Hummock Pond

2012 Water Quality Program

A Summary of Physical, Chemical and Biological Monitoring

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TABLE OF CONTENTS

TABLE OF CONTENTS

Page

Chapter 3 The Water Quality of Hummock Pond During 2012 (continued)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

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The University of Massachusetts Boston Nantucket Field Station loaned different pieces of equipment on a regular basis, without which, the 2012 sampling program would not have been possible.

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Hummock Pond

2012 Water Quality Program

Chapter 1

Executive Summary

1.0 Program Location and Boundary

Hummock Pond is located in Nantucket County, Massachusetts, and appears on the United States Geological Survey (USGS) 7.5 minute quadrangle map, Nantucket, with a seasonal, created outflow to the Atlantic Ocean located at latitude 43°05'32" and longitude 73°46'08" (Figure 1-1).

Figure 1.1 Aerial photograph of Hummock Pond.

The Pond and its watershed are situated within the Town of Nantucket and the Town is responsible for stewardship of the Pond. Hummock Pond is primarily a contact recreational body of water, being used for boating, kayaking, fishing, sailing and swimming, and also provides important habitat for a variety of waterfowl, both migrating and resident populations.

Hummock Pond is listed as one of seven Great Ponds located within Nantucket County by the MA Department of Environmental Protection. Beginning in 1994, the Nantucket Marine and Coastal Resource Department initiated monthly monitoring of water quality parameters on Hummock Pond during the ice-free period of the year, focusing on temperature, dissolved oxygen, salinity, Secchi depth, water depth and nutrient chemistry, and issued annual reports each year.

1.1 Purpose of the 2012 Program

The last water quality report for Hummock Pond issued by the Nantucket Marine and Coastal Resource Department was in 2008 (Conant). In 2009, Sutherland and Oktay conducted a study on the pond and also sampled Head of Hummock Pond. Hummock Pond was sampled during 2010, 2011, and 2012 as part of an Island-wide water quality monitoring program with support from the Coastal Systems Program at the University of Massachusetts-Dartmouth, School for Marine Science and Technology (SMAST), although the frequency of sampling and the parameters sampled varied among years. A primary goal of this 2012 study was to follow up on the 2009 study that revealed the extremely poor water quality so prevalent in Hummock Pond.

A secondary goal of the 2012 study was to maintain current record of water quality data since interest has occurred among pond shoreline property owners and other local residents to consider the implementation of aquatic vegetation management to deal with excessive levels of submersed aquatic plant species in the pond.

Harvesting would remove plant biomass from the pond, thereby reducing the internal loading of nutrient and also would improve the recreational experience on the pond.

The specific objectives of the present study were to

- Define the current water quality of Hummock Pond during the 2012 growing season and,
- Compare the 2012 results with the 2009 data and with the historical water data from the pond and determine whether any significant trends are developing over time.

A primary factor that motivated the current investigation was an apparent lack of funding within the Town of Nantucket to maintain the regular water quality monitoring program on Hummock Pond initiated during the early 1990's. The report author (JWS) developed a brief proposal for the 2012 study and the Nantucket Land Council, Inc. provided the funds for costs associated with the study.

1.2 Program Description

Hummock Pond was sampled during 2012 about every three weeks for an eight month period. The study began during early April and continued through early November. A total of 11 sampling trips were conducted; a single station at the wide portion of the pond was sampled during each trip. The early and late sampling trips were scheduled to collect important water quality data before and after the spring and fall openings of the pond to the Atlantic Ocean in an effort to determine whether the process of opening the ponds is beneficial or detrimental to water quality and the entire estuarine ecosystem.

1.3 Presentation of Report

Chapter 1 summarizes the pond-related problems, the findings of this study, goals for improving pond water quality, and a summary of the recommendations.

Chapter 2 describes the 2012 sampling program on the pond and the methods used in the sampling program.

Chapter 3 describes the existing water quality of Hummock Pond as evaluated through the analysis of physical, chemical and biological data.

Chapter 4 presents a comparison of the 2012 and 2009 data collected by the author and then compares these data with historical water quality data collected from HP by previous investigators.

Chapter 5 presents a summary of the historical water quality data collected from Hummock Pond and compares the recent (2009 and 2012) data collected by the author with the historical data.

Chapter 6 includes a summary of 2012 findings, discussion of the data, conclusions and general recommendations that should be considered when developing a water quality management strategy for Hummock Pond.

An **Appendix** included at the end of the report contains certain material referenced in the report.

1.4 Program Findings and Conclusions

Hummock Pond continues to exhibit eutrophic water quality, even though the 2012 chlorophyll ***a*** and Secchi depth data, when analyzed, placed the pond closer to the mesotrophic-eutrophic boundary than the 2009 data for the same parameters (see page ##, Chapter 4). Previous reports had labeled the pond 'eutrophic' but did not use any analytical criteria to evaluate the historical data collected from the pond.

The phytoplankton community dynamics documented in Hummock Pond during 2012 did not correspond to a normal year and should not be used to evaluate water quality improvement in the pond. The extreme salinity that was prevalent in the pond until late in the growing season affected the algal seed bank and the species that were able to successfully grow, and also the timing and appearance of major groups of algae in the normal seasonal succession expected in Hummock Pond.

The elevated total phosphorus (TP) values that occur in Hummock Pond are autochthonous (internal) in origin. Presumably, there is considerable phosphorus release from the sediments through wind-induced mixing which promotes high phytoplankton and aquatic plant productivity as the phosphorus becomes available. The high productivity provides biomass for decomposition at the micro-zone within the sediment-water interface which then undergoes phosphorus release and perpetuates the cycle of productivity described above.

The average concentrations of total nitrogen (TN) measured in Hummock Pond during mid-summer and fall of 2009 and 2012 were similar (~1.0 mg $N \cdot L^{-1}$) and within a range of concentrations considered to be background levels for a water body with this level of watershed development and in this type of geologic setting. There is considerable potential for watershed loading of this nutrient to become problematic, however, and for the assimilative capacity of the Hummock Pond system to be exceeded. A source of nitrogen probably is derived from individual septic systems in the Hummock Pond watershed which are of different ages and working efficiencies and operated on a seasonal basis.

Several Cyanophyte species identified in Hummock Pond during 2009 and 2012 that are identified as toxin-producers in the literature. Cyanotoxins can pose a public health and safety issue for recreational users of the pond and home-owners living along the shoreline of the pond. The severity of the Cyanophyte issue became more elevated during 2012 when microcystin was detected in water samples collected from the pond.

A brief summary of the potential problems affecting Hummock Pond are as follows:

- There is considerable development occurring within the watershed(s) and a large number of individual septic systems whose operating efficiency is unknown,
- Phosphorus loading in the pond appears to be internal in nature and can be managed through the removal of biomass in the form of the current dense growth of aquatic macrophytes,
- Nitrogen loading should be considered a potential problem for future water quality of Hummock Pond via the groundwater that enters the ponds and is the primary source of water for the pond,
- Hummock Pond currently is 'unusable' by the public for either contact recreation or aesthetic enjoyment in its present state of water quality, and
- Although Hummock Pond has been studied since 1994, there is very little scientific information available concerning the effects of the surrounding watershed on the pond.

Based upon the current level of knowledge related to the Hummock Pond ecosystem, the report author has presented a series of recommendations that should be considered for implementation.

1.5 Recommendations

(1) Hummock Pond requires attention focused on a series of water quality issues that have been exhibited for the better part of the previous two decades, including considerable nutrient enrichment and the occasional severe, extended Cyanophyte blooms that produce neurotoxins and can pose a public safety threat for local residents.

(2) In the absence of Town of Nantucket ability to either fund or participate in the continued water quality monitoring of Hummock Pond, it would be appropriate for another organization to exercise continued long-term vision toward water quality management and remediation for an important local water resource. The Nantucket Land Council (NLC), Inc., is a logical candidate for this stewardship role and is an organization that helped sponsor the 2009 study of Hummock Pond and also has sponsored three years (2010,2011, 2012) of water quality studies on Head of Hummock Pond.

(3) As the government entity responsible for Hummock and Head of Hummock Ponds, the Town of Nantucket should retain a consultant to prepare a detailed Management Plan for these two bodies of water following completion of the Nitrogen Management Report, and using this report for the basis of the Management Plan. However, a detailed Management Plan should not be prepared for the ponds until there has been a more thorough assessment of factors affecting the water quality of the ponds and, in some cases, additional data gathering must occur to overcome deficiencies in the current status of information. These deficiencies are addressed below.

(4) Potential watershed deficiencies that should be evaluated prior to the development of a Management Plan include (1) detailed GIS land use analysis within the watershed, documenting individual parcels, the amount of development and types of structures/impervious areas on each parcel, (2) enhanced groundwater monitoring including installation of more wells, funds for certified chemical analyses, and studies to determine the direction of subsurface flows to define the exact contributory areas and continue the program of Title 5 inspections within the watershed, and (3) evaluation of current soil maps and upgrading of these maps if warranted by a lack of necessary resolution, particularly since the use of fertilizer in the watershed is becoming so controversial and the effectiveness of soil in removing nutrients is uncertain.

(5) Pond deficiencies should be addressed prior to the development of the Management Plan and include (1) enhanced water quality sampling before and after the breaching of Hummock Pond with the Atlantic Ocean to evaluate the effect of the breaching, (2) installation of a continuous water level recorder to assist with preparation of a water budget for the ponds, (3) updated bathymetry of the ponds, and (4) chemical analysis of bottom sediments.

(6) The current shore-line of Hummock Pond should be delineated along with detailed mapping of the shoreline *Phragmites* population using high resolution GPS. In some areas, the *Phragmites* is encroaching into the open water in measureable amounts each year and eventually will cause the pond to segment into smaller water bodies, particularly along the narrow northeast end of Hummock Pond.

(7) Beginning in the late spring of 2013, regular, bi-weekly samples of the phytoplankton community should be collected from Hummock Pond. These samples should be submitted to a certified algologist for identification and enumeration and also submitted to SUNY-ESF for algal toxin analyses.

(8) Until control of nutrient loading to the ponds can be achieved, there should be funding options explored to purchase a mechanical harvester to remove aquatic plant biomass from Hummock Pond. Owning and

operating the harvester would be the most practical approach and the equipment could be used on other Island ponds with vegetation problems. Initial costs would include the harvester, conveyor (to off-load vegetation) and dump truck. Local farms or landscape professionals might use the harvested material as compost; otherwise, the material could be composted at the local landfill.

(9) It is important that a close watch be maintained over the Hummock Pond aquatic plant community to provide early detection of the introduction of an invasive species, such as *Myriophyllum spicatum*, Eurasian watermilfoil. It is surprising that no invasive species have been detected in the pond so far, particularly given the high waterfowl traffic from Cape Cod and other areas along the eastern seaboard where invasive plant species are a well-documented problem.

(10) Continue to sample water quality of Hummock Pond and Head of Hummock Pond before and after the opening to the Atlantic Ocean in order to evaluate the effect of the opening.

1.6 Literature Cited

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Hummock Pond

2012 Water Quality Program

Chapter 2

Description of the 2012 Program and Methods

2.0 Introduction

The Hummock Pond ecosystem includes both physical and chemical environments and the biotic community. The physical environment of the pond, which includes water temperature, wind-induced turbulence, and the duration and intensity of light in the water column, is directly affected by climate. The chemical characteristics of the pond are determined, primarily, by the interaction of the following three factors

- the geologic watershed and its contents,
- land use in the watershed and related human activities, and
- the hydrology of the pond

The biotic community of the pond is the result of the physical and chemical environments and reflects the quality of these components through species composition and abundance of organisms.

2.0.1 Purpose of the 2012 sampling program.

Water quality data have been collected from Hummock Pond since 1994 by the Marine and Coastal Resource Department (MCRD) on Nantucket Island. However, recent gaps have occurred in the program as a result of budgetary shortfalls during difficult economic times. The last MCRD study of Hummock Pond water quality was conducted during 2007. Subsequently, Sutherland and Oktay (2010) issued a comprehensive report on 2009 Hummock Pond water quality. Recent local awareness of nuisance levels of aquatic vegetation in Hummock Pond have drawn attention to vegetation harvesting as a potential water quality management option for the pond. The 2012 sampling program for Hummock Pond was designed to provide some minimum levels of water quality data that would assist with the evaluation of future management options for the pond.

2.0.2 Description of the 2012 sampling program.

2012 water quality was monitored from early April through early November at a single station located at the wide area of the pond. This station was designated Station #2 and was the same location of Station #2 sampled during 2009, which had been selected to coincide with the location of a similar station sampled during previous surveys in the 1990s and 2000s.

Sampling was conducted on about a tri-weekly basis. The Pond was sampled a total of 11 times and the sampling dates are listed below.

Table 2.1 Summary of 2012 Hummock Pond sampling dates.

Hummock Pond – 2012 Sampling Dates			
April 10th	April 30th	May 21st	June 11th
July 2nd	July 24th	August 21st	September 13th
October 2nd	October 22nd	November 6th	

The data and samples collected regularly from stations on the Pond included the following

1. Depth profiles of temperature and dissolved oxygen (concentration and percent saturation)
2. Secchi depth transparency
3. Raw pond water for the analysis of total phosphorus, a nitrogen series, chlorophyll ***a***, algal toxins, specific conductance, pH and
4. A sample for phytoplankton community dynamics (identification, enumeration, and estimation of biomass/biovolume of all algal taxa in the samples collected).

Table 2.2 summarizes the water quality parameters that were monitored in Hummock Pond during the 2012 sampling season.

Table 2.2 Parameters monitored from April until November 2012 to assess the water quality of Hummock Pond.

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 (concentration and saturation)
Biological	
	phytoplankton community response
	Chlorophyll ***a***, species composition, diversity, relative abundance, biomass/biovolume
	Cyanophyte toxins

2.1 Methods

2.1.1 Routine sample collection and processing. Sample collection occurred at Station #2 near the wide section of the pond (Figure 2-1). The boat was anchored at the station and total depth of the water column was measured with a weighted Secchi disk on a marked line, and recorded. In some instances, latitude-longitude was recorded using a SporTrak Pro Magellan GPS unit.

Figure 2.1 Aerial photograph of Hummock Pond showing the location of sampling station #2.

Secchi depth transparency was measured using a standard 20-cm weighted disk on a marked line. Measurements were taken on the side of the boat away from the sun in order to avoid any glare that would interfere with the readings. The disk was lowered into the water column to the depth at which it just disappeared. This depth was noted. The disk then was raised from out of the range of visibility to the depth where it re-appeared. This depth was noted. The average of the 2 depths was recorded as the Secchi depth transparency at the station on that sampling date.

Vertical profiles of water temperature and dissolved oxygen were measured in-situ at 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 were collected from the water column following a determination of whether the column was stratified, either thermally or in terms of oxygen concentration. The upper zone of the water column at similar temperature (epilimnion) was sampled using the integrated hose technique; the lower zone of different temperature or oxygen concentration was sampled with a horizontal Van Dorn bottle. The collected samples were transferred to cleaned and pre-rinsed 500 mL PE sample bottles and then stored on ice and in the dark until processing, usually within 2 hours of collection.

A subsample of water collected from the upper and lower levels of the water column at each station was analyzed on-site for specific conductance, total dissolved solids, and pH using an Ultrameter II™ (Myron L Company). These data were recorded on individual station field sheets (Appendix 1).

The water chemistry, chlorophyll ***a*** and phytoplankton samples were processed at the author's home immediately following each pond visit. The water sample for chemistry was processed by pouring off separate 75-100 mL aliquots of raw sample into 4 - 125 mL PE containers with screw caps labeled with **TP**, **TN**, **NH3** and **NO3** and with accession numbers (sample label code) for the 2012 Nantucket Island sampling program. The accession format was **12-NIP-###**, with **###** being a series of consecutive numbers, starting at 076, that identified each set of collected samples.

The samples for chlorophyll ***a*** determination were concentrated by filtration through a 0.45µm glass fiber filter; subsequently, 0.2 mL of MgCO3 suspension was added for preservation during the final phase of filtration. The filters were kept frozen and in the dark until delivery to the analytical laboratory.

The processed chemistry and chlorophyll *a* samples were placed in a cooler with gel packs and shipped via FedEx (either Overnight Priority or 2Day A.M. delivery) to the Keck Water Research Laboratory in Troy, NY. This lab is located on the campus of Rensselaer Polytechnic Institute (RPI) and NYS certified to process and analyze the parameters included in this investigation. A Chain of Custody form (Appendix 1) accompanied the samples to the analytical lab.

The phytoplankton samples were transferred to 125 mL amber PE bottles, preserved with glutaraldehyde solution and then sent to Ms. Jill Scaglione at Aquatic Analysts, Inc. in Middleville, NJ for analysis. Ms. Scaglione is certified for phytoplankton analysis and these types of samples are part of her responsibility with the environmental management firm where she is employed.

2.2 Analytical Techniques

The methods for on-site water column measurements and field collections are summarized in Table 2.3. The analytical procedures for water chemistry and biological samples are presented in Table 2.4.

The author and NLC staff collected all data and samples in the field, and the author processed these samples at his home laboratory within several hours following collection.

The samples for water column nutrients were analyzed by the Keck Water Research Laboratory on the RPI Campus in Troy, NY, using the standard procedures presented in Table 2.3.

Chlorophyll ***a***, retained by filtration, was broken down by grinding, extracted in 90% acetone, centrifuged, and then determined fluorometrically (Table 2.3).

Table 2.3 Physical, chemical and biological parameters included in the 2012 Hummock Pond study of water quality, the collection technique and methodology.

PARAMETER	COLLECTION TECHNIQUE	ANALYTICAL METHODOLOGY
Physical Characteristics (Light, Dissolved Oxygen, Secchi, Temperature)	Vertical profiles at 1m 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 (Integrated epilimnetic sample archived)	chlorophyll a, species identification and enumeration, biomass
Biological Characteristics - Phytoplankton	Integrated photic zone sample (Integrated epilimnetic sample archived)	microcystin, cylindrospermopsin and anatoxin-a analysis

Table 2.4 Chemical parameters and analytical methods for the 2012 study of water quality in Hummock Pond.

PARAMETER	ANALYTICAL METHOD
pH	Electrometric (US EPA Method 150.1)
Specific Conductance	Wheatstone Bridge type meter (US EPA Method 120.1)
Dissolved Oxygen	Membrane Electrode (US EPA Method 360.1)
Inorganic Anions (Cl, NO_3, SO_4)	Ion Chromatography (US EPA Method 300.0)
Total Nitrogen	Persulfate Oxidation
Phosphorus (total)	Colorimetric (US EPA Method 365.2)
Ammonium	Flow Injection Analysis (Lachat)
Chlorophyll	Fluorimetric (Turner 1985)

2.2.1 Phytoplankton. The microscopic protocol for phytoplankton identification and enumeration is detailed in the following sections.

Counting method. At least 200 ml of properly preserved (glutaraldehyde) sample is required for analysis. The inverted microscope is used routinely for phytoplankton counting. 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 are allowed to settle for a sufficient period (1 hour settling time/mm of column depth or approximately 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 slid off with a cover slip, removing all but 1 mL of sample in a small well at the chamber bottom.

The sample is first scanned using low magnification to determine the taxa present. It is then analyzed at 1000x using oil immersion in order to accurately count cells which may be present below 10-20 um in size. For biomass estimates, it also is necessary to have high magnification in order 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 is usually 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 with an ocular micrometer in the eyepiece and a stage micrometer. The number of cells counted for each taxa is determined with 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 = total area of bottom of settling chamber, mm^2

V = volume of sampled settled (50 ml)

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

F = number of fields counted

Conversion to biovolume (mg^3/mL) - biomass (mg/m^3). Phytoplankton data derived on a volume-per-volume basis are more useful than numbers per milliliter. Algal cell sizes can differ in various bodies of water or within the same body of water at different times of the year. Therefore, average measurements are made from approximately 20 individuals of each species 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) 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) by 1,000.

