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The relationship between a phytoplankton community and nutrient dynamics during a growth season – A study from the eutrophic Lake Årungen

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Environment and natural resources

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Abstract

The nutrients phosphorus and nitrogen are necessary for phytoplankton growth, but nutrient enrichment (eutrophication) can be of global and national concern. Lake Årungen is a eutrophic lake that has been plagued by visible cyanobacteria blooms, which can be toxic. This thesis examined the succession in the phytoplankton community and investigated if there were any connections between phytoplankton growth and nutrient dynamics in Lake Årungen. Data was collected as water samples and in situ measurements on biweekly field trips, where the water samples were later analysed at the lab for nutrients and phytoplankton pigments.

Diatoms dominated at the beginning and end of the season, and were also present during the peaks of other phytoplankton groups. In August a visible cyanobacteria bloom began to form on the lake surface. Principal component analysis (PCA) found a correlation between total phosphorus (TP) and chlorophyll a, indicating a relationship between the two. Total nitrogen (TN) and nitrate correlated with the TN and nitrate for the outlet, but not to any of the pigments.

The main findings in this study were the domination of diatoms, the succession of phytoplankton groups in Lake Årungen, and the coupling between TP and phytoplankton growth. Another important finding is that Lake Årungen was feeding the outlet with nitrogen, with possible adverse effects further down in the river system. This study challenges the assumption that all eutrophic lakes are dominated by cyanobacteria and highlights the need for more understanding of phytoplankton dynamics throughout the summer.

Sammendrag

Næringsstoffene fosfor og nitrogen er nødvendige for fytoplankton vekst, men økt tilførsel av næringsstoffer (eutrofiering) kan være et globalt og nasjonalt problem. Årungen er en eutrof innsjø som har lenge vært plaget av synlige blågrønnbakterie oppblomstringer, som kan være giftige. Denne studien har gransket suksesjonen i fytoplankton-samfunnet og undersøkt om det er noe sammenheng mellom fytoplanktonvekst og næringsstoffdynamikk i Årungen. Data ble samlet inn som vannprøver og in situ målinger annenhver uke, hvorav vannprøvene senere ble analysert på laboratoriet for næringsstoffer og fytoplanktonpigmenter.

Kiselalger dominerte på starten og slutten av sesongen, og var samtidig til stede under de andre fytoplanktonene sine topper. I august var det en tydelig blågrønnbakterieoppblomstring på toppen av innsjøen. Prinsipal komponentanalyse (PCA) fant en korrelasjon mellom total fosfor (TP) og klorofyll a, noe som indikerer et forhold mellom dem. Total nitrogen (TN) og nitrat korrelerte med TN og nitrat for utløpet til Årungen, men ikke til noen av fytoplanktongruppene.

Hovedfunnene i denne oppgaven var dominansen av kiselalger, suksesjonen av fytoplankton grupper i Årungen og sammenhengen mellom TP og fytoplankton vekst. Et annet viktig funn var at innsjøen bidro med nitrogen til utløpet, noe som kan ha negative effekter lengre ned i vassdraget. Denne studien utfordrer antakelsen om at alle eutrofe innsjøer domineres av blågrønnbakterier og understreker behovet for mer forståelse av fytoplanktons dynamikk gjennom sommeren.

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Introduction

Eutrophication, characterized by increased primary production as a consequence of nutrient enrichment in lakes, is of global and national concern. According to the Norwegian Environment Agency, approximately 200 Norwegian lakes fail to achieve good ecological status due to eutrophication (Solheim et al., 2022). Nutrient runoff from human activities such as agriculture or sewage can accelerate natural processes in lakes, leading to algae blooms (Brönmark & Hansson, 2017a). In most cases these blooms consist of phytoplankton, which are small photosynthesizing algae floating freely in the water column. A study found that the intensity of phytoplankton blooms has increased globally since the 1980s (Ho et al., 2019). Different phytoplankton groups can be responsible for these blooms. The most infamous one is the cyanobacteria, which often cause visible blooms on the lake surface and can be toxic (Paerl et al., 2001). However, cyanobacteria does not always dominate and the phytoplankton composition may change throughout the summer season or on a yearly basis (Laugaste et al., 1996). Various factors contribute to these changes, including nutrient input and weather conditions.

Since Schindler (1974) documented the profound impact of phosphorus on phytoplankton dynamics in nutrient-poor lakes, phosphorus has been widely regarded as the most important limiting nutrient in lakes (Sterner, 2008). Whereas for marine systems nitrogen is regarded as the limiting nutrient. Other studies show that freshwater systems may not be limited by a single nutrient, but co-limited by both nitrogen and phosphorus (Elser et al., 2007; Müller & Mitrovic, 2015). Numerous strategies aimed at reducing phytoplankton biomass through phosphorus management are implemented but hindered by internal loading of phosphorus. Since phosphate is highly reactive, it readily binds to iron in lakes and sinks to the sediment, rendering it unavailable for phytoplankton uptake. However, under anoxic conditions in the hypolimnion, phosphate may be released due to the reduction of iron (Brönmark & Hansson, 2017a). Eutrophication often causes anoxic conditions in the hypolimnion (Jenny et al., 2016), reinforcing eutrophication by making more phosphorus available for the phytoplankton. A study conducted by Jensen & Andersen (1992) found that high nitrate concentrations sustain iron oxidation, thereby preventing the release of phosphorus from the sediment. It has therefore been proposed that nitrate addition could serve as a potential management strategy for reducing phytoplankton biomass in lakes (Søndergaard et al., 2000).

Weather conditions have a large effect on both the nutrient distribution in lakes and the ecological dynamics of phytoplankton communities. Phytoplankton are small but have a higher density than water. Stable weather with little wind promotes stratification in dimictic lakes during the summer, thereby trapping phytoplankton lacking effective adaptions against sinking in areas without light (Brönmark & Hansson, 2017a). Certain phytoplankton taxa, such as diatoms, rely on turbulence to move in the lake (Granéli & Turner, 2006), thus favouring periods with more wind and turbulence. Other groups like cyanobacteria prefer stratification and can quickly form blooms as soon as favourable conditions present themselves (Granéli & Turner, 2006). Rainfall events can transport nutrients from the catchment areas into lakes, potentially leading to elevated nutrient concentrations, particularly in agricultural regions (Brönmark & Hansson, 2017a). Projections from the Norwegian Centre for Climate Services (NCCS) anticipate more intense and frequent rainfall events in Norway (Hisdal et al., 2017). How this will affect future lakes is not clearly understood yet, but important to consider.

Lake Årungen is situated in southern Norway and has long been plagued with high nutrient levels and recurrent phytoplankton blooms. Sediment analyses reveal that the lake's natural state is mesotrophic, due to its geological bedrock with nutrient-rich marine clay deposits (Romarheim, 2012). Nearly half of the catchment area is dedicated to agriculture, owing to the nutrient-rich bedrock. Since the 1930s, agricultural practices have shifted in the catchment, moving from domination of pastures to cereal cultivation and increase in fertilizer use (Riise et al., 2013). The lake was previously a popular recreational spot, especially for swimming, before the water quality quickly deteriorated in the 1960s and fish deaths caused by anoxia were witnessed (Borch et al., 2007). Measures were put in place in the 1980s to reduce the phytoplankton biomass, and efforts included sewage treatment and better agricultural practice (Borch et al., 2007). While these efforts yielded some improvements, the lake failed to fully revert to its original mesotrophic state. In the same period, researchers recorded more nitrogen-fixating species of cyanobacteria in the lake (Romarheim & Riise, 2009).

Lake Årungen is currently still not meeting the goal of good ecological status and is classified to be in a moderate status (Stabell et al., 2022). Several problems make it difficult to improve its status, largely due to external and internal nutrient inputs. Frostad's master thesis (2018) investigated the possibility of internal loading of phosphorus in Lake Årungen and concluded that nitrate and phosphate were coupled. Internal loading of phosphorus was witnessed for several years when the nitrate values were low and the hypolimnion was anoxic (Frostad, 2018). Given the lake's high nutrient levels through the summer, nutrient levels are probably in surplus during large parts of the growing season, and phytoplankton may be limited by other factors than nutrients. Previous research has suggested light limitation as a key factor (Romarheim, 2012). Various particles, such as organic matter, may shade for the phytoplankton, or the phytoplankton may become trapped outside of the euphotic zone due to turbulence caused by wind. According to Romarheim et al. (2012), in these situations cyanobacteria may produce gas vesicles and float to the surface when the wind situation calms down. This can cause an "overshoot" reaction, where large amounts of the cyanobacteria gather at the surface causing large blooms and continuing the cycle of light limitation in the lake (Romarheim et al., 2012).

Prior studies (Frostad, 2018; Romarheim, 2012) have focused on nutrient dynamics and limiting factors for phytoplankton growth in the lake, and less on the phytoplankton community itself. Therefore, this thesis aims to assess the phytoplankton community and investigate if there are any connections between phytoplankton growth and nutrient dynamics in Lake Årungen at a time with changing and more variable weather conditions. Based on the water samples taken and measurements obtained, this thesis addresses the following questions:

Is there any discernible succession among phytoplankton groups in Lake Årungen?

Is there a coupling between phytoplankton growth and nutrient dynamics in the thermally stratified Lake Årungen?

Methods

Site description

Lake Årungen is situated between the municipalities Ås and Frogn in Akershus County. According to Köppens climate zones, the lake is in the temperate cold zone (Mamen, 2021). This climate zone is known to have cold winters and mild summers. The lake stretches three kilometres long and covers an area of 1.2 km^2. It is oriented in a south-north direction and is highly exposed to wind (Romarheim & Riise, 2009). The deepest point of the lake is 13.2 m and the average depth is 8 m (Riise et al., 2013). According to Borch et al. (2007), the lake has a theoretical retention time of four and a half months. Lake Årungen follows a dimictic pattern, undergoing two distinct periods of whole-lake circulation annually. These periods are in spring and autumn, meanwhile the lake is thermally stratified during the summer.

Årungen's catchment area is approximately 52 km^2 and encompasses parts of Ås, Ski and Frogn municipalities (Figure 1). The catchment ranges between 33 m to 160 m above sea level (Borch et al., 2007), while the lake sits at 34 m. Six streams flow into the lake, mainly from agricultural areas that make up about half of the catchment. Bølstadbekken is the largest of these streams and originates from Lake Østensjøvann. According to the map service NEVINA from the Norwegian Water Resources and Energy Directorate (NVE), the rest of the catchment is mainly forest (35%), and urban areas (5%) (Appendix 1, Figure A1). Lake Årungen has one major outlet stream called Årungselva, which drains into Bunnefjorden. The lake and the stream are part of the Årung river system which helps supply water to Oslofjorden.

Figure 1: Map over Lake Årungen and its catchment and sub-catchments (Borch et al., 2007).

Sampling and treatment of samples

Data in this study consists of water samples and in situ measurements from Lake Årungen in the period May to October 2023. The data was collected in Lake Årungen at a two-week interval. The first sampling occurred on May 24, and the last on October 13 (Appendix 2, Table A1). There was some variation in the sampling interval, with the longest time between sampling being three weeks and the shortest nine days. In total, there were 11 samplings. The sampling site was at the deepest part of the lake. With the help of a Swedaq Hydro- X water sampler, water from seven different depths was collected in 500 ml plastic bottles. These depths were: 0.5 m, 1 m, 3 m, 5 m, 8 m, 11 m, and 12 m. Each time the water bottles were cleansed with water from the corresponding depth.

In addition to the samples from Lake Årungen, one sample was collected from the outlet every time. The water sample from Årungselva was collected with a plastic bottle from the surface of the stream. This meant that eight water samples were collected at every field trip. All the samples from Lake Årungen and the outlet resulted in a total of 88 samples.

The water samples were brought back to the lab within an hour. Two unfiltered 10 ml samples were taken from each plastic flask for later total nitrogen (TN) and total phosphorus (TP) analysis. This resulted in 176 unfiltered water samples. Afterwards, 300 ml were measured from the flasks and filtered with 1.2 µm glass fibre filters. There was one sampling conducted on June 7, where only 200 ml were used for filtration. From the filtered liquids, 50 ml were collected in separate test flasks. All the filters from the lake samples were collected in separate plastic containers for later pigment analysis. The samples from Lake Årungen were also measured for their pH and absorbance (abs). pH was measured with unfiltered water from the samples. A pHenomenal meter from VWR was utilized for this task. Around 10 ml of filtered samples were used to measure absorbance with the UV-1201 spectrophotometer from Shimadzu at 410 nm. The same spectrophotometer was later used in the ammonium and total phosphorus analyses. After finishing all the tests, the samples were frozen for later analyses.

In situ measurements

Four parameters were measured in situ: oxygen concentration, oxygen saturation, temperature, and Secchi depth. The three first parameters were measured with an optical oxygen measurer from YSI. Measurements started at half a meter, and were then measured at every depth from one to twelve meters. The Secchi depth was measured with a standard square, white Secchi disk. This was later multiplied by 2.5 to give an estimate for the euphotic zone. To calculate the approximate euphotic zone, Equation 1 was used:

$$Secchi\ depth\ x\ 2{,}5 = Euphotic\ Zone$$

(Equation 1)

Laboratory analysis

The analysis was done at the laboratory in Jordfagsbygningen at NMBU. All autoclaving was done by the laboratory personnel at the building. Other tasks were also performed by the laboratory personnel, which are highlighted in each respective analysis.

Total phosphorus

The unfiltered samples all include phosphorus in different forms. Phosphorus can be bound to clay particles, exist within phytoplankton and bacteria, or be in a form that is otherwise difficult to measure. Therefore, to be able to measure the total phosphorus concentration in the water samples, all phosphorus in the samples was oxidized to phosphate. The procedure followed the Norwegian Standard (NS-EN 1189). Two millilitres of potassium peroxydisulfate was added to half of the 10 ml unfiltered water samples, resulting in 88 samples for total phosphorus analysis. Subsequently, the samples were autoclaved at 121°C and 1 bar pressure for 30 minutes.

Total phosphorus was measured through a colour reaction and with a spectrophotometer. With the addition of ascorbic acid, the pH in the samples was lowered and through a reaction with molybdate, the solutions took on a strong blue colour depending on the amount of phosphorus present in the sample. Five millilitres of each sample were pipetted and added to glass tubes. Then 0.25 ml of ascorbic acid was added to lower the pH, and the samples were centrifuged. Afterwards, 0.25 ml of molybdate was added to the samples, and centrifuged once again. The samples were then left to rest for 30 minutes before they were analysed at 880 nm in the photometer.

Five blank tests of distilled water and five standard samples followed the same procedure, whereas the latter was used to create a standard curve (Appendix 3, Figure A2). The standard samples were created with 1mg/l PO4-P with concentrations of 0.2, 0.4, 0.6, 0.8, 1mg/l PO_4-P. The blanks were used to account for background colour in the samples.

Total nitrogen

Similar to phosphorus, nitrogen appears in many forms in the unfiltered water samples. To analyse for total nitrogen, all the forms of nitrogen in the sample need to be oxidized to nitrate. The analysis did not account for dinitrogen (N_2). Dinitrogen is very stable and is only used by very few specialized cyanobacteria. Since dinitrogen is not a form of nitrogen most organisms can use, lacking dinitrogen from total nitrogen will still give an indication of the total nitrogen accessible for most organisms in lakes.

The procedure followed a modified version of the Norwegian Standard (NS 4743). To oxidize the samples, 5 ml of a solution consisting of potassium peroxydisulfate and NaOH was added to the other half of the unfiltered water samples. The samples were then autoclaved at 121°C and 1 bar pressure for 30 minutes. The rest of the analysis was done with the help of the lab personnel at Jordfagsbygningen. Total nitrogen was measured by Flow Injection Analysis (FIA). This was measured with a FIAstar 5000 analyzer from FOSS.

Ammonium

To analyse ammonium (NH_4) a colour reaction and photometer were utilized. This was done following a modified version of the Norwegian Standard (NS 4746). Ammonium in the water samples will react with hypochlorite to form monochloramine, which will produce 5-aminosalicylate when salicylate is added. The samples will then turn blue depending on the amount of ammonium. The colour intensity has a positive linear correlation with the concentration of ammonium, giving a stronger blue colour for higher concentrations.

Before analysing the water samples, standard samples were prepared. Five standard samples at the concentrations of 0.2, 0.4, 0.6, 0.8, and 1 mg/l NH_4-N were made and went through the same procedure as the water samples. These were then used to make a standard curve to identify the correlation between ammonium concentration and the absorbance in the water samples (Appendix 3, Figure A2). In addition, five blank tests made with distilled water were also analysed to account for background colour from the chemicals and water.

First, 3 ml of the filtered water samples were collected in glass tubes and 0.5 ml of hypochlorite was added. This was then centrifuged before 0.5 ml of salicylate was added.

Afterwards, the samples were centrifuged again and subsequently left to develop colour for one hour. A spectrophotometer with 2 cm cuvettes was used to measure the absorbance of the samples at 655 nm. The results were compared with the absorbance of the standard curve (Appendix 3, Figure A2).

Nitrate and phosphate

Ion chromatography was used to gather information about the concentration of nitrate and phosphate in the water samples. Nitrate and phosphate are negatively charged ions, making this method well-suited for their analysis. To prepare for the test, 1 ml was collected from all the filtered samples in small plastic tubes with lids. The samples were then run through an ion chromatography system (Dionex ICS-6000) by the lab staff at Jordfagsbygningen. The instrument calculates the concentrations of the ions by comparing them with known standard solutions.

Pigments

Phytoplankton use pigments for photosynthesis, and some pigments are group-specific. Therefore, pigments can be used to identify what type of phytoplankton are present in the lake, and the amounts of phytoplankton. All phytoplankton have chlorophyll a, which was used as a measurement for total phytoplankton volume. The analysis focused on these pigments (Table 1):

Table 1: List of pigment groups analysed and corresponding phytoplankton group.

Pigment	**Found in**
Alloxanthin	Cryptomonads
Chlorophyl a	All phytoplankton
Fucoxanthin	Dinoflagellates and diatoms
Peridinin	Dinoflagellates

The lab staff at Jordfagsbygningen performed the analysis. All pigments had to be extracted, which was accomplished by using the filters from the filtration of the samples. Since these filters contained about 0.5 ml of water, all the filters were freeze-dried for 24 hours. Afterwards, 3 ml of acetone was added to the filters before leaving them overnight in a cool dark place. Before proceeding with the pigment analysis, the samples were centrifuged for 15 minutes at 3000 G to remove plant particles. They were then pipetted into smaller brown tubes, where 20% of water was added. Since the pigments are polar, the water will improve the separation of pigments in the later analysis (Hagman et al., 2019).

Pigment analysis was conducted by using High-Performance Liquid Chromatography (HPLC) with the modified procedure established by Hagman (Hagman et al., 2019). A Dionex Ultimate 3000 was used for this analysis. The machine was calibrated once, but known standards are used to test the machine and assure its accuracy.

Microscope identification of cyanobacteria

At the sampling on September 6, a microscope was used to identify phytoplankton from the visible bloom. The identification was done with the help of Professor Thomas Rohrlack, and was only identified to genus.

Treatment and analysis of data

All the data was collected in Excel and sorted (see Appendix 2, 4, 5 for further details). Some of the simpler figures were created with Excel (version 16.77.1), meanwhile the more advanced isopleth plots were made in R-Studio (version 2023.09.1+494) with the ggplot package. R-studio was utilized for the Principal Component Analysis (PCA) using the factoextra and ggplot2 packages.

Some of the PCA analyses included data from an aqua monitor operated by the Norwegian Institute for Water Research (NIVA). This monitor is placed at the outlet of Lake Årungen and measures among other variables phycocyanin. Phycocyanin is a pigment found in many types of cyanobacteria. In addition to the extra data from NIVA, meteorological data was collected from the field station BIOKLIM at NMBU (Appendix 7, Table A5).

Chlorophyll a, fucoxanthin and total phosphorus contained values with large differences and did not fit contour plots. To enhance the readability of the contour plots, a square root transformation was applied to the parameters. This transformation was necessary to ensure that the range of values across the parameter was more evenly distributed and allowed for a clearer representation of the relationship between variables in the contour plots.

Artificial intelligence

ChatGPT is an artificial intelligence model developed by OpenAI. It is designed to behave conversationally and can complete a wide variety of tasks. This thesis used ChatGPT for coding. Examples include asking for simple code to enhance the design of figures, or to explain errors given by R-studio. It was also used to detect writing errors and enhance writing. All help from ChatGPT was thoroughly inspected to avoid errors.

Grammarly is another artificial intelligence tool developed by Grammarly, with the main objective of working as a writing partner. This tool points out errors in real-time and suggests improvements to sentence structure. While using Grammarly, all enhancements of the text were carefully considered to avoid losing the essence of the sentences.

Results

Weather

Figure 2 shows how the air temperature changed monthly in Ås in 2023 compared to normal values for 1991-2020. May, June and September experienced warmer temperatures, and June had the largest difference from the normal with 3.2°C. Meanwhile July, August and October were colder than normal.

