IB Biology Extended Essay

# An Investigation into the Summer Phytoplankton Succession in Lake Gentofte, Denmark

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**Abstract**

The question that I address, research and answer in this IB Extended Essay biology investigation is, "how do selected phytoplankton groups change and succeed each other over the summer season in Lake Gentofte, in relation to selected abiotic factors?"

I wanted to find out how the primary producers in the lake, the phytoplankton, varied over the summer, and how this might be tied into various abiotic and biotic factors. I planned my investigation from previous knowledge obtained on an ecology fieldtrip as well as literary information from different sources.

From my research I learned that the lake I would be investigating, was one of the cleanest in the Copenhagen area. Therefore, my hypothesis was that the summer phytoplankton succession would follow the pattern of a temperate naturally eutrophic lake in the summer.

My investigation involved making eleven sample runs at the lake over a span of nearly two months. On each sample run I would take a plankton sample from the lake, as well as recording water and air temperatures, water conductivity, light intensity, water and wind conditions, water visibility, and watercolor. I would then use a microscope at home to identify phytoplankton groups and species and count them, and also identify grazing zooplankton as well as their relative abundance.

I could not, however, link all of the abiotic and biotic data to the phytoplankton succession data that I obtained. Therefore the data I obtained from light intensity measurements, water and wind conditions, water visibility and color, and grazing zooplankton abundance, will not be included in this essay.

The remaining relevant data did tie into the phytoplankton succession pattern and my hypothesis was correct; the phytoplankton in Lake Gentofte did succeed each other in the summer pattern of a phytoplankton succession in a naturally eutrophic lake in a temperate climate.

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**Introduction**

I chose the topic of phytoplankton succession because I have a personal interest in aquatic organisms, and because phytoplankton, despite their small size, are the most abundant plants on earth and provide the base for life wherever there is water[1]. Phytoplankton is interesting and worthy of study because it can tell us many things about an aquatic environment, of which there are many on our planet. As a part of the primary producers of any given body of water, phytoplankton are dependent on light and are therefore found in the surface of the water column[2], which makes them relatively easy to collect and study. Phytoplankton exhibit an observable seasonal variation, influenced by abiotic and biotic factors, where the individual groups of phytoplankton dominate and succeed each other in a certain order[3].

Plankton, according to *Webster's School Dictionary*[4] is "the passively floating or weakly swimming usually minute animal and plant life of a body of water." Phytoplankton is "planktonic plant life."[5] As phytoplankton is the plant constituent of plankton, the different organisms that make up phytoplankton obtain their energy through photosynthesis, though not all constituent groups rely solely on photosynthesis for their energy.

Phytoplankton is composed of several different, main groups, of which the selected groups that I found in the chosen lake and will be studying are: *Chlorophyceae* (green algae), *Cyanophyceae* (blue-green algae / cyanobacteria), *Chrysophyceae* (golden-yellow algae), and *Diatomophyceae* (diatoms).[6]

Along with light, phytoplankton needs nutrients to survive and grow. Other factors also have a large influence on the growth of the phytoplankton and their populations. As the seasons change, the phytoplankton are exposed to continuously changing light levels, temperatures, nutrient levels, and amounts of grazing zooplankton

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[1] Olrik, Kirsten. Danmarks plante plankton, Gads Forlag: København, 1997. Reference from introduction, p. 7.
[2] Abrahamsen, SV.E. Biologiske ferskvandsundersøgelser, Teknisk Forlag: København, 1994. Reference from chapter 2 under the section on plankton types and their seasonal variation, p. 21.
[3] Abrahamsen, p. 21.
[4] Webster's school Dictionary, Merriam-Webster: U.S.A., 1986. P. 668.
[5] Webster's School Dictionary, p. 679.
[6] Abrahamsen, p. 21.

as well as other phytoplankton types around them. Because of these changes in their environment which occur throughout the year in close relation to seasonal changes, phytoplankton grow, dominate, and succeed each other in annual rhythms.[7]

The Danish Ministry of Environment and Energy has a monitoring program running where it monitors the ecology of 37 lakes in Denmark. Lake Gentofte is not one of these 37 lakes, so my investigation could be interesting to compare with the data from these 37 lakes, which is published annually.

Because of this, personal interest, the close proximity of Lake Gentofte to where I live and the relative ease in collecting phytoplankton, I chose to study the phytoplankton in Lake Gentofte during the summer.

Research Question:

How do selected phytoplankton groups change and succeed each other over the summer season in Lake Gentofte, in relation to selected abiotic factors?

This question was derived from a similar question, which also addressed the biotic factor of zooplankton as well as several abiotic factors. After the zooplankton data and some of the abiotic data gathered was found to be unusable, the research question was changed to the above.

Aim:

To observe how the selected phytoplankton groups change and succeed each other over the summer season in Lake Gentofte in relation to the selected, simultaneously changing abiotic factors: date, water and air temperature, and conductivity. These factors will be defined and explained in the *variables* section.

[7] Olrik, reference from introductory paragraph to chapter 4: Phytoplankton in the food web of the water column, p. 13.

Hypothesis:

As Lake Gentofte is one of the cleanest lakes in the greater-Copenhagen area[8] it is expected that the seasonal succession of phytoplankton should follow the pattern of a naturally eutrophic lake, because it does not receive nutrients from sources such as farmland or wastewater and yet still is rich in plant life. It should also follow a pattern for the Danish climate, which is temperate. In a naturally eutrophic lake located in a temperate climate, phytoplankton succession during the spring and summer would follow this description[9]: Diatomophyceae have a maximum abundance during the spring and therefore dominate throughout April and May. In May the water becomes dominated mainly by Chlorophyceae and some Chrysophyceae, which turn into dead organic material by the grazing of zooplankton, creating the base of organic nutrient for the Cyanophyceae dominance to begin in late June or early August.[10]

Therefore, I expect to see that the phytoplankton samples will be dominated by Chlorophyceae and Chrysophyceae from June throughout July, and then in late July/early August they will both be succeeded by Cyanophyceae which will dominate in early august. The Diatomophyceae will have already surpassed their dominance in the spring, so I expect this group to have a low abundance relative to the other groups throughout the duration of the investigation.

