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Phytoplankton and zooplankton communities in Swedish lakes covering a gradient of inorganic aluminium (Ali) concentrations

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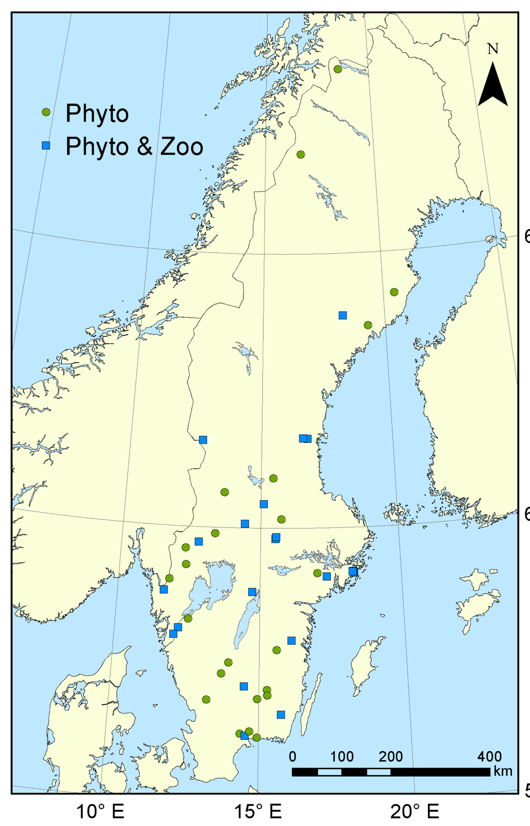
Introduction

Labile inorganic aluminum (Ali) is highly toxic to many aquatic organisms such as fish and benthic fauna. Different studies exhibit a range in critical concentrations. This suggests that there is a complex relationship between Ali concentration and toxicity, possibly modulated by TOC and fluoride concentrations as well as pH. We also hypothesize that there are differences in the responses on the species level.

Here we present results from a field survey in which we explore in situ relationships between phytoplankton and zooplankton communities and Ali and compare with the response to pH.

Study lakes & methods



Lakes with median total P <20 µgP L⁻¹ and pH<6.5 were selected from Swedish national and regional monitoring programs (N=43). Water chemistry and phytoplankton were analysed in all lakes and zooplankton were analysed in 21 lakes. Lakes were sampled 4-8 times per year for 3-18 years (median 14) during the period 1992–2010. Water chemistry data from April to August and phytoplankton from July and zooplankton from July and August was used in the data analysis.

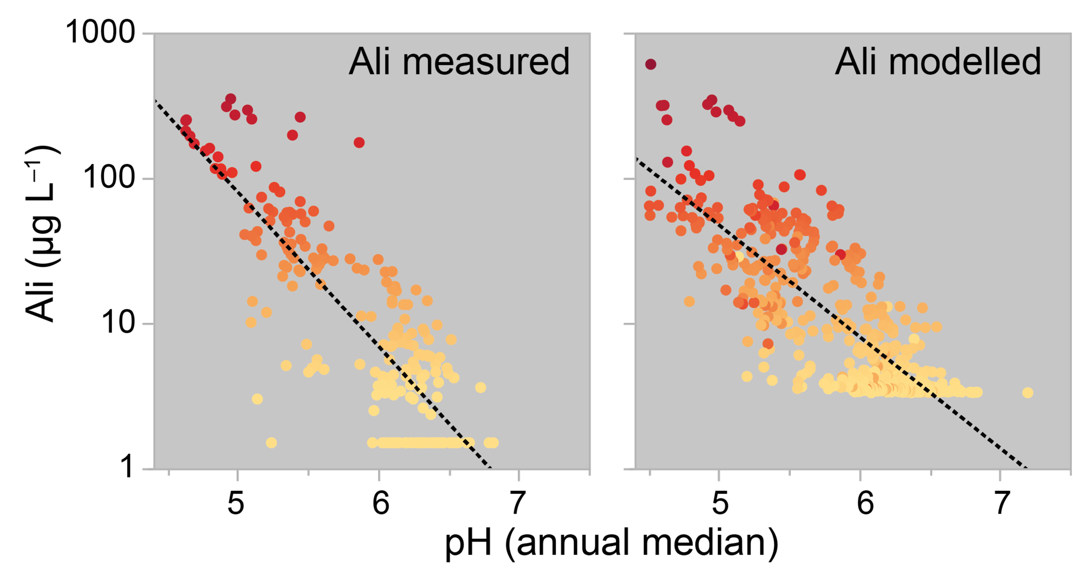
Water chemistry and plankton were analysed using standard methods: http://www.slu.se/en/departments/aquatic-sciences-assessment/laboratories/

