Cyanobacterial populations in Lake Hjorten and Lake Vångaren depending on increased temperature

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Nyckelord
Cyanobacteria, phytoplankton, temperature, water quality, climate change, lake.
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Abstract

Västervik Municipality has had problems with odorous compounds in its primary water source, Lake Hjorten. Geosmin and cyanobacterial blooms have been detected in the lake. This report aims to experimentally investigate the cyanobacterial populations in the primary and secondary freshwater lakes depending on the climate change factor temperature. An understanding of number of cells is the foundation to understand the potential harmful chemical levels. This provides an opportunity to predict the water quality in the lakes in the future due to climate change. The results show that cyanobacteria did not benefit from an increase in temperature from 10°C to 18°C solely during autumn. However, the diatom Aulacoseira did increase in numbers although it is not known to produce odorous compounds. Consequently a warmer Swedish autumn would not cause worse drinking water quality in absence of other contributing factors according to this study.

Introduction

Background

Västervik Municipality’s main waterworks is called Hjortenverket and its primary water source is Lake Hjorten. Lake Vångaren is the waterworks’ reserve water source. Lake Hjorten is currently used to its maximum potential. Therefore a pipe has been installed to allow for transfer of water from Lake Vångaren to Hjorten. The municipality’s water supply is consequently depending on good water quality in Lake Hjorten. The lake has been affected severely by algal blooms and chemical compounds causing odorous smell and taste. The levels of microcystin in Lake Hjorten has been below 0.1 µg/liter during both the two latest cyanobacterial blooms (Toxicon 2015; Toxicon 2014). These analyses have found odorous compounds in large quantity in one of the investigated lakes, Hjorten. The chemical compounds are thought to be linked to cyanobacteria during summer and autumn. Currently, there is an on-going investigation to find out if Lake Vångaren would be a better main water source. This study will serve as part of that investigation.

Temperature affecting phytoplankton

The composition and presence of phytoplankton are mainly affected by temperature, light, nutrition and wind (Blaha et al 2009; Jöhnk et al 2008; Aneer & Löfgren 2007; Granéli & Turner 2006; Glibert et al 2005; Tikkanen & Willén 1992; Goldman & Ryther 1976). Light seems to be the most important factor (Yang et al 2012; Tikkanen & Willén 1992). Most organisms prefer warmer water where growth and physiological rates increase (Tikkanen & Willén 1992; Granéli & Turner 2006). Fresh water is populated by most organisms during the late summer and least organisms during the winter (Madigan et al 2012; Tikkanen & Willén 1992). Cyanobacteria dominate during summer because of their relatively higher temperature optima of approximately 25°C (Valeria Fiorda Giordanino et al 2011; Robarts & Zohary 1987; Konopka & Brock 1978). A part of the explanation is their photosynthesis advantage for higher production of carbohydrates towards other phyla in warmer temperatures (Coles & Jones 2000; Valeria Fiorda Giordanino et al 2011). Growth of especially *Microcystis* sp. is almost absent in temperatures under 15°C (Chu et al 2007; Robarts & Zohary 1987; Konopka & Brock 1978). *M. aeruginosa* increase very little in growth from 15°C to 20°C but doubles if temperature increase from 20°C to 25°C (Nicklisch & Kohl 1983 cited by Chorus 2001). Plasticity enables populations to adapt to temperatures +/- 5°C so they can function well in different environments (Konopka & Brock 1978). Cyanobacteria like *M. aeruginosa* can form harmful algal blooms. In
contrast, diatoms bloom during spring and autumn when the water is colder than cyanobacteria and green alga prefer (Tikkanen & Willén 1992; Konopka & Brock 1978). From winter to summer the temperature increase from 10 to 30°C in New York, USA, and the phytoplankton composition shifts from domination by diatoms to green alga to cyanobacteria (Canale & Vogel 1974 cited by Davis et al 2009). Seasonal changes as well as climate change is therefore affecting the composition and size of phytoplankton worldwide (Granéli & Turner 2006; Jöhnk et al 2008). Harmful algal blooms thrive in warm temperatures (Paerl & Huisman 2008) and are in fact likely to increase in eutrophic freshwater ecosystems (Jöhnk et al 2008).

