Master Thesis
TVVR21/5020

Patterns and factors affecting brownification in a boreal river

A study on the brownification in River Storån, the biggest sub-catchment of Lake Bolmen in Southern Sweden

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Water Resources Engineering
TVVR21/5020
ISSN 1101-9824Lund 2021
www.tvrl.lth.se

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English title:	Patterns and factors affecting brownification in a boreal river
Supervisor:	Kenneth M. Persson
Examiner:	Magnus Larson
Language	English
Year:	2021
Keywords:	Bolmen; brownification; precipitation; discharge; sulfur deposition; land use; trend analysis

Abstract

During the last decades a brownification of the lakes and streams in the northern hemisphere has been observed. The change has been attributed to an increase of organic content in the water, leached from the top soil layers, called humic substances. Several theories have been proposed to explain the drivers behind the brownification process, among them the decrease of sulfur deposition from reduced industrial emissions, changes in land use through increased industrial forestry and changing patterns of precipitation, stream discharge and water temperature. More recently, the relationship between iron concentration and color has also been highlighted. The aim of this study was to examine these potential drivers and their relationship with color in River Storån catchment, a forested catchment in Southern Sweden located near the important drinking water source Lake Bolmen. Color values were retrieved from samples taken at four locations in the catchment between 1978 and 2018 by the river basin organization Lagans Vattenråd, and compared to data on precipitation, temperature and land use collected for the same period from various sources. The color in River Storån was found to be increasing, both when examining the average color and the extreme color values in the 95th percentile, which showed a positive linear trend. The precipitation in the catchment was also found to be increasing, as was the frequency of extreme precipitation events. A moderate to high correlation was established between precipitation and color, the highest being 0.74 near the precipitation measuring station in the catchment. A moderate negative correlation between sulfate concentration and color was found in River Storån, in several sampling points. A significant positive correlation was found between iron and color in River Storån, the highest being 0.81. A high correlation was also found between iron concentration and yearly precipitation, which seem to support the theory that the increase of iron is the result of wetter conditions in the upper soil layers due to increasing precipitation. The differences in land use between the sub catchments around Lake Bolmen seem to be related to freshwater color, as the catchments having the highest forest and wetland coverage also have the highest color values. An interesting observation of an increase in color from upstream to downstream in River Storån suggest that the wetlands in the catchment might contribute significantly to the color, however further investigations are needed to confirm this theory. Brownification seem to be the product of several different factors, and as the color of Lake Bolmen continues to change it is important to take the right steps to more accurately monitor the parameters related to this process.

Table of contents

Background

During the last decades an ongoing brownification of the lakes and streams in the northern hemisphere has been observed, a process through which clear water bodies become increasingly brownish in color. The change is in many places so apparent that it is visible to the human eye, but it can also be measured through chemical analysis or spectrophotometry. The change has been attributed to an increase of organic content in the water, leached from the top soil layers, called humic substances. Several theories have been proposed explaining the drivers behind this process. One of these suggests that a decrease in the emissions containing sulfur into the atmosphere since the 1980s is the main driver, since the decreasing the content of sulfate in the precipitation raises the pH in the natural environment, making the organic compounds in the top soil layer more dissolvable. This explanation has however been questioned as being the main driver behind the process, partly because the relationship in certain catchments is not as strong as expected, and perhaps more importantly because the color in many lakes have continued to increase beyond the levels measured before the emergence and peak of sulfur emissions (Kritzberg, 2017). Other studies have examined the land use as another driver for the brownification, and found a clear correlation with the increase in land dedicated to forestry and brownificiation, especially linking spruce coverage to the increase of color (Kritzberg, 2017). Several studies also suggest a correlation with hydrological parameters, in particular stream discharge and precipitation (Haaland, et al., 2010).

The brownification process also affect our drinking water sources. Higher contents of organics can lead to several issues considering drinking water production, among them challenges related to the formation of flocs, which can entail an increased use of chemicals and in turn higher costs. In drinking water plants that add chlorine as a disinfectant higher dosages are required which increases the formation of carcinogenic byproducts. Therefore it is important to describe and analyze the mechanism behind brownification, partly in order to estimate how changes in human activities or climatological or hydrological factors might predict changes in water color, but also to develop tools in order counteract or halter these processes (Persson, 2010).

Brownification has also been observed in Lake Bolmen, which through a 82 km long tunnel provides drinking water for 12 municipalities in Scania in Southern Sweden. The increased levels of organic matter can become a costly issue for the drinking water production and is therefore a prioritized field of research for Sydvatten, the utility which manages the treatment and distribution of drinking water from Bolmen. A project has been devised by Sweden Water Research, a joint venture between Sydvatten and another regional drinking water utility NSVA, with the objective to create a hydrodynamic model for the transport of humic substances in the lake. The hydrological profiling of River Storån catchment can thus be seen as part of a greater work to create a detailed model of how the water quality in the lake is affected by the brownification process. River Storån catchment is the largest catchment in the Lake Bolmen area and has also been found in earlier studies to be the biggest contributor to the increasing color of the lake (Tumdedo, 2010). As the Lake Bolmen area is situated in a relatively small geographical area, many of the drivers behind brownification could be expected to behave similarly in other catchments around Lake Bolmen.

Aims and objectives

The overall aim is to investigate how the color of the water in River Storån has changed during the last 40 years and how this is related to changes in precipitation, temperature, sulfate deposition and land use, as well as to examine the contribution of color from River Storån catchment to Lake Bolmen and the color variation within the catchment.

What long terms trends can be seen in the color variation in River Storån from 1978 to 2018?
What are the interannual patterns of color variation in River Storån and how has this changed since 1978?
How has the sulfate concentration, precipitation and temperature affected the color in River Storån and what are the long-term trends of precipitation and temperature in the area (changes happening during a decade or longer)
What is the relationship between iron concentration and color in River Storån?
What are the impacts of land use on color in River Storån and in the area around Lake Bolmen?
What are the possible future scenarios regarding color in River Storån and Lake Bolmen? What measures can be taken in order to better monitor and understand the factors affecting brownification?

Methodology

Observation data of color, total organic carbon (TOC), iron (Fe) and sulfate concentration were retrieved from web page of the river basin organization of River Lagan, Lagans Vattenråd. Data on precipitation and discharge, as well as temperature and air quality data on sulfur deposition were retrieved from the Swedish Meteorological and Hydrological Institute (SMHI). Information about the river basin and its surroundings was gathered from a variety of sources including the local authorities and supported with a field trip to the area. A characterization of the land use in River Storån catchment was done based on open source data from Lantmäteriets website. The open source free-to-use software R project was used to perform the Mann-Kendall tests on the precipitation, color and temperature data series. The Mann-Kendall test is used for its capabilities to identify a monotonic positive or negative trend in data with different distributions or with seasonal variety (Meals, et al., 2011), as is hypothesized to be the case with color, precipitation and temperature.

Scope and delimitations of the study

The observations of color from Lagans Vattenråd contains measurements of color from 1978 to 2018, however other parameters such as TOC, iron and sulfate appear with varying frequency and consistency. The only consistent time series for Fe and sulfate were taken between 2011 and 2017, and thus the investigation of their relationship with color is limited to this narrow time period.

No relevant measurements of stream flows or water level in the inflows to Lake Bolmen could be found. Instead, the stream flows in the report were derived from modeled data based on

SMHI’s HYPE-model, a hydrological model for whole Sweden. The model is calibrated and validated with real flow observations, of which the nearest point is further downstream at the outlet of Lake Bolmen.

The amount of precipitation data for the catchment is in turn also limited to a daily sum of precipitation, which makes it difficult to assess specific rainfall events, especially those of short duration and high intensity. Data reduction had to be made for both the color, precipitation and temperature measurements in order to perform the Mann-Kendall tests.

Theory

Drivers behind brownification of boreal lakes and streams

The drivers behind the brownification process can vary from catchment to catchment due to geographical location, hydrogeological situation and the presence of anthropogenic sources of organics or other color inducing substances. However, there are a few general theories on which are the main drivers behind brownification in boreal lakes and streams.

One of the potential drivers behind the process is the decrease of sulfur deposition through precipitation (decrease of acid rain), decreasing the pH and increasing the mobility iron, which in turn has been proven to have positive correlation with dissolved organic matter and color (Björnerås, et al., 2017) (Temnerud, 2014).

Changes in land use has also been identified as potentially driving the trend of increasing color, especially focusing on the development of modern forestry and how it has shifted the landscape, removing wetlands and smaller farms and agricultural lands and replacing it with forests (Kritzberg, 2017). A positive correlation between forest or wetland coverage and concentrations of iron, organic matter and color in boreal catchments and have also been identified (Temnerud, 2014).

Another driver is the changes in hydrological or climatological patterns, mainly changes of precipitation and temperature, which are parameters either shown to correlate directly with color (Weyhenmeyer, et al., 2016) or augment other processes driving brownification (Kritzberg, 2017). Studies have shown that annual precipitation is increasing in many geographic locations in the northern hemisphere, including southern Sweden (Bengtsson & Rana, 2014). Climate predictions put a high probability in annual mean conditions becoming wetter and warmer through climate change (Räisinen & Alexandersson, 2002), as well as a high probability in the increase of precipitation intensity (Chen, et al., 2015).

Certain studies also point to a correlation between increases in the magnitude of color and increases of iron concentrations in fresh water lakes and streams. Although iron can in itself increase the visual absorbance of light (Maloney, et al., 2005), most theories revolve around iron forming complexes with organic compounds, which can increase the leaching of both iron and organic matter. However, the increase in organic matter might not solely explain the increase of iron. According to (Kritzberg & Ekström, 2012) changing redox conditions that make iron more mobile is instead responsible for the increase of iron. A shift to more anoxic conditions makes iron more mobile, which is also why wetlands have a larger iron export compared to other land types. The anoxic conditions could in turn be the result of a wetter or warmer climate, which is in line with the changes that have taken place in Scandinavia during the period which brownification has become an issue (Kritzberg & Ekström, 2012).

Other studies point to a similar relationship, where the increase in iron can not only be explained by the increase of organic matter. The iron is believed to reach a saturation point where for a certain amount of dissolved organ carbon available no further increases of complexation or absorbance occurs (Xiao, et al., 2013). Increased precipitation leading to faster water flushing through the landscape should therefore lead to increased iron levels and also increased organic material (Weyhenmeyer, et al., 2014).

The increase of iron concentration also seems to differ across regions in the northern hemisphere. A study by (Björnerås, et al., 2017) that compared data from different regions shows that the increase of iron in freshwaters has been especially noticeable in northern Europe, and particularly in Scandinavia. This could have an interesting correlation with the changing precipitation patterns, as the Scandinavian peninsula show a relatively large proportional increase in precipitation, compared to for example North America, where precipitation is unchanged or decreasing in certain areas (Björnerås, et al., 2017).

The stream discharge has also been shown to be linked with increasing color, although precipitation and runoff are usually closely linked to this parameter (Weyhenmeyer, et al., 2014). In this report, measurements of color in River Storån will be compared with the sulfate concentration, precipitation, water and air temperature, land use as well as stream discharge and iron concentration.

Measurement techniques for color

Color can be measured using various chemical or spectral methods. One is the so called Platinum-Cobalt (Pt-Co) method, where the color number is defined by a standard solution of hexachloroplatinate in water containing hydrochloric acid, expressed in the unit mg/l Pt. The scale was developed by chemist Allan Hazen for the American Public Health Association (APHA) and is therefore sometimes also called the APHA or Hazen color scale (Thermofisher, 2013). With the Pt-Co color number the color range from colorless (<1) to light yellow- orange (500) is detected. Since this method was originally developed for waste water samples that have a slight yellow tint, it is not ideal for measuring organic content in more dark brownish samples of natural waters (SLU, 2021).

Other methods utilize spectrophotometers to measure the light absorption at different wavelengths. These are common modern techniques to use for drinking water samples, as the variance of color usually is greater for natural water samples. Some examples of colors scales include the SAC, Spectral Absorption Coefficient, or the ABS420/5 which measures the absorbance of a water sample at 420 nm. The samples by Lagans Vattenråd that are discussed in this report includes both measurements using the Pt-Co method and the ABS420/5 method (Franke, 2017).

Pollutant load

In order to calculate the pollutant load from stream source, the simplest way is to use numeric integration, where to load is given by Equation 1.

Equation 1

$$Load = \sum_{i=1}^{n} c_i \, q_i t_i$$

Where c_i is the concentration for the i^{th} sample , q is the stream flow, and t is the represented time interval for the i^{th} sample (Meals, et al., 2013).

Mann-Kendall test and Seasonal Mann-Kendall test

The Mann-Kendall test is a so called non-parametric test, which can be used to detect monotonic trends, i.e. a trend representing a gradual change consistent in a positive or negative direction. The Seasonal Mann-Kendall test is a special case of the Mann-Kendall test, where the influence of seasonal variance in the data set is considered. Both tests assume that the observations are independent and measures their association with one another, based on their rank (Meals, et al., 2011).

The null hypothesis H_0 for the test is that there is no trend in the series, with the data being identically distributed. The three alternative hypotheses are that there is a negative, non-null, or positive trend. The test is explained by Equations 1-3 below.

S is the number of positive differences minus the number of negative differences for the i^{th} month (see Equation 2 below).

Equation 2

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign(x_{ij} - x_{ik})$$

Variance of S is explained by Equation 3 below:

Equation 3

$$\sigma_s = \sqrt{\left(\frac{n}{18}\right) \times (n-1) \times (2n+5)}$$

The seasonal statistics are summed and a standard normal test statistic Z is computed according to Equation 4:

Equation 4

$$Z_S = (S \pm 1)/\sigma_S$$

The variable Tau (τ), indicates if the monotonic trend is positive or negative and is calculated as in Equation 5:

Equation 5

$$\tau = \frac{S}{n(n-1)/2}$$

Important conclusions examining the p-value and a tau value. If the p-value is less than 0.05, then there is a monotonic trend with 95% confidence. The tau value decides then if the trend is positive or negative. If the tau value is positive there is a positive monotonic trend and tau value is negative, there is a negative monotonic trend. If the p-value is above 0.05 the null hypothesis is confirmed and no trend in the data (Naturvårdsverket, 2018).

Pearson and Spearman correlation

The Pearson correlation coefficient is one of the most common to use to denote linear association between two variables, in the equation below shown as X and Y:

Equation 6

$$\rho_{X,Y} = \frac{\sum(X_i - X)(Y_i - Y)}{\sqrt{\sum(X_i - X)^2 \sum(Y_i - Y)^2}}$$

The Spearman correlation can be considered a special case of Pearson, which indicates the direction of association between on independent and one dependent variable, i.e. the tendency of the dependent variable to increase or decrease when the independent variable increases or decreases. It measures a monotonic association, based on rank of values rather than the means and variances. If the dependent variable tends to increase when the independent variable increases, this means that the Spearman coefficient is positive. If it’s the other way around, the coefficient is negative. A perfect positive monotone correlation means that for any two pairs of values from the data series, for example X_j, Y_j and X_k, Y_k, $X_k - X_j$ and $Y_j - Y_k$ will always have the same sign. The Spearman correlation has a similar formula to Pearson’s, but notably it uses the ranks of values instead of the raw data, as shown in the equation below (United States Environmental Protection Agency, 2000).

Equation 7

$$\rho_{rank\ X, rank\ Y} = \frac{cov(rank\ X, rank\ Y)}{\sigma_{rank\ X}\sigma_{rank\ Y}}$$

Description of Lake Bolmen and the catchment of River Storån

Lake Bolmen and the surrounding area

Lake Bolmen is Sweden's tenth largest lake, covering an area of 183 km^2, with a depth stretching down to 36 m at the greatest (VISS, 2017). It provides drinking water for 12 (circa 750.000 people) municipalities in southern Sweden through the Bolmentunnel, a 82 km long tunnel which transports water from the water works near Skeen in the southern part of Lake Bolmen to Ringsjöverket treatment plant in Stehag, Skåne, where the raw water is treated and distributed for consumption (Sydvatten, 2016).

Lake Bolmen also has an important function for tourism and recreational purposes, where fishing has become a valued activity. The surrounding catchments are dominated by forests, with relatively little land used for agriculture and very small percentages made up of urbanized or industrial zones (Sydvatten, 2016). Many small streams provide Lake Bolmen with inflowing water, but the four main tributaries are River Storån, Lake Unnen, River Lillån and River Murån (see Figure 1). Out of these River Storån is the largest, with an average flow of about 9,1 m^3/s. The outlet of River Storån to Lake Bolmen is located at the northern border of the lake, close to the outlet of River Lillån, which is the second largest contributor in terms of inflow at 2,4 m^3/s. Lake Unnen, which is the third largest inflow, is a lake connected to the larger Lake Bolmen through a stream in the southwestern part, with a flow of approximately 3,0 m^3/s. River Murån is the most southerly of the four main inflows and also the smallest, with an average flow of 0,3 m^3/s (SMHI och Havsvattenmyndigheten, u.d.).

Lake Bolmen falls under the responsibility of several different regional authorities, as the county borders of Jönköping county, Kronobergs county and Halland county intersect in the northern part of the lake. Projects involving the lake are therefore usually a cooperative effort. In the late 1990s, the project "Lake Bolmen 2000" was launched to better organize and evaluate the status of the lake and its surrounding catchments and related activities in the area (Länsstyrelserna i Kronoberg, Halland och Jönköping, 2001). The river basin organization Lagans vattenråd, working with water management activities in the larger basin of River Lagan in which Lake Bolmen is located, have been conducting measurements of water quality in the area since the late 1960s, measuring parameters such as pH and color (Lagans Vattenråd, u.d.).

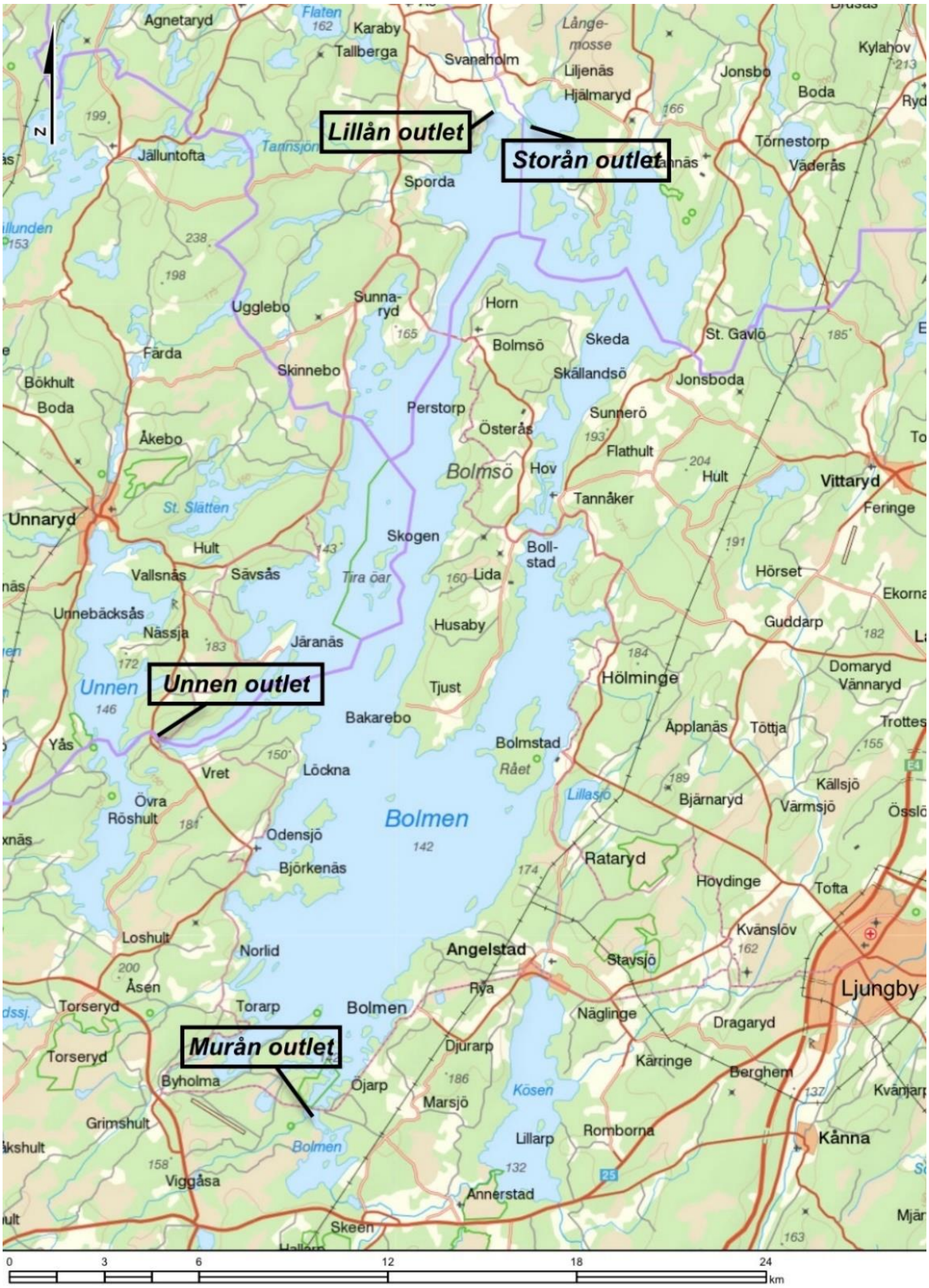

Figure 1. Map of Lake Bolmen showing the four main inflows to the lake: River Storån, River Lillån, Lake Unnen and River Murån.

The catchment of River Storån

The catchment of River Storån lies to the north of Lake Bolmen, and includes the main tributary to Lake Bolmen, River Storån. It is a part of the larger regional catchment of River Lagan, defined by SMHI as one of the 22 main catchments of Sweden. In Figure 2 below the borders of the catchment are shown as defined by SMHI's HYPE model, along with major water bodies, urban areas as well as sampling locations of Lagans Vattenråd.

River Storån is the main water course in the catchment. The river originates in the northern part of the catchment at the outlet of Lake Långasjön at latitude 57.362, longitude 13.984 (Datum WGS 1984, see Figure 2), where it also carries the name River Västerån. It serves both as the main inflow and outlet of Lake Flaten, and is fed by many smaller tributaries as well as lakes on its way to Lake Bolmen, including Lake Kävsjön, Lake Hästhultasjön and Lake Herrestadsjön. It has a meandering characteristic which is more or less consistent along its total length of about 61 km from lake Långasjön to Lake Bolmen. The river outlet/inflow to Lake Bolmen is located in the southernmost part of River Storån catchment at latitude 57.058, longitude 13.752 (VISS, 2017).

Along River Storån a few urban settlements are located, of which the biggest are Hillerstorp and Forsheda, that have a direct connection to the river shore. The two localities have population of circa 1500 inhabitants each. In addition the locality of Bredaryd, also with approximately 1500 inhabitants, is situated in the southwestern part of the catchment without a physical connection to River Storån. Hillerstorp serves as the location for several industrial activities which have a direct effect on the water quality of the river, among them small mechanical engineering industries that uses halogenated solvents to perform metal finishes, manufacturers of color or glue or industries involving electrolytic and chemical processes. Some are also responsible for emissions of heavy metals (VISS, 2017).

Despite this, River Storån is deemed to have a “good” ecological status as defined by VISS, with little or no eutrophication problems, medium levels of acidification and good conditions as indicated by measurement of parameters such as algae growth and the morphology of the river which retains a relatively natural and unmodified flowpath (VISS, 2017). There are however concerns with the activities in the immediate borders of the water course in which 68% consists of cultivated areas or altered surfaces (VISS, 2017). The river does not attain “good” chemical status, because of the deemed high amounts of industrial emissions in the form of mercury and bromated diphenyl ether (flame retardant) (VISS, 2017) (Länsstyrelsen i Jönköping, 2006).

