

The coastal wetland systems of northern Tuscany: Massaciuccoli Lake and ex Porta Lake. State of knowledge and new opportunities for multidisciplinary approach

I sistemi della fascia umida costiera della Toscana settentrionale: Lago di Massaciuccoli e ex Lago di Porta. Stato delle conoscenze e nuove opportunità di approccio multidisciplinare

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Riassunto: Il lago di Massaciuccoli e l'ex Lago di Porta sono stati selezionati come Siti di Importanza della Comunità Europea per le particolari biocomunità che ospitano. Queste aree hanno una storia complessa che ha visto l'uomo intervenire costantemente nei secoli in particolare con interventi di bonifica, tanto che il paesaggio che vediamo oggi è il risultato di un ambiente naturale fortemente plasmato dall'attività umana. In particolare, la zona umida di Massaciuccoli oggi è in una grave situazione di degrado ambientale dovuta a pressioni antropiche che hanno causato sostanziali cambiamenti nella funzionalità e negli aspetti naturalistici di questo ecosistema. In questo lavoro si è cercato di valutare la disponibilità e distribuzione dei dati stratigrafici per il sottosuolo dell'area di studio utilizzando le stratigrafie raccolte nella banca dati IGGDATABASE, rivelando che sono necessari studi di dettaglio multidisciplinari per meglio definire la recente (Pleistocene-Olocene) evoluzione paleoambientale e l'architettura deposizionale del sottosuolo di queste aree. Inoltre, un monitoraggio dettagliato di questi sistemi sia per i parametri abiotici che biotici è necessario come mezzo essenziale per la loro protezione e conservazione.

Abstract: The Massaciuccoli lake of and the ex Porta Lake have been selected as Sites of Importance of the European Community for the particular biocommunities that they host. These areas have a complex history that has seen human intervening constantly over the centuries specifically with reclamation operations. Therefore, the landscape we see today is the result of a natural environment strongly shaped by human. In particular, the Massaciuccoli wetland today is in a serious situation of environmental degradation due to anthropic pressures that have caused substantial changes in the functionality and naturalistic aspects of this ecosystem. In this work, an evaluation of the availability and distribution of stratigraphic information for the study area was performed using the stratigraphies collected in the IGGDATABASE, underlining that multidisciplinary detailed studies are necessary to better define the recent palaeoenvironmental evolution (Pleistocene-Holocene) and the depositional architecture of the subsurface of these areas. Moreover, a detailed monitoring of these systems both for abiotic and biotic parameters is needed as essential tool for their protection and preservation.

Keywords: Massaciuccoli Lake, ex Porta Lake, wetlands.

Parole chiave: Lago di Massaciuccoli, ex Lago di Porta, aree umide.

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Introduction

Lake Massaciuccoli and the former Lake Porta are wetlands located in the plain named Piana Versiliese, between the south-western limit of the Apuan Alps and the Tyrrhenian Sea (Fig. 1). These areas have a complex history that has seen human intervening constantly over the centuries especially with reclamation operations, so that the landscape we see today is the result of a natural environment strongly shaped by human. They have been reduced to such an extent that today they are considered critical areas for the conservation of biodiversity, including a large number of animal and plant species. Given their great variability, as areas of transition between sea and land, they are very fragile and easily vulnerable receiving pressures and impacts from numerous sources, first of all the anthropic activity that takes place in the surrounding areas.

The Massaciuccoli lake and the ex Porta Lake are considered among the most important wetlands in the Mediterranean Basin that have been selected as Sites of Importance of the European Community for the particular biocommunities that they host. In addition, the Regione Toscana has identified the

