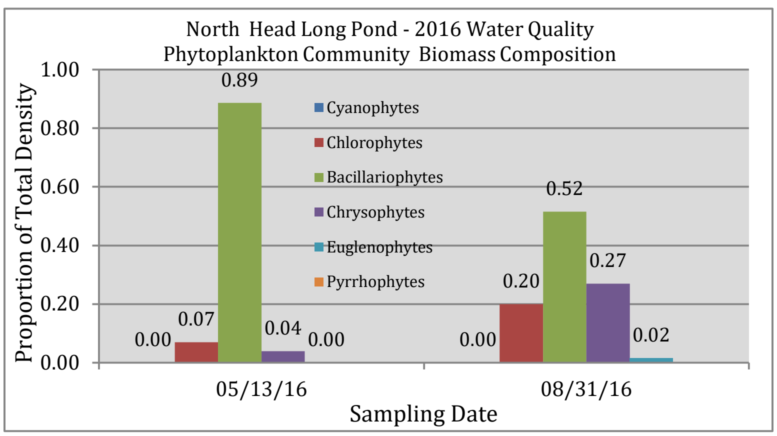
(Figure 8-6). The May 2016 biomass is noteworthy because it is the lowest biomas value recorded from Nantucket Island ponds since surveys began 8 years ago.

Figure 8-6. Phytoplankton community biomass in North Head of Long Pond, 2016.



With respect to community biomass (Figure 8-7), the May phytoplankton assemblage was comprised primarily of Bacillariophytes (89 percent) with lesser amounts of Chlorophytes (7 percent) and Chrysophytes (4 percent).

Figure 8-7. Biomass composition of the phytoplankton community in North Head of Long Pond, 2016.



By August 31st, the biomass composition of the phytoplankton community was more diversified, as was also demonstrated with respect to density, with composition still dominated by Bacillariophytes (52 percent), but with greater amounts of Chrysophytes (27 percent) and Chlorophytes (20 percent) present in the community.

Dominance. A ranking of phytoplankton taxa dominance in North Head of Long Pond on the 2016 sampling dates is summarized in Table 4-2. Taxa are considered community dominants when they comprise at least 5 percent of the total community biomass. There were 6 dominant taxa in the phytoplankton community on May 13th and 6 dominant taxa in the community on August 31st (Table 8-2).

Diversity. Phytoplankton diversity in North Head of 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.

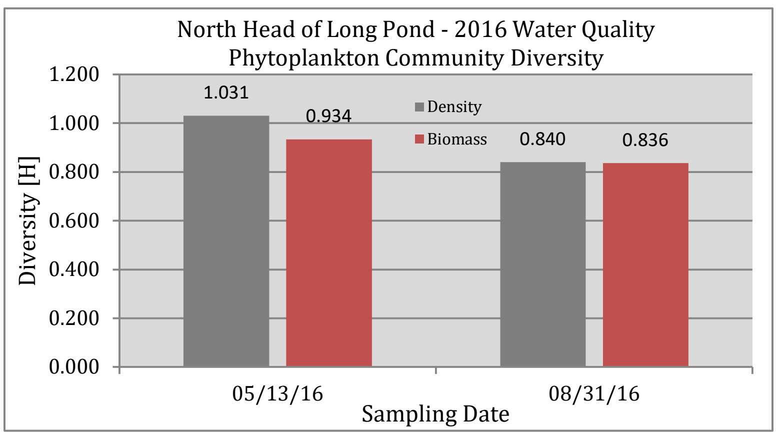
An increase in either factor (number of taxa, proportion of individuals) will increase the value of the diversity index. Calculated values that approach 1.0 indicate conditions of maximum diversity in the distribution of the population.

Table 8-2. Rank of phytoplankton taxa dominance, using biomass, in North Head of Long Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*Aulacoseria granulata* (Bacillariophyte)	1	21
	Cyclotella sp. (Bacillariophyte)	2	21
	Gomphonema spp. (Bacillariophyte)	3	16
	Navicula spp. (Bacillariophyte)	4	12
	Synedra acus (Bacillariophyte)	5	6
	Pyramimonas tetrarhyncus (Chlorophyte)	6	5
8/31/16	*Tabellaria flococosa* (Bacillariophyte)	1	34
	Ochromonas sp. (Chrysophyte)	2	27
	Pediastrum duplex (Chlorophyte)	3	9
	Schroederia Judayi (Chlorophyte)	4	7
	Amphora sp. (Bacillariophyte)	5	6
	Cyclotella sp. (Bacillariophyte)	6	5

Diversity in North Head of Long Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Figure 8-8.

Figure 8-8. Phytoplankton community diversity in North Head of Long Pond, 2016.



The diversity of the 2016 community was high on both sampling dates, and there was little difference in the diversity values regardless of whether density or biomass was used in the calculation.

Cyanophytes. There were no Cyanophytes identified in the North Head of Long Pond phytoplankton community during 2016 which is the first time this group of algae have been absent from any pond community since water quality surveys began back in 2009.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in the pond were 3.8 $\mu g \cdot L^{-1}$ on May 13th and 7.8 $\mu g \cdot L^{-1}$ on August 31st. which are reasonable values for a body of water with moderate productivity.

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. 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 North Head of Long Pond during 2016 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 May 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* = 5.8 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (5.8)] + 30.6
TSI = (9.81)(1.76) + 30.6
TSI = 47.8

Total phosphorus
Average total phosphorus = 63.70 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (63.70)] + 4.15
TSI = (14.42)(4.15) + 4.15
TSI = 64.1

Secchi depth
Average Secchi depth = 0.76 m
Secchi TSI = 60 – [14.41*[ln (0.76)]
TSI = 60 – (14.41)(-0.27)
TSI = 64.0

The TSI indices calculated for total phosphorus and Secchi depth were situated well within the eutrophic range of productivity, while chlorophyll ***a*** was within the mesotrophic, or moderate, range of productivity as shown in Table 8-3 below.

Table 8-3. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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

It should be mentioned here that TSI calculations usually are performed on average *mid-summer* values of a parameter because these values represent the conditions when maximum productivity occurs in a body of water. In the case of North Head of Long Pond and the other Natucket Island ponds surveyd during 2016, there was only 1 mid-summer value and thus the spring values also were considered in order to obtain an average value.

8.2 Summary

Based upon the data collected during 2015, North Head of Long Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has moderate-to-high productivity 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 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.

8.3 Literature Cited

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Nantucket Island Ponds

Chapter 9

Summary of Water Quality in Nantucket Island Ponds Surveyed

By the Nantucket Land Council, Inc. since 2009

9.0 Introduction

This chapter provides a brief water quality summary of Nantucket Island ponds that have been monitored by the Nantucket Land Council 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 11 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 ponds on the Island 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.

9.1 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 2016 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 8 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 which was described back in Chapter 1 and also in the individual pond chapters in this report. These 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 much better than not having any data and evaluations for individual ponds alwys 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 similar 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 all 11 Nantucket Island ponds since 2009, 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.

9.2 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 9-1. A summary of maximum, minimum and average values for the suite of parameters that have been monitored during the past 8 years on the 11 Nantucket Island ponds surveyed by The Nantucket Land Council, Inc. to date. 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	5.8	83.2	0.011	0.005	0.208	0.020	99	153	6.75
maximum value	2.57	42.8	100.6	0.080	0.057	0.986	0.289	1514	2040	8.17
average value	1.98	20.3	92.2	0.038	0.026	0.605	0.069	708	975	7.41
year monitored: 2009										
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	110.8	0.005	0.005	0.69	73.3	410	600	6.28
maximum value	2.03	187.5	37.6	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										
Maxcy Pond										
minimum value	na	2.4	94.1	0.005	0.004	0.194	7.0	65	102	5.05
maximum value	na	8.1	102.2	0.033	0.010	0.480	36.6	89	137	6.55
average value	na	4.8	98.8	0.012	0.006	0.364	22.5	74	113	5.53
year monitored: 2014, 2016										
Tom Nevers Pond										
minimum value	0.21	2.1	86.0	0.005	0.009	0.600	21.6	52	81	5.60
maximum value	0.64	14.0	98.7	0.005	0.024	1.348	796	245	226	6.35
average value	0.36	6.1	93.9	0.005	0.018	1.107	265.4	116.4	143.3	5.96
year monitored: 2014, 2016										
Washing Pond										
minimum value	1.3	2.1	105.9	0.005	0.005	0.400	0.020	85	134	5.99
maximum value	3.5	24.6	89.7	0.028	0.071	0.671	0.051	98	156	7.53
average value	2.0	10.7	99.1	0.011	0.013	0.566	0.039	94	148	6.75
year monitored: 2014, 2016										

Table 9-2 (continued).

Nantucket Island Ponds	Secchi	Chl *a*	DO	NO3-N	NH4-N	TN	TP	TDS	spC	pH
	(m)	(µg/L)	(% sat)	(mg/L)	(mg/L)	(mg/L)	(µg/L)	(mg/L)	(µS/cm)	(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*	0.005	0.250	2.03	65.5	27960*	28390*	8.79*
year monitored: 2015										
Gibbs Pond										
minimum value	0.35	7.5	103.7	0.005	0.020	0.56	216.7	60	93	6.21
maximum value	0.89	216.6	104.1	0.005	0.030	1.85	477.6	62	97	8.51
average value	0.62	112.1	103.9	0.005	0.025	1.21	347.2	61	95	7.36
year monitored: 2016										
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										

Table 9-2. A summary of Trophic Status Indices calculated for total phosphorus, chlorophyll ***a*** and Secchi depth transparency for all 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		
POND	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD
Miacomet	E	E	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									
Maxcy																M	M	na				M	E	na
Tom Nevers																E	M	HE				HE	E	HE
Washing																E	E	E				E	E	M
Capaum																			HE	HE	HE			
Pest House																			E	E	na			
Gibbs																						HE	HE	E
Little Weweeder																						M	E	E
North Head Long																						E	M	E

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

Table 9-3. 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
Anabaena circinalis							2015				
Anabaena flos aquae	2009	2009, 2012	2009, 2011, 2012, 2013, 2014, 2015	2014	2016	2016	2015	2015	2016	2016	
Anabaena spiroides	2009	2009	2009, 2010, 2011								
Anabaenopsis Elenkinii			2010, 2014	2014	2016						
Aphanocapsa elachista			2010, 2011, 2013								
Aphanizomenon flos aquae	2009		2013, 2015	2014, 2016		2014	2015	2015	2016	2016	
Chroococcus dispersus		2012	2012, 2013, 2014, 2015	2014, 2016	2014, 2016	2014, 2016	2015				
C. limneticus	2009	2009, 2012	2009, 2011, 2012, 2014, 2015			2014				2016	
C. turgidus			2011								
Coelosphaerium Naegelianum	2009		2009, 2012								
Gloeocapsa rupestris			2010, 2011								
Gomphosphaeria lacustris compacta			2014, 2015		2014, 2016	2014, 2016	2015		2016		
Lyngbya sp.			2015								
Merismopedia glauca		2012, 2013			2014, 2016				2016		
Merismopedia punctata	2009	2009									
Microcystis aeruginosa	2009	2009	2009, 2014, 2015	2014		2014	2015				
Microcystis incerta		2012	2009, 2010, 2011, 2012, 2013								
Oscillatoria sp.								2015			
Woronichinia naegeliana						2014, 2016	2015		2016	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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Nantucket Island Ponds and Water Quality

Chapter 1

A Basic Water Quality Primer

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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, 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 $TSI\ (TSIC) = 9.81 * [\ln(Chlorophyll\ a\ average)] + 30.6$
- $Secchi\ disk\ TSI\ (TSIS) = 60 - (14.41 * [\ln(Secchi\ average)])$

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.

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

Table 1-1. Relationships between Trophic Index, chlorophyll, ohosphorus, Secchi depth and Trophic Class.

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

1.7 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 have 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 Water Quality

Chapter 2

Water Quality Sampling Protocol

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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 each 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. Water quality parameters typically sampled on 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*) or oxygen saturation is sampled using the integrated hose technique; the lower zone of different temperature or oxygen saturation is sampled with a horizontal Van Dorn sampler. The collected water samples are transferred to clean, pre-rinsed 500-mL polyethylene (PE) amber sample bottles and stored on ice and in the dark until processed for shipment, usually within 2 hours of collection.

A subsample of the 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 (shown in Attachment 1) accompanies the samples to the analytical lab.

Depending upon conditions observed at each pond, a subsample of raw pond water collected from the epilimnion might be tested for the presence of algal toxins (microcystins). Testing could involve either an Abraxis, LLC Algal Toxin Strip Test for Recreational Water or the sample might be sent to GreenWater Laboratories in Palatka, Florida on certain occasions for microcystin analysis. The strip test was designed to screen for the presence/absence of toxins in pond water and to facilitate appropriate follow-up based upon the results. Since 2013 was the first season that this screening process was used on Nantucket Island ponds, samples of raw pond water also are shipped to GreenWater Laboratories for analysis of microcystins even though the Strip Test may indicate toxin concentrations of 0 ppb or 0-1 ppb for each sample. A 125 PE bottle containing about 100 mL of raw pond water is placed in a small cooler with gel packs and shipped FedEx overnight to the lab.

2.3 Analytical Techniques

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

Table 2-2. The methods and protocols for measurements and sample collection on Nantucket Island ponds.

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:

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

where, C = number of cells counted (average of two settling chambers)

A_s = area of settling chamber bottom, (mm^2)

V = volume of sample settled (50 mL)

A_f = area of field (determined by the microscope calibration), (mm)

F = number of fields counted

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

Cyanophyte toxin analysis. At GreenWater Laboratories, samples received for analysis of *microcystin* (MC) are ultra-sonicated to lyse cells and release the toxins. In some cases, a duplicate sample (Lab Fortified Matrix, LFM) was spiked at 1.0 µg/L MCLR, which provided quantitative capability and additional qualitative confirmation. A *microcystin* enzyme linked immunosorbent assay (ELISHA) is utilized for the quantitative and sensitive congener-independent detection of MCs.

2.4 Summary

This chapter provided 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.

2.5 Literature Cited

Nantucket Island Ponds and 2016 Water Quality

Chapter 3

Tom Nevers Pond

3.0 Introduction

Tom Nevers Pond was surveyed by the Nantucket Land Council on two (2) occasions during September 2014, which was reported elsewhere (Sutherland and MacKinnon 2015). This chapter presents a summary and discussion of the physical, chemical and biological data collected from Tom Nevers Pond by Nantucket Land Council staff during 2016 and also compares the 2016 data with the 2014 data.

3.1 Results

Tom Nevers Pond was sampled on May 13th and on August 30st 2016. The maximum water depth recorded was 5.5 feet (1.7 m) on May 13th at the sampling location in the approximate center of the pond; the maximum depth recorded on August 30th was 3.6 feet (1.1 m).

Following the collection of temperature and dissolved oxygen profile data, integrate samples were collected from the surface down to 5 feet on May 13th and 2 feet on August 30th 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 an absence of any visible submerged attached aquatic vegetation during May; there were no additional comments recorded during August 2016.

3.1.1 Physical characteristics

General. Tom Nevers Pond is an irregular shaped body of water with its axis oriented in a northwest-southeast direction (Figure 3-1). 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 or Tom Nevers. The outlet of Tom Nevers Pond at the south end drains toward the Low Beach area and the Atlantic Ocean (Figure 3-1).

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

Temperature. Temperature profile data were collected on both 2016 sampling dates. The May temperature from surface to bottom was isothermal (less than 1^0C variation), and the average temperature was 17.6^0C. The water column still was warming under the influence of rising spring temperatures. By August 30th, the average temperature was 26.6^0C, with a slight 3°C decrease in temperature from surface to bottom.

Since the pond is relatively 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 May 13th 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 Secchi depth transparency measured at Tom Nevers on May 13th was 2.1 feet (0.6 m) while the reading on August 30th was 0.7 feet (0.2 m). Water clarity usually is greater in the spring because the water temperature is rising and conditions still are not ideal for accelerated growth of phytoplankton.

The Secchi depth transparency was recorded as 1.0 feet (0.3 m) on both September 2nd and September 24th 2014. It is common for transparencies to be reduced late in the growing season due to abundance of phytoplankton in the water column (see later in this chapter).

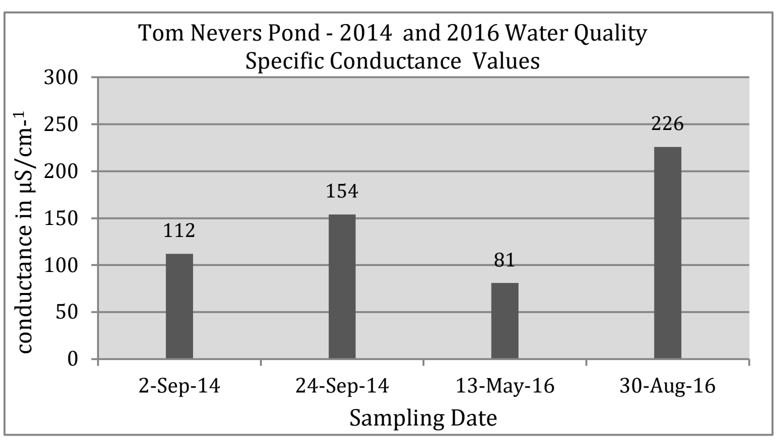
In addition, water color on all 2014 and 2016 sampling dates was listed as 'brown' which is the color of small ponds such as Tom Nevers when there is a strong influence of bog-like vegetation growing around the perimeter of the pond and also draining into the pond from areas upland in the watershed. 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

Specific conductance. The individual conductance values measured at Tom Nevers Pond during 2016 were 81 $\mu S \cdot cm^{-1}$ and 226 $\mu S \cdot cm^{-1}$ on May 13th and August 30th, respectively. Figure 3-2 presents the conductance values measured at Tom Nevers Pond during 2014 (112 $\mu S \cdot cm^{-1}$ on September 2nd; 154 $\mu S \cdot cm^{-1}$ on September 24th) as well as the 2016 values.

The value of 226 $\mu S \cdot cm^{-1}$ recorded on August 30th 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 to the water column which also would raise dissolved ions in the water and, therefore, the conductivity readings.

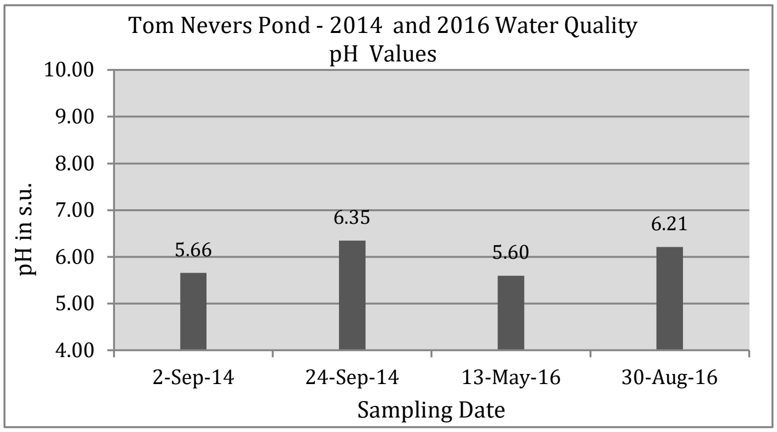
Figure 3-2. Specific conductance measured in Tom Nevers Pond, 2014 and 2016.



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 (5.60 s.u.) on May 13th and then higher (6.21 s.u.) on August 30th. Both values reported from the pond, however, were less than pH 7.00 s.u., which is considered 'neutral' along the pH scale from 0.0-14.0 s.u. The pH values measured in Tom Nevers Pond during 2014 and 2016 are presented in Figure 3-3.

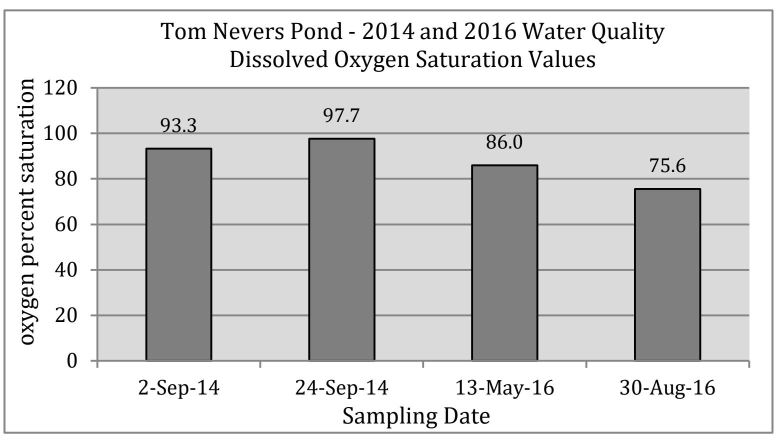
Figure 3-3. pH measured in Tom Nevers Pond, 2014 and 2016.



