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Nutrient Retention in Constructed Wetlands

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Näringsretention i anlagda våtmarker

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Abstract

Eutrophication, a surplus of nutrients, is a problem in aquatic environments and one of the Swedish Environmental Goals is that there should be no eutrophication caused by human activities. Constructed wetlands (CW:s) is a measure that could be implemented to decrease the transport of nutrients to water bodies through retention. To optimize the placement of CW:s, this project aims to understand how different factors affect the retention of P (phosphorus) and N(nitrogen) in constructed CW:s and if there are geographical and seasonal variations in retention. Water samples were collected during three sampling periods from CW:s in Halland, in south-western and Mälardalen in eastern Sweden. The variation in retention of P and N between Halland and Mälardalen and between the different sampling occasions was then investigated. The effect of different factors in the catchment area such as percentage of clay, silt and sand, agricultural land, P-AL (phosphorus extracted with ammonium lactate) in the soil, erosion risk class and the depth of the CW:s on the retention of P and N was also tested.

The TP (total phosphorus) load and retention differed between the CW:s in Halland and Mälardalen. In Mälardalen, the load was slightly higher, and had a higher variation in TP load, which can be related to the differences in erosion risk classes as more easily eroded soils usually release P during periods with a lot of runoff. TP retention deviated more from zero in Mälardalen compared with Halland. The retention of TN (total nitrogen) seemed to be higher during August despite the lower TN load. This could be because during the warmer season, there is more retention of inorganic N through denitrification and plant uptake.

Many factors such as soil type, erosion risk class, share of agricultural land and hydraulic load (HL) was found to be positively correlated with the load. However, most of the examined factors in the catchment area showed no correlation with the retention of N or P. The percentage of clay in the area had a negative effect on the retention of TP, which is not coherent with previous studies. This could be because the TP retention was mostly zero or negative, which was thought to be because most of the sampling was during periods with high HL and colder weather, especially in Mälardalen, which may have resulted in poor retention and resuspension of nutrients from the sediments. For TN the only factor which had a correlation was the depth of the CW, which had a negative correlation.

Keywords: Constructed wetlands, nutrient retention, phosphorus, nitrogen, catchment area factors

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REFERAT

Näringsretention i Anlagda Våtmarker

Övergödning, överskott av näringsämnen, är ett problem i vattenmiljöer. Ett av de svenska miljömålen är att det inte ska ske någon övergödning orsakad av människan. Anläggning av våtmarker är en åtgärd som kan vidtas för att minska transporten av näringsämnen till vattendrag genom retention. Anlagda våtmarkers effektivitet beror på olika faktorer såsom jordtyp, markanvändning, utformning och årstid. För att optimera placeringen av anlagda våtmarker, syftar detta projekt till att förstå hur de olika faktorerna påverkar retentionen av fosfor (P) och kväve (N) i anlagda våtmarker och om det finns geografiska och säsongsmässiga variationer i retention. Vattenprover togs vid tre provtagningstillfällen från anlagda våtmarker i Halland, i sydvästra Sverige och Mälardalen i östra Sverige. Variationen i retentionen av P och N mellan Halland och Mälardalen och mellan de olika provtagningstillfällena undersöktes därefter. Effekten på retentionen av olika faktorer i avrinningsområdet såsom andel lera, silt och sand, jordbruksmark, P-AL (fosfor extraherat från jord med ammoniumlaktat) i marken, erosionsriskklass och medeldjupet av de anlagda våtmarkerna på retentionen av P och N undersöktes också.

Belastningen och retentionen av TP (totalfosfor) skiljde sig mellan de anlagda våtmarkerna i Mälardalen och Halland. I Mälardalen var belastningen något högre, samt hade högre variation i TP-belastning, vilket kan relateras till skillnaderna i erosionsriskklasser då mer lätteroderade jordarter oftast släpper P under perioder med mycket avrinning. TP retentionen avvek mer från noll i Mälardalen jämfört med Halland. Retentionen av TN (totalkväve) var förhållandevis hög under augusti trots den förhållandevis lägre TN-belastningen jämfört med höst-och vinterprovtagningarna. Detta kan bero på att det under den varmare årstiden sker mer retention av oorganiskt kväve genom denitrifikation och växtupptag.

Många faktorer såsom jordart, erosionsriskklass, andel jordbruksmark och hydraulisk belastning (HL) var positivt korrelerade med näringsbelastningen. Däremot visade de flesta av de undersökta faktorerna i avrinningsområdet inget samband med retentionen av N eller P. Andelen lera i området hade en negativ effekt på retentionen av TP, vilket inte stämmer överens med tidigare studier. Detta kan bero på att TP-retentionen mestadels var noll eller negativ, vilket ansågs bero på att det mesta av provtagningen skedde under perioder med hög HL, vilket kan ha resulterat i dålig retention och resuspension av P från sediment. Den enda faktorn som var relaterad med TN retentionen var djupet i de anlagda våtmarkerna, som minskade med våtmarkens djup.

Nyckelord: Anlagda våtmarker, näringsretention, fosfor, kväve, avrinningsområdesfaktorer

PREFACE

This Master thesis of 30 credits was written for the master's Program in Environmental and Water Engineering at Uppsala University and the Swedish University of Agricultural Sciences. Supervisor was Pia Geranmayeh at the department of Aquatic Sciences and Assessments at the Swedish University of Agricultural Sciences (SLU) and the subject reader was Ingrid Wesström at the Department of Soil and Water, also at SLU.

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POPULÄRVETENSKAPLIG SAMMANFATTNING

Näringsämnen är livsviktiga för ekosystem, då de är grundläggande för växter och andra primärproducenters tillväxt, vilket i sin tur utgör grunden för ekosystemens energi. Utan näringsämnen kan det därför inte ske någon tillväxt. Dock kan halter av näringsämnen över den naturliga ha negativa effekter för akvatiska ekosystem, vilket kallas för övergödning. För mycket tillväxt av växter och alger innebär mer nedbrytning av material när dessa dör, vilket leder till fler nedbrytare som förbrukar mer syre på botten. Syrebristen på botten leder till att arter beroende av syre blir negativt påverkade. En annan konsekvens av övergödning är så kallad algblomning, som kan ge tillväxt av giftiga alger som i sin tur kan vara farliga för djur och människor.

Ett av Sveriges miljömål är ingen övergödning. För att uppfylla målet behöver den största minskningen av utsläpp av näringsämnen ske från jordbruket. En åtgärd som utförts för att minska dessa utsläpp är anläggandet av våtmarker. När vatten rinner in i våtmarkerna saktar det in, vilket gör att näringsämnena kan hållas kvar i våtmarken genom olika processer. Detta brukar kallas för retention. De anlagda våtmarkernas retentionsförmåga kan påverkas av flera olika faktorer, många av dessa faktorer är i sin tur kopplade till belastningen det vill säga mängden näringsämnen som kommer till våtmarken. Generellt sett ökar retentionen ju större belastningen är, men kan även variera beroende på till exempel säsong där kallare väder och mycket avrinning kan leda till att retentionen minskar eller att det till och med släpps ut näringsämnen. Faktorer som påverkar belastningen är exempelvis jordartsfördelning, där större andel lera leder till mer utsläpp av fosfor, medan det motsatta gäller för kväve. Jordens erosionsbenägenhet kan också påverka läckaget av fosfor främst transporteras med jordpartiklar. Andra faktorer som påverkar belastningen av näringsämnen är markanvändningen, där större andel jordbruksmark ger högre belastning, men även lutningen på marken och säsong. En faktor som kan påverka själva våtmarkens förmåga är djupet på våtmarken. Hur djupet påverkar kan variera, ett större djup innebär att vattnet stannar i våtmarken under en längre tid vilket underlättar retentionsmekanismer såsom sedimentation. Dock kan ett större djup även leda till att utbytet mellan botten och det inkommande vattnet minskar, vilket leder till att det tar längre tid för näringsämnen att sedimentera till botten. Grundare våtmarker är speciellt viktigt för retentionen av kväve då den främsta retentionsmekanismen är denitrifikation, vilket innebär att mikroorganismer omvandlar kvävet till olika gaser. För denitrifikationen är utbytet mellan det inkommande vattnet och botten viktigt, då denitrifikationsbakterierna lever i sedimentet.

I detta projekt har vattenprover tagits i tre olika provtagningsomgångar från in-och utloppet från 40 våtmarker, 19 i Halland och 21 i Mälardalen. Halland och Mälardalen har skillnader i klimat, jordart och markanvändning vilket innebär att det kan finnas skillnader i belastningen av fosfor och kväve, vilket i sin tur kan påverka retentionen. I projektet jämfördes även retentionen mellan de olika provtagningsomgångarna för att se säsongsvariationen. Vidare undersöktes även hur retentionen påverkas av olika faktorer i avrinningsområdena, såsom andelen av lera, sand och silt, andelen jordbruksmark, erosionsrisk och djup. Ytterligare en faktor som undersöktes är den hydrauliska belastningen, vilket innebär mängden vatten som kommer till våtmarken. Den är relaterad till våtmarkens storlek, samt hur den förhåller sig till avrinningsområdets storlek. Till exempel får en våtmark som är liten i förhållande till sitt avrinningsområde, en stor mängd vatten och hög hydraulisk belastning.

Resultaten för retentionen av fosfor visade att den generellt sett var relativt liten, under vissa säsonger släppte till och med vissa våtmarker ut en större mängd fosfor än vad som kom in.

Orsaken bakom detta kan vara att de tre provtagningsomgångarna skedde främst under höst och vinter, då det generellt sett är lägre retention. Det beror på att den större mängden inkommande vatten gör att vattnet hålls kvar i våtmarken under en kortare tid vilket leder till att det blir mindre tid för sedimentering. Mycket vatten kan även leda till resuspension av näringsämnen från sedimentet, vilket kan vara orsaken bakom de negativa retentionsvärden. Det kan även ha lett till att retentionen av fosfor visades ha ett negativt samband med lera och silt, vilket i tidigare studier visats ha ett positivt samband. Anledningen till att det tidigare visats ha ett positivt samband med retentionen är för att mer belastning av fosfor lett till mer retention, men under perioder med lägre retentionsförmåga skulle en högre belastning istället kunna leda till negativ retention. Vad gäller skillnader mellan Halland och Mälardalen kunde inga statistiska skillnader visas för retentionen. Vid betraktande av belastningen kunde det dock ses att den var mer varierad i Mälardalen. Det kan bero på att jordarterna i Mälardalen generellt sett är mer lätteroderade, vilket leder till att mer fosfor bundet till partiklar läcker ut när det blir mer avrinning. Fosforbelastningen visade sig vara större för de mest lätteroderade jordarna jämfört med de minst lätteroderade.

För kväveretentionen verkade den generellt sett vara mer positiv i Halland jämfört med Mälardalen, speciellt under den varmaste säsongen, augusti. Belastningen av kväve visade sig vara lägre under augusti jämfört med den säsongen med den högsta belastningen, februari. Trots det hade våtmarkerna i Halland generellt sett högre retention under denna tid, vilket antagligen beror på att det fortfarande var växtsäsong och den högre temperaturen gjorde denitrifikationsbakterierna mer aktiva. Faktorer som påverkade retentionen av kväve var bland annat djupet på våtmarken, där retentionen ökade ju grundare våtmarken är, vilket antagligen beror på att det ökar utbytet mellan det inkommande vattnet och sedimentet där denitrifikationen sker samt att temperaturen i vattnet blir högre.

ABBREVIATIONS

Aw:Ac: The ratio between the area of the constructed wetland and the catchment area.

CW: Constructed wetland

L:W: Ratio between the length and width of the constructed wetlands.

N: Nitrogen

P: Phosphorus

P-AL : Plant available phosphorus in soil, extracted with ammonium-lactate.

HL: Hydraulic load i.e., the amount of water the constructed wetland receives.

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1.INTRODUCTION

1.1 BACKGROUND

Nutrients are substances that are necessary for the growth of photosynthesizing organisms, especially macronutrients phosphorus (P) and nitrogen (N) (SMHI, 2021). P is often the limiting nutrient for freshwater bodies, such as lakes and rivers, while N is often the limiting nutrient for saltwater. In the Baltic Sea, which consists of brackish water, both P and N can be the limiting nutrient depending on the location. The coastal areas are often limited by P, while the open sea is limited by N. In Västerhavet, on the west coast of Sweden, the limiting nutrient is often N (Österling, 2007). Although nutrients are necessary for the ecosystems to function, too much nutrients can have detrimental effects. This is called eutrophication and causes various problems in aquatic environments, such as oxygen depletion and cyanobacterial blooms. These problems can in turn affect the organisms in the aquatic environments and the biodiversity. One of the Swedish environmental goals is no anthropogenic eutrophication. Although the measures that have been taken have had an effect on eutrophication, as of 2021 this goal has not been met. P needs to decrease with 510 tonnes per year to reach the goal of no eutrophication for freshwater lakes and rivers and 635 tonnes per year for coastal waters. For coastal water a decrease with 5 500 tonnes of N per year is also needed. The major decrease in nutrient emissions is needed from agricultural lands, which is the largest anthropogenic source of nutrients in Sweden (Naturvårdsverket, 2021). However, the reduction of emission of nutrients from agricultural point sources, such as a decrease of fertilizer usage, is complicated. This is because large amounts of nutrients can continue to leach from the soil for a long time after the use of fertilizer (Räike, 2019).

