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Ephemeral Streams in Boreal Landscapes: A Surface Water Statistical Analysis of Ephemeral Streams Chemical Components

Efemära vattendrag i borealt landskap: En statistisk analys av efemära vattendrags kemiska komponenter

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DEPARTMENT OF EARTH SCIENCES
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Abstract

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Boreal landscapes cover a large part of both Sweden and the northern hemisphere. The hydrology of the boreal landscape is complex, with several factors that can affect it in a physical and/or chemical manner. In the Krycklan catchment area, 68km^2, located in northern Sweden close to Umeå, data has been collected at several sites giving both stream flow and water chemistry information. In 2017 samples from 34 sites were collected and analysed from ephemeral streams within the Krycklan catchment area for the first time ever.

In this project, data that has been collected from the ephemeral streams will be correlated with data from the perennial streams in the catchment area. There are several hypotheses at the start of this project that suggests that within the ephemeral streams the DOC will be lower, and the CO2 will be the same. The aim of the project is to find out if there are any patterns that differentiates the ephemeral streams from the perennial streams or if there are no patterns at all. Since there is not so much data available for the ephemeral streams, the conclusions that might be reached in this project won’t be completely reliable. However, if interesting patterns are found the project could expand in the future and more samples can be taken to use for more precise analyses.

Key words: Ephemeral streams, boreal landscapes, Krycklan, DOC

Independent Project in Earth Science, 1GV029, 15 credits, 2019
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Sammanfattning

Efemära vattendrag i borealt landskap: En statistisk analys av efemära vattendrags kemiska komponenter
Oscar Davies

Boreala landskap täcker en stor del av både Sverige och norra halvklotet. Det boreala landskapets hydrologi är komplext, med flera faktorer som kan påverka det på ett fysiskt och/eller kemiskt vis. I Krycklans avrinningsområde, 68 km^2, beläget i norra Sverige nära Umeå, har data samlats in på flera platser som erbjuder data för både flöde och vattenkemi. År 2017 samlades prover från 34 efemära strömmar och analyserades för första gången inom Krycklans avrinningsområde.

I det här projektet kommer data som samlats från de efemära strömmarna att korreleras med data från de konstanta vattendragen i avrinningsområdet. Det finns ett par hypoteser i början av detta projekt som tyder på att inom de efemära strömmarna kan DOC halter vara lägre och CO_2 halter kommer att vara densamma.

Syftet med projektet är att ta reda på om det finns några anmärkningsvärda skillnader mellan de efemära strömmarna och de konstanta vattendragen. Eftersom det inte finns så mycket data tillgänglig för de efemära strömmarna kommer de slutsatser som kan uppnås i detta projekt inte att vara helt tillförlitliga. Om intressanta mönster finns däremot kan projektet expandera i framtiden och fler prover kan tas för att användas för mer exakta analyser.

Nyckelord: Efemär, Boreal landskap, Krycklan, DOC

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1. Introduction

Boreal landscapes compromise a large part of the land in the northern hemisphere. In Sweden nearly 60% of the land is classified as boreal landscape.

To understand how a stream network operates a good idea would be to take several samples at several different places along the stream to see how the stream reacts to different seasons and changes in streamflow, temperature and other factors. These types of analyses and reports have been conducted for about three decades now within the Krycklan catchment area. Reports of future climates indicate that the northern hemisphere will be one of the areas most affected by global warming, which will affect both snow cover area and precipitation patterns. The expected precipitation patterns in the northern hemisphere include increased precipitation during rain events and longer droughts in-between each event (Collins et al. 2013). This change will most likely result in ephemeral streams playing a bigger role in the surface water chemistry all year round, not only during snow melt seasons. A trend of an earlier snowmelt season within the Krycklan catchment area has already been recorded (Oni et al. 2013). Some research has been completed looking at how future climates might affect ephemeral streams in boreal landscapes in the USA (Brooks, 2008), however these studies have not been taking the chemistry of the ephemeral streams into consideration. With these climate changes it is important to be able to predict how the hydrology within the boreal landscape in Sweden might react.

Most of all research of the surface water hydrology done so far within the Krycklan catchment area has been using data from the perennial streams. Since these are the streams that eventually will reach lakes and the sea understanding how they function is an important task. To be able to further expand our knowledge of how parts of the surface water hydrology works, research has been done to determine the sources and variations for the stream's chemical compositions, such as DOC (Laudon et al. 2011; Grabs et al. 2012;) CO_2 (Wallin et al. 2012) and other components. Earlier research hasn't really taken ephemeral streams into consideration too much, and recent research conducted shows that during the times of high flow ephemeral streams can stand for the biggest part of the total stream network (Ågren et al. 2015).

In 2017 at five separate occasions in May and June samples were collected in the Krycklan catchment area. These samples were collected from 24 sites (not all sites were sampled on each occasion). Each of these sites were in an ephemeral stream and was later analysed for several chemical components.

The purpose of this report is to analyse these samples taken from ephemeral streams and then through statistical analyses compare the ephemeral streams data with the perennial streams. In the report the chemical parameters of DOC, CO_2, pH, Nitrogen and SUVA have been analysed. Since samples like these have not been collected before it is quite difficult to anticipate what the outcome might be. With help of earlier research done on the perennial streams a couple of initial hypotheses do exist on how some components might compare to the perennial streams. One of these hypotheses is that the DOC values for the ephemeral streams will be lower than in the perennial streams. This is due to the riparian zone that generates a big amount of the DOC within the stream, and the placement of the riparian zone is along the perennial streams (Grabs et al. 2012; Seibert et al. 2009). Another part of the theory is that the ephemeral streams will be placed at a higher altitude than the perennial streams. This might lead to the ground being dried out at times which would lead to a lower concentration of DOC, due to a more oxygen rich environment.

The results of this project will give information about how the ephemeral streams in their own way affect the perennial streams content. This can help to determine how the perennial streams might react to future climates.

2. Study area

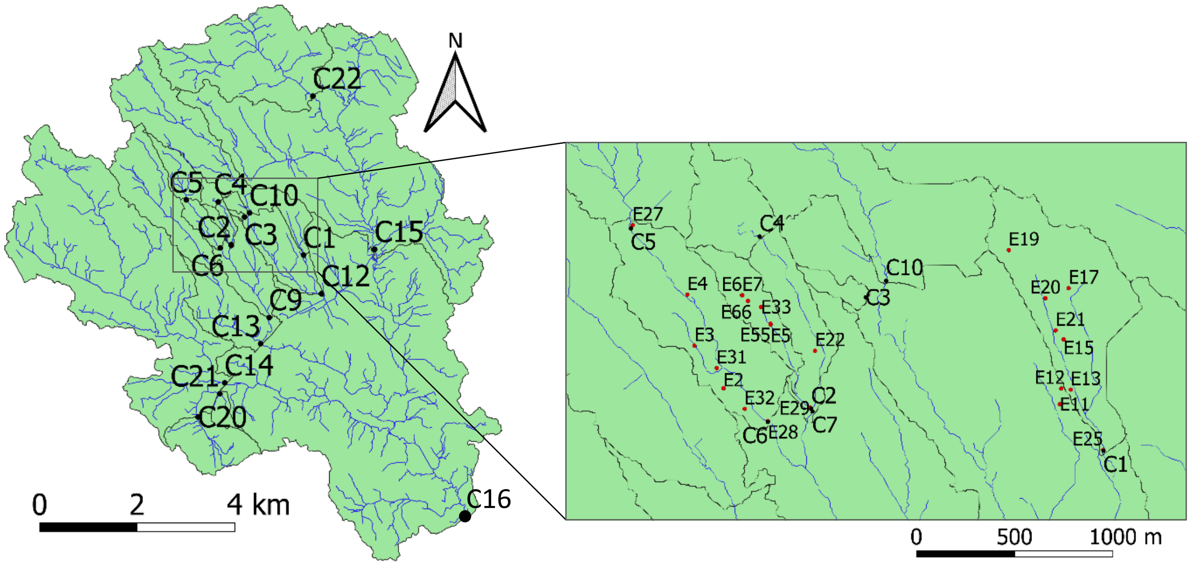


Figure 1. Map of Krycklan catchment area and perennial sites (left), with insert map showing ephemeral sites (right).

