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# Monitoring of alpine lakes: approach and results from Canton Ticino


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Repubblica e Cantone Ticino


## Background

Alpine ecosystems are facing environmental change including climate warming and the atmospheric deposition of pollutants. Alpine catchments offer valuable vantage points to monitor global environmental changes, because they are often remote and free from local pressures. Moreover, because of their vulnerability, these catchments are considered to be among the most sensitive sentinels of environmental change (Beniston et al., 1997).
The southern slope of the Central Alps is highly affected, due to its proximity to the heavily industrialised Po Valley, Italy. For example, in Canton Ticino, atmospheric deposition of nitrogen ranks among the highest recorded in mountain areas worldwide (up to 30-40 kg·ha$^{-1}$·yr$^{-1}$, Steingruber, 2015) while air temperature has been increasing nearly twice as fast as the global average (MeteoSwiss, 2016).
To assess the consequences of these environmental changes on alpine ecosystems, Canton Ticino and the Swiss Federal Office for the Environment (FOEN) have funded two synergistic monitoring programs: (i) an extensive survey of 20 alpine lakes and 3 streams (Fig. 1) and (ii) an intensive monitoring of the Lago Nero catchment (Fig. 2). The extensive survey was designed to assess the spatial extent of the impacts of atmospheric deposition, whereas the intensive programme aims at developing predictive models of ecosystem responses to environmental change.

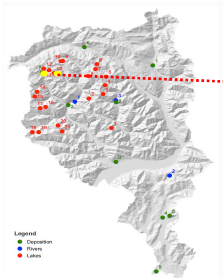


**Figure 1:** Topographic map of Canton Ticino with the sites of the extensive survey. Nr. 11 represents Lake Nero and the green nr. 7 represents the site where deposition of nitrogen and sulphur is monitored.

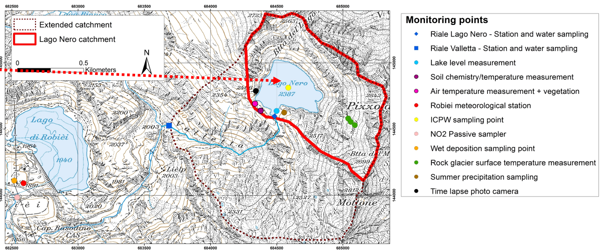


**Figure 2.** Location of the two sampling stations at the intensive sampling point Lake Nero

Together, these programmes contribute to form a basis for decisions on environmental management at national and international levels. The international influence of these programmes is enhanced through the participation to the Convention on Long-range Transboundary Air Pollution of the UNECE, namely the international cooperative programmes on waters (ICP-Waters, BOX 1 which involves the extensive programme) and integrated monitoring (ICP-Integrated Monitoring, BOX 2 which involves the intensive programme).

## Results

**The extensive programme** has been running for over 30 years. A main goal of the programme was to assess the effects of acid deposition, which was most severe in the 1970s and 1980s. The long-term results have chronicled a remarkable recovery in the chemistry of the deposition and the water of receiving lakes, which reflects international efforts to manage sulfur (S) emissions (Rogora et al., 2013). For example, between the early 1980s and 2014, most of the lakes displayed trends toward lower concentrations of sulfate (13 of 20 lakes) and higher alkalinity (14 of 20). However, nitrate decreased less frequently (7 of 20), probably because N deposition declined comparatively less and more lately than S deposition.

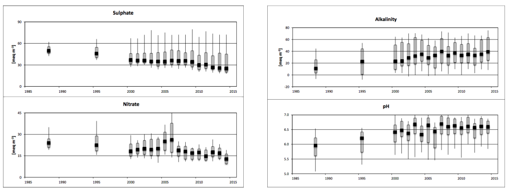


**Figure 3.** Temporal variations of annual median values and their 10th, 25th, 75th, 90th percentiles of sulphate, nitrate, alkalinity and pH, measured in 20 Alpine lakes from 1988 to 2014 (calculated from autumn mean values).

**The intensive programme** started in 2014 with a pilot study, and the results are preliminary. Nonetheless, the high N concentrations recorded at the outlet throughout the 2014-2015 hydrological year (including the vegetative season) indicate that the soils of Lake Nero's catchment have become saturated with this nutrient (Stoddard, 1994). An input-output budget for nitrogen suggests that the catchment of Lake Nero retains a substantial percentage of the yearly input (Fig. 5). Although the export peaked during the snow melt period, N-leaching was observed also during the subsequent vegetative period, indicating that the catchment soils have become saturated with this nutrient.