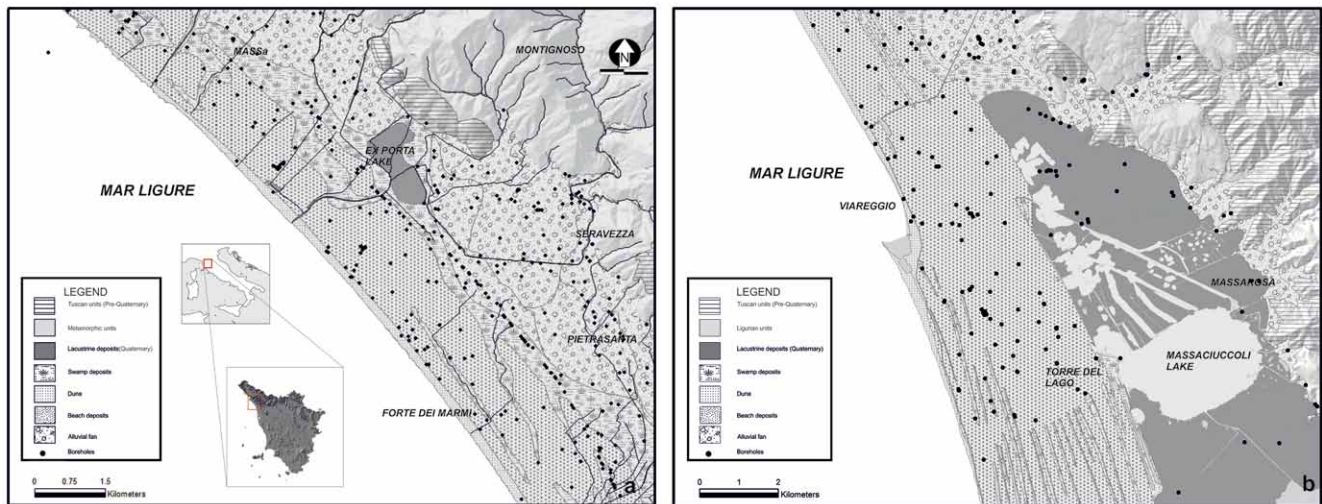


Fig. 1 - Geographical and geological setting (from: Regione Toscana "Database geologico regionale" modified) of the studied area, reporting the IGGDATABASE.

Fig. 1 - Inquadramento geografico e geologico (da: Regione Toscana - "Database geologico regionale") dell'area di studio, ubicazione dei sondaggi contenuti nella banca dati IGGDATABASE.

Massaciuccoli lake as a sensitive area, and the lake basin as an area vulnerable to nitrates (in accordance with D.Lgs. 152/99).

These environments were formed for the progressive isolation of the marine waters produced by the coastal system and the consequent migration of the coastal sandy deposits, which occurred during the late Holocene (Federici 1993; Bini et al. 2009; Amorosi et al. 2013).

The purpose of this note is to make a geo-environmental survey of the two areas based on the data available in the literature, to identify the state of the art for these wetlands and highlight future critical issues and needs for their preservation and valorisation.

Data and Methods

For stratigraphic considerations, a dataset of logs and sediment cores organised in Q-GIS (Quantum Geographic Information System) by the Institute of Geosciences and Georesources of CNR (IGGDATABASE) is used. Micropaleontological, sedimentological and stratigraphical information by previous published studies (e.g. Federici 1993; Antonioli et al. 1999; Bergamin et al. 2006; Carboni et al. 2010) and collected stratigraphic logs are also included in this database.

Geochemical data on Massaciuccoli waters have been collected from already published works.

Geological setting and palaeoenvironmental evolution of the Versilian Plain

From a geological point of view, the Versilian Plain, which hosts the wetlands included in this text, is located in the Viareggio Basin, a tectonic basin, originating since the Upper Miocene following the development of the Apennine chain. According to classical geodynamic models, following the migration of the compressive Apennine front eastwards, in the innermost areas of the chain, from the Upper Miocene an extensive regime is established, which determines the formation

of subsiding basins (Malinverno and Ryan 1986; Patacca et al. 1990). These basins, as shown by deep and seismic surveys (Ghelardoni et al. 1968; Pascucci 2005), are filled with marine, transitional and continental sediments. In the depocentre, the Viareggio Basin is made up of a stratigraphic sequence over 2000 m thick (Ghelardoni et al. 1968; Pascucci 2005). The most superficial deposits in the Versilian Plain were investigated since the first half of the last century (Blanc 1937, 1942) and allowed to start defining the stratigraphic structure of the subsurface, highlighting the importance of studies conducted on continuous core drilling (Federici 1993), and with sequential stratigraphy methodology (Amorosi et al. 2013; Rossi 2014).

In the Massaciuccoli area, several Holocene units, both outcrops and in the most superficial portion of the subsurface, can be identified (Federici 1993). These units have peculiar lithological and sedimentological features and are referred to different depositional environments (Federici 1993; Antonioli et al. 1999; Bergamin et al. 2006; Carboni et al. 2010; Rossi et al. 2014). The geological map in Figure 1 highlights the presence of lacustrine deposits (silt and sand with freshwater microfossils) and swamp deposits (peat), that surround the lake itself and that extend for several kilometres in the Apennine direction. Alluvial fan sediments outcrop in the foothills, while marine and aeolian deposits are limited to a coastal strip that spreads throughout the Versilian Plain (Federici 1983; Menichini et al. 2017).

Sand sediments, relative to a shallow water marine environment (beach deposits), radiometrically dated and referred to late Holocene, have been found at a depth of a few metres in boreholes located on the western and eastern side of Massaciuccoli lake (Federici 1993; Boschian et al. 2006). These sediments were deposited during the period of maximum sea level rise during the Holocene (Boschian et al. 2006). This indicates that the Versilian transgression went as far as the reliefs near Massarosa town (Boschian et al. 2006). The analy-

sis of numerous boreholes showed that the thickness of the peat, situated above the siliceous sands of the marine environment, varies until it reaches a thickness of more than 5 metres (Federici 1993). The radiometric dating confirms a late Holocene age of these sediments (Carboni et al. 2010). The slow progradation, determined by the interplay between accommodation and sediment supply, has led to the formation of wetlands at the back of the dunes that extend parallel to the coast. This slow progradation of the depositional system is evidenced by the different ages of the watchtowers that were built in the Versilian area in historical times and by archaeological remains (Boschian et al. 2006; Bini et al. 2009).