The Krycklan catchment study can be found about 50 km northwest of the Swedish city of Umeå. Research started in 1980 with three catchments being monitored (C2, C4 and C7) and by 2002 it had expanded to 18 monitored catchment sites, all within the Krycklan catchment area (Figure 1). Ephemeral sampling sites within the Krycklan catchment area lies with the catchments of perennial sites C1, C2, C6 and C7 (Laudon 2013).

3. Data

The ephemeral stream data used in this project were sampled in June and July 2017. The samples were taken at 24 different sites and at five different occasions. The dates of the sampling are the 6th, 7th, 16th and 19th of May and the 27th of June. Not all sites were visited on each date. Some sites therefore have data to correlate with from five different occasions and some as few as one. Most sites have about 3-4 samples taken from them. The samples collected have been analysed using national standard methods to show the DOC, Nitrogen, pH, conductivity, CO_2 and CH_4. The samples also went through analyses to show what wavelengths got absorbed by the samples, like abs254, abs365, abs420 and abs436. In this project the DOC, Nitrogen, pH, CO_2 and abs254 values were used. The DOC and abs254 is used to calculate the SUVA value.

Streamflow data was not available for the ephemeral streams, however since the coordinates for the sites were known the streamflow recorded at site C2 was mainly used because of it being nearly completely forest landscape, which best correlates to the ephemeral stream sites (Figure 2). Streamflow is recorded each day at the perennial sites and for each day that ephemeral data were collected the daily recorded streamflow value could be used.

The ephemeral data were then compared to data from the perennial streams. This includes data from 2017 from 17 sites on perennially flowing streams that are regularly tested for DOC, Nitrogen, pH and abs254. The CO_2 data was compared with data sampled from a separate project (Wallin et al. 2012). These data included samples collected regularly 2006-2009 with about 25 samples collected each year. The CO_2 samples were collected at the same perennial sites as the other chemical components.

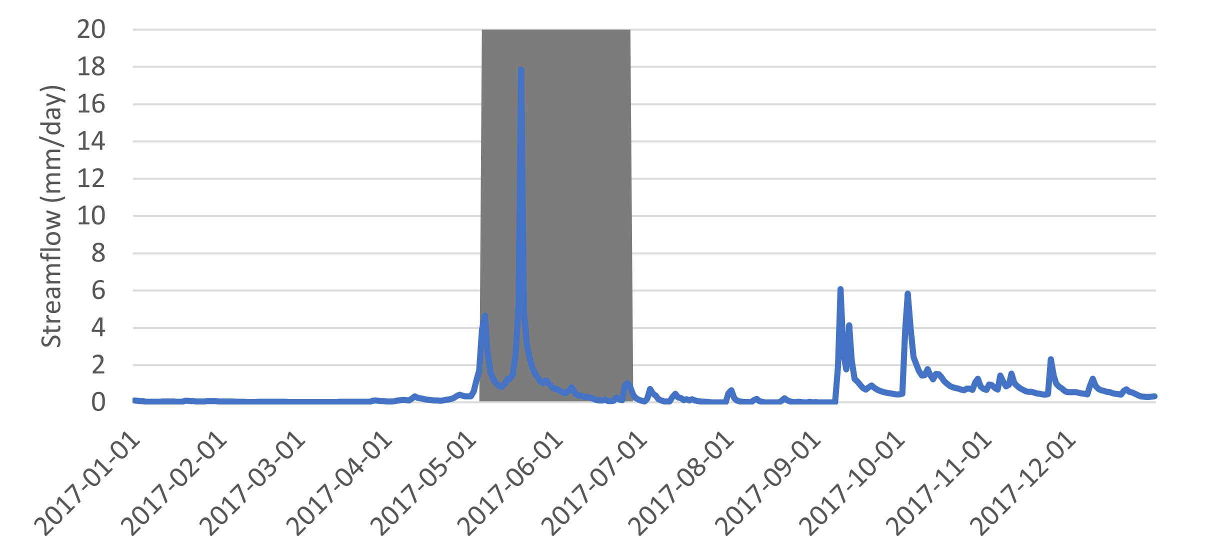


Figure 2. Streamflow record from site C2 during 2017. Ephemeral samples were collected within the gray area.

4. Method

When comparing the data sets of the ephemeral streams with the perennial several different methods were used. Since there were only a couple of hypotheses about the chemical content of the ephemeral streams differing to the perennial streams, the first step was to compile as much statistical data as possible to use for comparison. The first step included calculating the mean, range, median, minimum and maximum values for all the sites in both types of streams. The methods used to compare the different data sets were box plots, linear regression models and combined diagrams.

4.1 Boxplots

Boxplots were used for the comparison of the two different stream types. Two different types of boxplots were made for each chemical compound. One boxplot uses all the ephemeral stream data in one plot and all the perennial stream data from all the sites that fall within the same dates as the ephemeral samples. This boxplot gives two generalised values that can be compared. To add to the first boxplot three other boxplots were made for each chemical compound. These boxplots are divided into the three catchment areas from sites C1, C2 and C6. For the C1 boxplot the values of site C1 was plotted together with each ephemeral site that lies within the C1 sites catchment area. The same method was used for site C2 and C6.

4.2 Linear regression model

Linear regression models were used to examine how the chemical compounds in the streams reacted to increases and decreases of streamflow. To be able to compare the ephemeral streams with the perennial streams linear regression models were made for both types. Each ephemeral site might have its own specific base value, consequently, a linear regression model was made for each site and a trendline for each model was created. All the values for each chemical parameter from these trendlines were added to a table. To be able to compare the ephemeral data with the perennial, site C2 was used as a standard for the perennial sites, as a result of it being nearly completely forested. To get an accurate trendline for site C2 data values for the whole of 2017 were used for all chemical components except CO_2. Instead CO_2 data from 2006-2009 was used.

During one day of the sampling of data for the ephemeral streams the streamflow was much higher than the rest of the days and was the highest on record for site C1 since 2001. Data collected from the ephemeral streams were conducted at five different occasions. Considering this, the day of uniquely high streamflow affects the trend lines of each scatter plot quite a lot. Therefore, two sets of linear regression models were made, one including the day with the peak flow and one excluding it; these are presented in appendices 1 and 2.

To be able to compare the results from the linear regression models, mean values of the trendline slope of each model were calculated for each chemical parameter. When calculating the mean values, the slopes that consisted of two or less datapoints were excluded. These mean values were then placed in two new tables. To these tables the 10^{th} and 90^{th} percentile value was added to give an indication of the range of the slopes and the mean R^2-value. The number of slopes included in the mean value was also added.

4.3 Combined diagram

To be able to visualise how the chemical components reacted to variations in streamflow, combined diagrams were developed. These diagrams combine the difference in streamflow day by day, with the content of the samples taken at all sites at specific dates, for both ephemeral and perennial streams. This visualises if the two different types of streams react in the same way or differently to streamflow variations.

4.4 p-values

To determine the reliability of what the boxplot diagrams are showing, p-values for each chemical parameter were calculated. This was done by doing a z-test in excel. To be able to do a z-test a normal distribution is required, therefore the z-test was only done once per chemical parameter and using all ephemeral data and all perennial data within the same dates for each component in each test. The p-value that is determined from a z-test indicates the probability that of whether a difference in the mean values between the ephemeral and perennial data is due to chance or if it really does represent a different mean value. The significance level used is 0.05, meaning if the p-value is less than 0.05 then the chemical component of the ephemeral streams will be thought of as significantly different from the perennial streams.

5. Results

The results of the statistical analyses are divided into the five separate components tested. Only the mean values from the linear regression models are compiled together into two separate tables, one including the day with 18 mm/day streamflow and one with the results when excluding it.

The linear regression models are displaying a similar reaction of streamflow variations between the two stream types for all components, except SUVA. This is judging from the fact that if a component in the perennial linear regression model has an increased content when streamflow increases so does the ephemeral streams and vice versa. This is the case both when including the day of high streamflow (table 1) and when excluding it (table 2).

