Università Commerciale Luigi Bocconi, April 2022

A cross-temporal analysis of environmental rehabilitation policies: The Lake Varese case.

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In commemoration of Franco Fornara, former President of the Novara Province.
During his mandate he played a decisive role in the implementation of liming procedure in favour of the rehabilitation of Lake Orta from 1989 until 1990.

Abstract

The appropriate management of hydric resources represents a critical environmental challenge of today's political agendas. Within this context, Lake Varese, located in Northern Italy, represents an emblematic and challenging case of water management. Starting in 1960s, the Lake has experienced issues of cultural eutrophication, resulting in a constant deterioration of the quality of its waters.

This thesis aims at providing a comprehensive review of the different rehabilitation policies that have been implemented in Lake Varese over the years. First, the network and normative context will be presented by illustrating the water quality requirements imposed at the national and European levels. A cross temporal analysis of the different rehabilitation attempts will follow.

Some preliminary results will be presented by comparing the implemented measures with the evolution of the quality indicators required by the Water Framework Directive of the European Union. This comparison will confirm the ongoing inability of Lake Varese to meet these quality standards.

Despite the unsatisfactory outcomes, this research will offer a qualitative model of positive externalities that could arise from the complete rehabilitation. Eventually, this will serve to provide an encouraging vision for the future of Lake Varese which could represent a successful case of environmental policy management.

Key words

lake management, environmental rehabilitation policies, cultural eutrophication, European Union Water Framework Directive.

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Introduction

General context

Water resources and their appropriate management are essential for human life. It is indeed a fundamental asset for the development of humankind and a crucial component of most economic activities and social relations[1]. In addition to this, water is also indispensable for the stability and the durability of most natural ecosystems and for climate regulation. Despite this relevance, because of unregulated urban and industrial development there is also widespread awareness that the future availability of water resources is limited and at risk, both in terms of quality and quantity, due to its unsustainable exploitation and pollution[2].

As for today, there exist different types of challenges concerning the management of the waters. Specifically, the most relevant issue regarding the quality of water is cultural eutrophication in fresh waters, which corresponds to the acceleration of the pollution and degradation of ecosystems caused by harmful human activities[3]. Most scientists agree that this phenomenon results from an increase in the population of cyanobacteria[4] in the waters of lakes and rivers. The principal effect of a substantial expansion of these bacteria is the proliferation of harmful green-blue algal blooms visible on the shores of lakes and rivers. Additionally, other consequences include the increase in mortality of the fish population or other problems related to the freshness of the waters for the populations leaving within reach.

It is important to note that the expansion of cyanobacteria that comes with cultural eutrophication scarcely ever happens in nature; instead, in most cases it is intensified by

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[1] European Commission (2010)

[2] Quadri (2016)

[3] Schindler (2008)

[4] Cyanobacteria are microscopic prokaryotic organisms with very simple cells that photosynthesise and contribute very positively to generating oxygen, recycling nutrients and sequestering atmospheric carbon and nitrogen into water. If in large number, they can easily be seen by the human eye as an agglomeration of blue-green algae.

man-made activities which accelerate the degradation of water quality[5]. The main explanation to the blooming of these bacteria is the increase in the intakes of phosphorus and nitrogen which are remarkably present in households' sewages, in animal excrements and in synthetic fertilizers. Despite an overall agreement on the causes and consequences of cultural eutrophication in fresh waters, there is lower consensus among the scientific community on what the most appropriate and sustainable solutions to this phenomenon should be [6].

A distinct example in Italy of cultural eutrophication can be found in the Lake Varese case, which has a long history of water quality deterioration due to an increase in the population of cyanobacteria and confirms the inability to find an effective solution to this environmental challenge.

Lake Varese Context

The number of lakes in Italy amounts to more than 2000. Among these, 389 are of freshwater (natural, enlarged natural and reservoirs)[7]. At national level, the most important lake district is in the subalpine area located in the North-Western part of the country, which includes some deep subalpine lakes (for instance, Lake Maggiore, Lake Orta, Lake Garda or Lake Como) together with small-medium insubrian lakes (see Figure 1). Lake Varese would fall in the second mentioned category.

Figure 1 Lake district of Lombardy (Source: Regione Lombardia)

[5] Chirico et al (2020)
[6] Schindler (2012)
[7] Premazzi (2003)

Lake Varese's origins date back to the melting of glacier waters of the Verbano area, around seventeen thousand years ago[8]. Despite this, its autonomous separation from the Comabbio, the Monate and the Biandronno lakes is more recent (during the second half of the 19th century and the first decades of the 20th century) and results from the gradual decrease in water levels[9]. The principal tributary is the Brabbia river, and its only envoy is the Bardello River which flows directly into the Lake Maggiore (see Figure 2).

Figure 2 Catchment area of Lake Varese (Source: Provincia di Varese)

Concerning its morphometric features, Lake Varese has a relatively wide surface area of 14.5 km^2 and a volume of 160 x 10^6 m^3. Its mean depth is 11 m, reaching the maximum profoundness at 26 m [10]. With such measures, Lake Varese is commonly classified as a lake with limited size (specially compared to other neighbouring lakes such as Lake Maggiore and Lake Garda, which have a surface of 212,5 km^2 and 370 km^2 respectively) and limited depth (compared to the maximum profoundness of 372 m of Lake Maggiore and 346 m of Lake Garda). Correspondingly, according to the Directive 2000/60/EC of the European Commission (the Water Framework Directive) Lake Varese is classified as "small, shallow lake on predominantly calcareous substrate"[11].

Lake Varese is placed in one of the most densely populated areas in Italy, reaching up to 700 inhabitants/km^2 [12]. It is in this context and location that many industries have flourished in the post Second World War period, mainly in the sector of leather, of

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[8] Wateronline (2016)
[9] Stadera (1998)
[10] CNR-IRSA (1984)
[11] European Community (2000)
[12] Premazzi (2003)

aeronautical and of footwear[13]. From these industries, many successful commercial and manufacturing activities of the region have derived (for instance: Ignis, Aermacchi, Augusta), confirming again that the area of Lake Varese has experienced a flourishing economic development making it an important source of profit for the entire region.

Besides the industrial activities, Lake Varese is considered as a centre of attraction for leisure activities and tourism by virtue of its picturesque landscapes, its cultural heritage[14] and its temperate climate[15]. Before the Covid-19 pandemic, the Province of Varese had reached its record numbers after a decade of growth, reaching a total of 2,242,100 tourists arrivals during the year 2019[16]. In this respect, the Chamber of Commerce of Varese together with other local entities have developed an online portal called "#VareseDoYouLake?" aimed at a further expansion of the tourism sector. Among other activities, the initiative promotes cycling tours, rowing ventures and hiking trails, located mainly in the proximity of Lake Varese.

All the above mentioned economic and touristic activities, added to the numbers related to the local population, confirm that Lake Varese is greatly interconnected with different types of human activities. Because of this, the condition and the quality of its waters can potentially directly or indirectly have an impact on a wide range of individuals.

Problematic

As already mentioned, global development and population growth represent a serious threat to freshwater ecosystems and their corresponding biodiversity in view of the fact that they lead to growth of nutrient inputs and to the magnification of problems

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[13] Wateronline (2016)

[14] A noteworthy example of the cultural heritage of Lake Varese can be found in the Isolino Virginia (i.e. the lake's small island). Isolino Virginia is an archaeological area containing the oldest prehistoric pile-dwelling site of the alpine region. Today, the site is one of the nineteen prehistoric pile-dwelling locations in the Alps that are classified as Unesco World Heritage Site since 2011.

[15] Bettinetti (2018)

[16] OsserVa (2021)

related to cultural eutrophication, particularly in lakes[17]. Indeed, an example can be found in the case of Lake Varese.

Starting from the 1960s, the province of Varese experienced in fact a major post-war urbanisation phenomenon. The industries around the Lake started to flourish, causing an increase in the overall economic production levels of the province[18]. Most of the developed sectors required large amounts of innovative chemical compounds to be disposed as liquid waste[19]. In addition to this, over the years, the surrounding population increased and changed their living attitudes significantly, mainly with the introduction of new modern domestic household appliances. Families were not only consuming more, but they also started to take advantage of new home appliances such as washing machines and dishwashers. As a result of these two developments, there was an explosion of hydric resources and of residuals from detergent products (with high phosphorus volumes) to be disposed[20].

These changes resulted into an unprecedented rise in the amount of waste released directly inside the waters of Lake Varese, consequently altering the chemical-physical composition of its waters. Precisely, this translated into an excessive phosphorus input from the catchment area, making Lake Varese one of the first cases of cultural eutrophication in Italy[21].

On top of this, the effects of climate change have adversely impacted Lake Varese in the more recent years and have exacerbated the already present symptoms of cultural eutrophication. Worldwide, climate change alters directly and indirectly the community

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[17] Jeppesen (2014)

[18] Among others, it is worth mentioning that in the 1960s one of the main companies polluting the Lake's waters with their direct discharges was "Ignis di Cassinetta" located in the Biandronno municipality. Founded in 1943 the company became over the years one of the main Italian producers of household appliances. However, the outstanding success of the company also translated into an increase of the production discharges that were in the majority of cases directly disposed in the waters of Lake Varese.

[19] Save Lake Varese (2021)

[20] Wateronline (2016)

[21] Armengol (2005)

structure and functioning of freshwaters ecosystems[22]. The main consequences of climate change in cases like Lake Varese include variations in the temperature of the water, in the rainfall patterns and the emphasising of extreme events (both rainy and dry periods). For instance, in the Po River Basin area (which is located relatively close to Lake Varese), an increase of 2°C in the average temperature of the waters has been perceived since 1960[23]. Overall, these effects produce an increment of nutritional element for the wildlife, including the cyanobacteria, amplifying the man-made cultural eutrophication phenomenon[24]. It follows that, in a context of global warming, to counteract eutrophication it is necessary to implement measures that are strong enough to maintain the stability of freshwaters.

Relevance of the topic

Altogether, because of the presence and development of toxic cyanobacteria, the use of freshwaters resources for recreational and drinking purposes has been severely compromised in Lake Varese. Above all, these detrimental conditions to which the Lake is subject to, have potentially a critical impact on the health of its citizens. In addition to this, they do not allow to take advantage of all the possible economic and touristic benefits that the Lake could otherwise offer.

The significance of the Lake Varese case, besides its purely scientific relevance, comes from the numerous efforts and policies carried out over the years which have made it a unique case of lake management in Italy[25]. These efforts are intertwined with the following legal frameworks:

- at the national level, with different legislative decrees related to the Water Framework Directive[26];

[22] Jeppesen (2010)
[23] Pedro-Monzonìs (2016)
[24] Osservatorio del Lago di Varese (2017)
[25] Premazzi et al (2003)
[26] Water Framework Directive as abbreviated to WFD

- at the European level, with various initiatives and directives of the European Parliament and of the Council of the European Union.

Both need to be taken into consideration in the interplay of all the different policies.

On top of this, the topic of climate change has consistently acquired more relevance and has positioned itself at the centre of many political agendas at the international, national but also at the local level. Under this context, Lake Varese represents a pertinent case. On one side, as already mentioned its freshwaters have been heavily influenced by the rise in worldwide temperatures. On the other side, the consequences of an appropriate rehabilitation of the Lake could potentially become an additional case of success and set the ground rules and good practices for future initiatives of ecosystems protection.

Scope of the research

As anticipated by this introduction and as it will be emphasized in more detail during this research, the ambition of the rehabilitation of Lake Varese requires further clarification in terms of what has been already achieved and what has gone wrong or has been interrupted in order to understand what the plausible perspectives for the future could be. This research aims at answering these questions by showing a higher level of transparency on the issue that will hopefully contribute to reaching the final objective of rehabilitation in a satisfactory time.

This research will begin by undertaking a 1) meticulous description of all the public and private actors that operate in the framework of the rehabilitation of Lake Varese and the significance of their roles in this peculiar public network. To further improve the accuracy of the context, 2) the main legal frameworks in which the different actors operate will be presented, to understand what the limitations are, but also the existing incentives that rule the situation. The main portion of this work will be dedicated to carrying out a 3) cross temporal analysis of the relevant past policies and interventions executed with the purpose of rehabilitating the freshwaters of Lake Varese starting from the early 1990s. Eventually, 4) these interventions will be compared with the evolution of the different water quality indicators in order to assess whether these interventions are reasonably correlated to an improvement in the hydric resources. At the end, this paper will hopefully contribute to give a useful outline of the policies related to the rehabilitation of Lake Varese, including their limitations and possible future perspectives.

1.0 Network of actors involved in the rehabilitation

In the specific case of the rehabilitation policies of Lake Varese, the list of actors involved during the different interventions is indeed diverse, with actors that range from public institutions to private companies and organizations from the civil society. These actors unavoidably differ in terms of size, resources and connections with the other actors, making some of them more central and influential in the overall public network than others.