2.2.2 Cyanophyte toxins

Samples were collected for analysis of algal toxins on 5 different dates during 2012 and shipped FedEx Priority Overnight to the laboratory at SUNY-ESF in Syracuse, NY. At the SUNY-ESF Jahn Lab, filters with the algal cells are extracted in 10 mL of 50% methanol using ultrasound as described in Boyer 2008. Samples were clarified by centrifugation, and voucher samples stored at -20°C. Microcystin hepatotoxins were determined using the protein phosphatase inhibition assay (PPIA), an enzymatic test closely tied to biological activity of the toxins, using a standard curve of microcystin–LR between 6 and 40 ug per liter. The other toxins including the ATX group consisting of Anatoxin-a and homo-Anatoxin-a; the CYL group including cylindrospermopsin, epi-cylindrospermopsin & deoxycylindrospermopsin; free beta methyl amino alanine (BMAA), and confirmation of microcystin activity or determination of the microcystin variants were done using liquid chromatography coupled with mass spectroscopy (LC-MS) or tandem mass spectrometry (LC-MS/MS). The sensitivity of these tests is dependent on the volumes filtered, therefore the actual method detection limit for any samples that tested negative are provided preceded by a "<" sign. This gives an upper threshold of toxicity and does not mean that samples are necessarily toxic.

2.3 Literature Cited

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Hummock Pond

2012 Water Quality Program

Chapter 3

The Water Quality of Hummock Pond During 2012

3.0 Introduction

The Hummock Pond ecosystem includes physical and chemical environments and the biotic community. The physical environment of the pond, which includes water temperature, wind-induced turbulence, and the duration and intensity of light in the water column, is directly affected by climate. The chemical characteristics of the pond are determined, primarily, by the interaction of three factors including the geologic watershed and its contents, land use in the watershed and related human activities, and the hydrology of the pond. The biotic community of the pond is the result of the physical and chemical environments and reflects the quality of these components through species composition and abundance of organisms.

3.1 Results

This chapter presents a summary and discussion of the Hummock Pond water quality data collected during 2012.

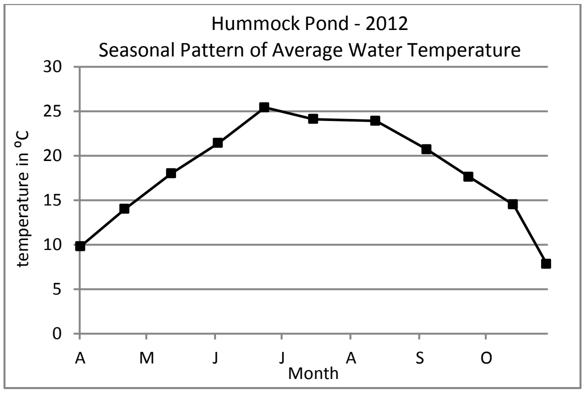
3.1.1 Physical characteristics

General. Hummock Pond is about 2.3 miles long and lies in a southwest to northeast axis from the barrier beach at the Atlantic Ocean. The surface area is about 142 acres at normal water level (Conant, 2008). The widest part of the Pond, 1500–2000 feet depending upon water level, is toward the southwest end. Toward the northeast end, the Pond tapers in width considerably, with some areas only 50–100 feet between shore-lines. Near the northeast tip of Hummock Pond, a narrow channel about 5-10 feet wide provides access to Head of Hummock Pond, a small kettle-type body of water with a surface area of ≈15 acres. Hummock Pond has no outlet but is purposely breached two times each year to promote flow and water exchange with the Atlantic Ocean.

Sampling station. There were 11 trips to sample Hummock Pond during 2012. Even though the total depth at the mid-pond site (Station #2) was consistently shallow (<2.4 m [7.9 ft]) on each sampling visit, it was decided to take separate samples from the upper and lower regions of the water column to test for thorough mixing or whether significant differences could occur between the ***upper*** and ***lower*** regions. There was no bottom sample collected on April 10th, the first sampling date. Bottom grab samples were collected on all other 10 sampling dates. Where appropriate, these results for ***upper*** and ***lower*** regions of the water column are reported in the graphs that follow.

Thermal cycle. The average water column temperature in Hummock Pond during 2012 is shown in Figure 3.1.

Figure 3.1 Average water column temperature in Hummock Pond during 2012.



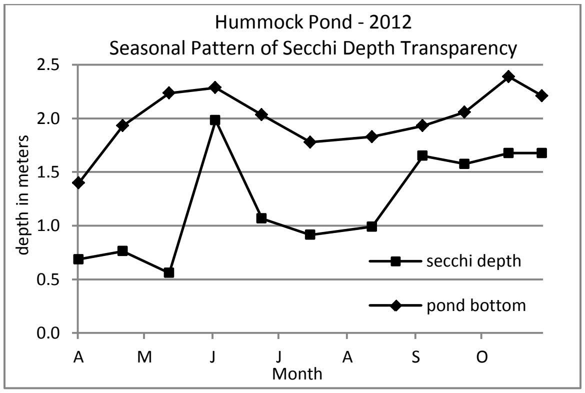
Water depth is too shallow along the main body of HP to develop mid-summer thermal stratification and the water column mixes from surface to bottom throughout the ice-free period. This type of circulation pattern is typical of *polymictic* lakes which are a subset of the broader category, *holomictic* lakes. HP should be considered a *cold polymictic* water body since it usually forms an ice cover each winter.

The water column at Station #2 on Hummock Pond was isothermal on all 11 sampling dates during 2012, with water temperatures varying less than 1°C between the surface and the bottom. With an average depth of 76 inches (± 11) measured at Station #2 during 2012, this part of the pond is sufficiently shallow to promote continual mixing throughout the water column. In addition, the longitudinal axis of the pond is oriented in a southwest-to-northeast direction which is the primary wind orientation during the growing season and promotes mixing.

As shown in Figure 3-1, the average temperature of the water column in Hummock Pond during 2012 forms a bell-shaped curve, with the highest average temperature of 25.4°C realized on 2 July. Graphs of the 2012 temperature profiles collected from Hummock Pond are presented in Appendix 1.

Transparency. Hummock Pond was moderately turbid during portions of the 2012 sampling season as indicated by the Secchi depth transparency which ranged between 0.6 and 2.0 meters (1.8-6.5 feet). The seasonal pattern of transparency is summarized in Figure 3-2.

Figure 3.2 Seasonal pattern of Secchi depth transparency in Hummock Pond during 2012.



The figure above presents Secchi depth at Station #2 in relation to the total depth of the pond at that site during each sampling period. It is clear that transparency exhibited a bi-modal curve with a single peak in June and then a subsequent more extended peak of transparency during September and October.

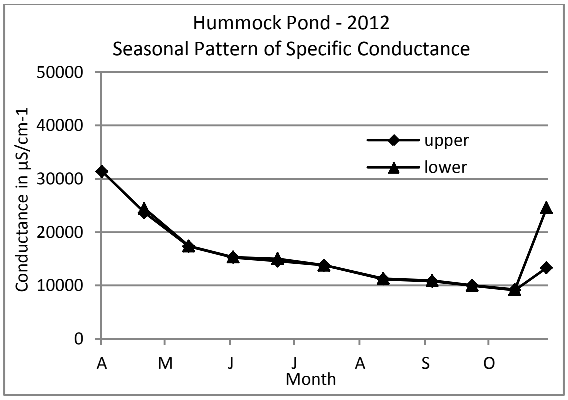
3.1.2 Chemical characteristics

Specific conductance. Specific conductance measures a solution's resistance to flow of an electrical current; the resistance decreases as the ionized salt content of the water increases. Water with a low concentration of major ions such as HCO_3 (bicarbonate), CO_3^{-2} (carbonate), K^+ (potassium), Na^+ (sodium), Ca^{2+} (calcium), Cl^- (chloride), SO_4^{-2} (sulfate) and $Mg^{=2}$ (magnesium) will have the greatest resistance to electron flow. Water with a high concentration of these major ions, such as with sea-water, will have the least resistance to electron flow.

Figure 3.3 summarizes the seasonal pattern of specific conductance values at Station #2 in Hummock Pond during 2012; the values were highest early in the spring and declined steadily throughout the remainder of the season. In addition, the specific conductance values of samples collected from *upper* and *lower* areas of the water column were very similar on all sampling dates (Figure 3.3).

Also, the water column conductance levels at Station #2 were incredibly high during 2012, ranging between ≈9100-31000 µS/cm^{-1}, reflecting estuarine conditions and high salt water intrusion from late winter, prior to the spring opening to the Atlantic Ocean possibly from the influence of a late winter storm.

Figure 3.3 Seasonal pattern of specific conductance in Hummock Pond during 2012.

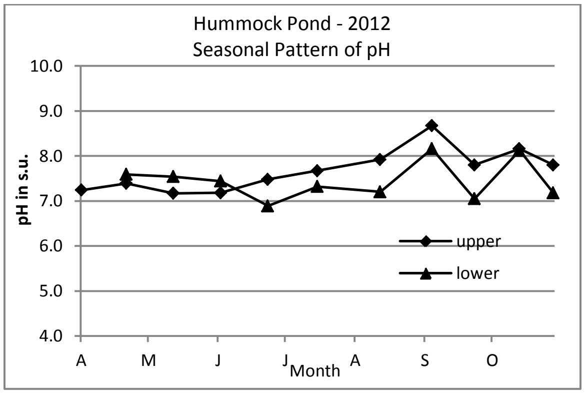


pH. 'pH' is a mathematical transformation of the hydrogen ion [H$^+$] concentration and expresses the acidity or basicity of water. The lowercase 'p' in pH refers to 'power' or exponent, and pH is defined as the negative logarithm of the hydrogen ion concentration. A change of one pH unit represents a ten-fold change in hydrogen ion concentration. Conditions become more acidic as pH decreases; more basic as pH increases.

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

The pH at Station #2 usually was within the pH range of 7-8 standard units except on two separate occasions (September 13th and October 22nd) when the pH was elevated above 8 standard units (Figure 3.4).

Figure 3.4 Seasonal pattern of pH in Hummock Pond during 2012.



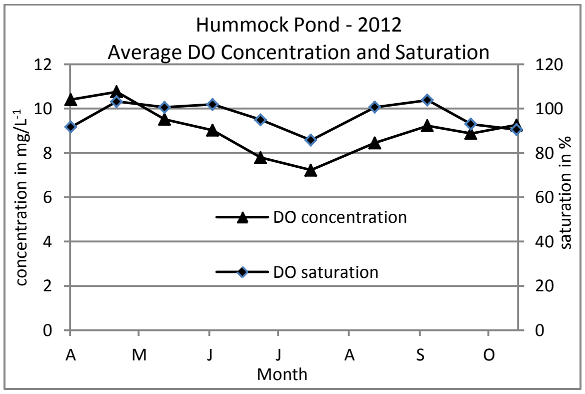
Although there was some difference between the *upper* and *lower* readings on each sampling date (except October 22nd), the differences were small and within the range of 1 pH unit.

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

Oxygen concentration and saturation. Dissolved oxygen in surface water constantly is consumed and the two primary mechanisms that replenish the supply are exchange with the atmosphere at the air-water interface and photosynthetic activity of plant material, both phytoplankton and rooted plants, in the water. Oxygen consumption results from the respiration of aerobic organisms and decomposition in the lower waters by organisms that metabolize organic material settling down from the productive upper levels of the water column.

Station #2 exhibited normal levels of dissolved oxygen concentration and saturation during the 2012 sampling period, ranging from ≈8-10 mg/L and 85–105 percent saturation, respectively, between early April and early November (Figure 3.5). Graphs of the 2012 dissolved oxygen concentration and saturation profiles are presented in Appendix 1.

Figure 3.5 Seasonal pattern of DO concentration and saturation in Hummock Pond during 2012.



Values of chlorophyll *a* were low-to-moderate in the water column during this period, ranging from 2-22 µg/L^{-1} and averaging 10.4 µg/L^{-1}. These values are indicative of moderate levels of phytoplankton productivity and suggest a normal role of these organisms in replenishing the dissolved oxygen content in the water column. The orientation of Hummock Pond along a southwest-northeast axis and prevailing winds from the south and southwest during most of the growing season also suggests that wind-driven turbulence is an important factor in dissolved oxygen replenishment of the water column along this portion of the pond.

3.1.3 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 is comprised of organic forms and inorganic forms including nitrate (NO_3^-), nitrite (NO_2^-), un-ionized ammonia (NH_4), ionized ammonia (NH_3^+) and nitrogen gas (N_2). The relationships of these nitrogen forms are

Total nitrogen (TN) = Organic nitrogen + 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, however, since it is readily converted to **nitrate** if enough oxygen is present in the water for oxidation.

Total nitrogen is an essential nutrient for plants and animals; however, an excess amount of nitrogen in a waterway can lead to low levels of dissolved oxygen and negatively alter various 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.

Bacterial oxidation and reduction of various nitrogen compounds in lake water produces forms of nitrogen that are photosynthetically assimilated by aquatic plants. 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. 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 of 7.00 and below, NH_4^+ predominates and is a good source of nitrogen for plants. At the higher pH values, NH_4OH can occur in concentrations that are toxic to biological growth. The pH values at Station #2 in Hummock Pond during the 2012 growing season averaged 7.61 (± 0.48) units indicating that NH_3-N probably is a good source of nitrogen for algae and higher plants, even though NH_4OH is present

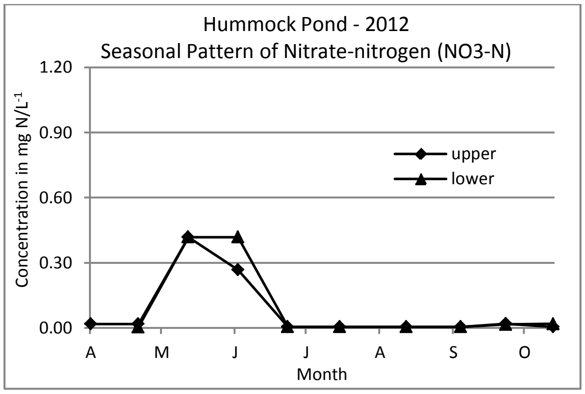
Nitrate-nitrogen, **NO_3-N**, is produced by the bacterial conversion of organic and inorganic nitrogenous compounds from a reduced state to a more oxidized state and is readily assimilated by algae and other green plants. **Nitrate** and **ammonia**, collectively, provide most of the nitrogen available 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 of the lake water.

Some important features of the nitrogen dynamics in Hummock Pond during 2012 are as follows:

- All forms of nitrogen appeared to be well-mixed in the water column during 2012 as shown by the 'upper' and 'lower' time-series plots that are presented below,
- Concentrations of nitrate were low throughout most of the season, exhibiting a single peak in late spring, which is characteristic of north temperate lakes and ponds,
- Concentrations of ammonia also were low during most of the season, exhibiting separate peaks in late spring and again in mid-summer,
- Organic nitrogen concentrations reflected moderate levels of plankton and seston in the water column and exhibited some seasonal dynamics during 2012,
- Total nitrogen concentrations were highest in the spring, then declined and peaked again during mid-summer before stabilizing during September and October,
- The average concentration of total nitrogen during 2012 suggests a moderately productive condition when evaluating the water quality of Hummock Pond and comparing results to other bodies of water.

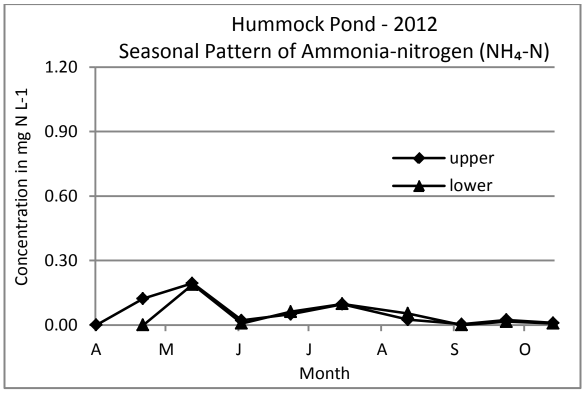
Nitrate-nitrogen concentrations at Station #2 averaged 0.077 mg $N \cdot L^{-1}$ for the upper region of the water column and 0.100 mg $N \cdot L^{-1}$ for the lower region of the water column for the 11 sampling dates in 2012. The highest values recorded during the year in both regions of Station #2 occurred on May 21st and June 11th, which probably represents the period between the spring pulse of (cold-water) diatoms and the green algae that predominate during warmer temperatures. As shown in Figure 3.6, all other nitrate-nitrogen concentrations measured during 2012 were either just above or at the lowest level of detection for the analytical technique used in the laboratory.

Figure 3.6 Seasonal pattern of nitrate-nitrogen in Hummock Pond during 2012.



Ammonia-nitrogen values were below 0.20 mg N·L^{-1} at Station #2 during 2012 and averaged 0.055 mg N·L^{-1} in the upper region of the water column and 0.49 mg N·L^{-1} in the lower region of the water column for the 11 sampling dates during the season. As shown in Figure 3.7, there were elevated concentrations of ammonia-nitrogen detected in Hummock Pond during late April and late May, and then another smaller peak measured during July.

Figure 3.7 Seasonal pattern of ammonia-nitrogen in Hummock Pond during 2012.

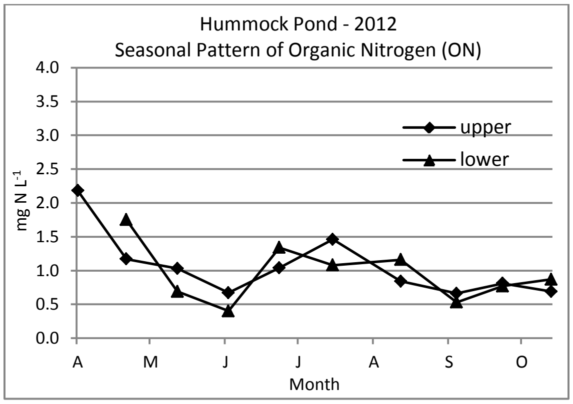


These data are somewhat more difficult to interpret since the distribution of ammonia in lake water can be highly variable regionally, seasonally and spatially within the same system in relation to the level of productivity and the extent of pollution from organic matter entering the system.

However, a condition of low, or non-detectable, concentrations of nitrate and ammonia during the growing season and higher values prior to, and following, the growing season usually is a pattern that characterizes moderately productive waters (Hutchinson, 1967; Wetzel, 1975). The fact that both of these forms of nitrogen were reported at low-to-moderate values in Hummock Pond during 2012 and exhibited a similar seasonal pattern provides evidence of a moderately productive phytoplankton community with typical seasonal dynamics.

Organic nitrogen can be determined by subtracting ammonia + nitrate concentrations from the measured TN concentration. The 2012 results for Hummock Pond are presented in Figure 3.8.

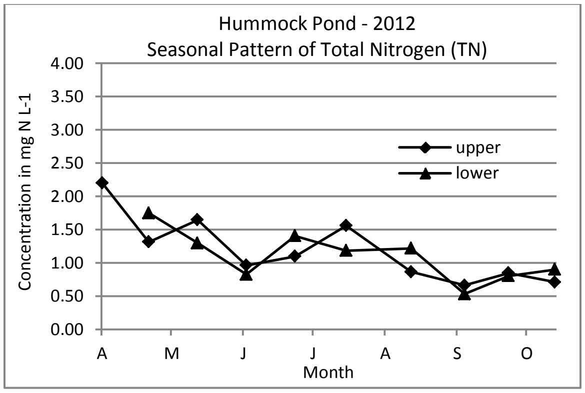
Figure 3.8 Seasonal pattern of organic nitrogen in Hummock Pond during 2012.