**Variables**

Independent variables*:

*Date*: Phytoplankton succeed and dominate each other as the seasons change. As the summer continues, the phytoplankton will vary in a way that is related to the seasonal change involved, as the season develops. The other variables also change in relation the

[8] http://www.dofkbh.dk/lokalit/gentofte.htm [June 13th, 2003]
[9] Abrahamsen, p. 21.
[10] Abrahamsen, p. 22.
* Originally, as can be seen in the equipment and method sections, my investigation took light intensity, water and wind conditions, and water visibility into account as independent variables. These factors are important to the phytoplankton succession cycle, yet regrettably I had to omit the results that I obtained for these factors because the data could not be applied for reasons that will be explained in the discussion and evaluation section.

change of season. Whether or not the pattern follows the one described in the hypothesis can be concluded after the investigation.

*Air and water temperature*: The water temperature is related to the air temperature, and is also an indicator of seasonal change. The water temperature can have a great effect on the phytoplankton formation and survival as it increases the growth and multiplication of both phytoplankton and zooplankton.[11] Some types of plankton are more temperature dependent than others; for example Cyanophyceae are thermophilic organisms and thrive in warm water.[12]

*Conductivity*: The conductivity of the water measures the waters ability to conduct an electric current and is directly related to the total dissolved salts (ions) in the water. This measurement can indicate the amount of nutrients in the lake, which are very important for phytoplankton survival and growth. Conductivity is also proportionately related to water temperature; as the water temperature increases, so does the conductivity.[13]

Dependant variable:

*Phytoplankton abundance*: It is the abundance of this subcategory of plankton that my investigation is centered on. The independent variables will affect how abundant the phytoplankton groups are, which groups dominant throughout the summer, and when.

**Equipment**

Background:

Deciding what equipment to use for my plankton sampling and investigating was influenced greatly by an ecology field trip my biology class went on where one of the activities was to collect plankton and take several measurements from a lake.

To investigate my extended essay research question thoroughly I needed to be able to measure biotic and abiotic factors in and around the lake to see how they related to the plankton succession.

[11] http://www.biology-online.org/6/16_plankton.htm [June 5th,2003]
[12] Abrahamsen, p. 68.

After ordering a handheld plankton net, I researched into which factors have the greatest determining influences on phytoplankton and their populations. I found that the most important factors affecting phytoplankton populations seasonally are light intensity and water transparency, temperature, wave and wind action, abundance of inorganic nutrients, and grazing zooplankton populations.[14] My school had a light intensity meter, and a temperature meter. Measuring the abundance of inorganic nutrients was my main problem, as it requires advanced equipment. With a conductivity meter, however, I could measure the conductivity of the water and see how it changed in the lake over the course of my summer investigation. I could use the data as an indicator of nutrient levels in the lake; in my literary research I found that the conductivity of water "Measures water's ability to conduct an electric current and is directly related to the total dissolved salts (ions) in the water."[15]

Gentofte Lake is not very deep, especially at the site of my sample collection (only 1 meter), and is sheltered by tall reeds and surrounding trees. Therefore I decided to simply observe and note down the wind, wave/current, and water visibility conditions. I obtained microscopes, slides, sample jars, and pipettes from my school biology lab. After figuring out what exact materials I needed to carry out my investigations, and obtaining them all, my materials list was as follows:

List:

-One handheld plankton net. (Mesh size: 30 micrometers.)

-One 5-liter bucket.

-Two sample jars.

-One temperature meter and probe.

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[13] http://wow.nrri.umn.edu/wow/under/glossary.html [June 6th, 2003]
[14] http://wow.nrri.umn.edu/wow/under/primer/page14.html [June 6th, 2003]
[15] http://wow.nrri.umn.edu/wow/under/glossary.html [June 7th, 2003] This is an online glossary where I looked up the word conductivity.

-One light intensity meter and probe.

-One conductivity meter and probe.

-One notebook with pen.

-One microscope. *(magnification: x160.)*

-5 slides, each with a circular groove in the center.

-Two pipettes.

**Method**

Background:

I came up with the final method after visiting the sample site for a pre-investigation run. I found an optimal spot, which was out over the lake on a wooden footpath. Here I could tie my plankton net to a railing and easily fill the water bucket with lake water to filter through the net. I decided to filter 20 buckets (100 liters) of water through the net because it would be a manageable number to work with if I should decide to make volumetric calculations of the plankton. I decided to measure air and water temperature, light intensity, and water conductivity before and after the water filtration, to see if any changes occurred in the mean time, and to get more consistent data. The factors such as water visibility, wind and wave/current conditions, and water color, I decided were to be noted down upon arrival at the location, and any changes to be noted after water filtration. Viewing the sample as quickly as possible was important, so that the zooplankton would not graze upon the phytoplankton in the sample, and alter the phytoplankton counts. I decided for consistency and ease of calculation to examine five slides with 0.1 ml of the sample in each, after each sampling run, giving me phytoplankton population counts for 0.5 ml of each sample.

Data collection:

Plankton samples were collected from the same location at Lake Gentofte, on eleven different sample runs: June 17th, June 23rd, June 26th, June 29th, July 2nd, July 20th, July 30th, August 2nd, August 5th and August 8th of the year 2003. It was intended for a sample and measurements to be taken every third day, but due to overlapping events, there are gaps in the sample dates. On each of these sample runs the method for plankton sample collection below was followed.

