A Short Insight into the History of

Lake Eutrophication Research

…and how this relates to Nature based solutions!

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What are Nature Based Solutions (Nbs)?

- NbS – solutions to societal challenges that involve <u>working with nature</u>
- NbS are actions such as
  - the protection, restoration or management of natural and semi-natural ecosystems,
  - sustainable management of working lands and aquatic systems,
  - the creation of <u>novel ecosystems</u>

→ Often portrayed as the *Holy Grail* to solve **climate crises** and **biodiversity loss**

(Seddon et al., 2021, GCB)

Eutrophication

- Increasing aquatic plant growth (biological productivity) in a water body over time
- Includes "water quality problems"
- Natural eutrophication: from pristine lake to a swamp - takes thousands of years
- Human activities accelerate the natural process:

  'Cultural Eutrophication'

→ (Man made-) nutrient loads as the key variable for aquatic primary production

Throphic Levels of Lakes

Class	Biomass		Clarity
Oligotrophic	low productivity		clear
Mesotrophic	moderate	“	slightly turbid
Eutrophic	high	“	turbid
Hyper eutrophic	very high	“	very turbid

https://en.wikipedia.org/wiki/Eutrophication

Why care about Eutrophication?

Effects of eutrophication in freshwaters

- Phytoplankton blooms
- Hypoxia/anoxia
- Cyanobacteria (neurotoxins, hepatotoxins)
- Toxicity to wildlife


https://www.conserve-energy-future.com/cause-effects-and-solutions-to-eutrophication.php

Nutrient supply – aquatic PP

The Redfiled Ratio (1934)

R 176 – 192

ON THE PROPORTIONS OF ORGANIC DERIVATIVES IN SEA WATER AND THEIR RELATION TO THE COMPOSITION OF PLANKTON[1]

ALFRED C. REDFIELD

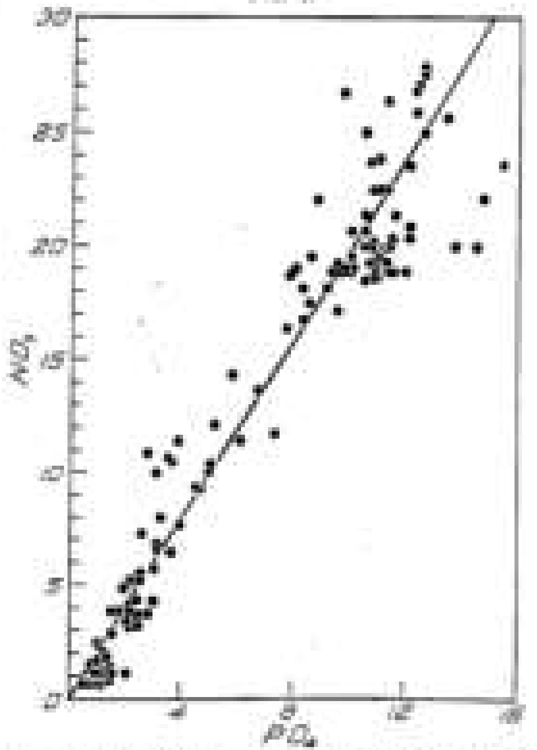
(Received September 5, 1933)

"Chemical analysis shows that the animal and plant body is mainly built up from the four elements, nitrogen, carbon, hydrogen, and oxygen. Added to these are the metals, sodium, potassium and iron, and the non-metals, chlorine, sulphur and phosphorus. Calcium or silicon are also invariably present as the bases of calcareous or siliceous skeletons. All these, with some others, are indispensable constituents of the organic body, and in an exhaustive study of the cycle of matter from the living to the non-living phases, and vice versa, we should have to trace the course of each." JAMES JOHNSTONE, "Conditions of Life in the Sea," p. 273. 1908.

The ratio of carbon to nitrogen to phosphorus is

106:16:1 **P**

throughout the world's oceans, in both phytoplankton biomass and in dissolved nutrient pools.



