

Climate change effects on Lake Maggiore ecosystem



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Long term research

Within the research funded by the CIP AIS, the limnological campaigns represent an important diagnostic tool for the status of the lake and a resource establishing valuable **time series** of limnological data

For Lake Maggiore, more than 30-years data exist, on physical, chemical and biological aspects, describing the **long-term evolution** of biotic and abiotic elements in response to natural and anthropogenic drivers

Established **protocols and standard methods** for sampling and analyses, coupled with data quality checks, contribute to produce robust and time consistent data

Long-term data on Lake Maggiore have fostered the inclusion of the lake in important **research and monitoring networks** such as the incoming EU research infrastructure eLTER



Lake Maggiore and its watershed

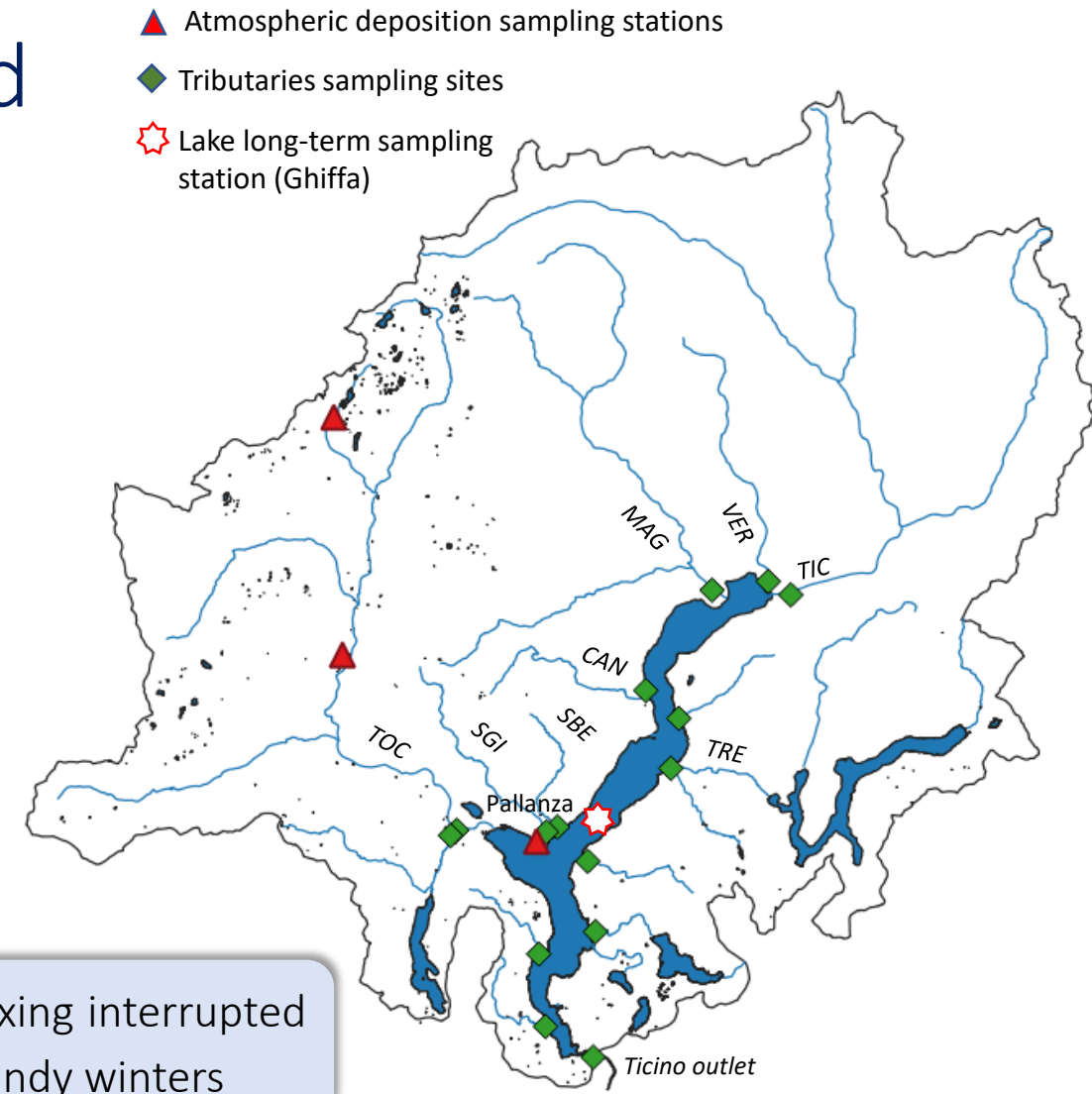
Administrative division:

Provinces (I): Novara, Verbano Cusio Ossola (Piedmont region);

Varese, Como (Lombardy region)

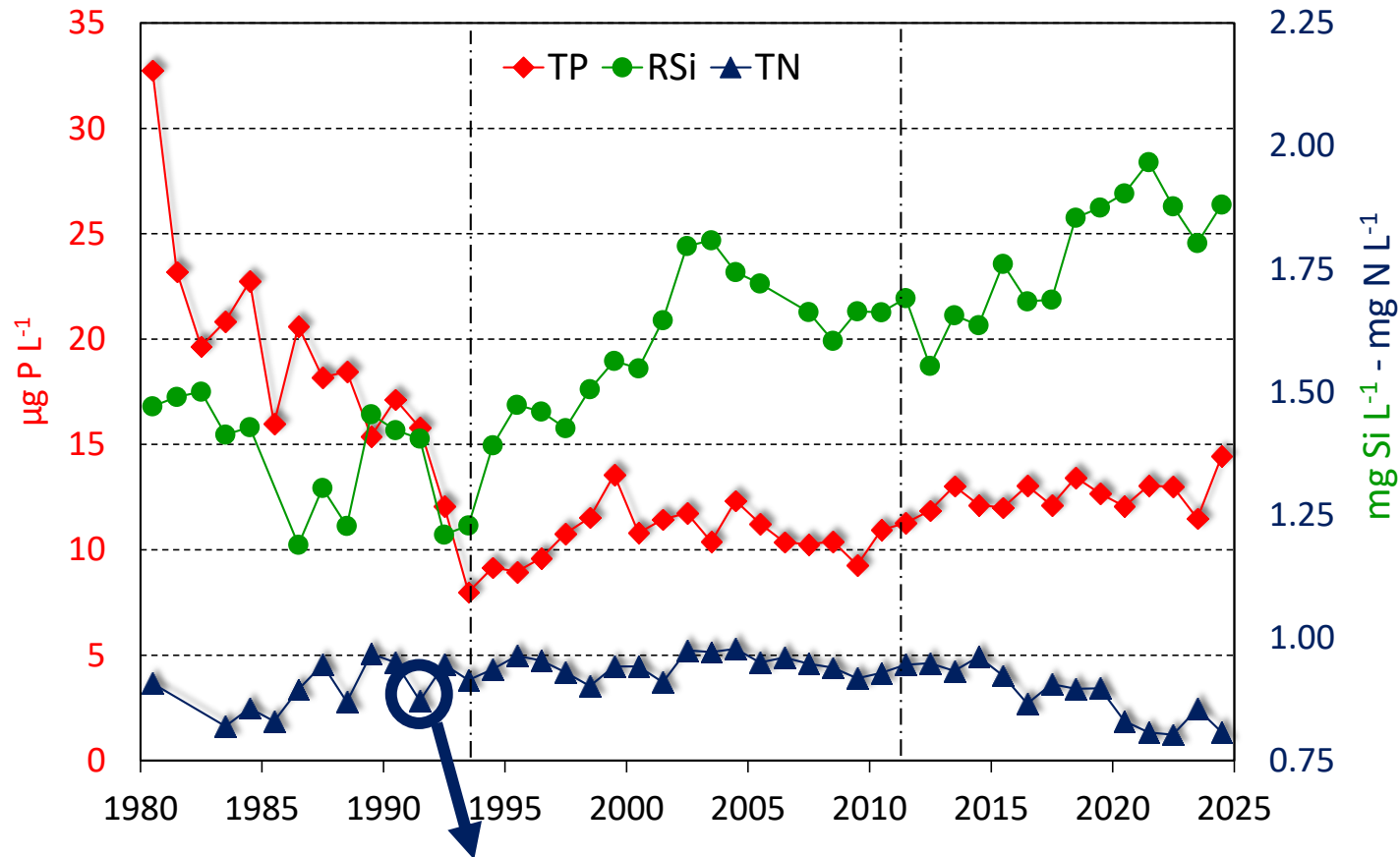
Cantons (CH): Grigioni, Ticino and Vallese

