I can see clearly now:
why the shift from turbid to clear water conditions in eutrophic lakes is good for breeding, staging and wintering waterbirds

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Fishpond management, Climate Change and Biodiversity Conference

Jindřichův Hradec, Czech Republic

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Nutrients and lakes

Human derived nutrients, mostly phosphorus but to some degree nitrogen as well, elevated above biologically limiting levels, are one of the most damaging of environmental changes in aquatic ecosystems in modern times

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Nutrients and lakes

Especially since 1900, human sewage, industrial waste, soil erosion and leachate from agricultural and forestry has contributed disproportionately to aquatic ecosystems, removing nutrient limitation as a constraint on biological productivity

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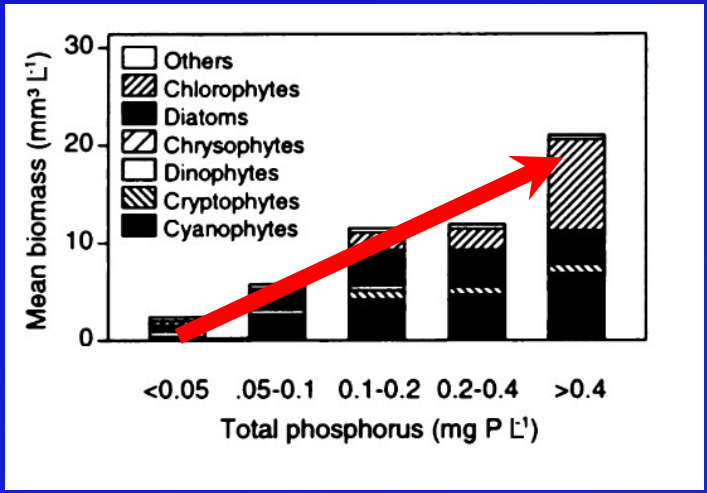
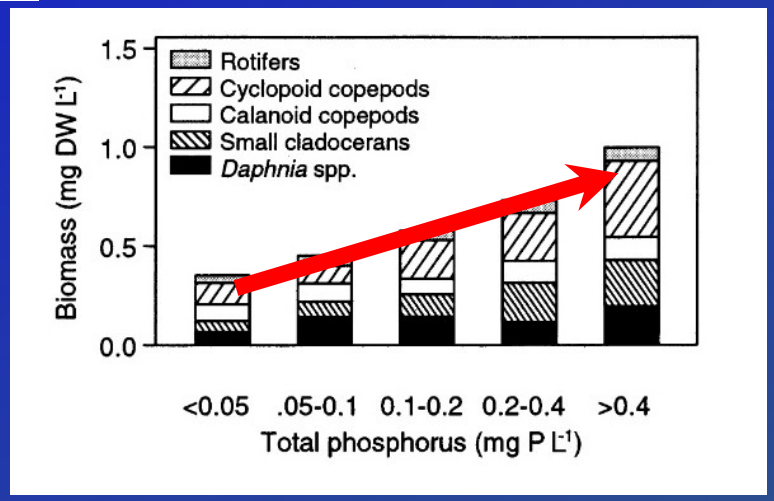
Nutrients and lakes

Essentially, more phosphorus results in more primary production among the phytoplankton and lower level consumers, such as zooplankton



From the classic study of 71 shallow Danish lakes

Jeppesen et al. (2000) *Freshwater Biology* **45:** 201–218.



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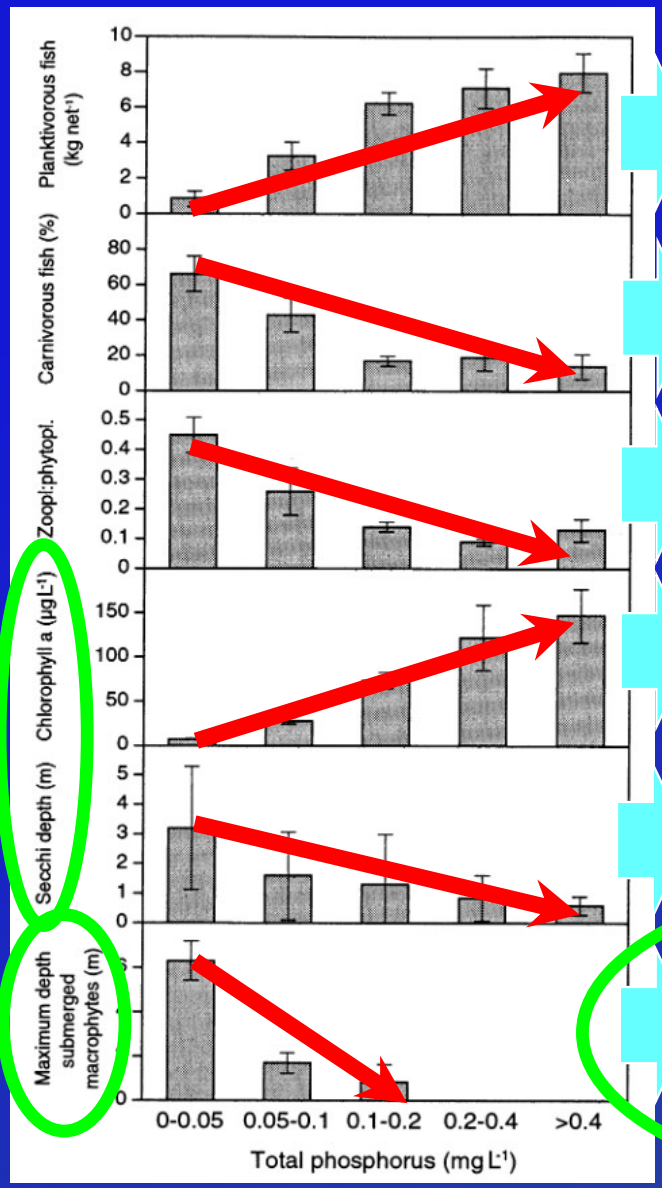
Nutrients and lakes

However, in terms of biodiversity, and specifically waterbirds, there are winners and losers as lakes progress along this gradient of nutrients

Jeppesen et al. (2000) *Freshwater Biology* **45:** 201–218.



Good for **piscivorous birds (grebes, Goosander, cormorants)** if the size class distribution makes these fish attractive to them

Potentially good for breeding birds removing large Pike that predate ducklings

Bad for species like **Shoveler** that specialize in zooplankton feeding

Dreadful, because few, if any, waterbird species can survive by grazing algae alone

Grim for all waterbirds that forage by sight during underwater feeding

Terminal for waterbirds grazing submerged macrophytes (**dabbling ducks, swans**) or diving for them or their seeds and turions (**Coot, Ferruginous Duck, Pochard, Red-crested Pochard**), kleptoparasitise for them (**Wigeon Gadwall**), feed on the invertebrates living within them (***Aythya* diving duck species, Goldeneye**, also many **dabbling ducks**)