The main actors involved in the rehabilitation of Lake Varese are those belonging to the "*Accordo Quadro di Sviluppo Territoriale Lago di Varese*" (AQST). The AQST is an agreement based on the territorial development framework specifically created and signed in 2019 for the safeguard of Lake Varese, making it *de facto* an institutionalised public network. The main objectives of the agreement relate to the rehabilitation of the lake and are essential to the establishment of the priorities of the network. The regional strategic objectives are:

- To "*Recover and safeguard the environmental characteristics of aquatic environments and water body buffer strips*";
- To "*Promote the increase of the usability of aquatic environments as well as the implementation of projects and good management practices aimed at restoring or maintaining ecosystem services of water bodies*";
- To "*Maintain good chemical status of waters*";
- And to "*Achieve good ecological status of waters*"[27].

In addition to the above-mentioned objectives, the AQST also aims at assuring the possibility of using the fresh waters for bathing purposes and the protection of the species and their natural habitat.

[27] AQST (2021)

The agreement established a Coordination Committee aimed at coordinating the actions performed. The Committee is chaired by the Environment and Climate Counsellor and was initially composed of the most influential members of the network (see Annex II*)*, in particular:

- Province of Varese;
- Municipalities of: Azzate, Bardello, Biandronno, Bodio Lomnago, Buguggiate, Cazzago Brabbia, Daverio, Galliate Lombardo, Gavirate, Inarzo and Varese;
- ARPA Lombardia, i.e. the Regional Environmental Protection Agency[28];
- ATS Insubria, i.e., the Health Protection Agency of the Insubria district[29];
- Varese District Office[30];
- ALFA, i.e., the operator of the integrated water system;

Following the first meetings of the Committee, the participation was enlarged for the first time to other relevant subjects in the matter, which matched the meaning and purpose of the AQST, namely:

- University of Insubria;
- CNR IRSA Verbania, i.e., the National Research Council[31] office based in Verbania, near Lake Maggiore;
- Lake Basin Authority of Lakes Maggiore, Comabbio, Monate and Varese[32];
- Other municipalities belonging to the agglomeration, i.e., Casciago, Casale Litta, Comerio, Barasso and Luvinate;
- Superintendence of Archaeology, Fine Arts and Landscape for the provinces of Como, Lecco, Monza and Brianza, Pavia, Sondrio and Varese;
- Lake Varese fishermen's cooperative[33];

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[28] *Agenzia Regionale per la Protezione dell'Ambiente*
[29] *Agenzia di Tutela della Salute*
[30] *Ufficio d'Ambito Territoriale Ottimale della Provincia di Varese*
[31] *Consiglio Nazionale delle Ricerche*
[32] *Autorità di Bacino Lacuale dei laghi Maggiore, Comabbio, Monate e Varese*
[33] *Cooperativa pescatori lago di Varese*

- Chamber of Commerce;
- Bardello River Water Users' Consortium[34];
- Representative of environmental associations.

The Coordination Committee of the AQST meets at least twice a year upon convocation by its President. These meetings are essential to define the priorities and contents of the AQST and to discuss other matters such as the integration of additional public and private members, the evaluation of new proposals or the monitoring of the implemented activities[35].

Ultimately, the institutionalization of this public network forces the continuous collaboration and interaction of the different involved entities which would have otherwise worked in a more isolated and non-coordinated way. Hence, the interactions created by the AQST play an essential role in making the different participants more accountable and in making the different rehabilitation policies more effective.

[34] *Consorzio utenti delle acque del fiume Bardello*
[35] Regione Lombardia (2019)

2.0 Legal framework

In order to assess the quality of the waters of Lake Varese, the first step to undertake should be to define which indicators are needed to establish a certain quality level. These criteria are found in the legal framework governing the water field in Italy, issued at two different levels: the European and the Italian level. As a matter of fact, the legal reference regarding the safeguarding of surface and ground water finds its primary reference in the Directive 2000/60/EC of the European Parliament and of the Council (i.e. the above mentioned Water Framework Directive[36], WFD), which came into force on October 23rd, 2000, and constitutes the action framework in the field of water for all the Member States of the European Union. Alongside the WFD, the Italian legislation also includes a series of legislative decrees on the protection of freshwaters: some of these decrees anticipated, in a sense, the principles and contents of the WFD, whereas others are substantial modifications of the existing national legislation issued to adapt to the new requirements arising from the WFD[37]. The main piece of the Italian legislation for water quality protection and monitoring can be found in the Legislative Decree of the April 3rd, 2006, n. 152 "Regulations on environmental matters"[38], which modifies and integrates the previous Italian legislation (from the Galli law 36/94 to the Legislative Decree of the 11th of May 1999 n. 152) with the European WFD. Following the approval of the Italian Legislative Decree 152/06, a series of implementing decrees in the field of water protection have also been issued[39], mainly:

- the Decree of June 16th, 2008, n. 131[40] on the categorization of water bodies;
- the Decree of April 14th, 2009, n. 56[41] on the monitoring criteria for water bodies;

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[36] Water Framework Directive abbreviated as WFD
[37] Premazzi (2003)
[38] Decreto Legislativo 3 aprile 2006 n.152 "Norme in materia ambientale"
[39] Bettinetti (2018)
[40] Decreto 16 giugno 2008, n. 152 "Criteri tecnici per la caratterizzazione dei corpi idrici – Attuazione articolo 75, Dlgs 152/2006"
[41] Decreto 14 aprile 2009, n.56 "Criteri tecnici per il monitoraggio dei corpi idrici – Articolo 75 Dlgs 152/2006"

- the Environmental Decree of November 8th, 2010, n. 260[42] on the technical criteria for the classification of the status of surface water bodies.

Besides these two main levels of law (the European and the Italian), there exist other normative frameworks that highly influence the standards of quality of freshwaters, for instance the guidelines from the World Health Organization (WHO), from the Organisation for Economic Co-operation and Development (OECD) or from the Italian Superior Institute of Health[43] (ISS). The aim of this chapter will be, in particular:

1) to identify and describe these legal frameworks;
2) to recognize the criteria used to assess freshwater's quality, allowing for a clearer quality classification of Lake Varese's water resources over the years.

2.1 General principles

The above-mentioned legislation has basic common principles. Broadly speaking, the environmental policy of the European Union pursues the objectives of: *"preserving, protecting and improving the quality of the environment; protecting human health; prudent and rational utilisation of natural resources […]"*[44]. Indeed, the sustainable management of freshwater resources would fall inside these objectives. More precisely, the main objective of the European and Italian legal frameworks envisages the achievement of minimum standards of environmental quality for water bodies which are established in the frameworks themselves. These environmental standards require that:

- the environmental quality objective of 'good' status is maintained or achieved for surface and groundwater bodies;
- the environmental quality objective of 'high' is maintained, where it is already achieved.

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[42] D.M. Ambiente 8 novembre 2010, n.260 "Criteri tecnici per la classificazione dello stato dei corpi idrici superficiali – Modifica norme tecniche Dlgs 152/2006"
[43] Istituto Superiore di Sanità
[44] European Union (2016)

According to the legal frame, these quality standards must be achieved by December 22nd, 2015, with the possibility of delaying the deadline up to the end of 2021 or 2027 at the latest, conditioned to the fact that quality deterioration does not occur and that reasonable explanations are provided[45]. In addition to this main objective, the legislative basis also introduces the obligation to prevent the deterioration of water resources and to protect and improve the conditions of aquatic ecosystems (hence, also embracing the protection of soil ecosystems that are directly dependent on the respective aquatic ecosystems to meet their water requirements). Moreover, the Directive and the national decrees also promote a sustainable and durable use of water resources founded on the long-term protection of the available resources and on the safeguarding of the existing animal and plant communities.

2.2 Tools and mechanisms established in the legal frameworks

As in the case of the European Directive 2000/60/EC, also the Italian Decree 152/2006 identifies a series of operational tools that are essential to implement the environmental objectives on the protection of hydric resources. These tools can be classified in three main macro categories:

a. The categorization of surface water bodies,
b. The monitoring methods of surface water bodies,
c. The technical and quantitative criteria for the classification of the quality status of surface water bodies.

a. *The categorization of surface water bodies*

One of the main tools of the WFD, which sets the basis for quality monitoring, relates to the classification of the different river and lake bodies constituting every river basin district in each member state[46]. According to the WFD, the categorization is conducted with two different methods, System A and System B, which relate to

[45] ARPA Lombardia – Dipartimento di Varese (2013)
[46] ARPA Lombardia – Dipartimento di Varese (2013)

geographical and morphometric characteristics: the lakes are classified based on their latitude, altitude, geological substrate, depth of the basins and their surface (see Annex I). Taking into consideration the fact that lacustrine ecosystems have specific characteristics that are highly influenced by their geographical location, the identification of homogeneous groups of lakes is highly important to subsequently provide monitoring systems and solutions which are specifically tailored for each lake type. The competence of this classification lies on the hands of each Member State which must establish a competent national authority charged with the creation of a 'river basin management plan'. This categorization approach is also in line with the Italian legislation, as the Legislative Decree 152/2006 requires that the protection and management of waters is carried out at a 'river basin district' scale. According to these classifications, Lake Varese would fall in the category of as "small, shallow lake on predominantly calcareous substrate"[47].

b. *The monitoring methods of surface water bodies*

Monitoring is a fundamental component for the execution of the WFD. In particular, the WFD defines three types of water monitoring:

1. Operational monitoring: to supervise the water bodies which are at risk of not achieving the "good status" and to assess changes resulting from the applied measures;
2. Surveillance monitoring: to monitor long term trends and assessment of the overall surface water status;
3. Investigative monitoring: to scrutinize the reasons of unknown exceedances and investigate in cases of accidental pollution.[48]

In Italy, the Regions are charged with water monitoring activities and the Central Government is empowered with supervision, coordination, and regulation tasks to ensure

[47] Lombardi (2021)
[48] Nixdorf B., Rektins A., Mischke U. (2008)

that the minimum requirements of the national legislation are fulfilled[49]. For Lake Varese, the type of monitoring carried out corresponds to the operational monitoring since 2009 and is performed by ARPA Lombardia. This monitoring is carried out in five different stations that are listed in Table 1:

Table 1: Monitoring sites of Lake Varese

Municipality	***Station name***
Varese	Lido di Schiranna
Cazzago Brabbia	Lago di Piazza
Azzate	Campeggio
Biandronno	Pontile Isolino Virginia
Gavirate	Lido di Gavirate

c. Technical and quantitative criteria for the classification of the quality status of surface water bodies.

As abovementioned, the normative framework stipulates that the environmental quality status of surface water bodies shall reach the status of "good" as an ultimate target, for those bodies that have not reached it yet. The environmental status is classified as "good" in the event that both the ecological profile and the chemical profile are categorized at least as "good".

According to the WFD, the ecological status relates to the quality of the structure and functioning of the different aquatic ecosystems. As indicated by Figure 3, the ecological status can be classified in five different classes: high (in blue), good (in green), moderate (in yellow), poor (in orange) and bad (in red). Moreover, the classification of the ecological status applies the "one-out, all-out" principle, meaning that the assigned status corresponds to the lower class among the different considered elements[50]. The most important elements of the ecological profile are biological quality elements. Alongside

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[49] Premazzi (2003)
[50] Ternjej (2017)

these, biological elements are supported by: general chemical and physicochemical quality elements, specific chemical polluting elements and hydro morphological quality elements[51].

The assessment of the chemical status of surface water bodies is determined by the presence of chemical substances that are specifically listed as priority substances and dangerous substances[52]. In this case, the classification is binary: "good" (in blue) or "fail" (in red). Water bodies can obtain the positive classification only if all the quality standards are satisfied, otherwise the classification will highlight the failure to comply with a good chemical status[53].

