Biological recovery in mountain lakes in north-eastern Norway due to reduced acidification

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Introduction

- Lakes in the Jarfjord Mountains in eastern Finnmark (Arctic region of northern Norway) are affected by emissions of SO_2 as well as Ni and Cu from the smelters in Nikel and Zapoljarnij municipalities, Russia.
- Acidification followed by reduced biodiversity was recorded in the late 1980s. A significant chemical recovery has occurred during recent years, as shown by increasing pH and acid neutralizing capacity (ANC).
- From 1998 lakes in the Jarfjord Mountains were included in the Norwegian monitoring program for long-range transported air pollutants – biological effects in lakes (**figure 1**).

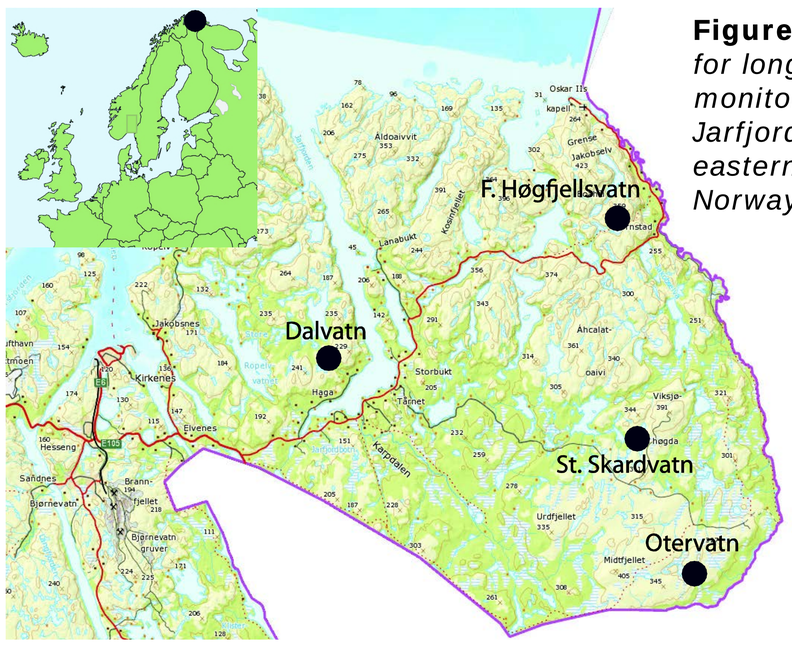

Figure 1. *Arctic lakes for long-term monitoring in the Jarfjord Mountains, eastern Finnmark, Norway.*

Questions

- How does the biological recovery vary between lakes and groups of organisms?
- Which factors may explain differences in biological recovery?

Material and methods

- The initial surveys were carried out between 1987 and 1997 (only microcrustaceans and fish), while the lakes were monitored regularly from 1998 (Lake Dalvatn) or 2000 (lakes Otervatn, Store Skardvatn and Første Høgfjellsvatn) onwards. Water chemistry, macroinvertebrates and microcrustaceans are monitored either yearly (Lake Dalvatn) or every fourth year whereas fish is monitored every fourth year. From Lake Første Høgfjellsvatn only data on microcrustaceans are assessed.
- Acidification status is assessed according to the WFD, taking type-specific reference conditions into account.

Results

- The degree of biological recovery varied between lakes and habitats (littoral zone of lake vs outlet river) as well as between groups of organisms. While the lake fish populations are recovered nearly completely, the recovery of invertebrate communities are more variable.
- The between-years variation in species numbers and fraction of acid sensitive invertebrates in these Arctic lakes are high (**figure 2-3**) compared to acid sensitive lakes in Southern Norway. The reason may be short and variable growing seasons.
- The benthic fauna of the lakes Otervatn and Store Skardvatn did not show signs of damage. Highly acid-sensitive invertebrates were found in both the littoral zone and in the outlet river at all sampling dates (not shown). On the contrary, Lake Dalvatn was more unstable showing episodic acid stress. Presence of acid-sensitive species in the outlet river in years between 2001 and 2006 has been followed by an acid tolerant fauna from 2007 onwards (**figure 2**).
- In Lake Dalvatn, the abundance of the highly acid-sensitive cladoceran *Daphnia longiremis* showed the same pattern as the presence of acid sensitive macroinvertebrates in the lake's outlet river. After a period of relative high abundance, only a few specimens were found in years after 2005 (data not shown). Although high species richness of micro-crustaceans in Lake Dalvatn, the fraction of acid-sensitive species was lower than expected in most years (**figure 3**). The microcrustaceans of the other three lakes showed no or only minor deviation from expected reference conditions (taking differences in calcium- and TOC content into account), except for 2008.
- Delayed recovery of invertebrate communities may be due to increased concentrations of nickel and cupper in lakes in this area from 2004 (see report M-173/2014 from the Norwegian Environmental Directorate).

