

FLORA, PLANT COMMUNITIES AND VEGETATION MAPPING OF THE LAKE D’OTRI (GARGANO, APULIA, ITALY)

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Abstract: The Lake d'Otri is a small, temporary pond located in a doline at 794 m above sea level on the karst plateau of Gargano (SE Italy). The flora of this habitat consists of 27 plant taxa, of which only three are proper hydrophytes. The herbaceous vegetation is represented by the following plant associations: *Ranunculo baudotii* - *Callitrichetum brutiae* **ass. nova hoc loco**, *Plantagini majoris* - *Menthetum pulegii*, *Caricetum remotae* and *Lemnetum minoris*. *Rubus* sp. scrub and a *Populus nigra* grove occur toward the doline margins, where the floods last much less. In summer the lake dries up completely and the coenoses of *Ranunculo baudotii* - *Callitrichetum brutiae* disappear. Seven vegetation units are represented at large scale on a phytosociological map.

Keywords: bathymetric zonation; hydrophytes; Mediterranean temporary ponds; *Ranunculo baudotii* - *Callitrichetum brutiae*; phytocoenosis classification; vernal/aestival fenoaspects

Introduction

The temporary ponds of the Mediterranean region constitute a very specialized habitat type due to periods of flooding during the winter - spring months alternating with dry periods during the summer [8]. Therefore, the European Union Directive 92/43/EEC of 21 May 1992 (known as the "Habitats Directive") recognizes Mediterranean temporary ponds as priority habitats of community interest (code 3170*). These particular habitats usually host several hydrophytes that have lately become rare, following the generalized trend of wetland area degradation/reduction due to land reclamation, eutrophication, global warming, invasive species and other threats [9].

Given the importance for nature of these habitats, we aimed at assessing the flora and plant communities of the Lake d'Otri, which has never been studied before in terms of vegetation composition. In addition, we planned to produce a detailed map of plant communities that could be used in the future for the monitoring of vegetation cover.

Study area

Lake d'Otri, locally called "Cutino d'Otri", is located on the karstic plateau of Gargano (Apulia) within the Umbra Forest (41°48'12" North and 16°01'43" East), at an altitude of 794 m a.s.l. The geomorphological context is given by a rather irregular limestone plateau (polje) with scattered dolines. This is covered by a vast beech forest which belongs to the association *Anemono appenninae* - *Fagetum sylvaticae*.

The plateau area is characterized by a temperate oceanic bioclimate, lower supratemperate thermotype and upper subhumid ombrotype [14]. Biogeographically this area belongs to the Mediterranean region, East-Mediterranean subregion, Adriatic province and Apulian sector [16].

The investigated temporary pond occupies the bottom of a small sinkhole (about 5000 m² large), which was partly reshaped by local farmers more than a century ago by setting up a typical cistern (locally called "swimming pool") surrounded with a drystone fence (Fig. 1). The maximum water depth of the pond (20 cm) is reached in spring, during the period of maximum flooding (Fig. 2).



Fig. 1: Aestival fenoaspect of the Lake d'Otri with *Mentha pulegium* distributed on the bottom of the doline (photo taken on 8 September 2020)



Fig. 2: Vernal fenoaspect of the Lake d'Otri showing the maximum water level (photo taken on 7 April 2020)

Materials and Methods

The vegetation surveys were carried out both in summer and spring (10 August 2020, 7-8 September 2020, 25-26 May 2021, 7 April 2022), using the methodology of the Zürich-Montpellier school [2]. For the nomenclature of plant taxa we mainly followed the checklist of the Italian vascular flora [4, 5], while also considering the newest monograph on the Italian flora [15]. The syntaxonomic framework was adopted from various regional or local vegetation classifications [17, 6, 19].