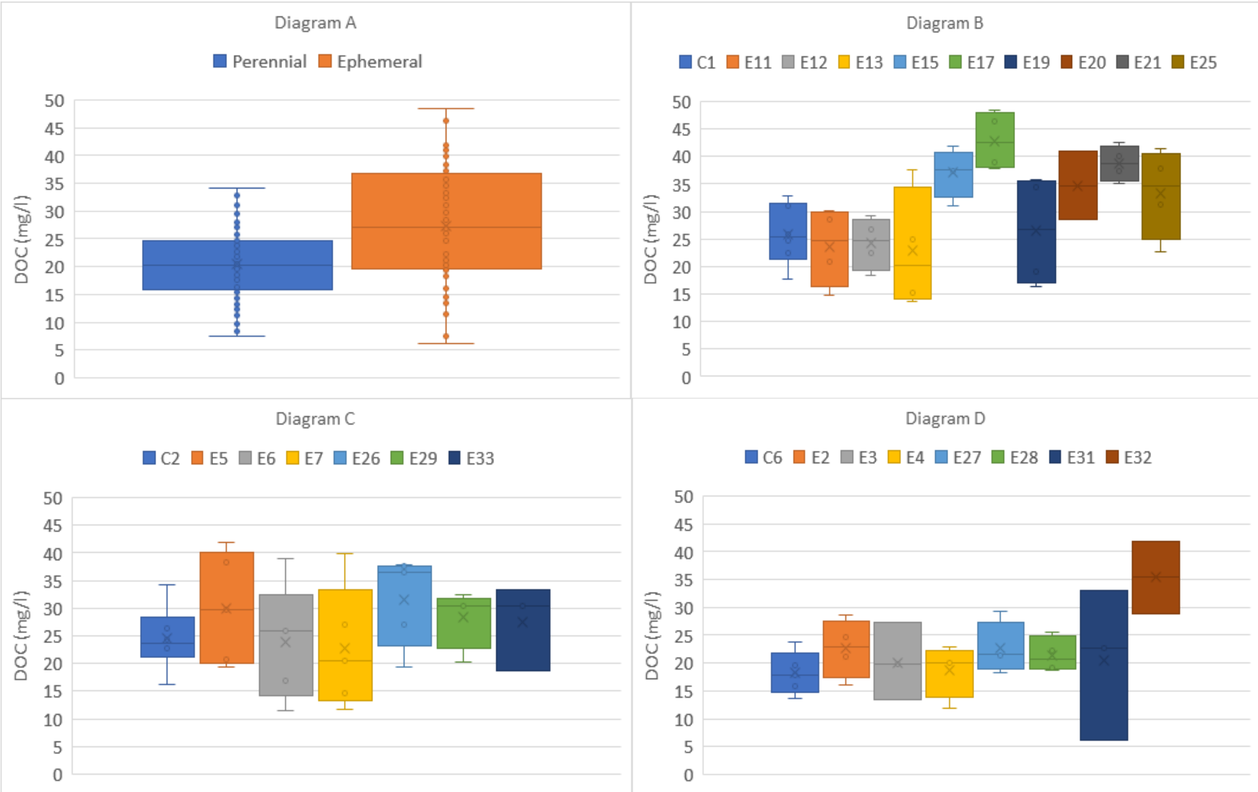
Table 1. Values calculated from linear regression models including the day with streamflow of 17.86 mm/day. Results of the linear regression models for each chemical parameter tested, presented as mean values and range of each parameters. Table includes ephemeral stream values from regression lines, such as regression slope mean value (Ephemeral slope mean), the 10th and 90th percentile values of the regression lines slope (ephemeral slope 10%/90%), the amount of slopes included (ephemeral n), the mean value of the R^2 value for each regression line (ephemeral R^2 mean), the 10th and 90th percentile values of the regression lines R^2 value (ephemeral R^2 10%/90%) and including slope value from perennial site C2s regression line (perennial slope mean).

	DOC	CO_2	PH	NITROGEN	SUVA
EPHEMERAL Slope mean	0,4	-86,2	-0,021	0,0031	-0,0006
EPHEMERAL Slope 10%/90%	-0,47/1,28	-221/5,86	-0,042/0,0006	-0,014/0,016	-0,001/8,6E-5
EPHEMERAL n	21	21	21	21	21
EPHEMERAL R^2 mean	0,37	0,46	0,57	0,45	0,45
EPHEMERAL R^2 10%/90%	0,015/0,86	0,13/0,96	0,02/0,98	0,025/0,92	0,04/0,98
PERENNIAL Slope mean	1,72	-500	-0,15	0,026	0,0005

Table 2. Values calculated from linear regression models excluding the day with streamflow of 17.86 mm/day. Results of the linear regression models for each chemical parameter tested, presented as mean values and range of each parameters. Table includes ephemeral stream values from regression lines, such as regression slope mean value (Ephemeral slope mean), the 10th and 90th percentile values of the regression lines slope (ephemeral slope 10%/90%), the amount of slopes included (ephemeral n), the mean value of the R^2 value for each regression line (ephemeral R^2 mean), the 10th and 90th percentile values of the regression lines R^2 value (ephemeral R^2 10%/90%) and including slope value from perennial site C2s regression line (perennial slope mean).

	DOC	**CO_2**	**PH**	**NITROGEN**	**SUVA**
EPHEMERAL Slope mean	2,27	-331	-0,074	0,018	-0,0028
EPHEMERAL Slope 10%/90%	-0,53/6,4	-907/42,3	-0,17/0,08	-0,02/0,08	-0,0038/ -0,0014
EPHEMERAL n	18	17	10	18	17
EPHEMERAL R^2-mean	0,51	0,50	0,63	0,50	0,84
EPHEMERAL R^2 10%/90%	0,02/0,98	0,08/0,97	0,005/0,999	0,09/0,93	0,44/0,999
PERENNIAL Slope mean	1,72	-500	-0,15	0,026	0,0005

5.1 DOC



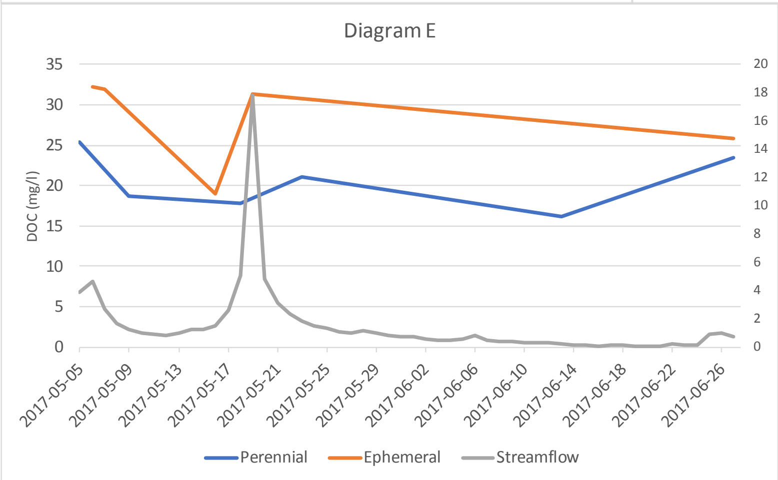


Figure 3. Diagrams comparing DOC concentrations in the ephemeral streams with the perennial streams. All diagrams use data collected between 2017-05-05 and 2017-06-27. Diagram A, a boxplot diagram using all values from all sites of both ephemeral and perennial streams. Diagram B, C and D compares data from sites C1, C2 and C6 with ephemeral data from sites that lie within each respective catchment area. Diagram E is a combined diagram that visualises how both perennial and ephemeral streams react to streamflow variations during the sampling period.

The DOC values recorded in the ephemeral streams are showing a slightly higher value than the DOC values from the perennial streams (Figure 3). When comparing all sites using the same dates from both the ephemeral and perennial in a boxplot, as seen in diagram A (Figure 3), the median, 1st quartile and 3rd quartile are all higher in the ephemeral streams than in the perennial. Results of Diagram B, C and D is showing similar results to Diagram A with slightly varying results. In Diagram D, which includes site C6 and ephemeral sites within its catchment area, every ephemeral site is producing a higher median value of DOC content than C6 (Figure 3).

Diagram E (Figure 3) is producing two lines that seem to follow a similar pattern for both stream types when compared to streamflow, additionally this diagram is showing a higher value of DOC for the ephemeral stream.

