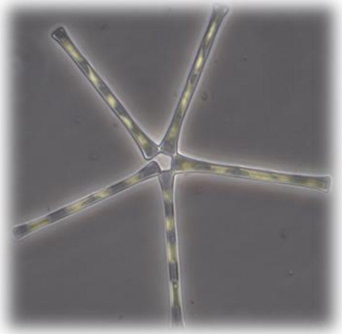
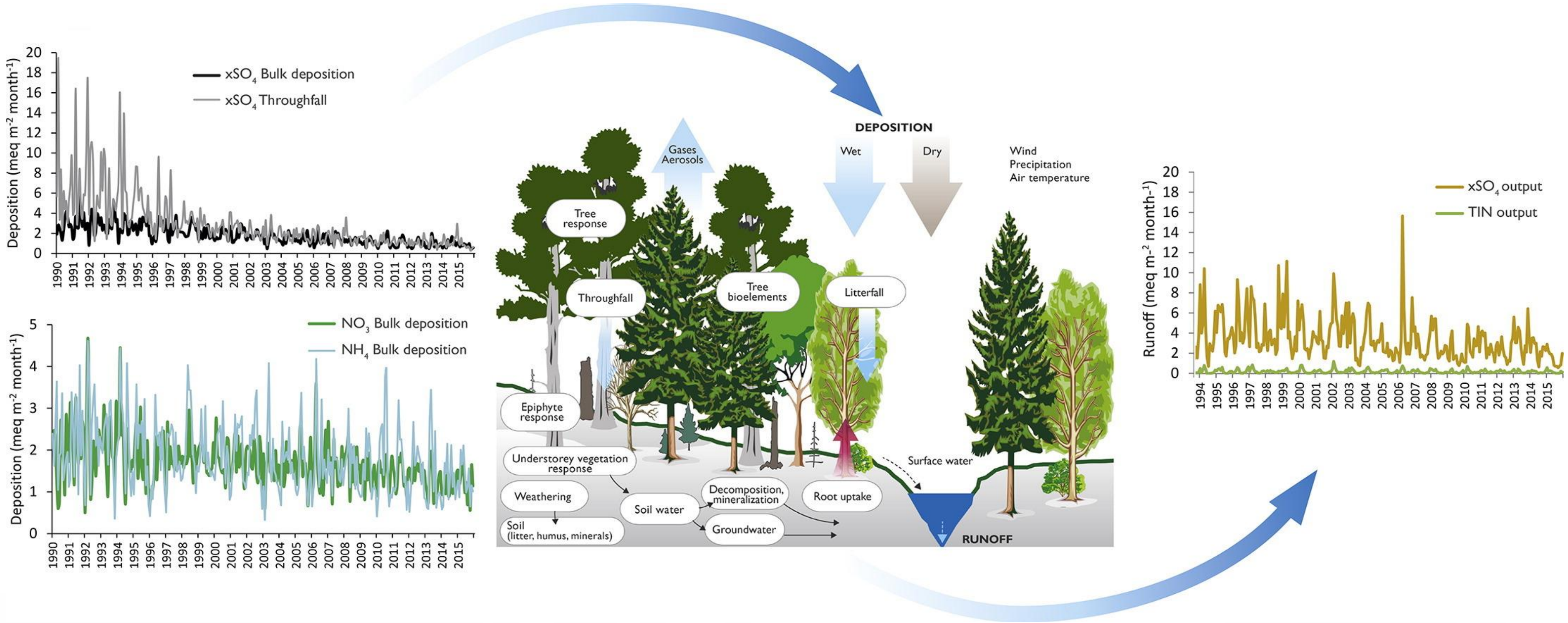



Reactive Nitrogen – impacts on freshwaters

Topic for the 2019 thematic report

Jan Erik Thrane, Benoit Demars and Heleen de Wit


Nitrogen deposition accumulates in catchments and leads to leaching of DIN to surface waters



