Contribution to the knowledge of Mediterranean wetland vegetation: *Lemnetea* and *Potamogetonetea* classes in Western Sicily

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Abstract

The freshwater aquatic vegetation of the *Lemnetea* and *Potamogetonetea* classes in Western Sicily was surveyed and analyzed. 85 lakes and small pools were investigated collecting 147 phytosociological unpublished relevés to integrate the very scarce available data (only 3 relevés). By applying statistical analyses on abundances data and on the bases of physiognomy and dominant species, two alliances (*Lemnion minoris* and *Stratiotion*) and four different coenoses have been identify for the *Lemnetea* class; while 11 associations, assigned to two orders (*Potamogetonetalia pectinati* and *Callitricho hamulatae-Ranunculetalia aquatilis*) and four alliances (*Potamogetonion*, *Nymphaeion albae*, *Ranunculion aquatilis* and *Ranunculion omiophyllo-hederacei*) have been recognized for the *Potamogetonetea* class. A new association (*Junco bufonii-Ranunculetum omiophylli* ass. nov.) and a new subassociation (*Ranunculetum peltati ranunculetosum rionii* subass. nov.) have been proposed, whereas other six vegetation units were found to be new for the study area (*Potamogetono-Ceratophylletum submersi*, *Potamogetonetum pusilli*, *Ranunculetum aquatilis*, *Ranunculetum peltati* and *Ranunculetum rionii*, *Lemno-Callitrichetum obtusangulae*). For all the coenoses recognized, new insights on the floristic composition, syntaxonomy, synphysiognomy, synecology and synchorology are reported, offering a reasoned overview of the aquatic vegetation of the western sector of the main Mediterranean island.

Keywords

aquatic vegetation, biological conservation, Mediterranean islands, phytosociology, plant community classification, Sicily, small standing-water ecosystem

Introduction

Inland small standing-water ecosystem act as prominent hotspots for biodiversity although they are globally threatened (Bolpagni et al. 2019). Reclamation, eutrophication, fragmentation, and alien species invasion along with the effects of climate change are just some of key threats affecting freshwaters and wetlands (Benavent-González et al. 2014; Angiolini et al. 2017; Reid et al. 2019). Indeed, freshwater biota, and macrophytes in particular, are counted among the biological components that are most at risk of extinction under Anthropocene conditions (Bolpagni et al. 2018; Dudgeon 2019). This is especially true for the Mediterranean islands which are the backbone of one of the most diverse biodiversity-rich areas worldwide (Cañadas et al. 2014).

To this respect, Sicily – the largest Mediterranean island – is a key case study due to the intrinsic rarity of humid habitats and macrophytes (Troia & Lansdown 2016; Minissale et al. 2017; Romanov et al. 2019). Inland small standing-water ecosystem are normally found in small depressions from the low hills to the mountainous areas...
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(Caldarella 2014), interspersed within different land use types (e.g., agricultural areas, pastures, prairies, garrigue, forest clearings, wooded environments). Furthermore, they are under the control of a multiplicity of local environmental (e.g., exposure, altitude, shading, surrounding vegetation, hydroperiod, water supply) and anthropogenic drivers (e.g., trampling, water withdrawals, reshaping of banks).

This kind of habitats has always generated interest from botanists. Indeed, in Sicily the wetland flora investigation dates back to the dawn of floristic research (Gussoni 1827-1828, 1842-1845; Lojacono-Pojero 1888-1909; Giardina et al. 2007). Despite this, the knowledge of wet vegetation, particularly the strictly aquatic one, remains scarce and fragmented, often limited to few contributions referring to single biotopes. Some examples of this are the “Gorghi Tondi” and the Preola Lake in the Trapani area (near Mazzara del Vallo; Suppl. material 2, Figure S2f) (Brullo and Ronsisvalle 1975), the wetlands of the “Bosco del Cappelliere” in the surroundings of Palermo (Gianguzzi and La Mantia 2004; Caldarella et al. 2013b; Caldarella 2014; Caldarella and Gianguzzi 2018), the lakes of Serradifalco and “Bosco” in the Caltanissetta area (Marcenò and Raimondo 1977), the “Gorghi” of Carcaci and Carcaciotto (Suppl. material 2, Figure S3a) on the Sicani Mountains (Gianguzzi et al. 2007), and the “Gorgo di Monte Cofano” (Gianguzzi and La Mantia 2009; Suppl. material 2, Figure S1e).

To fill this knowledge gap, the present work concerns the phytosociological survey on the aquatic coenoses of the Lemnetea and Potamogetonetea classes, carried out through numerous unpublished relevés, in addition to the scarce available data (only 3 relevés). The survey involved the most representative biotopes of the Western Sicily (85 different lakes and small freshwater ponds and pools), distributed from the coastal area to the mountain belt, spread over various geological formations and with different hydroperiods.

Materials and methods

Study area

The study area comprises the western sector of Sicily, including the provinces of Trapani, Palermo, Agrigento, and Caltanissetta (Figure 1). The target sites (85) embrace water bodies with different hydroperiods (permanent vs temporary), and origin (natural, semi-natural and artificial) (Suppl. material 1, Table S1).

From a biogeographical point of view, this area is part of the Italo-Tyrrhenian Province and of the Sicilian Subprovince (Brullo et al. 1995), encompassing the “Drepano-Panormitano” (Trapani, Palermo, Trabia and Sicani Mts), “Madonita” (Madonie Chain), and the “Agrigentino” (Chalky-sulphurous series of Sicily inlands; Musarella et al. 2018) districts, and various other intermediate (e.g., Bosco Granza, Rocca Busambra) or border (e.g., “Sciare of Mazara”, Carboj River and the Mandrarossa Stream catchments) areas.

Figure 1. The study area with distribution of investigated habitats (see Supplementary material 1: Table S1).
Most of studied biotopes fall within the Tyrrenian orographic ridge, characterized by limestone, limestone-dolomite, and dolomite substrates whose formation dates back to the Mesozoic to Tertiary periods. Moving from the Madonie Chain towards west, altitudes tend to decrease up to the Trapani Mts (from 1979 m a.s.l. of the Pizzo Carbonara to the 751 m a.s.l. of the Monte Erice), with internal peaks including the Rocca Busambra (1613 m a.s.l.) and the Sicani Mts with the Monte Cammarata (1578 m a.s.l.) (Figure 1). The Agrigento and Nisseno sectors are instead part of an evaporite complex which includes soils of the Chalky-sulphurous Formation of the upper Miocene (Musarella et al. 2018).

The study area is characterized by a Mediterranean macroclimate, with three different subtypes: xeric-oceanic, pluviseasonal-oceanic and Temperate/submediterranean (Rivas-Martínez 2004). As detailed by Gianguzzi et al. (2016), the following phytosociological syntaxonomic systems are in accordance with Mucina et al. (2016), with some references also to the “Vegetation Syndinamical analyses” (Theurillat et al. 2020).

The clusters of associations are closely overlapped each other at the upper levels, as many species are largely shared between relevés of the various communities investigated. This is mainly due to the strong spatial overlap of coenoses that tend to colonize thin concentric strips along the shoreline of the studied water bodies. Despite this, cluster fidelity is 97%, as only 4 relevés belonging to two clusters (10, Ramunculetum aquatilis, and 12 Lemno-Callitrichetum obtusangulae) have been subjectively classified exclusively based on physiognomy and dominant species.

1. LEMNETUM MINORIS von Soó 1927 (Tables 1 and 15)

**Diagnostic taxa (% constancy)** – *Lemna minor* L. (100%, dominant).

**Syntaxonomic note** – Concerning the communities dominated by *L. minor* L., several authors agree in identifying a basic unit with an “association value” (Géhu and Pedrotti 1992; Schratt 1993; Rivas-Martínez et al. 2001). However, other authors, including Müller (1977), Scoppola (1982), and Pott (1995), do not find the ground for the definition of a specific syntaxon due to the wide ecological and biogeographical values of this species (Sburlino et al. 2004). The *Lemnetum minoris* is rather common in Europe including the Mediterranean area (Ninot et al. 2000; Bruullo et al. 2002; Šumberová 2011a; Felzine 2012; Zervas et al. 2020). The dominant species develops in several habitat types, often forming mono-paucispecific stands (Maiorca et al. 2007; Sburlino et al. 2011a; Bolpagni and Piotti 2015; Spampinato et al. 2012; Zervas et al. 2020). The association can be found on marginal zone of coenoses that tend to colonize thin concentric strips along the shoreline of the studied water bodies. Despite this, cluster fidelity is 97%, as only 4 relevés belonging to two clusters (10, Ramunculetum aquatilis, and 12 Lemno-Callitrichetum obtusangulae) have been subjectively classified exclusively based on physiognomy and dominant species.

**Short description** – Acropleustophytic aquatic community dominated by *L. minor*, able to form more or less dense free-floating stands in temporary or permanent ponds, which hardly exceed 1.5 meters in depth. This community

Results and Discussion

The dendrogram obtained from the cluster analysis (Figure 2) allowed the identification of 4 plant communities belonging to the *Lemnetea* class (Table 15) and 11 to the *Potamogetonetea* class (Table 16), respectively, as detailed in the syntaxonomical scheme.

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is typical of sunny, stagnant water bodies, sheltered from the wind, and tends to interpenetrate with other aquatic coenoses. In the studied area, its growth optimum is in late spring, whereas it tends to regress in the presence of summer drying events, and stationing of livestock.

**Syndynamism** – Pioneer community which tends to be invasive, limiting the growth of submerged hydrophytes. At Gorgo Lungo (Godrano, PA) the association is in contact with the *Potamogetono-Ceratophylletum submersi* (Table 4).

**Bioclimate in Sicily** – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

**Synchorology** – *L. minor* is a subcosmopolitan species, with an oceanic climatic optimum, which is present in North America, Europe, Africa, and Western Asia (Landolt 1986). *L. minor* communities have a wide distribution and are quite widespread in continental Italy (Brullo et al. 2001; Sburlino et al. 2004) and large islands (Biondi and Bagella 2005). In Sicily, they were recognized on the Nebrodi and Sicani Mts (Brullo et al. 1994; Marino et al. 2005), and in the Trapani (Guarino and Pasta 2017) and Palermo (at Bosco Granza; Gristina and Marcenó 2009) surroundings.

**Local distribution** – In the study area, this association is quite rare; it was detected at the Bosco Ficuzza (Gorgo Lungo, Margiazzo del Vallone Arcere, Contrada Sovarita and Contrada Cannitello), and Bosco Granza at Bomes Lakes (Figure S3d) and Portella Granza.