Constructed wetlands (CW:s) is one measure to mitigate the leaching of nutrients. When water enters the wetland, it slows down (EPA, 2004). This in turn allows for nutrient retention through various processes such as sedimentation, microbiological activity and uptake from plants and algae (Jordbruksverket, 2004). Wetlands provide many ecosystem services and can be constructed for different purposes besides nutrient retention, including enhanced biodiversity, flood-and drought prevention and recreation. During the years 2010 - 2020, 5 700 ha of wetlands were constructed or restored for different purposes with financial support from the Swedish government (Naturvårdsverket, 2021).

The effectiveness of the CW:s retention of nutrients can vary depending on different factors. Most of them are related to the nutrient load which is the amount of nutrients entering the wetland, as higher load generally leads to more retention (Land et.al, 2016). Important factors for the retention are the soil type, land use, season, and design. To optimize the retention, it is therefore important to know how these factors affect the retention to find the best placement when constructing wetlands for the removal of nutrients (Naturvårdsverket, 2009). This thesis is part of the research project WetKit (802-0083-19) financed by the Swedish Environmental Protection Agency, with the goal of optimizing the placement and design for the retention of nutrients in constructed wetlands while providing biodiversity and decreasing the release of greenhouse gasses from them (WetKit, no date). This thesis will focus on the retention of nutrients in wetlands and catchment factors affecting it by studying 40 wetlands.

1.2 AIM AND RESEARCH QUESTIONS

The aim of the project is to study the retention of the nutrients P and N in CW:s during different flow regimes and determine if there are variations in retention between seasons. Another aim is to investigate whether there are any differences in load and retention between the wetlands located in Halland, in south-western Sweden and Mälardalen in eastern Sweden. These locations differ in catchment factors such as soil type and climate.

The following research questions are to be answered:

- How much does the retention of P and N vary between the constructed wetlands in Halland and Mälardalen?
- How can the retention of P and N be linked to the following factors in the catchment area: the amount of clay, silt, and sand, share of agricultural land, mean slope of arable land, HL and P-AL?
- How does the retention of P and N differ between the seasons?
- How does the depth of wetlands affect nutrient retention?

2.THEORY

Described below are the mechanisms behind the retention of N and P and how different factors in the catchment area and the design can affect the retention.

2.1 NUTRIENT RETENTION

N can be retained in the CW:s through various processes, with different levels of permanency. N bound to particles or in organic form can sink to the sediment, however this is not permanent as it can be released to the water again. Permanent removal of N can occur through microbial process converting the N to gases. These include volatilization, which converts N to ammonium gas and denitrification. While the removal of N through volatilization is generally considered negligible, denitrification is an important process for the N retention in wetlands as the process rates are higher (Mendes, 2021). Through microbiological activity, nitrate (NO_3-) is reduced to nitrite and then nitrogen gas or nitrous oxide. The nitrogen gas is then eventually released to the atmosphere and thus it leaves the system (Jordbruksverket, 2004). The effectiveness of denitrification on the retention of N varies depending on several factors. One important factor for the removal of N through denitrification is the NO_3- load, where a higher load increases the removal rate. During colder seasons, the microbial activity decreases, which means less denitrification. However, during colder periods, there are often more organic materials flushed into the wetlands, which function as substrate for the microorganisms (Mendes, 2021). Another important factor for denitrification in wetland is the opportunity for microorganisms to reach the nutrients. Since the microorganisms that can do denitrification often live on plants or at the bottom of the wetland, the exchange of water between deeper and shallower parts is necessary for more effective denitrification (Jordbruksverket, 2004). Furthermore, the denitrification is enhanced by vegetation as plants can function as a growing location and source of carbon for denitrifying bacteria (Mendes, 2021).

Plants can also take up both N and P and use it to build up biomass during the growing season. However, when the plants wither some of the nutrients will be released back to the water. One way to remove the nutrients with plants is by harvesting the plants, which means that the nutrients are removed from the wetland. Another function of the plants is that it affects the water flow into the wetlands, so that it slows down. The roots also give stability to the sediment (Jordbruksverket, 2004).

Sedimentation is an important mechanism for the retention of particle bound phosphorus, PP. Most of the P that is retained in agricultural wetlands are retained as PP through sedimentation (Mendes et.al, 2018). P can be transported in dissolved form in water but is mainly transported bound to particles and in inorganic or organic form (Sanström et.al, 2020). Sedimentation is when the particles sink to the bottom of the wetland. The bigger the particle size, the faster and easier the sedimentation is. This means that particles originating from coarser soils such as gravel or sand sink faster. However, fine clay particles can form larger aggregates which can sink faster than separate clay particles. Even though sedimentation is mainly a mechanism for the retention of P, N in particulate organic form can also be retained through sedimentation (Lee et.al, 2009). However, this is not permanent as sediment can be resuspended from the bottom and be transported out of the wetland. The mineral complexes that bind P can also become saturated, meaning that P can no longer be adsorbed (Mendes, 2020). P can more easily adsorb to complexes in the soil particles compared to N, although it can also be resuspended when there is a high flow of water (Jordbruksverket, 2004). This sorption capacity of P also means that dissolved P can be retained in the CW:s through sorption to solids, which can then sink to the sediment (Mendes et.al, 2018). The stability of the P binding to the mineral complexes are enhanced by oxidizing conditions (Mendes, 2020). During anoxic conditions the change in redox can cause P bound to the sediment to be released in a process called internal loading (Jordbruksverket, 2004).

2.2 FACTORS AFFECTING NUTRIENT RETENTION

One important factor for both P and N is the nutrient load. Retention of nutrients increases with the higher nutrient load (Mendes, 2020, Mendes, 2021, Land, 2016). This means that the location of the wetland is important, since a CW located in an area with a high nutrient loading also will have a higher retention (Jordbruksverket, 2015). As a proxy for nutrient loading, the land use distribution in the catchment area can be used (Djodjic et.al, 2021). There is for example generally higher nutrient load when there is more agricultural land, as agriculture is a source of nutrients. The nutrient load is in turn dependent on the hydraulic load (HL), the amount of water entering the CW (Naturvårdsverket, 2009).

Soil type in the catchment area is another factor that affects the nutrient load since the losses of nutrients from the surrounding area varies depending on the characteristics of the soil. P load is enhanced by clay soils because the leaching increases. As PP is mainly released from the soil when there is macropore flow or surface runoff, easily eroded soils therefore also influence the leakage of P, where more easily eroded soils have a higher leakage. The leakage, however, is mainly during periods with high runoff, such as during spring flood or snowmelt (Johnson et.al, 2019). N load is enhanced by coarser soils such as loamy or sandy soils. This is because the N leaching decreases with higher share of clay and increases with loamy or sandy soils (Aronsson et.al, 2017). Another factor affecting the P leakage is the P content of the soil extracted with ammonium lactate (P-AL) (Fergusson, 2018).

Another factor that can influence the load of P into CW:s is the mean catchment slope. The slope can affect the load since a steeper slope leads to more runoff (Johannesson et.al, 2015). This mainly affects particle bound P (Johnson, 2016). Soils that have a poor infiltration capacity, such as clay soils and soils with a poor structure often have the higher nutrient leaking when there are steep slopes since there is more runoff from these types of soils (Aronsson et.al, 2017).

The nutrient retention also varies depending on the season. P leakage from the soil is generally more affected by extreme weather than N leakage (Aronsson et.al,2017) During periods with high flow, the loss of PP from the surrounding land becomes higher, resulting in a higher loading and retention of P (Kynkäänniemi et.al, 2014). However increased runoff during periods with high flows can also lead to the resuspension of nutrients in the sediment, which may make the wetland a temporary source of nutrients (Jordbruksverket, 2004). Periods with ice cover and low flow have also been shown to affect the retention of P negatively (Kynkäänniemi, 2014).

HL is related to the nutrient load and has been shown to affect the retention of P in wetlands, mainly for particle bound P. Since HL and the nutrient loading affects the retention of nutrients, CW:s should be placed where there is a lot of agriculture and water entering the wetland (Naturvårdsverket, 2009). As a proxy for HL, the wetland to catchment area ratio (Aw:Ac) can be used, as they are closely related (Djodjic et.al, 2020). Long term HL can be calculated using modeled runoff values for a larger catchment area and then fit it to the smaller catchment area of the CW. The HL can be calculated with the flow for a sub-catchment and fit it to the catchment area of the wetland (Fergusson, 2019).

2.3 WETLAND DESIGN

The hydraulic retention time, HRT, is the average time that the water stays in the CW and affects the nutrient retention. Almost all the processes for nutrient retention are enhanced by longer HRT, as the nutrients are available for these processes for a longer time. When the volume of the CW increases, the HRT becomes longer. This means that larger area and depth increases the HRT. However, if the wetland is too deep it takes longer for the particles to reach the bottom, which inhibits sedimentation. Also, if the water is too still it can lead to anoxic conditions and internal loading from the sediment (Jordbruksverket, 2004). Furthermore, to enhance the retention of both N and P the length to width ratio (LW) should be high, meaning the wetlands should be long and narrow. This causes the flow to become more evenly distributed over the CW, thus increasing its hydraulic efficiency. It also decreases the resuspension of settled material in the CW:s (Persson et.al, 1999).

CW:s can be specifically designed to retain P, so called P-wetlands. These wetlands often have a sedimentation zone at the inflow. This zone is deeper, which allows the water to slow down and the coarser particles to settle. Following this zone is a shallower zone (0.2-0.4 m) with plants that allows for further sedimentation of particles that have not sedimented in the sedimentation zone. Vegetation also decreases the amount of P that is resuspended because the plants' roots give structure to the sediment (Börling, 2010).

For the retention of N, the most optimal design are wetlands that are large and shallow that have a high amount of sunlight reaching the water surface (Börling, 2010). This enhances the denitrification in the wetland as it leads to more contact between the nutrient rich water entering the wetland and the vegetation and sediment where the denitrifying bacteria lives (Koskiaho et.al, 2003). However, since HRT is an important factor, the N retention in smaller CW:s could benefit from a deeper depth, particularly if it has a high hydraulic load (Mendes, 2021).

3. MATERIALS AND METHODS

3.1 SITE DESCRIPTIONS

In this project, a total of 40 wetlands were studied, 19 located in Halland and 21 in Mälardalen. Halland is located by the west coast of Sweden with a normal annual runoff of 400-500 mm (1961-1990) (SMHI,2017). Mälardalen, located near the coast of the Baltic Sea have a lower annual runoff (200-300 mm) (ibid.). All the wetlands in Halland and six in Mälardalen, were classified as ponds, while 15 were classified as P-wetlands in Mälardalen. All the wetlands had a similar length to width ratio (LW).

The geographical distribution and size of the catchment areas in Halland are represented in figure 1 and in Mälardalen in figure 2. Seven of the CWs (VA14a through g), were located close to each other in a chain. Water flowed from VA14g, which was most upstream of the CWs, to VA14f and so on to VA14a. Other connected CWs were EA16 and EA17, which were connected by a small stream from the outlet of EA16 to the inlet of EA17. BA4 and BA5 were also directly connected to each other through a pipe, where water from BA5 flowed into BA4. These CW:s also had overlapping catchment areas. There was also other CW:s in Halland that had overlapping catchment areas. VA5 were located downstream of VA14A-G. and EA16 had a catchment area that overlapped EA17 and EA18. The catchment areas varied between 20 ha for Sky and 1410 ha for Tor, both located in Mälardalen (Appendix, Table 5).