Ali was measured in 23 of the lakes (Driscoll 1984, Andrén & Rydin 2009). Ali was modelled in 39 of the lakes using a chemical equilibrium model (Sjöstedt et al. 2010) with pH, total aluminium, iron, organic carbon, fluoride, sulfate, and charge balance ANC as input data.

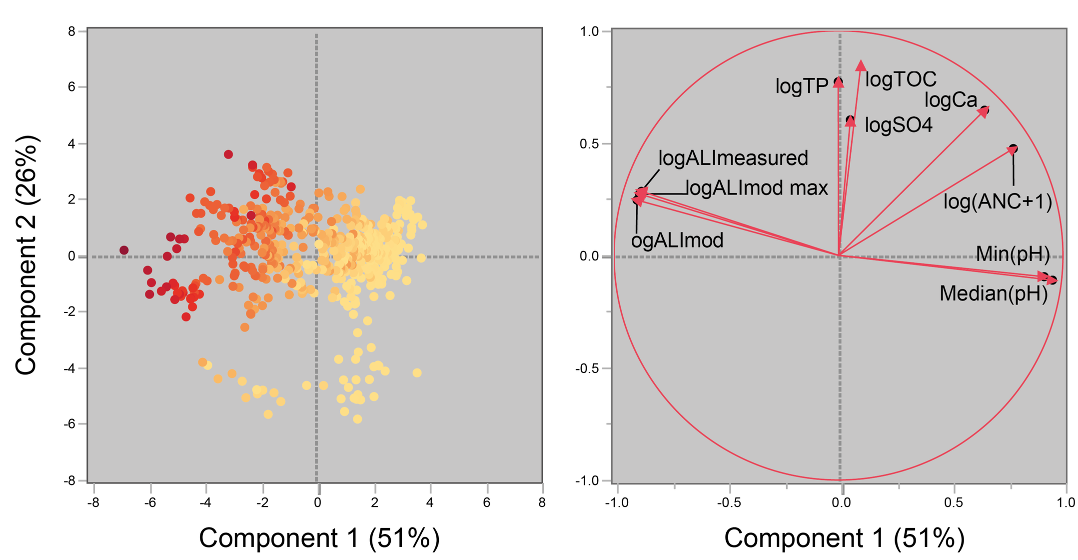
WATER CHEMISTRY

Correlations between some of the water chemistry parameters. Note that total P (TP) and TOC are weakly correlated with pH and Ali whereas the latter are strongly correlated with each other (positively or negatively).

	pH	pH min	logAli measured	logAli modelled	logAli modelled max	logTP	logTOC
pH	1	0.94	-0.86	-0.82	-0.80	-0.11	-0.04
pH min	0.94	1	-0.82	-0.75	-0.76	-0.10	-0.04
logAli measured	-0.86	-0.82	1	0.83	0.83	0.14	0.21
logAli modelled	-0.82	-0.75	0.83	1	0.96	0.12	0.03
logAli modelled max	-0.80	-0.76	0.83	0.96	1	0.14	0.06
logTP	-0.11	-0.10	0.14	0.12	0.14	1	0.68
logTOC	-0.04	-0.04	0.21	0.03	0.06	0.68	1

