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Has Lake Orta completely recovered from its heavy polluted condition? A seventy years long history

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ABSTRACT

Taking in account the results obtained from the 16 previous papers, the present conditions of Lake Orta are stated. While chemical features are now almost normal, it was demonstrated that sediments still contain large amounts of heavy metals in the upper 10 cm and are thus to be considered still toxic for benthic fauna. Algal community shows evidence of increasing complexity and stability, so does zooplankton, albeit to a lesser extent. Benthic fauna is still affected by past water pollution and is very poor both in number of species and of individuals.

Key words: sediment and water chemistry, phytoplankton zooplankton and benthos, paleolimnology, sediment toxicity

1. INTRODUCTION

We have made till now a long journey throughout the years: from 1926 to 2000 three quarters of a century passed away, scanned by a lot of research work (Bonacina 2001a) and by historical turning points such as the rise of a widespread ecological consciousness that no longer tolerated the foolish environmental exploitation. As a consequence, anti-pollution laws were approved and kept, and the improvement of the environmental conditions in Lake Orta made a direct intervention on the whole lake not only a working hypothesis but a real possibility: it could be done; it was done (Bonacina 2001b; Calderoni & Tartari 2001).

Now it is time to put together the results of so many investigations and try to state the real conditions of the lake, taking into account the conclusions reached by our authors in the above papers.

2. WATER CHEMISTRY

As a consequence of the liming, the alkaline reserve showed a continuous increase until March 2000, when total alkalinity values levelled off at 0.10 meq l^{-1}; as a consequence, the whole water mass was completely neutralised and pH reached values of 6.7-6.9 units (Calderoni & Tartari 2001). This increase followed a full recovery of nitrification processes (ammonium has been practically absent since the end of 1992) and a progressive reduction in the concentration of toxic metals, so that in 1999 the content of copper and aluminium was close to zero in the whole lake. The nitrate in-lake concentration has almost halved compared with the mean concentrations measured before the liming (Calderoni & Tartari 2001), in spite of a first rise due to enhanced nitrification; this is attributable to losses throughout the outlet, no longer balanced by the inputs from the basin, and to biological consumption enhanced by the increase in algal population.

The situation of Lake Orta has therefore improved enormously, but this situation cannot be regarded as definitive, as a stable balance between the input and output of some important chemical species, such as bicarbonate and nitrogen compounds, has not yet been achieved in the budget of the lake.

3. SEDIMENT CHEMISTRY

The liming resulted in the deposition of a large portion of the metals dissolved in the lake water; the increase of metal concentration in the sediments was high especially for those elements whose solubility is low at the near neutral pH reached by lake water after the liming. Increase of Ca content was also due to its high content in the limestone used for the liming. Only concentrations of Si, Al, K and Mg showed a decrease after the liming, most probably due to a "dilution" effect (limestone addition plus increased deposition of autochthonous organic material substained by enhanced phytoplankton productivity, Baudo & Beltrami 2001).

An interesting evidence emerged from flux calculations made on cores collected in the southern basin during 1994 (four years after the liming), that is a 5 times increase in denitrification (Adams & Baudo 2001).

4. PHYTOPLANKTON

Compared with the two years prior to liming, in the course of the years 1989 and 1990, 17 algal species or genera disappeared, 18 survived and 41 new species appeared. As a result, the number of species was more than doubled (Morabito *et al*. 2001). Particularly noteworthy was the invasion of the groups Cyanobacteria and Bacillariophyceae, which also are the two most important groups in the deep and large Italian lakes. Noticeable is the reduction of the chlorophytes, which could be related to the continuous decrease of the metal concentration, in particular of Cu and Al.

A certain interannual variability inside the dominant species assemblage is however still present, meaning that the phytoplankton community is still evolving from year to year.

5. ZOOPLANKTON

In 1986, when ammonia concentration dropped to about 1.5 mg N l^{-1} (mean for the whole lake), *Daphnia obtusa* appeared, although pH was still low and copper content still high (pH about 4 and 40 µg Cu l^{-1}, mean values for the whole lake).

But it was only after the liming, when the whole lake was neutralised and toxic metals precipitated, that the zooplankton community began to show a more complex structure. Once the toxic effect of both copper and low pH had been reduced or stopped, other species could survive in the pelagic waters, namely *Keratella quadrata*, *Diaphanosoma brachyurum*, *Bosmina longirostris* and *D. longispina* which finally substituted *D. obtusa*.

As demonstrated by yearly variations in species composition, the biological community is far from being settled, mainly because there is still a lack of predators, apart from *Asplanchna* spp. and *Cyclops abyssorum*. In this situation, opportunistic species may be expected to be very successful for a limited period of time, and then be rapidly replaced by others, as happened with the pair *Daphnia obtusa-Daphnia longispina* (Bonacina & Pasteris 2001).