- → Phosphorus supply as the key variable for aquatic primary production in Freshwaters?
- → Experimental evidence through whole lake addition experiments

Experimental Work in the 1970

- Experimental Lakes Area (ELA) Canada
- Phosphate additions to Lake 227

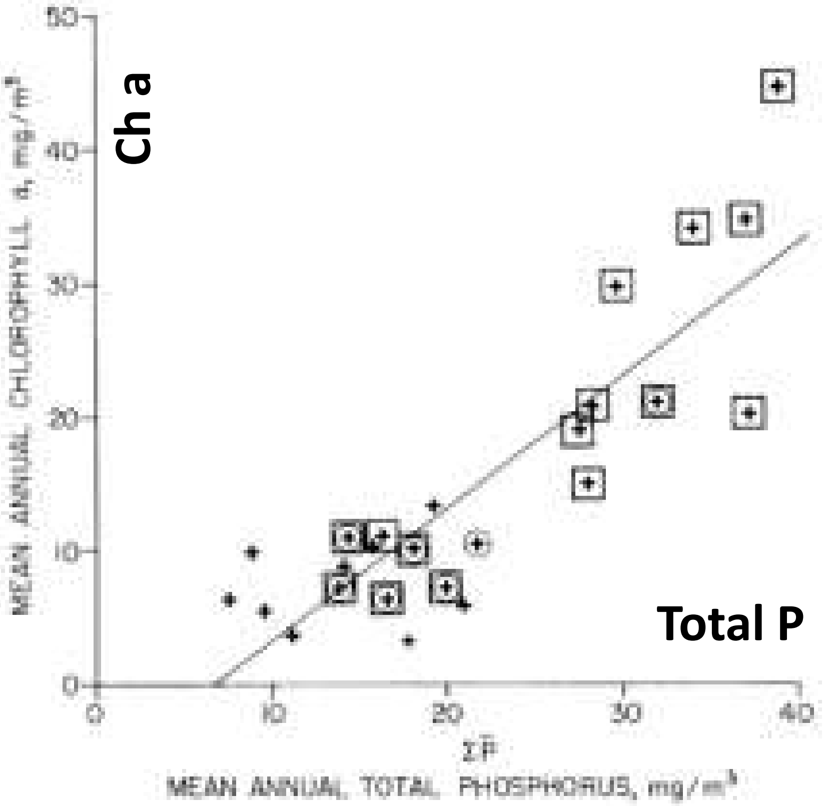
Work in Experimental Lakes Area, Canada

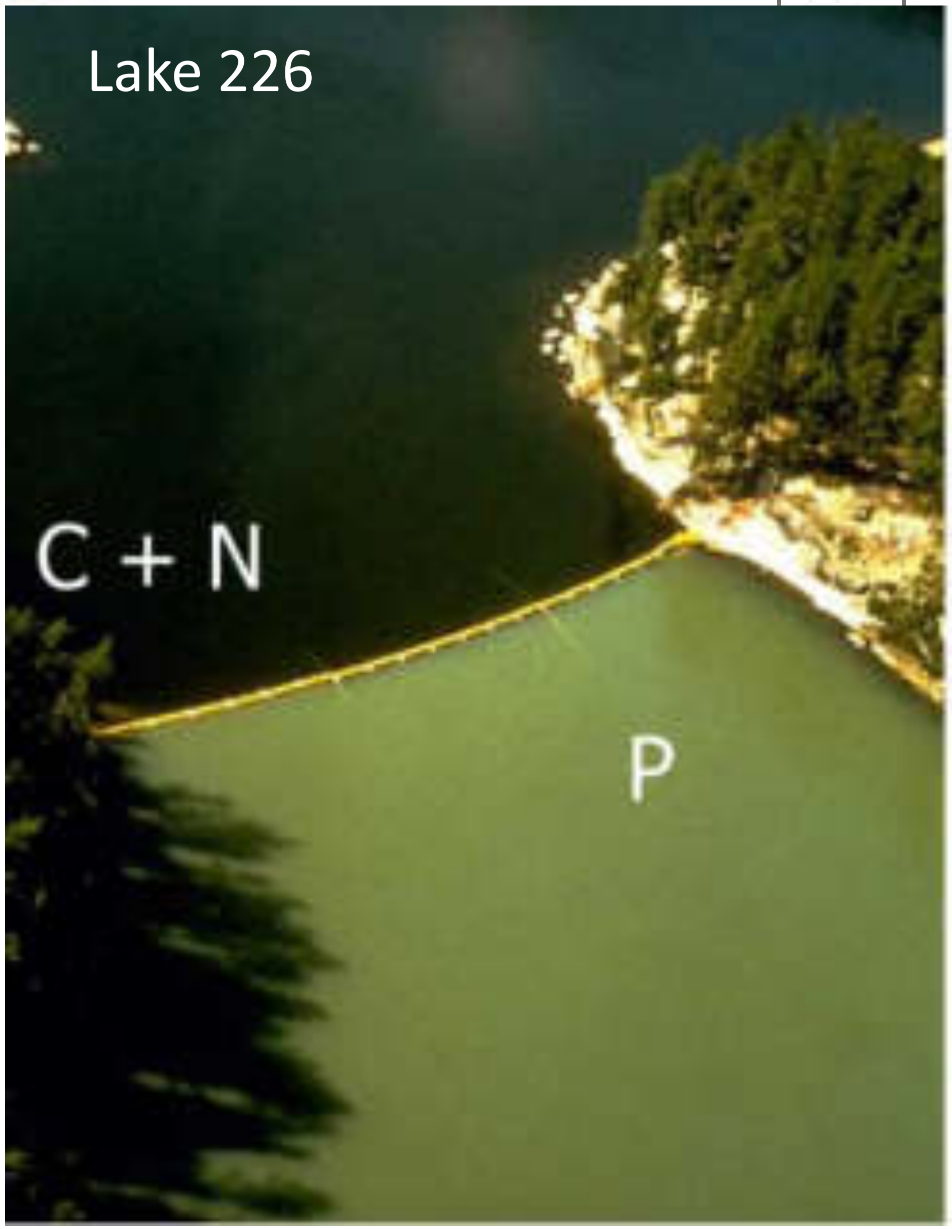
Schindler (1977)