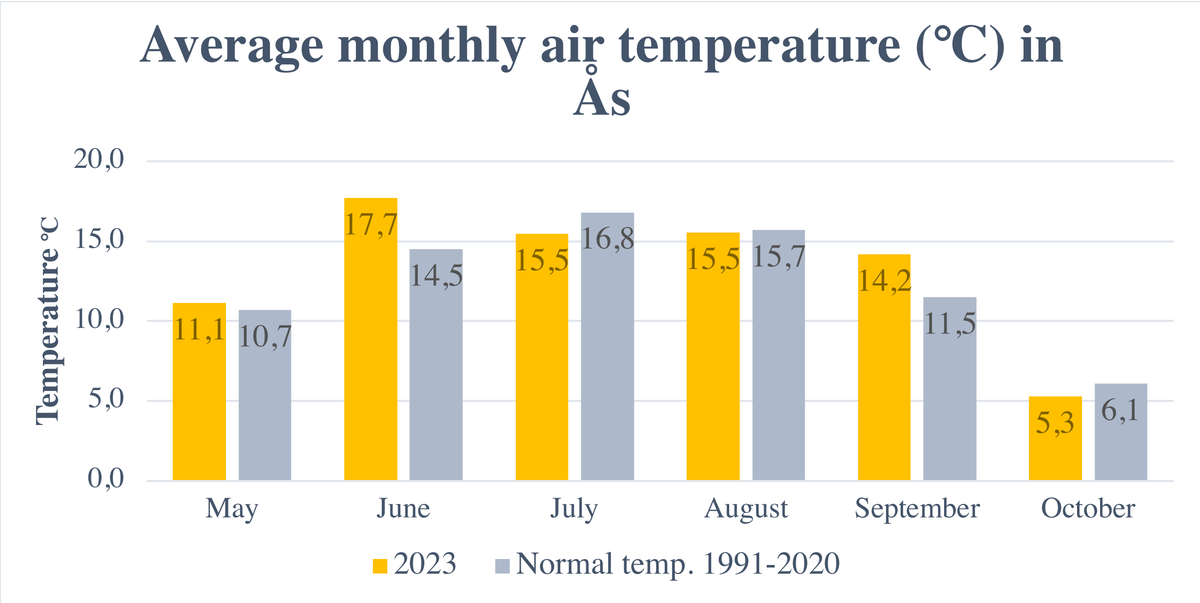

Figure 2: Average monthly temperature (°C) in Ås from May to October in 2023. The yellow bars show the temperature for 2023, while the grey bars show the normal temperature for 1991-2020 (NMBU).

Comparisons between precipitation values in Ås from 2023 and the normal values for 1991-2020 are shown in Figure 3. There is a notable difference for each month, except for September which was close to the normal. The season started quite dry with May registering only a fourth of the normal precipitation, and June less than half of the normal. This changed in July which recorded 58 ml more precipitation, and 77 ml more in August. October was another dry month with only a fourth of the normal precipitation.

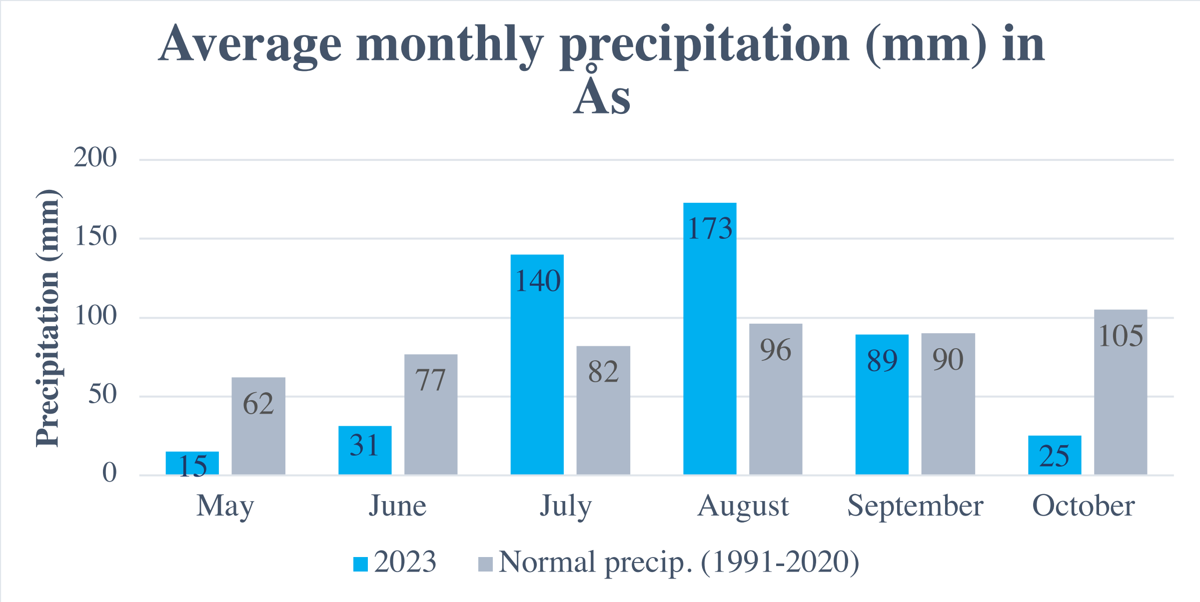

Figure 3: Average monthly precipitation (mm) in Ås from May to October in 2023. The blue bars show the precipitation for 2023, while the grey bars show the normal precipitation for 1991-2020 (NMBU).

Water temperature and oxygen

From the first sampling date on May 24, the lake was beginning to become thermally stratified (Figure 4). Thermocline is the layer between the hypolimnion and epilimnion, where the temperature drastically changes (Klaveness, 2018). The thermocline started at three to four meters and moved to between six and eight meters later in the season. Water temperature in Ås was the highest in the middle of June with values up to 22°C. The largest difference in temperature between hypolimnion and epilimnion occurred June 21 with a 14°C difference through the water column. October 13 had the smallest difference with the highest temperature at 11.7°C and the lowest 9.8°C. At this point, the lake was almost back to full circulation. October was also the month with the lowest temperature in the epilimnion.

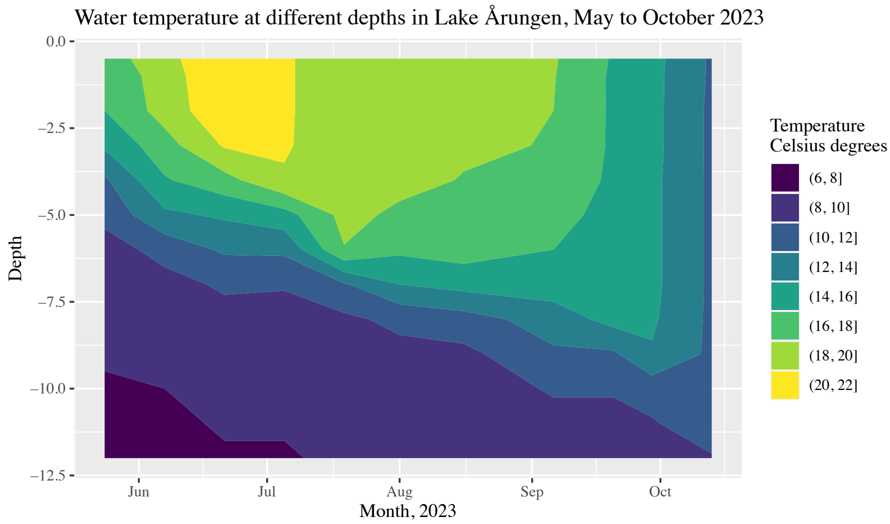

Figure 4: Time-depth profile of water temperature (°C) in Lake Årungen from May 24 to October 13, 2023.

The measurement from May 24 showed that oxygen was present throughout the whole water column (Figure 5). This was the case until the measurement on July 5. From this date and until the last sampling in October, oxygen was below the detection limit and the bottom of the hypolimnion was presumably anoxic. From July 19 and until September the bottom seven metres of the lake was anoxic. From September this area decreased, until October 13 when only the deepest sampling point was anoxic. In October most of the water column had the same oxygen concentration.

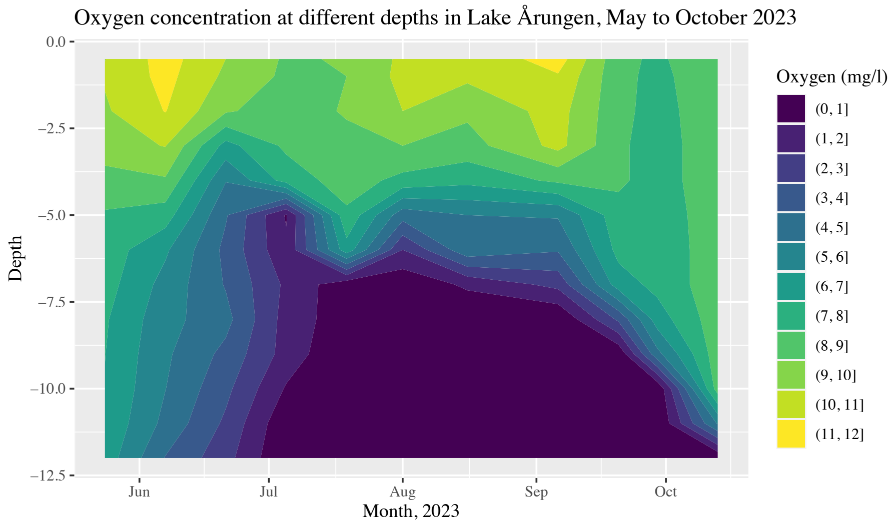

Figure 5: Time-depth profile of oxygen concentration (mg/l) in Lake Årungen from May 24 to October 13, 2023.

Figures 5 and 6 both display changes in oxygen, however the latter shows changes in oxygen saturation. Almost identical peaks and lows were recorded for the two oxygen variables. Figure 6 shows two periods with oxygen saturation above 100% on the surface and down to three meters depth, between May 24 and June 21, and between August 1 and September 6.

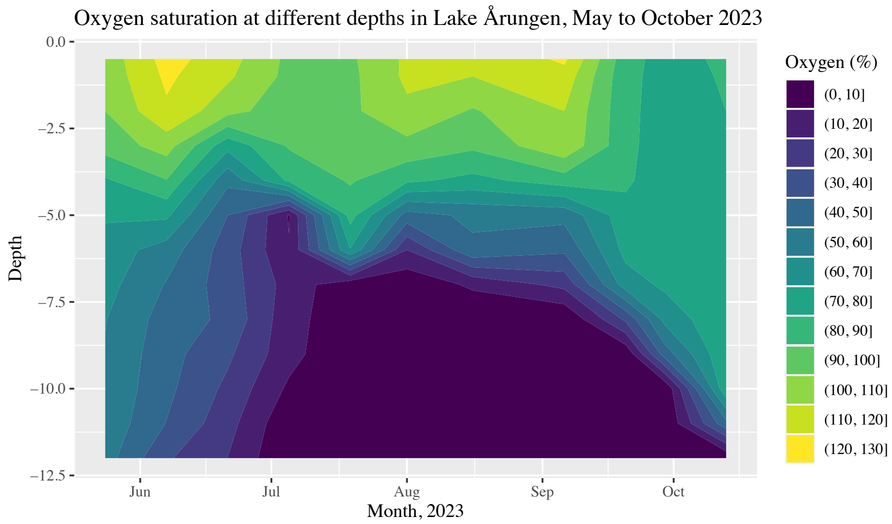

Figure 6: Time-depth profile of oxygen saturation (%) in Lake Årungen from May 24 to October 13, 2023.

Light

Secchi- and euphotic depth depend on each other, as the euphotic depth was calculated from the Secchi depth. Therefore, both had the same peaks and lows. Figure 7 shows that the season began with a Secchi depth only reaching 90 cm on May 24 and continued onto the second sampling date on June 7. The Secchi depth peaked on June 21 at 160 cm, followed by a period of clearer water. This stopped on September 6, before the shallowest Secchi depth was recorded on September 20 with only 80 cm.

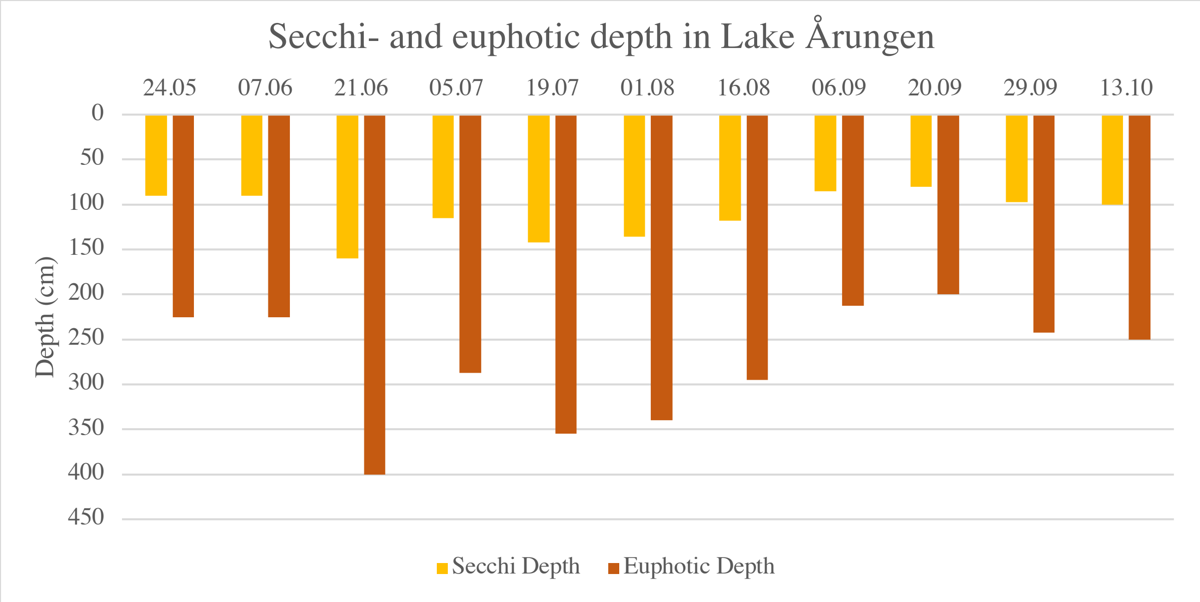

Figure 7: Secchi- (yellow bars) and euphotic (red bars) depth (cm) in Lake Årungen measured at each sampling date in 2023.

pH

Figure 8 shows the changes in pH from May 24 to October 13. The pH reached a maximum of 9.4 at one meter on June 7. The pH was highest at the top of the lake, never going below pH 7.4. The bottom of the lake had a lower pH, ranging between 6.6 and 7.0 through the sampling season.

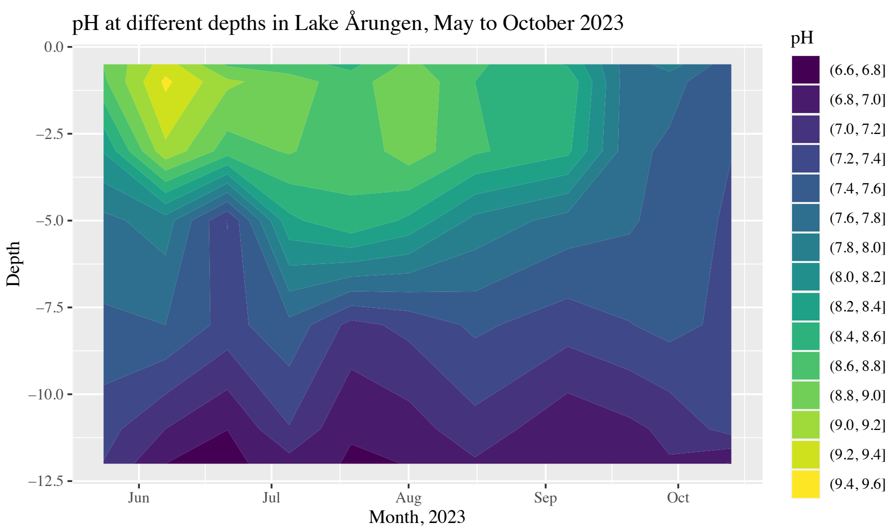

Figure 8: Time-depth profile of pH in Lake Årungen from May 24 to October 13, 2023.

Total phosphorus and phosphate

Total phosphorus varied through the summer, with the highest amount of 130 µg/l at 0.5 meters on May 26 (Figure 9). The second highest measurement was at the same date at three meters with 91 µg/l. Total phosphorus never went below 10 µg/l throughout the season. Two other peaks were registered: one at 75 µg/l at eight meters on July 19, and the last one between 11-12 meters depth at the end of September with a value of 68-69 µg/l.

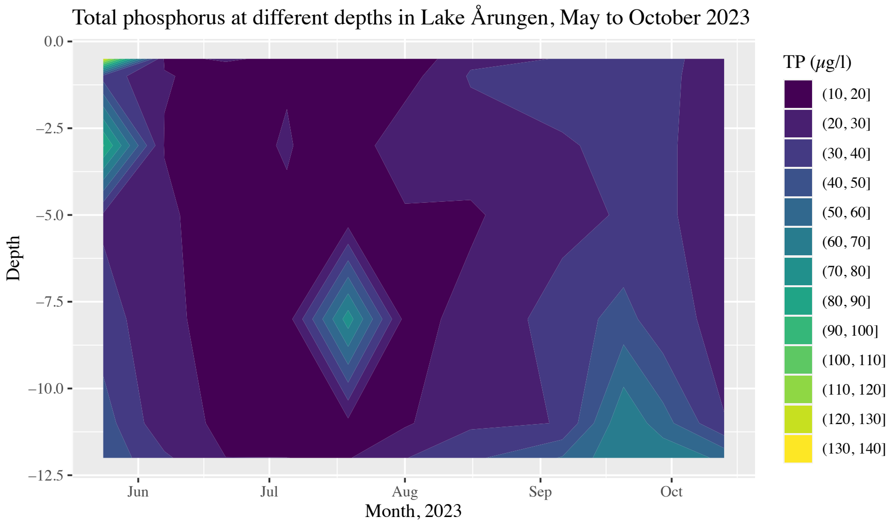

Figure 9: Time-depth profile of total phosphorus (µg/l) in Lake Årungen from May 24 to October 13, 2023.

Phosphate levels remained consistently low throughout the entire season, punctuated by occasional peaks shown in Figure 10. A total of four peaks were recorded: one at a depth of 1 meter on May 24, another at 11 meters on August 16, a third between 0.5-1 meter on September 20, and the final one occurring from September 29 to October 13, beginning at a depth of 12 meters and continuing at 11 meters.

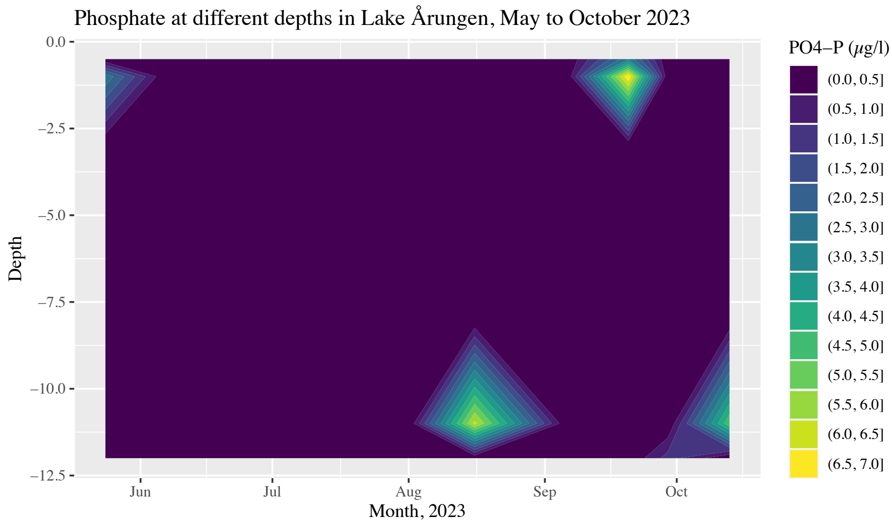

Figure 10: Time-depth profile of phosphate (µg/l) in Lake Årungen from May 24 to October 13, 2023.

Total nitrogen, nitrate and ammonium

Total nitrogen peaked on May 24 at three meters depth with values of 4400 µg/l (Figure 11). Nitrogen values then decreased during the summer, decreasing mostly in the top five metres during July and August. In September it shifted, and the concentration of total nitrogen in the upper parts of the water column increased, while the concentration at the bottom decreased. The total nitrogen amount never went below 2070 µg/l.

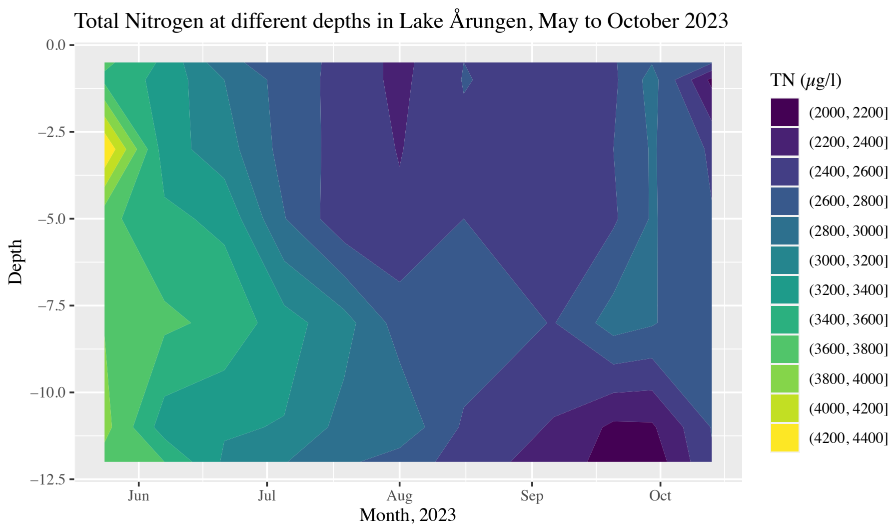

Figure 11: Time-depth profile of total nitrogen (µg/l) in Lake Årungen from May 24 to October 13, 2023.

Figure 12 maps out the changes in nitrate concentration from May to October. Nitrate started generally well-mixed in the water column, with higher values around eight meters from May to August. However, in September nitrate decreased rapidly below eight meters. The lowest value was recorded on October 13 at 12 meters, with values of 699 µg/l. The highest value was recorded on May 24 at eight meters depth with 3101 µg/l.