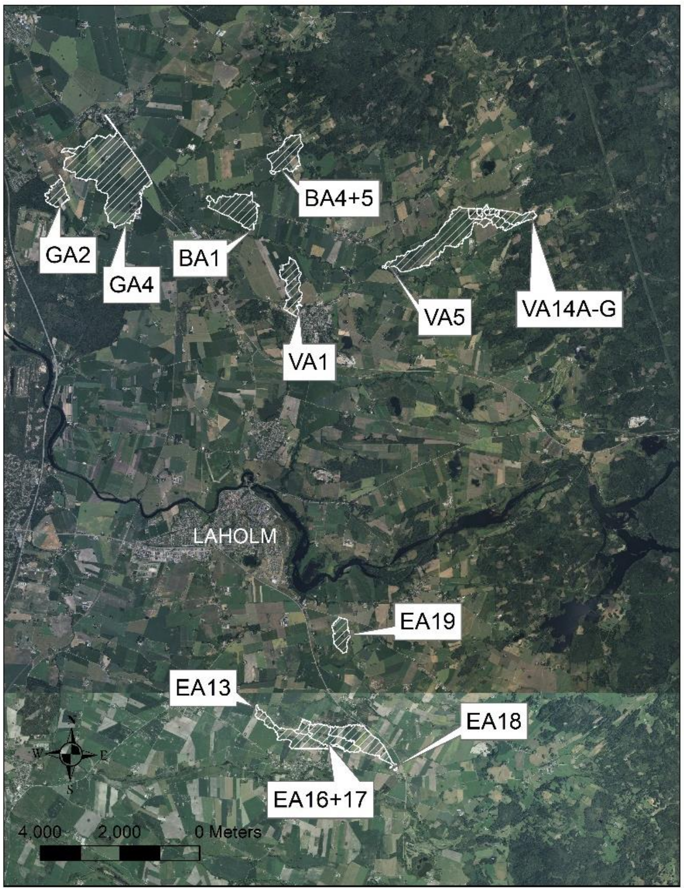

Figure 1: Shows the geographical distribution and size of the CW. s catchment areas in Halland. Background: Ortophoto 2019 and 2020, ©Lantmäteriet.

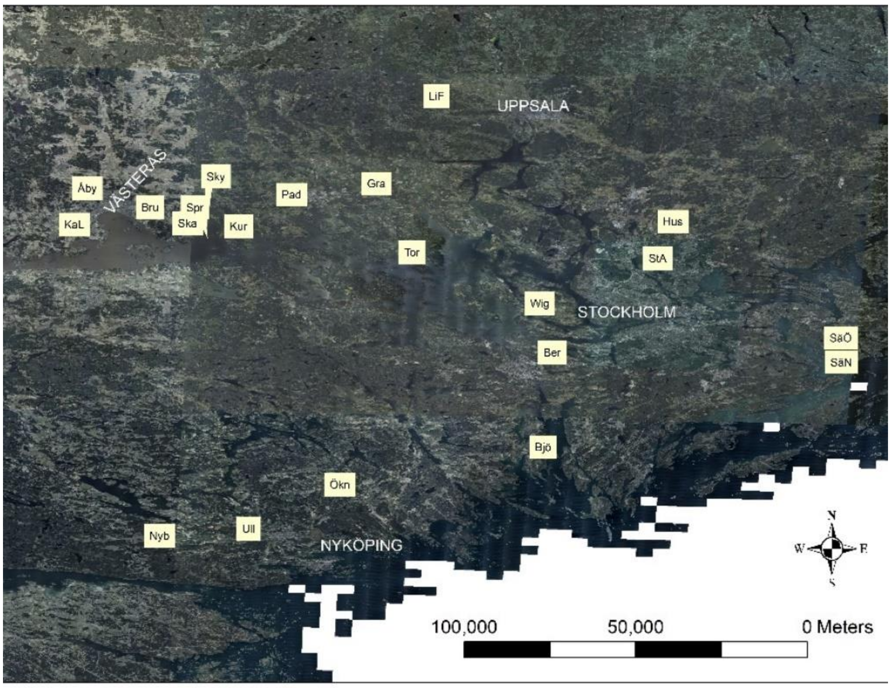

Figure 2: Shows the geographical distribution of the CW. s catchment areas in Mälardalen. Background: Orthophoto 2019 and 2020, ©Lantmäteriet.

The CW:s was in agricultural areas and often surrounded by fields or located near animal pastures. In Table 1 the shares of clay, silt and sand are represented. Share of clay in the catchment soils varied between 6.5% and 48%. In Halland, the clay contents in the catchment areas were lowest, varying between 7% and 11%. In Mälardalen, the variation in clay content was higher 32- 49%. The catchments of the wetlands south of Mälaren generally had lower clay content than the CW:s north of Mälaren. The share of sandy soils in the catchment areas had an opposite geographical distribution. In Table 1 it can also be seen that in Halland, the fraction of sandy soil was higher, ranging between 42 % and 75%, whereas the sand content in Mälardalen varied between 10 % and 41%. Silt content in the soil was slightly higher in Mälardalen than in Halland. In Mälardalen the silt content varied between 32 and 46%, whereas the silt content in Halland was between 17 and 34%.

Table 1: Soil characteristics, percentage of clay, silt and sand, erosion risk class, P-AL and mean slope of arable land. VA 1 to GA 4 are located in Halland, while LiF to Spr are located in Mälardalen.

CW	Clay (%)	Sand (%)	Silt (%)	Erosionsklass	P-AL (mg/100g)	Slope (deg)
VA 1	17	49	34	5	10.4	7.9
VA 5	9	68	22	5	10.0	8.7
VA 14A	9	65	26	7	10.0	9.7
VA 14B	9	64	26	7	10.0	8.7
VA 14C	10	64	27	7	10.0	8.3
VA 14D	10	63	27	7	10.0	9.6
VA 14E	10	63	27	7	10.0	9.1
VA 14F	10	63	27	7	10.0	8.5
VA 14G	10	63	27	7	10.0	7.8
VA14	9	65	26	7	10.0	9.7
EA 13	8	72	21	7	12.0	5.7
EA 16	7	75	19	7	12.0	5.6
EA 17	7	75	19	7	12.0	5.4
EA 18	7	74	20	7	12.0	4.2
EA 19	7	74	19	7	11.3	2.9
BA 1	16	54	30	6	9.8	3.8
BA 5	20	43	37	4	10.0	7.8
BA4	20	43	37	4	10.0	7.9
GA 2	8	75	17	7	9.7	6.9
GA 4	16	53	30	5	9.7	4.5
LiF	46	10	44	5	5.0	3.1
Tor	44	16	41	4	5.2	3.0
Gra	40	18	41	4	5.2	2.0
Kur	49	11	40	5	5.4	2.3
SäN	36	28	36	5	3.7	6.2
Wig	44	16	40	5	5.8	3.4
Åby	41	16	43	4	4.9	3.2
Ber	35	31	34	4	4.6	6.1
Bjö	45	15	40	3	5.3	6.3
Hus	41	18	40	4	4.9	2.9
StA	43	16	40	5	5.7	4.3
SäÖ	27	41	32	5	5.7	6.9
Nyb	36	18	46	3	5.2	3.6
Ull	34	47	20	3	5	5.7
Ökn	37	21	42	4	5.1	6.2
Pad	46	13	41	4	4.8	3.2
Bru	46	11	43	4	5.7	1.6
KaL	48	10	42	5	4.8	3.4
Sky	40	18	42	3	5.7	3.8
Skä	46	14	40	3	5.7	3.5
Spr	46	11	44	3	5.4	4.0

3.2 CATCHMENT AREAS

The CW:s in Mälardalen had catchment areas for the CW:s that had been delineated previously. In Halland, the catchment areas had to be calculated in ArcMap. The catchment areas were delineated by using pre-made rasters for flow accumulation and flow direction. Pour points for the calculation of the catchment areas were made by creating a new shapefile with points placed on the inlet and outlet of the wetland. The points were placed by using the flow accumulation file to locate where the inlet and outlet were located. Then, the pour points were converted to raster format using the tool *snap pour point.* By using the tool *watershed* catchment areas could be created from the pour points and the flow direction raster. To remove the area of the wetlands, the tool *erase* was used where the catchment areas were used as input and the wetlands as erase features.

3.3 ARABLE LAND

To determine the share of agricultural land in the catchment areas in Halland, blocks over the arable land were obtained from the Swedish Board of Agriculture. The data contained the blocks and information on the arable land, eligible for financial support in Sweden in 2021 (Jordbruksverket, 2021). In ArcMap, the tool *Intersect* was used with the inputs as the blocks with arable land and the catchment areas without the wetlands. With *Intersect* a new shapefile with the arable land in the catchment areas was created.

For Mälardalen, share of agricultural land was obtained from a previous study done by (Fergusson, 2019). One of these, LiF, was recalculated due to a difference in catchment area.

3.4 SOIL TYPE

Data for the characteristics of the soil of the arable land was obtained from the Swedish Geological Survey (SGU) from the digital arable soil map of Sweden (DSMS). The soil type maps were in tiff-format, with 50 m x 50 m grids. The data contained maps of the percentage of clay, sand, and silt in the topsoil of Swedish soils. The maps have been constructed using a combination of soil analysis and sensory data such as mapping with gamma radiation. Silt percentage has been calculated from the values for clay and sand (Söderström & Piiki, 2016).

To determine the soil types in the catchment areas, the tool *Zonal statistics as table* in ArcMap 10.8 was used to determine the mean values for the percentage of clay, sand, and silt.

3.5 P-AL IN SOIL

The map of the plant available P (P-AL) in the topsoil was in raster format with 10x10 km squares. Mapping was performed from results from extraction of P with ammonium-lactate with the unit mg /100 g. The raster had been constructed with moving median interpolation (Jordbruksverket, 2015b). To calculate the P-AL in the catchment areas, the *zonal statistics as table* tool was used the same way as for the soil type.

3.6 SOIL EROSION CLASS

A map of the soil erosion risk for the accumulated water flow was used to determine the erosion risk classes in the catchment areas. The map was divided into 7 risk classes, where the lowest erosion risk class was 7 and the highest 1 (Jordbruksverket, 2019). The erosion risk classes are for the worst-case scenario, during winter when there is less vegetation which means that the soils are more sensitive to erosion than during the vegetation period. The map had been created using elevation data from the Swedish mapping, cadastral and land registration authority, soil type data from the DSMS and runoff data (Djodjic & Markensten, no date).

Erosion classes for the catchment areas were determined in ArcMap by checking the erosion risk class at the inlet of the wetland, as the accumulation files show the normalized values for the area.

3.7 MEAN SLOPE OF ARABLE LAND

The mean catchment slope of the arable land was calculated by using the polygons created for determining the share of arable land in the catchment areas (section 3.3). The mean slope was calculated using a Digital Elevation Model (DEM) -file with 2x2 m resolution, obtained from the Swedish mapping, cadastral and land registration authority, with the tool *Slope* in ArcMap 10.8. To calculate the mean value of the slope in the catchment areas, the tool *zonal statistics as table* was used with the catchment areas as the input zones.

3.8 HYDRAULIC LOAD

The HL of the CW:s were modeled using runoff data from the Swedish Meteorological and Hydrological Institute (SMHI) for the sub-basin catchments where the CW:s were located. Flow data was based on modeling using the S-HYPE model (SMHI, 2021b). Data for the annual runoff in m^3/s between the earliest year, 2004 and 2021 was used to calculate a flow for each sub-basin catchment. The annual runoff in m^3/s was then converted to m^3/yr. To calculate the runoff for the smaller catchment area of the wetland, this runoff was multiplied by the ratio between the area of the sub-catchment and the catchment area of the wetland:

$$\mathrm{Qcw} = \frac{A_{SC}}{A_{cW}} \mathrm{QSC} \qquad (1)$$

Qcw= Runoff for wetland (m^3/yr)
Q_{SC} = Runoff for sub-basin (m^3/yr)
A_{SC} = sub-basin catchment area (m^2)
A_{CW} = CW catchment area (m^2)

The HL in m/yr could then be calculated by dividing the water flow for the wetland with the area of the wetland in ha.

3.9 WATER SAMPLING

Sampling took place during a total of two weeks during early February 2022. The first week (31/1-3/2) the sampling was for the CW:s in Halland and the second week (7/2-11/2) for Mälardalen.

During the sampling occasion in Halland, there was a thin ice cover on some of the CW:s, however the inlets and outlets were not frozen and there was a lot of water flowing. In Mälardalen the weather was colder and most of the CW:s had thick ice on the surface, but most had a free water surface by the inlet and outlet (Figure 3). One CW, Hus, had no flowing water out of the CW and was frozen solid near the outlet, therefore water samples were taken as close to the outlet as possible where there was water.

Water was sampled from the inlet and outlet from each CW, except for BA4 which was connected directly with BA5 through a pipe, therefore the outlet of BA5 could be considered to be the same as the inlet of BA4. The water was collected as closely to the inlet and outlet as possible, when there was a drainage pipe the samples were collected directly as the water flowed through the pipe. If a drainage pipe, ditch or stream could not be found the water was collected near the location of where the water should be flowing in or out of the wetland. The water was sampled in four different bottles, two 100 ml bottles and 250 ml bottles where each bottle was used for different analyses. Each bottle was rinsed with water from the CW and then filled with water and marked. At the end of each day, the samples were sent to the geochemical lab at SLU for analysis of TP, PO4-P-, TOC, TN, NO2-+NO3. During sampling, a sensor, HANNA HI 9829 which measured pH, redox, conductivity, water temperature and air pressure was used. Another sensor used, FluoroSense^{TM} handheld fluorometer, measured chlorophyll (Figure 4).

Figure 3: Different ice conditions during sampling in February. Left: The deep section of SäÖ in Mälardalen with ice cover. Middle: EA18 in Halland without ice cover. right: VA14A with a thin ice cover.