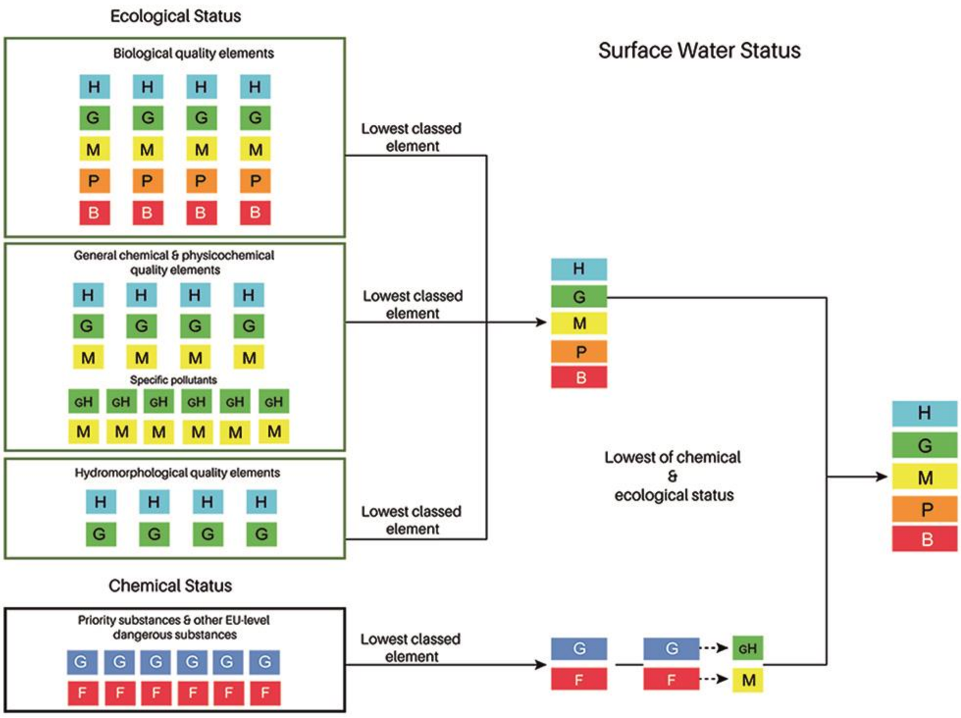

Figure 3 Classification scheme of surface water status (Source: Ternjej, 2017)

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[51] Nixdorf (2008)
[52] The list of chemical priority substances that are classified as dangerous by the European Commission if discharged on water bodies include: alachlor, anthracene, atrazine, benzene, brominated diphenylethers, cadmium and its compounds, chloroalkanes, chlorfenvinphos, chlorpyrifos, dichloroethane, dichloromethane, DEHP, diuron, endosulfan, fluoranthene, hexachlorobenzene, hexachlorobutadiene, hexachlorocyclohexane, isoproturon, lead and its compounds, mercury and its compounds, naphthalene, nickel and its compounds, nonylphenols, octylphenols, pentachlorobenzane, pentachlorophenol, polyaromatic hydrocarbons, simazine, tributylin compounds, trichlorobenzanes, trichloromenthane and trigluralin.
[53] ARPA (2013)

The main challenges of Lake Varese relate to the failure of obtaining a "good" classification for the ecological status. As Table 2 indicates, in terms of its chemical status, Lake Varese has achieved the "good" classification for almost the whole last decade, meaning that all the standards related to the chemical status were in compliance with the established limits. The only exception (i.e., failure classification) was established for the triennium of 2009-2011 explained by an excess of mercury compared to the maximum concentration allowed[54]. Due to the highly eutrophic environment of Lake Varese, the successful results on the chemical side are not shared by the ecological status that has been classified only as "moderate" since the adoption of the present classification mechanism.

Table 2 Environmental classification of Lake Varese from 2009 to 2019 (Source: AQST 2021)

ECOLOGICAL STATUS			
2009-2011	2012-2014	2014-2016	2017-2019
MODERATE	MODERATE	MODERATE	MODERATE

CHEMICAL STATUS			
2009-2011	2012-2014	2014-2016	2017-2019
FAIL	GOOD	GOOD	GOOD

Since the challenges that Lake Varese faces to obtain the "good" environmental classification relate to deficiencies in terms of ecological status (rather than chemical), it is essential to further analyse the different indicators that constitute this status and the respective thresholds that determine the assignment of a certain water quality status.

The first indicators that need to be analysed for the establishment of ecological status are biological quality elements for lakes, which specifically include the composition and abundance of phytoplankton, of macrophytes and microphytobenthos, of invertebrate fauna and of fish fauna. Concretely, the selection of a class of biological quality is

54 AQST (2019)

established by the value of the Ecological Quality Ratio (EQR)[55], i.e., the ratio between the observed value of the selected biological parameter and the reference value of the same parameter in ideal (close to natural) conditions with no or little anthropic disturbances. In view of the fact that the main issue that affects the Lake is eutrophication, the principal indicator selected for biological quality is the composition, abundance and biomass of phytoplankton. In Lombardy, a new method of classification was selected for the measurement of the presence of phytoplankton: The Italian Phytoplankton Assessment Method (IPAM)[56],[57]. The IPAM index considers two quantitative measures, i.e., concentration of "chlorophyll a" and of bio volume and one qualitative measure, i.e., PTlot. The calculation of the index derives from the computation of average index of composition of the three measurements[58]. Moreover, in the case of operational monitoring (i.e., the one assigned for Lake Varese), the IPAM for Lake Varese is checked on a yearly basis; however, the final classification index is established by computing the mean of the three annual IPAM values. Tables 3, 4 and 5 display respectively the quantitative limits of chlorophyll a, biovolume and PTlot that are used to establish the different classes of biological quality elements in accordance with the current legislation[59].

[55] "*Rapporto di Qualità Ecologica (RQE)*"
[56] "*Metodo italiano di valutazione del fitoplancton (IPAM)*"
[57] From: COMMISSION DECISION (EU) 2018/229 establishing, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, the values of the Member State monitoring system classifications because of the intercalibration exercise and repealing Commission Decision 2013/480/EU
[58] ARPA (2020)
[59] Ministero dell'ambiente e della tutela del territorio e del mare (2010)

Table 3: EQR class limits for the average annual concentration of chlorophyll a (Source: AQST, 2019)

Reference value (μg/l)	*High (H)/Good (G)*		*Good(G)/Moderate(M)*		*Moderate(M)/Poor(P)*		*Poor (P)/Bad (B)*	
	Value (μg/l)	EQR	Value (μg/l)	EQR	Value (μg/l)	EQR	Value (μg/l)	EQR
3.0	4.0	0.75	7.30	0.41	13.50	0.23	24.60	0.13

Table 4: EQR class limits for average annual biovolume (Source: AQST, 2019)

Reference value (mm^3/l)	*High (H)/Good (G)*		*Good(G)/Moderate(M)*		*Moderate(M)/Poor(P)*		*Poor (P)/Bad (B)*	
	Value (mm^3/l)	EQR	Value (mm^3/l)	EQR	Value (mm^3/l)	EQR	Value (mm^3/l)	EQR
0.60	0.95	0.63	2.30	0.26	5.95	0.10	14.95	0.04

Table 5: EQR class limits for the Plot index (Source: AQST, 2019)

Reference value (mm^3/l)	*High (H)/Good (G)*		*Good(G)/Moderate(M)*		*Moderate(M)/Poor(P)*		*Poor (P)/Bad (B)*	
	Value (mm^3/l)	EQR	Value (mm^3/l)	EQR	Value (mm^3/l)	EQR	Value (mm^3/l)	EQR
3.55	3.37	0.95	3.01	0.85	2.66	0.75	2.31	0.65

In the event that the biological quality elements reach at least the "moderate" level, the subsequent step corresponds to the evaluation of the general chemical and physicochemical quality elements that support the biological quality elements. In this case, the elements used as indicators are total phosphorus, transparency and dissolved oxygen. These elements are altogether synthesized in the LTLeco index (i.e., trophic level of lakes for ecological status). The LTLeco index is obtained as follows: first, in accordance with the established regulations[60], each individual element is assigned a score based on the corresponding concentration; second, the scores are summed up to obtain the LTLeco; finally, the obtained LTLeco index is matched to the respective class determining the ecological status. Moreover, each chemical and physicochemical quality element must be monitored every two months and even in this case, the final status classification is provided on a triennial basis. Tables 6, 7 and 8 illustrate the thresholds for each chemical and physicochemical quality element, whereas Table 9 indicates the final classification classes.

[60] Ministero dell'ambiente e della tutela del territorio e del mare (2010)

Table 6: class limits for total phosphorus (µg/l) (Source: AQST, 2019)

	Level 1	*Level 2*	*Level 3*
Score	5	4	3
Phosphorus (µg P/l) (*)	≤ 12(**)	≤ 20	>20

(*) Volume-weighted average or layer height-weighted average over the full circulation period at the end of the winter season
(**) Reference value <10 µg /l

Table 7: class limits for dissolved oxygen (saturation %) (Source: AQST, 2019)

	Level 1	*Level 2*	*Level 3*
Score	5	4	3
Transparency (saturation %) (*)	>80% (**)	>40% <80%	≤ 40 %

(*) Volume-weighted or height-weighted average of layers at the end of the stratification period
(**) Reference value >90%

Table 8: class limits for levels of transparency (meters) (Source: AQST, 2019)

	Level 1	*Level 2*	*Level 3*
Score	5	4	3
Transparency (meters) (*)	≥ 6(**)	≥ 3	<3

(*) Average of values found during the monitoring year
(**) Reference value >10 m

Table 9: Class limits for LTLeco

Status classification	*Class limits*	*Class limits in case of reduced transparency due to natural causes*
High (H)	15	10
Good (G)	12-14	8-9
Moderate (M)	<12	<8

The following step would be the assessment of specific chemical polluting elements and of hydro morphological quality elements. However, the evaluation of Lake Varese does not go any further than the examination of chemical and physicochemical quality elements, given that as Table 2 previously showed, the Lake fails to obtain at least the "good" status needed for this category.

3.0 Rehabilitation policies: cross temporal analysis

"The case study of Lake Varese is highlighted because it represents a case of lake management which is unique in Italy, in which lake restoration technology is applied to accelerate the return to earlier (more natural) conditions, after being impacted by eutrophication."

Premazzi (2003)

Both external and internal remedial actions have been executed to attempt the rehabilitation of water quality of Lake Varese and to counter the severe environmental consequences of heavy industrialization and urbanization in the post bellum period and those of climate change in more recent years. Considering that after continuously receiving direct discharge of untreated sewage into its waters the Lake was classified as hypertrophic[61], the objective of these interventions was indeed to try to re-establish the quality parameters back to its natural status, or at least as close as possible. Nevertheless, the analysis of the implemented policies will demonstrate how most of these actions allowed for an improvement in terms of quality however in most cases this improvement has been only temporary and has failed to successfully complete the expected environmental rehabilitation of Lake Varese.

3.1 Urban sewerage diversion system (1994)

The first rehabilitation policy applied to Lake Varese dates to the late 1980s and corresponds to the construction of a circumlacual sewerage collector system impacting all the municipalities surrounding the Lake, coupled with the creation of a centralized wastewater treatment plant. A sewerage system, or wastewater collection system, is defined as "*a network of pipes, pumping stations, and appurtenances that convey sewage from its points of origin to a point of treatment and disposal*"[62]. The origin of the sewage includes

[61] Zaccara (2007)
[62] Ambulkar (2021)

superficial waters (coming for instance from rainfalls or washing activities) and waste waters generally coming from human activities[63].

In the specific case of Lake Varese, the actions related to the sewerage system find their origins in the "Voluntary Consortium for the Protection and Water Restoration"[64] which was established in 1965 to address the management problem of the Lake. Eventually, the construction activities started in the late 1980s and resulted in the early 1990s into the creation of: a sewerage network, a circumlacual diversion system and a centralized waste treatment plant[65]. The action plan involved sixteen neighbouring municipalities: Azzate, Barasso, Bardello, Biandronno, Bodio Lomnago, Buguggiate, Casale Litta, Casciago Brabbia, Comerio, Daverio, Galliate Lombardo, Gavirate, Inarzo, Luvinate and Varese[66]. The applied sewerage system is composed by two collectors of Lake Varese and the Collector of Lake Comabbio (Figure 4). The first collector, also known as northern shore collector, is around 13,7 km long and receives the waters coming from the municipalities of Barasso, Buguggiate, Casciago, Comerio, Gavirate, Luvinate and Varese. Instead, the southern collector is around 13,2 km long and collects water from the sewers of the municipalities of Azzate, Daverio, Galliate Lombardo, Bodio Lomnago, Inarzo, Cazzago Brabbia, Biandronno, Bardello and Casale Litta. The northern branch operates normally following

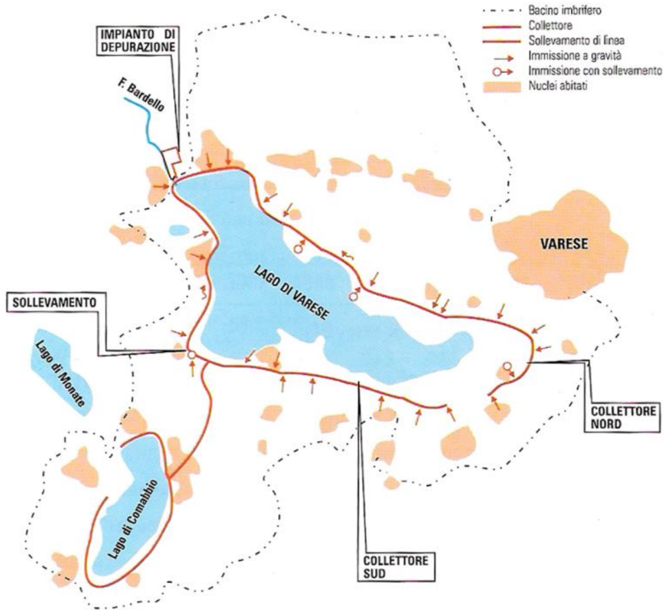

Figure 4 Circumlacual Sewerage Collection System

[63] AQST (2019)
[64] Consorzio Volontario di Tutela e Risanamento delle Acque
[65] Premazzi (2005)
[66] Provincia di Varese (2005)

its gravity-based functioning, whereas the southern branch has a section that does not allow its gravity-based functioning; for this reason, it was necessary to build a mechanical lifting of water. Both branches of the collector convey the urban wastewater in the sewerage treatment plant located in Gavirate, where they get properly treated before they are released in the Bardello river[67].