Vuorenmaa et al. 2018 Stoten

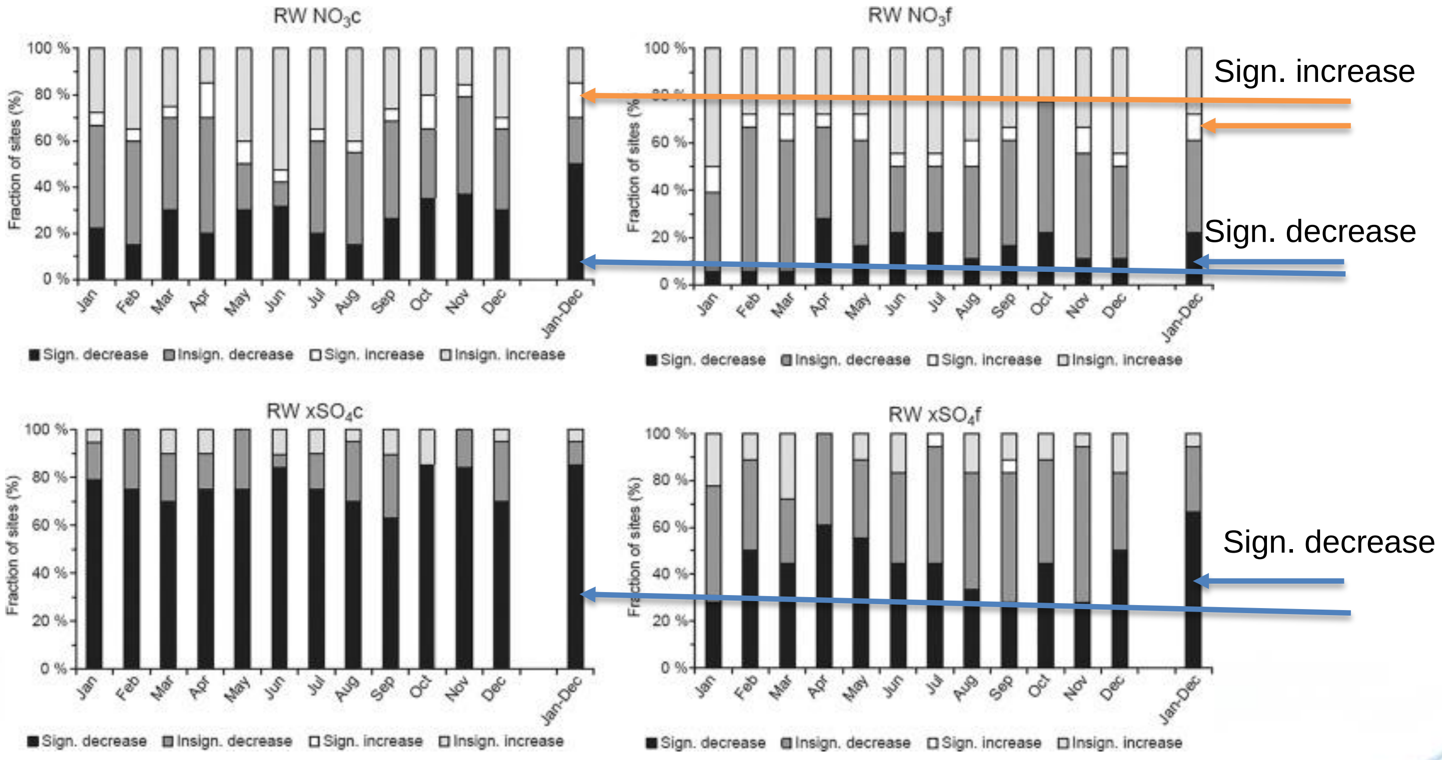
Trends in NO3 concentrations and fluxes

concentrations

Fluxes

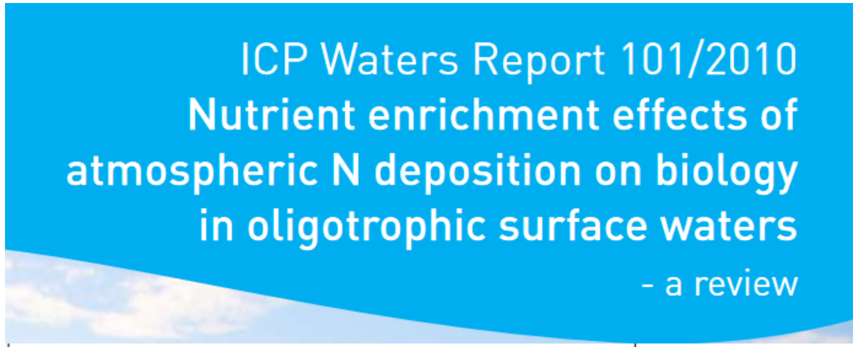
NO3

SO4



Vuorenmaa et al. 2018 Stoten

Aren’t freshwaters just P-limited?



Schindler 1977:
– whole-lake manipulations show that lakes are P-limited

P-limitation paradigm has been Challenged by Sterner and Elser, and others

All three papers that critically review the P limitation paradigm (Elser et al., 2007; Lewis and Wurtsbaugh, 2008; Sterner, 2008) agree that there is compelling evidence that phytoplankton productivity can be limited both by N and P. They also agree that the mechanism proposed by

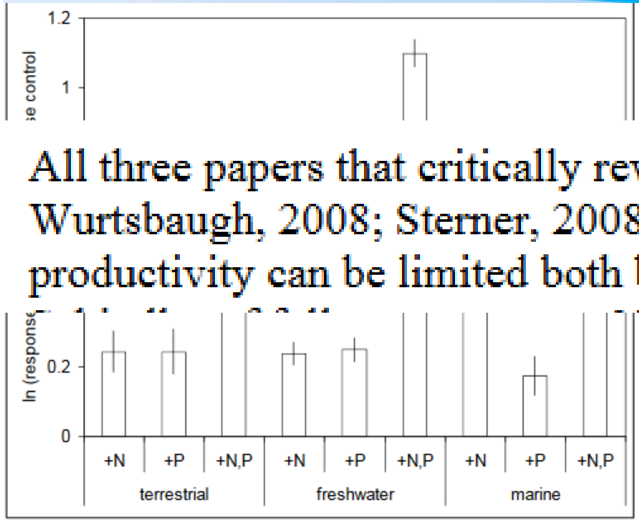
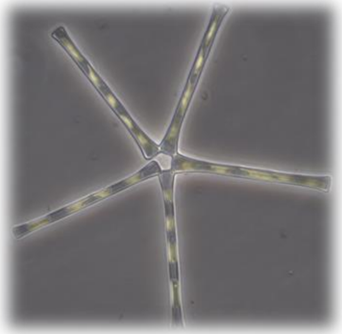