The highest elevations in the catchment reach just above 300 MSL (meters above sea level), while the lowest points are just below 150 MSL. This can be compared with Lake Bolmen, which has an average height above sea level of about 141 MSL (VISS, 2017). The catchment displays a slight valley-like appearance, with higher elevations found near the western and eastern edges, and lower values in the central parts. A clear inclination of the topography from north south is also visible, where the elevation decreases in a north to south direction. This mirrors the general flow direction of River Storån, which flows from north to south.

Lagans Vattenråd have collected their samples at six points in River Storån catchment (see Figure 2). The sampling points will be referred in this report using the numbers designated by Lagans Vattenråd and their Swedish names translated to English. From upstream to downstream the points are number 568 “Västerån uppströms Långasjön” (Eng: “River Västerån upstream

Lake Långasjön”), number 560 Flaten (Lake Flaten), number 558 River Storån nedströms Forsheda (River Storån downstream of Forsheda), number 554 River Storån nedströms Törestorp (River Storån downstream of Törestorp) and number 550 River Storåns Utlopp (outlet of River Storån). There is also one sampling point located in the northern part of Lake Bolmen, number 530 Lake Bolmen norra (Northern Lake Bolmen).

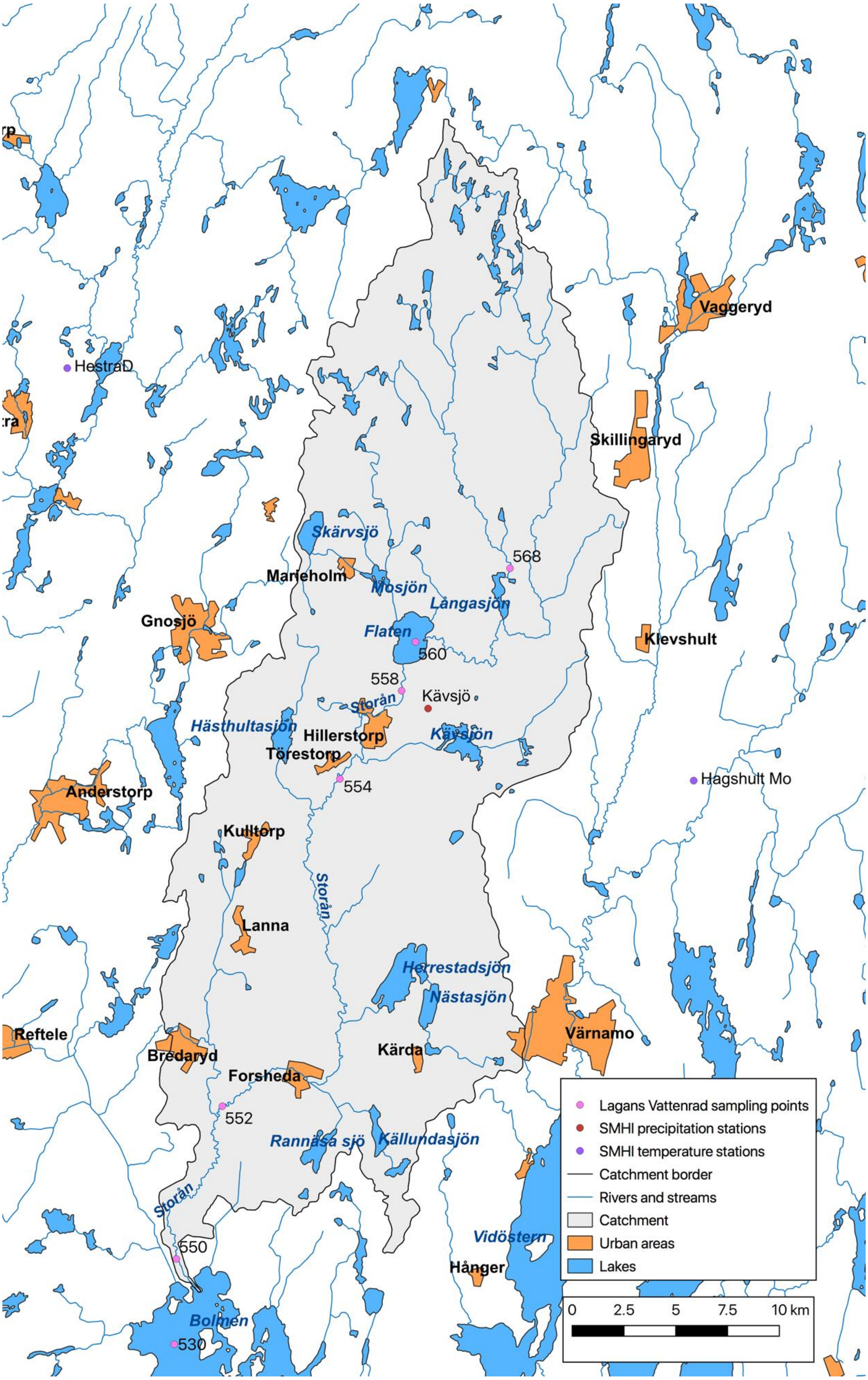

Figure 2 Overview of River Storån catchment showing Lagans Vattenråd's sampling points, SMHI's measuring stations, urban areas and water bodies. The catchment is in light grey with a black line marking its borders. The map is based on data from Lantmäteriet's open data web platform (Lantmäteriet, 2018).

Contribution of color from River Storån compared to other inflows to Lake Bolmen

Although River Storån is by far the biggest contributor of water volume it does not have the highest average color of the four main tributary inflows. As can be seen in Table 1. *Average color (mean) for the four main inflows to Lake Bolmen between 2011 and 2017.* below, both River Murån and River Lillån have a higher average color between 2011 and 2017.

Table 1. Average color (mean) for the four main inflows to Lake Bolmen between 2011 and 2017.

Stream	Average color (mg/Pt l)
Storån	192
Lillån	234
Unnen	105
Murån	291

Since the concentration does take into account the flow, this does not represent the actual pollutant load or in this case the contribution of color from the catchment. In the table below the contribution to the total load is shown in percentages for all four streams between 2011 and 2017. Yearly averages of concentration as well as stream flows from SMHI's HYPE model were used to estimate the load for each stream.

Table 2. Contribution to total pollutant load/color flux by the four main inflows to Lake Bolmen between 2011 and 2017, using yearly averages of stream flow from SMHI and color averages from Lagans Vattenråd.

Stream	Contribution to total color/pollutant load (%)
Storån	64
Lillån	21
Unnen	12
Murån	3,5

Assuming that these streams covers the overall contribution of color originating outside of lake, these percentages could be considered decent estimations of each sub-catchment's contribution to the brownification of Lake Bolmen.

Land use

A characterization of the land use in River Storån catchment was made using data from Lantmäteriet in the application QGIS, which was then compared to the land use information used in SMHI's HYPE model (SMHI och Havsvattenmyndigheten, u.d.). The distribution of different types of land use can be seen in Table 3. The catchment is dominated by forest, which comprises about 70% of the area. Almost all the forested areas are coniferous or a mix between coniferous and deciduous, with about 2% of the total area considered to be wholly deciduous. Agricultural lands comprise about 6-8%, while mires and wetlands make up for about 13 %. Urban and industrial areas account for about 1%. Figure 3 shows the distribution of different land types based on the data provided by Lantmäteriet, divided into forest, wetlands, open fields, urban areas, lakes and rivers and streams. The location of national park Store Mosse is also shown on the map, along with the sampling points used by Lagan's Vattenråd.

Table 3. Land use in River Storån catchment, based on model data from SMHI and data from Lantmäteriet.

Land use based on data from SMHI		**Land use based on data from Lantmäteriet**	
Land type	**Coverage (%)**	**Land type**	**Coverage (%)**
Forest	69,2	Forest (coniferous and mixed)	67,8
		Decidious forest	1,9
Mires and wetlands	13,1	Other open areas without forest contours	13,5
Agricultural fields	8,2	Agricultural fields	5,9
Moors and other land types	4,0	Other open areas	5,7
Water surfaces	4,1	Water surfaces	4,6
Urban areas	1,0	Sparsely populated settlements	0,4
Impermeable surfaces	0,4	Industrial areas	0,2

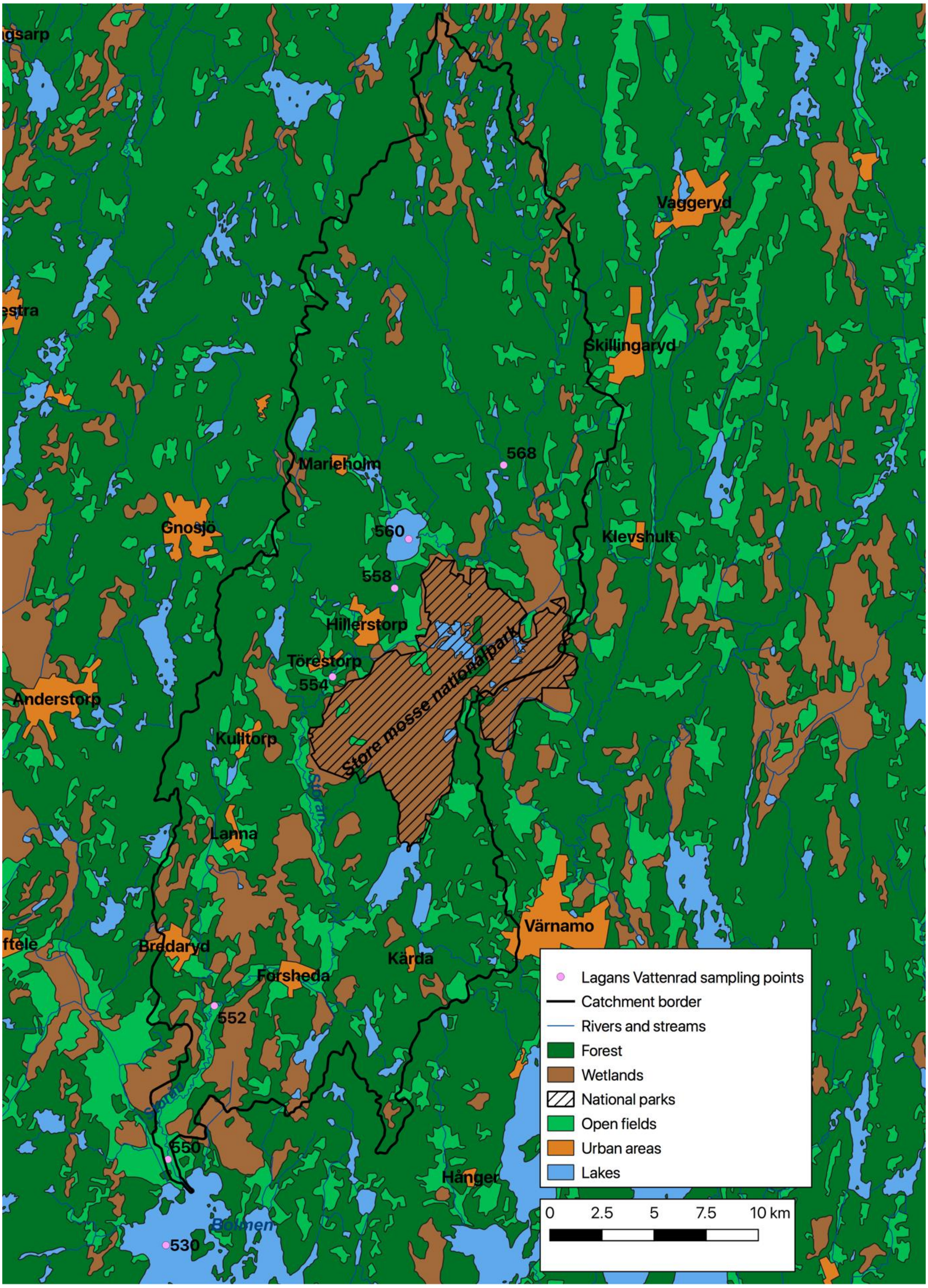

Figure 3. Map of the land use in River Storån catchment, divided into forest, wetlands, open fields, urban areas, lakes and rivers and streams. Lagans Vattenråd's sampling points are also shown. The catchment borders are marked with a black line. The map is based on data from Lantmäteriet (Lantmäteriet, 2018).

Areas with potential of high TOC contribution/leakage

Even though the urban and industrial areas take up a small percentage of the whole catchment, they could still serve as significant contributors of TOC, considering for example the high organic content in emissions from saw mills or pulp and paper mill plants. However, there seem to be no such activity performed on a large scale in the catchment. Land fills could also be a potential high risk areas.

When it comes to non-exploited areas, wetlands are normally important contributors of TOC because of the accumulation of organic material in these areas. Wetland can have a significant contribution, especially during extreme wet years where organic material is flushed away with the runoff, increasing the color of the water in nearby streams (Strock, et al., 2016). The color export from catchments have also been shown to be positively correlated with the percentage of peatland cover (Sarkkola, et al., 2009). In the catchment of River Storån, areas covered by wetlands make up for about 13%. The peat bog Stora Mosse is located in the eastern part of the catchment and is since 1982 a part of the Store Mosse national park. The park has an aeral extent of 7682 hectars, of which a majority of 5335 hectars is wetland, and is situated in relatively flat area at around 165 MSL (Naturvårdsverket, 2015).

The water color has also been closely linked with forestry, and especially with cultivation of spruce, where the leaching of organic content is thought increase with the age of the forest, as the organic soil horizon takes approximately at least 40 years to develop (Kritzberg, 2017). Forested areas constitute about 70% of the total catchment area and is mostly of coniferous type. Since spruce is the most common cultivated conifer species in the counties of Jönköping, Kronoberg and Halland that make up the catchment, it can be assumed that a large portion of the forest coverage consist of spruce (Skogsstyrelsen, 2014).

Dams and flow withdrawal

There are several small dams and weirs located along River Storån in the southern part of the catchment near the outlet to Lake Bolmen. Among them is a small dam owned by the private company Slättö kvarn (Slättö Kvarn AB, u.d.) and a larger dam managed by the company Forshedaverken AB (Forshedaverken AB, u.d.), both with turbines installed to generate hydroelectricity. The connectivity in the river is deemed by Länsstyrelsen to be poor, mainly due to artificial obstructions along the river. The impact of obstructions and regulations of the flow can however be considered to be relatively small on the overall morphology of the river, as indicated by the overall status of the river morphology classified as “good” by Länsstyrelsen (VISS, 2017).

Flow measurements

SMHI has no currently active measuring station along River Storån, however there have been measurements conducted in the past, near the outlet of River Storån as well as further upstream in the catchment. On request SMHI could only provide water level measurements conducted for a limited time period, with no exact location given or specification of the geometry of the river to support the data. Computed discharge of River Storån using the rainfall-runoff model HYPE-S is available through SMHI’s web platform for hydrological data (SMHI och Havsvattenmyndigheten, u.d.).

Results and Discussion

Variation in color

The color at the outlet of River Storån measured in Pt/mg l show a positive linear trend during the last 40 years, as demonstrated Figure 4 which shows the variation of color from samples taken by Lagans Vattenråd from 1978 to 2017. The positive linear trend is represented by a black dotted line.

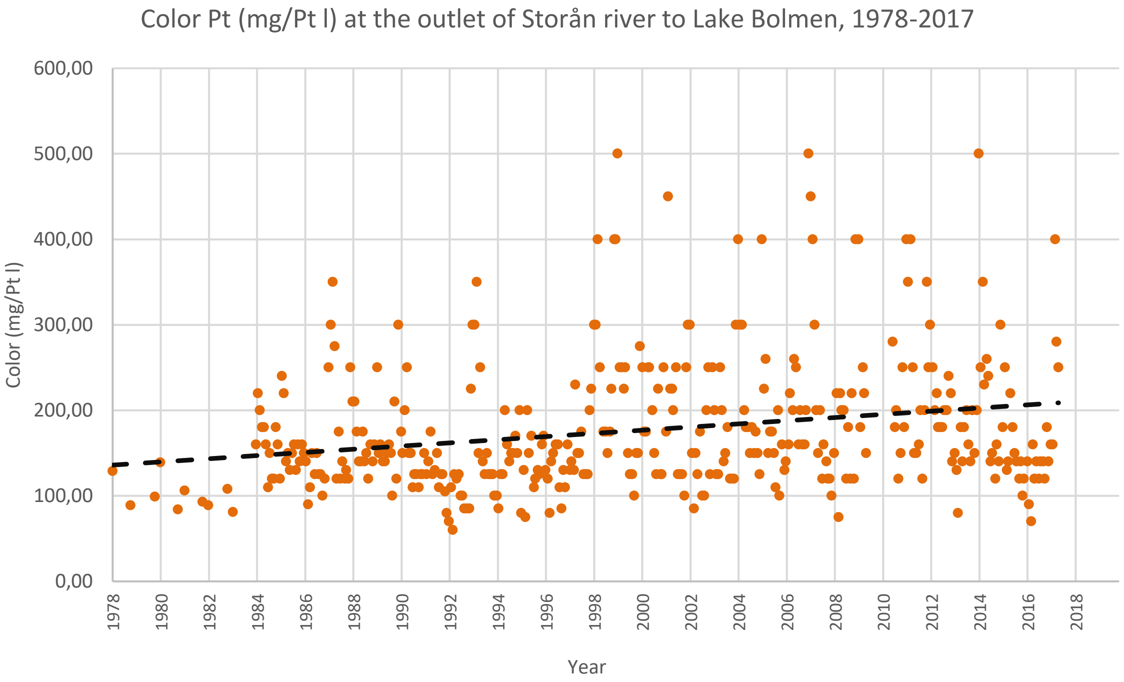

Figure 4. Variation of color (mg/Pt l) at the outlet of River Storån to Lake Bolmen between 1978 and 2017.

The available measurements of color using the ABS420/5 method are much fewer, as monthly samples have only been taken using this method between 2011 and 2017, with no samples taken during 2013. Figure 5 shows the variation of color using the absorbance method. The samples show no significant trend.

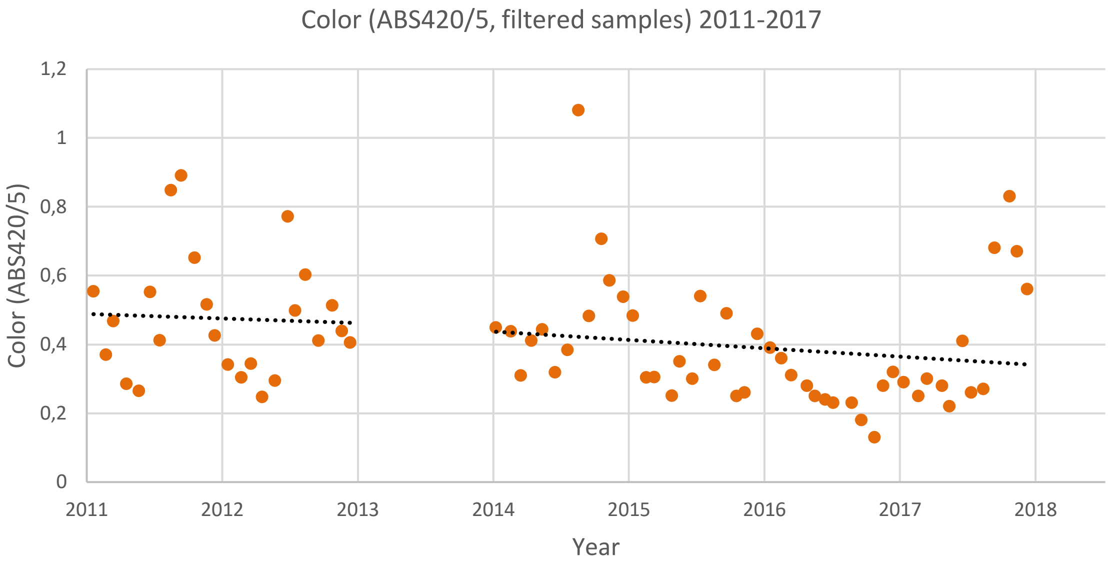

Figure 5. Variation of color (ABS420/5) at the outlet of River Storån between 2011 and 2017.

Mann-Kendall test for color

To confirm whether there is actually a gradual positive trend in the color values, a Mann-Kendall test was performed on the color data series for the outlet of River Storån. The result can be seen in Table 4.

Table 4. Results of seasonal Mann-Kendall test on monthly color samples (mg/Pt l) from 1978 to 2017 at the outlet of River Storån.

Variable	Value
Tau (τ)	0.156
p-value	$1.0*10^{-5}$

The two-sided p-value is below 0.05 and the tau value is positive, meaning that there is a positive monotonic trend in the color data series. The linear trend line and the results of the Mann-Kendall tests indicate that the color of the water in River Storån has been steadily increasing since 1978.

Correlation between TOC and color

The highest correlation between TOC and color measured with the Pt-Co method was found at the outlet of River Storån, with a Pearson correlation coefficient of 0.79, indicating a moderate to high correlation. The other sampling points upstream in the catchment showed moderate to high positive correlations, ranging from 0.63-0.80, except for the furthest point upstream number 568, which had a correlation of 0.47. Figure 6-Figure 11 shows the correlation of TOC and color based on monthly samples at the six sampling points in the catchment, with TOC in mg/L and color in mg/Pt l.

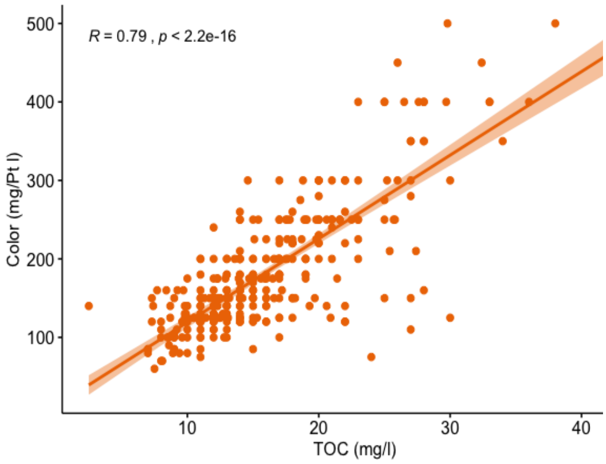

Figure 6. Correlation between TOC and color based on monthly samples at point 550 (the outlet of River Storån).

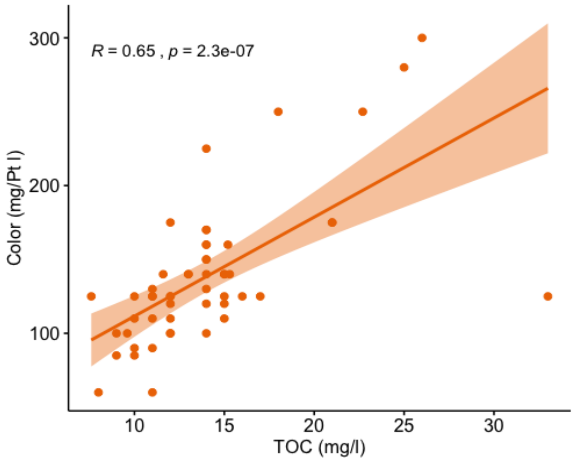

Figure 7. Correlation between TOC and color based on monthly samples at point 552 (downstream of Forsheda).

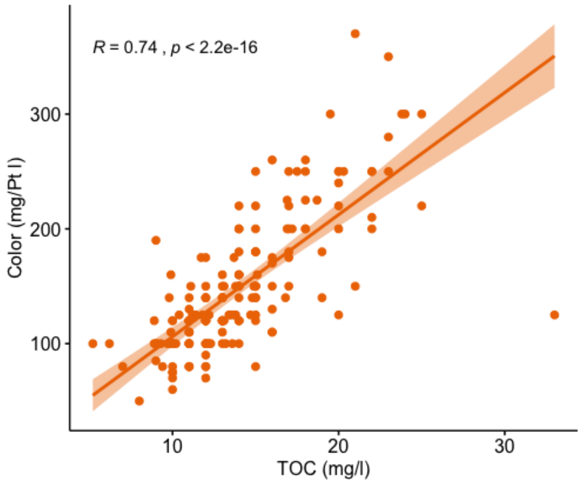

Figure 8. Correlation between TOC and color based on monthly samples at point 554 (downstream of Törestorp).

