Contribution to the knowledge of Mediterranean wetland biodiversity: Plant communities of the Aquila Lake (Calabria, Southern Italy)

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Abstract

As part of researches undertaken on the aquatic and marsh vegetation of southern Italy, a study on the Aquila Lake, a small lake basin in southern Calabria near Rosarno (RC), is here presented. Overall, 86 phytosociological relevés were carried out. The phytosociological study allowed the identification of several aquatic and marsh phytocoenoses, many of which not yet known for the region. They are referable to the following 8 classes: Lemnetea minoris R. Tx. ex O. Bolòs & Masclans 1955, Potametea pectinati R.Tx. & Preising 1942, Phragmito australis-Magnocaricetum elatae Klíka in Klíka & Novák 1941, Agrostietea stoloniferae Oberdorfer 1983, Galio aparines-Urticetea dioicae Passarge ex Kopecký 1969, Molinia-Arthenatheretea Tüxen 1937, Salicet purpureae-Populettea nigræ Rivas-Martínez & Cantó ex Rivas-Martínez et al. 2001, Querco robur-Fagetea sylvaticae Br.-Bl. & Vlieger in Vlieger 1937. A peculiar marsh vegetation is the Cladetum marisci Allorge 1922 ex Zobrist 1935 (habitat of Community interest, according to the EEC directive 43/92 - 7210 “Calcareaus fers with Cladium mariscus and species of the Caricion davallianae”). In the Aquila Lake, some rare aquatic plant communities highlight the importance of this biotope for biodiversity conservation. In particular, we found the pleustophytic associations Lemno-Spiruletum polyrhizae Koch 1954, Lemno minoris-Hydrocharitetum morsus-ranae Passarge 1978 and the aquatic rooted vegetation of Nymphaceae albae Volkm. 1947. Despite the heavy pressures on this area, the biotope harbours a well-differentiated and structured aquatic and marsh vegetation that allows the presence of a rich bird life, both sedentary and migratory. The area, privately owned, is not protected; hunting and fishing are practiced and water is pumped for irrigation with negative consequences on the integrity of the entire aquatic ecosystem. Because of its naturalistic peculiarities and its remarkable biodiversity, this biotope certainly deserves more attention and should be proposed as a protected area.

Key words: Cluster analysis, Italy, phytosociology, Reggio Calabria, wetland vegetation.

Introduction

Wetlands are special places for biodiversity conservation. They host very peculiar plant and animal communities living only in these environments and a remarkable habitats richness, diversified even by minimal variations in chemical-physical parameters, water levels or soil composition (Dudgeon et al., 2006). Due to the importance that wetlands assume for biodiversity conservation, they are object of several national and European projects and initiatives, such as MedWet (2018) and WetVegEurope (2018).

Wetlands are in sharp contraction through the world, mainly due to climate change and the expansion of agricultural and urban areas. Water and marsh habitats are among the most threatened of extinction.

As testified by several authors (De Leone, 1783; Galanti, 1792), the coastal strip of Calabria was occupied by extensive marshy areas until the beginning of the 19th century, and subsequently subjected to intense reclamation activities to combat malaria and obtain land for agricultural activities (Petrucci, 1997). A diachronic analysis of historical maps and flora inventories available for the Calabria region has highlighted the changes that have affected the coastal wetlands of Calabria in the last two centuries and the consequences on the reduction of wetlands and the impact of the flora, highlighting a contingent of species in rarefaction, or already disappeared (Spampinato et al., 2007).

Wetland flora and vegetation in southern Italy have often been a subject of scientific interest and several studies have been carried out to increase the knowledge of these particular ecosystems. We can find many scientific contributions especially in Sicily (Minissale & Spampinato, 1987; Brullo & Spampinato, 1990; Brullo et al., 1994; Brullo & Sciandrello, 2006; Scian-
In previous contributions, we highlighted the importance of Aquila Lake for the conservation of the flora and marsh habitats (Cannavò et al., 2008). In fact, many anthropic sources of disturbance threaten the equilibrium of the lake.

In this paper, we present the results of a phytosociological survey of the lake vegetation, based on numerical analyses. The aim of this work is to improve knowledge on a valuable wet ecosystem in order to emphasize its peculiarity and conservation value and contribute preventing its realistic risk of loss.

**Materials and Methods**

**Study area**

The Aquila Lake is one of the few natural lakes in the Calabria Region, the only one in the Province of Reggio Calabria. It is located on the Tyrrenian side of Calabria, at an altitude of about 33 m a.s.l.; it has a perimeter of about 1.3 km and an area of 4.5 km² (Fig. 1). Some small tributaries with constant flow and small springs feed it. The lake has an emissary (Fosso dell’Aquila) that joins the Mesima River. The central area of the lake, about 4 m deep, is not very extensive compared to the rest of the lake, generally characterized by depths between 1 and 2 m. The surrounding hills, characterized by quaternary sedimentary formations (Pleistocene and neogenic), are 80-90 m high.