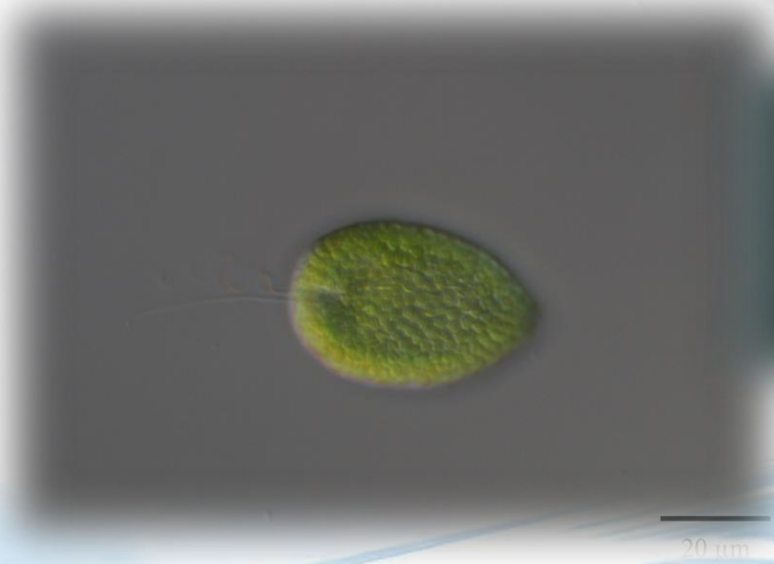
Figure 1 Responses of autotrophs to single enrichment of N or P or to combined N + P enrichment in terrestrial, freshwater and marine ecosystems. Data are given as natural-log transformed response ratios (RRx) in which autotroph biomass or production in the enriched treatment is divided by its value in the control treatment and then ln-transformed. Error bars indicate + or – one standard error. Redrawn from Elser et al. (2007) (Figure 1)

De Wit and Lindholm 2010
ICP Waters report 101/2010

Phytoplankton in oligotrophic lakes

- Microscopic, unicellular organisms that do photosynthetis
- The basis for pelagic food chains in lakes
- Needs light, CO_2, and macro- and micro nutrients to grow
- Most important macronutrients are **nitrogen** and **phosphorus**
    - These may limit growth rate and biomass



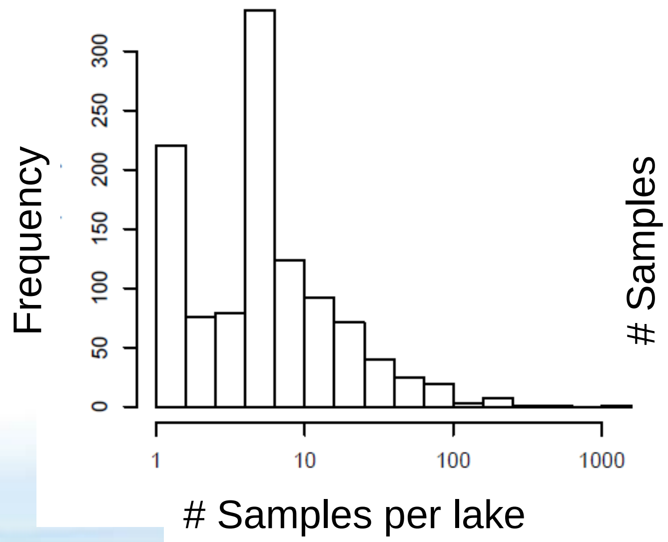


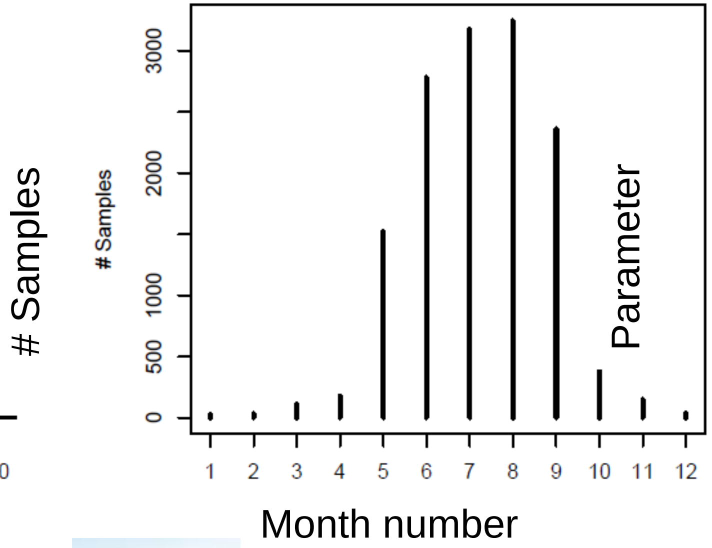
Reactive nitrogen – preliminary data exploration

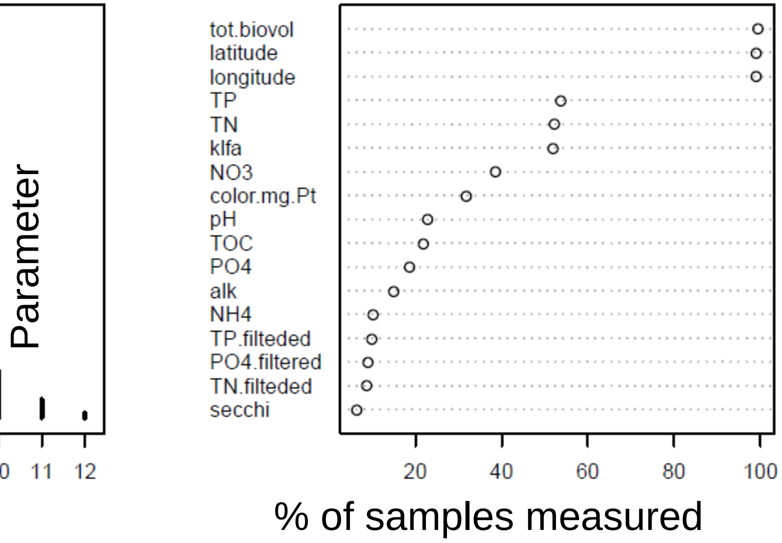
- Based on existing Norwegian database where water chemistry has been linked to data on phytoplankton, in 1100 lakes
- Contains many data from eutrophic, agriculturally impacted lakes
- So far:
  - Separate lakes with <TP 15 µg/L from the rest.
  - Test relationships between 'algal biovolume' (a proxy for algal biomass) and water chemical parameters
  - Test relationships between community (nr of taxa) and water chemistry.
  - Key question – is reactive nitrogen limiting freshwater productivity?