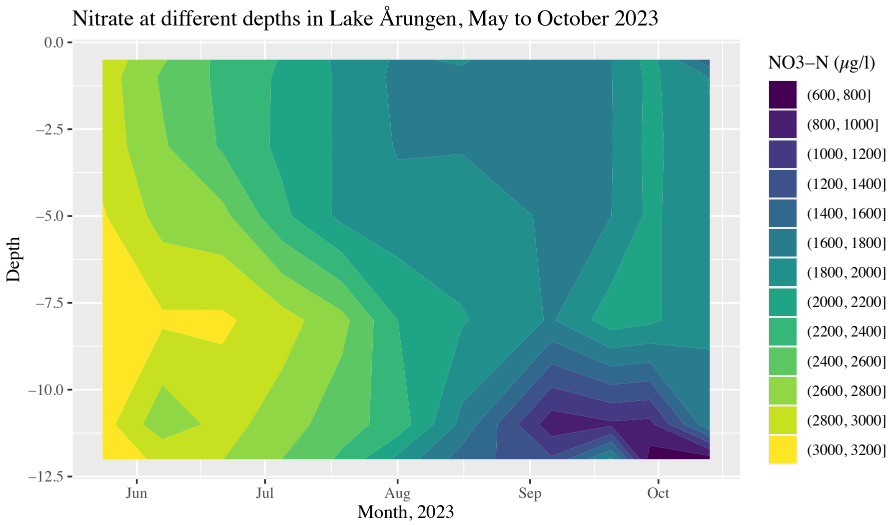

Figure 12: Time-depth profile of nitrate (µg/l) in Lake Årungen from May 24 to October 13, 2023.

Ammonium peaked on October 13 with 146µg/l at 12 meters depth (Figure 13). The lowest concentration of ammonium was 7.4 µg/l recorded on August 1 at eight meters. From August it increased in the 8-12 meters depth until it increased continuously closer to the sediment.

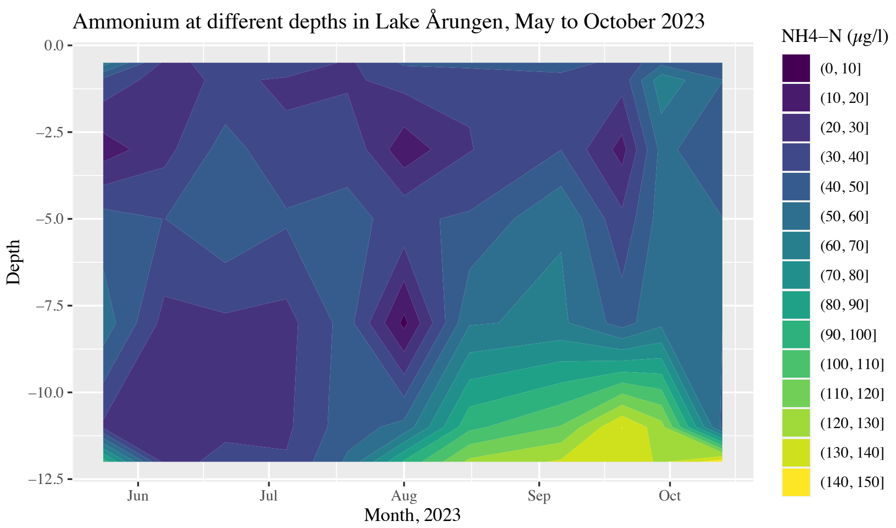

Figure 13: Time-depth profile of ammonium (µg/l) in Lake Årungen from May 24 to October 13, 2023.

Pigments

Chlorophyll a peaked on May 23 at three meters with 114 µg/l (Figure 14). There was no chlorophyll a at 12 meters throughout the season, except on October 13. Most of the chlorophyll a is in the upper parts of the water column, before mixing through the entire water column in October.

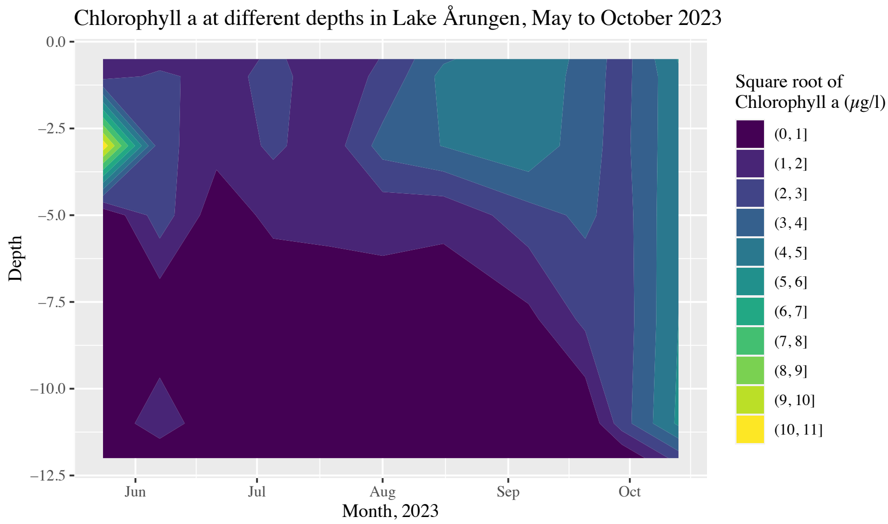

Figure 14: Time-depth profile of chlorophyll a (µg/l) from May 24 to October 13, 2023. The values for chlorophyll a have undergone square root transformation to clarify the relationship between variables.

Fucoxanthin peaked at three meters on May 24 with values of 37 µg/l (Figure 15). The pigment was found throughout the season. From mid-August fucoxanthin was found at almost all depths, reaching deeper down into the water column. In October the values increased and were mixed throughout the entire water column with lower values at 12 meters.

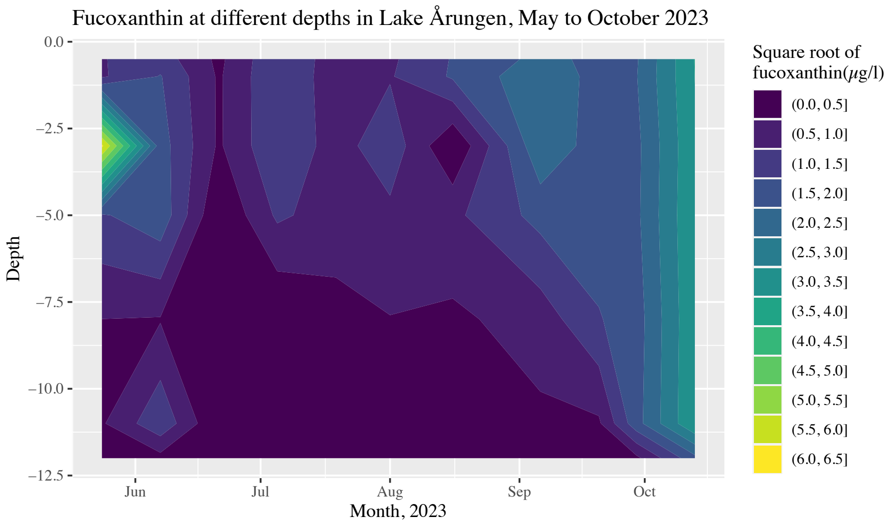

Figure 15: Time-depth profile of fucoxanthin (μg/l) from May 24 to October 13, 2023.. The values for fucoxanthin have undergone square root transformation to clarify the relationship between variables.

Peridinin was only found in-between July 5 and August 16 (Figure 16). The concentration peaked at 1.28 μg/l at three meters on August 1.

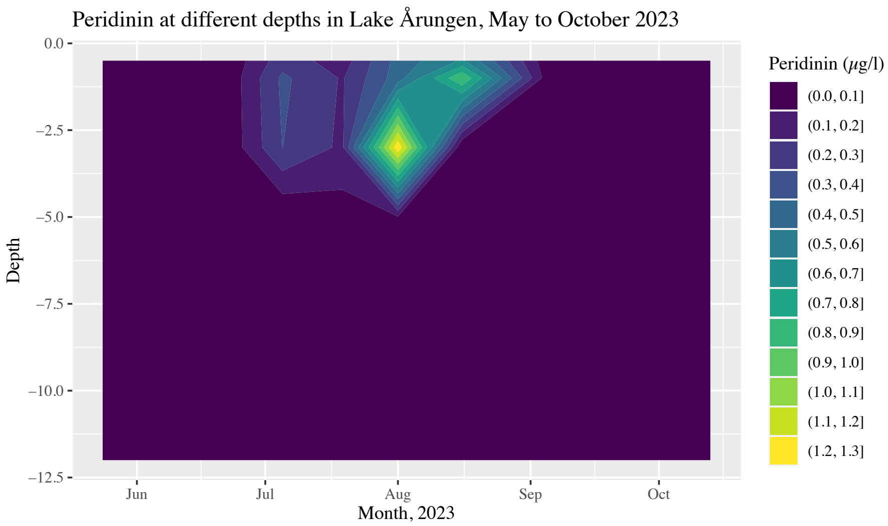

Figure 16: Time-depth profile of peridinin (μg/l) in Lake Årungen from May 24 to October 13, 2023.

Alloxanthin peaked at 1.3 μg/l on July 21 at one meter (Figure 17). At the end of July and the start of August, alloxanthin was mixed through almost the entire water column, with the highest values in the epilimnion. On September 29 no alloxanthin was discovered at all in the water column.

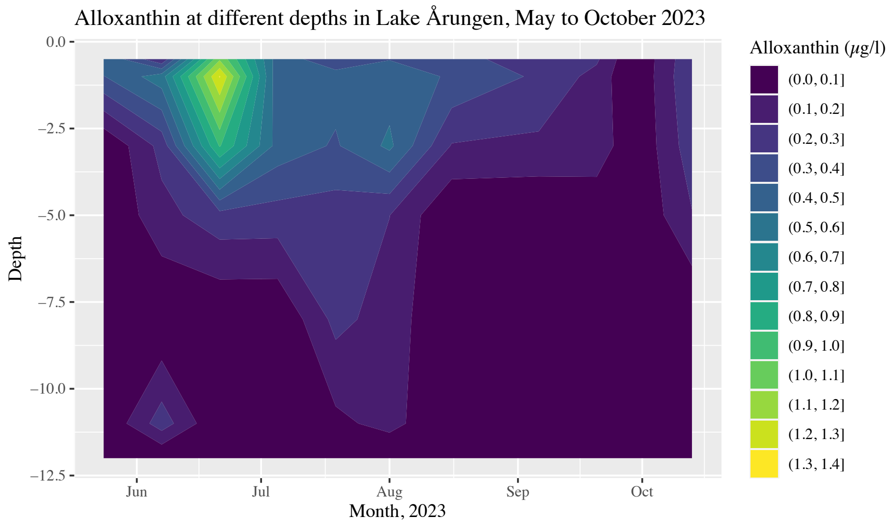

Figure 17: Time-depth profile of alloxanthin (µg/l) in Lake Årungen from May 24 to October 13, 2023.

Phycocyanin

Phycocyanin is a pigment found in cyanobacteria. The data in Figure 18 is collected from NIVAs monitor in Årungselva and given in Relative Fluorescence Units (RFU). Phycocyanin had its first and largest peak on August 22. The values had been relatively low before they suddenly increased on this day. The second peak on September 11 was almost as large as the first. Smaller peaks followed afterwards, but none at the same scale as the first two peaks.

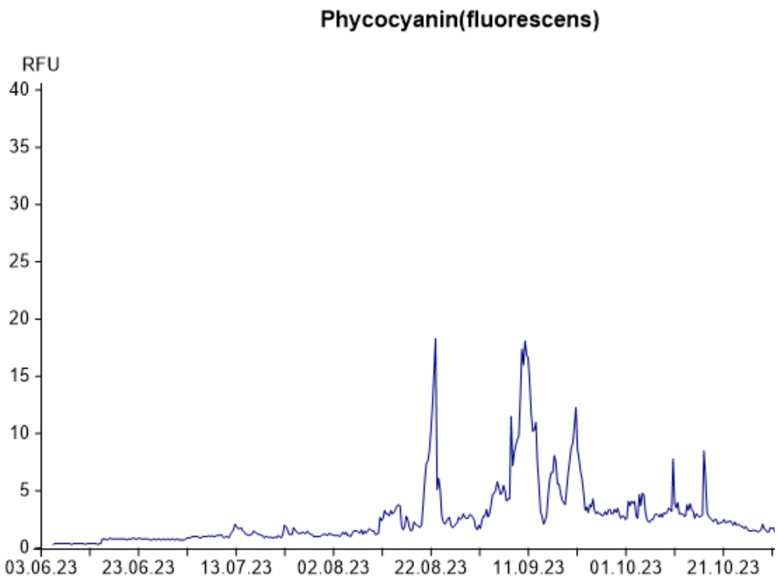

Figure 18: Changes in the pigment phycocyanin measured in Relative Fluorescence Units (RFU). Data is collected from the Norwegian Institute for Water Research (NIVA)'s water monitor in Årungselva. Data is from June to October 2023.

Field observations

In August a visible phytoplankton bloom began to form at the surface of the lake. This is depicted in the photograph from September 6, which is photographed from land (Figure 19). A small water sample was brought back, and the phytoplankton was identified with a microscope. Figure 19 shows the phytoplankton in question, which was identified to belong to the cyanobacteria genus *Anabaena*.

Figure 19: Cyanobacteria bloom in Lake Årungen on September 6, 2023 (left), Anabaena gathered from the bloom and analysed in a microscope (right).

Nitrate and phosphate coupling

Figure 20 shows the dynamics between nitrate and phosphate at 12 meters depth in Lake Årungen. Phosphate was solely registered on September 29, reaching values of 1.27 µg/l. Nitrate decreased steadily from the first sampling, with a small increase on September 20, before it continued to decrease. The phosphate peak came quickly after the small nitrate increase.

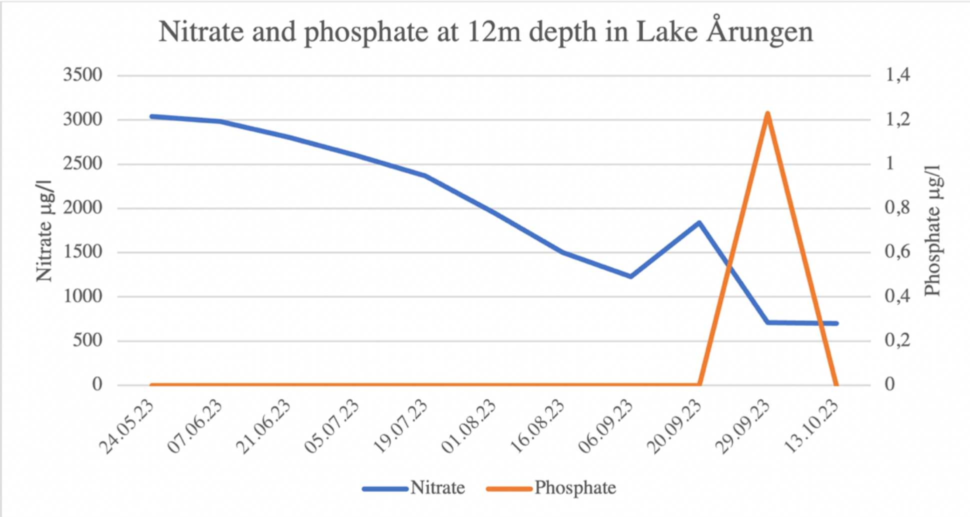

Figure 20: Nitrate and phosphate at 12 meter depth in Lake Årungen from May 24 to October 13. All values are given in µg/l.

Principal component analysis

Figure 21 shows a PCA correlation circle of the average top five meters for the variables in Lake Årungen between May and October. All the PCAs except Figure 24 use an average for the different variables for the top five metres in Lake Årungen. The PCA are composed of two principal components, the vertical axis dimension 1 (Dim1), and the horizontal axis dimension 2 (Dim2). Both principal components include a percentage showing how much of the total variance is explained. Since Dim1 has a higher percentage (41.3%) explaining the total variance than Dim2 (25%), differences between the variables along the horizontal axis weigh more than for the vertical axis. The two principal components explain 66.3% of the total variance. All the variables are represented as arrows in the correlation circle, with the length of the arrows representing the contribution of each variable to the principal component. Longer arrows indicate higher contribution. The correlation between the variables is shown by their proximity, with the closer the variables are the more correlated they are. Orthogonal variables are unrelated to each other, while variables pointing in opposite directions are negatively correlated.

All the PCAs include the variable day, which corresponds to the number of days from the first sampling (Appendix 6, Table A4). The variables peridinin and fucoxanthin point in opposite directions and are negatively correlated. Chlorophyll a and fucoxanthin are close to each other indicating a correlation between the two variables. TP is somewhat correlated with chlorophyll a and fucoxanthin. Phosphate has a small contribution to the total variance but is in the same area as chlorophyll a and fucoxanthin. Temperature is negatively correlated with fucoxanthin and chlorophyll a. Both TN and NO_3 point in the same direction and are close, meaning they are correlated. Alloxanthin and ammonium are negatively correlated, as they are pointing in opposite directions. pH and absorbance are negatively correlated.

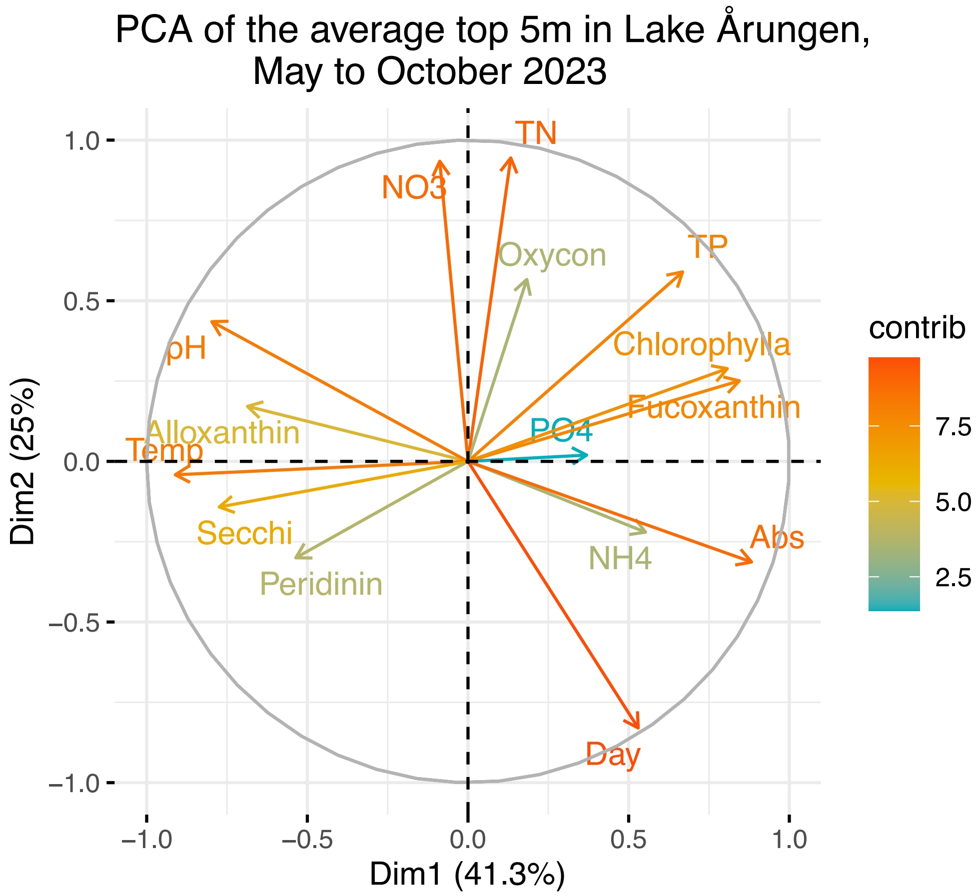

Figure 21: Correlation circle from a principal component analysis of the average of the variables in the top five meters depth of Lake Årungen from May to October.

The second correlation circle is from a PCA of the variables in Lake Årungen from June 7 to October 13 (Figure 22). This PCA also includes another variable differing from Figure 21, namely RFU. Dim1 and Dim2 account for 69.4% of the total variance in the data. The correlation circle shows a large cluster of variables compromised of RFU, TP, absorbance, chlorophyll a, day and fucoxanthin. RFU are almost completely correlated with chlorophyll a. On the opposite side of Figure 22, alloxanthin, pH, and temperature appear in the same area. These are negatively correlated with the large cluster. TN and nitrate are not negatively correlated with any of the other variables, and are relatively close to each other, indicating some correlation.

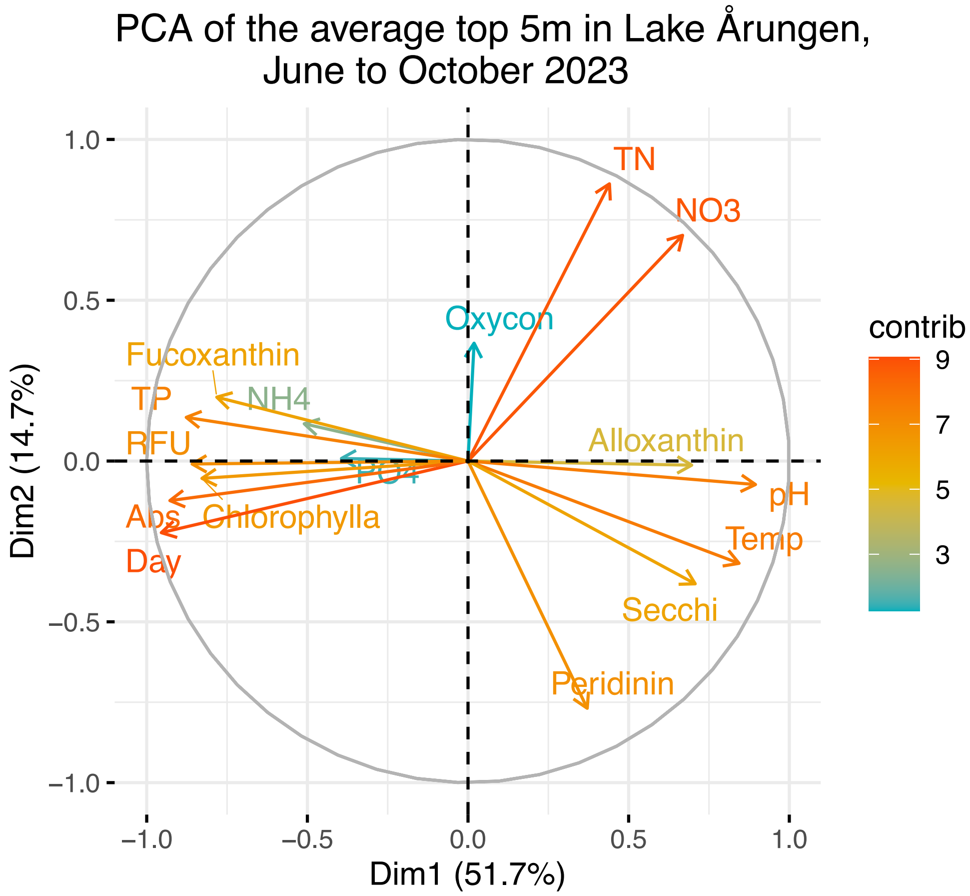

Figure 22: PCA Correlation circle of variables of the average top five meters from June to October in Lake Årungen.

