

Are Swiss alpine lakes recovering from acidification?

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Introduction

During the last three decades, European countries have gone through considerable effort to reduce emissions of acidifying sulfur (S) and nitrogen (N) compounds. For example, at the continental scale, S emissions have been reduced by $\geq 60\%$ since the end of the 1970s, while emissions of oxidized-N have been reduced by $\geq 30\%$ since the 1990s¹.

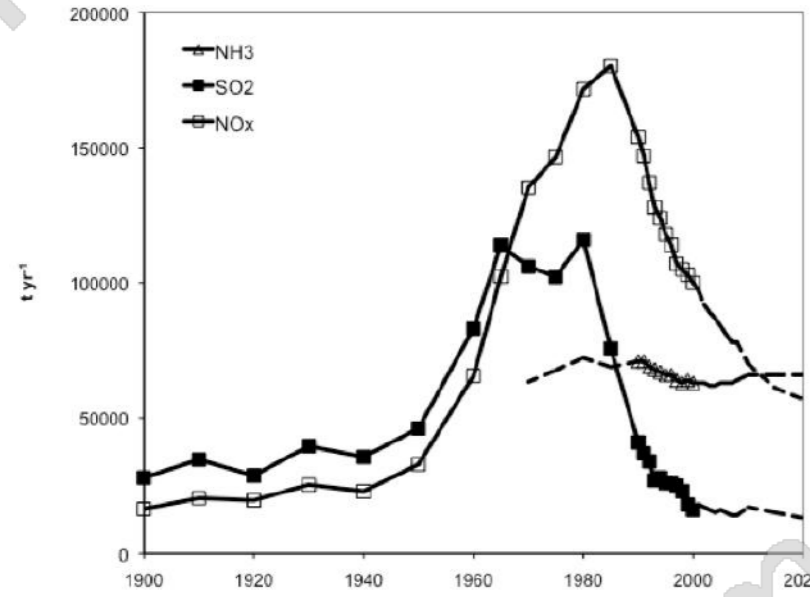


Fig. 1: Annual sulphur dioxide, nitrogen oxides and ammonia emissions in Switzerland, 1900-2010



Lake inferiore and Superiore

What are the effects on acid-sensitive ecosystems? Drawing from long-term monitoring data, we evaluated trends in the chemistry of 20 high-elevation lakes in Canton Ticino, Switzerland, an Alpine region that was severely impacted by acid deposition in the past. We report on the trends of the main acid anions (sulfate and nitrate), alkalinity, and pH in the lakes from 1986 to 2011, and compare these trends to changes in regional atmospheric deposition during the same period.