2. **LEMNETUM GIBBAE** Miyawaki et J. Tüxen 1960 (Tables 2 and 15)

**Diagnostic taxa** (% constancy) – *Lemna gibba* L. (100%, dominant).

**Syntaxonomic note** – Due to the very poor and constant composition, the stands dominated by *L. gibba* L. are generally ascribed to the *Lemnetum gibbae* (Sburlino et al. 2004), typical of stagnating eutrophic to hypertrophic waters, often subjected to direct anthropic disturbance and/or pollution (Scoppola 1982; Ninot et al. 2000; Sburlino et al. 2004; Šumberová 2011a; Lastrucci et al. 2014).

**Short description** – Acropleustophytic aquatic association dominated by *L. gibba*. It forms dense free-floating populations, which tend to cover the entire surface of small ponds. This association is typical of weakly flowing environments, artificial basins, and ditches used for watering livestock, up to 150 cm deep, sunny and/or partially shaded. The association’s growth optimum is in late spring and it tolerates summer water stress conditions. Based on the present relevés, two distinct aspects have been described: one represented by monospecific or strictly paucispecific stands; and a second one characterized by a richer presence of hydrophytes, even if with very low cover values.

**Bioclimate in Sicily** – Mediterranean xeric-oceanic/Mediterranean pluviseasonal-oceanic (from infra-Mediterranean dry to meso-Mediterranean subhumid/humid).

**Syndynamism** – This association is a pioneering assemblage, sometimes able to act as invasive. Due to the
progressive eutrophication of waters with the advance of season (e.g., progressive concentration of solutes), in conjunction with higher summer water temperatures, it tends to locally replace the Lemnetum minoris of which can be considered as a seasonal vicariant.

**Synchorology** – This association is rather common in Italy and it was also largely reported for the Italian territory, including the Mediterranean regions (e.g., Maiorca et al. 2007, 2020; Minissale and Spampinato 1990; Sburlino et al. 2004). In Sicily it was recognized by several authors (Abbadessa et al. 2005; Marino et al. 2005; Giardina et al. 2007, 2020; Minissale and Spampinato 1990; Sburlino et al. 2004). In a phytosociological point of view, in Italy this species forms communities attributed at different associations such as Azollo filiculoidis-Lemnetum minuscolae (Banfi and Galasso 2010), locally considered as invasive in many other Italian regions (Galasso et al. 2018). From a phytosociological point of view, in Italy this species forms communities attributed at different associations such as Azollo filiculoidis-Lemnetum minuscolae (Felzines & Loiseau 1991 or Lemnetum minuto-gibbae) Liberman Cruz, Pedrotti & Venanzoni 1988, even if some authors consider these assemblages as a basal phytocoenon (Sburlino et al. 2004; Viciani et al. 2020 and references therein).

**Local distribution** – It is a rather rare association. It was found at the Bosco Ficuzza area (Case Cuttitta, Gorgo Cerro and Gorgo Lungo), at the Monte Palmeto near Carini (PA), and at the mouth of the Mandrarossa Stream along the Agrigento coast (Menfi, AG).

### Table 1. *Lemnetum minoris* von Soó 1927.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---------------|---|---|---|---|---|---|---|---|---|----|----|
| Altitude (m a.s.l.) | 827 | 827 | 530 | 530 | 776 | 908 | 863 |
| Plot size (m²) | 1.5 | 1.5 | 1.5 | 1 | 1.5 | 1.5 | 1.5 |
| Height of vegetation (cm) | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| N° species for relevé | 4 | 4 | 5 | 5 | 3 | 3 | 4 |
| Localities (see Suppl. material 1, Table S1) | 43 | 43 | 65 | 65 | 31 | 78 | 76 |

**Char. of association and upper units**

| I nat | *Lemna minor* L. |
|-------|------------------|
| G rhiz | Glyceria natans Chevall. |
| H scap | Mentha aquatica L. |
| I rad | Callitriche obtusangula Le Gall |
| I rad | Ranunculus rionii Lagger |
| Other species | |
| G rhiz | Elodea canadensis Michx. ex J. T. Ser. |

### Table 2. *Lemnetum gibbae* Miyawaki et J. Tüxen 1960.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---------------|---|---|---|---|---|---|---|---|---|----|----|
| Altitude (m a.s.l.) | 5248 | 248 | 615 | 615 | 464 | 472 | 890 | 890 | 738 | 738 |
| Plot size (m²) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Total cover (%) | 80 | 80 | 90 | 100 | 100 | 100 | 100 | 100 | 100 | 90 | 90 |
| Height of vegetation (cm) | 1 | 5 | 0.5 | 1 | 1 | 1 | 1 | 1 | 5 | 5 | 3 |
| N° species for relevé | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 5 | 5 | 3 |
| Localities (see Suppl. material 1, Table S1) | 79 | 82 | 82 | 30 | 30 | 81 | 4 | 37 | 37 | 72 | 72 |

**Char. of association**

| I nat | *Lemna gibba* L. |
|-------|------------------|
| G rhiz | Glyceria natans Chevall. |
| H scap | Mentha pulegium L. |

### 3. *LEMNA MINUTA* community (Tables 3 and 15)

**Diagnostic taxa (% constancy)** – *Lemna minuta* Kunth (100%, dominant).

**Syntaxonomic note** – *L. minuta* Kunth is an alien species native to the temperate and subtropical America (Banfi and Galasso 2010), locally considered as invasive as in many other Italian regions (Galasso et al. 2018). From a phytosociological point of view, in Italy this species forms communities attributed at different associations such as Azollo filiculoidis-Lemnetum minuscolae (Felzines & Loiseau 1991 or Lemnetum minuto-gibbae) Liberman Cruz, Pedrotti & Venanzoni 1988, even if some authors consider these assemblages as a basal phytocoenon (Sburlino et al. 2004; Viciani et al. 2020 and references therein).

**Short description** – Acropleustophytic aquatic community dominated by *L. minuta*. It is able to form dense free-floating populations that can spread rapidly and cover the entire surface of the colonized water bodies, with a growth optimum in spring. It occurs in shaded environments, even if it is well suited to conditions of high insolation, and hypereutrophy. Indeed, this association is
frequently found in artificial habitats, or deeply impacted water bodies, with depths up to 1.8 m. Our relevés show monophytic or very poor stands, showing an extremely impoverished aspect of the *Lemnetum minuto-gibbae* association. Within this community in the study area another alien species such as *Paspalum distichum* L. is frequently recorded.

**Bioclimatic region** – Mediterranean xeric-oceanic (thermo-Mediterranean dry/subhumid).

**Syndynamism** – *L. minuta* acts as a pioneering taxon, often becoming invasive.

**Synchorology** – In Northern and Central Italy (Sburlino et al. 2004; Ceschin et al. 2016), the species has shown a recently rapid spread. In southern Italy it has also started to spread by colonising lakes with high naturalness (Spampinato et al. 2019). Before the present work, the only reports for Sicily concerned two small ponds at the Monte Pellegrino, near Palermo (Marrone and Naselli Flores 2011).

**Local distribution** – It is a rather rare community; it was confirmed for the Monte Pellegrino at the Gorgo of Santa Rosalia (Suppl. material 2, Figure S1b) and Cozzo della Grattalora, and in the Trapani surroundings, near the city of Mazara del Vallo.

4. **POTAMOGETONO-CERATOPHYLLETUM SUBMERSI** Pop 1962 (Tables 4 and 15; Suppl. material 2, Figure S1c)

**Diagnostic taxa** (% constancy) – *Ceratophyllum submersum* L. (100%, dominant).

**Syntaxonomic note** – *C. submersum* L. is a very rare species, both in Sicily and in Italy in general (Lastrucci et al. 2019a). Due to the rarity of this species, only scarce phytosociological data are available, at least for Italy. According to the phytosociological databases LISY (Bracco et al. 2007) and VegItaly (Landucci et al. 2012), communities dominated by *C. submersum* have been reported only for few wetlands in Northern Italy (Gerold et al. 1979; Piccoli 1998; Pedrotti 2003). According to Šumberová (2011a), *C. submersum*-dominated communities can be attributed to the association *Potamogetono-Ceratophylletum submersi* Pop 1962 typical of shallow, well-isolated, and warm in summer ponds, with remarkable water level variations (see also Hrívnák 2002). The association can also include the presence of lemnids.

**Short description** – Submerged community with cera-tophyllid habit dominated by *C. submersum*. It is typical of shallow ponds, where the species tends to occupy the entire water body. It tolerates some degree of shading and can be favoured by the presence of a thin layer of floating pleustophytes (e.g., *Lemna minor* and *L. gibba*), as well as by a progressive seasonal eutrophication of waters and high summer temperatures. Its growth optimum is in late spring.

**Bioclimatic region** – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid).

**Syndynamism** – In the study area, the association is in close contact with the *Lemnetum minoris*, which it replac-

| Table 3. *Lemna minuta* community. |
|------------------------------------|
| Relevé number | 1 | 2 | 3 | 4 |
| Altitude (m a.s.l.) | 392 | 392 | 234 | 4 |
| Life | 2 | 2.5 | 1 | 1 |
| Form | 90 | 100 | 100 | 100 |
| Total cover (%) | 3 | 3 | 3 | 3 |
| N° species for relevé | 2 | 2 | 1 | 1 |
| Localities (see Suppl. mat. 1, Table S1) | 73 | 73 | 74 | 84 |

| Characteristic species | |
|------------------------|---|
| *L. minuta* Kunth | 5 | 5 | 5 | 5 | 4 |

| Other species | |
|---------------|---|
| *Paspalum distichum* L. | + | 1 | . | . | 2 |

| Table 4. *Potamogetono-Ceratophylletum submersi* Pop 1962. |
|----------------------------------------------------------|
| Relevé number | 1 | 2 | 3 | 4 |
| Altitude (m a.s.l.) | 890 | 890 | 890 | 890 |
| Life | 2 | 2.5 | 5 | 5 |
| Form | 90 | 100 | 100 | 100 |
| Total cover (%) | 4 | 4 | 70 | 80 |
| Height of vegetation (cm) | 7 | 5 | 6 | 7 |
| N° species for relevé | 37 | 37 | 37 | 37 |
| Localities (see Suppl. mat. 1, Table S1) | |

| Char. of association | |
|---------------------|---|
| *Ceratophyllum submersum* L. | 3 | 3 | 5 | 4 | 4 |

| Char. of upper units | |
|----------------------|---|
| *L. minuta* | 5 | 5 | 3 | 2 | 4 |
| *L. gibba* | + | + | + | + | 4 |

| *Potamogetonetum* units | |
|--------------------------|---|
| *Callitricha obtusangula* Le Gall | 1 | + | 2 | 1 | 4 |
| *Ranunculus aquatilis* L. | 1 | 1 | + | 1 | 4 |
| *Ranunculus rionii* Laggar | . | . | . | . | 1 |

| Other species | |
|---------------|---|
| *Alisma aequalis* Sobol. | 1 | + | + | 3 |
| *Glyceria notata* Chevall. | + | . | . | 1 |

5. **POTAMOGETONETUM NATANTIS** Hild 1959 (Tables 5 and 16; Suppl. material 2, Figure S1g)

**Diagnostic taxa** (% constancy) – *Potamogeton natans* L. (100%, dominant).

**Syntaxonomic note** – In Sicily, and in the Nebrodi Mountains in particular, *P. natans* L. was considered a characteristic species of two different associations: the *Utriculario-Potametum natantis* Raimondo, Marino & Schicchi 2011, that belongs to the order *Utricularietales* Den Hartog & Segal 1964 (Raimondo et al. 2011), and the *Polygono-Potametum natantis* Soó (1927 1964, as reported by Brullo et al. (1994). This latter appears as a rather complex vegetation type, with two different as-

es in the deeper sectors of the Gorgo Lungo pond, where this species tends to spread into the wettest sectors of the helophytic belts dominated by *Sparganium erectum* L. and *Schoenoplectus lacustris* (L.) Palla.