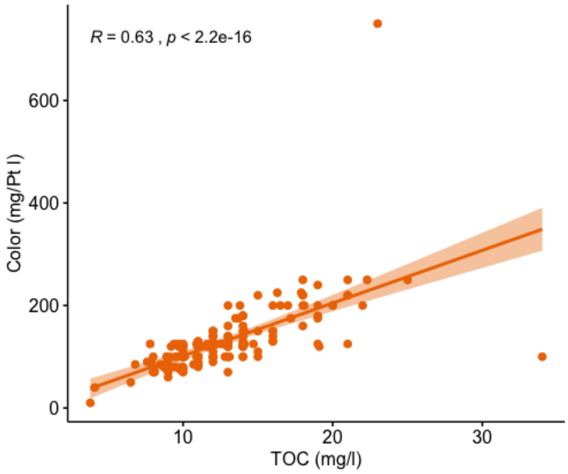

Figure 9. Correlation between TOC and color based on monthly samples at point 558 (outlet of lake Flaten).

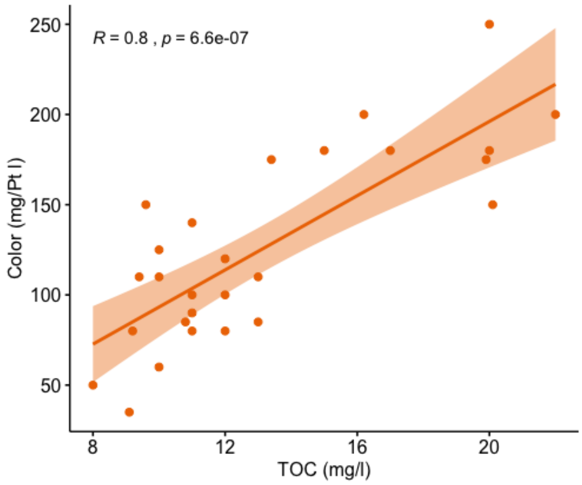

Figure 10. Correlation between TOC and color based on yearly samples at point 560 (lake Flaten).

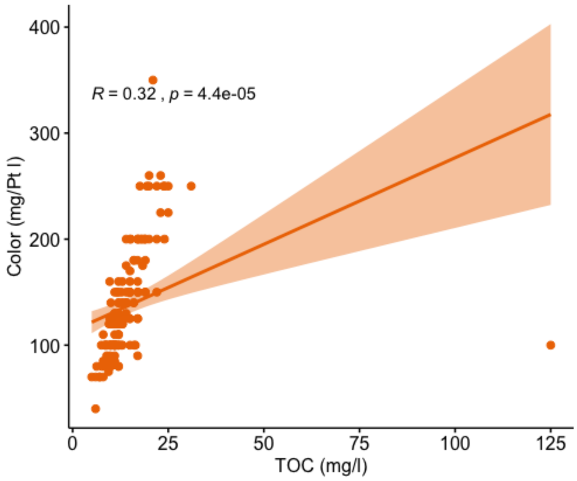

Figure 11. Correlation between TOC and color based on monthly samples at point 568 (Västerån river).

Color measurements using the ABS420/5 method showed a high correlation with TOC for all points where there was available data, ranging from 0.82-0.98 using the Pearson correlation coefficient. The highest correlation was found at the outlet of River Storån, and the lowest at sampling point 560 (lake Flaten).

Interannual variation of color

Figure 12 shows how the color varies between different months of the year in the outlet of River Storån, by arranging the values after which month they were measured, for the period 1978-2017. The high extreme values are found within the period July-October, and the low extremes are found in February to April. The dotted black line in the figure denotes the average by month for the whole period.

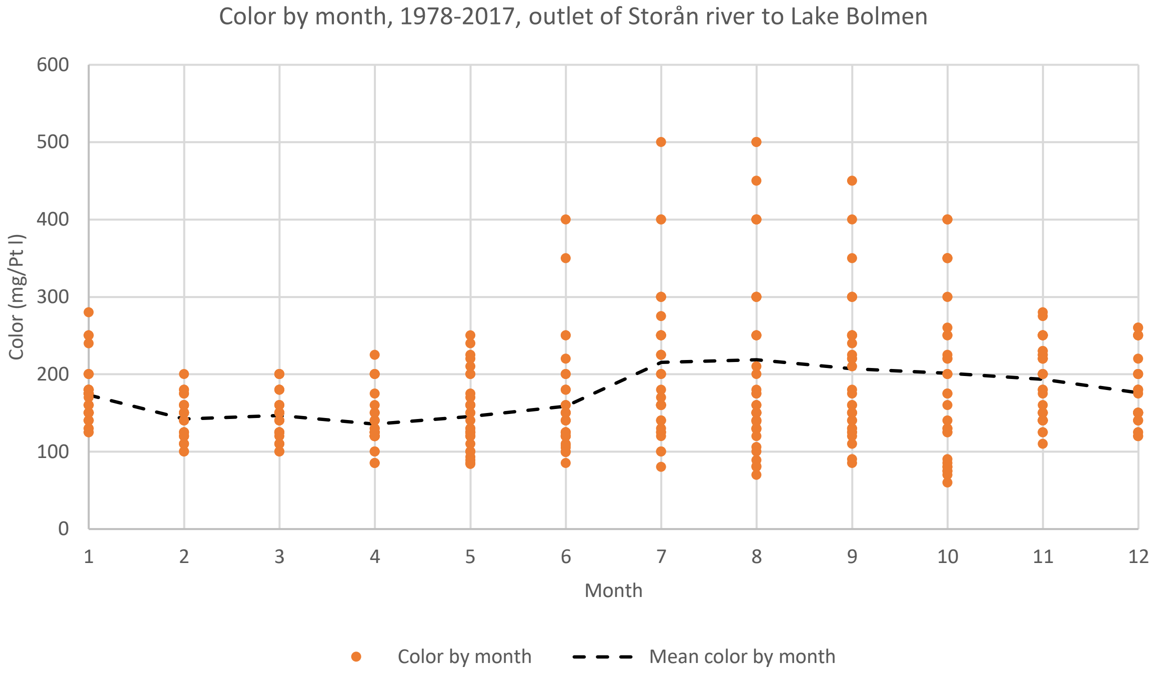

Figure 12. Color (mg/Pt l) sorted by month for the period 1978-2017. The dotted black line shows the average (mean) value for each month.

Table 5 shows the mean values of color sorted by month for the period 1978-2017 at the outlet of River Storån. The period with highest color is July-October, with August having the highest mean value, and the months February, March and April have the lowest mean, with April having the overall lowest mean value. Precipitation patterns seem to well describe the interannual variation of color, especially the extreme values of color, which can be found in the months with highest precipitation.

Table 5. Mean values of color at the outlet of River Storån to Lake Bolmen.

Mean values of color (mg/Pt l) by month for the period 1978-2017	
January	173
February	142
March	147

April	136
May	146
June	159
July	215
August	219
September	207
October	202
November	193
December	176

Color variation along stream flow in River Storån

Since there are six sampling points along River Storån, it is possible to sort the color measurements from upstream to downstream and analyze the color development in a north-south direction. In Figure 13 the color is shown for all five sampling locations in River Storån, from upstream to downstream, for the month of August (usually the month having the highest color value) every fifth year from 1987 to 2017.

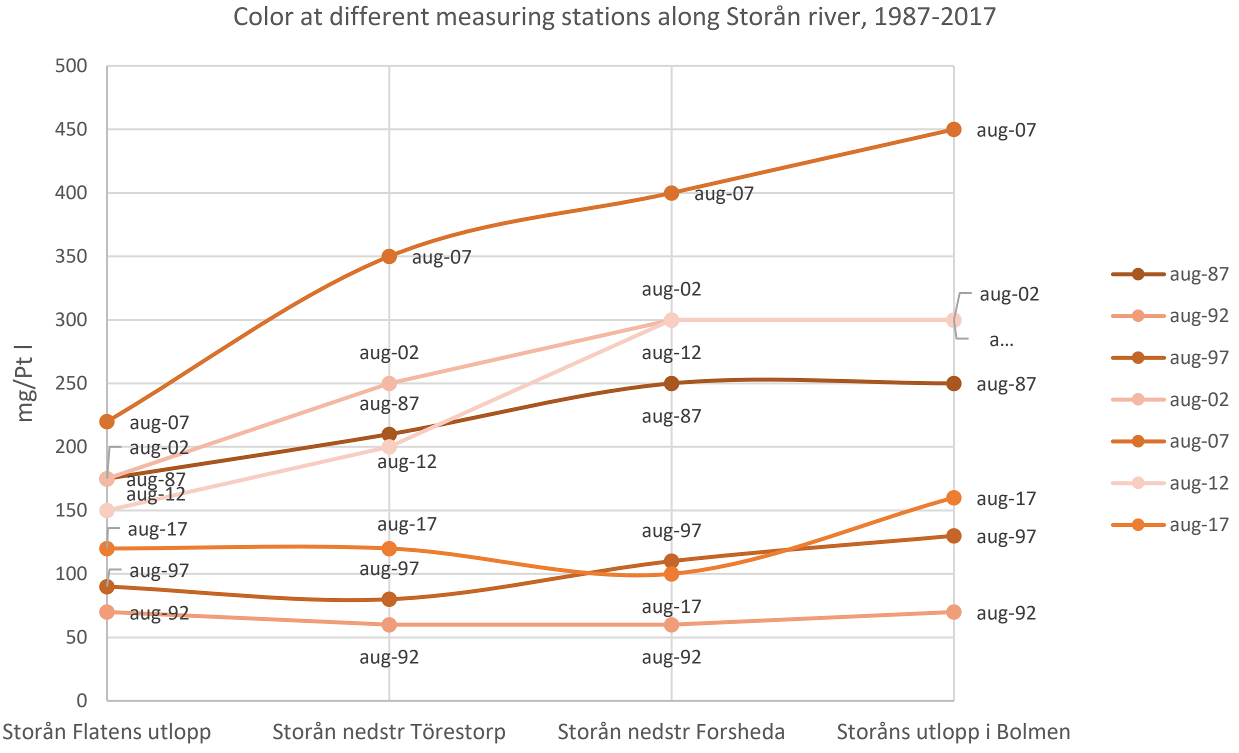

Figure 13. Color for august every fifth year at different measuring stations in River Storån, 1987-2017.

For some of the years, the color increases from upstream to downstream in the river while for others, as in august 2017 and august 1992, the color is more even throughout the path of the river. A similar pattern emerges when comparing the color for all points in April and August each year (the two months that tend to coincide with the annual minimum and maximum). In Figure 14 the color values for each April and August are arranged after measurement point, from upstream to downstream. The general trend seems to be that for measurements taken in

April, the color either remains relatively unchanged from upstream to downstream or shows only a slight increase, while some of the measurements taken in August show a very steep increase from upstream to downstream, especially between sample locations 554 and 552.

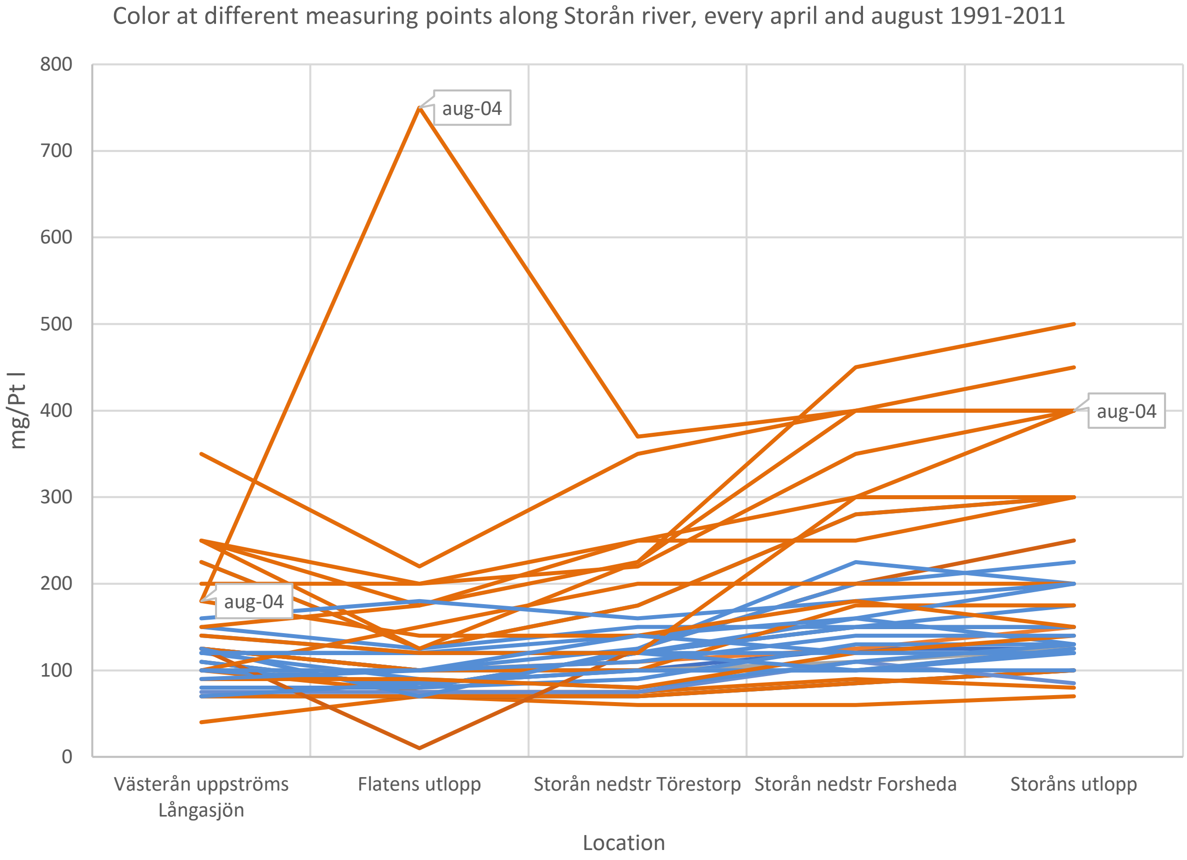

Figure 14. Color in April and August at different measuring locations in River Storån, from upstream to downstream, from 1991 to 2011. The samples taken during the same year in August are shown as orange lines and the samples taken in April as blue lines.

The variation of color from upstream to downstream in the river in April and August, differ substantially in certain years. While the color is mostly constant or shows a slight increase in April, for some samples in August the color increases dramatically from upstream to downstream. The accumulation of organic material in the stream might be attributed the presence of wetlands, which are more abundant in the middle and southern part of the catchment, with the national park Store Mosse in relatively close proximity to where the most dramatic increase seem to be taking place. The profile with increasing color from upstream to downstream also seems to occur during years with a high yearly precipitation, although there is no statistically significant relationship confirmed.

The years during which the August sample show an increase from upstream to downstream in color all have an above average yearly precipitation, with four of them being in the 95th percentile in terms of yearly precipitation sum (see table Table 6). However, this is also true for august 2004 in which a significant decrease can be seen from upstream to downstream. The trend is not as clear when examining the precipitation sum of the specific months, where there seems be less of a correlation with the wetness (precipitation sum ranked from highest to lowest).

Table 6. Yearly and monthly precipitation sum for the years in which the august sample show an increase in color from upstream to donwstream, along with the wetness rank of that year based on monthly and yearly precipitation.

August with increasing trend upstream to downstream	Yearly precipitation sum (mm)	Rank Wetness	Monthly precipitation sum (mm)	Rank Wetness
1993	813,6	Below 90th percentile	69,9	Above average
1998	1030,8	95th percentile	92,1	Above average
1999	977,4	95th percentile	115,5	90th percentile
2000	856,3	Below 90th percentile	59,4	Below average
2002	875,1	Below 90th percentile	22,2	Below average
2005	698,1	Below 90th percentile	132	90th percentile
2007	1015,5	95th percentile	106,9	Above average
2009	785,9	Below 90th percentile	71,7	Above average
2011	995,3	95th percentile	164,9	95th percentile
August outlier (decreasing trend)				
2004	1015,4	95th percentile	95,2	Above average

Trends for extreme values of color

Figure 15 below shows the occurrence of samples per year belonging to the 95th percentile, demonstrating an increasing trend in the occurrence of extreme color values.

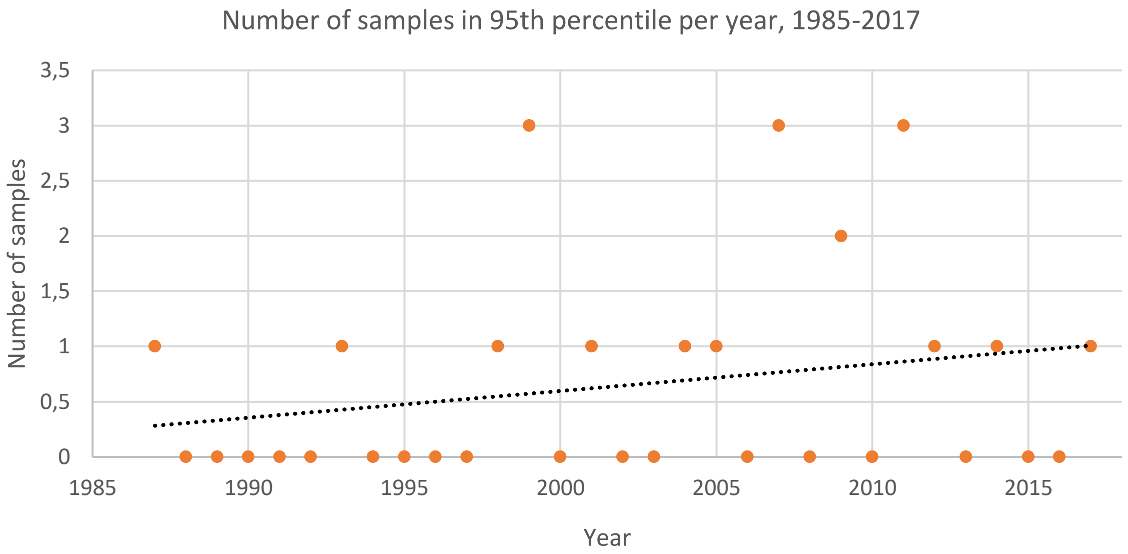

Figure 15. Number of extreme samples (95th percentile) per year from 1985 to 2017, based on monthly samples at the outlet of River Storån.

Precipitation

Within the catchment there is one currently active measuring station for precipitation run by SMHI, in Kävsjö near Hillerstorp (latitude 57.3222, longitude 13.9264 - see Figure 2). The station was put in use on January 1, 1945 and has been measuring daily precipitation since then.

The daily precipitation shows a slight increase, which is consistent with larger climate prediction models for Sweden. The number of days with precipitation per year as well as the number of days with extreme rainfall (in the 95th percentile) are also increasing, as indicated by the positive linear trends of both data sets.

The monthly sum of precipitation seems to show a slight increase regarding the average precipitation from the 1970s and onward, however the trend is not very distinguishable for the whole period for which data is available, from 1908 to 2018 (Figure 16).

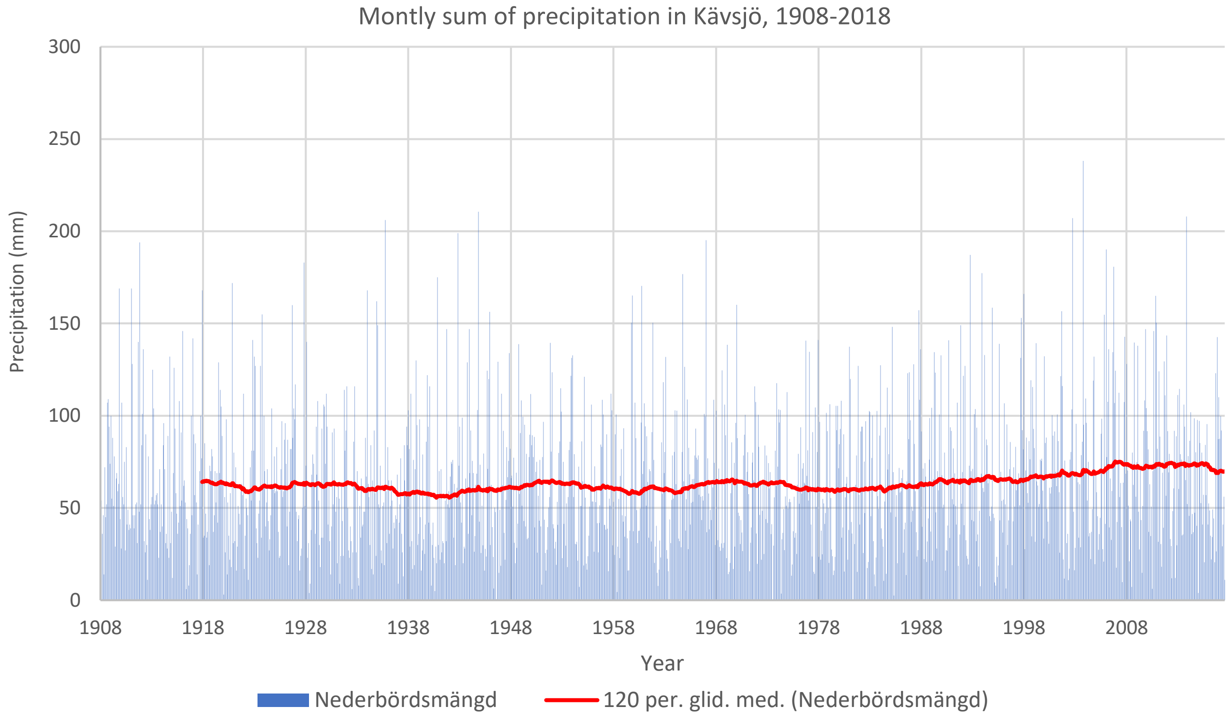

Figure 16. Monthly sum of precipitation ("Nederbördsmängd") measured at SMHI's station in Kävsjö, from May 1908 to May 2018, with moving 10-year average in red ("120 per. glid. med. (Nederbördsmängd)").

The yearly precipitation sum shows a more clearly visible positive linear trend, both for the whole period from 1908 to 2017 as well as for the last 40 years (1908-2017, see Figure 17). Both the winter and summer precipitation are increasing, with the trend being slightly stronger for the summer precipitation. Figures of summer and winter precipitation can be found attached in the appendix (see 11.3 Summer and Winter Precipitation).

The number of days per year with extreme precipitation is also increasing, as can be seen in Figure 18, which shows the linear positive trend of the number of days per year with precipitation in the 95th-percentile.

Furthermore, the overall number of days with precipitation is also increasing. When counting the number of days per year with precipitation, i.e. days with a precipitation sum >0 mm, a positive linear trend from 1945 to 2017 can be seen (see Figure 19).