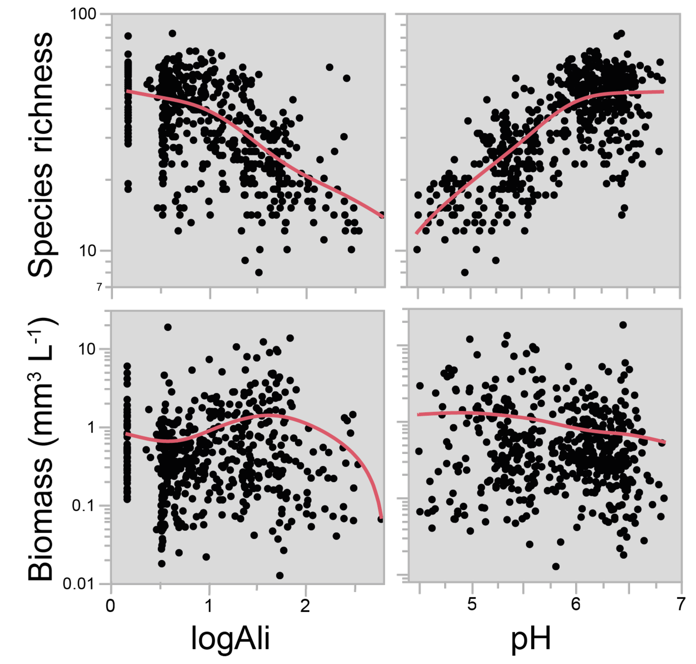


Measured and modelled Ali show similar relationships with pH. Note that there is a substantial variation in Ali at a given pH. Each data point represents the annual median in one lake. Dotted line: linear regression curves. Colour coding show increasing Ali measured.



Principal component analysis of selected water chemistry parameters. Axis 1 largely represent the pH vs. Ali gradient and axis 2 total phosphorus (TP) and total organic carbon (TOC) gradients. Colour coding of markers show increasing Ali measured concentrations.

