UMEÅ UNIVERSITET

MACROINVERTEBRATES AND BUFFERS

The influence of riparian buffers on stream communities influenced by forest management.

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Examensarbete i biologi avseende kandidatexamen 15 hp
VT 2019

MACROINVERTEBRATES AND BUFFERS: The influence of riparian buffer width on stream communities influenced by forest management by Rikard Orvegård

Abstract

Forest management, including timber harvesting, is the primary land use activity in most of Sweden. However, clear cutting forests (i.e., final felling) can create a number of environmental problems in aquatic ecosystems and their communities. To combat these affects, intact riparian ‘buffer zones’ are typically left along streams and lakes in the Swedish landscape. There are many ideas on how wide a buffer zone has to be, to maintain an optimal ecological and hydrological state of a stream. Not only is the width of buffer zones debated, but also their overall design, including whether un-buffered stream segments could be beneficial. This study aims to test the effects of riparian buffers on macroinvertebrate biodiversity and community composition in streams draining catchments with clear cutting. To do this, I estimated the family richness and a variety of additional metrics from nine streams from southern Sweden in the Jönköping area. Three of the streams had intact buffers (<5 meter), three had no buffers, and three were unharvested (i.e., forested) catchments that served as controls. This study used data and benthic invertebrate samples collected as part of a bigger study, which were picked and manually sorted by the author. Richness ranged from 3 families at one site to as many as 13 at another one. Total abundance ranged between sites from 19820/m^2 to 27920/m^2 individuals. Overall, the results showed no significant difference in any of the invertebrate metrics across the three stream types. However, family richness increased among sites as a function of water temperature. The lack of buffer effects reported here may reflect the extremely warm summer of 2018, which caused a massive drought and was the warmest one ever recorded in the parts of Sweden where the invertebrates were collected.

Key words: macroinvertebrates, forest management, riparian buffers

1. Background

The total area of Sweden is 40,8 million hectares and of these, 28 million hectares are considered forested. Of this forested area, 23,6 are considered productive with biomass production rates of at least one cubic meter per hectare and year (Nilsson et al. 2019). In the end of the 1800's, the industrialization led to a higher demand for wood, which started an era of clearcutting in Sweden (Lundmark, Josefsson and Östlund 2013). Clearcutting is a form of forestry that is the most common one practiced in Sweden. It is the process of cutting the vast majority of timber in an area all at once, resulting in a high level of production and therefore has the highest economical value among different forestry methods, according to the forestry companies (Sveaskog 2015). While this is an effective, yet controversial way of harvesting biomass, it comes with potential environmental costs. For example, clearcutting can lead to changes in animal behavior, soil biology, acidity, hydrology, erosion and temperature (Keenan and Kimmins 1993), and may also alter the ecosystem process reducing the heterogeneity of the broader landscape (Garcia-Tejero 2018).

Leaving intact (i.e., unharvested) riparian buffer zones around water bodies (streams, rivers, and lakes) has emerged as a common management tool to mitigate the effects of clearcutting. For example, in the United states, guidelines have been formed in order to protect the riparian zone from logging (Blinn and Kilgore 2004). Recommendations and regulations in the Nordic countries, however, are often very under-developed. The riparian zones in connection to streams in the forested landscape provide the aquatic ecosystem with many important services. Specifically, buffer zones can be used to prevent excess soil nutrients from reaching the water, as well as to stabilize banks, control temperature, provide shade and protect biodiversity (Gundersen et al. 2010). Accordingly, these zones are thought to mitigate the unwanted effects of clearcutting on water quality and aquatic communities.

While buffers are widely used in Sweden, there is an ongoing debate regarding how these should be designed. In this context, one current question is how wide buffer strips need to be to achieve environmental goals. Because of the relative ease of implementation, most of the boreal timber producing regions now protect the riparian zone in a fixed width buffer. A fixed width buffer is however not a guarantee for reaching conservation goals because they may reduce spatial heterogeneity while not taking into account the spatial structure of land-water connections in most landscapes (Kuglerová et al. 2014). However, there are other types of buffer designs. For example, hydrologically adapted buffers, (HAB) calls for wider buffers also sensitive groundwater discharge hotspots, but thinner zones of protection elsewhere along stream reaches. Similarly, buffers may be designed to emulate natural disturbance (END), which promotes successional processes, more diverse plant communities, and patchy canopy gaps along streams (Kreutzweiser et al. 2012). The forest research community in Sweden is currently evaluating these different buffer designs, with managers already recommending various aspects of them to land owners and forest companies (Skogsstyrelsen 2016).