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 was 86.0 percent on May 13th 2016 and 75.6 percent on August 30th 2016. On both dates, there was a distinct gradient in saturation between the surface and the bottom, which was most pronounced on the latter 2016 sampling date. The 2014 and 2016 oxygen saturation values recorded at Tom Nevers Pond are presented in Figure 3-4.

Figure 3-4. Average dissolved oxygen saturation in Tom Nevers Pond, 2014 and 2016.



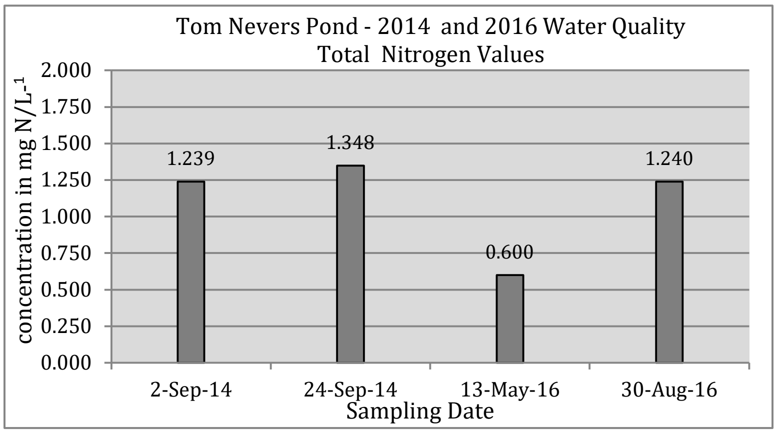
There is nothing particularly noteworthy about the oxygen saturation values measured in Tom Nevers Pond in 2014 and 2016. Gradients in oxygen concentration from surface to the bottom of ponds typically occurs during periods when there are no winds which cause mixing and the calm water exhibits gradients due to decomposition of organic material on the bottom which consumes oxygen and establishes the gradient.

3.1.3 Plant Nutrients

Nitrogen. N**itrate-nitrogen** concentrations measured in Tom Nevers during May and August 2016 were below the detection limit, which also occurred during both September 2014 sampling dates. And while there were measureable levels of **ammonia-nitrogen** on both 2016 sampling dates, the levels were low (0.020 mg $N \cdot L^{-1}$ on both dates) and were the same during 2014. 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 was 0.600 mg $N \cdot L^{-1}$ on May 13th 2016 and 1.230 mg $N \cdot L^{-1}$ on August 30th; the 2014 and 2016 values are shown in Figure 3-5.

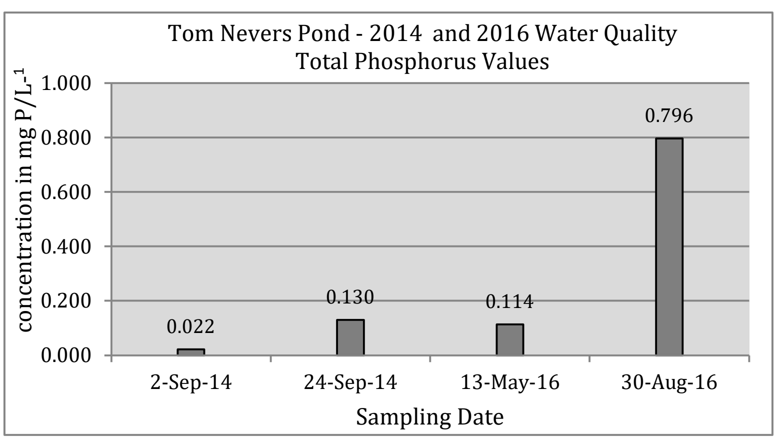
Figure 3-5. Total nitrogen concentrations measured in Tom Nevers Pond, 2014 and 2016.



The low concentrations of **nitrate-** and **ammonia-nitrogen** measured in 2014 and 2016 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 is not unusual because water temperatures in the spring still are warming and below the optimum levels for maximum growth and productivity of phytoplankton.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Tom Nevers during 2016 were 0.114 and 0.796 mg $P \cdot L^{-1}$ on May 13th and August 30th, respectively. The May value is in the range of the 2014 **TP** concentrations (0.022 and 0.130 mg $P \cdot L^{-1}$ on September 2nd and 24th, respectively) in the pond (Figure 3-6).

Figure 3-6. Total phosphorus concentrations measured in Tom Nevers Pond, 2014 and 2016.



The August 2016 value (0.796 mg $P \cdot L^{-1}$) is in the high range of values measured in other Nantucket ponds.

For purposes of comparison, the reader is referred to Chapter 9, Table 9-1 for a summary of **TN** and **TP** values measured in other Nantucket Island ponds by NLC-sponsored projects since 2009.

3.1.4 Phytoplankton

Description of the assemblage. The May 2016 assemblage contained 21 taxa while the August assemblage had 42 taxa; 46 different taxa were identified from both 2016 sampling dates and are listed in Table 3-1.

Table 3.1 Major groups and taxa of phytoplankton identified in Tom Nevers Pond, 2016.

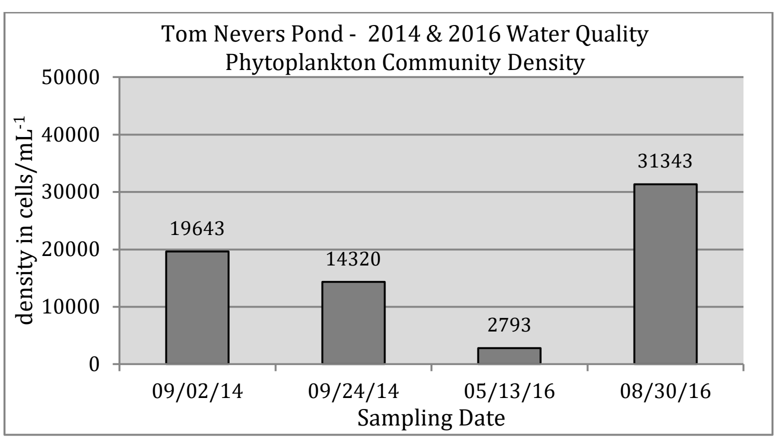
Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Pyramimonas tetrarhyncus*	*Nitzschia* sp.
Anabaenopsis Elenkinii	*Quadrigula lacustris*	*Pinnularia* sp.
Chroococcus dispersus	*Scenedesmus abundans*	*Planothidium* sp.
Gomphosphaeria lacustris compacta	*S. quadricauda*	*Rhoicosphenia curvata*
Merismopedia glauca	*Schroederia Judayi*	*Stephanodiscus* sp.
Chlorophytes	*Selenastrum capricornutum*	*Synedra acus*
Ankistrodesmus falcatus	*Sphaerocystis Schroeteri*	*S. fulgens*
Arthrodesmus sp.	*Spirulina sp.*	*S. ulna*
Closteriopsis longissima	*Staurastrum natator var. crassum*	*Tabellaria floccosa*
Closterium sp.	**Chrysophytes (Bacillariophyceae)**	**Chrysophytes (Chrysophyceae)**
Coelastrum cambricum	*Achnanthes* sp.	*Mallomonas* sp.
Cosmarium spp.	*Aulacoseria granulata*	*Synura uvella*
Monoraphidium arcuatum	*Cyclotella* sp.	**Euglenophytes**
M. contortum	*Cymbella* sp.	*Peranema* sp.
Oocystis Borgei	*Gomphonema* spp.	*Trachelomonas* sp.
O. pusilla	*Gyrosigma* sp.	**Pyrrhophytes (Cryptophyceae)**
O. solitaria	*Navicula* spp.	*Cryptomonas erosa*

The reader is referred to Sutherland and MacKinnon (2015) for a complete listing of the phytoplankton taxa identified in Tom Never Pond during 2014; there were 34 taxa identified on September 2nd 2014 and 26 taxa identified on September 24th 2014.

Community richness was calculated to be 32 (±14.8) taxa for the two sampling periods in 2016 and 30.0 (±5.7) taxa for both 2014 sampling dates.

Density. During 2016, the community density was 2,793 cells·mL^{-1} on May 13th and then increased by 10-fold to 31,343 cells·mL^{-1} by August 30th.

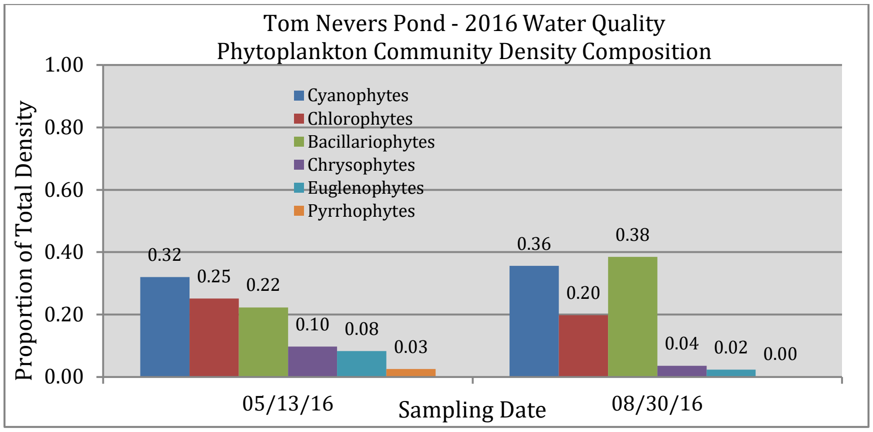
Figure 3-7. Phytoplankton community density in Tom Nevers Pond, 2014 and 2016.



As shown in Figure 3-7, which summarizes the 2014 and 2016 phytoplankton density data, the 2016 values proved to be the low and high values for all four (4) sampling dates on the pond.

All major groups of phytoplankton were represented in the May 13th 2016 assemblage and included Cyanophytes (32 percent), Chlorophytes (25 percent), Bacillariophytes (22 percent), with Chrysophytes (10 percent), Euglenophytes (8 percent) and Pyrrhophytes (3 percent) also present (Figure 3-8).

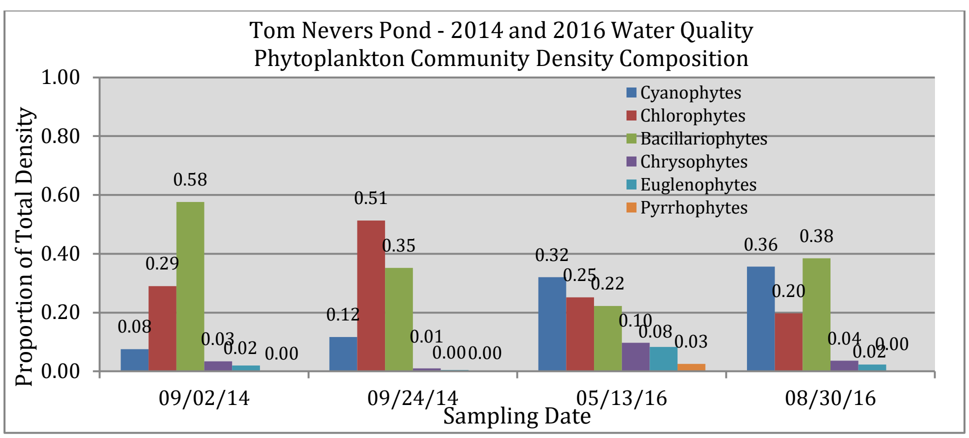
Figure 3-8. Density composition of the phytoplankton community in Tom Nevers Pond, 2016.



As shown above, the same 3 major groups were predominant in the pond during August 2016, although the relative amounts had changed slightly; Bacillariophytes were the dominant group (38 percent), and Pyrrhophytes were not present in the assemblage (0 percent).

As shown in Figure 3-9, a major portion of the September 2014 phytoplankton density was distributed among only 2 major groups, the Chlorophytes (33 percent on the 2nd, 34 percent on the 24th) and the Bacillariophytes (51 percent on the 2nd, 59 percent on the 24th).

Figure 3-9. Density composition of the phytoplankton community in Tom Nevers Pond, 2014 and 2016.



The increased density of the Cyanophytes (Blue-green algae) during 2016 is most noteworthy when comparing the community distributions that were documented in 2014 and 2016; this group averaged about 10 percent of the community in 2014 and 34 percent of the community during 2016. The significance of this change in the community will be discussed below.

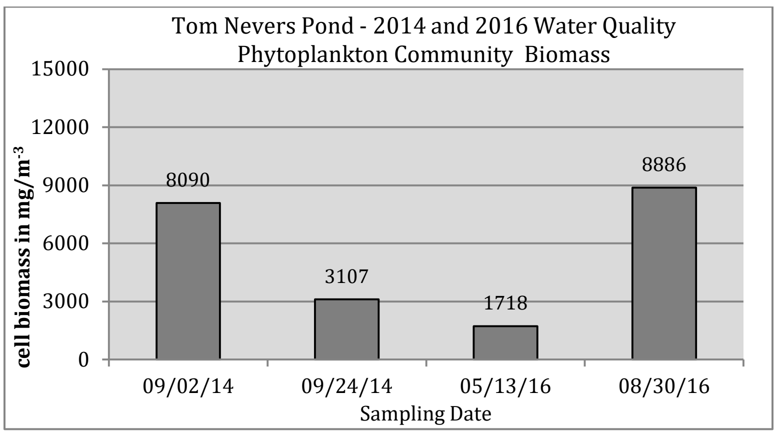
Given the shallow depth of Tom Nevers Pond and the greatly reduced water clarity caused by the 'brown stain' of the water color, the phytoplankton community cell densities measured in Tom Nevers Pond during 2014 and 2016 are considered normal for a pond with these characteristics.

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·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.

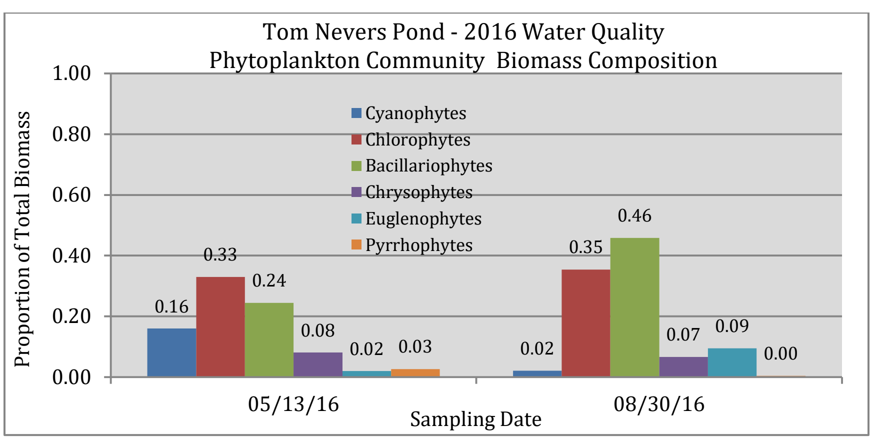
The 2016 phytoplankton community biomass was 1,718 mg·m^{-3} on May 13th and 8,886 mg·m^{-3} on August 30th. These values appear to be consistent with the biomass values recorded during 2014, i.e., 8,090 mg·m^{-3} on September 2nd and 3,107 mg·m^{-3} on September 24th. The 2014 and 2016 values are presented in Figure 3-10.

Figure 3-10. Phytoplankton community biomass in Tom Nevers Pond, 2014 and 2016.



Referring to the 2016 biomass in Figure 3-11, there was a major shift in the community biomass between the spring and late summer composition, especially with regard to the Bacillariophytes (diatoms) that doubled in biomass between the 2 sampling dates.

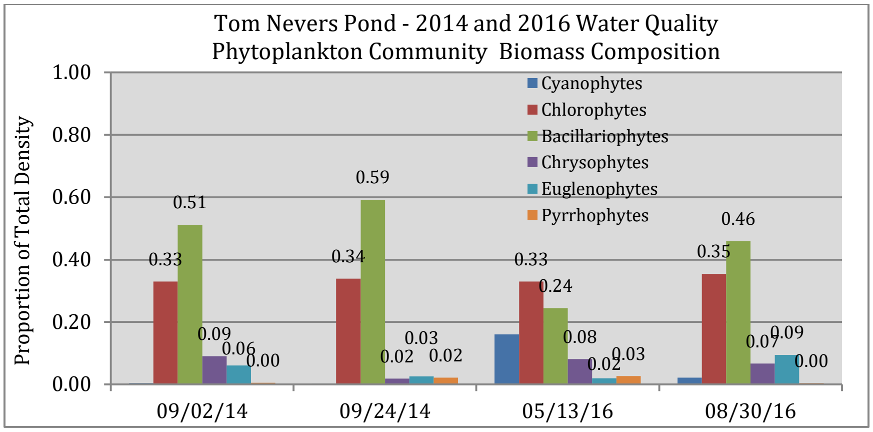
Figure 3-11. Biomass composition of the phytoplankton community in Tom Nevers Pond, 2016.



Other noteworthy changes included a substantial reduction in the Cyanophytes between spring (16 percent) and late summer (2 percent) 2016.

The 2014 and 2016 biomass composition for the Tom Nevers Pond phytoplankton community is presented in Figure 3-12. Particularly noteworthy is the consistency of the Chlorophytes and Bacillariophytes as community dominants during the 2 years where sampling was conducted.

Figure 3-12. Biomass composition of the phytoplankton community in Tom Nevers Pond, 2014 and 2016.



The appearance of Cyanophyte (Blue-green) biomass during 2016 also is noteworthy because this major group was not identified in the 2014 samples collected from the pond.

Dominance. A ranking of phytoplankton taxa dominance in Tom Nevers Pond on both 2016 sampling dates is summarized in Table 3.2. 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 on both sampling dates; 5 of the 6 taxa were biomass dominants on both sampling dates.

Table 3.2 Rank of phytoplankton taxa dominance, using biomass, in Tom Nevers Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*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
8/30/16	*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

The reader is referred to Sutherland and MacKinnon (2015) for a summary of the dominant biomass taxa identified in Tom Nevers Pond during 2014.

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

[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.

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 diversity calculated for Tom Nevers Pond during 2014 and 2016 were very consistent and not that different from a value of 1.0, regardless of whether density or biomass was used in the calculation. The density and biomass diversity values calculated for the pond on the 2014 and 2016 sampling dates are summarized in Table 3-3.

Table 3-3. Phytoplankton community diversity in Tom Nevers Pond, 2014 and 2016.

Tom Nevers Pond Sampling Date	Phyto Density Diversity Value	Phyto Biomass Diversity Value
Sept 2nd 2014	0.989	1.058
Sept 24th 2014	0.858	1.019
May 13th 2016	0.960	1.004
August 30 2016	1.010	1.026

All of these diversity values indicate that, on all sampling dates, the total community was very evenly apportioned and that dominance did not reside with a single, or even a few, taxa.

Cyanophytes. As a major phytoplankton group, Cyanophytes were identified in all 2014 and 2016 samples collected from Tom Nevers Pond. Table 3-4 summarizes the species identified in the 2014 and 2016 samples and their percent of the total phytoplankton community composition when the samples were collected.

Table 3-4. Cyanophyte species identified in 2014 and 2016 samples from Tom Nevers Pond.

Species	Sept 2nd 2014	Sept 24th 2014	May 13th 2016	August 30th 2016
*Anabaena flos aquae**	no	no	yes (32%)	no
*Anabaenopsis Elenkinii**	no	no	no	yes (3%)
Chroococcus dispersus	no	yes (1%)	no	yes (3%)
Gomphosphaeria lacustris compacta	yes (8%)	no	no	yes (5%)
Merismopedia glauca	no	yes (11%)	no	yes (25%)
'yes' = present, 'no' = absent; (##) proportion of community on a sampling date * Species that are known to produce algal toxins				

Of particular concern, however, is the significant increase between 2014 and 2016 in the proportion of the total community represented by Cyanophyte species and the fact that some of these species are recognized as potentially producing algal toxins that can impact the health of animals and humans (Table 3-4).

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Tom Nevers Pond were 2.1 $\mu g \cdot L^{-1}$ on May 13th and 14.0 $\mu g \cdot L^{-1}$ on August 30th; the 2014 chlorophyll ***a*** concentrations were 6.2 $\mu g \cdot L^{-1}$ on September 2nd and 2.1 $\mu g \cdot L^{-1}$ on September 24th. The values measured during 2014 and 2016 indicate a low level of algal productivity in the pond on all occasions except August 30th 2016 when there might have been an algal bloom in progress.

Tom Nevers 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 9, Table 9-1 for a summary of water quality parameters measured by the NLC in all 11 ponds surveyed since 2009.

3.1.5 Trophic Status

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

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

Sufficient water quality data were collected from Tom Nevers Pond during 2016 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 May and August sampling dates. The average values then were substituted into the appropriate equations (Chapter 1) to calculate the TSI values for each variable.