Water chemistry

- TN and TP measured in 53 % of the samples (~7500 observations)
- NO3 in ca. 40 %
- NH4 in < 20%
- Several observations per lake (some > 100) and year



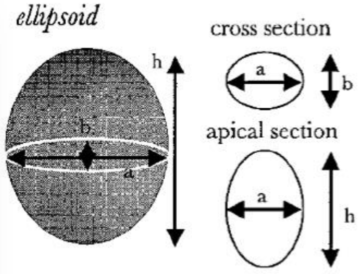




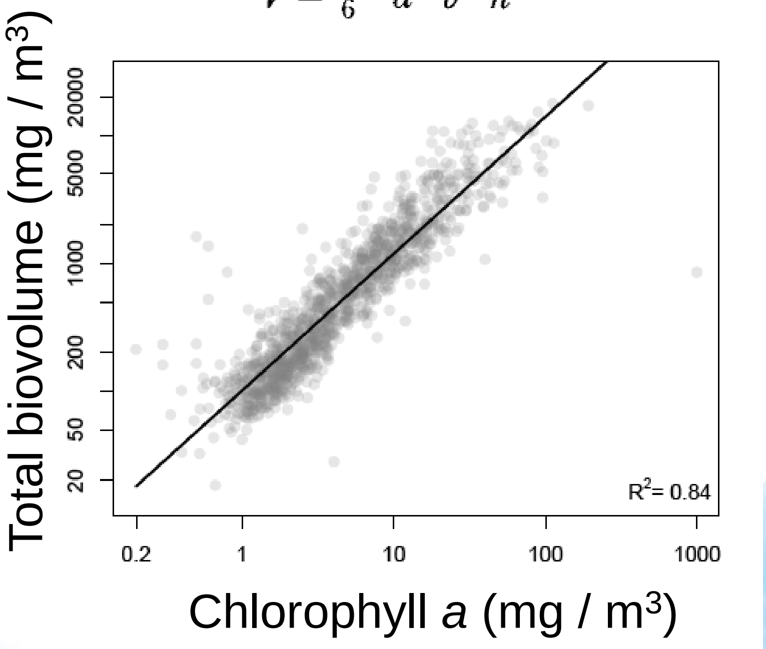
Algal biomass

- 15 000 observations of phytoplankton total biovolume
  - **Biovolume** = the volume of an algal cell
  - Calculated based on the shape of the cell, e.g an ellipspoid
  - **Total biovolume** = the sum of the volumes for all cells of all taxa present in the sample

  - Well correlated with **chl *a*** concentration



$$V = \frac{\pi}{6} \cdot a \cdot b \cdot h$$

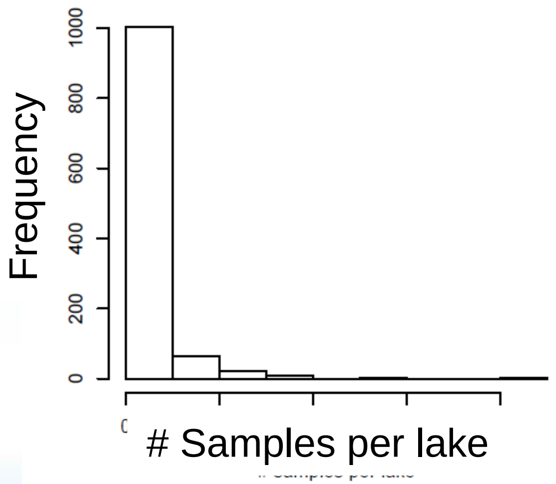


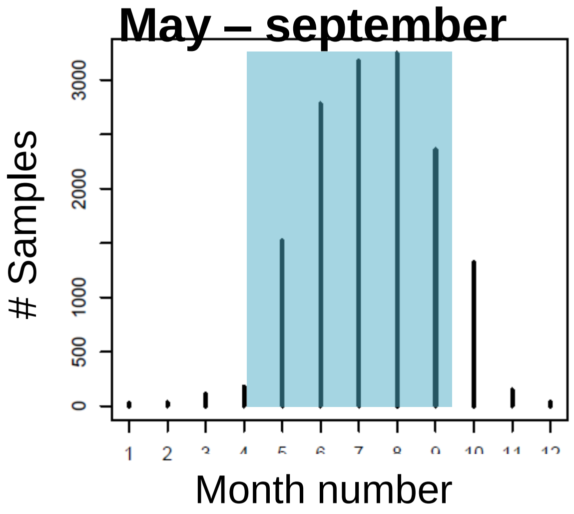
TP, TN and algal biomass

- TN and TP is measured on unfiltered water samples
- Contains both dissolved and particulate N and P.
  - A large fraction of the total P pool is bound in phytoplankton.
  - Almost always > 40%, often > 90 %
    - In oligotrophic water, humus-rich water possibly lower
- There will necessarily be an autocorrelation when relating TP to algal biovolume or chl *a.*
- The same is true for TN, but a smaller fraction of TN is bound in algal biomass
  - Median fraction of 15 % based on data from 75 Norwegian and Swedish lakes