In the years following its implementation, the positive impacts of the sewerage system were considerable. The main results observed related to the progressive reduction of the phosphorus load entering the Lake. In particular, it has been estimated that before 1986 the load of phosphorus in the Lake amounted to 50 t P/year[68]. After eight years from the introduction of the treatment plant, i.e., in 1994, the amount of load turned out to be reduced to 16 t P/year, meaning that the installation of the new sewerage system allowed for a reduction of 68% of the phosphorus load[69].

As for today, the two systems of circumlacual sewerage collectors find themselves in a rather critical condition. The system has gradually suffered from technical deterioration and ageing of the pipelines and of the structures. For instance, some of the sections of the collector, mainly those located in the southern shore collector, suffer from hydraulic insufficiency causing operational pressure and/or the reversal of the flow against the required direction. These complications frequently result in the inability of the pipelines to contain the flows of waters (including non-treated), which consequently get discharged directly inside the Lake. The degradation of the sewerage diversion system was not necessarily accompanied by the appropriate maintenance and/or renovation measures. In addition to this, the infrastructure also started to become unable to contain the direct inputs towards the Lake because of the growth of the human pressure derived from the population increase[70]. In order to provide an insight regarding this growth, it is noteworthy to mention that the population of the Province of Varese went from 581.528

[67] AQST (2019)
[68] Tons of phosphorus per year
[69] Zaccara (2007)
[70] Bettinetti (2018)

residents in 1961, to 787.679 in 1982, and finally to 885.085 in 2019[71]. As a matter of fact, both the significant rise of the adjacent population and the increase of the impermeable surfaces were not taken into account in the design of the sewerage system, resulting in its obsolescence of the system (the system is now considered inadequate and outdated). Consequently, with the setting of the AQST, one of the main focuses for the rehabilitation of the Lake in the most recent years has been the implementation of diverse actions that tackle the issue of improving the sewerage network (which will be later presented in this chapter).

3.2 Hypolimnetic withdrawal (2000)

It is not uncommon that during the summer months of stratification, eutrophic lakes are affected by a decrease of the dissolved oxygen concentration (known as anoxia). This happens because of the sedimentation and accumulation of organic substances in the bottom of the lake. Anytime this phenomenon is particularly substantial, at the end of the summer period the deeper waters suffer from severe oxygen deficiency[72]. This condition of anoxia leads to an increase of dissolved phosphorus which worsens the already existing eutrophic condition of the lake. Indeed, Lake Varese, as a eutrophic lake, is also impacted by such phenomenon.

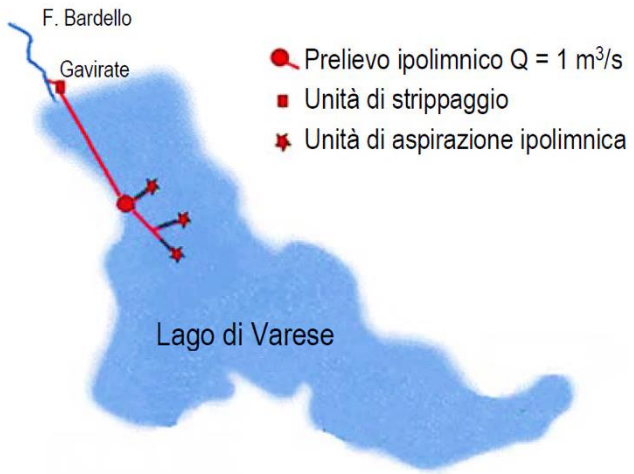

Figure 5 Hypolimnetic withdrawal (source: Provincia di Varese (2005)

In 1998, after more than a decade from construction of the new urban diversion sewerage system, the positive effects on the quality of the waters of Lake Varese were no longer that evident. In fact, prediction models calculated that it would take between 25

[71] ISTAT (2019)

[72] Provincia di Varese (2005)

and 30 years to reach the equilibria level of phosphorus concentration (i.e., equal to 40-45μg/L[73])[74]. Hence, with the beginning of the new millennium, experts on the issue predicted that the execution of new internal interventions were necessary to accelerate the rehabilitation of the Lake. The feasibility and appropriateness of different in-lake interventions were then evaluated, until the final selection of two actions. The first internal action that was promoted for Lake Varese was the hypolimnetic water withdrawal[75]. Such intervention was beneficial to the Lake in many ways. First, the main objective of the hypolimnetic water withdrawal is to extract the phosphorus loads that originated from the lake's sediments, reducing its total concentration in the deeper waters. In addition to this, the application of this technology also contributes to removing the anoxic waters, to reduce the water turnover time and to stabilize the stratification of the Lake[76].

The trial system of hypolimnetic water withdrawal was introduced by the Province of Varese from the year 2000 until 2003, on average 130 days per year during the months from May to November (which coincide with the months in which the Lake is the most stratified). The main structure was set in correspondence with the deepest point of the Gavirate basin at 20-25m depth (Figure 5). The installation comprised at the deepest point of the Lake by 7km of HDPE[77] plastic tubing with a diameter of 800mm and suspended at 1.5 m above the Lake bottom by twelve perforated pipes with a diameter of 400 mm. These pipes functional to siphoning the bottom waters without generating any water turbulences and without interfering in the interaction between water and sediments[78]. Once the water is properly siphoned, it is discharged directly on the Bardello river.

In the first 306 operational days (i.e., the first two years), the withdrawal installation removed a total volume of 22 million m^3 of hypolimnetic water. In other words, in only ten

[73] NB: the equilibria level considered in this prediction model is even more lenient compared to the level required by the WFD which is equal to 20 μg/L.
[74] Premazzi (2003)
[75] Zaccara (2007)
[76] Provincia di Varese (2005)
[77] HDPE plastic is made with high-density polyethylene and has a high strength-to-density ratio which is ideal for the fabrication of corrosion-resistant pipelines.
[78] Premazzi (2005)

months the waters at the deepest level were replaced around three times, which is rather impressive taking into consideration that normally the water replacement process in Lake Varese naturally takes around one year and nine months on average[79]. Eventually, altogether during the total working period (520 days), it has been estimated that the system managed to withdraw a total volume of approximately 40 million m^3 of hypolimnetic water. Table 10 summarizes the physical description of the internal rehabilitation action of the hypolimnetic water withdrawal applied in summer months from 2000 to 2003.

Table 10 Hypolimnetic water withdrawal, operational data (Source: Provincia di Varese 2005)

	2000	**2001**	**2002**	**2003**	**Tot**
Summer working days	150	133	156	79	520
Discharge, m^3/s	0.4 -1	0.7 -1	0.4 -1	1	
Total volume of withdrawn water (10^6 m^3)	10.32	11.96	11.12	6.83	40.23
Renewed volume of bottom water (%)	130	150	140	85	
TP, t $year^{-1}$	4.176	5.029	4.297	3.045	16.547
TN, t $year^{-1}$	27.472	42.110	28.181	18.423	116.186
NH_4-N, t $year^{-1}$	15.674	39.513	24.664	10.679	90.530

In addition to the removal of hypolimnetic waters, the installation also contributed to extract a series of nutrients which are key to the eutrophication levels of the Lake. In fact, the operation allowed exporting average annual loads of about 4.1 tonnes of phosphorus $year^{-1}$, 29 tonnes of nitrogen $year^{-1}$ and 22.6 tonnes of ammonia $year^{-1}$. It is important to note that the reduction of phosphorus (i.e., the main nutrient contribution to the eutrophication of the Lake), was approximately 30% of the total quantity of phosphorus present in the winter overturn[80]. Figure 6 summarizes the yearly evolution of the quantities of total phosphorus, total nitrogen and total ammonia that were removed during all the operational years. The negative trending line for all the nutrient types is

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[79] Premazzi (2005)
[80] Zaccara (2007)

explained by the fact that the last operational year is characterised by a lower number of operational days (see Table 10) compared for instance to 2001 which is the most significant year in terms of outcomes and number of working days.

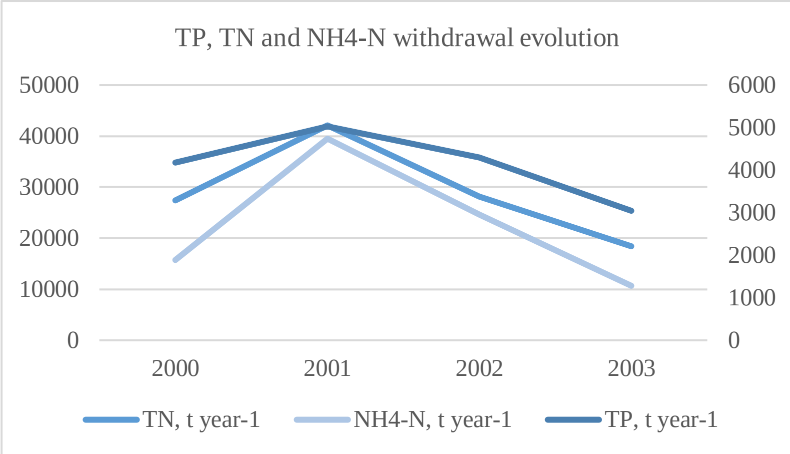

Figure 6 TP, TN NH4-N evolution (Source: Provincia di Varese, 2005)

Despite the positive contributions that the hypolimnetic withdrawal system had on reducing anoxic waters and nutrients that enhanced the Lake's eutrophication, the system was stopped in 2003. The decision was adopted in view of the fact that the cost-benefit ratio was not considered to be advantageous anymore. First, in four years after starting the implementation of this system, the phosphorous effects were not considered to be relevant enough compared to the costs of the plant[81]. Second, the hypolimnetic water withdrawal system constituted a potential risk factor for the Bardello river and the Maggiore Lake in which the extracted polluting substances got discharged[82]. Finally, the installation also produced unpleasant odours in correspondence to the discharging point in which the drained waters were discharged in the Bardello river because the dimensions of the stripping station[83] were inadequate and underestimated for the treated loads of water[84].

[81] Zaccara (2007); Crosa (2013); Osservatorio del lago di Varese (2017)
[82] Provincia di Varese (2018)
[83] The stripping station was composed by a covered water collection tank, an oxygenation and deodorisation system, an electrical panel containment building and a water discharge pipe into the Bardello river. Its objective should have been to reduce the unpleasant smells released by the hypolimnetic waters.
[84] Regione Lombardia (2019)

Despite this, the installation was never fully dismantled, while waiting for a future evaluation regarding its use.

3.3 *Oxygenation of the waters at the bottom of the Lake*

Together with the hypolimnetic water withdrawal, another internal in-lake rehabilitation action was implemented in the same period: the oxygenation of the waters of the Lake. The purpose of this second action was to counter the anoxic conditions of Lake Varese during the summer periods of stratification. Ideally, this would have led to optimum level of oxygen concentration of the waters, allowing for the sustenance of the local fish fauna and for a reduction of the releases phosphorus from the sediments, without risking the destratification of the water column[85]. The oxygenation operation was carried out in the shallow basins of Cassinetta (in the Biandronno municipality), of Bodio Lomnago and of Schiranna (in the Varese municipality). The intervention managed to introduce a total of 2138 tonnes of oxygen in the Lake during the 515 days in which the system was operating. The total amounts of oxygen that were injected in the Lake each year are summarized in Table 11.

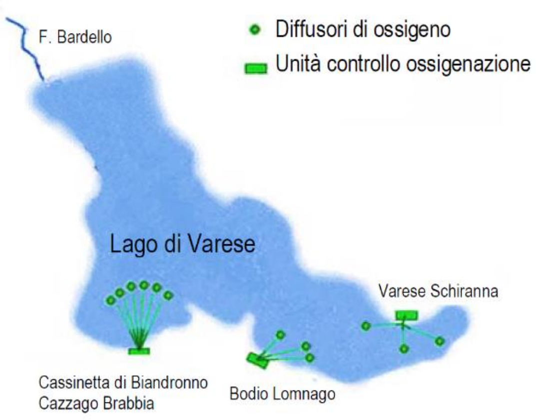

Figure 7 Hypolimnetic oxygenation unit

Table 11 Oxigenation unit, operating data (Source: Provincia di Varese 2005)

	2000	**2001**	**2002**	**2003**	**Tot**
Summer working days	100	165	120	130	515
Cazzago Brabbia (t O_2)	181	143	126	113	563
Bodio Lomnago (t O_2)	206	176	198	169	749
Varese Schiranna (t O_2)	111	181	190	150	632

[85] Cooke (1993)

Stripping station (t O_2)	36	51	66	40	193
Total injected oxygen (t O_2)	535	551	580	472	2138

Ultimately, the overall evaluation for the oxygenation treatment was negative due to its inefficient cost-benefits ratio, as for the case of the hypolimnetic withdrawal[86]. As a matter of fact, the insertion of pure oxygen in Lake Varese's waters did not result in a significant diminution of the volume of anoxic waters neither did it produce a shortening of the period of anoxia[87]. This failure is explained by the fact that the depth of the diffusers that was selected was not sufficient to reach an effective level of oxygen solubility. Nevertheless, a lower depth for the diffusers would have been detrimental to the thermal stratification of the Lake. Therefore, only after four years of its creation, the installation was completely dismantled, without any future perspective to reinstall it.