Watershed area	km ²	6599
Watershed average altitude	m a.s.l.	194
Lake area	km ²	212.5
Perimeter	km	170
Max depth	m	370
Mean depth	m	176.5
Volume	km ³	37.5
Theretical renewal time	ys	4.1



Holo-oligomictic: long periods of incomplete mixing interrupted by complete overturns promoted by cold and windy winters

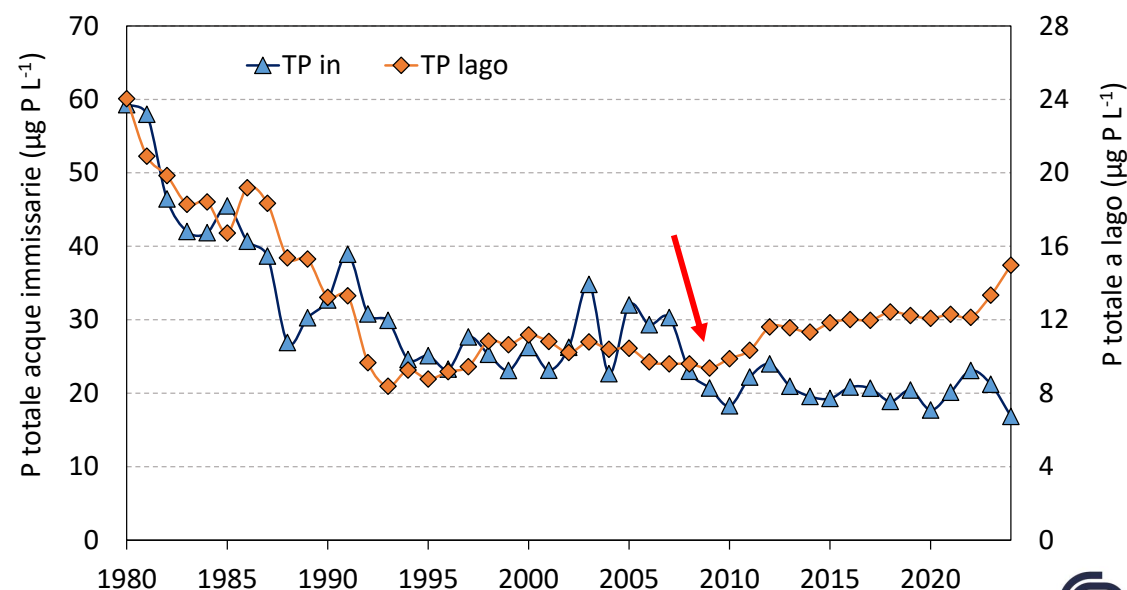
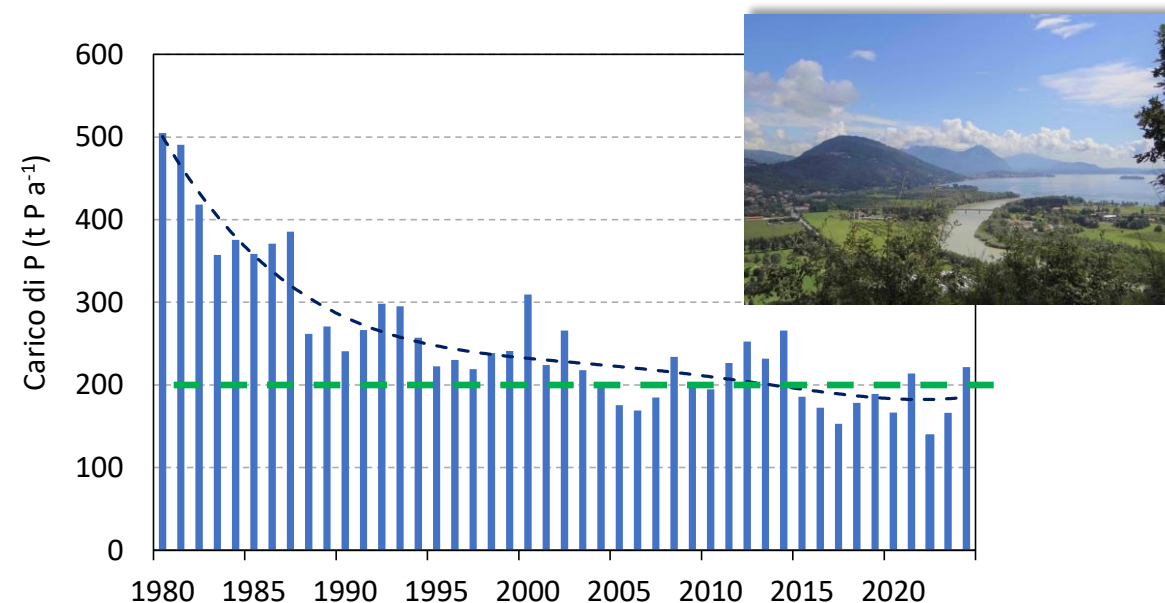
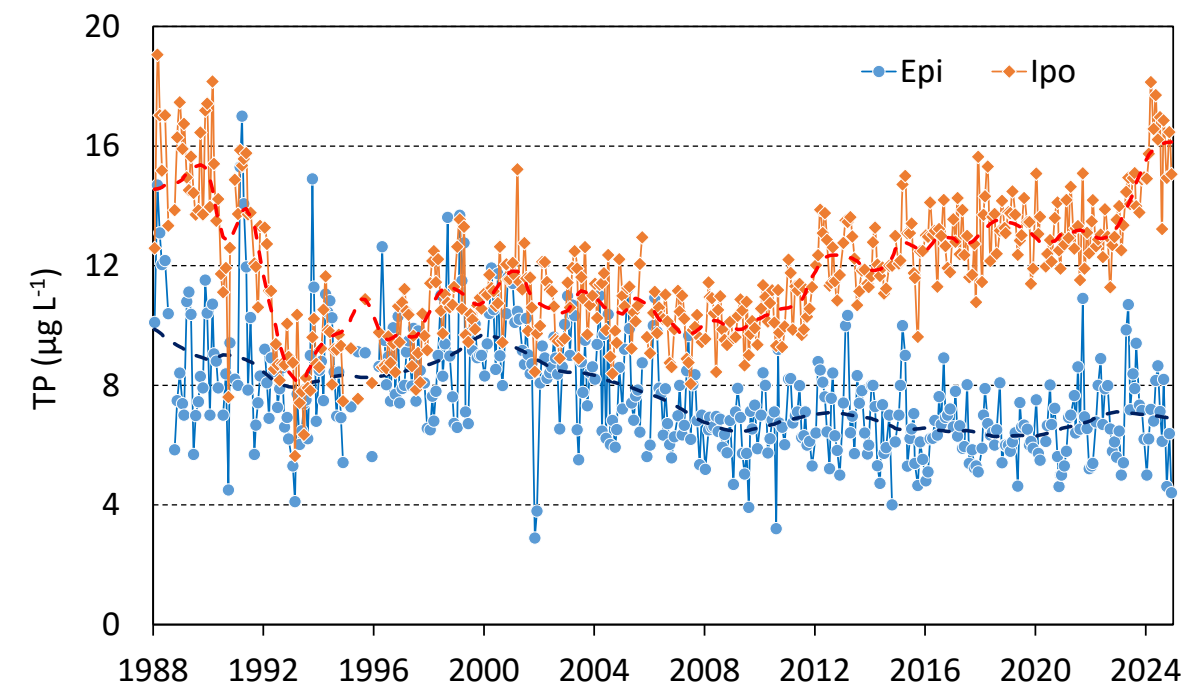
Nutrients and trophic status