**Synchorology** – In Sicily, *C. submersum* is quite rare: the Gorgo Lungo near Godrano (PA) is the only ascertain species for the western sector of Sicily so far (Lastrucci et al. 2019a).

**Local distribution** – Gorgo Lungo (Godrano, PA).
Table 5. *Potamogetonetum natantis* Hild. 1959.

| Relevé number | Altitude (m a.s.l.) | Life Form | Plot size (m) | Height of vegetation (cm) | Total cover (%) | N° species for relevé | Localities (see Suppl. material 1, Table S1) |
|---------------|---------------------|-----------|---------------|---------------------------|-----------------|----------------------|-------------------------------------------|
| 1             | 1002               | 10        | 100           | 250                       | 100             | 2                    | 20 77 75 12 13 15 14 21 60 47 16 77 23 26 59 64 63 19 19 |
| 2             | 950               | 8         | 100           | 200                       | 100             | 1                    | -                                         |
| 3             | 1285              | 8         | 100           | 100                       | 100             | 1                    | -                                         |
| 4             | 925               | 8         | 100           | 150                       | 100             | 1                    | -                                         |
| 5             | 478               | 8         | 100           | 250                       | 100             | 1                    | -                                         |
| 6             | 368               | 8         | 100           | 200                       | 100             | 1                    | -                                         |
| 7             | 378               | 8         | 100           | 150                       | 100             | 1                    | -                                         |
| 8             | 652               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 9             | 790               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 10            | 503               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 11            | 1323              | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 12            | 950               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 13            | 953               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 14            | 953               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 15            | 707               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 16            | 692               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 17            | 757               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 18            | 741               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 19            | 741               | 10        | 100           | 100                       | 100             | 1                    | -                                         |
| 20            | 868               | 10        | 100           | 100                       | 100             | 1                    | -                                         |

**Char. of association**

| L. | Potamogeton natans L. |
|----|-----------------------|
| 1  | Potamogetonetea le Gall |
| 2  | Potamogeton natans L. |
| 3  | Potamogeton natans L. |
| 4  | Potamogeton natans L. |
| 5  | Potamogeton natans L. |
| 6  | Potamogeton natans L. |
| 7  | Potamogeton natans L. |
| 8  | Potamogeton natans L. |
| 9  | Potamogeton natans L. |
| 10 | Potamogeton natans L. |
| 11 | Potamogeton natans L. |
| 12 | Potamogeton natans L. |
| 13 | Potamogeton natans L. |
| 14 | Potamogeton natans L. |
| 15 | Potamogeton natans L. |
| 16 | Potamogeton natans L. |
| 17 | Potamogeton natans L. |
| 18 | Potamogeton natans L. |
| 19 | Potamogeton natans L. |
| 20 | Potamogeton natans L. |

**Other species**

| G rhiz | Glyceria notata Chevall. |
| G rhiz | Potamogeton pusillus L. |
| G rhiz | Typha angustifolia L. |
| G rhiz | Lemna minor L. |
| G rhiz | Phragmites australis (Cav.) Trin. ex Steud. |

**Local distribution**

This association was found in both natural and artificial ponds in the hills, mountains, and valleys of Sicily. It is also present in several reservoirs of the Dolabella, a second one dominated by *Persicaria amphibia* (L.) Delile, and a third one dominated by *Potamogeton natans* L. and *Phragmites australis* C. E. Hubb., respectively, in the study area. The association is rather common in Europe (Macquet et al. 1982; Doll 2008; Piccoli 1998; Bracco et al. 2000; Tomaselli et al. 2006; Sburlino et al. 2011). Since *P. natans* contributes only marginally to the composition of the association, its role is not considered in this study.
za and Rocca Busambra area, on the Sicani Mountains at Monte Carcaci and further east at the Bosco Granza, at the Madone al Gorgo di Pollicino (Suppl. material 2, Figure S3c) and at the Pietra Giordano, as previously recorded by Sortino et al. (1977).

6. POTAMOGETONETUM PUSILLI von Soó 1927 (Tables 6 and 16; Suppl. material 2, Figure S1f)

Diagnostic taxa (% constancy) – Potamogeton pusillus L. (100%, dominant).

Syntaxonomic note – P. pusillus L. often shows a certain ecological amplitude being able to establish in freshwater habitats with both standing and weakly flowing waters (Preston 1995). In Italy, the communities of P. pusillus are generally ascribed to a basal phytocoenon (Biondi et al. 1997, 2004; Piccoli 1998; Tomaselli and Bernardo 2006, Lastrucci et al. 2008; Sburlino et al. 2008). However, in lentic habitats, such as small pools (Lastrucci et al. 2012) or natural lakes (Landucci et al. 2011), the P. pusillus communities show a greater compositional constancy that justifies the attribution to an association (Potamogetoneto-

mum pusilli).

Short description – The association is typical of mesotrophic to eutrophic water bodies. It occupies a wide range of depths (0.5–3.0 m), often colonizing disturbed habitats, or representing early successional stages of pond evolution (Šumberová 2011b). In the study area, P. pusil-

lus is often associated to other sporadic hydrophytes, such as Ranunculus aquatilis L. and Callitriche brutia Petagna. The Potamogetonetum pusilli stands are rather dense (> 90% in coverage) and colonize depths of about 80–100 cm, occupying the intermediate vegetation belt between central, deeper sectors and shorelines. It has its growth optimum in spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid-humid).

Syndynamism – In the study area, this association is mainly represented by paucispecific stands and replace the Ranunculon aquatilis at deeper waters. In the innermost sectors of ponds, it spreads into others Potamogetonetea class units and algal assemblages (Chara spp.). Along the littorals, it is in close contact with the helophytic consortia of the Phragmitea-Magnocaricetetum class.

Synchronyology – P. pusillus is a species with a circumboreal distribution (Preston 1995). Communities dominated by P. pusillus are reported for Germany (Pott 1995), Poland (Nowak et al. 2007), and various regions of Italy, such as Friuli Venezia Giulia, (Sburlino et al. 2008), Lombardy (Bolpagni 2013), Veneto (Pingitore et al. 2013), Emilia Romagna (Biondi et al. 1997; Piccoli 1998), Tuscany (Lastrucci et al. 2008), Umbria (Landucci et al. 2011), and Calabria (Tomaselli and Bernardo 2006). In Sicily, this species had been detected for the Nebrodi Mts, in the frame of the following associations: Utricularietum australis Müller et Görs 1960 (Brullo et al. 1994), and Utricu-

lario-Potametum natantis (Raimondo et al. 2011).

Local distribution – This association has been found only in a few locations, both on flyschoid and carbon-
Table 6. *Potamogetonetum pusilli* von Soó 1927.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------------|---|---|---|---|---|---|---|---|
| Altitude (m a.s.l.) | 638 | 707 | 678 | 678 | 620 | 707 | 620 | 6 |
| Life | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 |
| Form | Total cover (%) | 100 | 100 | 100 | 100 | 100 | 100 | 90 |
| Height of vegetation (cm) | 35 | 35 | 30 | 30 | 40 | 30 | 45 | 5 |
| N° species for relevé | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 9 |
| Localities (see Suppl. material 1, Table S1) | 6 | 26 | 1 | 1 | 5 | 26 | 5 | 3 |

**Char. of association**
- *Potamogeton pusillus* L.
- *Potamogetonetum pusilli* – *Callitriche bractea* Petagna

**Other species**
- *Glyceria notata* Chevall.
- *Elocha phalasir* (L.) Roem. et Schult.
- *Chara sp.*
- *G. rhiz.* *juncus articulatus* L.

Table 7. *Potamogetonetum pectinati* Carstensen ex Hilbig 1959.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------------|---|---|---|---|---|---|---|---|
| Altitude (m a.s.l.) | 464 | 1002 | 543 | 566 | 578 | 2 | 547 | 637 |
| Life | 20 | 10 | 10 | 10 | 10 | 7 | 5 | 10 |
| Form | Total cover (%) | 100 | 90 | 100 | 100 | 80 | 100 | 100 |
| Height of vegetation (cm) | - | 250 | 200 | 250 | 200 | 150 | 200 | 250 |
| N° species for relevé | 4 | 5 | 3 | 2 | 1 | 1 | 3 | 4 |
| Localities (see Table S1) | 81 | 20 | 58 | 53 | 7 | 80 | 55 | 52 |

**Char. of association**
- *Potamogeton pectinatus* L.
- *Potamogetonetum pectinati* – *Chara rhiz.*
- *Chara al.*
- *G. rhiz.* *Callitriche obtusangula* L. Cham. et Schltdl.
- *G. rhiz.* *Cladophora* L.
- *G. rhiz.*

**Other species**
- *Chara sp.*
- *P. australis* (Lam.) Baker
- *P. angustifolia* L.
- *C. sp.*
- *G. notata* Chevall.

is mentioned for some river mouths, and lentic habitats in the Hyblean sector (Bartolo et al. 1982; Spampinato and Scandirollo 2013), in the Trapani (Brullo and Ronisville 1975) and in the Nisseno areas (Marcenò and Raimondo 1977; Brullo and Scandirollo 2006; Scandirollo 2009).

