Impacts of human land use on fish populations in boreal lakes

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The effect of agriculture and forestry

Aquatic inland lake ecosystems are under constant pressure due to intensive, local land-use–induced changes (Roulet & Moore 2006). In particular, boreal lakes are often surrounded by forests and peatlands, which affect the leaching of organic substances (Finér et al. 2021). Commonly, this results in an increase in the concentration of organic substances, leading to brownification. This has a dramatic impact on the physical environment by, for example, altering thermal dynamics and causing hypolimnetic anoxia (Roulet & Moore 2006)

Aim of the study

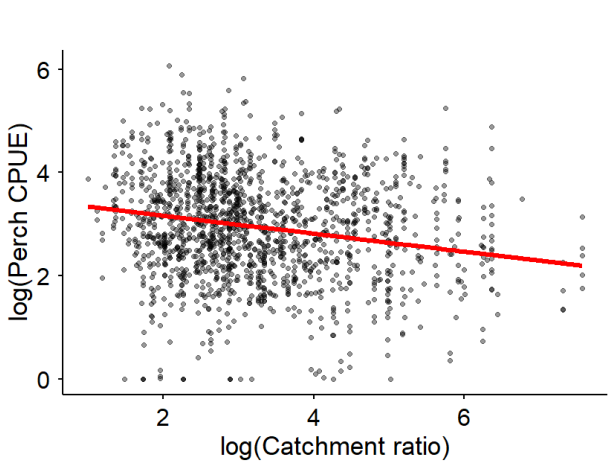
In the present study, we aim to identify important land-use-related variables and their effects on fish populations mediated through water quality. We use Nordic gillnet catches as indicators of fish populations, while land-use variables are calculated for catchment areas.

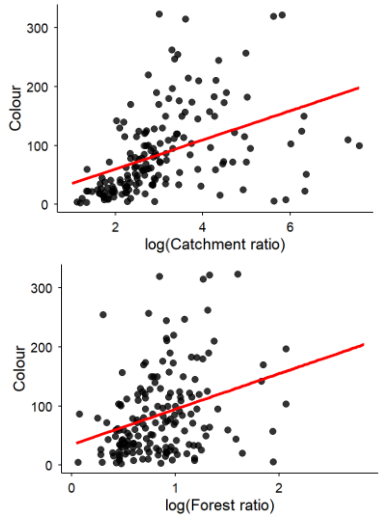
Material and methods

Historical forest cover (trees > 5 m) (Hansen forest loss data) in the year 2000 for lake catchment areas (WSFS-Vemala/Syke) was used as a proxy for forestedness, which strongly correlates with annual forest loss (cor = 0.77). Agricultural land use was estimated using CORINE data (SYKE) and calculated as an average across the years 2000, 2006, 2012, and 2018. All land-use variables were normalized by lake size to produce ratio variables (Horppila et al. 2019). Here, we present results from linear mixed-effects models (LMMs), in which the studied variables, including latitude, were modeled as fixed effects, while lake and year were included as random effects. All continuous variables, except latitude, were log-transformed.

Results

The size of the catchment area relative to lake size shows a predominantly negative correlation with Nordic gillnet catch rates. Forest cover relative to lake size also shows a mainly negative correlation; however, it is strongly correlated with annual forest loss. Agricultural area relative to lake size had a strong positive effect on CPUE.





Conclusion

The results suggest that catchment-related leaching of nutrients and organic substances is an important factor explaining gillnet catches, both through changes in fish populations and through changes in catchability. The forest cover ratio is strongly correlated with annual forest loss, making the effect of forest harvesting ambiguous. The positive effect of agriculture is likely related to the leaching of variables that enhance primary productivity. Mitigating excessive leaching of organic substances is key to sustaining productivity in boreal lakes.

Table 1. Results of species-spesific LME or GLMM models for variables of interests. Relationship are indicated with (+-) signs.

	Catchment ratio	Forest ratio	Agriculture ratio
Perch CPUE	(-)***		(+)**
Perch BPUE	(-)*	(+)**	
Roach CPUE	(-)**		(+)***
Roach BPUE	(-)***		(+)***
Ruffe CPUE		(-)***	(+)**
Ruffe BPUE	(-)*	(-)***	(+)**
Bleak CPUE	(+)***	(-)***	(+)**
Bleak BPUE	(+)***	(-)***	(+)***
Pike CPUE		(+)***	(+)**
Pike BPUE	(-)*		(+)***
Pikeperch CPUE	(+)***	(-)***	(+)**
Pikeperch BPUE	(+)***	(-)***	(+)***

References:
Roulet N, Moore T. 2006. Browning the waters. *Nature* **444**, 283–284. https://doi.org/10.1038/444283a
Finér L, Lepistö A, Karlsson K, Räike A, Härkönen L, Huttunen M, Joensuu S, Kortelainen P, Mattsson T, Piirainen S, Sallantaus T, Sarkkola S, Tattari S, Ukonmaanaho L. 2021. Drainage for forestry increases N, P and TOC export to boreal surface waters. Sci Total Environ. 2021 Mar 25, 762:144098. doi: 10.1016/j.scitotenv.2020.144098.
Horppila J, Holmroos H, Niemistö J, Tammeorg O. 2019: Lake catchment characteristics and exter nal P load — cultivated area/lake area ratio as a tool for evaluating the risk of eutrophication from land use information. Boreal Env. Res. 24, 13–23.