Climate change

Climate change is causing the number of days with extremely high temperatures to increase worldwide (Gruza et al 1999; Bonsal et al 2001; Wang & Gaffen 2001; cited by Houghton et al 2001). The increase of average temperature will not cause severe consequences, but the increased frequency of extreme weathers can be severe (Bernes 2007). Consequently this can lead to temperatures never before recorded. Furthermore the number of days with minimum temperature of 0°C are decreasing in northern and central Europe (Heino et al 1999; Bonsal et al 2001; Zhai et al 1999). The growing season length in many regions have increased by 5 – 15 % so far (Frich et al 2001). The climate that characterize countries south of the Mediterranean Sea, i.e. elevated temperature and drought, can become increasingly dominating northward (Bernes 2007). If you look more closely at Sweden, the global warming will be slightly more severe than the average for the rest of the world. Even more detailed information from Bernes explains the global warming effects in the coasts and southern parts. The city of Västervik is located at the east coast which will be affected more by global warming than the west coast, due to the nearby Atlantic that has a cooling effect. Västervik is located in southern Sweden which can possibly obtain a similar climate to France within the next 100 years. Bernes also concludes that within these next 100 years the lowest temperature recorded may rise with 8 – 12°C and the highest temperature increase by 5°C.

Nutrient availability

Phosphorous and nitrogen are the two most required nutrients causing eutrophication and algal bloom (Yang et al 2012; Willén 2001; Tikkanen & Willén 1992). Higher nitrogen levels regardless of temperature improve the growth of species like Microcystis aeruginosa (Yang et al 2012). Cyanobacteria use nitrate or ammonia as source for nitrogen (Madigan et al 2012). Furthermore nitrogen-fixing species are common. Nitrogen limitation decreases growth of cyanobacteria like M aeruginosa (Singh & Singh 2015; Yang et al 2012; Moreno et al 1998). If there is more nitrogen available, bacterial production increases (Peixoto et al 2013). Eutrophication of lakes causes harmful algal blooms to occur more frequently and increase in magnitude (Glibert et al 2005). This is a problem in Västervik and the rest of the world. Lakes of higher trophy are generally dominated by cyanobacteria like Microcystis, Planktothrix, Limnothrix, Anabaena or Aphanizomenon (Dokulil & Teubner 2000). Oligotrophic lakes are dominated by diatoms, golden algae and cryptomonads (Tikkanen & Willén 1992). In this experiment water from Lake Hjorten and Lake Vångaren is used. They are classified as eutrophic and mixotrophic respectively (Medin 2015).
Toxins and odorous compounds

Some cyanobacteria are known to reproduce massively and produce toxins that can kill fish and warm-blooded animals (Madigan et al 2012; Tikkanen & Willén 1992). 25 – 75 % of cyanobacterial blooms are toxic (Chorus 2001). The toxins can be classified in five groups: hepatotoxins, neurotoxins, cytotoxins, dermatoxins and irritant toxins (Plugmacher & Wiegand 2005). They are named after the toxin’s targets, e.g. hepato means liver (Blaha et al 2009; Willén 2001). Not only cyanobacteria produce toxins - diatoms are capable as well (Pan et al 2001 cited by Granéli & Turner 2006). Microcystin is a hepatotoxin with more than 80 structural variants that is produced by genera like Microcystis, Anabaena, Planktothrix and Aphanocapsa (Carmichael 1992 cited by Plagmacher & Wiegand 2005; Chorus 2001; Clercin). Recently it has been found that Merismopedia, formerly thought to be harmless, also produce low concentrations of microcystin (Mohamed & Al Shehri 2010). Anabaena and Planktothrix can potentially produce neurotoxin that cause life-threatening muscular paralysis (Clercin). Limnothrix has been found to produce a kind of unknown cyanobacterial toxin that has been shown to be acute toxic to small mammals (Humpage et al 2012). It is complex to understand what triggers microcystin levels to rise. Some data indicate that the maximum amount of toxin is found at temperatures of 20 - 24°C even though the optimum temperature for cellular growth in these cases were higher (van der Westhuizen & Eloff 1985). Other data binds microcystin production tightly to cellular division (Orr & Jones 1998). These findings also indicate that the levels of microcystin does not change while the cells are in stationary or death phase.