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

Chlorophyll *a*
Average chlorophyll *a* = 8.05 μg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (8.05)] + 30.6
TSI = (9.81)(2.09) + 30.6
TSI = 51.1

Total phosphorus
Average total phosphorus = 454.9 μg/L^{-1}
Total phosphorus TSI = 14.42*[ln (454.9)] + 4.15
TSI = (14.42)(6.12) + 4.15
TSI = 92.4

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 51.1 calculated for chlorophyll ***a*** was just above the threshold of 50 for the mesotrophic region (see Table 3-5 below), while the TSI calculated for total phosphorus (92.4) was well within the hyper-eutrophic region, which has a lower threshold of TI value of 70. The average 2016 Secchi depth (0.43 meters) resulted in a calculated TSI value of 72.2 which also is within the hyper-eutrophic region.

Table 3-5. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

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

Taken at face value, the TSI values calculated for Tom Nevers Pond portray water quality during 2016 that ranges between mesotrophic and hyper-eutrophic conditions, depending upon which independent water quality variable is used as a reference.

There are certain limitations that should be considered, however, when interpreting the 2016 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 basis for using Secchi depth to calculate a TSI value. In addition, the average 2016 TP concentration (454.9 $\mu g/L^{-1}$) used in the calculation was heavily biased by the very high September reading (795.9 $\mu g/L^{-1}$) which could have resulted from a wind event, mixing water from the pond surface to the bottom and re-suspending nutrient material contained in the sediments.

Taking all of the above into consideration, it seems most appropriate to use the TSI value calculated for chlorophyll ***a*** (51.1) as the most accurate indicator of the pond's trophic state during 2016.

3.2 Summary

Tom Nevers Pond can be characterized as a low-to-moderate 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. 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.

3.3 Literature Cited

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 Nantucket Land Council, Inc. 43 pp.

Nantucket Island Ponds and 2016 Water Quality

Chapter 4

Gibbs Pond

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4.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Gibbs Pond by the Nantucket Land Council, Inc. during 2016.

4.1 Results

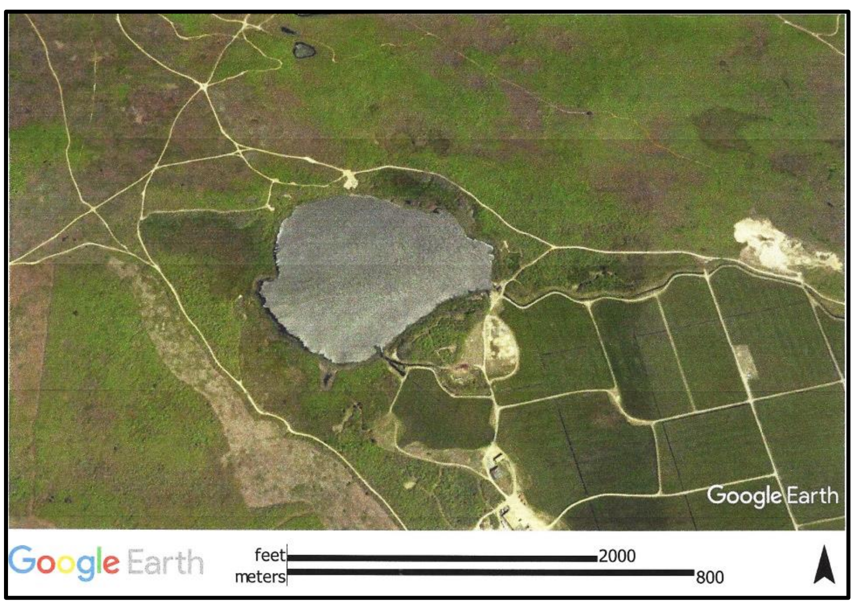
Gibbs Pond was sampled on May 13th and August 30th 2016. The maximum water depth recorded was 14.5 feet (4.4 m) on May 13th and 13.7 feet (4.2 m) on August 30th at the sampling location in the approximate center of the pond.

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) feet on May 13th and 10 feet (3.0 m) on August 30th for the water chemistry and phytoplankton samples. No additional samples were collected on May 13th; however, a grab sample for water chemistry was collected from the 12-foot (3.7 m) depth on August 30th. Observations recorded while the pond was being sampled included an algal 'bloom in progress' on August 30th.

4.1.1 Physical characteristics

General. Gibbs Pond is located north of Milestone Road, about 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 4-1 is an aerial view of Gibbs Pond.

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



The pond is used to flood the cranberry bogs on the Island and there is a single outflow, Phillips Run, that 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.

Temperature. Temperature profile data were collected during both 2016 sampling excursions. The May 13th temperature from surface to bottom varied by about 4.5°C and averaged 15.6°C. On August 30th, the difference between the surface and bottom temperature was 2°C and the average from surface to bottom was 25.7°C. There is nothing particularly noteworthy about the Gibbs Pond water column temperatures and they are not presented here in graphic form.

Transparency. The Secchi depth transparency measured at Gibbs Pond on May 13th was 2.9 feet (0.9 m) and the reading on August 30th was 1.1 feet (0.35 m). Water clarity usually is greater in the spring because the water temperature still is rising from mid-winter lows and conditions in the pond still are not ideal for phytoplankton growth and productivity. Water color observations recorded when the pond was sampled included 'reddish/brown' color on May 13th and 'green' on August 30th when clarity was low.

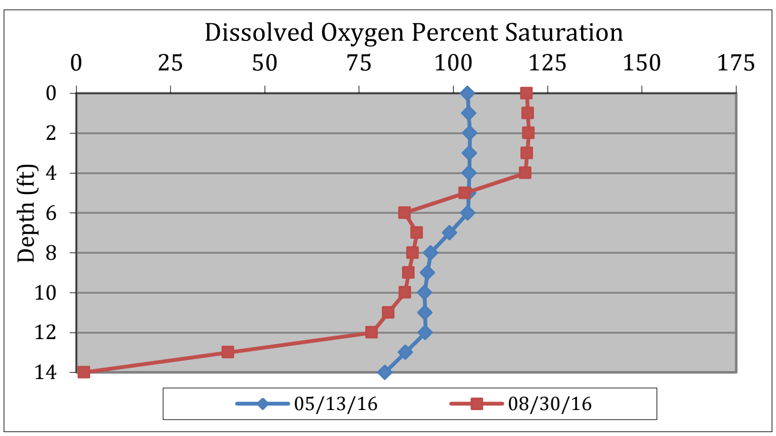
4.1.2 Chemical characteristics

Specific conductance. All 2016 conductance values were similar and noticeably 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 revealed a conductance value of 93 $\mu S \cdot cm^{-1}$ on May 13th, while the August 30th value for the ***upper*** sample was 97 $\mu S \cdot cm^{-1}$. The ***lower*** region value for specific conductance collected on August 30th was 99 $\mu S \cdot cm^{-1}$.

pH. A pH of 6.21 s.u. was recorded for the ***upper*** region of the pond on May 13th. The pH values recorded on August 30th were 8.51 s.u. in the ***upper*** region and 7.73 s.u. in the ***lower*** region. The high value for the ***upper*** region recorded on August 30th reflects high productivity from phytoplankton in the water column and a potential imbalance between respiration and photosynthesis.

Dissolved oxygen percent saturation. The average oxygen saturation values for the Gibbs Pond water column was 97.4 percent on May 13th and 89.8 percent on August 30th. There was a distinct gradient in saturation values with increasing pond depth on both sampling dates; the gradient was most pronounced on August 30th. The depth profiles of oxygen saturation for both 2016 sampling dates are presented in Figure 4-2.

Figure 4-2. Dissolved oxygen saturation values with depth in Gibbs Pond, 2016.



While the location of Gibbs Pond is in an open area, making the pond susceptible to wind, the depth profile of oxygen saturation measured on August 30th suggests that wind conditions had been calm for long enough to allow the water column to stratify with regard to temperature and, particularly, dissolved oxygen as suggested in Figure 4-2.

4.1.3 Plant Nutrients

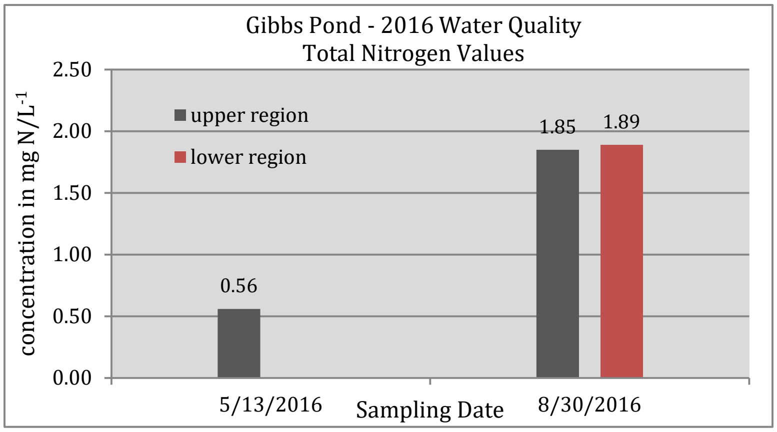
Nitrogen. Nitrate-nitrogen was not detectable in Gibbs Pond on either 2016 sampling date which is not unusual since this form of nitrogen is taken up by phytoplankton during the process of photosynthesis.

Measureable levels of **ammonia-nitrogen** occurred in the water column on both sampling dates, including 0.030 mg N·L^{-1} in the May 13th integrate, 0.020 mg N·L^{-1} in the August 30th sample from the ***upper*** region and 0.120 mg N·L^{-1} measured in the August 30th ***lower*** region sample.

Whereas Gibbs Pond exhibited slight temperature and dissolved oxygen stratification on August 30th, 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 of organic decomposition by bacteria of material accumulated near, or on, the pond bottom.

The 2016 Gibbs Pond **TN** concentrations are summarized in Figure 4-3.

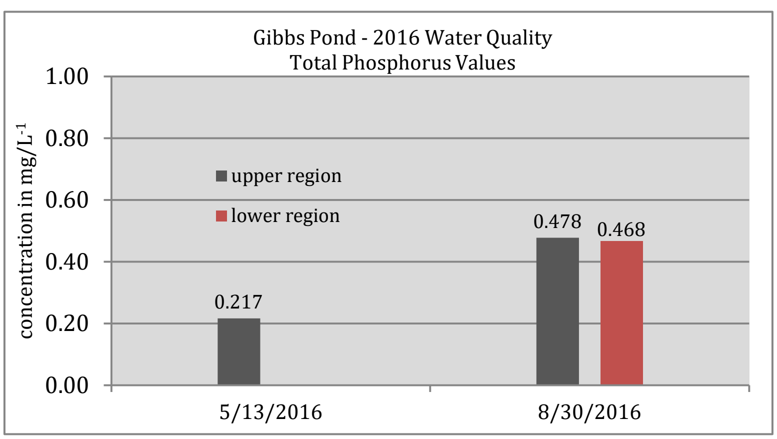
Figure 4-3. Total nitrogen concentrations measured in Gibbs Pond, 2016.



On May 13, the **total nitrogen (TN)** concentration in Gibbs Pond was 0.56 mg N·L^{-1}, which is a reasonable spring value following ice-out and mixing of the water column following winter stagnation. However, by August 30th, the TN concentration had increased to 1.85 and 1.89 mg N·L^{-1} in the ***upper*** and ***lower*** regions, respectively.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Gibbs Pond during 2016 are shown in Figure 4-4**.**

Figure 4-4. Total phosphorus concentrations measured in Gibbs Pond, 2016.



On May 13th, the **TP** concentration was 0.217 mg P·L^{-1}, which is a high value but not unreasonable considering the possibility of any recent wind-driven mixing of the water column. However, by August 30th, the ***upper*** region TP concentration was 0.478 mg P·L^{-1} and the ***lower*** region concentration was

0.468 mg P·L^{-1}. These concentrations are considered elevated and indicate a high level of productivity in the pond, which is substantiated by the field observation on August 30th of an algal 'bloom in progress'.

The reader is referred to Chapter 9 of this report for a comparison of water quality among the 11 ponds that have been monitored by the NLC since 2009 when there was a cooperative effort with the UMass Filed Station to survey Miacomet and Hummock Ponds.

4.1.4 Phytoplankton

Description of the assemblage. There were 26 phytoplankton taxa identified in the 2016 May community and 30 taxa identified in the August community from Gibbs Pond; 42 taxa were identified in the pond during 2016 (Table 4-1).

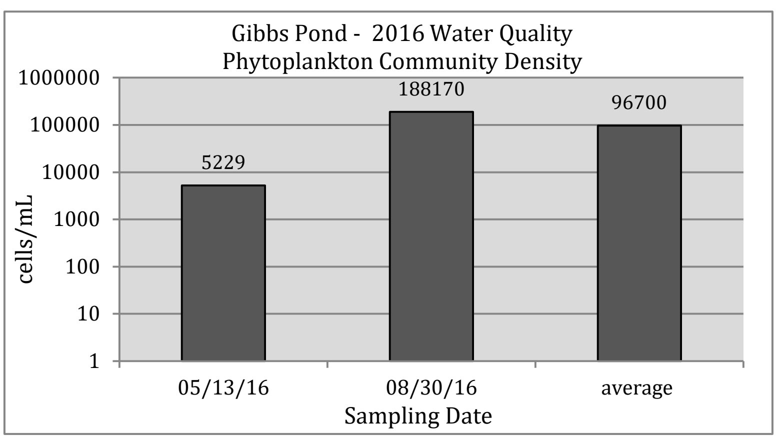
Table 4-1. Major groups and taxa of phytoplankton identified in Gibbs Pond, 2016.

Cyanophyta	**Chlorophyta**	**Chrysophyta (Bacillariophyta)**
Anabaena flos aquae	*Pediastrum duplex*	*Cyclotella* sp
Aphanizomenon flos aquae	*Pyramimonas tetrarhyncus*	*Navicula* spp.
Gomphosphaeria lacustris compacta	*Quadrigula lacurstris*	*Nitzschia* sp.
Merismopedia glauca	*Scenedesmus abundans*	*Planothidium* sp.
Woronichinia naegeliana	*S. arcuatus*	*Stauroneis* sp.
Chlorophyta	*S. Bijuga*	*Stephanodiscus* sp.
Ankistrodesmus falcatus	*S. quadricauda*	*Synedra acus*
Closteriopsis longissima	*S. tetraedon*	**Chrysophyta (Chrysophyceae)**
Closterium sp.	*Sphaerocystis Schroeteri*	*Dinobyron divergens*
C. gracile	*Spirulina* sp.	*Mallomonas* sp.
Coelastrum cambricum	*Staurastrum natator var. crassum*	**Euglenophyta**
Cosmarium spp.	*Tetraedron minimum*	*Peranema* sp.
Monoraphidium arcuatum	**Chrysophyta (Bacillariophyta)**	*Trachelomonas* sp.
M. contortum	*Achnanthese* sp.	**Pyrrhophyta (Cryptophyceae)**
Oocystis Borgei	*Aulocoseria granulata*	*Cryptomonas erosa*
O. solitaria	*Cocconeis* sp.	

Community richness for the 2016 samples was calculated to be 28 ± 2.8 taxa.

Density. Phytoplankton community density in Gibbs Pond was 5,229 cells·mL^{-1} on May 13th and 188,170 cells·mL^{-1} on August 30th; average density was 96,700 cells·mL^{-1} for both dates (Figure 4-5).

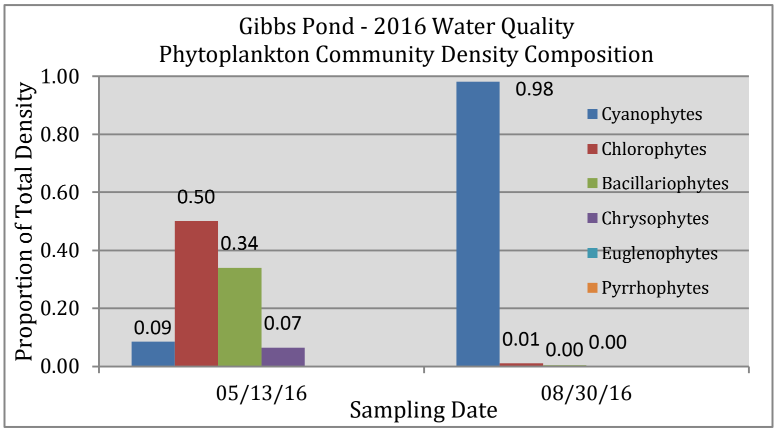
Figure 4-5. Phytoplankton community density in Gibbs Pond, 2016.



The *y*-axis in Figure 4-5 is a logarithm scale which means that each major increment represents a 10-fold increase in cell density. The May 13th density is typical of a spring phytoplankton assemblage when productivity is low and water temperatures in the pond are warming; the August value, however, is extremely high and further evidence that an algal bloom was in progress as was recorded in the field notes on that sampling date.

The May 13th phytoplankton assemblage (Figure 4-6) 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.

Figure 4-6. Density composition of the phytoplankton community in Gibbs Pond, 2016.

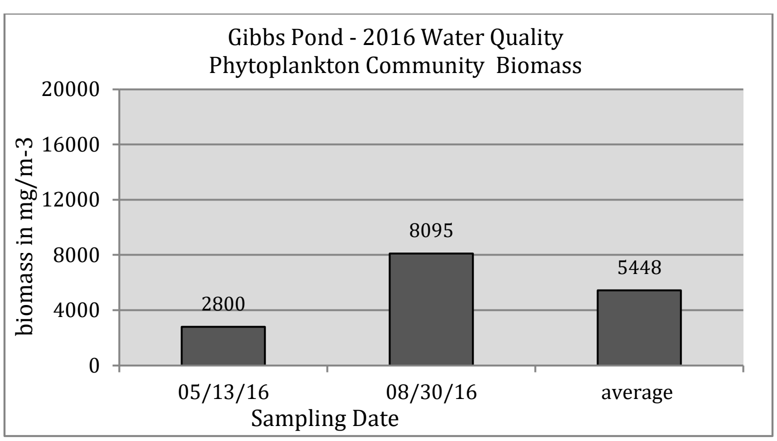


By August 30th, the phytoplankton assemblage had undergone a dramatic change and 98 percent of the community density was comprised of Cyanophytes (Figure 4-6).

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.

The phytoplankton community biomass documented in Gibbs Pond on May 13th and August 30th is presented in Figure 4-7.

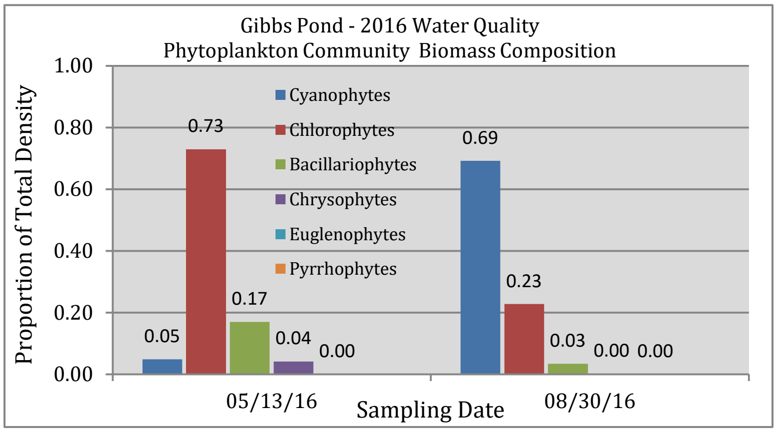
Figure 4-7. Phytoplankton community biomass in Gibbs Pond, 2016.



The biomass in the pond was 2,800 mg·m^{-3} on May 13th and 8,095 mg·m^{-3} on August 30th; an average of 5,448 mg·m^{-3} for both 2016 sampling dates (Figure 4-7).

With respect to community biomass, the May phytoplankton assemblage was comprised primarily of Chlorophytes (73 percent) and Bacillariophytes (17 percent), with lesser amounts of Cyanophytes (5 percent), Chrysophytes (4 percent) and Euglenophytes (<1 percent)(Figure 4-8).

Figure 4-8. Biomass composition of the phytoplankton community in Gibbs Pond, 2016.



By August 30th, the biomass composition of the phytoplankton community had changed dramatically and consisted primarily of Cyanophytes (69 percent) and Chlorophytes (23 percent).

Dominance. A ranking of phytoplankton taxa dominance in Gibbs Pond during 2016 is summarized in Table 4-2.

Table 4-2. Rank of phytoplankton taxa dominance, using biomass, in Gibbs Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*Sphaerocystis Schroeteri* (Chlorophyte)	1	26
	Staurastrum natator var. *crassum* (Chlorophyte)	2	26
	Cyclotella sp. (Bacillariophyte)	3	15
	Pediastrum duplex (Chlorophyta)	4	10
	Anabaena flos aquae (Cyanophyte)	5	5
8/30/16	*Woronichinia naegeliana* (Cyanophyte)	1	52
	Aphanizomenon flos aguae (Cyanophyte)	2	15
	Coelastrum cambricum (Chlorophyte)	3	12

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 and 3 dominant taxa in the community on August 30th (Table 4-2).

