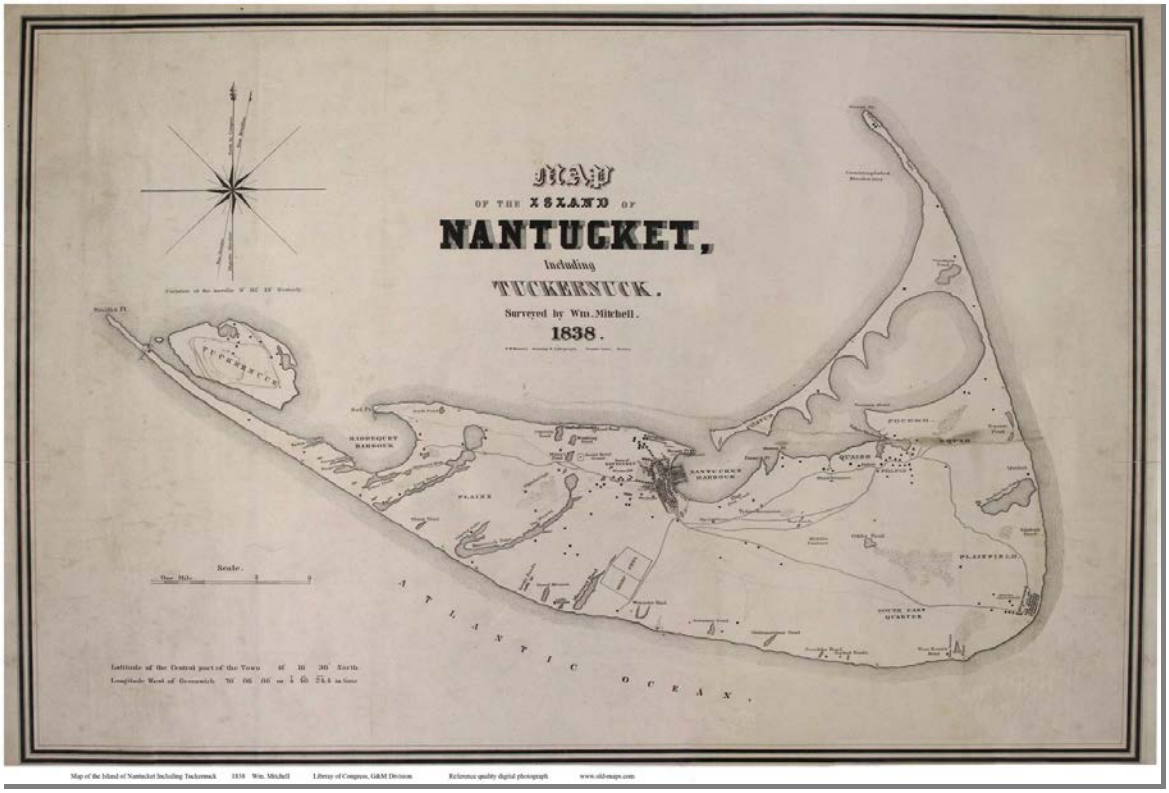
Nantucket Island Ponds and Their Water Quality

The 2015 Program – Capaum Pond and Pest House Pond

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

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1.0 Introduction

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

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

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

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

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

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

1.1 Water Quality - Physical characteristics

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

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

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

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

1.2 Water Quality - Chemical characteristics

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

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

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

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

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

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

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

1.3 Water Quality - Plant Nutrients

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

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

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

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

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

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

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

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

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

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

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

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

1.4 Water Quality - Phytoplankton

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

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

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

1.5 Water Quality - Trophic Status

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

indicators are used to describe trophic state such as phosphorus, water clarity, chlorophyll, rooted plant growth and dissolved oxygen.

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

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

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

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

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

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

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

Table 1.1

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

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2.0 Background

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

2.1 Sampling Protocol

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

Table 2.1

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) accompanies 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

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

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

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

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

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

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

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

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

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

V = volume of sample settled (50 mL)

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

F = number of fields counted

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

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

2.4 Summary

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

2.5 Literature Cited

Nantucket Island Ponds and Their Water Quality

Chapter 3

Capaum Pond - 2015

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3.0 Introduction

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

3.1 Results

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

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

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

3.1.1 Physical characteristics

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

Figure 3.1

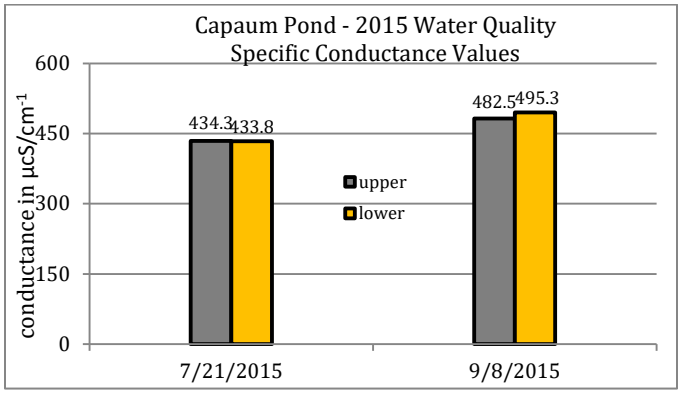
Temperature. Temperature profile data were collected on both 2015 sampling excursions. Due to the pond's shallow depth, there was only 2-3 degrees of temperature fluctuation from surface to bottom on both sampling dates. The average temperature was 25.4°C on July 21st and 25.6°C on September 8th.

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

3.1.2 Chemical characteristics

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

Figure 3.2

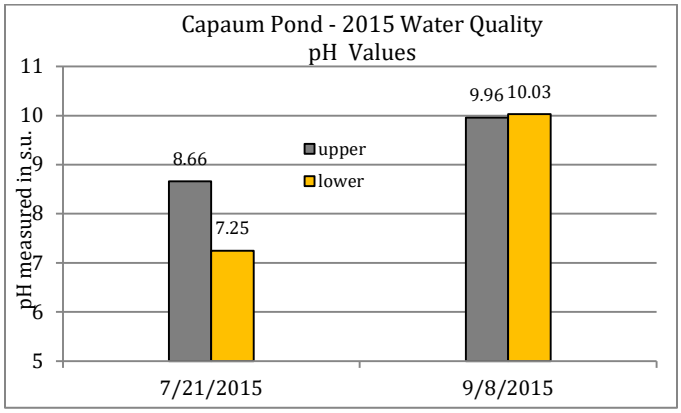


The similarity of the *upper* and *lower* conductance values on both 2015 sampling dates reflects the shallow nature of Capaum Pond and the fact that the water column probably mixes from the surface to the bottom when any substantial wind (> 10 mph) blows across the Island.