-The handheld plankton net was tied to the railing of the wooden footpath and hung over the lake.

-The wind condition, weather condition, water movement (wave/current), water visibility, and watercolor were observed and recorded.

-The temperatures of the air and surface water* were measured and recorded before and after the plankton sampling.

-The light intensity just above the water surface was measured and recorded before and after the plankton sampling.

-The conductivity of the surface water was measured and recorded before and after the plankton sampling.

-The 5-liter bucket was filled with surface water from the lake and poured into the handheld plankton net so that the 5 liters of water were filtered through it for plankton. This was done twenty times so that one hundred liters of surface lake water were filtered for plankton in total per sample run.

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* Surface water means, in the context of my investigation, water at a depth of 0 – 20 centimeters below the water level.

-The concentrated plankton sample was emptied into the sample jar, which was then closed tightly.

Examining plankton:

Immediately after the plankton sample was collected, the sample was brought to the examination area. Here it was studied on the same day, to identify plankton species present in the sample.

-The pipette was used to collect some of the plankton sample and pour 0.1 ml of it into the circular groove of a slide.

-The slide was placed under the microscope and viewed at a magnification x160. Zooplankton species and their relative abundances were noted by description, comparison, and estimation, but not counted, as it was impossible to count the moving organisms.

-The selected phytoplankton group species were identified and counted by moving across the slide area containing the sample with the microscope, and writing down the number of each phytoplankton from each species seen.

-This was repeated four times so that in total five slides, equivalent of 0.5 ml of the sample, were examined for zooplankton and phytoplankton.

**Data Processing**

The calculated and applied data tables and calculation examples can be found in the appendix. The applied data is displayed below as figures.

Calculations:

- For the water and air temperature, and conductivity measurements I took readings from before and after the plankton sample was collected, on each sampling run, so that I could take the average of the two readings and get an average value for the measurements at the time that the plankton was collected. Adding the two values together and dividing them by two gave their average value.

  Value before = $b$

  Value after = $a$

  $$(b + a) \div 2 = average$$

  For an example see Appendix A.

- The percent abundance of each of the selected groups of phytoplankton was calculated by counting all the phytoplankton that belonged to each of the groups in 0.5 ml of the sample that was collected. By counting all the green algae, blue-green algae, golden-yellow algae, and diatoms in 0.5 ml of a sample, I could calculate the percent abundance of each of those selected groups on that day. This was done by adding up the total number of phytoplankton counted in the 0.5 ml of the sample that was examined. Then, the total number of phytoplankton counted for each of the four selected groups was divided by the total number of phytoplankton counted in the 0.5 ml of the sample, and then multiplied by 100. This then gave the percent abundance of each of the selected phytoplankton groups in the sample, which was rounded to the nearest whole number. For an example see Appendix A.

- The phytoplankton evaluation, also known as the *Modified Nygaard Compound Quotient*, is an index that gives an impression of the level of nutrients in a lake or pond. From the number of species of 5 different groups of phytoplankton, an index value can be calculated which can indicate and classify the level of pollution in a lake or pond.

Phytoplankton Quotient = Q

$$Q = \frac{B+G+C+E}{D}$$

The *numerator* includes phytoplankton with eutrophic tendency:

B = Cyanophyceae

G = Chlorophyceae

C = Diatomophyceae

E = Euglenaceae*

The denominator includes phytoplankton with dystrophic – oligotrophic tendency:

D = Desmidiaceae*

$Q < 3$ = nutrient poor – slightly polluted

$3 < Q < 10$ = nutrient rich – polluted

$Q > 10$ = heavily polluted

For an example see Appendix A.

*In my investigation I found no Euglenaceae phytoplankton. The Desmidiaceae are a subcategory of Chlorophyceae, and through the use of identification books, I could identify the desmids from the remaining Chlorophyceae species.

**Data Presentation and Analysis**

Figure 1: Selected phytoplankton counts in Lake Gentofte on sampling dates, 2003.