The average concentration of organic nitrogen at Station #2 during 2012 ranged from 0.40–2.18 mg N·L^{-1} during the entire sampling season, and comprised about 90 percent of the total nitrogen values measured on a particular date. Average values of organic nitrogen were 1.06 mg N·L^{-1} in the upper region of Station #2 and 0.95 mg N·L^{-1} in the lower region of the sampling site. Although some, probably small, portion of the organic nitrogen is in soluble, or dissolved, form, the organic nitrogen concentrations measured in Hummock Pond are considered moderate values and correspond to moderate concentrations and biomass of phytoplankton in the water column.

The seasonal pattern of total nitrogen (TN) concentration in Hummock Pond during 2012 is shown in Figure 3.9. The highest values occurred early in the season and then declined thereafter, with a mid-summer peak exhibited before values stabilized during the fall. The average values at Station #2 were 1.19 and 1.10 mg N L^{-1} in the upper and lower regions, respectively.

Insert Figure 3.9 Seasonal pattern of total nitrogen in Hummock Pond during 2012.



Phosphorus. This nutrient plays 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 in lake water is bound organically with living material or associated with decaying material (Wetzel, 1975).

The **total phosphorus** (**TP**) content of unfiltered lake water is important in the metabolism of lakes and consists of **particulate phosphorus** (in suspension in particulate matter) and the **dissolved**, or **soluble**, **phosphorus** fraction.

Particulate phosphorus can include three forms: (1) phosphorus in living organisms (e.g. phytoplankton and zooplankton), (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 varies in lakes and ponds, probably as a function of allochthonous material containing phosphorus, which enters the lakes at different seasons of the year.

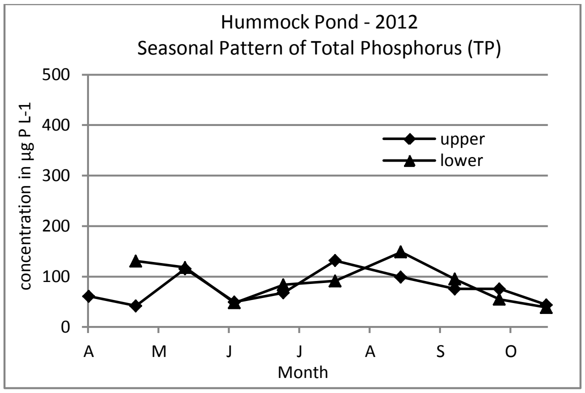
A typical lake would receive significant inputs of phosphorus during periods of high runoff, such as spring snowmelt. In many north temperate lakes and ponds of the northeastern US, the period of spring runoff represents about 60-70 percent of the average annual runoff that enters systems from the surrounding watershed (Sutherland et al., 1983). Hummock Pond has a much different hydrologic cycle, however, and does not receive large inputs of TP via runoff due to the relatively flat topography of the surrounding watershed, the low relative proportion of impervious structures in the watershed, and the sandy, permeable nature of the watershed soils.

The total phosphorus dynamics in Hummock Pond during 2012 included the following:

- The concentrations of total phosphorus upper and lower regions in the water column at Station #2 appeared to be well-mixed as shown by the similarity of the time-series plots provided below.
- The concentration of total phosphorus in Hummock Pond during 2012 demonstrated a seasonal pattern with high values detected during late spring-early summer and again during mid-summer.
- There was no obvious depletion of total phosphorus concentration at Station #2 during the height of the mid-summer productivity indicating that a continual source of this nutrient was available in the water column either in the form of autochthonous or allochthonous material.

As shown in Figure 3.10, the seasonal pattern of total phosphorus concentration was similar in both upper and lower regions of the water column at the sampling station.

Figure 3.10 Seasonal pattern of total phosphorus in Hummock Pond during 2012.



The concentration of total phosphorus (TP) in the water column of Hummock Pond was moderate-to-high during 2012, ranging from 42.0-131.7 µg P L^{-1} and averaging 76.1 µg P L^{-1} for the 2012 sampling season, which included 11 sampling dates.

The most probable source of TP in the water column of Hummock Pond is release from the bottom sediments under both oxic and anoxic conditions. Mixing processes such as this in shallow water environments is widely recognized as an important factor in phosphorus mobilization back into the water column. Other sources of total phosphorus would include (1) resident and transitory waterfowl populations that spend time on the pond, (2) groundwater flow at a rate directly influenced by the cycle of precipitation, and (3) precipitation falling on the pond. The actual concentration of TP in the groundwater probably is a function of land use in the watershed, effectiveness of soils at nutrient removal, and the effectiveness of individual septic systems that contribute groundwater discharge to the Ponds. The flow of ground-water in the watershed varies depending upon the precipitation patterns. The amount of total phosphorus entering the pond from waterfowl is more difficult to calculate but is probably a larger amount, on an annual basis, than most people would suspect.

3.1.4 Phytoplankton

Overview. The planktonic algae reflect water quality and other conditions in lakes and ponds through parameters such as diversity, composition, dominance and biomass (biomass). As discussed at length by Hutchinson (1957), certain algal associations occur repeatedly among lakes with different levels of nutrient enrichment and these associations are used to characterize the trophic status of water bodies. In spite of certain limitations, these characterizations are useful because they demonstrate the connection, or interface, between available nutrient supply and the qualitative and quantitative abundance of algal species.

An accurate evaluation of the phytoplankton community in HP and HHP was not possible due to the short-term nature of the study. The parameters that were measured and the species associations that were observed during this period are not necessarily the same ones that would characterize the community over a longer period of time (i.e., several years). As a result, there are certain limitations attached to predicting the trophic status of the Pond based upon the phytoplankton community.

In spite of the limitations mentioned above, the phytoplankton community observed in HP and in HHP did exhibit important features that characterize the general water quality of the Ponds during the period of study. These features were as follows

- *Cell density* - Cell densities in the phytoplankton community were low-to-moderate during the season and peaked during mid-to-late August
- Community dominance in Hummock Pond usually was concentrated among 3-4 species on any particular sampling date although more species were dominant during periods of transition,
- *Biomass* – Cell biomass (biovolume) was low during the entire 2012 season and peaked with cell density,
- There was a seasonal succession within the phytoplankton community that included Bacillariophytes, Chlorophytes, Cyanophytes, Pyrrhophytes, and Chrysophytes,
- Diversity levels were high during most of the season, reflected a community that was spread among several individuals and not concentrated in one or two species.
- Hummock Pond exhibited moderate levels of chlorophyll ***a*** and there was a distinct seasonal pattern exhibited during 2012,
- Several species of toxin-producing Cyanophytes were identified in Hummock Pond during 2012 and microcystin was detected in the water column at different times during the season, representing 'low' to 'minimal' risk.

The phytoplankton characteristics, individually and collectively, reflect a level of water quality in Hummock Pond that can be classified as moderately productive and indicative of poor water quality.

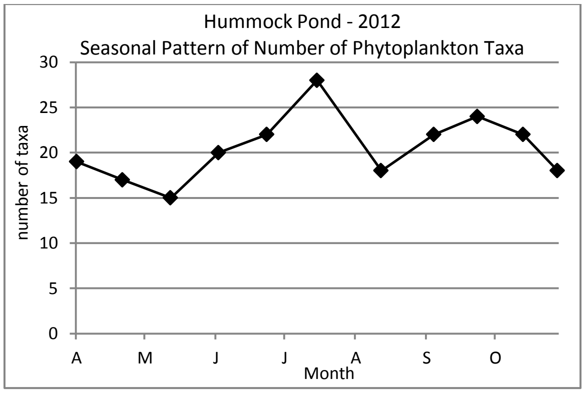
Description of the assemblage. There were 53 taxa identified in phytoplankton samples collected from Hummock Pond during 2012. As shown in Table 3.1, most of the major algal groups were represented. The Bacillariophytes (diatoms) had the largest representation in the community with 23 taxa identified; the Chlorophytes (greens) had the next largest representation with 16 taxa identified. There were five (5) different genera including *Chrococcus*, *Oocystis*, *Scenedesmus*, *Synedra* and *Dinobyron*, that had more than one species identified in the 2012 community.

Table 3.1 Major groups of phytoplankton and taxa identified in Hummock Pond during 2012.

Cyanophytes	**Chlorophytes**	**Chrysophytes (Bacillariophytes)**
Anabaena flos aquae	*Sphaerocystis schroeteri*	*Rhoicosphenia curvata*
Chroococcus dispersus	*Tetraedron minimum*	*Stauroneis* sp.
C. limneticus	**Chrysophytes (Bacillariophytes)**	*Surirella* sp.
Merismopedia glauca	*Achnanthes* sp.	*Synedra acus*
Microcystis incerta	*Achnanthidium* sp.	*S. fulgens*
Chlorophytes	*Amphora* sp.	*S. ulna*
Ankistrodesmus falcatus	*Attheya* sp.	**Chrysophytes (Chrysophytes)**
Closteriopsis longissima	*Aulacoseria granulata*	*Dinobyron barvicum*
Cosmarium sp.	*Cocconeis* sp.	*D. divergens*
Langerheimia quadriseta	*Cyclotella* sp.	*Ochromonas sp.*
Mougoetia sp.	*Cymbella* sp.	**Euglenophytes**
Oocystis borgei	*Eunotia* sp.	*Peranema* sp.
O. pusilla	*Fragilaria islandica*	*Trachelomonas spp.*
O. solitaria	*Gomphonema* spp.	**Pyrrhophytes (Cryptophytes)**
Pyramimonas tetrarhyncus	*Gyrosigma* sp.	*Chroomonas sp.*
Scenedesmus bijuga	*Navicula* spp.	*Cryptomonas ovata*
S. bijuga var. alternans	*Nitzschia* sp.	*Gymnodinium* sp.
S. quadricauda	*Pinnularia* sp.	*Peridinium cinctum*
Schroederi judayi	*Planothidium* sp.	
Selenastrum minutum	*Rhizosolenia* sp.	

The total number of taxa in the phytoplankton community ranged between 15 and 28 during the 2012 season. As shown in Figure 3.11, the greatest number of taxa (28) occurred on July 24th while the least number of taxa (15) occurred during late spring (May 21st).

Figure 3.11 Seasonal pattern of number of phytoplankton taxa in Hummock Pond during 2012.



The seasonal pattern of the number of taxa in the community was a bi-modal curve, with a second peak (24) on October 2nd. Species richness (# of taxa) generally was one-third to one-half of the total pool of phytoplankton identified from the 2012 samples. The average species richness for the entire 2012 season was 20.5 (±3.6).

Table 3.2 lists the phytoplankton taxa that occurred most frequently during 2012 and some characteristics for each taxon including cell biomass, seasonality, and number of times the taxon was dominant in the community. Biomass is used to evaluate taxon biomass, or productivity, since density does not account for the significant size difference among phytoplankton taxa. A taxon was considered to be dominant if it contributed >5 percent of the total community biomass.

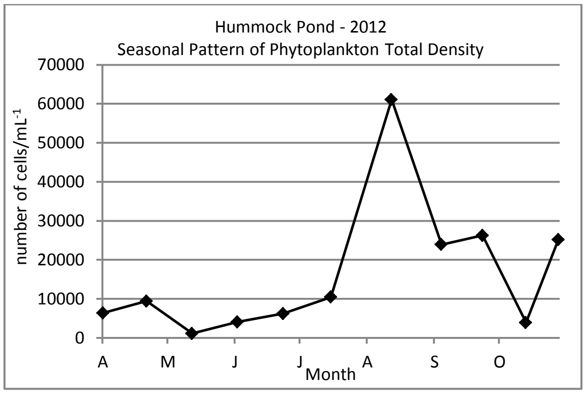
As shown in Table 3.2, 15 different genera appeared in at least six (6), or more, of the 11 samples collected during 2012. Most of these genera were from the Bacillariophytes (6) and Chlorophytes (4). It is readily apparent that presence/absence (frequency of occurrence) in the community has nothing to do with dominance in the community. *Cocconeis* sp., a diatom, was a density dominant three times and a biomass dominant seven times and was present in the community throughout the sampling season. Two other taxa, *Navicula* spp. and *Selenastrum minutum*, also occurred in all of the 2012 samples (Table 3.2).

Table 3.2 Characteristics of the most common phytoplankton taxa in Hummock Pond during 2012.

Major Group	Cell Biomass	Number of times the taxa			2012
Taxon-species	(µm^3)	Occurred	DN dominant	BM Dominant	Seasonality
Cyanophytes					
Chroococcus dispersus	33.5	2	2	2	early fall → fall
Microcystis incerta	3.0	3	3	1	early fall → fall
Chlorophytes					
Oocystis borgei	518.0	7	1	3	summer → fall
O. pusilla	135.0	7	2	2	late spring → fall
O. solitaria	518.0	6	0	1	summer → fall
Pyramimonas tetrarhyncus	100.0	8	5	4	all year
Scenedesmus bijuga	100.0	10	1	0	all year
S. quadricauda	100.0	9	2	0	all year
Selenastrum minutum	30.9	11	3	1	all year
Bacillariophytes					
Achnanthes sp.	80.0	8	0	0	all year
Cocconeis sp.	500.0	11	3	7	all year
Cyclotella sp.	268.0	10	1	2	all year
Cymbella spp.	120.0	7	0	0	all year
Navicula spp.	350.0	11	1	2	all year
Planothidium sp.	80.0	10	3	0	all year
Chrysophytes					
Ochromonas sp.	450.0	6	0	1	early spring| mid-summer |fall
Euglenophytes					
Peranema sp.	100.0	6	0	0	early spring|mid-summer→fall
DN = density;BM = biomass; * = biomass unknown					

Density. The 2012 seasonal pattern of phytoplankton density in Hummock Pond is presented in Figure 3.12. Phytoplankton density in the water column ranged from 1,085-61,092 cells·mL^{-1} and averaged 16,163 cells·mL^{-1} for the entire 2012 season.

Figure 3.12 Seasonal pattern of phytoplankton density in Hummock Pond during 2012.



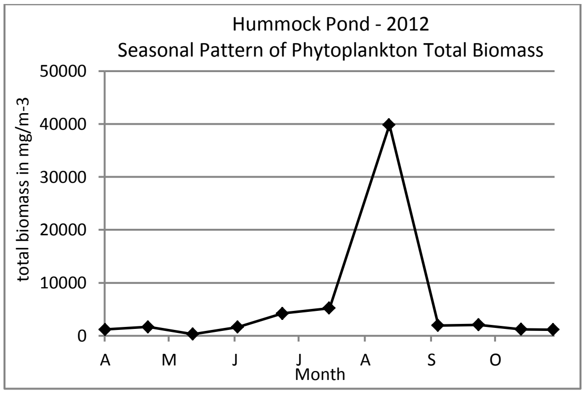
As shown in Figure 3.12, the peak in cell density occurred on August 21st; thereafter, the community density declined in a step-wise manner until October 22nd before increasing once again on the last sampling date (November 6th). The phytoplankton community density was below 10,000 cells·mL^{-1} on seven (7) of the 11 sampling dates that occurred during 2012.

Biomass. Cell biovolume (biomass) also was used as an indicator to evaluate phytoplankton productivity in Hummock Pond during 2012 since cell counts and conversion into density (# of cells/unit volume) does not necessarily account for the significant size difference among various phytoplankton taxa.

The problem of using phytoplankton cell density as a community descriptor is apparent when viewing the individual cell biomass listed in Table 3.2 and noting that the size difference between different forms such as *Microcystis incerta* cells (3.0 µm^3) and *Cocconeis* sp. cells (500 µm^3) is two orders of magnitude. Huge differences in cell biomass explain how small numbers of cells can position a taxon as a dominant member in the assemblage of the phytoplankton community.

The seasonal pattern of phytoplankton community biomass in Hummock Pond is summarized in Figure 3.13. Biomass ranged from 305-39,840 mg·m^{-3} during 2012 and averaged 5,495 mg·m^{-3} during the entire season.

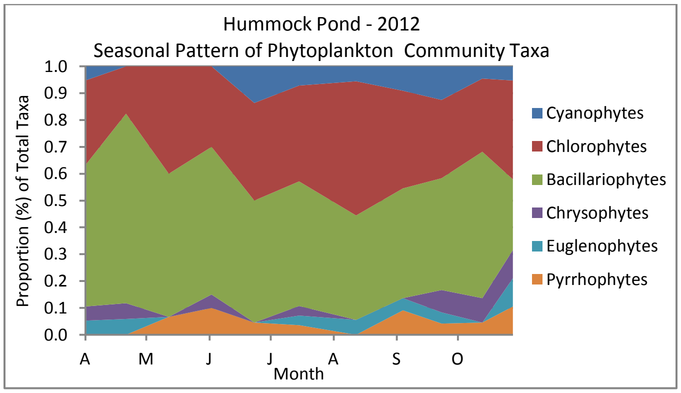
Figure 3.13 Seasonal pattern of phytoplankton biomass in Hummock Pond during 2012.



The peak in community biomass occurred on August 21st, the same date for the peak in community density. Total biomass of the phytoplankton community was 5,000 mg·m^{-3} or less on 10 of the 11 sampling dates during 2012.

Seasonality and associations. Figure 3.14 illustrates the proportion of major groups in the phytoplankton community as the 2012 season progressed from spring through fall.

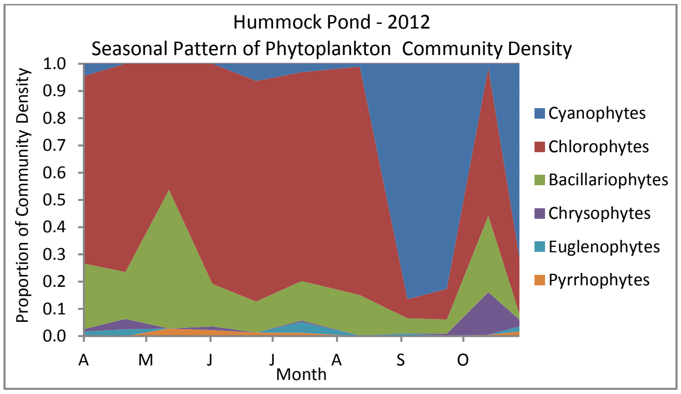
Figure 3.14 Seasonal distribution of major phytoplankton groups in Hummock Pond during 2012.



All of the major groups were represented throughout most of the season with the chlorophytes and diatoms comprising most of the taxa in the community throughout the year. The seasonal importance of different groups in the community is not highlighted in this illustration.

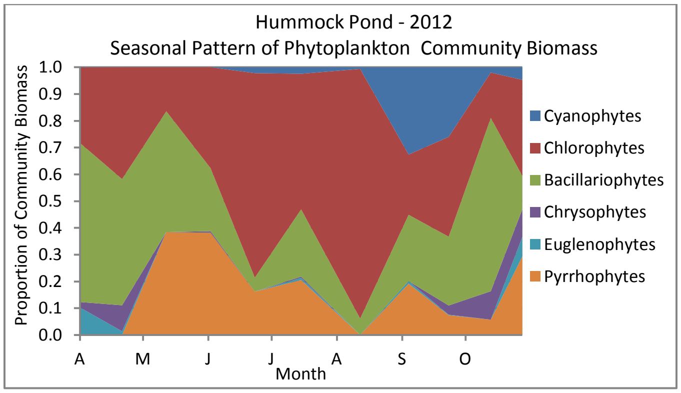
Graphs presented below for density (Figure 3.15) and biomass (Figure 3.16) provide better illustrations of the seasonal succession of the 2012 phytoplankton community dynamics in Hummock Pond.

Figure 3.15 Seasonal pattern of phytoplankton community density in Hummock Pond during 2012.



While both community variables portray an accurate pattern of seasonal succession, the biomass summary probably is the more realistic representation of instantaneous community conditions since the size of individual cells is considered instead of cell density, which is the actual number of cells present and we know that cell size can varies by several orders of magnitude.

Figure 3.16 Seasonal pattern of phytoplankton community biomass in Hummock Pond during 2012.



