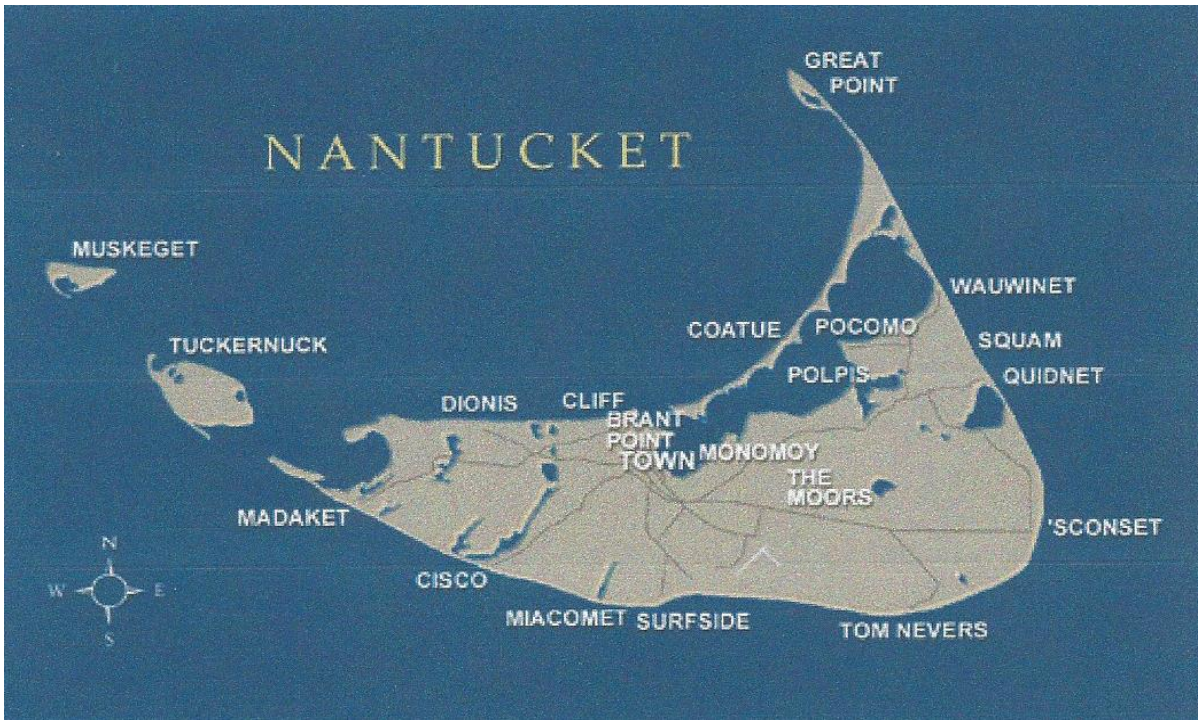
Nantucket Island Ponds and Their Water Quality

The 2014 Program – Tom Nevers, Washing and Maxcy Ponds

A Summary of Physical, Chemical and Biological Monitoring



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Nantucket Island Ponds and Their Water Quality

Chapter 1

A Basic Water Quality Primer

1.0 Introduction

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

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

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

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

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

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

1.1 Water Quality - Physical characteristics

Transparency. Transparency measures the ease with which light can pass through a substance. In lakes and ponds, transparency usually is measured by the depth of light penetration through the water column. Plants and algae require light to grow and photosynthesize, so their distribution in the water column and on the bottom of the water body is determined by the depth of light penetration and the quality of light at depth. The upper region of the water body that sunlight penetrates is called the *euphotic* zone; the area around the shoreline where depth is shallow enough for plants to receive sunlight transmitted through

the water is called the *littoral* zone. The deep area of the lake where plants are not able to grow is the *limnetic* zone.

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

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

1.2 Water Quality - Chemical characteristics

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

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

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

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

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

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

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

1.3 Water Quality - Plant Nutrients

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

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

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

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

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

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

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

Although **total nitrogen** (**TN)** is an essential nutrient for plants and animals, an excess amount of nitrogen in a water body can lead to low levels of dissolved oxygen and negatively alter plant life and

organisms. Sources of nitrogen include wastewater treatment plants, runoff from fertilized lawns and croplands, failing septic systems, runoff from animal manure and storage areas, and industrial discharges that contain corrosion inhibitors.

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

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

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

1.4 Water Quality - Phytoplankton

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

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

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

1.5 Water Quality - Trophic Status

'Trophic' means nutrition or growth. The trophic state of lakes refers to biological production, plant and animal, that occurs in the lake and the level of production is determined by several factors but primarily phosphorus supply to the lake and by the volume and residence time of water in the lake. Many different

indicators are used to describe trophic state such as phosphorus, water clarity, chlorophyll, 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 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

1.6 Summary

This chapter presented the basic elements for understanding the concept of water quality including the physical, chemical and biological information and data usually collected from water resources when some sort of an evaluation is required. This information and the assessment procedure that has been described can be applied to any fresh water or salt water lake or pond but were presented here in the

context of the process that has been applied and conducted on Nantucket Island ponds since 2009 when the Nantucket Land Council sponsored water quality investigations on Miacomet and Hummock Ponds.

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Nantucket Island Ponds and Their Water Quality

Chapter 2

Water Quality Sampling Protocol

2.0 Background

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

2.1 Sampling Protocol

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

Table 2.1 Parameters monitored to assess the short-term water quality of Nantucket Island ponds.

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

2.2 Methodology

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

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

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

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

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

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

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

The samples collected for nutrient chemistry and chlorophyll ***a*** are prepared for shipment immediately following each pond visit. The 500 mL amber PE bottles were placed in a Styrofoam cooler with gel packs and shipped via FedEx (2nd day delivery) to a contract laboratory that is certified to process and analyze the nutrient chemistry analytes and chlorophyll ***a***. A Chain of Custody form (shown in Attachment 1) accompanied the samples to the analytical lab.

Depending upon conditions observed at each pond, a subsample of raw pond water collected from the epilimnion is tested for the presence of algal toxins (microcystins) using an Abraxis, LLC Algal Toxin Strip Test for Recreational Water. The test was designed to screen for the presence/absence of toxins in pond water and to facilitate appropriate follow-up based upon the results. Since 2013 was the first season that this screening process was used on Nantucket Island ponds, samples of raw pond water also are shipped to GreenWater Laboratories in Palatka, Florida on certain occasions for the 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 Physical, chemical and biological parameters included in the study of water quality on Nantucket Island ponds, their collection technique and methodology.

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

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

Phytoplankton identification-enumeration. The protocol used for the microscopic examination of phytoplankton for identification and enumeration is detailed below.

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

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

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

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

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

Conversion to biovolume ($mg^3\ mL^{-1}$) - biomass ($mg\ m^{-3}$). Phytoplankton data derived on a volume-per-volume basis are more useful than numbers per milliliter (density) since algal cell sizes can differ in various bodies of water or within the same body of water at different times of the year. Average measurements were made from approximately 20 individuals of each taxon for each sampling period. The simplest geometric configuration that best fits the shape of the cell being measured (i.e., sphere, cone, cylinder) is used, and calculations made with corresponding formulas for that shape. The total biomass (um^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 presented the standard protocol currently used when sampling Nantucket Island ponds for water quality. The use of consistent sampling techniques ensures that the most accurate water quality assessments and evaluations are performed even if several different personnel conduct the sampling during the growing season.

2.5 Literature Cited

Nantucket Island Ponds and Their Water Quality

Chapter 3

Tom Nevers Pond - 2014

3.0 Introduction

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 2014.

3.1 Results

Tom Nevers Pond was sampled twice during 2014, on September 2nd and again on September 24th. The maximum water depth in the pond was 3.6 feet (43 inches) on September 2nd at the sampling location in the approximate center of the pond; the sampling depth on September 24th was 3.2 feet (38 inches). Following the collection of temperature and dissolved oxygen profile data on both dates, integrate samples were collected from the surface down to 3 feet of depth for the chemistry and phytoplankton samples. There were no other water samples collected from the pond on either sampling date. Observations recorded while on the pond included the following: there was an absence of any visible submerged attached aquatic vegetation and the bottom material was a dark organic material.

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. The pond outlet 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 2014 sampling excursions. Due to the pond's shallow depth, the temperature from the surface to the bottom essentially was isothermal (the same temperature) on both dates. The average temperature of the pond was 24.7ºC on September 2nd and 19.1ºC on September 24th.

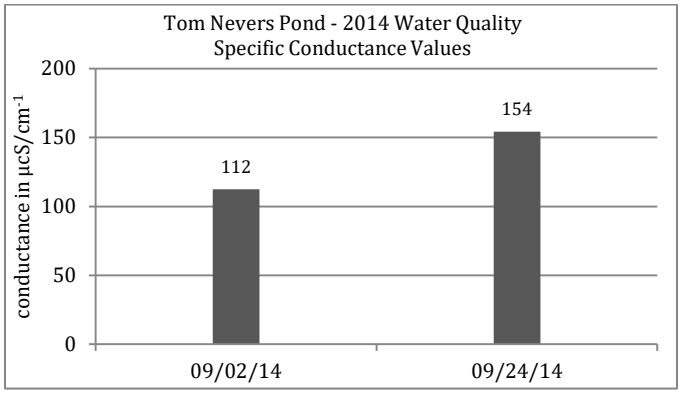
Transparency. The Secchi depth transparency measured at Tom Nevers Pond on both September sampling dates was 1.0 foot which is very shallow and indicates low light penetration from the pond surface down through the water column. Water color on both sampling dates was listed as 'brown' which is the color 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 within 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 vegetation.