The Porta lake, as evidenced by the archaeological finds, was formed in Pre-Roman times (Boschian et al. 2006). On the geological map, alluvial, swamp and lacustrine deposits are reported in this area (Fig. 1). The marine and aeolian sediments of the Holocene are bordering the coastal areas (Federici 1987), and, as the boreholes show, they tend to decrease in thickness, following a wedge-shaped geometry, moving inland (Menichini et al. 2017). At the edge of the reliefs, above the rocky substratum represented by formations of the Tuscan Units formations, there are sediments referred to alluvial fan system. As evidenced by the archaeological remains, these Pleistocene alluvial fans, in Roman times, were already outcropped (Boschian et al. 2006). The Pleistocene alluvial fan deposits seem to pass laterally to the lacustrine sediments of the Porta Lake. These last one has a maximum thickness of 10 meters (Menichini et al. 2017). However, in this area, sequential stratigraphic studies would be necessary to better define the subsurface deposits geometries and to better track the palaeoenvironmental evolution.

The knowledge of the events that have marked the palaeoenvironmental evolution and that have determined the current stratigraphic architecture, it is an important prerequisite for the understanding of the whole system. The geo-stratigraphic characters, in fact, affect other elements of the system, such as the microclimate, the chemism of surface and underground waters, the fauna and flora distribution. The stratigraphic information available for the areas focus of this note is often devoid of micropaleontological, radiometric and sedimentological data, which provide fundamental chronostratigraphic and geometric constraints for subsurface reconstructions.

Current environmental situation and critical issue

Today Lake Massaciuccoli does not look like the ancient brackish lagoon of the past, but it is considered a typical small lake because of its average depth of 2 m (the maximum depth is 4,40 m) and its salinity is less than 500 mg/l. The surface of the basin has strongly decreased in the last centuries due to the continuous reclamation works carried out especially in the 20th century.

In the historical evolution of Lake Porta human activity was also crucial. The canalization of some local watercourses has caused the partial filling of the lake that has reduced its surface and has become over time a pond.

The Massaciuccoli lake waters nowadays belong to the

Na-Cl type, they are quite well mixed along depth without stratification and the spatial variation is low compared to the temporal (seasonal) chemical variability (Baneschi 2007; AAVV 2013). The salinity of lake water is mostly due to evaporation and anthropogenic causes (Baneschi 2005, 2007), conversely, the northern palustrine area is influenced by the seawater ingression from the caves and the Canale Burlamacca (Doveri et al. 2009). The oxygen concentration of lake waters is near the saturation limit during all the year, with low variation between summer and winter season. The lake samples are characterized by low levels of orthophosphate and dissolved organic carbon (DOC), which confirms the dominance of photosynthesis and related orthophosphate uptakes. The carbon biogeochemical cycle in the lake system shows a seasonal cycle related to photosynthesis process, with summer samples characterized by the highest pH values and the lowest pCO₂ values. Both in summer and autumn the concentration of ammonia (NH₃) is higher in the palustrine water than in the lake, due to the more reducing characteristics of the marshy environment. In autumn the concentration of N-NH₃ in the channels is almost one order of magnitude higher than in summer. The seasonal changes in phosphate and nitrate concentrations are very small, even if the concentrations measured in the autumn are in average lower than those recorded during the summer period.

Detailed research carried out in the period 1940-42 indicated that the lake was oligotrophic and slightly brackish (Brunelli and Cannicci 1942). Within about 10 years, the Lake had lost most of its submerged macrophytes in favour of a phytoplankton dominant system, with an associated loss of habitat quality and water transparency (Cenni et al. 1998). Hence, nowadays the Massaciuccoli wetlands resulted in an environmental situation of degradation due to anthropic pressures that have caused substantial changes in the functionality and naturalistic aspects of this ecosystem (Baldaccini 2018). Moreover, a groundwater numerical model implemented for the north-western sector, between Torre del Lago and Viareggio, pointed out that the pumping wells represent an important output from the aquifer system (Bravini et al. 2015).

Massaciuccoli Lake, ex Porta Lake and the surrounding wetlands represent a naturalistic heritage as important as fragile. The strong anthropic impact in the past has affected the existence of these important ecosystems and the associated ecosystem services. Hence, the need to undertake a conservation plan that is sustainable over time and that allows the prosperity of these habitats and their knowledge to the new generations as the undisputed heritage of all mankind should be a priority. Such an ambitious project must necessarily begin with an understanding of the characteristics of the system: from its origin as a geological element to its evolution as a geo-biological system.

To better define the recent palaeoenvironmental evolution (Pleistocene-Holocene) and the depositional architecture of the subsurface of these areas, multidisciplinary studies are necessary. A sequential stratigraphic approach, supported

by radiometric dating, can provide essential temporal and geometrical constraints for the stratigraphic characterization of the sites covered by this note. In this context, the IGGDATABASE could be a useful tool for performing proper stratigraphic reconstructions. Moreover, a detailed monitoring of these systems both for abiotic and biotic parameters is needed as essential mean for their protection and preservation.

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