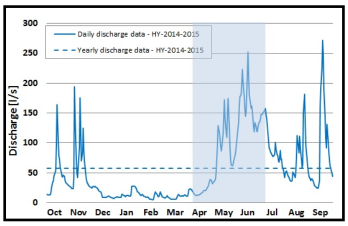


**Figure 4:** Daily mean values of discharge (L/s) continuously measured in Riale Lake Nero.

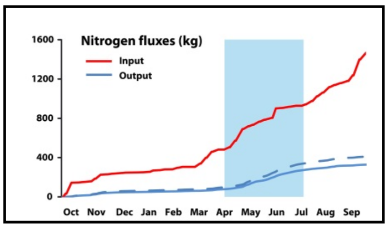


**Figure 5:** Budget of nitrogen for the Lago Nero catchment during the hydrological year 2014/2015. The dashed line represents an estimate for total nitrogen in the output based on measured dissolved nitrogen. The blue square represents the snow-melt period.

## Discussion

The synergistic monitoring programmes provide the following main advantages: (i) comparison and extrapolation of findings from Lake Nero to the regional scale and (ii) understanding the ecological effects of environmental change detected at the regional scale.
As climate warms and N deposition increases at the global scale, monitoring **programmes in mountain catchments will become increasingly important** to detect the effects as early as possible and prevent damage to these important landscape features.
Because the southern slope of the Alps appears to be changing particularly fast, monitoring programmes in this region might play an especially important role in detecting early signals of environmental change.

## References


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### BOX1 - International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Rivers and Lakes

ICP Waters was established in July 1985 under the United Nation Economic Comission for Europe (UNECE) Executive Body of the Convention on Long-Range Transboundary Air Pollution (LRTAP). ICP Waters is a programme for monitoring of 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.

**Figure 6**: Present-day network of ICPW sites, http://www.icp-waters.no

LRTAP Long-range Transboundary Air Pollution

### BOX2 - International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM)

The multi-disciplinary Integrated Monitoring programme (ICP IM) is part of the effect-oriented activities under the 1979 LRTAP, which covers the region of the UNECE. ICP IM belongs to a group of six specialist ICP Programmes (ICPs) which have been set up under the LRTAP Convention's Working Group on Effects to look at relevant receptors and environmental issues. The ICP IM sites are catchments/plots located in natural or semi-natural areas.

**Figure 7**: Present-day ICP IM network, 2016, http://www.syke.fi/nature/icpim

### BOX3 – Methods

Surveying methods vary according to the programme goals.
✓The **extensive monitoring programme** (started in the 80's) places emphasis on the chemistry of surface waters during the ice-free season, although biological responses (benthic invertebrates) are also measured at a subset of 20 lakes.
✓The **intensive programme** (started in 2014) at Lake Nero measures a wider array of ecosystem responses, including hydrology, physicochemistry of outflow and tributaries, chemistry of atmospheric deposition, ecosystem budgets of nitrogen and sulphur, soil and soil water chemistry, soil temperature and terrestrial vegetation
✓Sampling frequency depends on the response, varying from nearly continuous (e.g. runoff) to every five years (e.g soil and vegetation. Future investigations will also examine ice-out and snow melt, runoff generation and the temperature of surface waters.

**Figure 8:** Automated sampler used to collect waters samples during spring snowmelt installed near Lake Nero

### BOX4 – Modeling long term changes in water chemistry

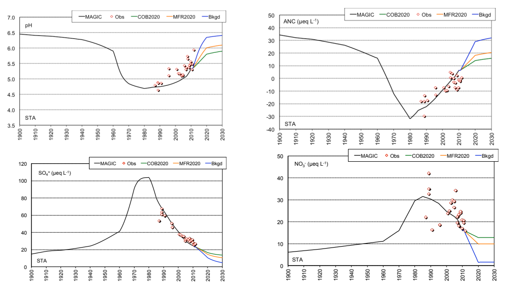


**Figure 9**: Simulated (MAGIC) and observed (Obs) pH-values, ANC, sulphate and nitrate for lake Starlaresc. Three deposition scenarios are considered: COB2020 actual legislation, MFR 2020, maximum feasible reduction, Bkgd, background deposition only.


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