Study site

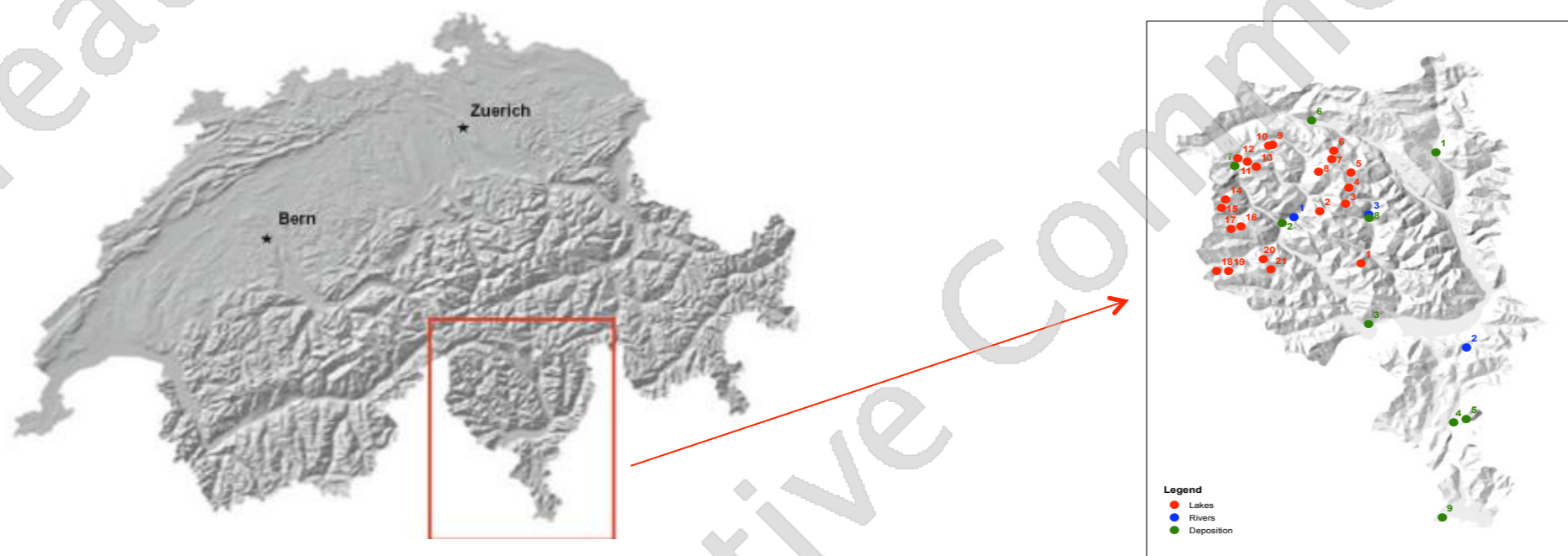


Fig. 2: Study area with lakes, river and deposition sampling points



Helicopter sampling

Methods

Sampling methods

In order to monitor and assess acidification of freshwaters in acid sensitive areas of southern Switzerland water chemistry of 20 Alpine lakes and 3 rivers and wet deposition has been monitored.

From 2000 to 2005 lake surface water was sampled twice a year (once at beginning of summer, once in autumn). After 2006 lakes were monitored three times a year (once at beginning of summer, twice in autumn). Before 2000 lake surface water was sampled irregularly. Lake surface water was collected directly from the helicopter. Weekly sampling of rainwater with wet-only samplers started in 1988.

Analytical methods

The following parameters were measured; pH, conductivity, alkalinity, Ca, Mg, Na, K, NH₄, SO₄, NO₃, NO₂, Cl, soluble reactive and total P, soluble reactive Si, DOC, Al, Cu, Zn, Pb, Cd. The quality of the data was assured by participating regularly to national and international intercalibration tests. In addition, data were accepted only if the calculation of the ionic balance and the comparison of the measured with the calculated conductivity corresponded to the quality requests indicated by the programme manual of ICP Waters². Furthermore, the data were checked for outliers.

Results

Since 1986, sulfate and nitrate concentrations have declined in the majority of the lakes monitored, although nitrate declined to a lower extent (range=0.2-1.4 $\mu\text{eq l}^{-1} \text{yr}^{-1}$ vs. 0.2-0.7 $\mu\text{eq l}^{-1} \text{yr}^{-1}$) and later (from ~2006 vs. the onset of monitoring) than sulfate. These declines were consistent with regional reductions in S and N deposition. Alkalinity and pH have increased in most lakes, with potentially positive consequences for acid-sensitive organisms. If in 1988 40% of the lakes had an average pH < 6, which is harmful to certain aquatic organisms, such conditions now persist in only 15% of the lakes³.