This PCA includes variables from the average of the top five meters in Lake Årungen from June 7 to October 13, but also includes variables from Årungselva in the same period (Figure 23). TN and nitrate for both the lake and river form a cluster, indicating they are correlated. Like Figure 22, chlorophyll a, TP, RFU, absorbance, day and fucoxanthin are spaced closely together. Alloxanthin appears to be negatively correlated with chlorophyll a, RFU and absorbance. pH and TP are negatively correlated, which Secchi and temperature also are with fucoxanthin. Secchi and temperature are correlated with each other. Peridinin and outlet TP are somewhat negatively correlated.

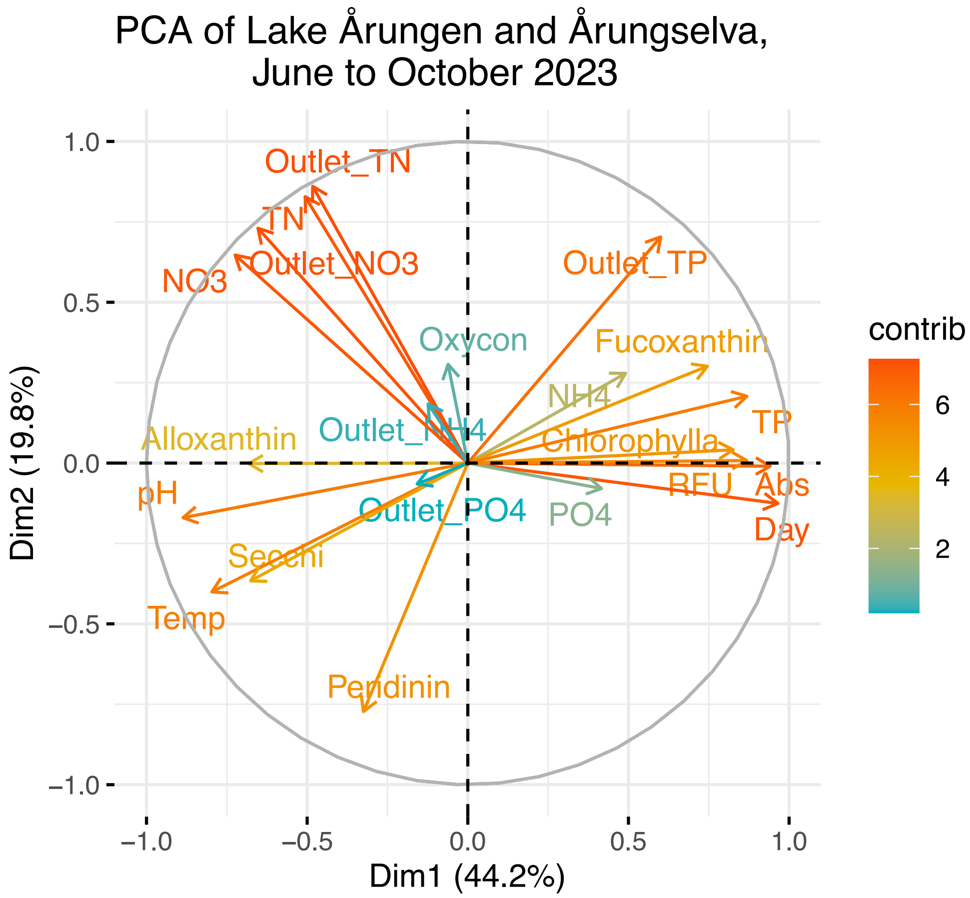

Figure 23: PCA Correlation circle of variables from the average top five meters of Lake Årungen and Årungselva from June to October.

Figure 24 shows a PCA containing only the nutrients in Lake Årungen and the depth. Unlike the previous PCAs, this one includes all depths and contains no averages. 46.2% of the total variance is explained by this PCA. Nitrate and total nitrogen are correlated, and negatively correlated with the number of days and phosphate. Total phosphorus forms a small cluster with depth and ammonium, whereas none of them are negatively correlated with any of the other nutrients.

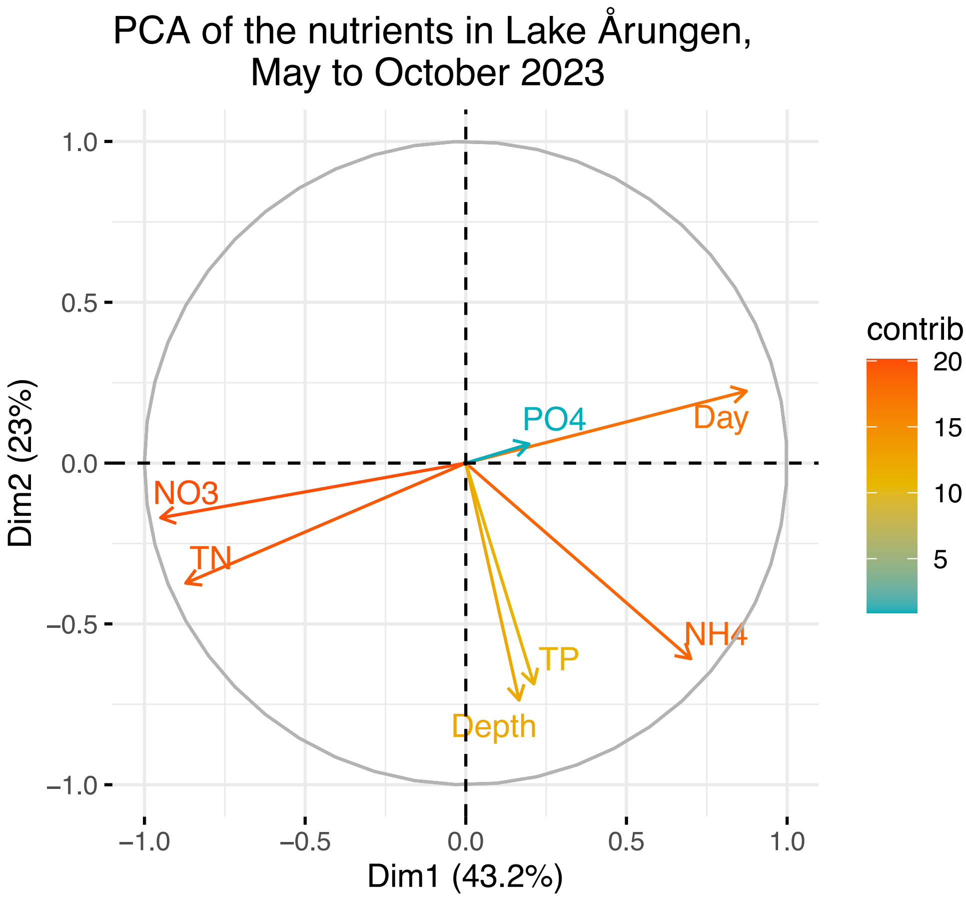

Figure 24: PCA Correlation circle of nutrient variables from of Lake Årungen and Årungselva from June to October.

Discussion

This discussion provides an overview of the general conditions in Lake Årungen in 2023, regarding temperature, precipitation, oxygen, and light. The next part discusses the nutrient dynamics for May to October, before answering the main objectives of the thesis.

General conditions in Lake Årungen 2023

The air temperature in Lake Årungen in 2023 was higher than the normal values for 1991-2020 (Figure 2). High temperatures together with sun radiation promote thermal stratification (Wetzel, 2001a), which became apparent in the lake in May (Figure 4). Furthermore, high temperatures often lead to good growth conditions. The precipitation values were abnormal compared to the normal (1991-2020), starting extremely dry and ending with several heavy precipitation events (Figure 3). In fact, the BIOKLIM station in Ås recorded 40 mm of precipitation on August 7 (Appendix 7, Table A5). Two further events of heavy precipitation events occurred on August 20 and 26 with 32 mm and 46 mm, respectively. Heavy rainfall events may lead to runoff rich in nutrients, especially in agricultural areas (Brönmark & Hansson, 2017a).

Lake Årungen was thermally stratified from May, and in July oxygen was below the detection limit from six meters depth (Figure 5). It is widely accepted that thermal stratification in eutrophic lakes is connected to anoxic conditions in the hypolimnion (Wetzel, 2001b). Lakes have two main sources of oxygen: diffusion from air and photosynthesis (Brönmark & Hansson, 2017a). Phytoplankton can cause an oversaturation of oxygen in the epilimnion, which was documented in periods for Lake Årungen (Figure 6). The oxygen produced from photosynthesis in the epilimnion was however not exchanged with the hypolimnion due to thermal stratification. Processes like the biological oxidation of organic material by bacteria and microorganisms in the hypolimnion further consume large amounts of oxygen (Wetzel, 2001b), facilitating the anoxic conditions. In turn, phytoplankton will avoid the hypolimnion due to the lack of oxygen.

Earlier research by Romarheim (2012) uncovered light limitation for phytoplankton in Lake Årungen. During the sampling season of 2023, several tests with the Secchi disk uncovered shallow visibility and turbid waters. Upon examining Figures 4 and 7, the thermocline extends downward from four meters while the euphotic zone was 276 cm on average. This indicates that the epilimnion extended beyond the euphotic zone throughout the season, leading to situations where phytoplankton located deeper within the epilimnion may have experienced periods of insufficient light. Another finding was an observed cyanobacteria bloom in August and early September (Figure 19). Cyanobacteria may float to the surface and form blooms in search of better light conditions (Romarheim et al., 2012) and to perform photosynthesis. Surface blooms of cyanobacteria can lead to a decrease in the euphotic zone by diminishing water transparency (Sukenik et al., 2015). This explains why the observed bloom coincides with the lowest recorded euphotic depth in Lake Årungen (Figure 7).

Nutrient dynamics in Lake Årungen 2023

A principal component analysis of the results shows that total phosphorus was not correlated with any other nutrients. However, there was a correlation with depth (Figure 24). There are two possible main explanations as to why total phosphorus increases with depth. The first explanation is that phosphorus is often bound to particles or trapped inside phytoplankton. When these particles and phytoplankton sink to the bottom, they are included in the water samples as total phosphorus. As mentioned earlier, heavy rainfall events can transport particles into the lake (Brönmark & Hansson, 2017a). Considering the increase of phytoplankton (Figure 14) and the heavy rainfall events in August (Figure 3), this seems as a likely explanation as to why the amount of phosphorus increases with depth in this period.

The second explanation is internal loading of phosphorus. According to Brönmark & Hansson (2017a), internal loading of phosphorus is induced by anoxic conditions. They explain that lack of oxygen in the hypolimnion causes a low redox potential close to the sediment and affects complexes in the lake. Iron often forms complexes with phosphate, and a low redox potential can reduce iron and separate the complexes. Phosphate is then released from the sediment and becomes available for phytoplankton when whole-lake circulation returns (Brönmark & Hansson, 2017a). However, the internal loading can be delayed by nitrate promoting oxidative conditions in the lake (Ma et al., 2021).

Pia Frostad (2018) investigated the coupling between phosphate and nitrate in Lake Årungen and found clear evidence of internal loading in 2009, 2013, and 2017. However, in this study, phosphate was only recorded at a depth of 12 meters on September 29 (Figure 10). Phosphate was under the detection limit for most of the sampling season, except for a few small peaks in the epilimnion and at a depth of 11 meters. When comparing this study's findings on phosphate close to the sediment with Frostad's findings in 2017, the phosphate values are 39 times lower in 2023. The maximum phosphate in 2009 and 2013 were respectively 287 µg/l and 400 µg/l (Frostad, 2018) - a clear contrast to the much lower values in 2017 and 2023 (Figure 10). These findings support the notion that the total phosphorus was unlikely greatly affected by internal loading of phosphate in 2023, and question whether internal loading is of any great concern for the future. It must be pointed out that this study only sampled down to 12 meters, while Frostad's studies sampled down to 13 meters. Because of this potential limitation, comparisons between the years might give a wrongful impression of the change in internal loading in Lake Årungen.

Total nitrogen and nitrate clustered together in the PCA (Figure 24) and were negatively correlated with the number of days passing. A large fraction of total nitrogen is nitrate, explaining the nutrients' shared pattern. As shown in Figures 11 and 12, both shared a large decrease close to the sediment in September. This decrease was likely the result of bacterial denitrification. In anoxic conditions, bacteria can use nitrate as an electron acceptor and produce dinitrogen gas (Burgin & Hamilton, 2007). Dinitrogen gas is available to some nitrogen-fixating cyanobacteria (Paerl et al., 2001) but is often considered a permanent elimination of nitrogen from the lake (Burgin & Hamilton, 2007). As explained in the method section, the total nitrogen analysis did not account for dinitrogen. Denitrification therefore provides a good explanation as to why total nitrogen and nitrate concentrations had a large decrease close to the sediment.

In contrast to nitrate, ammonium did not share a pattern with total nitrogen (Figure 13). Instead, ammonium increased greatly in the anoxic conditions close to the sediment from August. Bacterial decomposition of organic material in anoxic conditions can release ammonium (Brönmark & Hansson, 2017a). An increase in ammonium leads to the implication of more available nitrogen for phytoplankton. Though ammonium appeared in considerably lower amounts than nitrate and total nitrogen, it is still of concern. Ammonium is in a reduced form, and therefore more easily assimilated by phytoplankton (Brönmark & Hansson, 2017a). This can become a problem when the whole-lake circulation resumes and spreads ammonium throughout the water column. In addition, the ammonium may be transported to the outlet and travel to Bunnefjorden. This connection between increased ammonium and transport to the outlet should be investigated in further research.

By comparing the results from this study with previous findings by Frostad (2018), a clear decrease in both nitrogen and phosphorus is apparent. Total nitrogen values have on average decreased by 1300 µg/l for the whole sampling season since 2017. Because nitrogen in the lake correlates with nitrogen in the outlet (Figure 23), one can assume that a continued decrease of nitrogen in the lake will lead to lower concentrations in the outlet. Several management strategies have been implemented around Lake Årungen (Vann-nett), which may explain the reduction of nitrogen and phosphorus in the lake. It is important to note that 2023 was affected by extreme weather events, and the reduction may be caused by other factors than management efforts. However, a reduction in nutrients may have unintended consequences. Earlier research has discussed the possibility of nitrate as a management strategy to delay internal loading of phosphorus (Søndergaard et al., 2000). Figure 20 shows that phosphate increased when nitrate decreased, indicating a coupling between the two. This raises the question as to how phosphate concentrations in the lake will be affected if nitrate is further reduced. However, Søndergaard et al. (2000) found that even low nitrate concentrations delay the accumulation of phosphate. This should be further investigated to ensure optimal nutrient levels in both Lake Årungen and the outlet.

Phytoplankton succession in Lake Årungen 2023

The first objective of this study is:

Is there any discernible succession among phytoplankton groups in Lake Årungen?

The results demonstrated a pattern of succession between the different groups of phytoplankton investigated. Diatoms dominated first, quickly followed by cryptomonads, then dinoflagellates before cyanobacteria had a bloom, ending with diatoms resuming domination. These results tie well with a report from 2022 by PURA, where diatoms and cyanobacteria follow a similar pattern (Stabell et al., 2022). Earlier research in Lake Årungen highlighted cyanobacteria dominance (Romarheim & Riise, 2009), however the results from 2022 and 2023 show that cyanobacteria only dominated in August. It is not uncommon for phytoplankton composition to change over time, which has been documented in other lakes (Laugaste et al., 1996). When comparing this study's results to those of older studies (Romarheim & Riise, 2009; Stabell et al., 2022), it must be pointed out that sampling has been executed with different methods and at possibly different locations in the lake. Even so, this study shows the succession of phytoplankton groups in a year marked by changing weather and extreme weather events.

The pigments chlorophyll a, fucoxanthin, peridinin, and alloxanthin were investigated at every depth in Lake Årungen. Chlorophyll a is found in all photosynthesizing phytoplankton and indicates which periods had high phytoplankton volume. The other pigments are group-specific, as fucoxanthin is found in diatoms and dinoflagellates, peridinin in dinoflagellates, and alloxanthin in cryptomonads. The season began with high values of fucoxanthin, which are found in diatoms and dinoflagellates. However, the PCA (Figure 21) shows that peridinin and fucoxanthin are negatively correlated. Since peridinin is found solely in dinoflagellates, and peridinin is not correlated with fucoxanthin, one can assume that fucoxanthin only or mostly represents diatoms. This means that diatoms were the major phytoplankton group in Lake Årungen in May.

After diatoms dominated in May, cryptomonads peaked in the middle of June. Cryptomonads were found throughout the whole season, except for a small period at the end of September (Figure 17). They did not dominate the lake for long, as they were quickly followed by dinoflagellates at the beginning of August. The rapid growth of dinoflagellates quickly after and during the peak of cryptomonads, may be explained by dinoflagellates' predation habits. Dinoflagellates can be mixotrophic, feeding on prey and utilising photosynthesis (Carty, 2014). Cryptomonads are small in size and can be categorized as highly edible (Brönmark & Hansson, 2017b). Therefore, one can assume that an abundance of cryptomonads worked as a large nutrient source for dinoflagellates. Dinoflagellates also prey on diatoms (Carty, 2014), which were present during the cryptomonads peak and throughout the summer. In contrast to diatoms and cryptomonads, dinoflagellates did not persist for long. They were only recorded between July and September (Figure 16) before the Secchi depth decreased and the cyanobacteria bloomed.

Cyanobacteria made a grand appearance in August with a visible surface bloom (Figure 19). Figure 18 shows how the pigment phycocyanin, a pigment found in cyanobacteria, increased from August to September. The bloom persevered into September, which is the same time as dinoflagellates vanished for the rest of the sampling period. Cyanobacteria can worsen light conditions (Sukenik et al., 2015) and may have hindered dinoflagellates from prevailing. Because of differences in sampling, it is challenging to ascertain if cyanobacteria dominated the lake. All pigments were measured at identical depths in the lake with the same procedure, except for phycocyanin which was measured at the outlet with NIVA's water monitor. Only the surface water in Lake Årungen flows out of the outlet, which can lead to aggregations of surface-fleeting cyanobacteria. In addition, the outlet is blocked by a dam and only allows water outflow at a certain height. Dry periods like May and June may have had less water outflow, potentially resulting in less phycocyanin recorded by the monitor. Even so, the monitor together with the observed cyanobacteria bloom can give us an impression of when there were more cyanobacteria.

Diatoms increased after the cyanobacteria bloom and resumed domination of the lake. The visible bloom of cyanobacteria and the large amounts of diatoms indicate a strong season for the two phytoplankton groups. Several factors can explain this dominance. Wind may have helped diatoms stay afloat in the epilimnion by creating circulation. Diatoms are heavy and can involuntarily sink to the hypolimnion (Bates & Trainer, 2006). During a period of increased wind cyanobacteria may mass-produce gas vesicles to stay afloat, resulting in a visible surface bloom when the wind situation calms down (Romarheim et al., 2012). Another factor is that Lake Årungen is very nutrient-rich and had a high pH in the upper five metres almost the entire season. Diatoms thrive in basic water (Brönmark & Hansson, 2017c) and waters rich in nutrients (Bates & Trainer, 2006). Nutrient-rich conditions and high pH are preferred by cyanobacteria (Brönmark & Hansson, 2017c). All these factors result in a season favouring cyanobacteria and diatoms, which may not be representative of all years.

Dynamics between nutrients and phytoplankton growth in Lake Årungen 2023

This section aims to answer the following objective:

Is there a coupling between phytoplankton growth and nutrient dynamics in the thermally stratified Lake Årungen?

As shown in Figures 21, 22, and 23, total phosphorus is the only nutrient with a large contribution and is correlated with chlorophyll a. This suggests that the other nutrients did not play a major role in affecting general phytoplankton growth dynamics. Total nitrogen values stayed consistently high from start to finish, including the more available form of nitrogen nitrate. Nitrogen limitation is dependent on a lack of nitrogen, which was never the case in Lake Årungen. Other studies have found support for the possibility of co-limitation by phosphorus and nitrogen in lakes (Elser et al., 2007; Müller & Mitrovic, 2015), but this is likely not the case for Lake Årungen due to the current extreme nitrogen values. However, Lake Årungen may be light-limited (Romarheim, 2012), which could be co-limiting together with phosphorus. Either way, the possibility of co-limitation in Lake Årungen should be investigated in further research.

On the first day of sampling a peculiar peak for chlorophyll a, total phosphorus, and total nitrogen were recorded (Figures 9, 11 and 14). At three meters depth on May 24, they all exhibited values much higher than the rest of the season, whereas chlorophyll a was five times higher than peaks later in the season. It remains unclear why this outlier occurred, and whether it was naturally occurring or pollution of the samples. One explanation is that high nutrient concentrations and warm weather allowed for a short-lived imperceptible bloom at a depth of three meters. Another possibility is that an aggregation of phytoplankton found its way into the water sample during sampling. This could have led to large outlier values, and not been representative for the date. Though the values spiked from the normal, the data cannot be simply termed as an outlier and discarded without clear proof. However, the outlier will need to be handled with some caution to avoid misinterpretations.