Climatic data from the Rosarno thermo-pluviometric station, the closest one to the lake, records 17.0°C as the mean annual temperature and 917 mm as the mean annual rainfall in the period 1970-2000.

According to the bioclimatic classification of Rivas-Martínez (1996-2009) the area belongs to the “Mediterranean Pluviseasonal-Oceanic” Macrobioclimate with low mesomediterranean termotype and subhumid ombrotype (Fig. 2).

The lake is what remains of an extensive and articulated marsh system existing until the early 20th century, almost completely disappeared to date, due to land reclamation activities (Spampinato et al., 2007). The land around the lake is intensely cultivated with various types of crops, mainly woody and irrigated, such as orchards (e.g. citrus fruits).

The Waters Thematic Service of the Provincial Department ARPA CAL of Reggio Calabria (Italy) carried out chemical and physical analyses of water (Tab. 1). They show a neutral pH, on average 7.65 (spring) + 7.50 (summer), with values closer to the neutrality at the centre of the lake (7.20-7.50), tending slightly to alkaline near the outlets of the small tributaries (7.50-7.90). The dissolved oxygen has a seasonal trend,
with under-saturation values (75-50%) in depth, until it reaches anoxia in the summer period and values higher than the saturation on the surface in the spring period, in correspondence with the maximum photosynthetic activity of the hydrophytes. Conductivity has considerable differences in the various sample points: higher values in the centre (922-924 μS/cm) probably due to the effects of greater evaporation, while lower (885-887 μS/cm) in other parts, due to dilution of the waters by the tributaries. This trend is maintained even in the summer period with values higher than the spring period and between 917÷1022 μS/cm.

In addition, manganese has a relevant seasonal trend: in the spring, concentrations in the central area of the lake reach maximum values of 110 μg/l in the summer period, they reach maximum values of 1072 μg/l in the deep sample. It is well known that manganese is, as a trace element, in the chlorophyll of the hydrophytes and its increase appears particularly significant precisely in conjunction with their summer decomposition. Overall, the waters are meso-eutrophic, rich in calcium sulfate in the spring and calcium bicarbonate in the summer. Similarly to many Mediterranean lakes, the Aquila Lake is a warm monomictic type, with a thermal stratification and a single period of full circulation at the end of winter, followed by a progressive stratification with maximum gradient in summer (Lewis, 1983).

### Data collection and analysis

The vegetation study is based exclusively on original data and follows the plant sociological method of Braun-Blanquet (1964). According to innovative concepts specified by Biondi (2011) and Pott (2011), much more importance has been given to the minimum surface of the relevés in the vegetation survey, to avoid detecting ecotones and mosaics, frequent in these vegetation types. We consider the phytosociological approach, as a useful tool for the management of natural resources, in accordance with several authors (Brullo et al., 1999; Cano et al., 2017; Mendes et al., 2015; Piñar Fuentes et al., 2017; Pott, 2011; Quinto-Canas et al., 2018a, 2018b; Spampinato et al., 2018; Vila-Viçosa et al., 2015). The fieldwork was carried out during the period 2014-2018. Overall, 86 relevés have been performed.

Nomenclature of native vascular species follows Bartolucci et al. (2018), while the alien taxa are reported in accordance with Galasso et al. (2018).

Considering the relatively scarce internal heterogeneity of wet meadows, megahorbes vegetation, shrubby communities, riparian and mesophyous woods, they have been separated without applying statistic analyses, mostly based on physiognomy and dominant species. Due to the high diversity of aquatic and marsh vegetation, a separate hierarchical Cluster Analysis of the relevés of these two macrotypes only has been performed (Linkage: Ward's method; Distance measure: Euclidean) using PC-ORD 6 software. To this purpose, the original Braun-Blanquet scale was transformed into the ordinal scale according to Van der Maarel (1979). The subsequent arrangement in tables allowed the identification of the plant communities, that were then framed according to the phytosociological syntaxonomic system. The nomenclature of the higher rank syntaxa (Classes, Orders and Alliances) is in accordance with the Prodrome of Italian Vegetation (Biondi & Blasi, 2015).

### Results and discussion

The dendrogram deriving from the cluster analysis of the relevés of aquatic vegetation allowed the identification of five plant communities belonging to Lemneta minoris and Potameta pectinati classes (Fig. 3). The cluster analysis of the marsh vegetation (Fig. 4) points
out seven groups of relevés that can be referred to well defined plant communities belonging to Phragmitetalia australis and Magnocaricetalia elatae. In the latter analysis, the most isolated group of relevés should be ascribed to the Cypero longi-Caricetum otrubae, whose syntaxonomic location in the Phragmitio australis-Magnocariceteta elatae class is the subject of different opinions as will be discussed later. The dendrogram highlights the intermediate position of the Cladietum marisci among the communities of the orders Phragmitetalia australis and Magnocaricetalia.