3.4 Phoslock trial

In the years following the trial execution of the above-mentioned internal actions (and their subsequent dismantlement), other alternative strategies were considered in order to confront the rehabilitation of Lake Varese. The most discussed option was the application of modified clay compounds during the summer stratification times. Theoretically, the insertion of these clays can lock up the phosphorus released from the sediments during a period of anoxia[88]. In the case of Lake Varese, during the years 2009 and 2010, the Varese Province decided to support and finance the testing of the Phoslock technology, i.e., an active substance that is created from the mixture of lanthanum ions and clay. This technology works thanks

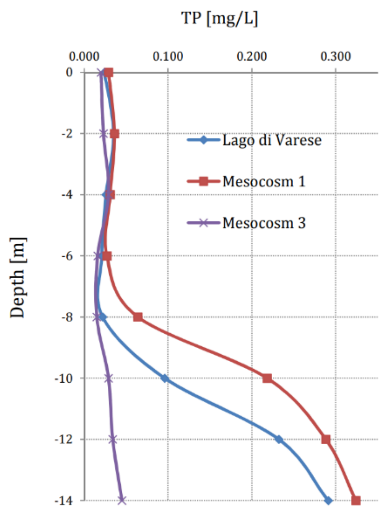

Figure 8 Depth profile of average total phosphorus (TP) concentrations in the mesocosms (Source: Finsterle (2014))

[86] AQST (2019)
[87] Zaccara (2007)
[88] Douglas (1999)

to the introduction of lanthanum that allows to capture the phosphorus present in the Lake through an ionic bonding and it also mitigates its release from the sediments. The project was proposed by the society Phoslock Europe GmbH in participation with the Limologisches Institut Dr. Nowak. The project started on February 24th, 2009, and the trial started on March 6th of that same year. It was agreed that it would last for a total of twelve years, at an overall cost of 72.000,00 euros[89].

The introduction of Phoslock had clear outcomes on the phosphorus concentrations. During the entire experimentation, within the treated "mesocosms" (isolated areas), the total phosphorus concentration remained constant at about 0.025 mg/L. On the other hand, the control mesocosm and the Lake levels of phosphorus increased to more than 0.1 mg/L accordingly to changes in the anoxic conditions of the Lake explained by the releases of phosphorus from the sediments (see Figure 8)[90].

However, since the beginning, the trial raised two main concerns. The first related to the effectiveness of Phoslock since prior to the experimentations in Lake Varese it had only been applied to smaller basins. To face this, the trial was carried out by installing three polyethylene cylinders (of which two were treated and the third was used as a control) from the surface of the Lake to the sediments, with the purpose of creating isolated environments (technically referred to as mesocosm)[91]. The second concern derived from the chemical compound of Phoslock, mainly the large presence of Lanthanum, a toxic metal. Nevertheless, because of strong gusts of wind during the month of July, the infrastructures were heavily damaged, and the trial had to be interrupted until November. Once the damage was fixed a similar adverse meteorological event permanently lacerated the mesocosm system, causing the total and final termination of the trial. Consequently, the effects of the Phoslock trial should be considered as limited for Lake Varese since the trial was never entirely completed.

89 Wateronline (2016)
90 Finsterle (2014)
91 ARPA Lombardia (2011)

3.5 *Rehabilitation activities within the current AQST approach*

To accomplish the goal of the AQST "Safeguarding and restoring Lake Varese"[92], the strategy applied to the Action Program is based on the subdivision of the Program itself in six Macro-actions. These groups cover a large variety of issues, from the management of the sewerage system to the awareness raising of the population on the topic. Each Macro-action is in turn divided in multiple Actions which are respectively composed by specific activities (see complete list in Annex III). For each Action the Program assigns a Coordinating Entity which must handle, orchestrate, and monitor the execution of the said Action by the different implementing parties in order achieve the expected results[93]. In addition, each activity features the corresponding required financial resources, the origin of the fund, the location of implementation and the chrono programme with specific time limits.

For further guidance, Figure 9 summarizes all the actions performed in the context of the AQST agreement alongside each corresponding entity. In particular the Figure depicts the responsible entity at the top of the hierarchy, the coordinating entity for each action and the implementing entity for each specific activity.

The first macro-action (Macro-action A) relates to operations aimed at improving the sewerage system, i.e., the collector and depuration systems linked to Lake Varese's basin. The primary objective of this group of actions is to reduce the amount of external load that gets discharges directly into the Lake's waters, which as previously mentioned is one of the main sources of pollution of the basin. The Coordinating entity of Macro-action A is the Varese District Office[94]. The first section of activities relates to studies, topographical surveys and in-depth analyses on the present status of the sewerage system. These analyses also include the evaluation of the system's shortcomings and performing failures, for instance the recurring overflows during intense rain precipitations. Additionally, the

[92] AQST Salvaguardia e risanamento del lago di Varese
[93] AQST (2021)
[94] i.e. *Ufficio d'Ambito di Varese*

second portion of activities concerns the internal measures performed to improve the detected deficiencies of the sewerage system. Notably, the activity A.2.2. (Design and implementation of the actions identified in Action 1 and 2) is the one which receives the higher level of financial support in the whole program with 4.401.800 euros funded by Lombardy Region and 278.102 euros funded by ALFA, for a total of 4.679.901,37 euros, stating it as a distinct priority of the Program. From the initial analysis of 80% of the sewerage system performed by ALFA, it has been decided that in September 2021 ALFA will start the construction of a lamination tank in correspondence to the southern shore collector. This would create a large basin dug to allow the containment of the water that, in case of large precipitations, the present system is not able to keep. In addition to this it has also been concluded that in 2022-2023 a series of operations will be implemented to complete the sewerage drainage from the municipality of Barasso towards the Lake's waters[95].

[95] AQST (2021)

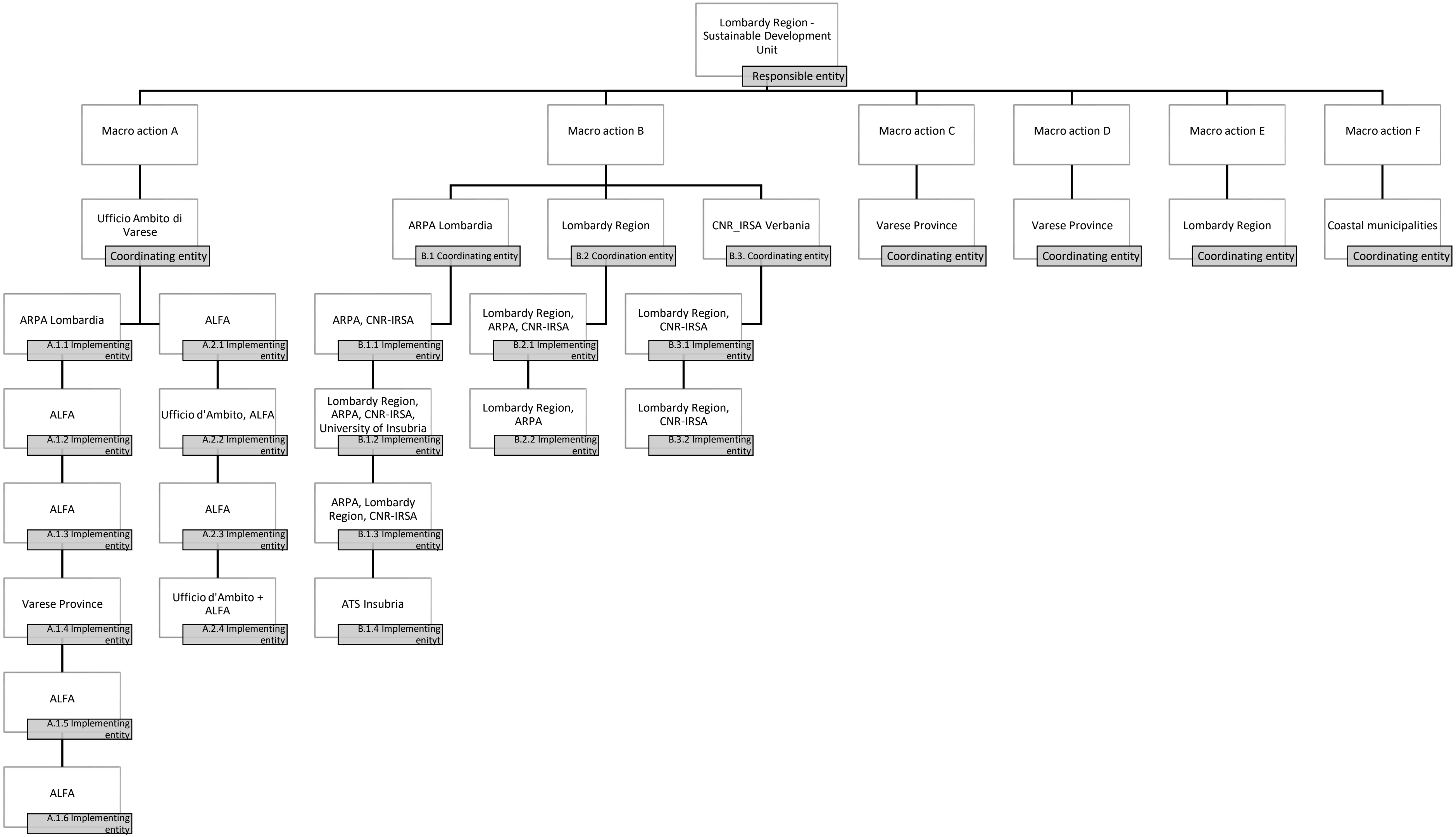

Figure 9 AQST Macro-actions coupled with the respective entities in charge

Macro-action B is centred on the monitoring procedures of the state of Lake Varese in terms of quality of freshwaters, including those of the Bardello River. The main goal of the included action in this case is to assess how Lake Varese is performing with respect to the hydric quality indicators determined by Lombardy Region (at the federal level), by the Italian government (at the state level) and by the European Union (at the European level). The monitoring process is essential in order to establish which dimensions have a bigger impact on the pollution and eutrophication of the Lake. Only in this way, the Program can measure the impact of the different activities and prioritize the actions set by the AQST to restore the quality of the waters. This Macro-action is specifically supervised by ARPA Lombardy as the Coordination entity. The first section of the macro-action includes a series of actions, such as the installation of limnologic buoys, that aim at investigating the evolution of the biological, physical, and chemical characteristics of the waters, including the development of bacteria populations such as cyanobacteria. In addition to this, the second section includes the development of models to assess the evolution of the phosphorus levels and of the total amounts of external and internal loads. A third section includes a series of models aimed at predicting scenarios on how the quality of the waters and the various analysed indicators will evolve in the forthcoming years. Finally, the last section evaluates what are the most suited and effective technologies among the proposed ones that should be implemented in order to restore the quality indicators to the desired level.

Macro-action C concerns the planning and execution of the works needed to reactivate the hypolimnetic withdrawal system. The objectives of this action coincide with those that were originally planned for the hypolimnetic withdrawal system implemented in the year 2000 (i.e., to reduce the volume of internal loads of phosphorus and other nutrients from the Lake in order to reduce consequently the eutrophic levels of the Lake), with the particularity that this time an evaluation of different solutions would be included to avoid the issues that caused the interruption of the system on its first experimentation. The analysis performed under this Macro-action include the evaluation of the state of firmness and conservation of the plant and all the attached technical components (pipes, pumps, equipment, stripping tank, etc.) and the assessment of the required adaptation measures or additions for its effective functioning. Moreover, this Macro-action also contains the actions that have been performed to effectively reactivate the hypolimnetic withdrawal system, that has in fact started to work again from the year 2020 (first year in which the reactivation has been tested). Ever since, it has been estimated that the system managed to remove 2 tonnes of phosphorus and 18 tonnes of nitrogen in 2020, and during its second year of reactivation an additional 1,5 tonnes of phosphorus and 12 tonnes of nitrogen up to April 2021[96].

Macro-action D is focused on the safeguard of the biodiversity of Lake Varese. The actions relate to improvements in the management of two natural areas present in the Lake that have a special condition in terms of preservation and protection. Specifically, the focus is set on the feasibility of introducing a system of public electrical navigation in the Lake.

Macro-action E addresses all the actions related to the communication and to raising awareness about the activities and outcomes of the AQST to the population and to those that are employed in the various activities. The last includes, for instance, the diffusion of content in social platforms or the planning of training and information thematic workshops in the province.

