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LIMNOLOGICAL RESERCH ON LAKE MAGGIORE AS A CONTRIBUTION TO TRANSBOUNDARY COOPERATION BETWEEN ITALY AND SWITZERLAND

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The Institute of Ecosystem Study of the National Research Council (CNR-ISE) performs research activity on structure and functioning of aquatic and terrestrial ecosystems, focusing on anthropogenic pressure and global change. The Institute headquarter, located at Verbania Pallanza, on the shore of Lake Maggiore, is mainly involved in limnology and aquatic ecology studies, and a significant part of the activity is addressed to Lake Maggiore. This water body, is the second largest (212 km^2; volume of 37 km^3) and deepest (370 m) Italian lake, is one of the most investigated lakes in Europe. The 6600 km^2 of the watershed are shared approximately in equal parts from Italy (Regions Piedmont and Lombardy) and Switzerland (Canton Ticino). As much as 50% of this area lies above 1283 m a.s.l. and 1.1% of it is composed of glaciers. It includes several other lakes, the most important being lakes Lugano and Orta, the first one again shared between Italy and Switzerland. The socio-economical system of this region depends strongly on the presence of the lake, whose waters are subject to many uses, including tourism, recreational-environmental activities, public and private navigation, professional and sport fishery, hydroelectric production, irrigation and, sector in expansion, drinking use. The waters inflowing the lake are widely used in artificial reservoirs for the production of hydroelectric power, both in Italy and Switzerland, for a total of 600 million m^3. Furthermore the lake plays an important role in the context of the Po River plain, the main agricultural and urban area in Italy, both as a source of water for irrigation and for flood control. Since the 12^{th} century a wide area of this plain has been affected by the construction of a dense web of navigable canals, originating from the sub-lacustrine Ticino River. These channels subsequently were destined to irrigate valuable crops, such as rice and forage. To rationalize these uses, in 1943 a weir with mobile sluices was constructed on the lake outflow.
However the lake, due to the morphological nature of the catchment and its location in a high precipitation climatic zone, is a water body with a high hydro-geological risk. Furthermore the human activities of about 600,000 inhabitants equally distributed between Italy and Switzerland, produced in the decades following the Second Word War a progressive deterioration of the quality of the waters, primarily due to eutrophication (Marchetto *et al.*, 2004). Other early pollution problems are related with mercury, used in industrial activities e.g. for the hydrolysis of sodium chloride, to produce chlorine for industrial purposes, including the synthesis of DDT (Guzzella *et al.*, 1997).

To handle the many problems rising from the management of the lake and its watershed, in 1882 an International Commission for the Fisheries in Italian Swiss waters was created between Italy and Switzerland. Many decades later, in 1972, a second Body (International Commission for the protection of Italian Swiss Waters, CIPAIS) was created with the aim to study the increasing water eutrophication, locating the main sources of algal nutrients and proposing possible remediation actions. Since 1978 the studies were organized in five-years programs, covering the main aspects of basic limnology, climatology, hydrology and chemical loads of the tributaries, physical, chemical and biological characteristics of the lake water, the latter including several topics such as phyto- and zooplankton, bacteria and macrophytes. The same programs were carried out in parallel on lakes Maggiore and Lugano, the first by CNR-ISE, the second from the Cantonal Agency for Water and Soil Protection. The results permitted to document the worsening of lake trophic conditions in the seventies and to identify phosphorus as the main cause of eutrophication (Salmaso *et al.*, 2007). The studies on the tributaries allow to highlight the areas of the watershed mostly contributing to the P load, and to identify the main activities responsible for the P discharge. These evidences allowed to recommend to the authorities, through the CIPAIS, measures for the P reduction in the detergents, adopted in the first half of the ’80 in Switzerland and Italy. Furthermore it was indicated to add the tertiary treatment to sewage plants, in part already under construction for sanitary uses, for a more effective P reduction. The sewage treatment was conducted with different strategies in Canton Ticino and in the two Italian regions, Piedmont and Lombardy. The continuous monitoring of the tributaries documented the positive effects of the treatment in Ticino and Piedmont, while the situation, although improved, remained unsatisfactory in Lombardy. Lake Maggiore, because of its volume and of resilience processes, reacted slowly to the decreased P load. However the total P concentrations, which reached the highest values of 38 µg P L^{-1} over the whole water volumes at the end of the 80s, in the 90s started decreasing, reaching the present level of 10-12 µg P L^{-1} in 1995 which set the lake in the oligo-mesotrophic condition. Also the biological compartments responded to the changed hydrochemistry, highlighted by a strong reduction in chlorophyll concentration. It must be pointed out that, at present, Lake