- P consitently limited growth
- Strong algal bloom after P addition

Schindler (2008)

- N-limitation not possible



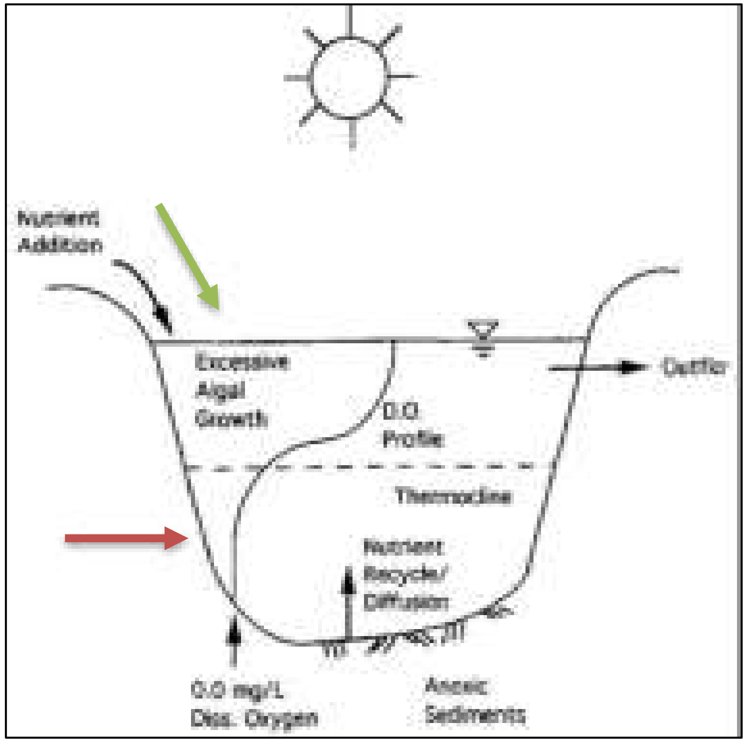


→ Phosphorus is <u>the key</u> parameter limiting aquatic productivity!