3.1.2 Chemical characteristics

Specific conductance. Figure 3.2 presents the conductance values measured at Tom Nevers Pond during September 2014; the individual values measured were 112 and 154 $\mu S \cdot cm^{-1}$ on September 2nd and September 24th, respectively.

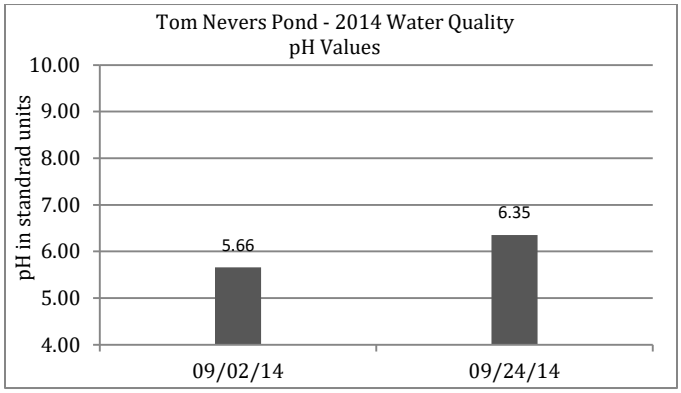
Figure 3.2 Specific conductance measured in Tom Nevers Pond, September 2014.



These values measured at Tom Nevers Pond are within the range of specific conductance values expected from ponds considered to be fresh water.

pH. The pH of Tom Nevers Pond was acidic (5.66 s.u.) on September 2nd and somewhat higher (6.35 s.u.) on September 24th (Figure 3.3). 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.

Figure 3.3 pH measured in Tom Nevers Pond, September 2014.

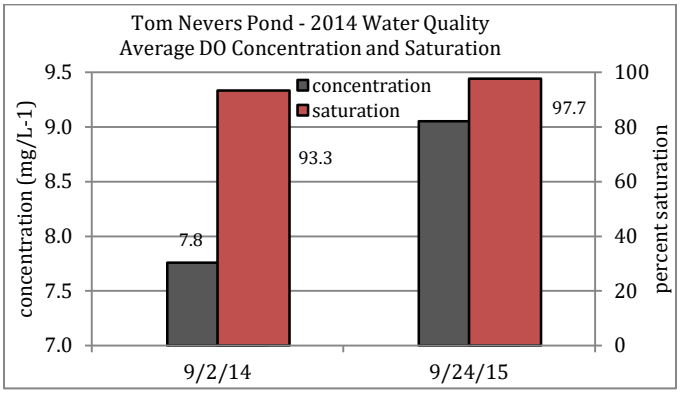


The pH documented in Tom Nevers Pond during early September 2014 is very similar to the year-round conditions that occur in small lakes and ponds in the Adirondack Region of New York State where leaching of humic and fulvic acids from the surrounding shorelines and watersheds imparts a dark brown coloration to the water and acid conditions. Based upon the very limited water clarity (low transparency) observed during

2014, most of the biological productivity (from phytoplankton) was occurring in the upper region of the pond where sufficient light is received to support photosynthesis.

Dissolved oxygen concentration-percent saturation. The oxygen concentration and saturation patterns in Tom Nevers Pond during September 2014 are shown in Figure 3.4.

Figure 3.4 Average dissolved oxygen concentration/saturation in Tom Nevers Pond, September 2014.

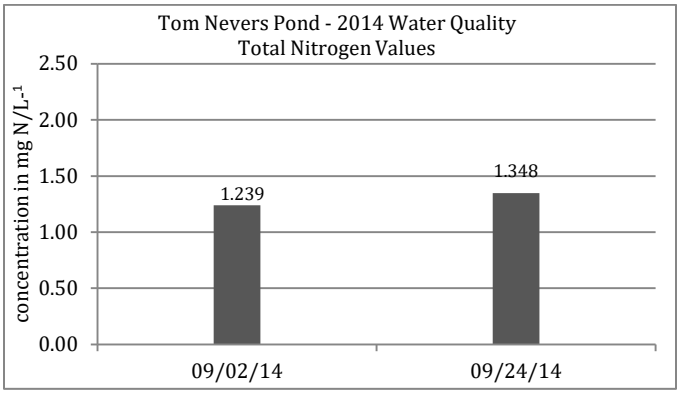


The values shown are average values for the individual readings taken from the surface down to 3 feet of depth since there was hardly any variation in the readings on either sampling date. There is nothing noteworthy about these oxygen concentration and saturation values measured in Tom Nevers Pond.

3.1.3 Plant Nutrients

Nitrogen. The September concentrations of **nitrate-nitrogen** in the pond were below the limit of detection on both sampling dates which is not unusual since this form of nitrogen is readily taken up by phytoplankton in the water column when it is available. And although there were measureable levels of **ammonia-nitrogen** on both September sampling dates, the levels were low (September 2nd=0.024 mg $N \cdot L^{-1}$; September 24th=0.024 mg $N \cdot L^{-1}$), which is not unusual since this form of nitrogen is readily taken up by phytoplankton.

Figure 3.5 Total nitrogen concentrations measured in Tom Nevers Pond, September 2014.



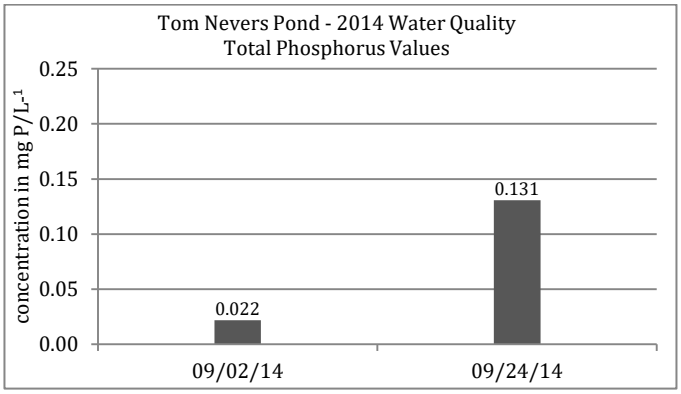
The **total nitrogen** (TN) measured in Tom Nevers Pond during September 2014 was similar on both sampling dates and is shown in Figure 3.5.

Based upon the low concentrations of **nitrate-** and **ammonia-nitrogen** measured during September 2014, essentially all of the **total nitrogen** measured in Tom Nevers Pond is contained in organic material in the form of phytoplankton and seston (other organisms and non-living particulate matter).

In addition, the **TN** concentrations measured in Tom Nevers Pond are elevated when compared with TN values measured in other Nantucket Island ponds. For example, the September 2012 **TN** value in *Hummock Pond* averaged 0.60 mg $N \cdot L^{-1}$ (Sutherland, 2013), while the September 2013 **TN** value in *Head of Hummock Pond* averaged 1.16 mg $N \cdot L^{-1}$ (Sutherland and MacKinnon, 2014).

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Tom Nevers Pond during September 2014 were 0.022 and 0.131 mg $P \cdot L^{-1}$ on the 2nd and 24th, respectively, and are shown in Figure 3.6**.**

Figure 3.6 Total phosphorus concentrations measured in Tom Nevers Pond, September 2014.



While these **TP** levels are not particularly high, it is interesting how the concentration on September 24th increased 6-fold over the concentration on September 2nd. In comparison to Tom Nevers Pond, average **TP** levels were 0.085 mg $P \cdot L^{-1}$ in *Hummock Pond* during September 2012 and 0.252 mg $P \cdot L^{-1}$ in *Head of Hummock Pond* during 2013.

3.1.4 Phytoplankton

Description of the assemblage. There were 42 taxa identified in the September 2014 phytoplankton samples collected from Tom Nevers Pond and all of the major algal groups were represented (Table 3.1).

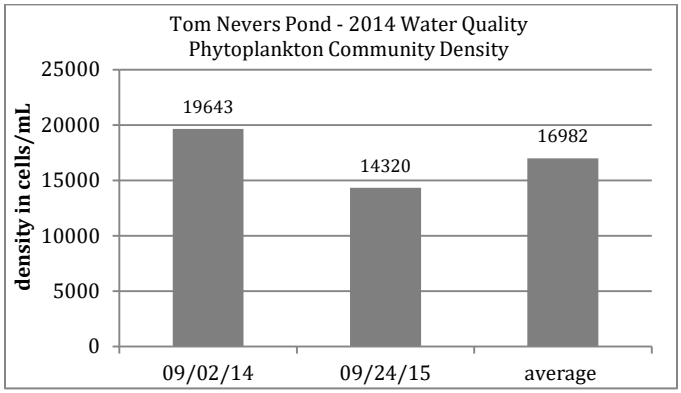
Table 3.1 Major groups and taxa of phytoplankton identified in Tom Nevers Pond, September 2014.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Chroococcus dispersus	*Monoraphidium contortum*	*Gyrosigma* sp.
Gomphosphaeria lacustris compacta	*Oocystis borgei*	*Navicula* spp.
Merismopedia glauca	*O. pusilla*	*Nitzschia* sp.
Chloromonadophytes	*Pediastrum duplex*	*Pinnularia* sp.
Gonyostomum semen	*Pyramimonas tetrarhyncus*	*Rhoicosphenia curvata*
Chlorophytes	*S. bijuga*	*Synedra acus*
A. convolutus	*S. quadricauda*	*S. fulgens*
Chlamydomonas sp.	*Spirulina* sp.	*S. ulna*
Closteriopsis longissima	*Staurastrum natator var. crassum*	**Chrysophytes (Chrysophyceae)**
Closterium sp.	**Chrysophytes (Bacillariophyceae)**	*D. divergens*
Coelastrum cambricum	*Achnanthes* sp.	*Mallomonas* sp.
Crucigenia quadrata	*Asterionella formosa*	**Euglenophytes**
Eudorina elegans	*Aulacoseria granulata*	*Phacus* sp.
Golenkinia radiata	*Cocconeis* sp.	*Trachelomonas* sp.
Kirchneriella lunaris	*Cyclotella* sp.	**Pyrrhophytes (Cryptophyceae)**
Micrasterias radiata	*Gomphonema* spp.	*Cryptomonas ovata*

There were 34 taxa identified in the pond's phytoplankton community on September 2nd and 16 taxa on September 24th; community richness for the 2 sampling periods was calculated to be 30.0 (±5.7) taxa.

