

THE COASTAL LAKES OF CAMPI FLEGREI: BETWEEN BIODIVERSITY AND ANTHROPIZATION

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Abstract – Campi Flegrei (from Greek *phlegraios* = burning) is a volcanic area north west of Naples, extended from Agnano crater until Cuma. Pozzuoli, Bacoli, Monte di Procida e Quarto, some northern neighborhoods of Naples. In this area there are three coastal lakes: Fusaro, Miseno, Lucrino. Our study analyses geomorphological, botanical, historical and anthropic features of their ecosystems.

Fusaro lake, between Cuma and Monte di Procida, in the Bacoli administration, is the largest in surface area (1 km²). A coastal dune with maquis is between the lake and the sea, exchanging water through three channels. It has a volcanic origin and a smaller basin size than the original crater because of the sea level rise. There are still fumaroles and gas emissions, while thermal water was discovered in the '60s.

Nearby, between Monte di Procida and Capo Miseno, there is lake Miseno (also called dead sea), it was formed by the sea over-washing inside an inactive volcanic crater, separated from the sea by the later emersion of a submerged dune. Its current size is 0,4 km², its average depth is 2,25 m and it is connected to the sea by two estuaries.

Lucrino lake measures less than 0,7 km², is connected to the sea through a 1,5 m wide channel. It is under the city of Pozzuoli administration between Averno lake, Monte Nuovo and the Stufe di Nerone spa.

Depending in formation and shaping by the Campi Flegrei caldera, it shows secondary volcanic phenomena dating back to roman time when Virgilio described sulfur boiling in it.

All together they form a lake-net very important for migrating and resident birds and the conservation of the flora of wet areas. Their uncommon conditions create numerous microenvironments, some harsh, determining plants communities. Some lake biosystems prolong into the coastal systems.

Introduction

The lakes in this study are included in the crater field of the Campi Flegrei, a large quiescent volcano that has produced numerous different eruptive centers for 39 000 years to date.

The term Campi Flegrei (from the Greek *phlegraios* = burning) indicates an area of the province of Naples from the Posillipo hill to Cuma.

The ecological importance of the three lakes is evident by their being listed among the European Sites of Community Importance (Lago Fusaro IT8030015, Lago Lucrino IT8030016, Lago Miseno IT8030017). In addition, they are close or connected with other areas of high natural value (Lago d'Averno IT8030014, Cuma forest and Montenuovo protected area). All together they include 16 species and 8 habitats listed in the Habitat Directive [1].

They all differ by their hydrologic conditions and the status of their banks: lakes Fusaro and Lucrino had part of their shores cemented from a long time; lake Fusaro because of an old embankment, right in front of the Casina Vanvitelliana and lake Lucrino because of a terrace joined to a restaurant from the beginning of last century. Lake Miseno has not proper embankment or terraces but does not show the proper riparian zone anymore for a relevant portion of its shore. None of the lakes still retains the richness of species they experienced in the past. However even though many studies have been carried out on these lakes, still little is known about the current loss from the flora and fauna they were hosting in their pristine natural conditions.

Materials and methods

Lake Lucrino was a large bay that in the 1st century BC was transformed by an isthmus in a lake, in order to provide a safe harbour to the Roman fleet. It is fed today by a small thermal spring, currently exploited for tourism, in south-west, at the foot of Monte delle Ginestre.

The depth is rather low and strongly influenced by the oscillations of Phlegraean bradyseism, so that, since Roman times, the isthmus has had to be raised more than once. The documented period of maximum submergence was between the ninth and fourteenth centuries, when the effects of the sea storms reached the lake Averno more inland. The lake was named after *lucrum* because of the flourishing fisheries in Roman times. His fame grew in 37 BC. when Marco Vipsanio Agrippa, during the war between Ottaviano and Sesto Pompeo, created an imposing military port: Portus Julius, in honor of Gaius Julius Caesar Octavian. The construction works were entrusted to the architect Lucio Cocceio Aucto. In ancient times, the port was defended by a long dam thrown onto the beach, which starting from the Punta dell'Epitaffio joined Punta Caruso, on which the Via Herculeana passed. A canal opened in the dam allowing ships to enter the Lucrino basin from which, with another rock-dugged canal, they moved to the lake of Averno, which served as a dry dock.