In this study, I explored the effects of riparian buffer width on stream macroinvertebrate communities. Macroinvertebrates play a big role in almost all aquatic ecosystems on earth. They are considered the base of the food chain in the aquatic ecosystem and are eaten by fish and other animals. They are also important in the way that they break down detritus into forms of energy, made to be consumed by other animals (Michaluk 2019). The terrestrial settings strongly influence the aquatic ecosystems, and the vegetation in the riparian zone can change hydrology, geomorphology and the in-stream retention of both inorganic and organic material (Feijo-Lima et al. 2018). The diversity of macroinvertebrates in streams is strongly connected to surrounding land use, with lower richness often observed in agricultural and urban streams compared to forested streams (Allan 2004) Furthermore, intact forested riparian zones may also promote higher biodiversity compared to streams where buffer zones are degraded or absent (Moore and Palmer 2005). Different types of macroinvertebrates are known to be more or less sensitive to pollution, and orders such as *Plecoptera, Ephemeroptera and Trichoptera*, known as the EPT's are known to be sensitive to pollution and known to live in what would be considered a good water quality environment. On the other edge of the spectrum are *Chironomidae,* who are known to be able to inhabit polluted waters and are considered less sensitive to pollution than the EPT's (Plafkin 1989). Finally, stream macroinvertebrates can also be categorized into groups based on their traits, which also provide insight into environmental changes that affect stream ecosystems. In particular, trophic habit can be divided into five groups, which focuses on feeding. These groups are collector-gatherers, collector-filterer, herbivores, predators and shredders (Poff et al. 2006). Investigating changes in these different feeding groups can therefore provide insight into how land uses (include riparian buffer design) is altering the resource base of small streams (e.g., increases in algae or reductions of the detritus) (Nislow and Lowe 2006).

1.1 Aim of the study and questions

The primary goal of this thesis project is to test the effect of riparian buffers on macroinvertebrate communities in headwater streams in southern Sweden that have been exposed to recent clear-cutting in the catchment. Specifically, I evaluated the following questions:

1. How do macroinvertebrate communities vary among streams with thin buffers, versus no buffers, versus reference site without recent clear cuts?

2. How is the functional trait group of shredders influenced by the presence or absence of riparian buffer zones?

3. How are indicator taxa influenced by these riparian conditions?

2. Method and material

This bachelor thesis uses the macroinvertebrate samples from an ongoing, larger study at the Swedish University of Agricultural Science. As part of this study, quantitative benthic samples have already been collected. I worked to complete the processing of these samples in the lab and characterized the communities based on family-level taxonomic resolution. The methods described here are the ones that are relevant to this thesis.

2.1 Study sites

The samples gathered come from Jönköping in the south of Sweden and all samples come from 9 streams no longer than 100km from each other. Within these nine, there were 4 sites from where the samples were collected. This thesis uses the categories (streams) of no buffer, where there were no adult trees on either side of the stream. The thin buffer, which had no more than 2 rows of trees along the stream (<5 m wide), and finally the reference, where no cutting or harvesting of forest had taken place. The samples were collected in mid-September to mid-October of 2018 using a Surber sampler in a sampling area of 20x25 cm, (500 cm2). Light and temperature was measured using a HOBO Pendant® Temp/Light 64K data logger every hour from July to October of 2018, and light/canopy cover was also measured with a densiometer, used right above the water.

2.2 Lab work

The samples were picked using two sieves with the mesh sizes of 1mm and 0,16mm. All the leaf litter and material that stuck in the sieves were looked through using a stereo microscope with the magnification of 10x and a strong light source. The number of individuals in each family of macroinvertebrates were then counted and separated into different test tubes filled with a 70% ethanol solution. Macroinvertebrates were picked out using soft pincers and then sorted and identified to family level using the two taxonomic handbooks Aquatic insects of North Europe 1 and 2 by Nilsson A (1997;2008).