Photo Stephen Carpenter

Revised Trophic classification

- Hypoxia/Anoxia
- Revised Trophic classification based on P-Levels



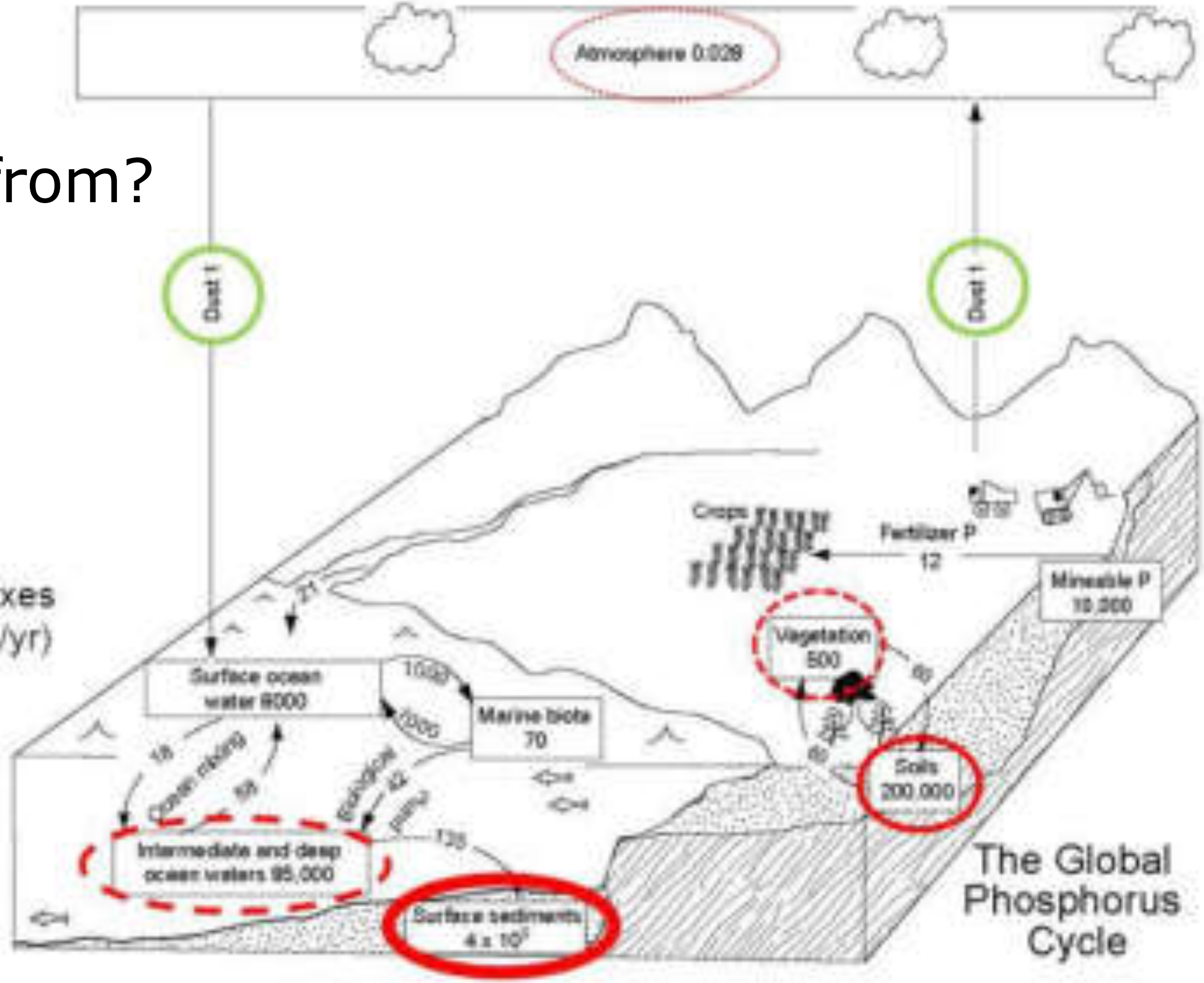
LEVEL OF PRODUCTIVITY	TOTAL P (µg/L)
ULTRA OLIGOTROPHIC	<5
OLIGO MESOTROPHIC	5-10
MESO EUTROPHIC	10-30
EUTROPHIC	30-100
HYPEREUTROPHIC	>100

→ Where does the Phosphorus come from?

Global P Availability

- Where does P come from?