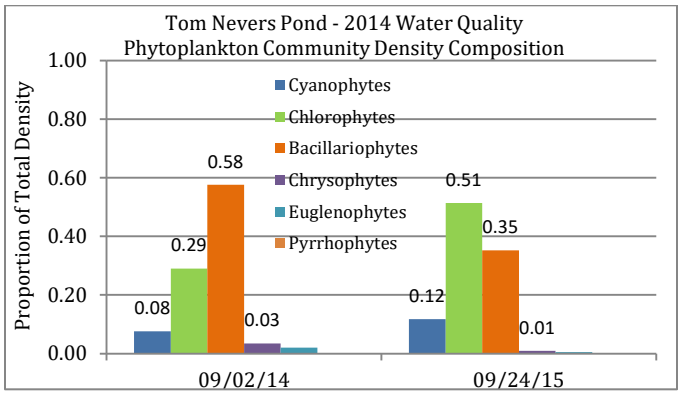
Density. The phytoplankton community density was 19,643 cells·mL^{-1} on September 2nd and 14,320 cells·mL^{-1} on September 24th, and averaged 16,982 cells·mL^{-1} for both sampling dates (Figure 3.7).

Figure 3.7 Phytoplankton community density in Tom Nevers Pond, September 2014.



The September 2nd phytoplankton assemblage in Tom Nevers Pond included primarily the Bacillariophytes (diatoms) with 58 percent of the community density and Chlorophytes (green algae) with 29 percent of the community density (Figure 3.8).

Figure 3.8 Density composition of the phytoplankton community in Tom Nevers Pond, September 2014.



The relative importance of these two major groups was reversed on September 24th, with the Chlorophytes comprising 51 percent and the Bacillariophytes representing 35 percent of the community density.

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 density measured in Tom Nevers Pond during 2014 is considered normal for a pond with these characteristics.

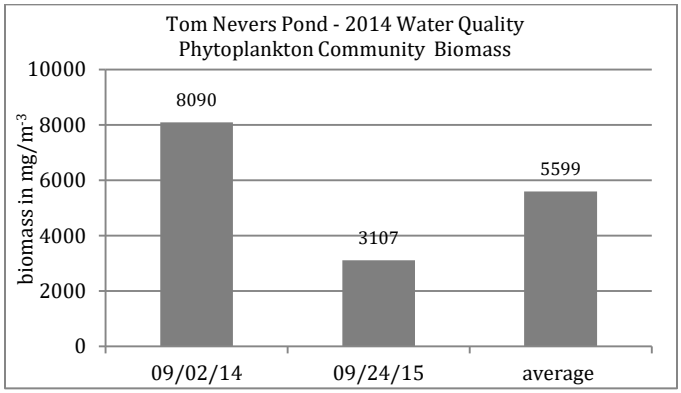
Biomass. Cell biovolume also was used to evaluate phytoplankton taxon biomass, or productivity, since cell counts and conversion into density does not account for the significant size difference among the various phytoplankton taxa that occur in the pond.

The misleading nature of density as a reliable 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 a dominant member in the phytoplankton community.

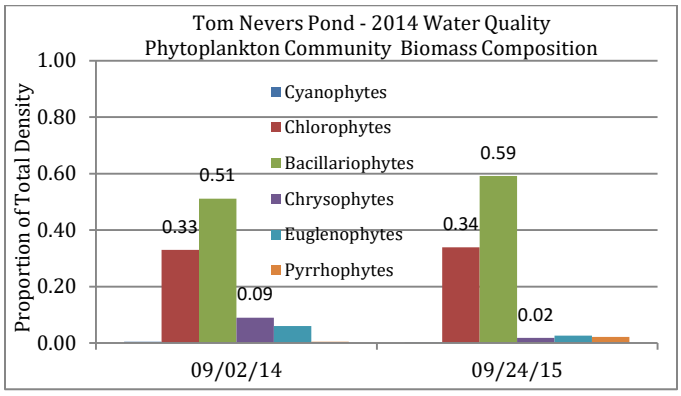
The phytoplankton community biomass was 8,090 mg·m^{-3} on September 2nd and 3,107 mg·m^{-3} on September 24th, and averaged 5,599 mg·m^{-3} for both sampling dates (Figure 3.9).

Figure 3.9 Phytoplankton community biomass in Tom Nevers Pond, September 2014.



With regard to biomass, the September 2nd phytoplankton assemblage in Tom Nevers Pond included primarily the Bacillariophytes (diatoms) with 51 percent of the community density and the Chlorophytes (green algae) with 33 percent of the community (Figure 3.10).

Figure 3.10 Biomass composition of the phytoplankton community in Tom Nevers Pond, September 2014.



The relative importance of these two major groups essentially remained the same on September 24th, with the Bacillariophytes comprising 59 percent and the Chlorophytes representing 35 percent of the total community biomass.

Dominance. A ranking of phytoplankton taxa dominance in Tom Nevers Pond on both of the September sampling dates is summarized in Table 3.3. Taxa are considered dominant in the community if they comprise at least 5 percent of the total community biomass. There were 7 dominant taxa in the phytoplankton community on September 2nd and 6 dominant taxa in the community on September 24th (Table 3.2). As discussed above, the diatoms and the green algae comprised the major portion of the phytoplankton community biomass with the diatoms averaging about 50 percent of the total on both sampling dates.

Table 3.2 Rank of phytoplankton taxa dominance, using biomass, in Tom Nevers Pond, September 2014.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
9/2/14	*Synedra acus* (Bacillariophyte)	1	30
	Cyclotella sp. (Bacillariophyte)	2	12
	Closterium sp. (Chlorophytes)	3	10
	Staurastrum natator var. *crassum* (Chlorophyte)	4	9
	Mallomonas sp. (Chrysophyte)	5	9
	Asterionella formosa (Bacillariophyte)	6	7
	Trachelomonas sp. (Euglenophyte)	7	5
9/24/14	*Cyclotella* sp. (Bacillariophyte)	1	22
	Synedra acus (Bacillariophyte)	2	21
	Asterionella formosa (Bacillariophyte)	3	13
	Kirchneriella lunaris (Chlorophyte)	4	11
	Closterium sp. (Chlorophytes)	5	8
	Staurastrum natator var. *crassum* (Chlorophyte)	6	6

There were a total of 8 different taxa (3 diatoms, 4 greens, and 1 euglenoid) that comprised at least 80 percent of the total community biomass on both September sampling dates (Table 3.2).

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

The diversity calculated for Tom Nevers Pond during September 2014 was 0.989 on September 2nd and 0.858 on September 24th, indicating that the portion of individuals was distributed quite evenly throughout the community and that dominance did not reside with a single taxa or only a few taxa.

Cyanophytes. As a major phytoplankton group, Cyanophytes were identified in both September samples collected from Tom Nevers Pond; however, only 3 taxa were identified (*Gomphosphaeria lacustris compacta*, *Chroococcus dispersus*, *Merismopedia glauca*), and none of these taxa are known to produce algal toxins.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Tom Nevers Pond were 6.23 µg·L^{-1} on September 2nd and 2.12 µg·L^{-1} on September 24th, indicating a low level of algal productivity in the pond on both occasions.

In comparison to Tom Nevers Pond, chlorophyll ***a*** levels measured in other Nantucket Island ponds during recent years include 6.98 µg·L^{-1} in *Hummock Pond* during September 2012 and an average of 143.93 µg·L^{-1} in *Head of Hummock Pond* during September 2013.

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.

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

The 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 2014 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 September sampling dates. The average values then were substituted into the appropriate equations (Chapter 1) to calculate the TSI values for each variable.

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

Chlorophyll *a*
Average mid-summer chlorophyll *a* = 4.18 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (4.18)] + 30.6
TSI = (9.81)(1.43) + 30.6
TSI = 44.6

Total phosphorus
Average mid-summer total phosphorus = 75.98 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (75.98)] + 4.15
TSI = (14.42)(4.33) + 4.15
TSI = 66.6

Secchi depth
Average mid-summer Secchi depth = 0.30 m
Secchi TSI = 60 – [14.41*[ln (0.30)]
TSI = 60 – (14.41)(-1.20)
TSI = 77.3

The TSI of 44.6 calculated for chlorophyll ***a*** was just above the threshold of 40 for the oligotrophic-to-mesotrophic region (see Table 3.3 below), while the TSI calculated for total phosphorus (66.6) was at the upper region of the eutrophic region and just below hyper-eutrophic conditions. The average 2014 Secchi depth (0.3 meters) resulted in a calculated TSI value of 77.3 which is within the hyper-eutrophic region.