In order to aid the vegetation mapping, aerial high-resolution imaging was taken with a drone (model DJI MAVIC 2 PRO) according to a recently developed protocol [12]. In this regard, the following steps were followed:

- recognition of the vegetation units on the ground by carrying out phytosociological relevés;
- execution of aerial photographs using the drone;
- photo-interpretation of the vegetation boundaries in the laboratory;
- verification of the photolimits on the ground and final delimitation of the vegetation units;
- assignment of vegetation units to syntaxa (associations, alliances, orders and classes);
- final validation via field ground-truthing;
- elaboration of the map legend and colouring the mapping units.

Results and Discussion

Flora

The list of all vascular species occurring in the pond and on its shores at the time of the surveys is reported below (in alphabetical order): *Acer campestre* L., *Alopecurus aequalis* Sobol., *Arum italicum* Mill., *Bellis sylvestris* Cyril., *Callitriche brutia* Petagna, *Carex remota* L., *Carpinus betulus* L., *Ficaria verna* Huds., *Glyceria notata* Chevall., *Hedera helix* L., *Lamium garganicum* L., *Lapsana communis* L. subsp. *communis*, *Lemna minor* L., *Mentha pulegium* L., *Plantago major* L., *Poa annua* L., *Populus nigra* L., *Ranunculus baudotii* Godr., *Ranunculus lanuginosus* L., *Ranunculus neapolitanus* Ten., *Rubus* sp., *Rumex sanguineus* L., *Solanum nigrum* L., *Stellaria media* L., *Urtica dioica* L., *Veronica anagallis-aquatica* L., *Veronica serpyllifolia* L.

Of the 27 observed plant taxa, only three are true hydrophytes, namely *Callitriche brutia* (recently reported in 2021, for the first time in Gargano) [18], *Ranunculus baudotii* and *Lemna minor*. The others are hygrophilous species (*Carex remota*, *Veronica anagallis -aquatica* and *Glyceria notata*) or species of environments subject to water level variations during the year, such as *Mentha pulegium*.

Overall, the pond flora is rather species-poor, but two of them (*Callitriche brutia* and *Ranunculus baudotii*) are particularly important as diagnostic species of the new plant association described here. Moreover, *Ranunculus baudotii* has been recently evaluated as a near-threatened species at national level [10].

Vegetation classification

The vegetation is characterized by aquatic communities of rooted macrophytes that develop in a temporary shallow pond, which eventually dries out in the summer. Apart from the floristic differences, the two contrasting phenological aspects (vernal and aestival) are distinguishable based on the total vegetation cover, i.e., high coverage in (late) spring (Fig. 2) and

much less coverage in late summer (Fig. 1). In the central part of the pond, with deeper waters, two vernal vegetation layers are noticeable: an upper one characterised by the floating laminar leaves of *Ranunculus baudotii* and its flowers, and an underwater layer dominated by *Callitriche brutia*. The large variation range of the water level determines a seasonal succession of plant species and, obviously, of the vegetation types.

The plant associations, distinguished on the basis of phytosociological relevés, are reported below in a syntaxonomic scheme:

Isoëto-Nanojuncetea Br.-Bl. & R. Tx. ex Westhoff et al. 1946

 Isoëtetalia Br.-Bl. 1935

 Preslion cervinae Br.-Bl. ex Moor 1937

 Ranunculo baudotii-Callitrichetum brutiae **ass. nova hoc loco**

Lemnetea minoris O. Bolòs & Masclans 1955

 Lemnetalia minoris O. Bolòs & Masclans 1955

 Lemnion minoris O. Bolòs & Masclans 1955

 Lemnetum minoris Soó ex Müller et Görs 1960

Agrostietea stoloniferae Oberdorfer 1983

 Potentillo anserinae-Polygonetalia avicularis Tuxen 1947

 Potentillion anserinae Tuxen 1947

 Plantagini majoris-Menthetum pulegii De Foucault in Royer et al. 2006

Montio fontanae-Cardaminetea amarae Br.-Bl. & Tüxen ex Klika et Hadac 1944

 Montio fontanae-Cardaminetalia amarae Pawlowski in Pawlowski et al. 1928

 Caricion remotae Kästner 1941

 Caricenion remotae Zechmeister et al. 1994

 Caricetum remotae (Kästner 1941) Schwickerath 1944

The first two hydrophytic community types are exclusive to the spring facies, whereas the last two are noticeable during the entire year. Along with the above-mentioned plant communities, the *Rubus* scrub and the *Populus nigra* grove must be added, but these could be classified only at the order level, i.e., *Pyro spinosae-Rubetalia ulmifolii* Biondi et al. 2014 and respectively, *Populetales albae* Br.-Bl. ex Tchou 1949.