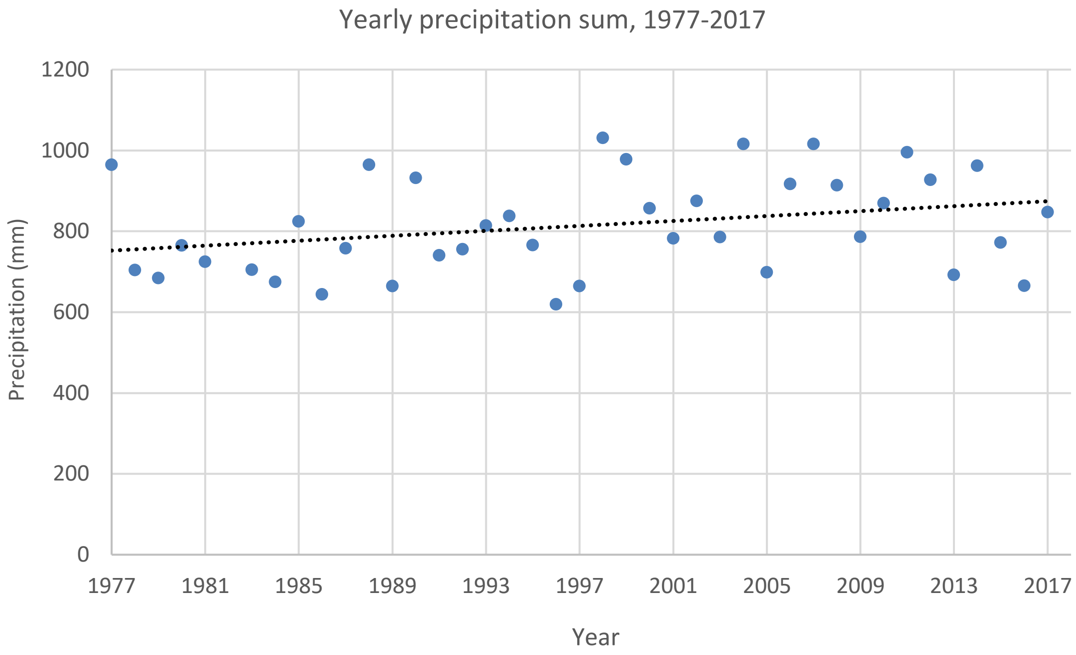

Figure 17. Yearly precipitation sum from 1977 to 2017 with linear trend represented with a dotted black line.

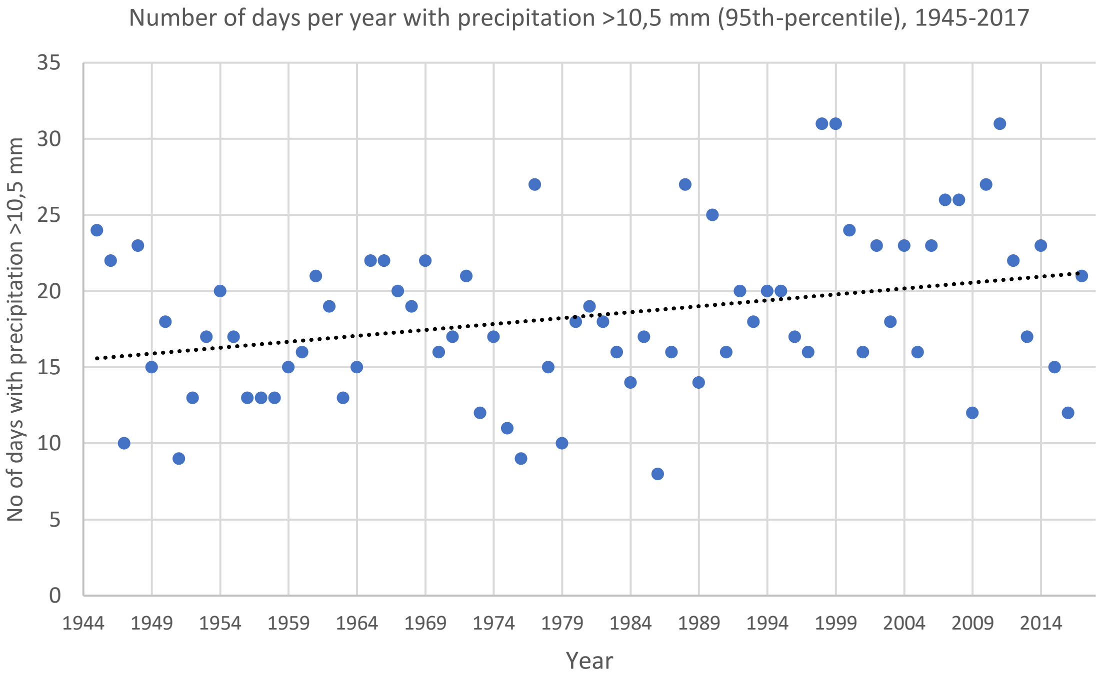

Figure 18. Number of days per year with precipitation above the 95th percentile from 1945 to 2917, with linear trend as dotted black line.

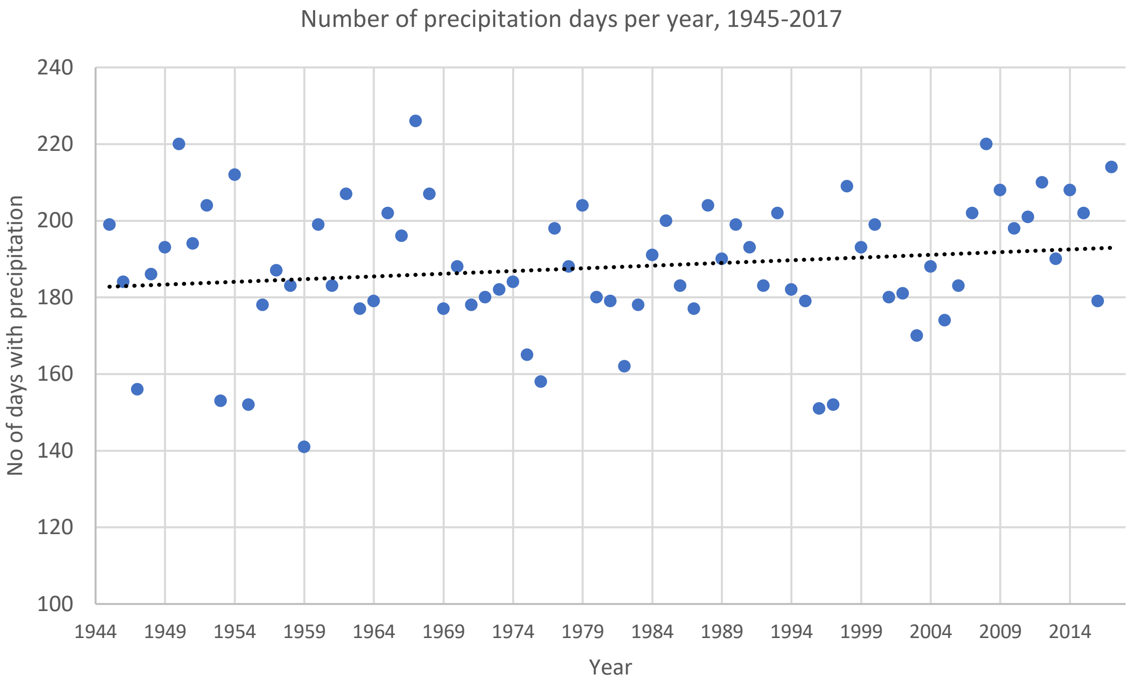

Figure 19. Number of days with precipitation per year from 1945 to 2017. Linear trend is represented by a dotted black line.

Seasonal Mann-Kendall test for precipitation

A seasonal Mann-Kendall test was performed on the monthly precipitation data to confirm if the precipitation is in fact increasing (see Table 7 below). A positive tau-value and a p-value below 0.05 indicate a positive monotonic trend taking place.

Table 7. Results of the Mann-Kendall test performed on the monthly precipitation recorded at SMHI's measuring station in Kävsjö, from 1908 to 2017.

Variable	Value
Tau (τ)	0.063
p-value	$4*10^{-4}$

Correlation between precipitation and color

The highest Pearson correlation between precipitation and color was found using the yearly mean precipitation in Kävsjö and the yearly mean color at point 554 (downstream of Törestorp), with a correlation coefficient of 0.74. Figure 20-25 shows the correlation between yearly precipitation sum in mm and the yearly mean color in mg/Pt l for all sampling points in the catchment.

There is only a weak positive linear correlation between the monthly precipitation and the monthly samples of color. The difficulty to establish a clear relation between the variables might have to do with the fact that that there is a lag effect in the response of the color to rainfall events. Since the color is measured only once a month at most, it is hard to assess the effect of specific rainfall events.

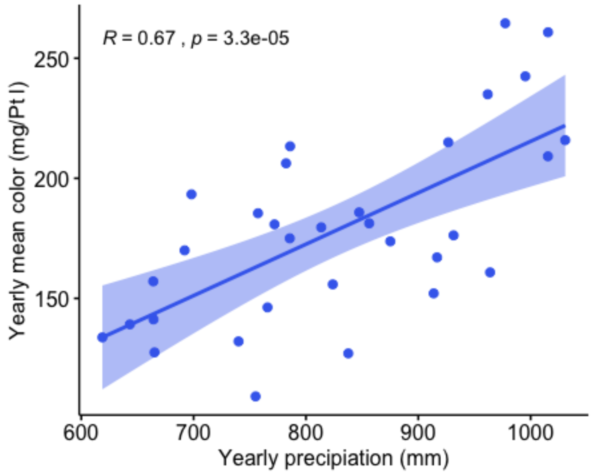

Figure 20. Correlation of yearly precipitation and yearly mean color at point 550 (outlet of River Storån).

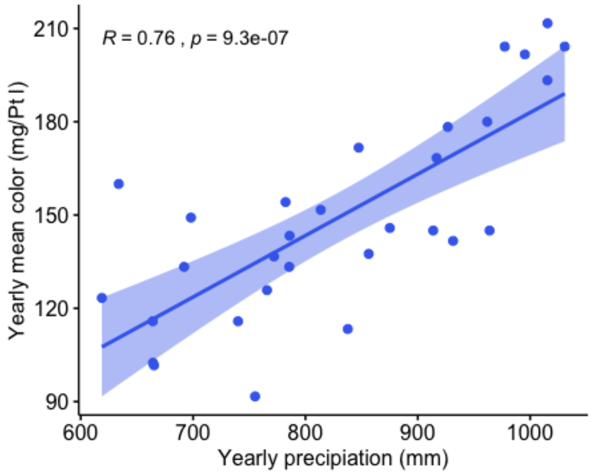

Figure 21. Correlation of yearly precipitation and yearly mean color at point 554 (downstream of Törestorp).

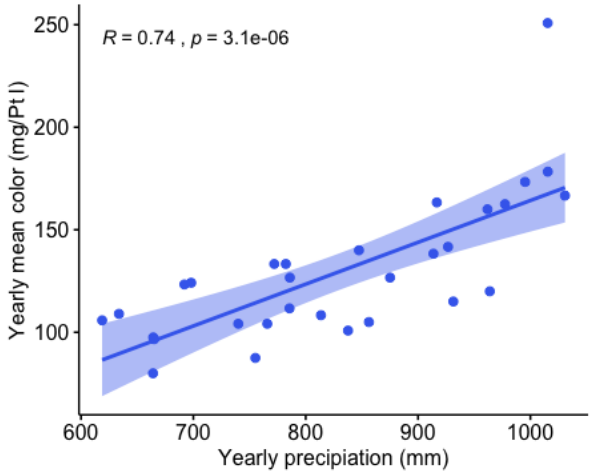

Figure 22. Correlation of yearly precipitation and yearly mean color at point 558 (outlet of Lake Flaten).

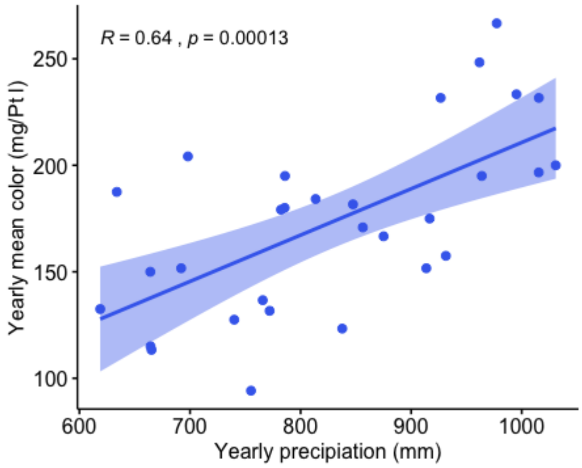

Figure 23. Correlation of yearly precipitation and yearly mean color at point 552 (downstream of Forsheda).

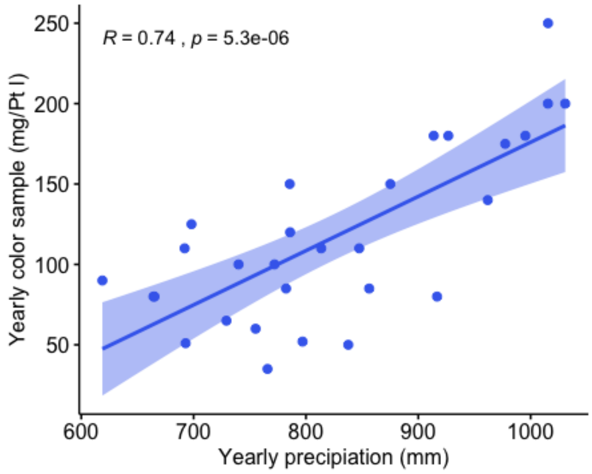

Figure 24. Correlation of yearly precipitation and yearly mean color at point 560 (Lake Flaten).

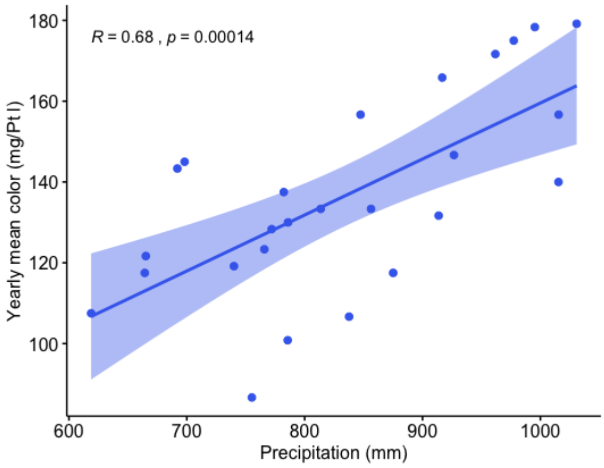

Figure 25. Correlation of yearly precipitation and yearly mean color at point 568 (inlet to Lake Långasjön).

By comparing the color values and mean precipitation for the whole period 1978-2017 sorted by month, a visible correlation can be found between rainfall and color. Figure 26 below shows the color values sorted by month as well as the mean color for each month in relation to the mean precipitation for each month. This visualization show that the months with higher mean color values as well as a higher frequency of extreme color values also experience the highest levels of precipitation.

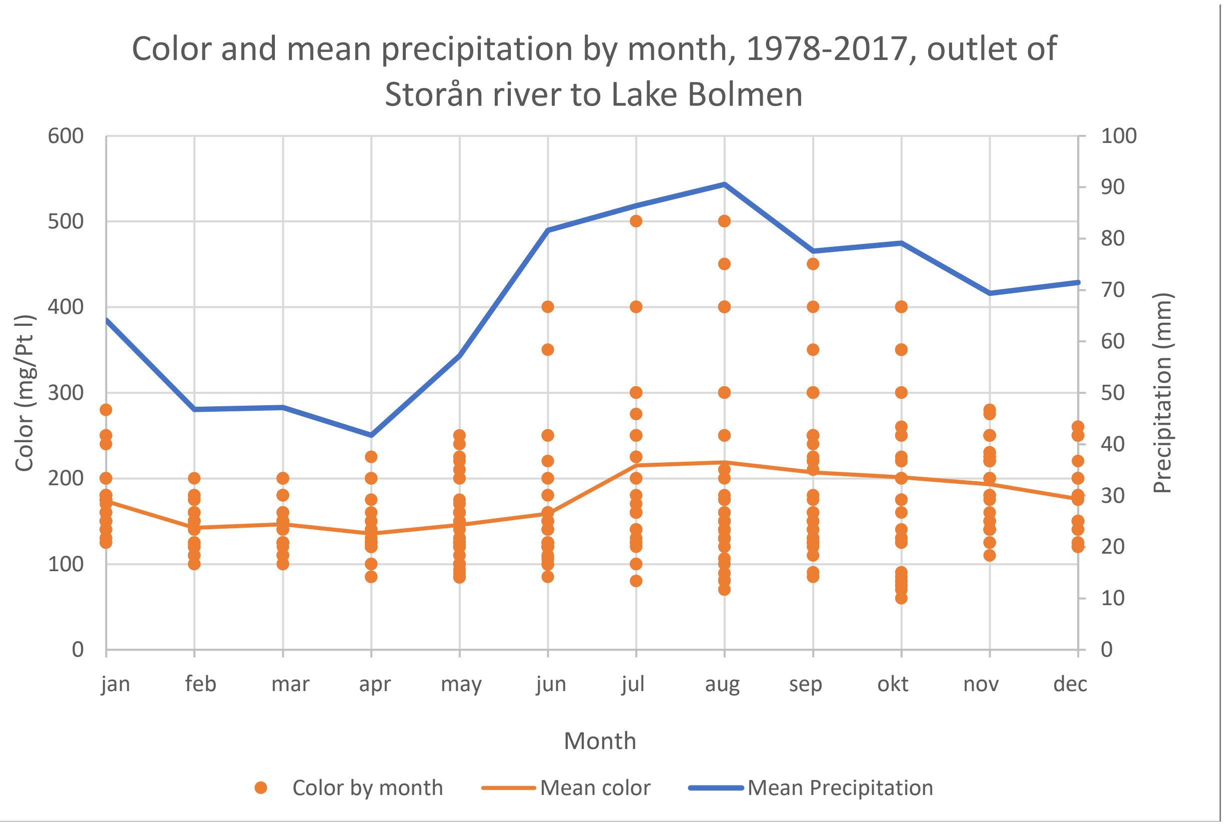

Figure 26. Color (mg/Pt l) sorted by month and mean of monthly sum of precipitation for the period 1978-2017 in the outlet of River Storån to Lake Bolmen.

Pearson and Spearman correlation between precipitation and color

Table 8. Correlation coefficients for yearly precipitation and yearly average of color using Pearson and Spearman methods as well as linear regression.

Method	Correlation coefficient	p-value
Pearson	0.67	$3.3*10^{-5}$
Spearman	0.65	$9.0*10^{-5}$

Correlation between extreme rainfall events and color

A useful method to examine extreme rainfall events is to plot the rainfall intensity-frequency distribution. Since the data from SMHI station in Kävsjö only contains daily sum of precipitation and no hourly data, the frequency distribution of daily precipitation was used, which is displayed in Figure 27.

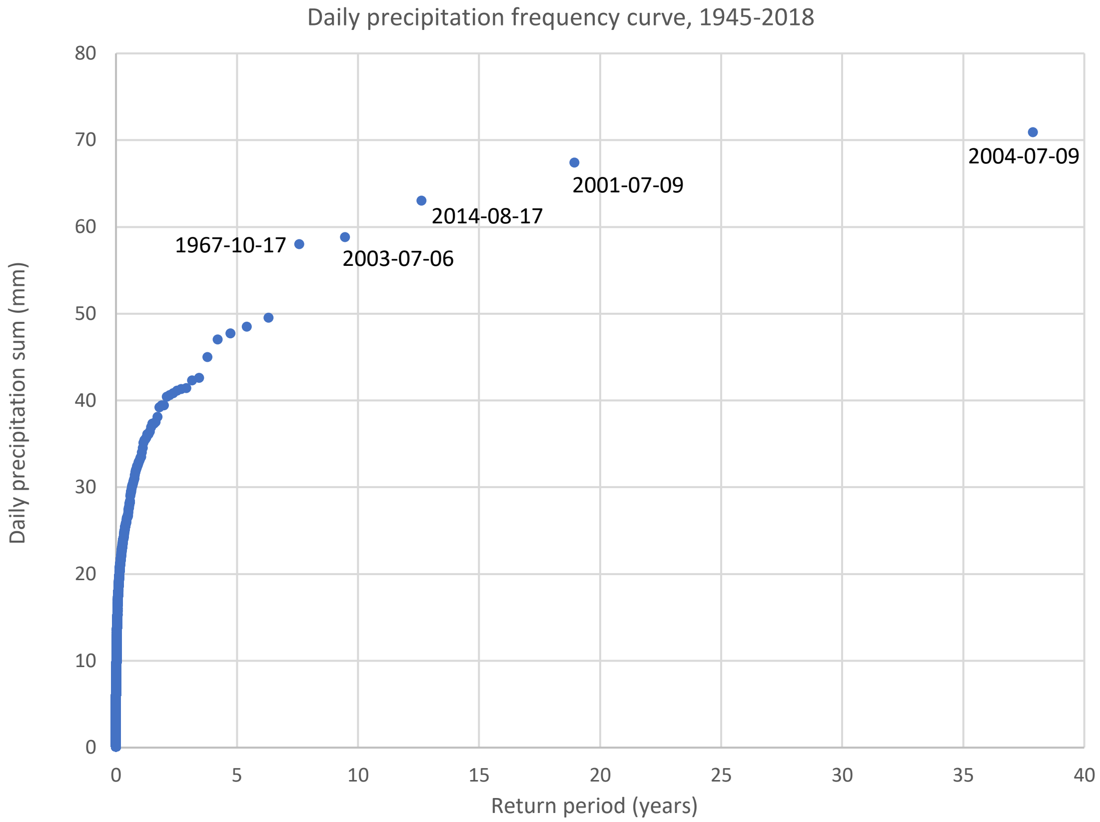

Figure 27. Daily precipitation frequency curve with precipitation in mm and return period in years.

Of the five days with the highest daily precipitation sum, four were recorded between 2001 and 2014.
In case of the of the highest daily precipitation measured in 2004-07-09, the closest following color sample is also very high at 400 mg Pt/l, the maximum for that year. This indicates a direct effect on the color. For other dates with extreme precipitation, the effect on color is not as clear, as for example with 2001-07-09, for which the following color sample is 250 mg Pt/l, which is quite high but well below the maximum measured that same year in September (400 mg Pt/l).

Since no hourly data on rainfall is available from the measuring stations within the catchment, it is difficult to assess how the duration or intensity of specific rainfall events have changed. Other studies examining data from southern Sweden that have found a positive trend for the occurrence of large precipitation events (Bengtsson & Rana, 2014).

A more detailed view of the monthly precipitation and monthly color samples during the last 15 years is shown in Figure 28. It is remarkable that there is no large increase in color after hurricane Gudrun in the spring of 2005 (8-9th of January) and hurricane Per in 2007 (14th January). Both hurricanes caused great damage to forests in Southern Sweden, with almost 75 million cubic meters of forest destroyed during hurricane Gudrun and 12 million cubic meters blow down during hurricane Per. Neither is there a large increase seen in 2013, when the storm Simone swept over the area in that year on October 28th, which resulted in great forest damages in Kronoberg county and in Southern Sweden as a whole, with about 1,5-2 millions cubic meters of forest blown down (Skogssverige, u.d.). A natural explanation for this could be that these storms all took place during relatively cold periods of the year (Gudrun and Per in beginning January, Simone in late October) when temperatures are below 0 °C on average, decreasing the amount of overall flow but also the transport and leaching/flushing of organic material. But using this logic the effect of this events should still be visible, but postponed until warmer months. This is however not the case, since the spring and summer months following these events do not show significantly higher values than the averages for these years. Therefore, it can be assumed that the seasonal changes have a much larger impact on the color of the river than the occurrence of extreme rainfall events.