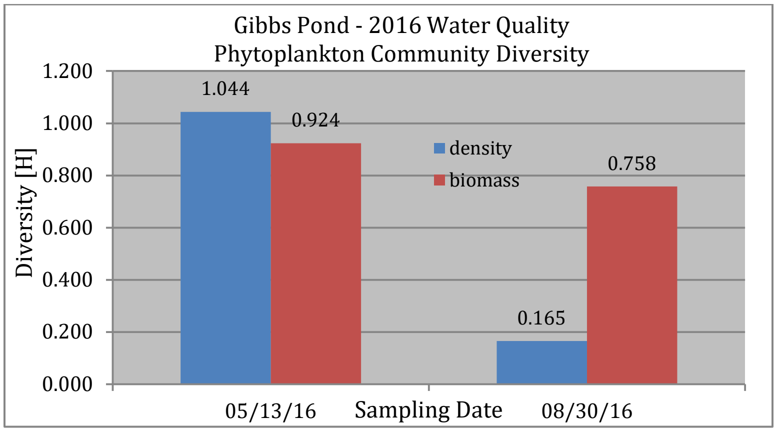
Diversity. Phytoplankton diversity in Gibbs Pond was measured using the Shannon-Wiener function[1] which calculates diversity, **[H]**, using number of taxa and the portion of individuals among the taxa on each sampling date.

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.

[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.

Diversity in Gibbs Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Figure 4-9. The data shown below highlight the importance of considering both density and biomass when considering phytoplankton community characteristics in a particular body of water.

Figure 4-9. Phytoplankton community diversity in Gibbs Pond, 2016.



Using density as the primary variable, diversity [H] values calculated for Gibbs Pond were 1.044 and 0.165 in May and August 2016, respectively. With biomass, the diversity values were 0.924 during May and 0.758 during August. Regardless of which variable is used to calculate diversity, the most noteworthy feature is the dramatic difference between using density or biomass to calculate the August 2016 community metric.

Cyanophytes. Cyanophytes were identified in both the May and August samples collected in Gibbs Pond during 2016 (Table 4-3). There were 5 taxa identified including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, *Gomphosphaeria lacustris compacta*, *Merismopedia glauca* and *Woronichinia naegeliana*.

Table 4-3. Cyanophyte species identified in Gibbs Pond, 2016.

Species	May 13th 2016	August 30th 2016
*Anabaena flos aquae**	yes (9%)	yes (<1%)
*Aphanizomenon flos aquae**	no	yes (3%)
Gomphosphaeria lacustris compacta	no	yes (1%)
Merismopedia glauca	no	yes (1%)
*Woronichinia naegeliana**	no	yes (93%)

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 chlorophyll ***a*** concentrations measured in Gibbs Pond 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.

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.

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 Gibbs Pond during 2016 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 May 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* = 112.05 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (112.05)] + 30.6
TSI = (9.81)(4.72) + 30.6
TSI = 76.9

Total phosphorus
Average total phosphorus = 347.15 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (347.15)] + 4.15
TSI = (14.42)(5.85) + 4.15
TSI = 88.5

Secchi depth
Average Secchi depth = 0.62 m
Secchi TSI = 60 – [14.41*[ln (0.62)]
TSI = 60 – (14.41)(-0.48)
TSI = 66.9

The TSI indices calculated for chlorophyll ***a*** and total phosphorus were situated well within the 'hyper-eutrophic' range of values, while Secchi depth transparency was well within the 'eutrophic' range, as shown by comparing the TSI values calculated above with the information in Table 4-4 below.

Table 4-4. Trophic State Indices calculated for 2016 water quality data measured in Gibbs Pond.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 Gibbs Pond suggest that certain water quality standards for contact recreation are in question and that further investigation should occur with regard to this pond being used for swimming during the summer months.

4.2 Summary

Based upon the data collected during 2016, Gibbs Pond exhibits water quality similar to certain 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 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.

4.3 Literature Cited

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Nantucket Island Ponds and 2016 Water Quality

Chapter 5

Little Weweeder Pond

5.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Little Weweeder Pond by Nantucket Land Council staff during 2016.

5.1 Results

Little Weweeder Pond was sampled on May 13th and August 30th 2016. The maximum water depth located in the pond was 4.6 feet (1.4 m) on May 13th at the sampling location in the approximate center of the pond. The maximum water depth located on August 30th was 3.9 feet (1.2 m).

Following the collection of temperature and dissolved oxygen profile data on May 13th, an integrate sample was collected from the surface down to 4 feet of depth for the chemistry and phytoplankton samples. A grab sample was not collected due to the shallow pond depth.

The depth of integrate sample collection on August 30th was from 0-3 feet of depth and there was no grab sample collected on this sampling date either.

5.1.1 Physical characteristics

General. Little Weweeder Pond is located along the south shore of Nantucket Island, at the end of Folger Avenue and about 0.7 mile east of Miacomet Pond. The pond has an elongated shape with a slight indentation along the western shoreline (Figure 5-1).

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

The surface area of the pond is estimated at about 9,200 ft^2, or about 0.21 acres. There are no permanent streams flowing into the pond, and there is a connection between Little Weweeder and a larger pond to the south through a culvert beneath the road.

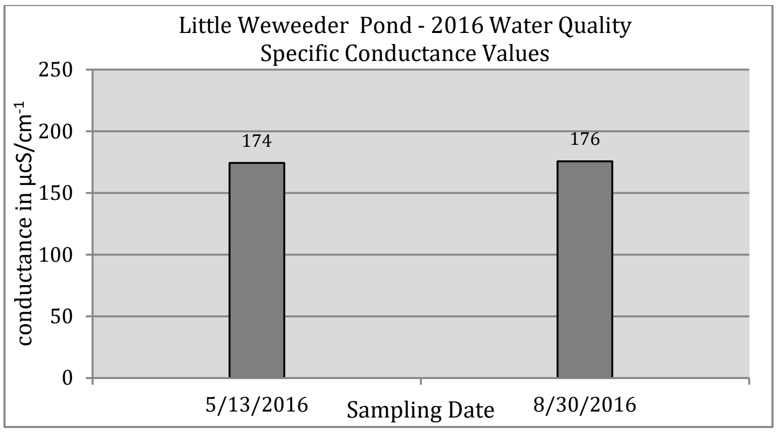
Temperature. Temperature profile data were collected on both 2016 sampling excursions to Little Weweeder Pond. The temperature collected on both sampling dates essentially was isothermal from the surface to the bottom with only slight differences observed; the average temperature of the water column was 17.5°C on May13th and 24.5°C on August 30th.

Transparency. The Secchi depth transparency measured at Little Weweeder Pond on May 13th was 4.0 feet (1.2 m) and could not be determined on August 30th due to vegetation growing on the bottom which obscured visibility of the disc. In addition, the water color was noted as 'clear' on both sampling dates by NLC staff sampling the pond.

5.1.2 Chemical characteristics

Specific conductance. Figure 5-2 presents the specific conductance values measured at Little Weweeder Pond on May 13th and August 30th 2016.

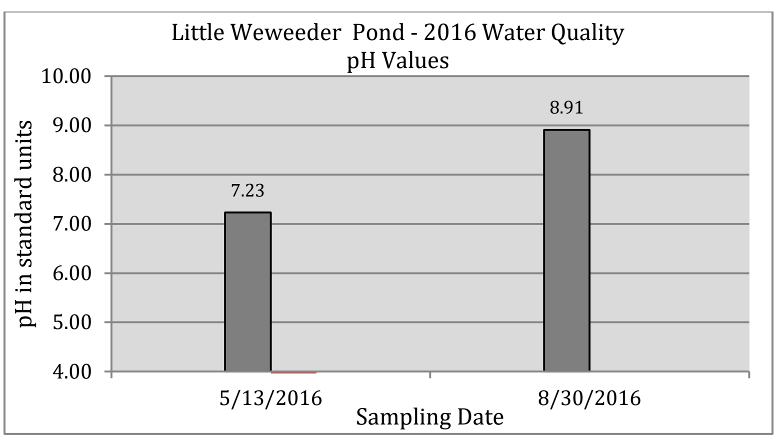
Figure 5-2. Specific conductance measured in Little Weweeder Pond, 2016.



The results for the 2 integrate samples essentially were the same; 174 and 176 $\mu S \cdot cm^{-1}$ on May 13th and August 30th, respectively. These values are within the range expected for a small freshwater pond located in this area that is subject to the influence of salt spray from the Atlantic Ocean.

pH. As shown in Figure 5-3, Little Weweeder Pond had a neutral pH (7.23 s.u.) on May 13th, and an elevated pH (8.91 s.u.) on August 30th.

Figure 5-3. pH measured in Little Weweeder Pond, 2016.



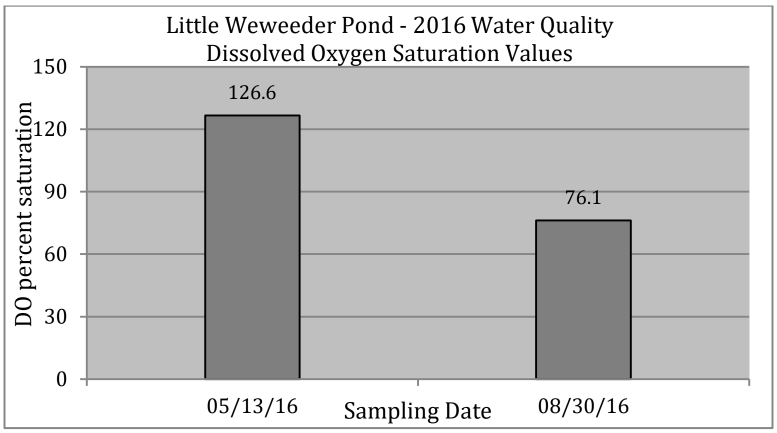
The high value recorded on August 30th reflects high productivity from phytoplankton in the water column and a potential imbalance between respiration and photosynthesis.

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 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 dissolved oxygen saturation values measured in Little Weweeder Pond during May and August 2016 are shown in Figure 5-4.

Figure 5-4. Dissolved oxygen saturation values measured in Little Weweeder Pond, 2016.



The percent saturation value of 126.6 percent recorded on May 13th (126.6) indicates a supersaturated condition in the water column which occurs when any combination or all of the following occur: (1) water temperatures are low, (2) there is mixing in the pond, and (3) phytoplankton respiration is occurring (and replenishing oxygen) at a greater rate than photosynthesis (which consumes CO_2) which occurs slower at lower temperatures.

5.1.3 Plant Nutrients

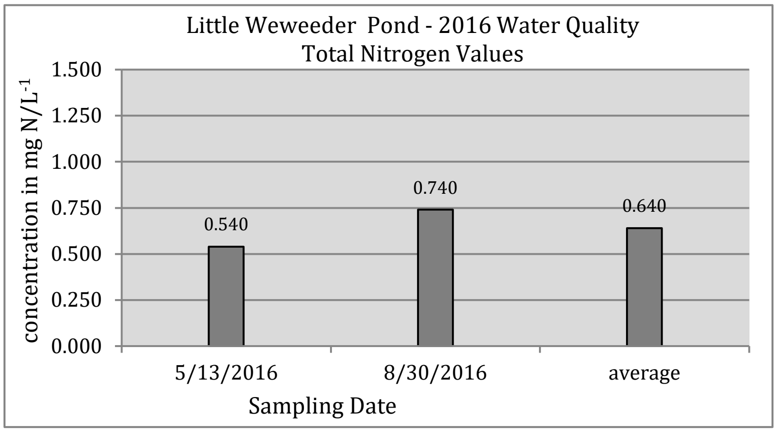
Nitrogen. Nitrate-nitrogen was not detectable in Little Weweeder Pond on either May 13th or August 30th; i.e., concentrations were 0.005 N·L^{-1}, which is not an unusual phenomenon in fresh-water systems since this form of nitrogen is readily taken up by phytoplankton for metabolism when it does become available in the water column.

Although there were measureable levels of **ammonia-nitrogen** in the water column on both 2016 sampling dates, the levels were low, which also is not unusual since this form of nitrogen also is available for uptake by phytoplankton. The levels of **ammonia-nitrogen** measured in Little Weweeder Pond were 0.020 mg N·L^{-1} on both May 13th and August 30th.

The **TN** concentrations measured in the pond were 0.540 mg N·L^{-1} on May 13th and 0.750 mg N·L^{-1} on August 30th, an average of 0.640 mg N·L^{-1} for both sampling dates (Figure 5-5). Based upon the undetectable and very low **nitrate-** and **ammonia-nitrogen** concentrations, respectively, measured in Gibbs Pond during 2016, about 95 percent of the 2016 **TN** concentrations were was tied up as organic nitrogen (phytoplankton and other seston) in the water column.

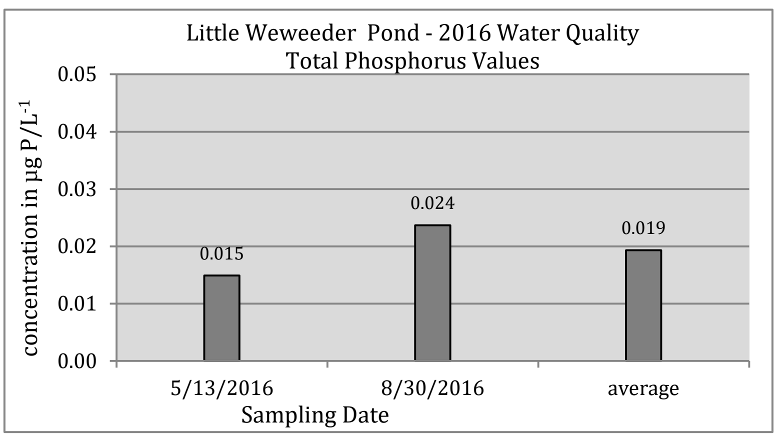
The 2016 **TN** concentrations measured in Gibbs Pond are moderate concentrations when compared with other Nantucket Island ponds that have been surveyed by the NLC since 2009. The reader is referred to Chapter 9 of this report for a summary and comparison of these water quality parameters.

Figure 5-5. Total nitrogen concentrations measured in Little Weweeder Pond, 2016.



Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Little Weweeder Pond during May and August 2016 are shown in Figure 5-6. On May 13th, the **TP** concentration was 0.015 mg $P{\cdot}L^{-1}$ in the water column and by August 30th, the TP concentration had increased to 0.024 mg $P{\cdot}L^{-1}$. The average value for the 2016 season was 0.019 mg $P{\cdot}L^{-1}$.

Figure 5-6. Total phosphorus concentrations measured in Little Weweeder Pond, 2016.



The concentrations of TP measured in Little Weweeder Pond reflect low productivity in the system and this situation is considered normal in dilute systems such as Little Weweeder Pond.

As a comparison to Little Weweeder Pond, average **TP** levels documented in other Nantucket Island ponds during 2016 were 0.266 mg $P{\cdot}L^{-1}$ in *Tom Nevers Pond* and 0.039 mg $P{\cdot}L^{-1}$ in *Washing Pond*.

5.1.4 Phytoplankton

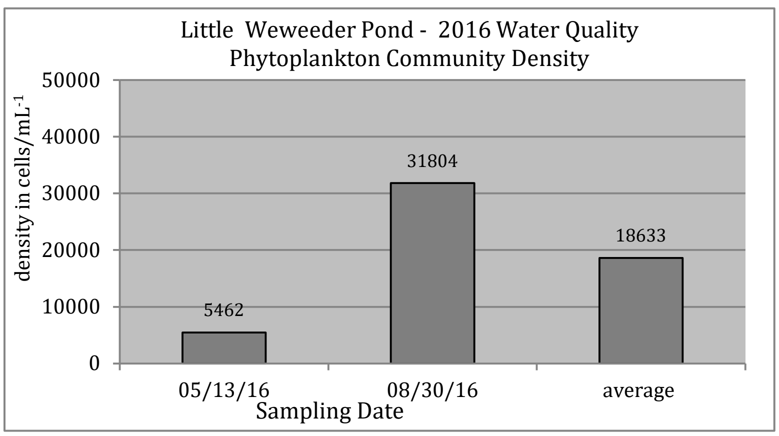
Description of the assemblage. There were 35 taxa identified in the 2016 phytoplankton samples collected from Little Weweeder Pond and all of the major algal groups were represented (Table 5-1). A total of 18 taxa were identified in the May 13th sample and 29 taxa were identified in the August 30th sample. The community richness calculated for the 2016 sampling dates was 23.5 (±7.8) taxa.

Table 5-1. Major groups and taxa of phytoplankton identified in Little Weweeder Pond, 2016.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Oocystis pusilla*	*Gomphonema* spp.
Aphanizomenon flos aquae	*O. solitaria*	*Navicula* spp.
Chroococcus limneticus	*Pandorina morum*	*Nitzschia* sp.
Woronichinia naegeliana	*Pediastrum duplex*	*Rhoicosphenia curvata*
Chlorophytes	*Pyramimonas tetrarhyncus*	*Stauroneis* sp.
Ankistrodesmus falcatus	*Quadrigula lacustris*	*Synedra acus*
Arthrodesmus sp.	*Scenedesmus arcuatus*	*Tabellaria floccosa*
Closteriopsis longissima	*S. bijuga*	**Euglenophytes**
Closterium sp.	*Sphaerocystis Schroeteri*	*Peranema* sp.
C. gracile	**Chrysophytes (Bacillariophyceae)**	*Trachelomonas* sp.
Coelastrum cambricum	*Achnanthes* sp.	**Pyrrhophytes (Dinophytes)**
Cosmarium spp.	*Cyclotella* sp.	*Peridinium cinctum*
Mougeotia sp.	*Cymbella* sp.	*Cryptomonas erosa*

Density. The phytoplankton community density in Little Weweeder Pond was 5,462cells·mL^{-1} on May 13th and 31,804 cells·mL^{-1} on August 30th; the average density was 18,633 cells·mL^{-1} for both 2016 sampling dates (Figure 5-7). The phytoplankton densities measured in Little Weweeder Pond during 2016 are low when compared with other Island ponds that have been monitored by the NLC during recent years.

Figure 5-7. Phytoplankton community density in Little Weweeder Pond, 2016.

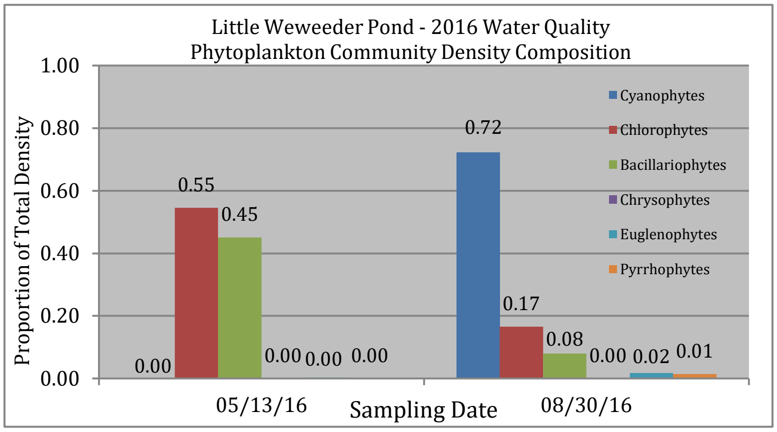


The May 13th phytoplankton assemblage in Little Weweeder Pond was comprised entirely of Chlorophytes (green algae) with 55 percent of the community density and Bacillariophytes (diatoms) with 45 percent of the community density (Figure 5-8). All other major groups of phytoplankton were absent from the community during the spring of 2016.

On August 30th, there had been a major shift in the community composition (Figure 5-8) with Cyanophytes (Blue-green algae) the major phytoplankton group comprising 72 percent of the community density. At that time, Chlorophytes were 17 percent of the community, followed by the diatoms (8 percent), Euglenophytes (2 percent), and Pyrrhophytes (1 percent).

When small ponds exhibit major shifts in community composition similar to the situation observed in Little Weweeder Pond during 2016, it is not clear whether the changes are due to instability in the community that is exhibited from one year to the next, or a seasonal succession that occurs every year with a major shift in community structure as the pond progresses through its annual cycle. This is why several years of water quality data should be collected from a pond before any evaluations are performed to categorize the status and dynamics of productivity.

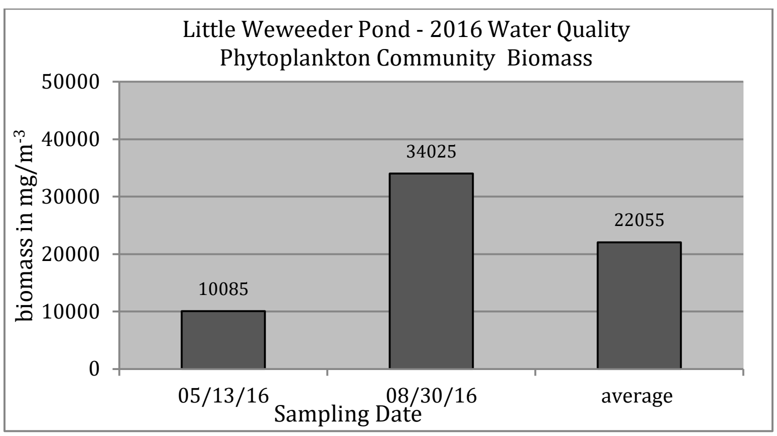
Figure 5-8. Density composition of the phytoplankton community in Little Weweeder Pond, 2016.