Table 3.3 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 September 2014 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 2014 TSI numbers calculated for Tom Nevers Pond. For example, the extremely low transparency measured at the pond (0.3 m on both sampling dates) was the result of organic material (humic and fulvic acids) in the water and not the result of algal productivity which is the basis for using Secchi depth to calculate a TSI value. In addition, the average 2014 **TP** concentration (75.98 µg/L^{-1}) used in the calculation was heavily biased by the very high September reading (130.3 µg/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 (44.6) as the most accurate indicator of the pond's trophic state during 2014.

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. 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

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Nantucket Island Ponds and Their Water Quality

Chapter 4

Washing Pond - 2014

4.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Washing Pond by Nantucket Land Council staff during 2014.

4.1 Results

Washing Pond was sampled on August 26th and September 15th 2014. The maximum water depth located in the pond was 14.1 feet (169 inches) on August 26th at a sampling location in the approximate center of the pond; the maximum water depth detected on September 15th was 14.2 feet (170 inches).

Following the collection of temperature and dissolved oxygen profile data on August 26th, an integrate sample was collected from the surface down to 8 feet of depth for the chemistry and phytoplankton samples; a grab sample was collected at the 12-foot depth for water chemistry.

The depth of collection on September 15th was 0-6 feet for the integrate sample and 12 feet for the grab sample. There were no other water samples collected from the pond on either sampling date.

4.1.1 Physical characteristics

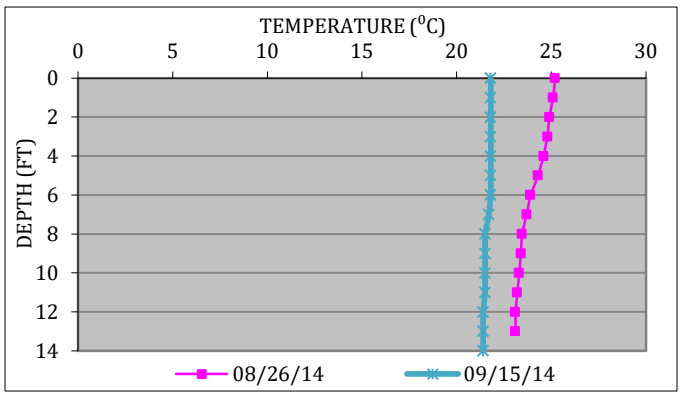
General. Washing Pond is rectangular in shape with a middle bugle giving it the appearance of an ellipse with its axis oriented in a north-south direction (Figure 3.1). The surface area of the pond is about 8 acres. There are no permanent streams flowing into the pond, and there is no outlet located along the shoreline.

Figure 4.1 Aerial view of Washing Pond (from *Google*™ earth)

Washing Pond has a moderate total depth of 14 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 2014 sampling excursions to Washing Pond. The profile data collected on both sampling dates are presented in Figure 4.2 and show that the pond was isothermal (the same temperature) from the surface to the bottom. The average temperature of the pond was 24.0°C on August 26th and 21.6°C on September 15th.

Figure 4.2 Temperature profiles collected at Washing Pond, August-September 2014.



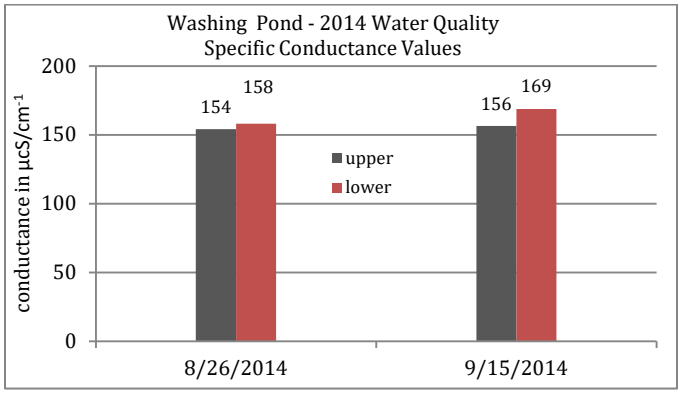
Transparency. The Secchi depth transparency measured at Washing Pond was 6.1 feet (73 inches) on August 26th and 4.9 feet (59 inches) on September 15th. Water color was recorded as 'cloudy green' on August 26th which could be an indication of an algal bloom in progress.

Water color on September 15th was recorded as 'brown', which either could be indicative of diatoms(algae) in the water column or 'staining' of the water by humic and fulvic acids leaching into the water from vegetation in the surrounding watershed.

4.1.2 Chemical characteristics

Specific conductance. Figure 4.3 presents the conductance values measured at Washing Pond on August 26th and September 15th.

Figure 4.3 Specific conductance measured in Washing Pond, August-September 2014.



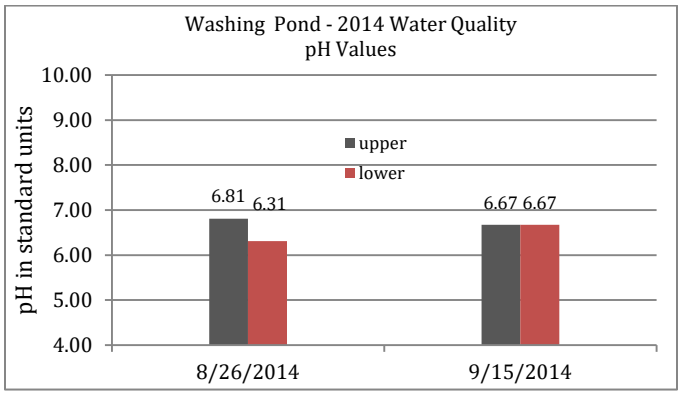
The conductance results for the integrate and grab samples on each sampling date essentially were the same, 154 and 158 $\mu S \cdot cm^{-1}$ in the *upper* and *lower* regions of the pond, respectively, on August 26th, and 156 and 169 $\mu S \cdot cm^{-1}$ in the *upper* and *lower* regions of the pond, respectively, on September 15th.

These values measured at Washing Pond are within the range of specific conductance values expected in ponds considered to be fresh water.

pH. As shown in Figure 4.4, Washing Pond was very close to neutral pH (7.0) on both sampling dates and there was little, if any, difference between the pH in different regions of the Pond.

The results for the integrate and grab samples collected on both sampling dates are as follows: 6.81 s.u. and 6.31 s.u. in the *upper* and *lower* regions of the pond, respectively, on August 26th, and 6.67 s.u. in the upper and lower regions on September 15th.

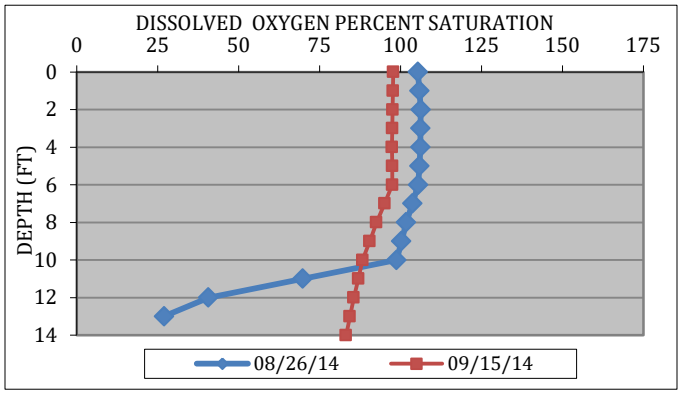
Figure 4.4 pH measured in Washing Pond, August-September 2014.



Dissolved oxygen concentration-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 oxygen saturation patterns in Washing Pond during August and September 2014 are shown in Figure 4.5.

Figure 4.5 Dissolved oxygen saturation profiles in Washing Pond, August-September 2014.



The data collected on August 26th show oxygen saturation values around 100 percent from the pond surface down to a depth of 10 feet; below that depth, the saturation values decline rapidly toward the bottom sediment (Figure 4.5). These conditions indicate a period of relative calm on the Island with little or no wind to promote mixing of the water column. Calm conditions can result in an oxygen saturation deficit in the lower region due to the decomposition of organic matter in this region.

4.1.3 Plant Nutrients

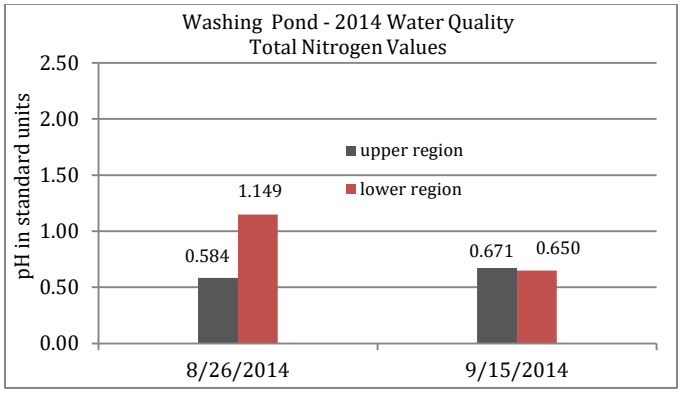
Nitrogen. Nitrate-nitrogen was detectable in Washing Pond on August 26th and the concentration was 0.028 mg $N \cdot L^{-1}$ in samples collected from the *upper* and *lower* regions of the pond. When the pond was

sampled on September 15th, **nitrate-nitrogen** was below the limit of detection (0.005 mg $N \cdot L^{-1}$) in both regions of the pond. Low (undetectable) **nitrate-nitrogen** 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.

And although there were measureable levels of **ammonia-nitrogen** in the water column on both sampling dates, the levels were low, which also is not unusual since this form of nitrogen is available for uptake by phytoplankton. The levels of **ammonia-nitrogen** measured in Washing Pond were as follows: 0.021 and 0.071 mg $N \cdot L^{-1}$ in the *upper* and *lower* regions, respectively, on August 26th, and 0.020 and 0.016 mg $N \cdot L^{-1}$ in the *upper* and *lower* regions, respectively, on September 15th.