Figure 21 showed that total phosphorus correlated mildly with chlorophyll a, and diatoms, while it was negatively correlated with dinoflagellates. In the two PCAs excluding May (Figures 22 and 23), total phosphorus is negatively correlated with cryptomonads. Schindler (1974) showed the effect of phosphorus pollution on a nutrient-poor lake, and solidified phosphorus as the major limiting nutrient in lakes. Therefore, one would assume that more phosphorus ought to increase the growth of all phytoplankton groups. Even though cryptomonads and dinoflagellates are negatively correlated with total phosphorus, this does not necessarily mean that these two groups are not phosphorus-limited. As discussed earlier, a part of total phosphorus includes unavailable phosphorus contained within particles or phytoplankton. In periods characterized by increased total phosphorus and chlorophyll a, it may indicate more phytoplankton and more competition for the remaining available phosphorus. A negative correlation with total phosphorus reveals then which groups are outcompeted by more opportunistic groups capable of utilizing nutrients more efficiently. In conclusion, cryptomonads and dinoflagellates were likely driven away by cyanobacteria and diatoms.

Like total phosphorus, phosphate showed a negative correlation with both dinoflagellates and cryptomonads (Figure 21). However, these results may not be representative. One concern about the findings of phosphate was that the values were quite low and only recorded on four occasions. Most of the PCAs in this study are focused on the average for the top five meters, resulting in the exclusion of the two phosphate peaks under five meters. Since RFU was not recorded in May, two of the PCAs exclude May to include data on cyanobacteria. This means that in Figures 22 and 23, only one phosphate peak was included in the PCAs. Phosphate had a weak contribution in every PCA, even when including all depths (Figure 24). It could be argued that principal component analysis was not the optimal tool for investigating the dynamics between phosphate and phytoplankton, or phosphate did not play a large role this season. However, when inspecting the time-depth profiles of the pigments (Figure 14, 15, 16, 17), phosphate was found during the peak of chlorophyll a and diatoms in May. Later phosphate was also found before the increase of chlorophyll a and diatoms at the end of September. Therefore, phosphate should not be completely discarded due to the weak contribution in the PCAs.

Total nitrogen and nitrate did not have any correlation to any of the pigments in the PCAs (Figures 21, 22, 23). The lack of correlation could be explained by the high concentration of nutrients in the lake. Total nitrogen never went below 2070 mg/l and nitrate's lowest value was 700 mg/l. The amount of available nitrogen stays high throughout the whole growth season. In a guide from Norwegian Environmental Agency, total nitrogen of 2070 mg/l equals severely bad water quality for all lake types in Norway (Direktoratsgruppen vanndirektivet, 2018). Likely, the phytoplankton in Lake Årungen is not limited by nitrogen due to these extreme values.

As mentioned before, the nitrogen-fixating cyanobacteria Anabaena instigated a surface bloom in Lake Årungen during the sampling in 2023 (Figure 19). Nitrogen-fixating cyanobacteria have earlier been recorded in Lake Årungen by Romarheim (2012). Another study (Schindler et al., 2008) researched the composition of phytoplankton in a lake exposed to different types of nutrient pollution. The study found that nitrogen-fixating cyanobacteria will appear in lakes where nitrogen exposure is removed (Schindler et al., 2008). Several management strategies have been implemented to reduce the nutrient pollution in Lake Årungen, and there has likely been a reduction in nitrogen over the decades. This reduction may have triggered a change in cyanobacteria composition, leading to the prevalence of nitrogen-fixating cyanobacteria. How nitrogen fixation affects the nitrogen budget in Lake Årungen is poorly understood. Therefore, the effect of nitrogen-fixating cyanobacteria should be further investigated in Lake Årungen to ensure a continuous reduction of nitrogen.

At the end of the season, an increase in chlorophyll a, diatoms and cryptomonads occurred (Figures 14, 15, 17). As shown in Figures 9 and 13, both ammonium and total phosphorus increased simultaneously. The release of ammonium close to the sediment contributed to a much higher concentration of the nutrient. A weak internal loading of phosphate happened at the same time (Figure 10). Whole-lake circulation was beginning to take place at the last sampling date, with little difference in temperatures between epilimnion and hypolimnion. It can be assumed that when the whole-lake circulation resumed, ammonium and phosphate were transported upwards and distributed through the lake. This could have provided the different phytoplankton groups with more available nutrients and allowed for an increase in growth.

Conclusion

This thesis aimed to investigate the phytoplankton community and the connections between phytoplankton growth and nutrient dynamics in the eutrophic Lake Årungen. By assessing these dynamics, this thesis provides a unique insight into the changing phytoplankton community in the lake.

The main findings in this thesis can be summarized as such:

- *Diatom domination*. Cyanobacteria are often assumed to be the dominating phytoplankton in eutrophic lakes due to visible blooms. However, this study establishes that diatoms dominated in Lake Årungen throughout most of the season in 2023.
- *Succession between phytoplankton groups*. Diatoms dominated the start of the season before cryptomonads had a peak. Afterwards, dinoflagellates made an appearance but were quickly replaced by cyanobacteria. At the end of the season, diatoms increased again.
- *Total phosphorus coupled with chlorophyll a*. Chlorophyll a works as an indicator of total phytoplankton volume and was correlated with total phosphorus through the whole season.
- *Internal loading of phosphate was weak*. Earlier years have shown a clear case of internal phosphate loading, but in 2023 very low values were recorded.
- *Lake Årungen still supplies Årungselva with high values of total nitrogen and nitrate*. Although total nitrogen and nitrate values have gone down since 2017, the lake is still a large supplier of nitrogen to Årungselva. Internal loading of ammonium might also strengthen this supply and call for the need for action.

These results challenge the understanding of phytoplankton communities in eutrophic lakes and highlight the need for more understanding of diatoms in eutrophic lakes. Although Lake Årungen experienced a season with diatom domination, the external factors differed greatly from earlier years. The comparison to the normal weather period for 1991-2020 shows that the year 2023 was unique and may have affected the common pattern of phytoplankton succession in the lake.

Further research should include cyanobacteria pigments in the analysis to ensure a clearer picture of the phytoplankton succession. In addition, sampling down to a depth of 13 meters should also be considered. This will allow for a better comparison with earlier years and give a truer presentation of the internal loading of phosphorus in Lake Årungen. Since diatoms dominated throughout the season, other nutrients like silica should also be investigated. The phytoplankton composition should be investigated in a year more like the normal period, as 2023 experienced uncommon temperatures and precipitation. Yet one should also question what the new normal will be for lakes in a changing climate, and whether the conditions observed this season will significantly differ from those in future seasons.

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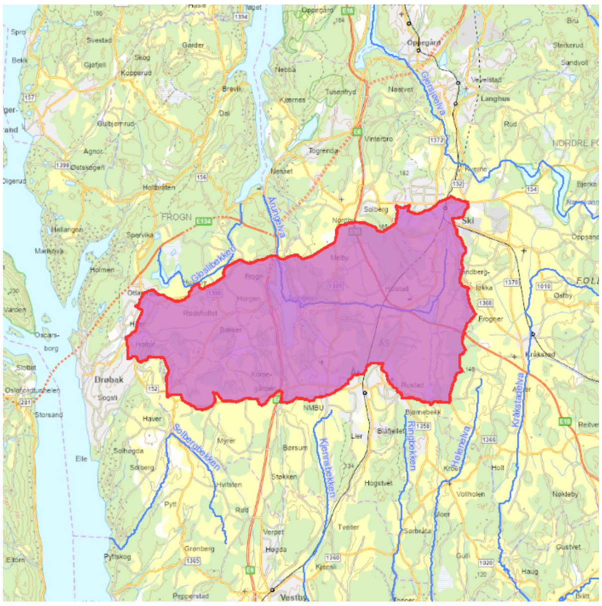
Appendices

Appendix 1 – NEVINA



Norges vassdrags- og energidirektorat

NVE

Kartbakgrunn:	Statens Kartverk
Kartdatum:	EUREF89 WGS84
Projeksjon:	UTM 33N
Beregn.punkt:	260279 E 6625853 N

Nedbørfeltgrenser og feltparametere er automatisk generert og kan inneholde feil. Resultatene må kvalitetssikres.

Nedbørfeltparametere

Vassdragsnr.:	005.3B
Kommune.:	Frogn
Fylke.:	Viken
Vassdrag.:	Årungelva

Feltparametere

Areal (A)	49.9	km²
Effektiv sjø (A_{SE})	2.55	%
Elvleengde (E_L)	9.3	km
Elvegradient (E_G)	7.9	m/km
Elvegradent$_{1085}$ ($E_{G,1085}$)	8.5	m/km
Helning	3.7	°
Dreneringstetthet (D_T)	1.0	km^{-1}
Feltlengde (F_L)	7.4	km

Feltparametere Tilløp

Effektiv sjø – Tilløp (A_{SE-T})	0.19	%
Feltlengde – Tilløp (F_{L-T})	6.6	km

Arealklasse

Bre (A_{BRE})	0	%
Dyrket mark (A_{JORD})	48.4	%
Myr (A_{MYR})	0.1	%
Leire (A_{LEIRE})	66.0	%
Skog (A_{SKOG})	33.9	%
Sjø (A_{SJO})	3.1	%
Snaufjell (A_{SF})	0	%
Urban (A_U)	4.9	%
Uklassifisert areal (A_{REST})	9.5	%

Hypsografisk kurve

Høyde$_{MIN}$	34	m
Høyde$_{10}$	59	m
Høyde$_{20}$	69	m
Høyde$_{30}$	79	m
Høyde$_{40}$	89	m
Høyde$_{50}$	99	m
Høyde$_{60}$	106	m
Høyde$_{70}$	117	m
Høyde$_{80}$	124	m
Høyde$_{90}$	135	m
Høyde$_{MAX}$	163	m

Klima- /hydrologiske parametere

Avrenning 1961-90 (Q_N)	15.7	l/s*km²
Sommernedbør	384	mm
Vinternedbør	430	mm
Årstemperatur	5.3	°C
Sommertemperatur	13.3	°C
Vintertemperatur	-0.4	°C

Rapportdato: 28/09/2023

Figure A1: Årungen's catchment parameters calculated with the help of the map service NEVINA (NVE & Statens Kartverk)

Appendix 2 – Data and measurements from Lake Årungen

Table A1: The data presented is collected from in situ measurements and laboratory analysis of water samples from Lake Årungen 2023.

Sample	Date	Depth (m)	Temp (°C)	O_2 (mg/l)	O_2 %	pH	TP (µg/l)	TN (µg/l)	NO_3-N (µg/l)	NH_4-N (µg/l)	PO_4-P (µg/l)	Chl. a (µg/l)	Peri. (µg/l)	Fuco. (µg/l)	Allox. (µg/l)	Abs. (nm)
1	24.05.2023	0,5	17,0	9,98	103,80	8,81	130,12	3650,00	2930,76	64,96	0,00	3,00	0,00	0,95	0,50	0,13
2	24.05.2023	1	16,4	10,10	103,20	8,76	35,76	3550,00	2901,93	36,91	2,87	2,67	0,00	0,87	0,40	0,13
	24.05.2023	2	16,0	9,87	100,00											
3	24.05.2023	3	14,3	9,59	94,10	8,21	91,15	4400,00	2919,57	14,76	0,00	114,75	0,00	37,18	0,00	0,14
	24.05.2023	4	11,7	8,56	78,70											
4	24.05.2023	5	10,6	7,90	71,40	7,74	28,24	3660,00	3020,49	44,29	0,00	0,00	0,00	2,07	0,00	0,15
	24.05.2023	6	9,1	7,55	65,20											
	24.05.2023	7	8,6	7,41	63,60											
5	24.05.2023	8	8,3	7,12	60,40	7,56	34,39	3790,00	3101,17	56,11	0,00	0,09	0,00	0,25	0,00	0,17
	24.05.2023	9	8,1	7,02	59,30											
	24.05.2023	10	7,9	6,95	58,50											
6	24.05.2023	11	7,8	6,82	57,10	7,28	44,65	3870,00	3092,57	28,05	0,00	0,00	0,00	0,19	0,00	0,18
7	24.05.2023	12	7,4	6,57	54,40	7,19	47,38	3710,00	3039,85	95,97	0,00	0,00	0,00	0,14	0,00	0,19
9	07.06.2023	0,5	19,3	11,42	124,00	9,30	18,67	3360,00	2623,72	28,05	0,00	2,77	0,00	1,59	0,21	0,12
10	07.06.2023	1	19,0	11,31	121,89	9,45	20,72	3330,00	2571,87	25,10	0,00	4,74	0,00	2,34	0,56	0,03
	07.06.2023	2	18,8	11,04	118,40											
11	07.06.2023	3	17,2	10,04	104,40	9,15	19,35	3290,00	2624,37	26,58	0,00	5,49	0,00	2,97	0,23	0,04
	07.06.2023	4	15,8	8,88	89,60											
12	07.06.2023	5	13,6	7,49	72,00	7,90	22,77	3450,00	2722,91	39,86	0,00	6,64	0,00	3,40	0,16	0,04
	07.06.2023	6	10,7	6,16	55,50											
	07.06.2023	7	9,3	5,65	49,30											
13	07.06.2023	8	8,4	5,35	45,70	7,60	22,77	3640,00	3030,38	26,58	0,00	0,00	0,00	0,22	0,00	0,07
	07.06.2023	9	8,1	5,17	43,70											
	07.06.2023	10	8,0	5,02	42,40											
14	07.06.2023	11	7,8	4,72	39,70	7,00	22,77	3300,00	2659,66	28,05	0,00	3,19	0,00	1,91	0,25	0,04
15	07.06.2023	12	7,7	3,95	31,30	6,80	31,66	3600,00	2985,85	26,58	0,00	0,00	0,00	0,11	0,00	0,06
17	21.06.2023	0,5	21,9	10,00	114,00	8,77	20,72	2850,00	2342,72	32,48	0,00	2,50	0,00	0,15	1,08	0,08
18	21.06.2023	1	21,8	9,80	111,70	9,04	16,62	3000,00	2353,26	32,48	0,00	2,87	0,00	0,19	1,31	0,08
	21.06.2023	2	21,6	9,12	103,50											
19	21.06.2023	3	20,2	6,64	73,30	8,70	16,62	3090,00	2376,50	44,29	0,00	1,80	0,00	0,18	0,91	0,08
	21.06.2023	4	17,3	5,05	52,60											
20	21.06.2023	5	14,3	4,10	40,00	7,19	11,83	3350,00	2657,50	48,72	0,00	0,12	0,00	0,00	0,26	0,11
	21.06.2023	6	12,3	3,74	35,00											
	21.06.2023	7	10,3	3,92	35,00											
21	21.06.2023	8	9,3	4,32	37,70	7,33	15,25	3550,00	3037,70	28,05	0,00	0,00	0,00	0,00	0,00	0,13
	21.06.2023	9	8,6	3,72	31,90											
	21.06.2023	10	8,3	3,26	27,70											
22	21.06.2023	11	8,1	2,81	23,80	6,80	18,67	3220,00	2875,68	28,05	0,00	0,00	0,00	0,00	0,00	0,12
23	21.06.2023	12	7,9	2,36	19,90	6,74	20,03	3170,00	2804,25	32,48	0,00	0,00	0,00	0,00	0,00	0,12
25	05.07.2023	0,5	20,2	8,86	97,60	8,68	18,67	2700,00	2188,44	39,86	0,00	4,55	0,26	2,08	0,45	0,12
26	05.07.2023	1	20,2	8,80	97,20	8,90	19,35	2720,00	2164,99	28,05	0,00	5,03	0,32	2,14	0,43	0,08
	05.07.2023	2	20,2	8,50	94,00											
27	05.07.2023	3	20,2	8,20	91,00	8,82	20,72	2730,00	2152,51	32,48	0,00	4,75	0,30	2,12	0,46	0,08
	05.07.2023	4	19,8	7,40	82,00											
28	05.07.2023	5	15,2	0,90	9,30	8,35	18,67	2810,00	2247,18	41,34	0,00	1,66	0,00	1,17	0,26	0,10
	05.07.2023	6	12,4	1,20	10,60											
	05.07.2023	7	10,2	1,80	16,00											
29	05.07.2023	8	9,1	1,60	13,60	7,54	14,56	3280,00	2882,35	26,58	0,00	0,00	0,00	0,00	0,00	0,11
	05.07.2023	9	8,7	1,60	13,70											
	05.07.2023	10	8,3	0,90	8,20											
30	05.07.2023	11	8,1	0,20	2,00	7,19	17,30	3190,00	2707,64	28,05	0,00	0,00	0,00	0,00	0,00	0,12
31	05.07.2023	12	7,9	0,00	0,00	6,92	20,03	3010,00	2598,98	31,01	0,00	0,00	0,00	0,00	0,00	0,12
33	19.07.2023	0,5	19,1	9,10	98,30	8,55	14,56	2540,00	1948,97	28,05	0,00	2,41	0,15	0,57	0,34	0,08
34	19.07.2023	1	19,1	9,00	97,50	8,70	13,20	2520,00	1967,25	28,05	0,00	2,38	0,19	0,51	0,44	0,08
	19.07.2023	2	19,1	9,10	98,00											
35	19.07.2023	3	18,9	8,70	94,10	8,64	13,88	2520,00	1970,70	38,39	0,00	2,05	0,18	0,59	0,39	0,08
	19.07.2023	4	18,8	8,50	91,00											
36	19.07.2023	5	18,6	7,80	84,00	8,58	12,51	2460,00	1948,75	41,34	0,00	1,31	0,05	0,61	0,25	0,08
	19.07.2023	6	17,9	6,60	69,40											
	19.07.2023	7	11,8	0,30	2,50											
37	19.07.2023	8	9,6	0,40	3,20	7,13	75,42	3080,00	2663,31	44,29	0,00	0,44	0,00	0,10	0,23	0,10
	19.07.2023	9	8,8	0,00	0,00											
	19.07.2023	10	8,7	0,00	0,00											
38	19.07.2023	11	8,4	0,00	0,00	6,82	17,30	2930,00	2474,18	45,77	0,00	0,05	0,00	0,00	0,07	0,12
39	19.07.2023	12	8,2	0,00	0,00	6,77	19,35	2840,00	2367,46	51,68	0,00	0,00	0,00	0,00	0,00	0,12
41	01.08.2023	0,5	19,7	10,20	112,00	8,84	11,83	2340,00	1772,31	41,34	0,00	4,13	0,44	0,83	0,40	0,12
42	01.08.2023	1	19,7	10,30	112,00	8,98	15,93	2350,00	1753,60	33,96	0,00	4,71	0,45	0,92	0,45	0,08
	01.08.2023	2	19,6	10,00	108,00											
43	01.08.2023	3	19,2	9,00	97,00	8,92	26,87	2390,00	1783,93	13,29	0,00	11,71	1,28	1,78	0,52	0,08
	01.08.2023	4	18,6	7,70	82,00											
44	01.08.2023	5	17,6	4,40	46,00	8,36	18,67	2430,00	1868,28	38,39	0,00	1,64	0,09	0,75	0,20	0,09