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

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

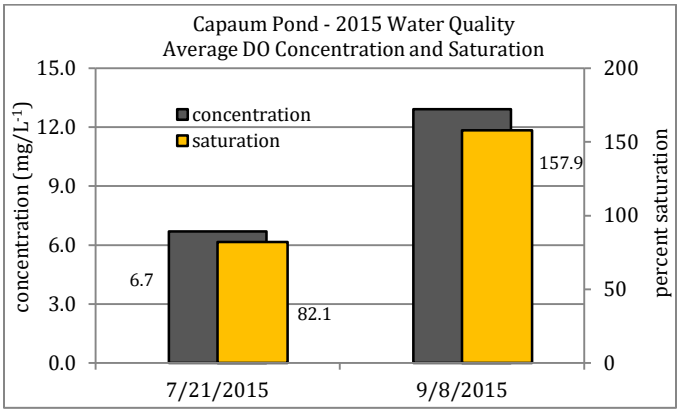
Figure 3.3



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

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

Figure 3.4



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

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

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

3.1.3 Plant Nutrients

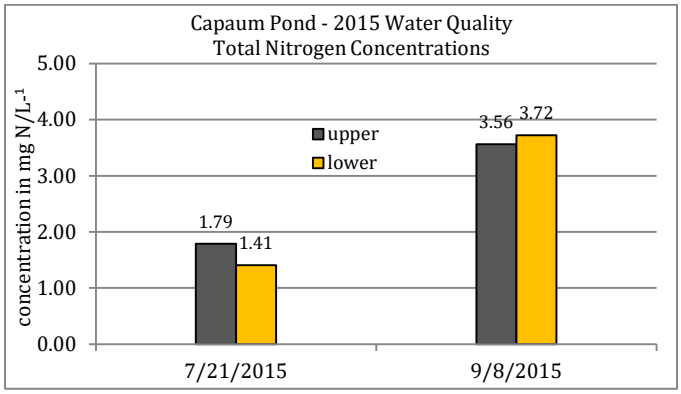
Nitrogen. The July and September concentrations of **nitrate-nitrogen** measured in the *upper* and *lower* regions of Capaum Pond were below the limit of detection on both sampling dates. This phenomenon is not unusual in ponds during the growing season because this form of nitrogen is readily taken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

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

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

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

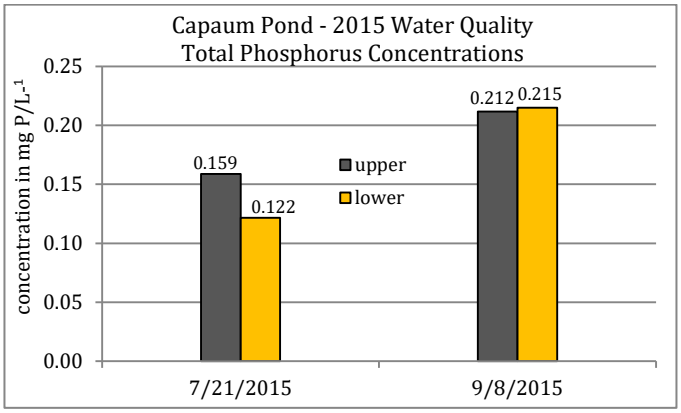
Figure 3.5



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

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

Figure 3.6



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

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

3.1.4 Phytoplankton

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

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

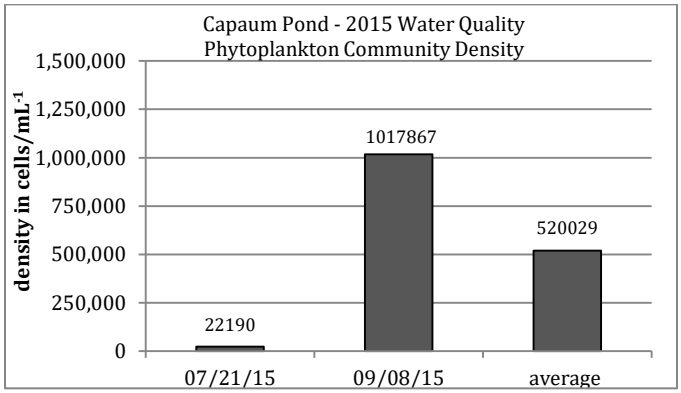
The greatest representation of phytoplankton taxa occurred within the Chlorophytes (green algae), where 20 different taxa were identified. The next most abundant groups were the Bacillariophytes (9 taxa) and Cyanophytes (7 taxa).

Table 3.1

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

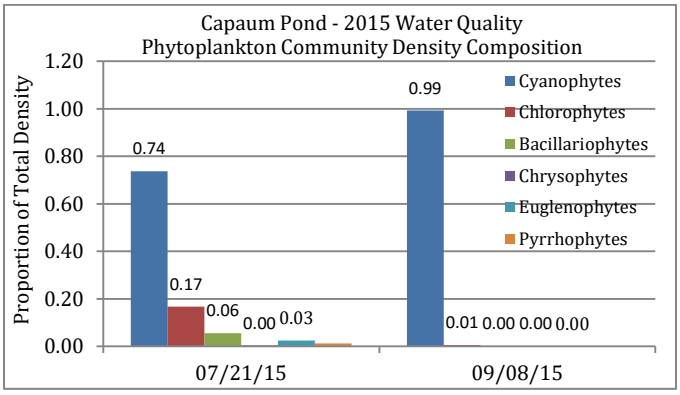
Density. Phytoplankton community density was 22,190 cells·mL^{-1} on July 21st and 1,017,867 cells·mL^{-1} on September 8th, about a 50-fold increase in density between the two sampling dates (Figure 3.7).