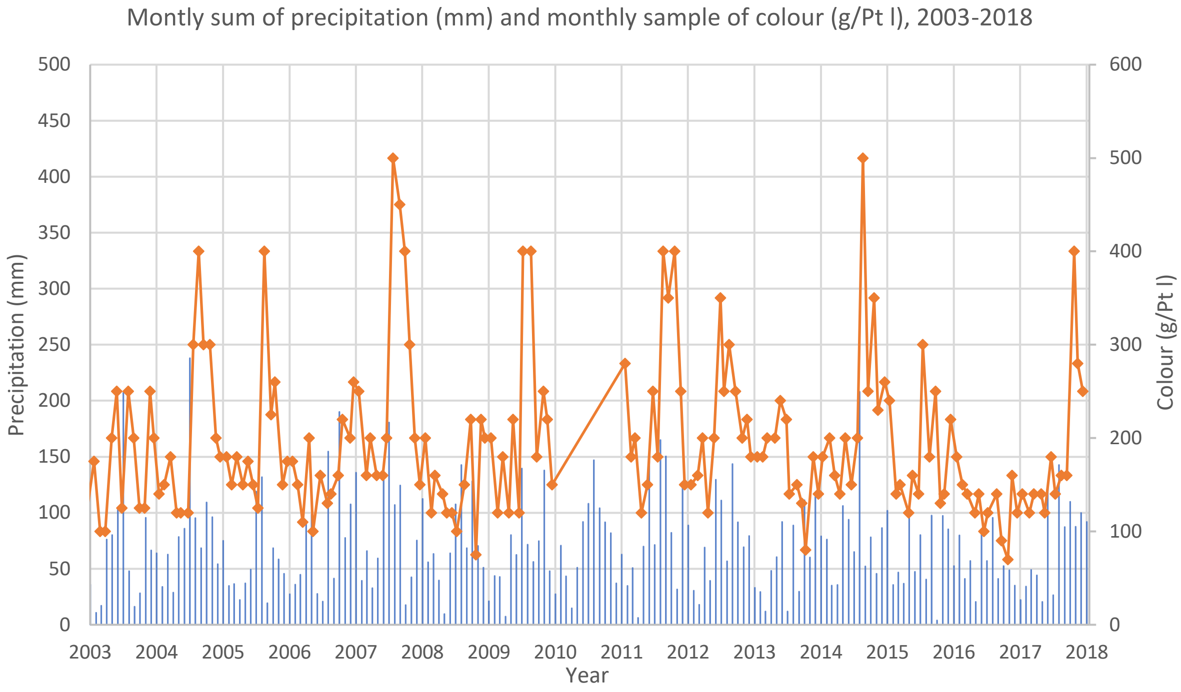

Figure 28. Monthly sum of precipitation and monthly samples of color at the outlet of River Storån, 2003-2018

Discharge

Since no flow measurements were found for River Storån during the same period the color samples by Lagans Vattenråd were taken, the modeled flow from SMHI's HYPE model was used to investigate the correlation between discharge and color.

The highest Pearson correlation coefficient of 0.72 was found between the yearly modeled average discharge and yearly average color in point 554, while the rest of the sampling points showed a less significant correlation, varying between 0.52 to 0.62. The results from the Pearson correlation tests between discharge and color at the different can be seen in Figure 29-33 below.

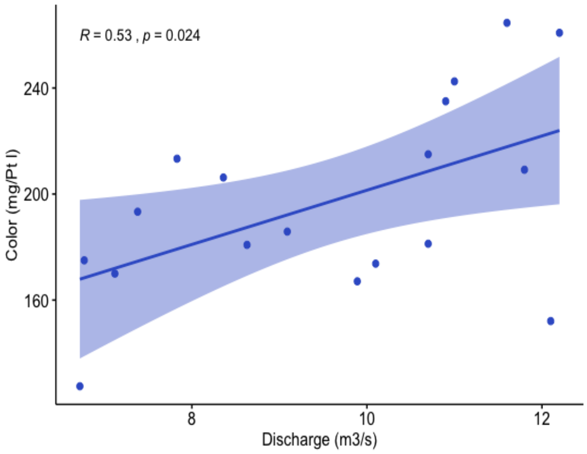

Figure 29. Correlation between discharge and yearly mean color at point 550 (outlet of River Storån).

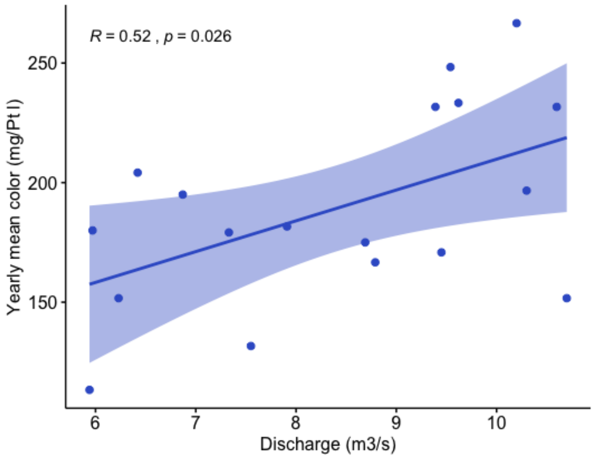

Figure 30. Correlation between discharge and yearly mean color at point 552 (downstream of Forsheda).

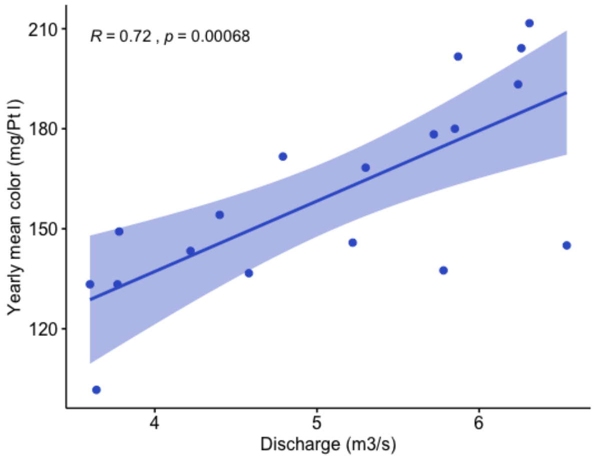

Figure 31. Correlation between discharge and yearly mean color at point 554 (downstream of Törestorp).

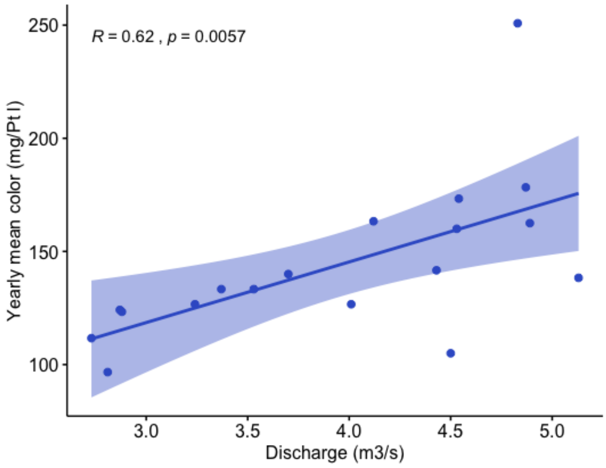

Figure 32. Correlation between discharge and yearly mean color at point 558 (outlet of Lake Flaten).

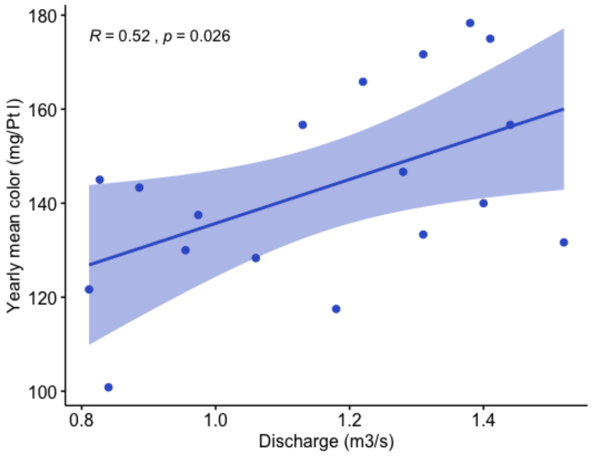

Figure 33. Correlation between discharge and yearly mean color at point 568 (inlet to Lake Lånagsjön)

The correlation between discharge and color in River Storån was found to be relatively poor, with the highest correlation of 0.53 noted between yearly averages of discharge and color. The correlation between yearly discharge and color is also lower than that between yearly precipitation and color, contradicting what has been found studies performed on similar catchments. This could either indicate that precipitation in this particular case is more indicative of color or that the modeled discharge of River Storån differs substantially from the actual observed flow.

When comparing the precipitation measured by SMHI in Kävsjö with the modeled outflow of River Storån, there seem to be very low correlation, which might indicate a poorly modeled flow for the catchment (see Figure 34). As the catchment of is only a small part of the larger model SMHI's model, which is only calibrated and validated with the observed outflow of Lake Bolmen at Skeen, it is plausible that this is the case.

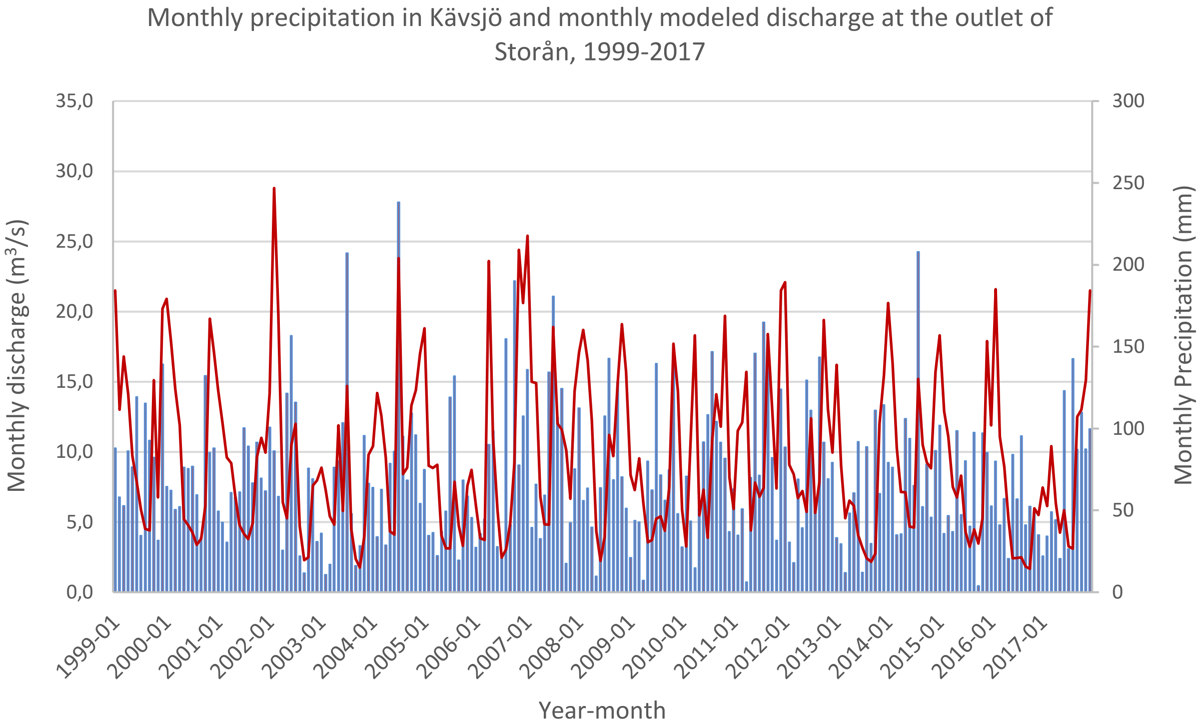

Figure 34. Monthly precipitation recorded at SMHI's measuring station in Kävsjö and monthly modeled discharge from SMHI's HYPE model.

Correlation between temperature and color

As the processes involved in the leaching of organic material takes place in the soil in a partly aquatic environment, it seems natural to investigate the variation of water temperature and its relationship with color. However, since there only exist a short series of measurement for water temperature in River Storån, it can also be interesting to look at the long-term changes in air temperature.

No currently or previously active SMHI measuring station for air temperature could be found in the catchment, but there are many to be found in the nearby area, with the three closest ones located near Hagshult (about 20 km east of Kävsjö), Hestra (about 25 km northwest of Kävsjö) and Stora Segerstad (about 30 km southwest of Kävsjö). The station in Hagshult has daily air temperature observations dating back to 1949, while measurements in Hestra began in 1973 and in Stora Segerstad in 1969, with the two latter ones being inactive since 1999. All of the stations have quite similar air temperature curves, and therefore Hagshult Mo was chosen to represent the area, for its short proximity to the catchment as well as having the most complete data set. The air temperature shows a slow but steady linear increase for the last 40 years (1978-2018) of 0.04 C°/year.

Seasonal Mann Kendall test for air temperature

In Table 9 the result of the Seasonal Mann-Kendall test performed on the monthly average air temperature in Hagshult Mo is shown. The tau value is positive and the p-value is below 0.05, indicating that there is a positive monotonic trend in the data series.

Table 9. Results of the Seasonal Mann-Kendall test performed on the monthly average air temperature based on data from SMHI's measuring station in Hagshult Mo.

Variable	Value
Tau	0.056
p-value	0.018

Correlation between temperature and color

No significant relationship could be established between either air or water temperature and color, using any correlation method (Pearson, Spearman and regular linear regression). The correlation coefficients for the three methods are displayed in the Table 10 below.

Table 10. Pearson and Spearman correlation coefficients between air temperature and color and water temperature and color at the outlet of River Storån, based on yearly averages and monthly samples from 1985 to 2017.

Air temperature	Correlation coefficient	p-value
Pearson	-0.02	0.91
Spearman	-0.004	0.98
Water temperature		
Pearson	0.19	$3*10^{-4}$
Spearman	0.11	0.04

Sulfate

The sulfate deposition from industries in Sweden have been decreasing since the peak in the 1980s, mainly due to the restrictions that were implemented on such emissions. The deposition of sulfur through precipitation has decreased nationwide, also in the region of Småland where Lake Bolmen and River Storån is located (Länsstyrelsen Jönköping, 2003). In Figure 35 the sulfur deposition is shown together with the monthly precipitation sum and the pH for the period

1983-2008 measured in Aneboda, which is located about 50 km southeast of Kävsjö. The sulfur deposition through precipitation has been steadily decreasing in Aneboda, while the pH has been increasing during the same period.

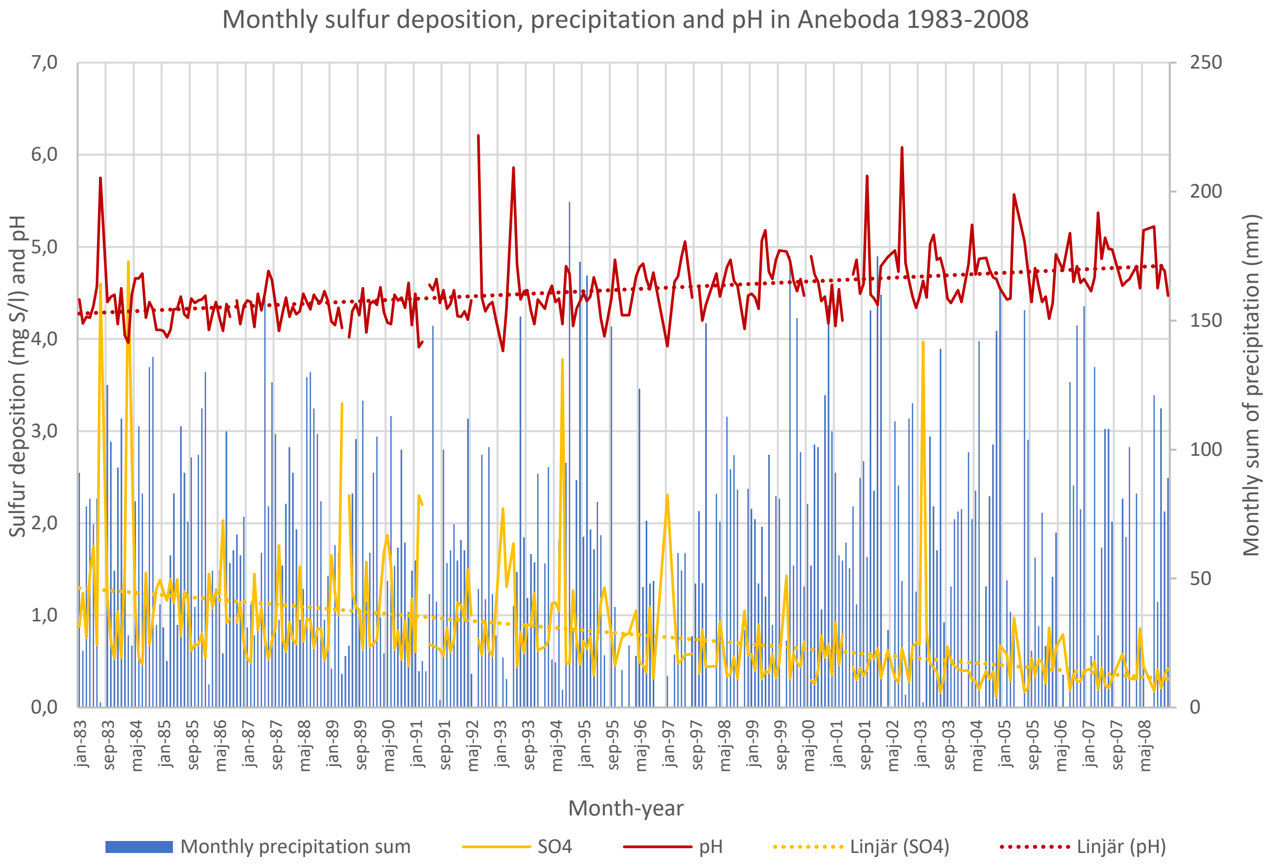

Figure 35. Monthly sulfur deposition, precipitation and pH in Aneboda 1983-2008 (from SMHI's data base on air quality).

A short series of sulfate measurements were performed at the outlet River Storån between 2011 and 2017 by Lagans Vattenråd. In Figure 36 the sulfate concentration in mg/L between 2011 and 2017 is shown, which does not demonstrate any observable trend. This is somewhat expected, since decreasing sulfur concentration is most likely only observable over several decades, and could be hard to detect over a time period of just a few years. Note that for the year 2013, there is no available data.

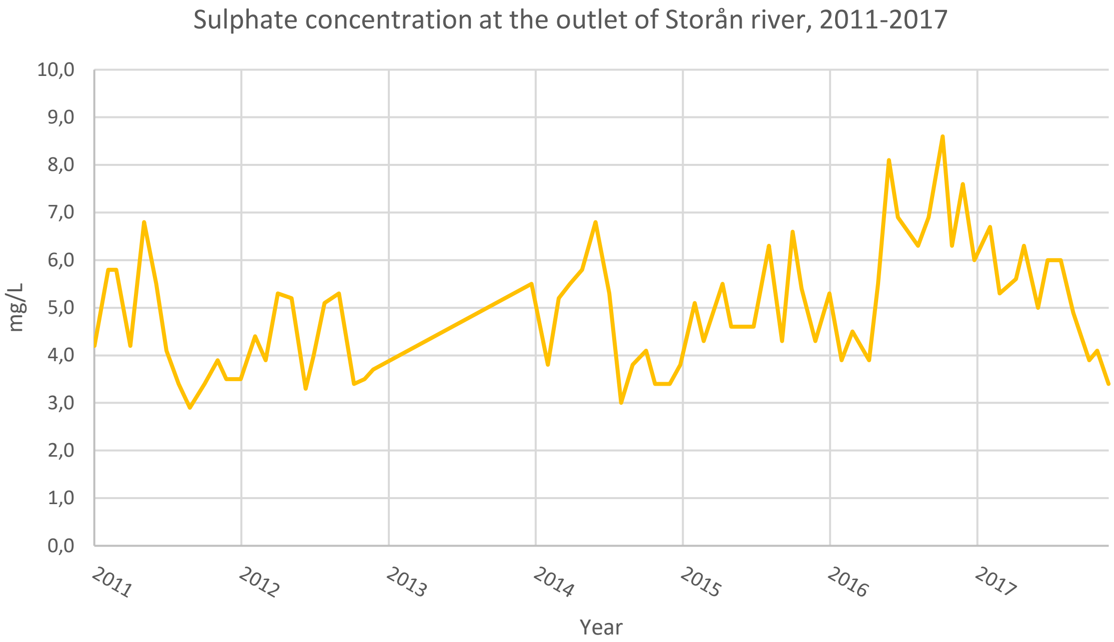

Figure 36. Sulfate concentration at the outlet of River Storån to Lake Bolmen (mg/L), from 2011 to 2017. No measurements were performed during 2013.

Figure 37 shows the variation of Sulfate in the northern part of Lake Bolmen between 1982 and 2017, based on samples taken once a year during late summer/autumn (August-September). Even though the samples are quite few it still gives an indication on the downward trend of sulfate concentration since 1980s. The negative value for the year 2005 is likely due to a measurement error.

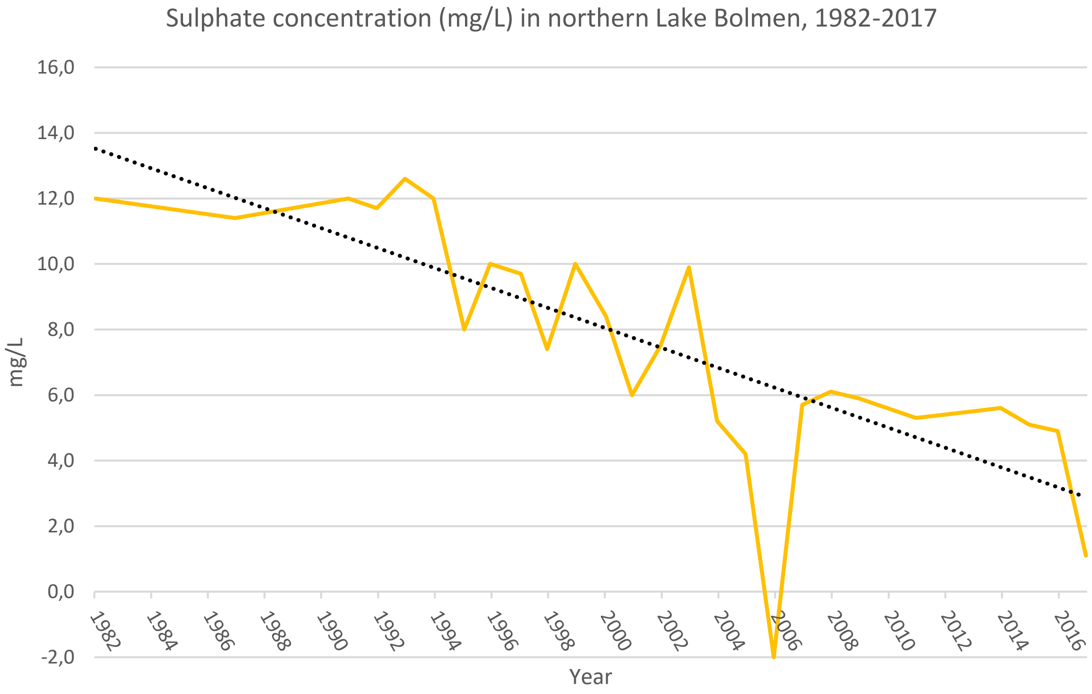

Figure 37. Sulfate concentration (mg/L) from a measurement point in the northern part of Lake Bolmen between 1982 and 2017

Correlation between sulfate concentration and color

Figure 38-42 show the correlation between sulfate concentration at the different sampling points in the catchment, based on monthly samples between 2011 and 2017. The Pearson correlation coefficient is 0.63, indicating a moderate correlation. The highest correlation between sulfate concentration and color measured with the Pt-Co-method was found in sampling point 558, with a Pearson correlation coefficient of -0.70. The lowest correlation was found in point 568, with the Pearson coefficient of -0.51.