2.3 Statistical analysis

All data were analyzed in Excel analysis tool pak where all the calculations were made. I used analysis of variance (ANOVA) to compare average invertebrate metrics among three groups of streams (thin buffer, no buffer, and forest reference; n=3). I decided on a limit for P-value of <0,05. The categories analyzed with the ANOVA were family richness, EPT family richness, % *Chironomidae*, and % shredders. In addition to the ANOVA, I used simple linear regression analysis to evaluate whether any of the macroinvertebrate metrics varied among sites as a function of differences in light or temperature.

3. Results

Macroinvertebrate abundance ranged from 19820/m² to 27920/m² among sites but did not differ statistically among stream types. The highest abundance was at the site with the thin buffer, with a total abundance of 27920/m², the reference site held an abundance of 19820/m² and the site with no buffer had 22600/m² (Figure 1).

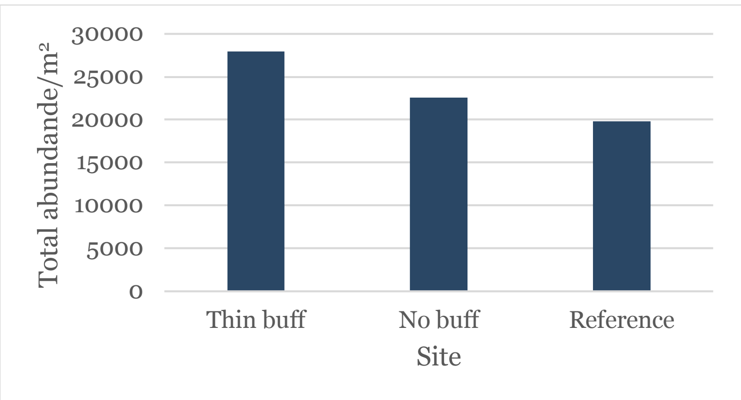


Figure 1. The total abundance of macroinvertebrates of the three sites.

Community richness also varied among sites, but overall were not significantly different among the three stream types ($p > 0.05$; Appendix, Table 1). For example, EPT family richness was the lowest across the reference sites, where an average of 2.3 (Standard error (SE) = 0.4) families were found. By comparison, the highest EPT richness was found at sites with the thin buffer, where the average EPT family richness was 4.4 (SE = 0.5) and in the middle the no buffer which had an EPT family richness of 4,25 (SE = 0.7) (Figure 2a).

The thin buffer also had the highest number of the overall family richness, with an average number of 9,6 families (SE = 1.0). The no buffer had a number of 9,3 (SE = 0.8) average families and the reference had a 5,8 (SE = 0.7) average of family richness (Figure 2b).

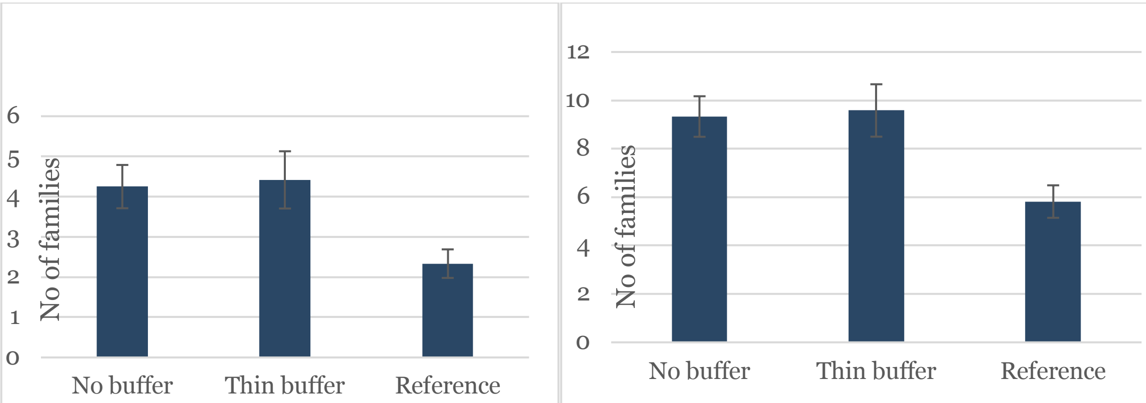


Figure 2a. The EPT family richness of the three sites Means and SE displayed. Figure 2b. The overall family richness of the three sites. Means and SE displayed.