**Local distribution** – In the study area, it was found in different artificial reservoirs, near Rocca Busambra (Contrada Casale, Contrada Cicio, and Contrada Alpe Cucco), on the Sicani Mountains (at the Gorgo di Sant’Andreà; Figure S3b) and at the mouth of the Carboj River along the Agrigento coast.

8. *GROENLANDIETUM DENSAE* Segal ex Schipper et al. in Schaminée et al. 1995 (Tables 8 and 16)

**Diagnostic taxa** (% constancy) – *Groenlandia densa* (L.) Fourn. (100%, dominant).

**Syn.** – *Groenlandietum densae* Bolòs 1957 (phantom); *Groenlandietum denseae* Segal 1965 (nom. nud., art. 2b); *Potamogeton Korneck* 1969 (art. 3c).

**Syntaxonomic note** – Community of oligo-mesotrophic water bodies, and limestone substrates (Ferrez et al. 2011), distributed in Central and Southern Europe (Brullo et al. 1994). Several *G. densa*-associations have been described for the Iberian Peninsula (Loidi et al. 1997), both for flowing waters [*Ranunculo trichophylli-Groenlandietum denseae* (Kohler et al. 1974) Passarge 1994], and lentic habitats (*Groenlandio denseae-Zannichelliellietum pelatae* Velayos, Carrasco & Cirujano 1989). This latter unit is replaced by the *Potametem denso-nodosi* O. Bolòs 1957 in habitats with greater nutrient availability (Melendo et al. 2003).

**Short description** – Rhizophytic community dominated by *G. densa*, only sporadically associated with other hydrophytes, such as *Callitriche obtusangula* Le Gall., occurs predominantly in sunny, permanent habitats, where develops medium coverage stands (up to 80%). This species prefers groundwater-dependent ecosystems, and spring waters which contribute to mitigate the excessive heating of water in summer. It preferably colonises littorals (up to
80-100 cm), on both flyschioide and carbonate sediments waterproofed by silty-clayey deposits.

**Bioclimate in Sicily** – Mediterranean pluviseasonal-oceanic and Mediterranean pluviseasonal-oceanic (from thermo-Mediterranean dry to meso-Mediterranean subhumid/humid).

**Syndynamism** – This association is often in contact with other Potamogetonetea and algal assemblages (Chara spp.), whereas along littorals it spreads into helophytic belts, as testified by the presence of several helophytes with high frequency values in the collected relevés.

**Synchorology** – *R. rionii* is a species with wide distribution in North Africa, Europe, and Central-Western Asia (Wiegleb et al. 2017); despite this, the *Ranunculetum rionii* is mainly known for Eastern Europe (Korotkov et al. 1991; Dubyna 2006; Kubalová 2009; Hrvínák and Csíky 2009) and France (Felzines 2016).

**Local distribution** – It has been recognized in several small ponds (both natural and artificial), distributed around the Sicani Mts, Rocca Busambra, Palermo Mts (at the Gorgo di Rebuttone; Altofonte – Suppl. material 2, Figure S1a), on the south side of the Monte Palmeto (Carini), and further east on the limestone platforms of Mazara del Vallo (at the Garufi plain; Suppl. material 2, Figure S2e).

10. **RANUNCULETUM AQUATILIS** Géhu 1961 (Tables 10 and 16; Suppl. material 2, Figure S2b)

**Diagnosic taxa (%) constancy** – *Ranunculus aquatilis* L. (100%; dominant).

**Taxonomic and Syntaxonomic note** – The presence of *R. aquatilis* in Italy is rather debated. The species was reported with several regional lacunae for the flora of Italy (Pignatti 1982; Conti et al. 2005), until Desfayes (2008, 2011) proposed to exclude it from the entire Italian territory. This proposal was accepted by Bartolucci et al. (2018) but not by the editors of the second edition of the “Italian Flora” by Pignatti (2017–2019) that lists this species as present in Italy. Even if the *R. aquatilis* group is a very critical group, in our opinion, *R. aquatilis* is recognizable in the study area and distinguished from *Ranunculus pelatus* Schrank for various characters such as the length of peduncles, the leaf margin shape, length of the petals and the morphology of nectar pits, as reported by many European determination keys (Pignatti 1982; Cook 1986; Pizarro 1995; Wiegleb et al. 2017). From a phytosociological point of view, *R. aquatilis*-assemblages are attributed to the association *Ranunculetum aquatilis* Géhu 1961, growing on clear, stagnant or slow-running, sunny, neutr-basophilous and nutrient-rich waters, on silty-clayey
### Table 9. Ranunculetum rionii Hejný et Husák in Dykyjová et Květ 1978.

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Altitude (m a.s.l.) | 863 | 863 | 863 | 868 | 868 | 868 | 868 | 868 | 868 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 | 1002 |
| Plot size (m²) | 5 | 5 | 5 | 5 | 10 | 4 | 5 | 5 | 5 | 10 | 10 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Total cover (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Height of vegetation (cm) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| N° species for relevé | 4 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 4 | 3 | 5 | 5 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 2 | 3 | 5 | 6 | 4 |
| Localities (see Suppl. material 1, Table S1) | 1071 | 35 | 73 | 41 | 100 | 20 | 59 | 100 | 50 | 20 | 50 | 100 | 50 | 20 | 50 | 100 | 50 | 20 | 50 | 100 | 50 | 20 | 50 |

### Char. of association

**Ranunculus rionii Lagger**

| Potamogetonetea units | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**Other species**

| G rhiz | Glycera notata Chevall. | - | - | + | - | - | - | - | - | + | + | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H scap | Mentha pulegium L. | - | - | + | - | 1 | - | - | + | - | + | - | 1 | 1 | - | - | - | - | - | - | - | - | - | - |
| I rad | Alisma lanceolatum With. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G rhiz | Juncus articulatus L. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H scap | Mentha aquatica L. | - | 1 | - | + | + | - | + | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G rhiz | Eleocharis palustris (L.) R. et S. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H scap | Typha angustifolia L. | - | 1 | - | + | 1 | - | + | + | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G rhiz | Juncus effusus L. | - | 1 | - | + | 1 | - | + | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| T rept | Cornus sanguinea (Forsk.) Asch. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G rhiz | Bulboschoenus maritimus (L.) Palla | - | 1 | - | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + |
| H scap | Oenanthe fistulosae L. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G rhiz | Persicaria amphibia (L.) Delarbre | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| G rhiz | Phalacroloma dictyum L. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H scap | Rumex crispus L. | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| H scap | Ranunculus aquatilis C. Presl | - | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
bottom, occasionally subject to desiccation or eutrophication (Buchwald 1994; Passarge 1992).

*Short description* – Batrachid community, with a clear predominance of *R. aquatilis*, which is associated with *Glyceria notata* Chevall. and other sporadic taxa of the Potamogetonetea class (Callitriche stagnalis Scop., *C. brutia* and *C. obtusangula*). It is typical of sunny ponds, characterized by strong seasonal water variations, situated on flyschoid substrates, but in some cases also on calcareous substrates. This association contributes to form a continuous belt along the external edges of colonized water bodies, at depths between about 50 cm and shores, therefore well adapted to the rapid drying of temporary Mediterranean ponds. The association’s growth optimum is in late spring.

*Bioclimate in Sicily* – Mediterranean pluviseasonal–oceanic (meso-Mediterranean subhumid/humid).

*Syndynamism* – This association is in close contact with submerged algal assemblages (*Chara* spp.) or with coenoses of the Potamogetonetea and Lemnetea classes. Often, the association forms actual transitional communities towards deeper vegetation belts (Rels 13–14, table 10). Along the outer edges of the colonized water bodies, this association is progressively replaced by helophytic belts of the Phragmito-Magnocaricetea class, and sometimes it spreads into the Isoeto–Nanojuncetea Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946 communities in habitats subjected to rapid seasonal water variations and the progressive drying of sediments.

**Table 10. Ranunculetum aquaticus Géhu 1961.**

| Relevé number | 1 2 3 4 5 6 7 8 9 10 11 12 13 14 |
|---------------|----------------------------------|
| Altitude (m a.s.l.) | 797 800 543 707 704 678 678 474 474 842 738 643 890 890 |
| Life | 3 3 6 5 3 8 6 5 5 3 5 5 6 4 |
| Form | Total cover (%) |
| Height of vegetation (cm) | 100 100 100 100 90 90 100 95 100 100 100 100 100 100 |
| N° species for relevé | 6 3 3 5 6 4 4 5 5 6 5 3 6 6 |
| Localities (see Suppl. material 1, Table S1) | 27 28 58 26 2 1 39 39 42 72 29 37 37 |

**Char. of association**

| I rad | Ranunculus aquaticus L. |
|-------|-------------------------|
| I rad | Callitriche stagnalis Scop. |
| I rad | Ranunculus rionii Lagger |
| I rad | Potamogeton pusillus L. |
| I rad | Callitriche brutia Petagna |
| I rad | Callitriche obtusangula Le Gall |
| I rad | Potamogeton pectinatus L. |
| I rad | Potamogeton natans L. |

**Others species**

| G rhiz | Glyceria notata Chevall. |
|--------|-------------------------|
| H caesp | Alopecurus aequalis Br.-Bl. & Passarg. |
| G rhiz | Eleocharis palustris (L.) Roem. et Schult. |
| I rad | Alisma lanceolatum With. |
| H nat | Lemna minor L. |
| H scap | Rumex pulcher L. |
| H bienn | Jacobaea erratica (Bertol.) Fourn. |
| T scap | Ranunculus ophioglossifolius Vill. |
| H scap | Rumex conglomeratus Murray |

**Synchorology** – *R. aquatilis* is a subcosmopolitan species, with a wide Euro-Asian distribution, as well as in North Africa and North America. In Italy, associations dominated by *R. aquatilis* have been reported mainly for Central Italy (e.g., Biondi et al. 1999). As put in evidence by several authors (Géhu and Meriaux 1983; Passarge 1992), one of the main issues related to the correct recognition of this association depends on the fact that many authors do not separate the assemblages dominated by *R. aquatilis* and *R. pelatus*, respectively. Consequently, the Ranunculetum aquaticus is often considered as a macro-association to which populations of both species can be attributed (see also Sumberová 2011). Nevertheless, Géhu and Meriaux (1983) highlighted how in France the two species differentiate two distinct associations, ecologically and geographically vicariant. In particular, the Ranunculetum aquaticus shows a wide ecological amplitude, and a greater preference for organic and nutrient rich waters. In the study area, a clear distinction between the typical habitats of these two coenoses has been recognized. *R. aquatilis* prefers water bodies located at higher altitudes (hilly and sub-mountain horizons) and shows a more mesophilic character. Conversely, *R. pelatus* is also found at low-altitude locations (200–250 m s.l.m), even in coastal areas of North-Western Sicily.