Last but not least, Macro-action F includes actions to develop and enhance the already existing pedestrian and cycling path surrounding Lake Varese.

For ease of reference, Table 12 summarizes all the implemented policies in the context of the rehabilitation of Lake Varese. The table includes the financial resources spent for each intervention, which for the case of the macro-actions of the AQST are equivalent to the estimates calculated at the beginning of each year of activity[97].

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[96] AQST (2021)
[97] AQST (2019, 2020, 2021)

Table 12 Rehabilitation policies of Lake Varese from 1986

Rehabilitation policy	*START DATE*	*END DATE*	*RESPONSIBLE SUBJECTS*	*FINANCIAL RESOURCES (In euros)*	*MAIN ACTIONS*
Urban sewerage diversion system	Between 1986 and 1988	Still in function	Voluntary Consortium for the Protection and Water Restoration	N/A	Construction of a new sewerage network, a circumlacual diversion system and a centralized waste treatment plant.
Hypolimnetic withdrawal coupled with Water oxygenation	2000	2003	Varese Province	550.390.955,88 (approximately 8.593.910.954 Italian Lire)	Extract phosphorus loads from the Lake's sediments + Voluntary introduction of oxygen in the Lake's waters.
Phoslock trial	2009	2010	Phoslock Europe GmbH	72.000,00	Release of lanthanum ions and clay that captures the phosphorus in the Lake's sediments.
AQST macro-action A	2019	ongoing	Ufficio Ambito di Varese	850.000,00 (2019) 4.520.000,00 (2020) 9.740.601,37 (2021)	Improvements in the sewerage diversion system.
AQST macro-action B	2019	ongoing	ARPA Lombardia, Lombardy Region, CNR-IRSA Verbania	373.000,00 (2019) 373.000,00 (2020) 498.200,00 (2021)	Monitoring of the water status of Lake Varese.
AQST macro-action C	2019	ongoing	Varese Province	1.736.000,00 (2019) 2.603.000,00 (2020) 3.084.166,20 (2021)	Re-activation of the hypolimnetic withdrawal plant.
AQST macro-action D	2019	ongoing	Varese Province	70.000,00 (2019) 316.000,00 (2020) 321.000,00 (2021)	Preservation of protected areas of Lake Varese.
AQST macro-action E	2019	ongoing	Lombardy Region	20.000,00 (2019) 37.500,00 (2020) 49.500,00 (2021)	Communication and promotion of the AQST activities and citizens awareness.
AQST macro-action F	2020	ongoing	Coastal Municipalities	50.000,00 (2020) 50.000,00 (2021)	Development activities and territorial enhancement of the shores and of the bike path.

4.0 Analysis of the past rehabilitation policies and considerations about future developments

Ecosystem rehabilitation policies are primarily aimed at restoring the ecosystems themselves so that the conditions are as close as possible to their initial natural environment. This objective is applicable to the analysed interventions implemented in the case of Lake Varese to overturn the detrimental effects that cultural eutrophication and its natural conformation have had over the years. In this sense, the commonly used measures for assessing the impact of those policies relate mainly to the biological, physical, and chemical indicators. Although focusing on the environmental returns would indeed be correct, rehabilitation policies are valuable also in other spheres of society such as public health, tourism, real estate or education. For this reason, the policies should derive from a multidisciplinary network with a high degree of knowledge sharing in different disciplines[98]. Indeed, the approach that started with the creation of the AQST network is a correct step towards this direction. The aim of this chapter will be to analyse the consequences of the performed policies on Lake Varese.

1. In the first instance, the environmental impact will be evaluated by correlating the implementation of the policies with the evolution of the water quality indicators over time.
2. Following this, a qualitative model of additional positive externalities will be presented. This will demonstrate how the complete rehabilitation of Lake Varese could potentially have multiple benefits ranging from social to economic ones that go beyond the nevertheless important environmental impact. Figure 10 provides an initial overview of these benefits which will be discussed in more detail at the end of the chapter.

[98] Hagen et al. (2013)

Rehabilitation completion of Lake Varese	**Environmental benefits** Compliance with water quality standars
	Health benefits Eradication of health risks
	Tourism Benefits Possibility of exploiting the lake for bathing puposes
	Economic benefits Increase in value of the adjecent real estate
	Social benefits Higher population awarness on environmental themes

Figure 10 Possible positive externalities resulting from the rehabilitation of Lake Varese

4.1 Water quality evolution over time

The first step needed to assess the evolution of the quality of the waters of Lake Varese is the analysis of the indicators required by the legal framework. As Table 2 previously indicated, Lake Varese fails to achieve the "good" ecological status and is classified as "moderate" because of the poor outcome in terms of the general chemical and physicochemical quality elements, i.e., transparency, dissolved oxygen, and total phosphorus. Using the available data collected by ARPA from 2011 to 2020 it becomes clear that these indicators are not only far from reaching the desired levels but also that in most of the cases their trends move in the opposite direction.

In relation to the concentration of total phosphorus, the required value to reach the following quality level corresponds to 20 μg/l, i.e., the average amount of phosphorus in Lake Varese should be lower than this value. As Figure 11 illustrates, the amounts of total phosphorus have been for the last decade always above the requested level, reaching a peak in 2019 with a total of 114 μg/l of phosphorus. Moreover, the trend line (dotted in the graph) shows how total phosphorus has been following a growth trend since 2011 that increases the distance from the desired target quantity of 20 μg/l[99]. Indeed, these levels of phosphorus to the circulation are excessively high and are distinctive of a highly eutrophicated environment which contribute negatively to the classification of the ecological quality status[100].

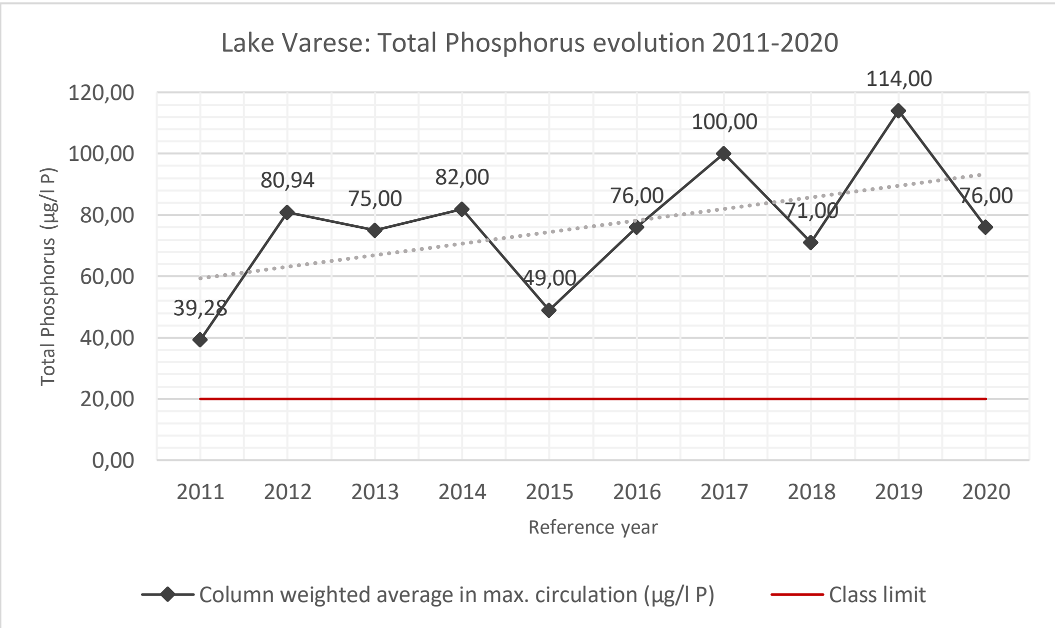

Figure 11 Total Phosphorus evolution (Source: ARPA Lombardia)

[99] It is important to note that the levels phosphorus for the years 2011 and 2015 are peculiarly anomalous compared with the actual condition of Lake Varese. These results are caused by problems during the laboratory analysis and for this reason they are often not considered by ARPA Lombardia (i.e. the responsible entity for the monitoring of the Lake). This consideration should also apply for the forthcoming analysis of Figure 14.

[100] ARPA Lombardia (2020)

With regard to the levels of dissolved oxygen, its saturation percentage should be greater than 40% to reach the following quality class. Just as for the case of phosphorus, the evolution of this indicator for Lake Varese is not encouraging. As Figure 12 shows, since 2011 the percentage of dissolved oxygen has never exceeded 6,30% and has reached levels close to or even equal to 0%, indicating a high overall deficiency of oxygen in the Lake. Also for this indicator, the trend line follows the opposite direction with respect to the desired concentration, showing how the levels of oxygen have been decreasing over the last decade instead of increasing.

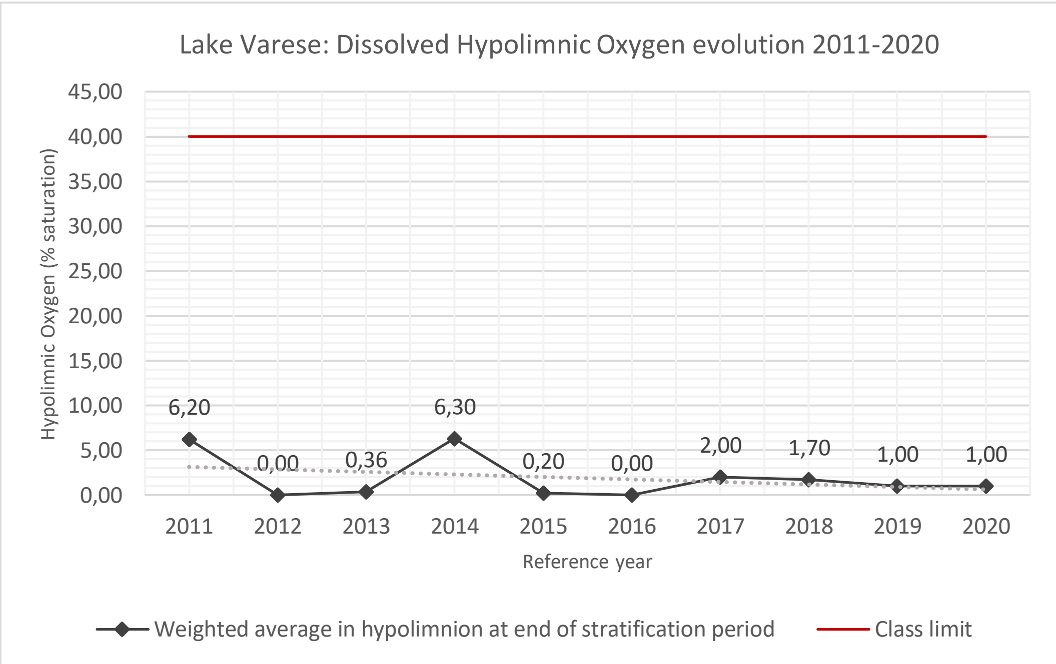

Figure 12 Dissolved Hypolimnic Oxygen evolution (Source: ARPA Lombardia)

For Lake Varese transparency is the only exception in terms of quality. The limit of the lowest level of quality corresponds to 3 meters. As Figure 13 illustrates, with the only exception of the year 2013, the average values found during the monitored years are always above this limit. Transparency has also been following an increasing trend since 2011, suggesting that it is not a particularly problematic quality indicator for Lake Varese.

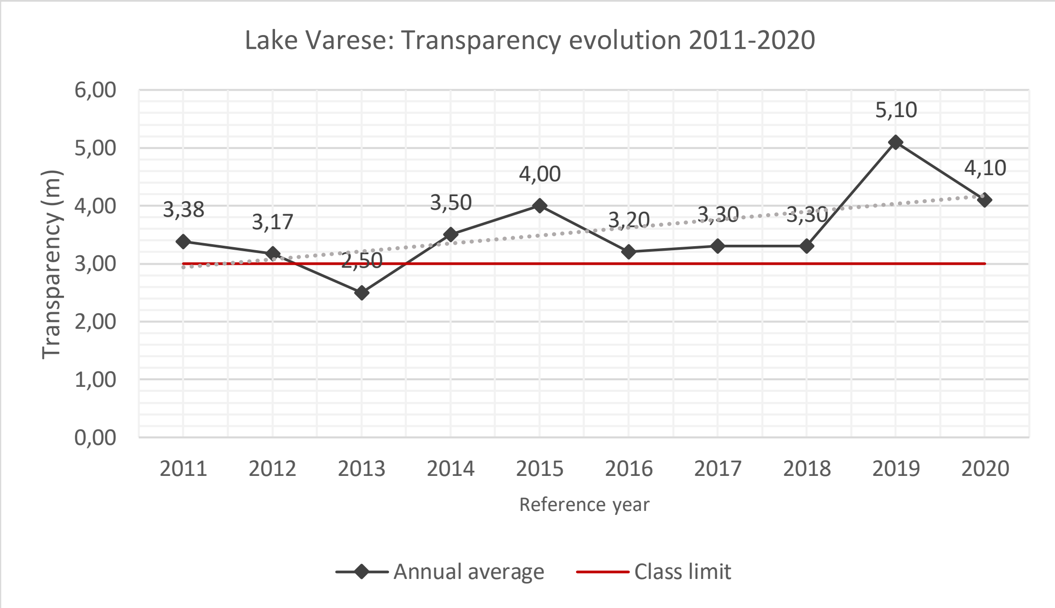

Figure 13 Transparency evolution (Source: ARPA Lombardia)

The oxygen and phosphorus levels from 2011 to 2020 confirm the severity of the issue of eutrophication of Lake Varese and the urgency of implementing policies aimed at reverting the natural conditions of the Lake.

