Sediment Fe:PO$_4$ ratio as a diagnostic and prognostic tool for the restoration of aquatic biodiversity in fens
Eutrophication and pollution

Eutrophication of Dutch peat lakes
In a major part of The Netherlands allochtonous river Rhine water is used to counteract desiccation problems.

This leads to strong eutrophication.

External loads decreased due to P-stripping and decrease of P in Rhine water.

However, $\text{HCO}_3^-$, $\text{SO}_4^{2-}$ and Cl$^-$ still high: eutrophication of fen waters increased!
Eutrophication and pollution

**Shallow fen waters / peat lakes: undisturbed**

- Clear water
- Aerobic conditions
- Rooting macrophytes

**Iron**
- Iron phosphate
- Iron sulphides
**Eutrophication and pollution**

**Shallow fen waters / peat lakes: eutrophied & polluted**

- Lemna sp. & blue algae
- Turbid water
- Phosphate mobilisation
- Anoxic water layer
- Toxic sulphide
- Nutrients and Sulphate
- No rooting macrophytes
- Phosphate
- Iron phosphate
- Iron sulphide
- Sulphate
- Anoxic soil
- Shallow fen waters
- Peat lakes
- Eutrophied
- Polluted
Hypothesis

**Water quality data**
- used for predicting restoration potential of aquatic macrophyte diversity
- strong temporal fluctuations (seasons, growth of plants & algae)

**Sediment (pore water) data**
- less fluctuating in time – less frequent sampling needed
- indicators of biogeochemical processes in the sediment, especially Fe-S-P interactions (shallow lakes; 1-2 m)
  - “early warning system” for *future* changes in water quality
  - prognosis of biodiversity response after restoration measures
145 fen waters in 17 different areas in the Netherlands, Ireland and Poland:

- Surface water and pore water samples
- Vegetation relevées → threatened species
- Sediment samples from 79 locations
- Correlations and other statistical methods
Surface water quality and aquatic vegetation

- Highest biodiversity at lowest PO$_4$ concentrations
- Red List species $\rightarrow$ stronger related to surface water chemistry than others
- Red List species present $\rightarrow$ lower turbidity, pH, SO$_4$, PO$_4$ and NH$_4$ concentrations

![Graphs showing the relationship between surface water PO$_4$ concentrations and species cover and number of species.](image-url)
Sediment and surface water quality

- PO₄ mobilization trigger at pore water PO₄ > 6.5 µmol L⁻¹
- Thresholds for pore water Fe:PO₄ < 3.5 mol mol⁻¹ and for total sediment Fe:P < 10 mol mol⁻¹
- Low ratios / PO₄ mobilization ↔ SO₄ pollution / sulphide production

Smolders et al. 2001

![Graphs showing relationships between variables]
Sediment quality in relation to aquatic vegetation

- Fe:PO$_4$ ratios → only correlation with Red List species
- Number of species increased at Fe:PO$_4$ > 1
- Abundance increased at Fe:PO$_4$ > 10
- Red List species → more sensitive to toxic sulphide and ammonium
- Turbid, alkaline, P- and S-rich: only eutrophic and hypertrophic species.
- High pore water Fe:PO$_4$ ratio: more mesotrophic, oligotrophic and Red List species.
- Most helophytes: high S, Al and Fe:PO$_4$ and low PO$_4$.
Conclusions

The pore water Fe:PO$_4$ ratio is an indicator for both biogeochemical processes and biodiversity.

It is a valuable tool to:

- understand biogeochemical key processes
- predict future changes in water quality
- evaluate the chances for reestablishment of aquatic vegetation after restoration
- select the most promising locations for restoration
- optimize restoration measures
Many thanks to

- Hein Pijnappel, Judith Sarneel, Babette Bontes, Marjolijn Christianen, Artur Banach, Marlies van der Welle, Bas Bierens, Kim Kobes, Jan van de Graaf, Martin Versteeg, Jelle Eygensteyn, Roy Peters, and Germa Verheggen

- The Dutch Ministry of Agriculture, Nature and Food Quality for funding the research

- All nature managers involved

- You, for listening!