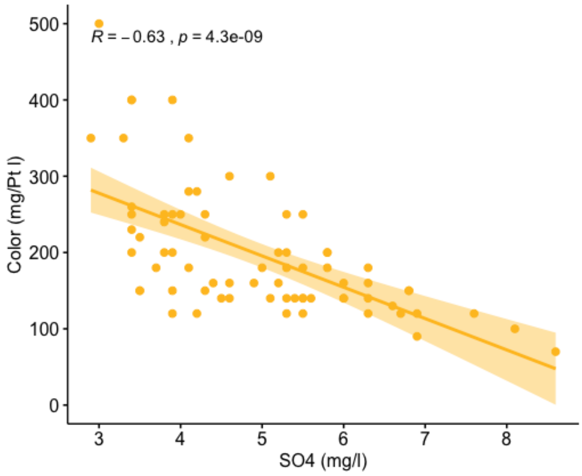

Figure 38. Correlation between sulfate concentration and color in point 550 (outlet of River Storån).

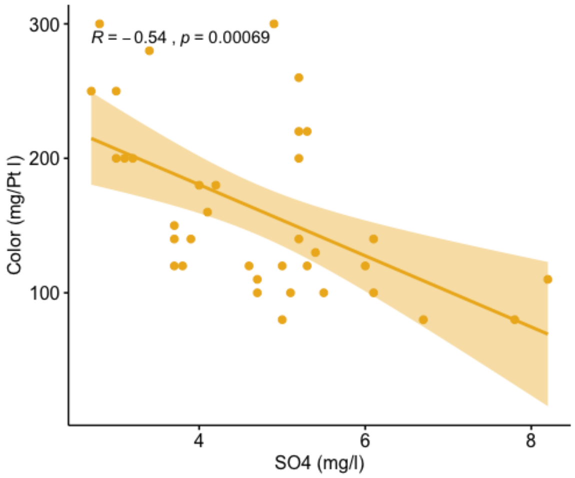

Figure 39. Correlation between sulfate concentration and color in point 554 (downstream of Törestorp)

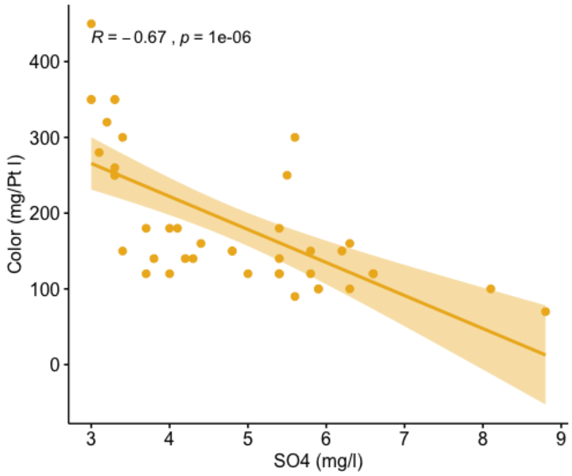

Figure 40. Correlation between sulfate concentration and color in point 552 (downstream of Forsheda).

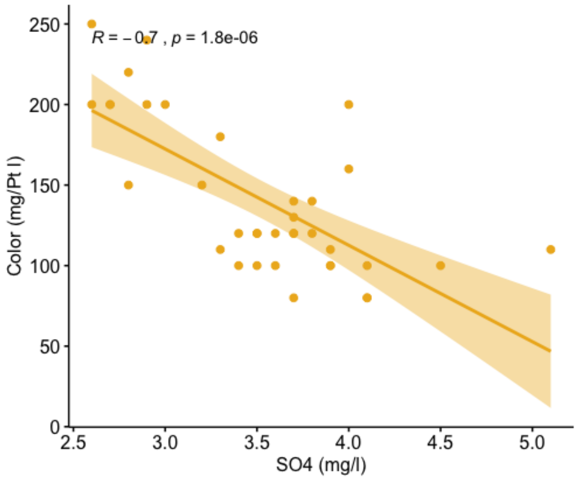

Figure 41a. Correlation between sulfate concentration and color in point 558 (outlet of Lake Flaten).

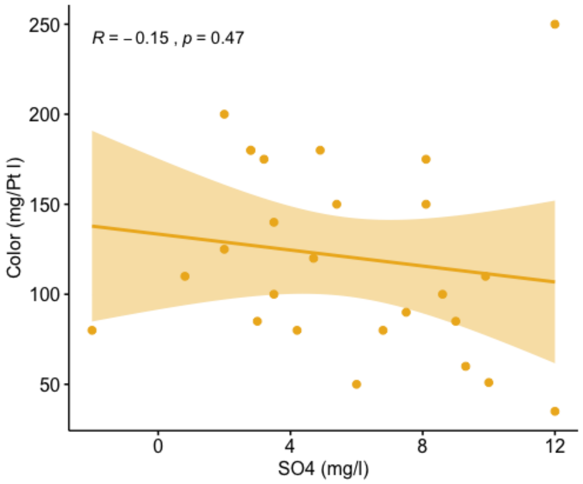

Figure 41b. Correlation between Sulfate concentration and color in point 560 (Lake Flaten).

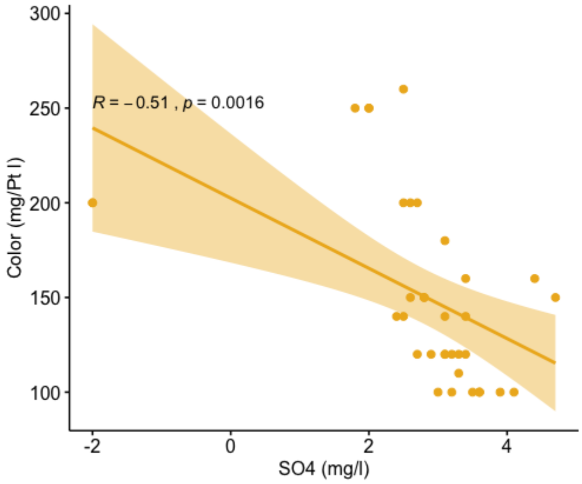

Figure 42. Correlation between Sulfate concentration and color in point 568 (inlet to Lake Långasjön).

Table 11. Correlation coefficients and p-values for Sulfate concentration and color at the outlet of River Storån, using the Pearson and Spearman methods.

	Correlation coefficient	**p-value**
Pearson	-0.65	$4.33*10^{-9}$
Spearman	-0.63	$4.42*10^{-5}$

A moderate negative correlation was found between monthly samples of Sulfate concentration and color between 2011 and 2017 in River Storån. The high correlation between yearly precipitation and yearly average Sulfate concentration suggest that a high proportion of the Sulfate originates from deposition from the air, but the with short series of measurements it is hard to draw any conclusions.

A very poor correlation was found between the Sulfate concentration and the color in the northern part of Lake Bolmen, based on yearly samples from 1982 to 2017. Though these samples cover a much longer time period, they were taken with very low frequency (once a year), which increases the risk of measurement errors or outliers affecting the outcome of trend analysis.

In short, the limited number of samples taken in River Storån and the northern part of Lake Bolmen are not enough to accurately assess if and how the sulfate concentration relates to the increasing color in the lake. With more data collected between consistent intervals, the relationship with both color and precipitation could be more thoroughly investigated.

Sulfate concentration and precipitation

No significant correlation was found between monthly sum of precipitation and monthly samples of sulfate, however there was a strong linear correlation between yearly precipitation sum and yearly average sulfate concentration, with a Pearson correlation coefficient of -0.88 based on samples at the outlet of River Storån between 2011 and 2017.

Correlation between land use and color

Land use history in the area around River Storån and Lake Bolmen

Changes in land use have been pointed out as a contributing factor or even the major cause to the brownification of boreal lakes. More specifically, the transition from a more diverse landscape with mixed forests and traditional agriculture to modern forestry practices promoting a more homogenous landscape is believed to have caused an increase in the leaching of organic matter. In particular, the increase of spruce coverage has been shown to have a positive correlation with increasing organic content in lakes and streams when taking into consideration the lag effect that comes from the planting/expansion and growth of forests (Kritzberg, 2017). Because of this lag effect, the expansion of forestry that took place decades ago can affect and continue to affect the chemistry of our lakes and streams today. The problem with studying this relationship is therefore to gain enough credible information of land use from the late 19th century and early 20th century, when the majority of the expansion of modern forestry took place (Fredh, et al., 2012).

One method to examine the changes in land use back in time is to use the pollen analysis method. Using sediments samples pollen from different species can be identified to estimate the tree cover and proportion of different species before the modern era. Generally, the major shift in land use is said to have been taking place roughly between 1880-1940, during which time the modern forest industry was formed. A study conducted on the sediments of Lake Fiolen, located about 50 km east of Lake Bolmen, shows that the spruce coverage increased from about 15-20% in the 1880s to over 50% the 1940s (Fredh, et al., 2012). If these numbers also apply to the area around Lake Bolmen, it is possible that land use also could have been a factor in the brownification of the lake. However, because there is limited data on changes in land use during the most expansive period of the forest industry, it is difficult to draw any conclusions on the relationship between spruce coverage and brownification.

Forest and wetland coverage related to color export

When it comes to the major tributaries of Lake Bolmen, including River Storån, River Lillån, River Murån and Lake Unnen, all of them have different compositions when it comes to forest and wetland coverages. Comparing the average color value for each stream with the forest and wetland coverage gives a broad estimate for its influence of the brownification process. In Table 12 the average color of each stream is shown for the period 2011- 2017, along with the wetland coverage in percentages.

Table 12. Forest and wetland coverage in percentage and average color value in mg/Pt l for Lake Bolmen's four biggest tributary streams, from 2011 to 2017.

Tributary	Forest coverage (%)	Wetland coverage (%)	Forest and Wetland coverage (%)	Average color (mg/Pt l)
Lillån	64,8	6,8	71,6	234
Unnen	71,8	7,3	79,1	105
Storån	69,2	13,1	82,3	192
Murån	76,9	16,2	93,0	291

Comparing the catchments, there seem to be a positive correlation between wetland and forest coverage and average color with River Lillån being the outlier, as the river has a relatively high average color value (234 mg/Pt l), but the lowest percentage of wetland and forest coverage (6,8 and 64,8% respectively). In the three other catchments a high average color seem to correspond to a high forest and wetland coverage, with River Muràn having the highest coverage percentage of 93,0 % and also the highest average color of 291 mg/Pt l, followed by River Storån with 82,3 % coverage and an average color of 192 mg/Pt l, and Lake Unnen at 79,1 % coverage and an average color of 79,1 mg/Pt l. The highest average color of 291 mg/Pt l in River Muràn is 2,7 times higher than the lowest average of 105 mg/Pt l in Lake Unnen.

According to (Ågren, et al., 2008), during periods with relatively low flow in catchments with wetland coverage above 10%, streams appear to be dominated by wetland-derived DOC. It is possible that much of the organic matter found in River Muràn as well as in River Storån originates from wetlands. The contribution of organic matter from wetlands in a catchment normally changes during the year, which in turn can be attributed to changes in discharge but also redox conditions which influences the ability of organic matter to form complexes with other compounds such as iron (Kritzberg & Ekström, 2012).

Regarding the much lower average color in the tributary Lake Unnen, the higher proportion of the catchment consisting of water surface could provide an explanation, as it has a positive effect on the retention time, even more so than wetlands. A longer retention has been shown to have a positive correlation with color, due to increased sedimentation and longer periods for chemical and biological processes to act on the organic matter (Temnerud, 2014) (Weyhenmeyer, et al., 2014). Similarly, a possible explanation for the comparatively high average color value in River Lillån could be the relatively high proportion of land use dedicated to agriculture in combination with the higher stream flow, resulting in lower retention time and a greater magnitude of color. The agriculture can also lead to increased concentrations of phosphorus and nitrogen, of which phosphorus have been identified to have positive correlation with color in other studies of boreal catchments (Kortelainen, 1984).

The importance of wetlands to the color export could also be supported by the fact that River Storån shows an accumulation of organic material from upstream to downstream in certain months, with the largest increase taking places in a part of the catchment in relative close proximity to the national park Store Mosse, a large peatland.

A way to further examine the relationship between wetland coverage and color could be to use tracers in order to assess how much water flowing through the wetlands ends up in River Storån, in combination with samples of color on suitable locations near the wetlands. A considerable disadvantage is the lack of historical data on wetland coverage, which if it were available could give a more established link between wetland and color export from the catchment.

Correlation between Iron and color

Figure 42-
Figure *46* show the correlation between iron and color in mg/Pt l in the different sampling points in the catchment, based on monthly samples between 2011 and 2017. The highest Pearson correlation coefficient of 0.81 was found at the outlet of River Storån, indicating a high correlation. For the other sampling points further upstream in the catchment the Pearson coefficient ranged from 0.74 to 0.78, with the exception of number 568 which showed a much lower correlation of 0.47.

A significant positive correlation was found between monthly samples of iron and color. Even though there is a correlation between the two parameters, it is unclear whether iron is actually contributing in itself to the color, or if iron is simply responding similarly to changing conditions in the environment as the factors causing the increase of color. Some studies have pointed to the ability of iron and organic material to form complexes together, which enhances the solubility of the organic material and enables increased transport of both substances (Maloney, et al., 2005) (Heikkinen, 1994). While this can explain some of the covariance between color and iron, it is unlikely that it accounts for all of the increase in iron, as shown by a study made in the UK which concluded that about 5% of the organic matter will be bound to ferrihydrite, iron in its water-soluble form (Neals, Lofts, Evans, & Reynolds, 2008). Although conditions might differ from Southern Sweden, it still suggests that this complexation process might not fully explain the variance of iron in freshwaters. As suggested by (Kritzberg & Ekström, 2012) there is reason to believe that changes in redox conditions in the upper soil layers, which heavily influence mobility of iron, might be a better explanation for the increase of iron. As the upper soil layers gets more wetter due to increases in precipitation and runoff, the environment gets more anoxic, which increases the mobility of iron. Hence, the increasing iron concentrations might be the result of increasing precipitation. This is supported by the strong relationship between yearly precipitation and yearly mean concentration of iron found in River Storån, although the short period of measurements (2011-2017) means that it is hard to draw any definitive conclusions. In order to better understand the relationship between iron and color and iron and organic matter, more measurements need to be performed over a longer period of time, with a consistent frequency.

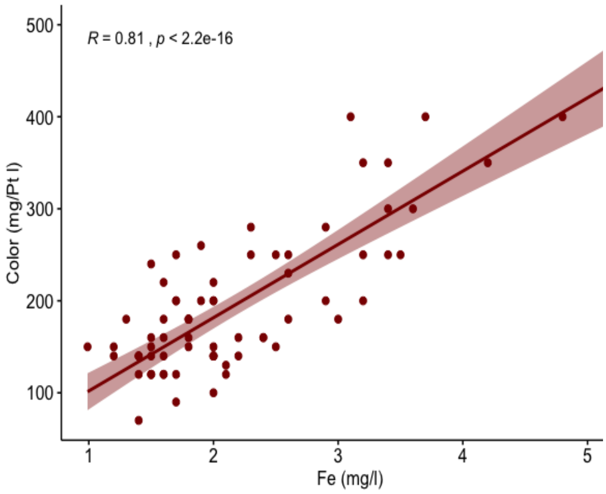

Figure 42. Correlation between iron and color at point 550 (outlet of River Storån).

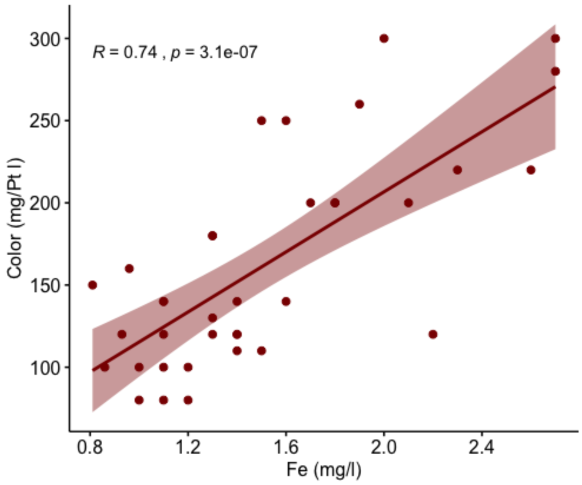

Figure 43. Correlation between iron and color at point 554 (downstream of Törestorp).

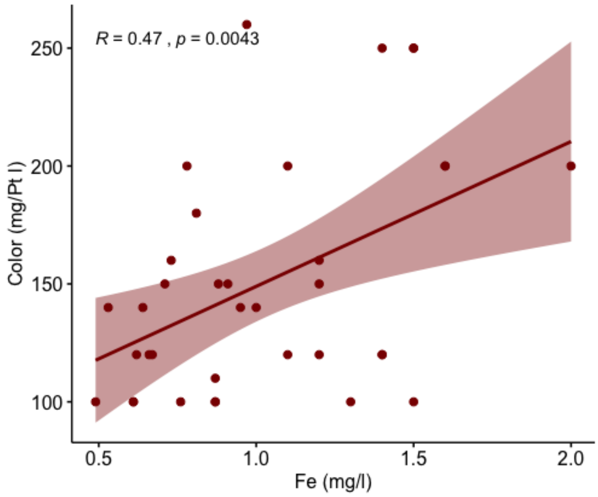

Figure 44. Correlation between iron and color at point 568 (Inlet of Lake Långasjön).

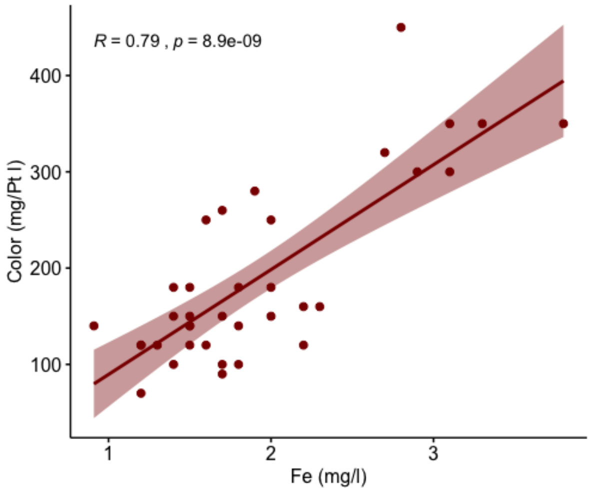

Figure 45. Correlation between iron and color at point 552 (downstream of Forsheda).

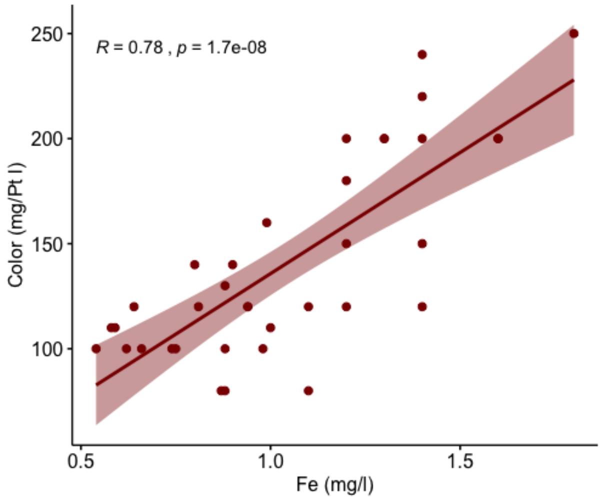

Figure 46. Correlation between iron and color at point 558 (outlet of Lake Flaten

In Figure 48 the correlation between Fe and TOC is shown, based on monthly samples at the outlet of River Storån between 2011 and 2017. The Pearson correlation coefficient is 0.72, indicating a moderate to high correlation. For the other sampling points in the catchment the coefficient was found to be 0.70 in point 552, 0.72 in point 558 and 0.5 in point 568.

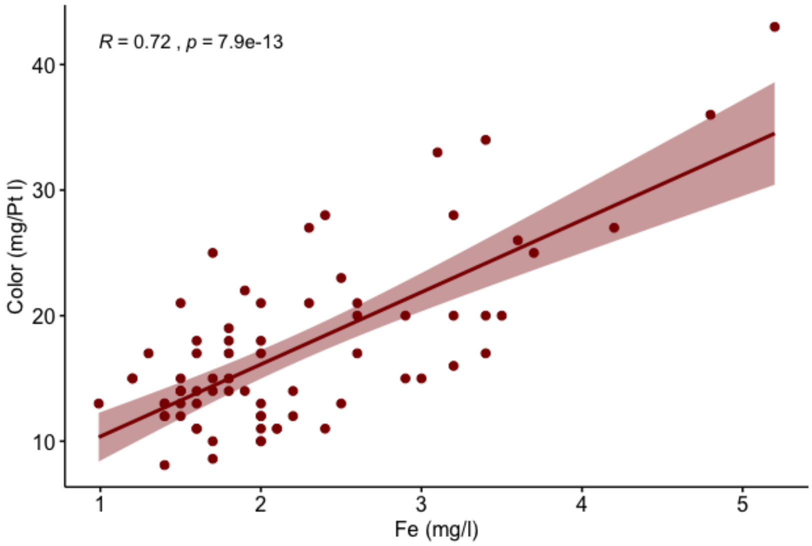

Figure 47. Correlation between Fe and TOC based on monthly measurements at the outlet of River Storån to Lake Bolmen between 2011 and 2017.

Correlation between iron and other parameters

No significant correlation was found between monthly precipitation and monthly samples of iron using any of the statistical methods. The yearly precipitation and the average yearly concentration of iron showed a positive correlation of 0.93 using the Pearson method. A significant negative correlation was also found between yearly average concentrations of sulfate and iron, with a correlation coefficient of -0.85 using the Pearson method.

Antecedent conditions and reliability of data

Some of the relationships investigated in this report between color and different parameters rely on data that is either modelled or contain inconsistencies, making it difficult to assess and compare these relationships.

The data from Lagans Vattenråd is inconsistent in frequency, with the number of measurements of color varying from year to year. Measurements of sulfate and iron were only conducted between 2011 and 2017 and contains a gap of one year during 2013 when no samples were taken. The absence of a continuous data series for these parameters during the whole investigated period means it is hard to examine their relationship with color or brownification. To be able to draw more conclusions on their relationship with color a longer time period of study would be more adequate, as the change in color is a slow process happening over decades.

No observed flow data was available for the catchment of River Storån. Instead the discharge data for River Storån were generated from the SMHIs HYPE model, which is calibrated with observed flow data measured at the outlet of Bolmen. The HYPE model is used for large scale modeling of for example phosphorus load to the Baltic Sea, and while it might be optimal for such large scale conditions it might not be suited to accurately model flow of minor rivers or streams in sub-catchments such as that of River Storån. To better understand the relationship of discharge and color, ideally one would measure observed flows on multiple points along River Storån, for varying depths or stream channel types, in combination with measurements of color.

Many of the data series used in the study are incomplete and where not taken between consistent intervals. This proves a difficulty when trying to establish relationships with other parameters when parts of the data have different sample frequency or when there is data missing for certain periods of time. To compare the precipitation with color, a challenge was presented as the available measurements on precipitation from SMHI were made with small and consistent frequencies while the color data from Lagans Vattenråd consisted of monthly samples with varying intervals in between.

The problem with just looking at the monthly values and the corresponding measurement for each month is that there should be a time lag between a rainfall and an eventual increase in water color, as the leaching of the organic material and its transport through catchment creates a delay in the response of water color to rainfall. The precipitation is measured at Kävsjö, situated relatively far upstream the catchment, which also could complicate the time lag effect. This can explain why there is only a weak positive correlation between monthly precipitation and monthly samples color, while there is a somewhat higher moderate correlation for yearly averages between the two parameters.

The amount of precipitation data for the catchment is in turn also limited to a daily sum of precipitation, which makes it difficult asses specific rainfall events, especially those of short duration and high intensity. Data reduction had to be made for both the color, precipitation and temperature measurements in order to perform the Mann-Kendall tests.