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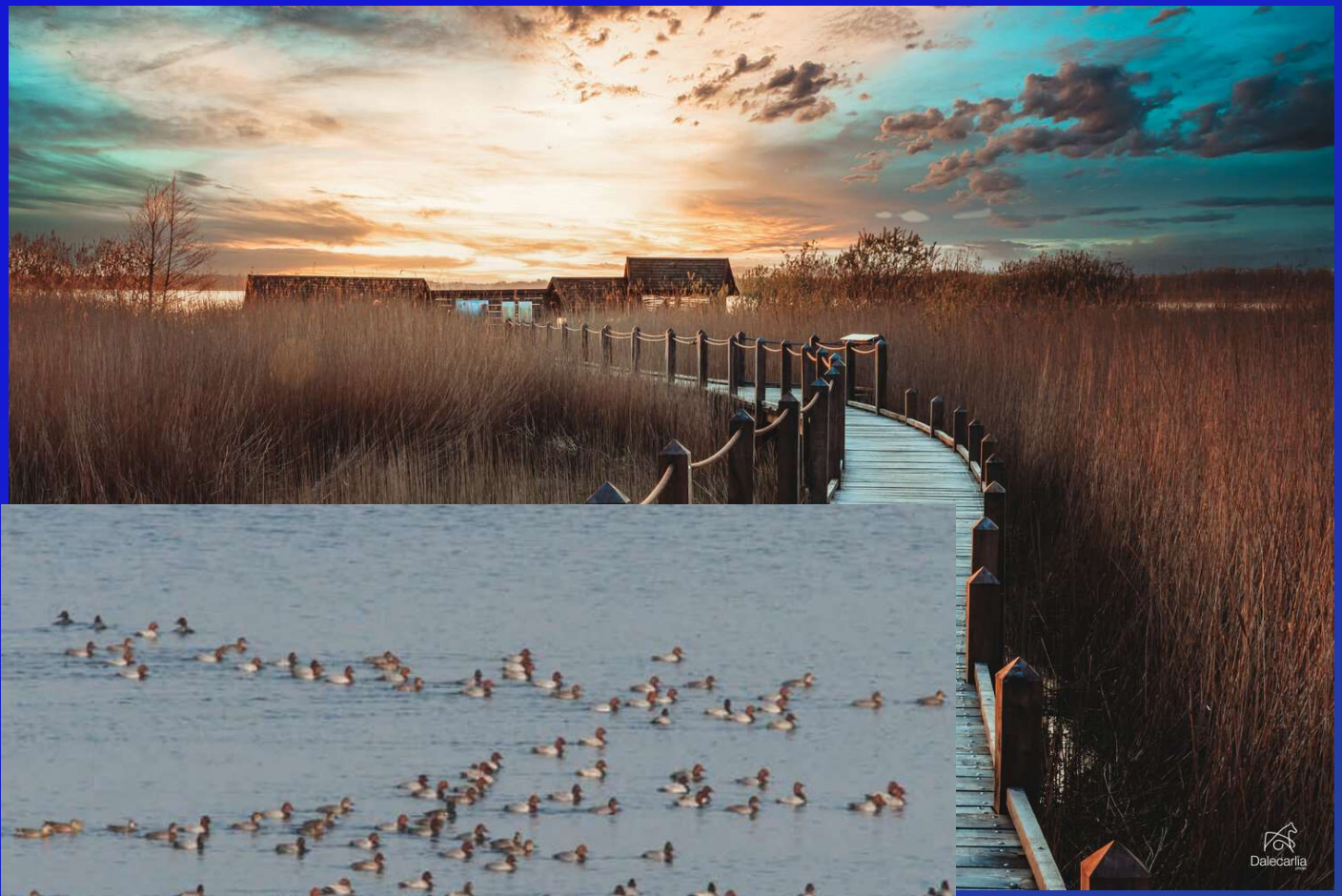
Turbidity and waterbirds

After a decade of algal blooms and no submerged vegetation, Lake Krankesjön in southern Sweden, the water column became clear and submerged vegetation (*Potamogeton* and *Chara*) returned and with them, many waterbirds

Hargeby *et al*. (1994) *Hydrobiologia* **279**: 83-90.



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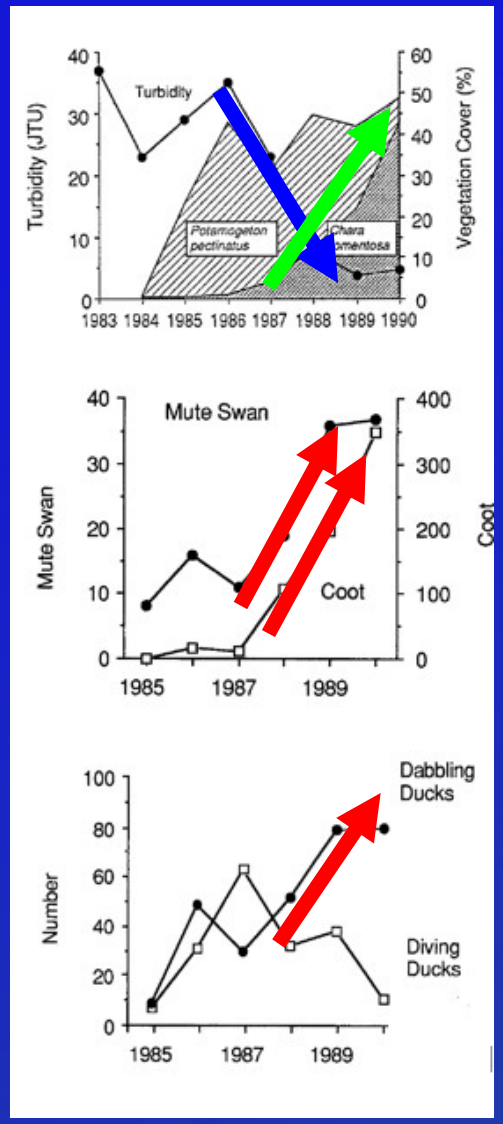
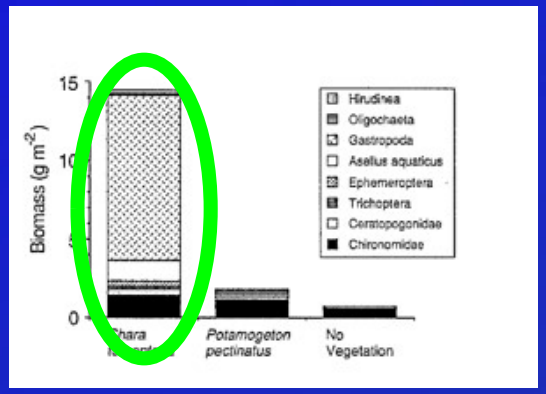
Turbidity and waterbirds

It is not clear what caused the switch from turbid conditions to clear water, but the effect on the submerged vegetation and the birds was clear – grazing waterbirds and dabbling ducks returned, as did the invertebrate biomass associated with the submerged vegetation.

Hargeby *et al*. (1994) *Hydrobiologia* **279**: 83-90.





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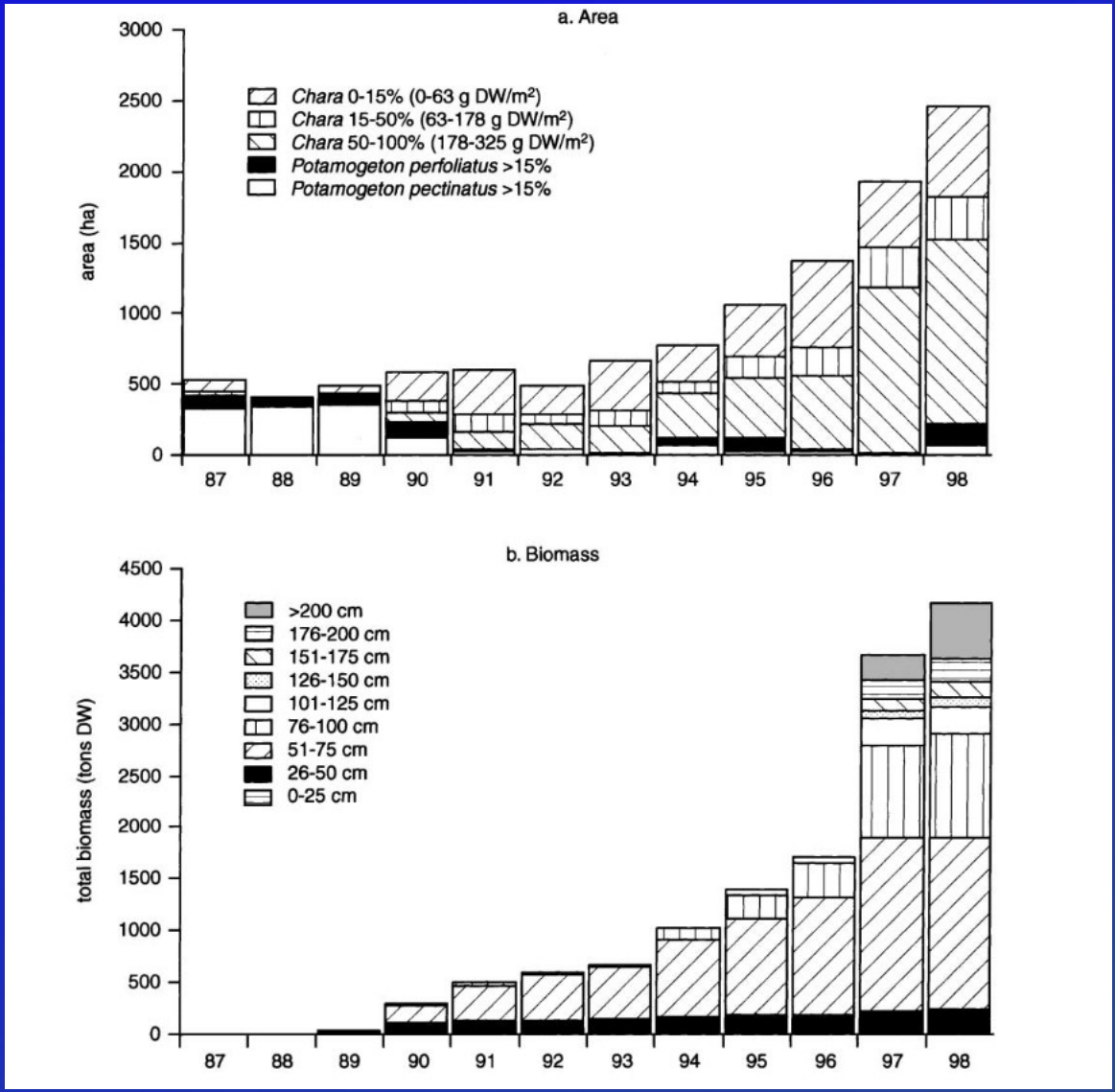
Turbidity and waterbirds

These experiences are reported from many similar lakes, where attempts to reduce eutrophication have led to improved water quality, and increased submerged macrophyte communities, for instance at Lake Veluwemeer, Netherlands

Noordhuis *et al*. 2002 *Aquatic Botany* **72**: 349-367.