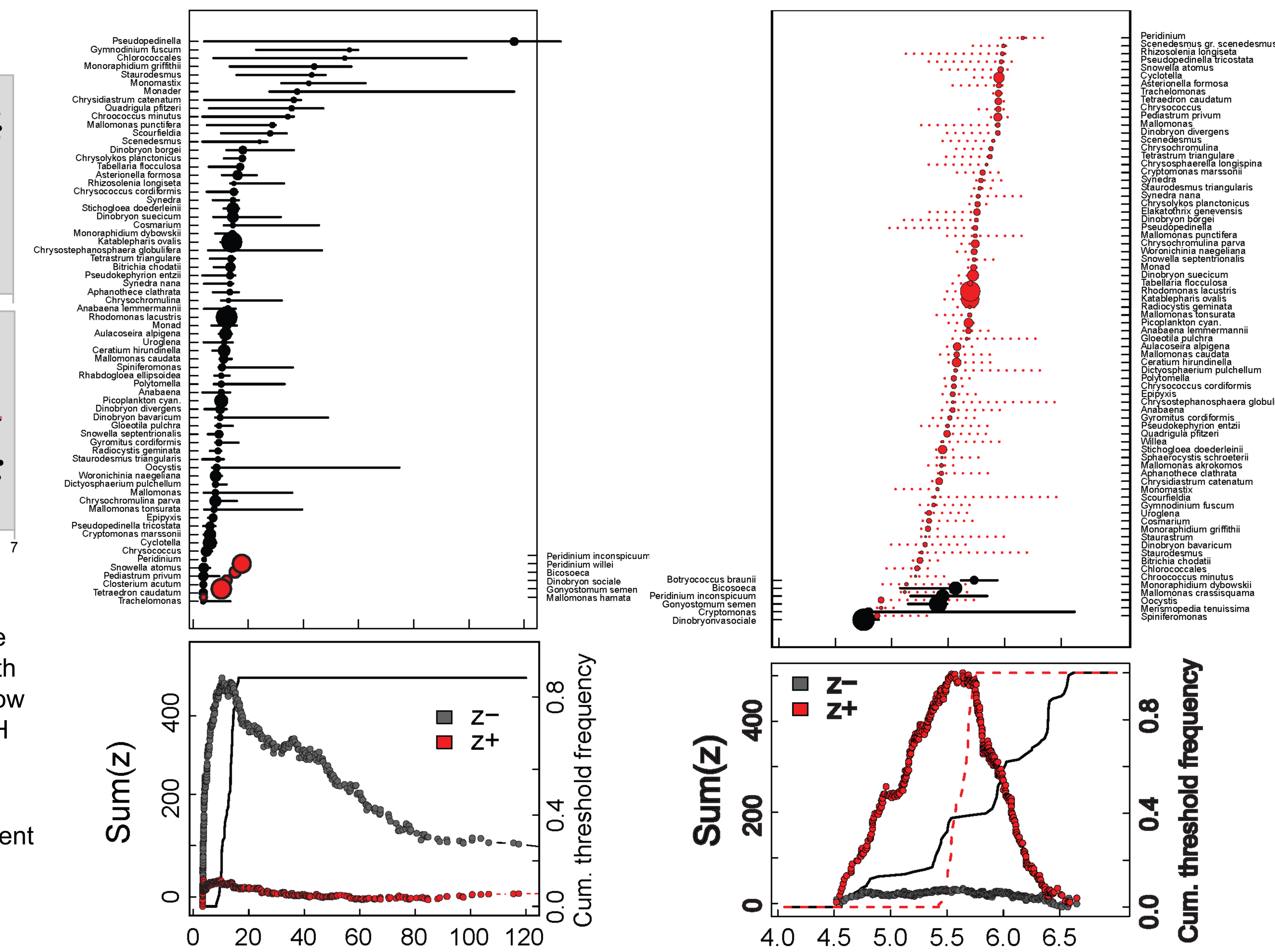
PHYTOPLANKTON



Phytoplankton species richness and total biomass. Red lines show smoothing spline fits to data. **Species richness** declines both with increasing Ali and decreasing pH (below pH=6). There is no strong effect of Ali or pH on **total biomass**.

The % contribution to total biomass responded differently to Ali and pH in different classes. Three response types were identified:

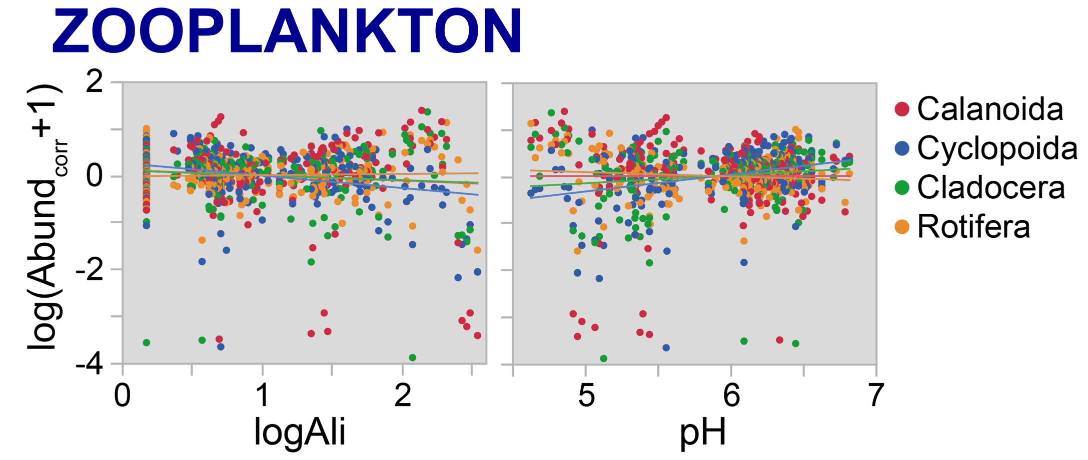
1) no change along pH and Ali gradients (Chlorophyceae)
2) declining % contribution with increasing Ali and decreasing pH (Bacillariophycea, Cryptophyceae, Chrysophyceae, Cyanophyceae, Eulenophyceae)
3) Increasing % contribution with increasing Ali and decreasing pH (Dinophyceae and Raphidophyceae). However, Raphidophyceae disappeared at Ali>100 whereas Dinophycea increased above Ali=100.