However, despite the negative trends in the last decade, if a larger time frame is taken into consideration, the evolution in the quality of the water is more encouraging. In particular, Figure 14 illustrates the evolution of total phosphorus concentration since 1973 (i.e. when cultural eutrophication started to be a severe problematic) together with the different public policies that have been implemented ever since.

First and formost, by analysing Figure 14 it becomes evident that the biggest decrease in terms of phosphorus has been experienced after the interventions on the sewerage system. In fact, in the 15 years from 1985 (which corresponds to the highest peak of total phosphorus concentration) to 2000, the levels of phosphorus present in the Lake waters decreased of roughly 76,34%, representing the biggest decrease that Lake Varese has ever experienced. However, after 12 years from the construction of the sewerage system, the positive decrease of phosphorus concentrations is no longer observable[101]. This

[101] Zaccara (2007)

steady-state condition in the last two decades is alarming in the view of the fact that, as Figure 14 also shows, the main deadline of 2015 (and the first possibility of postponement in 2021) originating from the WFD has already passed and the Lake is still failing to obtain the required levels of phosphorus.

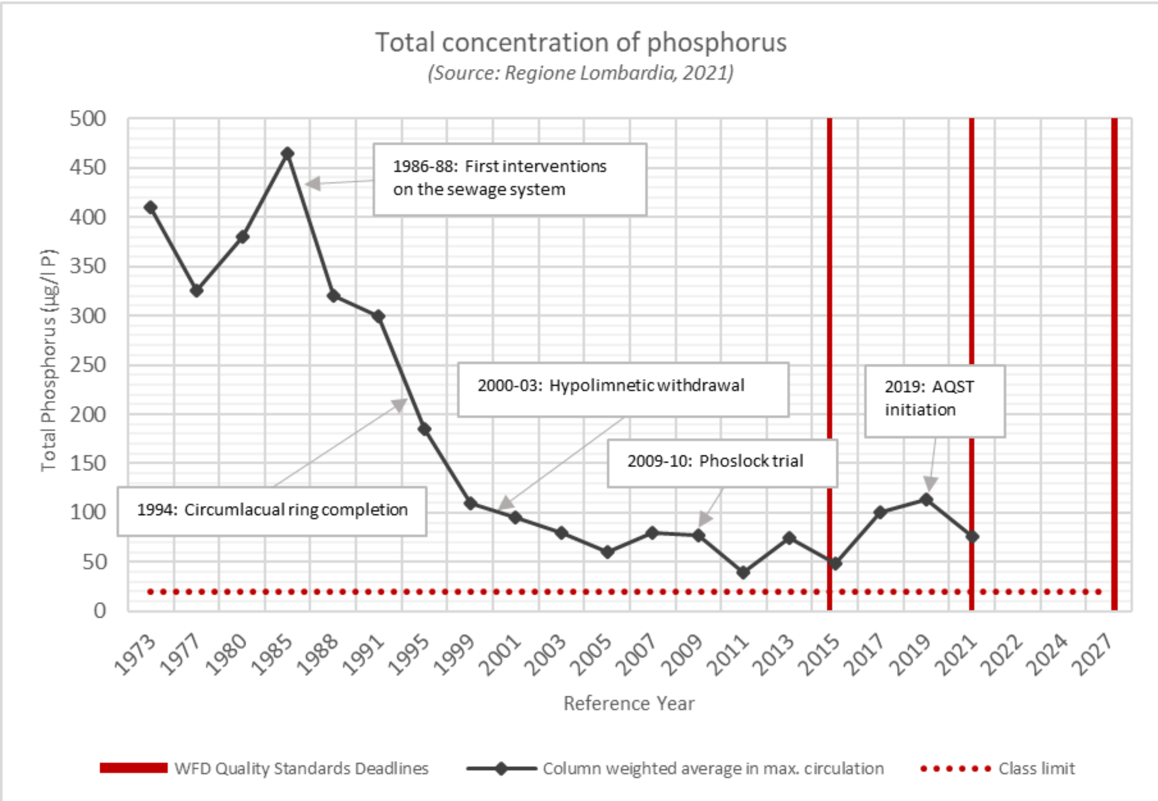

Figure 14 Total Phosphorus Concentration (Source: Regione Lombardia, 2021)

Although no causal relationship can be concluded, the initial positive results experienced with the interventions on the sewerage system are not comparable with the results of the other rehabilitation policies. This indicates a discrepancy in terms of outcomes between external (i.e. the interventions on the sewerage system) and internal (i.e. the hypolimentic withdrawal coupled with oxyegentation or the phoslock trial) rehabilitation actions. This difference could be explained by two reasons, the first one being the nature of the policies themselves. In this sense, internal rehabilitation policies were never expected to give the same results as external ones, since internal measures are considered to be interventions that contribute to the rehabilitation rather than interventions that solve the issue of eutrophication by themselves[102]. Subsequently, this would confirm and highlight the importance in controlling the quantity and quality of substances that get discharged in the Lake waters to obtain more impactful results from the implemented policies. The second possible explaination of these insufficient results could be the fact that neither the hypolimentic withdrawal nor the phoslock trial were fully completed since both had to be interrupted for the different reasons (as previously explained).

In addition, always assuming that no causal relationship can be established, other reasonable explainations can be given to certain variations of total phosphorus concentrations. For instance, the levels of phosphorus experienced a change in 2020, decresing significantly. In this case specifically, one must take into consideration the impact that the Covid-19 pandemic has had on the reduction of industrial and productive activities which were on hold for almost three months.

Moreover, there exist other two explanatory factors that should not be disregarded for understanding the difficulties in archieving a "good" ecological classification. These are climate change and population pressure. In general, population growth[103] (and the consequent increase of demands deriving from it) triggers an increase in agricultural land use, in urbanisation and in industrialization. These developments, in conjunction with the aggravation of climate change, have severe impacts on the quality of the Lake's waters, mainly: complications in the discharge dynamics, changes in the nutrient/substances surplus and modifications in current dynamics among others.[104] As a matter of fact, these water alterations resulting from population growth and climate change hinder the positive impacts of the rehabilitation policies for Lake Varese, partially explaining the steady state of phosphorus and the inability to reach the target levels required by the WFD.

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102 Premazzi (2003)

103 Which as previously mentioned, for the provice of Varese reprecents a percentage increase of 52,2%: from 581.528 residents in 1961 to 885.085 residents in 2019.

104 Verdonschot (2012)

Eventually, if these possible explainations and concerns are properly taken into account when designing new policies, there is a space of opportunity and improvement for the outcomes that the present and future policies could have on the Lake, within the AQST upcoming initiatives.

4.2 Potential positive externalities

Certainly, the urgency for the complete rehabilitation of Lake Varese originates, mostly, from the need to comply with the environmental quality standards required by the legal frame. The standards and the relative indicators are set in a way to prioritize the biological, chemical, and physical status of the Lake. Having said this, rehabilitation policies can potentially generate other positive externalities.

The first positive externality that could arise from the rehabilitation policies of Lake Varese relates to health. In fact, having a healthy lake can potentially contribute to the human health of the affected population in different ways. For instance, the Lake would not represent anymore a health risk in case the human body would come in contact with its water by bathing or by carrying out sporting activities. In addition to this, eventually, the rehabilitation would represent a favourable opportunity for the hydric resources since they could be utilized for water consumption and for the human consumption of the Lake fish. The case study of the rehabilitation of the Laurentian Great Lakes located in the United States and Canada confirms the importance of health externalities[105]. In this concrete example, the results from a population survey indicated how among many other reasons for restoring and conserving the lakes (for instance: promoting economic revitalization of the region, protecting native species, educating future generations, or supporting the recreational use), the population attributed the higher importance score to the promotion of human health. The Great Lake case demonstrates that having a healthy lake and protecting the human health of its close inhabitants is a major concern for the related population. Indeed, this should be taken into consideration also for Lake Varese as

[105] Tyner et al (2020)

its rehabilitation could positively improve the population perception in terms of human health.

The quality of the hydric resources of Lake Varese is also strictly related to the previously mentioned possibility of using the Lake for bathing purposes. As for today, the possibility of bathing is classified by the Italian Health Ministry as "temporarily banned for pollution reasons" for all the shores of the Lake[106]. Such a prohibition is determined by the same indicators used in the WFD. The eventuality of meeting the required levels of decontamination represents a significant opportunity in terms of tourism related activities for Lake Varese. In this sense, the tourism could flourish even more by allowing and expanding different leisure activities such as swimming, camping, fishing, etc. In addition to this, the already existing activities such as electrical in-lake navigation, rowing or biking can also only benefit from allowing the possibility of exploiting the Lake for bathing purposes since it would be a value added to an already pleasant experience. An expansion of tourism would also mean an economic opportunity for the Varese Province as it would allow for the creation of new job opportunities, new forms of investments and an increase in capital spending in relation to the third sector.

Furthermore, with the completion of the rehabilitation of Lake Varese, a potential externality could also be perceived in the real estate realm. In fact, the value of the properties surrounding the Lake could be affected positively. This phenomenon would result from the buyers' willingness to pay more for properties that are encompassed by a greener environment, by a better quality of water and by improved environmental landscapes. Moreover, homebuyers would also be attracted by the decrease of unpleasant odours and by the potential reduction of disturbing mosquitoes. This potential externality has been confirmed for instance by the restoration of water pollution in the Guangzhou region in Southern China[107]. In practice, the rehabilitation of the lakes and rivers of the region resulted in an increase in apartments prices of 4.61% because the homebuyers

[106] Ministero della Salute (2021)
[107] Chen (2017)

highly appreciated the consequences of the mentioned policies. On top of this, the study shows how after the completion of the rehabilitation policies, homebuyers were also willing to pay an extra 0.9% to improve the quality of the waters even further.

Finally, another positive externality that should be considered concerns the educational aspect of the rehabilitation of Lake Varese. The completion of such a challenging public work could ensure a higher environmental consciousness for the current population and for future generations. In this regard, the communication and dissemination activities of the AQST would play an essential role by contributing at raising awareness on issues of sustainable development and on the protection of natural habitats and biodiversity. By underlying the importance of environmental policies and by providing practical knowledge that could be applied in other similar settings, the successful rehabilitation of Lake Varese has all the potential to set a virtuous example of good practices locally but also outside the Italian borders, in particular at the EU level.

Altogether, these final considerations offer an encouraging perspective for the future developments of Lake Varese. In fact, in the event that the present AQST rehabilitation policies are successfully completed, the "good" ecological classification would be likely obtained within the limits of postponement imposed by the WFD. Ultimately, as Figure 15 shows, these two accomplishments would give rise to multiple externalities that could benefit the surroundings of the Lake in a way that goes beyond the more evident environmental indicators and compliance issues. Indeed, these externalities must be properly taken into account when performing a costs-benefits analysis and should be viewed as strong incentives for the complete rehabilitation of Lake Varese.