Description of the plant associations

Ranunculo baudotii* - *Callitrichetum brutiae

Holotype: relevé 2 in Table 1

Diagnostic taxa: *Ranunculus baudotii* and *Callitriche brutia*

Ranunculo baudotii-*Callitrichetum brutiae* is the community of hydrophytes that occupies the central part of the pond. This is a new plant association whose holotype is the relevé 2 (see Table 1). The association is very poor in species, with *Callitriche brutia* reaching very high cover levels, sometimes almost 100%. Although isolated plants of *Ranunculus baudotii* are widespread throughout the pond, they accumulate a very low degree of cover (Fig. 3).

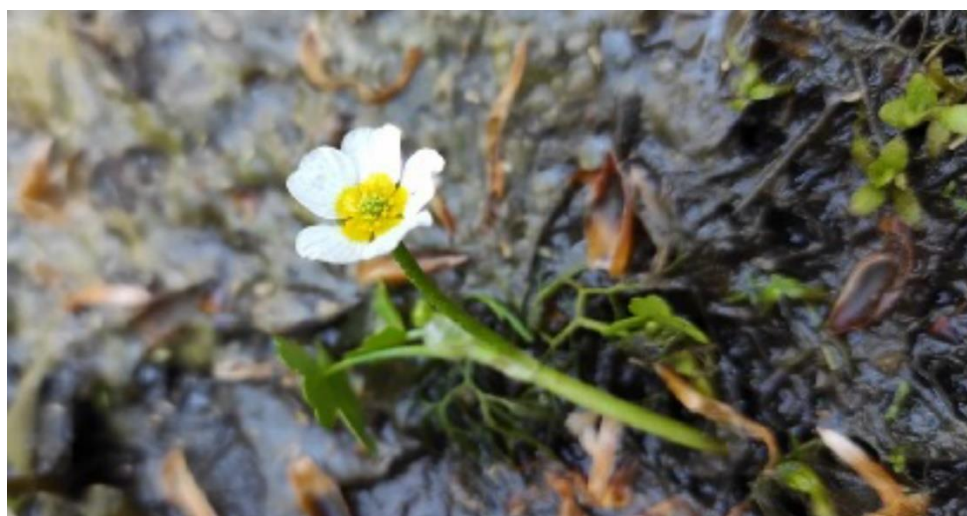


Fig. 3: Flowering of *Ranunculus baudotii* in the Lake d'Otri (photo taken on 19 April 2022)

A floristically similar plant association (*Ranunculo ophioglossifolii* - *Callitrichetum brutiae*) occurs in Apulia, namely near Cutrofiano town, in the Province of Lecce [19, 20].

Callitriche brutia is also a dominant/diagnostic species in other synvicariant plant associations distributed within the Mediterranean region, such as *Isoeto tigulianae* - *Callitrichetum brutiae* in Sardinia [1], *Ranunculo lateriflori* - *Callitrichetum brutiae* in Sicily [3], *Ranunculo peltati* - *Callitrichetum brutiae* in southern Spain [13] and *Ranunculo drouetii* - *Callitrichetum brutiae* in southern France [7].