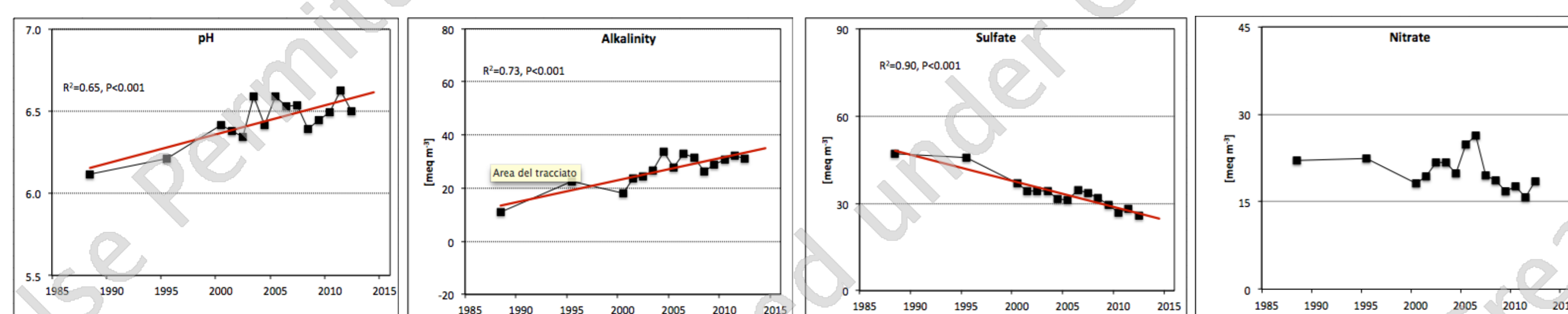


Fig. 3: Temporal variations of annual median values of pH, alkalinity, sulphate and nitrate in 20 Swiss alpine lakes from 1988 to 2011

Conclusions

- The chemistry of surface waters in acid-sensitive areas in the southern Swiss Alps has significantly improved as a consequence of emission abatement strategies.
- Acidification of alpine lakes and rivers is still an environmental concern affecting 15% of the alpine lakes of our study areas. The recovery is not complete, and further improvements will probably require a more substantial reduction in nitrate concentrations.
- Since lake-water nitrate depends not only on N deposition, but also on climatic factors, recovery trajectories in the future remain uncertain.
- Biological recovery can be expected and will be addressed in the future.

Bibliography

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International Cooperative Program Waters, ICPW

ICP Waters was established in July 1985 under the United Nations Economic Commission for Europe (UNECE) Executive Body of the Convention on Long-Range Transboundary Air Pollution (LRTAP). ICP Waters is a programme for monitoring the effects of acid rain and air pollution on water and water courses. Twenty countries (18 European countries, USA and Canada) participate and supply monitoring data to the programme's central database at NIVA.



Fig. 4: Present-day network for chemistry ICP Waters sites



Acidifying Deposition

Because of its particular meteorology the air quality in southern Switzerland is not only influenced by local emissions but also by transboundary air pollution originating from the Po Plain and the heavily polluted urban area of Milan. Furthermore, many high altitude soils and freshwaters of southern Switzerland are particularly sensitive to acidification due to the dominance of base-poor rocks.