Figure 3.7



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

Figure 3.8



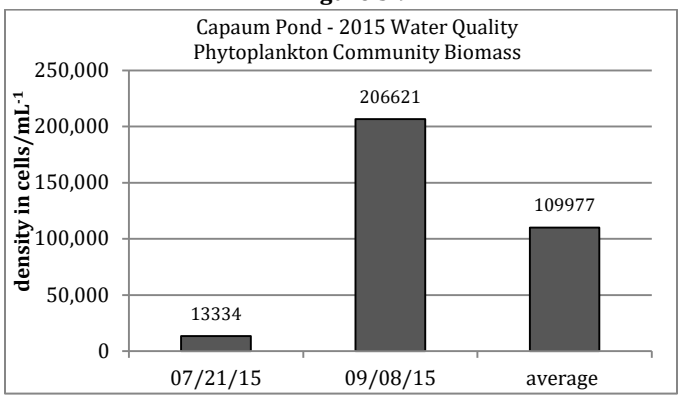
The relative importance of the Cyanophytes increased to 99 percent of the population on September 8th, with the Chlorophytes comprising the remaining 1 percent on this sampling date (Figure 3.8).

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

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

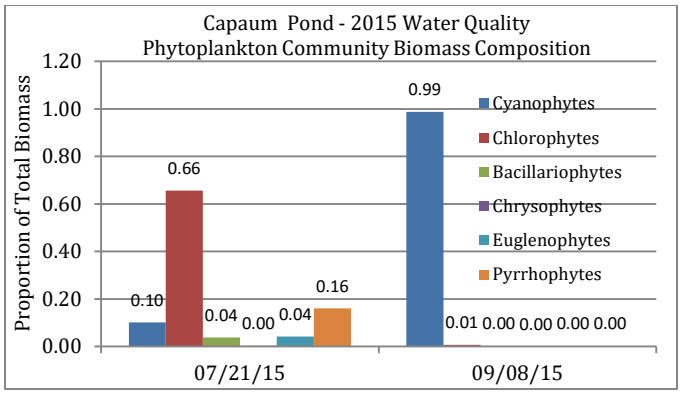
The phytoplankton community biomass was 13,334 mg·m^{-3} on July 21st and 206,621 mg·m^{-3} on September 8th, a 15-fold increase from the July value to the September value (Figure 3.9).

Figure 3.9



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

Figure 3.10



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

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

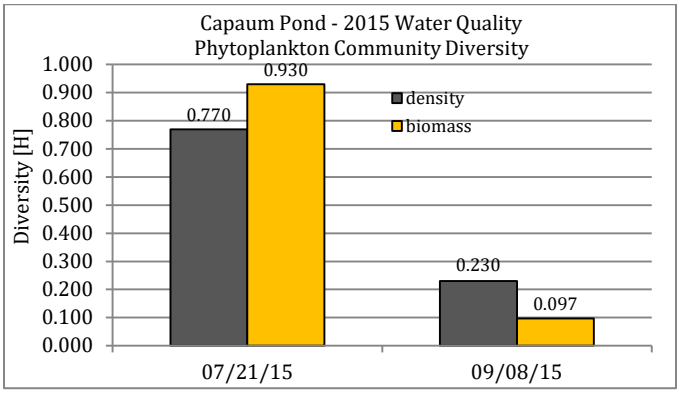
Table 3.2

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

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

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

Figure 3.11



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

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

Table 3.3

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

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

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

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

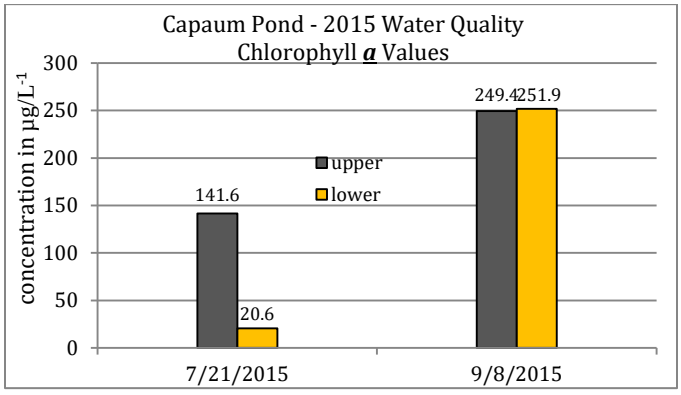
Table 3.4

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

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

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

Figure 3.12



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

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

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

3.1.5 Trophic Status

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

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

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

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

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

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

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

Table 3.4

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

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

3.2 Summary

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

3.3 Literature Cited

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

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

Nantucket Island Ponds and Their Water Quality

Chapter 4

Pest House Pond - 2015

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4.0 Introduction

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

4.1 Results

Pest House Pond was sampled on July 21st and September 8th 2015. Whereas access to the pond is quite difficult, the pond was sampled at the concrete pipe located at the west end of the pond that drains brackish water during the falling tide and brings saltwater into the pond on the rising tide.

There were no temperature data collected on either sampling date and dissolved oxygen and percent saturation data only were collected on July 21st.

4.1.1 Physical characteristics

General. Pest House Pond is located along the south-east shore of Nantucket Harbor, has a surface area of ~0.75 acres and is very shallow with the average depth of ~2 feet or less. It would appear from the aerial view provided in Figure 4.1 that the pond originally was about twice its current size.

Figure 4.1

The pond has no surface inlets and receives input from ground water, precipitation and surface runoff from the relatively small surrounding watershed.

4.1.2 Chemical characteristics

Specific conductance. A single conductance value of 28,390 $\mu S \cdot cm^{-1}$ was collected on the July 21st sampling date. This is a high value but expected for a body of water that receives saltwater input during the rising tide.

pH. A single pH value of 8.79 was recorded on the July 21st sampling date. This is an elevated value for mid-summer pH and suggests that there are high levels of productivity occurring in the pond that result in an imbalance between respiration and photosynthesis.

Dissolved oxygen concentration-percent saturation. A single set of dissolved oxygen concentration (8.80 $mg \cdot L^{-1}$) and percent saturation (95.2 %) readings was collected on July 21st. Although the water temperature of the pond was not recorded at the time these oxygen data were collected, the

concentration and saturation values seem normal for mid-summer conditions where the surface temperature is about 25ºC.