Figure 4: Materials used during sampling. Left: The four different sampling bottles. Right: Sensor used to measure pH, O_2, temperature etc. and the sensor used to measure chlorophyll.

From the water samples, measurements for P included phosphate (PO4-P-), total phosphorus (TP) in unfiltered water and TP in filtered water. The particulate P (PP) could be calculated as the difference between filtered TP and unfiltered TP. Some values for PO4-P and NH4-N were under the detection limit, which was 0,0004 for NH and 0,0003 for PO4-P.

For comparison between different seasons and flows, results from two earlier samplings were used. These had been sampled during August and November in Halland and during September and December in Mälardalen and the sampling had been conducted the same way as the sampling in February (Lundström, 2022).

3.10 NUTRIENT LOAD AND RETENTION

The retention of the different forms of N and P was defined in two ways.

Flow data from SMHI for the sub-basins was used and fitted to the CW:s smaller catchment area using equation (1), the same way as for the calculation of HL. The flow data used was from the day of sampling for each CW (SMHI, 2021b). Then, the load was calculated by multiplying the flow with the inlet concentration and then dividing it by the area of the CW to get a transport in mg month^{-1}m^{-2}. Thereafter, the difference between the concentration of nutrient in the outlet and in the inlet was multiplied by the flow for the CW on that day. The retention was then calculated according to two different calculations. Area-specific retention in mg month^{-1}m^{-2} was then calculated by dividing the difference with the CW area.

Relative retention in % was then calculated by dividing the retention with the load and multiplying it with 100.

3.11 STATISTICAL ANALYSIS

The statistical analyses were performed in Minitab. Firstly, the Ryan-joiner test were used to determine if the data was normally distributed. Since the data was found to not be normally distributed, the nonparametric Spearman correlation test was used to determine if the catchment factors were correlated with the retention and loading of nutrients.

To determine the differences between the load and retention between seasons and between Halland and Mälardalen, the one-way ANOVA test with the Tukey method was used. The test could be used although the data was not normally distributed because the sample size was larger than 20 (Minitab, 2015). The nonparametric Kruskal-Wallis's test was also used to compare the median values between the seasons and locations. For all the tests a confidence level of 95% was used.

4. RESULTS

Results represents water samples taken from 40 CW: s during three sampling periods. VA14A-VA14G was considered both individually and as one CW, which resulted in a total of 41 values for each sampling period. When considering differences with ANOVA the values from all seasons were considered, resulting in 123 values. The values for dissolved oxygen that was measured are represented in Appendix, Table 3.

4.1 NUTRIENT LOADING

4.1.1 P load

The loading of TP varied between seasons and CW:s. The highest TP load was for Sky, located in Mälardalen, during August/September with a load of 61 g TP $m^{-2}month^{-1}$ (Figure 5) two other CW:s in Mälardalen (Skä and Åby) also had especially high P loads during August/September, while SäN had high P load during February. In Halland, the highest TP load was for BA4 during February with a load of 10 g TP $m^{-2}month^{-1}$, which also had relatively high loads during the other sampling periods.

The TP load seemed to be generally higher and varied more in Mälardalen than in Halland. This resulted in that no statistical difference in mean values between Halland and Mälardalen could be found. The higher P load variations in Mälardalen between sampling periods (figure 5) could be related to the difference between erosion risk classes. In Halland BA4, BA5 and GA4 had generally higher loads than the other CW:s. This could also be related to the erosion risk as BA4 and BA5 also had a lower erosion risk class, meaning more easily erodible soils, than the other CW:s in Halland, with an erosion risk class of 4. Although the P load had no statistically significant difference between all erosion risk classes, it was found to be significantly different between the highest erosion risk class 7 and the lowest 3. GA4 had a relatively small catchment to area ratio (Aw:Ac) (0,13 %) compared to the other CW:s in Halland, only VA5 had a lower ratio (0.12 %). Furthermore, GA4 also had relatively low percentage of forest in the catchment area (Appendix, Figure 5). Silt and mean TP-load had a weak positive correlation (Table 2), but not between mean TP-load and the percentage of clay or sand in the catchment area.

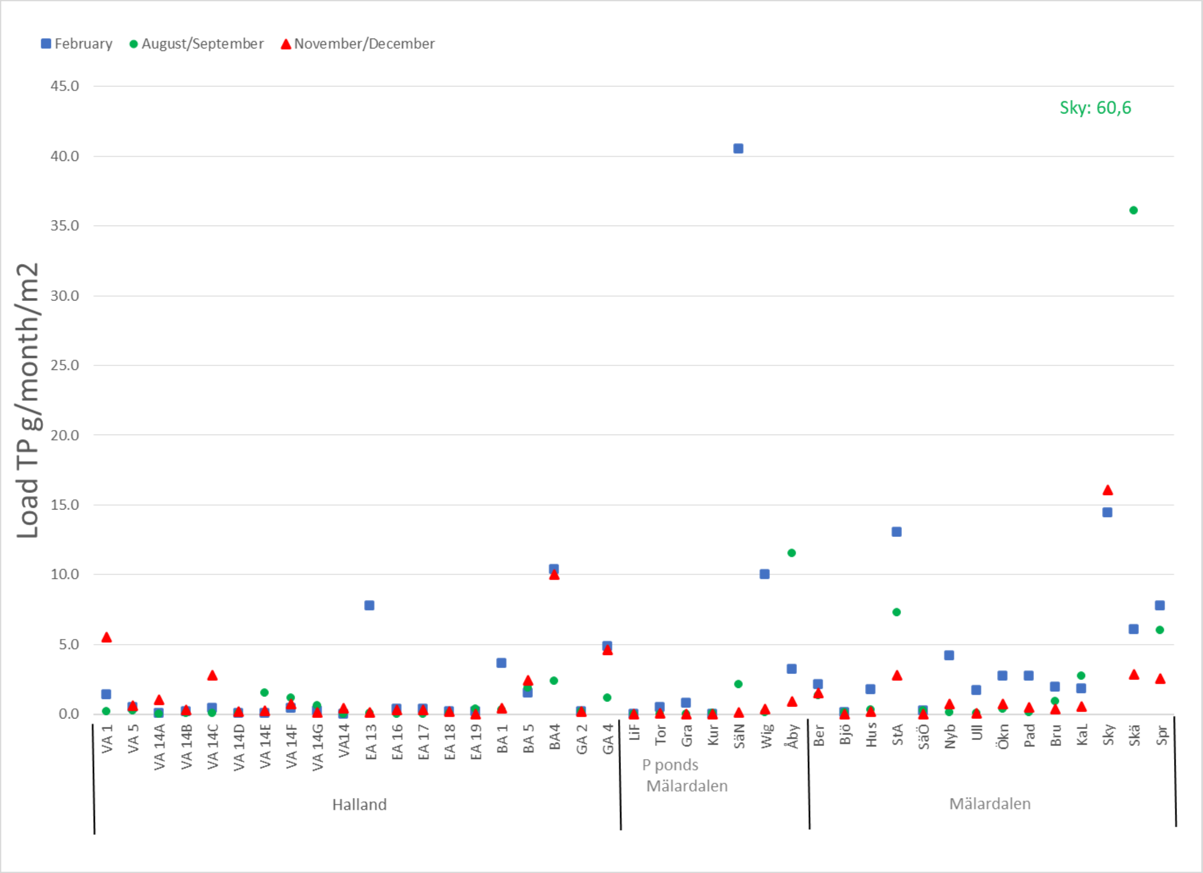

Figure 5: Loading of TP in g m^{-2} month^{-2} for the sampling in February (blue), November/December (red) and August/September (green) for the CW:s in Halland and Mälardalen. Outside the limits of the y-axis is the August/September TN load for Sky with a value of 60,6 g m^{-2} month^{-2}.

The load of PO4-P had a statistically significant higher mean value in Mälardalen (0.2 g m^{-2}month^{-1}) compared to Halland (0.04 g m^{-2}month^{-1}), the test had n = 123. It was positively correlated with clay and silt, while negatively correlated with sand (Table 2). Furthermore, PO4-P load also had a weak negative correlation with P-AL (Table 2).

Also, there was a positive correlation between HL and the mean load of all forms of P (Table 2).

4.1.2 N load

For TN, the highest load was 724 g TN m^{-2} month^{-1} for VA5 in Halland, during November/December. The highest TN load in Mälardalen was for Wig during February with a load of 347 g TN m^{-2} month^{-1} (Figure 6). There was no statistically significant difference in load between Halland and Mälardalen. However, there seems to be a higher TN load in Halland compared to Mälardalen, especially during November/December and February (figure 6). Generally, the TN load in August for Halland seemed to be lower than for the other two sampling periods, while in Mälardalen the loads varied more between seasons. This was also reflected in that there was a statistically significant higher TN load during February compared to August/September (number of samples, n =143). November/December was not statistically different from any of the other seasons (Figure 7). In Mälardalen, three CW:s, Sky, Skä and Åby had significantly high TN loads during August. CW: s in Halland with relatively high TN load during August were BA1, EA18-19, VA5 and GA4.

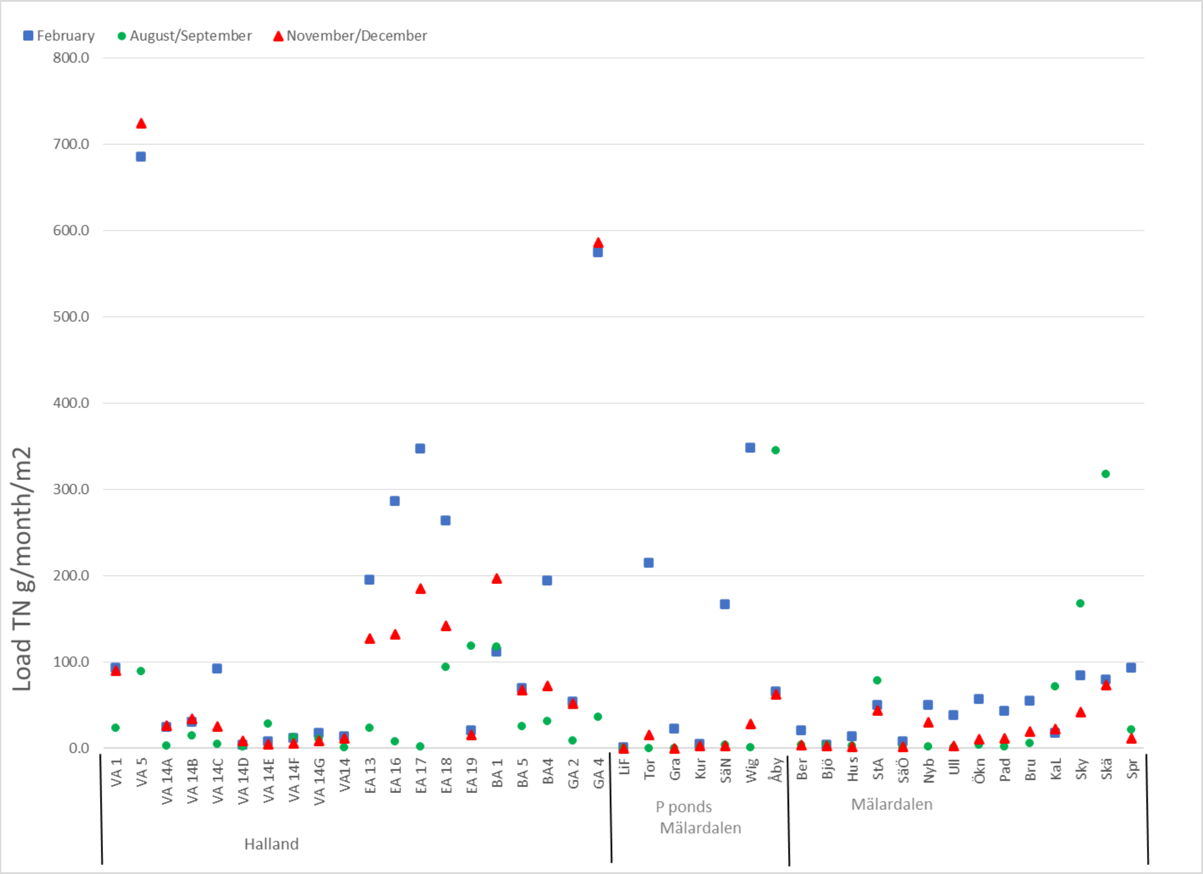

Figure 6: Loading of TN in g m^{-2} $month^{-2}$ for the sampling in February (blue), November/December (red) and August/September (green) for the CW:s in Halland and Mälardalen.