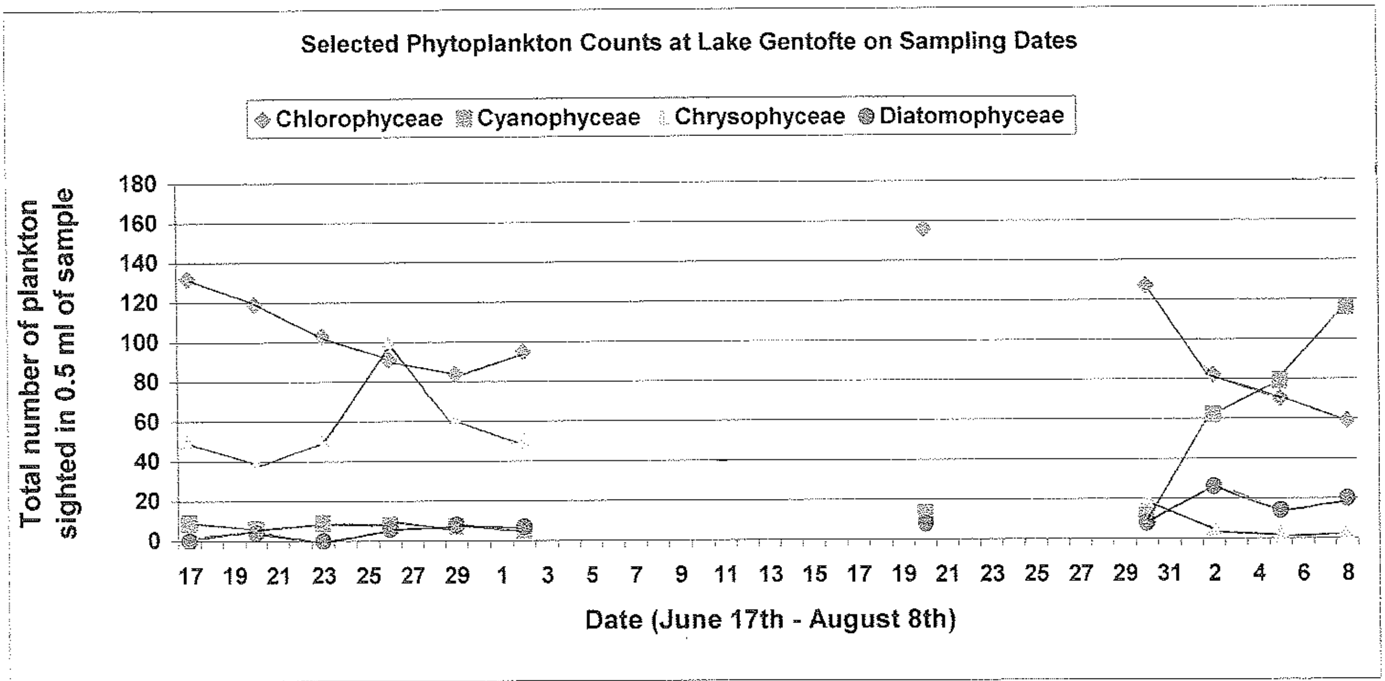
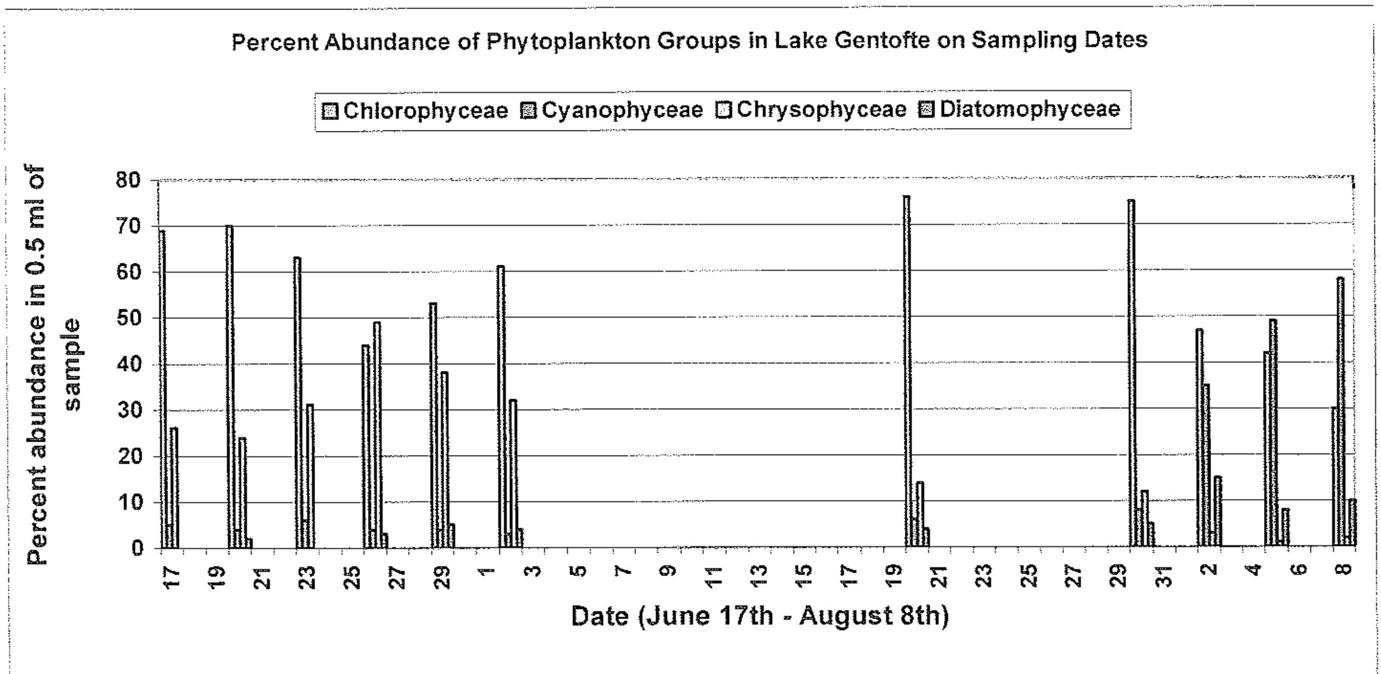



Figure 2: Percent abundance of selected phytoplankton in Lake Gentofte on sampling dates, 2003.



As can be seen on Figure 2, on the first three sample dates the Chlorophyceae are the must abundant phytoplankton in the samples, with abundances between 60 and 70 percent. Though their abundance decreases over these three sample days with an abundance of 63 percent on the third sample date, they are, throughout these first three samples, more than twice as abundant as any of the other selected groups. The second most abundant group is the Chrysophyceae, which maintain a steady abundance of around 25 percent, dropping slightly, however, on the second sample date, and then increasing on the third sample day with an abundance of 31 percent. This increase continues into the fourth sample date, the 26th of June, where they overtake the Chlorophyceae in abundance, and reach their maximum-recorded abundance of 49 percent. From the third sample date to the fourth sample date, the Chlorophyceae have continued to decrease in abundance and reach an abundance of 44 percent on the 26th of June; lower than that of the Chrysophyceae. The slight domination of Chrysophyceae is short lived; already on the next sample date, the 29th of June, have the Chlorophyceae again become the dominant phytoplankton group with an abundance of 53 percent. The Chrysophyceae have decreased to an abundance of 38 percent. The increase of the Chlorophyceae and the decrease of the Chrysophyceae continue into the 2nd of July, where the Chlorophyceae have an abundance of 61 percent and the Chrysophyceae one of 32 percent.