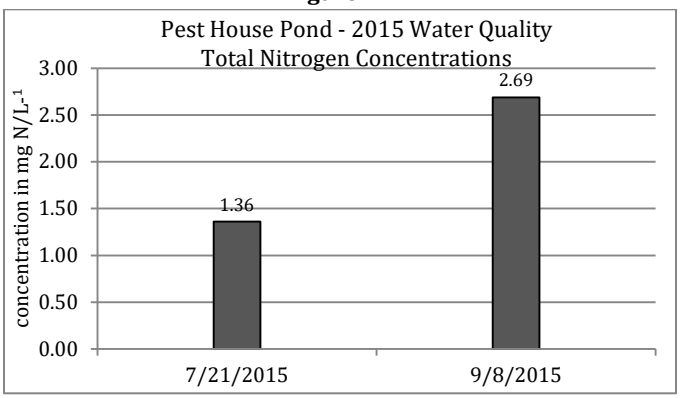
4.1.3 Plant Nutrients

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

Measureable levels of **ammonia-nitrogen** occurred in the water column on both sampling dates, 0.030 mg $N \cdot L^{-1}$ on July 21st and 0.470 mg $N \cdot L^{-1}$ on September 8th. Whereas Pest House Pond is extremely shallow, it is not unusual that warm mid-summer conditions would lead to a build-up of **ammonia-nitrogen** since this is the first nitrogen product of organic decomposition by bacteria of material accumulated on the pond bottom.

The 2015 **total nitrogen** (**TN**) concentrations measured in Pest House Pond are shown in Figure 4.2.

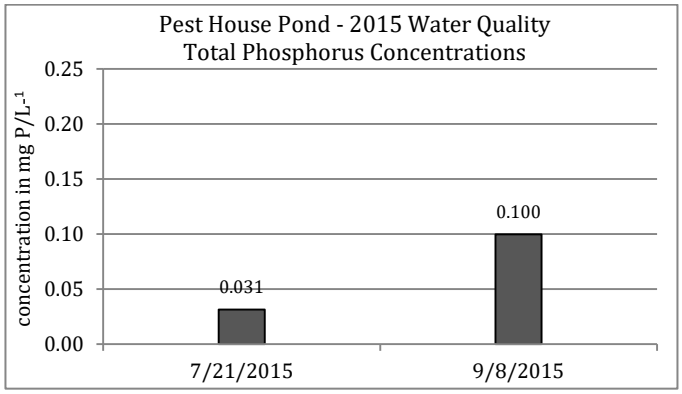
Figure 4.2



On July 21st, the **TN** concentration was 1.36 mg $N \cdot L^{-1}$, and by September 8th, the concentration had doubled to 2.69 mg $N \cdot L^{-1}$. These values are moderate-to-high and indicative of large amounts of organic nitrogen in the system in the form of phytoplankton and seston (other organisms and non-living matter).

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Pest House Pond during 2015 are shown in Figure 4.3**.**

Figure 4.3



On July 21st, the **TP** concentration was 0.031 mg $P \cdot L^{-1}$, while the concentration measured on September 8th was 0.100 mg P·L-1. While the September value is considered high, it would not be unusual to measure this level if a phytoplankton bloom was in progress at the time of sampling, which appears to have been the case and will be discussed in the next section of this report.

4.1.4 Phytoplankton

Description of the assemblage. A total of 27 taxa were identified in the 2015 July and September phytoplankton samples and all of the major algal groups were represented (Table 4.1).

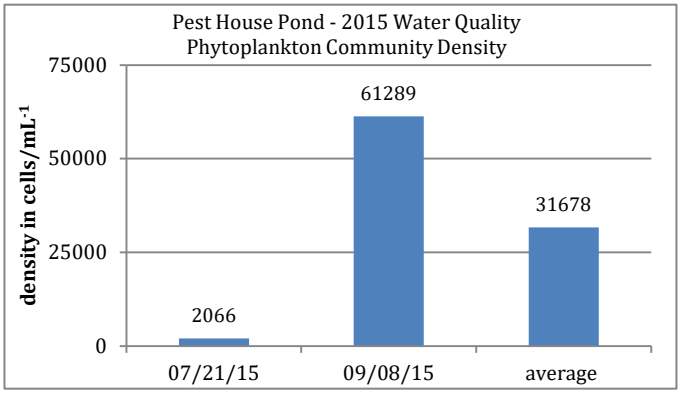
Table 4.1

Cyanophyta	**Chrysophyta (Bacillariophyceae)**	**Chrysophyta (Chrysophyceae)**
A. flos aquae	Cymbella sp.	Ochromonas sp.
Aphanizomenon flos aquae	Gomphonema spp.	Synura uvella
Oscillatoria sp.	Navicula spp.	**Euglenophyta**
Chlorophyta	Nitzschia sp.	Peranema sp.
Monoraphidium contortum	Planothidium sp.	Phacus sp.
Pyramimonas tetrarhyncus	Rhoicosphenia curvata	**Pyrrhophyta (Cryptophyceae)**
Schroederia Judayi	Stauroneis sp.	Cryptomonas erosa
Chrysophyta (Bacillariophyceae)	Surirella sp.	C. ovata
Achnanthes sp.	Synedra acus	**Pyrrhophyta (Dinophyceae)**
Cocconeis sp.	S. fulgens	Peridinium cinctum
Cyclotella sp.	Tabellaria fenestrata	

There were 23 taxa identified in the pond's phytoplankton community on July 21st and 17 taxa present on September 8th; community richness for the 2015 samples was calculated to be 20.0 (±4.2) taxa.

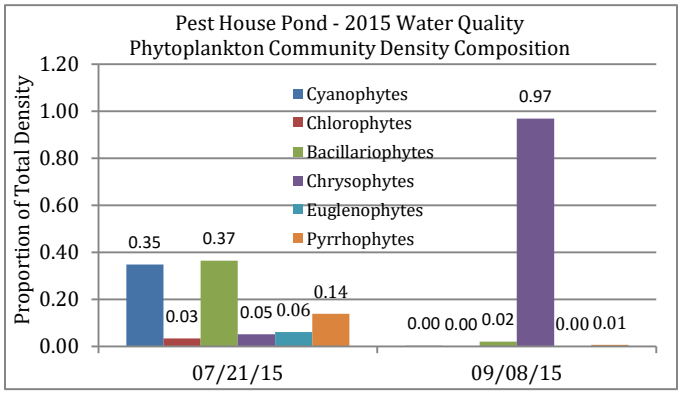
Density. Phytoplankton community density in Pest House Pond was 2,066 cells·mL^{-1} on July 21st and 61,289 cells·mL^{-1} on September 8th; average density was 31,678 cells·mL^{-1} for both dates (Figure 4.4).

