Phosphorus enrichment: an underestimated threat for biodiversity in temperate wetlands

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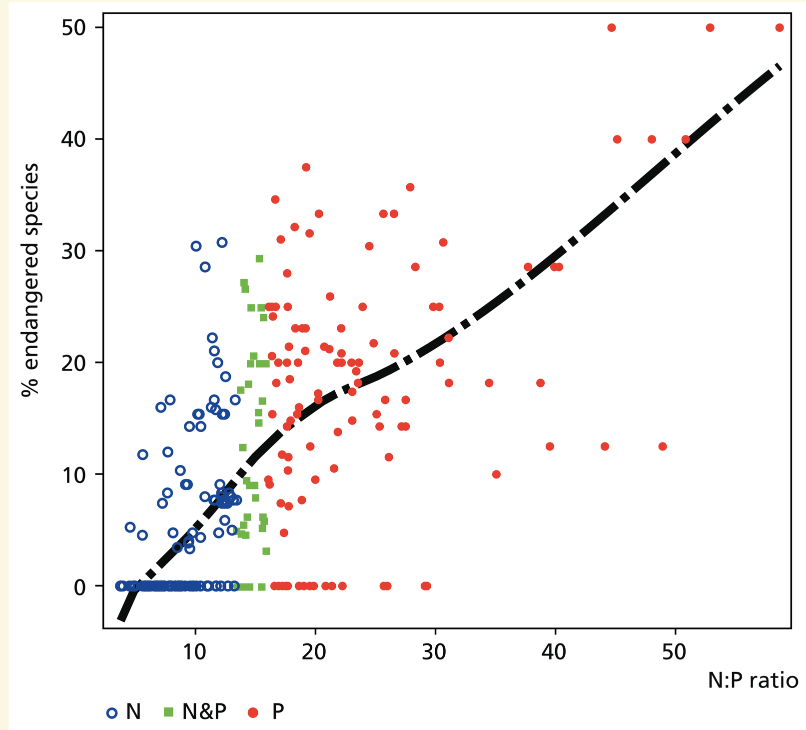
Phosphorus is the key

Nitrogen enrichment is widely thought to be responsible for the loss of plant species from temperate terrestrial ecosystems. However, as the type of nutrient limitation has never been examined on a large geographical scale the causality of N enrichment for species loss is uncertain. We assessed the type of nutrient limitation (N, P, K) and investigated species richness in herbaceous wetlands, sampled along a transect through temperate Eurasia that represented a gradient of declining levels of atmospheric nitrogen deposition.

We showed that many more endangered plant species persist under phosphorus-limited than under nitrogen-limited conditions. We concluded that enhanced phosphorus is in Western Europe more likely the cause of species loss than nitrogen enrichment.

Our results highlight the need for a better understanding of the mechanisms of phosphorus enrichment. Sources of P enrichment already were taken away in the 1980s by introducing phosphate-free washing powder and introducing a third step in sewage treatment plants. Still, many soils are phosphate saturated and in wetlands P enrichment is not anymore from external sources but caused by changed soil processes through human alterations.



Relationship between frequency of Western European endangered plant species (vertical) and type of nutrient limitation indicated by the N:P ratio (horizontal). Each symbol represents a sample from a different ecosystem.

Samples were collected in Western Europe, Poland and Western Siberia. Blue symbols indicate ecosystems in which nitrogen is the limiting resource; red symbols indicate phosphorus-limitation and green symbols N and P co-limitation. Red symbols with a high N:P ratio indicate strong phosphorus limitation under which many endangered plant species persist. In Western Europe low phosphorus conditions have become rare.
Wassen et al 2005, Nature 437: 547-551.

Related mechanisms for P-enrichment are:

1. Increased release of organic-P from organic matter through increased drying-wetting dynamics
2. Increased P-mineralization induced by enhanced root phosphatase activity stimulated by atmospheric N-deposition
3. Increased release of phosphate from chemically bound mineral-P because of increased SO_4 reduction.

The significance of these processes, and particularly of their interactions, to P-enrichment are currently examined. Short-term effects are tested by means of two full-factorial experiments with wet-dry, N-addition, and SO_4 addition as factors: one at controlled conditions using soil cores, and one at field conditions. Phytometric plants and soil extractions are used to assess P-release rates. Long-term aspects will be tested in 2007/2008 by evaluating effects of re-wetting on P-release in paired study sites (re-wetted and nearby drained sites) in wetlands across Europe. The sites vary in (i) time after re-wetting, (ii) re-wet water type (SO_4 enriched or clean), and (iii) N deposition rate.

Conclusions:

Preliminary results of the laboratory experiment are shown in Figure 2 and 3.
Two of the three proposed mechanisms showed to be at least partially valid in the controlled experiment. Firstly, adding of SO_4 rich water increased the phosphate availability in the soil. Secondly, although we did not detect a clear response in soil phosphorus availability upon nitrogen addition, we indeed found phytometric plants to take up more N and enhance their phosphatase activity, resulting in extra growth. Therefore it seems plausible that N addition even in P limited sites may increase biomass production. This may negatively affect endangered plant species because both mechanisms increase P availability.