Throughout these first 6 sample dates, the Cyanophyceae and Diatomophyceae have not had high abundances. The Cyanophyceae have had the third highest abundance, only to be exceeded on the fifth and sixth sample dates by the Diatomophyceae.

The sample on July 20th, taken after a sampling break of 17 days, shows that the Chlorophyceae are the dominant phytoplankton group in the Lake, with an abundance of 76 percent, their maximum-recorded abundance in this investigation. The Chrysophyceae have an abundance of 14 percent, the Cyanophyceae have an abundance of 6 percent, and the Diatomophyceae have an abundance of 4 percent. In the next sample, 10 days later, July 30th, the situation is similar. Notably, the Cyanophyceae are beginning to rise, with an abundance of 8 percent, and the Chrysophyceae are decreasing even more, down to 12 percent abundance. The abundance of the Diatomophyceae is at a steady 5 percent.

Over the last three samples, taken on the 2nd, 5th and 8th of August, an interesting change occurs in the phytoplankton dominance: a succession. On the 2nd of August, the abundance of Chlorophyceae in the lake has been reduced dramatically to 47 percent, whereas the Cyanophyceae have increased in abundance to 35 percent.

The Diatomophyceae also show the first sign of any real abundance change on this date, increasing to an abundance of 15 percent. This, however, decreases to abundances of 8 and 10 percent in the next two samples on the 5th and 8th of August. The Chrysophyceae have also had a large change as they have begun to fade away on the 2nd of August with a drop to an abundance of 3 percent that drops to 1 percent on the 5th of August, and increases to 2 percent on the 8th.

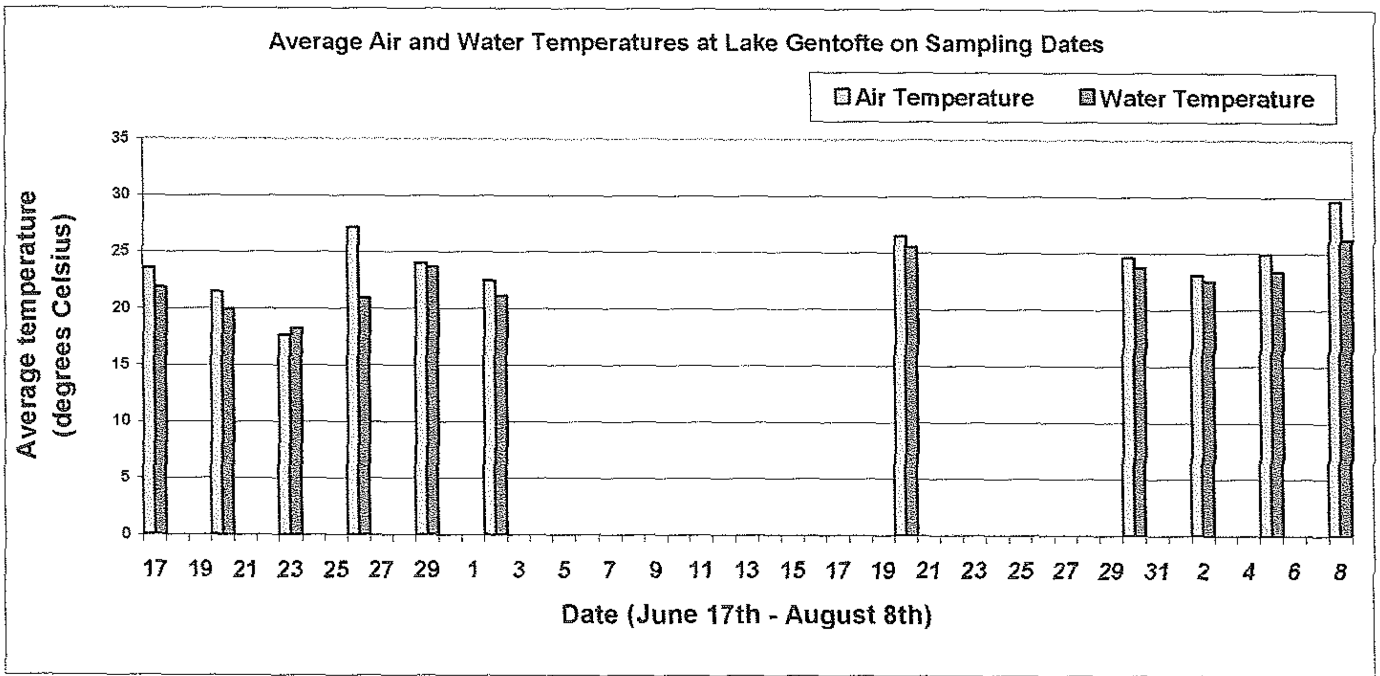
On the 5th of August, the change in the Chlorophyceae is continuing as they decrease to 42 percent abundance, and are succeeded by the Cyanophyceae with an abundance of 49 percent.

This change continues on to the last sample date, the 8th of August, where the Cyanophyceae continue their domination with a percent abundance of 58 percent as opposed to the abundance of Chlorophyceae, at 30 percent.

Therefore, in brief, the Chlorophyceae dominate in the lake from June to early August, only being succeeded once on June 26th by the Chrysophyceae, and in early August are succeeded in dominance by the Cyanophyceae.

This followed the pattern of dominance and succession that I was expecting, as stated in my hypothesis; that the phytoplankton samples will be dominated by Chlorophyceae and Chrysophyceae from June throughout July, and then in late July/early August they will both be succeeded by Cyanophyceae which will dominate in early August.

Figure 3: Average air and surface water temperatures at Lake Gentofte on sampling dates, 2003.