Algal associations documented during the study provide information about the general trophy of the pond. Diatoms characteristically are dominant in alkaline waters with nutrient enrichment (Hutchinson, 1967; Wetzel, 1975). Diatoms were present in the Hummock Pond phytoplankton community during the entire 2012 season and were dominant community forms during spring, late spring and fall. The appearance and importance of the Chlorophytes and Cyanophytes later in the season, during mid-summer and early fall, respectively, is a sequence of associations that provides additional evidence that the algal community reflects conditions of moderate productivity and poor water quality.

Diversity. Phytoplankton taxon diversity was measured with the Shannon-Wiener function[1] which calculates diversity, **[H]**, using number of taxa and the allotment of individuals among the taxa. An increase in either factor will increase the diversity value. Biomass was used in the calculation instead of numbers of individuals (density) since size can vary so significantly among individual taxa and biomass provides a better estimate of taxon rank or importance in the community.

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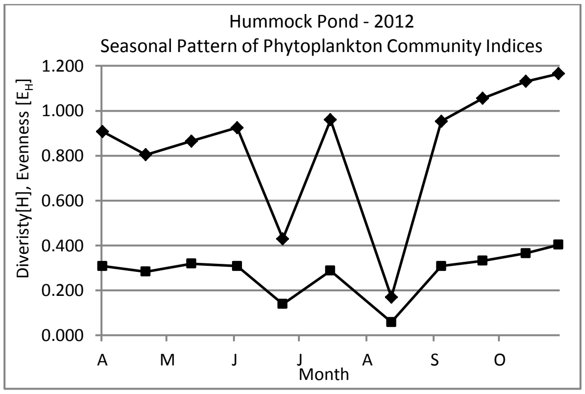
[1] $H = -\sum_{i=1}^{s} (p_i)(log_2)(p_i)$, in units of information per individual per unit volume or area, where p_i is the proportion of the total samples belonging to the ***i***th species and S in the number of species.

After diversity **[H]** was calculated for each sampling date, a value was calculated for **[H_{max}]**, which is the diversity value under conditions of maximum equitability or allocation on a sampling date. The next step in the process was the calculation of equitability, **[E_H]**, the ratio of **[H]/[H_{max}]**, for each sampling date, which locates the community somewhere along a scale from 0 (least equitable) to 1 (most equitable).

Community diversity **[H]** and equitability, or evenness, **[E_H]** in the Hummock Pond phytoplankton community during 2012 are presented in Figure 3.17.

Figure 3.17 Seasonal pattern of phytoplankton community indices in Hummock Pond during 2012.



Diversity was high in Hummock Pond during 2012 and averaged 0.851. Except on July 2nd and August 21st when the diversity dropped to 0.430 and 0.170, respectively, the 2012 values ranged between 0.800 and 1.200 for the remainder of the season. The extremely low values recorded on July 2nd and August 21st were periods when the Chlorophytes comprised 76 percent and 93 percent of the total community biomass, respectively. Fall was the most stable period for the phytoplankton community diversity with values ranging from 0.950-1.200

Evenness values ranged between 0.059 and 0.403 (Figure 3.17) during 2012. While the seasonal pattern of evenness **[$E_{H]}$]** mirrored the seasonal pattern of diversity, the low absolute values for evenness during the entire 2012 season reflect the dominance of diatoms, greens and dinoflagellates (Pyrrhophytes) in the community.

Dominance. There were two sampling dates during 2012, July 2nd and August 21st, when 90 percent and 98 percent, respectively, of the phytoplankton community biomass was allocated between two species. On all of the other sampling dates, the total community biomass was allocated among 4-8 species (taxa) in the community. Table 3.3 presents a summary of the phytoplankton taxa dominance, using biomass, in Hummock Pond on each 2012 sampling date. The most frequent dominant taxa were *Cocconeis* sp. (7 dates), *Peridinium cinctum* (5 dates, and *Pyramimonas tetrarhyncus* (4 dates).

The succession of the spring to early summer phytoplankton community is marked by changes in the types and numbers of dominant taxa among sampling dates with cold-water forms (Bacillariophytes, Pyrrhophytes) making up the major proportion of the spring biomass, followed by Pyrrhophytes and Chlorophytes in the late spring and summer, followed by a transition to Cyanophytes and all other major groups during the fall period.

Cyanophytes. As a major group of phytoplankton, Cyanophytes were (1) identified in eight (8) of the 11 phytoplankton samples collected during 2012, (2) density dominants on five (5) dates (April 10th, September 13th, October 2nd, November 6th), and (3) biovolume dominants on September 13th, October 2nd, and November 6th.

Table 3.3 Rank of phytoplankton taxa dominance, using biomass, in Hummock Pond on each 2012 sampling date.

Sampling Date	Biomass Rank	Taxon (Major Group)	% of Total Biomass
April 10th	1	*Surirella* sp. (Bacillariophyte)	24
	2	*Cocconeis* sp. (Bacillariophyte)	21
	3	*Pyramimonas tetrarhyncus* (Chlorophyte)	21
	4	*Trachelomonas* spp.(Euglenophyte)	10
	5	*Navicula* spp. (Chlorophyte)	8
April 30th	1	*Pyramimonas tetrarhyncus* (Chlorophyte)	41
	2	*Stauroneis* sp. (Chloropphyte)	21
	3	*Cocconeis* sp.(Bacillariophyte)	10
	4	*Ochromonas* sp.(Chrysophyte)	10
	5	*Achnanthidium* sp. (Bacillariophyte)	5
May 21st	1	*Cryptomonas ovata* (Pyrrhophyte)	39
	2	*Cocconeis* sp.(Bacillariophyte)	13
	3	*Pyramimonas tetrarhyncus* (Chlorophyte)	9
	4	*Gomphonema* spp. (Bacillariophyte)	8
	5	*Navicula* spp. (Chlorophyte)	8
	6	*Scenedesmus bijuga* var. *alternans* (Chlorophyte)	6
June 11th	1	*Peridinium cinctum* (Pyrrhophyte)	28
	2	*Oocystis borgei* (Chlorophyte)	20
	3	*Scenedesmus bijuga* var. *alternans* (Chlorophyte)	13
	4	*Gymnodinium* sp. (Pyrrhophyte)	10
	5	*Gyrosigma* sp. (Bacillariophyte)	8
	6	*Stauroneis* sp. (Chloropphyte)	7
July 2nd	1	*Sphaerocystis schroeteri* (Chlorophyte)	74
	2	*Peridinium cinctum* (Pyrrhophyte)	16
July 24th	1	*Sphaerocystis schroeteri* (Chlorophyte)	36
	2	*Peridinium cinctum* (Pyrrhophyte)	21
	3	*Gyrosigma* sp. (Bacillariophyte)	8
	4	*Surirella* sp. (Bacillariophyte)	5
August 21st	1	*Sphaerocystis schroeteri* (Chlorophyte)	92
	2	*Cyclotella* sp. (Bacillariophyte)	6
September 13th	1	*Chroococcus dispersus* (Cyanophyte)	32
	2	*Peridinium cinctum* (Pyrrhophyte)	16
	3	*Cocconeis* sp. (Bacillariophyte)	12
	4	*Oocystis borgei* (Chlorophyte)	11
October 2nd	1	*Chroococcus dispersus* (Cyanophyte)	21
	2	*Oocystis borgei* (Chlorophyte)	15
	3	*Cocconeis* sp. (Bacillariophyte)	12
	4	*Oocystis pusilla* (Chlorophyte)	9
	5	*Oocystis solitaria* (Chlorophyte)	9
	6	*Peridinium cinctum* (Pyrrhophyte)	7
	7	*Gomphonema* spp. (Bacillariophyte)	6
October 22nd	1	*Surirella* sp. (Bacillariophyte)	23
	2	*Cocconeis* sp. (Bacillariophyte)	10
	3	*Gomphonema* spp. (Bacillariophyte)	9
	4	*Dinobyron divergens* (Chrysophyte)	7
	5	*Cryptomonas ovata* (Pyrrhophyte)	6
November 6th	1	*Cryptomonas ovata* (Pyrrhophyte)	18
	2	*Chroomonas* sp. (Pyrrhophyte)	11
	3	*Dinobyron divergens* (Chrysophyte)	9
	4	*Selenastrum minutum* (Chlorophyte)	8
	5	*Oocystid pusilla* (Chlorophyte)	7
	6	*Pyramimonas tetrarhyncus* (Chlorophyte)	7
	7	*Cocconeis* sp. (Bacillariophyte)	6
	8	*Microcystis incerta* (Cyanophyte)	5

There were five (5) genera of Cyanophytes identified in the 2012 phytoplankton samples from Hummock Pond including *Anabaena flos-aquae*, *Chroococcus dispersus*, *C. limneticus, Merismopedia glauca*, and *Microcystis incerta*. Both *Anabaena flos-aquae* and *Microcystis incerta* are known to produce toxins that can pose a public health issue when present in recreational waters (DiTomaso, 1994).

A Cyanophyte bloom was detected in Hummock Pond on September 13th and October 2nd. Since there was a 3-week sampling frequency in 2012, the bloom could have extended from late August through late October, a total duration of 6-8 weeks. There is no way of knowing the actual duration of the bloom without more frequent sampling. On the September 13th and October 2nd sampling dates, Cyanophytes comprised 87 and 83 percent of the community density, respectively, and 33 and 26 percent of the community biomass, respectively.

Algal toxins. The data presented in Table 3.4 were provided by the State University of New York, College of Environmental Science and Forestry in Syracuse, New York, where five (5) filtered water samples from Hummock Pond were received and analyzed for algal toxins.

None of the three (3) samples in which microcystins were detected by PPIA were above the World Health Organization threshold for drinking water if 1 µg microcystins per L. In addition, none of the samples submitted for analysis during 2012 tested positive for Anatoxin-a, homo-anatoxin-a or cylindrospermopsin.

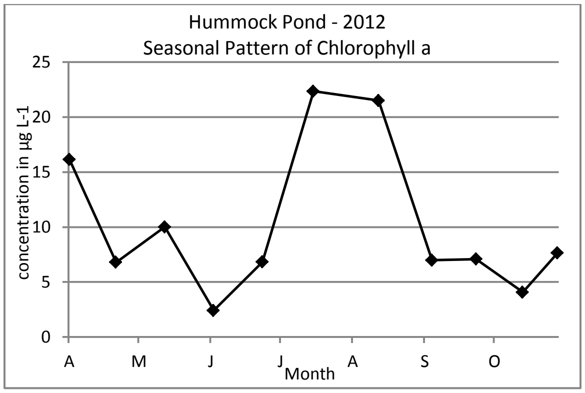
Table 3.4 Summary of algal toxins detected in water samples from Hummock Pond during 2012.

Sample			Microcystin-LR	Anatoxin	Cylindrospermopsins	Status
Date	# submitted	Volume filtered	(µg/L)	(µg/L)	(µg/L)	
7/2/12	1	500	nd (<0.12)	nd (<0.13)	nd (<0.3)	minimal risk
7/24/12	1	500	nd (<0.12)	nd (<0.11)	nd (<0.3)	minimal risk
8/21/12	1	500	0.14	nd (<0.22)	nd (<0.6)	minimal risk
9/13/12	1	500	0.26	nd (<0.11)	nd (<0.1)	minimal risk
10/22/12	1	900	0.09	nd (<0.11)	nd (<0.1)	minimal risk
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)						

The highest level of microcystin, 0.26µg/L^{-1}, was measured on September 13th which was the first date that the Cyanophyte bloom was detected in Hummock Pond. There was no follow-up sample collected on October 2nd, the second date that Cyanophytes were in bloom during 2012.

Chlorophyll *a*. The primary photosynthetic pigment of all oxygen-evolving photosynthetic organisms, and present in all algae. Chlorophyll *a* samples collected at Station #2 on 11 sampling dates during 2012 averaged 10.2 µg·L^{-1} and ranged from 2.4 µg L^{-1} to 22.4 µg L^{-1}. The 2012 seasonal pattern of chlorophyll *a* is presented in Figure 3.15.

Figure 3.18 Seasonal pattern of chlorophyll *a* in Hummock Pond during 2012.



Peak concentrations of chlorophyll a in the water column occurred during mid-to-late July and mid-to-late August which normally is considered the height of the growing season and corresponded to the period of high average temperature (24°C) in the water column. The second peak in chlorophyll a concentration corresponded to the peak in cell density and biomass that occurred on August 21st.

Community standing crop, estimated from chlorophyll a concentration is one of the primary factors used to predict lake trophic status. In the case of Hummock Pond during 2012, regardless of whether one uses the mid-summer average concentration (11.0 µg L^{-1}) or the average for the entire season (10.4 µg L^{-1}), both values are within range of 10-15 µg chlorophyll $a \cdot L^{-1}$ which is the border between mesotrophic and eutrophic conditions in lakes and ponds (Vollenweider and Kerekes 1980).

3.1.5 Trophic Status

The trophic state of lakes and ponds has been a phenomenon of interest for many decades. The word 'trophic' means nutrition or growth. A **eutrophic** water body is well-nourished and has high nutrients and considerable plant growth. Water bodies with low nutrients and plant growth are **oligotrophic**. **Mesotrophic** lakes and ponds fall somewhere between the eutrophic and oligotrophic categories. Lakes and ponds with extreme conditions may be considered **hyper-oligotrophic** or **hyper-eutrophic**.

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, three independent variables can be used to calculate the Carlson index including chlorophyll pigments, total phosphorus and Secchi depth. Individual TSI values can be 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 will yield the most accurate index since it is the most accurate predictor of biomass in the ecosystem. Phosphorus may be a more accurate predictor of the summer trophic status of a water body than chlorophyll if the measurements also are made during the winter months, which they were not. Secchi depth probably is the least accurate measure but also is the most affordable and easiest measure to obtain since it is a subjective visual determination.

Following are the relationships between Trophic Index (TI), chlorophyll (in µg/L), phosphorus (in µg/L), Secchi depth (in meters), and Trophic Class (after Carlson, 1996):

Table 3.5 Summary of associations among water quality parameters and trophic class:trophic index ranking system.

Trophic Index	Chlorophyll	Phosphorus	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

There was sufficient water quality information collected from Hummock Pond during 2012 to justify using all three variables to calculate the Carlson TSI. However, instead of using all of the data collected during the 8-month period of study, it was decided to utilize only the mid-summer values when the water column temperature in Hummock Pond was at 18°C or greater. This restriction of water temperature lowered the number of sampling dates to seven including May 21st, June 11th, July 2nd, July 24th, August 21st, September 13th and October 2nd.

Average values were calculated for each variable for Hummock Pond for the seven mid-summer sampling dates. The average values then were substituted into the equations above to calculate the TSI values for the three variables. The stepwise calculation and results of the analysis are as follows:

Chlorophyll *a*
Average mid-summer chlorophyll *a* = 11.0 µg L^{-1}
Chlorophyll a TSI = 9.81*[ln (11.0)] + 30.6
TSI = (9.81)(2.4) + 30.6
TSI = 54.1

Total phosphorus
Average summer total phosphorus = 87.8 µg L^{-1}
Total phosphorus TSI = 14.42*[ln (87.8)] + 4.15
TSI = (14.42)(4.5) + 4.15
TSI = 69.0

Secchi depth
Average summer Secchi depth =1.2 m
Secchi TSI = 60 – [14.41*[ln (1.2)]
TSI = 60 – (14.41)(0.2)
TSI = 56.8

TSI analysis of all three variables results in about the same relative TSI reading for Hummock Pond, clearly placing the Pond well within the eutrophic range regardless of which variable is used. In fact, based upon the TSI for phosphorus, the Pond is not that far away from being considered hyper-eutrophic.

Some states, e.g., Florida, classify lakes and ponds based upon the average concentrations of TN measured in a system. When considering the average TN concentrations measured at Station #2 during 2012, Hummock Pond would fall in the 'eutrophic' category used to classify Florida LAKEWATCH (2000) systems; systems with TN values between 0.60 and 1.50 mg N/L are classified as 'eutrophic'.

3.2 Literature Cited

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Hummock Pond

2012 Water Quality Program

Chapter 4

A Comparison of 2009 and 2012 Water Quality

4.0 Introduction.

This chapter compares the water quality in Hummock Pond during 2009 (Sutherland and Oktay, 2010) and 2012. Having several years of water quality data available for a lake or pond provides the opportunity to compare datasets and determine whether certain characteristics are consistent from one survey to the next and whether trends are developing. Although two years of data collected during a 4-year period are not sufficient to determine long-term water quality trends, there is inherent value in examining the data sets to see where similarities and differences may occur.

4.1 Analysis of Data and Presentation of Results

A straightforward method for evaluating different sets of water quality data is to compare mean, or average, annual values for certain parameters collected each year. For the Hummock Pond water quality data collected by this investigator, there was a 4-month (late June to late October) dataset available for 2009 and an 8-month (April-November) dataset collected during 2012.

There were 8 sampling visits to Hummock Pond in 2009 and 11 sampling visits in 2012. The 2012 dataset is more robust than the 2009 dataset, which can bias the results of the data analysis. In order to compensate for the different durations of the 2009 and 2012 studies, the 2012 dataset has been summarized in two different formats: (1) to represent the entire sampling period (April-November) and (2) to represent the same 4-month period (late June-late October) that was monitored in 2009.

4.2 Comparison of 2009 and 2012 Data

The following sections provide the results and discussion of the 2009 and 2012 summarized data for Hummock Pond. The chapter format that follows is similar to Chapter 3 which described the physical, chemical and biological characteristics of Hummock Pond as interpreted from the 2012 water quality data.

4.2.1 Physical characteristics

In the following material, data from similar 4-month periods (late June to late October) are reviewed when comparing the 2009 data with the 2012 data. However, not all sections of the material that were discussed in the previous chapter are presented here. Only those sections of the water quality data that provide meaningful interpretation are presented.

Water depth. Water depth has been included in the present discussion to highlight (emphasize) a basic inadequacy in the suite of water quality data collected from Hummock Pond, namely, the lack of reliable water level information. Although water depths were recorded on each sampling visit to Hummock Pond during 2009 and 2012, there depths are not useful unless there is some point of reference for determining the exact pond level in relation to an ASML (above mean seas level) datum. No such reference point currently exists.

In order to understand the hydrologic cycle of Hummock Pond, the installation of a continuous water level recording system on the pond should be considered a priority task among the items that are considered for future water quality management. The collection of a continuous record of water level data provides the basis for interpreting the important components of the Hummock Pond hydrologic cycle which is influenced primarily by (1) water input via precipitation as either rain or snow, (2) ground-water flow from the surrounding watershed, and (3) loss of water through evaporation from the pond surface and transpiration by aquatic plants.

Water level data are particularly important during the spring and fall when Hummock Pond is opened to the Atlantic Ocean and the pond hydrologic conditions are altered significantly for a brief period of time which is variable in duration during each opening event.

The results comparing the physical and chemical data collected from Hummock Pond during 2009 and 2012 are presented in Table 4.1.

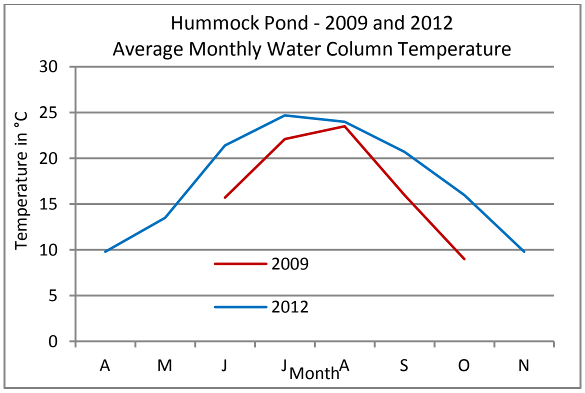
Table 4.1. Summary of physical and chemical parameters in Hummock Pond during 2009 and 2012. The 2012 data are summarized for the entire season and for a 4-month period similar to the duration of the 2009 sampling program.