Specific diatoms are capable of secreting phycotoxins under perfect light conditions (Granéli & Turner 2006). Furthermore they can form a bloom that later on sink to the bottom and cause local oxygen depletion. These diatoms have adapted a survival mechanism that works efficiently under nutrient depletion. They create a frustule out of available silicon that requires less energy than synthesizing an organic cell wall (Raven 1983 cited by Granéli & Turner 2006).

Many different phytoplankton groups produce non-toxic compounds that cause problems in waterworks (Madigan et al 2012; Granéli & Turner 2006; Willén 2001; Lin 1977). These compounds can cause musty-earthy taste and smell odor in freshwater but are harmless (WHO 2015; Lin 1977). The major compounds responsible for most cases of bad taste and smell in aquatic environments are geosmin and 2-methylisoborneol (WHO 2015; Wang & Li 2015; Madigan et al 2012). The list of odor-producing phytoplankton is long but some genera worth mentioning are: Asterionella, Cyclotella, Fragilaria, Tabellaria, Dinobryon, Scenedesmus, Staurastrum, Dictyosphaerium, Gomphosphaeria, Pediasstrum, Diatoma, Stephanodiscus, Synedra and several flagellates (Lin 1977). Growth-inhibiting temperature cause the chemical levels of 2-methylisoborneol and geosmin produced by some cyanobacteria to increase (Wang & Li 2015). The levels of cyanotoxins does not follow a similar pattern (WHO 2015). Levels of odorous compounds does in fact seem to be unrelated to cyanotoxins.

Cyanobacteria and other phytoplankton

Cyanobacteria harvest light with their phycobilisomes opposed to plants (Campbell et al 1998). Cyanobacteria gain their characteristic blue-green colour by chlorophyll-a and phycocyanin (Madigan et al 2012; Tikkanen & Willén 1992; Willén 2001). Other pigments are yellow carotenoids and red phycocerythrin (Madigan et al 2012; Tikkanen & Willén 1992; Willén 2001). By synthesizing these different pigments it is possible to absorb light of different wavelengths and therefore inhabit deep water and tolerate very strong light (Willén 2001). There are
approximately 280 planktonic species of cyanobacteria in Sweden according to Willén. They represent a major phyla of bacteria. The morphological diversity is huge as they can be unicellular, filamentous, colonial and heterocystous (Madigan et al 2012). Furthermore these heterocystous cyanobacteria possess heterocysts that may perform nitrogen fixation. They reproduce in different asexual ways.

*Microcystis sp* is one of the most common bloom-forming cyanobacteria (Kim et al 2006; Dokulil & Teubner 2000). *M.aeruginosa* dominates in many freshwater lakes (Granéli & Turner 2006). It is unicellular and forms colonies (Granéli & Turner 2006). Temperature is thought to be the primary factor causing *Microcystis* blooms although nutrient availability is important too (Jöhnk et al 2008). *Microcystis* possess extensive morphological differences between and within species (Otsuka et al 2000; Wilson et al 2006). Different strains possess great variation in morphology, toxicity and maximum population growth rates (Wilson et al 2006). The taxonomy is still complicated and morphology is thought to be a poor indicator to determine species (Granéli & Turner 2006). Instead, Granéli & Turner believe that molecular taxonomy is more reliable.