Figure 4.4



The July 21st phytoplankton assemblage was comprised primarily of Bacillariophytes (diatoms) with 37 percent of the density and Cyanophytes (Blue-green algae) with 35 percent of the density (Figure 4.5).

Figure 4.5

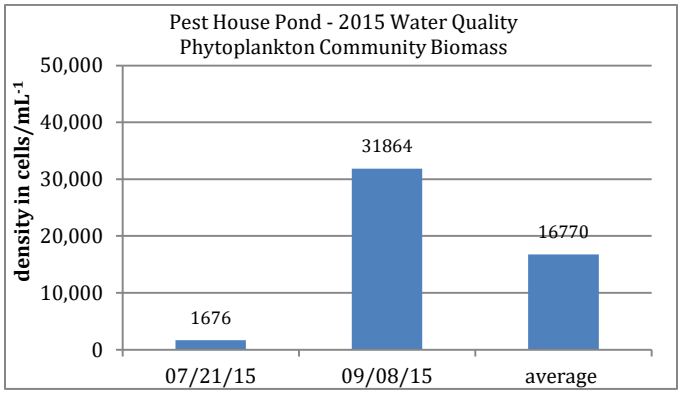


By September 8th, the density characteristic of the assemblage had completely changed and was comprised almost exclusively (97 percent) of Chrysophytes, which are cold-water, flagellated cells (Figure 4.5)

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

The phytoplankton community biomass documented in Pest House Pond during July and September 2015 is presented in Figure 4.6.

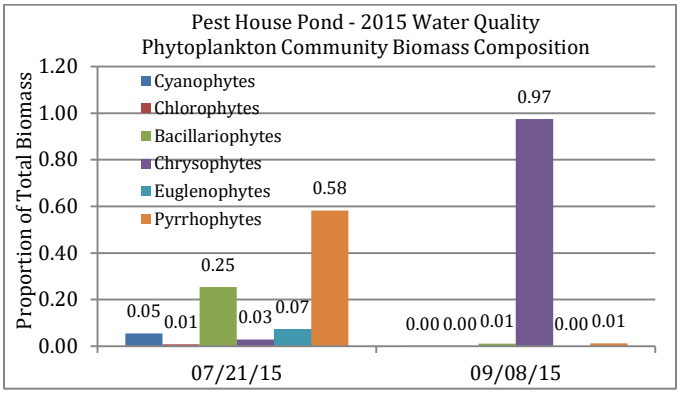
Figure 4.6



The biomass in the pond was 1,676 mg·m^{-3} on July 21st and 31,864 mg·m^{-3} on September 8th, which is an average of 16,770 mg·m^{-3} for both sampling dates (Figure 4.6).

With respect to biomass, the July phytoplankton assemblage was comprised primarily of Pyrrhophytes (58 percent) and Bacillariophytes (25 percent)(Figure 4.7).

Figure 4.7



By September 8th, the biomass composition of the phytoplankton community had changed dramatically and In September, the community was almost entirely comprised of Chrysophytes (97 percent).

Dominance. A ranking of phytoplankton taxa dominance in Pest House Pond on the 2015 sampling dates is summarized in Table 4.2.

Table 4.2

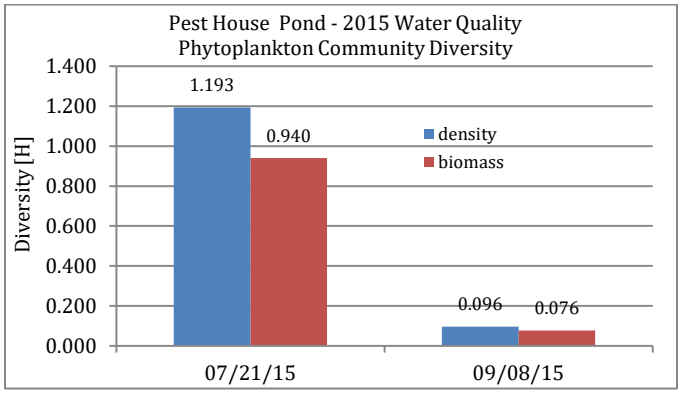
Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
7/21/15	*Cryptomonas ovata* (Chrysophyte)	1	31
	Peridinium cinctum (Pyrrhophyte)	2	27
	Phacus sp. (Euglenophyte)	3	7
	Surirella sp. (Chrysophyte)	4	5
9/8/15	*Synura uvella* (Chrysophyte)	1	97

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 July 21st and 1 dominant taxon in the community on September 8th (Table 4.2).

Diversity. Phytoplankton diversity in Pest House 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 Pest House Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Figure 4-8.

Figure 4.8



Using density as the primary variable, diversity calculated for Pest House Pond was 1.193 and 0.096 in July and September, respectively. With biomass, the diversity values were 0.940 and 0.076 during July and September, respectively. Regardless of which variable is used to calculate diversity, the most noteworthy feature is the drastic decline in diversity between July and September.

Cyanophytes. As a major phytoplankton group, the Cyanophytes were identified in both the July and September samples collected in Pest House Pond. A total of 3 taxa were identified including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, and *Oscillatoria* sp. Two of these species, *Anabaena flos aquae*, and *Aphanizomenon flos aquae* 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 Pest House Pond produce any algal toxins, recreational users of the pond should be aware that Cyanobacteria can be present during the mid-summer periods.

[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 Pest House Pond were 1.8 µg·L^{-1} on July 21st and 28.0 µg·L^{-1} on September 8th, indicating a normal concentration in July and a concentration that indicates an algal bloom in progress on September 8th.

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 Pest House Pond during 2015 to calculate the Carlson Trophic State Index (TSI) using chlorophyll a and total phosphorus. Average values were calculated for each variable for the July and 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* = 14.90 µg/L^{-1}
Chlorophyll *a* TSI = 9.81*[ln (14.90)] + 30.6
TSI = (9.81)(2.70) + 30.6
TSI = 57.1

Total phosphorus
Average mid-summer total phosphorus = 65.45 µg/L^{-1}
Total phosphorus TSI = 14.42*[ln (65.45)] + 4.15
TSI = (14.42)(4.18) + 4.15
TSI = 64.4

Both TSI indices were situated well within the eutrophic range of values as shown in Table 4.4 below. Given that the period between sampling dates was about 6 weeks in duration (late July to early September), it is likely that the key parameters used to calculate trophic state (total phosphorus and chlorophyll a) were well within the eutrophic range of values for a greater duration during the growing season.