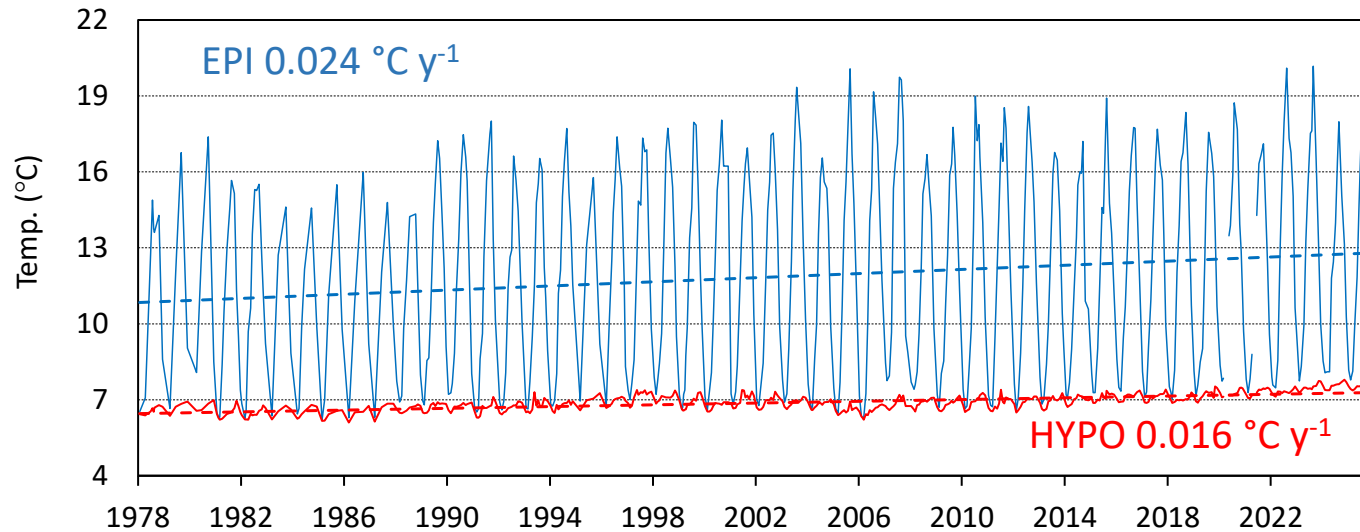
- ☐ Oligotrophication since the 1990s thanks to reduction of catchment loads
- ☐ Presently **oligo-mesotrophic** according to total P concentrations