Aggregated dataset

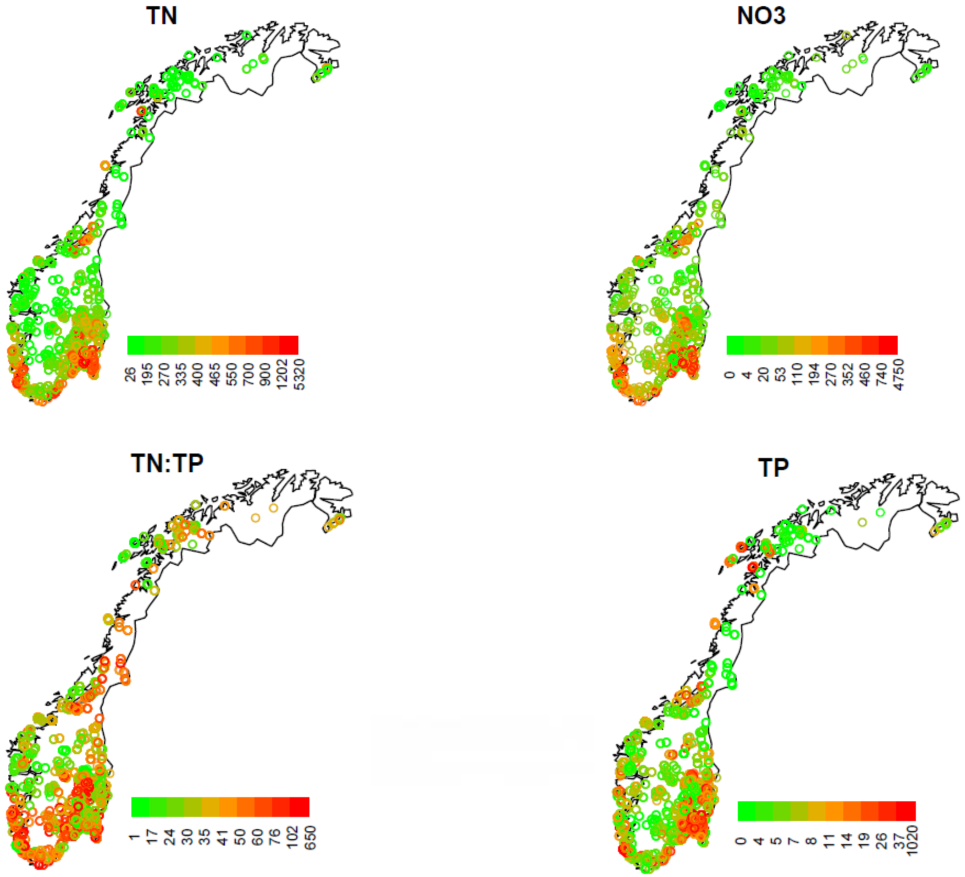
- Subset to the algal growth season (May-Sept)
- Aggregated by taking the mean for each lake within each year
  - Reduced the dataset from 15 000 to about 2500 datapoints for biovolume
  - From ca. 7500 til 1250 obs for TN and TP
  - Most lakes now with < 10 samples per lake

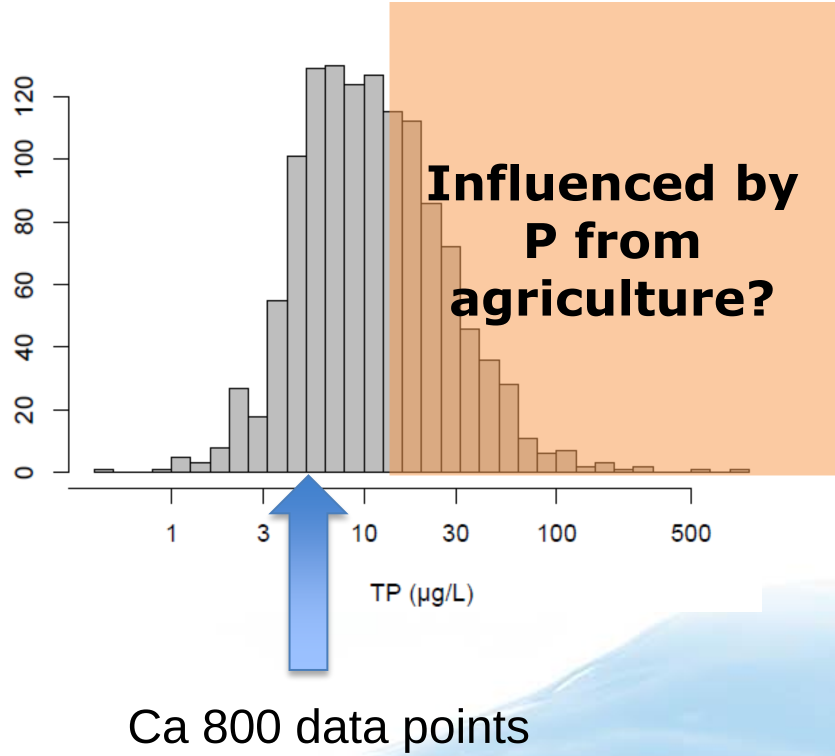




NB! Preliminary analyses are done on this dataset, but the datapoints are not independent (later: e.g. use of mixed effect models to account for dependeny within lakes)

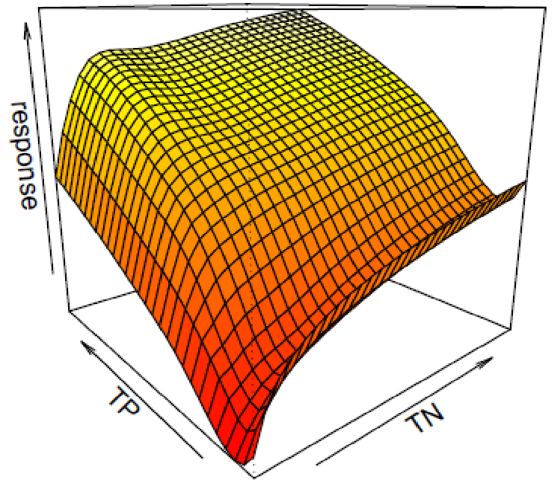
Distributions of N, P, NO_3 and N:P in the database