	AVERAGE FOR THE ENTIRE SAMPLING PERIOD								
	Secchi (m)	TP (µg L^{-1})	NO_3 (mg L^{-1})	NH_4 (mg L^{-1})	NO_3+NH_4 (mg L^{-1})	TN (mg L^{-1})	Org N (mg L^{-1})	spC (µS cm^{-1})	pH (su)
2009	1.04	86.7	0.289	0.025	0.317	0.94	0.66	5122	7.55
2012	1.23	72.4	.070	.050	.120	1.18	1.06	15476	7.68
	AVERAGE FOR SIMILAR 4- MONTH SAMPLING PERIODS								
	Secchi (m)	TP (µg L^{-1})	NO_3 (mg L^{-1})	NH_4 (mg L^{-1})	NO_3+NH_4 (mg L^{-1})	TN (mg L^{-1})	Org N (mg L^{-1})	spC (µS cm^{-1})	pH (su)
2009	1.04	86.7	0.289	0.025	0.317	0.94	0.66	5122	7.55
2012	1.41	77.5	0.044	0.033	0.077	0.96	0.88	12096	7.84

Most of the data discussed in the following sections are accompanied by figures to aid in the description of the material. There also is a summary of the biological data (phytoplankton) presented later in this chapter.

Thermal cycle. Figure 4.1 is a summary of the average monthly water column temperature recorded in Hummock Pond during 2009 and 2012. All of the data collected during these two monitoring periods is presented.

Figure 4.1 Summary of average monthly temperature in Hummock Pond during 2009 and 2012.

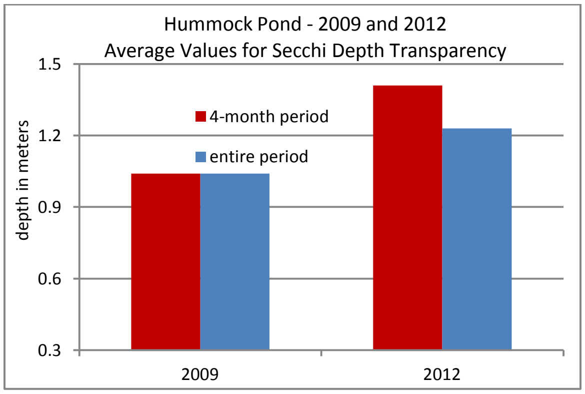


From the temperature data presented, the water column of Hummock Pond warmed up earlier in the season (June and July) during 2012 than in 2009, reaching an average temperature in excess of 20°C during June, while average temperature during June 2009 was around 15°C.

In addition, the average temperature in this section of the pond was warmer during June, July, August, September and October of 2012 than during the same period in 2009. This sizeable difference in average water column temperature should extend the duration of the growing season during 2012, which would directly affect the water quality of the pond through an implied increased robustness of the phytoplankton community.

Transparency. A comparison of the Hummock Pond Secchi depth transparency data collected from Station #2 in 2009 and 2012 is presented in Figure 4.2.

Figure 4.2 Summary of average Secchi depth transparency values in Hummock Pond during 2009 and 2012.

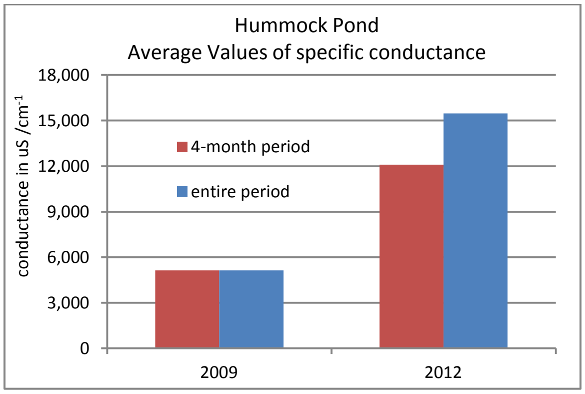


The Secchi depth transparency was greater during 2012 than during 2009, averaging 1.4 m during the comparable 4-month period and 1.2 m during the entire monitoring period. These values were higher than the value of 1.0 m during 2009 (Figure 4.2) suggesting a lower relative level of productivity in the pond in the form of algal cells that would interfere with the depth of visibility.

4.2.2 Chemical characteristics

Specific conductance and pH. The conductance levels measured in Hummock Pond during 2009 were the lowest recorded for the two sets of monitoring data, regardless of whether average values for the entire season or the similar 4-month datasets were compared (Table 4.1 and Figure 4.3).

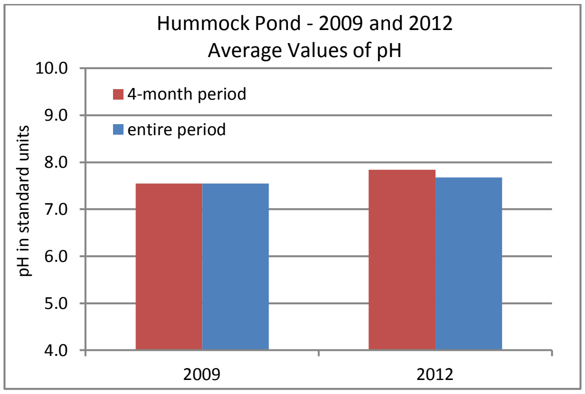
Figure 4.3 Summary of average specific conductance measured in Hummock Pond during 2009 and 2012.



In fact, the 2012 average values for the comparable 4-month and entire period represented a 3-fold increase over the 2009 values, averaging 12,096 and 15,476 $\mu S \cdot cm^{-1}$, respectively. Since the annual spring and fall openings of Hummock Pond to the Atlantic Ocean are the only significant direct inputs of salt-water to Hummock Pond each year, the exceptional differences between the 2009 and 2012 conductance concentrations warrant further examination and will be discussed later in this chapter.

The average pH values in Hummock Pond during 2009 and 2012 were very similar, regardless of which dataset was considered (Figure 4.4).

Figure 4.4 Summary of average pH measured in Hummock Pond during 2009 and 2012.



The 4-month (July-October) average pH was 7.55 during 2009 and 7.84 during 2012. Levels in excess of 8.0 pH units were measured on 2 occasions in 2009 and on 2 occasions during 2012.

Dissolved oxygen: concentration and percent saturation. The patterns of oxygen concentration and saturation during 2009 and 2012 (not shown) were similar and characterize a water body that contains low-to-moderate levels of algal productivity. The entire water column at Station #2 usually was either near-saturation or super-saturated with dissolved oxygen with no definite depth gradient in concentration or saturation being apparent during the course of the growing season.

During extended periods with no wind and no mixing of the water column from the pond surface down to the bottom, the volume of pond water adjacent to the bottom becomes deprived of oxygen (termed ‘hypoxia’) and may become almost totally devoid of oxygen (termed ‘anoxia’) as organic material settling down from the upper levels of the pond undergoes decomposition and utilizes dissolved oxygen in the process. These conditions of extremely low dissolved oxygen provide conditions suitable for the mobilization of nutrients bound in the sediment to be released into the water column where they become available for uptake by photosynthetic algae and plants.

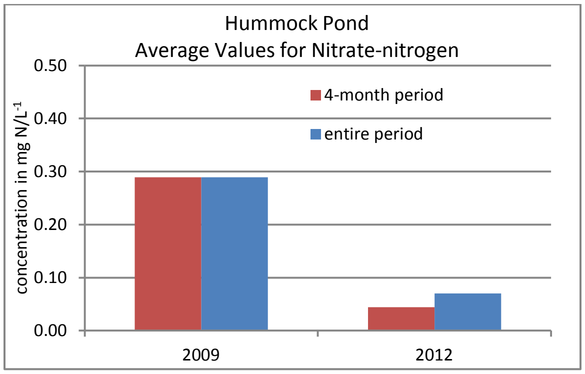
During extended periods of wind of sufficient velocity across the surface of the pond, the entire volume of water in the pond is set in motion and the pond will eventually ‘mix’ from the surface to the bottom, thus distributing the mobilized nutrients into the water column and back into the cycle of pond productivity. This process of bound nutrients being released back into the water column also is termed ‘internal loading’.

Studies have shown that water movement near the sediment interface in shallow areas is capable of re-suspending plant nutrients from the sediment back into the water column. This condition does not depend upon oxygen depletion near the sediment-water interface (Ryding and Forsberg, 1977).

4.2.3 Plant Nutrients

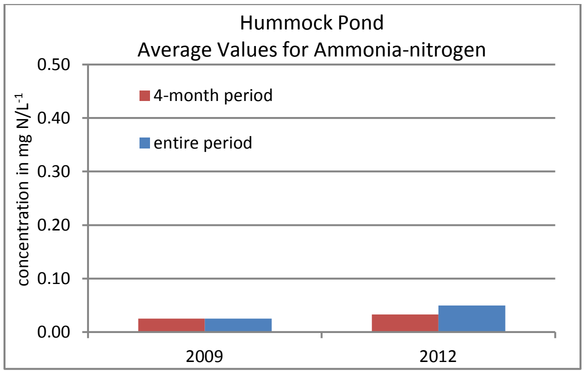
Nitrogen. The average nitrate-nitrogen concentrations in Hummock Pond were considerably lower during 2012 as compared with 2009, regardless of whether the entire season or the 4-month period was considered (Figure 4.5). The average concentration at Station 32 during 2009 was 0.289 mg $N{\cdot}L^{-1}$, while the 4-month and 8-month average concentrations at the same station during 2012 were 0.044 and 0.076 mg $N{\cdot}L^{-1}$, respectively.

Figure 4.5 Summary of average nitrate-nitrogen measured in Hummock Pond during 2009 and 2012.



The average ammonia-nitrogen values measured in Hummock Pond at Station #2 were similar in 2009 and 2012 regardless of whether the 4-month period or entire sampling season were considered (Table 4.1 and Figure 4.6).

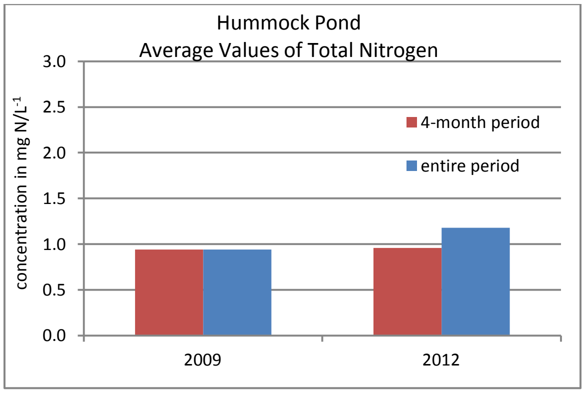
Figure 4.6 Summary of average ammonia-nitrogen measured in Hummock Pond during 2009 and 2012.



Most of the mid-summer ammonia-nitrogen during 2009 and 2012 probably was in the form of NH_4^+ and not toxic to biological growth since the pH levels during mid-summer generally were in the range of 7.0-8.0. There were only two sampling dates during each year when the pH measured in the pond was above 8.0 for a brief period of time.

Total nitrogen (TN) averaged 0.96 mg $N \cdot L^{-1}$ during 2012 as compared with 0.94 mg $N \cdot L^{-1}$ measured during the same 4-month period in 2009 (Figure 4.7).

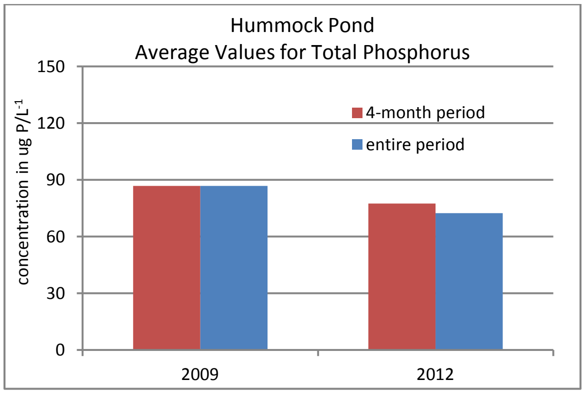
Figure 4.7 Summary of average total nitrogen concentrations in Hummock Pond during 2009 and 2012.



The higher average TN concentration during the entire 8-month sampling period in 2012 (1.19 mg N·L^{-1}) was primarily the result of an elevated value of 2.20 mg N·L^{-1} measured on the first sampling date (April 10th). The similar TN concentrations measured during 2009 and 2012 suggest that phytoplankton community biomass and chlorophyll a were similar during the two monitoring seasons.

Phosphorus. Total phosphorus (TP) averaged 86.7 µg P·L^{-1} during 2009 and 77.5 µg P·L^{-1} during the same 4-month period in 2012 (Table 4.1 and Figure 4.8).

Figure 4.8 Summary of average total phosphorus values in Hummock Pond during 2009 and 2012.



The average TP concentration measured in Hummock Pond during the entire 8-month period in 2012 was slightly lower, at 76.1 ug P L^{-1} (Figure 4.8).

4.2.4 Phytoplankton

This section compares the phytoplankton communities that occurred in Hummock Pond during the 2009 and 2012 sampling periods. The 2009 phytoplankton samples were collected from Station #1 and the 2012 samples collected from Station #2. Although these stations are separated by a distance of about 1 mile (1600 meters), it is likely that the communities of both sites are very similar given the prevalent wind direction from the south-southwest during the growing season and the constant mixing that would be induced in the water column.

The 2012 phytoplankton data presented in Table 4.2 have been summarized to reflect (1) the entire 8-month sampling season and (2) just the 4-month sampling season that is similar to the sampling period in 2009.

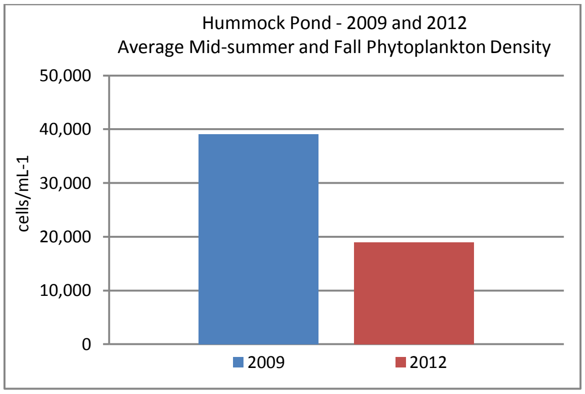
Table 4.2. Summary of phytoplankton community parameters in Hummock Pond during 2009 and 2012. The data are summarized for the entire season and a 4-month period similar to the duration of the 2009 sampling program.

	ENTIRE SEASON			4-MONTH PERIOD	
Category	2009	2012		2009	2012
Avg. Chlorophyll ***a*** (µg mL^{-1})	29.3	10.2		29.3	10.2
Avg. # taxa	18.0	20.5		18.0	22.3
Avg. Density (cells mL^{-1})	39082	16163		39082	19396
Avg. Biomass (mg m^{-3})	8523	5495		8523	8019
Avg. Diversity (H]	0.463	0.851		0.463	0.803
Avg. Evenness (E_H)	0.160	0.283		0.160	0.257

Total assemblage. There were 55 taxa identified in the 2009 HHP phytoplankton assemblage and 53 taxa identified in the 2012 assemblage; 26 taxa were common to both assemblages. A few of the taxa not common to both assemblages were taxa that occurred in 2012 during the early spring and late fall which were periods not sampled during 2009. The 2009 and 2012 assemblages contained an average of 21 and 22 taxa, respectively, for the similar 4-month sampling period (Table 4.2). None of these phytoplankton assemblage characteristics are particularly helpful in describing or identifying differences between the 2009 and 2012 communities and we must now look at some of the other community parameters.

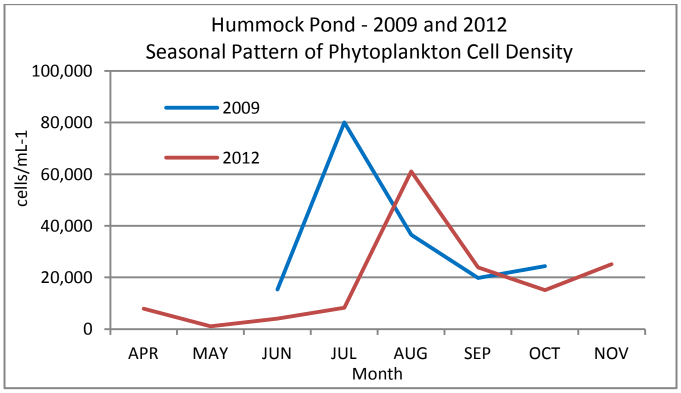
Density. This particular characteristic of the phytoplankton assemblage provides the first evidence of significant differences between the 2009 and 2012 communities (Table 4.2 and Figure 4.9). The 4-month average density was 39,082 cells·mL^{-1} in 2009 compared with 18,993 cells·mL^{-1} in 2012, a substantial difference between densities.

Figure 4.9 Summary of mid-summer and fall phytoplankton average density in Hummock Pond during 2009 and 2012.



The seasonal pattern of phytoplankton cell density presented in Figure 4.10 also highlights the considerable density difference between the two years that the Hummock Pond community has been monitored.

Figure 4.10 Seasonal pattern of average monthly phytoplankton density in Hummock Pond, 2009 and 2012.

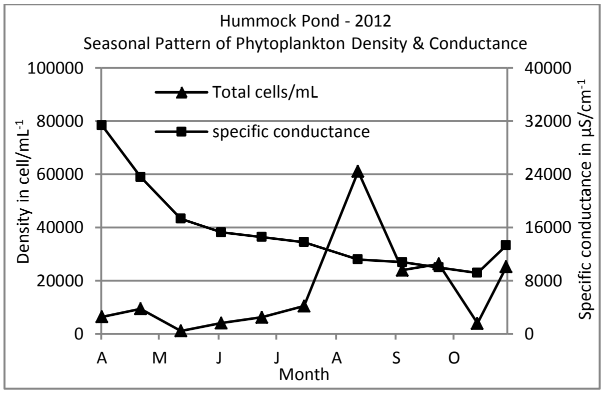


The assemblage starts out with low densities each year following ice-out and the breaching of Hummock Pond with the Atlantic Ocean, and then community density increases to maximum levels during mid-summer and fall before declining toward the end of each season. The sudden shock of sea-water and its high salt content following the spring breaching of Hummock Pond probably has more control over the density of phytoplankton in the pond at that time than any other environmental factor beside water temperature, which regulates the rate of cell growth.

As shown in Figure 4.10, the 2012 peak in phytoplankton community density occurred in mid-to-late August, while the density peak during 2009 occurred in mid-to-late July. This difference in growth pattern is interesting and noteworthy since the water column temperature during 2012 (Figure 4.1) warmed earlier and to a higher level than the temperature during 2009 and we would expect the phytoplankton community to respond with an earlier increase in density.

The environmental factor most likely responsible for the different growth patterns was the extremely high salt content in the pond water during 2012. As shown in Figure 4.11, there was growth of the phytoplankton community, albeit very slow growth, early during the season when specific conductance concentrations exceeded 15,000 µcm·cm^{-1}. Once the conductance dropped below this level, the phytoplankton community exhibited a rapid and significant increase in density (Figure 4.11).

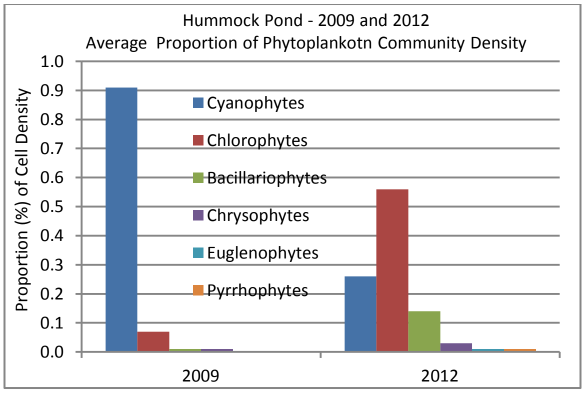
Figure 4.11 Seasonal pattern of phytoplankton density and specific conductance in Hummock Pond during 2012.



Specific conductance did not affect phytoplankton cell density in Hummock Pond during 2009. The average conductance that year was 5122 µS·cm^{-1} and the highest concentration was 6144 µS·cm^{-1}. There apparently is a threshold salt concentration above which phytoplankton are not adapted to exhibit normal rates of growth.