Many species of cyanobacteria are able to move vertically in the water (Willén 2001). It can give the cell a more favourable position (Tikkanen & Willén 1992). This can be done with a specific organelle, the gas vacuoles (Madigan et al 2012; Willén 2001). Each cell can contain hundreds of spindle-shaped vesicles made of protein (Madigan et al 2012). The vesicles described are permeable to gas but not water. If the vacuole is filled, the cell has potential to rise in the water (Willén 2001). Other ways to rise in the water are: Reducing its own density, drops of oil, mucous sheaths (Tikkanen & Willén 1992). The shape of the organism also affects the floating abilities according to Tikkanen & Willén. They also describes the content of the cell (protoplasm) heavier than water which makes the organisms naturally sink. Photosynthesis products also heavy the cells down (Willén 2001). A calm environment enables the organisms to rise to the surface and bloom while wind and waves hinder the cyanobacteria from rising (Cao et al 2006; Tikkanen & Willén 1992). *Microcystis* species are known to rise if they are affected by low light intensity (Singh & Singh 2015).

**Aim**

The aim was to analyse cyanobacterial community changes as affected by a climate change factor, temperature, in two lakes that serve as drinking water source. My hypothesis based on this background was that the number of cyanobacterial cells will increase more when cultured in 18°C compared to 10°C.
Material and Methods

Field trial

Lake Hjorten and Vångaren are located a few kilometres west of Västervik. They are mixotrophic and oligotrophic, respectively. A boat was used to sample water in the middle of each lake. The methodology of field sampling were done according to the description provided by Tikkanen & Willén (1992). In Lake Hjorten the sampling was done close to the fresh water intake to the waterworks. In order to obtain all planktonic species represented in the middle of the lakes a water pump was used at three different depths in the photic zone. The photic zones were determined with a Secchi-disc. Samples were taken near the surface, at the bottom of the photic zone and approximately halfway in-between. In Lake Vångaren the sampling depths were therefore at the surface, 1 meter and 2.5 meter. Lake Hjorten’s photic zone differed slightly so the sampling depths were chosen to be surface, 1.5 meter and 3.3 meters. A boat was necessary to sample in the middle of the lake, close to the fresh water intake to the waterworks. Temperatures in the lakes were measured at the time of sampling.

Experimental settings

The water from the different depths were then mixed equally into large five-liter glass vials in the laboratory at Linköping University. That means each vial was filled with one third water retrieved on each of the three depths. The start of the laboratory experiment followed 2 hours after the field trial in the 17th of November. Twelve glass vials were used in total for the experiment. Six for each lake. Three for each lake were placed in a 10°C climate room to serve as control equal to lake temperature. The other three for each lake were placed in an 18°C climate room to serve as experimental factor. Temperature was kept constant during day and night. The light in the rooms was set to a value approximately equal to autumn day light, 5500 and 5700 lux. Perfect similarity between the rooms was not achieved due to practical issues. During approximately 7 hours per day the lights were shut off to simulate night. The water in all the glass vials was stirred manually once per day. During weekends there was no stirring or darkness due to practical issues. No nutrients were added to the vials during the experimental period.

Sampling

In order to follow the community changes of cyanobacteria across time, samples were collected 11 times during 24 days. Not all 11 samplings were finally analysed and presented. Only 6 of the conserved samples from different dates were necessary to analyse in order to obtain representative data of the progression. The daily stirring of the water was done right before the sampling procedure. Water was taken from the middle of the vial using a plastic syringe and transferred into 50 ml falcon tubes. These samples were conserved with formaldehyde to a final concentration of 0.4 %, as described by Tikkanen & Willén 1992.