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 to observe size differences among different types of phytoplankton of several orders of magnitude.

The 2016 phytoplankton community biomass documented in Little Weweeder Pond on May 13th and August 30th is presented in Figure 5-9.

Figure 5-9. Phytoplankton community biomass in Little Weweeder Pond, 2016.

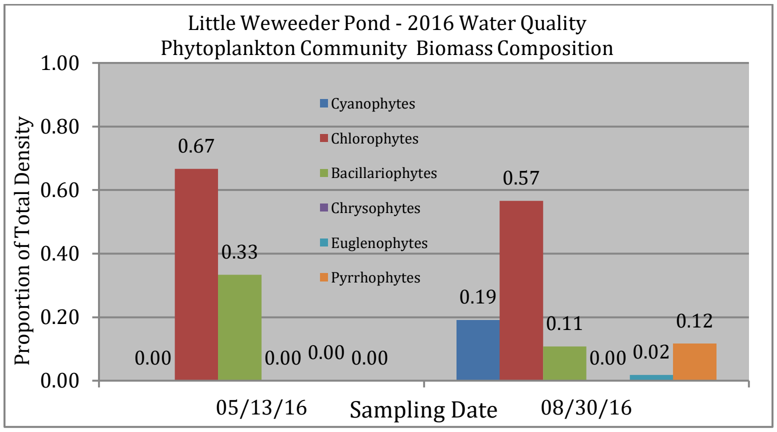


Biomass was 10,085 mg·m^{-3} on May 13th and then tripled to 34,025 mg·m^{-3} on August 30th; the average biomass of the 2016 sampling dates was 22,055 mg·m^{-3} (Figure 5-9).

The May 13th biomass assemblage in Little Weweeder Pond was similar to the density of the assemblage discussed above, with Chlorophytes and Bacillariophytes making up the entire community with 67 percent and 33 percent, respectively (Figure 5-10).

By August 30th, however, Chlorophytes (57 percent) still maintained a major portion of the community, while the Cyanophytes (19 percent) were considerably less important in terms of biomass (Figure 5-10). The August 30th biomass assemblage also included Bacillariophytes (11 percent), Euglenophytes (2 percent) and Pyrrhophytes (12 percent).

Figure 5-10. Biomass composition of the phytoplankton community in Little Weweeder Pond, 2016.



Dominance. A ranking of phytoplankton taxa dominance in Little Weweeder Pond on the 2016 sampling dates is summarized in Table 5-2. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 5-2. Rank of phytoplankton taxa dominance, using biomass, in Little Weweeder Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*Closterium* sp. (Chlorophyte)	1	57
	Tabellaria floccosa (Bacillariophyte)	2	25
	Stauroneis sp. (Bacillariophyte)	3	5
8/30/16	*Staurastrum natator* var. *crissum* (Chlorophyte)	1	48
	Anabaena flos aquae (Cyanophyte)	2	19
	Peridinium cinctum (Pyrrhophyte)	3	12
	Tabellaria floccosa (Bacillariophyte)	4	10

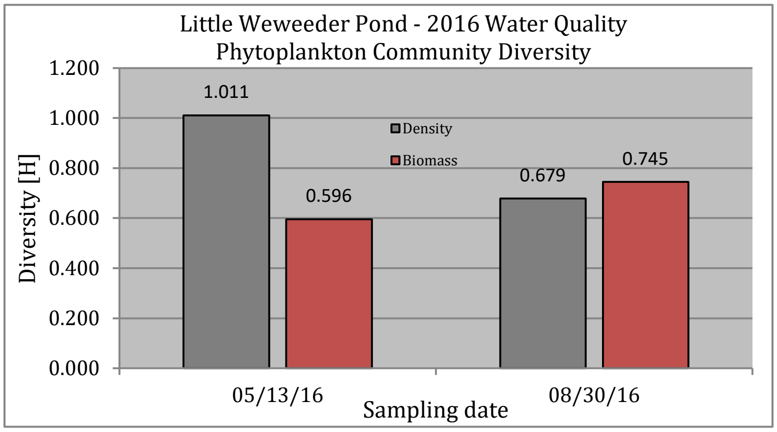
There were 3 dominant taxa in the phytoplankton community on May 13th and 4 dominant taxa in the community on August 30th (Table 5-2). As discussed above, the green algae and diatoms comprised a major portion of the community in May, and in late summer (August 30th), the greens, and Blue-greens were the major components of the community.

Diversity. Phytoplankton diversity in Little Weweeder 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 Little Weweeder Pond was calculated using both the community density and biomass in the equation. The results are presented in Figure 5-11, and highlight the differences that can occur when either density or biomass is used to perform the calculation. For example, the diversity [H] calculated using density was 1.011 on May 13th, whereas the diversity calculated using biomass on that date was 0.596. By August 30th, in contrast, the diversity [H] for both community parameters was similar with density at 0.679 and biomass at 0.745. The argument concerning which phytoplankton community variable is most important is purely philosophical in nature and has no impact other than to define the instantaneous community conditions from 2 different perspectives.

[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.

Figure 5-11. Phytoplankton community diversity in Little Weweeder Pond, 2016.



Cyanophytes. As a major phytoplankton group of aquatic ecosystem importance, the Cyanophytes were identified only in the August 2016 phytoplankton samples collected from Little Weweeder Pond. There were 4 species present on that date, including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, *Chroococcus imneticus* and *Wornichinia naegeliana*.

Three of these Cyanophyte genera, including *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 Little Weweeder Pond produce any algal toxins, recreational users of the pond should be aware that Cyanophytes (Blue-greens) are potential components of the summer phytoplankton community.

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Little Weweeder Pond were 23.4 $\mu g \cdot L^{-1}$ on May 13th and 16.7 $\mu g \cdot L^{-1}$ on August 30th, indicating a moderate level of algal productivity in the pond on both occasions. The average chlorophyll ***a*** concentration for both 2016 sampling dates was 20.05 $\mu g \cdot L^{-1}$.

In comparison to Little Weweeder Pond, chlorophyll ***a*** levels measured in Nantucket Island ponds during 2016 included an average of 6.1 $\mu g \cdot L^{-1}$ in *Tom Nevers Pond* during May and August and an average of 10.6 $\mu g \cdot L^{-1}$ in *Washing Pond* during May and August.

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.

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

There were sufficient TP and chlorophyll ***a*** data from Little Weweeder Pond during 2016 to calculate the Carlson Trophic State Index (TSI) using those 2 variables. Average values were calculated for chlorophyll ***a*** and total phosphorus 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 calculation and results of the analysis are as follows:

Chlorophyll _a_
Average chlorophyll _a_ = 20.05 µg/L^{-1}
Chlorophyll _a_ TSI = 9.81*[ln (20.05)] + 30.6
TSI = (9.81)(3.00) + 30.6
TSI = 60.0

Total phosphorus
Average total phosphorus = 19.30 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (19.30)] + 4.15
TSI = (14.42)(2.96) + 4.15
TSI = 46.8

Table 5-3 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 5-3. Relationships among Trophic Index, chlorophyll _a_, total phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll (µg L^{-1})	TP (µg L^{-1})	Secchi Depth	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 value calculated for chlorophyll **_a_** (60.0) using the 2016 data, Little Weweeder Pond was well within the eutrophic region of productivity. With regard to total phosphorus, however, the pond was within the mesotrophic range of productivity during 2016.

5.2 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. During 2014, the Nantucket Land Council 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.

5.3 Literature Cited

Nantucket Island Ponds and 2016 Water Quality

Chapter 6

Maxcy Pond

6.0 Introduction

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

6.1 Results

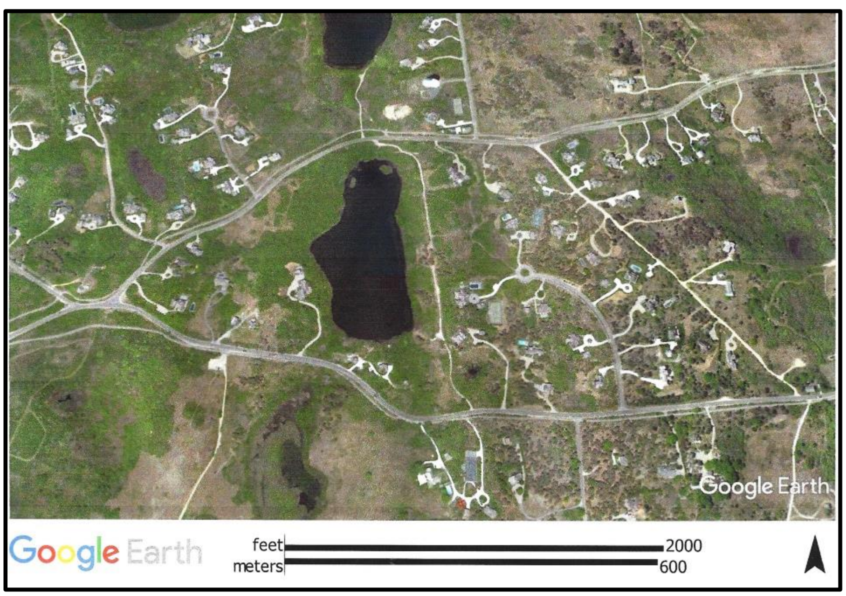
Maxcy Pond was sampled on May 19th and August 31st 2016. The maximum water depth located in the pond was 6.2 feet (1.9 meters) on May 19th at the sampling location in the approximate center of the pond. The maximum water depth located on August 31st was 5.0 feet (1.5 meters).

Following the collection of temperature and dissolved oxygen profile data on May 19th, an integrate sample was collected from the surface down to 4 feet of depth for the chemistry and phytoplankton samples. A grab sample was not collected since the pond was so shallow. The depth of integrate sample collection on August 31st also was from 0-4 feet of depth and there was no grab sample collected on this sampling date either.

6.1.1 Physical characteristics

General. Maxcy Pond has an irregular shape with a bulge along the western shoreline and its axis is oriented in a north-south direction (Figure 3.1). The surface area of the pond is estimated at about 10 acres. There are no permanent streams flowing into the pond, and there is no outlet located along the shoreline.

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.

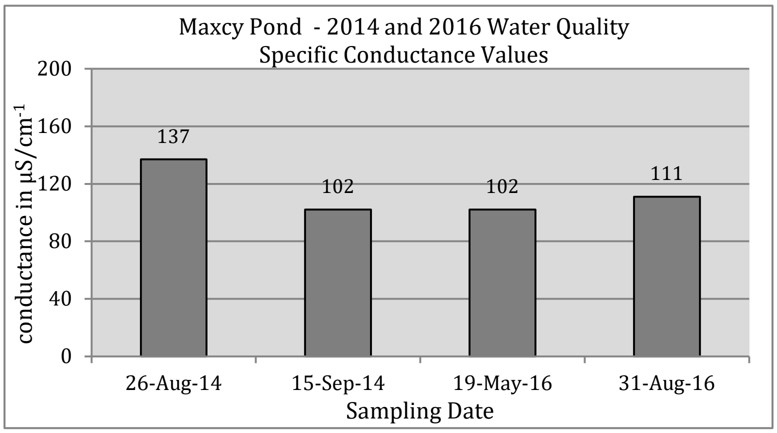
Temperature. Temperature profile data were collected on both 2016 sampling excursions to Maxcy Pond, and the temperature collected on both occasions essentially was isothermal from the surface to the bottom; the average temperature of the water column was 17.1°C on May 19th and 25.8 °C on August 31st.

Transparency. The Secchi depth transparency measured at Maxcy Pond was 'on the bottom' on both sampling dates which means that the pond had exceptional clarity and was not deep enough to measure the actual Secchi depth transparency. In addition, the water color was noted as 'clear' on both sampling dates by NLC staff sampling the pond.

6.1.2 Chemical characteristics

Specific conductance. The specific conductance measured at Maxcy Pond on May 19th was 102 $\mu S \cdot cm^{-1}$, while the value for the integrate sample collected on August 31st was 111 $\mu S \cdot cm^{-1}$. Figure 6-2 presents the specific conductance values measured at Maxcy Pond during 2014 and 2016.

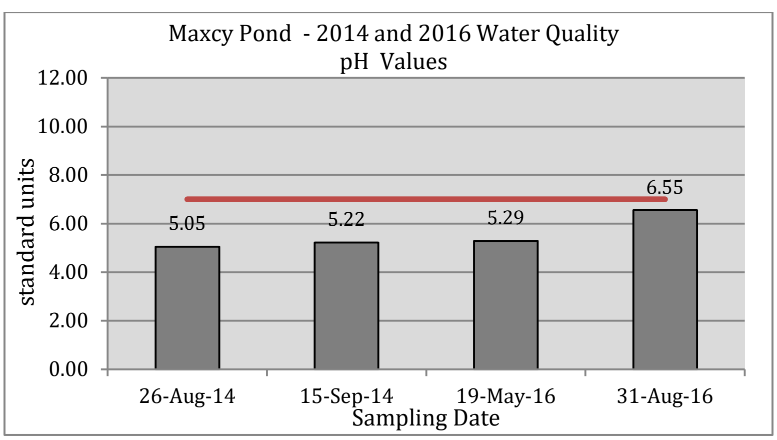
Figure 6-2 Specific conductance measured in Maxcy Pond, 2014 and 2016.



The results for the 2 years that Maxcy Pond has been sampled are low, but are within the range of specific conductance values expected in ponds considered to be fresh water.

pH. The pH measured at Maxcy Pond on May 19th was acidic at 5.29 s.u., and the value measured on August 31st was 6.55 s.u. All pH values measured at Maxcy Pond during 2014 and 2016 are shown in Figure 6-3.

Figure 6-3. pH measured in Maxcy Pond, 2014 and 2016.



The horizontal 'red' line shown on Figure 6-3 indicates the region along the pH scale that is considered 'neutral'. Low pH such as measured in Maxcy Pond on 3 of 4 occasions 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.

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 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 dissolved oxygen saturation values in Maxcy Pond during May and August 2016 were essentially the same from the surface of the pond down to the bottom and were not noteworthy for any particular reason. The data collected on May 19th revealed an average oxygen saturation value of 97.0 percent, while the average value measured on August 31st was 85.9 percent. Lower saturation would be expected during the height of mid-summer, and particularly during periods of low, or no, wind because organic matter settling toward the pond bottom would start to decompose and consume oxygen in the process.

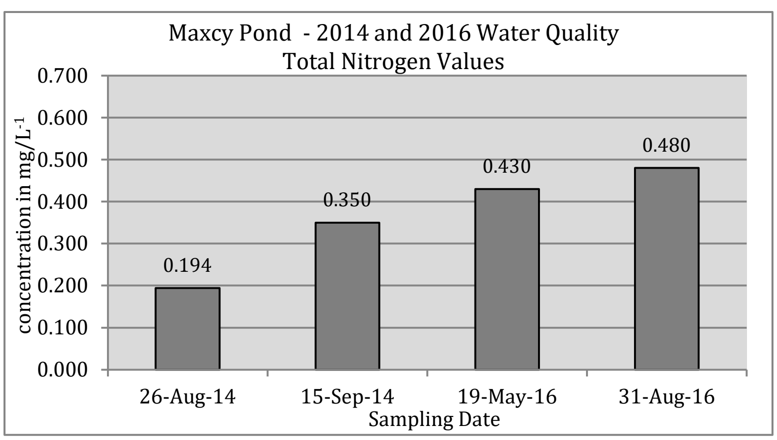
6.1.3 Plant Nutrients

Nitrogen. **Nitrate-nitrogen** was not detectable in Maxcy Pond on either 2016 sampling date. 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 in the water column. During 2014, there was nitrate-nitrogen present at 0.033 mg $N \cdot L^{-1}$ on August 26th, but the value was below detection (0.005 mg $N \cdot L^{-1}$) on September 15th.

There was no measureable **ammonia-nitrogen** in the water column on either 2016 sampling date. During 2014, the ammonia-nitrogen concentration was 0.010 mg $N \cdot L^{-1}$ on August 26th and below detection (0.005 mg $N \cdot L^{-1}$) on September 15th. As with nitrate-nitrogen, low levels of ammonia-nitrogen are not uncommon because this form of nitrogen is available for uptake by phytoplankton.

The 2016 **total nitrogen** (**TN**) concentrations measured in Maxcy Pond on May 19th and August 31st were 0.430 mg $N \cdot L^{-1}$ and 0.480 mg $N \cdot L^{-1}$, respectively, and were the highest concentrations recorded in the pond during the 2 years (2014 and 2016) that the pond was sampled (Figure 6-4).

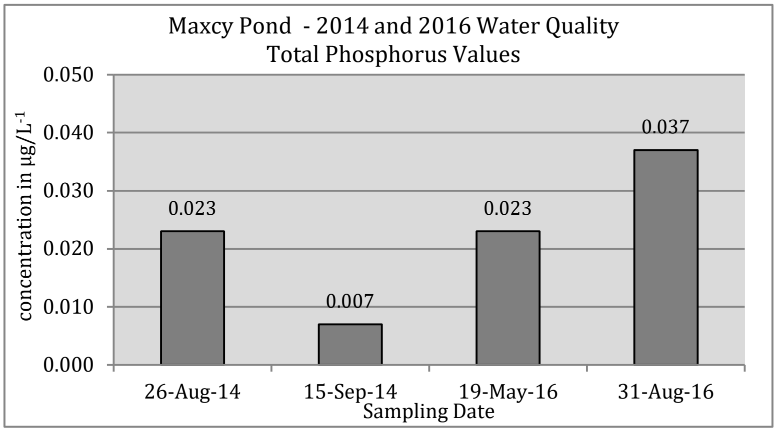
Figure 6-4. Total nitrogen concentrations measured in Maxcy Pond, 2014 and 2016.



The **TN** concentrations measured in the pond during 2014 were 0.194 mg $N \cdot L^{-1}$ on August 26th and 0.350 mg $N \cdot L^{-1}$ on September 15th, and are low concentrations when compared with other Nantucket Island ponds. The reader is referred to Chapter 9 of this report where there are several tables that compare the water quality characteristics of the 11 Nantucket Island ponds surveyed by the NLC since 2009.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Maxcy Pond during 2016 were 0.023 mg P·L^{-1} on May 19th and 0.037 mg P·L^{-1} on August 31st. As shown in Figure 6-5, the 2016 concentrations are similar to the range of concentrations measured during 2014.

Figure 6-5. Total phosphorus concentrations measured in Maxcy Pond, 2014 and 2016.



The concentrations of TP measured in Maxcy Pond during 2014 and 2016 reflect low productivity in the system and this situation is considered normal in dilute waters such as Maxcy Pond. Situations similar to this one occur in the Adirondack Mountain region of New York State where lakes and ponds have been impacted by acid deposition and often reflect low productivity in the water column.

6.1.4 Phytoplankton

Description of the assemblage. There were 23 taxa identified in the 2016 phytoplankton samples collected from Maxcy Pond and all of the major algal groups were represented in the samples (Table 6-1).

Table 6-1. Major groups and taxa of phytoplankton identified in Maxcy Pond, 2016.

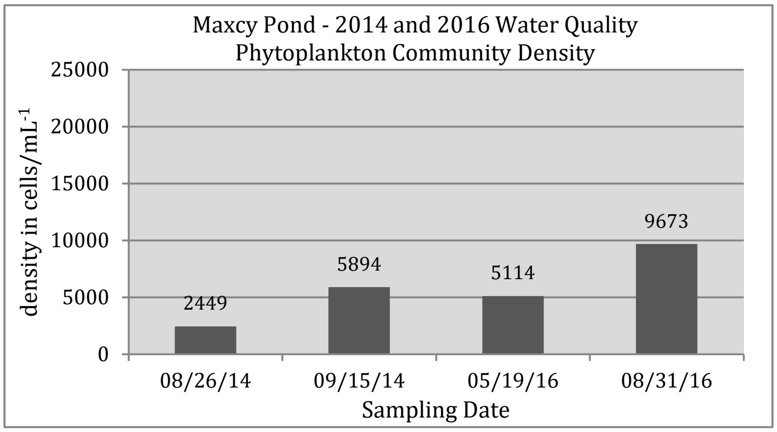
Cyanophytes	**Chrysophytes (Bacillariophyceae)**	**Chrysophytes (Chrysophyceae)**
Anabaena flos aquae	*Achnanthes* sp.	*Dinobyron divergens*
Chroococcus dispersus	*Cyclotella* sp.	*Ochromonas* sp.
Chlorophytes	*Cymbella* sp.	**Euglenophytes**
Ankistrodesmus falcatus	*Navicula* spp.	*Euglena* sp.
Closterium spp.	*Planothidium* sp.	*Peranema* sp.
Oocystis solitaria	*Rhoicosphenia curvata*	*Trachelomonas* sp.
Pandorina morum	*Stephanodiscus* sp.	**Pyrrhophytes (Cryptophytes)**
Scenedesmus bijuga	*Synedra acus*	*Cryptomonas erosa*
Tetraedron minimum		**Pyrrhophytes (Dinophytes)**
		Peridinium cinctum

There were 16 taxa identified in the pond's phytoplankton community on May 19th and 11 taxa on August 31st; community richness calculated for the 2016 sampling periods was 13.5 (±3.5) taxa.