**Local distribution** – The association has been detected in several hilly and submontane water bodies, both of natural and artificial origin, permanent and semi-permanent (with a hydroperiod of 9–10 months). It is distributed in the foothills north of the Rocca Busambra (e.g., Gorgo...
Lungo, Gorgo dei Palermitani, Gorgo Cerro), at altitudes between 738 and 890 m a.s.l., in the Trabia (at the Gorgo di Pizzo Selva a Mare) and in the Palermo Mts (at the Gorgo di Rebuttone).

11. RANUNCULETUM PELTATI Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldencoop 1969 subass. TYPICUM (Table 11a rels 1–7; tab. 16; Suppl. material 2, Figure S2c)

Diagnostic taxa (% constancy) – Ranunculus peltatus Schrank (100%, dominant).

Syntaxonomic note – R. peltatus (Suppl. material 2, Figure S2d) shows a high adaptability to different ecological conditions (Garbey et al. 2004), implying that this species may differentiated more than one community (see also Lastrucci et al. 2007). The association Ranunculetum peltati is typical of small, clear lentic water bodies, with depths not exceeding 80–100 cm. These habitats can be moderately rich in nutrients, subjected to summer desiccation and livestock impacts, however the Ranunculetum peltati is particularly sensitive to pollution and shading (Passarge 1992). Two subassociations, the subass. typicum and the subass. potamogetonetosum were identified and typified by Passarge (1992). The Ranunculetum peltati was also reported for the Mediterranean area by Gradsden and Smittenberg (1977). In addition, for the oligotrophic, neutroc-filidophilous deep standing and cold waters of temperate and Mediterranean siliceous areas of the Iberian Peninsula, the association Callitricho brutiae-Ranunculetum peltati Pizarro & Rivas Martinez 2004 was described. This latter association is considered as a geosynvarient of the Ranunculetum peltati, and it was recently reported for some wetlands in Tuscany by Lastrucci et al. (2007) due the presence of some characteristic species of the association, such as C. brutia and Myriophyllum alterniflorum DC. In the study area, however, C. brutia is rather rare and only rarely found in the coenoses dominated by R. peltatus. Therefore, it seemed more appropriate to assign the Sicilian assemblages to the Ranunculetum peltati. Furthermore, the ecological conditions observed in Sicily seem rather far from those recorded for Spain. Here, the studied water bodies are not characterized by cold waters, and their depth is rather low. Based on this, we identified a new subassociation differentiated from R. rionii and species indicating high water fluctuations, such as Oenanthe fistulosa L. and Alisma lanceolatum With.

Short description – Batrachid community with a clear predominance of R. peltatus, only occasionally associated with other hydrophytes. It is typical of ponds characterized by strong seasonal water level variations, situated on carbonate substrates, with oligo-mesotrophic waters. This coenosis prefers the sunniest sectors of colonized habitats, sometimes extending over the entire surface of reservoirs/ponds, developing in these conditions submerged stems up to depths greater than 2 m. With the progressive and rapid lowering of the water level, R. peltatus tends to go up to the emerged banks tolerating the initial phases of seasonal desiccation. Its growth optimum is in the late spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (from thermo-Mediterranean dry to meso-Mediterranean subhumid/humid).

Syndynamism – This association is continuous with other coenoses of the Potamogetonetea class and sub-

| Table 11. Ranunculetum peltati subass. typicum Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldencoop 1969 (a: Rels 1–7) and subass. ranunculetosum rionii subass. nova (b: Rel 8–14) (*holotypos rel. 13). |
|---|
| **Relevé number** | 71 | 82 | 82 | 83 | 83 | 81 | 23 | 22 | 23 | 40 | 40 | 9 | 9 | 38 | 38 |
| **Altitude (m a.s.l.)** | 777 | 248 | 248 | 197 | 197 | 934 | 934 | 953 | 925 | 925 | 863 | 863 | 859 | 859 |
| **Life** | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 3 | 4 | 5 | 5 |
| **Plot size (sqm)** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 95 | 90 | 100 | 100 | 100 | 100 | 100 |
| **Total cover (%)** | 45 | 45 | 40 | 35 | 35 | 40 | 40 | 60 | 30 | 30 | 30 | 35 | 35 | 25 | 20 |
| **Height of vegetation (cm)** | 4 | 4 | 3 | 4 | 4 | 5 | 5 | 5 | 5 | 7 | 6 | 5 | 6 |
| **Locality** | 71 | 82 | 82 | 83 | 83 | 81 | 23 | 22 | 23 | 40 | 40 | 9 | 9 | 38 | 38 |
| **Char. subss. Typicum** | Schrank | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 14 |
| **Char. subss. ranunculetosum rionii** | Laggar | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 7 |
| **H. scop** | Oenanthe fistulosa L. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 7 |
| **I. rad** | Alisma lanceolatum With. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 7 |
| **Potamogetonetea units** | Potamogeton trichoides Cham. et Schldfl. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| **I. rad** | Callitrichia brutia Petagna | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **I. rad** | Potamogeton natans L. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| **Others species** | G. rhiz | Glyceria notata Chevall. | 2 | 2 | 1 | 2 | 1 | + | + | + | 1 | 2 | + | + | 1 | + | 14 |
| **R. rhiz** | Eleocharis palustris (L.) Roem. et Schult. | 1 | 2 | 2 | 2 | 1 | + | + | + | + | + | + | + | + | + | 7 |
| **I. nat** | Lemna gibba L. | 1 | 2 | 2 | 2 | 1 | + | + | + | + | + | + | + | + | + | 7 |
| **H. scop** | Mentha pulegium L. | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| **T. scop** | Mysoditis sicula Guss. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| **H. scop** | Galium debile Desv. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| **H. scop** | Mentha aquatica L. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
| **H. scop** | Veronica anagallis-aquatica L. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 |
merged algal assemblages (*Chara* spp.); among littorals, it tends to be replaced by amphibian vegetation often dominated by *G. notata*.

**Synchorology** – *R. peltatus* is a European species restricted to the temperate and southern areas of Europe, North Africa, and West Asia (Wiegleb et al. 2017).

**Local distribution** – It is present in several small ponds (both natural and artificial) located along the southern side of the Rocca Busambra (at the Piano Guddei; Godrano, PA), at the Monte Carcaci (Castronovo di Sicilia, PA), and further west in the Trapani surroundings (at the Pantani of Anguillara; Calatafimi), and at the Gorgo di Monte Cofano (Custonaci; Gianguzzi and La Mantia 2009, originally reported as *Ranunculetum baudottii* Br.-Bl. in Br.-Bl., Roussine & Nègre 1952).

*RANUNCULETOSUM RIONII* subass. nov. (Table 11b rels 8–14 – holotypus rel. 13; tab. 16)

**Diagnostic taxa (% constancy)** – *Ranunculus rionii* Laggar (100%, dominant), *Oenanthe fistulosa* L. (> 80%).

**Short description** – This subassociation differs from the typical aspect of the *Ranunculetum peltati* mainly because it colonizes littorals (with depths up to 50–60 cm) and muddy sediments. The community is characterized by the constant presence of *R. rionii* and *O. fistulosa*, accompanied with a certain frequency by *A. lanceolatum*. It has the growth optimum in spring, and it prefers higher altitude habitats than the association *typicum*.

**Bioclimatic in Sicily** – Mediterranean pluviseasonal–oceanic (meso-Mediterranean subhumid/humid).

**Local distribution** – It is present in some ponds distributed in the core sector of the study area, at altitudes between 850 and 950 m a.s.l., along the southern side of the Rocca Busambra (contrade Marosa and Guddemi), and at the Sicani Ms (at the Gorgo di Carcaci).

### Table 12. *Lemno-Callitrichetum obtusangulae* (Philippi 1978) Passarge 1992.

| Relevé number | Altitude (m a.s.l.) | Plot size (mq) | Total cover (%) | Height of vegetation (cm) | N° species for relevé | Localities (see Suppl. mat. 1, Table S1) |
|---------------|---------------------|---------------|-----------------|--------------------------|----------------------|---------------------------------------|
| I rad         | *Lemna minor* L.    |               |                 |                          |                      | 16 17 41 77 19 22 22 33 68 36 65 64 44 78 76 37 37 |
| I rad         | *Lemno-Callitrichetum obtusangulae* Le Gall | 5 5 5 5 5 5 5 5 4 5 5 5 5 5 5 5 4 5 17 |                 |                          |                      |                                       |
| I rad         | *Ranunculus obtusangulatus* |               |                 |                          |                      |                                       |
| I rad         | *Ranunculus rionii* Lagger |               |                 |                          |                      |                                       |
| I rad         | *Potamogeton natans* L. | 1 1           |                 |                          |                      |                                       |
| I rad         | *Ranunculus aquatilis* L. |               |                 |                          |                      |                                       |
| I nat         | *Ranunculus aquatilis* L. |               |                 |                          |                      |                                       |
| I rad         | *Glyceria scaposa* |               |                 |                          |                      |                                       |
| H scap        | *Menyanthes trifoliata* |               |                 |                          |                      |                                       |
| H scap        | *Menyanthes palustris* L. |               |                 |                          |                      |                                       |
| H scap        | *Ranunculus ophirihoseus* Vill. |               |                 |                          |                      |                                       |
| H scap        | *Ranunculus muricatus* L. |               |                 |                          |                      |                                       |
| H scap        | *Rumex conglomeratus* Murray |               |                 |                          |                      |                                       |
| I rad         | *Ceratophyllum submersum* L. |               |                 |                          |                      |                                       |
| H scap        | *Lythrum junceum* Banks et Sol. |               |                 |                          |                      |                                       |
| I rad         | *Alisma lanceolatum* With. |               |                 |                          |                      |                                       |
| G rhiz         | *Eleocharis palustris* (L.) Roem. et Schult. |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Alisma lanceolatum* With. |               |                 |                          |                      |                                       |
| H scap        | *Eleocharis palustris* (L.) Roem. et Schult. |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
| H scap        | *Rumex palustris* |               |                 |                          |                      |                                       |
in the relevé matrix). Furthermore, given the importance of *L. minor* in differentiating the communities of *C. obtusangula* in the study area, it seems most appropriate to attribute these coenosis to the *Lemno-Callitrichetum obtusangulae*, also reported for the northern Italy by Sbrullino et al. (2008). Passarge (1992) placed this association in the alliance *Lemna-Callitrichion Passarge* 1992, that currently has been placed in synonym with the *Ranunculion aquatilis* (Mucina et al. 2016). The *Lemno-Callitrichetum obtusangulae* is typical of summer-warm waters, rich in nutrient, tolerating drying periods, eutrophication, and slight salinity, but fearing cold winters and anthropogenic pollution (Passarge 1992).