Analysing the number of cells

An inverted microscope was used to count the number of cyanobacterial cells in sedimentation chambers. This method is well established as an accurate way to determine phytoplankton composition and was described in 1958 (Utermöhl 1958) and modified in 2000 (Paxinos & Mitchell 2000). The down-sides of the method is that it is time consuming and it may be difficult to classify species (Willén 1976). In the water samples there were many types of organisms and
different sizes. The colonies of colony-forming organisms that did not seem significantly large were excluded from the counting. For example, Aphanocapsa sp colonies had to be more than 15 µm in diameter. This was important because very small filaments or colonies were abundant. Generas that form individual cells were counted separately. Species with few representatives may be difficult to count accurately (Willén 1976). Sedimentation chambers filled with a volume of 10 ml were prepared one day prior to counting to let the cells settle. This time is more than enough to let the organisms sediment (Lund et al 1958 cited by Willén 1976). A microscopy scale was used to determine how long the “diameter” in the field of vision turned out to be, using a 40X ocular giving 400-600 times magnification (Tikkanen & Willén 1992). This was transformed mathematically into how big volume each transect in the water chamber covered. If the number of cells was abundant enough to make the counting difficult, the water samples were first diluted before added to the sedimentation chamber. The decision of dilution was based on the number of cells in the previous counting. The dilution was later taken into account when transforming the values to number of cells per liter. In order to obtain an accurate representative mean number of cells per liter per species, at least 400 organisms were counted per chamber.

Statistics

The two lakes were not compared to each other. The experiment aimed to analyse growth due to temperature increase. Therefore the control groups of 10°C were compared to the 18°C groups. Mean values for each of the four experimental groups with three vials each were calculated for each day tested. A non-parametric Mann-Whitney test was performed on that data. The test has to be non-parametric because the number of cells on one date depends on the date before. The Mann-Whitney test with 5 % significance describes if there is significant differences in means for each genera depending on the experiment variable temperature.

Results

The general picture for both lakes was that the number of organisms initially decreased (figure 1 and 2). After this drop the number of organism increased until 13 or 17 days after the start of incubation. After 17 days of incubation the cells decreased heavily (data not presented). Most data obtained in this experiment indicated no significant difference in cellular growth between 18°C and 10°C. In other words the cellular counts of all dates presented in the graphs was not statistically different between the red and blue lines. But there was one genera that benefitted from the higher temperature, Aulacoseira Hijorten (U = 0.00122). Aphanocapsa Vångaren (U = 0.00304) was the only genera that showed statistically significant more cells while growing in 10°C.

Table 1 shows the generas that were frequently occurring in the water samples. Members of the class Coscinodiscophyceae were counted without attempting to divide them in generas. Table 2 presents generas that were found in the water samples but few individuals of each. The exception was flagellates and ciliates that were abundant but hard to distinguish and not of great interest in this study.
Table 1: Genera of organisms that were frequently present in water samples.

<table>
<thead>
<tr>
<th>Cyanobacteria</th>
<th>Diatoms</th>
<th>Green algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limnothrix</td>
<td>Coscinodiscophyceae</td>
<td>Scenedesmus</td>
</tr>
<tr>
<td>Aphanocapsa</td>
<td>Aulacoseira</td>
<td>Pediastrum</td>
</tr>
<tr>
<td>Microcystis</td>
<td>Fragilaria</td>
<td>Ankyra</td>
</tr>
<tr>
<td>Planktothrix</td>
<td>Tabellaria</td>
<td>Closterium</td>
</tr>
<tr>
<td></td>
<td>Asterionella</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Genera of organisms that were found in water samples but not frequently.

<table>
<thead>
<tr>
<th>Various flagellates</th>
<th>Gomphosphaeria</th>
<th>Staurastrum/Staurodesmus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various ciliates</td>
<td>Nitzschia</td>
<td>Chroococcus</td>
</tr>
<tr>
<td>Merismopedia</td>
<td>Navicula</td>
<td>Acanthoceras</td>
</tr>
<tr>
<td>Gloeocapsa</td>
<td>Frustulia</td>
<td>Dinobryon</td>
</tr>
<tr>
<td>Coelastrum</td>
<td>Urosolenia</td>
<td>Dictyosphaerium</td>
</tr>
</tbody>
</table>
Figure 1: Average number of cells per liter over time for different genera in water from Lake Hjorten. Days after the start of incubation in the 17th of November are presented on the X-axis. The red lines and standard errors represent water samples incubated in 18°C while the blue ones are for 10°C.
The temperature difference between the depths of sampling was negligible. Furthermore both lakes displayed similar temperature around 10°C. The difference between Lake Hjorten and Vångaren was negligible.