The **total nitrogen** (**TN**) concentrations measured in Washing Pond during August and September 2014 are presented in Figure 4.6.

Figure 4.6 Total nitrogen concentrations measured in Washing Pond, August-September 2014.



On August 26th, the **TN** concentration measured in the *upper* region of the pond (0.584 mg $N \cdot L^{-1}$) was about one-half the concentration measured in the *lower* region of the pond (1.149 mg $N \cdot L^{-1}$).

Based upon the dissolved oxygen profile collected on August 26th and presented earlier in this chapter, 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 would explain the discrepancy in the *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.

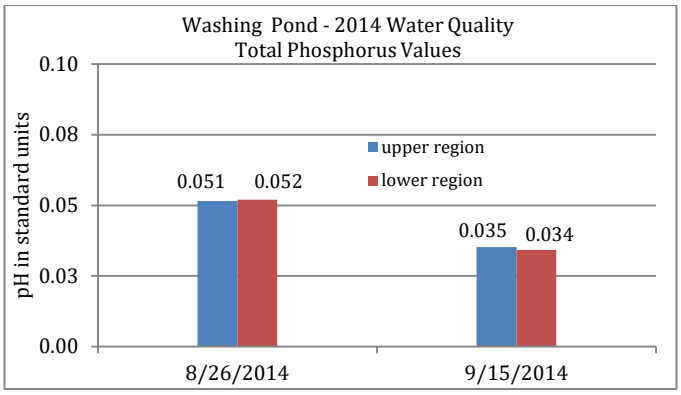
The same oxygen saturation differences in the profile data were not apparent on September 15th (see Figure 4.4) and it is noteworthy that **TN** concentrations in the *upper* and *lower* regions were very similar at 0.671 and 0.650 mg $N \cdot L^{-1}$, respectively, which would be expected under conditions of sufficient mixing of the pond.

Furthermore, the **TN** concentrations measured in Washing Pond during 2014 are similar to **TN** values measured in other Nantucket Island ponds during previous studies conducted by this report author. For example, the September 2012 **TN** value in *Hummock Pond* averaged 0.60 mg $N \cdot L^{-1}$ (Sutherland, 2013), while

the September 2013 **TN** concentration in *Head of Hummock Pond* averaged 1.16 mg $N \cdot L^{-1}$ (Sutherland and Mackinnon, 2014).

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Washing Pond during August-September 2014 are shown in Figure 4.7**.** On August 26th, **TP** concentrations were the same in the upper and lower regions of the pond at 0.051 and 0.052 mg $P \cdot L^{-1}$, respectively. **TP** concentrations on September 15th were reduced from August levels, but also the same values in both *upper* and *lower* regions of the pond at 0.035 and 0.034 mg $P \cdot L^{-1}$, respectively.

Figure 4.7 Total phosphorus concentrations measured in Washing Pond, August-September 2014.



As a comparison to Washing Pond, average **TP** levels were 0.085 mg $P \cdot L^{-1}$ in *Hummock Pond* during September 2012 and 0.252 mg $P \cdot L^{-1}$ in *Head of Hummock Pond* during 2013.

4.1.4 Phytoplankton

Description of the assemblage. A total of 47 taxa were identified in the August 26th and September 15th phytoplankton samples collected from Washing Pond and all of the major algal groups were represented in the samples (Table 4.1).

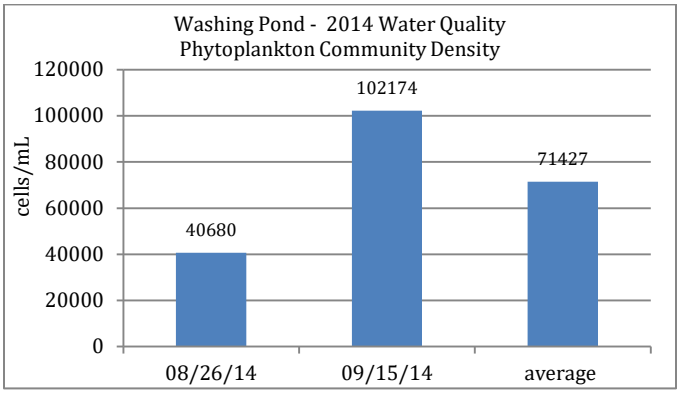
Table 4.1 Major groups and taxa of phytoplankton identified in Washing Pond, August-September 2014.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Aphanizomenon flos aquae	*Kirchneriella lunaris*	*Rhoicosphenia curvata*
Chroococcus dispersus	*Micrasterias radiata*	*Stauroneis* sp.
C. limneticus	*Monoraphidium contortum*	*Synedra acus*
Gomphosphaeria lacustris compacta	*Oocystis pusilla*	*S. ulna*
Merismopedia glauca	*O. pusilla*	**Chrysophytes (Chrysophyceae)**
Microcystis aeruginosa	*Pandorina morum*	*Dinobyron bavaricum*
Woronichinia naegeliana	*Quadrigula lacustris*	*D. divergens*
Chloromonadophytes	*Staurastrum natator* var. *crassum*	*Mallomonas* sp.
Gonyostomum semen	*Tetraedron minimum*	*Ochromonas* sp.
Chlorophytes	**Chrysophytes (Bacillariophyceae)**	**Euglenophytes**
Ankistrodesmus falcatus	*Achnanthes* sp.	*Peranema* sp.
A. convolutus	*Aulacoseria granulata*	*Phacus* sp.
Chlamydomonas sp.	*Cocconeis* sp.	*Trachelomonas* sp.
Closteriopsis longissimi	*Cyclotella* sp.	**Pyrrhophytes (Cryptophytes)**
Closterium sp.	*Gomphonema* spp.	*Cryptomonas ovata*
Coelastrum cambricum	*Navicula* spp.	**Pyrrhophytes (Dinophytes)**
Cosmarium spp.	*Nitzschia* sp.	*Peridinium cinctum*
Eudorina elegans	*Pinnularia* sp.	
Golenkinia radiata	*Planothidium* sp.	

The were 37 taxa identified in the pond's phytoplankton community on August 26th and 28 taxa on September 15th; community richness was calculated for the 2 sampling periods and was 32.5 (±6.4) taxa.

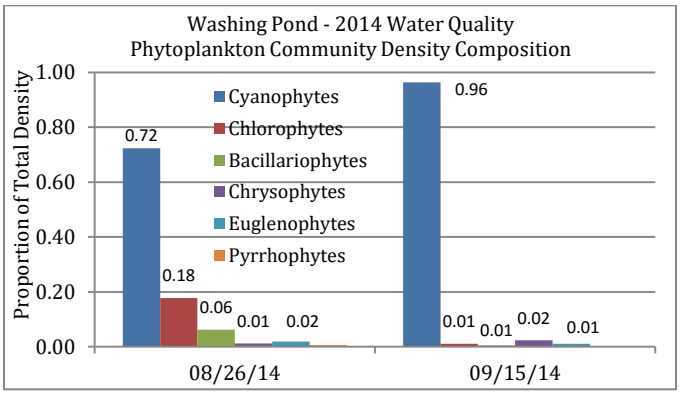
Density. The phytoplankton community density in Washing Pond was 40,680 cells·mL^{-1} on August 26th and 102,174 cells·mL^{-1} on September 15th, average density was 71,427 cells·mL^{-1} for both dates (Figure 4.8).

Figure 4.8 Phytoplankton community density in Washing Pond, August-September 2014.



The August 26th phytoplankton assemblage in Washing Pond was comprised primarily of Cyanophytes (Blue-green algae) with 72 percent of the community density and Chlorophytes (green algae) with 18 percent of the community density (Figure 4.9).

Figure 4.9 Density composition of the phytoplankton community in Washing Pond, August-September 2014.



The other 4 major groups of phytoplankton, the Bacillariophytes (diatoms), the Chrysophytes, the Euglenophytes and the Pyrrhophytes, made up the remaining 10 percent of the phytoplankton community.

The relative importance of the Chlorophytes was greatly diminished by September 15th and the Cyanophytes totally dominated the phytoplankton community with 96 percent of the total density. The other 4 phytoplankton classes comprised the remaining 4 percent of the community density on September 15th.

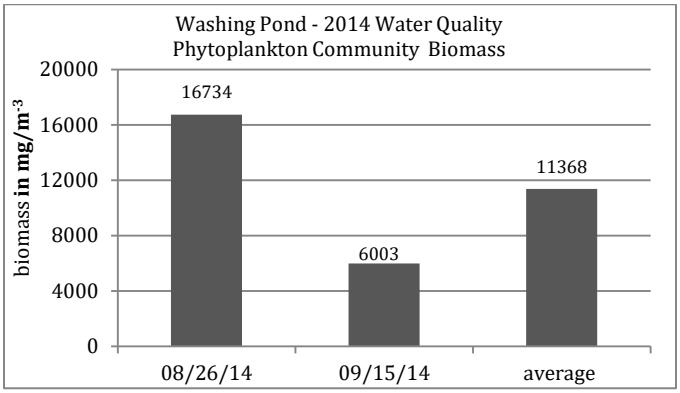
The conditions that existed in Washing Pond on September 15th with regard to phytoplankton density in the water column and the dominance of the Cyanophytes on that sampling date suggest that an algal 'bloom' was in progress.

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 of several orders of magnitude.

The phytoplankton community biomass documented in Washing Pond during August and September 2014 is presented in Figure 4.10.