Table 4.3

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 2015, Pest House Pond exhibits water quality similar to other Island ponds studied by the Nantucket Land Council. The pond has high productivity characterized as eutrophic based upon the numerical analysis of 2 separate water quality variables that were sampled. Many of the Island ponds probably are very similar due to their extremely shallow nature and the highly

enriched organic material contained in the sediments from aquatic vegetation that has decomposed and accumulated in that region. Nutrients such as nitrogen and phosphorus that are trapped in these bottom sediments are subject to being released into the water column at various times during the mid-summer growing season when mixing of the water column occurs due to sufficient winds blowing across the Island that generate water currents throughout the pond.

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.

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

Nantucket Island Ponds and Their Water Quality

Chapter 5

Summary of Water Quality Data Collected By The Nantucket Land Council

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5.0 Introduction

The Nantucket Land Council (NLC) has been actively involved in water quality monitoring on Nantucket Island since 2009 when Sutherland and Oktay conducted extensive surveys on Miacomet and Hummock Ponds. Since that time, the NLC has sponsored numerous water quality investigations, not only on ponds but also focused on ground water and the impact it has on certain Island ponds.

This chapter presents a brief summary and discussion of the physical, chemical and biological data collected from Nantucket Island ponds with funds provided by the NLC since 2009.

5.1 Summary and Analysis of Recent Water Quality Data

A listing of the water quality investigations sponsored by the NLC on Nantucket Island ponds is presented in Table 5.1 below.

Table 5.1

Year	Pond	Sampling Frequency	Analytes	Investigator
2009	Miacomet	8 times; June-October	Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Oktay
2009	Hummock	8 times; June-October	Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Oktay
2010	Head of Hummock	16 times; April-November	Secchi, temp, DO, field, TP, N series; phyto; toxins	Sutherland
2011	Head of Hummock	17 times; April-November	Secchi, temp, DO, field, TP, N series; phyto; toxins	Sutherland
2012	Hummock	11 times; April-November	Secchi, temp, DO, field, TP, N series; phyto; toxins	Sutherland
2012	Head of Hummock	11 times; April-November	Secchi, temp, DO, field, TP, N series; phyto; toxins	Sutherland
2013	Head of Hummock	11 times; April-November	Secchi, temp, DO, field, TP, N series; phyto; toxins	Sutherland & Molden
2014	Tom Nevers	2 times; September	Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Molden
2014	Washing	2 times; August-September	Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Molden
2014	Maxcy	2 times; August-September	Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Molden
2014	Head of Hummock	8 times; April-October	*Secchi, temp, DO, field, TP, N series; phyto; toxins	Sutherland & Molden
2015	Capaum	2 times; July, September	Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Molden
2015	Pest House	2 times; July, September	*Secchi, temp, DO, field, TP, N series; phyto	Sutherland & Molden
2015	Head of Hummock	8 times; June-September	phyto	Sutherland & Molden

Codes: Secchi (transparency); temp (temperature); DO (dissolved oxygen); field (pH, conductance); TP (total phosphorus); N series (nitrogen series); CHLa (chlorophyll ***a***); phyto (algal taxa, density, biomass, chlorophyll ***a***); toxins (algal toxins).

* = not all parameters collected on every sampling date

The information summarized above represents a sincere and dedicated commitment on the part of the NLC during the past 7 years to evaluate and understand the water quality of certain ponds on Nantucket Island which, collectively, represent a significant resource of brackish and fresh bodies of water.

5.2 Review of Recent NLC Water Quality Data

While the duration and frequency of sampling varied among the years reported, there appeared to be a genuine interest in determining the overall water quality during spring, mid-summer and fall and whether any trends were developing in terms of the ambient water quality. There also were indications that the Town of Nantucket was interested in determining the functioning of pond openings to the Atlantic Ocean with respect to alleviating flooding, nutrient flushing, increasing salinity, and providing fishery migration (Knoecklein, 2006).

In view of the variable monitoring conditions during the 19 years since monitoring was initiated on Hummock Pond, the period of June through September, each year, was selected to standardize the comparison of water quality among the years where data were available. This 4-month period generally represents the growing season in the pond, when the average temperature throughout the water column exceeds 18°C and the most favorable conditions are available for productivity.

The pond has no surface inlets and receives input from ground water, precipitation and surface runoff from the relatively small surrounding watershed.

4.1.2 Chemical characteristics

Specific conductance. A single conductance value of 28,390 $\mu S \cdot cm^{-1}$ was collected on the July 21st sampling date. This is a high value but expected for a body of water that receives saltwater input during the rising tide.

pH. A single pH value of 8.79 was recorded on the July 21st sampling date. This is an elevated value for mid-summer pH and suggests that there are high levels of productivity occurring in the pond that result in an imbalance between respiration and photosynthesis.

Dissolved oxygen concentration-percent saturation. A single set of dissolved oxygen concentration (8.80 $mg \cdot L^{-1}$) and percent saturation (95.2 %) readings was collected on July 21st. Although the water temperature of the pond was not recorded at the time these oxygen data were collected, the concentration and saturation values seem normal for mid-summer conditions where the surface temperature is about 25°C.

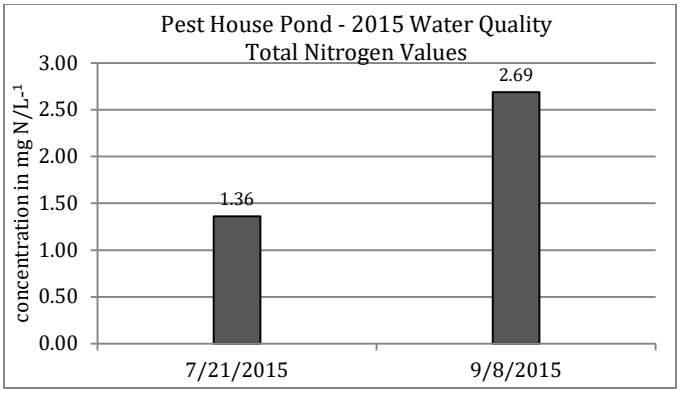
4.1.3 Plant Nutrients

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

Measureable levels of **ammonia-nitrogen** occurred in the water column on both sampling dates, 0.030 mg $N \cdot L^{-1}$ on July 21st and 0.470 mg $N \cdot L^{-1}$ on September 8th. Whereas Pest House Pond is extremely shallow, it is not unusual that warm mid-summer conditions would lead to a build-up of **ammonia-nitrogen** since this is the first nitrogen product of organic decomposition by bacteria of material accumulated on the pond bottom.