**Short description** – Aquatic vegetation dominated by *C. obtusangula*, with the frequent presence of *L. minor*. This community is typical of small, semi-permanent water bodies lying on quartzarenitic substrates, with high levels of clay or sometimes with sandy sediments. It prefers muddy bottoms, and conditions of partial sunshine, growing at depths not exceeding 60 cm, and tolerating slightly eutrophic conditions. The association’s growth optimum is in late spring.

**Bioclimate in Sicily** – Mediterranean pluviseasonal-oceanic and Temperate/submediterranean (from meso-Mediterranean to supra-Mediterranean subhumid-humid).

**Syndynamism** – Towards the deepest part of the water body sectors, this association is in contact with other kinds of *Potamogetonetea* and *Lemnetea* vegetation, while along littoral it spreads into the *Phragmito-Magnocaricea* belts.

**Synchorology** – The association is distributed in the temperate-sub-Atlantic regions of Europe (Passarge 1992), while in Italy it has been previously reported only for the Veneto region (Sbrullino et al. 2008).

**Local distribution** – Ponds located in the northern foothills of the Rocca Busambra, at altitudes between 500 and 650 m a.s.l., in the surroundings of Godrano (Gorgo Lungo, Gorgo Pizzo Campana, Case Franco, Vallone Frattina and Coda di Riccio), Monreale (Zotta Frascino and Vallone Arcere), and Marineo (Cozzo Bileo and Sovarita). Further east, it is found in the Sclafani Bagni area (at Bosco Granza and Lake Bomes; PA), as well as at the Madonie Mts (at Pietra Giordano; Geraci Siculo, PA).

### Table 13. *Callitriches stagnalis* community

| Relevé number | 1 | 2 | 3 | 4 | 5 |
|---------------|---|---|---|---|---|
| Altitude (m a.s.l.) | 1030 | 801 | 1028 | 898 | 738 |
| Form | | | | | |
| Life | Plot size (mq) | 5 | 2 | 2 | 5 | 5 |
| Total cover (%) | 90 | 90 | 85 | 80 | 95 |
| Height of vegetation (cm) | 15 | 10 | 10 | 10 | 10 |
| N° species for relevé | 4 | 4 | 4 | 3 | 7 |
| Localities (see Suppl. material 1, Table S1) | 48 | 24 | 49 | 45 | 72 |

| Diff. species | Presence |
|---------------|----------|
| *Callitriches stagnalis* Scop. | 4 | 4 | 4 | 5 | 4 | 5 |
| *Potamogetonea unitis* | | | | | | |
| *Ranunculus aquatilis* Ten. | 1 | 1 | 1 | 1 | . | 4 |
| *Ranunculus ophioglossifolius* Vill. | . | . | . | . | . | 1 |

**Others species**

| I rad | Presence |
|-------|----------|
| *Glyceria notata* Chevall. | 2 | 2 | 3 | 2 | 3 | 5 |
| *Veronica anagallis-aquatica* With. | 1 | . | . | . | . | 1 |
| *Lythrum junceum* Banks et Sol. | . | 1 | . | . | . | 1 |
| *Mentha pulegium* L. | . | . | . | . | . | 1 |
| *Alpecurus aequalis* Sobol. | . | . | . | . | 1 | 1 |
| *Oenanthe aquatica* (L.) Poir. | . | . | . | . | . | 1 |
| *Lemna gibba* L. | . | . | . | . | . | + | 1 |
| *Ranunculus ophioglossifolius* Vill. | . | . | . | . | . | + | 1 |
Small wet habitats on the northern side of the Rocca Busambra near the Bosco Ficuzza.

14. Junco bufonii-Ranunculetum omiophylli ass. nov. (Table 14 - holotypus rel. 8; tab. 16; Suppl. material 2, Figure S3f)

Diagnostic taxa (% constancy) – Ranunculus omiophyllus Ten. (100%, dominant), Juncus bufonius L. (> 80%).

Syntaxonomic note – R. omiophyllus is mainly distributed in the Atlantic Europe, from North Spain to British Islands, but with an extension in the Mediterranean, from North Africa to Sicily, and Southern Italy (Pizarro 1995; Pignatti 2017–2019). According to Rivas-Martínez et al. (2001, 2002), R. omiophyllus is a characteristic taxon of the Ranunculion omiophyllo-hederacei Rivas-Martínez et al. 2002, a peculiar alliance characterized by rooted stoloniferous helophytic ranunculids with floating leaves, as Ranunculus hederaceus L. or R. omiophyllus, (Rivas-Martínez et al. 2002). For Spain, two associations dominated by R. omiophyllus have been described: the Ranunculetum omiophylli Braun-Blanquet & Tüxen (1943) 1952, and the Myosotido stoloniferae-Ranunculetum omiophylli Rivas-Martínez et al. 2002. The first association includes, besides R. omiophyllus (= Ranunculus lenormandi F.W. Schultz.), other species such as Potamogeton oblongus Viv., Juncus bulbosus L., C. brutia var. hamulata. Conversely, the second one is characterized by Myosotis stolonifera (DC.) J. Gay ex Leresche & Levier, Montia fontana

Table 14. Junco bufonii-Ranunculetum omiophylli ass. nov. (*holotypus rel. 8).

| Relevé number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8* | 9 | 10 | 11 |
|---------------|---|---|---|---|---|---|---|----|---|----|----|
| Altitude (m a.s.l.) | 708 | 710 | 856 | 842 | 936 | 1015 | 1089 | 1081 | 797 | 1030 | 1028 |
| Life form | Total cover (%) | 100 | 90 | 85 | 100 | 85 | 70 | 75 | 100 | 90 | 85 |
| Height of vegetation (cm) | 15 | 15 | 10 | 10 | 20 | 10 | 10 | 10 | 15 | 15 | 10 |
| N° species for relevé | 6 | 5 | 5 | 6 | 5 | 9 | 5 | 6 | 6 | 8 | 7 |
| Localities (see Suppl. material 1, Table S1) | 66 | 67 | 51 | 42 | 44 | 50 | 45 | 24 | 46 | 48 | 49 |

**Char. of association**

| Ranunculus omiophyllus Ten. | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 11 |

**Isoeto-Nanojuncetalia units**

| Juncus bufonius L. | 2 | 1 | 2 | 1 | . | . | 7 |

**T aescp**

| Poa interna Kunth | 1 | 1 | + | . | + | 1 | 1 | . | . | . | 7 |
| Mentha pulegium L. | 1 | . | . | + | . | . | . | . | . | . | 1 |

**T scap**

| Isopogon cernua (Vahl.) Roem. et Schult. | . | . | . | . | . | . | . | . | . | . | 1 |
| Trifolium micranthum Viv. | . | . | . | . | . | . | . | . | . | . | 1 |
| Ranunculus maricatius L. | . | . | . | . | . | . | . | . | . | . | 1 |
| Ranunculus angustifolius C. Presl | . | . | . | . | . | . | . | . | . | . | 1 |

**T rad**

| Callitrichaceae-Ranunculaceae aquatilis units | . | . | 1 | 2 | 2 | 1 | + | 5 |

**I rad**

| Callitriche stagnalis Scop. | . | . | 1 | . | + | . | . | . | . | . | 2 |
| Callitriche obtusangula Le Gall | . | . | . | . | . | . | . | . | . | . | 1 |
| Ranunculus aquatilis L. | . | . | . | . | . | . | . | . | . | . | 1 |

**Othes species**

| G. rhiz | . | . | 1 | 1 | + | . | . | 2 | 1 | 1 | 6 |

**H. scap**

| Lythrum junceum Banks et Sol. | 1 | 1 | 1 | + | . | . | . | . | . | . | 5 |
| Cyperus basius Desf. | . | . | 1 | . | . | . | . | + | 1 | 3 |

**H rhiz**

| Rumex conglomerates Murray | . | . | + | . | . | . | 1 | . | . | . | 2 |
| Juncus effusius L. | . | . | . | . | . | . | . | + | 1 | 2 |
| Juncus articulatus L. | . | . | . | . | . | . | . | . | . | . | 2 |
| Trifolium repens L. | . | . | . | . | . | . | . | . | . | . | 1 |
| Rumex pulcher L. | . | . | . | . | . | . | . | . | . | . | 1 |
| Iacobaea erratica (Bertol.) Fourn. | . | . | . | . | . | . | . | + | . | . | 1 |

**H. caesp**

| Veronica anagallis-aquatica With. | . | . | . | . | . | . | . | + | . | . | 1 |

**Othes species**

| Ranunculus omiophyllus | 2 | 1 | 2 | 1 | + | . | . | 2 | 1 | 1 | 6 |
L. subsp. amporitana Sennen, and Stellaria al sine Grimm. Both these associations, therefore, appear quite different from the Sicilian assemblages. In Western Sicily, the assemblages dominated by R. omiophyllus host several differential species belonging the class Isoëto-Nanojuncetea (see Bruullo and Minissale 1998) leading us to propose the institution of a new association, the Junco bufonii-Ranunculetum omiophylly. Its typical composition is made of species from both the Calliricthe-Ranunculetalalia and the Isoëto-Nanojuncetea classes.

**Short description** – Slightly sciophilous, batrachid community with a clear dominance of R. omiophyllus, frequently associated with annual micro-helophytes of the Isoëto-Nanojuncetea class such as Juncus bufonius L. and Poa infirma Kunth. The coenosis develops on muddy bottoms of shallow depressions (up to 10–20 cm) on clayey substrates. Its typical water bodies are small and have prolonged flooding phases, that last until the beginning of the summer season (June-July), and are also subjected to intense trampling disturb. The growth optimum of this new association is in late spring.

**Bioclimate in Sicily** – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

**Syn dynamics** – This association is in contact with several aquatic rooted coenoses (Potamogetonetum class) and in particular with Calliricthe stagnalis communities, while it spread into the communities of the Isoëto-Nanojuncetea and Molino-Arrenantheretae. Tüxen 1937 classes along the littorals of colonized wet depressions.