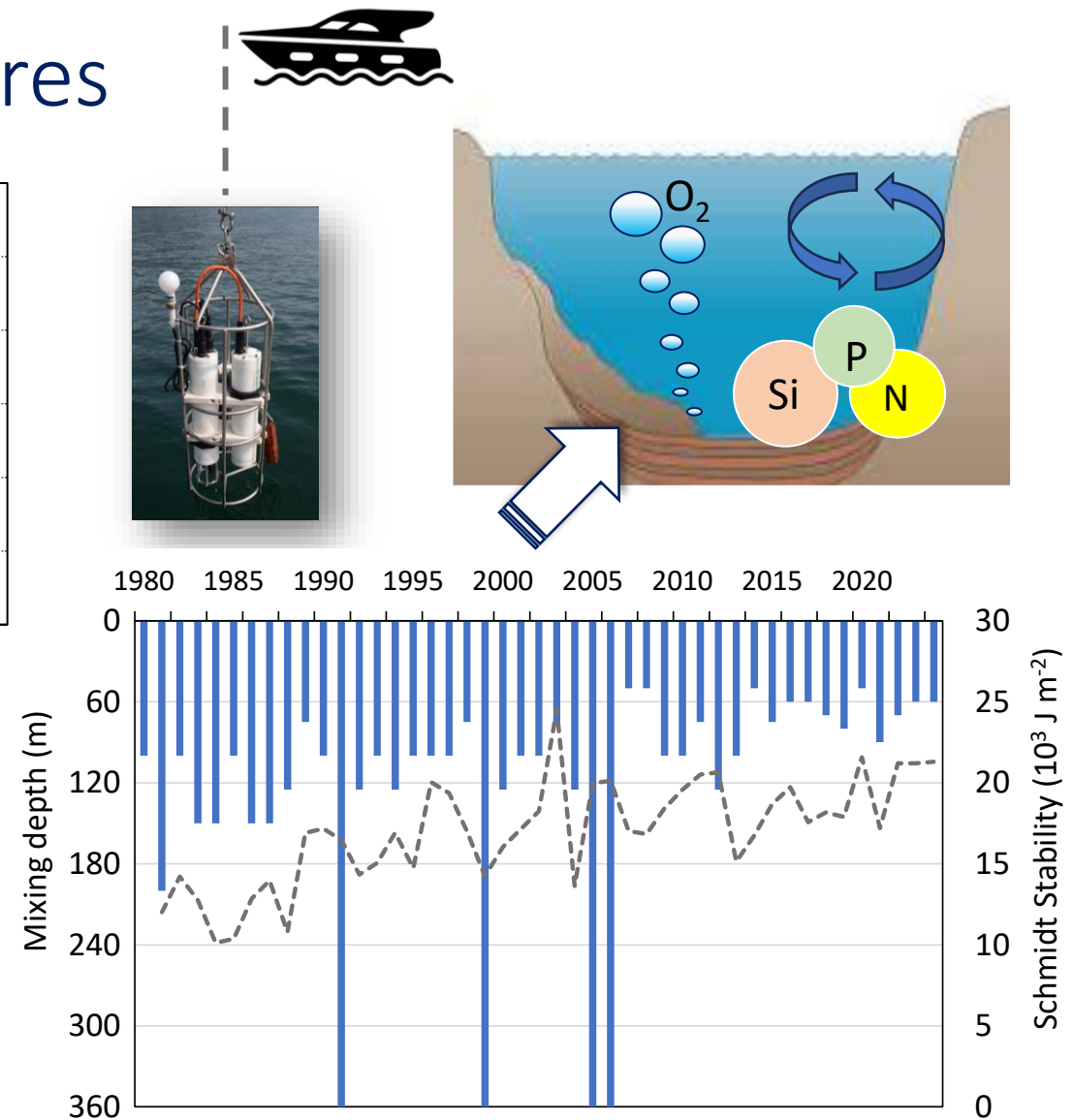
Internal vs external processes

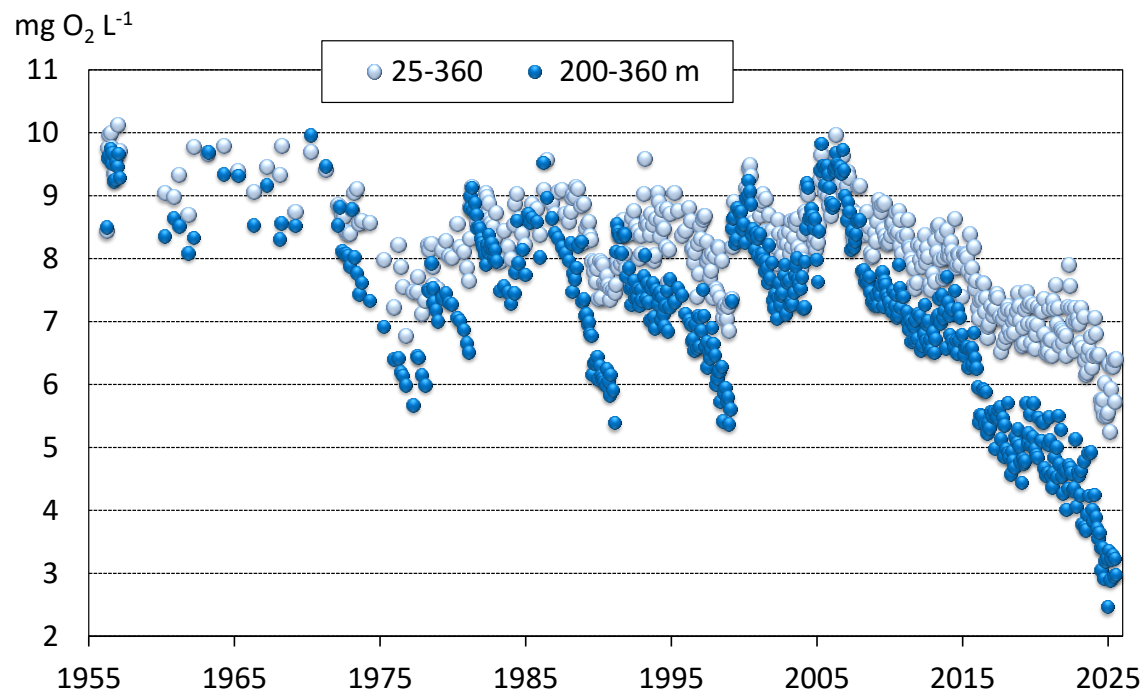


Thermal and hydrodynamical features

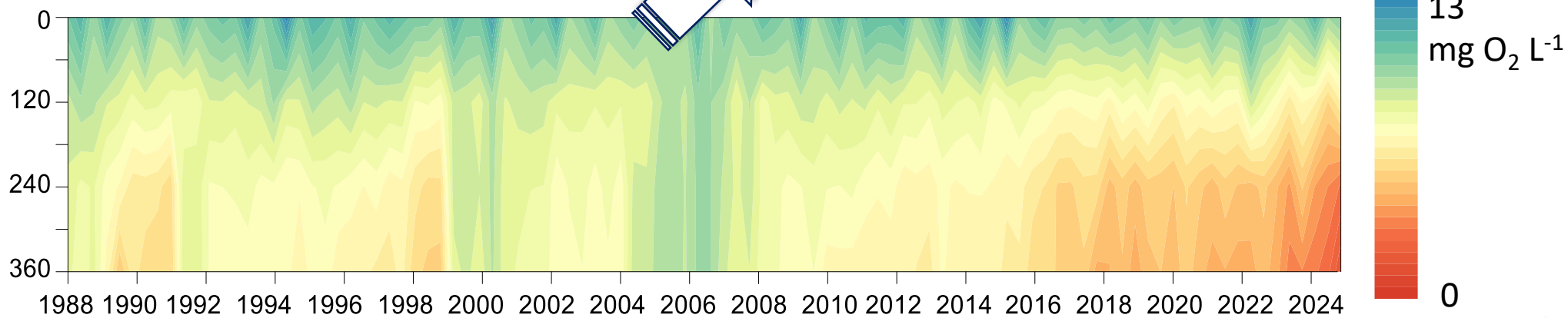
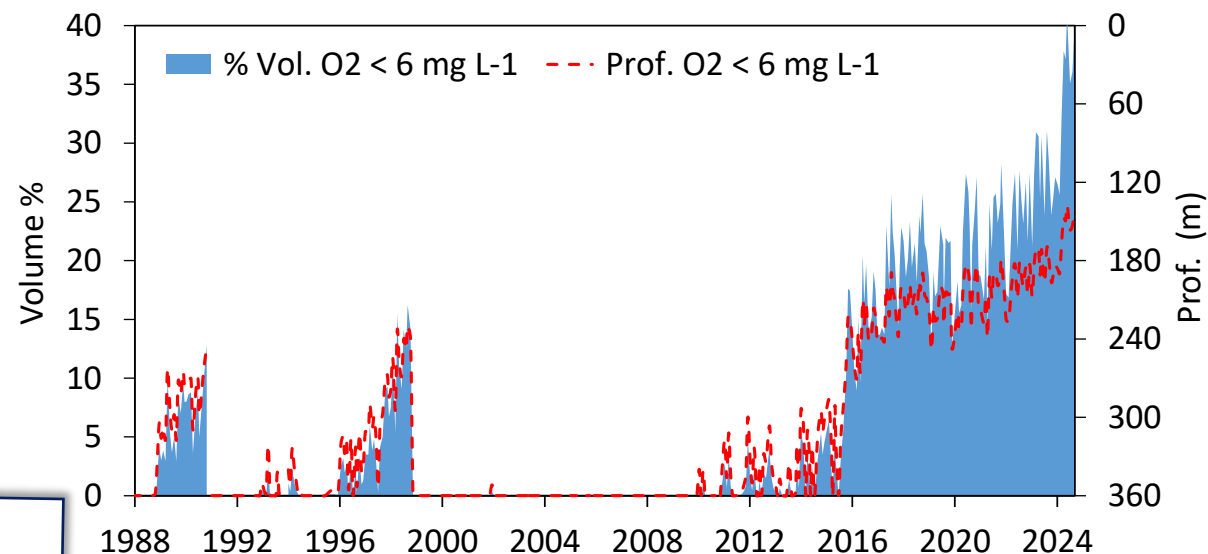


- ❑ Nutrient accumulation in deep layers
- ❑ Lack of nutrient replenishment to the trophogenic layers
- ❑ Enhanced oligotrophic conditions in surface waters





Oxygenation status



Global trends

Geophysical Research Letters

Research Letter | [Open Access](#) |

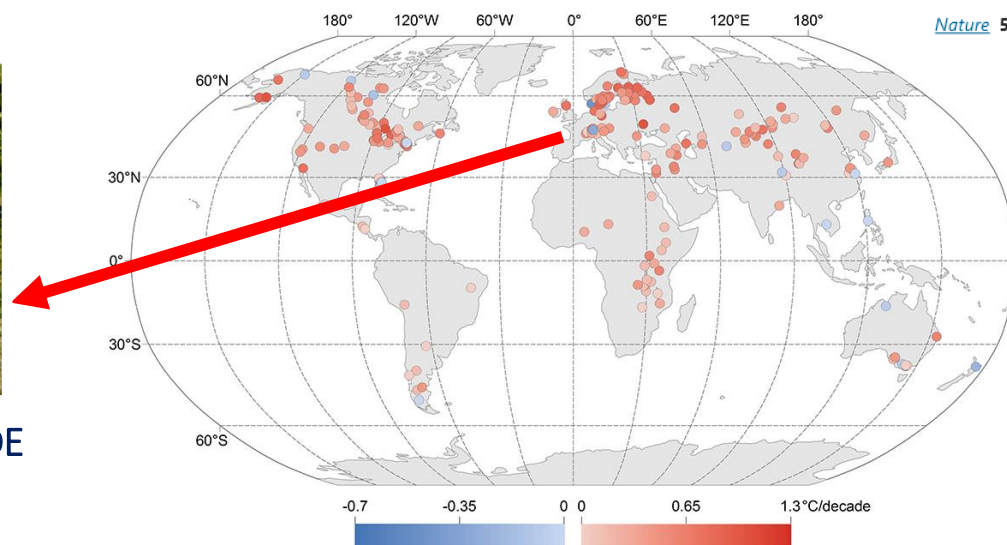
Rapid and highly variable warming of lake surface waters around the globe