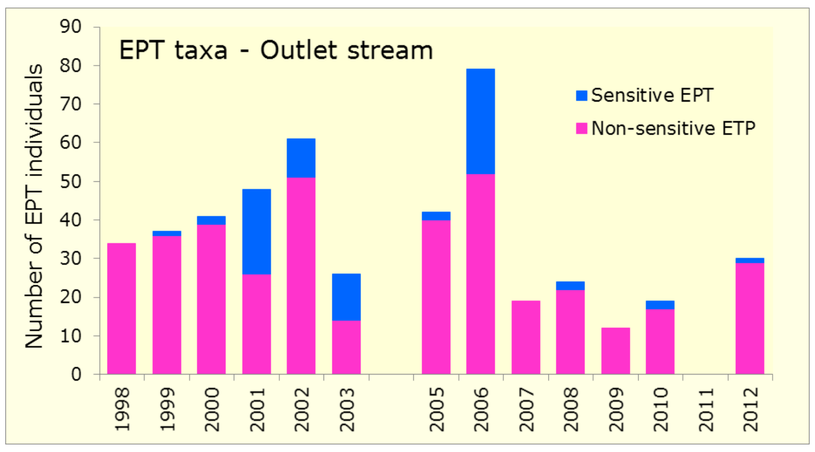

Figure 2. *Number of specimens of acid-sensitive and -tolerant macro-invertebrates (EPT: Ephemeroptera, Plecoptera and Trichoptera) in Lake Dalvatn outlet river, 1998-2012.*

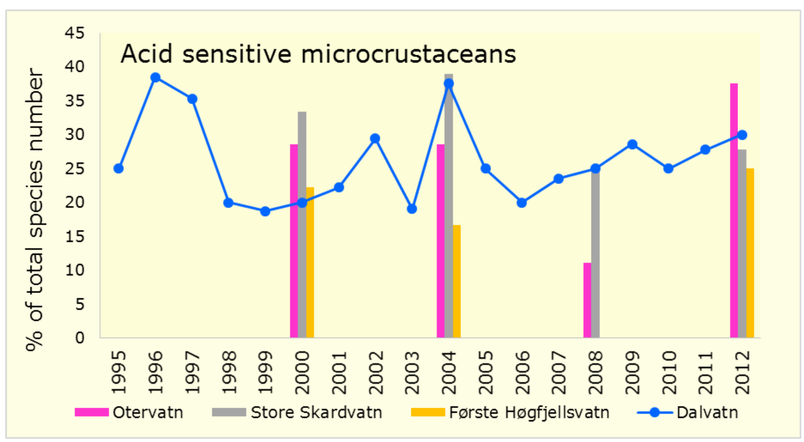

Figure 3. *Relative number of acid-sensitive species in the lakes Otervatn, Store Skardvatn, Første Høgfjellsvatn and Dalvatn, 1995-2012. NB. Very low calcium- and TOC content in Lake Første Høgfjellsvatn.*

- The population of brown trout in Lake Otervatn has recovered almost completely during recent years (**figure 4**); both pH and ANC explained a significant fraction of the variability in Cpue. There has also been an increase in the catches of brown trout in the lakes Dalvatn and Store Skardvatn, which also contain Arctic charr. These two populations of Arctic charr have decreased in abundance during recent years, probably due to interspecific competition from brown trout.

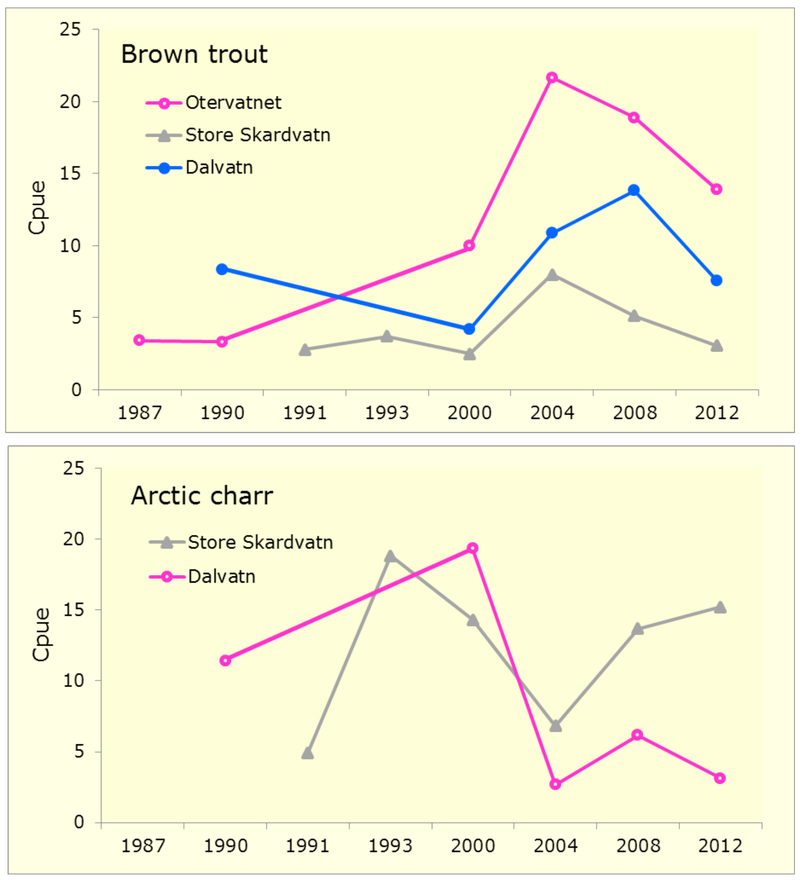

Figure 4. *Gillnet catches of brown trout and Arctic charr (all age classes) per unit effort (Cpue) in the epibenthic zones of the lakes Otervatn, Store Skardvatn and Dalvatn, 1987-2012.*

Conclusions

- Our results from lakes in the Jarfjord Mountains indicate that the degree of biological recovery vary between lakes and habitats as well as between groups of organisms.
- The biological recovery process is complex, involving a multitude of physical, chemical and biotic interaction like climatic conditions, trace metal pollution and biological interactions.

Acknowledgements

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