Sample	Date	Depth (m)	Temp (°C)	O_2 (mg/l)	O_2 %	pH	TP (μg/l)	TN (μg/l)	NO_3-N (μg/l)	NH_4-N (μg/l)	PO_4-P (μg/l)	Chl. a (μg/l)	Peri. (μg/l)	Fuco. (μg/l)	Allox. (μg/l)	Abs. (nm)
	01.08.2023	6	16,4	2,00	20,00											
	01.08.2023	7	14,0	0,20	2,00											
45	01.08.2023	8	10,5	0,00	0,00	7,26	16,62	2710,00	2200,49	7,38	0,00	0,32	0,00	0,23	0,15	0,09
	01.08.2023	9	9,4	0,00	0,00											
	01.08.2023	10	9,0	0,00	0,00											
46	01.08.2023	11	8,6	0,00	0,00	6,91	18,67	2950,00	2323,14	53,15	0,00	0,00	0,00	0,06	0,14	0,11
47	01.08.2023	12	8,4	0,00	0,00	6,80	29,61	2700,00	1951,33	91,54	0,00	0,00	0,00	0,00	0,00	0,13
49	16.08.2023	0,5	19,4	10,20	110,00	8,64	28,24	2600,00	1821,37	44,29	0,00	14,96	0,61	2,36	0,36	0,10
50	16.08.2023	1	19,1	10,20	110,00	8,60	30,97	2610,00	1757,25	31,01	0,00	18,63	0,89	2,44	0,39	0,10
	16.08.2023	2	18,5	9,20	99,00											
51	16.08.2023	3	18,3	8,60	92,00	8,63	24,82	2560,00	1789,53	29,53	0,00	16,26	0,00	0,00	0,19	0,10
	16.08.2023	4	17,9	7,30	77,00											
52	16.08.2023	5	17,1	5,00	52,00	7,94	18,67	2600,00	1884,63	41,34	0,00	1,53	0,00	0,79	0,00	0,11
	16.08.2023	6	16,9	4,70	48,00											
	16.08.2023	7	14,7	1,20	12,00											
53	16.08.2023	8	11,2	0,00	0,00	7,44	22,77	2730,00	2018,89	59,06	0,00	0,14	0,00	0,16	0,00	0,10
	16.08.2023	9	9,5	0,00	0,00											
	16.08.2023	10	9,0	0,00	0,00											
54	16.08.2023	11	8,8	0,00	0,00	7,13	28,24	2570,00	1744,34	97,45	6,16	0,00	0,00	0,00	0,00	0,12
55	16.08.2023	12	8,5	0,00	0,00	6,97	37,81	2520,00	1504,00	122,55	0,00	0,00	0,00	0,00	0,00	0,11
57	06.09.2023	0,5	18,2	11,50	122,00	8,38	30,29	2550,00	1618,47	50,20	0,00	22,78	0,00	4,58	0,21	0,15
58	06.09.2023	1	18,1	10,90	116,00	8,56	31,66	2510,00	1606,64	32,48	0,00	24,39	0,00	5,69	0,28	0,15
	06.09.2023	2	18,0	10,40	110,00											
59	06.09.2023	3	17,9	10,30	108,00	8,45	29,61	2490,00	1622,77	39,86	0,00	23,57	0,00	5,80	0,18	0,15
	06.09.2023	4	17,5	8,20	85,00											
60	06.09.2023	5	16,5	5,10	53,00	7,71	26,87	2590,00	1777,91	59,06	0,00	6,60	0,00	2,79	0,00	0,15
	06.09.2023	6	16,0	4,10	42,00											
	06.09.2023	7	15,1	2,30	23,00											
61	06.09.2023	8	12,9	0,00	0,00	7,29	34,39	2590,00	1778,98	62,01	0,00	0,53	0,00	0,52	0,00	0,14
	06.09.2023	9	11,7	0,00	0,00											
	06.09.2023	10	10,2	0,00	0,00											
62	06.09.2023	11	9,4	0,00	0,00	6,85	30,29	2380,00	878,30	110,73	0,00	0,00	0,00	0,16	0,00	0,13
63	06.09.2023	12	9,2	0,00	0,00	6,91	50,80	2290,00	1230,10	131,40	0,00	0,00	0,00	0,13	0,00	0,16
65	20.09.2023	0,5	15,8	8,30	84,00	7,68	30,29	2580,00	1797,92	32,48	2,87	13,63	0,00	3,53	0,22	0,14
66	20.09.2023	1	15,7	8,30	83,00	7,66	33,03	2560,00	1794,91	33,96	6,98	12,25	0,00	3,27	0,17	0,14
	20.09.2023	2	15,7	8,30	83,00											
67	20.09.2023	3	15,7	8,20	83,00	7,65	30,97	2600,00	1788,24	16,24	0,00	10,86	0,00	3,02	0,18	0,14
	20.09.2023	4	15,6	8,20	82,00											
68	20.09.2023	5	15,5	7,60	76,00	7,63	30,97	2570,00	1800,07	32,48	0,00	10,35	0,00	3,05	0,00	0,15
	20.09.2023	6	15,4	7,30	73,00											
	20.09.2023	7	15,2	6,50	65,00											
69	20.09.2023	8	14,7	3,20	32,00	7,39	43,97	2890,00	2108,40	45,77	0,00	5,08	0,00	2,15	0,00	0,16
	20.09.2023	9	11,7	0,20	2,00											
	20.09.2023	10	10,2	0,10	1,00											
70	20.09.2023	11	9,4	0,00	0,00	6,95	68,58	2160,00	964,15	140,26	0,00	0,00	0,00	0,18	0,00	0,18
71	20.09.2023	12	9,1	0,00	0,00	6,91	69,26	2130,00	1838,59	135,83	0,00	0,00	0,00	0,07	0,00	0,19
73	29.09.2023	0,5	14,7	7,80	76,00	7,90	30,97	2790,00	2074,41	47,25	0,00	6,36	0,00	3,80	0,00	0,15
74	29.09.2023	1	14,6	7,70	76,00	7,67	31,66	2880,00	2044,93	66,44	0,00	6,79	0,00	3,90	0,00	0,16
	29.09.2023	2	14,6	7,60	75,00											
75	29.09.2023	3	14,6	7,50	74,00	7,57	30,97	2820,00	2056,33	53,15	0,00	7,15	0,00	3,51	0,00	0,16
	29.09.2023	4	14,5	7,50	73,00											
76	29.09.2023	5	14,5	7,40	73,00	7,50	30,97	2820,00	2044,93	54,63	0,00	6,28	0,00	3,59	0,00	0,16
	29.09.2023	6	14,5	7,30	72,00											
	29.09.2023	7	14,5	7,30	72,00											
77	29.09.2023	8	14,3	6,50	63,00	7,47	33,03	2820,00	2045,57	57,58	0,00	5,91	0,00	3,10	0,00	0,16
	29.09.2023	9	13,8	4,70	45,00											
	29.09.2023	10	10,9	0,10	1,00											
78	29.09.2023	11	9,8	0,00	0,00	7,05	54,22	2170,00	938,55	124,02	0,00	6,46	0,00	3,28	0,00	0,17
79	29.09.2023	12	9,4	0,00	0,00	6,98	67,90	2070,00	709,83	128,45	1,23	0,00	0,00	0,15	0,00	0,20
81	13.10.2023	0,5	11,7	8,90	82,00	7,47	28,24	2620,00	1459,89	42,82	0,00	25,65	0,00	12,37	0,28	0,15
82	13.10.2023	1	11,7	8,80	81,00	7,44	26,19	2150,00	1793,19	50,20	0,00	22,90	0,00	12,30	0,29	0,15
	13.10.2023	2	11,6	8,70	80,00											
83	13.10.2023	3	11,6	8,70	80,00	7,40	27,00	2570,00	1816,42	41,34	0,00	22,80	0,00	11,90	0,26	0,15
	13.10.2023	4	11,6	8,70	80,00											
84	13.10.2023	5	11,6	8,60	79,00	7,37	26,87	2610,00	1819,44	50,20	0,00	24,33	0,00	12,13	0,19	0,15
	13.10.2023	6	11,6	8,60	79,00											
	13.10.2023	7	11,6	8,60	79,00											
85	13.10.2023	8	11,6	8,60	79,00	7,34	27,56	2600,00	1819,01	50,20	0,00	25,04	0,00	11,97	0,00	0,15
	13.10.2023	9	11,6	8,60	79,00											
	13.10.2023	10	11,5	8,50	78,00											
86	13.10.2023	11	11,3	5,10	47,00	7,28	30,29	2610,00	1751,23	47,25	4,92	26,97	0,00	12,14	0,00	0,15
87	13.10.2023	12	9,8	0,10	1,00	6,78	57,64	2580,00	699,50	146,17	0,00	5,92	0,00	3,42	0,00	0,19

Appendix 3 – Standard curves

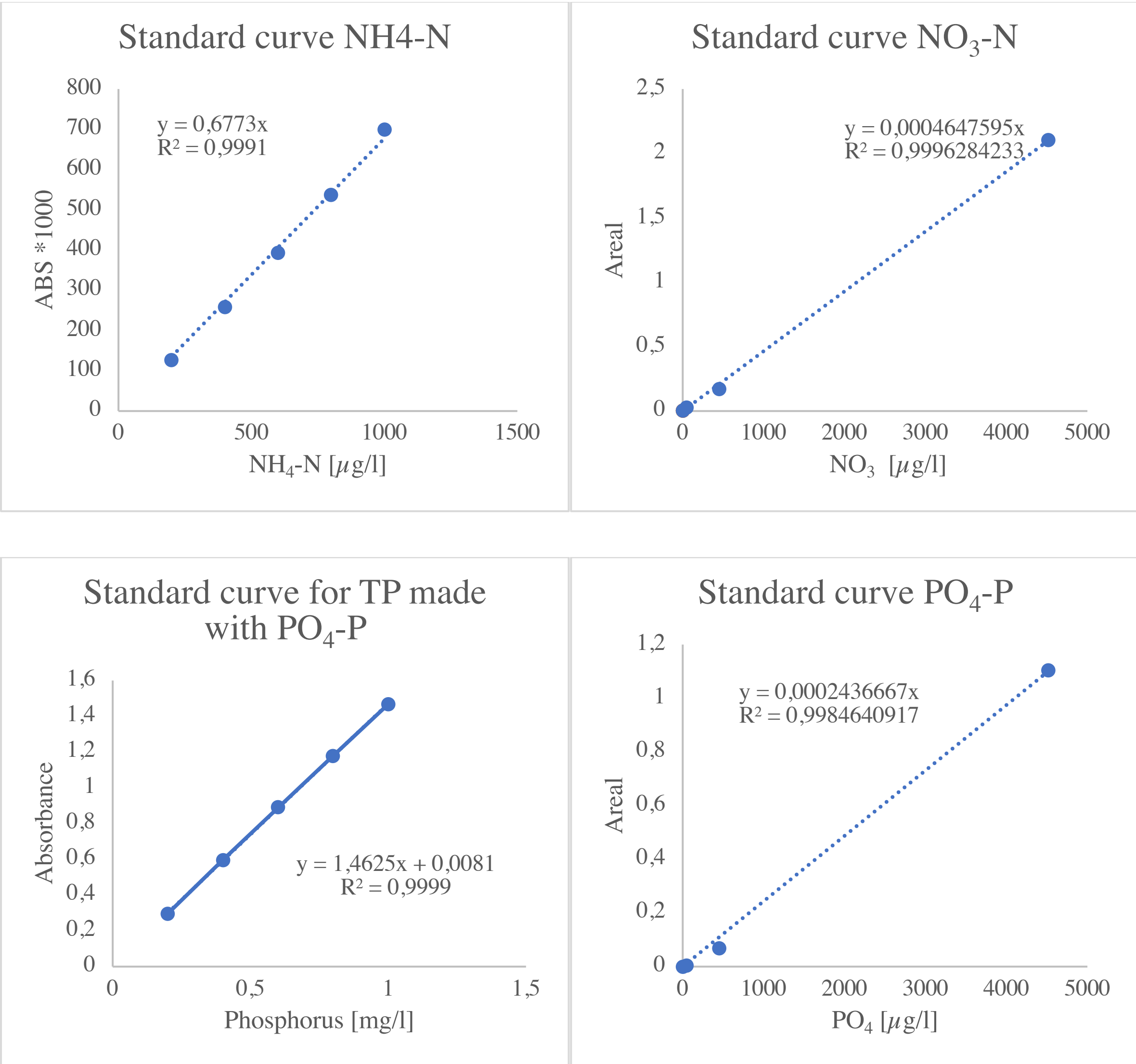


Figure A2: Standard curves used in the calculation of NH_4-N (µg/l) (upper left), NO_3-N (µg/l) (upper right), total phosphorus (TP) (mg/l) (lower left), and PO_4-P (µg/l) (lower right).

Appendix 4 – Data from Årungselva

Table A2: Data collected from laboratory analysis of water samples from Årungselva, and Phycocyanin data collected from NIVAs water monitor (NIVA).

Sample	**Dato**	**NO_3**-N (μg/l	**TN (μg/l)**	**NH_4**-N(μg/l)	**TP (μg/l)**	**PO_4**-P (μg/l)	**Phycocyanin (RFU)**
8	24.05.23	2746	3670	34	45	0	
16	07.06.23	2701	3320	41	26	0	0,3
24	21.06.23	2248	2930	61	27	0	0,8
32	05.07.23	2013	2670	35	23	8	0,9
40	19.07.23	1932	2530	37	15	0	1
48	01.08.23	1744	2420	49	15	0	1,2
56	16.08.23	1833	2540	38	20	0	2,1
64	06.09.23	1677	2500	43	31	0	4,4
72	20.09.23	1616	2410	43	29	0	10,5
80	29.09.23	1999	2790	41	31	2	3,1
88	13.10.23	1839	2630	47	30	0	7,5

Appendix 5 – Secchi depth and euphotic depth in Lake Årungen

Table A3: Secchi depth and euphotic depth in Lake Årungen.

Date	Secchi Depth (cm)	Euphotic Depth (cm)
24.05.2023	90	225
07.06.2023	90	225
21.06.2023	160	400
05.07.2023	115	287,5
19.07.2023	142	355
01.08.2023	136	340
16.08.2023	118	295
06.09.2023	85	212,5
20.09.2023	80	200
29.09.2023	97	242,5
13.10.2023	100	250

Appendix A6: Dates and days

Table A4: Corresponding sampling date and day number.

Date	Day
24.05.2023	0
07.06.2023	14
21.06.2023	28
05.07.2023	42
19.07.2023	56
01.08.2023	69
16.08.2023	85
06.09.2023	105
20.09.2023	119
29.09.2023	128
13.10.2023	142

Appendix 7 – BIOKLIM data

Table A5: Meteorological data for May to October 2023 from the BIOKLIM station in Ås (NMBU).

FAKULTET FOR REALFAG OG TEKNOLOGI

Meteorologiske data for Ås
Mai 2023

DATO	TEMPERATURER (°C)									FUKT.	TRYKK	VIND(10m)		
		Hytte				Jord(cm)						Mid	Max	Retn.
	Mid	Min	Max	2	5	10	20	50	100	rf(%)	(hPa)	(m/s)	(m/s)	
01	3,4	0,9	6,3	4,9	5,0	4,8	4,8	4,2	3,8	79	998,6	2,0	4,1	N
02	6,6	-0,5	11,9	5,1	5,0	4,7	4,6	4,3	3,9	55	1004,2	2,5	5,5	NV
03	6,7	-1,4	12,1	5,6	5,4	5,1	4,8	4,3	4,0	55	1013,3	2,0	5,6	N
04	5,7	1,1	10,0	6,2	6,0	5,6	5,2	4,4	4,0	42	1018,6	2,5	4,1	NØ
05	5,5	-3,8	11,4	5,9	5,7	5,5	5,3	4,6	4,1	46	1018,4	1,9	4,6	Ø
06	6,4	-1,1	12,7	6,1	5,9	5,6	5,4	4,7	4,2	47	1016,4	2,3	5,0	SØ
07	7,3	-1,2	13,6	6,5	6,3	5,9	5,5	4,8	4,2	52	1016,2	2,2	6,9	SV
08	8,6	0,0	14,6	6,8	6,6	6,2	5,8	4,9	4,3	57	1015,3	2,9	8,1	S
09	11,1	5,2	15,9	7,7	7,4	6,9	6,3	5,2	4,4	57	1006,8	4,1	8,4	S
10	12,7	5,6	18,3	8,5	8,2	7,5	6,8	5,5	4,5	52	1003,1	2,6	6,4	SV
11	10,9	6,1	14,1	8,2	8,1	7,7	7,2	5,9	4,7	64	1007,6	1,4	3,0	NV
12	13,3	4,3	21,1	9,3	8,8	8,2	7,4	6,1	4,9	66	1012,7	1,8	5,4	SV
13	14,4	8,5	20,5	10,5	10,0	9,3	8,3	6,5	5,0	61	1013,1	2,1	5,6	SV
14	14,3	5,4	21,2	10,5	10,1	9,5	8,8	6,9	5,2	56	1009,1	2,7	8,2	S
15	14,4	7,9	20,2	11,2	10,8	10,1	9,2	7,3	5,4	64	1001,0	1,9	5,4	Ø
16	12,2	9,3	16,7	11,2	10,9	10,3	9,6	7,6	5,6	71	995,3	2,9	6,5	NV
17	10,3	5,1	15,0	10,2	10,1	9,8	9,5	7,9	5,9	38	1002,6	4,6	8,8	NV
18	9,3	0,0	15,8	9,6	9,6	9,3	9,1	8,0	6,1	49	1014,3	2,5	5,5	SV
19	10,7	6,6	14,4	10,4	10,2	9,7	9,2	7,9	6,2	82	1017,5	3,2	5,6	S
20	13,8	9,1	19,7	11,9	11,3	10,6	9,7	8,0	6,3	65	1018,0	1,8	4,3	SV
21	15,0	5,2	22,7	11,8	11,5	10,8	10,1	8,3	6,4	51	1013,7	1,3	3,2	V
22	15,5	6,8	22,1	12,2	11,8	11,2	10,4	8,6	6,6	63	1008,8	1,9	5,1	SV
23	14,1	11,4	17,6	12,8	12,4	11,8	10,9	8,9	6,7	79	1002,3	2,3	4,6	SØ
24	14,8	8,5	19,3	12,5	12,2	11,7	11,0	9,2	6,9	64	1004,8	3,3	7,7	S
25	12,5	7,6	16,3	11,3	11,3	11,1	10,8	9,3	7,1	40	1008,7	4,6	8,0	V
26	12,5	6,9	16,8	11,1	11,0	10,7	10,5	9,3	7,3	39	1011,8	3,3	5,6	NV
27	10,9	3,6	16,5	10,9	10,9	10,6	10,3	9,3	7,4	66	1009,4	3,6	7,9	S
28	12,3	7,7	17,1	11,4	11,2	10,8	10,4	9,3	7,5	49	1004,6	4,2	9,0	NV
29	10,7	3,4	15,3	10,7	10,7	10,4	10,2	9,3	7,6	49	1009,8	2,2	4,7	NV
30	13,8	6,7	19,4	11,6	11,2	10,7	10,3	9,2	7,6	55	1012,6	2,9	6,7	S
31	15,8	6,6	21,9	12,5	12,0	11,4	10,7	9,3	7,7	48	1006,5	3,0	5,6	N
Mid.	11,0	4,5	16,3	9,4	9,2	8,7	8,2	7,0	5,6	57,1	1009,6	2,6	6,0	
Min.		-3,8												
Max.			22,7											

Normal temperatur (1931-1960): 10,2 °C Normal temperatur (1961-1990): 10,3 °C Normal temperatur (1991-2020): 10,7°C

DATO	STRÅLING								Jord-varmeflux	Fordampning	Nedbør	Snø-dybde
	Global	Diffus	Balanse	UV	Synlig	Irød	PAR	Albedo				
		(MJ/m2)			(% av global)		(mol/m2)		(MJ/m2)	(mm)	(mm)	(cm)
01	7,26	6,56	0,61	6,1	28,5	65,4	19,5	0,25	-0,21		8,4	0,0
02	20,07	6,82	6,63	4,7	32,7	62,7	47,4	0,24	0,38		0,0	0,0
03	19,46	9,57	7,11	4,6	32,4	62,9	46,3	0,24	0,50		0,1	0,0
04	22,04	9,36	8,70	4,6	33,0	62,4	51,8	0,24	0,53		0,0	0,0
05	25,99	5,35	9,52	4,4	32,8	62,9	60,2	0,25	0,46		0,0	0,0
06	26,18	5,25	9,89	4,4	32,5	63,1	61,0	0,25	0,53		0,0	0,0
07	25,72	5,58	9,43	4,5	32,7	62,9	60,7	0,24	0,51		0,0	0,0
08	24,47	8,10	9,50	4,6	32,8	62,6	59,0	0,24	0,62		0,0	0,0
09	18,39	13,74	6,93	5,0	33,1	61,9	45,6	0,23	0,78		0,0	0,0
10	22,00	12,91	8,26	4,6	32,1	63,3	52,4	0,24	1,01		0,0	0,0
11	5,90	5,67	1,87	6,0	31,4	62,6	15,5	0,23	0,27		0,0	0,0
12	25,20	7,14	10,95	4,6	34,0	61,4	60,1	0,24	1,27		0,0	0,0
13	23,76	9,61	10,67	4,7	33,8	61,5	57,3	0,23	1,25		0,0	0,0
14	25,67	8,93	10,71	4,5	32,9	62,6	61,2	0,24	0,95		0,0	0,0
15	21,33	13,25	9,48	4,8	33,7	61,5	51,7	0,23	1,11		0,5	0,0
16	13,68	11,32	4,05	5,0	32,8	62,2	33,8	0,22	0,52	2,2	1,8	0,0
17	24,68	10,39	9,94	4,7	32,2	63,1	59,1	0,24	0,05	5,2	0,7	0,0
18	27,72	6,35	10,76	4,5	32,5	63,0	66,1	0,24	0,38	4,2	0,0	0,0
19	19,64	12,14	8,72	5,0	31,7	63,3	48,1	0,23	0,66	3,4	0,0	0,0
20	25,27	7,86	12,04	4,7	33,7	61,6	61,0	0,23	1,26	4,3	0,0	0,0
21	27,56	7,05	12,19	4,6	33,6	61,8	66,6	0,24	1,03	4,5	0,0	0,0
22	21,70	13,64	9,77	4,9	33,1	61,9	53,0	0,24	1,00	3,9	1,5	0,0
23	13,58	11,35	4,67	5,4	32,9	61,6	34,5	0,22	0,84	2,3	0,6	0,0
24	22,53	13,64	9,71	4,9	33,3	61,8	55,7	0,23	0,68	5,2	0,0	0,0
25	26,30	11,54	9,50	4,4	32,7	62,9	61,2	0,24	0,15	6,7	0,0	0,0
26	27,45	11,71	10,38	4,4	33,0	62,6	63,9	0,24	0,47	5,8	0,0	0,0
27	21,73	13,03	9,27	4,9	32,9	62,2	53,4	0,23	0,39	4,4	0,6	0,0
28	27,79	8,87	11,05	4,5	33,2	62,3	66,1	0,23	0,48	5,9	0,0	0,0
29	22,26	15,47	8,87	4,9	32,1	63,0	54,3	0,24	0,29	3,7	0,0	0,0
30	29,39	6,56	12,17	4,6	33,2	62,2	70,9	0,24	0,88	5,1	0,1	0,0
31	29,10	8,18	12,33	4,6	33,6	61,8	69,4	0,24	1,00	6,5	0,0	0,0
Sum	664,7	288,8	263,4				1597,3		19,04		14,3	
Mid.	22,16	9,63	8,78	4,8	32,7	62,5	53,2	0,24	0,63			
Max.											8,4	

Normal nedbør (1931-60): 49 mm Normal nedbør (1961-90): 60 mm Normal nedbør (1991-20): 62,1 mm