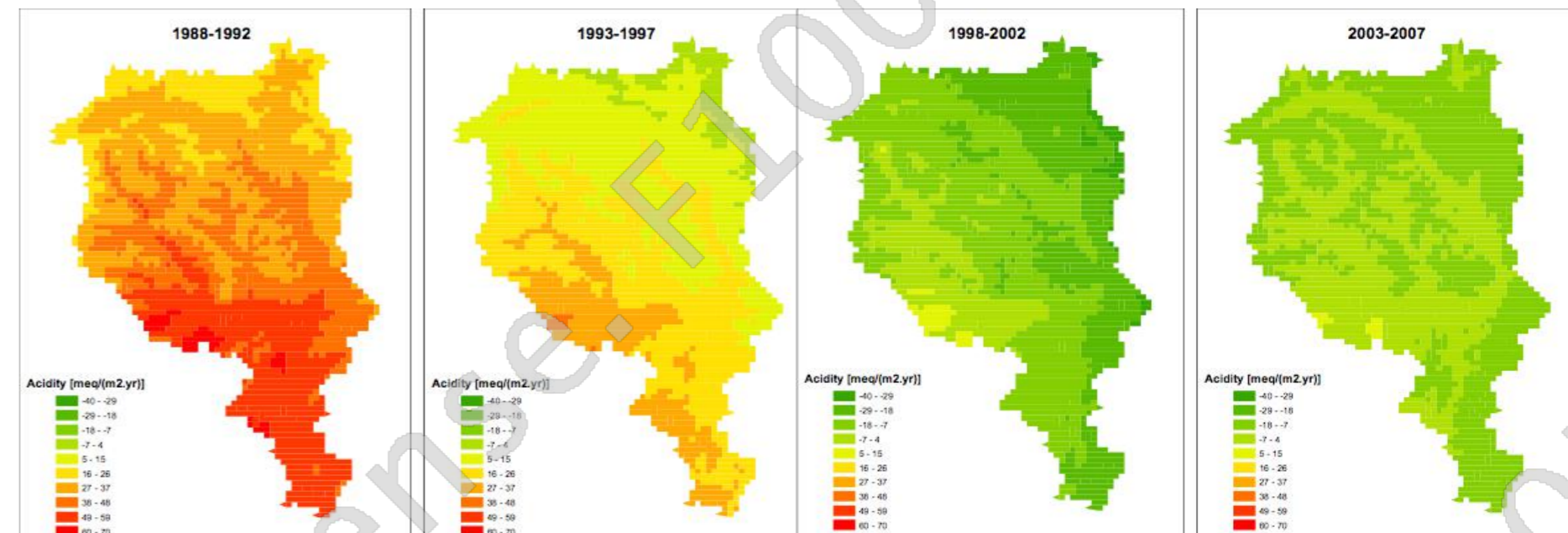
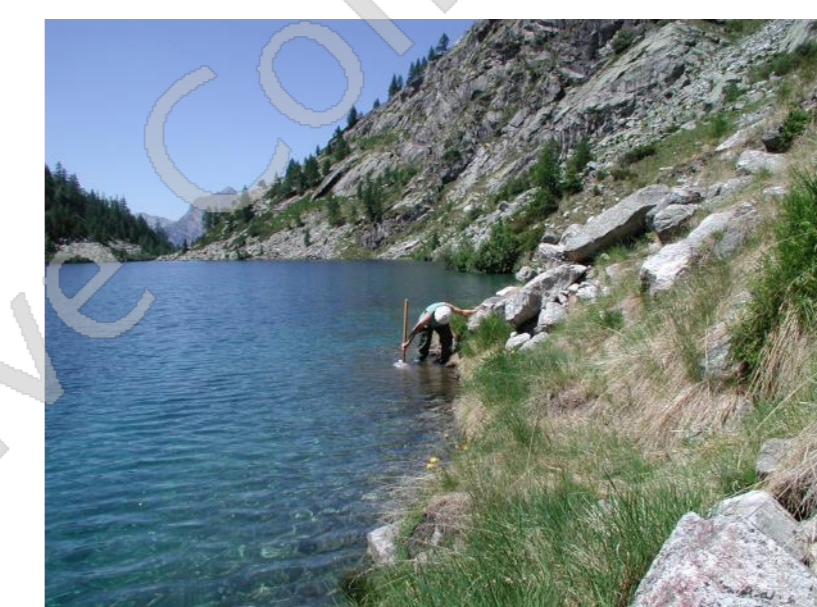


Fig. 5: Deposition of acidity in southern Switzerland, 1988-2007

As a consequence of decreased sulphate concentrations and increased concentrations of base cations, acidity of rain water decreased and therefore pH values increased. After 2000 the mean annual acidity became negative at most sites⁴.

Biology: Is the biota recovering too?

To appraise the biological response to reduced acid deposition we monitor macroinvertebrate assemblages at a subset of five lakes since 2000, which include 2 acidic lakes, 2 acid sensitive lakes (with pH always > 6) and 1 circumneutral lake as control. Invertebrates are sampled yearly from littoral habitats and outlet streams. We observed that the outlet population of acid sensitive lakes is very similar to that of the circumneutral lake with the presence of few acid sensitive taxa, suggesting that recovery might have occurred before biological sampling started⁵. In one of the acidic lakes with pH still below 6 but with concentrations of aluminium decreasing significantly after 2000 biological recovery might be expected. However up to now only Turbellaria (probably the acid sensitive Crenobia sp.) seem to have benefitted from this decrease. Biological recovery might be lagging behind chemical recovery due to poor dispersal ability of acid-sensitive invertebrates; alternatively, it might be hindered by continuing episodic acidification.