How did the simultaneously changing selected abiotic factors affect and relate to the phytoplankton group changes and successions? They will have to be addressed one at a time.

Firstly, the temperature of the water in and air around the lake can be seen on Figure 1, to have fluctuated greatly in June, providing unstable conditions for thermophilic phytoplankton, particularly Cyanophyceae. From June 17$^{th}$ to the 23$^{rd}$ the temperatures dropped, then rose on the 26$^{th}$ only to drop again till July 2$^{nd}$. When a stable, continuous increase in both temperatures occurred in late July and on into August, the Cyanophyceae were provided with the stable, increasingly warm environment that they need to survive and grow in as thermophiles. Therefore it can be seen that the water and air temperatures are related to the specific phytoplankton succession pattern, and tie into it. It can partially explain why the Cyanophyceae succeed the other groups in early August instead of early June for example.

Figure 4: Average conductivity of surface water in Lake Gentofte on sampling dates, 2003.

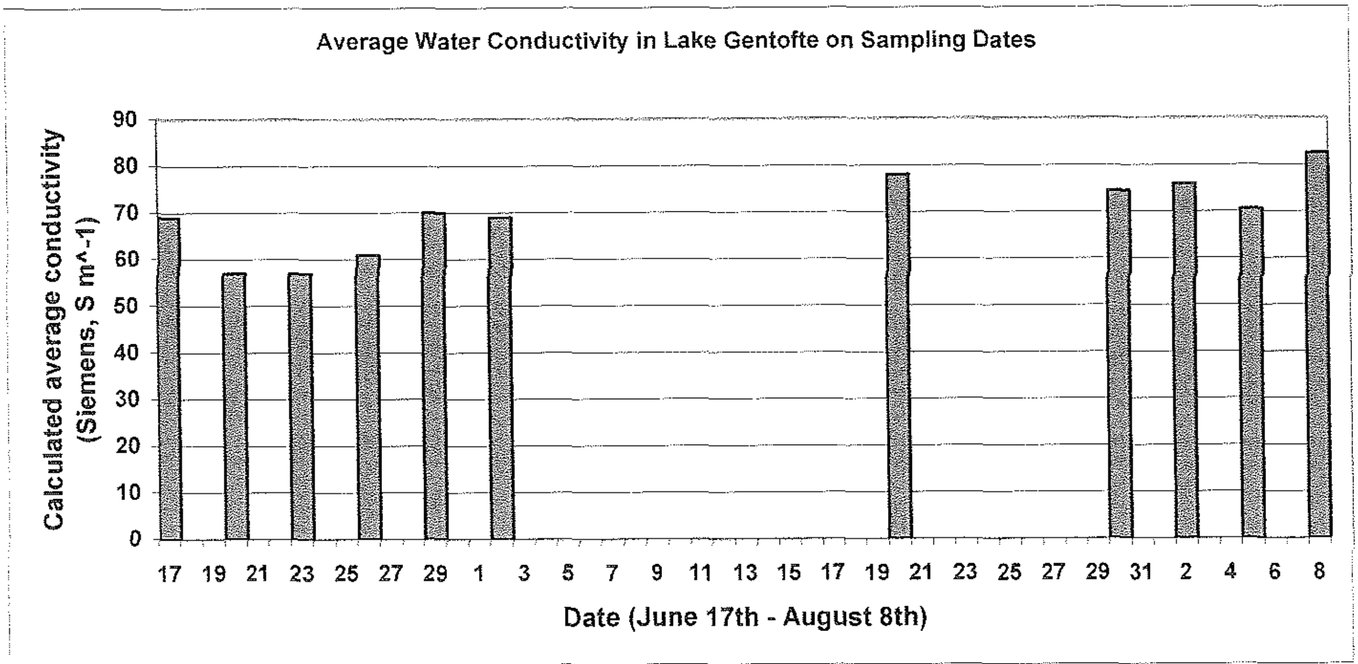



Figure 5: Phytoplankton quotient in Lake Gentofte on sampling dates, 2003.