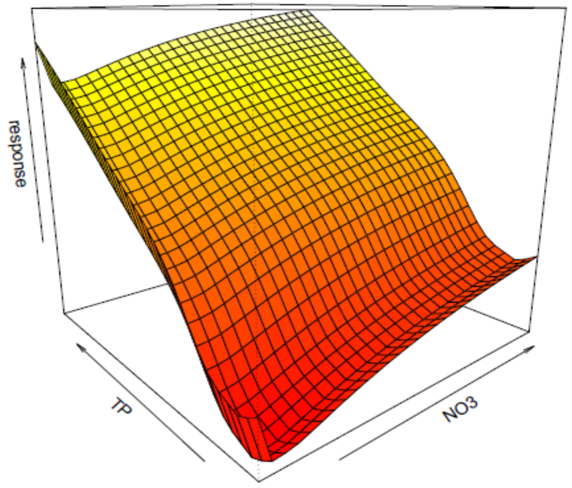




Co-limitation? Responses of phytoplankton biomass to N and P

- Strong relationship between total biovolume and TP alone (whole dataset: $R^2 = 0.61$; oligotrophic lakes: $R^2 = 0.3$)
- Moderate relationship with TN alone (whole dataset: $R^2 = 0.41$; oligotrophic lakes: $R^2 = 0.2$)
- Including both variables increased the explained variation slightly (whole dataset: $R^2 = 0.64$; oligotrophic lakes: $R^2 = 0.37$)
- Plots show response of biomass to TN and TP (upper), and NO3 and TP (lower) for oligotrophic lakes (TP < 15 µg/L)
    - Strong TP-effect for all N-concentrations
    - A postive effect of N, but generally only in the lower end of the N-gradient





Effects of atmospheric nitrogen deposition on nutrient limitation and phytoplankton biomass in unproductive Swedish lakes

2005

Ann-Kristin Bergström[1]
Department of Ecology and Environmental Science, Umeå University, SE-901 87 Umeå, Sweden

Peter Blomqvist[2]
Department of Limnology, Evolutionary Biology Centre, Uppsala University, Norbyvägen 20, SE-752 36 Uppsala, Sweden

Mats Jansson
Department of Ecology and Environmental Science, Umeå University, SE-901 87 Umeå, Sweden

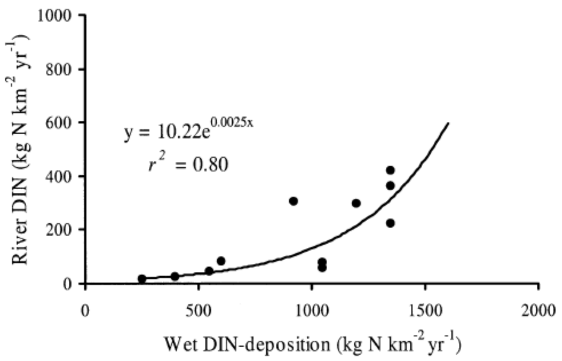
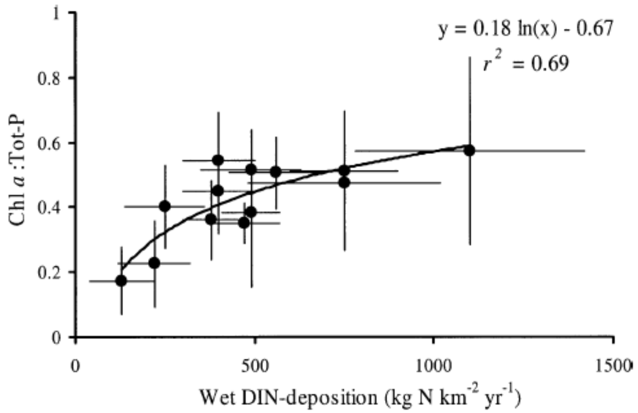


Fig. 3. The relationship between mean river transport of inorganic nitrogen (river DIN) and mean wet inorganic nitrogen deposition (wet DIN deposition) for different river catchments in Sweden (mean values from 1995–2001).