**Discussion**

The results from this experiment indicated that cyanobacteria during autumn in Lake Hjorten and Vångaren would not benefit significantly from a temperature-peak solely. At least the results did not strengthen the hypothesis. This partly contradicts the findings of Jöhnk et al (2008) who showed that temperature was the primary factor for *Microcystis* growth. However, other findings support the obtained results. Brock (1978), Robarts & Zohary (1987) and Chu et al (2007) showed that the growth of *Microcystis* was severely reduced under 15°C and the increase in growth was very small at 20°C. Regarding the *Aphanocapsa* in Vångaren that grew better in 10°C, this might have been because of competition amongst species. The outcomes of such scenarios with competition for nutrients etc. are very difficult to predict, especially because it was not studied prior to the experiment. Furthermore the data may be slightly deceptive because it only considered numbers of colonies, not the size of them. So the number of individual cells was approximated by an average sized colony. The results of the experiment must be carefully interpreted due to several factors such as competition and predation. Zooplankton predation on cyanobacteria would affect the results. The temperature differences may affect zooplankton differently and therefore influence the populations of cyanobacteria or other phytoplankton. Population dynamics like these are complicated. It is important to point out that zooplankton were rarely encountered in the microscope.

Determining the species identity of *Microcystis* was very difficult, especially with only morphology to back it up. Therefore my data may not be totally accurate. But I strongly believe a bloom of Microcystis would be easily detected if it existed, both in the glass vials and in the sedimentation chamber. Many or most graphs provided a hint that cells grew better in the warmer water during certain consecutive days or weeks although the Mann-Whitney test
showed almost all of them to be insignificant. Repeating and refining the experiment with more replicates would probably lower the standard error and show a statistical difference between temperatures. The experimental model with glass vials in climate rooms seemed to be successful. In order to retrieve better results, a well-trained taxonomist should perform the counting. Furthermore a solid system for evaluating number of cells in colonies should be used.

This report presents data of phytoplankton numbers over 17 days, a fairly short time. This is because a single temperature-peak would probably not last for longer time. Also the number of cells decreased drastically somewhere after 13 or 17 days of incubation. I speculate that this occurred because of nutrient depletion. Diatoms seemed to be more tolerant against this because they remained in large numbers for a longer time. Genera like Dinobryon, Planktothrix and Urosolenia increased drastically after the 30th of November in water from Vångaren cultured in 18°C (data not presented). Planktothrix is a nitrogen-fixing cyanobacteria and this ability was surely an asset during nutrient depletion. Flagellates showed similar pattern, they remained in large number for a longer time. In this study some of the flagellates may be cryptomonads. It is possible that the explanation is that golden algae and cryptomonads are relatively tolerant against nutrient depletion. They are known to be able to dominate in oligotrophic lake.

Temperature is not the only factor affecting the population of phytoplankton. Other contributing factors are nutrition and light. According to the studied information, an accumulative situation with higher nutrition availability would trigger more cyanobacteria (Davis et al 2009). The results from this experiment indicate that temperature alone is not enough to trigger an algal bloom. Light was kept constant and no additional nutrients were added because the environment surrounding the lakes are unknown to me. It is probable that reality was not simulated in an exact way regarding light and nutrients. This is almost an impossible task but the experimental setting can be done relatively similar to reality. Perhaps an algal bloom in Lake Hjorten and Vångaren can be predicted theoretically by looking at weather.