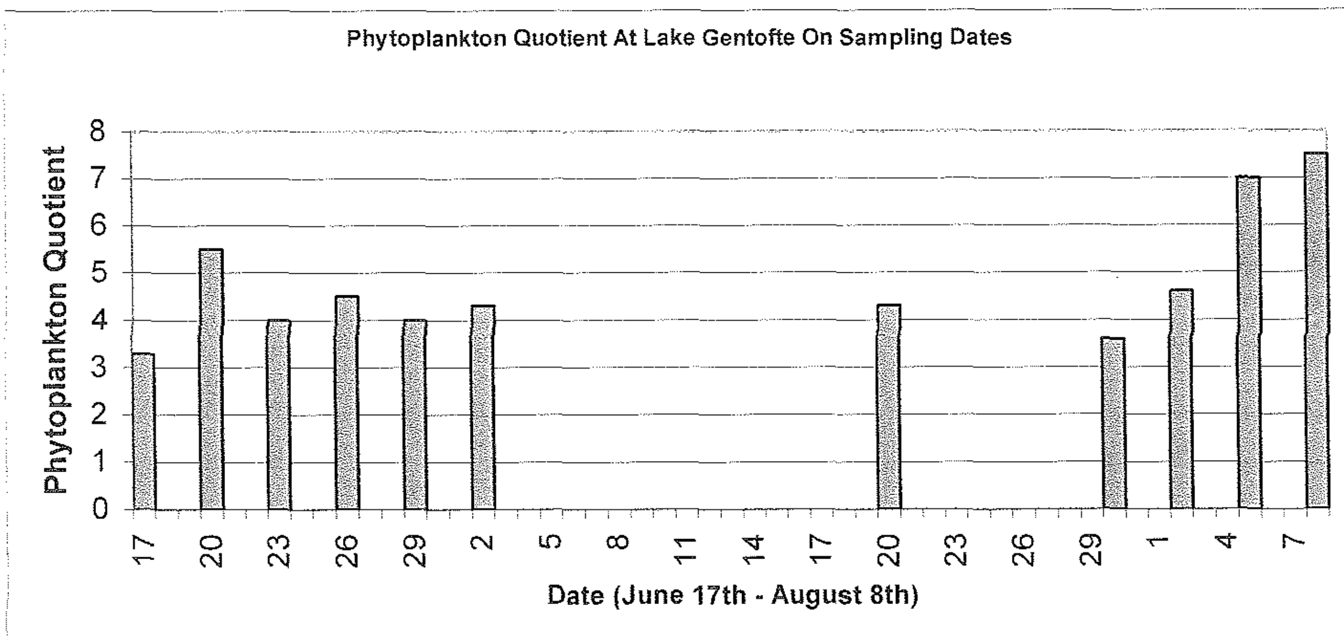



Figure 4, the lake conductivity, and Figure 5, the phytoplankton quotient, are both indicators of nutrient levels in the Lake. The conductivity levels in Figure 4 are higher in late July and August than they are in June, indicating the build up of nutrients from dead organic matter that has been broken into salts and ions by decomposers, providing nutrients for the growing Cyanophyceae population. Figure 5 also shows that there is a nutrient increase, by making a quotient from the species present. Because the conductivity cannot solely be credited to nutrients, the phytoplankton quotient is a good indicator of nutrients, and it clearly shows that there is an increase towards the end of July, in nutrients, where the level has remained fairly stable until then. This again ties into the specific phytoplankton succession pattern as it can explain the sudden succession on the Cyanophyceae. The build up of dead organic matter supplies the Cyanophyceae with nutrients for their leap at dominance in the Lake.

**Conclusion, Discussion and Evaluation**

Conclusion:

In conclusion, my investigation and the applied data shows that the selected phytoplankton groups in Lake Gentofte moved in a succession pattern that followed that of a naturally eutrophic lake, as I predicted in my hypothesis. The monitored abiotic factors tied into the succession in a way that supports the succession.

Discussion and evaluation:

There were data and observations that I collected throughout my investigation that were not used analytically for various reasons. The light intensity measurements could not be applied to the phytoplankton data because the sensor was inaccurate and gave readings that were incorrect. It did show that there were different light levels on some of the sample dates; still, this could not be used effectively in analyzing the phytoplankton data. Even if the sensor had been working correctly, the data obtained from it would only reflect the light intensities at those exact moments that they were read. Shifting cloud cover, for example, could change the light intensity at the sample location in a very short period of time, so that later, after taking a reading, the light intensity might be completely different. Therefore I could not use the light intensity data in my investigation analysis.

The observations I made on grazing zooplankton were impossible to apply to the quantitative phytoplankton data, as it was only descriptive. I could not draw and scientific connections between the descriptions of the grazing zooplankton abundance and the numerical phytoplankton succession data.

The accuracy of my phytoplankton counts should have been measured with a percentage error calculation, but I did not take down notes for this to be possible.

Though I noted wind and water conditions throughout the sampling runs, the notes were mere observations that only described conditions at that exact moment in time. Therefore I did not consider using those observations in connection with understanding the phytoplankton succession pattern.

For a high school investigation I think that my method was extensive and attempted to cover many pertinent variables, and more. The amount of data that I gathered was far more than I needed to answer my hypothesis, and some of it was also useless. Therefore I had to re-examine my research question and narrow it down, so that I would be better suited to answer it.

If I were to conduct this investigation again I would want to address all the factors that I originally intended to monitor. I would use a light intensity sensor that would be at the sample location permanently for the investigation duration, to track the change in light intensity continuously. This could then show a change over the time of the investigation, which could then be applied to the phytoplankton succession.

To be able to count the zooplankton I would add formaldehyde to my samples, which would kill the organisms and enable me to count them.

I would also try to measure the nutrients in an even more accurate way, so that the nutrient data could be even more reliable.

**Appendix**

A: Calculations examples.

**Average**:

20.5°C = *b*

22.5°C = *a*

(20.5 + 22.5) ÷ 2 = 21.5°C

21.5°C = *average*

**Phytoplankton percent abundances**:

Number of Chlorophyceae counted: 119

Number of Cyanophyceae counted: 6

Number of Chrysophyceae counted: 40

Number of Diatomophyceae counted: 4

Total number of selected phytoplankton counted: 169

Chlorophyceae percent abundance: 100(119 ÷ 169) = 70.41 = 70%

Cyanophyceae percent abundance: 100(6 ÷ 169) = 3.55 = 4%

Chrysophyceae percent abundance: 100(40 ÷ 169) = 23.66 = 24%

Diatomophyceae percent abundance: 100(4 ÷ 169) = 2.36 = 2%

**Modified Nygaard Compound Quotient**:

B = 2

G = 8

C = 0

E = N/A

D = 3

(2 + 8 + 0) ÷ 3 = 3.3

Q = 3.3: nutrient rich – polluted.

**B**: Processed data tables.

Table 1: Sensor Probe data. This table includes calculated average temperatures (air and water), and the water conductivity for each of the sampling dates. These averages are taken from sensor probe data collected on each sampling run, and are made to give a view of what the overall conditions addressed by these variables were, during the day on that specific date.