Overall, according to the results of the cluster analysis and to investigated literature, the Aquila Lake vegetation includes 8 classes and 23 plant communities reported in the syntaxonomic scheme.

**Floating aquatic vegetation**

*Lemnetea minoris* Tüxen ex O. Bolós & Masclans 1955 Tab.2

The most widespread floating aquatic vegetation is the *Lemnetum minoris* that covers the greatest surfaces in the lake (Tab. 2, rels. 3-4). *Lemna minor* is a pleustophyte with a wide ecological amplitude, behaving as a pioneer and able to adapt to strong variations in environmental parameters, with particular regard to the water level and degree of trophy (Sburlino et al., 2004), colonizing both ephemeral environments, such as temporary ponds, and permanent water bodies. In the surveyed community *Lemna minuta* also occurs, an alien species recently reported and rapidly expanding in Italy, adapted to waters rich in nutrients and poorly oxygenated (Ceschin et al., 2018; Musarella et al., 2019).

More localized is the *Lemno minoris-Spirodeletum polyrhizae* (Tab. 2, rels. 1-2), due to changes in the water level that lead to variations in the degree of water trophy. This phytocoenoses is characterized by *Spirodea polyrhiza*, a very rare floating hydrophyte in Calabria. This community occurs in the marginal parts of the marsh vegetation of the lake, in areas with limited anthropic disturbance, with still and non-shaded waters.

Finally, *Lemno minoris-Hydrocharitetum morsus-ranae* (Tab. 2, rels. 5-7), a pleustophytic paucispecific community, characterized by the dominance of *Hydrocharis morsus-ranae*, recently reported in wet habitats of Calabria by Bartolucci et al. (2019). In the Aquila Lake, this vegetation is rare and localized in a loop,
in correspondence of the introduction of water coming from a source. This phytocoenosis prefers stagnant or slow-flowing waters, subject to summer heating but not to desiccation. It settles on organic or mineral substrates with mesotrophic to eutrophic, non-shaded waters (Passarge, 1996) having few suspended sediments.

**Macrophytic Aquatic vegetation**

*(Potametalia pectinati Klika in Klika & Novák 1941)*

Tab. 3
Most of the lake surface is occupied by *Nymphaeetum albae* (Tab. 3, rels. 1-3), association characterized by rooting hydrophytes with floating leaves (nimpheids), settled on silt-clay sediments rich in organic substance, about 1-2 m deep, in mesotrophic to eutrophic lakes (Sumberová, 2011). The detected stands are poor in species, or even monospecific with the dominance of *Nymphaea alba*, which prefers banks with standing waters, as it is sensitive to the movements of the waves. Communities with *Nymphaea alba*, very rare in southern Italy, are reported for central and northern Italy (Lastrucci et al., 2017).

In the central part of the lake, up to 4 m deep, the association *Ceratophylletum demersi* has been detected (Tab. 3, rels. 4-7), a submerged, floating, non-rooted macrophyte community, known in Calabria for the mouth of the Crat River (Maiorca et al., 2007), common in the lowland and hilly areas of Europe (Lastrucci et al., 2014). *Ceratophyllum demersum* is a pleustophyte that sporadically is associated with rooting hydrophytes (rhizophytes), including *Potamogeton trichoides*. *Ceratophyllum demersum* tolerates water anoxia conditions in summer and strong variations in ecological parameters. It is found in eutrophic lakes due to natural or anthropic causes (Rodwell, 1995), adapting to the shaded conditions due to the floating aquatic vegetation or to the surrounding tree cover (Best & Van Der Werf, 1986).

**Perennial helophytic marsh vegetation**

*(Phragmitetalia australis-Magnocaricetalia elatae Klika in Klika & Novák 1941)*

Tab. 4
Along the shores of the Aquila Lake, wetland vegetation dominated by tall helophytes is well developed. According to Landucci et al. (2013), this vegetation includes various phytocoenoses, arranged in specific patterns related to the submersion period and the degree of water trophic content.

**Reed swamps and other tall helophyte vegetation**

*(Phragmitetalia australis W. Koch 1926)* Tab. 4
The most widespread marsh vegetation occurring along the shores of the lake is represented by the reed-beds dominated by *Phragmites australis*, a species with a wide ecological value. The reeds at the Aquila lake are attributable to *Polygono salicifolii-Phragmitetum australis*, a phytocoenosis linked to fresh waters, characterized by *Persicaria decipiens* (= *Polygonum salicifolium*), *Iris pseudacorus*, *Galium elongatum*, and other strictly freshwater marsh species (Tab. 4, rels. 1-8). This phytocoenosis is adapted to even considerable oscillations in the water level and its chemical and physical parameters. It is known for various localities of Sicily (Pavone et al., 2007) and Calabria (Maiorca et al., 2007).