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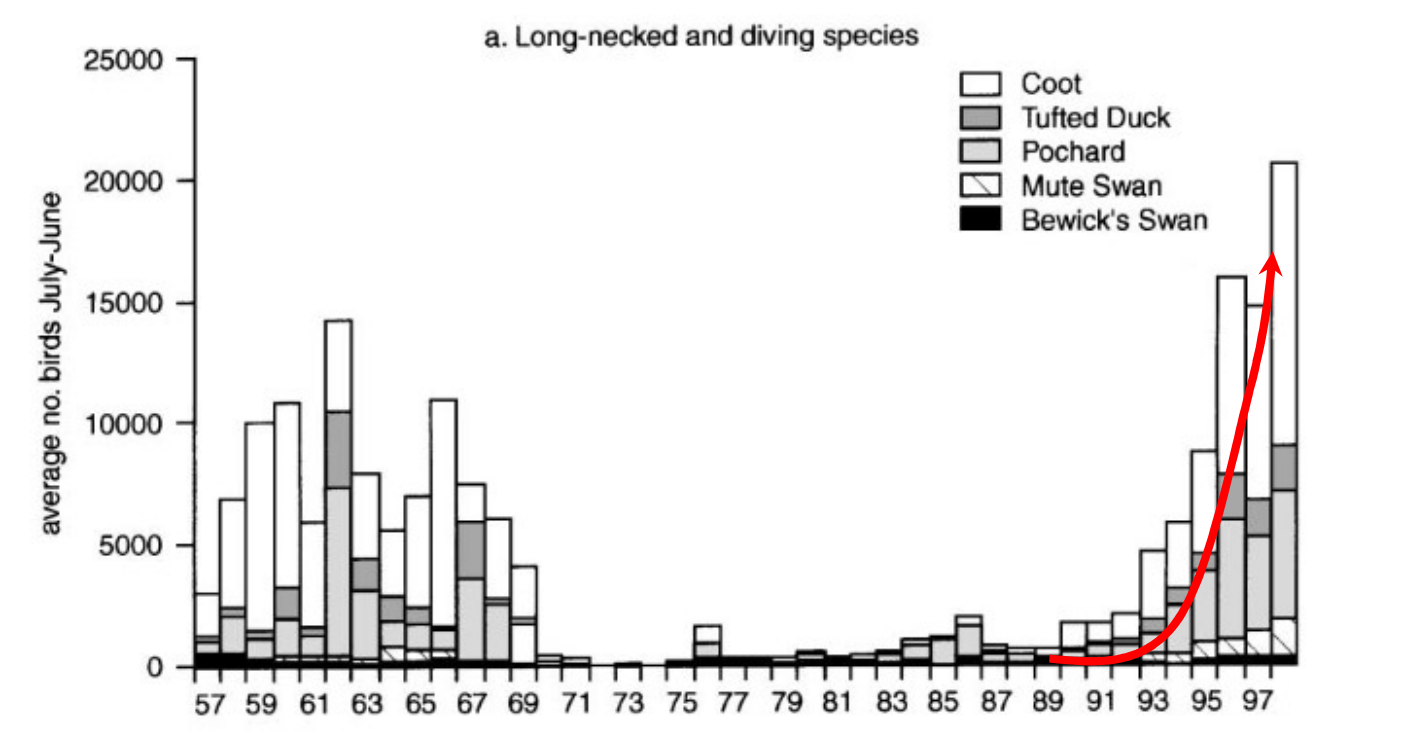
Turbidity and waterbirds

At Lake Veluwemeer, the restoration of submerged macrophytes also corresponded with the recovery of long-necked and diving herbivorous waterbirds at the site

Noordhuis *et al*. 2002 *Aquatic Botany* **72**: 349-367.



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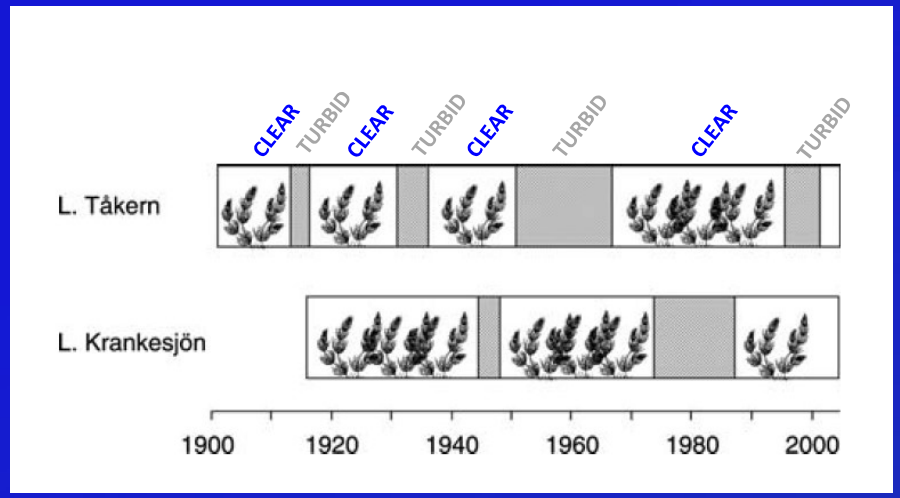
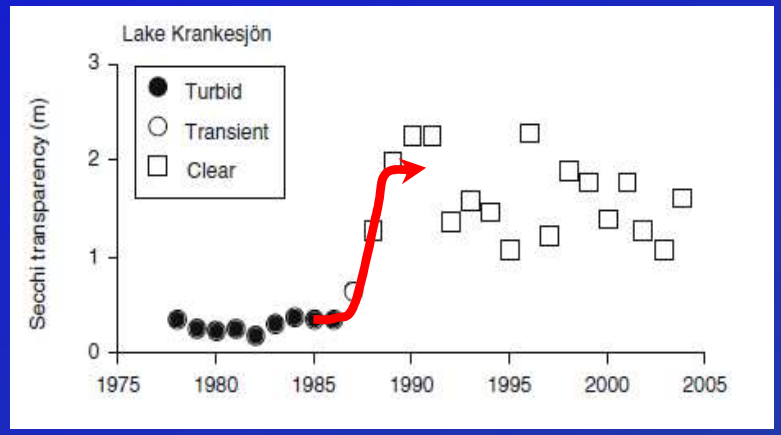
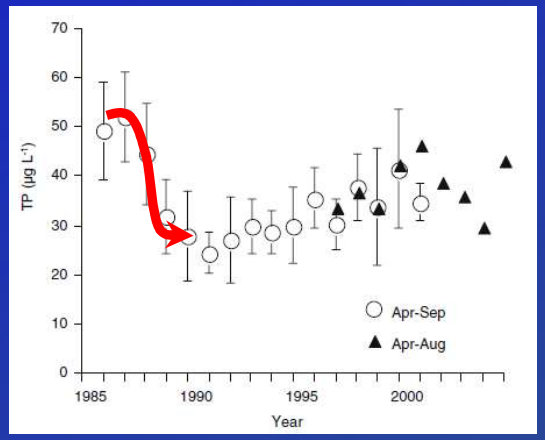
Turbidity, N and P



Unfortunately, life is more complicated than this – some lakes flip between turbid and clear water states, as is the case with Lakes Krankesjön and Tåkern in Sweden, ostensibly because catchment inputs to the lakes affect the annual total dissolved P





Hargeby *et al*. (2007) *Ecosystems* **10**: 28-35.