Because of gas vacuoles there is a risk that cyanobacteria could float and thus be excluded from being counted in the water chamber. This should not have caused serious problems in this experiment, as the gas vacuoles are filled when light is sparse, which was not the case. The formaldehyde treatment would damage or conserve the cells the way they were, and also cells with a functional gas vacuole should have sunk to the bottom due to zero turbulence in the water chamber. These facts together should have prevented the cells from floating and being excluded from the counting. Regarding the methodology for analysing phytoplankton growth, there are other possibilities. One example is chlorophyll-a analysis, but this can only determine biomass, not species, (Li et al 2012) and was therefore not suitable. Furthermore, cyanobacteria produce more chlorophyll-a if the temperature is low (Wang & Li 2015) which would have made the results in this experiment more difficult to interpret.

Dates from the time of sampling, 17th of November and 17 days forward were chosen to illustrate the changes in number of cells. Samples from the 10°C and 18°C water should have been identical at the first cell counting occasion because the water had only been mixed. For many generas this was not the case which suggests a non-perfect blending or difficulties with the counting method. For the Mann-Whitney test, only data from day 3 until day 17 was used. This is because almost every species showed a strong decrease from the 17th of November until the next measurement on the 20th. I speculate that this may be because the cells must adapt to a
new environment before initiating or resuming growth. However this can possibly imply that the laboratory environment was not similar to reality in the lakes. It becomes obvious that a perfectly executed study would be performed inside the lake itself under controlled temperature. The downside is that it is very difficult to do practically. It would also require a lot more finances.

When interpreting these results it is important to understand that the starting community was sampled during Swedish autumn in the 17th of November. The phytoplankton composition and density was depending on this.

When water samples from the lakes were analysed one thing was remarkable. According to the morphological study, nearly all of the genera found are known to be potential producers of odorous compounds and/or toxins. This unfortunate phytoplankton composition is surely the basis for the historical outbreaks of odorous compounds in the drinking water. But I want to point out that this cannot be guaranteed without tools like molecular taxonomy and a well-trained taxonomist. Besides geosmin, the levels of toxins are difficult to predict. Some species like Microcystis seems to be most prone to excrete toxin when they increase in number the most. Other species excrete toxins when environmental conditions are bad and they need to raise their relative fitness towards other genera. Chemical levels of odorous compounds or toxins were not analysed in this experiment. I do not see any great reason to do so because my results did not show dominance by cyanobacteria. If cyanobacteria had been dominating, a possible explanation could be allelochemicals that inhibit other genera. A chemical analysis could have confirmed such a scenario.

This report aims to give an understanding of cyanobacterial community changes due to temperature. This can be described as the foundation to chemical levels because more cells enable more compounds to be excreted into the freshwater. The results give some conclusions of evaluability. Total phytoplankton density and composition during autumn in Lake Hjorten and Vångaren did not change in response to a period of temperature increase. Cyanobacteria did not either. Aphanocapsa is possibly toxin-producing but did not benefit from higher temperature. Aulacoseira is not known to be a potential geosmin- or toxin producer but it benefitted from warmer climate in this experiment. Altogether this indicate that a warmer autumn without other contributing factors is not enough to increase the number of harmful cells in the lakes.
Acknowledgements

This research was supported and financed by Sweco Environment AB. They lent me material for the field trial and sponsored me with 10’000 SEK to pay laboratory costs, material and travels. I want to express my gratitude to Västervik Miljö & Energi for letting me be a part of this huge project together with Sweco Environment AB.

I would like to thank my academic supervisor, Alex Enrich-Prast; oceanographer, microbiologist and limnologist. He helped me with the planning of this project. Also, I thank my academic advisor, Laura Shizue Moriga Masuda; oceanographer. She assisted me in this project with everything and anything. Golden commitment!

I thank Eva Willén at Swedish University of Agricultural Sciences for helping with determining various species in my water samples.
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