Indices that describe other attributes of the community, including functional feeding were also not significantly different among sites ($p > 0.05$; Appendix Table 1). The percentage of shredders was highest among reference streams at 28,6% (SE = 9.3). By comparison, the no buffer streams average 22,9 % (SE = 3.5) shredders, while relative abundance of shredders in the thin buffer-streams averaged 9,7% (SE = 5.3) (Figure 4a). Finally, the percent of the community represent by *Chironomidae* (Diptera) were higher in the no buffer stream, with an average of 39,4% (SE = 6.3). The thin buffer had 29,8% (SE = 5.3) of the same and the reference stream had a percentage of 19,7 (SE = 5.5) (Figure 4b).

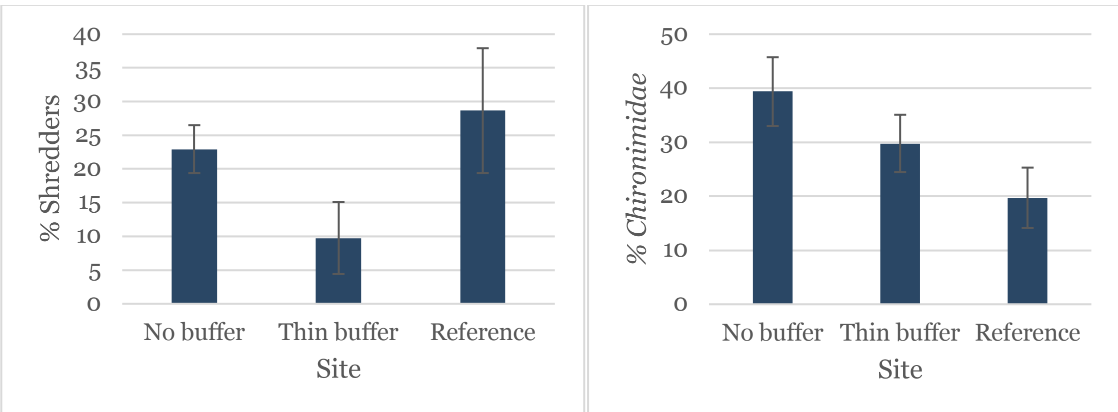
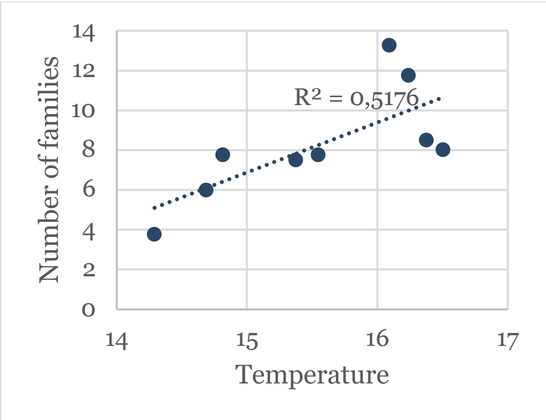


Figure 3a. Percent shredders of the three sites. Mean and SE. Figure 4b. Percent Chironomidae between the three sites. Mean and SE.

While there were few significant differences in macroinvertebrate indices among stream types, some of the variation in community structure was related to variation in light amongst all stream (n = 9; Appendix, Table 2). For example, total family richness increased among sites with temperature (r^2=0.51 p=0.02; figure 6a) but not with light (r^2=0.31 p=0.11; figure 6b).
EPT family richness among sites with temperature had a similar trend, but not enough to call it significant (r^2 = 0.38, p = 0.07; Appendix, Table 2) and light (LUX) (r^2 = 0.25, p = 0,16; Appendix, Table 2). The other macroinvertebrate indices showed similar trends with light and temperature, although most these were not significant (p > 0.05; Appendix, Table 2).