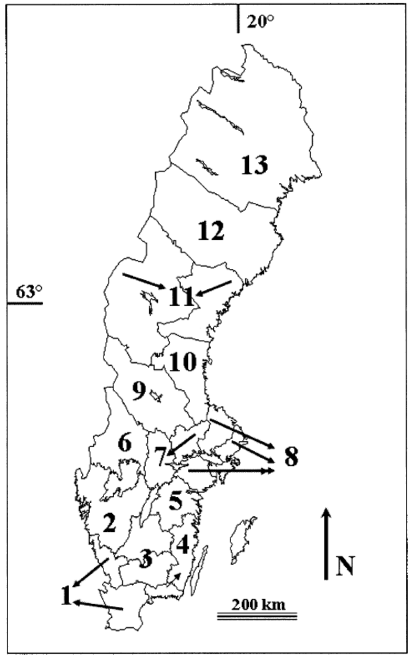
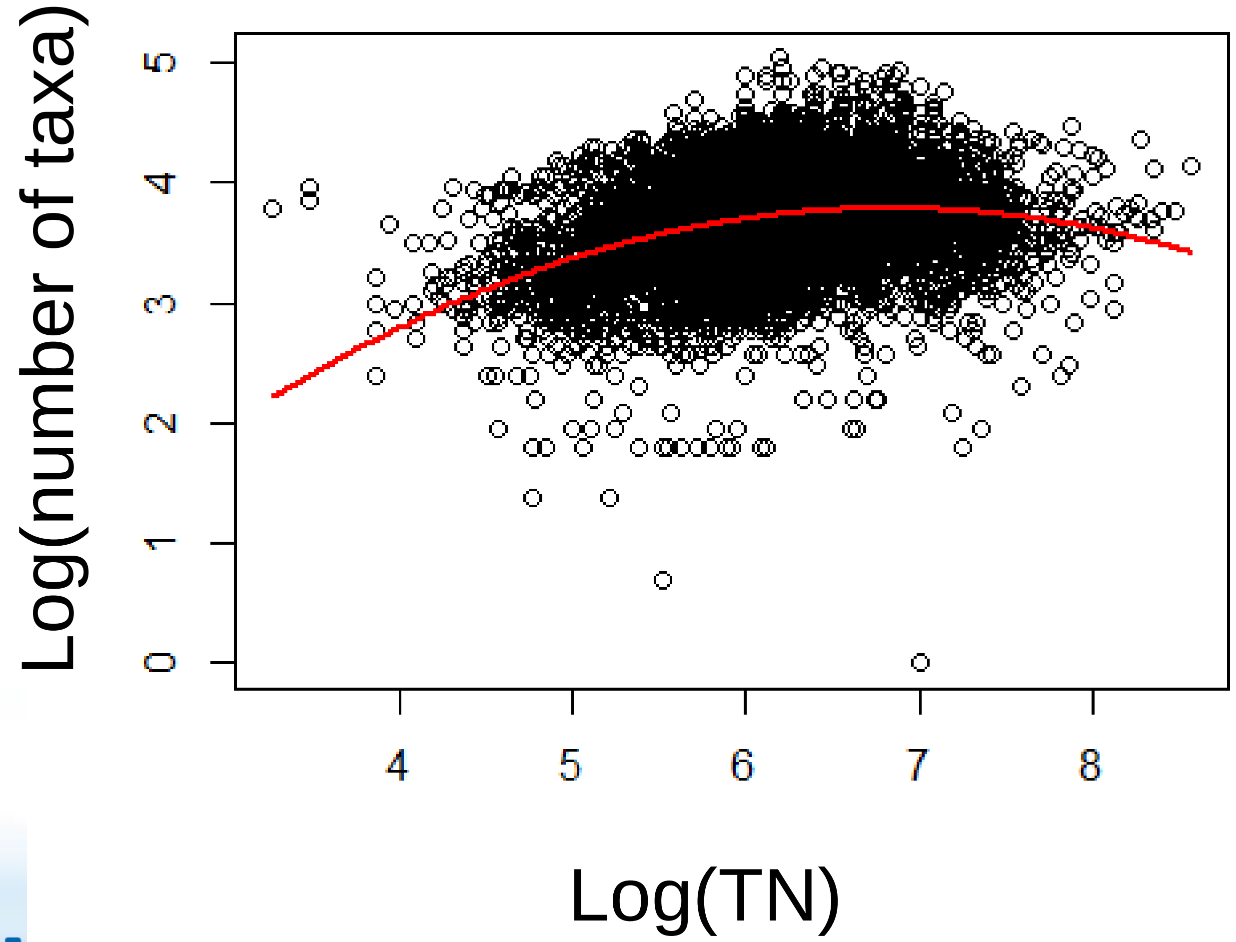


Fig. 1. The different Swedish regions used in this study.

Effect of total nitrogen on species diversity

Gaussian curve: looking for optimum TN for maximum number of taxa (richness)



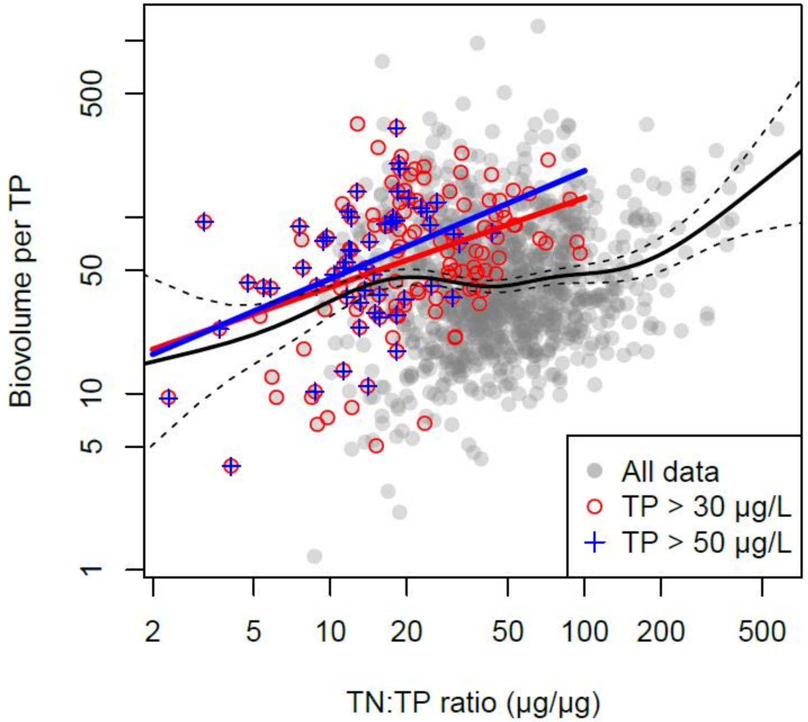
Optimum
915 µg N L^{-1}
Tolerance
121-6904 µg N L^{-1}
Maximum
41 taxa