An examination of the major phytoplankton groups that make up the Hummock Pond community during 2009 and 2012 and the relative proportion of these groups in the community composition illustrate some interesting differences between the two communities. Figure 4.12 summarizes this community composition and density information for similar 4-month periods in 2009 and 2012.

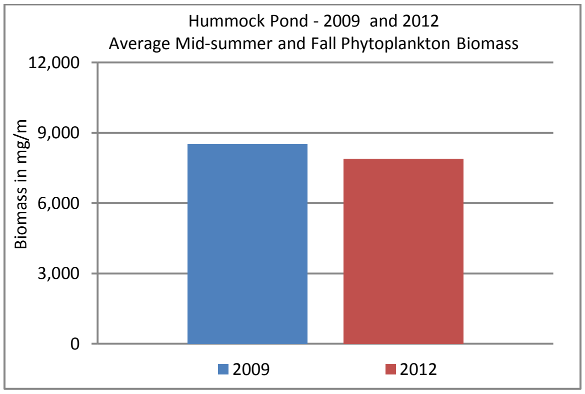
Figure 4.12 Average proportion of major groups in the Hummock Pond phytoplankton community density, 2009 and 2012.



As shown in Figure 4.12, the importance of Cyanophytes in the phytoplankton community declined substantially between the two years, from 91 percent in 2009 to 26 percent in 2012. At the same time, the proportion (importance) of Chlorophytes (green algae) in the community increased from 7 percent in 2009 to 56 percent in 2012. Continued monitoring of Hummock Pond during the next several years would be required to determine whether these differences in community composition represent a developing trend or whether the composition fluctuates between years and no trend is apparent.

Biomass. This quantifier of the phytoplankton community also reveals some differences between the 2009 and 2012 phytoplankton communities. Although the phytoplankton community was twice as dense during 2009 as compared with 2012, as shown in Figure 4.13, the average community biomass was about the same.

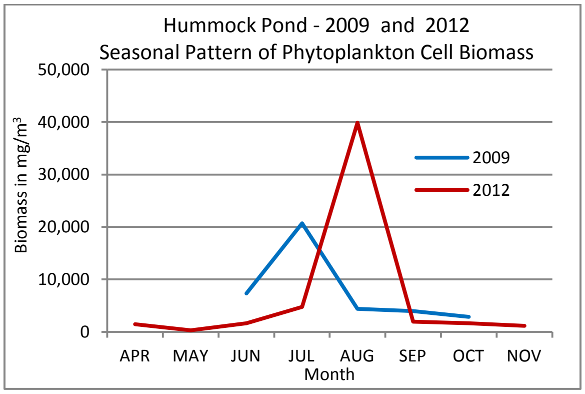
Figure 4.13 Summary of phytoplankton community average biomass during 4-month periods, 2009 and 2012.



The average community biomass during similar 4-month periods was 8523 mg·m^3 in 2009 and 7888 mg·m^3 during 2012. While these values are very similar, there may have been quite different average biomass values during the period between 2009 and 2012.

In spite of similarities in the average community biomass during mid-summer and fall, Figure 4.14 shows that the peak in 2012 mid-summer biomass was about twice as large as the peak exhibited during 2009; 39840 mg·m^3 during August 2012 versus 20692 mg·m^3 during July 2009.

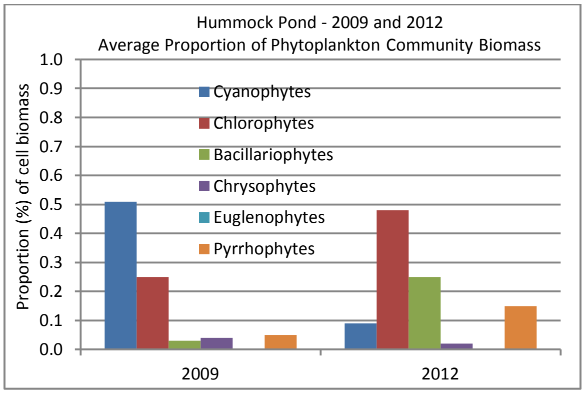
Figure 4.14 Seasonal pattern of average monthly phytoplankton biomass in Hummock Pond, 2009 and 2012.



In spite of large differences in relative biomass among years, the seasonal progression of community biomass is similar each year, with low biomass early in the season following ice-out and the breaching of Hummock Pond with the Atlantic Ocean, and maximum biomass occurring during the mid-summer and early fall, and then declining. The biomass maximum exhibited during 2012 corresponds to the cell density maximum and is delayed as a result of the extremely high salt concentrations in the pond.

As discussed in the density section above, an examination of the major phytoplankton groups that make up the Hummock Pond community during 2009 and 2012 and the relative proportion of these groups in the community composition provide some interesting observations. Figure 4.15 summarizes this community composition and biomass information for similar 4-month periods in 2009 and 2012.

Figure 4.15 Average proportion of major groups in the Hummock Pond phytoplankton community biomass, 2009 and 2012.

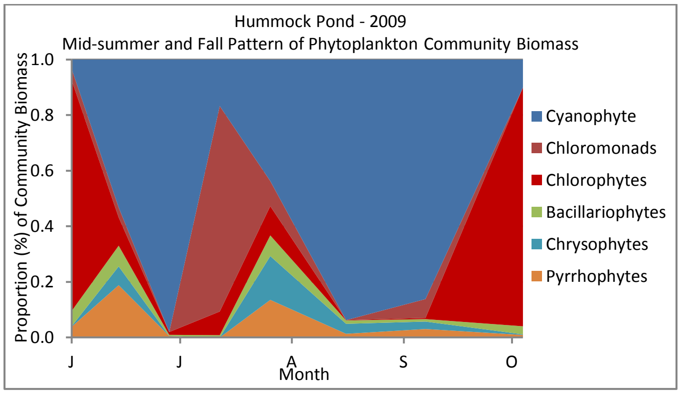


The mid-summer and fall community composition during 2009 and 2012 were very different when biomass was used in the evaluation. As shown in Figure 4.15, Cyanophytes and Chlorophytes were the two major classes in the 2009 community, comprising 51% and 25%, respectively. During 2012, the order of importance in the community biomass was Chlorophytes (48%)>Bacillariophytes (25%)>Pyrrhophytes (15%)>Cyanophytes (9%).

As mentioned previously, we would have to monitor the phytoplankton community in Hummock Pond during several consecutive years in order to see whether any distinct pattern of community composition was developing or whether the community composition fluctuated in a random manner from one year to the next year.

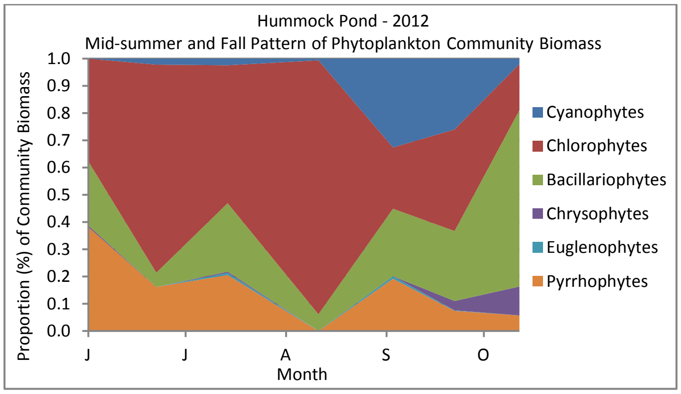
Seasonality. The phytoplankton associations documented in Hummock Pond during the corresponding mid-summer and fall periods of 2009 and 2012 were quite different in terms of major groups and their seasonal succession. Using biomass as the criteria for evaluation, Figures 4.16 and 4.17 summarize the phytoplankton community information for the two periods.

Figure 4.16 Mid-summer and fall pattern of phytoplankton community biomass in Hummock Pond during 2009.



The most significant difference between the 2009 and 2012 mid-summer and fall periods was the greatly reduced importance of Cyanophytes during 2012 as compared with 2009. The Chloromonads, a major component of the 2009 mid-summer community, were not identified in the 2012 phytoplankton community.

Figure 4.17 Mid-summer and fall pattern of phytoplankton community biomass in Hummock Pond during 2012.



There are other, more subtle differences in the seasonal progression of the 2009 and 2012 phytoplankton communities when viewing Figure 4.16 and 4.17. Several consecutive years of water quality monitoring on Hummock Pond would be required to accurately define whether mid-summer and fall seasons are always different, as with 2009 and 2012, or whether they usually have a similar seasonal progression, with the data collected during 2009 and 2012 being unusual in that regard. We also need to remember that the salt content of Hummock Pond was extremely high during 2012 and could be a major factor that affected the seasonal succession and taxa that occurred in the community.

Dominance. Many different taxa have dominated the Hummock Pond phytoplankton community during the mid-summer and fall of 2009 and 2012. As shown in Table 4.3, there were five dominant taxa in the pond during 2009 and 12 dominant taxa that occurred during 2012.

Table 4.3. Summary of dominant phytoplankton taxa in the 2009 and 2012 assemblages in Hummock Pond.

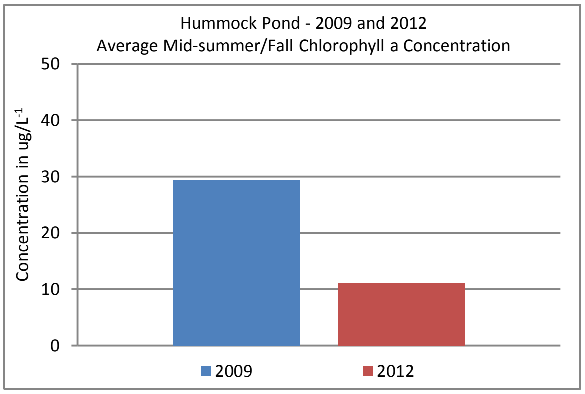
2009 Community Dominants	2012 Community Dominants
Taxon-Species (Major Group)	Taxon-Species (Major Group)
Anabaena spiroides (Cyanophyte)	*Chroococcus dispersus* (Cyanophyte)
Microcystis aeruginosa (Cyanophyte)	*Microcystis incerta* (Cyanophyte)
Gonyostomum semen (Chloromonadophyte)	*Oocystis borgei* (Chlorophyte)
Ankistrodesmus falcatus (Chlorophyte)	*O. pusilla* (Chlorophyte)
Dinobyron spores (Chrysophyte)	*O. solitaria* (Chlorophyte)
	Pyramimonas tetrarhyncus (Chlorophyte)
	Scenedesmus bijuga (Chlorophyte)
	S. quadricauda (Chlorophyte)
	Selenastrum minutum (Chlorophyte)
	Cocconeis sp. (Bacillariopohyte)
	Cyclotella sp. (Bacillariophyte)
	Planothidium sp. (Bacillariophyte)

There were no taxa common to both mid-summer and fall assemblages. While this points to the unique nature of each community, it also could be the result of the extreme salinity conditions that occurred during 2012 and represent taxa that are tolerant of high salt content and were able to flourish under those conditions. We also should consider the fact that the spring breaching of Hummock Pond to the Atlantic Ocean provides a regular 'shock' to most, if not all, phytoplankton taxa in the seed bank and levels the playing field until the most aggressive and adaptable species present can initiate growth and become dominant in the community.

Diversity. As summarized in Table 4.2, the comparable 4-month diversity **[H]** was 0.803 during 2012 and 0.465 during 2009. This was to be expected given the more robust nature of the 2012 assemblage with respect to the number of dominant taxa in the community. As with some of the other phytoplankton community parameters discussed in this chapter, the greatly increased diversity realized during 2012 could be the collective community response to the high salt concentrations in the pond and the inability of any one or a few species to dominate under these conditions.

Chlorophyll *a*. The 2012 chlorophyll *a* concentration was about one-third of the 2009 average concentration (29.3 µg·L^{-1}) regardless of whether the 4-month (10.2 µg·L^{-1}) or 8-month (10.4 µg·L^{-1}) concentration was considered (Figure 4.20). These data indicate that the standing crop of the phytoplankton community in Hummock Pond was more robust during 2009 than during 2012, even though the 2012 community was more diverse.

Figure 4.18 Summary of average chlorophyll *a* values in Hummock Pond during 2009 and 2012.



4.2.5 Trophic Status

As shown below, there were only slight differences among the TSI indices calculated for 2009 and 2012 using the chlorophyll *a*, total phosphorus and Secchi depth transparency data for each sampling period.

Table 4.4 Summary of Trophic Status Indices calculated from Hummock Pond data during 2009 and 2012.

	Trophic State Index (TSI) Based Upon		
Sampling	**Chlorophyll *a***	**Total Phosphorus**	**Secchi Depth**
2009	66.0 (E)	65.8 (E)	60.2 (E)
2012	53.4 (E)	66.9 (E)	55.1 (E)

The subtleties of exact placement by individual trophic state indicators among the years being compared really is inconsequential when it comes to the overall water quality of HHP. The pond is well within the range of eutrophy for each of the indicators under consideration and, in some cases, such as with total phosphorus, any slight increase of concentration could elevate the condition to hyper-eutrophy, an accelerated state of eutrophication. The pond has very poor water quality regardless of which criteria are used to make the evaluation.

4.3 Summary

The comparison of two separate years of water quality data from Hummock Pond uncovered certain similarities and differences that were summarized and discussed in this chapter. The plant nutrients, nitrogen and phosphorus, exhibited some variation among the two years that were monitored but the differences were subtle and not enough to affect the overall productivity of the pond which was well-embedded within a eutrophic state during both years.

Probably the most important finding when comparing the 2009 and 2012 monitoring data was the extreme specific conductance of the pond during an extended period through a large portion of the 2012 growing season. Initially, the high conductance was caused by elevated salt concentrations entering the pond during the spring breach with the Atlantic Ocean, an event that occurs every year. During most years, however, there is a steady decline of pond conductance (salt concentration) through the spring and early summer as dilution occurs from ground-water and precipitation. The problem during 2012 was a severe shortage of precipitation during the spring and early summer which greatly reduced the recharge of water in the pond.

The extreme conductance (salinity) of the pond had an effect on primary productivity during much of the 2012 season and the phytoplankton exhibited signs of recovery once the conductance dropped below a threshold level of about 15,000 $\mu S \cdot cm^{-1}$. As a result of this interaction between water chemistry and productivity, it was not possible to compare and evaluate the 2009 and 2012 phytoplankton community dynamics in any meaningful way.

Poor water quality was documented in Hummock Pond during another growing season. While some sort of remediation probably would improve water quality in the pond, a better understanding of internal and external nitrogen and phosphorus dynamics would aid in the selection of alternatives to address high nutrient conditions. We need to increase our present level of knowledge with regard to (1) the pond bottom sediments and the availability/extent of nitrogen and phosphorus mobilization, and (2) the influence of groundwater input on the nitrogen and phosphorus budgets in the pond. There will be more discussion regarding pond studies and possible remediation in the final chapter of this report. We also need to better understand the full impact of the pond breaching with the Atlantic Ocean and how that phenomenon ultimately effects the annual cycle of water quality that manifests itself each year.

4.4 Literature Cited

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Sutherland, J.W. and S.D. Oktay. 2010. *Hummock Pond Water Quality. 2009. A Summary of Physical, Chemical and Biological Monitoring*. 74 pp. + Appendix 1.

Hummock Pond

2012 Water Quality Program

Chapter 5

A Review of Historical and Current Water Quality Data

5.0 Introduction.

Water quality data are available from Hummock Pond starting in 1994 when the Nantucket Marine and Coastal Resource Department initiated a sampling program along the longitudinal axis of the pond. Although the monitoring record has been intermittent during the past 19 years, there are sufficient data available to warrant a summary and review of the information in an effort to identify water quality trends. These data are presented and discussed here and compared with the recent 2009 and 2012 data, collected by the author, in the context of water quality trends that may be occurring in Hummock Pond.

5.1 Analysis and Summary of Historical Data

Although several attempts were made to locate any and all water quality data collected from Hummock Pond, there is the possibility that some water quality data were missed. In other cases, such as during 1999 and 2008, there are indications that no samples or data were collected. Table 5.1 provides a summary of all known water quality data collected from Hummock Pond.

Table 5.1. A summary of all known water quality data collected from Hummock Pond.

Year	Sampling Frequency/Sampling	Analytes	Investigator
1994	6 times (Mar-Sep), multiple stations	Secchi, temp, DO, salinity, N series, TP	NMCRD
1995	7 times (Apr-Dec), multiple stations	Secchi, temp, DO, salinity, NH3	NMCRD
1996	9 times (Feb-Dec), multiple stations	Secchi, temp, DO, salinity, no record of nutrients	NMCRD
1997	11 times (Feb-Nov), multiple stations	Secchi, temp, DO, salinity	NMCRD
1998	9 times (Mar-Nov), multiple stations	Secchi, temp, DO, salinity, N series, TP	NMCRD
1999	no data found		
2000	8 times (Mar-Dec), multiple stations	Secchi, temp, DO, salinity, N series, TP	Curley
2001	10 times (Feb-Nov), multiple stations	Secchi, temp, DO, salinity, N series, TP	Curley
2002	7 times (Apr-Oct), multiple stations	Secchi, temp, DO, salinity, N series, TP	Curley
2003	8 times (Apr-Nov), multiple stations	Secchi, temp, DO, salinity, N series, TP	Curley
2004	8 times (Apr-Nov), multiple stations	Secchi, temp, DO, salinity, N series, TP	Curley
2005	8 times (Mar-Oct), multiple stations	Secchi, temp, DO, salinity, N series, TP	Knoecklein
2006	8 times (Apr-Nov), multiple stations	Secchi, temp, DO, salinity, N series, TP	Conant
2007	8 times (Apr-Nov), multiple stations	Secchi, temp, DO, salinity, N series, TP	Conant
2008	no data found		
2009	8 times (Jun-Oct), multiple stations	Secchi, temp, DO, field, N series, TP, phyto, plants	Sutherland-Oktay
2010	5 times (May-Sep), multiple stations	Secchi, temp, DO, salinity, N series, POC, PO4, CHLa	SMAST
2011	3 times (Jun-Sep), multiple stations	Secchi, temp, DO, salinity, N series, POC, PO4, CHLa	SMAST
2012	11 times (Apr-Nov); one station	Secchi, temp, DO, field, N series, TP, phyto, toxins	Sutherland
Codes: Secchi (transparency); temp (temperature); DO (dissolved oxygen); field (pH, conductance); N series (nitrogen series); POC (particulate organic carbon); TP (total phosphorus); PO4 (orthophosphate); CHLa (chlorophyll ***a***); phyto (algal taxa, density, biomass, chlorophyll ***a***); plants (aquatic macrophytes); toxins (algal toxins).			

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.

As described in Chapter 4 where comparisons of the 2009 and 2012 Hummock Pond data were presented, the most basic method for evaluating different sets of water quality data is a comparison of mean, or average, values for the analytes of interest selected from the suite of parameters collected each year. That procedure was used to compare the data collected from Hummock Pond since 1994.

There is another minor discrepancy among the data collected from Hummock Pond that should be mentioned. The raw water samples collected during 1994-2007 were grab samples collected from a specific depth and, as such, represent the water chemistry only at the depth collected. In contrast to the grab sample technique, almost all of the samples collected during 2009 and 2012 were integrated samples representing a composite of the water chemistry from the pond surface down to a lower depth just above the bottom of the pond. Grab samples can provide misleading chemistry results since the depth at which samples are taken often can be biased with high concentrations of phytoplankton located at a particular level of the water column where light conditions are optimal for photosynthesis during the daylight hours. The higher concentrations of these organisms in the collected water samples can bias the analytical results for parameters such as TP, TN and chlorophyll ***a***.