Table 1: *Ranunculo baudotii* - *Callitrichetum brutiae* ass. nova hoc loco

Relevé number	1	2*	3	4	5	6
Elevation (m a.s.l.)	794	794	794	794	794	794
Aspect	-	-	-	-	-	-
Slope (degrees)	0	0	0	0	0	0
Vegetation cover (%)	60	80	100	100	100	100
Area (m ²)	2	2	2	2	2	2
<i>Callitriche brutia</i>	5.5	4.4	5.5	5.5	4.4	4.4
<i>Ranunculus baudotii</i>	+	+	+	+	+	.
<i>Glyceria notata</i>	+	.	.	.	.	.

* holotype of the new plant association

Plantagini majoris*-*Menthetum pulegii

This plant association, dominated by *Mentha pulegium*, is generally developed along the pond banks (Table 2). However, these communities also extend toward the central part of the pond, where they interpenetrate with isolated nuclei of *Ranunculo baudotii* - *Callitrichetum brutiae*.

Caricetum remotae

This plant association dominated by *Carex remota* shares many species with *Plantagini majoris* - *Menthetum pulegii* (Table 3). The hydrophyte *Veronica anagallis-aquatica* occurs only sporadically. *Caricetum remotae* forms a fairly narrow band along the shores of the pond.

This association has been also recently reported on the shores of Lake Santa Colomba, in the Province of Trentino, where it is composed of very few species [11].

Table 2: *Plantagini majoris* - *Menthetum pulegii* De Foucault in Royer et al. 2006

Relevé number	7	8	9	10	11	12
Elevation (m a.s.l.)	794	794	794	794	794	794
Aspect	-	-	-	-	-	-
Slope (degrees)	0	0	0	0	0	0
Vegetation cover (%)	100	100	100	100	100	100
Area (m ²)	2	2	2	2	2	2
<i>Mentha pulegium</i>	4.4	5.5	3.3	5.5	5.5	5.5
<i>Ranunculus neapolitanus</i>	2.2	1.1	4.4	.	.	.
<i>Alopecurus aequalis</i>	+	+	+	+	.	+
<i>Veronica serpyllifolia</i>	+	+	+	.	.	.
<i>Glyceria notata</i>	.	.	.	1.1	+	+
<i>Veronica anagallis-aquatica</i>	.	.	.	+	.	.
<i>Plantago major</i>	+	.	.	.	.	.

Table 3: *Caricetum remotae* (Kästner 1941) Schwickerath 1944

Relevé number	13	14	15	16
Elevation (m a.s.l.)	794	794	794	794
Aspect	-	-	-	-
Slope (degrees)	0	0	0	0
Vegetation cover (%)	100	100	100	80
Area (m ²)	2	2	2	4
<i>Carex remota</i>	4.4	5.5	5.5	4.4
<i>Alopecurus aequalis</i>	+	.	.	.
<i>Mentha pulegium</i>	+	.	.	.
<i>Rumex crispus</i>	+	.	.	.
<i>Veronica serpyllifolia</i>	.	+	+	.
<i>Poa annua</i>	.	.	+	.
<i>Veronica anagallis-aquatica</i>	.	.	.	1.1
<i>Rumex sanguineus</i>	.	.	.	+
<i>Urtica dioica</i>	.	.	.	+
<i>Lapsana communis</i>	.	.	.	+
<i>Rubus</i> sp.	.	.	.	+

Lemnetum minoris

Lemna minor forms a monospecific community (Table 4) in the man-made basin inside the sinkhole (see the vegetation map below). Some plants of *Lemna minor* are also present in the waters of the natural pond.

Table 4: *Lemnetum minoris* Soó ex Müller et Görs 1960

Relevé number	1	2
Elevation (m a.s.l.)	794	794
Aspect	-	-
Slope (degrees)	0	0
Vegetation cover (%)	100	100
Area (m ²)	1	1
<i>Lemna minor</i>	5.5	5.5

***Populus nigra* grove**

Black poplar (*Populus nigra*) occurs as isolated trees along the shores of the whole lake, but on the north-eastern side it forms a grove (*Populetum nigrae* sensu lato) that appears like a wooded belt. The undergrowth is composed of juveniles of *Acer campestre*, *Carpinus betulus*, *Hedera helix* and *Rubus* sp., whereas the herbaceous layer includes – among others – some species typical for alluvial forests (e.g. *Ficaria verna*, *Ranunculus lanuginosus* and *Arum italicum*) but also some disturbance indicators (*Plantago major* and *Stellaria media*).