**Local distribution** – Frequent in small ponds located in the central-northern sector of the Bosco Ficuzza, within the municipalities of Godrano, Marineo, Mezzojuso, and Monreale.

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**Table 15.** Synoptic table of the identified associations and communities belonging to class Lemneta minora in Western Sicily: 1) Lemnetum minoris von Soó 1927; 2) Lemnetum gibbae Miyawaki et J. Tüxen 1960; 3) Lemna minuta community; 4) Potamogetonoceratophylletum submersi Pop 1962.

| Association number | Table number | Number of relevés |
|--------------------|--------------|-------------------|
| 1                  | 1            | 1,11, 4, 4, 100   |
| 2                  | 1            | 1, 2, 3, 4        |
| 3                  | 1            | 1                  |
| 4                  |              | 7, 11, 4, 4       |

**Char. of association and upper units of the cl. Lemneta**

| Lemna minor L. | 100  | 18  | 100 |
|----------------|------|-----|-----|
| Lemna gibba L. |      | 100 |     |
| Lemna minuta Kunth | 100 |     |
| Ceratophyllum aduncum L. |     | 100 |
| *Trasgr. species of cl. Potamogetonetea* |     |
| Callicirthe obscuratae Le Gall | 71  | 18  | 100 |
| Ranunculus rionii Lagger | 14  |     | 25  |
| Ranunculus aquatilis L. | 36  |     | 100 |
| Potamogeton trichoides Cham. et Schltdl. | 9 |     |   |

**Other species**

| Glycera notata Chevall. | 100 |     | 25  |
| Chara sp. | 57 |     |   |
| Chara sp. | 29 |     |   |
| Ranunculus ophioglossifolius Vill. | 29 |     |   |
| Equisetum telmateia Ehrl. | 14 |     |   |
| Allopecurus aequalis Vill. | 36 | 75  |   |
| Bolboschoenus maritimus (L.) Palla | 9 |     |   |
| Mentha pulegium L. | 9 |     |   |
| Paspalum distichum L. | 75 |     |   |

**Conclusions**

New insights on the aquatic communities of the Lemneta (Table 15) and Potamogetonetum (Table 16) classes, characterized by the predominance of threatened and rare macrophytes, have been offered for western Sicily. The study puts in evidence the presence of a rich diversified aquatic and wet vegetation, namely four free-floating communities (ascribed to two different alliances, Lemnion minoris and Stratition – Tables 1–4), and 11 rooted plant assemblages (belonging to four alliances, Potamogetonio, Nymphaeion albae, Ranunculion aquatilis, and Ranunculion omphiophylo-hederae – Tables 5–14).

This relative high vegetation diversity is probably mainly to be attributed to the wide ecological range of small-standing water ecosystems investigated, that includes both natural and artificial ecosystems, as well as permanent and temporary ponds, reservoirs, situated in turn on a variety of geo-lithological substrates (limestones, quartzarenites, clays, gyspum of the evaporitic series of the Sicilian interior) and altitudes, from the few meters a.s.l. of the mouth of the Carboj River (AG) to the 1,326 m a.s.l. of the Gorgo di Pietra Giordano (PA) (see Suppl. material 1, Table S1). Indeed, origin and hydropore of small water ecosystems are pivotal features in driving the complexity of vegetation in wetlands and small water bodies, especially in semi-natural or artificial contexts (Bolpagni and Piotti 2016; Bolpagni 2020).

Among the communities recognized, six are new for the study area (Potamogetono-Ceratophylletum submersi, Potamogetonetum pusili, Ranunculetum rionii, R. aquatilis, R. peltati, and Lemno-Callirichetea obtusangulae), and two have been described as new syntaxa: Junco bufonii-Ranunculetum omiophylly and Ranunculetum peltati subass. ranunculetosum rionii. The first is a batrachid community differentiated by annual micro-helophytes (juncus bufonius and Poa infirma); whereas the second one is another batrachid assemblage differentiated by Ranunculus peltatus and R. rionii, well adapted to strong seasonal water level variations.

The present data greatly broaden the floristic-phytosociological knowledge of the aquatic communities of the largest Mediterranean island, as well as their syntaxonomic, synecological, and distributive features. Our survey allowed almost punctual evaluation of scattered, isolated aquatic habitats that have a relevant conservation value considering the huge pressures exerted by climate change and human activities in the Mediterranean region (Gianguzzu et al. 2013, 2017; Benavent-González et al. 2014; Angiolini et al. 2017; Tomaselli et al. 2020). Thus, the described vegetation includes very peculiar phytoocoenoses, although the floristic originality of the aquatic communities monitored is generally low. Despite this, due to their rarity and to the fragmented distribution, vegetation dom-
Table 16. Synoptic table (simplified) of the identified associations and communities belonging to class Potamogetonetea in Western Sicily, with companion taxa with less than 20% constancy reported at the end: 5) Potamogetonetum natantis Hild 1959; 6) Potamogetonetum pusilli von Soó 1927; 7) Potamogetonetum pectinati Carstensen ex Hilbig 1959; 8) Groenlandictum densae Segal ex Schipper et al. in Schaminée et al. 1995; 9) Ranunculetum rioni Johannes et Husák in Dykyjová et Květ 1978; 10) Ranunculetum aquatilis Gehu 1961; 11a) Ranunculetum peltati subass. typicum Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldenkor 1969; 11b) Ranunculetum peltati subass. ranunculetosum rioni nov.; 12) Lemno-Calitrichetum obtusangulæ (Philipps 1978) Passarge 1992; 13) Callitriche stagnalis community; 14) Juncus bufonii-Ranunculetum omiophylli ass. nov.

| Association number | 5 | 6 | 7 | 8 | 9 | 10 | 11a | 11b | 12 | 13 | 14 |
|--------------------|---|---|---|---|---|----|-----|-----|----|----|----|
| Number of Relevés  | 20| 7 | 8 | 4 | 25| 14 | 7 | 7 | 17 | 5 | 11 |
| Char. of association, subass. and upper units of the class Potamogetonetea | | | | | | | | | | | |
| Potamogeton natantis L. | 100 | 14 | 13 | . | 12 | 7 | 14 | . | 12 | . | . |
| Potamogeton pusillus L. | 10 | 100 | . | . | 4 | 21 | . | . | . | . | . |
| Potamogeton pectinatus L. | . | . | . | 100 | 12 | 7 | . | . | . | . | . |
| Groenlandia densa (L.) Fourn. | . | . | . | 100 | . | . | . | . | . | . | . |
| Ranunculus rionii Laggers | 25 | 13 | 100 | 29 | 100 | 12 | . | . | . | . | . |
| Ranunculus aquatilis L. | 5 | 86 | 25 | . | 4 | 100 | . | 6 | 20 | 9 | . |
| Ranunculus peltatus Schrank | . | . | . | 100 | . | . | . | . | . | . | . |
| Callitriche obtusangula Le Gall | 5 | . | . | 50 | 8 | 14 | . | 100 | . | 18 | . |
| Callitriche stagnalis Scop. | . | . | . | . | 36 | . | . | 100 | 45 | . | . |
| Ranunculus omiophylli Ten. | . | . | . | . | . | 36 | . | . | 80 | 100 | . |
| Other species of the cl. Potamogetonetea | | | | | | | | | | | |
| Potamogeton trichoides Cham. et Schltdl. | 5 | . | 25 | . | . | 14 | 14 | . | . | . | . |
| Callitriche brataia Petagna | 5 | 29 | . | . | . | 14 | 14 | . | . | . | . |
| Trag. of the cl. Isoëto-Nanojuncetea | | | | | | | | | | | |
| Mentha pulegium L. | . | . | . | 32 | 29 | 14 | 28 | 29 | 20 | 36 | . |
| Juncus bufonius L. | . | . | . | . | . | . | . | . | 81 | . | . |
| Poa infirma Kunth | . | . | . | . | . | . | . | . | . | . | 64 |
| Isoplepis cernua (Vahl.) Roem. et Schult. | . | . | . | . | . | . | . | . | . | . | 9 |
| Trifolium picratium Viv. | . | . | . | . | . | . | . | . | . | . | 9 |
| Ranunculus maricitus L. | . | . | . | . | . | . | . | 12 | . | 9 | . |
| Ranunculus angustulus C. Presl | . | . | . | . | . | . | . | . | . | . | 9 |
| Other species | | | | | | | | | | | |
| Glyceria notata Chevall. | 15 | 86 | 13 | 100 | 56 | 86 | 100 | 100 | 59 | 100 | 55 |
| Eleocharis palustris (L.) Roem. et Schult. | . | 57 | . | 16 | 29 | 57 | 43 | 6 | . | . | . |
| Juncus articulatus L. | . | 29 | . | 50 | 24 | 14 | . | . | . | 18 | . |
| Chara sp. | . | 29 | 38 | 50 | 20 | . | . | . | . | . | . |
| Typha angustifolia L. | . | 10 | 25 | . | 12 | . | . | . | . | . | . |
| Lemna minor L. | 5 | . | . | 14 | . | . | . | 36 | . | . | . |
| Phragmites australis (Cav.) Trin. ex Steud. | . | 5 | 25 | . | . | . | . | . | 14 | 36 | . |
| Mentha aquatica L. | . | . | . | 25 | 20 | . | . | . | . | . | . |
| Lythrum junceum Banks et Sol. | . | . | . | 25 | . | . | . | . | . | 6 | 20 |
| Alisma lanceolatum With. | . | . | . | 28 | 14 | . | 57 | 6 | . | . | . |
| Oenanthe fistulosa L. | . | . | . | . | 4 | 14 | 86 | . | . | . | . |
| Juncus effusus L. | . | . | . | 8 | . | . | . | . | . | . | 18 |
| Alopecurus acutus Sobol. | . | . | . | 21 | . | . | . | 6 | 20 | . | . |
| Ranunculus ophioglossifolius Vill. | . | . | . | 7 | . | . | 25 | 20 | . | . | . |
| Rumex pulcher L. | . | . | . | 7 | . | . | 6 | . | 9 | . | . |
| Rumex conglomeratus Murray | . | . | . | 7 | . | . | 12 | . | 18 | . | . |
| Ceratophyllum submersum L. | . | . | . | 14 | . | . | 12 | . | . | . | . |
| Jacobaea erucifolia (Bertol.) Fourn. | . | . | . | 7 | . | . | 1 | . | 9 | . | . |
| Lemma gibba L. | . | . | . | . | 43 | . | . | 20 | . | . | . |
| Veronica anagalis-aquatica L. | . | . | . | 14 | . | . | 20 | 9 | . | . | . |
| Myosotis sicala Guss. | . | . | . | . | . | 29 | . | . | . | . | . |
| Cyperus badius Desf. | . | . | . | . | . | . | . | . | . | . | 27 |

Taxa with less than 20% constancy and presence in singular table: Tab. 6) Cladophora sp. 13%; Tab. 8) Coronopus squamatus 8%, Bolboschoenus maritimus 8%, Persicaria amphibia 4%, Paspalum distichum 4%, Rumex crispus 4%, Ranunculus angustatus 4%; Tab. 11a) Galium debile 14%; Tab. 13) Oenanthe aquatica 20%; Tab. 14) Juncus inflexus 9%, Trifolium repens 9%.
inated by lemnids or species of the genera Potamogeton or Ranunculus (sect. Batrachium) can be listed among the most endangered plant communities at national and European scale (Bolpagni et al. 2017; Maiorca et al. 2020). However, the study also highlights some critical issues including the presence of the invasive species Lemna minuta. We confirm its strongly invasive character, as shown elsewhere in Italy, especially in eutrophic environments (Ceschin et al. 2016; Lastrucci et al. 2016 and references therein).