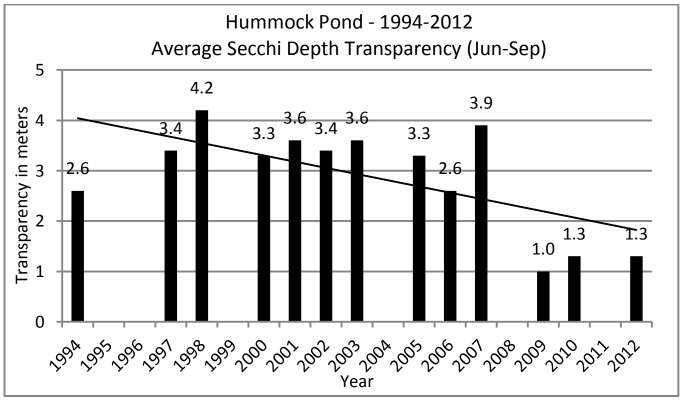
5.2 Review of Historical Data

The data summarized in this section of the report represent the most complete set of data-points that could be assembled from the total suite of available historical information. In some cases, whole months would be missing from the collection record. In other cases, certain analytes were found missing from the monthly record during a particular year. Only the categories of the water quality data that provide some sort of meaningful interpretation are considered in the following section.

5.2.1 Physical characteristics

Transparency. The mid-summer (June-September) average Secchi depth data collected for Hummock Pond during the period from 1994 through 2012 are summarized in Figure 5.1.

Figure 5.1. Average mid-summer Secchi depth transparency for Hummock Pond during 1994-2012.



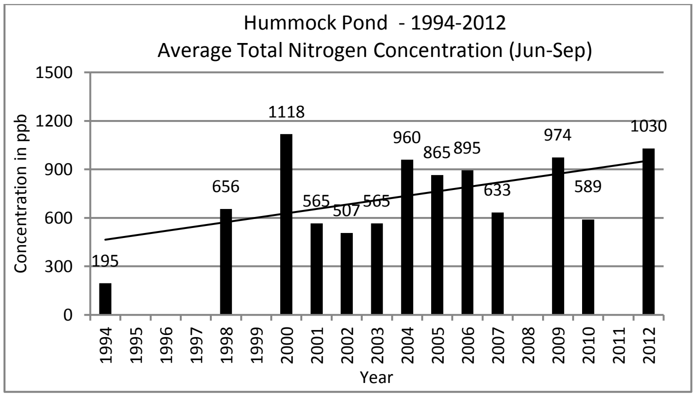
The average transparency always has been less than 5.0 m and almost all of the mid-summer average values since 1994 have been in the range of 2.0-4.0 meters with the exception of the recent readings collected during 2009, 2010 and 2012 which were all about 1.0 meters (Figure 5.1). While there is a distinct decreasing trend apparent over the 18-year period, there also is considerable scatter in the average values collected to date and more regular sampling should be conducted each year to determine whether there is a real trend and whether reduced transparency is the result of more intense algal blooms.

Although Hummock Pond phytoplankton data are only available during the 2009 and 2012 monitoring seasons, historical problems with phytoplankton blooms in Hummock Pond are mentioned in the Knoecklein (2006) report. In spite of this uncertainty from lack of data, it does seem likely that blooms of algae have been prevalent in the pond for some period of time and have become worse during recent years based upon the trends in transparency.

5.2.2 Plant Nutrients

Nitrogen. There were insufficient historical data for **nitrate-nitrogen** (NO_3-N) and **ammonia-nitrogen** (NH_4-N) for Hummock Pond during 1994-2012 to justify any meaningful interpretation of average values during the period. The summary of average **total nitrogen** (TN) concentration during the period from 1994 through 2012 is presented in Figure 5.2.

Figure 5.2 Average mid-summer total nitrogen values for Hummock Pond during 1994-2012.



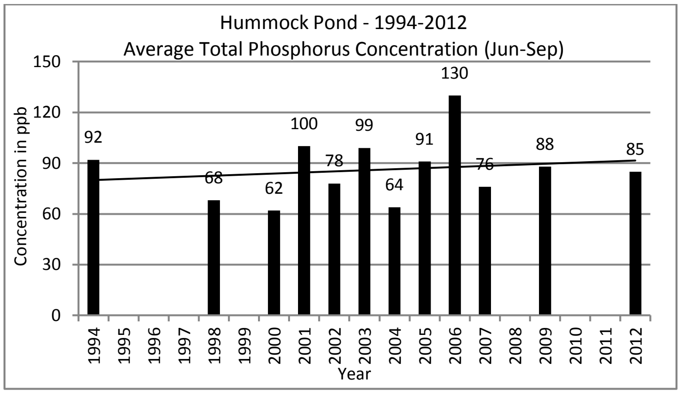
The average mid-summer values generally have been within the range of 500-1000 ppb each season and there is a general trend of increasing concentration in the main body of the pond. However, as pointed out with the Secchi depth transparency data (above), the average TN data exhibits considerable scatter during the period and should be the subject of more frequent sampling to determine the exact nature of trends in the pond.

The TN values documented in Hummock Pond during the past two decades emphasize both the nutrient-rich condition of the system and the need to better understand the dynamics of this ecosystem, especially the details that follow the annual spring opening to the Atlantic Ocean. Currently, it is not possible to reasonably estimate external versus internal loading of nitrogen to the pond without some detailed information on ground-water flow and related nutrient concentrations, the annual precipitation patterns, and some basic understanding the hydrologic cycle of the pond .

Phosphorus. The average mid-summer total phosphorus (TP) concentrations in Hummock Pond during the period from 1994 through 2012 are presented in Figure 5.3. Although there is a slight increase indicated during the past 18 years, the trend is reasonably flat with average values generally ranging between 60-100 ppb.

The limited body of TP data for Hummock Pond indicates that average mid-summer concentrations are high and fluctuate to a certain extent from one year to the next. The average values that occur during any season probably depend upon a variety of factors including the extent of water exchange when Hummock Pond is opened to the Atlantic Ocean, the pattern and amount of precipitation that occurs during spring and summer, and the dominant taxa of phytoplankton that set up in the pond early in the spring following the opening event.

Figure 5.3 Average mid-summer total phosphorus values for Hummock Pond during 1994-2012.



It appears that TN and TP concentrations have been high for at least the previous two decades (1990s and 2000s) and perhaps much longer. While average TN concentrations seem to be increasing with time, TP concentrations in the pond are essentially the same over time, but within a range that indicates high mid-summer productivity.

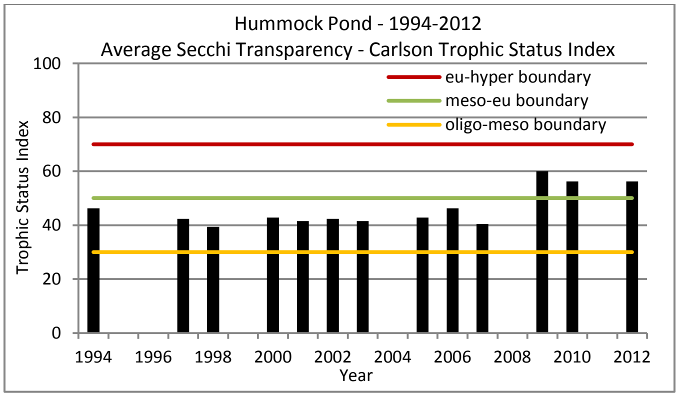
5.2.3 Phytoplankton

The first year that there was comprehensive collection of phytoplankton data from Hummock Pond was 2009. While there is no detailed historical record of this important biological component within the Hummock Pond ecosystem, other water quality data collected since 2004 seems to indicate that Cyanophyte blooms have been a common occurrence on the pond for quite some time. Knoecklein (2006) reported that a single phytoplankton sample was collected from Head of Hummock Pond during a bloom observed from August into October, 2005, but does not identify exactly when the sample was collected. The sample contained *Anabaena* and *Microcystis* spp. at densities of about 90,000 cells mL^{-1}. Both of those genera have been reported in Head of Hummock Pond during the past several seasons.

5.2.4 Trophic Status

The Trophic Status Index (TSI) was calculated for Secchi depth and total phosphorus (TP), but not for chlorophyll ***a*** since there were no data collected prior to 2009. The data were standardized for the period of collection from June through September. The results for the Secchi depth data are presented in Figure 5.4.

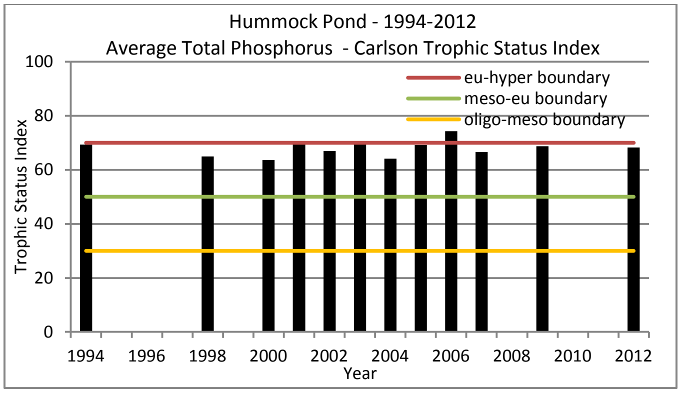
Figure 5.4 Summary of Trophic Status Indices calculated for average Secchi values in Hummock Pond, 1994-2012.



There were 13 years of transparency data that were sufficient for calculation of Trophic Status Indices. All indices calculated for the average Secchi depth readings between 1994 and 2007 were within the mesotrophic region and generally ranged between 40-50 on the scale. The 2009, 2010 and 2012 indices were the first time the Secchi TSI crossed over into the eutrophic range. Continued monitoring is recommended to determine whether this trend continues in the future.

There were 12 years of TP data available for the TSI calculation and the results are presented in Figure 5.5.

Figure 5.5 Summary of Trophic Status Indices calculated for average total phosphorus values in Hummock Pond, 1994-2012.



All of the TSI values calculated for TP are well within the eutrophic range of productivity and very close to the eutrophic-hyper-eutrophic boundary. A TSI of 74.3 calculated for the 2006 TP data was within the hyper-eutrophic range. More regular monitoring is recommended to determine what exactly is happening with average TP concentrations in Hummock Pond.

5.3 Summary

The current water quality of Hummock Pond continues to be poor and it appears that the pond has exhibited poor water quality for at least the past two decades when monitoring on the pond was initiated during 1994. While gaps do exist in the record of historical data that have been collected, there was sufficient continuity within many individual years that enabled the author to piece together a fairly complete water quality record for the pond. Unfortunately, there were no phytoplankton data collected from Hummock Pond prior to 2009. Without these data, it is not possible to determine the duration and severity of Cyanophyte blooms during the mid-summer and fall period similar to the blooms documented during 2009. A robust water quality monitoring program is recommended for continued surveillance of the pond and its current issues.

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Hummock Pond

2012 Water Quality Program

Chapter 6

Project Summary, Discussion, Conclusions and Recommendations

6.0 2012 Program Summary

Hummock Pond was monitored during 2012 to add more water quality data to a record of information that began in 1994 when the Nantucket Marine and Coastal Resource Department (NMCRD) initiated studies of the pond. The duration and frequency of pond sampling has 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 in ambient water quality were developing. There also were some 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).

The NMCRD program appeared to be in jeopardy when 2008 passed without any water quality information being collected. The author participated in a cooperative investigation of Hummock Pond during 2009 with the UMass Nantucket Field Station and the Nantucket Land Council. During 2010 and 2011, the author focused his attention specifically on Head of Hummock Pond and some of its unique water quality issues. Unfortunately, there was no monitoring conducted on Hummock Pond during this period of time except for some pre-breaching and post-breaching data collection in order to better understand the exact water quality effects of those events.

During 2011 and 2012, the author, staff from the Nantucket Land Council, and others held discussions concerning the initiation of a vegetation harvesting program on Hummock Pond. The meetings were held in response to a concern on the part of shoreline residents and others locals that native vegetation in the pond was reaching nuisance levels and interfering with recreational use of the pond, including canoeing, boating, sailing, kayaking and wind-surfing. There was sufficient interest created by these preliminary meetings to develop a *white paper* that described the problem and developed a specific management program with a budget that could be used to bring the program forward to implementation.

While it was anticipated that the vegetation harvesting program might be implemented during 2012, this was not the case and plans were put on hold for at least one more season while other more pressing local issues were addressed. That said, however, it was decided that water quality monitoring should be initiated on Hummock Pond during 2012 to continue the database that had been started 19 years ago and to accumulate a body of recent evidence that could be used to evaluate the effects of harvesting if, and when, it was initiated.

The 2012 study began during early April and continued until early November, sampling Hummock Pond at approximately tri-weekly intervals. Samples were collected for physical, chemical and biological parameters including temperature, dissolved oxygen, nutrient chemistry, chlorophyll *a*, the phytoplankton community, and algal toxins. Hummock Pond was sampled 11 times during 2012.

There continues to be compelling evidence from the 2012 program to support the *eutrophic* status attributed to the pond as a result of the author's 2009 efforts on the pond (Sutherland and Oktay, 2010) and the solid body of evidence provided from earlier studies by the NMCRD (Curley, 2004, 2003, 2001; Conant, 2006, 2008) and by Knoecklein (2006). In fact, thorough examination of the more recent chemical and biological results provides sufficient evidence that Hummock Pond is close to and occasionally enters a *hyper-eutrophic* state.

Hummock Pond continued to exhibit elevated levels of the plant nutrients TP and TN throughout the 2012 period of monitoring and average concentrations were about the same as the concentrations measured during 2009.

The primary water quality distinction between the 2009 and 2012 seasons was the much smaller standing crop of the 2012 phytoplankton community as substantiated by the greatly reduced average concentration of chlorophyll ***a*** and the reduced average density of phytoplankton. The TSI calculated for the 2012 chlorophyll ***a*** concentrations measured in Hummock Pond were considerably closer to the mesotrophic-eutrophic boundary than the TSI values calculated for the 2009 chlorophyll ***a*** data.

The total dominance of Blue-green algae (Cyanophytes) in the 2009 phytoplankton community of Hummock Pond was biological evidence of the unhealthy status of this aquatic ecosystem. From early July until late September, at least 90 percent of the community density was comprised of Cyanophytes, diversity was about one-half of the maximum possible, and a major, long-term bloom was in progress. During 2012, the Cyanophyte bloom was restricted to September and the average annual phytoplankton community diversity was twice the 2009 diversity.

While the phytoplankton community dynamics were completely different during 2012 and indicate an improvement from previous (2009) water quality trends, there were other important environmental factors that occurred during 2012 that must be considered here. First, the extremely high salt content of Hummock Pond during 2012 could have been a principal factor affecting phytoplankton community structure and dynamics. We know from previous data collected on Hummock Pond (2009) and on Head of Hummock Pond (2009, 2010, and 2011) that 2012 was unusual with very high specific conductance levels and likely impacted the normal seasonal succession of major phytoplankton groups that appeared in the pond. Second, algal toxins were detected in Hummock Pond during 2012. Although the levels reported were below the threshold for concern related to drinking water consumption and contact recreation, their detection in the water means that we must maintain an awareness of the water quality issue associated with this group of organisms and continue to monitor this aspect of Hummock Pond water quality.

6.1 Discussion

Hummock Pond and Head of Hummock Pond form a simple estuary system located on the Island of Nantucket, Massachusetts. Hummock Pond likely should be considered an estuarine system based upon its proximity to the Atlantic Ocean and the permeable, sandy soils that separate the pond from the Ocean. The pond is ‘managed’ by periodic breaching of the barrier beach usually twice each year in the spring and the fall. The pond usually closes the breach after a period of three to seven days, on average. The purpose of breaching is to lower nutrient levels, primarily nitrogen, raise salinity through the exchange of brackish pond water with higher quality marine waters and remove accumulated organic matter from the pond. Others reasons given for the breaching include alleviation of flooded conditions and enhancement of marine fisheries (Conant, 2008). It is not certain how long ago the practice was initiated, or whether a record even exits. However, material reviewed for this report has documented the spring and fall events as far back as 1994.

While the breaching of Hummock Pond has been carried out with regularity each year, there is a definite lack of water quality data to support any of the reasons given for following this practice. The author contends that while there may be some perceived water quality advantage gained through this practice, it is just as likely that significant water quality damage can result from the breaching. For example, lowering the water level increases the hydraulic head between the pond and surrounding ground-water in the watershed, thereby increasing the flow of ground-water into the pond. Ground-water transported from areas where poorly operating wastewater treatment systems are located would be nutrient-rich and would not accomplish the goal of flushing the pond.

Howes et al. (2006) attribute the nutrient enrichment problem affecting coastal embayments throughout the Commonwealth of MA and along the entire eastern seaboard to increasing population, development and changing land use in these areas. In many areas, these embayments have nutrient levels that are approaching or have exceeded assimilative capacity, causing decline in ecological health. The primary nutrient responsible for the increased impairment is nitrogen from wastewater disposal, fertilizers and changes in groundwater hydrology associated with development. The Sesachacha Pond Embayment on Nantucket Island has been described as a coastal system suffering from nitrogen enrichment, compounded by inadequate tidal exchanges when the system is breached for management purposes (Howes et al. 2006).

Based upon historical information, water quality data collected since 1994, the setting of the geologic watershed, and land use and local hydrology, it would appear that Hummock Pond is experiencing the same high nutrient (nitrogen) dilemma as Sesachacha Pond and other coastal embayments. However, there less background information and supporting data available for Hummock Pond than the corresponding information presented by Howes et al. (2006) for Sesachacha Pond.

The surface watershed of HP and HHP is ≈2,230 acres while the groundwater drainage area is ≈2000 acres. When considering the size of the pond (≈150 acres), these drainage values translate to a watershed to pond ratio of ≈15:1, which is a substantial contributory drainage into a relatively small volume of water; about 300 acre-feet at 'full' condition (Knoecklein, 2006). Given the sandy, well-drained soils, low overall slope of local topography and the fact that relatively little development exists along the shore-line of the ponds, groundwater appears to be the primary mechanism for the movement of water and nutrients into the system.

The watershed of Hummock Pond and Head of Hummock Pond lies within the Town of Nantucket. The major portion of the water and nutrient input to both ponds is groundwater from the watershed and precipitation falling directly on the surface of the pond. Water input from surface runoff is minimal since the watershed soils are well-drained and there are few tributaries. There is a small tributary originating near No Bottom Pond, northeast of the intersection of Crooked Lane and Madaket Road, which travels through Millbrook Swamp before entering the northeast end of Hummock Pond. Given the low flows observed in this channel over the past several years (JWS, unpublished data), it is not likely that this tributary provides any significant volume of surface runoff to the Hummock Pond and Head of Hummock Pond system. It is more likely that the tributary serves as a conduit for transport of nutrient material from Millbrook Swamp when the system becomes a 'source' during periods of high discharge following major storm events.

Groundwater could provide a substantial load of nitrogen to Hummock Pond since there is considerable development in the portion of the watershed north and east of the ponds. Almost all of the developed area within the watershed is served by individual waste water treatments systems of unknown working condition. Many of these systems are utilized for very brief periods during the summer and then remain dormant for the remainder of the year; system failures seem likely when inundated with high volumes of waste for brief periods of time. Even properly located and Title 5 validated septic systems that are functioning "as advertised" could contribute excess levels of nitrogen as nitrate to the surrounding groundwater in sandy soils.

Weiskel and Howes (1992) reported that phosphorus is highly retained during groundwater transport through sandy glacial outwash aquifers, such as in the watershed to the Sesachacha Pond System, by sorption to aquifer minerals. Since there is no information provided in Howes et al. (2006) on the specific soil type(s) in the watershed of Sesachacha Pond, it is impossible to known whether Hummock and Sesachacha Ponds share the same soil types.

There are two soil types in the Hummock Pond watershed that determine permeability and eroding capability. The northern section is classified as "Medisaprists-Barryland Variant association", consisting of organic mucky deposits, combined with outwash soils that are poorly drained. The southern section is classified as "Evesboro association" defined by gently sloping sandy soils that drain rapidly (Oldale, 1992).