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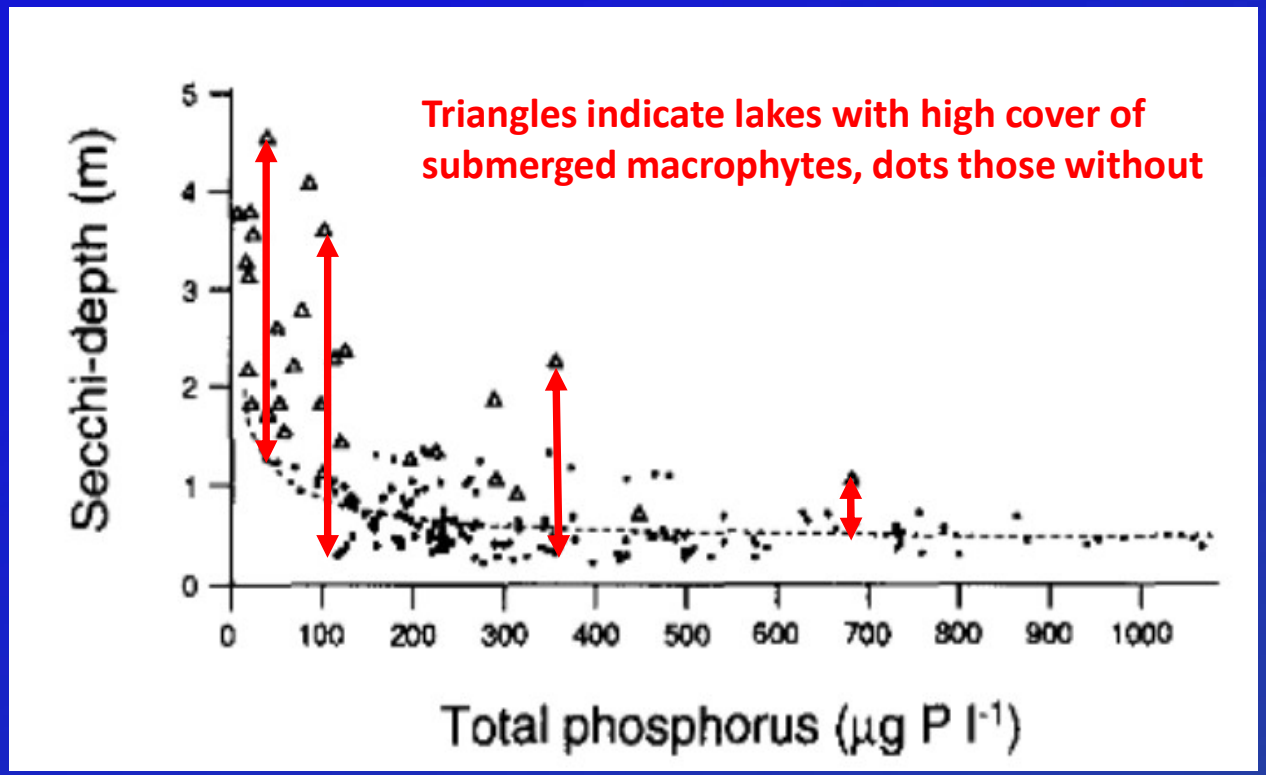
Turbidity, N and P



Unfortunately, life is more complicated than this – even if inputs of P and N are reduced, water turbidity may still persist, and yet clear water columns persist in shallow lakes with high P, so what is going on?

Scheffer *et al.* (1993) *TREE* **8**: 275-279.

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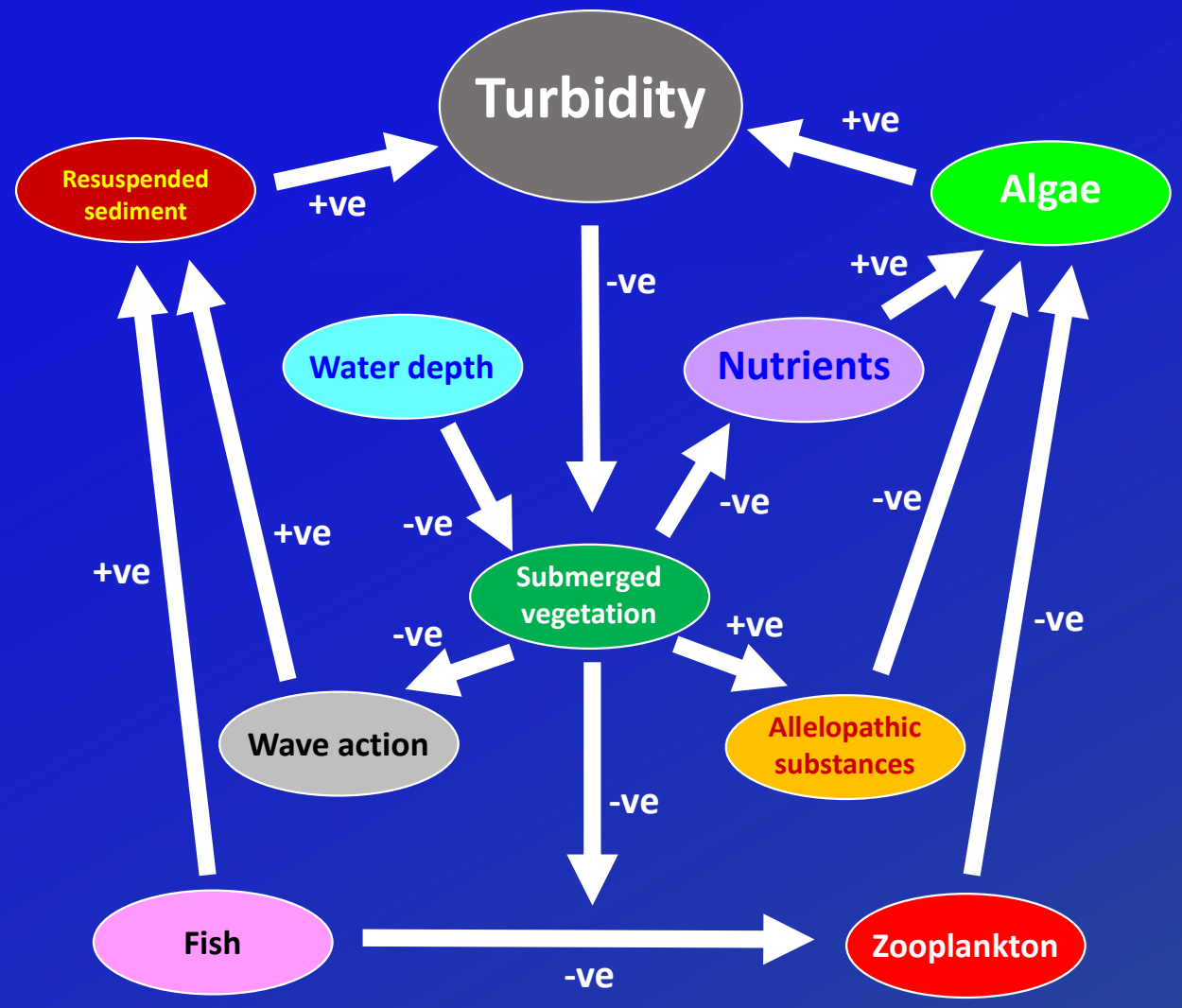
Turbidity, N and P

Submergent vegetation has multiple benefits for maintaining clear water aquatic systems

Scheffer *et al.* (1993) *TREE* **8**: 275-279.