Catherine M. O'Reilly, Sapna Sharma, Derek K. Gray, Stephanie E. Hampton, Jordan S. Read, Rex J. Rowley, Philipp Schneider, John D. Lenters, Peter B. McIntyre, Benjamin M. Kraemer, Gesa A. Weyhenmeyer, Dietmar Straile, Bo Dong, Rita Adrian ... [See a](#)

First published: 16 December 2015 | <https://doi.org/10.1002/2015GL066235> | Citations: 578



+ 0.31 °C/DECADE



nature

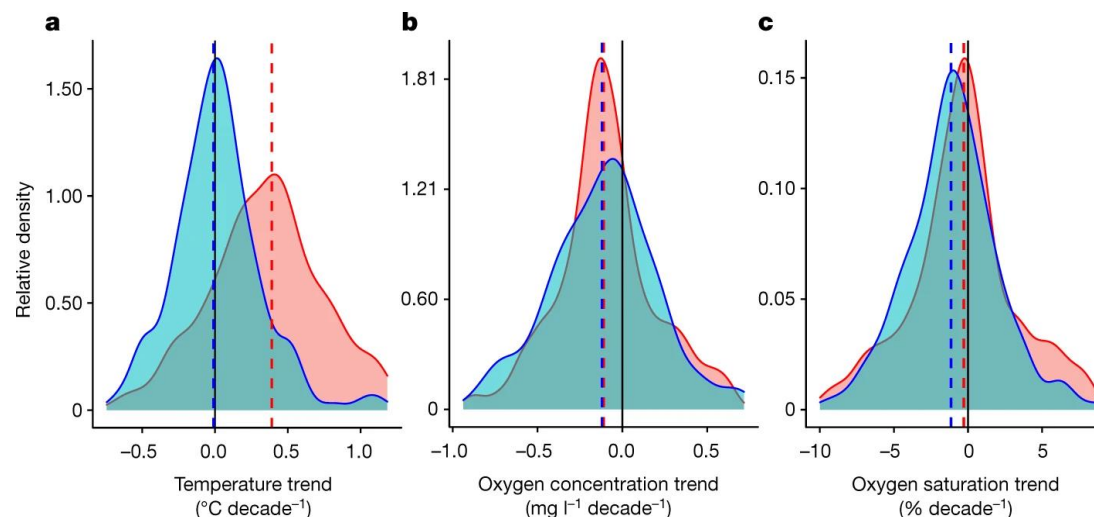
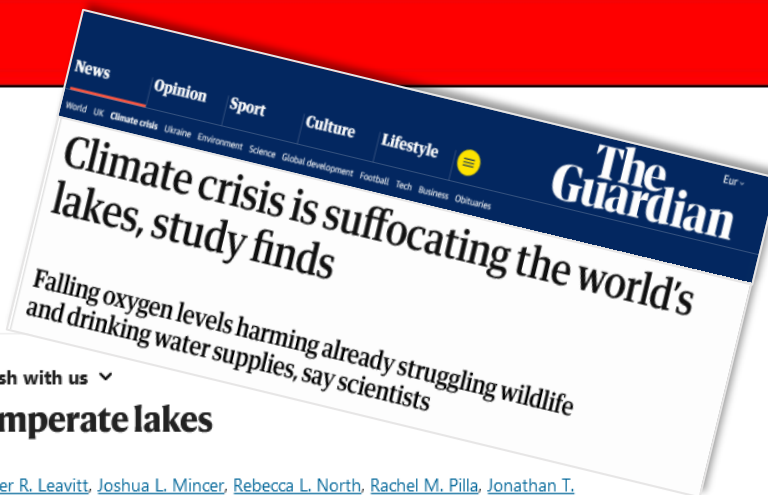
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Widespread deoxygenation of temperate lakes