The port was short-lived as the basin, being shallow and subject to silt up, became unsuitable for heavy Roman warships. For this reason, about a quarter of a century later, it was abandoned as a military port but continued to live for a long time as a port for civil and commercial purposes. Due to bradyseism and the retreat of the coast line, Portus Julius was abandoned at the end of the fourth century.

The volcanic origin of Lake Miseno does not appear immediately evident because of its irregular shape, included in a complex crater system between the eruptive mouths of Capo Miseno, Bacoli and Punta Pennata, active between 35 thousand and 10 thousand years ago.

The lake is named after Miseno, trumpeter of Aeneas's Trojan army (Aeneid - Virgil - book VI). He dared to challenge in a trumpet contest Triton (son of the sea god Poseidon); the latter, took offence and drowned him [2].

Legend has it that Enea, having found the body, buried it under a huge mound, Capo Miseno, whose square shape reminds that of a gigantic tomb.

At the end of the 1st century B.C. the Roman general Agrippa preferred it to the *Portus Julius* and transferred the Roman fleet to Miseno. Soon lake Miseno became the most important military harbour of the Roman imperial fleet (*Classis Misenensis*). The *Portus Misenum* was formed by two natural basins: the lake part was used for the construction and repair of ships while the bay was the actual port. To supply the numerous ships with water, one of the largest cisterns was dug in the tuff of the hill, later called *Piscina mirabilis*, collecting water from Augustan aqueduct [3].

Lake Fusaro is erroneously classified as a lagoon lake, but, geologically, it has a sulphureous volcanic origin, with about half of the crater now occupied by the coastal bar and marine waters.

The term Fusaro derives from the hemp maceration carried out in the Angevin era, because the basins for this activity were called *fusari*, from the Latin *fundere*, *fusum*, to dissolve [4].

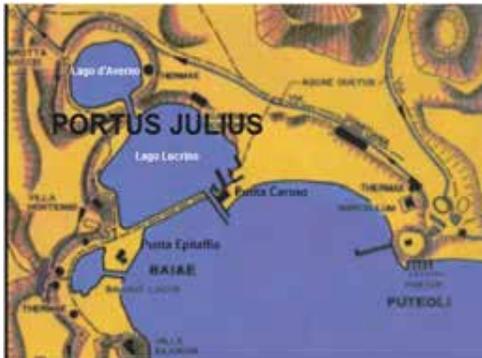


Figure 1 - *Portus Julius*.



Figure 2 - *Portus Misenum*.



Figure 3 - *Piscina Mirabilis*.



Figure 4 - *Casina Vanvitelliana*.

The area was marshy and sparsely populated, in the myth the lake was identified with the *Acherusia palus*, the infernal marsh formed by the Acheron river. On the other hand, the area was very rich in game so that, it become from 1752, a hunting and fishing reserve of the Bourbons who entrusted Luigi Vanvitelli with the first works for the transformation of the place. King Ferdinand IV of Bourbon (later Ferdinand I of the Two Sicilies) entrusted the completion of the work to Carlo Vanvitelli, son of the late Luigi, who in 1782 built, on an existing island, an elegant hunting and fishing casino known today as *Casina Vanvitelliana* [5].

The area around the Fusaro Lucrino and Miseno lakes, once a mainly agricultural territory inhabited by peasants and, along the coast by fishermen, had an extremely low building-density consisting mainly of rural houses inside small farms; small well-camouflaged houses in an extremely fertile area, rich in agricultural and spontaneous vegetation, that gave the environment a connotation almost unchanged for centuries; few larger than three-room buildings belonged to the wealthiest class and were located in dominant positions on the territory. For all of them local materials were used, mainly tuff, of which the area is rich, and the classic mortar with binder. Sometimes different techniques were used, well-cut tuff wall faces containing tuff debris and mortar when stronger structures were needed, usually in multi-story buildings. This practice, after several centuries, was disastrously altered after the middle of the 900, when even in those areas, the use of reinforced concrete became widespread for any building. Then new buildings were created to satisfy industrial use which should not have been meant for this area. Constructions have piled up without any order, any aesthetic and functional sense, consuming without any logic a territory once in perfect balance.