In the deeper stretches the *Polygono salicifolii-Phragmitetum communis* is replaced by the Schoenoplectetum lacustris settled in calm, eutrophic waters.
more than 30 cm deep on muddy or sandy bottoms, generally with little organic sediment (Lastrucci et al., 2014). Along the inner side of the lake, the *Schoenoplectetum lacustris* (Tab. 4, rels. 11-16) makes contact with the macrophytic vegetation of the *Nimphaeetum albae*.

In more disturbed areas of the banks, due to plant residues accumulation, as well as in the drainage channels of the cultivated areas adjacent to the lake, the *Typhetum latifoliae* grows (Tab. 4, rels. 9-10), a plant community linked to marsh habitats impacted by anthropic action with soils and waters rich in nutrients.

**TALL SEDGES MARSH VEGETATION**

*(Magnocaricetalia Pignatti 1953)* Tab. 5

In the outermost belt of the marsh vegetation, submerged only in the winter period during the maximum lake filling, the high sedges vegetation occurs. Currently, this vegetation is fragmented due to anthropic pressures, such as drainage and modification of banks, related to the increasing of cultivated areas. Variations in groundwater level and flooding time influence the presence of different phytocoenoses.

In the innermost part of the sedges belt the *Caricetum acutiformis* grows (Tab. 5, rels. 1-8), characterized by the dominance of *Carex acutiformis*, a species 1.4-1.6 m high, which demands soils affected by superficial groundwater even in summer.

To the outside, this community makes direct contact with the *Caricetum ripariae* (Tab. 5, rels. 9-13), growing on soils flooded for a shorter period.

A floating bed of *Cladietum marisci* (Tab. 5, rels. 16-21) occupies the west margin of the lake. *Cladium mariscus* develops its rhizomes on the waters of the
lake and forms a dense floating bed, poor in species. Among the few species present, *Thelypteris palastris* can be mentioned, known in Calabria only for this locality (Crisafulli et al., 2010). This rare fern, typical of the swampy *Alnus glutinosa* woods (Biondi & Blasi, 2015), is also known for occurring in *Cladidietum marisci* stands (Namura-Ochalska, 2005), as well as in other marsh associations, such as the *Thelypterido palastris-Phragmitetalia australis* (Lastucci et al., 2014). In the coastal lagoons of the Mediterranean basin, *Cladium mariscus* characterizes subalgalic communities, such as the *Soncho-Cladidietum marisci* (Br.-Bl. & O. Bolós 1957) Ciruiano 1980, reported in Sicily (Pavone et al., 2007) and in Apulia (Di Pietro et al., 2009). As highlighted also by the classification of the relevés, *Cladium mariscus* is a plant community with intermediate floristic characteristics between the orders *Magnocariceta* and *Phragmiteta*.

In the most elevated range of the sedge vegetation, the *Cypero-Caricetum cuprinus* (= *Cypero-Caricetum ortsrae* Tüxen in Tüxen & Oberdorfer 1958) occurs (Tab. 5, rels. 14-15). The syntaxonomic position of this association is not unanimous. Some authors place it in the alliance *Magnocaricion elatae* of the *Phragmito australis-Magnocariceta elatae* class (Venanzoni et al., 2018), others in the alliance *Mentho longifoliae-Juncion inflexi* Müller & Görs ex de Foucault 2008 of the *Agrostietea stoloniferae* Oberdorfer 1983 class (Lastucci et al., 2014). In fact, the cluster analysis (Fig. 4) separates this community from other sedges coenoses, showing an intermediate position between the marsh vegetation and the wet meadows.
Marsh vegetation of well-oxygenated flowing freshwater

(Nasturtio officinalis-Glycerietalia fluitantis) Tab. 6

In the lake’s small tributaries fed by perennial springs
the Helosciadietum nodiflori is present, a plant
community linked to shallow, well oxygenated running
waters, sunny and constant throughout the year (Tab.
6, rels. 3-4). This plant community is characterized by
the dominance of Helosciadium nodiflorum, normally
associated with a few other hydrophytes as Veronica
anagallis-aquatica.

In the loops of the lake with low-flowing waters due
small tributaries, the Sparganietum erecti has been
detected, a helophytic community growing in 50-70
cm deep water, characterized by the dominance of
Sparganium erectum, associated with Phragmites aus-
tralis and a few other helophytes (Tab. 6, rels. 1-2).

Wet meadow vegetation

(Molinio-Arrhenatheretalia Tüxen 1937) Tab. 7

The vegetation of the wet meadows settled on moist
soils outside the marshes of the surveyed area is very
disturbed and fragmented by agricultural activities and
pasturage. Some phytocoenoses can be identified as
Cirsio triumfetti-Eupatorietum cannabini (Tab. 7, rels.
3-4) on more humid stands, which take advantage of
the accumulation of organic materials, and Alopecurus
myosuroides community (Tab. 7, rels. 5-6) growing in
the most external surfaces on flat muddy-clayey soils,
periodically flooded and grazed. Finally, a community
with Althaea officinalis occurs in the more disturbed
sites (Tab. 7, rels. 1-2).