Meteorologiske data for Ås
Juni 2023

FAKULTET FOR REALFAG OG TEKNOLOGI

DATO	TEMPERATURER (°C)									FUKT.	TRYKK	VIND(10m)		
		Hytte		Jord(cm)								Mid	Max	Retn.
	Mid	Min	Max	2	5	10	20	50	100	rf(%)	(hPa)	(m/s)	(m/s)	
01	12,7	7,6	15,9	12,0	11,8	11,4	10,9	9,5	7,7	38	1007,9	3,3	5,9	NØ
02	10,9	3,9	17,3	11,6	11,4	11,1	10,7	9,6	7,8	45	1012,4	3,0	6,1	N
03	12,9	7,7	18,5	12,8	12,3	11,7	11,0	9,6	7,9	66	1008,9	2,3	6,0	N
04	15,0	5,8	22,0	13,0	12,6	12,0	11,3	9,7	8,0	50	1009,7	2,4	5,5	N
05	15,4	9,3	20,8	13,7	13,2	12,5	11,7	9,9	8,1	66	1007,7	3,1	6,2	N
06	16,9	11,4	23,6	14,7	14,1	13,3	12,2	10,2	8,2	60	1006,6	2,2	4,3	N
07	16,9	8,3	23,5	14,5	14,1	13,4	12,6	10,5	8,3	57	1007,2	2,9	7,0	S
08	16,8	11,4	21,5	14,7	14,2	13,6	12,8	10,8	8,5	48	1007,2	3,1	5,8	N
09	16,4	9,4	21,3	14,7	14,3	13,6	12,9	11,0	8,7	42	1012,7	2,0	3,8	SØ
10	15,8	6,7	21,7	14,2	13,9	13,4	12,8	11,1	8,8	37	1015,6	2,1	4,4	SØ
11	16,1	6,9	21,6	14,3	14,0	13,5	12,8	11,2	8,9	47	1014,7	2,9	6,4	Ø
12	17,3	6,7	23,4	14,3	14,0	13,5	12,9	11,2	9,0	46	1012,3	3,1	6,5	S
13	19,1	12,9	24,8	15,9	15,2	14,3	13,3	11,3	9,2	51	1009,7	2,0	5,0	SV
14	20,6	13,4	27,0	16,7	16,1	15,1	14,0	11,6	9,3	51	1010,0	1,6	4,8	SV
15	21,1	12,9	28,9	17,0	16,4	15,6	14,5	12,0	9,4	53	1007,8	1,5	4,9	NØ
16	22,3	12,9	29,4	17,5	16,8	16,0	14,8	12,3	9,6	51	1004,3	1,5	3,8	N
17	22,5	12,9	29,3	17,9	17,2	16,4	15,2	12,6	9,8	47	1003,1	1,5	3,6	NØ
18	17,9	15,3	21,4	16,7	16,5	16,0	15,3	12,9	9,9	70	1004,6	1,9	3,7	N
19	18,7	15,2	22,4	17,4	16,9	16,1	15,1	13,0	10,1	77	1002,6	2,1	4,2	Ø
20	18,2	15,8	21,1	17,4	17,1	16,3	15,4	13,2	10,3	83	1003,2	1,7	4,1	Ø
21	17,5	13,7	21,8	17,2	16,9	16,3	15,5	13,3	10,4	89	999,8	1,9	5,5	S
22	19,3	13,7	24,0	17,9	17,5	16,7	15,7	13,5	10,6	59	1001,1	3,5	5,8	SV
23	18,9	12,5	25,0	17,9	17,5	16,8	15,9	13,7	10,8	50	1003,9	2,5	5,2	NV
24	18,8	11,7	24,4	18,3	17,8	17,1	16,1	13,8	10,9	62	1006,8	2,2	4,5	SV
25	19,5	14,1	24,5	19,0	18,4	17,5	16,4	14,0	11,1	74	1006,3	2,2	4,8	SV
26	18,8	15,0	25,8	18,7	18,4	17,7	16,7	14,3	11,2	79	998,8	2,3	7,8	SØ
27	17,9	13,9	24,6	18,8	18,4	17,6	16,7	14,5	11,4	81	995,8	1,5	4,4	NØ
28	19,6	11,6	25,5	18,8	18,5	17,8	16,9	14,7	11,6	70	999,8	2,8	6,2	S
29	18,6	15,6	22,9	18,7	18,4	17,9	17,1	14,9	11,7	81	996,4	3,2	5,8	S
30	18,6	12,3	23,1	18,7	18,4	17,8	17,1	15,0	11,9	70	989,0	3,0	5,1	SV
Mid.	17,7	11,3	23,2	16,2	15,7	15,1	14,2	12,2	9,6	59,9	1005,5	2,4	5,2	
Min.		3,9												
Max.			29,4											

Normal temperatur (1931-1960): 14,4 °C Normal temperatur (1961-1990): 14,8 °C Normal temperatur (1991-2020): 14,5°C

DATO	STRÅLING								Jord-varmeflux	Fordampning	Nedbør	Snø-dybde
	Global	Diffus (MJ/m2)	Balanse	UV	Synlig (% av global)	Irød	PAR (mol/m2)	Albedo	(MJ/m2)	(mm)	(mm)	(cm)
01	26,54	11,39	10,37	4,5	32,6	63,0	62,4	0,24	0,38	7,5	0,0	0,0
02	26,95	6,23	12,30	5,1	24,9	70,0	72,2	0,27	0,57	5,8	0,0	0,0
03	26,65	13,10	11,37	4,6	33,5	61,9	64,0	0,24	0,98	4,8	0,0	0,0
04	29,73	6,56	12,58	4,6	33,3	62,0	70,9	0,24	0,97	5,5	0,0	0,0
05	29,19	7,69	12,09	4,7	33,1	62,2	70,0	0,24	1,04		0,0	0,0
06	29,19	7,37	13,36	4,7	34,0	61,4	69,9	0,24	1,27	5,5	0,0	0,0
07	29,81	7,58	12,33	4,6	33,6	61,8	71,2	0,24	0,94	7,3	0,0	0,0
08	30,25	7,00	13,46	4,6	33,7	61,7	72,1	0,24	0,90	7,5	0,0	0,0
09	30,35	7,97	13,18	4,6	33,6	61,8	71,8	0,25	0,81	7,4	0,0	0,0
10	30,70	7,90	13,09	4,6	33,8	61,7	72,2	0,25	0,64	7,0	0,0	0,0
11	30,47	8,04	12,30	4,6	33,2	62,2	72,8	0,24	0,70	7,5	0,0	0,0
12	30,05	9,18	11,94	4,6	33,0	62,3	72,0	0,24	0,76	7,5	0,0	0,0
13	25,49	15,95	11,44	4,9	33,7	61,4	62,4	0,24	1,22	6,2	0,0	0,0
14	25,46	11,60	11,33	4,9	33,7	61,4	62,1	0,24	1,27	6,1	0,0	0,0
15	22,65	11,66	9,51	4,9	33,7	61,4	55,8	0,25	1,07	4,3	1,2	0,0
16	26,02	11,93	12,16	4,8	33,8	61,4	63,7	0,24	1,17	7,4	0,0	0,0
17	27,82	12,61	11,90	4,6	34,1	61,3	66,9	0,25	1,25	7,3	0,0	0,0
18	6,60	6,38	0,46	6,3	30,4	63,3	17,8	0,24	0,21	1,7	6,3	0,0
19	15,32	12,51	7,77	5,6	31,7	62,8	38,5	0,22	0,90	6,3	0,5	0,0
20	11,47	10,17	4,12	5,6	30,8	63,6	28,9	0,22	0,61	2,2	1,8	0,0
21	8,49	8,00	2,35	5,9	31,9	62,2	22,1	0,21	0,53	3,7	8,3	0,0
22	27,24	11,72	11,92	4,8	33,3	61,8	66,5	0,21	0,96	5,9	0,0	0,0
23	30,65	7,93	14,08	4,7	33,8	61,5	74,3	0,21	0,85	6,4	0,0	0,0
24	28,69	10,37	13,33	4,8	34,0	61,1	70,4	0,21	0,91	6,4	0,0	0,0
25	27,81	9,36	13,53	4,9	33,7	61,4	68,3	0,20	1,14	6,1	0,1	0,0
26	18,75	10,53	9,41	5,2	33,3	61,5	46,9	0,20	0,77		8,0	0,0
27	18,67	11,42	8,99	5,2	33,5	61,2	46,3	0,20	0,90		4,7	0,0
28	29,70	7,51	14,29	4,8	33,4	61,8	73,3	0,21	0,80	6,4	0,0	0,0
29	16,49	13,39	7,81	5,2	32,7	62,1	41,2	0,21	0,55	3,4	0,2	0,0
30	19,45	12,87	8,51	5,3	32,3	62,4	48,0	0,20	0,58	4,7	0,2	0,0
Sum	736,7	295,9	321,3				1794,9		25,62		31,3	
Mid.	24,56	9,86	10,71	4,9	32,9	62,2	59,8	0,23	0,85			
Max.											8,3	

Normal nedbør (1931-60): 70 mm Normal nedbør (1961-90): 68 mm Normal nedbør (1991-20): 76,9 mm

FAKULTET FOR REALFAG OG TEKNOLOGI

Meteorologiske data for Ås
Juli 2023

DATO	TEMPERATURER (°C) Hytte Mid	Min	Max	Jord(cm) 2	5	10	20	50	100	FUKT. rf(%)	TRYKK (hPa)	VIND(10m) Mid (m/s)	Max (m/s)	Retn.
01	15,6	9,2	20,2	17,5	17,4	17,1	16,7	15,1	12,0	68	984,8	2,4	5,7	S
02	15,1	10,3	18,4	17,2	17,1	16,8	16,4	14,9	12,2	83	976,8	2,9	6,6	S
03	14,4	9,3	19,4	16,9	16,7	16,4	16,0	14,8	12,2	78	977,2	2,8	7,0	S
04	14,4	11,5	17,8	16,8	16,7	16,3	16,0	14,7	12,3	82	983,6	2,9	4,6	S
05	14,5	9,9	18,0	16,7	16,6	16,2	15,8	14,6	12,3	77	994,0	2,1	5,4	S
06	14,7	11,5	17,8	17,0	16,8	16,3	15,9	14,5	12,3	86	994,3	2,0	3,7	NØ
07	16,8	9,1	21,9	17,7	17,3	16,7	16,0	14,5	12,3	75	1003,8	1,8	5,3	NØ
08	19,1	12,9	24,2	18,5	18,1	17,4	16,6	14,6	12,3	70	1009,4	1,6	3,3	N
09	20,3	12,1	26,2	19,0	18,6	17,9	17,0	14,9	12,4	63	1009,6	1,8	4,3	SV
10	18,2	12,8	24,9	18,3	18,2	17,8	17,2	15,2	12,5	74	1004,8	1,7	6,9	Ø
11	16,0	14,3	17,5	17,6	17,6	17,3	17,0	15,4	12,7	88	999,6	2,8	6,6	S
12	15,9	14,3	16,6	16,9	16,9	16,6	16,5	15,3	12,8	93	992,0	2,7	4,9	SØ
13	16,3	13,3	19,9	17,2	17,1	16,7	16,4	15,2	12,9	80	991,8	3,8	7,1	S
14	16,0	9,2	20,3	17,2	17,1	16,7	16,4	15,1	12,9	66	997,6	2,7	6,0	S
15	14,6	12,8	16,5	16,5	16,6	16,4	16,3	15,1	13,0	90	996,4	3,0	5,6	SØ
16	16,1	15,0	18,3	16,5	16,5	16,2	16,0	15,0	13,0	87	989,0	5,6	9,9	N
17	16,1	12,8	18,3	16,4	16,4	16,1	15,9	14,9	13,0	78	991,0	5,7	8,6	S
18	15,6	10,2	20,3	16,3	16,3	16,0	15,7	14,9	13,0	61	994,4	2,8	6,2	SV
19	14,6	10,4	18,3	16,2	16,2	15,9	15,7	14,8	13,0	59	992,8	2,8	5,2	SV
20	13,8	6,8	19,8	16,1	16,1	15,8	15,6	14,7	13,0	69	990,4	1,9	6,4	SV
21	13,3	7,1	19,6	16,0	16,0	15,8	15,5	14,6	13,0	79	991,0	1,6	4,2	SØ
22	13,1	9,7	16,5	16,0	16,0	15,7	15,5	14,6	13,0	85	992,0	1,2	3,8	Ø
23	14,4	7,9	20,5	16,5	16,3	15,8	15,4	14,5	12,9	77	992,1	1,4	4,8	NØ
24	13,5	9,5	17,2	15,7	15,9	15,7	15,6	14,5	12,9	87	986,1	2,3	4,5	N
25	15,9	12,4	19,4	16,3	16,2	15,8	15,4	14,5	12,9	79	980,8	2,8	5,3	S
26	14,0	10,6	17,6	15,9	15,9	15,7	15,5	14,5	12,9	79	986,5	2,5	5,8	Ø
27	15,1	10,9	20,0	16,4	16,3	15,9	15,5	14,5	12,9	74	989,4	2,1	3,8	N
28	14,2	9,2	19,5	16,3	16,2	15,9	15,6	14,6	13,0	84	991,4	1,7	4,5	SV
29	16,6	12,6	20,8	17,3	17,0	16,5	15,9	14,6	13,0	79	990,5	2,2	4,9	Ø
30	16,3	14,4	20,2	17,4	17,2	16,8	16,3	14,8	13,0	86	988,8	3,3	6,4	S
31	15,1	11,9	18,9	17,4	17,3	16,8	16,3	15,0	13,1	85	988,5	1,7	3,6	SØ
Mid.	15,5	11,1	19,5	16,9	16,8	16,4	16,0	14,8	12,7	78,1	992,0	2,5	5,5	
Min.		6,8												
Max.			26,2											

Normal temperatur (1931-1960): 16,8 °C Normal temperatur (1961-1990): 16,1 °C Normal temperatur (1991-2020): 16,8 °C

DATO	STRÅLING Global (MJ/m2)	Diffus (MJ/m2)	Balanse (MJ/m2)	UV (% av global)	Synlig (% av global)	Irød (% av global)	PAR (mol/m2)	Albedo	Jord-varmeflux (MJ/m2)	Fordamp ning (mm)	Nedbør (mm)	Snø-dybde (cm)
01	24,86	13,79	11,16	4,9	32,4	62,7	60,8	0,21	0,40	5,9	0,6	0,0
02	17,83	12,04	6,36	5,3	31,8	63,0	44,1	0,20	0,30		24,0	0,0
03	18,22	14,23	9,06	5,3	32,5	62,2	45,8	0,21	0,44		0,8	0,0
04	14,96	13,05	6,90	5,4	32,1	62,5	37,6	0,20	0,36	2,8	0,2	0,0
05	20,70	10,67	10,41	5,0	32,9	62,1	50,8	0,20	0,50	3,5	1,4	0,0
06	14,83	11,56	4,37	5,2	33,0	61,8	37,1	0,20	0,44	1,3	11,8	0,0
07	24,22	12,77	12,47	5,1	33,0	61,9	60,9	0,21	0,96	3,9	0,1	0,0
08	22,03	13,78	10,80	5,2	32,7	62,1	55,0	0,22	1,00	4,0	0,0	0,0
09	28,81	7,19	14,12	4,8	33,9	61,3	70,8	0,21	1,07	5,8	0,0	0,0
10	13,74	10,56	5,65	5,3	31,8	62,9	34,5	0,22	0,31	2,4	1,5	0,0
11	9,09	8,15	3,29	5,8	31,0	63,2	23,4	0,20	0,01		23,0	0,0
12	6,62	6,26	1,27	6,3	37,4	56,3	17,9	0,19	0,15	6,4	7,5	0,0
13	24,54	11,78	11,79	4,8	33,2	62,0	60,9	0,21	0,53	3,4	0,5	0,0
14	28,86	7,26	13,16	4,8	32,9	62,3	70,7	0,22	0,56	5,1	0,0	0,0
15	5,74	5,54	-0,56	6,1	30,8	63,1	15,2	0,20	-0,24	0,9	6,2	0,0
16	12,85	10,59	5,96	5,5	32,0	62,4	32,4	0,21	0,28	3,2	3,0	0,0
17	15,02	12,81	6,58	5,4	32,2	62,3	38,1	0,21	0,24	4,0	0,5	0,0
18	25,43	9,15	11,39	4,8	33,0	62,2	62,1	0,22	0,37	4,4	0,7	0,0
19	21,83	13,04	9,51	4,8	33,0	62,1	53,6	0,22	0,10	4,1	0,0	0,0
20	25,95	7,81	11,92	4,8	33,4	61,8	63,9	0,22	0,40	4,2	0,1	0,0
21	21,69	10,54	10,11	4,9	33,3	61,8	54,1	0,23	0,29	2,5	3,8	0,0
22	12,99	10,04	3,69	5,0	32,5	62,5	32,5	0,23	0,15	2,6	5,5	0,0
23	23,89	9,56	11,79	4,9	33,2	62,0	58,7	0,22	0,79	3,9	0,0	0,0
24	6,22	5,76	1,26	5,9	31,1	63,0	16,8	0,23	-0,40		17,9	0,0
25	19,56	12,69	9,04	5,2	32,1	62,8	49,4	0,21	0,82	3,6	0,7	0,0
26	18,97	10,75	7,43	5,0	31,7	63,4	47,0	0,23	0,31	3,1	0,7	0,0
27	20,29	11,85	9,63	4,8	33,5	61,7	49,2	0,23	0,55	3,7	0,0	0,0
28	15,52	8,97	5,96	5,1	32,9	62,0	38,1	0,22	0,18	2,4	6,9	0,0
29	22,43	9,91	11,11	4,9	33,7	61,4	55,1	0,22	0,94	3,7	0,0	0,0
30	17,07	11,94	7,47	5,2	32,6	62,1	42,2	0,21	0,53	3,1	11,0	0,0
31	16,09	11,31	5,99	5,0	34,3	60,7	39,3	0,22	0,57	4,1	11,4	0,0
Sum	570,9	325,4	249,1				1417,8		12,91		139,8	
Mid.	18,42	10,50	8,04	5,2	32,8	62,0	45,7	0,21	0,42			
Max.											24,0	

Normal nedbør (1931-60): 79 mm Normal nedbør (1961-90): 81 mm Normal nedbør (1991-20): 82,1 mm

FAKULTET FOR REALFAG OG TEKNOLOGI

Meteorologiske data for Ås
August 2023

DATO	TEMPERATURER (°C) Hytte Mid	Hytte Min	Hytte Max	Jord(cm) 2	5	10	20	50	100	FUKT. rf(%)	TRYKK (hPa)	VIND(10m) Mid (m/s)	Max (m/s)	Retn.
01	15,2	9,0	21,3	17,3	17,2	16,8	16,4	15,1	13,2	81	983,4	0,8	2,8	N
02	16,7	13,5	21,8	18,1	17,9	17,3	16,7	15,2	13,2	80	981,5	1,7	3,8	N
03	17,0	12,5	22,5	18,3	18,1	17,6	17,0	15,3	13,3	80	982,8	1,7	3,6	N
04	15,8	11,8	20,2	17,9	17,8	17,4	17,0	15,5	13,4	86	990,6	1,7	4,7	N
05	15,3	11,7	20,3	18,0	17,9	17,5	17,0	15,6	13,5	85	996,6	1,7	6,0	SØ
06	14,9	12,1	17,4	17,4	17,4	17,1	16,8	15,6	13,5	82	998,3	2,0	3,8	N
07	14,7	12,9	17,3	16,0	16,2	16,1	16,2	15,6	13,6	94	982,3	3,3	6,2	N
08	15,8	13,4	17,3	16,5	16,4	16,1	15,8	15,3	13,7	92	971,2	2,0	3,6	NØ
09	13,5	12,0	16,0	16,6	16,6	16,3	16,1	15,3	13,7	86	985,6	2,0	3,6	NØ
10	14,2	11,2	17,5	16,7	16,6	16,3	16,0	15,2	13,7	80	998,7	1,8	3,7	NV
11	14,7	10,5	19,3	16,9	16,8	16,4	16,1	15,2	13,7	80	1002,9	2,3	6,2	S
12	16,4	13,3	21,0	17,1	16,9	16,5	16,2	15,2	13,7	85	1000,8	3,0	6,2	S
13	15,9	14,3	19,4	17,0	16,9	16,6	16,3	15,2	13,7	89	999,0	2,8	5,5	S
14	16,3	14,5	18,4	16,8	16,8	16,5	16,3	15,3	13,7	87	1001,9	3,3	5,6	S
15	16,6	14,4	18,8	17,0	16,9	16,6	16,3	15,4	13,7	94	1001,0	1,8	4,2	SØ
16	17,1	13,6	21,1	17,9	17,6	17,1	16,6	15,4	13,8	78	1003,2	2,1	4,4	S
17	16,9	12,2	22,2	17,9	17,8	17,3	16,8	15,5	13,8	74	1012,7	1,4	3,2	NØ
18	16,2	10,3	20,5	17,4	17,4	17,1	16,8	15,7	13,9	76	1014,8	1,9	3,8	N
19	17,5	16,5	19,2	17,7	17,6	17,2	16,8	15,7	13,9	82	1011,1	1,8	3,5	NØ
20	17,2	16,1	19,1	17,6	17,5	17,2	16,9	15,9	14,0	94	1005,2	2,7	4,8	SØ
21	17,6	11,3	23,1	18,2	18,0	17,6	17,1	15,9	14,1	75	1002,6	2,3	4,3	S
22	15,5	8,9	20,8	17,5	17,5	17,2	17,0	16,0	14,2	79	1001,9	1,7	4,1	NØ
23	16,2	11,9	20,0	17,6	17,6	17,2	17,0	15,9	14,2	88	999,8	2,2	6,0	S
24	15,0	7,8	20,7	17,1	17,1	16,8	16,7	15,9	14,2	78	1000,2	1,7	3,1	N
25	14,4	13,0	15,8	16,8	16,9	16,7	16,6	15,8	14,3	85	996,9	1,6	2,7	Ø
26	14,5	13,6	15,6	16,3	16,4	16,2	16,3	15,7	14,3	93	995,1	2,0	4,4	Ø
27	14,7	12,4	18,8	15,7	15,8	15,7	15,8	15,5	14,2	88	991,1	4,1	7,1	S
28	14,8	11,9	19,4	16,1	16,0	15,7	15,7	15,3	14,2	85	992,9	2,2	4,7	SØ
29	14,4	11,9	17,6	16,2	16,2	16,0	15,8	15,2	14,2	84	994,6	2,1	5,2	N
30	13,4	9,1	17,7	15,9	15,9	15,7	15,7	15,2	14,1	84	994,6	1,1	3,5	SØ
31	13,6	8,1	19,9	15,5	15,5	15,4	15,4	15,1	14,1	79	995,0	1,2	3,8	NV
Mid.	15,5	12,1	19,4	17,1	17,0	16,7	16,4	15,5	13,8	84,0	996,4	2,1	4,5	
Min.		7,8												
Max.			23,1											

Normal temperatur (1931-1960): 15,6 °C Normal temperatur (1961-1990): 14,9 °C Normal temperatur (1991-2020): 15,7°C