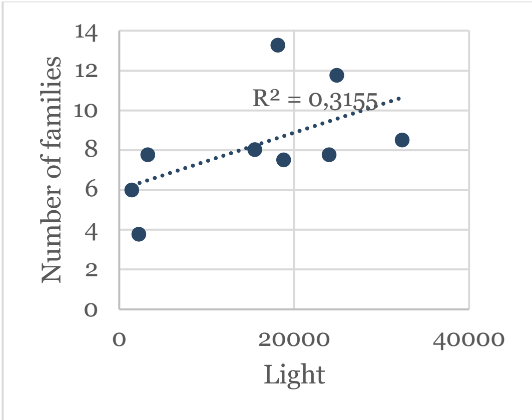


Figure 4a. Family richness in regression with temperature. Figure 6b. Family richness in regression to light (LUX).

In a correlation analysis between the two indicator-metrics used, % *Chironomidae* and EPT family richness, there was not a significant correlation (r^2 = 0,13, p =0,33; figure 8).

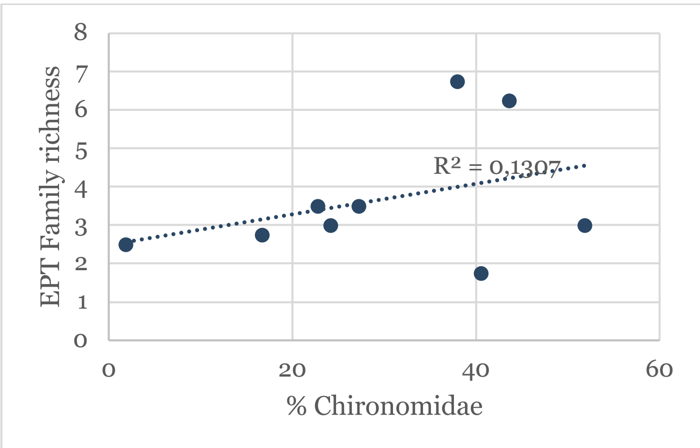


Figure 8. Regression analysis between % Chironomidae and EPT family richness.

4. Discussion

Riparian buffer zones are widely used to mitigate the effects of clear-cutting on-stream habitat conditions and communities. While there is evidence that these zones can be effective (Gundersen et al. 2010), there is ongoing debate in Sweden regarding how well current buffers are working and whether they should be designed in different ways (Kuglerová et al. 2017). To explore this issue, I evaluated how the presence of buffer zones influence macroinvertebrate communities in streams exposed to recent clear cuts. Overall, my results suggest that the stream communities sampled for this study, based on multiple metrics, were not influenced by the presence of riparian buffers. Specifically, I found no significant differences in community richness, composition, and functional groups among the three groups of streams. However, I did observe positive correlations between family richness and temperature and light, suggesting that local canopy cover regardless of buffer design, has influences on stream communities.

The lack of effects observed here contrast with other studies of riparian buffer zones. For example, Kreutzweiser et al. (2005) reported that a 3-meter undisturbed buffer was enough around streams in Canada in order to not have any significant changes on macroinvertebrate communities. However, in a study from Australia in 1994 suggests that there will be a significant difference of a stream if the buffer width is <30 meters (Davies and Nelson 1994). The lack of a powerful statistical result could be because of the small number of sites (low statistical power) used in this study. Given naturally high variability in aquatic communities, it is possible that more streams, and potentially more samples per stream, would be required to detect statistical difference among the three groups evaluated here. Regardless, at a minimum, my result suggest that it is always the case that buffer zones have positive effects on the diversity of stream macroinvertebrate communities.

Despite the lack of statistical results, there were interesting trends for indicator taxa among sites. However, my results indicate that common biomonitoring indicators may not be great for detecting riparian buffer influences. For example, EPT's are often used as indicators for good water quality (Peralta et al. 2019). At specific sites, there was possible to see that there were more EPT families found in the specific samples at the thin buffer-site than the reference-site and the site with no buffer at all. In addition, this study shows that the highest percent of *Chironomidae* were at the site with no buffer. Most of the Chironomids belong to the functional feeding group of collector-gatherer, with the only exception being that of the *Tanypodinae,* who are predators (Poff et al. 2006). Desrosiers et al. (2019) describes in a study from St. Lawrence river in North America that the functional feeding group of collector-gatherers were the most abundant trait niche found at sites that were the most polluted of their test sites. In this study however, the no buffer site had the second highest EPT family richness, and just slightly less than that of the thin buffer. Plafkin et al. (1989) showed that *Chironomidae* generally have a higher tolerance level regarding e.g. pollution than the more sensitive EPT's. The correlation analysis conducted in this study between the % *Chironomidae* and the EPT family richness could not show a correlation.