The **total nitrogen** (**TN**) concentrations measured in Pest House Pond during 2015 are shown in Figure 4.2.

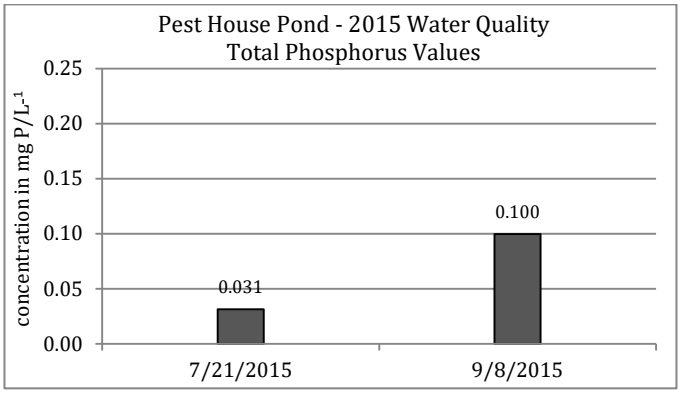
Figure 4.2



On July 21st, the **TN** concentration was 1.36 mg $N \cdot L^{-1}$, and by September 8th, the concentration had doubled to 2.69 mg $N \cdot L^{-1}$. These TN values are moderate-to-high and indicative of high concentrations of organic nitrogen in the system in the form of phytoplankton and seston (other organisms and non-living matter).

Phosphorus. The **total phosphorus** (**TP**) concentrations measured in Pest House Pond during 2015 are shown in Figure 4.3**.**

Figure 4.3



On July 21st, the **TP** concentration was 0.031 mg $P \cdot L^{-1}$, while the concentration measured on September 8th was 0.100 mg P·L-1. While the September value is considered high, it would not be unusual to measure this level if a phytoplankton bloom was in progress at the time of sampling, which appears to have been the case and will be discussed in the next section of this report.

4.1.4 Phytoplankton

Description of the assemblage. A total of 27 taxa were identified in the July and September 2015 phytoplankton samples collected from Pest House Pond and all of the major algal groups were represented in the samples (Table 4.1).

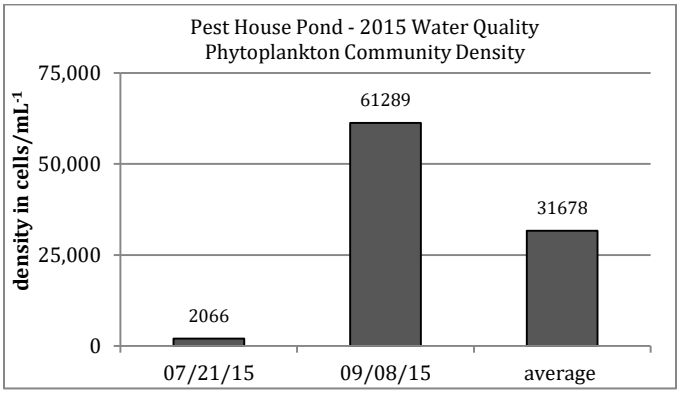
Table 4.1

Cyanophyta	Chrysophyta (Bacillariophyceae)	Chrysophyta (Chrysophyceae)
A. flos aquae	Cymbella sp.	Ochromonas sp.
Aphanizomenon flos aquae	Gomphonema spp.	Synura uvella
Oscillatoria sp.	Navicula spp.	**Euglenophyta**
Chlorophyta	Nitzschia sp.	Peranema sp.
Monoraphidium contortum	Planothidium sp.	Phacus sp.
Pyramimonas tetrarhyncus	Rhoicosphenia curvata	**Pyrrhophyta (Cryptophyceae)**
Schroederia Judayi	Stauroneis sp.	Cryptomonas erosa
Chrysophyta (Bacillariophyceae)	Surirella sp.	C. ovata
Achnanthes sp.	Synedra acus	**Pyrrhophyta (Dinophyceae)**
Cocconeis sp.	S. fulgens	Peridinium cinctum
Cyclotella sp.	Tabellaria fenestrata	

The were 23 taxa identified in the pond's phytoplankton community on July 21st and 17 taxa present on September 8th; community richness for the 2015 samples was calculated to be 20.0 (±4.2) taxa.

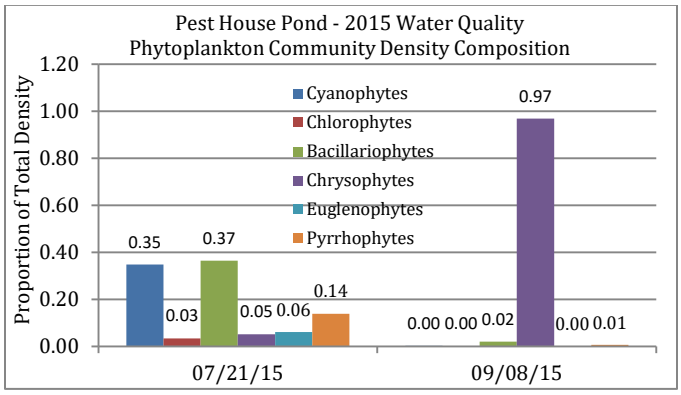
Density. The phytoplankton community density in Pest House Pond was 2,066 cells·mL^{-1} on July 21st and 61,289 cells·mL^{-1} on September 8th, the average density was 31,678 cells·mL^{-1} for both dates (Figure 4.4).

Figure 4.4



The July 21st phytoplankton assemblage was comprised primarily of Bacillariophytes (diatoms) with 37 percent of the community density and Cyanophytes (Blue-green algae) with 35 percent of the community density (Figure 4.5).