Vegetation zonation

The revealed plant associations are distributed in a more-or-less concentric manner according to a positive bathymetric gradient from the banks towards the centre of the pond (Fig. 4), as follows: a) *Caricetum remotae*; b) *Plantagini majoris* - *Menthetum pulegii*; c) *Ranunculo baudotii* - *Callitrichetum brutiae*. However, there are frequent vegetation mosaics mainly determined by the presence/absence of *Ranunculo baudotii* - *Callitrichetum brutiae* and its interspersions with other community types.

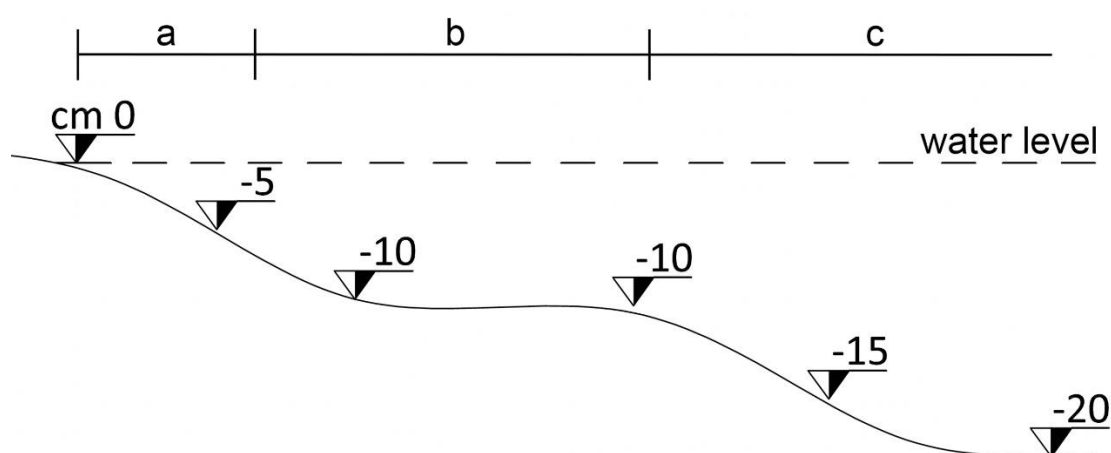


Fig. 4: Plant association zonation along the bathymetric profile of the Lake d'Otri: (a) *Caricetum remotae*; (b) *Plantagini majoris* - *Menthetum pulegii*; (c) *Ranunculo baudotii* - *Callitrichetum brutiae*

Vegetation map

The resulting map is a phytosociological map representing the current natural vegetation types (Fig. 5). A total of seven vegetation syntaxa were mapped through very differently shaped cartographic patches, i.e., from isodiametric (*Ranunculo baudotii-Callitrichetum brutiae*) to very elongated (*Caricetum remotae*). The *Lemnetum minoris* patch has by far the highest fractal dimension, given its very irregular shape. The communities of *Plantagini majoris-Menthetum pulegii* and the *Rubus* scrub cover together most of the mapped area (Fig. 5).