Kick sampling of macroinvertebrates



EPT macroinvertebrates

Modeling long term changes in water chemistry and evaluating the effective level of chemical recovery with respect to pre-acidification conditions (MAGIC model)

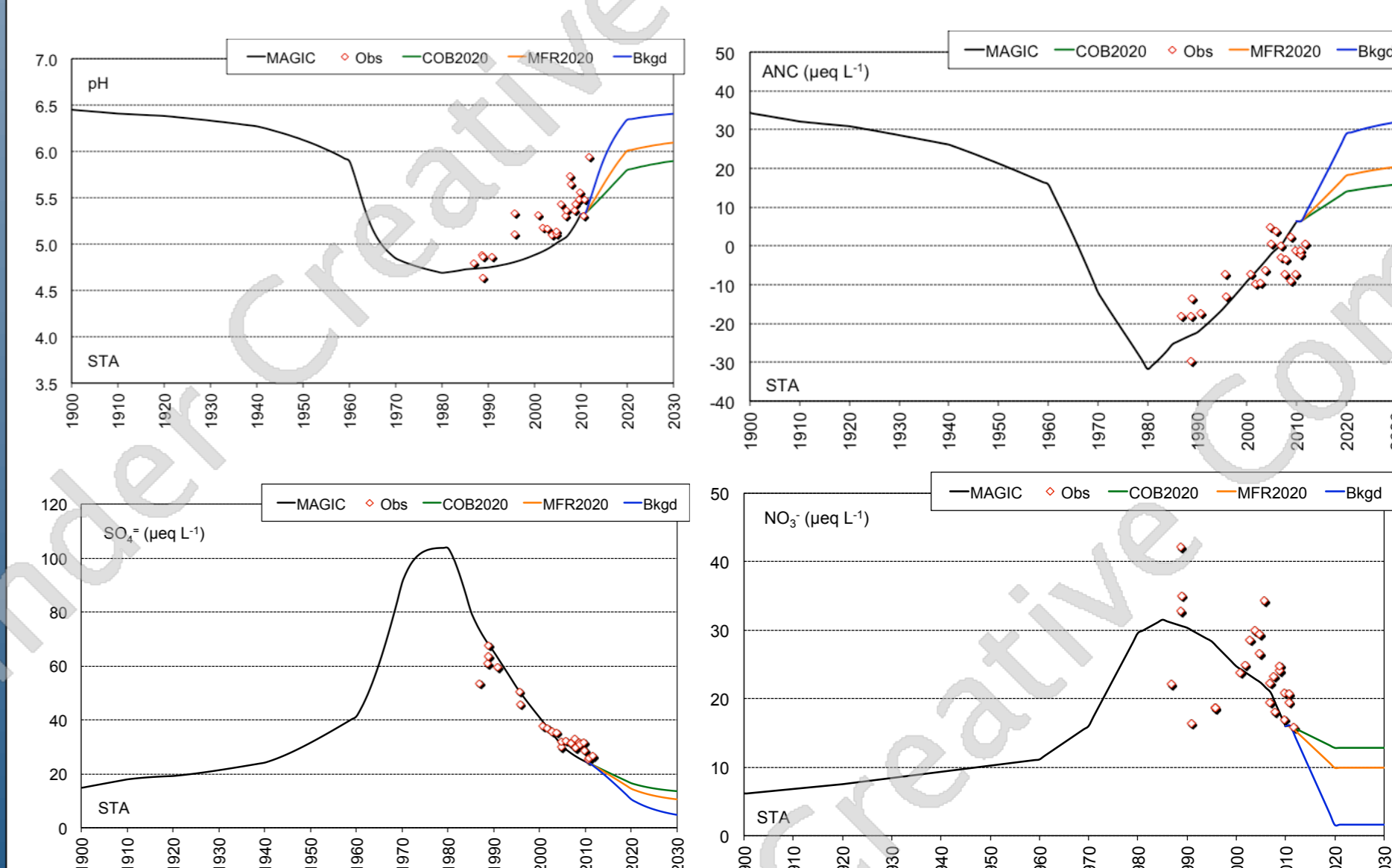


Fig. 6: Simulated (MAGIC) and observed (Obs) pH-values, ANC, sulphate and nitrate for lake Starlarescio. Three deposition scenarios are considered: COB2020 actual legislation, MFR 2020, maximum feasible reduction, and Bkgd, background deposition only.