5.2 CO_2

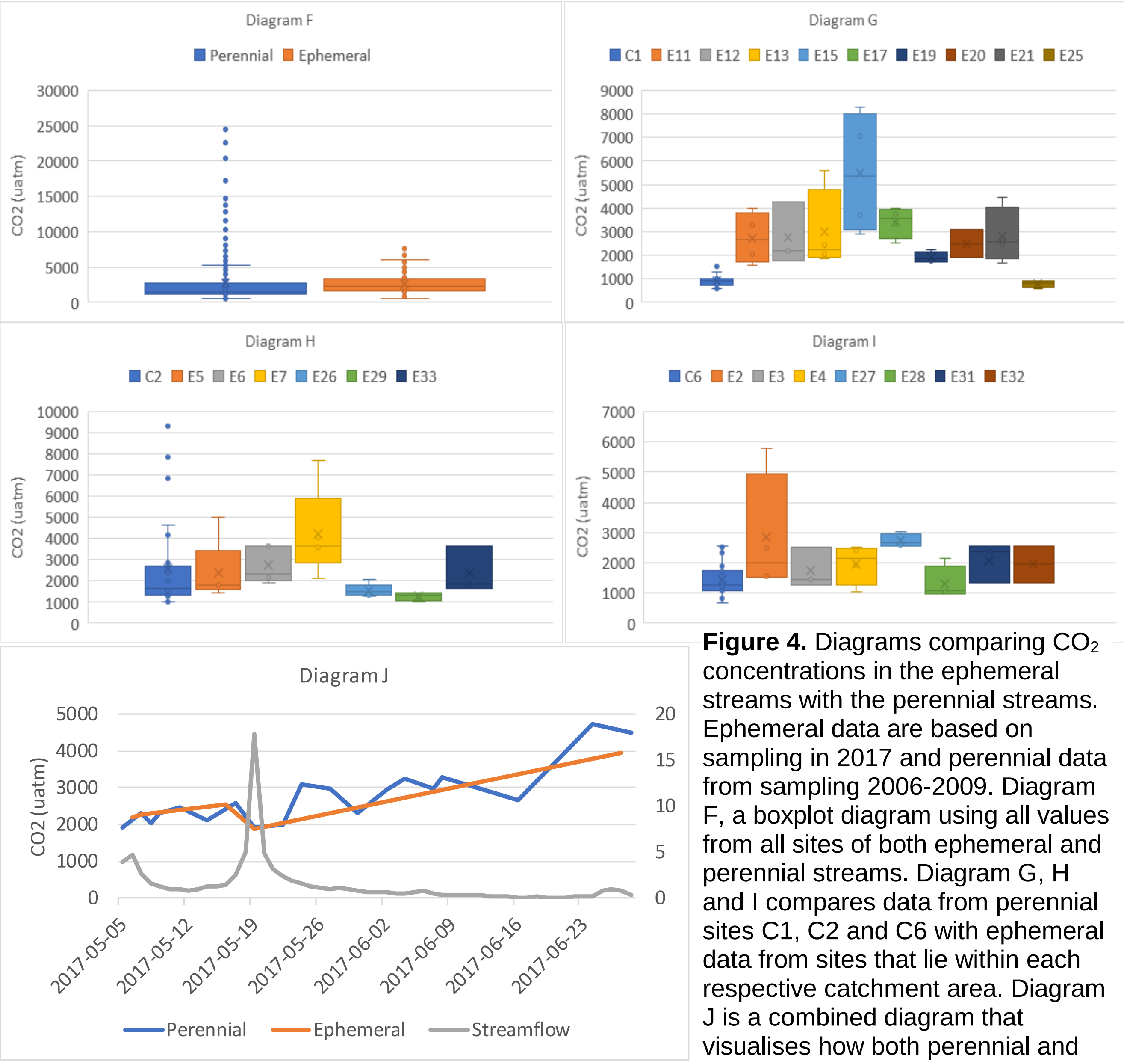
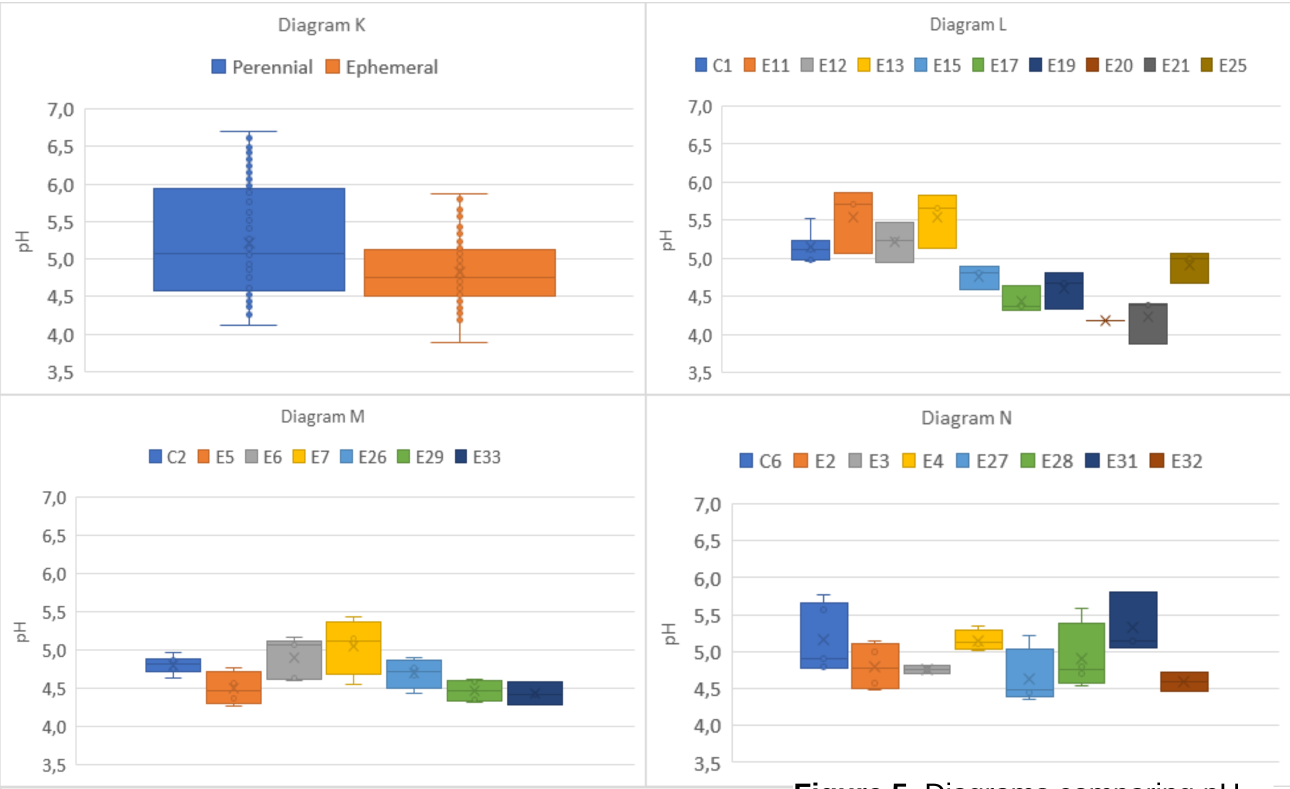


Figure 4. Diagrams comparing CO_2 concentrations in the ephemeral streams with the perennial streams. Ephemeral data are based on sampling in 2017 and perennial data from sampling 2006-2009. Diagram F, a boxplot diagram using all values from all sites of both ephemeral and perennial streams. Diagram G, H and I compares data from perennial sites C1, C2 and C6 with ephemeral data from sites that lie within each respective catchment area. Diagram J is a combined diagram that visualises how both perennial and ephemeral streams react to streamflow variations during the sampling period.

CO_2 values show a general trend of being higher in the ephemeral streams compared to the perennial streams. When compiling all sites as done in diagram F there are quite a few outliers with higher values for both the ephemeral streams and the perennial streams. In diagram F, which compares the values of all the sites of each stream type, the difference is not much compared to diagrams G, H and I, where the higher CO_2 values for the ephemeral streams are more distinct. Both stream types seem to react similarly to streamflow variations as seem in diagram J. In diagram J the values of the ephemeral streams seem quite similar again to the perennial stream values.