Tab. 6 - Phragmito australis-Magnocaricetalia elatae, Na-
surtio officinalis-Glyceretalia fluitantis. Se - Sparganietum
Rel. 3-4: 26-07-2013.

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<td>100</td>
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<th>Veronica anagallis-aquatica L.</th>
<th>Persicaria decipiens (R. Br.) K.L. Wilson</th>
<th>Phragmites australis (Cav.) Trin. ex Steud.</th>
<th>subsp. australis</th>
<th>Other species</th>
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Tab. 7 - Molinio-Arrhenatheretalia. Ao: Althaea officinalis
community, CE: Cirsio triumfetti-Eupatorietum cannabini,
Am: Alopecurus myosuroides community. Rel. 1-2: 26-07-
2013; Rel. 3-4: 12-09-2013; Rel. 5-6: 13-06-2014.

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<th>Cirsium arvense (L.) d'Urv.</th>
<th>subsp. triumfetti (Lacaita) K. Werner</th>
<th>Alopecurus myosuroides subsp. cannabinum</th>
<th>Althaea officinalis L.</th>
<th>Cirsium arvense (L.) d'Urv.</th>
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Hygro-nitrophilous, megahorbs vegetation

(Filipendulo ulmariae-Convolvuletea sepium Géhu &
Géhu-Franck 1987) Tab. 8

In areas heavily disturbed such as lake banks and
canals, Arundo donax communities occur, attribu-
table to the Calystegio silvaticae-Arundinietum donacis
(Tab. 8), a hygro-nitrophilous association described
by Brullo et al. (2001) for southern Calabria. Arun-
do donax is an alien invasive species (Galasso et al.
2018) introduced long time ago throughout the Medi-
terranean. This vegetation, known in other regions too,
replaces the wet meadow and marsh vegetation. It is a thermophylo us vicariant of the Arundini-Convolvuletum sepium, a community widely distributed in the Euro-Mediterranean territories (Giusso del Galdo et al., 2008).

**Riparian woods**

*(Salici purpureae-Populetea nigrae Rivas-Martinez & Cantó ex Rivas-Martinez, et al. 2001)* Tab. 9

The riparian and lowland woods, which probably covered the shores of the lake in former times, are nowadays reduced to small patches as a result of land use changes due to agriculture and plantation of hybrid poplars (*Populus x canadensis*), realized some decades ago on the western shore of the lake (Tab. 9, rels. 9-11).

Only very limited patches remain, on the right bank of the lake, characterized by the dominance of *Alnus glutinosa* (Tab. 9, rel. 5), to which other hygrophilous species are associated, including the very rare *Iris foetidissima*, a typical species of these habitats (Brullo & Spampinato, 1997).

High-shrub willows of *Salicetum albo-brutiae* form small patches in the northern part of the lake (Tab. 9, rels. 1-4). It is a pioneer plant community characterized by the codominance of *Salix alba* and *Salix brutia*, spread along the waterways of the region (Brullo & Spampinato, 1997).

Small patches or dense hedgerows of *Ulmus minor*, referable to the *Aro italic-i-Ulmetum minoris*, are still present on sandy or muddy soils in the most external parts of the lake zonation, occasionally flooded but provided with water reserves for most of the year (Tab. 9, rels. 6-8).

**Shrubby communities**

*(Rhamno catharticae-Prunetea spinosae Rivas Goday & Borja ex Tüxen 1962)* Tab. 10

In more elevated positions of the lake shores, shrub communities dominated by deciduous species such as *Cornus sanguinea* and *Rubus ulmifolius* occur. They are secondary formations originating from the riparian wood's degradation.

**Mesophylo us woods**

*(Querco roboris-Fagetea sylvaticae)* Tab. 11

Despite the surrounding land being very degraded by anthropic pressures, residual patches of mesophylo us woods grow on the northern hillside slopes. The tree layer is structured by species of particular value because they live at the limit of their distribution range, such as *Tilia platyphyllos* subsp. *psedorubra* and *Quercus robur* subsp. *brutia*. To date, this latter species was not known for the province of Reggio Calabria and it is very rare in the region, growing in residual planitlal forest of the *Alno-Quercion roboris* (Brullo & Spampinato, 1999). The nemoral flora is rich in species normally found in the mountain belt, such as *Helleborus boccone* subsp. *intermedius*, *Lathyrus venetus*, *Euphorbia mesclili*. In the past, these formations were certainly much more articulated and diversified in various plant communities, according to topographical and edaphic characteristics. The current situation, in which only two patches are present, makes their phytosociological classification very difficult and, at the moment, still uncertain.

**Habits of conservation interest**

The European Directive 92/43/EEC (Habitat Directive) is one of the main regulatory instruments for the conservation of biodiversity in Europe. The main goal of this Directive is the conservation of species and habitats of community interest through the Natura 2000 ecological network. Habitats listed in Annex I are identified mainly on a phytosociological basis (Biondi et al., 2009, 2012). Therefore, the phytosociological study of vegetation is necessary to diagnose and assess the habitats of Annex I and plan the management of natural resources (Gigante et al., 2016, 2018; Zivkovic et al., 2017).