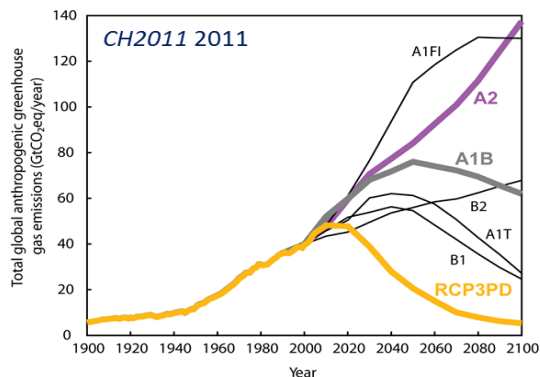
[Stephen F. Jane](#), [Gretchen J. A. Hansen](#), [Benjamin M. Kraemer](#), [Peter R. Leavitt](#), [Joshua L. Mincer](#), [Rebecca L. North](#), [Rachel M. Pilla](#), [Jonathan T. Stetler](#), [Craig E. Williamson](#), [R. Iestyn Woolway](#), [Lauri Arvola](#), [Sudeep Chandra](#), [Curtis L. DeGasper](#), [Laura Diemer](#), [Julita Dunalska](#), [Oxana Erina](#), [Giovanna Flaim](#), [Hans-Peter Grossart](#), [K. David Hambright](#), [Catherine Hein](#), [Josef Hejzlar](#), [Lorraine L. Janus](#), [Jean-Philippe Jenny](#), [John R. Jones](#), ... [Kevin C. Rose](#)

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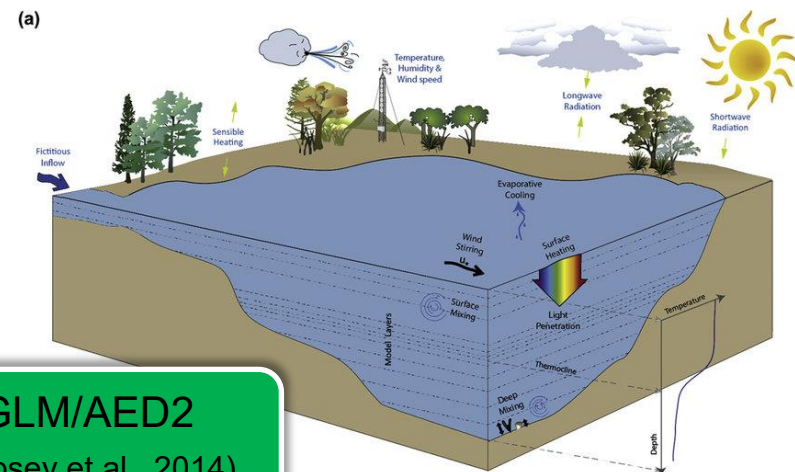
Hydrodynamical and ecological modelling