The averages were calculated using the *average calculation* method, shown on page 9 (example in appendix A).

| Date: | June 17th | June 20th | June 23rd | June 26th | June 29th | July 2nd | July 20th | July 30th | August 2nd | August 5th | August 8th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Average air temperature (°C) | 23.60 | 21.50 | 17.70 | 27.20 | 24.05 | 22.50 | 26.55 | 24.65 | 23.1 | 25.00 | 29.65 |
| Average water temperature (°C) | 21.90 | 20.00 | 18.30 | 20.95 | 23.70 | 21.20 | 25.55 | 23.75 | 22.6 | 23.45 | 26.25 |
| Average conductivity (S m^ -1) | 69.00 | 57.00 | 57.00 | 61.00 | 70.00 | 69.00 | 78.00 | 74.50 | 76.00 | 70.50 | 82.50 |

Table 2: Phytoplankton population data. This table shows the total count of plankton for each of the four selected groups that were monitored. The values were derived from species counts, which were then added together into the particular groups that they belong to.

| Date: | June 17th | June 20th | June 23rd | June 26th | June 29th | July 2nd | July 20th | July 30th | August 2nd | August 5th | August 8th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total number of Chlorophyceae counted in 0.5ml of sample: | 132 | 119 | 103 | 91 | 84 | 95 | 156 | 127 | 82 | 70 | 59 |
| Total number of Cyanophyceae counted in 0.5ml of sample: | 9 | 6 | 9 | 8 | 7 | 5 | 13 | 13 | 62 | 79 | 116 |
| Total number of Chrysophyceae counted in 0.5ml of sample: | 50 | 40 | 50 | 100 | 60 | 50 | 30 | 20 | 5 | 2 | 3 |
| Total number of Diatomophyceae counted in 0.5ml of sample: | 0 | 4 | 0 | 6 | 8 | 7 | 8 | 8 | 26 | 14 | 20 |
| Total phytoplankton from the selected groups found in 0.5 ml of sample: | 191 | 169 | 162 | 205 | 159 | 157 | 207 | 168 | 175 | 165 | 198 |

Table 3: Phytoplankton percent abundance. This table shows the percent abundance of each of the 4 selected phytoplankton groups that were monitored in this investigation, over the 11 sampling dates. The abundance shows which group is dominating and gives and indication of phytoplankton succession. The phytoplankton percent abundance values were derived from population data (as seen in Table 2), which was plugged into the *phytoplankton percent abundance calculation* (example in appendix A).

| Date: | June 17th | June 20th | June 23rd | June 26th | June 29th | July 2nd | July 20th | July 30th | August 2nd | August 5th | August 8th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlorophyceae percent abundance in sample: | 69 | 70 | 63 | 44 | 53 | 61 | 76 | 75 | 47 | 42 | 30 |
| Cyanophyceae percent abundance in sample: | 5 | 4 | 6 | 4 | 4 | 3 | 6 | 8 | 35 | 49 | 58 |
| Chrysophyceae percent abundance in sample: | 26 | 24 | 31 | 49 | 38 | 32 | 14 | 12 | 3 | 1 | 2 |
| Diatomophyceae percent abundance in sample: | 0 | 2 | 0 | 3 | 5 | 4 | 4 | 5 | 15 | 8 | 10 |

Table 4: Phytoplankton species counts. The species counts shown on this table represent the number of species seen that belong to one of the four selected groups of phytoplankton, over the duration of the investigation. These values are used in the calculation of the *Modified Nygaard Compound Quotient,* also called the Phytoplankton Quotient, which can be used to indicate nutrient levels in a lake. An example of the *Modified Nygaard Compound Quotient* can be seen in Appendix A.

| Date: | June 17th | June 20th | June 23rd | June 26th | June 29th | July 2nd | July 20th | July 30th | *August* 2nd | *August* 5th | *August* 8th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of *Desmediaceae* species in examined sample: | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| Number of other Chlorophyceae species in examined sample: | 8 | 9 | 6 | 6 | 8 | 8 | 8 | 7 | 7 | 7 | 8 |
| Total number of Chlorophyceae species in sample: | 11 | 11 | 8 | 6 | 11 | 11 | 11 | 10 | 10 | 9 | 10 |
| Number of Cyanophyceae species in sample: | 2 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 5 | 5 | 5 |
| Number of Chrysophyceae species in sample: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Number of Diatomophyceae species in sample: | 0 | 1 | 0 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 2 |

Table 5: Phytoplankton Quotient. The quotient is an indicator of nutrients in a specific body of water which, is derived from an equation analysis of phytoplankton species present in the water. The higher the quotient, the more nutrients are present in the water.

| Date: | June 17th | June 20th | June 23rd | June 26th | June 29th | July 2nd | July 20th | July 30th | August 2nd | August 5th | August 8th |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phytoplankton quotient, Q. | 3.3 | 5.5 | 4.0 | 4.5 | 4.0 | 4.3 | 4.3 | 3.6 | 4.6 | 7.0 | 7.5 |

**Bibliography**

Abrahamsen, SV. E. Biologiske ferskvandsundersøgelser, Teknisk Forlag, København, 1994.

Belcher, Hilary and Erica Swale. A beginner's guide to Freshwater Algae, Crown, Cambridge, 1978.

Biology Online. Available: www.biology-online.org

Dansk Ornitologisk Forening. Available: http://www.dofkbh.dk

Jensen, Jens Peder, et al. Ferske vandområder – Søer: Vandmiljøplanens Overvågningsprogram 1994, Miljø- og Energiministeriet, Danmarks Miljøundersøgelser, 1995.

Mandahl-Barth, G. Hvad finder jeg i sø og å, Politikens Forlag A/S, København, 1991.

Olrik, Kirsten. Danmarks Planteplankton, Gads Forlag, København, 1997.

Sand-Jensen, Kaj, et al. Basisbog i Ferskvands økologi, Gads Folrlag, København, 1991.

Water on the Web. Available: http://wow.nrri.umn.edu

Webster's School Dictionary. Merriam-Webster, U.S.A, 1986.