5.3 pH



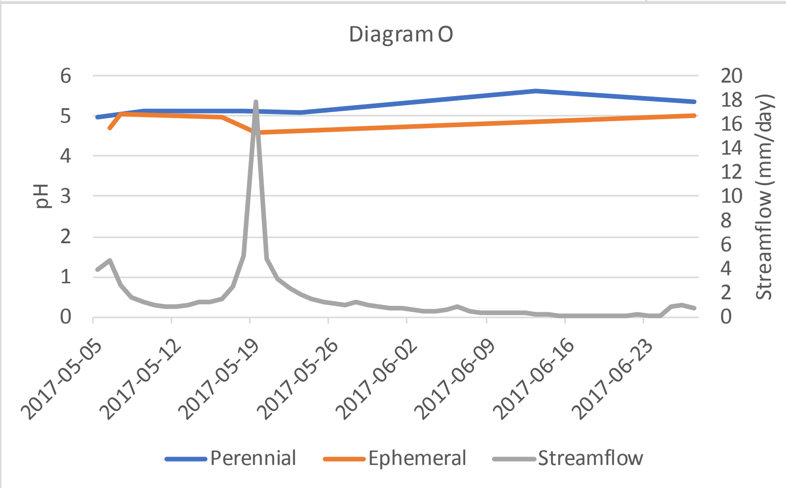
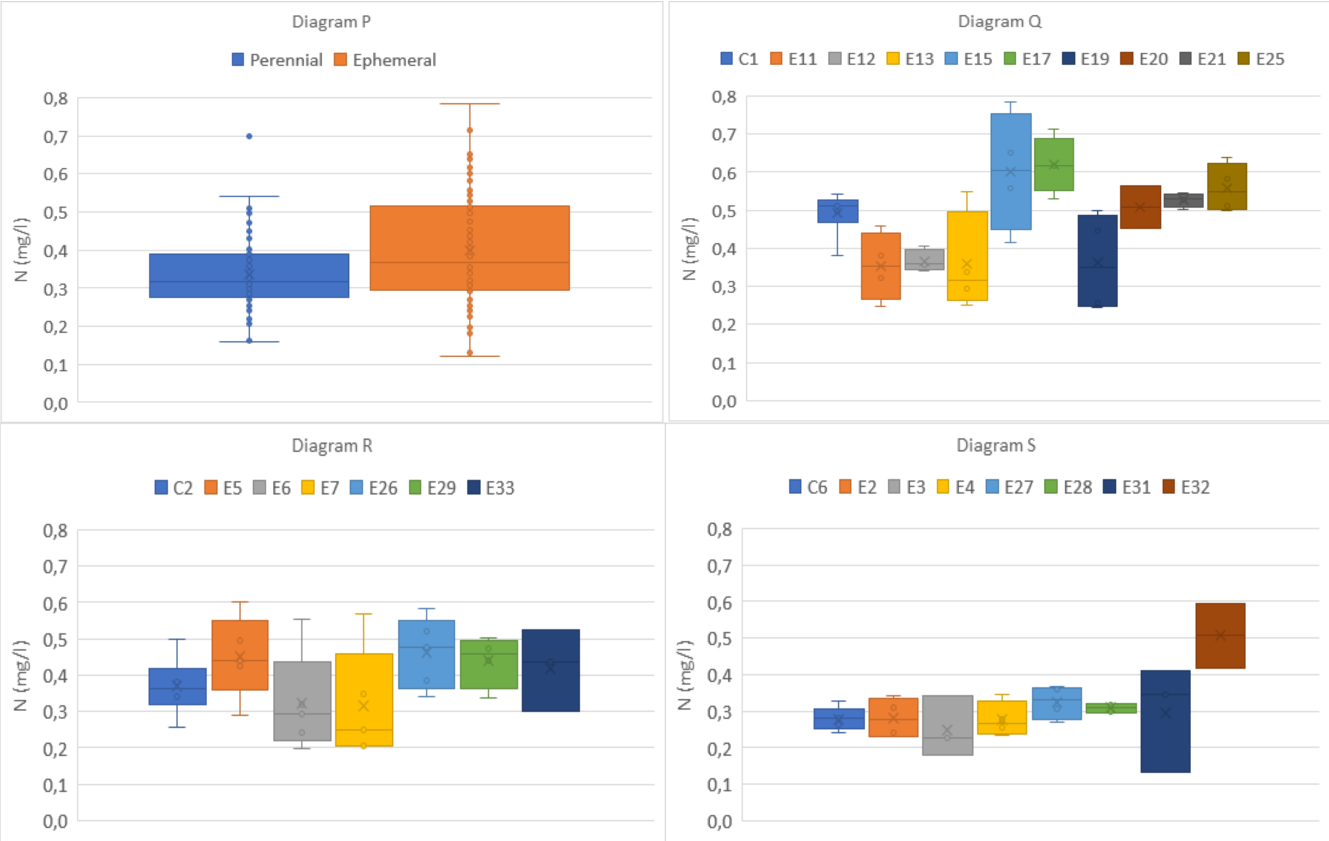


Figure 5. Diagrams comparing pH values in the ephemeral streams with the perennial streams. All diagrams use data collected between 2017-05-05 and 2017-06-27. Diagram K, a boxplot diagram using all values from all sites of both ephemeral and perennial streams. Diagram L, M and N compares data from perennial sites C1, C2 and C6 with ephemeral data from sites that lie within each respective catchment area. Diagram O is a combined diagram that visualises how both perennial and ephemeral streams react to streamflow variations during the sampling period.

General trend for pH values in ephemeral streams seem to be slightly lower than the perennial pH value. In diagram K, that compares the values from all sites, the lower pH value is quite evident. In diagrams L, M and N the results vary a bit, with diagram L and M showing most ephemeral sites with lower pH values than the perennial and a few with similar or higher values. Site C6 in diagram N is showing similar pH values as the ephemeral streams. Therefore, ephemeral streams seem to be slightly more acidic than the perennial streams.

5.4 Nitrogen



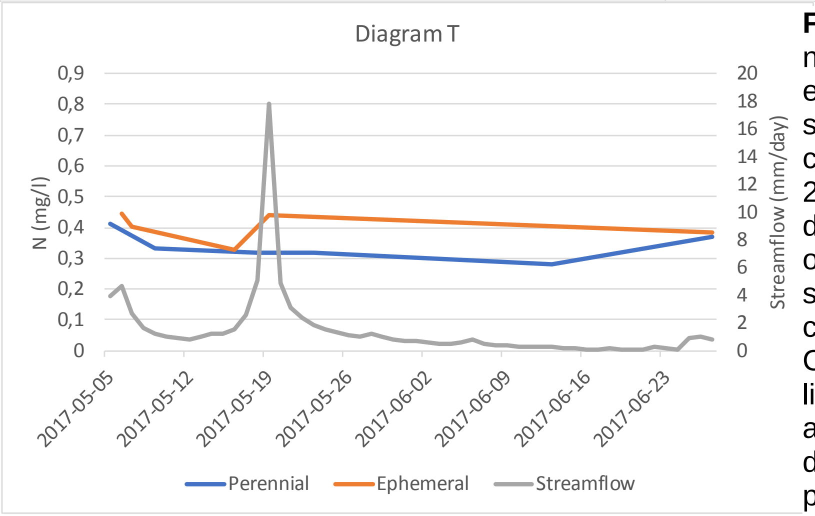
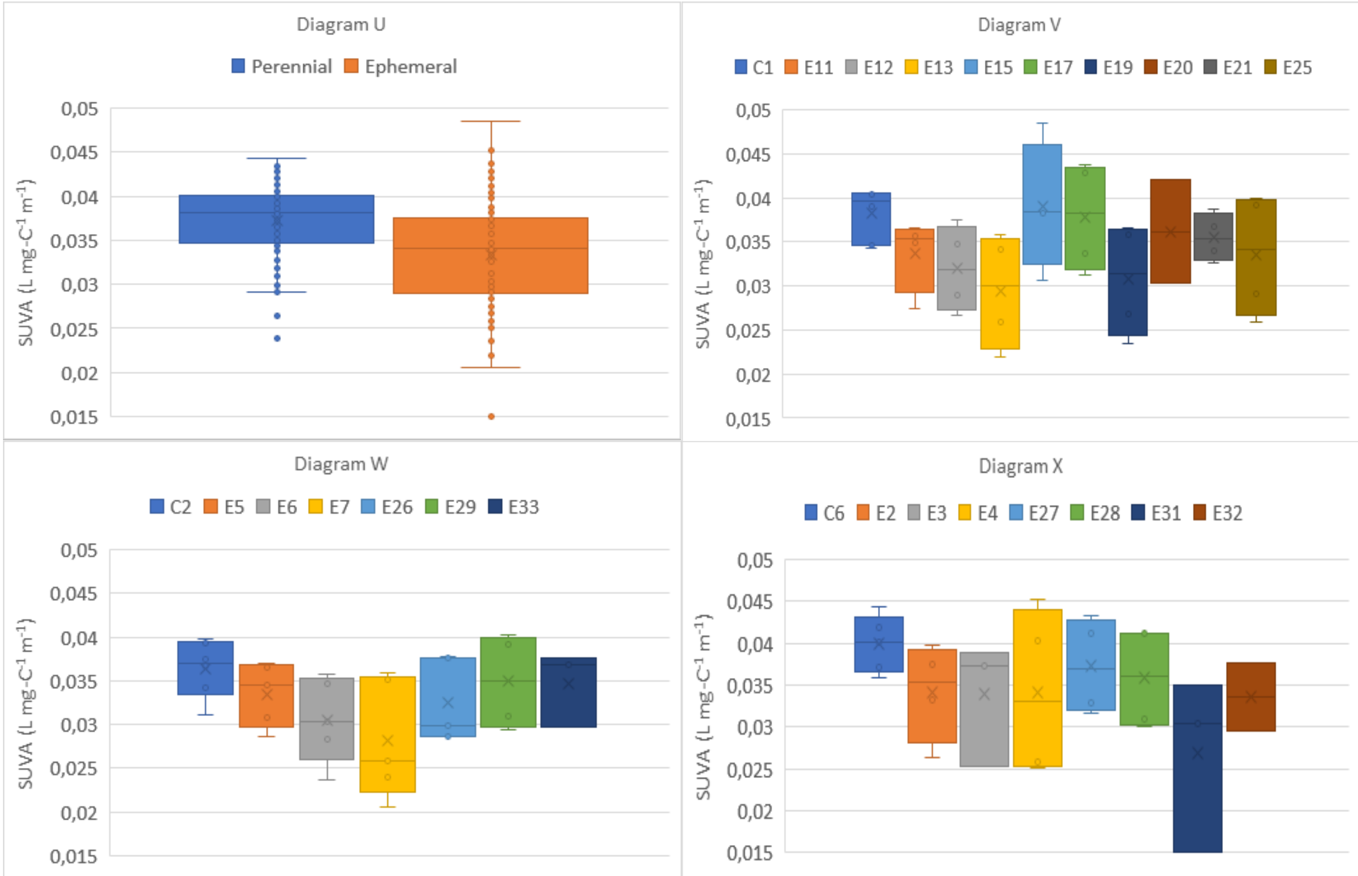