Similarly, there was no statistical evidence that buffer zones were influencing the abundance of invertebrates that consume terrestrial litter (i.e., shredders). However, when looking at the % Shredders, the highest percent were found in the reference streams (28,6 %). This would suggest there being more detritus, leaves and such at the reference site in comparison to the other two sites which would make sense based on the idea that the reference site should have more trees than the site with no buffer or the thin buffer. Other studies have shown that the representation of the functional feeding group shredders increased with a higher canopy cover, and that a site dominated by shredders could switch to being dominated by grazers and *Chironomidae* after logging (Nislow and Lowe 2006).

Lack of differences among the three groups of streams could reflect the extreme drought that dried out many small streams in the summer 2018. During this summer, many parts of Sweden had all time temperature records that preceded when these samples were collected (Swedish Meteorological and Hydrological Institute 2018). While drought is considered to be an important type of natural disturbance on streams, the effects of drought on a stream include alterations in richness, abundance and species composition which can change the entire community structure (Atkinson et al. 2014). Anecdotal observations from these streams suggest that forested streams may have been more affected by drought, likely because evapotranspiration from surrounding forests exacerbated low water conditions (L. Kuglerová, personal communication). Historically, drought has not been well studied in high latitude landscapes, but apparent increases recent extreme climate events in Sweden, more research on the effects of this disturbance in streams is warranted.

While there were no significant differences among groups of streams, there was evidence of local physical conditions did influence variation in macroinvertebrate communities among sites. Specifically, family richness increased with temperature and showed a non-significant trend increasing with light. These results are consistent with studies highlighting the local effects of temperature and light. For example, Wootton (2012), found that a reduction in canopy cover increased algal production and insect taxa, and also juvenile salmonids. In addition, Heaston et al. (2018) conducted a study focusing on a smaller change in light compared to Wootton, which shows that even a slight change in the patchiness and shading can have a big effect on the in-stream biota. Therefore, it would be possible that very local effects of light and canopy cover make a difference, and perhaps this should be taken into account when designing a buffer.

It is clear that further studies are needed to describe the possible difference between logging sites and different buffer widths.

Conclusions

This study could not show any significant differences between riparian buffer zones that were forested, had a thin buffer or were clear-cut in regard to the metrics that were tested for. Much of the literature cited however, suggests this is often the case. This study does however show that family richness increased with temperature and it is hard to know exactly how the drought and extremely warm summer of 2018 affected the conditions of the study. With more time and resources, I would use more samples, thus creating a stronger setup for a statistical analysis and perhaps even redo the sampling, in order to get a result unaffected by the drought of 2018.

5. Acknowledgements

I'd like to thank Ryan Sponseller (Umeå University) and Lenka Kuglerová (Swedish University of Agricultural Sciences) for all the supervision and help during this thesis.

6. References

Allan, David J. 2004. Landscapes and riverscales: The Influence of Land Use on Stream Ecosystem. *Annu. Rev. Ecol. Evol. Syst.* 2004. 35:257–84

Atkinson, Carla L. Julian, Jason P. Vaugh, Caryn C. 2014. Species and function lost: Role of drought in structuring stream communities. *Biological conservation* 176 (2014) 30-38

Blinn, Charles R. Kilgore Michael A. 2004. Riparian management practices in the eastern U.S.: A summary of state timber harvesting guidelines. *Water, air and soil pollution.* Vol 4, issue 1 pp 187-201

Davies, Peter E. Nelson M. 1994. Relationships between Riparian Buffer Widths and the Effects of Logging on Stream Habitat, Invertebrate Community Composition and Fish Abundance. *Aust. J. Mar. Freshwater Res* 1994. 45 1289-305