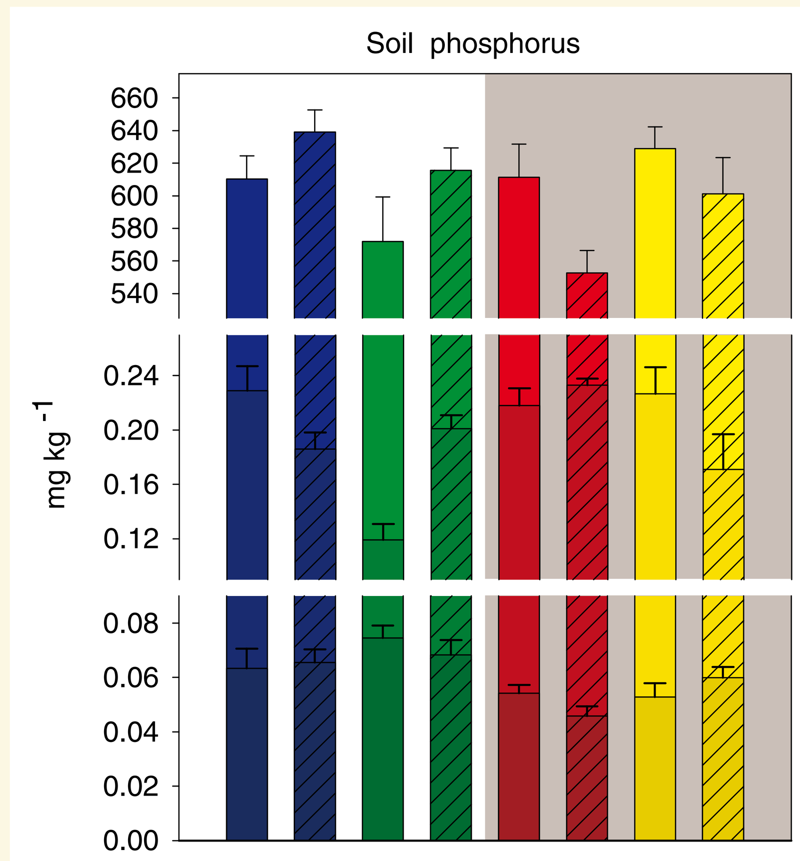


Figure 2. Soil P content of intact P-limited peat cores to which nitrogen was added (+N) and SO_4 (+S) and which were drained and rewetted (+R) or permanently wet (–R). The graph is divided in three panels. The panels show from bottom up; the water-extractable P, the acid extractable P (a measure for soil-adsorbed inorganic-P) and total P content. Addition of SO_4 lowered the Pacid: P_{water} ratio indicating a release of chemical bound P.
N addition increased the P_{total}:P_{water} ratio as well as the P_{acid}:P_{water} ratio which may be due to enhanced P-uptake.

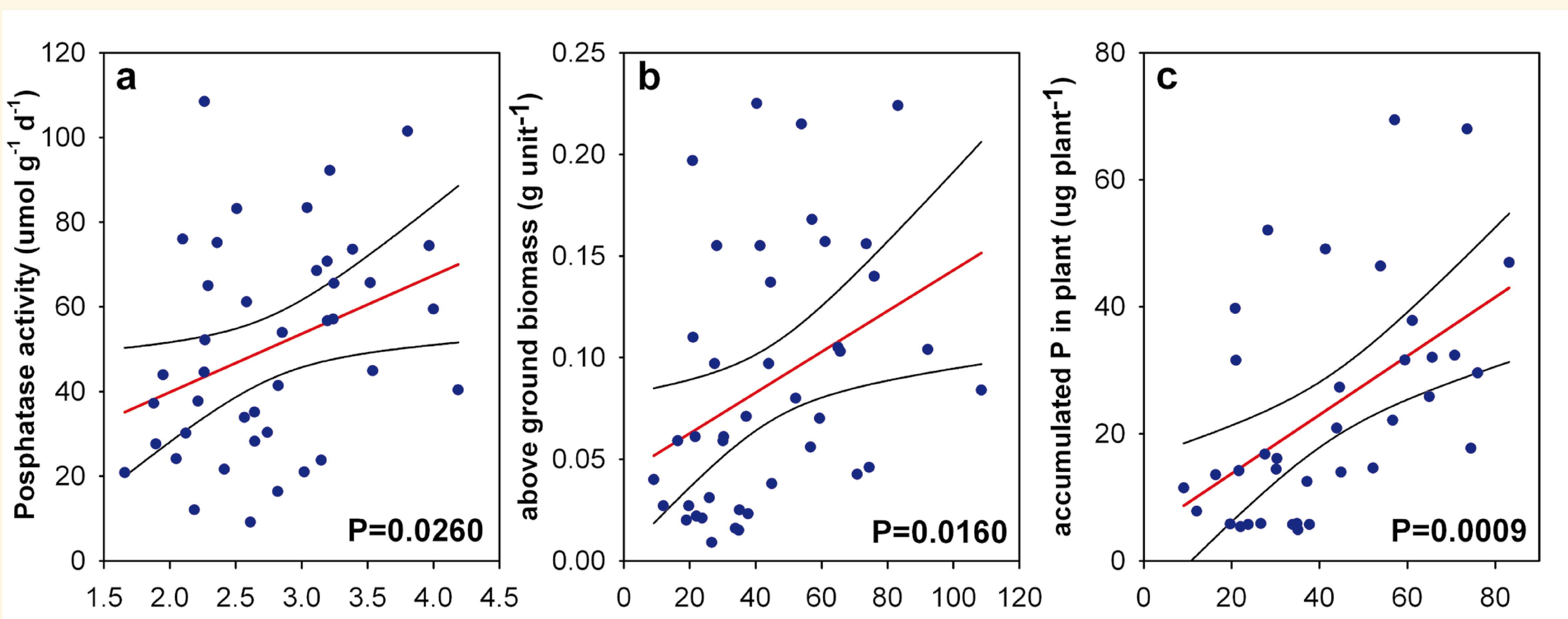


Figure 3. Correlations of a- Total N in plants with phosphatase activity, b- phosphatase activity with aboveground biomass and c- phosphatase activity with accumulated P in plants. Phosphatase activity was positive related to plant N content. Moreover, an increased phosphatase activity led to increased plant biomass resulting in higher accumulation rate of P.

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