Figure 6. Diagrams comparing nitrogen concentration in the ephemeral streams with the perennial streams. All diagrams use data collected between 2017-05-05 and 2017-06-27. Diagram P, a boxplot diagram using all values from all sites of both ephemeral and perennial streams. Diagram Q, R and S compares data from sites C1, C2 and C6 with ephemeral data from sites that lie within each respective catchment area. Diagram T is a combined diagram that visualises how both perennial and ephemeral streams react to streamflow variations during the sampling period.

The nitrogen values in the ephemeral streams are quite similar to the perennial values. In diagram P (Figure 6) the ephemeral streams do have a higher median value than the perennial streams, but this is not a pattern that exists in diagrams Q, R and S (Figure 6). In these diagrams the values seem very similar to the perennial streams. Diagram T (Figure 6) is also showing situations where the ephemeral streams have similar values to the perennial streams, except during high flow.

5.5 SUVA



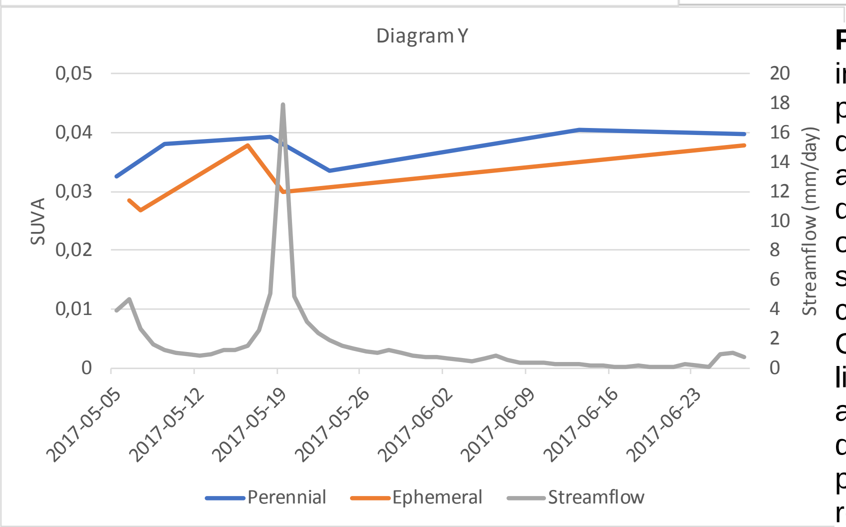


Figure 7. Diagrams comparing SUVA in the ephemeral streams with the perennial streams. All diagrams use data collected between 2017-05-05 and 2017-06-27. Diagram U, a boxplot diagram using all values from all sites of both ephemeral and perennial streams. Diagram V, W and X compares data from sites C1, C2 and C6 with ephemeral data from sites that lie within each respective catchment area. Diagram Y is a combined diagram that visualises how both perennial and ephemeral streams react to streamflow variations during the sampling period.

All diagrams in Figure 7 show that the ephemeral SUVA value is smaller than the perennial values. In diagram Y the perennial and ephemeral lines react correspondingly to the streamflow variations.

5.6 p-values

The calculated p-values from each chemical component are presented in table 3.

Table 3 p-values calculated for each chemical component using all the ephemeral data compared to all the perennial data from same timeline. A significance level of 0.05 is used, meaning each chemical component with a p-value less than that can be assumed to differ from the perennial streams.

	DOC	CO_2	PH	NITROGEN	SUVA
EPHEMRAL MEAN	27.3 (mg/l)	2630 (uatm)	4,83	0,42 (mg/l)	0,033
PERANNIAL MEAN	20,4 (mg/l)	2740 (uatm)	5,22	0,34 (mg/l)	0,037
P-VALUE	$3,9*10^{-9}$	0,31	$2,8*10^{-6}$	$3,6*10^{-6}$	$4,7*10^{-8}$

Results from the z-test suggests that the variations in the ephemeral streams are different from the perennial for DOC, pH, nitrogen and SUVA. However, the p-value for the CO_2 is significantly higher than the rest, which suggests the CO_2 content in the ephemeral streams doesn't vary from the perennial streams.

6. Discussion

6.1 Results

Results from the ephemeral streams show that several of the chemical components tested differs in content from the perennial streams. Both DOC and CO_2 shows patterns of being slightly higher in the ephemeral streams. pH and SUVA values seem to be slightly lower in the ephemeral streams and nitrogen content seems to be comparable to the perennial streams. Tested stream components seem to react in a similar way to streamflow variations in both the ephemeral and perennial streams.

The reasons for the higher recorded DOC value are not entirely understood. The hypothesis was that the DOC would be slightly lower in the ephemeral streams. This hypothesis was based on earlier research done in Krycklan catchment area that was suggesting that most of the DOC that exists in the perennial streams comes from the riparian zone. The p-value for the DOC suggests that the difference in mean that can be seen in DOC is most likely real.