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Maribo Lakes

Situated low down in the catchment on clay soils

In an intensively managed agricultural catchment (i.e. heavily fertilized)

Maribo town used to discharge all its sewage into the lake

From 1900 sugar beet factory discharged wastewater (high in organic matter and phosphorus) until stopped in 1962

In 1980s, water highly turbid, NO submerged vegetation, a fish fauna dominated by roach *Rutilus rutilus* and bream *Abramis brama*

Designated as EU Special Protection Area and Special Area for Conservation as well as Ramsar Wetlands of International Importance

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Maribo Lakes

Here, I will only talk about the three southern lakes

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Maribo Lakes

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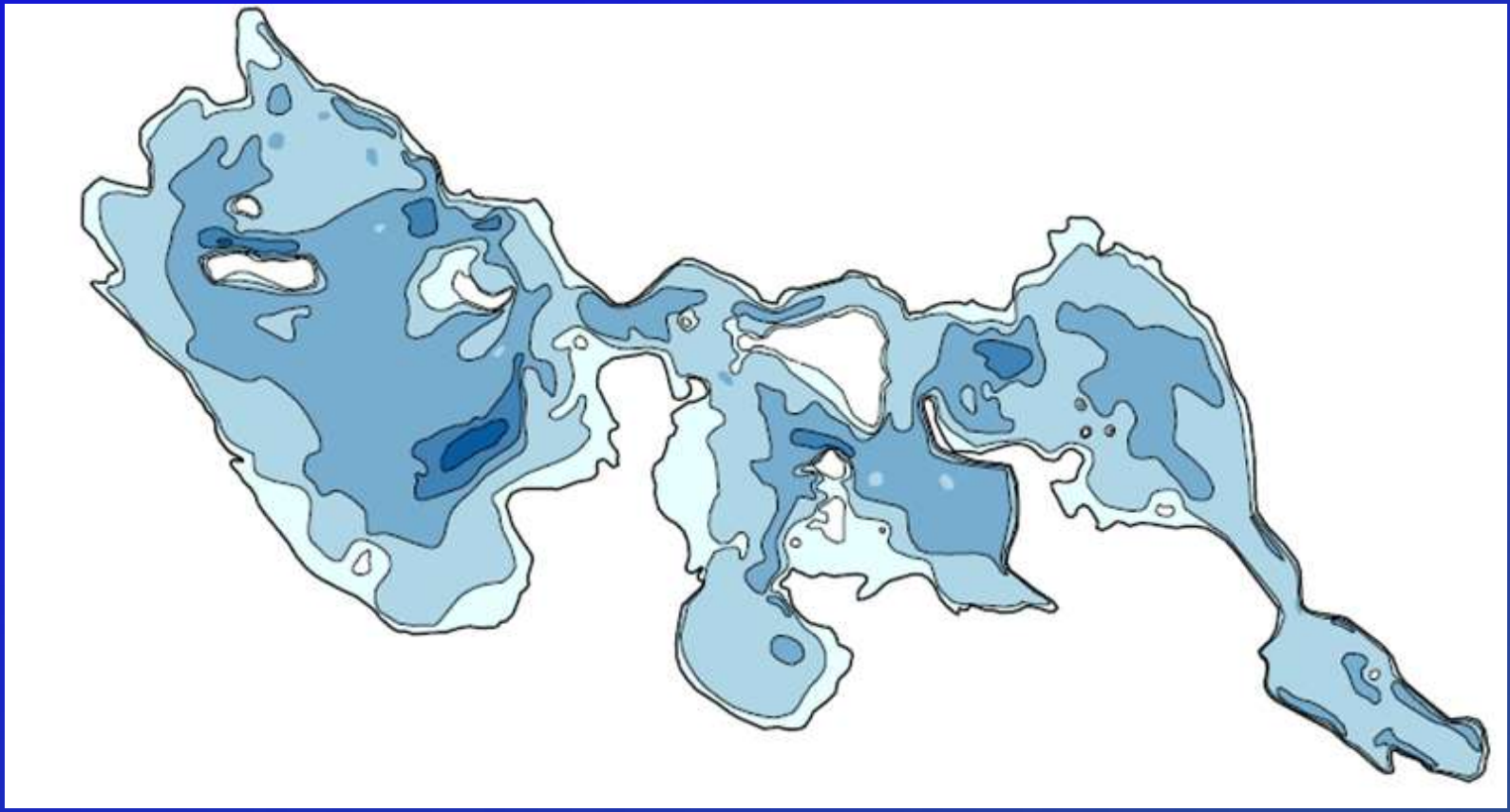
Maribo Søndersø

860 ha

Very shallow, deepest 5 m, blue shades indicate 1 m depth intervals

90% less than 2 m deep



Liboriussen, L., M. Søndergaard & E. Jeppesen (2007) *Søresuarering i Danmark. Del I: Tværgående analyser*. DMU Technical Report 636. Aarhus University. https://www2.dmu.dk/Pub/FR636_Del2

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Maribo Søndersø

Status 1989:

LOUSY!

No submerged vegetation,
Few breeding birds
Dreadful water quality
Very low biodiversity

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Maribo Lakes

Local authority coordinated a restoration plan in 1989

Reduction of agricultural runoff into the lakes

Sewage treatment from Maribo and surrounding villages

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Maribo Lakes

Results: not good!

While the plan was successful in reducing N and P input and stabilizing water quality…

…there was biological inertia in the system resisting regime change

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Maribo Lakes

Plankton and benthic feeding fish were stirring up N and P in the lake bed from previous times, remobilizing the nutrients, so:

132 tonnes of roach and bream removed

618,000 Perch *Perca fluviatilis* and Pike *Esox lucius* introduced

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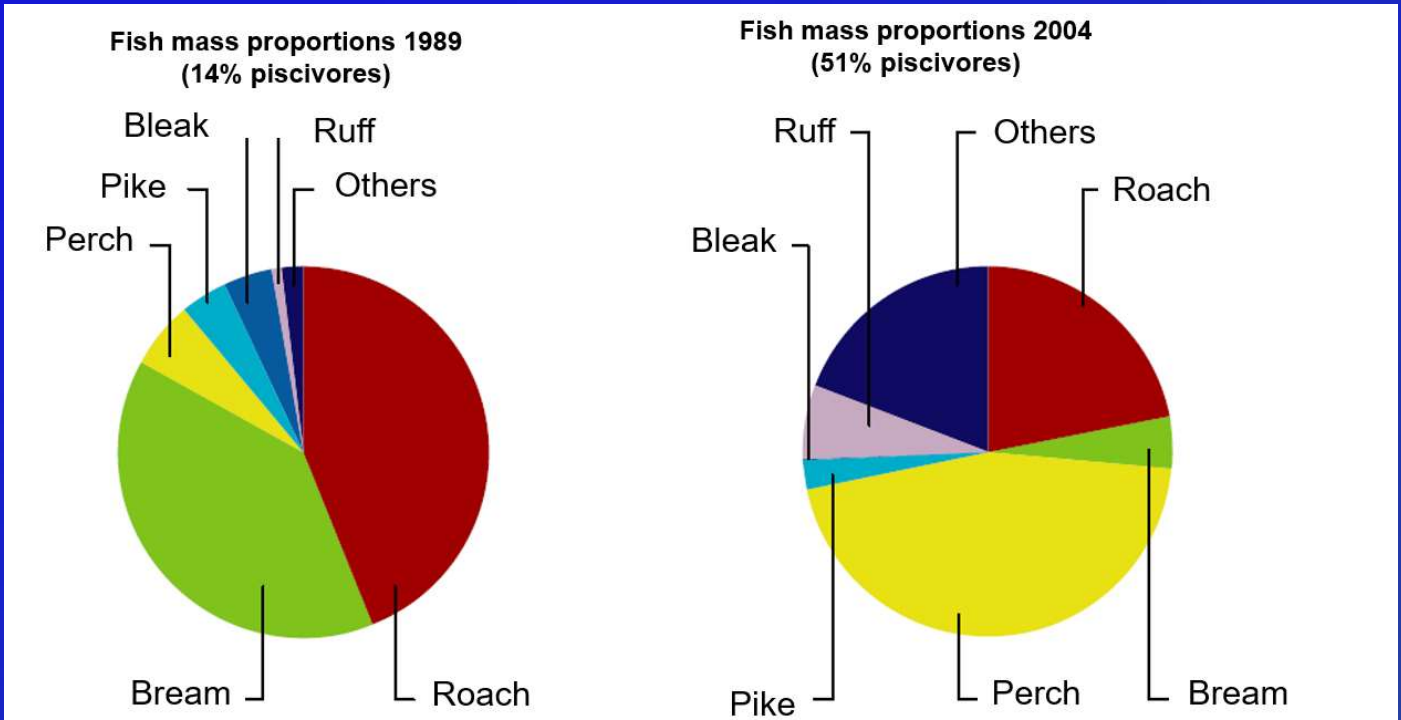
Maribo Lakes



Vitally important to shift the fish community from a plankton, benthic and herbivorous feeding guild, disturbing the substrate and remobilizing the N and P in the sediments, to a more balanced predominantly predatory fish community