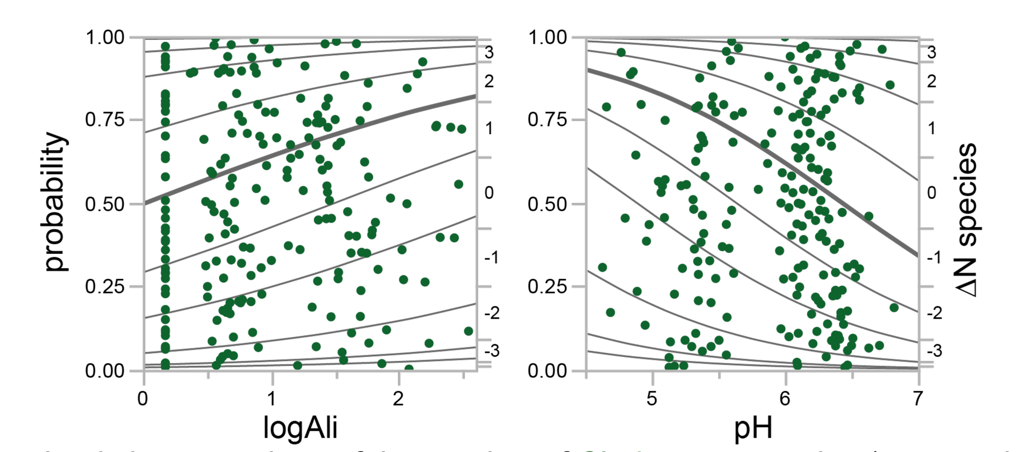
Top: **Negative (red) and positive (dark) indicator phytoplankton taxa** ordered after estimated change points along gradients in maximum Ali and minimum pH. Size of dots proportional to the z-score of the taxon, a measure of the strength of its response to change in the environment variable. Horizontal lines correspond to 95% bootstrap conficence intervals. Calculated using Threshold Indicator Taxa Analysis (TITAN) (Baker & King 2010).

Bottom: **Sum of z scores at all candidate change points**. Maxima are indicative of synchronous change of many taxa, and possible plankton community tresholds. Calculated using Threshold Indicator Taxa Analysis (TITAN) (Baker & King 2010).

ZOOPLANKTON



Both Ali and pH have weak but significant effects on Zooplankton **abundance** (corrected for the effects of TP and mean for each group). Cladocerans and Cylopoids respond negatively to increasing Ali and decreasing pH, whereas there is no effect on Calanoids and a positive response of Rotifers to increasing Ali and decreasing pH.



Logistic regressions of the number of Cladoceran species (corrected for expected **number of species** based on TP) on Ali and pH. The thick grey line show ΔN species = 0. The number of species did not change significantly with Ali or pH in rotifers, and there are too few copepod taxa for analysis.

CONCLUSIONS

- The effects of Ali and pH on plankton could not be separated in this data set (except for some interesting phytoplankton responses).
- Phytoplankton species richness decreased with increasing Ali and decreasing pH, but biomass did not change along these gradients.
- Zooplankton abundance was only weakly affected by Ali and pH.
- Cladoceran species number decreased with increasing Ali and decreasing pH.

PERSPECTIVES

- The (apparent?) effect of Ali on plankton appears to start already at Ali concentrations <20 µg L⁻¹. Hence, increased analytical and modelling precision would be very beneficial in future studies.
- To disentangle effects of Ali and pH we suggest studies focusing on lakes with similar water chemistry in terms of pH (in the range 5-6) and TOC and total P, but varying in fluoride (which affects Al speciation).

References

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ISELAW

Swedish Agency for Marine and Water Management

Integrated Studies of the Effects of Liming Acidified Waters (ISELAW) is a program for monitoring and assessment of the effects of liming in acidified lakes and streams. It is commissioned by the Swedish Agency for Marine and Water Management and executed by Swedish University of Agricultural Sciences and Stockholm University.