Conclusions and Recommendations

The color in River Storån is increasing, as is the precipitation in the catchment, which show a moderate to high correlation with color when comparing yearly precipitation with yearly average color in River Storån. The frequency of extreme precipitation events in the area as well as extreme color values in the river are also increasing, as evidenced by the linear positive trend of both precipitation events and color values in the 95^{th} percentile.

A moderate negative correlation between sulfate concentration and color was found in River Storån, in several sampling points. However, with the limited number of samples of sulfate concentrations it is hard to draw any conclusions. A more consistent data sampling on sulfate concentration could give a more accurate picture of how Sulfate concentration influences color.

A significant positive correlation was found between iron and color in River Storån. A positive correlation between iron and color have been found in other studies on lakes in the northern hemisphere (Maloney, et al., 2005) (Kritzberg & Ekström, 2012). It is unclear whether iron concentration is actually a driver for increasing freshwater color, or whether it is simply responding to the same changes in the environment as the drives behind color. The high correlation between yearly precipitation and iron concentration seem to support the theory that the increase in iron concentration is the result of more anoxic and wetter conditions in the upper soil layers, although the time period for data collection is much too short to give any definitive conclusions.

No clear relationship between air or water temperature and color could be established, however the air temperature in the area show an increasing trend.

The differences in land use between the catchments around Lake Bolmen seem to impact the color export from the catchments. Out of Lake Bolmen's four main catchments, River Murån catchment has the highest average color, and also the highest coverage of forest and wetlands. The average color in River Murån was 2,7 times that of the average in Lake Unnen catchment, which has the lowest forest and wetland coverage. The data available on the changes in land use around Lake Bolmen is limited and is not enough to properly investigate whether the changes in land use have an effect on the long-term variation of color more data collection needs to be done. An experiment with tracers could be carried in order to compare the color contribution of different land types, for example by studying stream and groundwater quality near areas with a high coverage of wetlands.

The difficulty with finding a significant linear correlation with color and one specific parameter could be the result of several factors playing an important role in the brownification process, with complexes relationship also existing between them. A proposed "lag" in the response of color precipitation and runoff could explain the relatively poor correlations with these parameters when studying the short-term effects of rainfall on the color in streams. The sampling frequency of color also makes it difficult to investigate more short-term response to isolated rainfall events.

The correlation between TOC and color was much weaker in the sampling point located furthest upstream in the catchment compared to all other sampling points. Interestingly, the same correlation was much higher when comparing TOC and color using the ABS420/5 method, indicating that the measurement technique might be at fault for the differing results. If the color in this point is very dark brownish, it is possible that the Pt-Co method might not have been giving correct values, since this method is optimal for relatively clear samples.

The correlation between Iron and color was also much lower in the same point furthest upstream (point 568) compared to the other sampling locations, both using color measurements with the Pt-Co and ABS420/5 method. When factoring in the very high correlation between TOC and color (using the ABS420/5 method), this might suggest that the contribution of TOC is much greater than that of iron in this point, suggesting a large input of organic material in the stream from the nearby catchment. As the point is located far north in the catchment, in a densely forested area with little alterations to the natural environment around the stream, it seems probable that there is a higher canopy cover. This in addition to a lower stream flow could mean that there is a larger contribution of organic material. Usually, smaller streams surrounded by a high coverage have a higher DOC content (Brönmark & Hansson, 1998).

The correlation between yearly precipitation and yearly average of color also varied between the sampling points, with the highest correlation found in the points 554, 558 and 560, which are also the points closest to SMHI’s measuring station in Kävsjö, indicating that there might be a spatial bias.

A step to better understand the relationships between the driving factors would be to construct a model that includes precipitation or runoff as well as other important parameters such Iron, Sulfate and DOC, and try to model the color export from the catchment. This model could then be validated and calibrated with color measurements and applied to the other catchments around Lake Bolmen. A useful first step would be to establish and quantify the relationship with TOC and DOC in the area, in order to more accurately measure the organic content.

As with many other processes concerning water quality in the natural environment, brownification seem to be the product of several different factors. This is very important to remember when researching the topic and applying and discussing theories of the driving factors behind the process. As the color Lake Bolmen and River Storån is increasing, and much likely will continue to increase, it is important to continue to monitor the water quality and the parameters related to brownification. With the right steps taken to better understand the relationships governing the process, improved predictions can be made regarding the water quality, which can help preserve the valuable resource that are our fresh water lakes.

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Appendix

Tables with summary of correlation

Table. Summary of Mann-Kendall tests and Seasonal Mann-Kendall tests performed on color, precipitation and air temperature.

	Color (monthly samples)	Precipitation (monthly sum)	Air temperature (monthly averages)
p-value	$1*10^{-5}$	$5*10^{-4}$	0.018
tau	0.156	0.063	0.056
Null hypothesis	Rejected, positive monotonic trend	Rejected, positive monotonic trend	Rejected, positive monotonic trend

Table. Pearson and Spearman correlation coefficients between precipitation and color, temperature and color as well as sulfate concentration and color at the outlet of River Storån

	Precipitation (Yearly averages 1985-2017)	Temperature (Yearly averages, 1985-2017)	Sulfate concentration (Monthly samples 2011-2017)	Iron (Monthly samples 2011-2017)
Pearson	0.67	No correlation	-0.63	0.81
Spearman	0.65	No correlation	-0.65	0.66

Table. Correlation cofficients (Pearson) between color (mg/Pt l) and important parameters for the six sampling points in River Storån

Sampling point	568 (Västerån river upstream of Lake Långasjön)	560 (Lake Flaten)	558 (Outlet of Lake Flaten)	554 (Downstream of Törestorp)	552 (Downstream of Forsheda)	550 (Outlet of River Storån)
TOC	0.32	0.80	0.63	0.74	0.65	0.79
Fe	0.47	Fe not measured	0.78	0.74	0.79	0.81
SO4	-0.51	-0.15	-0.70	-0.54	-0.64	-0.63
Precipitation (yearly mean)	0.67	0.74	0.74	0.76	0.64	0.67
Discharge (yearly mean)	0.52	Not applicable	0.62	0.72	0.52	0.53
Water temperature	0.27	0.05	-0.25	-0.08	0.25	0.19
pH	-0.06	-0.24	0.04	-0.23	-0.48	-0.33

Land use in River Storån catchment

Table. Land use based on catchment data from SMHI’s HYPE model, compared to the results of the analysis made in QGIS based on open source data from Lantmäteriet.

From SMHI (model data for HYPE-S, from vattenweb.smhi.se)		***From analysis in QGIS using open source data from Lantmäteriet (https://www.lantmateriet.se/sv/Kartor-och-geografisk-information/oppna-data/)***	
Land type	Coverage (%)	Land type	Coverage (%)
Sjö och vattendrag (Water surfaces)	4.1	Vattenyta (Water surfaces)	4.6
Skogsmark (Forest)	69.2	Skog, barr- och blandskog (Forest, coniferous and mixed)	67.8
Hedmark och övrig mark (Moors/open fields and other land types)	4.0	Åker (Agricultural fields)	5.9
Kalfjäll och tunna jordar (Barren rock)	0.00	Annan öppen mark (Other open areas)	5.7
Glaciär (Glaciers)	0.00	Låg bebyggelse (Sparsely populated settlements)	0.4
Myr- och våtmarker (Mires and wetlands)	13.1	Industriområde (Industrial areas)	0.2
Jordbruksmark (Agricultural fields)	8.2	Annan öppen mark utan skogskonturer (Other open areas without forest contours)	13.5
Tätort (Urban areas)	1.0	Lövskog (Decidious forest)	1.9
Hårdgjorda ytor (Impermeable surfaces)	0.4		

Summer and Winter Precipitation

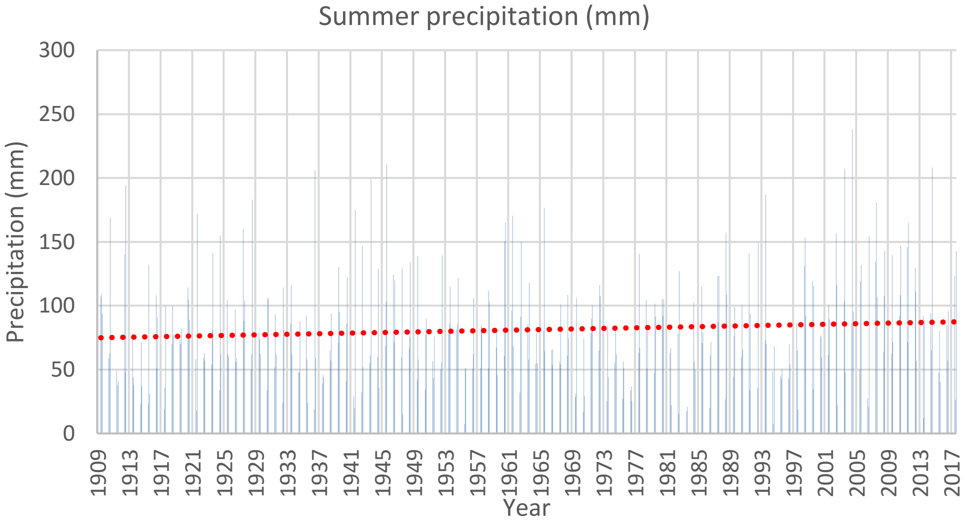

Figure. The summer precipitation (June-August) between 1908 and 2017, recorded at SMHI's station in Kävsjö. There is a positive linear trend of 0.36 mm/10 years.

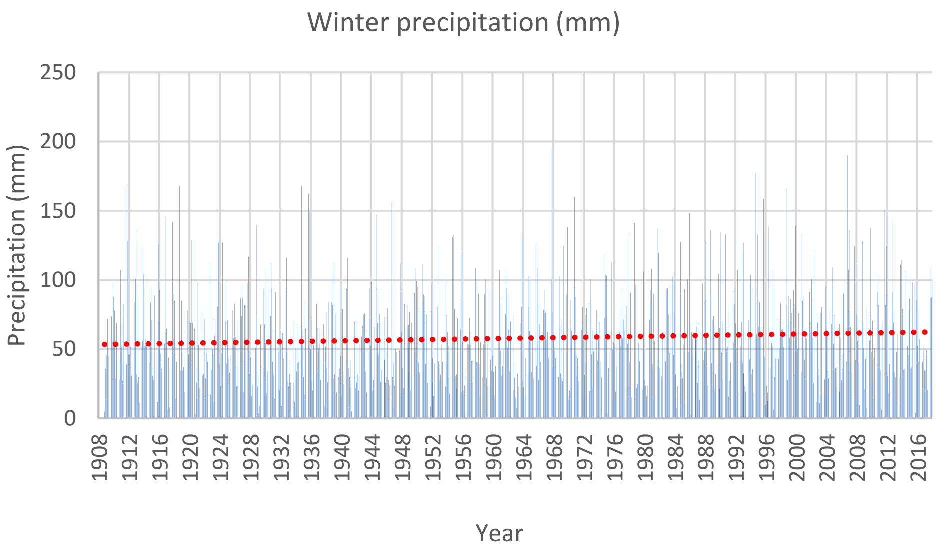

Figure. The figure below shows the winter precipitation (September-May) from SMHI's station in Kävsjö between 1908 and 2017. There is a positive linear trend of 0.024 mm/10 years.

Results from Mann-Kendall and Seasonal Mann-Kendall tests in R

Table. Results from Mann-Kendall and Seasonal Mann-Kendall tests on color (outlet of River Storån), precipitation (Kävsjö) and temperature (Hagshult Mo) in R.

Test type, data series	Tau	p-value
Mann-Kendall test, color	0.156	$1.0014*10^{-5}$
Mann Kendall test, precipitation	0.0626	0.00045264
Seasonall Mann-Kendall test, temperature	0.056	0.01781

Results from correlation tests in R

Precipitation correlation

Table. Results from correlation tests in R for yearly averages of precipitation in Kävjsö and color at the outlet of River Storån.

	Correlation coefficient	**p-value**	**df**	**t**	**S**
Pearson	0.6650416	$3.291*10^{-5}$	30	4.8775	
Spearman	0.6477273	8.965e-05			1922

Sulfate correlation

Table. Results from correlation tests in R for sulfate concentrations and color based on monthly samples by Lagans Vattenråd at the outlet of River Storån.

	Correlation coefficient	**p-value**	**df**	**t**	**S**
Pearson	-0.6537195	$4.326*10^{-9}$	70	-6.703	
Spearman	-0.6252469	$4.42*10^{-5}$			102920

Temperature correlation

Table. Results from correlation tests in R for air temperature and color and water temperature and color based on data from SMHI's measuring station in Hagshult Mo and monthly samples by Lagans Vattenråd at the outlet of River Storån.

Air temperature (Hagshult Mo, yearly averages)	**Correlation coefficient**	**p-value**	**df**	**t**	**S**
Pearson	-0.02182683	0.9056	30	-0.11958	
Spearman	-0,00366569	0.9848			5476
Water temperature (Lagans Vattenråd, monthly samples)					
Pearson	0.1949311	0.0002994	338	3.6539	
Spearman	0.1096487	0.04333			5832300

Iron correlation

Table. Results from correlation tests in R for iron concentration and color at the outlet of River Storån based on monthly samples by Lagans Vattenråd.

	Correlation coefficient	**p-value**	**df**	**t**	**S**
Pearson	0.8138677	$2.2*10^{-16}$	70	11.719	
Spearman	0.6600365	$2.851*10^{-10}$			21144

Correlation test in Python for all parameters (Pearson correlation)

Table. Correlation test for all parameters measured by Lagans Vattenråd at sampling point 550 (outlet of River Storån).

	Turbitity	Color	TOC	Conductivity_25C	pH	Alkalinity	NO2/3	NTot	PTot	O2	O2 (%)	Ca	Mg	Na	K	Cl	SO4	Fe	Mn	ABS	Temp
Turbitity(FNU)	1,00	0,45	0,39	-0,03	-0,20	0,00	-0,05	0,24	0,55	-0,32	-0,24	-0,16	-0,08	-0,16	-0,02	-0,22	-0,29	0,68	0,68	0,64	0,31
Color(mg*Pt/l)	0,45	1,00	0,79	-0,16	-0,33	-0,32	-0,27	0,11	0,35	-0,16	-0,05	-0,34	-0,29	-0,45	-0,38	-0,53	-0,63	0,81	0,53	0,93	0,19
TOC(mg/l)	0,39	0,79	1,00	-0,25	-0,52	-0,52	-0,42	0,12	0,44	-0,01	0,08	-0,41	-0,35	-0,49	-0,43	-0,52	-0,64	0,72	0,45	0,98	0,06
Conductivity_25C(mS/m)	-0,03	-0,16	-0,25	1,00	0,19	0,33	0,24	0,13	0,07	-0,18	-0,19	0,93	0,92	0,94	0,88	0,86	0,85	-0,14	-0,04	-0,60	0,14
pH	-0,20	-0,33	-0,52	0,19	1,00	0,69	0,11	-0,11	-0,40	-0,34	-0,30	0,66	0,61	0,56	0,46	0,50	0,67	-0,43	-0,38	-0,78	0,30
Alkalinity(mekv/l)	0,00	-0,32	-0,52	0,33	0,69	1,00	0,36	0,17	-0,09	-0,52	-0,60	0,95	0,90	0,85	0,79	0,74	0,82	-0,13	-0,09	-0,64	0,41
NO2/3(µg/l)	-0,05	-0,27	-0,42	0,24	0,11	0,36	1,00	0,57	0,13	-0,18	-0,34	0,64	0,64	0,79	0,73	0,74	0,73	-0,41	-0,18	-0,72	0,08

NTot(µg/l)	0,24	0,11	0,12	0,13	-0,11	0,17	0,57	1,00	0,29	-0,21	-0,25	0,25	0,33	0,30	0,26	0,20	0,03	0,46	0,42	0,42	0,15
PTot(µg/l)	0,55	0,35	0,44	0,07	-0,40	-0,09	0,13	0,29	1,00	-0,35	-0,29	-0,09	-0,01	-0,13	-0,03	-0,24	-0,33	0,73	0,75	0,69	0,36
O2(mg/l)	-0,32	-0,16	-0,01	-0,18	-0,34	-0,52	-0,18	-0,21	-0,35	1,00	0,84	-0,53	-0,51	-0,38	-0,42	-0,13	-0,23	-0,51	-0,34	-0,10	-0,94
O2(%)	-0,24	-0,05	0,08	-0,19	-0,30	-0,60	-0,34	-0,25	-0,29	0,84	1,00	-0,58	-0,53	-0,44	-0,50	-0,23	-0,27	-0,55	-0,38	-0,07	-0,65
Ca(mg/l)	-0,16	-0,34	-0,41	0,93	0,66	0,95	0,64	0,25	-0,09	-0,53	-0,58	1,00	0,95	0,86	0,80	0,72	0,75	0,08	0,02	-0,43	0,45
Mg(mg/l)	-0,08	-0,29	-0,35	0,92	0,61	0,90	0,64	0,33	-0,01	-0,51	-0,53	0,95	1,00	0,86	0,76	0,72	0,73	0,08	0,03	-0,37	0,43
Na(mg/l)	-0,16	-0,45	-0,49	0,94	0,56	0,85	0,79	0,30	-0,13	-0,38	-0,44	0,86	0,86	1,00	0,89	0,86	0,82	-0,09	-0,01	-0,50	0,30
K(mg/l)	-0,02	-0,38	-0,43	0,88	0,46	0,79	0,73	0,26	-0,03	-0,42	-0,50	0,80	0,76	0,89	1,00	0,79	0,71	-0,03	0,03	-0,45	0,34
Cl(mg/l)	-0,22	-0,53	-0,52	0,86	0,50	0,74	0,74	0,20	-0,24	-0,13	-0,23	0,72	0,72	0,86	0,79	1,00	0,82	-0,28	-0,16	-0,55	0,06
SO4(mg/l)	-0,29	-0,63	-0,64	0,85	0,67	0,82	0,73	0,03	-0,33	-0,23	-0,27	0,75	0,73	0,82	0,71	0,82	1,00	-0,33	-0,18	-0,66	0,18
Fe(mg/l)	0,68	0,81	0,72	-0,14	-0,43	-0,13	-0,41	0,46	0,73	-0,51	-0,55	0,08	0,08	-0,09	-0,03	-0,28	-0,33	1,00	0,73	0,75	0,46
Mn(mg/l)	0,68	0,53	0,45	-0,04	-0,38	-0,09	-0,18	0,42	0,75	-0,34	-0,38	0,02	0,03	-0,01	0,03	-0,16	-0,18	0,73	1,00	0,47	0,31
ABS_filtered420/5	0,64	0,93	0,98	-0,60	-0,78	-0,64	-0,72	0,42	0,69	-0,10	-0,07	-0,43	-0,37	-0,50	-0,45	-0,55	-0,66	0,75	0,47	1,00	0,10
Temp(C)	0,31	0,19	0,06	0,14	0,30	0,41	0,08	0,15	0,36	-0,94	-0,65	0,45	0,43	0,30	0,34	0,06	0,18	0,46	0,31	0,10	1,00

Table. Correlation test for all parameters measured by Lagans Vattenråd at sampling point 552 (downstream of Forsheda).

	Turbidity	Color	TOC	Conductivity_25C	pH	Alkalinity	NO2/3	NTot	PTot	O2	O2(%)	Ca	Mg	Na	K	Cl	SO4	Fe	Mn	Temp
Turbidity(FNU)	1,00	0,38	0,12	0,16	-0,08	0,25	0,29	0,22	0,58	-0,49	-0,32									0,45
Color(mg*Pt/l)	0,38	1,00	0,65	-0,34	-0,48	-0,33	-0,42	-0,07	0,51	-0,23	-0,10	-0,49	-0,52	-0,52	-0,44	-0,61	-0,64	0,79	0,52	0,25
TOC(mg/l)	0,12	0,65	1,00	-0,38	-0,58	-0,46	-0,29	-0,09	0,51	0,07	0,07									-0,05
Conductivity_25C(mS/m))	0,16	-0,34	-0,38	1,00	0,56	0,86	0,50	0,34	0,07	-0,33	-0,47									0,23

pH	-0,08	-0,48	-0,58	0,56	1,00	0,70	0,19	0,37	-0,13	-0,23	0,02	0,64	0,62	0,57	0,42	0,53	0,68	-0,52	-0,52	0,25
Alkalinity(mekv/l)	0,25	-0,33	-0,46	0,86	0,70	1,00	0,44	0,36	0,08	-0,45	-0,41	0,95	0,93	0,89	0,80	0,80	0,87	-0,23	-0,29	0,38
NO2/3(µg/l)	0,29	-0,42	-0,29	0,50	0,19	0,44	1,00	0,27	0,02	-0,04	-0,12									0,00
NTot(µg/l)	0,22	-0,07	-0,09	0,34	0,37	0,36	0,27	1,00	0,36	-0,27	-0,23									0,27
PTot(µg/l)	0,58	0,51	0,51	0,07	-0,13	0,08	0,02	0,36	1,00	-0,45	-0,22									0,48
O2(mg/l)	-0,49	-0,23	0,07	-0,33	-0,23	-0,45	-0,04	-0,27	-0,45	1,00	0,64	-0,40	-0,37	-0,40	-0,32	-0,02	-0,27	-0,47	-0,19	-0,95
O2(%)	-0,32	-0,10	0,07	-0,47	0,02	-0,41	-0,12	-0,23	-0,22	0,64	1,00	-0,04	0,01	-0,02	0,01	0,15	0,12	-0,54	-0,37	-0,41
Ca(mg/l)		-0,49			0,64	0,95				-0,40	-0,04	1,00	0,95	0,90	0,83	0,84	0,84	-0,08	-0,24	0,30
Mg(mg/l)		-0,52			0,62	0,93				-0,37	0,01	0,95	1,00	0,88	0,76	0,82	0,79	-0,16	-0,25	0,28
Na(mg/l)		-0,52			0,57	0,89				-0,40	-0,02	0,90	0,88	1,00	0,90	0,90	0,89	-0,20	-0,21	0,31
K(mg/l)		-0,44			0,42	0,80				-0,32	0,01	0,83	0,76	0,90	1,00	0,90	0,81	-0,15	-0,20	0,21
Cl(mg/l)		-0,61			0,53	0,80				-0,02	0,15	0,84	0,82	0,90	0,90	1,00	0,84	-0,34	-0,30	0,02
SO4(mg/l)		-0,64			0,68	0,87				-0,27	0,12	0,84	0,79	0,89	0,81	0,84	1,00	-0,38	-0,29	0,20
Fe(mg/l)		0,79			-0,52	-0,23				-0,47	-0,54	-0,08	-0,16	-0,20	-0,15	-0,34	-0,38	1,00	0,62	0,37
Mn(mg/l)		0,52			-0,52	-0,29				-0,19	-0,37	-0,24	-0,25	-0,21	-0,20	-0,30	-0,29	0,62	1,00	0,18
Temp(C)	0,45	0,25	-0,05	0,23	0,25	0,38	0,00	0,27	0,48	-0,95	-0,41	0,30	0,28	0,31	0,21	0,02	0,20	0,37	0,18	1,00

Table. Correlation test for all parameters measured by Lagans Vattenråd at sampling point 554 (downstream of Törestorp).