Figure 5 - Miseno Lake 1959.



Figure 6 - Miseno Lake 2020.

Few and not easily recognizable traces of a once unique and unrepeatably territory, only a few noticeable buildings could still be found inside a too dense mass of modern buildings, few exceptions like the Casina Vanvitelliana on the lake Fusaro or some ancient building on the edge of the hills or in the villages historical centers.

The three lakes, apart from their origins can be considered coastal lagoons; they have shallow water with salinity and volume different among them; more important they are separated from the coast by banks of sand or shingle or rocks (in their original condition). The natural continuity with the sea-shore environment is currently impaired in various degrees: the most dramatic one is apparent in lake Lucrino, secluded by the sea by one road, a railway and the sea cabins built for tourism at the beginning of the last century.

The lake Fusaro has got a differently wide expanse of vegetation, corresponding to old consolidated dunes, now small orchards, a road and a trenched railway separating it from the sea-shore (where, apart from the beach installations, dunes could still be seen in places). The lake Miseno has the less compromised condition, but still a road, parking lots and beach cabins are barriers to the ecological continuity between the lake and the sea-shore. The most obvious loss of all three lakes is the loss/big reduction of the riparian zone and the altered status of the natural water ways. Riparian zones have high ecological values in all water bodies: they provide filters for materials in and out, chemicals processing (both pollutants and nutrients), food and shelter for widely different species of aquatic and terrestrial environment, they regulate the water flows (from water bodies, rain and run off), provide a barrier to the erosion and facilitate the transition among ecosystems typical of wet zones; they are driving factors of biodiversity. The hydrological system provides the main character of a water body, setting it as a pond, a lake, a running water system, furthermore it determines the turnover of nutrients by the water circulation and the temperature. The alteration of water fluxes determines adjustments to new balances whose results are not often valuable from the ecological point of view.

Results and discussion

Current morphology of Lake Lucrino was built in 1538, after the eruption of Monte Nuovo which delimited the boundaries of the lake towards the north-east, definitively isolating it from Lake Averno [6]. Until then the area was home to numerous thermal springs, called *Balneum*, such as Ciceronis, Tripergula, Arcus and others, the most important of which was the Sudatorium Triuli, located in the hill of Tritoli, south-east of the current lake.

The connection with the sea is ensured by a narrow passage located in the north-east area, currently confined, both laterally and above, by a reinforced concrete structure. Right in this area there is the lowest depth, in the order of tens of centimeters, with occasionally formation of sandy islands, generated by the scarce movement water.

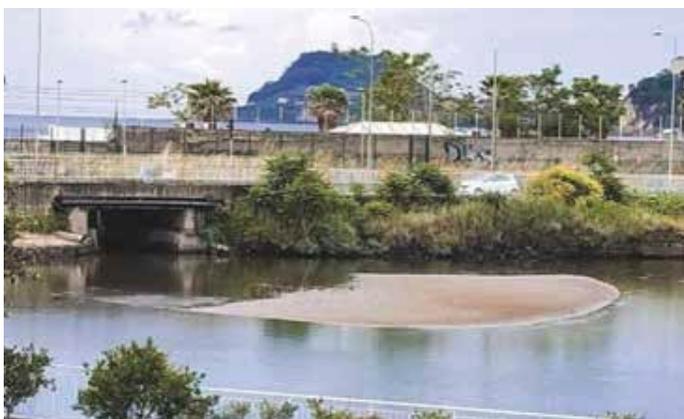


Figure 7 - Mouth of Lucrino Lake - Sandy island emergence in May 2020.



Figure 8 - Miseno Lake.

Initially the area of Lake Miseno was swampy but marine sedimentation subsequently isolated the lake from the sea, with the formation of the large beach, today the site of mainly touristic and agricultural activities, between Monte di Procida, Capo Miseno and Bacoli.

The lake depth could reach 4 meters and two mouths ensure a good exchange with the sea, but the great anthropogenic pressure and unauthorized use produce intense pollution making mussel farming impossible.