The water quality results from 2009 and 2012 suggest that a significant amount of phosphorus is remobilized within Hummock Pond (autochthonous source) during the summer months, based upon the combination of shallow depth and longitudinal axis of HP oriented parallel to the summertime prevailing winds which would afford thorough mixing and mobilization in this area. It is now widely recognized that the mixing processes induced principally by wind force and sometimes by motorboats which occur between sediments and the overlying water play an important part in the role of phosphorus release from the sediments under both oxic and anoxic conditions (Ryding and Forsberg, 1977). This factor would seem to confirm that internal loading of phosphorus is a more serious threat in shallow lakes than in deep lakes where the substances released are temporarily prevented from entering the epilimnion during periods of thermal stratification.

If internal loading of phosphorus, and probably nitrogen, from the shallow zones of Hummock Pond is a primary mechanism in the nutrient dynamics of this system, then the impact of waterfowl populations on nutrient loading needs to be considered along with all of the other potential nutrient sources. Hummock Pond offers ideal habitat for sizeable populations of different species since it is a large (>100 acres) open-water area that is relatively shallow with good access to an abundant attached aquatic plant community for feeding and the pond seldom freezes even during the height of winter.

The primary limitation usually associated with evaluating nutrient loading from waterfowl is accurate quantification and proper placement within the hierarchy of other sources of nutrients to a body of water. Unless loadings from all different sources can be quantified, it is difficult to state with any degree of certainty whether the waterfowl contribution is important or not and whether management of the problem is cost-effective.

While actual numbers of resident and transient waterfowl on the pond at any given time are impossible to predict, we can estimate the impact for reasonable numbers of individual species commonly observed on the pond. There is considerable information in the literature regarding the impact of waterfowl on water quality.

The following information relates specifically to a scenario involving Canada geese and nutrient values derived from the literature for the purposes of the current discussion. There also are sources of information in the literature for other types of waterfowl including dabbling ducks (mallards, black ducks, etc.) and diving ducks (canvasbacks, scaups, etc.).

The following material is from Sherer et al. (1995). The average Canada goose dropping has a dry weight of 1.2 grams (~0.04 ounces). Geese can defecate as many as 92 times each day (numbers reported in the literature range from 28-92 times). An average of 60 feces per day = 72 grams (2.5 ounces) of dry weight. Each dropping contains 76 percent carbon, 4.4 percent nitrogen and 1.3 percent phosphorus. Thus, each goose contributes 3.2 grams of nitrogen and 0.9 grams of phosphorus per day to the body of water on which they reside.

The following table extends the calculations for an individual goose into the total nutrient load to a body of water when different sized populations of geese are considered:

Table 6.1 Summary of theoretical nutrient loading from different sized populations of Canada geese on Hummock Pond.

	Each individual	50 geese	100 geese	500 geese	1000 geese
N per day in grams (kg)	3.2 (0.0032)	160 (0.16)	320 (0.32)	1600 (1.6)	3200 (3.2)
P per day in grams (kg)	0.9 (0.0009)	45 (0.045)	90 (0.09)	450 (0.45)	900 (0.90)
N per year in kg (lbs)	1.2 (2.2)	58.4 (128.7)	116.8 (257.5)	584 (1,288)	1168 (2,575)
P per year in kg (lbs)	0.3 (0.7)	16.4 (36.2)	32.9 (72.5)	164 (362)	329 (725)

A reasonable estimate of numbers of waterfowl present on Hummock Pond at any given time during the year would be 200-300 individuals, or an average of 250. Based upon the numbers provided above, 250 individuals would result in an annual loading of 644 lbs of nitrogen and 181 lbs of phosphorus to Hummock Pond.

Most of the fecal material produced by waterfowl would sink to the bottom of the pond. As a result of the shallowness of Hummock Pond and the persistent wind that blows year-round, it is likely that the nutrients in the fecal matter would became suspended in the water column and available for uptake by the phytoplankton and aquatic plants. There can be no doubt that the contribution of waterfowl to the nutrient dynamics of Hummock Pond needs to be considered when developing some sort of management strategy to improve water quality.

Cyanophytes are ubiquitous, occurring in almost every habitat, and the presence of small numbers of these organisms in the phytoplankton assemblage of aquatic ecosystems is part of a natural process or sequence of events. When present in large numbers as with 'bloom' conditions, however, Cyanophytes can induce physical, chemical and, eventually, biological changes in the aquatic environment in which they occur and eventually impart negative changes to the ecosystem which may require some direct remedial action to reverse or overcome. With only two years of phytoplankton data available for Hummock Pond, the exact nature and extent of the Cyanophyte problem cannot be defined at this time.

Intense concentrations (blooms) of Cyanophytes in the water column decrease transparency, thereby reducing the depth of the photic zone where photosynthesis can occur and the volume of water that supports other phytosynthetic organisms in the community. In addition, high concentrations of Cyanophytes in the water column result in high rates of cell die-off which settles to the bottom and causes oxygen depletion within the system through decomposition of the dead plant material. This de-oxygenation has a direct negative effect on aquatic organisms in the region that depend on oxygen for survival, as well as the indirect effect of toxic gas release and nutrient mobilization into the water column and, in a shallow system, mixing with the upper levels of water. The release of nutrients into the water exacerbates the cycle by encouraging increased primary productivity in an already over-productive system.

When a dense mat of algae floats on the surface of a lake or pond, the cells already have disrupted the aquatic ecosystem and, under certain conditions, can pose health and safety issues for users of the water body. In the case of Cyanophytes, cells floating on the surface and forming a blue-green, paint-like scum, already have died and lysed, releasing their cell contents into the surrounding environment.

The Cyanophytes identified in Hummock Pond during 2009 and 2012 were problematic for reasons related to both water quality and human health. As summarized below, at least two species identified during each season are capable of producing toxic metabolites, cyanotoxins, which can be neurotoxins, hepatotxins, cytotoxins and endotoxins. In addition to being toxic and dangerous to animals, such as cattle, dogs and cats, these cyanotoxins should be considered a public safety risk to the extent that contact and consumption by humans be avoided.

Table 6.2 Summary of Cyanophyte species identified in Hummock Pond, 2009 and 2012.

Cyanophytes - 2012	Cyanophytes - 2009
*Anabaena flos aquae**	*Anabaena flos-aquae**
Chroococcus dispersus	*A. spiroides*
C. limneticus	*Chroococcus limneticus*
Merismopedia glauca	*Merismopedia punctata*
*Microcystis incerta**	*Microcystis aeruginosa**
* capable of toxin formation; from DiTomaso, 1994.	

Raw water samples collected during 2012 were found to contain low levels of microcystin, which is a cyanotoxin produced by Cyanophytes and harmful to the public health of recreational users of the pond. Cyanotoxins were not sampled during 2009 and therefore not reported in the Hummock Pond ecosystem.

While the levels of microcystin reported during 2012 were below the threshold of concern for drinking water and contact recreation, the very presence of these substances in the pond ecosystem demands our continued attention with the monitoring and tracking of these substances.

In humans, exposure to these contaminants can occur through either direct contact with the water such as with recreational usage, or by breathing in airborne components distributed with the wind. Recent research at the Dartmouth-Hitchcock Medical Center (D-HMC) provides strong evidence for far more serious implications related to the Cyanophyte situation in the Northeast US and, potentially, in the local situation observed in Hummock Pond. Cyanophyte produce the toxin, ß-methylamino L-alanine (ßMAA), an amino acid that is demonstrably toxic to motor neurons and has been linked to ALS and neurodegenerative disease in humans. The researchers at D-HMC have identified a higher rate of ALS among New Hampshire residents living in close proximity to lakes and ponds where blooms of neurotoxin-producing Cyanophyte have been documented previously.

The following information is offered as a post-script to the present discussion focused on Hummock Pond since it is germane to the future of water quality efforts directed toward the pond. During the fall of 2012, the Town of Nantucket and the Massachusetts Estuaries Project formed a *Partnership for the Nitrogen Management of the Hummock Pond Embayment System* (September, 2012). The basic project description is: Data synthesis and modeling required for Massachusetts Estuaries Project linked watershed–embayment nitrogen management approach for the Hummock Pond embayment system in support of management and restoration. The project goal is the protection and restoration of the ecological health of the Hummock Pond Embayment System of the Town of Nantucket through watershed-embayment nitrogen management planning.

6.2 Conclusions

Hummock Pond continues to exhibit eutrophic water quality, even though the 2012 chlorophyll ***a*** and Secchi depth data, when analyzed, placed the pond closer to the mesotrophic-eutrophic boundary than the 2009 data for the same parameters (see Chapter 4). Previous reports based upon 1990s and 2000s data had labeled the pond 'eutrophic' but did not use any analytical criteria to evaluate the historical data collected from the pond.

The phytoplankton community dynamics documented in Hummock Pond during 2012 did not correspond to a normal year and should not be considered to reflect any sort of water quality improvement in the pond. The extreme salinity that was prevalent in the pond until late during the growing season probably affected the algal seed bank and the species that were able to successfully grow and also the timing and appearance of major groups of algae in the normal seasonal succession expected in Hummock Pond.

If we accept the view presented by Weiskel and Howes (1992) that there is high phosphorus retention in sandy glacial outwash aquifers, then the elevated total phosphorus values that occur in Hummock Pond are autochthonous (internal) in origin. Presumably, there is considerable phosphorus release from the sediments through wind-induced mixing which promotes high phytoplankton and aquatic plant productivity. This high productivity supplies biomass for decomposition at the micro-zone within the sediment-water interface which then undergoes phosphorus release and perpetuates the cycle of productivity described above.

The average concentrations of total nitrogen (TN) measured in Hummock Pond during mid-summer and fall of 2009 and 2012 were similar (~1.0 mg $N \cdot L^{-1}$) and within a range of concentrations considered to be background levels in this type of development and geologic setting. There is potential for watershed loading of this nutrient to become problematic, however, and for the assimilative capacity of the Hummock Pond system to be exceeded. A source of nitrogen presumably comes from individual septic systems in the Hummock Pond watershed which are of different ages and working efficiencies and operated on a seasonal basis.

There were Cyanophyte species identified in Hummock Pond during 2009 and 2012 that are known to produce cyanotoxins that pose a public health and safety issue for individuals using the pond recreationally and home-owners living along the shoreline adjacent to the pond. The situation becomes more serious with the finding, during 2012, that microcystin was present in the pond water albeit at low levels.

6.3 Recommendations

(1) Hummock Pond requires continued attention focused on a series of water quality issues that have been exhibited for the better part of the previous two decades, including considerable nutrient enrichment and severe and occasional, extended Cyanophyte blooms that produce neurotoxins and can pose a public safety threat for local residents.

(2) In the absence of Town of Nantucket ability to either fund or participate in the continued water quality monitoring of Hummock Pond, it would be appropriate for another organization to exercise long-term vision toward water quality management and remediation for an important local water resource. A logical candidate for this pond oversight role is the Nantucket Land Council (NLC), Inc., an organization that helped sponsor the 2009 study of Hummock Pond and also has sponsored three years of water quality studies on Head of Hummock Pond.

(3) As the government entity responsible for stewardship oversight of Hummock and Head of Hummock Ponds, the Town of Nantucket should retain a consultant to prepare a detailed Management Plan for these two bodies of water following completion of the *Partnership for Nitrogen Management* report, and using that report for the basis of the Management Plan. A detailed Management Plan should not be prepared for the ponds, however, until there has been a more thorough assessment of factors affecting the water quality of the ponds and, in some cases, additional data gathering must occur to overcome deficiencies in the current status of information. Some of the deficiencies that should be considered are addressed below and others likely will be presented in the *Partnership for Nitrogen Management* report.

(4) Potential watershed deficiencies that should be evaluated prior to the development of a Management Plan include (1) detailed GIS land use analysis within the watershed, documenting individual parcels, the amount of development and types of structures/impervious areas on each parcel, (2) enhanced groundwater monitoring including installation of more wells, funds for certified chemical analyses, and studies to determine the direction of subsurface flows to define the exact contributory areas and continue the program of Title 5 inspections within the watershed, and (3) evaluation of current soil maps and upgrading of these maps if warranted by a lack of necessary resolution, particularly since the use of fertilizer in the watershed is becoming so controversial and the effectiveness of soil in removing nutrients is uncertain.

(5) Pond deficiencies that should be addressed prior to the development of the Management Plan include (1) enhanced water quality sampling before and after the breaching of Hummock Pond with the Atlantic Ocean to evaluate the effect of the breaching, (2) installation of a continuous water level recorder to assist with preparation of a water budget for the ponds, (3) updated bathymetry of the ponds, and (4) chemical analysis of bottom sediments.

(6) The current shore-line of Hummock Pond should be delineated along with detailed mapping of the shoreline *Phragmites* population using high resolution GPS. In some areas, the *Phragmites* is encroaching into the open water in measureable amounts each year and eventually will cause the pond to segment into smaller water bodies, particularly along the narrow northeast end of Hummock Pond.

(7) Beginning in the late spring of 2010, regular (bi-weekly) samples of the phytoplankton community should be collected from Hummock Pond. These samples should be submitted to a certified algologist for identification and enumeration and also submitted to SUNY-ESF for algal toxin analysis.

(8) Until control of nutrient loading to the ponds can be achieved, there should be funding options explored to purchase a mechanical harvester to remove aquatic plant biomass from Hummock Pond. Owning and operating the harvester would be the most practical approach and the equipment could be used on other Island ponds with vegetation problems. Initial costs would include the harvester, conveyor (to off-load vegetation) and dump truck. Local farms or landscape professionals might use the harvested material as compost; otherwise, the material could be composted at the local landfill.

(9) It is important that a close watch be maintained over the Hummock Pond aquatic plant community to provide early detection of the introduction of an invasive species, such as *Myriophyllum spicatum*, Eurasian watermilfoil. It is surprising that no invasive species have been detected in the pond so far, particularly given the high waterfowl traffic from Cape Cod and other areas along the eastern seaboard where invasive plant species are a well-documented problem.

(10) Continue water quality sampling of Hummock Pond and Head of Hummock Pond before and after the opening to the Atlantic Ocean in order to evaluate the effect of the opening.

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Hummock Pond

2012 Water Quality Program

Appendix

Materials Referenced in the Report

Hummock Pond Field Sheet
Chain of Custody Form
2012 Temperature Profile Data
2012 Dissolved Oxygen Saturation Profile Data

HUMMOCK POND
2012 WATER QUALITY SAMPLING

STATION # ________________DATE ___________TIME START_________________TIME STOP__________________

CONDITIONS ____

TOTAL DEPTH _____________ WATER COLOR ______________________ LAT _______________________________

SECCHI DEPTH ____________ TEAM INITIALS _______________________ LONG _____________________________

COMMENTS ____

DEPTH	TEMP	D.O.	D.O.	spC	TDS	pH	ORP	FM DEPTH
(ft)	(ºC)	(mg/L)	(% sat)	(µmhos)	(ppm)	(s.u.)	(mv)	(ft)
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

SAMPLE #	SAMPLE DEPTH	COMMENTS
12-NIP-		
12-NIP-		

OTHER ____

____

Keck Water Research Lab COC Receipt & Subsample Log

PROJECT: **NANTUCKET ISLAND PONDS**

Field Personel: Please fill out first three columns and circle subsamples and initial if necessary

Please circle each analyte that was subsampled and initial

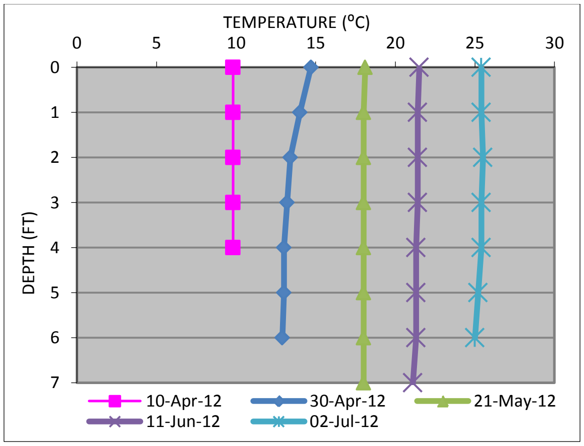
Bottle ID #	Sample Name	Sample Date/Time	SUBSAMPLE	Init	Filt	Init	Pres	Rec'd	Store
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				
			cond pH NH4 PO4 TP TN Metals Al TSS DIC		Anions PO4 DOC Si TFP Chl-a				

Custody of Samples

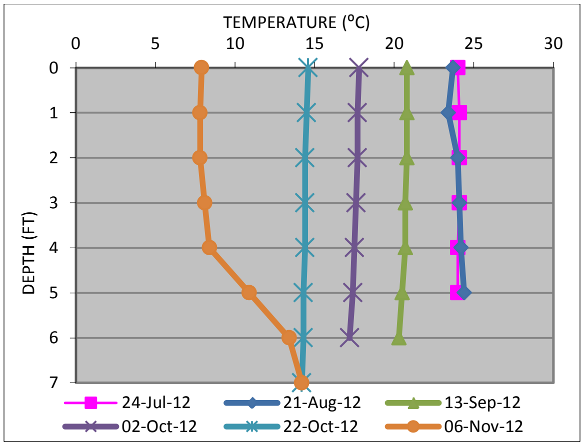
	Name	Affiliation	Date	Time
Sample Collected by :	______________________	___________________	___/___/_____	___:___
Sample Received by :	______________________	___________________	___/___/_____	___:___
Sample Received by :	______________________	___________________	___/___/_____	___:___

Cooler Temp Upon Arrival : _______________ °C

A series of graphs displaying the temperature profile data collected on 11 different dates during 2012 at Station #2 on Hummock Pond. Data from several different dates are included on each graph. The scale of temperature (in ^{o}C) is across the top, or X-axis, of the graph; the Y-axis on the left of each graph is the depth of the water column in the pond, with the surface at the top and the bottom sediment on the lower portion of the axis. Slight differences in total depth are due to variations in water level of the pond and differences in the exact location of the sample collection site each time.

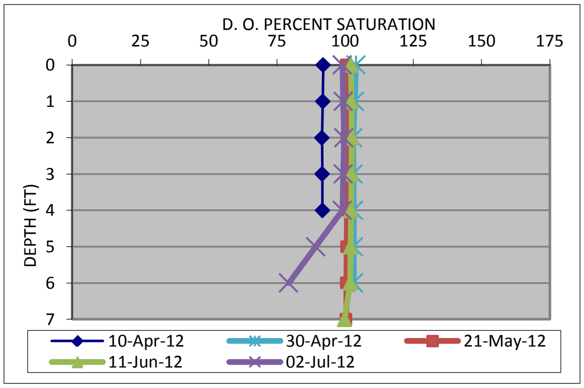


A

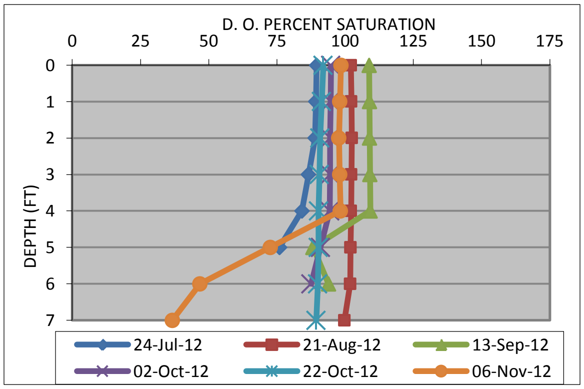


B

A series of graphs displaying the dissolved oxygen percent saturation profile data collected on 11 different dates during 2012 at Station #2 on Hummock Pond. Data from several different dates are included on each graph. The scale of dissolved oxygen percent saturation is across the top, X-axis, of the graph; the Y-axis on the left of each graph is the depth of the water column in the pond, with the surface on the top and the bottom area on the lower portion of the axis. Slight differences in total depth are due to variations in water level of the pond and differences in the exact location of the sample collection site each time..



A



B