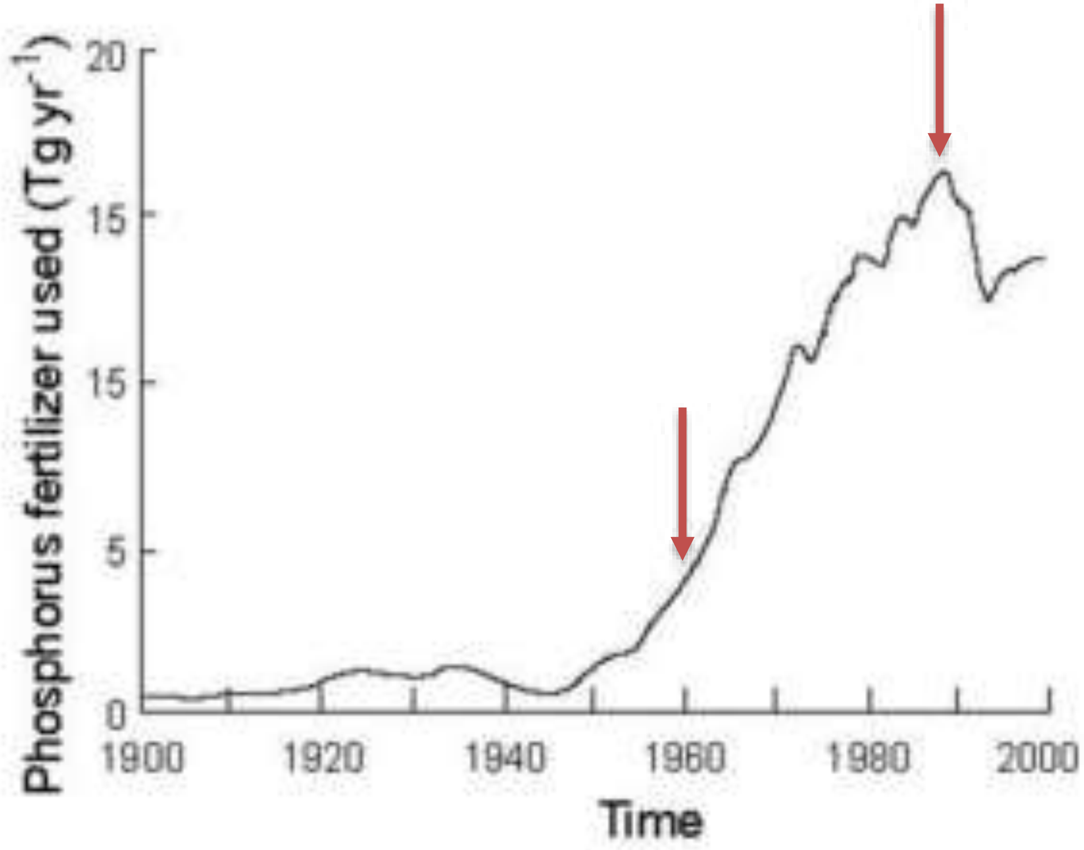
(P fluxes in Tg/yr)



Chapin et al. (2002) Fig 15.6

→ Most Phosphorus is stored in sediments, soils, vegetation

Global Phosphorus Use



Data from Smil (2000)

- P-amounts in the cycle have tripled since 1960 due to fertilizer use
- Peak of P-mining expected ~2030
- Crops only use ~45% of fertilizer P

→ World fertilizer use has enhanced active P pools

→ Export of 'extra' terrestrial P pools into surface waters!

Eutrophication of Lakes

Satellite Analysis show:

- 54% of lakes in Asia
- 53% in Europe
- 48% in North America
- 41% in South America
- and 28% in Africa

are Eutrophic

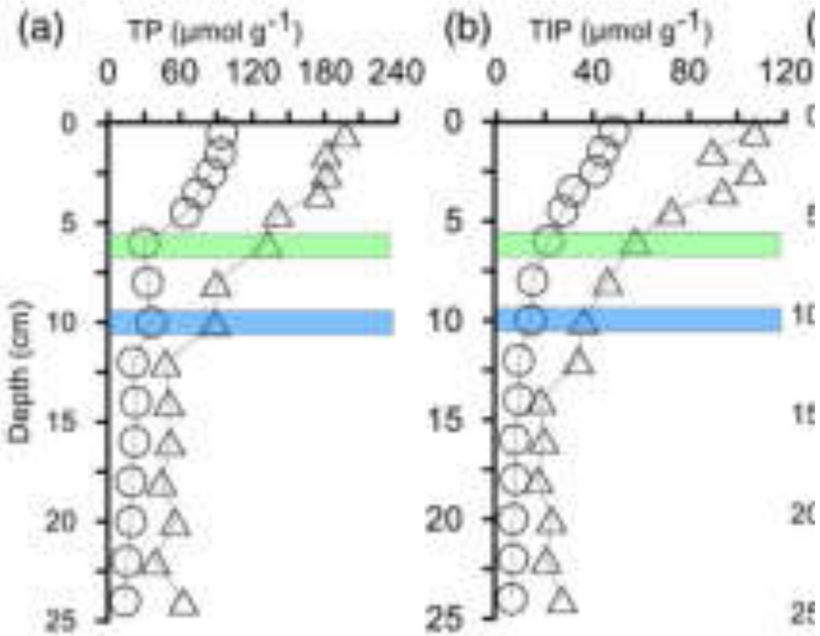
ILEC/Lake Biwa Research Institute [Eds]. 1988–1993 Survey of the State of the World's Lakes. Volumes I-IV. International Lake Environment Committee, Otsu and United Nations Environment Programme, Nairobi.

→ Will time solve this problem for us?