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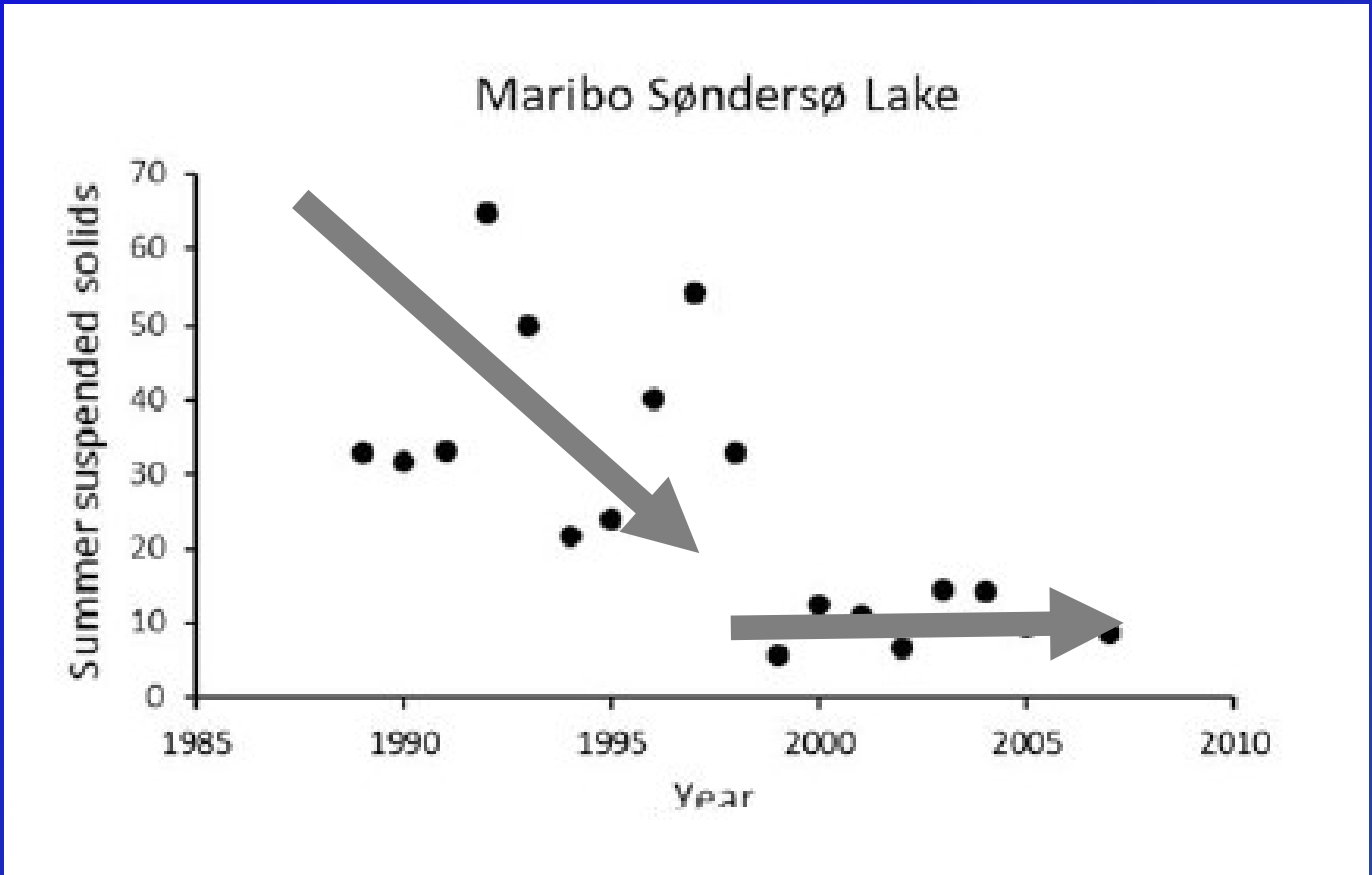
Maribo Søndersø

Little change in water chemistry, but a major success with improving water transparency



Fox et al. (2019) *Hydrobiologia* **380**: 33-44

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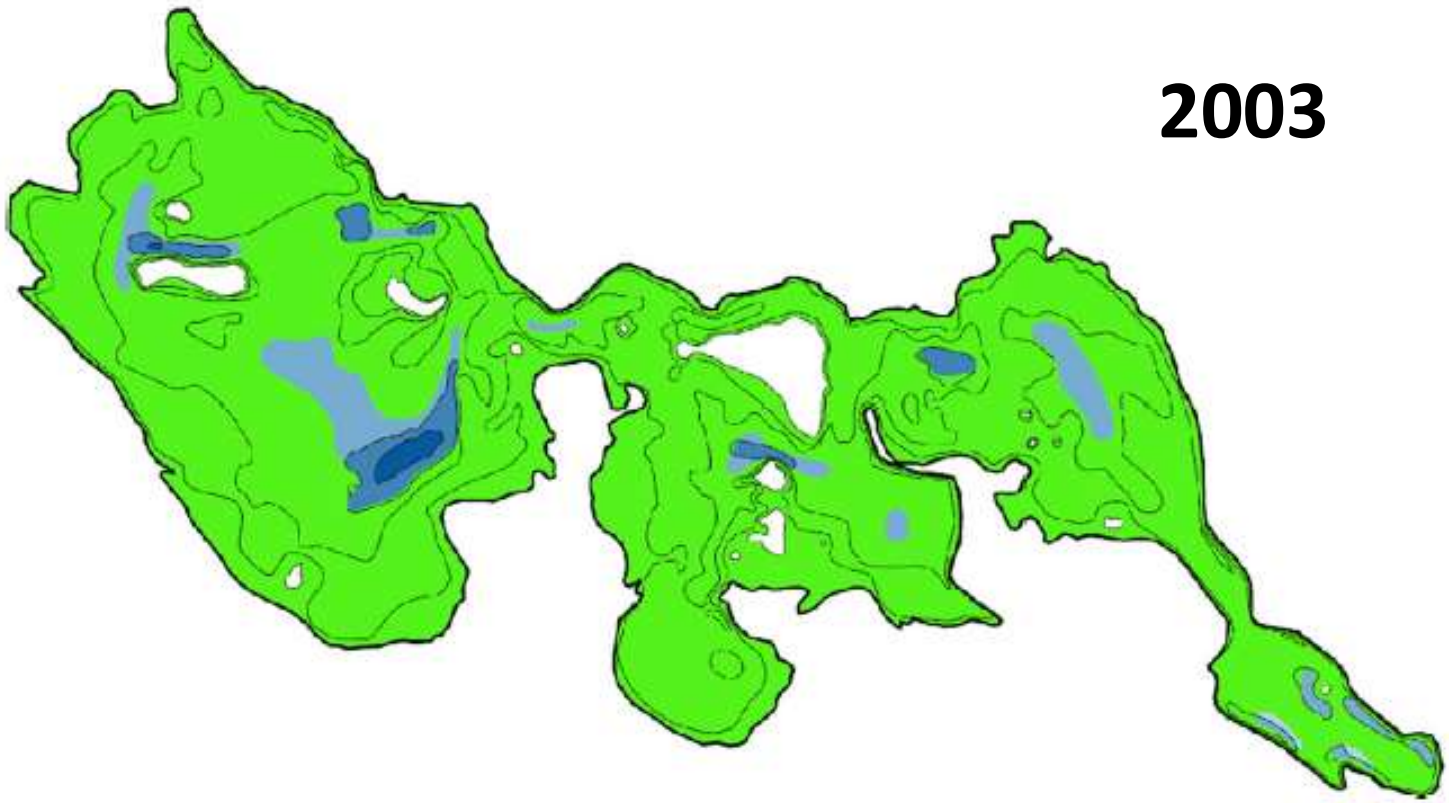
Maribo Søndersø

With improved water transparency comes recolonization by submerged macrophytes



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Maribo Søndersø

There has especially been a recovery by the Charaphytes, which benefit from improved light penetration through the water column, but many other species dramatically increased (such as *Potamogeton* species)

Liboriussen, L., M. Søndergaard & E. Jeppesen (2007) *Søresuarering i Danmark. Del I: Tværgående analyser*. DMU Technical Report 636. Aarhus University. https://www2.dmu.dk/Pub/FR636_Del2