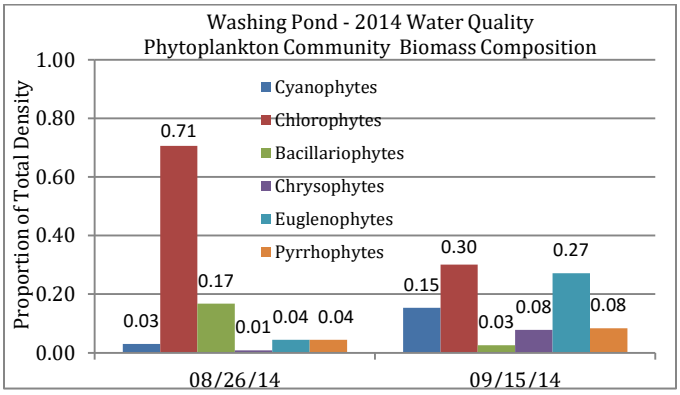
Figure 4.10 Phytoplankton community biomass in Washing Pond, August-September 2014.



The biomass in Washing Pond was 16,734 mg·m^{-3} on August 26th and 6003 mg·m^{-3} on September 15th, and averaged 11,369 mg·m^{-3} for both sampling dates (Figure 4.10).

In terms of biomass, the August 26th phytoplankton assemblage in Washing Pond included primarily the Chlorophytes (green algae) with 71 percent of the community density and the Bacillariophytes (diatoms) which comprised 17 percent of the community (Figure 4.11).

Figure 4.11 Biomass composition of the phytoplankton community in Washing Pond, August-September 2014.



By September 15th, the biomass composition of the phytoplankton community had changed dramatically. There were 5 major groups of algae that were important components of the assemblage including the Chlorophytes (30 percent), the Euglenophytes (27 percent), the Cyanophytes (15 percent), the Chrysophytes (8 percent) and the Pyrrhophytes (8 percent).

The misleading nature of density as a reliable community descriptor is evident when reviewing the September 15th Washing Pond cell biomass values and noting the substantial size difference between the Cyanophyte *Microcystis aeruginosa* cells (3.0 mg·m^{-3}) and the Chlorophyte *Staurastrum natator* cells (4000.0 mg·m^{-3}). Although *M. aeruginosa* comprised 92 percent of the phytoplankton density on September 15th with

94,000 cells, *S. natator* comprised 30 percent of the community biomass with only 90 cells. 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 a dominant member in the phytoplankton community.

Dominance. A ranking of phytoplankton taxa dominance in Washing Pond on the 2014 sampling dates is summarized in Table 4.2. 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 August 26th and 7 dominant taxa in the community on September 15th (Table 3.2). As discussed above, the green algae and the diatoms comprised a major portion of the community in August and in September, the greens, euglenoids and Blue-greens were the major components of the community.

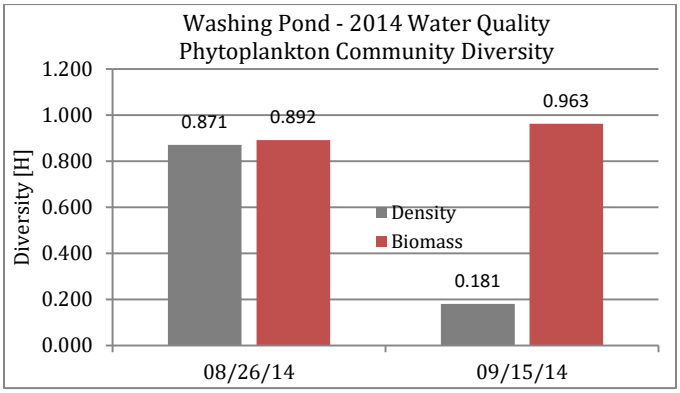
Table 4.2 Rank of phytoplankton taxa dominance, using biomass, in Washing Pond, August-September 2014.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
8/26/14	*Staurastrum natator* var. *crassum* (Chlorophyte)	1	47
	Aulacoseria granulata (Bacillariophyte)	2	14
	Closterium sp. (Chlorophytes)	3	6
	Gonyostomum semen (Chloromonadophyte)	4	6
9/15/14	*Staurastrum natator* var. *crassum* (Chlorophyte)	1	30
	Trachelomonas sp. (Euglenophyte)	2	16
	Aphanizomenon flos aquae (Cyanophye)	3	11
	Phacus sp. (Euglenophyta)	4	11
	Coelastrum cambricum (Chlorophyte)	4	6
	Mallomonas sp. (Chrysophyte)	6	6
	Microcystis aeruginosa (Cyanophyte)	7	5

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 Figure 4-12.

Figure 4.12 Summary of diversity calculation for Washing Pond, August-September 2014.



[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.

Using density as the primary variable. the diversity calculated for Washing Pond was 0.871 and 0.181 in August and September, respectively. With biomass, the diversity vales were 0.892 and 0.963 during August and September, respectively. The data presented for September 2014 in Figure 4-12 highlight the discrepancy that can occur when evaluating phytoplankton community dynamics using either density (0.181) or biomass (0.963) as the metric for comparison.

Cyanophytes. As a major phytoplankton group, the Cyanophytes were identified in both the August and September samples collected in Washing Pond. A total of 6 taxa were identified including *Aphanizomenon flos aquae*, *Chroococcus dispersus*, *C. limneticus*, *Gomphosphaeria lacustris compacta*, *Microcystis aeruginosa* and *Woronichinia naegeliana*. Three of these genera, *Aphanizomenon*, *Microcystis*, and *Woronichinia*, 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 Washing Pond produce any algal toxins, recreational users of the pond should be aware that Cyanobacteria can be present during the mid-summer periods.

Chlorophyll *a*. The chlorophyll ***a*** concentrations measured in Washing Pond were 5.02 $\mu g \cdot L^{-1}$ on August 26th and 10.86 $\mu g \cdot L^{-1}$ on September 15th, indicating a low level of algal productivity in the pond on both occasions.

In comparison to Washing Pond, chlorophyll ***a*** levels measured in Nantucket Island ponds during recent years include 6.98 $\mu g \cdot L^{-1}$ in *Hummock Pond* during September 2012 and an average of 143.93 $\mu g \cdot L^{-1}$ in *Head of Hummock Pond* during September 2013.

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 Washing Pond during 2014 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 September 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 mid-summer chlorophyll *a* = 7.94 $\mu g/L^{-1}$
Chlorophyll *a* TSI = 9.81*[ln (7.94)] + 30.6
TSI = (9.81)(2.07) + 30.6
TSI = 50.9

Total phosphorus
Average mid-summer total phosphorus = 43.37 $\mu g/L^{-1}$
Total phosphorus TSI = 14.42*[ln (43.37)] + 4.15
TSI = (14.42)(3.77) + 4.15
TSI = 58.5

Secchi depth
Average mid-summer Secchi depth = 1.68 m
Secchi TSI = 60 – [14.41*[ln (1.68)]
TSI = 60 – (14.41)(0.52)
TSI = 52.5

The TSI of 50.9 calculated for chlorophyll ***a*** was just above the mesotrophic-eutrophic threshold of 50 (see Table 4.3 below), while the TSI calculated for total phosphorus (58.5) was in the middle of the eutrophic region. The average 2014 Secchi depth (1.68 meters) resulted in a calculated TSI value of 52.5, just above the mesotrophic-eutrophic threshold of 50. The TSI values calculated from all 3 independent variables for Washing Pond during 2014 portray water quality during August-September that was in the eutrophic region.

Table 4.3 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	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

4.2 Summary

Based upon the data collected during 2014, Washing Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has high productivity 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 mixing of the water column occurs due to sufficient winds blowing across the Island.

4.3 Literature Cited

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

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Sutherland, J. W. and E. MacKinnon. 2014. Head of Hummock Pond. 2013 Water Quality Program. A Summary of Physical, Chemical and Biological Monitoring. Prepared for The Nantucket Land Council. 92 pp. + Appendices.

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Nantucket Island Ponds and Their Water Quality

Chapter 5

Maxcy Pond - 2014

5.0 Introduction

This chapter presents a summary and discussion of the physical, chemical and biological data collected from Maxcy Pond by Nantucket Land Council staff during 2014.

5.1 Results

Maxcy Pond was sampled on August 26th and September 15th 2014. The maximum water depth located in the pond was 5.1 feet (61 inches) on August 26th at the sampling location in the approximate center of the pond. The maximum water depth located on September 15th was 4.8 feet (58 inches).

Following the collection of temperature and dissolved oxygen profile data on August 26th, 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 September 15th also was from 0-4 feet of depth and there was no grab sample collected on this sampling date either.

5.1.1 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 5.1 Aerial view of Maxcy Pond (from *Google*™ earth)

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

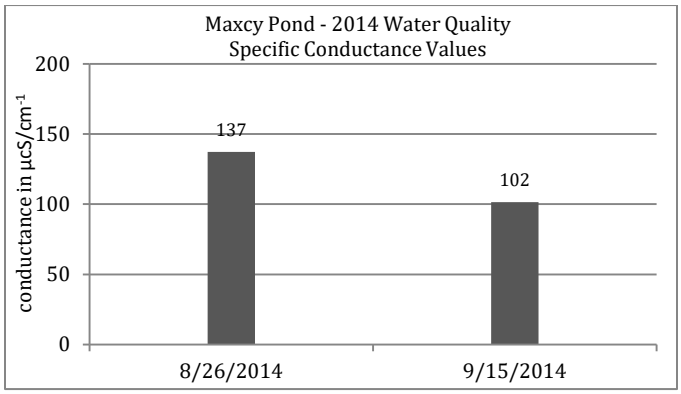
Temperature. Temperature profile data were collected on both 2014 sampling excursions to Maxcy Pond. The temperature collected on both sampling dates essentially was isothermal from the surface to the bottom; the average temperature of the water column was 24.1°C on August 26th and 20.8 °C on September 15th.