Desrosiers, Melanie. Usseglio-Polatera, Philippe. Archaimbault, Virginie. Larras, Floriane. Methot, Ginette. Pinel-Alloul, Bernadette. 2019. *Science of the total environment.* Vol 649. 2019. 233-246

Feijó-Lima, Rafael. Mcleay, Scott M. Silva-Junior, Eduardo F. Tromboni, Flavia. Moulton, Timothy P. Zandonà, Eugenia. Thomas Steven A. 2018. Quantitatively describing the downstream effects of an abrupt land cover transition: buffering effects of a forest remnant on a stream impacted by cattle grazing, *Inland Waters, 8:3, 294-311* 2018. DOI: 10.1080/20442041.2018.1457855

Garcia-Tejero, Sergio. Spence, John R. O'Halloran, John. Bourassa, Stephane. Oxbrough, Anne (2018) Natural succession and clearcutting as drivers of environmental heterogeneity and beta diversity in North American boreal forests. *PLoS ONE* 13(11): e0206931. https://doi.org/10.1371/journal. pone.0206931

Gundersen, Per. Lauren, Ari. Finer, Leena. Ring, Eva. Koivusalo, Harri. Sætersdal, Magne. Weslien, Jan-Olov. Sigurdsson, Bjarni D. Högbom, Lars. Laine, Jukka. Hansen, Karin. 2010. Environmental services provided from riparian forests in the Nordic countries. *AMBIO.* 2010. Vol 39, issue 8, pp 555-566

Heaston, Emily D. Kaylor, Matthew J. Warren Dana R. 2018. Aquatic food web response to patchy shading along forested headwater streams. *Can. J. Fish. Aquat. Sci.* Vol. 75, 2018

Keenan, Rodney J. Kimmins, Hamish JP. 1993. The ecological effects of clear-cutting. *Environmental Reviews* Vol. 1, No. 2 (1993), pp. 121-144

Kreutzweiser, David P. Capell, Scott S. Good, Kevin P. 2005. Macroinvertebrate community responses to selection logging in riparian and upland areas of headwater catchments in a northern hardwood forest. *J. N. Am. Benthol. Soc.*, 2005, 24(1):208–222

Kreutzweiser, David P. Sibley, Paul K. Richardson, John S. Gordon, Andrew M. 2012. Introduction and a theoretical basis for using disturbance by forest management activities to sustain aquatic ecosystems. *Freshwater Science*, 2012, 31(1):224–231

Kuglerová, Lenka. Ågren, Anneli. Jansson, Roland. Laudon, Hjalmar. 2014. Towards optimizing riparian buffer zones: Ecological and biogeochemical implications for forest management. *Forest Ecology and Management* 334 2014 74–84

Kuglerová, Lenka. Hasselquist, Eliza Maher. Richardson, John S. Sponseller, Ryan A. Kreutzweiser David P. Laudon, Hjalmar. 2017. Management perspectives on *Aqua incognita:* Connectivity and cumulative effects of small natural and artificial streams in boreal forest. *Hydrological processes* 2017;1-7 DOI: 10.1002/hyp.11281

Lundmark, Hanna. Josefsson, Torbjörn. Östlund, Lars. 2013 The history of clear-cutting in northern Sweden – Driving forces and myths in boreal silviculture. *Forest Ecology and Management* 307 2013. 112–122

Michaluk, Sonja. 2019. Macroinvertebrate. *Encyclopedia Britannica.* https://www.britannica.com/animal/macroinvertebrate (Read at 23 august 2019)

Moore, Aaron A. Palmer, Margaret A. 2005. Invertebrate biodiversity in agricultural and urban headwater streams: implications for conservation and management. *Ecological Applications,* 15(4), 2005, pp. 1169–1177

Nilsson, Anders (1997) Aquatic Insects of North Europe. A taxonomic handbook. Vol. 1: Ephemeroptera. Plecoptera, Heteroptera, Megaloptera, Neuroptera, Coleoptera, Trichoptera and Lepidoptera. 1996. 29 × 21 cm, 274 pp., 129 pl., hardbound, Apollo Books, DK-5771 Stenstrup, Kirkeby Sand 19, ISBN 87-88757-09-9