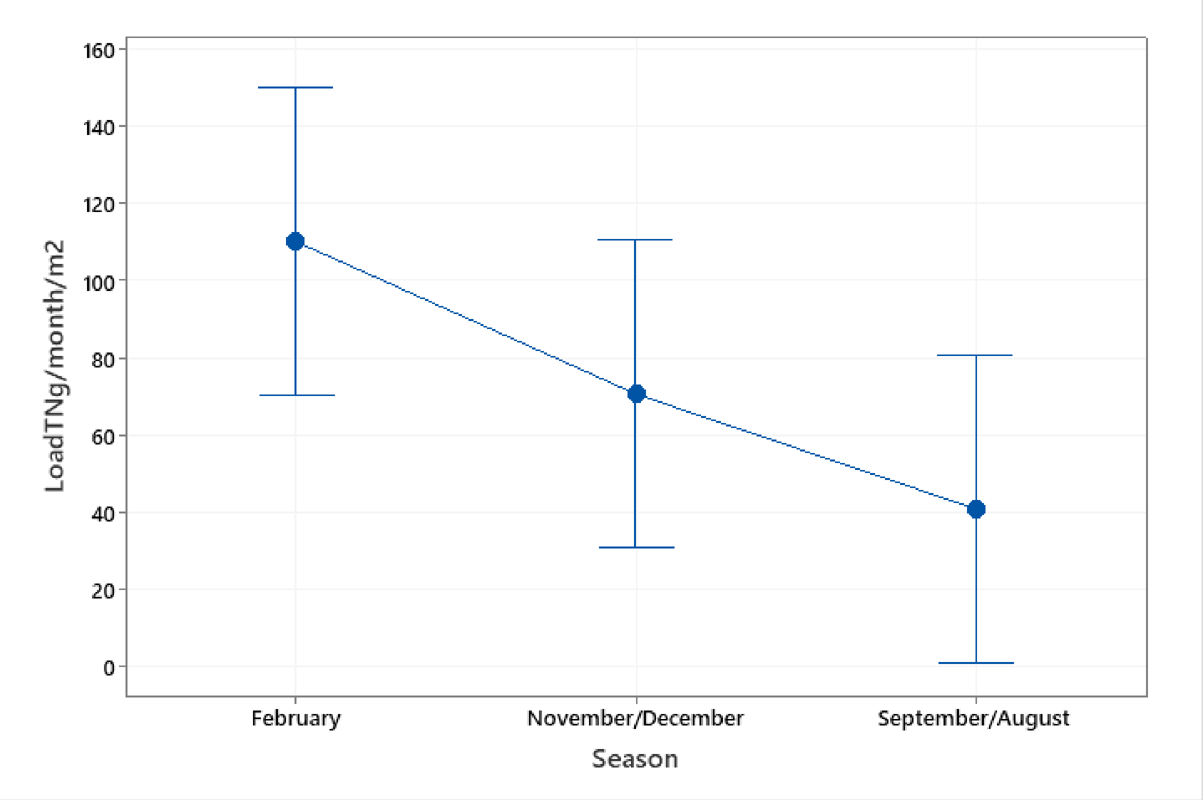

Figure 7: Individual value plot for the mean values of TN load during the three sampling occasions February, November/December, and September/August in Halland and Mälardalen, the number of samples, n = 143. The bars denote the intervals, calculated with pooled standard deviation.

Even though there was no statistical difference for the load of TN between Halland and Mälardalen, there was a statistical significance in mean NO2+NO3-N-N load between Halland (13,4 g month^{-1} m^{-2}) and Mälardalen (4,4 g month^{-1} m^{-2}) with the number of samples, n = 123.

TN loads for the sampling period in November/December had a positive correlation with sand (p-value 0.008, r^2 = 0.410) and negative correlations with clay (p-value 0.005, r^2 = -0.428) and silt (p-value 0.047, r^2 = -0,312). The mean load of NO2+NO3-N however had a negative correlation with clay and a positive with sand (Table 2).

Like for P there was a positive correlation between HL and the mean load of all N forms (Table 2).

Table 2: The p- and r^2-values for the statistically significant correlations with a confidence interval of 95%(p-value<0.05) for the mean values for the loads of the P and N forms. The variables without significant correlations are marked with -. For all correlations the number of samples, n = 41.

Mean value variable		**TP load (g/month/m^2)**	**TN load (g/month/m^2)**	**PP load (g/month/m^2)**	**PO4-P load (g/month/m^2)**	**NO2+NO3-N load(g/month/m2)**	**NH4-N load (g/month/m^2)**
Clay (%)	p-value	-	-	-	0.017	0.028	-
	r^2-value	-	-	-	0.372	-0.342	-
Sand (%)	p-value	-	-	-	0.017	0.036	-
	r^2-value	-	-	-	0.371	0.328	-
Silt (%)	p-value	0.016	-	-	0.025	<0.0001	-
	r^2-value	0.375	-	-	-0.351	0.603	-
P-AL	p-value	-	-	-	0.036	-	-
	r^2-value	-	-	-	-0.329	-	-
HL (m/yr)	p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
	r^2-value	0.641	0.717	0.603	0.685	0.680	0.564
Agricultural land (%)	p-value	-	0.042	-	0.036	0.016	-
	r^2-value	-	0.319	-	-0.329	0.373	-
Slope (deg)	p-value	-	-	-	-	-	-
	r^2-value	-	-	-	-	-	-

4.2 RETENTION

4.2.1 TP Retention

Most CW:s had an area specific retention of TP around zero or a negative retention, in KaL as much as -85 g month^{-1}m^{-2} was released (Figure 8). CW SäN had the highest area specific TP retention (39 g month^{-1}m^{-2}) during February, when also the TP load was highest (Figure 6). Furthermore, the CW:s in Mälardalen had more variations between CW:s and seasons, as both CW with the highest and lowest retention were located there. However, no significant difference for the area specific retention or relative retention of TP, PP nor PO4-P was found between Mälardalen and Halland. In Mälardalen, the P-ponds differed slightly from the CW:s as they did not have any large negative retention for any season, except for Åby, which had a negative retention of -10 g month^{-1}m^{-2} during February and -2 g month^{-1}m^{-2} during November/December (Figure 8).

There was no significant difference between TP retention and erosion class, location, or season. Neither was there a statistically significant correlation between the mean TP-load and retention. The only correlation between area specific retention and catchment factors was for the mean area specific TP retention that had a weak negative correlation with the percentage of clay in the catchment areas and with silt and a positive correlation with sand. The mean relative retention for PP showed a similar result. When considering the relative retention of TP there was the same correlation with the soil types (Table 2).

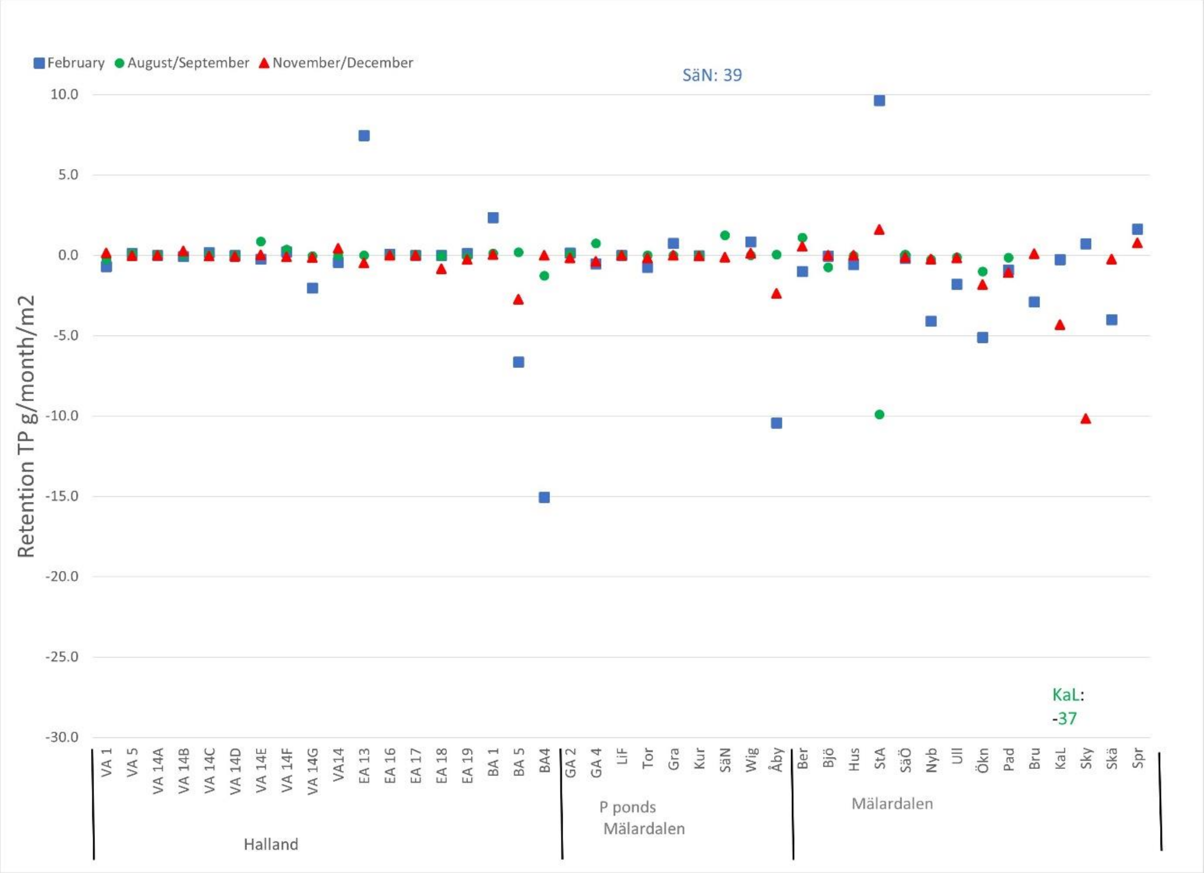

Figure 8: Area specific retention of TP in g m^{-2} *month*$^{-2}$ *for the sampling in February (blue), November/December (red) and August/September (green) for the CW:s in Halland and Mälardalen. The TP retention for SäN during February is above the limits for the y-axis with TP retention 39 g m*$^{-2}$ *month*$^{-2}$*. Likewise, the TP retention for KaL is below the limits for the y-axis with TP retention -37 g m*$^{-2}$ *month*$^{-2}$*.*

There was a positive correlation (p-value < 0.0001, $r = 0.630$) between the TP-load and TP retention during the sampling period in November/December of 2021. However, not during the other sampling periods. On the other hand, area specific retention of PO4-P was positively correlated to load (p-value 0.001, $r^2 = 0.480$).

HL showed a negative correlation with the mean area specific PP retention (Table 3). This means that the area specific PP retention decreased the higher the HL.

The percentage of agricultural land in the catchment area had a weak positive correlation with the mean area specific TP retention (Table 3), but not the load. PP had a similar result (table 2). PO4-P load had a weak negative correlation with agricultural land (Table 3).

Table 3: The p- and r^2-values for the statistically significant correlations with a confidence interval of 95%(p-value<0.05) for the mean values for the area specific and relative retention of the P and N forms with statistically significant correlations. The variables without significant correlations are marked with -. For all correlations the number of samples, n = 41.

Mean value variable		**TP retention (g/month/m^2)**	**TN retention (g/month/m^2)**	**PP retention (g/month/m^2)**	**TP relative retention (g/month/m^2)**	**TN relative retention (g/month/m2)**	**PP relative retention (g/month/m^2)**	**NH4-N relative retention (%)**
Clay (%)	p-value	0.021		0.02	-	-	0.013	0.05
	r^2-value	-0.359		-0.367	-	-	-0.391	-0.308
Sand (%)	p-value	0.017	-	0.02	-	-	0.013	0.038
	r^2-value	0.37	-	0.366	-	-	0.389	0.326
Silt (%)	p-value	0.008	-	0.011	-	-	0.024	0.015
	r^2-value	-0.48	-	-0.4	-	-	-0.356	-0.379
P-AL	p-value	-	-	-	-	-	0.037	-
	r^2-value	-	-	-	-	-	0.331	-
HL (m/yr)	p-value	-	-	0.003	-	-	0.033	-
	r^2-value	-	-	-0.46	-	-	-0.337	-
Agricultural land (%)	p-value		0.013	0.024	0.037		0.018	-
	r^2-value		0.389	-0.356	0.331		0.371	-
Mean Depth(m)	p-value	-	0.049	-	-	0.013	-	-
	r^2-value	-	-0.31	-	-	-0.383	-	-
Slope(deg)	p-value	-	-	-	-	-	-	-
	r^2-value	-	-	-	-	-	-	-

4.2.2 TN Retention

Figure 9 shows how the area specific TN retention varied, where many individual CW:s showed both positive and negative retention. Especially BA1 showed large variations in TN retention. The retention was relatively high during August/September (86 g month^{-1}m^{-2}), a retention just above zero during November/December (6 g month^{-1}m^{-2}), a relatively low retention during February (-77 g month^{-1}m^{-2}) (Figure 9).

All N forms had a positive correlation between the area specific retention and load. TN was only correlated in November/December (p -value 0,001, r = 0,492), while NO2+NO3-N (p -value 0,049, r = 0,309) and NH4-N was correlated between the mean values over the seasons as well (p-value 0,001, r^2 = 0.509).