DATO	STRÅLING Global	Diffus (MJ/m2)	Balanse	UV	Synlig (% av global)	Irød	PAR (mol/m2)	Albedo	Jord-varmeflux (MJ/m2)	Fordampning (mm)	Nedbør (mm)	Snø-dybde (cm)
01	15,75	12,07	6,18	5,2	34,1	60,7	39,0	0,23	0,55	3,2	0,5	0,0
02	17,35	-3,81	8,41	5,3	33,9	60,8	43,2	0,22	0,82	2,9	0,0	0,0
03	16,98	2,03	7,43	5,2	33,7	61,1	42,2	0,22	0,67	3,2	0,2	0,0
04	13,26	9,94	5,53	5,4	32,9	61,6	33,7	0,22	0,28	1,7	3,2	0,0
05	13,01	9,63	5,62	5,6	32,1	62,3	32,9	0,22	0,31	2,0	5,7	0,0
06	10,33	9,44	4,87	5,6	32,3	62,1	26,6	0,23	0,15	1,9	1,5	0,0
07	2,52	2,47	-0,50	6,9	29,3	63,8	6,8	0,19	-0,50	2,2	40,2	0,0
08	6,19	5,90	0,34	6,2	32,6	61,2	16,6	0,21	0,42	1,3	1,4	0,0
09	10,16	8,76	2,68	5,8	40,7	53,5	26,2	0,21	0,18	1,5	1,2	0,0
10	11,41	9,42	5,24	5,6	45,3	49,1	29,0	0,22	0,26	2,8	0,0	0,0
11	19,78	7,94	9,05	5,0	44,6	50,4	49,3	0,23	0,38	4,3	0,0	0,0
12	14,48	9,28	6,73	5,1	48,2	46,7	35,9	0,22	0,50	2,7	1,1	0,0
13	10,02	8,15	3,65	5,5	47,8	46,7	25,3	0,22	0,24	0,5	4,4	0,0
14	8,76	7,71	3,80	5,9	47,8	46,3	22,6	0,22	0,05	0,3	0,4	0,0
15	5,58	5,24	0,64	6,1	49,2	44,7	14,8	0,21	0,36	1,6	5,5	0,0
16	11,68									2,1	0,0	0,0
17	19,55	8,54	9,61	4,9	46,5	48,6	48,3	0,23	0,58	4,6	0,1	0,0
18	15,78	9,72	7,30	5,2	46,8	48,0	39,2	0,23	0,13	3,6	0,4	0,0
19	7,10	6,67	2,51	6,0	45,7	48,3	18,7	0,22	0,28	2,1	5,8	0,0
20	6,79	6,12	2,69	5,8	43,8	50,4	17,3	0,22	0,34	0,9	32,3	0,0
21	18,72	7,83	8,66	4,7	42,5	52,8	45,7	0,24	0,65	2,1	0,0	0,0
22	18,94	8,29	7,36	4,6	42,7	52,7	45,5	0,24	0,13	3,4	0,0	0,0
23	13,65	9,13	5,81	5,0	33,7	61,3	34,5	0,24	0,28	3,0	5,5	0,0
24	18,89	7,88	8,15	4,7	33,8	61,5	46,5	0,25	0,06	2,7	0,1	0,0
25	4,53	4,24	1,33	5,9	33,1	61,0	11,8	0,22	-0,18	1,4	0,1	0,0
26	3,64	3,57	0,53	6,4	31,1	62,5	9,8	0,21	-0,27	0,5	46,0	0,0
27	13,13	9,13	4,04	5,1	32,4	62,4	32,9	0,23	-0,12	2,0	17,4	0,0
28	14,54	7,26	6,14	4,9	33,7	61,4	35,7	0,23	0,22	2,3	0,0	0,0
29	12,32	8,37	4,63	5,0	34,1	60,9	30,2	0,23	-0,03	2,0	0,0	0,0
30	11,50	9,52	3,42	4,4	34,4	61,2	27,5	0,25	-0,19	2,4	0,0	0,0
31	17,01	8,92	6,45	4,3	35,3	60,4	40,5	0,25	-0,18	2,4	0,0	0,0
Sum	383,4	219,4	148,3				928,0		6,38	69,5	173,1	
Mid.	12,37	7,31	4,94	5,4	38,5	56,1	30,9	0,23	0,21	2,2		
Max.											46,0	

Normal nedbør (1931-60): 96 mm Normal nedbør (1961-90): 83 mm Normal nedbør (1991-20): 96 mm

FAKULTET FOR REALFAG OG TEKNOLOGI

Meteorologiske data for Ås
September 2023

DATO	Mid	Hytte Min	Max	Jord(cm) 2	5	10	20	50	100	FUKT. rf(%)	TRYKK (hPa)	VIND(10m) Mid (m/s)	Max (m/s)	Retn.
01	15,0	8,9	21,8	15,2	15,2	15,1	15,2	14,9	14,0	76	997,5	1,5	4,1	NV
02	15,2	8,4	20,3	15,2	15,2	15,1	15,0	14,7	13,9	68	1003,0	1,6	3,5	N
03	14,6	11,4	18,1	15,5	15,4	15,2	15,1	14,6	13,9	77	1006,6	1,9	4,5	S
04	17,7	12,6	23,6	15,7	15,7	15,3	15,1	14,6	13,8	79	1006,9	3,3	6,1	S
05	17,8	12,0	24,5	15,9	15,9	15,6	15,3	14,6	13,8	70	1005,4	2,1	4,6	S
06	14,8	8,4	20,3	15,3	15,4	15,2	15,2	14,7	13,7	69	1014,1	1,5	3,0	N
07	16,0	13,4	18,7	15,7	15,6	15,4	15,2	14,7	13,7	86	1014,0	2,6	5,8	S
08	16,0	14,7	17,5	16,1	16,0	15,6	15,4	14,7	13,7	95	1009,8	2,0	3,8	S
09	16,2	14,3	19,9	16,4	16,3	15,9	15,6	14,7	13,7	92	1005,2	1,3	3,1	S
10	17,1	15,0	21,7	16,8	16,6	16,2	15,8	14,9	13,7	92	1002,8	2,4	4,2	S
11	16,9	16,3	17,6	16,6	16,6	16,3	16,0	15,0	13,7	97	998,0	4,2	6,0	S
12	16,5	8,9	20,5	16,6	16,6	16,3	16,0	15,1	13,8	70	996,1	2,9	5,0	NV
13	11,5	4,2	16,2	14,2	14,7	14,9	15,3	15,1	13,9	61	1004,3	2,7	5,5	N
14	9,9	4,2	14,6	13,1	13,5	13,6	14,2	14,7	13,9	77	1008,5	1,5	3,2	N
15	13,4	11,0	16,5	14,0	14,1	13,9	14,0	14,2	13,8	89	1006,7	2,3	5,0	S
16	12,9	8,0	16,4	14,2	14,3	14,1	14,1	14,1	13,7	90	1005,8	2,9	5,5	N
17	9,7	4,8	15,1	12,9	13,2	13,3	13,7	13,9	13,6	82	1009,2	1,7	3,7	NØ
18	12,7	7,5	16,5	12,6	12,8	12,8	13,2	13,6	13,5	90	996,3	2,6	7,1	Ø
19	14,2	9,7	16,6	13,9	13,8	13,5	13,4	13,4	13,3	82	978,4	4,9	8,7	S
20	12,4	8,8	16,4	13,1	13,2	13,1	13,3	13,4	13,2	91	983,0	3,2	7,0	S
21	15,8	13,7	18,1	14,3	14,2	13,9	13,7	13,4	13,2	92	984,5	4,7	7,7	N
22	12,9	11,0	15,9	14,2	14,2	14,0	13,9	13,5	13,1	90	984,1	2,3	4,6	NV
23	12,0	7,1	16,4	13,4	13,6	13,5	13,7	13,6	13,1	84	991,5	2,6	6,3	S
24	10,5	3,7	14,9	12,3	12,6	12,7	13,1	13,5	13,1	78	1004,7	2,6	6,3	S
25	14,3	13,1	15,4	13,1	13,2	13,0	13,0	13,1	13,0	90	1005,7	5,6	8,4	S
26	14,0	10,9	16,7	13,3	13,4	13,1	13,2	13,1	13,0	88	1009,0	2,9	4,9	S
27	14,7	12,8	18,4	13,8	13,8	13,5	13,4	13,1	12,9	89	1004,8	3,3	5,8	SØ
28	14,3	11,9	16,8	13,9	13,9	13,7	13,6	13,2	12,9	91	1000,3	3,6	6,2	S
29	13,6	10,7	15,6	13,8	13,9	13,7	13,7	13,3	12,9	88	996,0	3,5	5,5	S
30	12,5	7,8	17,7	12,9	13,2	13,2	13,4	13,4	12,9	74	997,1	3,5	7,2	SV
Mid.	14,2	10,2	18,0	14,5	14,5	14,4	14,4	14,1	13,5	83,3	1001,0	2,8	5,4	
Min.		3,7												
Max.			24,5											

Normal temperatur (1931-1960): 10,9 °C Normal temperatur (1961-1990): 10,6 °C Normal temperatur (1991-2020): 11,5 °C

DATO	STRÅLING Global (MJ/m2)	Diffus	Balanse	UV (% av global)	Synlig	Irød	PAR (mol/m2)	Albedo	Jord-varmeflux (MJ/m2)	Fordampning (mm)	Nedbør (mm)	Snø-dybde (cm)
01	17,09	5,77	6,70	4,6	34,1	61,3	41,6	0,25	-0,12	3,1	0,0	0,0
02	16,95	6,77	6,48	4,5	34,0	61,5	41,0	0,26	-0,03	2,4	0,0	0,0
03	9,82	8,21	4,01	5,5	34,3	60,3	25,3	0,23	0,11	1,8	0,0	0,0
04	16,78	3,62	5,99	4,9	32,9	62,2	42,1	0,24	0,42	1,9	0,0	0,0
05	17,35	3,60	6,07	4,7	32,9	62,4	43,0	0,26	0,19	2,4	0,0	0,0
06	15,44	9,17	6,20	4,4	34,6	61,0	37,1	0,26	-0,23	3,6	0,0	0,0
07	7,73	6,96	3,87	5,2	33,0	61,9	19,7	0,23	0,21	3,4	0,0	0,0
08	4,02	3,95	1,94	5,8	31,6	62,6	10,4	0,23	0,33	2,8	0,0	0,0
09	7,10	6,36	3,30	5,3	33,9	60,9	18,1	0,24	0,39	3,5	0,0	0,0
10	10,62	6,01	4,73	5,0	34,3	60,7	26,2	0,24	0,53	3,4	0,0	0,0
11	1,64	1,62	0,02	6,6	32,3	61,1	4,6	0,19	0,16	1,5	0,6	0,0
12	13,62	7,43	3,99	4,6	35,3	60,0	32,9	0,25	-0,02	1,8	0,2	0,0
13	15,21	10,32	3,66	4,4	32,0	63,6	36,4	0,26	-1,29	2,0	0,0	0,0
14	8,98	7,60	2,79	5,1	33,3	61,6	22,3	0,24	-0,74	6,5	0,7	0,0
15	7,21	6,33	2,54	5,2	32,8	62,0	18,6	0,23	0,08	0,8	5,0	0,0
16	5,65	4,76	0,90	5,7	31,2	63,1	14,8	0,23	-0,20	2,3	0,7	0,0
17	14,41	3,33	4,03	4,4	32,3	63,2	35,0	0,27	-0,80	1,8	0,0	0,0
18	1,11	1,06	-1,01	7,4	40,3	52,2	3,2	0,16	-0,35	0,7	26,8	0,0
19	8,42	6,06	2,71	5,8	19,0	75,2	24,9	0,30	0,25	1,1	7,9	0,0
20	3,37	3,40	-0,53	6,1	30,5	63,4	8,8	0,21	-0,16	0,8	1,0	0,0
21	2,44	2,41	-0,32	6,2	32,4	61,3	6,6	0,20	0,43	0,3	16,6	0,0
22	8,06	5,05	1,28	4,7	34,5	60,8	19,5	0,25	0,05	1,6	19,7	0,0
23	11,49	4,79	1,76	4,6	32,2	63,3	27,9	0,26	-0,53	1,7	0,0	0,0
24	12,30	3,42	2,83	4,3	32,1	63,5	29,1	0,28	-0,59	1,8	2,4	0,0
25	2,38	2,36	-0,90	6,1	33,6	60,3	6,4	0,22	0,09	0,5	3,2	0,0
26	9,30	6,35	1,48	4,1	32,7	63,3	21,9	0,26	0,16	1,4	0,0	0,0
27	8,35	4,96	1,24	4,6	32,4	63,0	19,9	0,26	0,34	1,7	3,7	0,0
28	2,81	2,69	-0,44	5,8	33,5	60,7	7,3	0,21	0,02	0,8	0,6	0,0
29	5,67	4,77	0,21	5,1	32,7	62,2	14,0	0,23	-0,18	0,8	0,0	0,0
30	10,17	4,18	0,83	4,3	31,8	63,9	24,0	0,26	-0,63	1,4	0,0	0,0
Sum	275,5	153,3	76,3				682,6		-2,09	59,8	89,2	
Mid.	9,18	5,11	2,54	5,2	32,8	62,1	22,8	0,24	-0,07	2,0		
Max.											26,8	

Normal nedbør (1931-60): 86 mm Normal nedbør (1961-90): 90 mm Normal nedbør (1991-20): 90 mm

FAKULTET FOR REALFAG OG TEKNOLOGI

Meteorologiske data for Ås
Oktober 2023

DATO	TEMPERATURER (°C)									FUKT.	TRYKK	VIND(10m)		
		Hytte		Jord(cm)										
	Mid	Min	Max	2	5	10	20	50	100	rf(%)	(hPa)	Mid (m/s)	Max (m/s)	Retn.
01	9,5	3,5	14,1	11,7	12,1	12,2	12,7	13,2	12,9	80	1002,7	1,3	3,4	Ø
02	13,0	8,5	16,5	12,7	12,7	12,5	12,6	12,8	12,8	83	998,4	2,2	4,4	SV
03	9,5	6,3	14,2	11,8	12,1	12,1	12,4	12,7	12,7	84	990,6	1,2	2,7	Ø
04	10,1	5,8	16,0	10,9	11,2	11,4	11,9	12,5	12,6	73	992,0	2,2	6,4	SV
05	9,3	6,6	14,0	10,7	10,9	11,0	11,4	12,2	12,5	74	999,6	1,9	3,6	N
06	10,7	6,6	14,9	10,7	10,9	10,9	11,2	11,9	12,4	86	988,7	4,0	10,0	S
07	6,5	-0,4	11,5	9,9	10,3	10,5	11,0	11,7	12,3	60	999,6	2,2	4,8	N
08	4,0	-2,0	11,0	8,1	8,6	9,0	10,0	11,4	12,1	68	1010,3	1,5	4,0	NV
09	2,4	-2,8	9,1	7,3	7,8	8,1	9,1	10,8	12,0	79	1004,5	0,9	2,2	Ø
10	6,7	-1,2	13,9	7,2	7,5	7,7	8,5	10,3	11,7	88	994,5	3,1	7,2	S
11	11,6	6,3	13,9	9,3	9,3	9,1	9,1	9,9	11,5	69	976,7	6,1	10,0	SV
12	8,7	3,5	12,4	8,1	8,4	8,5	9,1	10,0	11,3	55	986,1	3,6	7,9	V
13	7,0	2,0	9,5	7,6	7,9	8,0	8,7	9,9	11,2	87	982,1	2,8	5,0	SØ
14	7,9	4,9	11,3	7,8	8,1	8,1	8,6	9,6	11,0	72	970,3	4,2	6,7	SV
15	7,9	1,5	10,9	7,5	7,8	7,9	8,4	9,5	10,9	52	989,5	2,5	4,8	NV
16	4,4	-2,5	9,4	6,1	6,5	6,8	7,8	9,3	10,7	65	1001,4	1,9	3,4	N
17	7,5	1,8	11,9	6,7	7,0	7,0	7,6	8,9	10,6	73	999,1	2,6	5,6	S
18	4,3	0,1	8,2	5,7	6,2	6,4	7,3	8,7	10,4	71	1005,3	1,8	4,2	NØ
19	1,2	-0,8	3,8	4,8	5,3	5,7	6,7	8,4	10,2	68	1006,5	2,9	4,3	NØ
20	1,8	-0,1	4,1	4,2	4,7	5,0	6,0	8,0	10,0	63	1005,6	4,4	6,0	NØ
21	2,0	0,8	2,9	3,9	4,3	4,7	5,6	7,6	9,8	75	1000,6	4,5	6,4	NØ
22	3,5	2,8	4,4	4,8	4,9	5,0	5,6	7,3	9,6	90	997,5	2,5	3,1	N
23	5,0	3,8	6,7	5,6	5,7	5,6	5,9	7,2	9,4	91	1000,2	2,1	3,2	N
24	4,8	3,1	6,3	6,1	6,2	6,1	6,4	7,3	9,2	85	1004,7	2,4	3,8	NØ
25	2,1	1,2	3,1	5,3	5,6	5,8	6,3	7,3	9,1	76	1002,0	3,7	5,3	NØ
26	2,1	1,2	3,5	4,8	5,1	5,3	5,9	7,2	9,0	72	996,3	3,1	4,7	N
27	1,1	0,6	1,7	4,3	4,7	4,9	5,6	7,0	8,9	68	993,3	2,7	3,6	N
28	0,6	-0,7	2,2	4,0	4,4	4,6	5,3	6,8	8,8	68	995,7	2,0	3,4	N
29	-0,1	-2,4	1,5	3,4	3,8	4,1	4,9	6,6	8,6	68	992,6	3,4	5,9	N
30	-1,0	-1,5	-0,1	3,2	3,5	3,8	4,6	6,3	8,5	87	987,0	4,9	6,4	N
31	-0,1	-1,0	0,6	3,2	3,5	3,6	4,4	6,0	8,3	80	989,5	5,3	7,0	N
Mid.	5,3	1,8	8,5	7,0	7,3	7,5	8,1	9,3	10,7	74,6	995,6	2,9	5,1	
Min.		-2,8												
Max.			16,5											

Normal temperatur (1931-1960): 5,7 °C Normal temperatur (1961-1990): 6,2 °C Normal temperatur (1991-2020): 6,1 °C

DATO	Global	Diffus	Balanse	UV	STRÅLING Synlig	Irød	PAR	Albedo	Jord-varmeflux	Fordamp ning	Nedbør	Snø-dybde
		(MJ/m2)			(% av global)		(mol/m2)		(MJ/m2)	(mm)	(mm)	(cm)
01	8,21	5,72	1,39	4,3	33,1	62,6	19,2	0,28	-0,73	2,4	0,3	
02	8,93	5,61	1,93	4,5	35,5	60,1	21,3	0,26	0,08	1,5	0,8	0,0
03	7,38	4,49	0,54	4,7	34,9	60,5	17,4	0,26	-0,61	2,0	0,0	0,0
04	9,37	3,43	0,91	4,3	34,0	61,7	21,8	0,27	-0,83	1,7	0,0	0,0
05	9,71	2,60	1,47	4,2	35,1	60,7	22,7	0,28	-0,47	1,9	0,0	0,0
06	3,57	3,48	-0,57	5,8	33,5	60,7	9,2	0,21	-0,30	1,1	4,7	0,0
07	8,56	3,79	-0,49	4,2	32,0	63,8	19,6	0,26	-1,16	1,5	0,0	
08	9,81	2,78	0,25	4,0	33,5	62,6	22,1	0,27	-1,52	2,2	0,0	
09	7,99	4,97	0,63	4,2	33,6	62,2	18,4	0,26	-1,34	2,2	0,0	0,0
10	5,64	3,59	0,65	4,6	32,1	63,3	13,6	0,25	-0,55	1,8	2,5	0,0
11	7,94	2,99	-0,27	4,3	33,1	62,5	18,5	0,26	0,13	1,2	0,4	0,0
12	6,87	4,19	-1,25	4,4	31,3	64,3	16,0	0,27	-0,87	1,6	0,0	0,0
13	1,92	1,98	-1,39	5,9	29,5	64,7	4,9	0,22	-0,61	1,0	9,9	0,0
14	6,26	3,95	-1,49	4,4	31,9	63,7	14,6	0,25	-0,65	1,4	0,0	
15	6,73	4,38	-1,06	4,2	33,6	62,1	15,5	0,27	-0,81	1,6	0,0	
16	7,60	3,62	0,15	3,9	33,7	62,4	17,0	0,28	-1,18	2,0	0,0	0,0
17	3,18	1,83	-1,51	4,7	35,0	60,3	7,5	0,26	-0,56	1,3	0,0	0,0
18	5,72	3,58	-1,00	4,3	34,0	61,8	13,2	0,27	-1,17	1,6	0,0	0,0
19	6,85	2,34	-1,64	4,1	32,6	63,4	15,3	0,29	-1,36	1,2	0,0	0,0
20	3,90	3,47	-1,56	4,8	31,2	64,0	9,3	0,24	-1,13	0,7	0,0	0,0
21	1,23	1,28	-1,79	5,8	25,3	68,9	3,1	0,20	-0,98	0,6	0,2	
22	1,84	1,89	-0,44	6,0	31,6	62,4	4,8	0,20	-0,31	0,4	1,5	
23	2,56	2,57	0,70	5,8	31,1	63,0	6,6	0,20	-0,01	0,1	0,0	0,0
24	2,48	2,46	0,66	5,7	32,6	61,8	6,3	0,21	-0,20	0,0	0,0	0,0
25	1,56	1,60	-0,18	6,7	28,7	64,6	4,0	0,21	-0,81	0,0	0,0	0,0
26	2,19	2,00	-0,14	6,2	29,3	64,5	5,5	0,23	-0,74	0,0	0,0	0,0
27	1,22	1,25	-0,45	6,9	29,3	63,8	3,2	0,22	-0,85	0,0	0,0	0,0
28	2,46	2,46	-0,12	5,5	31,9	62,7	6,1	0,23	-0,76	0,0	0,0	
29	1,23	1,27	-0,29	7,0	26,7	66,3	3,1	0,20	-1,01	0,0	0,2	
30	1,34	1,38	-0,23	6,8	29,7	63,4	3,7	0,78	-0,81	0,0	4,5	2,5
31	2,83	2,82	-0,20	5,6	31,2	63,2	7,3	0,74	-0,65	0,0	0,1	8,0
Sum	157,1	93,8	-6,8				370,8		-22,74	33,1	25,3	
Mid.	5,07	3,02	-0,22	5,1	32,0	63,0	12,0	0,28	-0,73	1,1		
Max.											9,9	

Normal nedbør (1931-60): 86 mm Normal nedbør (1961-90): 100 mm Normal nedbør (1991-20): 105 mm

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