Nilsson, Anders (2008) Aquatic insects of Northern Europe. A taxonomic handbook, Vol. 2: Odonata. Diptera. 1997, 29 × 21 cm, 440 pp., hardbound, Apollo Books, DK – 5771 Stenstrup, Kirkeby Sand 19, ISBN 87-88757-15-3

Nilsson, Per. Roberge, Cornelia. Fridman, Jonas. Wulff, Sören. 2019 Skogsdata. Official Statistics of Sweden. *Swedish University of Agricultural Sciences, Umeå 2019.* ISSN 0280-0543

Nislow, Keith H. Lowe, Winsor H. 2006. Influences of logging history and riparian forest characteristics on macroinvertebrates and brook trout (*Salvelinus fontinalis*) in headwater streams (New Hampshire, U.S.A.). *Freshwater Biology 51* (2006) 388–397

Peralta, Elfritzson M. Belen, Alexis E. Buenaventura, Gelsie Rose. Cantre, Francis Godwin G. Espiritu, Katharine Grace R. De Vera, Jana Nicole A. Perez, Cristine P. Tan, Aleziz Kryzzien V. De Jesus, Irisse Bianca B. Palomares, Paul. Briones, Jonathan Carlo A. Ikeya, Tohru. Magbanua, Francis S. Papa, Rey Donne S. Okuda, Noboru. 2019. Stream Benthic Macroinvertebrate Assemblages Reveal the Importance of a Recently Established Freshwater Protected Area in a Tropical Watershed. *Pacific Science*, vol. 73 no. 3, 2019, pp. 305-320.

Plafkin, James L. Barbour, Michael T. Porter, Kimberly D. Gross, Sharon K. Hughes, Robert M. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. *United States Environmental protection agency. Office of water.* EPA/440/4-89/001

Poff, LeRoy N. Olden, Julian D. Vieira, Nicole K. M. Finn, Debra S. Simmons, Mark P. Kondratieff, Boris C. 2006. Functional trait niches of North American lotic insects: traits-based ecological applications in light of phylogenetic relationships. *J. N. Am. Benthol. Soc.,* 2006, 25(4):730–755

Skogsstyrelsen. (Swedish forest agency) 2016. *Nya och reviderade målbilder för god miljöhänsyn: Skogssektorns gemensamma målbilder för god miljöhänsyn vid skogsbruksåtgärder*. Rapport 12. 2016.

Swedish Meteorological and Hydrological Institute (SMHI). 2018. *Sommaren 2018 - Extremt varm och solig*. https://www.smhi.se/klimat/klimatet-da-och-nu/arets-vader/sommaren-2018-extremt-varm-och-solig-1.138134 (Read at 20 August 2019)

Sveaskog. 2015. *Regeneration felling*. https://www.sveaskog.se/globalassets/kundutbildning/regeneration-fellingeng.pdf (Read at 23 August 2019)

Wootton, Timothy J. 2012. River Food Web Response to Large-Scale Riparian Zone Manipulations. *PLoS ONE 7(12):* e51839. https://doi.org/10.1371/journal.pone.0051839

7. Appendix

Appendix; Table 1.ANOVA-analysis between the sites. No significant variance (P>0,05) could be noted.

Categories	SS	df	MS	F	P-value	F crit
EPT Family richness	8.04	2	4.02	1.61	0.27	5.14
% *Chironomidae*	580.02	2	290.01	1.32	0.33	5.14
% Shredders	745.98	2	372.99	0.85	0.47	5.14
Family richness	26.37	2	13.18	2.11	0.20	5.14

Appendix; Table 2. Temperature and light effects on index-values. R, r2 and p-value of the different categories in a regression analysis.

Category	R	r2	p-value
Family richness temp	0.71	0.51	0.02
Family richness light	0.56	0.31	0.11
% Shredders Temp	0.47	0.22	0.19
% Shredders light	0.36	0.13	0.32
EPT family richness temp	0.61	0.38	0.07
EPT family richness light	0.50	0.25	0.16
% Chironomidae temp	0.23	0.05	0.54
% Chironomidae light	0.45	0.20	0.21