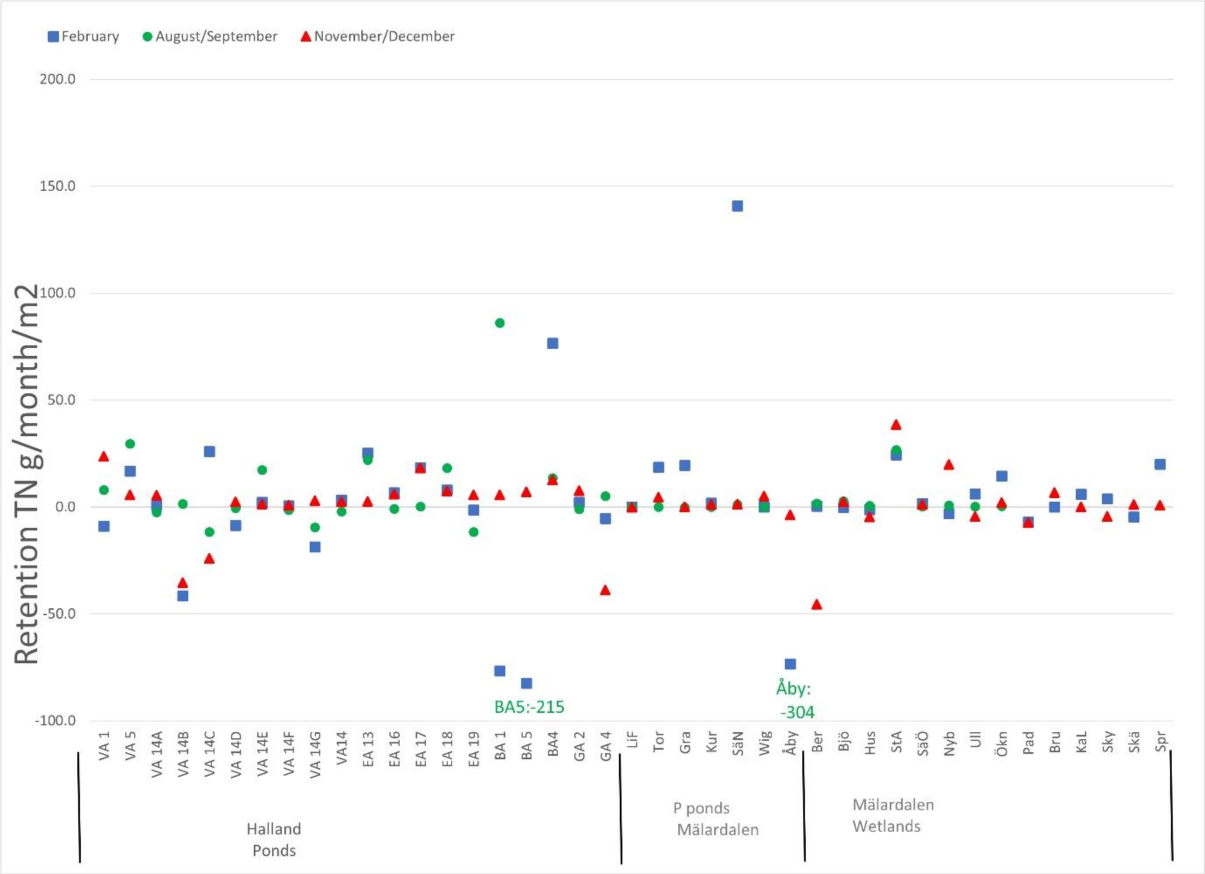

Figure 9: Area specific retention of TN in g m^{-2} month^{-2} for the sampling in February (blue), November/December (red) and August/September (green) for the CW: s in Halland and Mälardalen. The TN retention during August/September for BA5 and Åby were lower than the limits for the y-axis with TN retentions of -215 g m^{-2} month^{-2} and -304 g m^{-2} month^{-2} .

TN did not have any correlation between mean area specific retention or load or and any of the soil types (Table 3). However, the relative retention of NH4-N had a positive correlation with sand and a negative with clay and silt (Table 3, Figure 10).

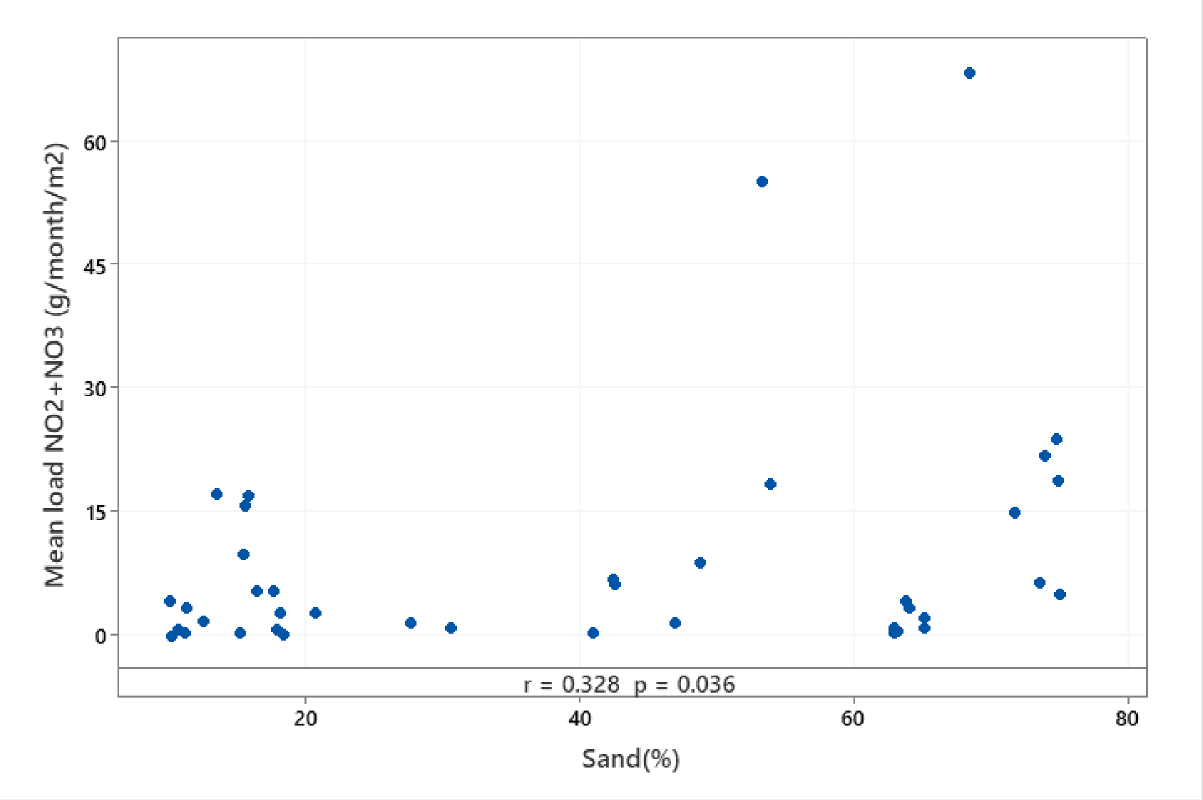

Figure 10: The mean area specific load of NO2+NO3-N plotted against the percentage of sand. At the bottom of the figure, the r^2 *value and the p- value is displayed.*

For the forms of N, the Area specific TN retention was not correlated with agricultural land, but the load had a weak positive correlation (Table 3). NO2+NO3-N retention did not have a correlation with the share of agricultural land, but with the load (Table 2). NH4-N did not have any correlation with retention or load and agriculture.

There was a weak negative correlation between the area specific retention of TN and mean depth of the CW: s (Table 3, Figure 11). However, when removing the outliers, BA5 and Åby there was no significant correlation (r^2 = -0.310, p= 0.061).

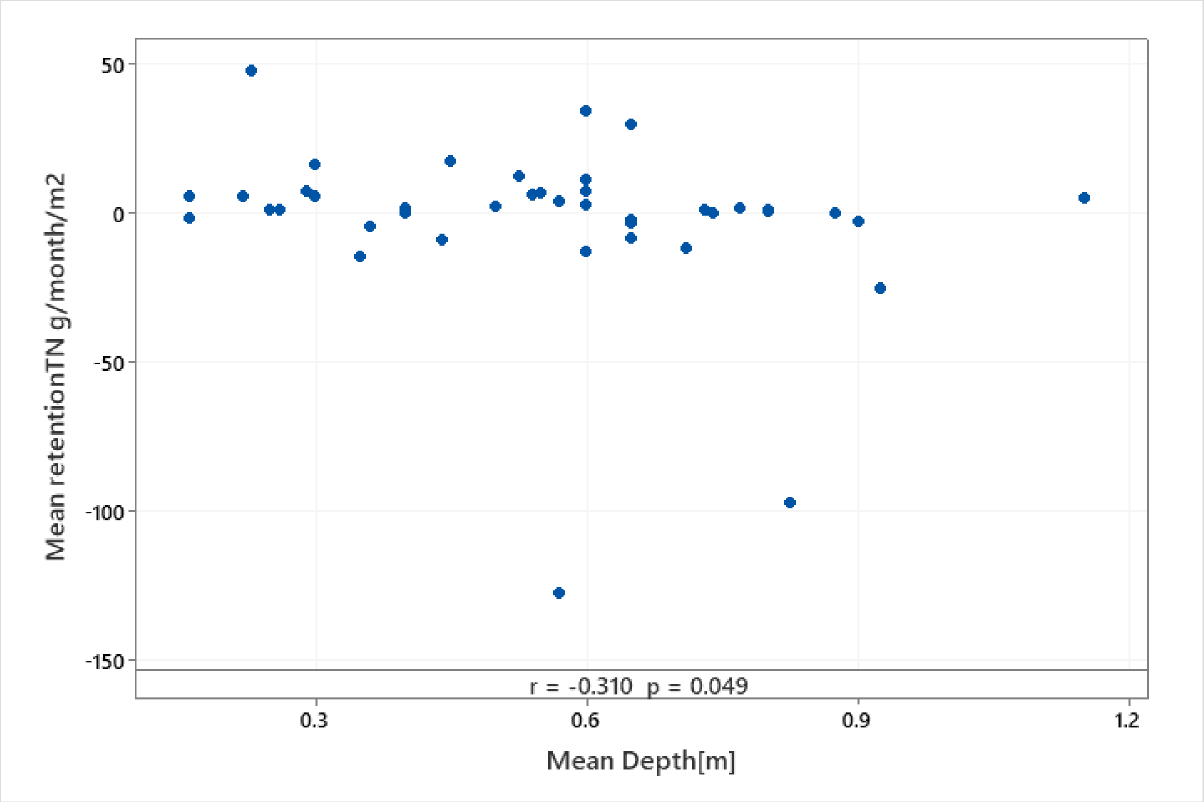

Figure 11: The mean area specific load of TN plotted against the mean depth of the CW:s. At the bottom of the figure, the r^2 *value and the p- value are displayed.*

5. DISCUSSION

5.1 VARIATIONS IN LOAD BETWEEN REGIONS AND SEASONS

The CW:s in this study were chosen to represent two regions, Halland and Mälardalen with differences in climate and soil type, and possible differences in load of P and N. As there is generally more clay content and easily erodible soils in Mälardalen than in Halland, which usually leads to more P load it could be expected that the P load should have been higher in Mälardalen. In this study the TP load seemed generally higher in Mälardalen and the load of TN higher in Halland when considering figures 5 and 6, although there were large variations between CW:s and sampling periods hence not a statistically difference. Previously, the areas in southern and western Sweden have been found to have higher losses of N compared to other areas in Sweden due to less amount of clay and more intensive farming (Johnson et.al, 2016). In the same study, the losses of P were found to increase with more clay and with more runoff. The Mälardalen region had relatively high P losses due to the high amount of clay in the region, while in the region where Halland is located there was also relatively high losses of P due to the large runoff in the region (Johnson et.al, 2016). During the samplings for this study, Halland had generally lower flow (Appendix, Table 4). This could also be the reason why no significant difference in mean values was found for TP. The long-term HL was found to have the strongest positive correlation with the load of all forms of N and P.

Furthermore, there were differences between the seasons. The mean TN load was significantly lower during August/September compared to the highest load in February. Since there is generally less precipitation and warmer weather during summer, leading to less runoff it is reasonable that the loads are lower during August/September. Looking at Table 4 in appendix, the flow during the August/September sampling period was lower than the other sampling periods. This was mainly for the flows in Halland which was sampled earlier than Mälardalen. There was no significant difference in seasonal TP load, as it varied between individual CW:s during each sampling occasion (see Figure 5). The TP losses are generally more affected by runoff and extreme weather events, causing erosion, compared to N and is therefore more affected by periods with high runoff (Johnson et.al, 2016). This could have resulted in local differences in weather and runoff having a greater effect on the TP load, leading to larger variations which in turn led to no statistically significant differences. There was a positive correlation with clay and TP load during February and August/September, although there was only a significant difference in TP load between the lowest erosion risk class and the highest, this still suggests that more easily erodible soils led to a higher P load. This could also explain the seemingly higher variations in TP load in Mälardalen, as more soil is eroded during periods with high runoff (Johnson et.al, 2019, Braskerud et.al, 2000). Furthermore, two CW:s in Halland (BA4 and BA5) had higher TP loads compared to the other CW:s in Halland during all three sampling periods, these two CW:s also had lower erosion risk class in the catchment areas (Table 3).