Based on Biondi et al. (2009), this study allowed the identification of four Annex I habitats at Lake Aquila. They are reported as follows and related to the analysed plant communities:

- 3150: Natural eutrophic lakes with *Magnopatamion* or *Hydrocharition-type vegetation* (*Lemnetetum minoris* Oberdorfer ex Müller & Görs 1960; *Lemno-Spirodeletum polyrhizae* Koch 1954; *Lemno minoris-Hydrocharitetum morsus-ranae* Passarge 1978;
Tab. 9 - Salici purpureae-Populetea nigrae. Sa: Salicetum albo-brutiae; Ag: Alnus glutinosa community; AU: Aro italic-i-Ulmetum minoris; Pp: Poplar plantations. Rel. 1: 22-05-2008; Rel. 2: 27-06-2008; Rel. 3-4: 12-09-2013; Rel. 5: 13-06-2014; Rel. 6-7: 12-09-2013; Rel. 8: 30-04-2014; Rel. 9-10: 22-05-2008; Rel. 11: 13-06-2014.

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| Other species           |   |   |   |   |   | + |   |   |   |
| Arisarum vulgare O. Targ.Tozz. |   |   |   |   |   |   |   |   |   |
| Arundo donax L.         |   |   |   | 2 | 1 |   |   |   |   |
| Asparagus acutifolius L. |   |   | 1 | + | 1 |   |   |   |   |
| Bryonia dioica Jacq.    |   |   | 2 |   |   |   |   |   |   |
| Carex riparia Curtis    |   |   | 1 |   |   |   |   |   |   |
| Cirsium ereticum (Lam.) d'Urv. |   |   |   |   | 1 |   |   |   |   |
| subsp. triumfetti (Lacaia) K. Werner |   |   | 1 |   |   |   |   |   |   |
| Convululus silvaticus Kit. | 1 |   |   |   |   |   |   |   |   |
| Daucus carota L. subsp. carota |   |   |   |   | 1 |   |   |   |   |
| Equisetum palustre L.   | 2 |   |   |   |   |   |   |   |   |
| Euonymus europaeus L.   |   |   | 1 |   |   |   |   |   |   |
| Eupatorium cannabinum L. subsp. cannabinum | 1 |   |   |   |   |   |   |   |   |
| Foeniculum vulgare Mill. subsp. piperitum (Ucria) Bég. |   | 1 |   |   |   |   |   |   |   |
| Fraxinus ornus L.        |   |   | 2 |   |   |   |   |   |   |
| Lotus rectus L.          | 1 |   |   |   |   |   |   |   |   |
| Myrtus communis L.       |   |   | 1 |   |   |   |   |   |   |
| Persicaria decipiens (R. Br.) K.L. Wilson |   |   | 1 |   |   |   |   |   |   |
| Phragmites australis (Cav.) Trim. ex Steud. subsp. australis | 3 | 2 | 1 | 1 | 1 | 1 | 1 |   |   |
| Pteridium aquilinum (L.) Kuhn |   |   |   |   | 1 |   |   |   |   |
| Robinia pseudoacacia L.  |   |   | 2 |   |   |   |   |   |   |
| Rosa sempervirens L.     |   |   | 2 | 1 | 1 |   |   |   |   |
| Rubia peregrina L.       |   |   | 1 | 3 |   |   |   |   |   |
| Rubus ulmifolius Schott  |   |   |   | 2 | 2 |   |   |   |   |
| Smilax aspera L.         |   | 1 |   |   |   |   |   |   |   |
| Urtica dioica L.         |   |   | 1 |   |   |   |   |   |   |
| Verbena officinalis L.   |   |   |   | 1 |   |   |   |   |   |

| Number of species        | 10 | 5 | 7 | 4 | 8 | 13 | 8 | 10 | 8 |


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<tr>
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<tr>
<td>Total cover (%)</td>
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Characteristic species
Rubus ulmifolius Schott
Convulvulus silvaticus Kit.
Clematis vitalba L.
Arundo collina Turra
Cornus sanguinea L.
Ficus carica L.
Galium aparine L.
Solana dulcamara L.
Equisetum telmateia Ehrh.
Eupatorium cannabinum L. subsp. cannabinum
Hypericum hircinum L. subsp. majus
(P) N. Robson
Persicaria decipiens (R. Br.) K.L. Wilson
Phytolaca americana L.
Pteridium aquilinum (L.) Kuhn
Quercus virgiliana (Ten.) Ten. (a)
Raphanus raphanistrum L. subsp. landra
(Moretti ex DC.) Bonnier & Layens
Rosa sempervirens L.
Silene latifolia Poir.

Number of species | 7 | 6 | 6

Among these, the priority habitat 7210* (Calcareous fens with Cladium mariscus and species of the Caricion davallianae) has particular importance, being very rare in the Mediterranean bioregion and present in Calabria only in another site (Maiorca et al., 2002).