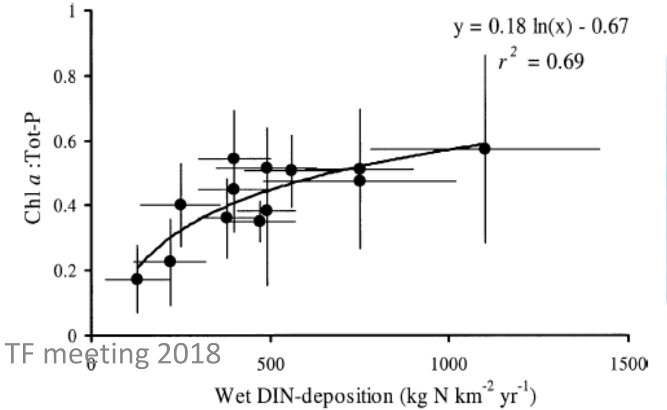
Conclusions

- Preliminary analysis supports that P-limitation of algal productivity is most common, but suggests co-limitation of P and N at low concentrations of N
- However…
  - The dataset contains (too) few data from oligotrophic lakes
  - Not clear which lakes are impacted only by deposition
- To be discussed
  - Availability of other data
  - Approach – key questions – methods
  - Interest of NFCs to participate in the analysis.

Responses of phytoplankton biomass to N and P

- When lakes are P-limited, we expect the ratio of biovolume to TP to be fairly constant
- If we have N-limitation, this is expected at low TN:TP ratios
- If N-limitation, we expect a decrease in biovolume per TP towards low TN:TP ratios
- There is some indication of that trend in the dataset (right)
- Mostly driven by high P (eutrophic) lakes (red dots: data with TP > 30 µg/L, blue crosses; data with TP > 50 µg/L; grey dots all data)

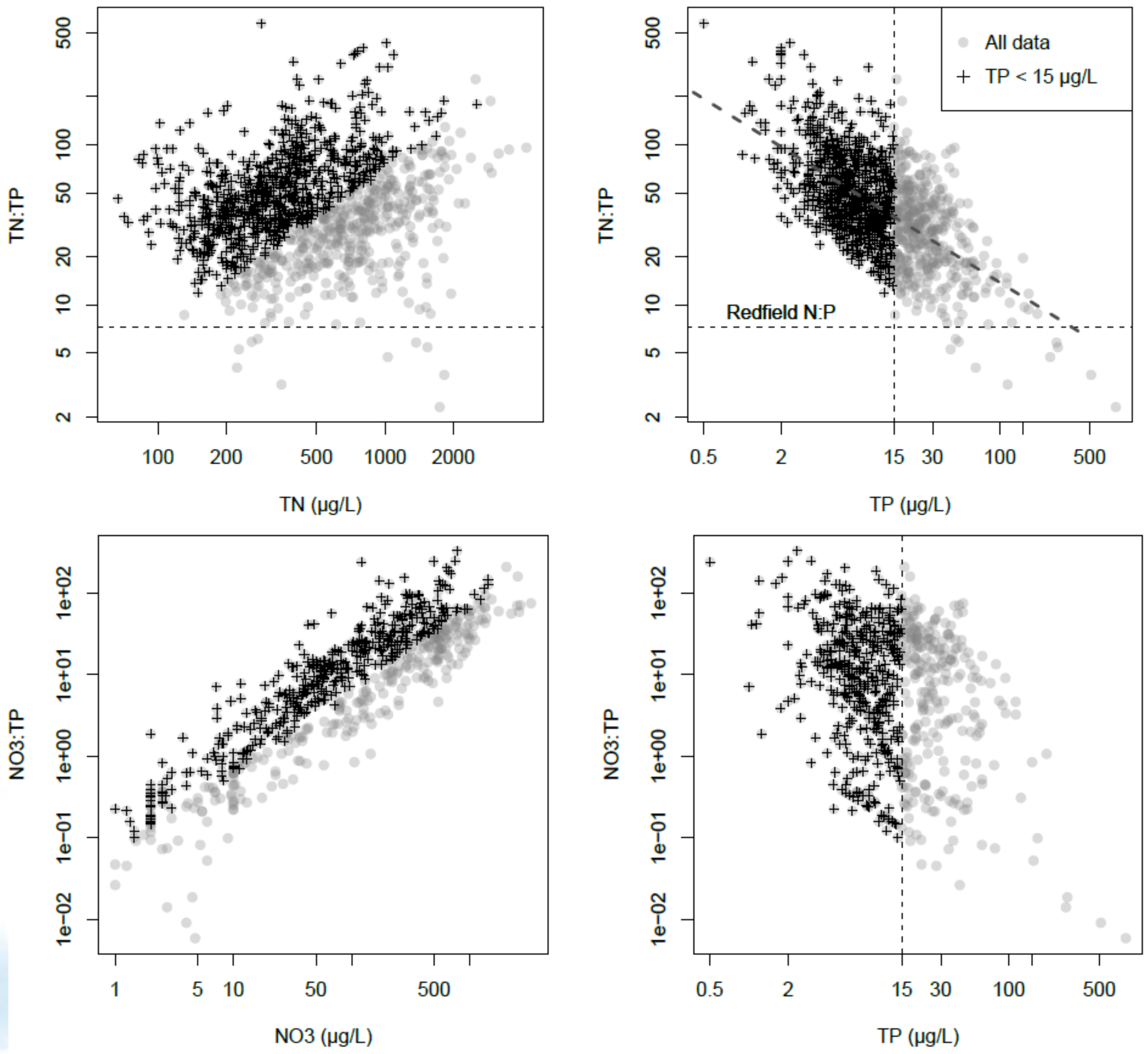




N:P ratios indicative of N or P limitation

- Majority of TN:TP ratios above Redfield N:P ratio, especially in oligotrophic lakes
  - Indicates P-limitation, rather than N-limitation

- NO3:TP is driven mainly by changes in NO3
  - Possible relationship between N-deposition and NO3



Species accumulation curve (sampling effort)