The load of another form of P, PO4-P, was positively correlated with silt and clay and negatively correlated with sand. Furthermore, PO4-P also had a positive correlation with P-AL in the soil. It has previously been shown that the higher amount of P-AL in the soil, the more dissolved P is released from the soils (Djodjic et.al, 2017). This should mean that a higher amount of P-AL should lead to higher load and possibly retention. The reason why this study showed different results could be because the soils in Halland generally had higher P-AL content, while having lower load of PO4-P likely due to the lower clay content. In other words, the P-AL content might not have had a great effect on the PO4-P load in this study, while other factors such as the amount of clay and erosion risk class had greater effect. Another possible explanation can be differences in pH in the soil between Halland and Mälardalen. The adsorption of PO4 to the soil can decrease with the pH, which could lead to more leakage of PO4 (Bowden, 1980).

Like for TP, there was no statistically significant difference in TN load between regions, but in figure 6 there still seemed to be higher TN loads in Halland especially during November/December and February. The reason for this could be the lower share of clay and higher share of sand, however there was only a correlation for the soil types during the sampling period in November/December. In contrast, the soluble NO2+NO3-N load was significantly higher in Halland than in Mälardalen, but not NH4-N. In previous studies on CW:s in agricultural areas, the main form of N entering the CW:s has been NO_3^- (Braskerud et.al, 2002, Braskerud et.al 2000, Koskiaho, 2003). It has also been shown that N is mainly leaching from the soil in the form of NO_3^-, as the positive charge of NH_4^+ ions mean that they adsorb to the soil particles easier (Kyllmar, 2019). The reason why NO2+NO3-N was the only form of N that had a difference in load for Halland and Mälardalen could be because it is the main form of N and differences between the locations such as the soil types could mainly affect NO3. Although there was no significant correlation between the soil types and the mean NO2+NO3-N load, there was a positive correlation with sand content and a negative correlation with clay content for the sampling occasions in February and November/December.

The reason why some CW:s in Mälardalen had higher TN loads during August/September could be because the sampling took place a couple of weeks later compared to Halland, which could have meant that the fall season with more runoff had started.

Long term mean HL was found to be correlated with both P and N loads. However, since flow data used to calculate the N and P loads were from the similar data and had been calculated using the S-HYPE model the correlation could have been due to this relation.

5.2 RETENTION VARIATIONS AND RELATION TO LOAD AND OTHER FACTORS

5.2.1 P Retention

The TP retention was found to be generally low for most of the CW:s (zero), as seen in figure 8. A few, especially in Mälardalen had high negative retention during August/September, but some also had negative retention during the other sampling periods. Regarding the geographical differences in TP retention, in Halland the retention values was more often closer to zero compared to Mälardalen even though many of the CW:s in Mälardalen had negative retention (figure 8). This could be related to the higher loads in Mälardalen, as a higher load and poor retention capacity could have led to more negative retention compared to Halland where there was lower TP load. As previously mentioned, periods with high runoff generally leads to more load and retention. However, the increased HL can also lead to a short retention time and less time for retention mechanisms such as sedimentation to take place (Johannesson et.al, 2016). There is also risk of resuspension of P from the soils (Jordbruksverket, 2004). While this study found no correlation between TP load and retention, there are other results that suggests that during the sampling periods, the CW:s had poor retention resulting in higher loads leading to less retention. As mentioned previously, a higher amount of clay leads to more leakage of P and higher loads, which was also found for two of the sampling periods. However, for the mean area specific retention, there was an opposite relation with a negative correlation with clay and a positive with sand. This could be due to different factors. Resuspension is one possible reason. The study on Finnish CW:s found that there was a release of solids, which is usually the main transportation for P in agricultural areas, during flooding in October as there was no protective vegetation (Koskiaho, 2003). As sedimentation of P to the sediment is an important mechanism for the retention of P, resuspension could lead to the CW release of P and negative retention. Like with N, it also found that there was a release of dissolved P during the same period, suspected to be due to the decay and subsequent release of nutrients from plants (Koskiaho, 2003). Since the samplings for this project took place during late summer, fall and winter these factors could have affected the P retention in the studied CW:s. Other factors for example the Aw:Ac (related to HL), could also be a reason to the poor TP retention as the CW:s in Mälardalen generally had lower Aw:Ac ratio meaning smaller CW areas compared to the catchment areas (see Appendix, Table 2). However, the differences are not very large, which might not have had a large effect on the TP retention.

Another possible explanation for the negative P retention is internal loading of P. This can occur during anoxic conditions when the change in pH causes P bound to mineral complexes in sediment to be released (Jordbruksverket, 2004). Periods with ice cover and low flow can lead to anoxic conditions (Kynkäänniemi, 2012) and previous studies have shown that during these periods there can be negative retention (Kynkäänniemi, 2014). Since negative retention due to resuspension mostly occurs during periods with high HL, internal loading could be a possible explanation for the negative TP retention during the February sampling period in Mälardalen where there were generally lower flows and thick ice covers. It could also be the cause of the negative retention during August/September due to summer stratification. Dissolved oxygen was measured, the values could however not explain the negative retention as they were not found to be significantly lower by the outlet in CW:s with high negative retention (Appendix, Table 3). However, the oxygen values were only measured by the inlet and outlet and the release of P from the sediment could have occurred at a different location in the CW and been transported to the outlet.

HRT has previously been found to be a factor for the retention (Mendes, 2020)), the HRT in turn becomes higher the deeper the CW is. In this study, no correlation between the mean depth and the retention of nutrients was found. One possible reason could be that, depth also decreases the contact between the incoming water and the bottom where processes such as denitrification and P adsorption occur (Koskiaho, 2003). Another study on P has shown that sediment accumulation, which is an indicator of PP settling, was higher in the deeper sections of the P-wetlands (Kynkäänniemi, 2014). However, this considered the sections and not the mean depth of the entire CW. This could be another reason as the mean depth of the entire CW was considered in this study and not the deep parts.

5.2.2 N Retention

In figure 9, the area specific TN retention showed slightly different results compared to TP. Despite the relatively low TN loads during August/September, the highest area specific retention values were for August, with BA1 and VA5 having especially high TN retention (figure 9). A higher nutrient load usually leads to more retention of both P and N (Jordbruksverket, 2004). The results from this study showed differing results regarding the relation between load and retention. TN increased with the load, however only during November/December. High TN retention during August/September despite the lower loads could be because the most important process for the retention of N is denitrification. Denitrification decreases with the temperature due to the denitrifying microorganisms becoming less active (Koskiaho,2003, Jordbruksverket, 2004). This could explain why the TN retention was higher since August was the warmest sampling period. Furthermore, since it was late summer, it could still have been more vegetation that could have taken up N and used as a carbon source for the denitrifying bacteria.

As seen in figure 6 the TN loads were generally higher during the sampling periods in November/December and February. Concerning the retention, although it varied, a few CW:s had high retention while some had negative retention during these periods. GA4 for example, had nearly six times higher TN load in February (574 g month^{-1}m^{-2}) and November/December (586 g month^{-1}m^{-2}) than in August (36 g month^{-1}m^{-2}), however it only had a positive retention during August (5 g month^{-1}m^{-2}). Furthermore, BA5 strongly deviated from the other CW:s during August, as it had a large negative retention (figure 9). The water that enters BA5 flows directly into BA4, which had a large positive retention. BA5 could have had large values in August because both CW:s are needed for the retention as BA5 receives more water and nutrients than BA4, but is too small to retain any N. The water then has more time to slow down in BA5 before it enters BA4. When the water then enters BA4 most of the retention can then occur. Apart from BA5, also Åby in Mälardalen had an exceptionally large negative retention during August/September (figure 9). A previous study on Finnish CW:s found that many of them released dissolved N during October, when the plants wither and release the previously stored nutrients (Koskiaho, 2003). This could possibly be the reason why for example Åby and other CW:s in Mälardalen had large negative retention as the sampling took place later than in Halland when the plants might have started to wither. During February and November/December plants are usually withered and denitrifying microorganisms is often less active during colder seasons which leads to less denitrification (Koskiaho, 2003). This could explain the negative retention during these periods in some CW:s in this study.

Some CW:s, especially in Halland, instead had relatively high area specific TN retention during the colder sampling periods, November/December, and February as well. This could be because of sedimentation. In a study on four small CW:s in Norway, sedimentation was found to be the most important process for the retention of N, where the retention of org-N was highest. It found that the retention of inorganic N decreased during periods with increased HL. However, when considering the organic particles with org N, the retention increased with increasing HL. This may have been because higher HL associated with periods of increased runoff erodes larger soil particles. Sedimentation increases with larger particles, which means that more N bound to organic particles could be retained in the CW:s despite the increased flow (Braskerud et.al, 2002). For BA4, VA1 and VA5 especially this could be possible since the erosion classes for these CW:s were lower compared to the other CW:s in Halland. During the periods with high HL, sedimentation was found to be the most important factor, since the lower temperature decreased the denitrification (ibid.). There had been a storm just before the sampling in February, which could have led to a lot of erosion and more sedimentation of N. Concerning the denitrification, it is also enhanced by anoxic conditions (Jordbruksverket, 2004). Periods with ice cover can lead to anoxic conditions (Kynkäänniemi, 2012). This could explain the results during February as the TN retention was slightly higher in Mälardalen compared to Halland. In Mälardalen, the ice covers were generally thicker compared to Halland. The anoxic conditions could also be a reason for the relatively high TN retention during the colder periods and why NO2+NO3-N had a positive correlation between load and retention despite two colder sampling periods.

A factor that was shown to affect the retention of TN was the depth of the CW:s, because this increases the HRT. The retention of N through denitrification is generally enhanced with shallower CW:s, because the exchange between incoming substrate rich water and the denitrifying bacteria in the sediment becomes larger. Also, the water temperature can become higher. Retention of inorganic N and P through plant uptake is also generally larger with shallower depths since it is easier for the plants to establish (Jordbruksverket, 2004). In this study the mean area specific retention of TN was found to have a weak negative correlation to the depth. When two outliers, BA5 and Åby was removed, there was however a negative non-significant correlation. Although there was no correlation when the outliers were removed, this could still indicate that the retention of TN decreases with depth due to the mentioned reasons.

5.3 METHOD UNCERTAINTIES

The water samples that were taken directly from the inlet or outlet which was mostly a pipe but in some cases a ditch or stream. However, for some CW:s the water samples could not be taken directly from drainage pipes due to difficulties in access or ice covers, which meant that samples were taken from further into the CW:s. The most extreme example was Hus, that had become frozen to the bottom near the outflow, which meant that the samples had to be collected at the nearest place where there was enough water. Another uncertainty is that there could have been subsurface drainage pipes, which could not be seen. This meant that water transporting nutrients could have entered the CW where there could not be any sampling.

Another uncertainty lies in the water sampling method itself. The method used is commonly called grab sampling, where only one sample was taken in each location. In a previous study, flow-proportional water sampling of P has been shown to be superior to grab sampling. When using grab samples, the difference between the inflow and outflow of P in a Swedish CW was shown to be lower than when flow-proportional sampling was used for the inlet (Kynkäänniemi, 2014c). With flow proportional sampling, extreme flow events that effects the load and retention can be detected, especially P that is more effected by extreme flow events. This could mean that the P retention calculated based on grab sampling could have been under- or overestimated in this study, as it could not have detected extreme flow events like for example the storm in Halland in February. This could have affected the correlation with factors in the catchment area and CW:s. It could also have affected the assessment of seasonal variations since flow variations could not be captured accurately. However, this study was conducted on 40 CW:s where samples were taken during a short period of time and did not investigate the retention variations for CW:s. The sampling method used could be sufficient when considering this purpose. When considering the scale of this project, it would not have been realistic to set up the apparatus for flow proportional sampling for all 40 CW:s sampled. The investigation of seasonal differences might have benefitted from flow-proportional sampling since there were local differences in weather and flow which lead to differences in retention. By comparing flow proportional samples there could have been a more exact comparison of flow regimes.