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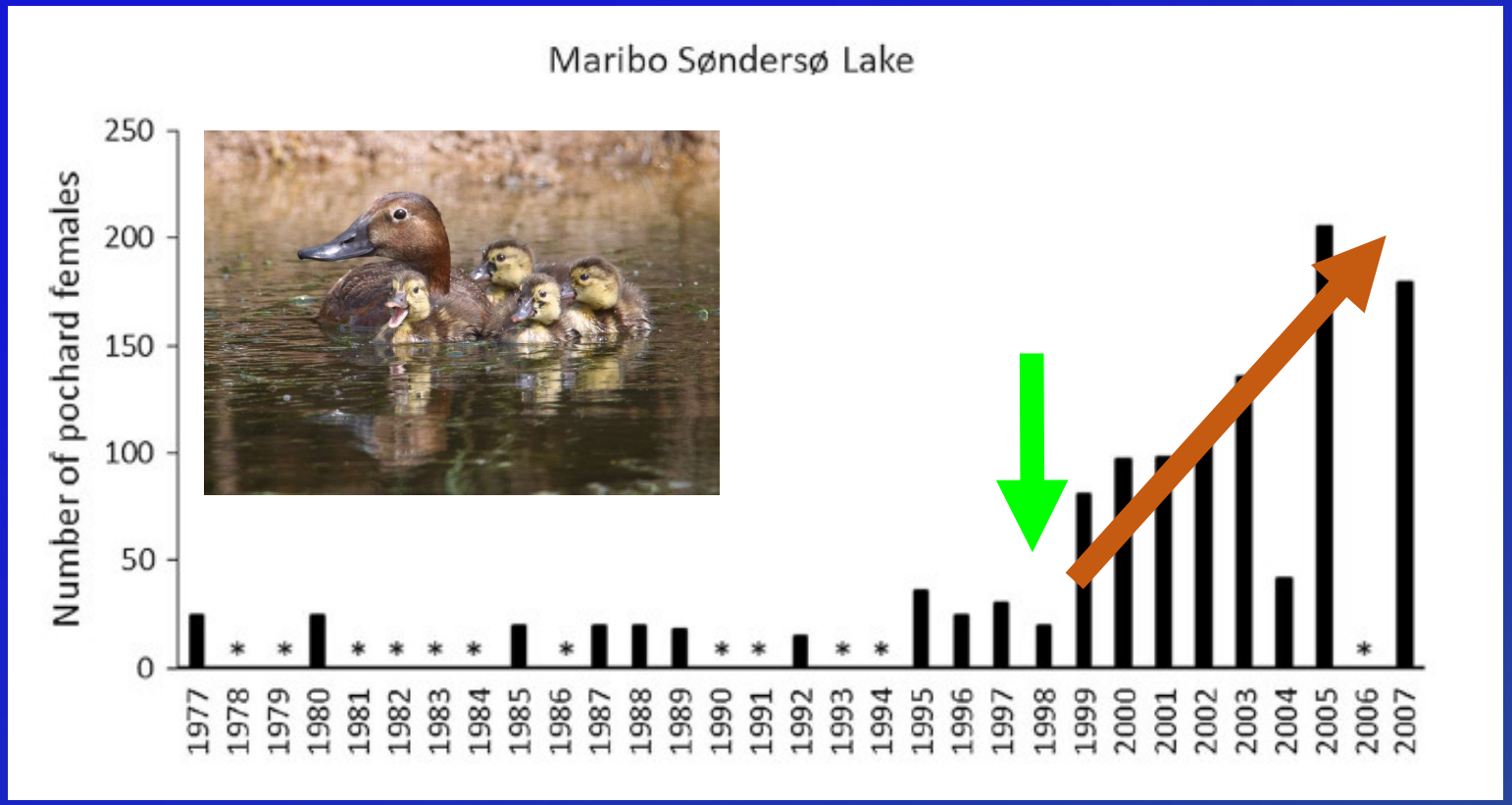
Maribo Søndersø

With the Charaphytes comes benefits to one specialist breeding diving duck that depends on these species, the Pochard *Aythya ferina*



Fox et al. (2019) *Hydrobiologia* **380**: 33-44

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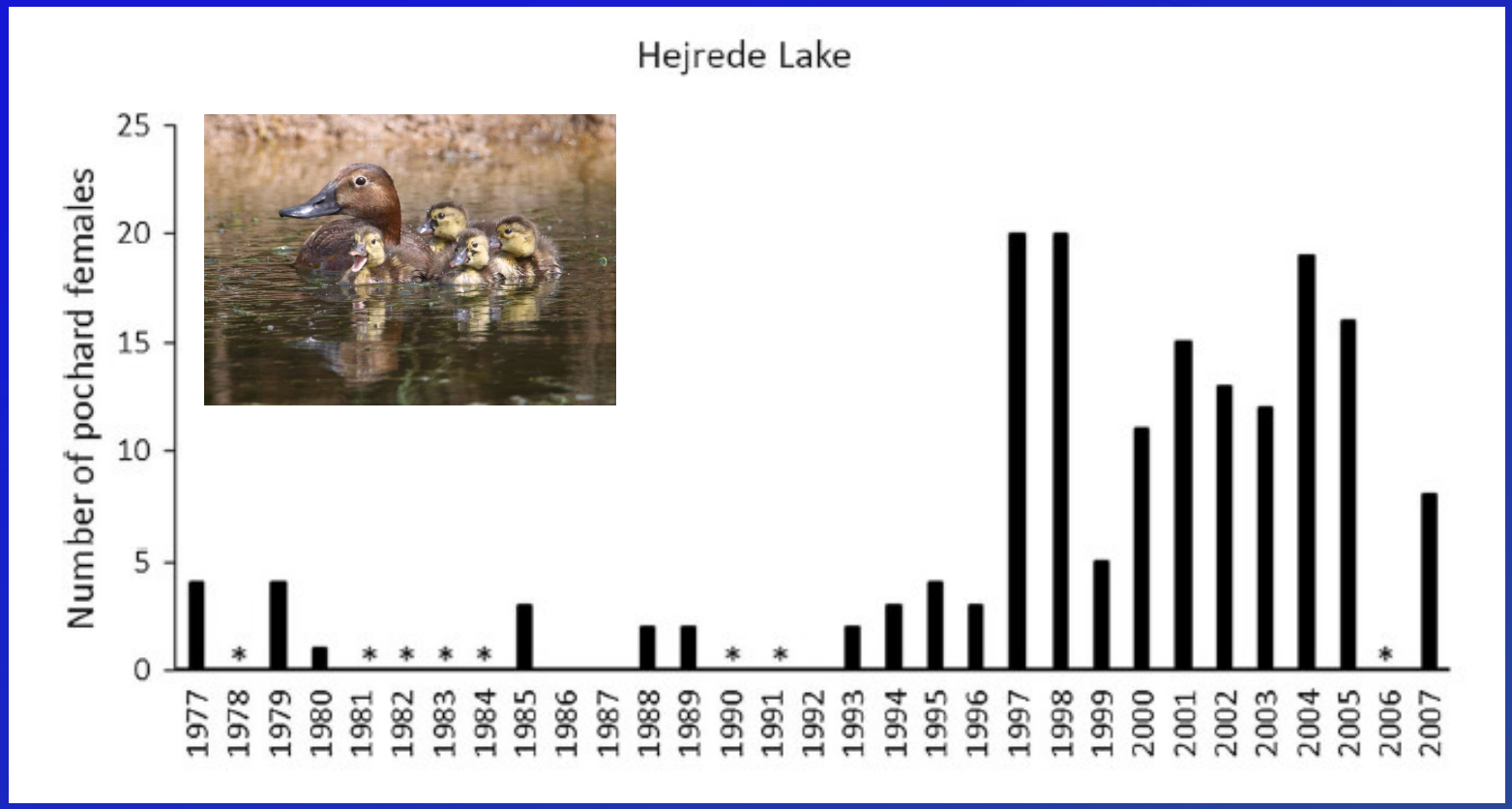
Maribo Hejrede Sø