Maggiore conditions are the best compared with that of the other deep southern alpine lakes (Garda, Como, Iseo and Lugano) which altogether constitute the main Italian lake district.
Besides the aspects directly related to the eutrophication processes, these studies permitted to obtain extremely valuable information on the lake physics, particularly on the heat accumulation in the hypolimnium (Ambrosetti & Sala, 2006). This is possibly related with the global heating and is affecting the mixing dynamic of the lake, with consequences on the distribution along the water column of oxygen and nutrients. Concomitant studies on the acid deposition affecting the southern part of the watershed, merged with the chemical loads transported from the different tributaries, pointed out the different origin of P and N. Results showed that P was mainly deriving from human activities, with a very low contribution from the watershed weathering, while the main source of N resulted to be the atmospheric deposition, followed from human activities (Rogora *et al.*, 2006). The interaction of atmospheric deposition with the watershed vegetation resulted in a N retention.
From the mid-'90 the research activities were enlarged to other type of pollution affecting the lake water, such as DDT, other persistent organic pollutants (POPs, e.g. PCBs) and trace metals. In fact, in 1993-95 high concentrations of pp'-DDT were found in some fish species by the Laboratorio Cantonale of Lugano. Accordingly, a fishing ban (both professional and recreational) for the main commercial species was proclaimed by the Italian Government because of this pollution. The ban lasted until 2000 after which it has been gradually released. Ironically enough the law limits set by the two States about the edibility of fishes are different (much more restrictive for Italy) and this produced different approaches on how to cope the environmental and social problem.
The Italian Government was therefore asked by the Italian Commission for Italian-Swiss Water protection to investigate on the origin of the DDT contamination in Lake Maggiore. Specific projects were thus undertaken on several ecosystem compartments such as water, mollusk, aquatic birds, atmospheric precipitations and overall lake and tributary sediments. At present the aim of a new research program, which is also included in a European Project, is the study of how climatic changes (temperature and humidity) may determine redistribution of toxic pollutants in the ecosystems and to identify and describe quantitatively the main processes and parameters controlling the mobilization of metals and POPs.
In spite of these negative aspects, the limnological conditions of Lake Maggiore on a whole significantly improved since the beginning of the studies, in the 70s. This is mainly true for eutrophication, whereas remain problems with the above mentionated POPs, whose concentration trends, however, are decreasing, and with the relatively high metal concentrations in lake sediments.
On the other hand other problems are facing the lake and new scientific activities are needed: these include the effects of climatic changes on biological and physical structure of the lake (Bertoni *et al.*, 2004).
The water temperature increase, already well documented, will likely widen the "trophogenic layer" and will increase the occurance of cyanobacteria blooms (Bertoni *et al.*, 2007). The effects of warming would be similar to those of eutrophication, with a cascading effects over the whole trophic chain (Manca *et al.*, 2007a; 2007b). A further aspect concerns the generally milder winter conditions compared with those experienced in past. This ameliorated meteorological conditions reduce the depth of spring water overturn making less frequent the full homogenisation of the water column, with the possibility of an oxygen depletion in the deepest water. Parallel variations on water chemistry with likely effects on the biology, should be expected because of the increased weathering and leaching of the watershed soils.

Most of the studies performed on Lake Maggiore were possible thank to the financial support of the CIPAIS, in addition to those of the National Research Council and from the European Union, thus making Lake Maggiore and its watershed the most documented and well known natural ecosystem in Italy including the socio-economic aspects. The very positive impact of the collaboration supported by the CIPAIS is even higher if we consider that Switzerland is not joining EU Treat, unlike all the other neighbouring Countries. Besides, the different level of correspondence of Environmental Swiss laws with those of the EU, although with the common attention to environmental problems, increase the value of the political and scientific agreement between Italy and Switzerland. The coordination role was and continues to be performed by CIPAIS, in a dynamic actions that are needed if we consider the emerging of new and differentiated environmental problems.

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