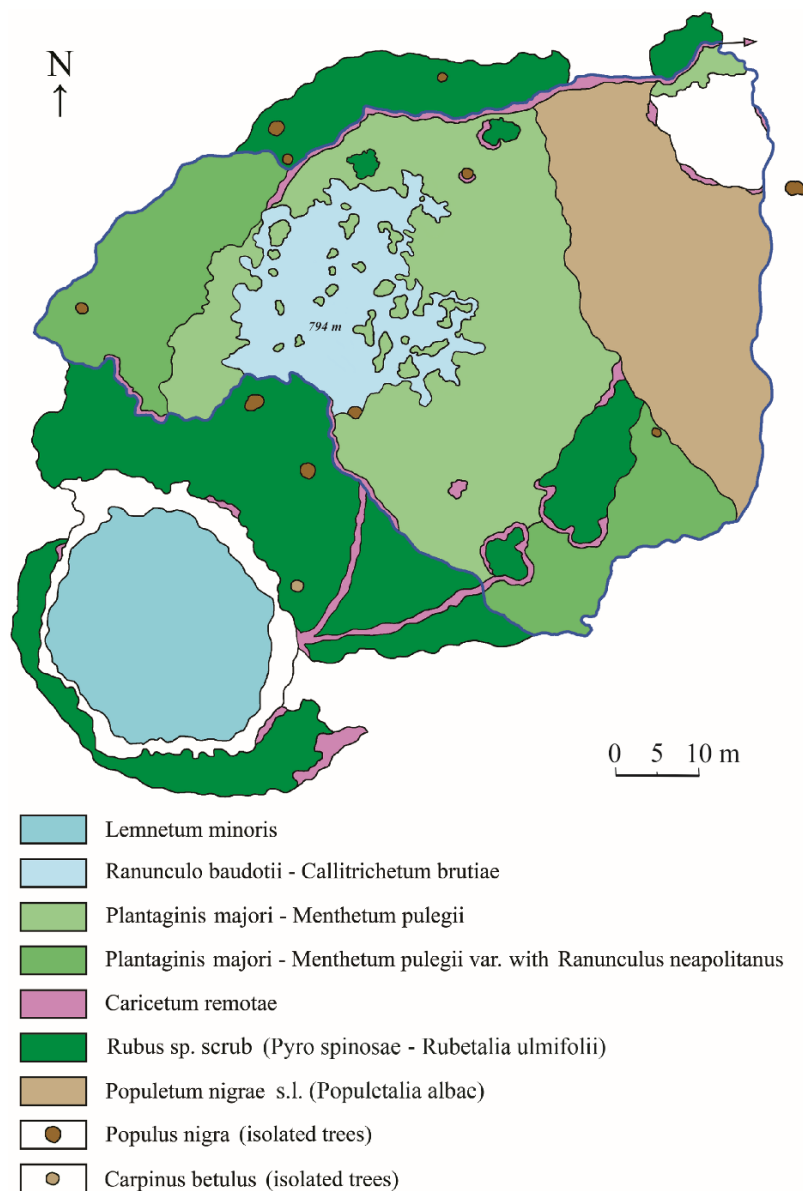


Fig. 5: Vegetation map of the Lake d'Otri

Concluding remarks

The presence of rare hydrophytes in the Lake d'Otri calls for particular conservation measures, even though this habitat is already included within the Gargano National Park.

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FLORA, COMUNITĂȚILE VEGETALE ȘI CARTAREA VEGETAȚIEI LACULUI D'OTRI
(GARGANO, PUGLIA, ITALIA)

(Rezumat)

Lacul d'Otri este mică baltă temporară situată într-o dolină la o altitudine de 794 m pe Platoul carstic Gargano (Puglia, Italia). Flora acestui habitat constă din 27 taxoni, dintre care numai trei sunt hidrofitе propriu-zise. Vegetația ierboasă este reprezentată de următoarele asociații vegetale: *Ranunculo baudotii* - *Callitrichetum brutiae* **ass. nova hoc loco**, *Plantagini majoris* - *Menthetum pulegii*, *Caricetum remotae* și *Lemnetum minoris*. Tufărișul de *Rubus* sp. și pâlcul de *Populus nigra* apar spre marginea dolinei, unde apa stagnează mult mai puțin. Vara, balta seacă complet și cenozele de *Ranunculo baudotii* - *Callitrichetum brutiae* dispar. Șapte unități de vegetație sunt reprezentate la scară mare pe o hartă fitosociologică.

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