To sum up, the present work offers a preliminary overview of the spatial representativeness of macrophyte communities in a rich set of small wetlands and ponds in western Sicily. Despite their very small size, which makes them very sensitive environments, they represent a fundamental component of semi-natural and natural ecosystems, which require adequate protection and monitoring actions in Sicily, and more generally in the Mediterranean region and in the world.

Syntaxonomical scheme

LEMNIEA MINORIS O. de Bolós et Masclans 1955
LEMNITALIA MINORIS O. de Bolós et Masclans 1955
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### Appendix - Localities and date of relevés

| Table | Rel. | Location |
|-------|------|----------|
| 1     | 1    | C.da Sovarita (Marineo) 03.06.2013; rels 3-4: Margiazzo del Vallone Arcere (Monreale) 02.06.2019; rel. 5: contrada Cannitello (Godrano) 23.04.2019; rel. 6: Portella di Granza (Sclafani Bagni) 25.05.2019; rel. 7: Lago Bomes (Sclafani Bagni) 25.05.2019. |
| 2     | 1    | Torrente Mandrarossa (Menfi) 08.08.2019; rels 2-3: Monte Cofano (Custonaci) [Tab. 3 in Gianguzzi & La Mantia (2008)]; rels 4-5: Case Cutitita (Godrano) 16.05.2013; rel. 6: Lago Sopran (Serradifalco) [pag. 16 in Marcone & Raimondo (1977)]; rel. 7: Monte Palmeto (Cinisii) 15.05.2019; rels 8-9: Gorgo Lungo (Godrano) 28.08.2020; rels 10-11: Gorgo Cerro (Monreale) 01.06.2018. |
| 3     | 1-2  | Gorgo S. Rosalia (Palermo) 02.05.2010; rel. 3: Cozzo Grattarola (Palermo) 10.03.2019; rel. 4: Gorghi Tondi (Mazara del Vallo) 06.05.2019. |
| 4     | 1-2  | Gorgo Lungo (Godrano) 16.05.2013; rels 3-4: Gorgo Lungo (Godrano) 01.06.2018. |
| 5     | 1    | c.da Cucco (Godrano) 11.06.2014; rel. 2: Bosco Granza (Sclafani B.) 25.05.2019; rel. 3: Gorgo Pollicino (Petralia Sop.) 01.07.2019; rel. 4: Monte Caracci (Castronovo S.) 03.06.2019; rel. 5: Case Scallieri (Corleone) 05.06.2014; rel. 6: Gole del Drago (Corleone) 05.06.2014; rel. 7: Gole del Drago (Corleone) 05.06.2014; rel. 8: Valle Maria (Godrano) 12.05.2014; rel. 9: Case Renzi (Monreale) 14.05.2013; rel. 10: Paraturuzzu (Messojuso) 12.05.2014; rel. 11: Pietra Giordano (Geraci S.) 01.07.2019; rel. 12: Bosco Granza (Sclafani B.) 25.05.2019; rels 13-14: Piano Gudmedi (Godrano) 07.05.2013; rel. 15: laghetto “ru zù Rusulinu” (Godrano) 20.05.2013; rel. 16: c.da Bifarrera alta (Monreale) 14.05.2013; rel. 17: c.da Bifarrera alta (Monreale) 14.05.2013; rels 18-20: c.da Coda di Riccio (Godrano) 25.05.2013. |
| 6     | 1    | Case Javuti (Casteldaccia) 24.05.2019; rels 2 and 6: Lago “ru zù Rusulinu” (Godrano) 01.06.2018; rels 3-4: Gorgo Pizzo Selva a Mare (Trabia) 24.05.2019; rels 5 and 7: Cozzo Valdaro (Trabia) 24.05.2019. |
| 7     | 1    | Lago Sopran (Serradifalco) [pag. 17 in Marcone & Raimondo (1977)]; rel. 2: c.da Alpe Cucco (Godrano) 11.06.2014; rel. 3: c.da Casale (Corleone) 05.06.2014; rel. 4: c.da Cicio (Corleone) 05.06.2014; rel. 5: Gorgo S. Andrea (Castronovo S.) 03.06.2019; rel. 6: Foce Fiiume Carboj (Menfi) 25.07.2019; rel. 7: c.da Casale (Corleone) 05.06.2014; rel. 8: c.da Nicolosi (Corleone) 05.06.2014. |
| 8     | 1-2  | Bosco Granza (Sclafani B.) 25.05.2019; rels 3-4: Monte Caracci (Castronovo S.) 29.05.2013. |
| 9     | 1    | Gorgo Caracci (Castronovo S.) 02.06.2018; rel. 2: Piano Garufi (Mazara del Vallo) 13.04.2019; rel. 3: Piano Gudmedi (Godrano) 17.05.2013; rel. 4: Chiano Prazini (Godrano) 20.05.2013; rel. 5: c.da Alpe Cucco (Godrano) 11.06.2014; rels 6-7: c.da Coda di Riccio (Godrano) 24.05.2012; rel. 8: c.da Coda di Riccio (Godrano) 01.06.2018. |
Table 10 rel. 1: Monticchio sopran (Godrano) 03.06.2013; rel. 2: Cannitello (Godrano) 03.06.2013; rel. 3: Casale (Monreale) 12.05.2014; rel. 4: Laghetto “ru zù rusulinu” (Godrano) 20.05.2013; rel. 5: Rebuttone (Altofonte) 04.07.2015; rels 6-7: Pizzo Selva a Mare (Trabia) 24.05.2019; rels 8-9: Gorgo Gla-viano (Godrano) 24.05.2019; rel. 10: Sovarita alta (Marineo) 03.06.2013; rel. 11: Gorgo Cerro (Monreale) 09.05.2013; rel. 12: Valle Maria (Godrano) 20.05.2013; rels 13-14: Gorgo Lungo (Godrano) 16.05.2013.

Table 11 - rel. 1: Gorgo dei Palermitani (Monreale) 09.05.2013; rels 2-3: MonteCofano (Custonaci) 05.05.2018; rels 4-5: Pantani d’Anguillara (Calatafini) 05.05.2018; rel. 6: Monte Carcaci (Castronovo) 02.06.2018; rels 7-8: Piano Guddemi (Godrano) 17.05.2013; rels 9-10: Gorgo Quattro Tummini (Godrano) 17.05.2013; rels 11-12: Gorgo Carcaci (Castronovo) 02.06.2018; rels 13-14: Marosa (Godrano) 17.05.2013.

Table 12 - rel. 1: Fosso Pietra Giordano (Geraci S.) 01.07.2019; rel. 2: Gorgo Pietra Giordano (Geraci S.) 01.07.2019; rel. 3: Sovarita (Marineo) 20.05.2013; rel. 4: Bosco Granza (Sclafani B.) 25.05.2013; rel. 5: Codà di Riccio (Godrano) 25.05.2013; rels 6-7: Case Franco (Godrano) 20.05.2013; rel. 8: Monticchio sot-tano (Godrano) 24.04.2014; rel. 9: Coda Frascino (Monreale) 07.05.2013; rel. 10: Pizzo Campana (Godrano) 10.05.2013; rels 11-12: Margiazzo Vallone Arcere (Monreale) 09.05.2013; rel. 13: Gorgo Porto (Marineo) 06.06.2013; rel. 14: Portella di Granza (Sclafani B.) 25.05.2019; rel. 15: Lago Bones (Sclafani B.) 25.05.2019; rels 16-17: Gorgo Lungo (Godrano) 16.05.2013.

Table 13 - rel. 1: Pizzo Angelo (Mezzojuso) 21.05.2014; rel. 2: Acqua Fono (Godrano) 10.05.2013; rel. 3: Acqua Accetta (Marineo) 07.05.2013; rel. 5: Gorge Cerro (Monreale) 09.05.2013.

Table 14 - rel. 1: Piano Carduna (Monreale) 09.05.2013; rel. 2: Piano Carduna (Monreale) 09.05.2013; rel. 3: Acqua Jenco (Mezzojuso) 21.05.2014; rel. 4: Sovarita alta (Marineo) 03.06.2013; rel. 5: Gorge Bileo (Marineo) 06.06.2013; rel. 6: Acqua Jenco (Mezzojuso) 21.05.2014; rel. 7: Sorge Acqua Accetta (Marineo) 07.05.2013; rel. 8: Valle Fono (Godrano) 10.05.2013; rel. 9: Sovarita alta (Godrano) 03.06.2013; rel. 10: Pizzo Angelo (Mezzojuso) 21.05.2014; rel. 11: Acqua Jenco (Mezzojuso) 21.05.2014.

Supplementary material 1

Table S1
Authors: Orazio Caldarella, Lorenzo Lastrucci, Rossano Bolpag-ni, Lorenzo Gianguzzi
Data type: geographical data
Explanation note: Location and physical features of the freshwa-ter habitats investigated.
Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.
Link: https://doi.org/10.3897/PlantSociology.58.66510.suppl1

Supplementary material 2
Figures S1–S3
Authors: Orazio Caldarella, Lorenzo Lastrucci, Rossano Bolpag-ni, Lorenzo Gianguzzi
Data type: images
Explanation note: Images of the study area and vegetation.
Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.
Link: https://doi.org/10.3897/PlantSociology.58.66510.suppl2