The CO_2 values are showing a higher value in the ephemeral streams when looking at individual catchment areas like diagram G, H, and I (Figure 3). This does however not relate when using values from all sites. Both diagram F and J (Figure 3) show a similar value for both stream types. Since the perennial sites are more spread out over the Krycklan catchment area than the ephemeral, which can be seen in Figure 1, this could be the reason for these two different types of results. If the CO_2 levels are generally higher in other locations in the catchment area, this could raise the median value for the perennial when looking at the whole catchment area. Research shows that wetland areas tend to produce higher CO_2 content in streams than forest covered areas (Wallin et al. 2012). With the exception for site C6, the individual sites used (C1, C2 and C6) have little wetland areas in their catchments. The wetlands in site C6 are quite a bit further upstream and a lot of the CO_2 might have left the stream by vertical evasion, which could be why it has lower CO_2 values than site C1 and C2. Values from catchment areas within the Krycklan catchment area that have more wetland cover may increase the median value when monitoring all sites. In diagram F (Figure 3) there are several outliers with high values in both the ephemeral and perennial streams. These outliers seem to form during low streamflow. Another reason for the perennial streams higher values when using all sites could be that there are areas further away from the ephemeral sample sites where precipitation was lower, which results in higher CO_2 values at these sites. The p-value also suggests that when comparing all the ephemeral sites with all the perennial there is no significant difference between them.

pH values were slightly lower in the ephemeral streams compared to the perennial streams. This is also confirmed when looking at the p-value from the z-test for pH. There could be several factors affecting the pH in ephemeral streams. Research done in Krycklan catchment area suggests a correlation between DOC values and acidity in boreal forest landscape. This research concludes that during higher DOC the water becomes more acidic (Buffam 2007). Since the DOC in the ephemeral seems to be higher than the perennial this might be the cause for the lower pH.

The Nitrogen content seemed to be the same when comparing the two stream types looking at the boxplot diagrams. However, the z-test shows a different result with quite a higher mean value for the ephemeral sites and a low p-value that indicates that there is a difference between the two stream types.

The SUVA values in the ephemeral streams seem to be slightly lower than in the perennial streams. The reasons for this are unknown but might have to do with dilution from perhaps a higher surface runoff rate that exists during high flow.

The linear regression models suggest that most of the chemical components are reacting in a similar way to streamflow variations in both ephemeral and perennial streams. Except perhaps for SUVA, which is reacting negative to an increased streamflow in the ephemeral whilst it reacts positively in the perennial streams. This could also be explained by a dilution created during higher surface runoff rates, that exists during high streamflow events.

6.2 Uncertainties

All results for this project have to take into consideration the fact that the samples used are all collected within a short period of time. Since each ephemeral sample that exists is collected at some point in May or June 2017, it might not depict the values that exist in ephemeral streams all year round.

The linear regression models that were created for this project are helpful in showing how the ephemeral streams may differ from the perennial not just in content but also in reaction to streamflow variations. The results given from the models however may not be completely reliable, due to the lack of samples for each site. Since only five samples were collected as a maximum for each site it is difficult to say how accurate the created models are depicting reality. Another factor is the day of high streamflow, that changes the inclination of the linear regression models a lot. Removing that data point as done in “attachments 2” does perhaps give a more correct inclination but with a loss of valuable data points. To avoid looking too closely at models that might not be representing the real inclination, the mean value of each table was compared with the perennial streams. The main point for this part of the project was to see if both streams react similarly to the variations in streamflow and not the specific values of the inclinations. So, if both streams have a negative inclination to an increase of streamflow, both stream types were considered to react the same way to streamflow variations. The results given show that in all components tested the ephemeral streams react correspondingly to the perennial streams. Another issue with the linear regression model was the streamflow estimates. Since there was no record of the streamflow for the ephemeral sites the streamflow for site C2 was used for all sites. Having the actual streamflow available would increase the credibility of the results given.

Concerning the calculated p-values, for these to be reliable, the data needs to be normally distributed. Just by looking at the CO_2 values when looking at all sites (Figure 4, Diagram F) it is quite clear that there are several outliers on one side of the median but not the other. This suggests that the CO_2 is not following a normal distribution.

7. Conclusions

Whether or not there are consistent differences in the chemistry of ephemeral streams compared to perennial streams in boreal landscapes is a question with very few answers in the published literature. This report found several differences between the ephemeral and perennial streams, but because of the small number of samples the accuracy of these conclusions is debatable. The conclusions made in this report are:

- DOC content is higher in ephemeral streams than in perennial streams, both when looking at the boxplots and according to the p-value.
- CO_2 content is higher in ephemeral streams than in perennial streams when looking at boxplot diagrams, but content is thought to be same according to p-value. The p-value can be unreliable since the CO_2 is most likely not following a normal distribution.
- pH value is lower in the ephemeral streams than in the perennial streams, both according to boxplot diagrams and the p-value.
- Nitrogen is higher in ephemeral streams compared to perennial according to the p-value. By looking at the boxplot diagrams the content seems to be similar in the two stream types.
- SUVA is lower in ephemeral streams compared to the perennial streams, both by looking at the boxplot diagrams and according to the p-value.
- All tested chemical components except SUVA react similarly to streamflow variations in the ephemeral streams compared to the perennial streams.

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Appendices

Appendix 1. Results from linear regression models from each ephemeral site, perennial site C2, covering each chemical compound. This table includes the day of high streamflow.

Content	Trend	C2	E2	E3	E4	E5	E6	E7	E11	E12
DOC	kx+m	1,72x + 20,8	**-0,04x + 22,9**	**-0,76x + 21,9**	0,12x + 17,9	0,26x + 28,6	0,44x + 21,4	1,42x + 14,9	0,67x + 19,5	0,48x + 21,2
	R^2	0,318	0,003	0,050	0,041	0,032	0,090	0,801	0,542	0,635
N	kx+m	0,026x + 0,312	**-0,0024x + 0,296**	**-0,016x + 0,287**	**-0,0023x + 0,292**	0,0024x + 0,438	0,0036x + 0,302	0,020x + 0,204	0,0097x + 0,293	0,0035x + 0,344
	R^2	0,403	0,127	0,164	0,140	0,023	0,033	0,874	0,749	0,937
pH	kx+m	**-0,15x + 5,25**	**-0,032x + 5,00**	0,0006x + 4,76	**-0,012x + 5,22**	**-0,022x + 4,63**	**-0,029x + 5,07**	**-0,037x + 5,28**	**-0,043x + 5,84**	0,0005x + 5,21
	R^2	0,42	0,6541	0,0004	0,4562	0,6368	0,5881	0,6458	0,9799	0,0003
SUVA	kx+m	**-0,0005x + 0,039**	**-0,0002x + 0,036**	**-0,0036x + 0,042**	**-0,0009x + 0,040**	0,0002x + 0,032	**-0,0001x + 0,031**	**-0,0007x + 0,032**	0,0001x + 0,033	**-0,0004x + 0,034**
	R^2	0,0406	0,0952	0,9949	0,4784	0,1598	0,0289	0,578	0,0775	0,3432
CO_2	kx+m	**-500x + 3970**	**-145x + 3739**	**-239x + 2293**	**-81,6x + 2481**	**-74,3x + 2794**	**-51,8x + 3017**	**-79,5x + 4668**	**-114x + 3431**	**-117x + 3656**
	R^2	0,1154	0,3281	0,5332	0,96	0,1285	0,1885	0,0734	0,6725	0,6179
Content	**Trend**	**C2**	**E13**	**E15**	**E17**	**E19**	**E20**	**E21**	**E22**	**E25**
DOC	kx+m	1,72x + 20,8	1,33x + 14,6	**-0,51x + 40,2**	**-0,31x + 44,8**	0,97x + 20,4	**-0,95x + 45,4**	**-0,07x + 39,2**	1,02x + 9,94	0,79x + 28,5
	R^2	0,318	0,926	0,831	0,221	0,577	1,000	0,028	0,868	0,577
N	kx+m	0,026x + 0,312	0,016x + 0,26	**-0,017x + 0,71**	**-0,008x + 0,67**	0,014x + 0,28	**-0,0085x + 0,60**	0,0003x + 0,53	0,014x + 0,17	0,0037x + 0,54
	R^2	0,403	0,970	0,763	0,730	0,700	1,000	0,023	0,811	0,208
pH	kx+m	**-0,15x + 5,25**	**-0,037x + 5,8**	**-0,015x + 4,9**	**-0,0054x + 4,5**	**-0,025x + 4,8**	N/A	0,014x + 4,1	**-0,053x + 5,5**	**-0,021x + 5,1**
	R^2	0,42	0,9659	0,8765	0,0923	0,9492	N/A	0,2044	0,9106	0,9828
SUVA	kx+m	**-0,0005x + 0,039**	**-0,0007x + 0,034**	**-0,0002x + 0,040**	**-0,0005x + 0,041**	**-0,0007x + 0,035**	0,0009x + 0,026	**-0,0002x + 0,037**	3E-05x + 0,03	**-0,0008x + 0,038**
	R^2	0,0406	0,775	0,0519	0,377	0,742	1	0,289	0,0386	0,719
CO_2	kx+m	**-500x + 3970**	**-114x + 3693**	**-262x + 7113**	**-78,6x + 3891**	**-13,4x + 1999**	**-89,0x + 3502**	**-112x + 3517**	**-152x + 5765**	10,0x + 737,1
	R^2	0,1154	0,2699	0,646	0,9568	0,2117	1	0,5709	0,6713	0,3559
Content	**Trend**	**C2**	**E26**	**E27**	**E28**	**E29**	**E31**	**E32**	**E33**	**E34**
DOC	kx+m	1,72x + 20,8	0,64x + 28,1	0,06x + 22,3	0,15x + 20,5	0,19x + 27,1	1,09x + 13,3	**-0,76x + 42,5**	0,50x + 24,1	N/A
	R^2	0,318	0,300	0,012	0,147	0,079	0,594	1,000	0,392	N/A
N	kx+m	0,026x + 0,31	0,0072x + 0,42	**-0,0041x + 0,35**	**-0,0009x + 0,31**	0,0028x + 0,42	0,0099x + 0,23	**-0,010x + 0,60**	0,009x + 0,36	N/A
	R^2	0,403	0,268	0,502	0,333	0,099	0,430	1,000	0,602	N/A
pH	kx+m	**-0,15x + 5,25**	**-0,022x + 4,83**	**-0,022x + 4,77**	**-0,038x + 5,14**	**-0,015x + 4,56**	**-0,024x + 5,49**	**-0,015x + 4,73**	**-0,013x + 4,52**	N/A
	R^2	0,42	0,8511	0,2043	0,4097	0,6108	0,3152	1	0,6452	N/A
SUVA	kx+m	**-0,0005x + 0,039**	**-0,0004x + 0,035**	**-0,0005x + 0,040**	**-0,0005x + 0,039**	**-0,0005x + 0,038**	**-0,0011x + 0,034**	**-0,0005x + 0,038**	**-0,0004x + 0,038**	N/A
	R^2	0,0406	0,3485	0,4558	0,4808	0,4285	0,9651	1	0,9848	N/A
CO_2	kx+m	**-500x + 3970**	**-18,3x + 1639**	**-10,7x + 2787**	**-36,7x + 1546**	16,3x + 1190	**-67,1x + 2540**	**-213x + 6159**	**-68,5x + 2845**	N/A
	R^2	0,1154	0,1837	0,1459	0,2807	0,421	0,9903	1	0,3605	N/A