Conclusions

Despite many anthropogenic pressures, the Aquila Lake harbours aquatic and marsh plant communities rather rare in the Mediterranean bioregion, such as the macrophytic vegetation of Nymphaetum albae, the floating aquatic vegetation of Lemno minoris-Hydrocharitetum morsus-ranae and the tall sedges marsh vegetation of Cladium marisci, all acknowledged as Annex I habitats deserving conservation efforts. The lake is a refuge site for many taxa with a northern distribution that disappeared from the surrounding territories, due to climate change and reclamation activities carried out in the last centuries, such as Thelypteris palustris, Cladium mariscus, Schoenoplectus lacustris, Hydrocharis morsus-ranae, Nymphaea alba subsp. alba and Quercus robor subsp. brutia.

The rarity of these species and habitats suggests the need of proper management guidelines aimed at the protection and conservation of the biotope, both through the maintenance of existing natural features and by operating with environmental restoration activities on degraded stretches through specific projects.

The Aquila Lake has not yet been included neither in any list of protected areas nor in sites of significant naturalistic or environmental importance. This study fills a knowledge gap to carry out forms of protection in this fragile and valuable biotope, threatened by agro-pastoral activities in the surrounding territory.

The most serious threat to aquatic and marsh habitats


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<td>Total cover (%)</td>
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<tr>
<td>Cover Tree layer (A) (%)</td>
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<tr>
<td>Cover Scrub layer (a) (%)</td>
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<tr>
<td>Cover Herb layer (c) (%)</td>
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<td>60</td>
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<td>Slope (%)</td>
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<td>Exposition</td>
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Characteristic species
Ostrya carpinifolia Scop.
Acer opalus Mill. subsp. obtusatum
Quercus robor L. subsp. brutia (Ten.) O. Schwarz
Cornus sanguinea L.
Fraxinus ornus L. subsp. ornus
Vina major L.
Helleborus viridis L. subsp. bocconei (Ten.) Peruzzi
Hedera helix L. (A)
Hedera helix L. (e)
Brachypodium sylvaticum (Huds.) P. Beauv.
Lathyrus venetus (Mill.) Wohlf.
Ulmus minor Mill.
Viola alba Besser subsp. delnhardtii (Ten.) W. Becker
Euphorbia muelschii Geltman
Polythichium setiferum (Forsk.) T. Moore ex Woy.
Tilla platyphyllos Scop. subsp. pseudorubra C.K. Schneid.
Castanea sativa Mill.
Symphytum bulbosum K.F. Schimp.
Drymoehlcyra drymeja (Mert. & W.D.J. Koch) Holub
Festuca heterophylla Lam.
Acer campestre L.

Other species
Rubia peregrina L.
Asparagus acutifolius L.
Clematis vitalba L.
Cytisus villosus Pourr.
Craetaegus monogyna Jacq.
Chamaeiris foetidissima (L.) Medik.
Luzula forsteri (Sm.) DC.
Pteridium aquilinum (L.) Kuhn
Quercus ilex L.
Rosa sempervirens L.
Rubus ulmifolius Schott
Simalax aspera L.
Asplenium onopteris L.
Aegionychon purpuracencualeum (L.) Holub
Cyclamen hederifolium Aiton
Carex distachya Desf.
Arundo plinii Turra
Hedera helix L.
Clematis vitalba L.
Asplenium onopteris L.
Aegionychon purpuracencualeum (L.) Holub
Cyclamen hederifolium Aiton
Carex distachya Desf.
Arundo plinii Turra
Hedera helix L.
Clematis vitalba L.
Asplenium onopteris L.
Aegionychon purpuracencualeum (L.) Holub
Cyclamen hederifolium Aiton
Carex distachya Desf.
is the terrestrialization processes, which over time has reduced the lake surface to the advantage of cultivated areas. In addition, the run-off of fertilizers, pesticides and herbicides that could pollute the aquifer has negative consequences on species and habitats linked to the wetland, more susceptible to the effects of pollutants.

According to Quinto-Canas et al. (2018b), in order to maintain a good level of biodiversity, it is necessary to reduce the use of herbicides and fertilizers, to avoid soil mobilization and to control or eradicate non-native plants. The last ones often grow mixed with the native ones and can replace them (Musarella, 2019).

Floristic and palynologic studies, but also the toponymy and archaeological evidence (Russo et al., 2018, Spampinato et al., 2007; 2017), highlight that the landscape of the lowland area of Calabria in the Holocene has been strongly modified by human activities. A drastic reduction of floodplain forests and wetland, up to their disappearance, due to the expanding of agricultural and settlement areas. The few relict wetland areas in the lowland, therefore, have high importance for biodiversity conservation.