→ Likely not! P is stored in terrestrial and aquatic systems

Storage & Recycling of P

- Sediment changes of ELA Lake 227



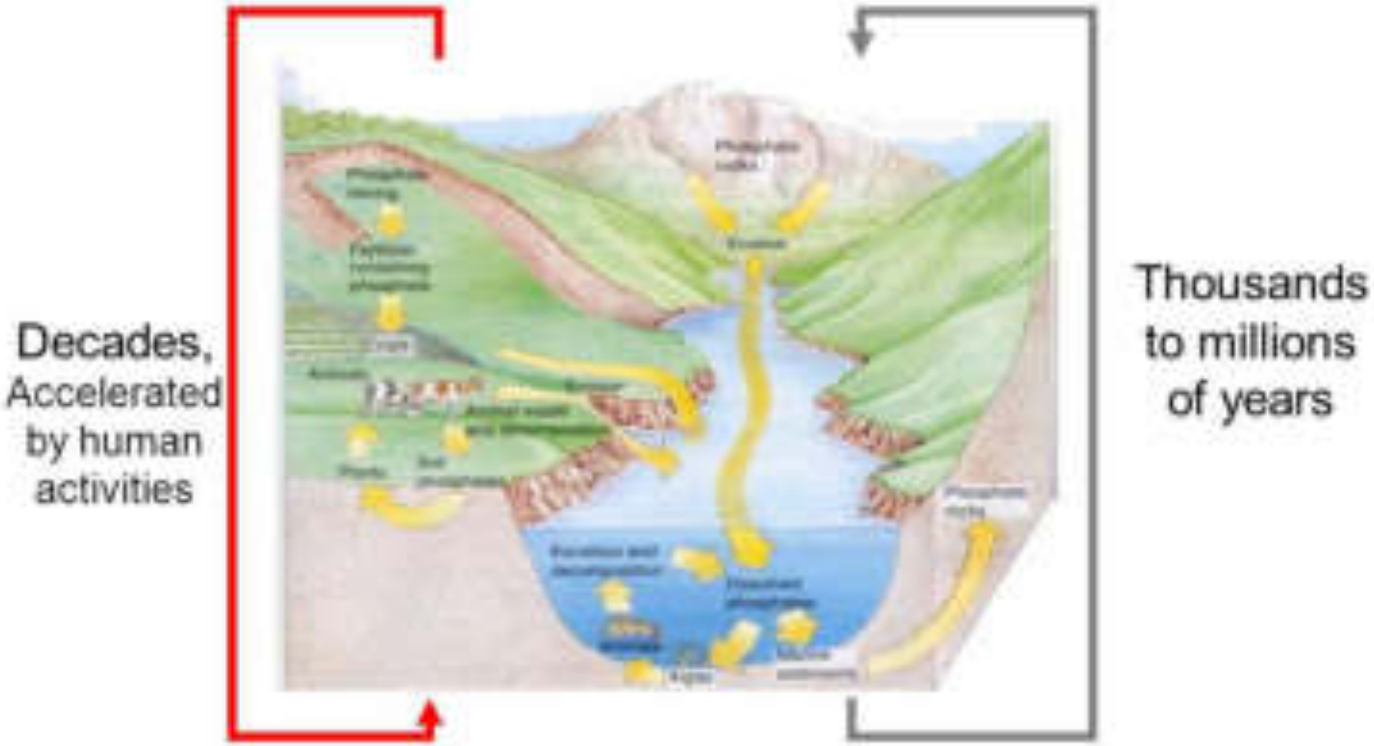
o = epilimnion and Δ = hypolimnion sediments.
Green Bar = epilimnion fertilization beginn
Blue Bar = hypolimnion fetilisation beginn

O'Conell et al., 2020;
JGR-Biogeosc.

→ P is stored and remobilized from lake sediments after decades

Eutrophication

- P becomes availiable for a long time



⟶ P is stored, remobilized and recycled in aquatic systems

⟶ What is the historic contribution of ‘cultural eutrophication’?

Drivers of historical Hypoxia/Eutrophication in Europe

- Study by Jenny et al., 2016, GCB:

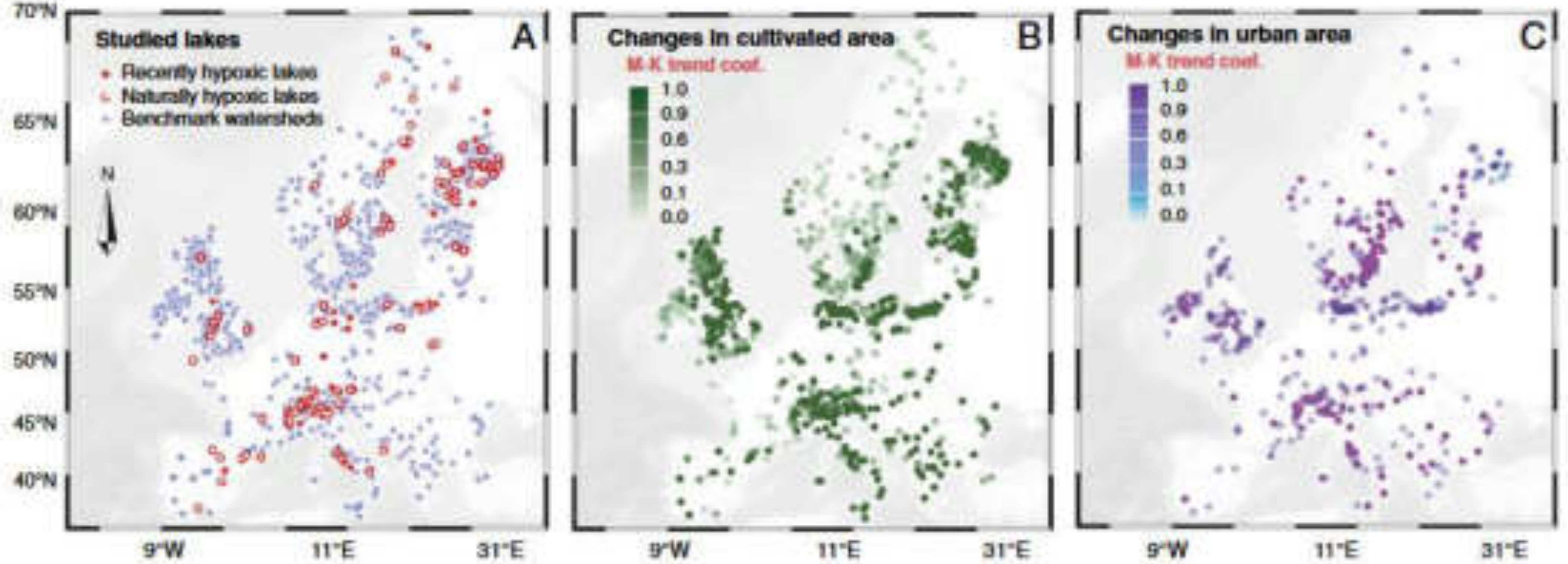
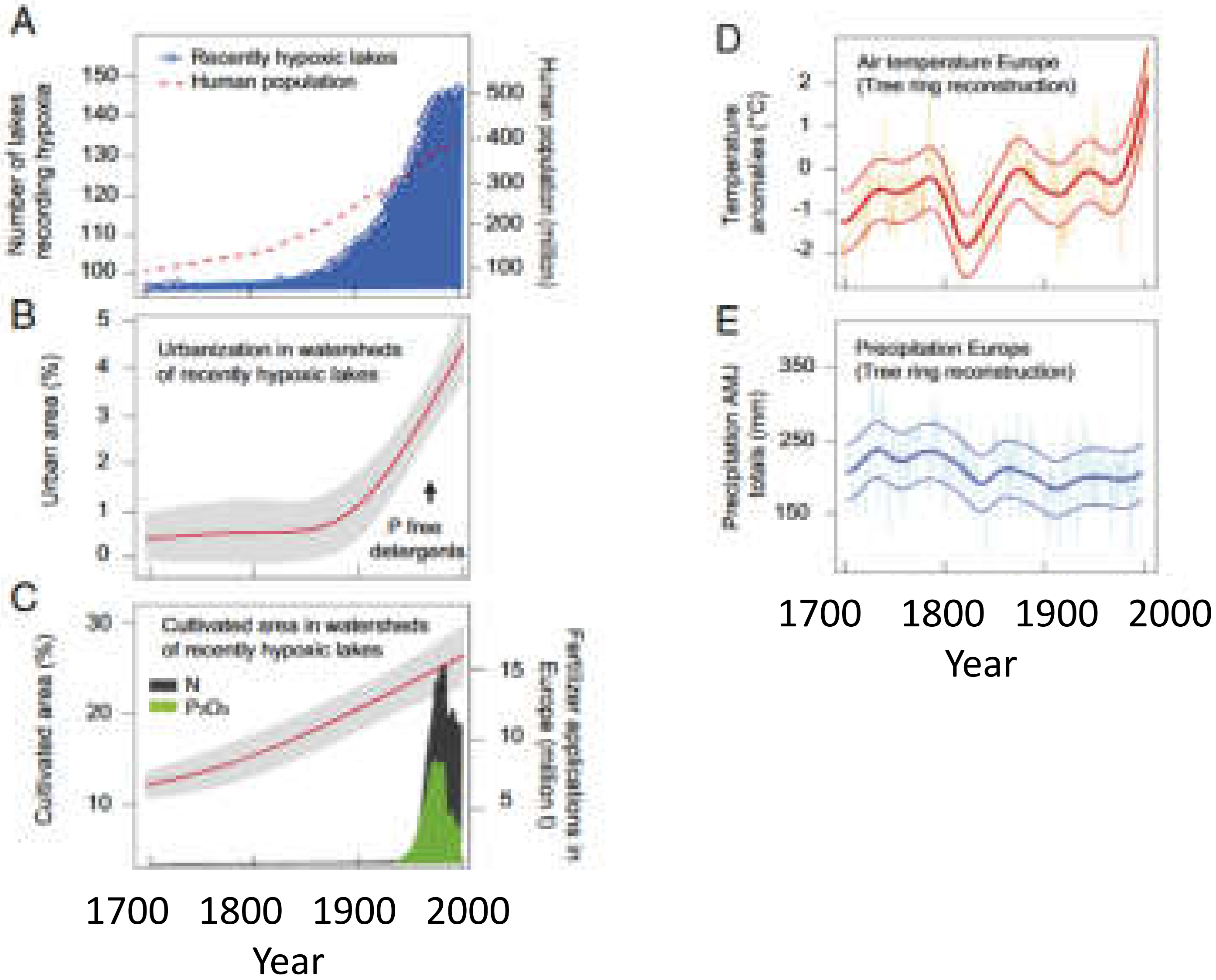