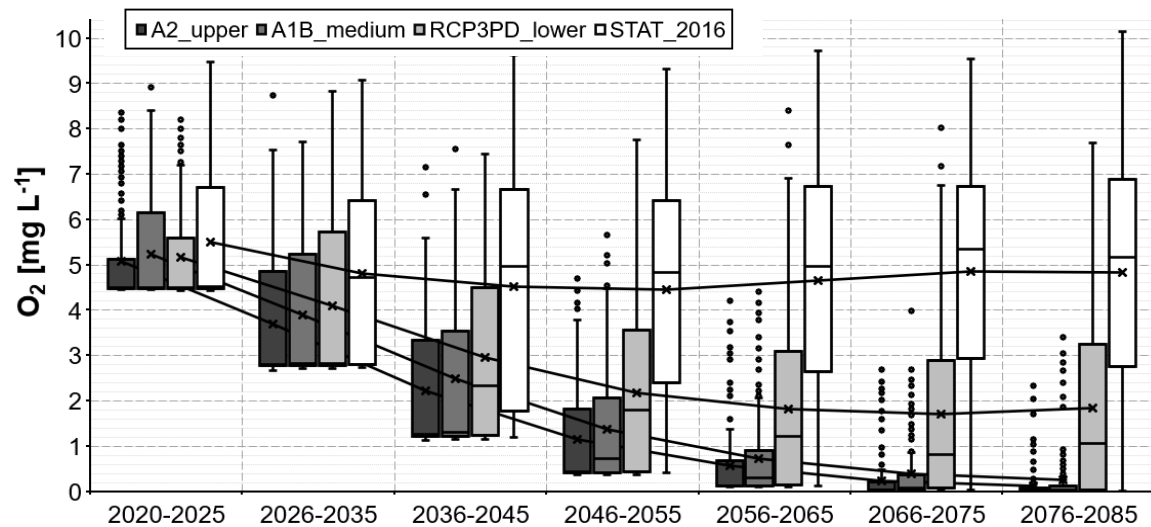
SCENARIOS

Climate change
+
Catchment loads
Remediation actions

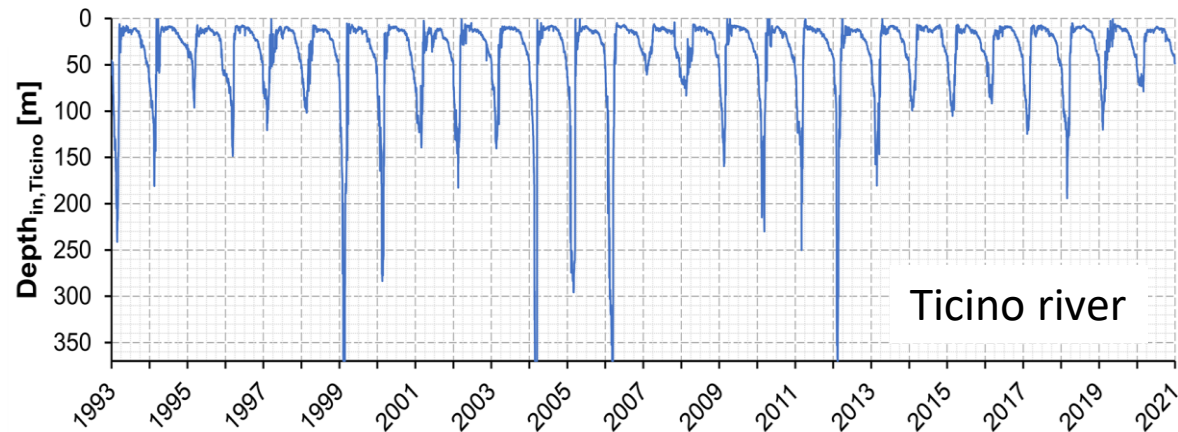
FORECAST



GLM/AED2
(Hipsey et al., 2014)

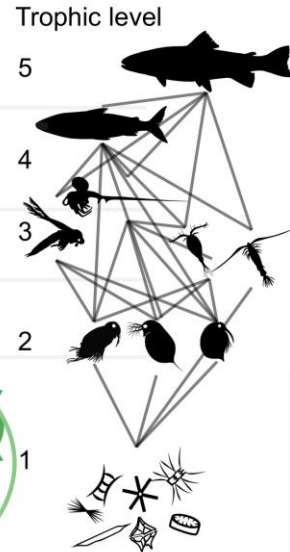
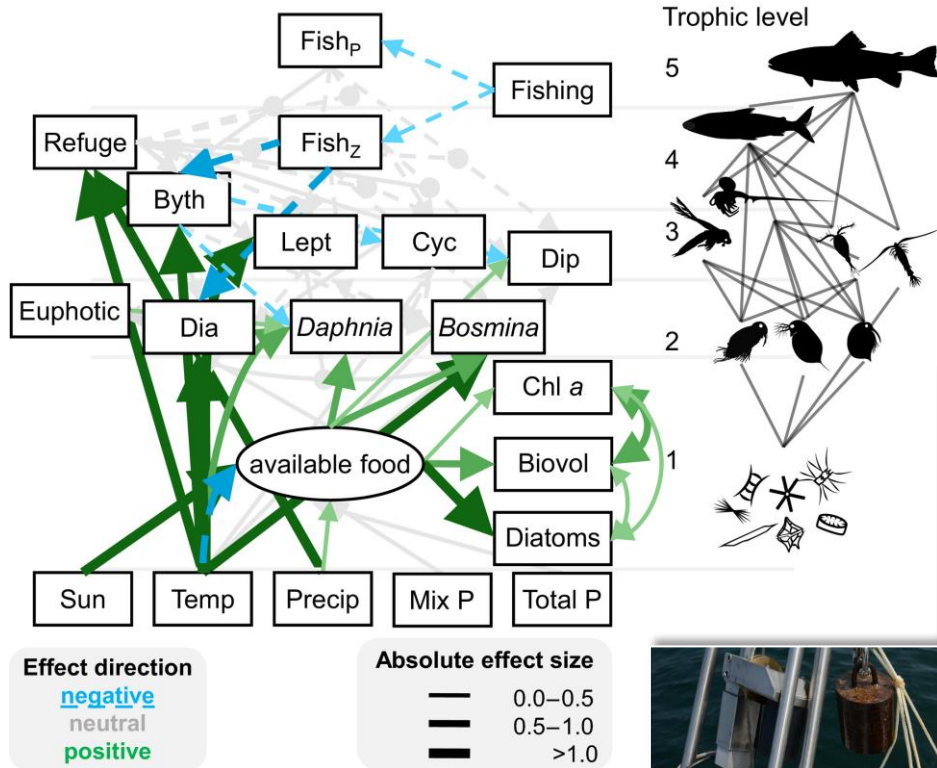