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

Density. The 2016 phytoplankton community density in Maxcy Pond was 5,114 cells·mL^{-1} on May 19th and 9,673 cells·mL^{-1} on August 31st. The densities for 2014 and 2016 are shown in Figure 6-6. All of these 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.

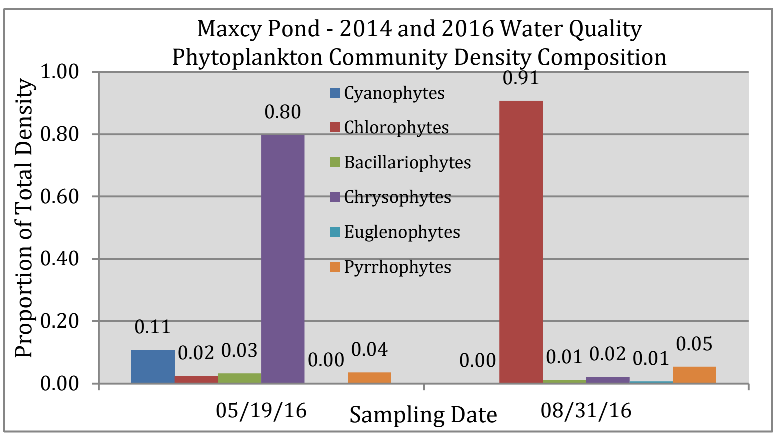
Figure 6-6. Phytoplankton community density in Maxcy Pond, 2014 and 2016.



The density composition of the 2016 phytoplankton assemblage in Maxcy Pond exhibited marked changes between the spring (May 19th) and late summer (August 31st) sampling periods (Figure 6-7).

The 2016 spring assemblage contained primarily Chrysophytes (80 percent), also known as 'golden' algae that have flagella, with lesser amounts of Cyanophytes (11 percent), Pyrrhophytes (4 percent), Bacillariophytes (3 percent), and Chlorophytes (2 percent).

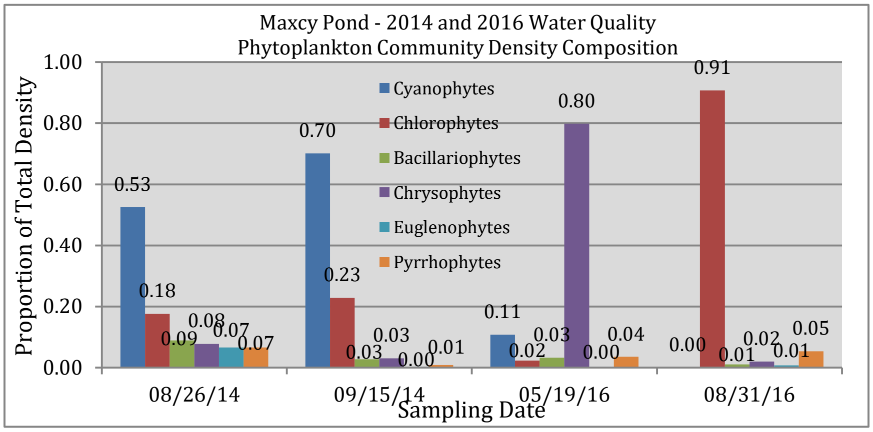
Figure 6-7. Density composition of the phytoplankton community in Maxcy Pond, 2016.



By August 31st, Chlorophytes comprised 91 percent of the phytoplankton community, with lesser amounts of Pyrrhophytes (5 percent), Chrysophytes (2 percent), Bacillariophytes (1 percent) and Euglenophytes (1 percent). There were no Cyanophytes (Blue-green algae) detected in the August assemblage.

The contrast between the community density composition in the 2014 and 2016 Maxcy Pond phytoplankton assemblages is immediately evident in Figure 6-8. During 2014, the major groups were Cyanophytes and Chlorophytes, with smaller contributions from the other major groups. During 2016, the Chrysophytes and Chlorophytes were principal components of the community assemblage, with smaller contributions from the other algal groups.

Figure 6-8. Density composition of the phytoplankton community in Maxcy Pond, 2014 and 2016.

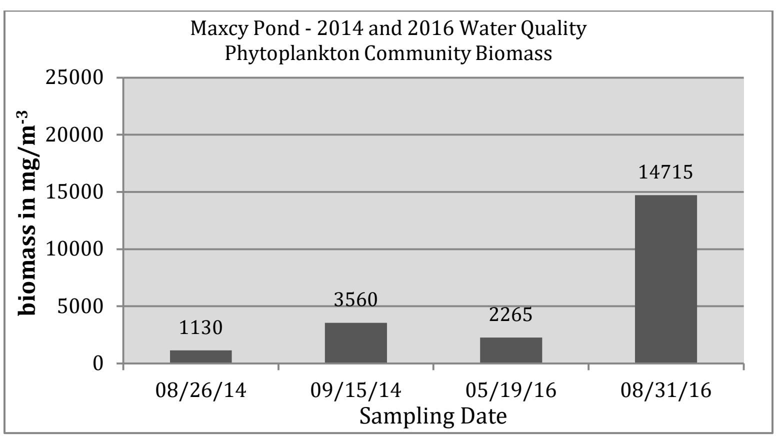


Biomass. Cell biovolume also was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond. It is quite common for size differences among different types of phytoplankton to range over several orders of magnitude.

The May 19th phytoplankton community biomass was low at 2,265 mg·m^{-3} and then increased about 7-fold to 14,715 mg·m^{-3} on August 31st.

When compared with the 2014 measured biomass values (Figure 6-9), the August 2016 concentration was the highest recorded for the pond during the 2 years of water quality survey.

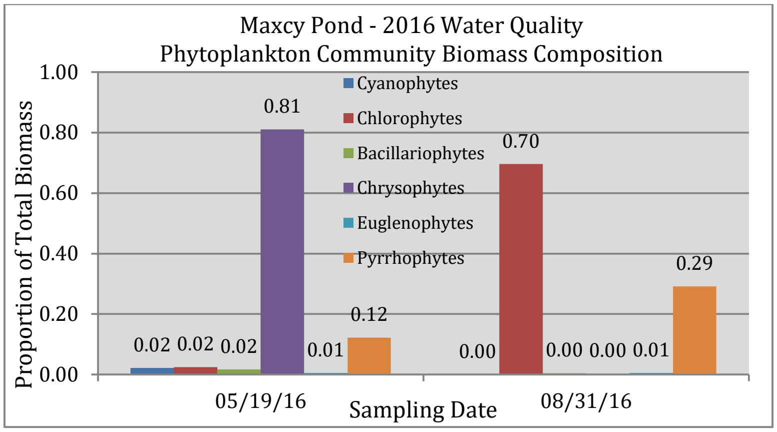
Figure 6-9. Phytoplankton community biomass in Maxcy Pond, 2014 and 2016.



The biomass composition of the 2016 phytoplankton community assemblage in Maxcy Pond (Figure 6-10) was very similar to the 2016 density composition described above, i.e., Chrysophytes dominated the community in May (81 percent) and Chlorophytes dominated the community in August (70 percent).

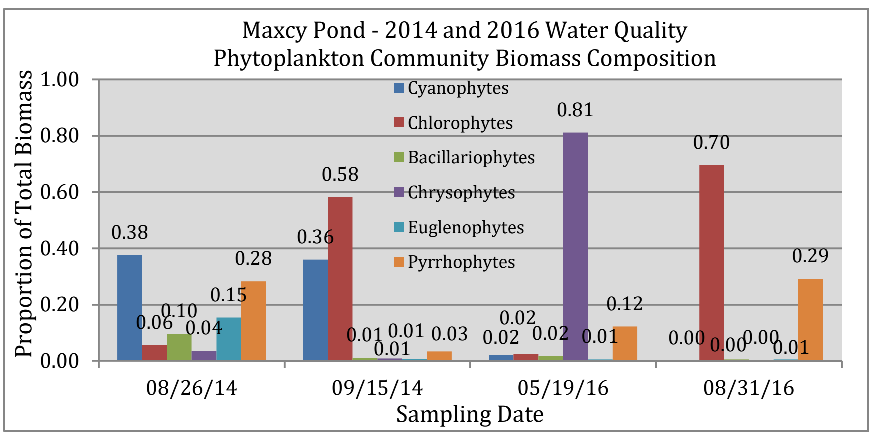
Another noteworthy change in the biomass composition during 2016 was the sizeable increase in Pyrrhophytes from 12 percent of the community composition in May to 29 percent of the community composition in August.

Figure 6-10. Biomass composition of the phytoplankton community in Maxcy Pond, 2016.



The 2014 and 2016 biomass composition of the Maxcy Pond phytoplankton communities is presented in Figure 6-11. From these data, it is evident that the communities were very different in composition. There do not appear to be any similarities between the two assemblages.

Figure 6-11. Biomass composition of the phytoplankton community in Maxcy Pond, 2014 and 2016.



Dominance. A ranking of phytoplankton taxa dominance in Maxcy Pond on the 2016 sampling dates is summarized in Table 6-2. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

Table 6-2 Rank of phytoplankton taxa dominance, using biomass, in Maxcy Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/19/16	*Ochromonas* sp. (Chrysophyte)	1	81
	Peridinium cinctum (Pyrrhophyte)	2	8
	Cryptomonas erosa (Pyhhhophyte)	3	5
8/31/16	*Pandorina morum* (Chlorophyte)	1	69
	Peridinium cinctum (Pyrrhophyte)	2	29

There were 3 dominant taxa in the phytoplankton community on May 19th and 2 dominant taxa in the community on August 31st (Table 6-2). As discussed above, the Chrysophytes dominated the community in May and, in August, the Chlorophytes and Pyrrhophytes were the major components of the community.

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. The results of the diversity calculations are presented in Table 6-3.

Table 6-3. Phytoplankton community diversity in Maxcy Pond, 2014 and 2016.

Maxcy Pond Sampling Date	Phyto Density Diversity Value	Phyto Biomass Diversity Value
Aug 26th 2014	1.058	0.83
Sept 15th 2014	0.886	0.740
May 19th 2016	0.393	0.320
August 31st 2016	0.358	0.330

The diversity calculations were very similar on each sampling date, regardless of whether density or biomass was used to evaluate this community characteristic (Table 3-3). 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. Any time there is a big decrease in community diversity, it means that a greater proportion of the community resides with fewer individuals instead of more individuals.

Cyanophytes. As a major phytoplankton group of aquatic ecosystem importance, the Cyanophytes were identified in certain samples collected during 2014 and 2016; Table 6-4 identifies which species were identified on the various 2014 and 2016 sampling dates and their percent contribution to the community.

Table 6-4. Cyanophyte species identified in Maxcy Pond, 2014 and 2016.

Species	Aug 26th 2014	Sept 15th 2014	May 19th 2016	August 31th 2016
*Anabaena flos aquae**	yes (32%)	no	no	no
*Anabaenopsis Elenkinii**	yes (9%)	yes (3%)	no	no
*Aphanizomenon flos aquae**	no	yes (67%)	yes (3%)	no
Chroococcus dispersus	yes (2%)	no	yes (8%)	no
Microcystis aeruginosa	yes (10%)	no	no	no
'yes' = present, 'no' = absent; (##) proportion of community 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 of these 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.

[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.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Maxcy Pond were 5.70 $\mu g \cdot L^{-1}$ on May 19th and 8.10 $\mu g \cdot L^{-1}$ on August 31st, indicating a low–to-moderate level of algal productivity in the pond on both occasions. The 2014 chlorophyll a levels in Maxcy Pond were even lower, 2.39 $\mu g \cdot L^{-1}$ on August 26th and 3.11 $\mu g \cdot L^{-1}$ on September 15th.

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 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 a valid Secchi depth reading on either sampling date, there were sufficient TP and chlorophyll ***a*** data from Maxcy Pond during 2016 to calculate the Carlson Trophic State Index (TSI) using those 2 variables. Average values were calculated for chlorophyll ***a*** and total phosphorus 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 calculation and results of the analysis are as follows:

Chlorophyll *a*
Average chlorophyll *a* = 6.90 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (6.90)] + 30.6
TSI = (9.81)(1.932) + 30.6
TSI = 49.5

Total phosphorus
Average total phosphorus = 29.95 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (29.95)] + 4.15
TSI = (14.42)(3.400) + 4.15
TSI = 52.3

Table 6-5 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 6-5. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 the 2016 data, Maxcy Pond was at the high end of the mesotrophic range of productivity based upon the 2016 chlorophyll a values measured. The slight increase in 2016 TP values detected in Maxcy Pond between 2014 and 2016 placed the pond at the low end of the eutrophic range of productivity during the current round of sampling.

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

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 2016 Water Quality

Chapter 7

Washing Pond

7.0 Introduction

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

7.1 Results

Washing Pond was sampled on May 19th and August 31st 2016. The maximum water depth located in the pond was 14.5 feet (4.4 m) on May 19th at a sampling location in the approximate center of the pond; the maximum water depth located on August 31st was 15.3 feet (4.7 m).

Following the collection of temperature and dissolved oxygen profile data on May 19th, an integrate sample was collected from the surface down to 10 feet of depth for the chemistry and phytoplankton samples; a grab sample was collected at the 13-foot depth for water chemistry. The depth of collection on August 31st was 0-6 feet for the integrate sample; no grab sample was collected from the deeper portion of the water column.

7.1.1 Physical characteristics

General. Washing Pond is rectangular in shape with a middle bugle giving it the appearance of an ellipse with its axis oriented in a north-south direction (Figure 7-1). The surface area of the pond is about 8 acres. There are no permanent streams flowing into the pond, and there is no outlet located along the shoreline.

Figure 7-1. 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.

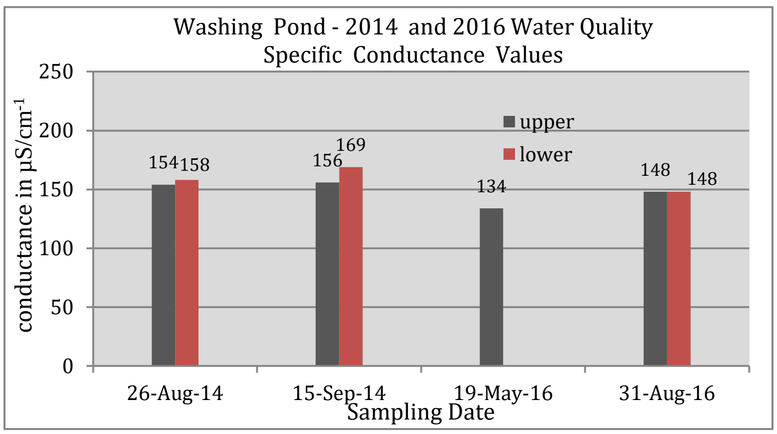
Temperature. Temperature profile data were collected on both 2016 sampling excursions to Washing Pond. The profile data essentially were isothermal on both occasions with only about 1°C difference between the surface and bottom temperatures. The average temperature of the pond was 16.5°C on May 19th and 25.5°C on August 31st.

Transparency. The 2016 Secchi depth transparency measured at Washing Pond was 3.5 m on May 19th and 1.3 m on August 31st. Water color on May 19th was recorded as 'clear', which accounts for the high Secchi depth recorded and indicates that there was no algal bloom in progress. Water color was recorded as 'clear-green brown' on May 19th which could be an indication of an algal bloom in progress and explains the lower transparency reading.

7.1.2 Chemical characteristics

Specific conductance. The 2016 specific conductance values measured in Washing Pond were 134 $\mu S \cdot cm^{-1}$ in the ***upper*** region on May 19th and 148 $\mu S \cdot cm^{-1}$ in the ***upper*** region on August 31st. There was sufficient oxygen percent stratification on August 31st to collect a ***lower*** region sample and conductance was the same as the ***upper*** region sample on that date, 148 $\mu S \cdot cm^{-1}$. Figure 7-2 presents the conductance values measured at Washing Pond during 2014 and 2016 when the pond was monitored.

Figure 7-2. Specific conductance measured in Washing Pond, 2014 and 2016.



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. There is nothing noteworthy to report concerning the pH values collected from Washing Pond during 2016 when the upper region of the pond exhibited a pH of 5.99 s.u. on May 19th and the measured values for the upper and lower regions were 7.53 s.u. and 7.14 s.u. on August 31st, respectively. In addition, all of the 2014 pH values essentially were within the range of 6.00 to 7.00 and none of these values indicate anything unusual occurring in the pond.

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 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.

On May 19th, oxygen saturation values decreased from 96.0 percent at the surface down to 90.7 percent at 14 feet; subsequently, the values dropped to 0.2 percent at 15 feet and 1.3 percent at 16 feet. The August 31st profile showed a more gradual decline through the water column on August 31st, with about 93 percent saturation at the pond surface, then a gradual decrease to 76.2 percent at 13 feet and 2.6 percent at 14 feet.

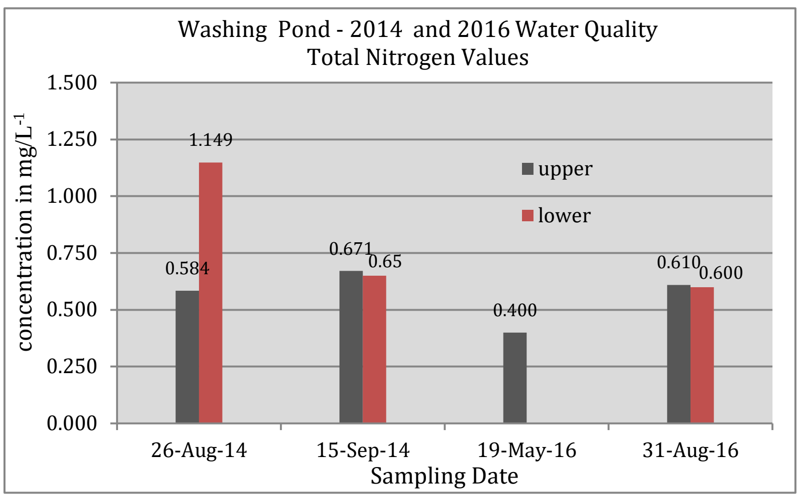
The conditions on May 19th suggest that the pond was in the process of mixing throughout the water column while there was little or no wind to promote mixing of the water column on August 31st which explains the gradual decrease of percent saturation with depth. Calm conditions can result in an oxygen saturation deficit in the lower regions due to the decomposition of organic matter in this region.

7.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was not detected on either 2016 date in samples collected from the *upper* and *lower* regions of the pond. The same situation was observed for **ammonia nitrogen** in the water column on both 2016 sampling dates. While both of these nutrients were measured in low (detectable) concentrations in Washing Pond during 2014, none of the measurements were noteworthy for any particular reason.

The **total nitrogen** (**TN**) measured in Washing Pond during 2016 was 0.400 mg N/L^{-1} in the integrate sample collected on May 19th and 0.610 and 0.590 mg N/L^{-1} in samples collected from the upper and lower regions of the pond on August 31st. The 2014 and 2016 **TN** concentrations are shown in Figure 7-3.

Figure 7-3. Total nitrogen concentrations measured in Washing Pond, 2014 and 2016.



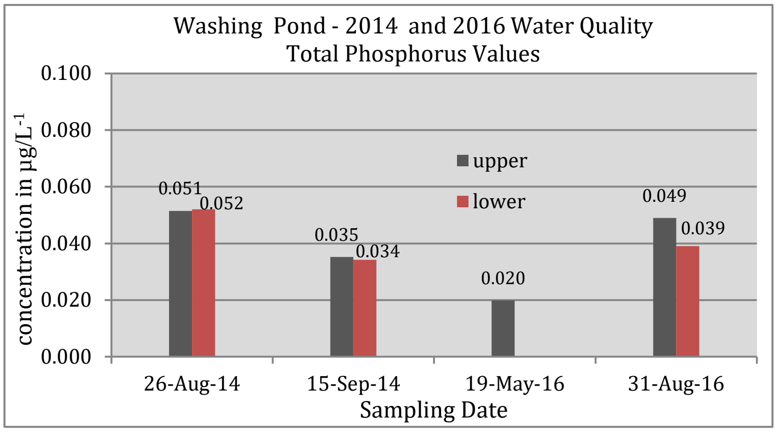
All of the TN concentrations measured in Washing Pond during 2014 and 2016 are within the range expected in a body of water that exhibits moderate productivity, except perhaps the value of 1.050 mg N/L^{-1} which occurred on August 26th 2014 and could be an outlier. Based upon the dissolved oxygen profile 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.

However, the total phosphorus (**TP**) data collected from Washing Pond on August 26th (see below) do not support the same internal loading scenario described here for **TN**, perhaps because **TP** generally is less available in fresh water lakes and ponds and would be more readily taken up by phytoplankton when available in the water column.