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.

5.1.2 Chemical characteristics

Specific conductance. Figure 5.2 presents the specific conductance values measured at Maxcy Pond on August 26th and September 15th.

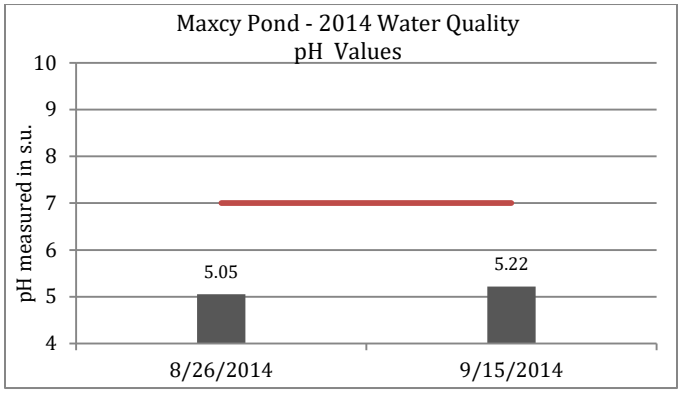
Figure 5.2 Specific conductance measured in Maxcy Pond, August-September 2014.



The results for the 2 integrate samples were similar; 137 and 102 $\mu S \cdot cm^{-1}$ on August 26th and September 15th, respectively, and the values measured in Maxcy Pond are low, but are within the range of specific conductance values expected in ponds considered to be fresh water.

pH. As shown in Figure 5.3, Maxcy Pond had an acid pH on both sampling dates, 5.05 s.u. on August 26th and 5.22 s.u. on September 15th.

Figure 5.3 pH measured in Maxcy Pond, August-September 2014.



The horizontal 'red' line show on Figure 5.3 indicates the region along the pH scale that is considered 'neutral'. Low pH such as measured in Maxcy Pond 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 along the pond shoreline.

Dissolved oxygen concentration-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 concentration and saturation values in Maxcy Pond during August and September 2014 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 August 26th show average oxygen concentration and saturation values of 8.4 mg/L^{-1} and 100.5 percent, respectively, while the average values measured on September 15th were 8.4 and 94.1 percent, respectively.

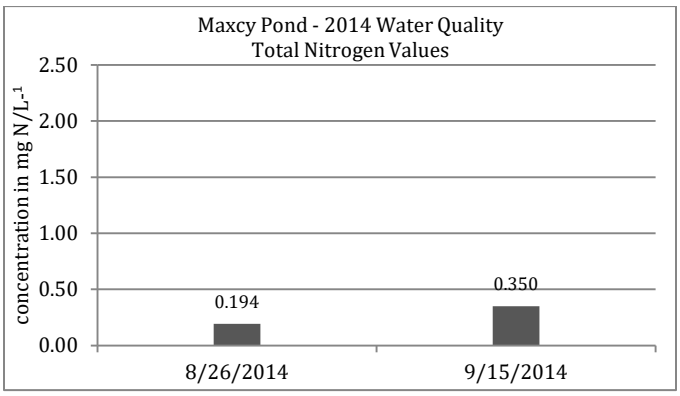
5.1.3 Plant Nutrients

Nitrogen. Nitrate-nitrogen was detectable in Maxcy Pond on August 26th and the concentration was 0.033 mg N·L^{-1}; on September 15th, the concentration was below the limit of detection which is 0.005 N·L^{-1}. 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.

Although there were measureable levels of **ammonia-nitrogen** in the water column on both sampling dates, the levels were low, which also is not unusual since this form of nitrogen is available for uptake by phytoplankton. The levels of **ammonia-nitrogen** measured in Maxcy Pond were as follows: 0.010 and 0.004 mg N·L^{-1} on August 26th and September 15th, respectively.

The **total nitrogen** (**TN**) concentrations measured in Maxcy Pond during August and September 2014 are presented in Figure 5.4.

Figure 5.4 Total nitrogen concentrations measured in Maxcy Pond, August-September 2014.

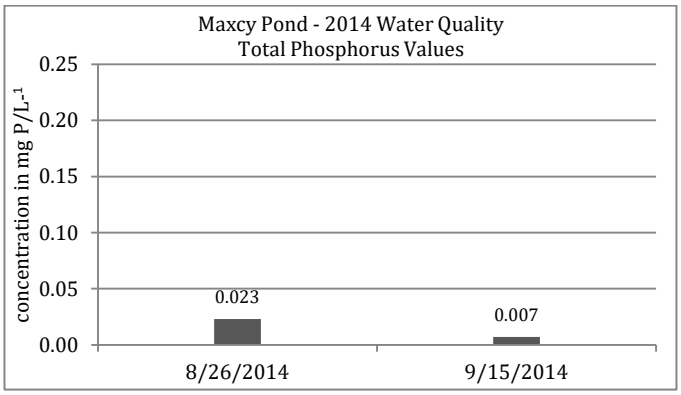


The **TN** concentrations measured in the pond were 0.194 mg N·L^{-1} on August 26th and 0.350 mg N·L^{-1} on September 15th, an average of 0.272 mg N·L^{-1} for both sampling dates, and are low concentrations when compared with other Nantucket Island ponds. Other ponds monitored by NLC staff during 2014 included Washing Pond and Tom Nevers Pond and average **TN** values from these ponds were 0.628 and 1.29 mg N·L^{-1}, respectively.

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Maxcy Pond during August-September 2014 are shown in Figure 5.5**.** On August 26th, the **TP** concentration was 0.023 mg P·L^{-1} in the

water column and by September 15th, the TP concentration had dropped to 0.007 mg P·L^{-1}. The average value for the 2014 season was 0.015 mg P·L^{-1}.

Figure 5.5 Total phosphorus concentrations measured in Maxcy Pond, August-September 2014.



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

As a comparison to Maxcy Pond, average **TP** levels documented in other Nantucket Island ponds during 2014 were 0.077 mg P·L^{-1} in *Tom Nevers Pond* and 0.043 mg P·L^{-1} in *Washing Pond*.

5.1.4 Phytoplankton

Description of the assemblage. There were 29 taxa identified in the 2014 phytoplankton samples collected from Maxcy Pond and all of the major algal groups were represented in the samples (Table 5.1).

Table 5.1 Major groups and taxa of phytoplankton identified in Maxcy Pond, August-September 2014.

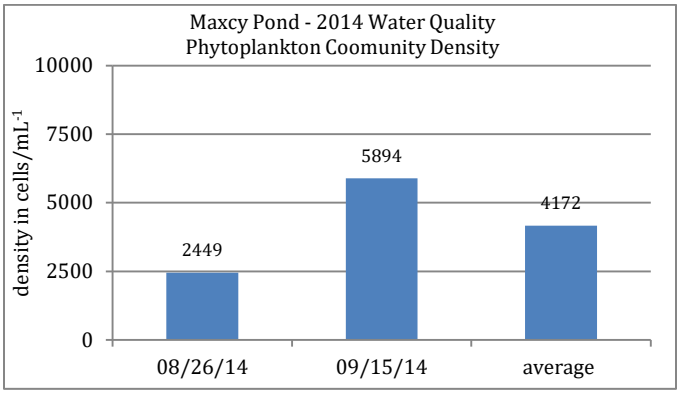
Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophyceae)**
Anabaena flos aquae	*Oocystis solitaria*	*Planothidium* sp.
Anabaenopsis Elenkinii	*Quadrigula lacustris*	**Chrysophytes (Chrysophyceae)**
Aphanizomenon flos aquae	*Scenedesmus bijuga*	*Dinobyron divergens*
Chroococcus dispersus	**Chrysophytes (Bacillariophyceae)**	*Ochromonas* sp.
Microcystis aeruginosa	*Achnanthes* sp.	**Euglenophytes**
Chlorophytes	*Asterionells formosa*	*Peranema* sp.
Ankistrodesmus falcatus	*Cocconeis* sp.	*Trachelomonas* sp.
A. convolutus	*Cyclotella* sp.	**Pyrrhophytes (Cryptophytes)**
Chlamydomonas sp.	*Gomphonema* spp.	*Cryptomonas erosa*
Closterium spp.	*Navicula* spp.	*C. ovata*
Monoraphidium contortum	*Nitzschia* sp.	**Pyrrhophytes (Dinophytes)**
Mougeotia sp.		*Peridinium cinctum*

There were 21 taxa identified in the pond's phytoplankton community on August 26th and 16 taxa on September 15th; community richness was calculated for the 2 sampling periods and was 18.5 (±3.5) taxa.

Density. The phytoplankton community density in Maxcy Pond was 2,449 cells·mL^{-1} on August 26th and 5,894 cells·mL^{-1} on September 15th, and the average density was 4,172 cells·mL^{-1} for both sampling dates (Figure 5.6). The phytoplankton densities measured in Macy Pond during 2014 are low when compared with other Island ponds that have been monitored by the report author during recent years. As mentioned

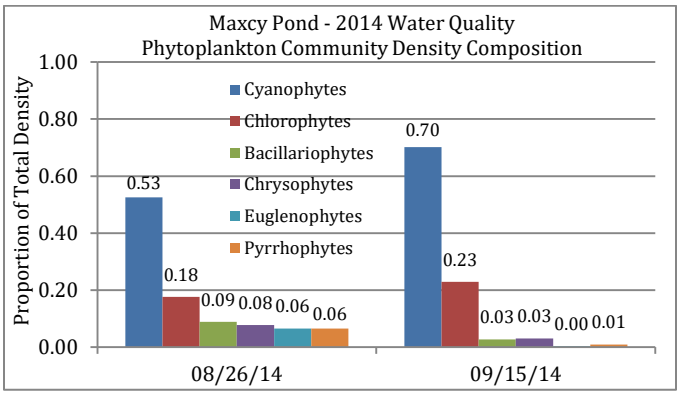
previously, Maxcy Pond appears to be a low productivity system that results from acidic conditions and this condition affects the physical, chemical and biological components of the pond.