There are also uncertainties related to the flow through the CW:s. For the calculation of flow to the CW:s for the calculation of nutrient load and retention, flow data from larger catchment areas from SMHI was used and the flow fitted to the smaller area of the CW:s catchment areas. This could lead to errors in flow to the CW:s and consequently the load and retention since there might be local differences between the amount of flow in the catchment areas. Furthermore, when calculating the nutrient load and the nutrient exiting the CW, water flow in and out of the CW was assumed to be the same. This could have had an effect mainly on the retention values since the differences in flow could influence the amount of nutrients entering and exiting the CW. This could also affect the correlations between load and retention, since they are both related to the flow.

In this study, the share of agricultural land was examined as a possible factor affecting retention. However, there was no further information on the agricultural land except for if it was pasture. There was for example no information on the number of animals, what kind of animals or what type of crops there were. Since these are factors that could have affected the leakage and thus load and retention (Johnsson et.al, 2019) factors could have been missed in this study.

CONCLUSIONS

The aim of this project was to get a better understanding of nutrient retention and the factors affecting it. When considering the results, the purpose could be considered fulfilled. The following conclusions could be drawn from the results obtained:

- The retention of P and N did not show significant differences in retention between the two regions, Halland and Mälardalen. However, the N loads was higher in Halland, and P load was higher in Mälardalen.
- Factors in the catchment area that mainly affect the retention of P are the share of clay, silt and sand and share of agricultural land. The load was also affected by the erosion risk class. Going by these results, to optimize the P retention, CW:s should be located where there is high share of agricultural land and low percentage of clay however this could be because of the seasons that the samplings were conducted. The retention of N was higher during the warmer period in August despite lower loads. Retention of P was often negative, especially during periods with high runoff. However, this could be because of the seasons for sampling and that the CW:s, especially in Mälardalen had low Aw:Ac ratio. It could also be because the sampling

method used did not capture large flow events or that the same flow was used for both the inlet and outlet. Furthermore, N retention was correlated to the load, which in turn is affected mainly by the HL, share of agricultural land and the share of clay and sand. To optimize the N retention CW:s should have a low HL and percentage of clay and a high percentage of sand in the catchment areas.

- Lower mean depth seems to have a positive effect on the retention of N; however, the retention of P was not affected by depth. According to this study, to optimize the retention of N the CW:s should be shallower. However, there could be a minimum depth for the N retention which could not have been detected in this study, which should be considered.

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APPENDIX

Table 1: The TP retention during the sampling periods.

	February		August/September		November/ December	
CW	Retention (g/month/m2)					
	TN	TP	TN	TP	TN	TP
VA 1	-8.9	-0.7	8.0	-0.45	23.7	0.14
VA 5	16.8	0.11	29.5	0.1	5.7	-0.03
VA 14A	0.9	0.01	-2.4	0	5.4	0
VA 14B	-41.5	-0.06	1.5	0.01	-35.4	0.26
VA 14C	25.9	0.18	-11.7	0.02	-24.0	-0.05
VA 14D	-8.6	-0.01	-0.5	-0.01	2.5	-0.07
VA 14E	2.2	-0.24	17.4	0.33	1.4	0.02
VA 14F	0.6	0.22	-1.4	0.01	0.7	-0.09
VA 14G	-18.6	-2.04	-9.4	-0.02	2.9	-0.14
VA14	3.3	-0.44	-2.0	0.02	2.3	0.43
EA 13	25.3	7.45	22.1	0	2.5	-0.49
EA 16	6.7	0.07	-0.8	-0.02	5.9	0.01
EA 17	18.5	0.01	0.3	0	18.3	0
EA 18	8.0	-0.01	18.3	-0.02	7.4	-0.85
EA 19	-1.3	0.12	-11.6	-0.04	5.6	-0.26
BA 1	-76.6	2.36	86.1	0.26	5.6	0.04
BA 5	-82.4	-6.65	-215.2	0.47	7.1	-2.74
BA4	76.6	-15.06	13.6	-7.54	12.7	0
GA 2	2.3	0.15	-1.0	0.22	7.6	-0.16
GA 4	-5.3	-0.53	5.0	2.33	-38.8	-0.37
LiF	0.0	0	0.0	0	0.0	0
Tor	18.7	-0.75	0.0	0.01	4.6	-0.17
Gra	19.6	0.75	0.0	-0.02	0.0	0
Kur	2.0	-0.02	0.1	0	1.1	-0.06
SäN	140.9	39.04	1.1	1.61	1.4	-0.13
Ber	0.0	-1.01	0.0	0.48	5.2	0.55
Bjö	-73.4	-0.05	-304.4	-0.03	-3.6	-0.01
Hus	0.4	-0.57	1.8	-0.02	-45.5	0
StA	-0.1	9.63	2.8	-18.6	2.4	1.61
SäÖ	-1.2	-0.19	0.5	0.08	-4.6	-0.12
Wig	24.4	0.83	26.8	0.03	38.7	0.13
Nyb	1.8	-4.1	0.2	-6.53	1.1	-0.24
Ull	-2.9	-1.79	0.7	-0.23	19.9	-0.16
Ökn	6.3	-5.1	0.3	-23.62	-4.3	-1.82
Pad	14.5	-0.92	0.4	-0.34	2.1	-1.08
Bru	-7.0	-2.89	0.5	0.64	-7.2	0.11
KaL	0.0	-0.27	0.8	-85.06	6.7	-4.31
Sky	6.0	0.71	-31.8	0	0.0	-10.15
Skä	3.8	-4	1.1	0.2	-4.5	-0.24
Spr	-4.6	1.62	-31.5	-0.09	1.2	0.78
Åby	20.0	-10.43	-2.9	0.21	0.8	-2.36

Table 2: The mean depth, HL and the areas for the catchment areas and CW areas in ha. The Aw:Ac ratio is also showed.

CW	Mean Depth[m]	HL(m/yr)	ARO (ha)	CW area(ha)	Aw: Ac (%)
VA 1	0.6	74	48	0.3	0.7
VA 5	0.5	471	176	0.2	0.1
VA 14A	0.8	21	51	1.2	2.3
VA 14B	0.9	74	45	0.3	0.7
VA 14C	0.7	172	43	0.1	0.3
VA 14D	0.7	32	26	0.4	1.6
VA 14E	0.6	40	25	0.3	1.2
VA 14F	0.9	56	23	0.2	0.9
VA 14G	0.7	47	21	0.2	1.1
VA14	0.7	9	51	2.8	5.4
EA 13	0.3	81	50	0.2	0.5
EA 16	0.6	113	112	0.4	0.3
EA 17	0.5	135	102	0.3	0.3
EA 18	0.6	101	63	0.2	0.4
EA 19	0.9	13	28	0.7	2.6
BA 1	1.2	102	68	0.4	0.6
BA 5	0.8	162	52	0.2	0.4
BA4	0.6	207	52	0.2	0.3
GA 2	0.6	37	25	0.4	1.5
GA 4	0.6	436	276	0.3	0.1
LiF	0.7	1	205	0.8	0.4
Tor	0.3	249	1410	1.1	0.1
Gra	0.5	4	25	1.3	5.2
Kur	0.3	12	65	1.1	1.7
SäN	0.2	73	15	0.1	0.3
Wig	0.8	507	142	0.1	0.0
Åby	0.6	322	229	0.2	0.1
Ber	0.4	81	27	0.1	0.3
Bjö	0.4	15	60	0.8	1.4
Hus	0.2	47	16	0.1	0.5
StA	0.7	108	31	0.0	0.2
SäÖ	0.3	30	31	0.3	0.8
Nyb	0.3	212	77	0.1	0.1
Ull	0.8	128	127	0.2	0.2
Ökn	0.2	135	45	0.1	0.1
Pad	0.4	198	170	0.2	0.1
Bru	0.5	185	119	0.1	0.1
KaL	0.4	150	57	0.1	0.2
Sky	0.4	340	20	0.0	0.1
Skä	0.7	360	51	0.0	0.1
Spr	0.2	88	36	0.1	0.2

Table 3: The dissolved oxygen values in % for taken for the inlet and outlet of each CW.

CW	Dissolved oxygen, In (%)	Dissolved oxygen, Out (%)
VA 1	118	74
VA 5	91	103
VA 14A	90	100
VA 14B	78	84
VA 14C	33	75
VA 14D	99	80
VA 14E	108	103
VA 14F	108	103
VA 14G	115	96
EA 13	94	85
EA 16	92	85
EA 17	87	90
EA 18	77	81
EA 19	63	100
BA 1	90	87
BA 5	90	84
BA4	84	47
GA 2	59	64
GA 4	97	96
LiF	42	63
Tor	58	99
Gra	70	90
Kur	71	87
SäN	79	77
Wig	102	96
Åby	96	70
Ber	97	68
Bjö	90	78
Hus	107	51
StA	96	63
SäÖ	75	32
Nyb	94	82
Ull	89	72
Ökn	91	78
Pad	88	95
Bru	99	95
KaL	95	83
Sky	76	76
Skä	89	65
Spr	65	70

Table 4: The runoff in the CW:s catchment areas.

CW	Q (Feb) [l/min]	Q(Nov/Dec) [l/min]	Q(Aug/Sep) [l/min]
VA 1	576	686	236
VA 5	2367	2723	985
VA 14A	670	745	331
VA 14B	587	653	290
VA 14C	558	621	276
VA 14D	342	286	169
VA 14E	320	268	158
VA 14F	294	246	145
VA 14G	276	231	136
VA14	670	745	331
EA 13	422	446	98
EA 16	1290	995	218
EA 17	1179	909	199
EA 18	726	559	122
EA 19	208	214	31
BA 1	1115	867	420
BA 5	748	921	472
BA4	1506	936	480
GA 2	736	361	151
GA 4	297	3943	1650
LiF	1632	11	24
Tor	464	1435	46
Gra	405	17	33
Kur	206	144	1118
SäN	1075	13	41
Wig	171	166	13
Åby	1359	841	117
Ber	3246	78	1650
Bjö	670	65	60
Hus	250	17	26
StA	257	47	14
SäÖ	252	28	6
Nyb	269	106	62
Ull	287	73	23
Ökn	38	58	143
Pad	185	445	2
Bru	330	212	643
KaL	125	213	108
Sky	434	65	42
Skä	14101	164	65
Spr	814	109	164

Table 5: Land use distribution in the CW:s catchment areas.

CW	Agricultural land [%]	Forest [%]	Non vegetaded other open land [%]	Vegetaded other open land [%]	Artifical surfaces, buildings [%]	Artificial surfaces [%]
VA 1	72	8.7	0.0	14.9	1.8	7.8
VA 5	89	5.4	0.0	2.4	0.1	1.5
VA 14A	80	11.2	0.0	16.4	0.5	4.6
VA 14B	78	12.1	0.0	15.1	0.6	5.2
VA 14C	78	8.3	13.9	0.6	0.3	7.4
VA 14D	69	12.1	0.0	13.9	0.6	5.3
VA 14E	70	19.2	0.0	20.8	0.8	6.8
VA 14F	71	18.0	0.0	19.4	0.8	6.7
VA 14G	71	18.3	0.0	19.8	0.8	6.9
VA14	80	16.3	0.0	18.0	0.9	7.0
EA 13	81	6.0	0.3	8.7	0.7	4.8
EA 16	82	10.8	0.1	7.8	0.6	3.5
EA 17	82	11.5	0.1	7.0	0.6	3.4
EA 18	79	14.7	0.0	6.4	0.7	3.5
EA 19	91	4.3	0.0	2.7	1.1	3.2
BA 1	91	1.2	0.0	3.4	0.9	4.5
BA 5	67	15.4	0.0	11.1	1.6	9.2
BA4	67	15.2	0.0	11.4	1.6	9.0
GA 2	71	12.3	0.4	14.7	0.2	5.4
GA 4	90	3.2	0.0	2.9	0.5	3.2
LiF	28	64.0	0.1	7.8	0.2	2.0
Tor	63	24.8	0.2	9.4	0.5	2.8
Gra	80	12.1	0.0	24.6	0.9	0.2
Kur	67	19.7	0.0	7.0	0.2	2.5
SäN	78	35.2	5.8	8.1	1.1	2.2
Wig	34	52.4	0.6	9.0	0.8	4.0
Åby	75	44.3	0.0	4.9	0.1	3.2
Ber	54	50.6	0.1	9.4	1.3	7.6
Bjö	90	52.2	0.7	7.4	0.2	2.5
Hus	50	13.7	5.0	11.6	0.8	4.9
StA	25	41.7	4.0	17.5	1.1	12.5
SäÖ	67	59.9	1.0	10.4	0.0	4.5
Nyb	50	53.4	0.0	4.9	0.1	4.0
Ull	49	39.9	0.1	6.5	0.1	3.7
Ökn	49	41.2	1.1	18.9	2.4	11.1
Pad	45	37.9	1.2	10.9	0.6	6.0
Bru	80	9.4	0.2	7.3	0.4	3.6
KaL	53	37.8	0.0	8.1	0.4	0.9
Sky	77	41.2	0.0	23.5	0.6	5.3
Skä	67	38.9	0.0	6.3	0.2	0.8
Spr	54	48.3	0.0	11.5	0.7	1.3