The **TN** concentrations measured in Washing Pond during 2014 and 2016 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 9 of this report for a comparison of water quality paramters for the suite of 11 Island ponds that have been surveyed during the past 8 years.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Washing Pond during 2016 were 0.020 µg P·L^{-1} on May 19th in the *upper* region and 0.039 and 0.049 µg P·L^{-1} on August 31st in the *upper* and *lower* region, respectively. The collective TP values for 2014 and 2016 are shown in Figure 7-4.

Figure 7-4. Total phosphorus concentrations measured in Washing Pond, 2014 and 2016.



The TP value of 0.020 µg P·L^{-1} measured on May 19th was the lowest value recorded in the pond during the 2 years of data collection. All of the TP values are within the range of concentrations for a body of water with moderate productivity.

7.1.4 Phytoplankton

Description of the assemblage. A total of 38 taxa were identified in the 2016 phytoplankton samples collected from Washing Pond and all of the major groups were represented in samples collected from Washing Pond and all of the major algal groups were represented in the samples (Table 7-1).

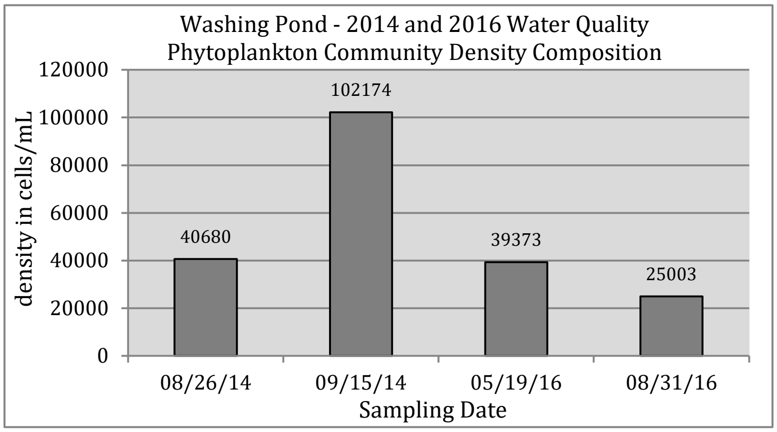
Table 7-1. Major groups and taxa of phytoplankton identified in Washing Pond, 2016.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Schroederia Judayi*	*Planothidium* sp.
Chroococcus dispersus	*S. tetraedon*	*Rhoicosphenia curvata*
Gomphosphaeria lacustris compacta	*Selanastrum capricornutum*	*Stephanodiscus* sp.
Woronichinia naegeliana	*S. minutum*	*Synedra acus*
Chlorophytes	*Sphaerocystis Schroeteri*	*Tabellaria floccosa*
Ankistrodesmus falcatus	*Staurastrum natator* var. *crassum*	**Chrysophytes (Chrysophyceae)**
Closterium acutum	*Tetraedron minimum*	*Dinobyron divergens*
Closterium gracile	*Volvex aureus*	*Mallomonas* sp.
Eudorina elegans	**Chrysophytes (Bacillariophyceae)**	**Euglenophytes**
Mougeotia sp.	*Aulacoseria granulata*	*Trachelomonas* sp.
Oocystis Borgei	*Asterionella formosa*	**Pyrrhophytes (Cryptophytes)**
O. pusilla	*Cocconeis* sp.	*Cryptomonas ovata*
Pandorina morum	*Cyclotella* sp.	**Pyrrhophytes (Dinophytes)**
Quadrigula lacustris	*Gyrosigma* sp.	*Ceratium hirundinella*
Scenedesmus quadricauda	*Navicula* spp.	

There were 24 taxa identified in the pond's phytoplankton community on May 19th and 27 taxa identified in the community on August 31st; 2016 community richness was calculated to be 25.5 (±2.1) taxa.

Density. Community density in Washing Pond was 39,373 cells·mL^{-1} on May 19th and 25,003 cells·mL^{-1} on August 31st 2016. The 2014 and 2016 community densities are shown in Figure 7-5.

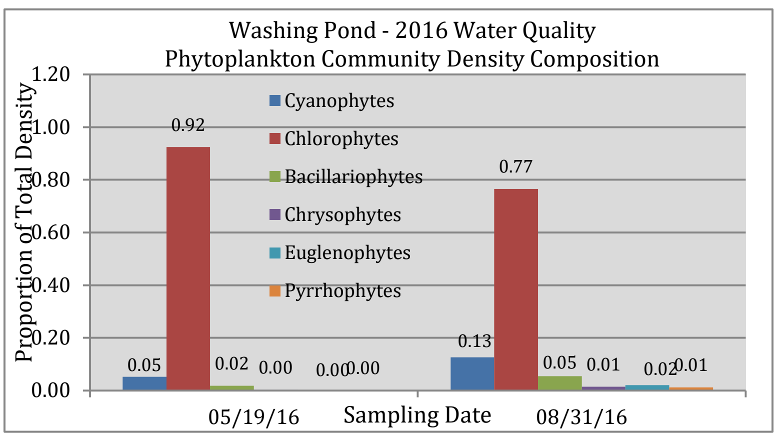
Figure 7-5. Phytoplankton community density in Washing Pond, 2014 and 2016.



The September 15th 2014 density is extremely high when compared with the other density values and there likely was a bloom in progress in the pond at that time.

The May and August density composition of the pond phytoplankton community were almost identical (Figure 7-6), with Chlorophytes the dominant group (92 percent and 77 percent, respectively) followed by Cyanophytes (Blue-greens) as the next largest group with 5 percent in May and 13 percent in August.

Figure 7-6. Density composition of the phytoplankton community in Washing Pond, 2016.

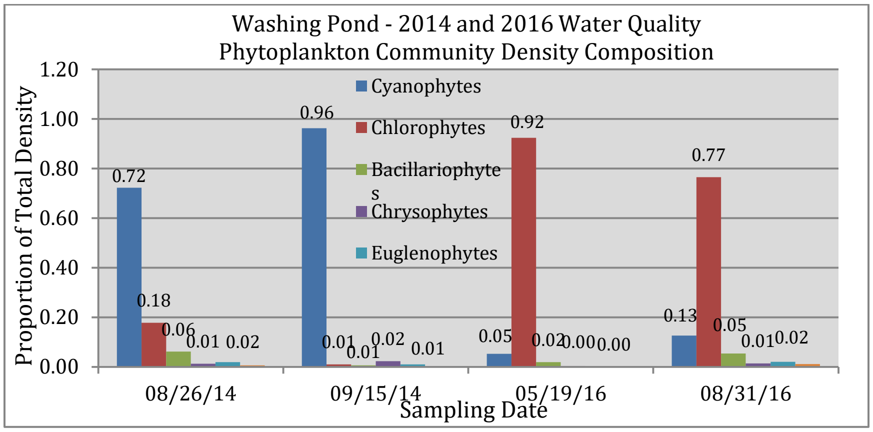


The diatoms (Bacillariophytes) were the only other major phytoplankton group present in May, while the August assemblage was represented by all 6 major groups,

The density composition of the phytoplankton community in 2014 and 2016 is shown in Figure 7-7. There was a dramatic change in the community structure when viewing the relative composition during these 2 years.

Cyanophytes were the dominant group during both 2014 sampling dates, exhibiting 72 percent and 96 percent of the community on August 26th and September 15th, respectively, and Chlorophytes dominated the community during both dates in 2016.

Figure 7-7. Density composition of the phytoplankton community in Washing Pond, 2014 and 2016.

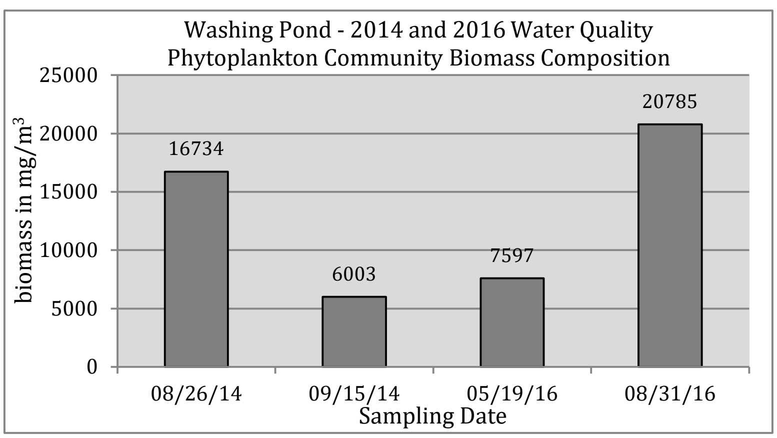


Data such as these from Washing Pond emphasize the importance of monitoring a body of water for several years instead of just one year when some interpretation of water quality is desired because some of the pond characteristics can change as exhibited by the phytoplankton community in Washing Pond.

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 documented in Washing Pond during May and August 2016 was measured at 7,597 mg/m^{-3} and 20,785 mg/m^{-3}, respectively, and averaged 14,191 mg/m^{-3}. These values are similar to the 2014 biomass values which are summarized in Figure 7-8 along with the 2016 data.

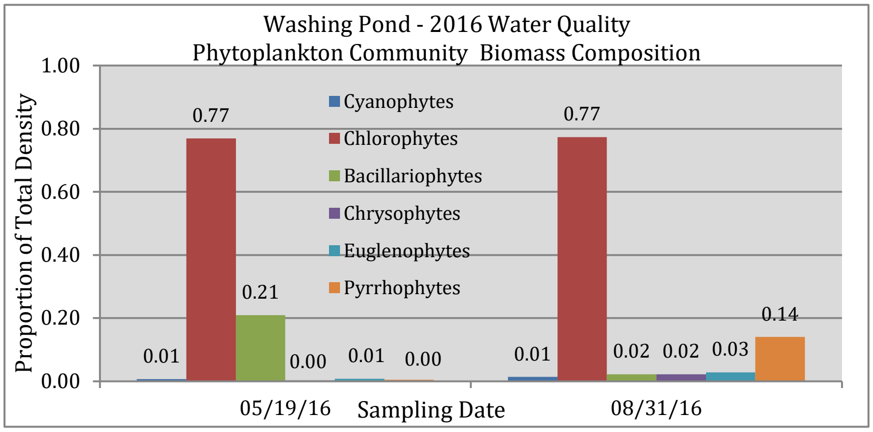
Figure 7-8. Phytoplankton community biomass in Washing Pond, 2014 and 2016.



The biomass in Washing Pond was 16,734 mg·m^{-3} on August 26th 2014 and 6003 mg·m^{-3} on September 15th 2014, and averaged 11,369 mg·m^{-3} for both 2014 sampling dates (Figure 7-8).

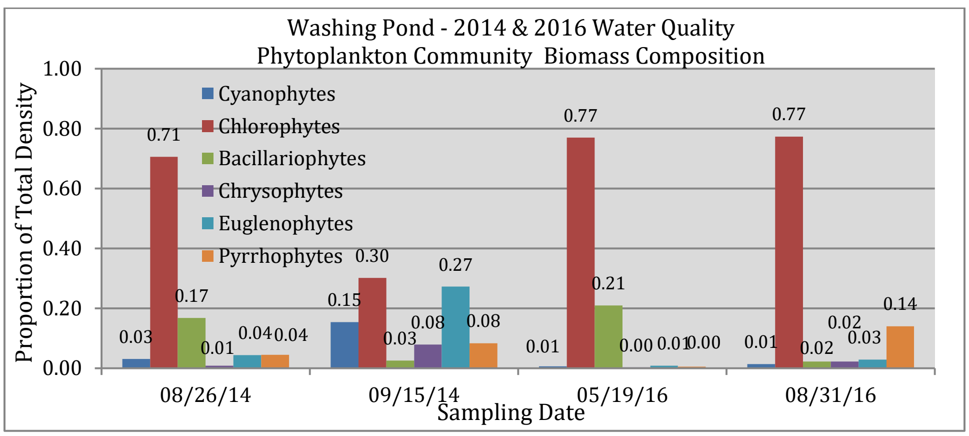
As shown in Figure 7-9, the May and August 2016 phytoplankton community compositions were very similar, with Chlorophytes comprising 77 percent of the total biomass on both dates. The Bacillariophytes (diatoms) were the next most important group on May 19th (21 percent) and Pyrrhophytes held that second ranking position on August 31st (14 percent).

Figure 7-9. Biomass composition of the phytoplankton community in Washing Pond, 2016.



The community biomass values measured in Washing Pond during 2014 and 2016 are presented in Figure 7-10 and show the differences that can occur when interpreting community structure using density or biomass.

Figure 7-10. Biomass composition of the phytoplankton community in Washing Pond, 2014 and 2016.



Based upon biomass, Chlorophytes clearly are the most important community group in Washing Pond during 2014 and 2016; September 15 2014 was the only time that Chlorophytes (30 percent) shared community dominance with another group, the Euglenophytes (27 percent).

Referring back to Figure 7-7 which presents density composition in Washing Pond during 2014 and 2016, we see that Cyanophyes were the density dominants and the Chlorophytes were greatly reduced in terms of community importance.

Dominance. A ranking of phytoplankton taxa dominance in Washing Pond on the 2016 sampling dates is summarized in Table 7-2. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass.

There were 4 dominant taxa in the phytoplankton community on May 19th and 3 dominant taxa in the community on August 31st (Table 7-2). As discussed above, the green algae (Chlorophytes) comprised a major portion of the community on both 2016 sampling dates.

The reader is referred to Sutherland and MacKinnon (2015) for a summary of the dominant biomass taxa identified in Washing Pond during 2014.

Table 7-2. Rank of phytoplankton taxa dominance, using biomass, in Washing Pond during 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/19/16	*Closteriumacutum* (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

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 7-3.

Table 7-3. Phytoplankotn community diversity in Washing Pond, 2014 and 2016.

Washing Pond Sampling Date	Phyto Density Diversity Value	Phyto Biomass Diversity Value
Aug 26th 2014	0.871	0.892
Sept 15th 2014	0.181	0.963
May 19th 2016	0.301	0.777
August 31st 2016	0.628	0.619

As discussed above with regard to the comparison between density and biomass, the choice of variable can greatly affect the character of the community because of extremely large size (biomass) differences among different species of phytoplankton, whereas numbers of individuals (density) is a relative variable.

For example, on September 15th 2014, diversity based upon biomass was high, with a value of 0.963 (1.00 is the highest diversity value), which suggests a balance in size among the community taxa. In contrast, diversity based upon density on that date was 0.181, which indicates that most of the community density resided with a single species, which was the case (*Microcystis aeruginosa*, 92 percent).

Cyanophytes. As a major phytoplankton group, the Cyanophytes were identified in both the May and August 2016 samples collected in Washing Pond. A total of 4 taxa were identified during 2016 and are listed in Table 7-4 along with the species of Cyanophytes identified in the 2014 samples collected from Washing Pond.

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.

[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.

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

Table 7-4. Cyanophyte species identified in Washing Pond, 2014 and 2016.

Species	Aug 26th 2014	Sept 15th 2014	May 19th 2016	August 31th 2016
*Anabaena flos aquae**	no	no	no	yes (3%)
Aphanizomenon flos aquae	yes (2%)	yes (2%)	no	no
Chroococcus dispersus	yes (1%)	no	no	yes (2%)
C. limneticus	yes (<1%)	no	no	no
Gomphosphaeria lacustris compacta	yes (8%)	no	yes (<1%)	no
Microcystis aeruginosa	yes (49%)	yes (92%)	no	no
*Woronichinia naegeliana**	yes (11%)	yes (2%)	yes (5%)	yes (8%)
'yes' = present, 'no' = absent; (##) proportion of community on a sampling date * Species that are known to produce algal toxins				

Chlorophyll *a*. The 2016 chlorophyll ***a*** concentrations measured in Washing Pond were 2.1 $\mu g \cdot L^{-1}$ on May 19th and 24.6 $\mu g \cdot L^{-1}$ on August 31st. 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. The 2014 chlorophyll ***a*** readings were 5.0 and 10.9 $\mu g \cdot L^{-1}$ on August 26th and September 15th, respectively.

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.

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 May 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* = 13.35 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (13.35)] + 30.6
TSI = (9.81)(2.59) + 30.6
TSI = 56.0

Total phosphorus
Average total phosphorus = 34.45 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (34.45)] + 4.15
TSI = (14.42)(3.54) + 4.15
TSI = 55.2

Secchi depth
Average Secchi depth = 2.40 m
Secchi TSI = 60 – [14.41*[ln (2.40)]
TSI = 60 – (14.41)(0.88)
TSI = 47.4

The TSI of 56.0 calculated for chlorophyll ***a*** was within the eutrophic range of productivity (see Table 7-5), which also was the case for the TSI calculated for total phosphorus (55.2). The average 2016 Secchi depth (2.4 m) resulted in a calculated TSI value of 47.4, at the high end of the mesotrophic range of productivity.

Table 7-5. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

Trophic State Index	Chlorophyll ($\mu g\ L^{-1}$)	TP ($\mu g\ L^{-1}$)	Secchi Depth	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 and 2016, we see that there was a slight change in water quality of Washing Pond between those 2 years (Table 7-6).

Table 7-6. Trophic State Indices (TSIs) calculated for Washing Pond in 2014 and 2016.

Year	Chlorophyll TSI	TP TSI	Secchi TSI
2014	50.9	58.5	52.6
2016	56.0	55.2	47.4

The chlorophyll ***a*** TSI increased between the 2 years (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

7.2 Summary

Based upon the data collected during 2016, 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 whenthe pond surface is exposed to sustained winds blowing across the Island.

7.3 Literature Cited

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 Nantucket Land Council, Inc. 43 pp.

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Nantucket Island Ponds and 2016 Water Quality

Chapter 8

North Head of Long Pond

8.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from the North Head of Long Pond by the Nantucket Land Council, Inc. during 2016.

8.1 Results

North Head of Long Pond was sampled on May 13th and August 31th 2016. The maximum water depth recorded was 4.7 feet (1.4 m) on May 13th and 4.6 feet (1.4 m) on August 31st at the sampling location in the approximate center of the pond.

Following the collection of Secchi depth transparency, and temperature and dissolved oxygen profile data, integrate samples were collected from the surface down to 4 feet on May 13th and 3 feet on August 31st for the water chemistry and phytoplankton samples. No additional water samples were collected on either sampling date. Observations recorded while the pond was being sampled included a lack of attached (rooted) vegetation growing on the bottom of the pond.

8.1.1 Physical characteristics

General. North Head of Long Pond is located in an area known as Dionis, north of Madaket Road and south of Eel Point Road, adjacent to the Town of Nantucket landfill. The pond is separated from the main body of Long Pond by a causeway which serves as the Madaket Road crossing (Figure 8-1). The surface area of the pond is about 42 acres and the maximum depth is 4-5 feet at the center of the pond.

Figure 8-1. Aerial view of North Head of Long Pond (from *Google*™ earth).

Much of the pond is surrounded by property owned by the Linda Loring Nature Foundation, and permanently protected with a Conservation Restriction held by the Nantucket Land Council. The pond receives input from ground water, precipitation and surface runoff from the relatively small surrounding watershed. The main body of Long Pond is connected to Hither Creek via the Madaket Ditch which may affect salinity.

Temperature. Temperature profile data were collected during both 2016 sampling excursions. The May 13th temperature was isothermal from surface to bottom at 17.4°C. On August 31st, there was a slight variation in temperature of the water column and the average temperature was 24.6°C.

Transparency. The Secchi depth transparency measured at the North Head of Long Pond on May 13th was 2.2 feet (0.7 m) and the reading on August 31st was 2.8 feet (0.9 m). Water color observations recorded when the pond was sampled were 'clear > brown' on August 31st.

8.1.2 Chemical characteristics

Specific conductance. All 2016 conductance values were similar and noticeably high 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 reading on May 13th was 14.3 mS/cm^{-1} and the reading on August 31st was 23.2 mS/cm^{-1}.

pH. pH values were 6.65 s.u. on May 13th and 6.83 s.u. on August 31st; there is nothing noteworthy about the pH values recorded at the North Head of Long Pond during 2016.

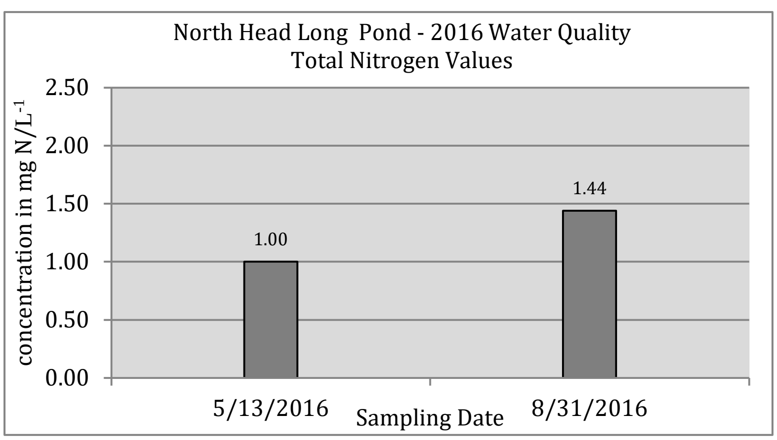
Dissolved oxygen percent saturation. The average oxygen saturation values for the pond were 95.4 percent on May 13th and 76.4 percent on August 31st. There was a slight percent saturation gradient with increasing water depth on the latter date which suggests that the pond experienced a period when wind was not blowing by a sufficient amount to mix the pond from surface to bottom that allowed the gradient to develop.