Return of Charaphytes also benefitted breeding Pochard



Fox et al. (2019) *Hydrobiologia* **380**: 33-44

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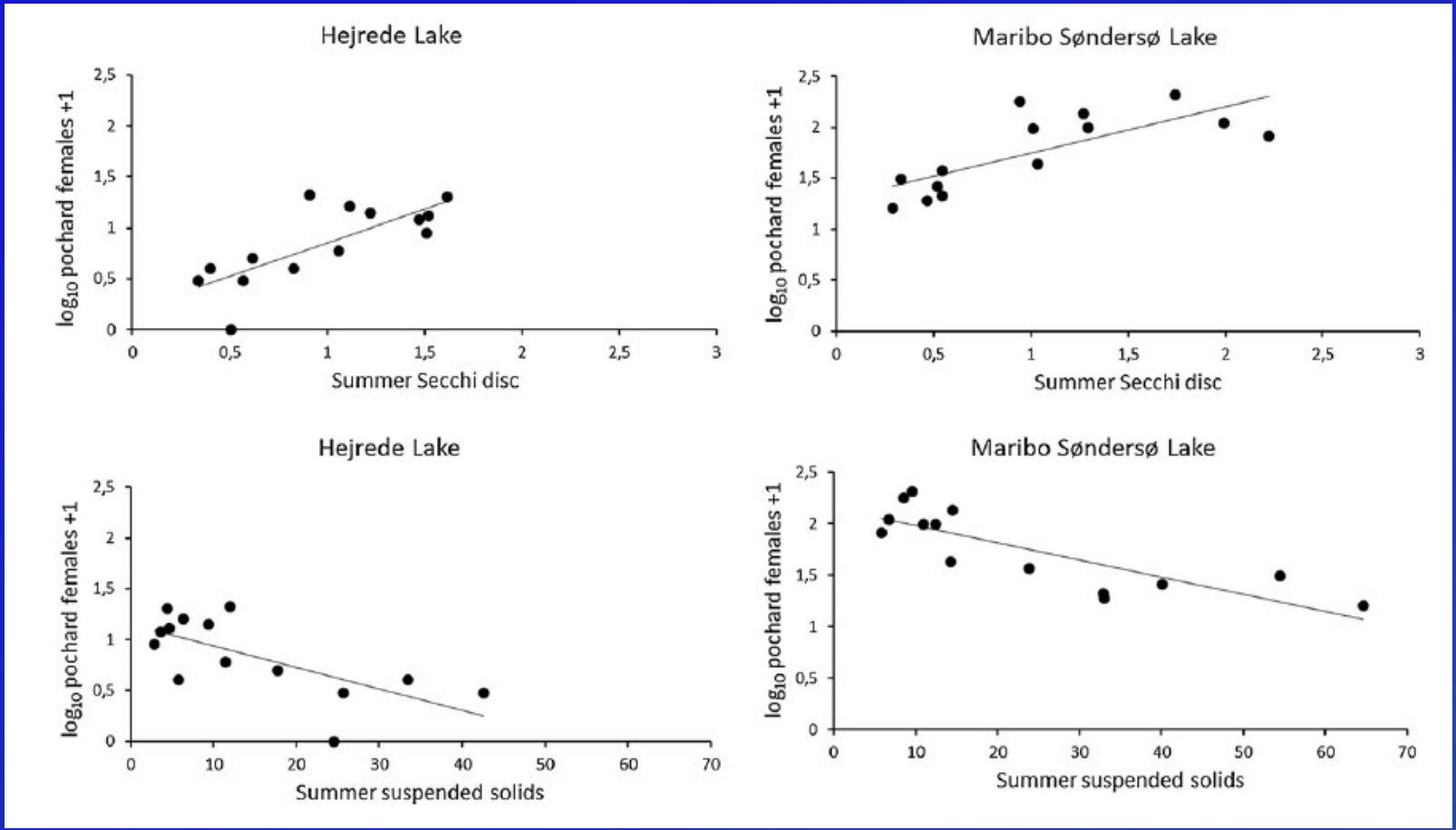
Maribo Lakes

Good correlations between measures of water clarity and Pochard breeding abundance at the two lakes



Fox et al. (2019) *Hydrobiologia* **380**: 33-44

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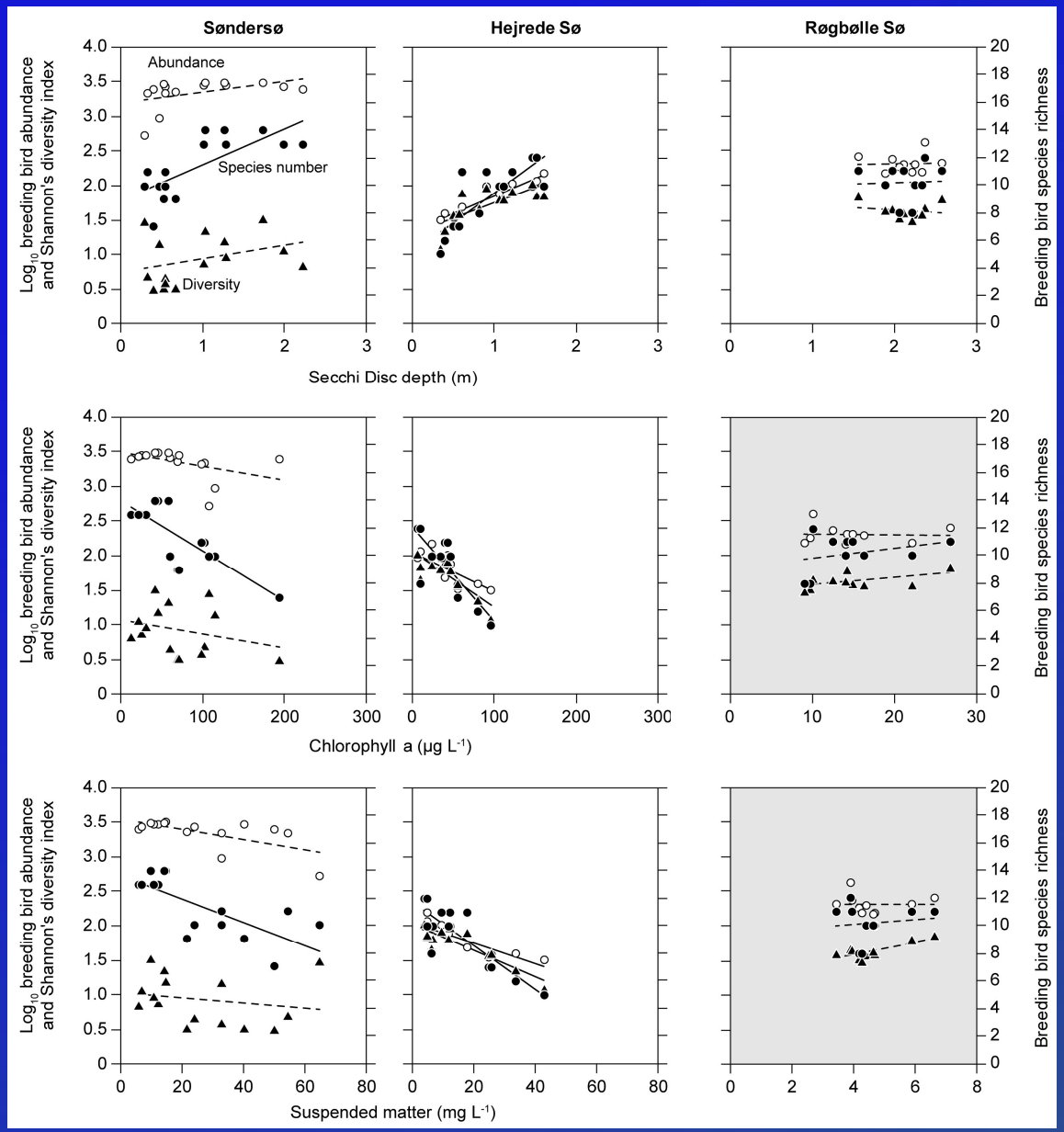
Maribo Lakes

The wider waterbird community has also benefitted from water clarity at the two lakes



Fox et al. (2020) *Aquat Conserv* **30:** 237-245

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Summing up

Thank goodness! That means he has nearly finished!

Catchment water management was spectacular at improving water quality

N and P loadings were radically reduced, but biodiversity benefits and ecosystem function was not immediately restored

Biological inertia (caused by fish stocks) inhibited achievement of biodiversity goals

Remobilisation of sediment N and P caused by plankton- and benthic feeding fish retained a turbid water column, inhibiting submerged macrophyte development until their removal and substitution with piscivorous fish stocks

Patience is a virtue

It is WORTH IT! It may take 10 years, but restoration of clear water columns resulted in major biodiversity conservation gains, especially for the poor Pochard which is doing so very badly in Europe

These results are replicated at c.80 other restored Danish lakes

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Thank you so much for your attention!

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AT LAST! I thought he would never stop!