6. LITTORAL BENTHOS

Gasteropoda and Crustacea are still absent, but on one occasion an *Asellus aquaticus* (Asellidae, Crustacea) was found . The macrobenthic community is formed by Oligochaeta Tubificidae, Diptera Chironomidae and two species of Trichoptera (*Mystacides azurea* and *Ecnomus tenellus*) (Bielli & Tesauro 2001). The liming did not favour either micro-organisms like bacteria and fungi, which take part in the decomposition pro??cesses, or epi-benthic macro-invertebrates colonising biological materials on the littoral bottom; on the contrary, it seems that it slightly makes worse the precarious although stable situation both of communities and of decaying processes. Analysis of alder leaves colonisation processes gave scanty and fragmentary results (Salmoiraghi *et al*. 2001).

7. PROFUNDAL BENTHOS

From the 51 stations sampled in 1996, a total of 45 taxa were identified. The main groups were Tubificidae (Oligochaeta) and Chironomidae (Diptera). Total macrofauna abundances are much lower than densities commonly reported for unpolluted freshwater environments, and Oligochaeta density is lower than that observed in 1993. Furthermore, *Spirosperma ferox* (Oligochaeta, Tubificidae) surely present in the past and disappeared at the onset of pollution (Bonacina *et al*. 1986), is still lacking from the sediments (Baudo *et al*. 2001a). Albeit the chemical composition of the sediment would still be classified as "heavily contaminated" (Baudo & Beltrami 2001), a clear correlation between metal content and distribution and abundance of benthic fauna has not been found.

Samples collected seasonally in the southern basin along a profile extending from the coast line to the maximum depth (30 m) confirmed these results, moreover showing that recolonisation is more evident in the littoral zone (Nocentini *et al*. 2001).

8. PALEOLIMNOLOGICAL RESEARCHES

Heavy pollution of lake waters resulted, in the sediments, in a marked decrease or a complete disappearance of the invertebrate organisms and diatoms, an increase of pigments derived from dead algae accumulation and, later on, in a strong modification in the species composition of depositing phytoplankton. The presence of teratological frustules of the diatom *Synedra tenera* and changes in mean body size of diatoms, thecamoebians and cladocerans were also reported. Unfortunately, the core sectioning adopted in the most recent studies (1 cm, =3-5 years) had not a sufficient resolution as to permit a detailed study of sub-fossil remains in relation to the lake recovery by liming (Guilizzoni *et al*. 2001).

9. ASSESSMENT OF SEDIMENT TOXICITY

Toxicity assays were conducted on sediment core samples from the three lake basins. The results showed that acute sediment toxicity still exists at depth of 5 cm and greater (Burton *et al*. 2001).

Seed germination and root elongation tests were also performed, using seeds of *Cucumis sativum*, *Lactuca sativa* and *Lepidium sativum*. These tests, too, demonstrated the persistence of sediment toxicity. However, the more contaminated layers are presently buried under less toxic sediments, showing a positive reaction to the restoration treatment (Barbero *et al*. 2001).

In-situ toxicity assays were finally conducted on four invertebrate species (*Daphnia obtusa*, *D. longispina*, *D. magna*, *Echinogammarus stammeri*). The results are consistent with those obtained in toxicity tests with other organisms and demonstrate that the sediments are still contaminated to an extent which can pose some problems for indigenous biota, possibly delaying the colonisation of most contaminated areas (Baudo *et al*. 2001a).

10. CONCLUSIONS

It is not very easy to forecast the evolution of both physico-chemical characteristics and the biological physiognomy of Lake Orta. We know, for instance, that the in-lake phosphorus concentration is low (4-5 $\mu g\ l^{-1}$) even though the annual phosphorus load from the drainage basin is very high (Calderoni *et al*. 1997). Most probably this is due to high in-lake concentrations of metals such Fe and Al which can precipitate phosphorus in form of Me-P complexes. Till now, iron still enters the lake with the loads from galvanic industries, and at almost neutral current pH values, the mechanisms of phosphorus removal is still active; but the possible new mechanisms involved in the phosphorus dynamics are unknown (Calderoni, pers. comm.). So we lack a basis to make reliable hypotheses about the evolution of the phytoplankton assemblage and, as a consequence, of all the trophic chain.

Most of the authors who contributed to this volume (Calderoni & Tartari 2001; Bonacina & Pasteris 2001; Morabito *et al*. 2001; Salmoiraghi *et al*. 2001) agree with the statement that the lake and its biological community have reached an equilibrium which is far from being stable. This sounds obvious, as at present Lake Orta has to be considered a "new" lake like, for instance, a just replenished man-made lake; but a final and least obvious consideration has to be done: as a consequence of the naturally low buffer power of Lake Orta waters, redox processes had been stressed and acidification greatly enhanced; but such processes normally happen in lakes, albeit with a lower intensity. The crucial point is the extremely low alkalinity of this lake, due to the nature of its drainage basin. This feature makes Lake Orta a fragile environment absolutely unable to receive and metabolise wastes of any nature but above all of industrial origin. And this is, in fact, the reason why it is indispensable a strict surveillance of any load, to make sure that this new, laboriously reached, and instable equilibrium is maintained, so permitting the development of a normal biological community.

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