Fenocchi et al., 2019

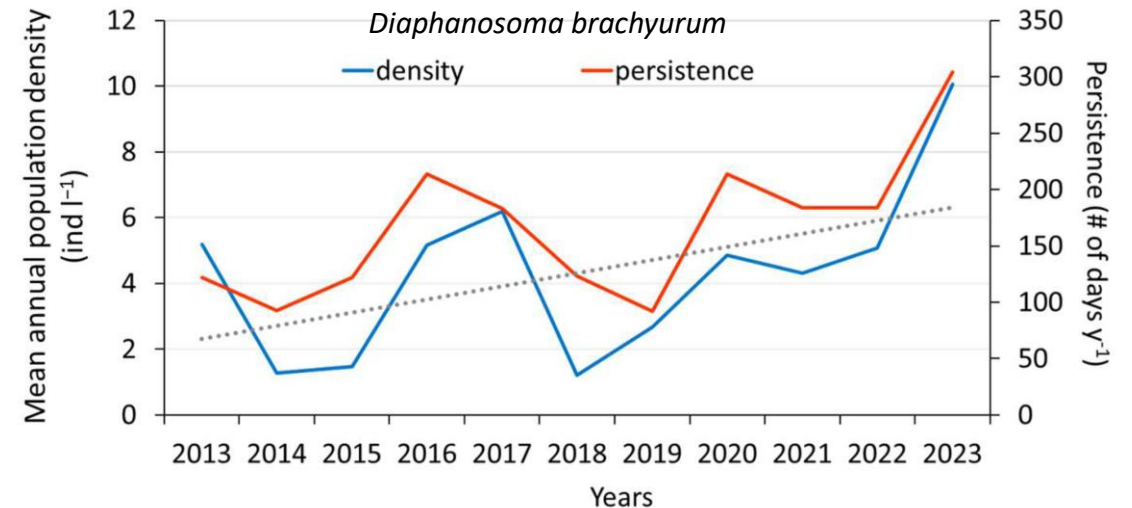


Dresti et al. 2022

Trophic web effects

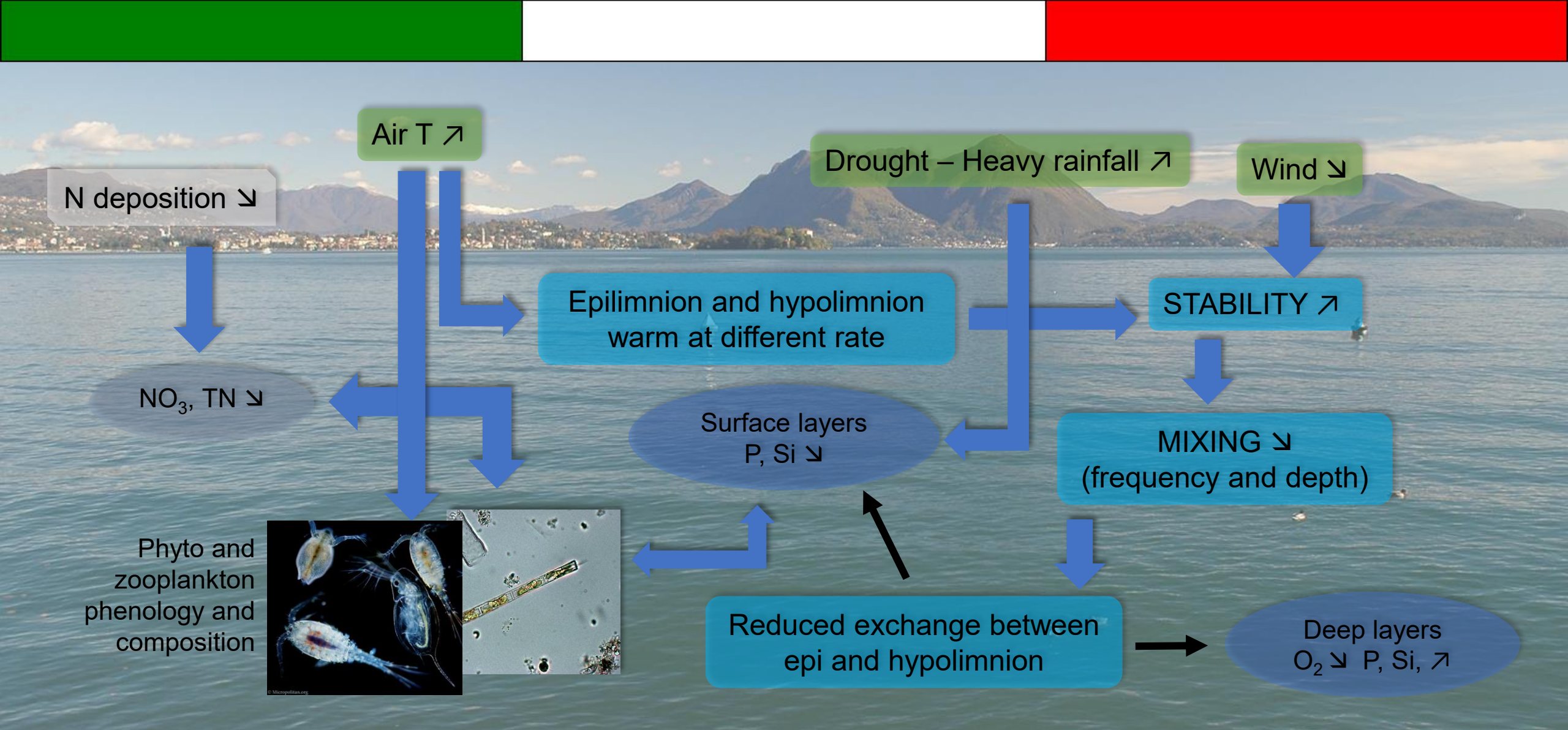


- Earlier biomass peaks (es. diatoms spring bloom)
- High interannual variability in community composition in relation to meteo-hydrological conditions
- Thermophilic and small dimension zooplankton species favoured
- Possible nutrient recycling in the euphotic zone



Tanentzap et al., 2022

Piscia et al., 2025



Conclusions and perspectives

Long-term data highlight the prominent role of meteo-climatic drivers, including extreme events, in lake functioning and evolution. Thermal and hydrodynamical changes affect oxygen and nutrient dynamics and the whole trophic web

Trends observed in Lake Maggiore are in common with the other subalpine lakes and with many deep lakes worldwide. On going tendencies will be exacerbated in the next decades, thereby interacting with other pressures

Climate change significantly affects the lake ecological status. The present evaluation framework under the WFD should be adapted to manage aquatic systems in the context of global change

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Research article

Climate change and ecological assessment in Europe under the WFD – Hitting moving targets with shifting baselines?

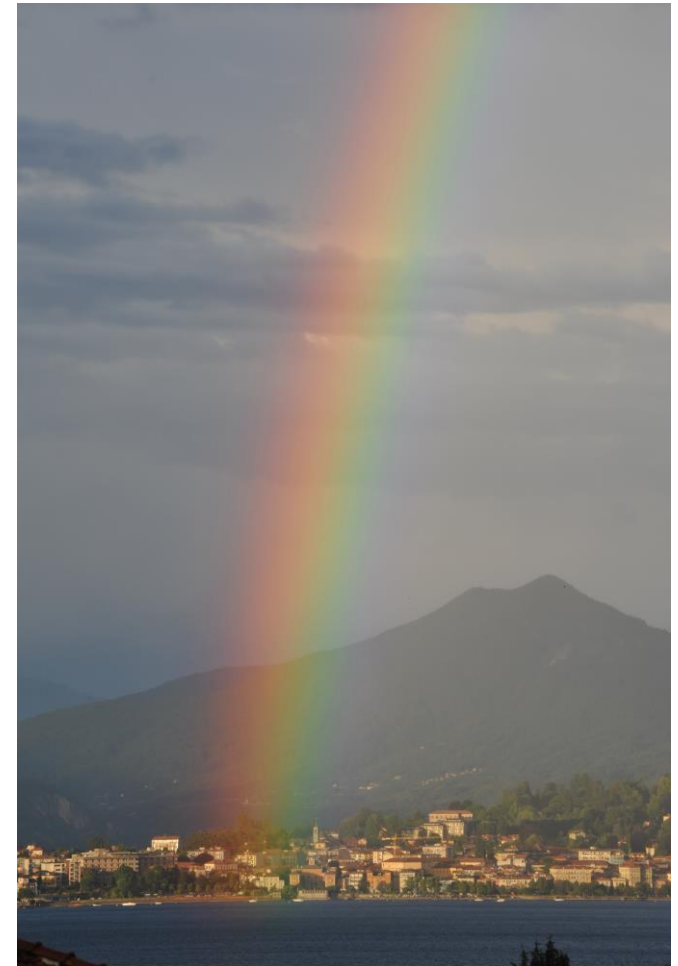
Gary Free^{a,*}, Sandra Poikane^a, Anne Lyche Solheim^b, Martina Bussetini^c, Catherine Bradley^d, Jean Smith^d, Rossana Caroni^e, Mariano Bresciani^e, Monica Pinardi^e, Claudia Giardino^e, Wouter van de Bund^a



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