Figure 4.5

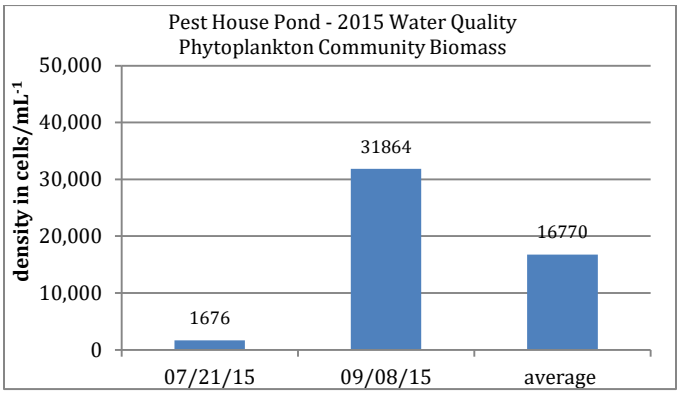


By September 8th, the density characteristics of the assemblage had completely changed and was comprised almost exclusively (97 percent) Chrysophytes, which are cold-water, flagellated cells (Figure 4.5)

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

The phytoplankton community biomass documented in Pest House Pond during July and September 2015 is presented in Figure 4.6.

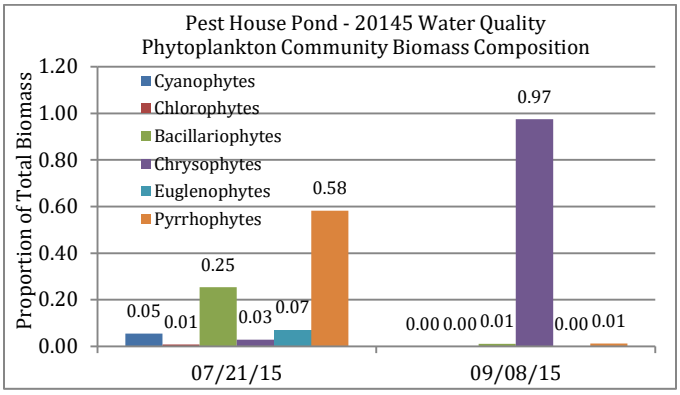
Figure 4.6



The biomass in the pond was 1,676 mg·m^{-3} on July 21st and 31,864 mg·m^{-3} on September 8th, which is an average of 16,770 mg·m^{-3} for both sampling dates (Figure 4.6).

With respect to biomass, the July phytoplankton assemblage was comprised primarily of Pyrrhophytes (58 percent) and Bacillariophytes (25 percent)(Figure 4.7).

Figure 4.7



By September 8th, the biomass composition of the phytoplankton community had changed dramatically and In September, the community was almost entirely comprised of Chrysophytes (97 percent).

Dominance. A ranking of phytoplankton taxa dominance in Pest House Pond on the 2015 sampling dates is summarized in Table 4.2.

Table 4.2

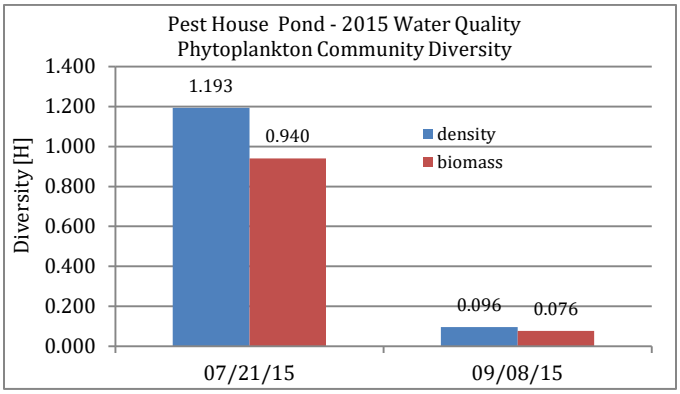
Sampling Date	Taxon (Major Group)	Biomass Rank	% of Total Biomass
7/21/15	*Cryptomonas ovata* (Chrysophyte)	1	31
	Peridinium cinctum (Pyrrhophyte)	2	27
	Phacus sp. (Euglenophyte)	3	7
	Surirella sp. (Chrysophyte)	4	5
9/8/14	*Synura uvella* (Chrysophyte)	1	97

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 July 21st and 1 dominant taxon in the community on September 8th (Table 4.2).

Diversity. Phytoplankton diversity in Pest House 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 Pest House Pond was calculated using both density and biomass in the equation. The results of the diversity calculations are presented in Figure 4-8.

Figure 4.8



Using density as the primary variable, diversity calculated for Pest House Pond was 1.193 and 0.096 in July and September, respectively. With biomass, the diversity values were 0.940 and 0.076 during July and September, respectively. Regardless of which variable is used to calculate diversity, the most noteworthy feature is the drastic decline in diversity between July and September.

Cyanophytes. As a major phytoplankton group, the Cyanophytes were identified in both the July and September samples collected in Pest House Pond. A total of 3 taxa were identified including *Anabaena flos aquae*, *Aphanizomenon flos aquae*, and *Oscillatoria* sp. Two of these species, *Anabaena flos aquae*, and *Aphanizomenon flos aquae* 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 Pest House 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 Pest House Pond were 1.8 µg·L^{-1} on July 21st and 28.0 µg·L^{-1} on September 8th, indicating a normal concentration in July and a concentration that indicates an algal bloom in progress on September 8th.

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.

[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 Washing Pond during 2014 to calculate the Carlson Trophic State Index (TSI) using chlorophyll a and total phosphorus. Average values were calculated for each variable for the July and 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* = 14.90 $\mu g/L^{-1}$

Chlorophyll *a* TSI = 9.81*[ln (14.90)] + 30.6

TSI = (9.81)(2.70) + 30.6

TSI = 57.1

Total phosphorus

Average mid-summer total phosphorus = 65.45 $\mu g/L^{-1}$

Total phosphorus TSI = 14.42*[ln (65.45)] + 4.15

TSI = (14.42)(4.18) + 4.15

TSI = 64.4

Both TSI indices were situated well within the eutrophic range of values as shown in Table 4.4 below. Given that the period between sampling dates was about 6 weeks in duration (late July to early September), it is likely that the key parameters used to calculate trophic state (total phosphorus and chlorophyll a) were well within the eutrophic range of values for a greater duration during the growing season.

Table 4.3

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

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 based upon the numerical analysis of 2 separate water quality variables that were sampled. Many of the Island ponds probably are very similar due to their extremely shallow nature and the highly enriched organic material contained in the sediments from aquatic vegetation that has decomposed and accumulated in that region. Nutrients such as nitrogen and phosphorus that are trapped in these bottom sediments are subject to being released into the water column at various times during the mid-summer growing season when mixing of the water column occurs due to sufficient winds blowing across the Island that generate water currents throughout the pond.

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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