Figure 5.6 Phytoplankton community density in Maxcy Pond, August-September 2014.



The August 26th phytoplankton assemblage in Maxcy Pond was comprised primarily of Cyanophytes (Blue-green algae) with 53 percent of the community density and Chlorophytes (green algae) with 18 percent of the community density (Figure 5.7).

Figure 5.7 Density composition of the phytoplankton community in Maxcy Pond, August-September 2014.



The other major phytoplankton groups, the Bacillariophytes (diatoms), the Chrysophytes, the Euglenophytes and the Pyrrhophytes, made up the remaining 29 percent of the community density on August 26th.

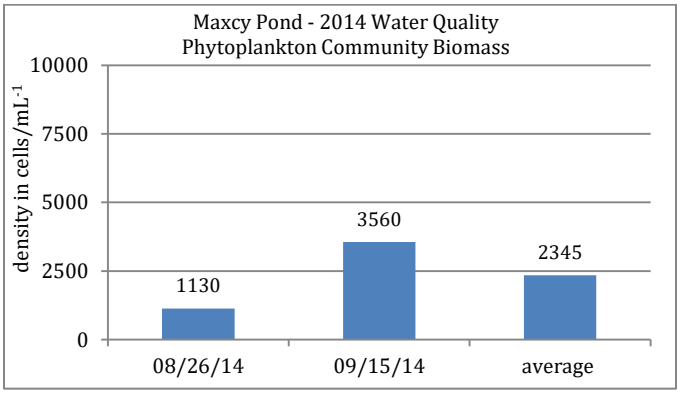
The relative importance of the Cyanophytes and the Chlorophytes increased on September 15th to 70 and 23 percent, respectively, while the other major groups of phytoplankton exhibited decreases in their relative proportion of the total density, comprising less than 10 percent of the community total on that sampling date.

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 of several orders of magnitude.

The 2014 phytoplankton community biomass documented in Maxcy Pond on August 26th and September 15th is presented in Figure 5.8. Biomass was low on both dates, 1,130 mg·m^{-3} on August 26th and 3,560 mg·m^{-3} on September 15th; the average biomass on the 2 sampling dates was 2,345 mg·m^{-3} (Figure 5.8). The low

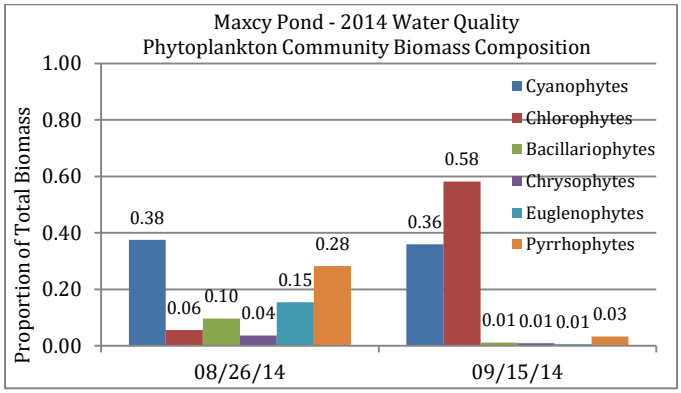
biomass documented on both 2014 sampling dates would explain the excellent water transparency recorded on that date since there was relatively little organic matter suspended in the water column to interfere with visual observations in the pond.

Figure 5.8 Phytoplankton community biomass in Maxcy Pond, August-September 2014.



The August 26th assemblage included primarily the Cyanophytes with 38 percent of the community density and the Pyrrhophytes (red-brown flagellated algae) with 28 percent of the community density (Figure 5.9). The other groups of phytoplankton in the assemblage were ranked as follows: Euglenophytes (15 percent), Bacillariophytes (10 percent), Chlorophytes (6 percent), and Chrysophytes (4 percent).

Figure 5.9 Biomass composition of the phytoplankton community in Maxcy Pond, August-September 2014.



By September 15th, the Cyanophytes comprised 36 percent of the community biomass and the Chlorophytes (green algae) had increased to 58 percent. The remaining groups of phytoplankton were distributed as follows: Pyrrhophytes (3 percent), Bacillariophytes, Chrysophytes and Euglenophytes (all with 1 percent).

Dominance. A ranking of phytoplankton taxa dominance in Maxcy Pond on the 2014 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.

There were 4 dominant taxa in the phytoplankton community on August 26th and 3 dominant taxa in the community on September 15th (Table 3.2). As discussed above, the Blue-green algae and red-brown flagellated algae comprised a major portion of the community in August, and in September, the greens, and Blue-greens were the major components of the community.

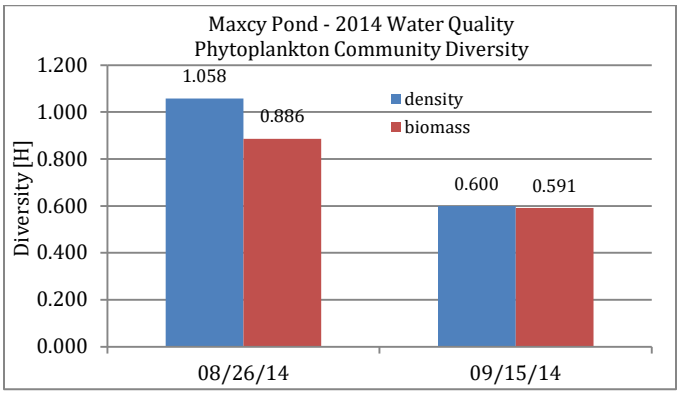
Table 5.2 Rank of phytoplankton taxa dominance, using biomass, in Maxcy Pond, August-September 2014.

Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
8/26/14	*Anabaena flos aquae* (Cyanophyte)	1	35
	Trachelomonas sp. (Euglenophyte)	2	15
	Peridinium cinctum (Pyrrhophyte)	3	15
	Cryptomonas erosa (Pyhhhophyte)	4	13
	Asterionella Formosa (Bacillariophyte)	1	6
9/15/14	*Mougeotia* sp. (Chlorophyte)	1	47
	Aphanizomenon flos aquae (Cyanophye)	2	35
	Cosmarium spp. (Chlorophyte)	3	8

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 Figure 5-10.

Figure 5-10. Phytoplankton community diversity in Maxcy Pond, August-September 2014.



The diversity calculations were very similar on each sampling date, regardless of whether density or biomass was used to evaluate this community characteristic (Figure 5-10). The important information in Figure 5-10 is the significant decline in diversity from August 26th to September 15th as a result of a greater proportion of the community residing within fewer individuals instead of more individuals. Cyanophytes and Chlorophytes comprised 94 percent of the total community on the September 15th sampling date.

Cyanophytes. As a major phytoplankton group of aquatic ecosystem importance, the Cyanophytes were identified in both the August and September samples collected in Maxcy Pond. A total of 5 taxa were identified 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.

[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 2.39 µg·L^{-1} on August 26th and 3.11 µg·L^{-1} on September 15th, indicating a low level of algal productivity in the pond on both occasions. The average chlorophyll ***a*** concentration for both 2014 sampling dates was 2.75 µg·L^{-1}.

In comparison to Maxcy Pond, chlorophyll ***a*** levels measured in Nantucket Island ponds during 2014 include an average of 4.18 µg·L^{-1} in *Tom Nevers Pond* during September and an average of 7.94 µg·L^{-1} in *Washing Pond* during August-September. (this report).

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.

Except for the absence of a valid Secchi depth on either sampling date, there were sufficient TP and chlorophyll ***a*** data from Maxcy Pond during 2014 to calculate the Carlson Trophic State Index (TSI) using those 2 variables. Average values were calculated for chlorophyll ***a*** and total phosphorus for the Ag=ugust and September sampling dates. The average values then were substituted into equations to calculate the TSI values for each variables. The stepwise calculation and results of the analysis are as follows:

Chlorophyll *a*
Average mid-summer chlorophyll *a* = 2.75 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (2.75)] + 30.6
TSI = (9.81)(1.01) + 30.6
TSI = 40.5

Total phosphorus
Average mid-summer total phosphorus = 15.07 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (15.07)] + 4.15
TSI = (14.42)(2.71) + 4.15
TSI = 43.3

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*, 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 values calculated using the 2014 data, Maxcy Pond was just within the mesotrophic region of productivity and close enough to the oligotrophic-mesotrophic boundary that even a slight change in pond conditions (significant input of rainfall, extended period of evapotranspiration) could cause the pond to shift in either direction. The TSI of 40.5 calculated for chlorophyll ***a*** was on the boundary of the

oligotrophic-mesotrophic scheme, while the TSI calculated for total phosphorus (43.3) was just within the mesotrophic zone.in the middle of the eutrophic region. The average 2014 Secchi depth (1.68 meters) resulted in a calculated TSI value of 52.5 which was just above the mesotrophic-eutrophic threshold of 50. The TSI values calculated from the TP and chlorophyll a variables for Maxcy Pond during 2014 accurately portray the low productivity water quality that was observed on the pond during the August-September sampling excursions.

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

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

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