8.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was not detectable in the pond on either 2016 sampling date which is not unusual since this form of nitrogen is taken up by phytoplankton during the process of photosynthesis. There was only a slight amount (0.030 mg $N \cdot L^{-1}$) of **ammonia-nitrogen** measured on May 13th and no detectable amount of **ammonia-nitrogen** on August 31st; this compound also is taken up by phytoplankton in the water column for productivity during the growing season.

On May 13, the **total nitrogen (TN)** concentration (Figure 8-2) measured in the pond was 1.00 mg $N \cdot L^{-1}$, which is a reasonable spring value when water temperatures are rising and productivity is increasing in the pond. By August 31st, the **TN** value had increased to 1.44 mg $N \cdot L^{-1}$ which is a value indicative of moderate productivity in this pond.

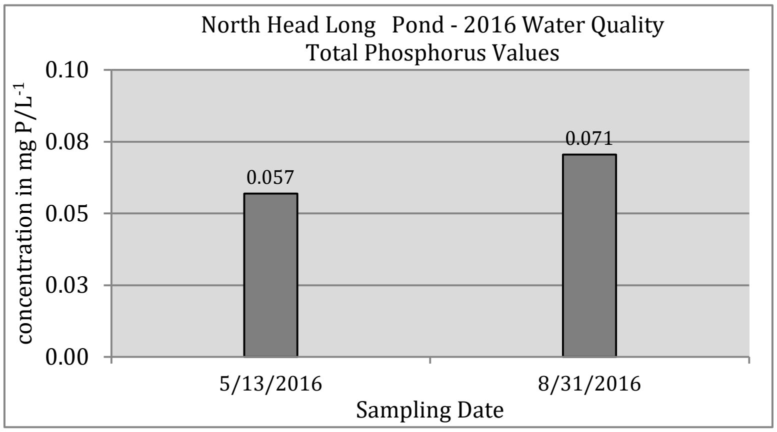
Figure 8-2. Total nitrogen concentrations measured in North Head of Long Pond, 2016.



Based upon the low **nitrate-nitrogen** and **ammonia-nitrogen** values recorded, virtually all of the nitrogen measured in North Head of Long Pond during 2016 was tied up in organic material, i.e., phytoplankton and other organisms in the water column.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in North Head of Long Pond were 0.057 mg $P \cdot L^{-1}$ and 0.071 mg $P \cdot L^{-1}$ on May 13th and August 31st, respectively (Figure 8-3).

Figure 8-3. Total phosphorus concentrations measured in North Head of Long Pond, 2016.



These **TP** concentrations are slightly elevated and indicate a moderate level of productivity in the pond, which also is substantiated by the chlorophyll ***a*** concentrations measured during 2016 (see below).

The reader is referred to Chapter 9 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.

8.1.4 Phytoplankton

Description of the assemblage. A total of 23 taxa were identified in the 2016 May and August phytoplankton samples collected from North Head of Long Pond (Table 8-1).

Table 8-1. Major groups and taxa of phytoplankton identified in Noth Head Long Pond, 2016.

Chlorophyta	**Chrysophyta (Bacillariophyta)**	**Chrysophyta (Bacillariophyta)**
Monoraphidium arcuatum	*Cocconeis* sp.	*Synedra acus*
Pediastrum duplex	*Cyclotella* sp	*S. ulna*
Pyramimonas tetrarhyncus	*Cymbella* sp.	*Tabellaria floccosa*
Scenedesmus bijuga	*Gomphonema* sp.	**Chrysophyta (Chrysophyceae)**
Schroederia Judayi	*Navicula* spp.	*Ochromonas* sp.
Chrysophyta (Bacillariophyta)	*Nitzschia* sp.	**Euglenophyta**
Achnanthese sp.	*Planothidium* sp.	*Peranema* sp.
Amphora sp.	*Stephanodiscus* sp.	*Trachelomonas* sp.
Aulocoseria granulata		

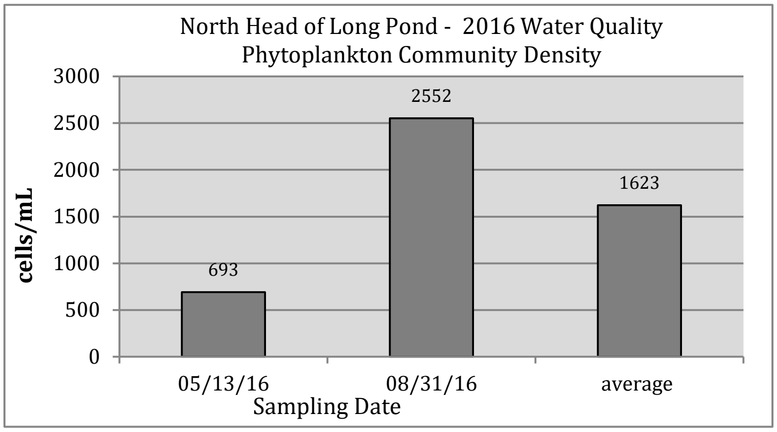
These data are noteworthy; this is the smallest assemblage of phytoplankton recorded for Nantucket island ponds since NLC surveys were first conducted starting in 2009. There were 14 taxa in the May assemblage and 16 taxa in the August assemblage.

Community richness for the 2016 phytoplankton samples collected from North Head of Long Pond was calculated to be 15.0 ± 1.4 taxa.

Also noteworthy is the observation that there were no Cyanophytes (Blue-green algae) observed in either of the 2016 phytoplankton samples collected from the pond.

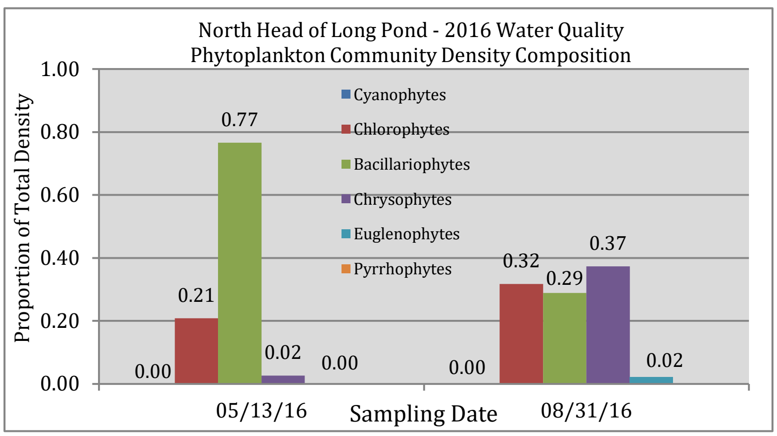
Density. Phytoplankton community density in the pond was 693 cells$\cdot$mL^{-1} on May 13th and 2,552 cells$\cdot$mL^{-1} on August 31st (Figure 8-4). Both of these recorded densities are low and indicate of a relatively diminished phytoplankton community in this body of water.

Figure 8-4. Phytoplankton community density in North Head of Long Pond, 2016.



The May 13th phytoplankton assemblage (Figure 8-5) was comprised primarily of Bacillariophytes (diatoms) with 77 percent of the total density and Chlorophytes (green algae) with 21 percent of the density; the remainder of the community consisted of Chrysophytes (2 percent). Cyanophytes, Euglenophytes and Pyrrhophytes were not identified in the May assemblage.

Figure 8-5. Density composition of the phytoplankton community in North Head of Long Pond, 2016.



By August 31st, the phytoplankton assemblage had become more diversified. There were about equal proportions of Chlorophytes (32 percent), Bacillariophytes (29 percent) and Chrysophytes (37 percent) in the community, with Euglenophytes (2 percent) the only other major group represented (Figure 8-5).

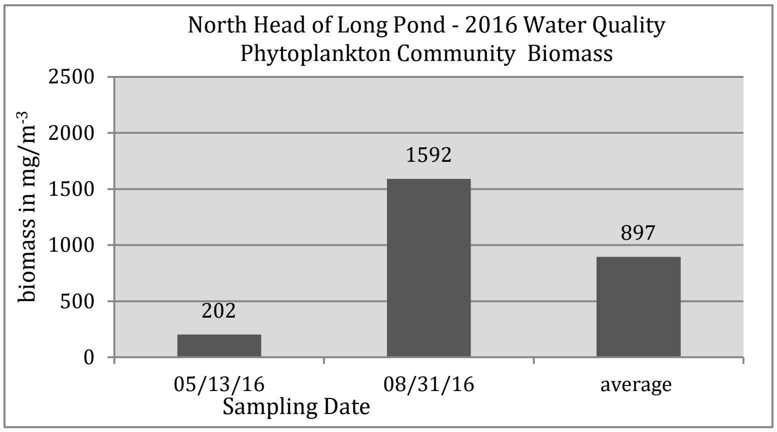
Biomass. Cell biovolume also was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond.

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 was mentioned above with regard to community density, the phytoplankton community biomass measured in North Head of Long Pond during 2016 also was low, with 202 mg·m^{-3} and 1,592 mg·m^{-3} measured May 13th and August 31st, respectively; the average 2016 community biomass was 897 mg·m^{-3}

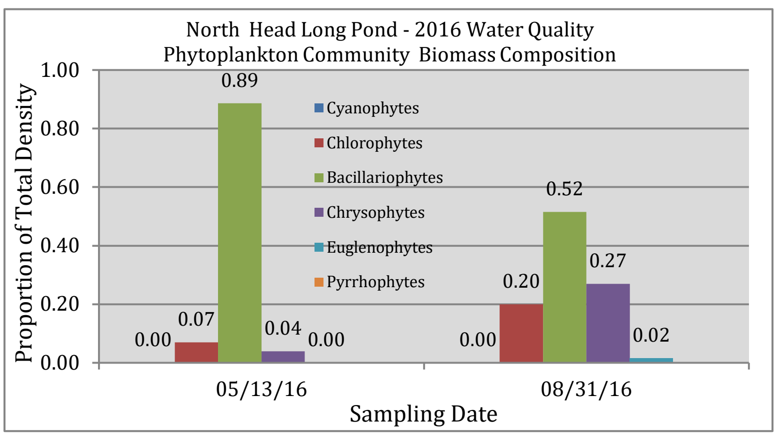
(Figure 8-6). The May 2016 biomass is noteworthy because it is the lowest biomas value recorded from Nantucket Island ponds since surveys began 8 years ago.

Figure 8-6. Phytoplankton community biomass in North Head of Long Pond, 2016.



With respect to community biomass (Figure 8-7), the May phytoplankton assemblage was comprised primarily of Bacillariophytes (89 percent) with lesser amounts of Chlorophytes (7 percent) and Chrysophytes (4 percent).

Figure 8-7. Biomass composition of the phytoplankton community in North Head of Long Pond, 2016.



By August 31st, the biomass composition of the phytoplankton community was more diversified, as was also demonstrated with respect to density, with composition still dominated by Bacillariophytes (52 percent), but with greater amounts of Chrysophytes (27 percent) and Chlorophytes (20 percent) present in the community.

Dominance. A ranking of phytoplankton taxa dominance in North Head of Long Pond on the 2016 sampling dates is summarized in Table 4-2. Taxa are considered community dominants when they comprise at least 5 percent of the total community biomass. There were 6 dominant taxa in the phytoplankton community on May 13th and 6 dominant taxa in the community on August 31st (Table 8-2).

Diversity. Phytoplankton diversity in North Head of 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.

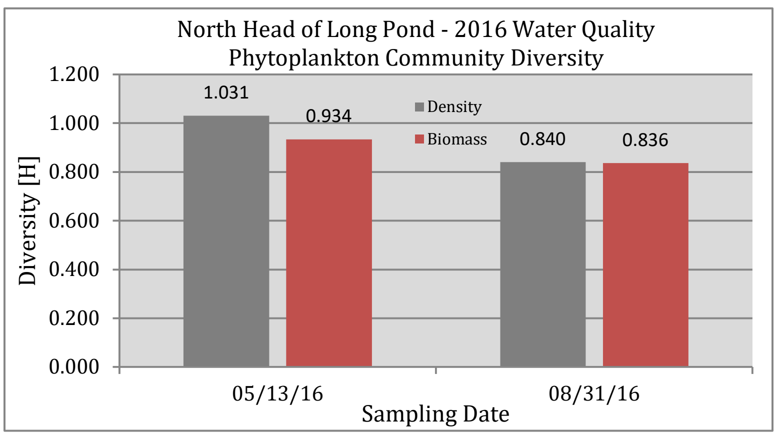
An increase in either factor (number of taxa, proportion of individuals) will increase the value of the diversity index. Calculated values that approach 1.0 indicate conditions of maximum diversity in the distribution of the population.

Table 8-2. Rank of phytoplankton taxa dominance, using biomass, in North Head of Long Pond, 2016.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
5/13/16	*Aulacoseria granulata* (Bacillariophyte)	1	21
	Cyclotella sp. (Bacillariophyte)	2	21
	Gomphonema spp. (Bacillariophyte)	3	16
	Navicula spp. (Bacillariophyte)	4	12
	Synedra acus (Bacillariophyte)	5	6
	Pyramimonas tetrarhyncus (Chlorophyte)	6	5
8/31/16	*Tabellaria flococosa* (Bacillariophyte)	1	34
	Ochromonas sp. (Chrysophyte)	2	27
	Pediastrum duplex (Chlorophyte)	3	9
	Schroederia Judayi (Chlorophyte)	4	7
	Amphora sp. (Bacillariophyte)	5	6
	Cyclotella sp. (Bacillariophyte)	6	5

Diversity in North Head of Long Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Figure 8-8.

Figure 8-8. Phytoplankton community diversity in North Head of Long Pond, 2016.



The diversity of the 2016 community was high on both sampling dates, and there was little difference in the diversity values regardless of whether density or biomass was used in the calculation.

Cyanophytes. There were no Cyanophytes identified in the North Head of Long Pond phytoplankton community during 2016 which is the first time this group of algae have been absent from any pond community since water quality surveys began back in 2009.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in the pond were 3.8 $\mu g \cdot L^{-1}$ on May 13th and 7.8 $\mu g \cdot L^{-1}$ on August 31st. which are reasonable values for a body of water with moderate productivity.

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. 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 North Head of Long Pond during 2016 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 May 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* = 5.8 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (5.8)] + 30.6
TSI = (9.81)(1.76) + 30.6
TSI = 47.8

Total phosphorus
Average total phosphorus = 63.70 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (63.70)] + 4.15
TSI = (14.42)(4.15) + 4.15
TSI = 64.1

Secchi depth
Average Secchi depth = 0.76 m
Secchi TSI = 60 – [14.41*[ln (0.76)]
TSI = 60 – (14.41)(-0.27)
TSI = 64.0

The TSI indices calculated for total phosphorus and Secchi depth were situated well within the eutrophic range of productivity, while chlorophyll ***a*** was within the mesotrophic, or moderate, range of productivity as shown in Table 8-3 below.

Table 8-3. Relationships among Trophic Index, chlorophyll *a*, phosphorus, Secchi depth and Trophic Class.

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

It should be mentioned here that TSI calculations usually are performed on average *mid-summer* values of a parameter because these values represent the conditions when maximum productivity occurs in a body of water. In the case of North Head of Long Pond and the other Natucket Island ponds surveyd during 2016, there was only 1 mid-summer value and thus the spring values also were considered in order to obtain an average value.

8.2 Summary

Based upon the data collected during 2015, North Head of Long Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has moderate-to-high productivity 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 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.

8.3 Literature Cited

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Nantucket Island Ponds

Chapter 9

Summary of Water Quality in Nantucket Island Ponds Surveyed

By the Nantucket Land Council, Inc. since 2009

9.0 Introduction

This chapter provides a brief water quality summary of Nantucket Island ponds that have been monitored by the Nantucket Land Council 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 11 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 ponds on the Island 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.

9.1 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 2016 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 8 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 which was described back in Chapter 1 and also in the individual pond chapters in this report. These 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 much better than not having any data and evaluations for individual ponds alwys 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 similar 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 all 11 Nantucket Island ponds since 2009, 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.

9.2 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 9-1. A summary of maximum, minimum and average values for the suite of parameters that have been monitored during the past 8 years on the 11 Nantucket Island ponds surveyed by The Nantucket Land Council, Inc. to date. 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	5.8	83.2	0.011	0.005	0.208	0.020	99	153	6.75
maximum value	2.57	42.8	100.6	0.080	0.057	0.986	0.289	1514	2040	8.17
average value	1.98	20.3	92.2	0.038	0.026	0.605	0.069	708	975	7.41
year monitored: 2009										
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	110.8	0.005	0.005	0.69	73.3	410	600	6.28
maximum value	2.03	187.5	37.6	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										
Maxcy Pond										
minimum value	na	2.4	94.1	0.005	0.004	0.194	7.0	65	102	5.05
maximum value	na	8.1	102.2	0.033	0.010	0.480	36.6	89	137	6.55
average value	na	4.8	98.8	0.012	0.006	0.364	22.5	74	113	5.53
year monitored: 2014, 2016										
Tom Nevers Pond										
minimum value	0.21	2.1	86.0	0.005	0.009	0.600	21.6	52	81	5.60
maximum value	0.64	14.0	98.7	0.005	0.024	1.348	796	245	226	6.35
average value	0.36	6.1	93.9	0.005	0.018	1.107	265.4	116.4	143.3	5.96
year monitored: 2014, 2016										
Washing Pond										
minimum value	1.3	2.1	105.9	0.005	0.005	0.400	0.020	85	134	5.99
maximum value	3.5	24.6	89.7	0.028	0.071	0.671	0.051	98	156	7.53
average value	2.0	10.7	99.1	0.011	0.013	0.566	0.039	94	148	6.75
year monitored: 2014, 2016										

Table 9-2 (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*	0.005	0.250	2.03	65.5	27960*	28390*	8.79*
year monitored: 2015										
Gibbs Pond										
minimum value	0.35	7.5	103.7	0.005	0.020	0.56	216.7	60	93	6.21
maximum value	0.89	216.6	104.1	0.005	0.030	1.85	477.6	62	97	8.51
average value	0.62	112.1	103.9	0.005	0.025	1.21	347.2	61	95	7.36
year monitored: 2016										
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										

Table 9-2. A summary of Trophic Status Indices calculated for total phosphorus, chlorophyll ***a*** and Secchi depth transparency for all 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		
POND	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD	TP	CHL	SD
Miacomet	E	E	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									
Maxcy																M	M	na				M	E	na
Tom Nevers																E	M	HE				HE	E	HE
Washing																E	E	E				E	E	M
Capaum																			HE	HE	HE			
Pest House																			E	E	na			
Gibbs																						HE	HE	E
Little Weweeder																						M	E	E
North Head Long																						E	M	E

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

Table 9-3. 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
Anabaena circinalis							2015				
Anabaena flos aquae	2009	2009, 2012	2009, 2011, 2012, 2013, 2014, 2015	2014	2016	2016	2015	2015	2016	2016	
Anabaena spiroides	2009	2009	2009, 2010, 2011								
Anabaenopsis Elenkinii			2010, 2014	2014	2016						
Aphanocapsa elachista			2010, 2011, 2013								
Aphanizomenon flos aquae	2009		2013, 2015	2014, 2016		2014	2015	2015	2016	2016	
Chroococcus dispersus		2012	2012, 2013, 2014, 2015	2014, 2016	2014, 2016	2014, 2016	2015				
C. limneticus	2009	2009, 2012	2009, 2011, 2012, 2014, 2015			2014				2016	
C. turgidus			2011								
Coelosphaerium Naegelianum	2009		2009, 2012								
Gloeocapsa rupestris			2010, 2011								
Gomphosphaeria lacustris compacta			2014, 2015		2014, 2016	2014, 2016	2015		2016		
Lyngbya sp.			2015								
Merismopedia glauca		2012, 2013			2014, 2016				2016		
Merismopedia punctata	2009	2009									
Microcystis aeruginosa	2009	2009	2009, 2014, 2015	2014		2014	2015				
Microcystis incerta		2012	2009, 2010, 2011, 2012, 2013								
Oscillatoria sp.								2015			
Woronichinia naegeliana						2014, 2016	2015		2016	2016	

Attachment 1

MA Department of Public Health

Microcystis and *Anabaena* Algae Blooms:

Frequently Asked Questions Concerning Health Impacts

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The Commonwealth of Massachusetts
Executive Office of Health and Human Services
Department of Public Health
Bureau of Environmental Health
250 Washington Street, Boston, MA 02108-4619
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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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The Commonwealth of 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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