Appendix 2. Results from linear regression models from each ephemeral site, perennial site C2, covering each chemical compound. This table excludes the day of high streamflow.

Content	Trend	C2	E2	E3	E4	E5	E6	E7	E11	E12
DOC	**kx+m**	1,72x + 20,8	1,87x + 18,8	**-0,76x + 21,9**	0,24x + 17,7	6,39x + 14,7	6,62x + 7,39	2,25x + 13,0	2,72x + 15,1	1,58x + 18,9
	R^2	0,318	0,363	0,050	0,008	0,856	0,877	0,320	0,654	0,594
N	**kx+m**	0,026x + 0,312	0,016x + 0,26	**-0,016x + 0,29**	**-0,009x + 0,31**	0,074x + 0,27	0,088x + 0,11	0,016x + 0,21	0,023x + 0,26	0,003x + 0,34
	R^2	0,403	0,334	0,164	0,099	0,923	0,869	0,154	0,515	0,358
pH	**kx+m**	**-0,15x + 5,25**	**-0,14x + 5,23**	0,0006x + 4,76	**-0,014x + 5,23**	**-0,094x + 4,78**	**-0,13x + 5,29**	0,090x + 5,01	**-0,21x + 6,02**	**-0,73x + 6,04**
	R^2	0,42	0,9928	0,0004	0,0504	0,8934	0,8033	0,9998	1	1
SUVA	**kx+m**	**-0,0005x + 0,039**	**-0,0035x + 0,043**	**-0,0036x + 0,042**	**-0,0047x + 0,048**	**-0,0014x + 0,036**	**-0,0022x + 0,036**	**-0,0033x + 0,038**	**-0,0021x + 0,038**	**-0,0027x + 0,039**
	R^2	0,0406	0,9996	0,9949	0,842	0,4297	0,4461	0,8216	0,9278	0,9957
CO_2	**kx+m**	**-500x + 3970**	**-846x + 5233**	**-239x + 2293**	**-137x + 2599**	**-702x + 4220**	**-169x + 3282**	**-708x + 6097**	**-469x + 4188**	**-533x + 4683**
	R^2	0,1154	0,6154	0,5332	0,8616	0,5201	0,1008	0,2596	0,9592	1

Content	Trend	C2	E13	E15	E17	E19	E20	E21	E22	E25
DOC	**kx+m**	1,72x + 20,8	2,84x + 11,4	**-0,50x + 40,2**	0,40x + 43,3	4,51x + 12,9	N/A	1,14x + 36,6	**-9,57x + 22,0**	2,63x + 24,5
	R^2	0,318	0,914	0,174	0,022	0,902	N/A	0,378	1,000	0,515
N	**kx+m**	0,026x + 0,312	0,016x + 0,26	**-0,039x + 0,75**	**-0,017x + 0,69**	0,053x + 0,19	N/A	0,006x + 0,51	**-0,166x + 0,37**	0,036x + 0,47
	R^2	0,403	0,592	0,486	0,390	0,950	N/A	0,332	1,000	0,929
pH	**kx+m**	**-0,15x + 5,25**	**-0,22x + 6,00**	0,14x + 4,70	0,44x + 3,97	**-0,18x + 4,95**	N/A	**-0,72x + 4,96**	0,39x + 4,98	**-0,096x + 5,15**
	R^2	0,42	1	1	1	1	N/A	1	1	1
SUVA	**kx+m**	**-0,0005x + 0,039**	**-0,0026x + 0,038**	**-0,0032x + 0,047**	**-0,0033x + 0,047**	**-0,0026x + 0,039**	N/A	**-0,0013x + 0,039**	**-0,0033x + 0,034**	**-0,0029x + 0,043**
	R^2	0,0406	0,9992	0,538	0,9422	0,99	N/A	0,7678	1	0,9879
CO_2	**kx+m**	**-500x + 3970**	**-525x + 4568**	**-1152x + 9010**	**-151x + 4046**	**-39,3x + 2054**	N/A	**-376x + 4080**	**-2971x + 8962**	27,9x + 698,9
	R^2	0,1154	0,3114	0,9922	0,97	0,0985	N/A	0,5091	1	0,1733

Content	Trend	C2	E26	E27	E28	E29	E31	E32	E33	E34
DOC	**kx+m**	1,72x + 20,8	3,93x + 20,6	2,72x + 16,6	1,85x + 16,9	0,58x + 26,3	X	N/A	**-16,0x + 42,9**	N/A
	R^2	0,318	0,593	0,989	0,980	0,035	1,000	N/A	1,000	N/A
N	**kx+m**	0,026x + 0,31	0,059x + 0,31	0,011x + 0,32	0,004x + 0,30	**-0,0014x + 0,43**	**-0,292x + 0,57**	N/A	**-0,186x + 0,58**	N/A
	R^2	0,403	0,880	0,524	0,498	0,001	1,000	N/A	1,000	N/A
pH	**kx+m**	**-0,15x + 5,25**	**-0,043x + 4,88**	**-0,17x + 5,08**	**-0,17x + 5,42**	**-0,066x + 4,67**	0,91x + 4,43	N/A	0,23x + 4,24	N/A
	R^2	0,42	0,5368	0,5691	0,4974	0,9223	1	N/A	1	N/A
SUVA	**kx+m**	**-0,0005x + 0,039**	**-0,0024x + 0,039**	**-0,003x + 0,046**	**-0,0031x + 0,045**	**-0,0029x + 0,043**	**-0,0065x + 0,040**	N/A	0,001x + 0,036	N/A
	R^2	0,0406	0,6682	1	0,9672	0,9919	1	N/A	1	N/A
CO_2	**kx+m**	**-500x + 3970**	**-80,2x + 1780**	3,08x + 2758	**-176x + 1844**	99,7x + 1013	**-243x + 2740**	N/A	**-2496x + 5597**	N/A
	R^2	0,1154	0,1743	0,0006	0,3544	0,9216	1	N/A	1	N/A


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