Currently in the area of Lake Fusaro there are fumarolic exhalations on the hills to the north-east, in the locality Mofeta, as well as from groundwater flowing about 40÷50 meters below the lake, to south-west. In the past, however, the volcanic manifestations had to be much more evident, as reported by writings of the third century B.C. [7].

The lake bottom has always been quite low, since Greek times when the lake was looking as a large bay that broke the linearity of the sandy coast. Geologically it is not possible to identify the period in which the coastal dune was formed, but analyzing the writings of Strabo and Seneca, it can be deduced that the isolation of the lake from the sea began, probably between 20 and 60 A.D. The whole area has always been influenced by Phlegraean bradyseism, certainly starting from the second century A.D., as evidenced by the archaeological remains currently submerged, dating back to that time.

Current conditions of the lakes are showing loss in biodiversity although a detailed up-to-date scientific assessment has not been carried out. In Natura 2000 dataforms most recent assessments dates back to 2013 and lack of site management is reported [8].

However, public administrations are often lazy and careless in paperwork and do not update informative sheets; this is the case of the Averno lake for which a nature path has been provided with informative panels but nothing of it is showed in Natura 2000 dataforms [9]. For lake Miseno the shore pathway has been hindered for the last two decades and now a complete circuit pathway is under construction. But still no plan is mentioned for any of them. A survey on the coastal dunes should be carried out because they should be the natural prosecution of these lake environments [10]. Unfortunately, the

dunal ecosystem innot properly protected nor integrated in the overdeveloped beach tourism [11]. Perspective transect have been sampled on lake shores: on Lucrino lake the bestpreservedriparian zone is the western area near the spa Stufe di Nerone. On the narrow strip of vegetation a few typical species were found along with secondary colonization of *Rubus* spp. signal of anthropic degradadation. Nearby small patches of *phragmites australis* are still offering shelter to grebes and coots whose major site is the near Averno lake. The same transect in some of thebetter-preservedriparian zones of Averno lake showed more than 6 species native of the lake-shore. Sampling on the Fusaro shore was not done because of the restricted area all in private property, nor along the Miseno lake because of the parking lot use. Springtime sampling was impossible because of the Pandemia restrictions.



Figure 9 - Fusaro Lake. In red the hypothetical original form of the crater.

Conclusions

Restauration of natural ecosystems and cultural landscape are imperative for the survival of this area. The approach to restauration, to be effective, must be an integrated one, all features of territory promotion should be considered to further high-quality tourism and better environment and life quality of residents, environmental conservation in both nature and culture features, economics improvement. Stakeholders should be involved in the process, without whom any restauration policy would be ineffective. Actions to be taken are:

Hydrogeological actions for natural water flow recovery:

In the lake Lucrino the dredging of the lake bottom, in particular in the mouth area is of utmost importance to ensure the quality of the water.

The three canals that connect Lake Fusaro to the sea have an average depth of 1 meter today and do not always ensure the right flow to the sea, also due to the presence of debris; therefore, an intervention is necessary to restore the full functionality of the mouths.

In the lake Miseno appears to be significant in the recovery of the ancient hyper chlorinated-sodium thermal springs used until the years preceding the Second World War.

Nature conservation measures:

Current status assessment: riparian ecosystem and ecotones, anthropogenic disturbances (soil use, water use/waste, water chemicals and ecological quality).

Restoration actions: restoration of riparian zone, riparian range, water quality development to a healthy state (wastewater control and treatment), agriculture environment-friendly techniques and waste control. It is noticeable that, apart from other kinds of protection, restauration of riparian zone is compulsory by the art. 15 d.lgs. n. 152, 2006 (T.U. ambiente).



Figure 10, 11 - Fusaro Lake: to the left waste water pipe, to the right tyres store on the lakeshore.

Landscape protection and restauration

It is late to stop the architectural degradation which has occurred in the last decades, but it is still possible to impose regulation on the keeping of the building and on the conservation of land uses in unoccupied areas; and it is particularly important to preserve.



Figure 12, 13 - Averno lake: traditional agriculture landscape.

Acknowledgments

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