	Turbidity	Color	TOC	Conductivity_25C(	pH	Alkalinity	NO2/3	NTot	PTot	O2	O2 (%)	Ca	Mg	Na	K	Cl	SO4	Fe	Mn	ABS	Temp
Turbidity(FNU)	1,00	0,27	0,17	0,26	0,03	0,28	0,02	0,23	0,33	-0,30	-0,28	0,03	0,04	0,07	-0,04	0,14	0,01	0,31	0,44	0,30	0,21
Color(mg*Pt/l)	0,27	1,00	0,74	-0,33	-0,23	-0,18	-0,34	-0,14	0,04	0,09	0,07	-0,35	-0,39	-0,47	-0,47	-0,25	-0,54	0,74	0,07	0,91	-0,08
TOC(mg/l)	0,17	0,74	1,00	-0,33	-0,30	-0,25	-0,28	-0,10	0,00	0,16	0,11	-0,24	-0,30	-0,34	-0,33	-0,17	-0,46	0,70	0,17	0,97	-0,14
Conductivity_25C(mS/m))	0,26	-0,33	-0,33	1,00	0,38	0,82	0,72	0,78	0,33	-0,50	-0,71	0,93	0,87	0,92	0,91	0,79	0,78	-0,22	0,09	-0,52	0,27
pH	0,03	-0,23	-0,30	0,38	1,00	0,58	0,08	0,15	-0,10	-0,42	-0,25	0,61	0,59	0,49	0,42	0,22	0,52	-0,37	-0,31	-0,58	0,43
Alkalinity(mekv/l)	0,28	-0,18	-0,25	0,82	0,58	1,00	0,49	0,67	0,26	-0,52	-0,63	0,94	0,92	0,80	0,74	0,63	0,70	-0,11	0,07	-0,50	0,36
NO2/3(µg/l)	0,02	-0,34	-0,28	0,72	0,08	0,49	1,00	0,75	0,08	-0,17	-0,45	0,48	0,42	0,61	0,63	0,54	0,52	-0,39	-0,13	-0,62	-0,04
NTot(µg/l)	0,23	-0,14	-0,10	0,78	0,15	0,67	0,75	1,00	0,23	-0,35	-0,53	0,61	0,46	0,66	0,68	0,63	0,44	0,21	0,33	0,12	0,15
PTot(µg/l)	0,33	0,04	0,00	0,33	-0,10	0,26	0,08	0,23	1,00	-0,39	-0,46	0,27	0,26	0,27	0,23	0,38	0,17	0,29	0,49	0,38	0,35
O2(mg/l)	-0,30	0,09	0,16	-0,50	-0,42	-0,52	-0,17	-0,35	-0,39	1,00	0,77	-0,45	-0,25	-0,41	-0,44	-0,19	-0,31	-0,02	-0,36	0,05	-0,93
O2(%)	-0,28	0,07	0,11	-0,71	-0,25	-0,63	-0,45	-0,53	-0,46	0,77	1,00	-0,27	-0,01	-0,29	-0,33	-0,06	-0,23	-0,27	-0,46	-0,17	-0,53
Ca(mg/l)	0,03	-0,35	-0,24	0,93	0,61	0,94	0,48	0,61	0,27	-0,45	-0,27	1,00	0,90	0,86	0,83	0,71	0,67	0,02	0,08	-0,34	0,44

Mg(mg/l)	0,04	-0,39	-0,30	0,87	0,59	0,92	0,42	0,46	0,26	-0,25	-0,01	0,90	1,00	0,77	0,64	0,64	0,62	-0,06	0,04	-0,37	0,30
Na(mg/l)	0,07	-0,47	-0,34	0,92	0,49	0,80	0,61	0,66	0,27	-0,41	-0,29	0,86	0,77	1,00	0,88	0,71	0,86	-0,13	0,18	-0,41	0,39
K(mg/l)	-0,04	-0,47	-0,33	0,91	0,42	0,74	0,63	0,68	0,23	-0,44	-0,33	0,83	0,64	0,88	1,00	0,77	0,71	-0,22	0,07	-0,41	0,40
Cl(mg/l)	0,14	-0,25	-0,17	0,79	0,22	0,63	0,54	0,63	0,38	-0,19	-0,06	0,71	0,64	0,71	0,77	1,00	0,61	-0,14	0,05	-0,25	0,18
SO4(mg/l)	0,01	-0,54	-0,46	0,78	0,52	0,70	0,52	0,44	0,17	-0,31	-0,23	0,67	0,62	0,86	0,71	0,61	1,00	-0,30	0,09	-0,49	0,31
Fe(mg/l)	0,31	0,74	0,70	-0,22	-0,37	-0,11	-0,39	0,21	0,29	-0,02	-0,27	0,02	-0,06	-0,13	-0,22	-0,14	-0,30	1,00	0,46	0,73	-0,07
Mn(mg/l)	0,44	0,07	0,17	0,09	-0,31	0,07	-0,13	0,33	0,49	-0,36	-0,46	0,08	0,04	0,18	0,07	0,05	0,09	0,46	1,00	0,19	0,29
ABS_filtered420/5	0,30	0,91	0,97	-0,52	-0,58	-0,50	-0,62	0,12	0,38	0,05	-0,17	-0,34	-0,37	-0,41	-0,41	-0,25	-0,49	0,73	0,19	1,00	-0,14
Temp(C)	0,21	-0,08	-0,14	0,27	0,43	0,36	-0,04	0,15	0,35	-0,93	-0,53	0,44	0,30	0,39	0,40	0,18	0,31	-0,07	0,29	-0,14	1,00

Table. Correlation test for all parameters measured by Lagans Vattenråd at sampling point 558 (outlet of Lake Flaten).

	Turbidity	Color	TOC	Conductivity_25C	pH	Alkalinity	NO2/3	NTot	PTot	O2	O2 (%)	Ca	Mg	Na	K	Cl	SO4	Fe	Mn	ABS	Temp
Turbidity(FNU)	1,00	0,70	0,15	0,04	0,07	0,21	-0,29	0,03	0,15	-0,31	-0,30	0,37	0,25	0,16	0,04	-0,06	-0,19	0,36	0,83	0,14	0,25
Color(mg*Pt/l)	0,70	1,00	0,63	-0,22	0,04	0,05	-0,21	0,34	0,11	0,01	-0,08	0,09	-0,23	-0,46	-0,34	-0,03	-0,70	0,78	0,04	0,93	-0,04
TOC(mg/l)	0,15	0,63	1,00	-0,28	-0,17	-0,22	0,06	0,42	0,08	0,26	0,12	0,05	-0,24	-0,41	-0,32	-0,08	-0,71	0,72	0,01	0,92	-0,25
Conductivity_25C(mS/m))	0,04	-0,22	-0,28	1,00	0,02	0,52	-0,01	-0,13	0,17	-0,13	-0,29	0,67	0,84	0,79	0,39	0,28	0,47	-0,04	0,24	-0,42	0,04
pH	0,07	0,04	-0,17	0,02	1,00	0,57	-0,51	-0,26	0,03	-0,25	0,23	0,38	0,43	0,30	0,15	-0,10	0,27	-0,14	0,19	-0,50	0,43
Alkalinity(mekv/l)	0,21	0,05	-0,22	0,52	0,57	1,00	-0,50	-0,16	0,21	-0,44	-0,34	0,80	0,80	0,60	0,38	0,03	0,37	0,18	0,40	-0,38	0,37
NO2/3(µg/l)	-0,29	-0,21	0,06	-0,01	-0,51	-0,50	1,00	0,29	-0,34	0,62	0,28	-0,62	-0,38	-0,20	-0,11	0,18	0,27	-0,45	-0,48	-0,08	-0,62
NTot(µg/l)	0,03	0,34	0,42	-0,13	-0,26	-0,16	0,29	1,00	-0,01	0,28	0,06	-0,13	-0,23	-0,41	-0,37	0,07	-0,53	0,56	-0,09	0,85	-0,29
PTot(µg/l)	0,15	0,11	0,08	0,17	0,03	0,21	-0,34	-0,01	1,00	-0,33	-0,19	0,58	0,44	0,24	0,00	-0,17	-0,36	0,55	0,44	0,29	0,34
O2(mg/l)	-0,31	0,01	0,26	-0,13	-0,25	-0,44	0,62	0,28	-0,33	1,00	0,61	-0,34	-0,09	0,00	0,02	0,37	0,22	-0,12	-0,66	0,12	-0,90
O2(%)	-0,30	-0,08	0,12	-0,29	0,23	-0,34	0,28	0,06	-0,19	0,61	1,00	-0,02	0,25	0,31	0,19	0,15	0,30	-0,40	-0,49	-0,38	-0,26
Ca(mg/l)	0,37	0,09	0,05	0,67	0,38	0,80	-0,62	-0,13	0,58	-0,34	-0,02	1,00	0,83	0,55	0,16	0,08	0,07	0,52	0,35	0,04	0,36
Mg(mg/l)	0,25	-0,23	-0,24	0,84	0,43	0,80	-0,38	-0,23	0,44	-0,09	0,25	0,83	1,00	0,82	0,39	0,25	0,39	0,19	0,16	-0,26	0,17
Na(mg/l)	0,16	-0,46	-0,41	0,79	0,30	0,60	-0,20	-0,41	0,24	0,00	0,31	0,55	0,82	1,00	0,49	0,37	0,52	-0,14	0,06	-0,44	0,10
K(mg/l)	0,04	-0,34	-0,32	0,39	0,15	0,38	-0,11	-0,37	0,00	0,02	0,19	0,16	0,39	0,49	1,00	0,12	0,30	-0,11	-0,07	-0,35	0,02
Cl(mg/l)	-0,06	-0,03	-0,08	0,28	-0,10	0,03	0,18	0,07	-0,17	0,37	0,15	0,08	0,25	0,37	0,12	1,00	0,39	-0,12	-0,26	-0,11	-0,33
SO4(mg/l)	-0,19	-0,70	-0,71	0,47	0,27	0,37	0,27	-0,53	-0,36	0,22	0,30	0,07	0,39	0,52	0,30	0,39	1,00	-0,58	-0,25	-0,72	-0,11
Fe(mg/l)	0,36	0,78	0,72	-0,04	-0,14	0,18	-0,45	0,56	0,55	-0,12	-0,40	0,52	0,19	-0,14	-0,11	-0,12	-0,58	1,00	0,36	0,76	0,01
Mn(mg/l)	0,83	0,04	0,01	0,24	0,19	0,40	-0,48	-0,09	0,44	-0,66	-0,49	0,35	0,16	0,06	-0,07	-0,26	-0,25	0,36	1,00	0,17	0,58

ABS_filtered420/5	0,14	0,93	0,92	-0,42	-0,50	-0,38	-0,08	0,85	0,29	0,12	-0,38	0,04	-0,26	-0,44	-0,35	-0,11	-0,72	0,76	0,17	1,00	-0,26
Temp(C)	0,25	-0,04	-0,25	0,04	0,43	0,37	-0,62	-0,29	0,34	-0,90	-0,26	0,36	0,17	0,10	0,02	-0,33	-0,11	0,01	0,58	-0,26	1,00

Table. Correlation test for all parameters measured by Lagans Vattenråd at sampling point 560 (Lake Flaten).

	Depth	Turbidity	Color	TOC	Conductivity_25C	pH	Alkalinity	NH4N	NO2	NTot	PTot	O2	O2(%)	VisiableDepth_wo	VisiableDepth_w)	Ca	Mg	Na	K	Cl	SO4	ChlorophyllA	ABS_unfiltered	ABS_filtered	Temp
Sample Depth(m)	1,00	0,15	-0,10	-0,08	0,13	0,24	-0,39	-0,68	-0,46	-0,34	-0,22	-0,15	-0,15	-0,10	-0,09	-0,62	0,10	-0,04	-0,47	0,47	-0,16	-0,27	0,00	-0,10	-0,12
Turbidity(FNU)	0,15	1,00	0,29	0,09	-0,18	0,03	0,28	-0,21	-0,22	-0,18	-0,19	-0,16	-0,08	-0,14	-0,19	-0,11	0,22	-0,10	-0,14	-0,22	-0,39	0,07	-0,08	0,01	0,08
Color(mg*Pt/l)	-0,10	0,29	1,00	0,80	-0,41	-0,24	-0,04	0,28	-0,21	0,39	-0,14	-0,45	-0,39	-0,70	-0,78	0,07	-0,16	-0,56	-0,40	-0,40	-0,15	0,07	0,90	0,83	0,05
TOC(mg/l)	-0,08	0,09	0,80	1,00	-0,30	-0,49	-0,29	0,22	-0,09	0,53	0,07	-0,46	-0,41	-0,44	-0,65	0,13	-0,26	-0,51	-0,29	-0,38	0,03	0,31	0,86	0,82	0,03
Conductivity_25C(mS/m))	0,13	-0,18	-0,41	-0,30	1,00	0,40	0,14	-0,11	-0,27	-0,14	-0,17	0,03	0,07	0,09	0,25	0,09	0,06	0,20	-0,23	0,25	-0,25	0,45	-0,51	-0,54	0,05
pH	0,24	0,03	-0,24	-0,49	0,40	1,00	0,77	-0,46	-0,14	-0,30	0,30	0,39	0,59	-0,14	0,51	0,28	0,13	0,10	0,02	0,16	-0,22	0,17	-0,69	-0,42	0,35
Alkalinity(mekv/l)	-0,39	0,28	-0,04	-0,29	0,14	0,77	1,00	0,25	-0,11	0,00	0,25	0,16	0,41	-0,24	0,26	0,48	0,17	-0,14	-0,02	-0,29	-0,50	0,22	-0,65	-0,49	0,41
NH4-N(µg/l)	-0,68	-0,21	0,28	0,22	-0,11	-0,46	0,25	1,00	0,27	0,47	0,07	-0,20	-0,30	-0,08	-0,12	0,42	-0,11	-0,16	0,13	-0,34	0,06	0,16	0,18	-0,05	-0,22
NO2/3(µg/l)	-0,46	-0,22	-0,21	-0,09	-0,27	-0,14	-0,11	0,27	1,00	-0,05	0,19	0,41	0,18	0,37	0,21	-0,17	0,10	0,15	0,85	-0,24	0,30	-0,07	0,00	0,23	-0,28
NTot(µg/l)	-0,34	-0,18	0,39	0,53	-0,14	-0,30	0,00	0,47	-0,05	1,00	0,06	-0,10	-0,12	-0,26	-0,34	0,27	-0,04	-0,21	-0,23	-0,46	0,08	0,09	0,45	0,18	-0,03
PTot(µg/l)	-0,22	-0,19	-0,14	0,07	-0,17	0,30	0,25	0,07	0,19	0,06	1,00	0,35	0,41	0,25	0,27	0,34	-0,24	-0,19	0,21	-0,12	0,03	-0,04	0,01	0,44	0,18
O2(mg/l)	-0,15	-0,16	-0,45	-0,46	0,03	0,39	0,16	-0,20	0,41	-0,10	0,35	1,00	0,80	0,34	0,45	0,01	0,12	0,32	0,39	-0,04	0,24	-0,16	-0,36	-0,51	-0,24
O2(%)	-0,15	-0,08	-0,39	-0,41	0,07	0,59	0,41	-0,30	0,18	-0,12	0,41	0,80	1,00	0,30	0,53	0,16	0,14	0,22	0,31	-0,05	-0,01	-0,09	-0,43	-0,48	0,40
Visible Depth_wo(m)	-0,10	-0,14	-0,70	-0,44	0,09	-0,14	-0,24	-0,08	0,37	-0,26	0,25	0,34	0,30	1,00	0,75	-0,33	0,12	0,30	0,56	-0,03	0,07	-0,17	-0,69	-0,69	-0,01
Visiable Depth_w(m)	-0,09	-0,19	-0,78	-0,65	0,25	0,51	0,26	-0,12	0,21	-0,34	0,27	0,45	0,53	0,75	1,00	-0,10	0,24	0,44	0,54	0,04	-0,03	-0,05	-0,60	-0,71	0,25
Ca(mg/l)	-0,62	-0,11	0,07	0,13	0,09	0,28	0,48	0,42	-0,	0,27	0,34	0,01	0,16	-0,33	-0,10	1,00	-0,	-0,	-0,	-0,	0,14	0,27	0,12	0,25	0,30

									17								46	19	13	09					
Mg(mg/l)	0,10	0,22	-0,16	-0,26	0,06	0,13	0,17	-0,11	0,10	-0,04	-0,24	0,12	0,14	0,12	0,24	-0,46	1,00	0,65	0,21	-0,17	-0,17	-0,13	-0,25	-0,29	0,00
Na(mg/l)	-0,04	-0,10	-0,56	-0,51	0,20	0,10	-0,14	-0,16	0,15	-0,21	-0,19	0,32	0,22	0,30	0,44	-0,19	0,65	1,00	0,38	0,27	0,40	-0,22	-0,29	-0,42	-0,13
K(mg/l)	-0,47	-0,14	-0,40	-0,29	-0,23	0,02	-0,02	0,13	0,85	-0,23	0,21	0,39	0,31	0,56	0,54	-0,13	0,21	0,38	1,00	-0,23	0,28	-0,09	-0,03	0,13	-0,03
Cl(mg/l)	0,47	-0,22	-0,40	-0,38	0,25	0,16	-0,29	-0,34	-0,24	-0,46	-0,12	-0,04	-0,05	-0,03	0,04	-0,09	-0,17	0,27	-0,23	1,00	0,24	-0,19	-0,36	-0,38	-0,04
SO4(mg/l)	-0,16	-0,39	-0,15	0,03	-0,25	-0,22	-0,50	0,06	0,30	0,08	0,03	0,24	-0,01	0,07	-0,03	0,14	-0,17	0,40	0,28	0,24	1,00	-0,40	0,48	-0,01	-0,32
ChlorophyllA_(µg/l)	-0,27	0,07	0,07	0,31	0,45	0,17	0,22	0,16	-0,07	0,09	-0,04	-0,16	-0,09	-0,17	-0,05	0,27	-0,13	-0,22	-0,09	-0,19	-0,40	1,00	-0,01	0,29	0,11
ABS_unfiltered_420/5	0,00	-0,08	0,90	0,86	-0,51	-0,69	-0,65	0,18	0,00	0,45	0,01	-0,36	-0,43	-0,69	-0,60	0,12	-0,25	-0,29	-0,03	-0,36	0,48	-0,01	1,00	0,94	-0,17
ABS_filtered420/5	-0,10	0,01	0,83	0,82	-0,54	-0,42	-0,49	-0,05	0,23	0,18	0,44	-0,51	-0,48	-0,69	-0,71	0,25	-0,29	-0,42	0,13	-0,38	-0,01	0,29	0,94	1,00	0,05
Temp(C)	-0,12	0,08	0,05	0,03	0,05	0,35	0,41	-0,22	-0,28	-0,03	0,18	-0,24	0,40	-0,01	0,25	0,30	0,00	-0,13	-0,03	-0,04	-0,32	0,11	-0,17	0,05	1,00

Table. Correlation test for all parameters measured by Lagans Vattenråd at sampling point 568 (Västerån river upstream of Lake Långasjön).

	Turbidity	Color	TOC	Conductivity_25C	pH	Alkalinity	NO2/3	NTot	PTot	O2	O2 (%)	Ca	Mg	Na	K	Cl	SO4	Fe	Mn	ABS	Temp
Turbidity(FNU)	1,00	0,28	0,14	0,19	0,15	0,36	-0,29	0,15	0,30	-0,47	-0,40	0,64	0,53	0,13	-0,07	-0,16	-0,46	0,79	0,82	0,38	0,42
Color(mg*Pt/l)	0,28	1,00	0,32	-0,31	-0,06	-0,11	-0,27	0,37	0,37	-0,20	0,08	0,44	-0,17	-0,27	-0,41	-0,40	-0,51	0,47	0,16	0,90	0,27
TOC(mg/l)	0,14	0,32	1,00	-0,16	-0,32	-0,22	-0,01	0,30	0,10	0,06	0,14	0,43	-0,20	-0,34	-0,47	-0,49	-0,61	0,50	0,32	0,96	-0,01
Conductivity_25C(mS/m))	0,19	-0,31	-0,16	1,00	0,16	0,55	0,08	-0,07	0,00	-0,17	-0,40	0,47	0,90	0,84	0,27	0,55	0,15	0,33	0,41	-0,32	0,09
pH	0,15	-0,06	-0,32	0,16	1,00	0,70	-0,25	-0,11	-0,16	-0,38	-0,19	0,40	0,60	0,32	0,05	0,08	-0,06	0,29	0,29	-0,46	0,38
Alkalinity(mekv/l)	0,36	-0,11	-0,22	0,55	0,70	1,00	-0,22	0,00	0,03	-0,49	-0,40	0,69	0,80	0,43	0,08	0,04	-0,14	0,58	0,50	-0,23	0,47
NO2/3(µg/l)	-0,29	-0,27	-0,01	0,08	-0,25	-0,22	1,00	0,09	-0,25	0,42	0,14	-0,60	-0,18	0,11	0,39	0,39	0,56	-0,67	-0,43	-0,59	-0,44
NTot(µg/l)	0,15	0,37	0,30	-0,07	-0,11	0,00	0,09	1,00	0,22	0,06	0,05	0,33	-0,05	-0,23	-0,35	-0,39	-0,40	0,43	0,29	0,79	-0,05
PTot(µg/l)	0,30	0,37	0,10	0,00	-0,16	0,03	-0,25	0,22	1,00	-0,27	-0,07	0,34	0,29	0,13	0,07	-0,15	-0,21	0,45	0,37	0,55	0,29
O2(mg/l)	-0,47	-0,20	0,06	-0,17	-0,38	-0,49	0,42	0,06	-0,27	1,00	0,69	-0,66	-0,40	0,04	0,17	0,44	0,48	-0,65	-0,62	-0,32	-0,95
O2(%)	-0,40	0,08	0,14	-0,40	-0,19	-0,40	0,14	0,05	-0,07	0,69	1,00	-0,34	-0,16	0,20	0,01	0,41	0,30	-0,45	-0,37	-0,24	-0,47
Ca(mg/l)	0,64	0,44	0,43	0,47	0,40	0,69	-0,60	0,33	0,34	-0,66	-0,34	1,00	0,56	0,22	-0,30	-0,18	-0,57	0,79	0,59	0,43	0,69

Mg(mg/l)	0,53	-0,17	-0,20	0,90	0,60	0,80	-0,18	-0,05	0,29	-0,40	-0,16	0,56	1,00	0,75	0,28	0,28	0,04	0,53	0,56	-0,15	0,40
Na(mg/l)	0,13	-0,27	-0,34	0,84	0,32	0,43	0,11	-0,23	0,13	0,04	0,20	0,22	0,75	1,00	0,30	0,72	0,18	0,11	0,19	-0,29	-0,02
K(mg/l)	-0,07	-0,41	-0,47	0,27	0,05	0,08	0,39	-0,35	0,07	0,17	0,01	-0,30	0,28	0,30	1,00	0,34	0,45	-0,07	-0,02	-0,41	-0,23
Cl(mg/l)	-0,16	-0,40	-0,49	0,55	0,08	0,04	0,39	-0,39	-0,15	0,44	0,41	-0,18	0,28	0,72	0,34	1,00	0,34	-0,27	-0,19	-0,48	-0,41
SO4(mg/l)	-0,46	-0,51	-0,61	0,15	-0,06	-0,14	0,56	-0,40	-0,21	0,48	0,30	-0,57	0,04	0,18	0,45	0,34	1,00	-0,63	-0,33	-0,59	-0,48
Fe(mg/l)	0,79	0,47	0,50	0,33	0,29	0,58	-0,67	0,43	0,45	-0,65	-0,45	0,79	0,53	0,11	-0,07	-0,27	-0,63	1,00	0,71	0,53	0,63
Mn(mg/l)	0,82	0,16	0,32	0,41	0,29	0,50	-0,43	0,29	0,37	-0,62	-0,37	0,59	0,56	0,19	-0,02	-0,19	-0,33	0,71	1,00	0,35	0,63
ABS_filtered420/5	0,38	0,90	0,96	-0,32	-0,46	-0,23	-0,59	0,79	0,55	-0,32	-0,24	0,43	-0,15	-0,29	-0,41	-0,48	-0,59	0,53	0,35	1,00	0,31
Temp(C)	0,42	0,27	-0,01	0,09	0,38	0,47	-0,44	-0,05	0,29	-0,95	-0,47	0,69	0,40	-0,02	-0,23	-0,41	-0,48	0,63	0,63	0,31	1,00