Fig. 1. Location of the 1,607 study sites and changes in land cover over the past 300 years (CE 1700–2000). (A) Fifty-one recently hypoxic lakes, 97 naturally hypoxic lakes, and 1,459 benchmark watersheds composed of 769 lakes from the Lake-Core Database and 690 randomly selected European lakes from the GLWD database. (B and C) Increases in cultivated areas (%) and urban areas (%) for the past 300 years were observed in all of the watersheds according to an M-K test, where a higher coefficient indicates a stronger increase (69).

Jenny et al., 2016, PNAS

- Increase in hypoxia from ~1860
- Urbanization from ~1900
- Fertilizers from ~1950
- Water Temp from ~1970



→ Sewer, industrial waste & storm runoff, and agriculture caused eutrophication

The Good News is... It actually works!

- Reduction of P inputs works
- Small oligotrophic ponds contribute to recovery of amphibians

Environmental Science & Technology

Feature

Reducing Phosphorus to Curb Lake Eutrophication is a Success

David W. Schindler, Stephen R. Carpenter, Steven C. Chapra, Robert E. Hecky, and Diane M. Orihel

PNAS | RESEARCH ARTICLE | APPLIED BIOLOGICAL SCIENCES | OPEN ACCESS

Bending the curve: Simple but massive conservation action leads to landscape-scale recovery of amphibians

Helen Moor, Ariel Bergamini, Christoph Vorburger, Rolf Holderegger, Christoph Bühler, Simon Egger, and Benedikt R. Schmidt

Edited by Peter Kareiva, University of California, Los Angeles, CA; received January 18, 2022; accepted August 2, 2022

Success stories are rare in conservation science, hindered also by the research-implementation gap, where scientific insights rarely inform practice and practical implementation is rarely evaluated scientifically. Amphibian population declines, driven by multiple stressors, are emblematic of the freshwater biodiversity crisis. Habitat creation is a straightforward conservation action that has been shown to locally benefit amphibians, as well as other taxa, but does it benefit entire amphibian communities at large spatial scales? Here,

Significance

The global decline of amphibians is part of the global freshwater biodiversity crisis. In human-

BIOTOP

waves of enthusiasm
since 1985

Summary

Take homes Messages

- Men-made phosphorus loads are the primary cause for Eutrophication
- Globally, ~50% of lakes are eutrophic!
- Problem will persist through sediment storage and remobilization for decades to centuries
- Eutrophication contributes to the Freshwater Biodiversity Crises

→ Relevant secondary driver for amphibian population decline

Are Swimming Ponds a Nature based solution?

- We built functional **aquatic ecosystems**
- We use P-limitation to create **oligotrophic systems**
- Our systems create **critical habitats** and counter species loss of amphibians
- The more habitats are created to higher the chance to '**Bend the curve**'

- The answer is up to you?

Thank you for your attention

Key References

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