Due to the importance of this peculiar biotope, we consider that specific conservation measures need to be taken in order to preserve its flora and vegetation. These conservation measures should also take into account bio-climatological features, because only considering bioclimate, it is possible to guarantee a correct management of biodiversity (Cano-Ortiz et al., 2015a, b; Cano et al., 2019).

Acknowledgements

We are very grateful to Dr. Giovanna Belmusto and Dr. Letteria Settineri of the Waters Thematic Service of the Provincial Department ARPACAL of Reggio Calabria (Italy) to have carried out the sampling and for the chemical and physical analysis of the lake waters.

Syntaxonomic scheme

LEMNETEA MINORIS Tüxen ex O. Bolòs & Masclans 1955
LEMNITALIA MINORIS Tüxen ex O. Bolòs & Masclans 1955
Lemnion minoris Tüxen ex O. Bolòs & Masclans 1955
Lemnetum minoris Oberdorfer ex Müller & Görs 1960
Lemno minoris-Spirodeletum polyrhizeae Koch 1954
Lemno minoris-Hydrocharition morsus-ranae Rivas-Martinez, Fernández-Gonzáles et Loidi 1999
Lemno minoris-Hydrocharitetum morsus-ranae Passarge 1978

POTAMETEA PECTINATI Klika in Klika & Novák 1941
POTAMETALIA PECTINATI W. Koch 1926
Nymphaetum albae Oberdorfer 1957
Nymphaetum albae Vollmar 1947 em. Oberd. in Oberd. et al. 1967
UTRICULARIETALIA Den Hartog & Segal 1964
Ceratophyllion demersi Den Hartog & Segal ex Passarge 1996
Ceratophylletum demersi Hild 1956

PHRAGMITO AUSTRALIS-MAGNOCARICETEA ELATAE Klika in Klika & Novák 1941
PHRAGMITETALIA AUSTRALIS W. Koch 1926
Phragmition australis W. Koch 1926
Polygono salicifolii-Phragmitetum australis Barbagallo, Brullo et Furnari 1979
Typhetum latifoliae Nowinski 1930
Schoenoplectetum lacustris Chouard 1924

MAGNOCARICETALIA ELATAE Pignatti 1954

Magnocaricion elatae Koch 1926
Cladetum marisci Allorge 1921
Caricetum acutiformis Eggler 1933
Caricetum ripariae Mâthé et Kovâcs 1959
Cypero-Caricetum cuprinae Tüxen & Oberdorfer ex T.E. Diaz 1975
NASTURTIO OFFICINALIS-GLYCERIETALIA FLITANTIS Pignatti 1953
Glycerio fluitantis-Sparganion neglecti Br.-Bl. et Sissingh in Boer 1942
Sparganietum erecti Philippi 1973
Apion nodiflori Segal in Westhoff et Den Held 1969
Helosciadietum nodiflori Maire 1924

MOLINIO-ARRHENATHERETEA Tüxen 1937

PLANTAGINETALIA MAJORIS Tüxen ex Von Rochow 1951

Lolio perennis-Plantaginion majoris Sissingh 1969
Cirsio triumfettii-Eupatorietum cannabini Brullo et Spampinato 1990

Community of Alopecurus aequalis

FILIPENDULO ULMARIAE-CONVOLVULETAE SEPIUM Gêhu & Gêhu-Franck 1987

Calystegion sepium Tüxen ex Oberdorfer 1957 nom. mut. propos. Rivas-Martínez et al. 2002
Calystegio silvaticae-Arundinetum donacis Brullo, Scelsi et Spampinato 2001

Community of Althaea officinalis

SALICI PURPUREAE-POPULETAE NIGRAE Rivas-Martínez & Cantó ex Rivas-Martínez, et al. 2001

POPULETALIA ALBAE Br.-Bl. ex Tchou 1948

Populion albae Br.-Bl. ex Tchou 1948
Community of Alnus glutinosa

Aro italici-Ulmetum minoris Rivas-Martinez ex López 1976
SALICETALIA PURPUREAE Moor 1958

Salicion albae Soó 1930
Salicetum albo-brutiae Brullo & Spampinato 1997

RHAMNO CATHARTICAE-PRUNETEA SPINOSAE Rivas Goday & Borja ex Tüxen 1962
PYRO SPINOSAE-RUBETALIA ULMIFOLII Biondi, Blasi & Casavecchia in Biondi et al. 2014

Pruno spinosae-Rubion ulmifolii O. Bolòs 1954
Rubus ulmifolius community

QUERCO ROBORIS-FAGETEA SYLVATICAE Br.-Bl. & Vlieger in Vlieger 1937

Quercion pubescenti-petraeae Br.-Bl. 1932
Tilio pseudorubrae-Ostryion carpinifoliae S. Brullo et al. 2001

Quercus robur subsp. brutia community

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G. Spampinato et al.

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Giusso del Galdo G., Marcenò C., Musarella C.M. & Sciadrello S., 2008. La vegetazione costiera della R.N.O. “Torre Salsa” (Siculiana - AG). Italian Botan-
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