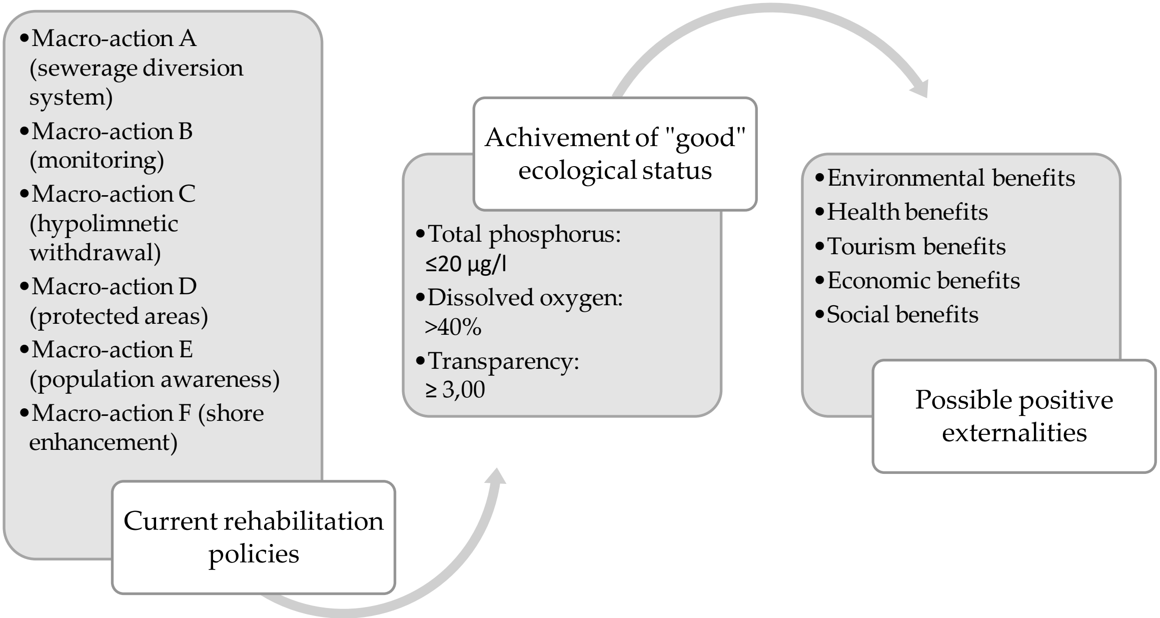

Figure 15 Future perspectives for Lake Varese

Conclusions

Ensuring the availability and access to clean water is constantly becoming a recurring challenge from the perspective of public health and ecological safeguard. Precisely, with the development of environmental challenges such as cultural eutrophication, the issues related to the protection and sustainable management of hydric resources are also continuously gaining importance in the realm of public policies. Indeed, the rehabilitation attempts of Lake Varese represent a unique case of hydric resources management in Europe in terms of complexity, definition and execution of the problematic. However, while there have been multiple efforts to counter the adverse effects of cultural eutrophication in Lake Varese, the existing literature commonly fails to provide a comprehensive picture of all the policies that have been implemented ever since the eutrophication issue began. In order to improve the decision-making process of the adequate measures to implement, this literature lacune must be addressed. This research intended to fill this gap not only by offering a clear and transparent description of all the policies executed over the years, but also by presenting the context in which these policies need to operate in terms of legislative obligations and of network dynamics.

With the intent of accomplishing the rehabilitation of the Lake and of complying with the environmental quality limitations imposed by the Water Framework Directive 2000/60/EC of the European Union and by national regulations (mainly D.lgs. n. 152/06), many interventions have indeed been performed in Lake Varese. Starting with the construction of the circumlacual sewerage system in the late 1980s, the rehabilitation process continued with two incomplete trials of hypolimnetic water withdrawal coupled with water oxygenation from 2000 to 2003 and of Phoslock application from 2009 to 2010. As for today, the main performed policies are carried out in the context of the AQST agreement which brings together public, private and third sector actors in different actions that among others include monitoring of the quality indicators, reinstalling of the hypolimnetic withdrawal, renovating the sewerage system, sensitize the local population, etc. Nonetheless, despite the different efforts Lake Varese continues to show unsatisfactory results in terms of ecological quality. Concretely, the Lake fails to obtain the required concentrations of total phosphorus and dissolved oxygen, i.e. a distinct consequence of cultural eutrophication combined with adverse climate conditions.

Some key takeaways can be confirmed from the cross-temporal analysis of the different rehabilitation policies. First, the evolution analysis of the different quality indicators confirms that, among the different performed activities, the reduction of external nutrient load from the construction of the sewerage system was indeed the intervention that allowed the greater improvement of the water quality. Nevertheless, this should not diminish the impact that internal remedial actions have, as they are also essential in assisting the whole rehabilitation process. In addition, the evolution of the different parameters also suggests the importance during the policy design process of calculating the impacts that external pressures such as climate change and population growth can have. Finally, the research also launched a new perspective by introducing a cluster of positive externalities that could result from the rehabilitation of Lake Varese that go beyond the ecological benefits, including economic, social, health and tourism advantages.

Ultimately, this study provided a comprehensive description of the rehabilitation policies performed in Lake Varese. Eventually, the next step in terms of research would be to carry out an evaluation of the different policies in order to confirm or dismiss the correlations found between the performed policies and the quality indicators and to perhaps establish a causal relationship between the two. Nevertheless, this additional research is at the moment time restrained since the results of this type of environmental policies are only perceivable in the long term and take years - possibly decades - to show significant results.

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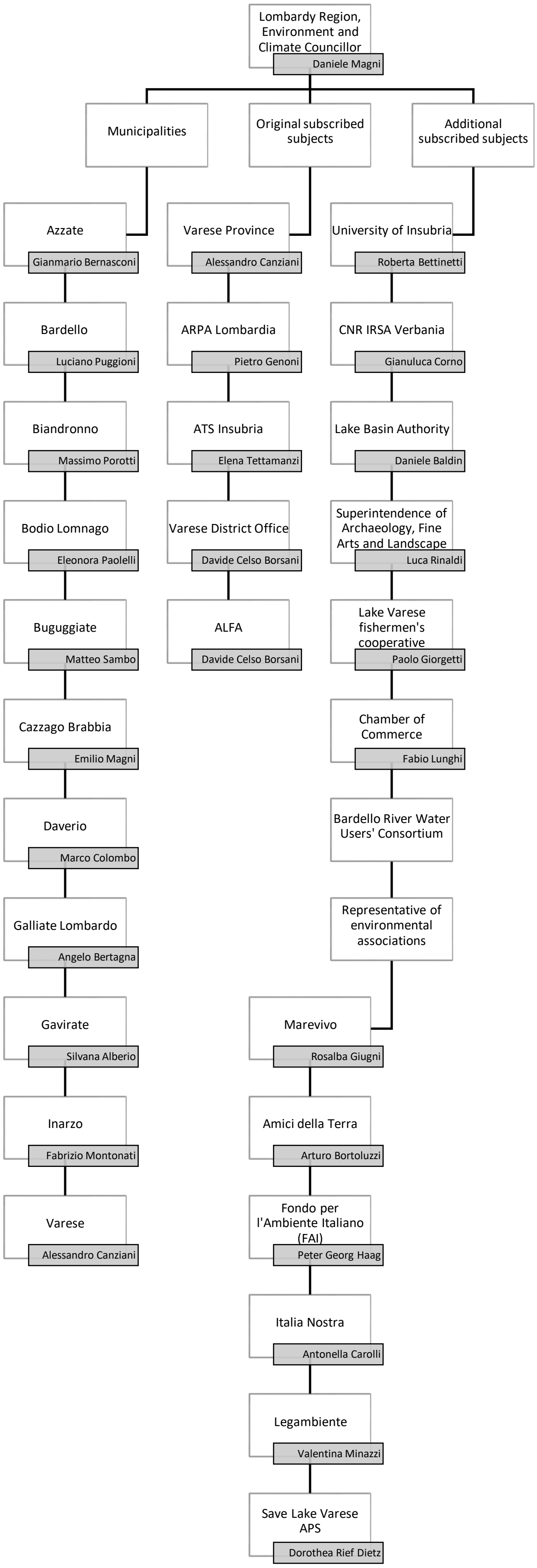
ANNEX I – Basin classification methods[108]

System A

Indicator	Range of values	Abbreviation	Classification
Altitude (meters above sea level)	>800	H	High altitude
	200 - 800	M	Middle altitude
	<200	L	Low altitude
Average depth (meters)	<3	VSh	Very Shallow
	3-15	Sh	Shallow
	>15	D	Deep
Surface (km^2)	0.5 - 1	VSm	Very Small
	1 - 10	Sm	Small
	10 - 100	La	Large
	>100	VLa	Very Large
Prevalent composition of the geological substrate	Calcareous	Ca	
	Siliceous	Si	

[108] Lombardi (2021)

ANNEX II – AQST Coordinating Committee



ANNEX III – AQST's list of Macro-actions [109]

Macro-action A. Improvement of the sewer network in the basin of Lake Varese.

Action A.1. Sewerage network studies and surveys

- Activity A.1.1. Collection and organisation of reports on the malfunctioning of the sewerage system.
- Activity A.1.2. Topographical survey of sewer network in the basin of Lake Varese.
- Activity A.1.3. Study of the loads overflown by the sewer spillways in rainy season
- Activity A.1.4. Census and evaluation of existing discharges in the lake basin
- Activity A.1.5. Update of the hydraulic modelling drawn up by the lake company
- Activity A.1.6. Flow monitoring for the Lake Varese agglomeration

Action A.2. Infrastructural interventions on the sewer network

- Activity A.2.1. Evaluation of existing design studies
- Activity A.2.2. Design and implementation of the interventions identified in actions 1 and 2
- Activity A.2.3. Extraordinary maintenance of the sewer network in the municipalities of the Lake Varese area
- Activity A.2.4. Sewerage Service Enhancement Plan

Macro-action B. Monitoring of the water status of the lake and its outlet and their evolution

Action B.1. Water quality monitoring of the lake and its tributary

- Activity B.1.1. Limnological buoys for continuous monitoring of the chemical and physical characteristics of the water and the development of cyanobacteria populations and remote sensing by satellite
- Activity B.1.2. Monitoring of biological, physico-chemical, and chemical elements, priority substances, antibiotic and metal resistance determinants, and the genetic

[109] AQST (2021)

heritage of cyanobacteria communities in Lake Varese. Description of the bacterial community and presence of potential pathogens in Lake Varese

- Activity B.1.3. Monitoring of biological, physico-chemical, and chemical elements, priority substances and determinants of antibiotic and metal resistance, description of the bacterial community and presence of potential pathogens in the Bardello River and Lake Maggiore
- Activity B.1.4. Monitoring of microbiological parameters and algal blooms for bathing purposes

<u>Action B.2. Development of a phosphorus mass balance model</u>

- Activity B.2.1. External load assessment
- Activity B.2.2. Internal load assessments

<u>Action B.3. Development of scenarios of water quality evolution in the lake for the evaluation of interventions</u>

- Activity B.3.1. Development and validation of a lake water quality forecast model
- Activity B.3.2. Preparation of modelling scenarios

<u>Action B.4. Assessment of best technologies for lake restoration</u>

- Activity B.4.1. Investigation and study of the possibility of using innovative techniques and technologies for the remediation of Lake Varese

Macro-action C. Reactivation of the hypolimnion sampling plant

<u>Action C.1. Preliminary studies for the reactivation of the plant</u>

- Activity C.1.0. Analysis of the state of consistency of the plant
- Activity C.1.1. Evaluation of the extension of the discharge pipe of the hypolimnionic sampling plant with provision for siphoning
- Activity C.1.2. Design of interventions

<u>Action C.2. Execution of works</u>

- Activity C.2.1. Modernisation and upgrading of hypolimnics' sampling facility
- Activity C.2.2. Arrangement of discharge from sampling plant
- Activity C.2.3. Preparation of plan (specifications) for operation of installation
- Activity C.2.4. Installation of photovoltaic system

Macroaction D. Preservation of the protected area of Lake Varese

Action D.1. Update of the management plan of the Special Area of Conservation (SAC)[110] "*Alnete del Lago di Varese*" and of the Special Protection Area (SPA)[111] "*Lago di Varese*".

- Activity D.1.1. Regulation and supervision of navigation on the lake
- Activity D.1.2. Evaluation of proposals for revision of navigation regulations
- Activity D.1.3. Development of electric navigation on the lake
- Activity D.1.4. Assessment of lake levels suifi for environmental protection and multiple use of water
- Activity D.1.5. Drafting and updating of the management plan for the SAC "*Alnete del Lago di Varese*" and the SPA "*Lago di Varese*". (Knowledge framework, planning of interventions, regulations) in order to maintain a satisfactory conservation status of habitats and species of Community interest.
- Activity D.1.6. Morpho-bathymetric survey of Lake Varese

Action D.2. Preparation of a three-year plan to rebalance the fish fauna present in the lake to be implemented through parallel fishing actions of thinning and management of catch and releases.

Macro-action E. Communication, promotion of AQST activities and citizens awareness

Action E.1. Communication and dissemination of the contents and activities of the agreement

- Activity E.1.1. Creation of a web site about AQST

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[110] From Italian *Zona Speciale di Consevazione (ZSC)*
[111] From Italian *Zona di Protezione Speciale (ZPS)*

- Activity E.1.2. Organization of thematic meetings on the territory

Action E.2. Citizen's awareness and citizen science activities

- Activity E.2.1. Dissemination and environmental education for citizens
- Activity E.2.2. Involvement of schools
- Activity E.2.3. Information posters and printing of informative material
- Activity E.2.4. Development of forms of economic participation by citizens and local governments to the costs of lake restoration
- Activity E.2.5. Regional day of "Clean Green" dedicated to the lake
- Activity E.2.6. Realization of training courses and thematic meetings for various types of subjects

Macro-action F. Development activities and territorial enhancement of the shores and the bike path

Action F.1. Enhancement of the bank area and the bike path

- Activity F.1.1 Drawing up of a study/project of territorial/landscape framework aimed at promoting the usability of the Lake Varese in a special way enhancing the circumlacustrine cycle path.
- Activity F.1.2. Implementation of interventions and works identified in the design phase