



# Dive into the Italian PONDY dataset: Pond vegetation data and water physico-chemical parameters\*

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Academic editor: Irena Axmanová ♦ Received 4 November 2025 ♦ Accepted 3 December 2025 ♦ Published 16 December 2025

## Abstract

Ponds are widespread yet highly vulnerable freshwater habitats that support diverse aquatic and terrestrial plant communities influenced by land use and water characteristics. The PONDY (Pond vegetation data and water physico-chemical parameters) dataset integrates vegetation and water physico-chemical data that have been collected to understand the responses of vegetation to environmental parameters. The dataset comprises 575 plots, of which 232 are aquatic and 343 are terrestrial, derived from 115 ponds across continental and insular areas of Italy. The dataset includes 743 vascular plant taxa and 5 macroalgae encompassing 364 genera and 89 families. Terrestrial plots host 690 taxa belonging to 87 families, while aquatic plots host 117 taxa belonging to 36 families. The dataset includes 10 taxa belonging to the Italian Red List and 39 alien species. Moreover, 11% of the aquatic plots have been classified in a Habitats Directive 92/43/EEC habitat type, while 48% have been classified in a EUNIS habitat type. The dataset contains, for each plot, measurements of physico-chemical water variables such as dissolved oxygen, water depth, and temperature, pH, turbidity, conductivity, and nutrient concentration. The PONDY dataset provides comprehensive information on plant diversity and abundance, community composition, habitat types, and water chemistry in Italian ponds, serving as a key resource for studying plant–environment relationships, developing predictive models, and supporting freshwater conservation efforts.

## Keywords

Aquatic vegetation, physico-chemical parameters, ponds, pondscape, vegetation data

## Introduction

Ponds offer vital resources and living spaces for a wide range of both aquatic and terrestrial organisms (Fehlinger et al. 2023). These small permanent aquatic systems, regardless of their origin (artificial or natural), provide

habitats to plants, amphibians, insects, and birds (Simma et al. 2016; Bubíková and Hrivnák 2018a; Zamora-Marín et al. 2021) and often rare species that are not found in larger water bodies (Oertli et al. 2002; Bolpagni et al. 2019). Despite their ecological importance, they are among the most vulnerable and endangered habitats

\* Topical Collection: “Vegetation databases: enhancing data integration and accessibility for ecological research”. Edited by Adrian Andreica, Kiril Vassilev, Pauline Delbosc, Federico Fernández-González, Irena Axmanová, Borja Jiménez-Alfaro, Gianmaria Bonari.

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in the world (Dudgeon et al. 2006). In particular, aquatic vegetation is undergoing significant decline driven by human activities, including urban expansion, habitat fragmentation and destruction, pollution, eutrophication, and the spread of invasive species (Akasaka et al. 2010; Bolpagni et al. 2019, 2020; Bolpagni 2020, 2021; Fernández-Aláez et al. 2020; Du Toit et al. 2021). Ponds represent one of the most common and widespread freshwater habitats, especially in human-modified landscapes. Despite their small size, ponds are essential for biodiversity conservation (Biggs et al. 2017) since they tend to host significantly higher numbers of species, including more unique and rarer species, than other types of water bodies (Oertli et al. 2005).

Pond vegetation is typically composed of wetland plants, including emergent species that are rooted in the sediment but extend their vegetative parts above the water, and aquatic plants, which include submerged species with entirely underwater leaves, along with rooted floating and free-floating types (Ervin 2023). Beyond hosting a rich diversity of strictly aquatic flora, ponds also provide suitable conditions for surrounding semi-terrestrial plant species, namely riparian vegetation (Scheff et al. 2022). These plants occupying the transition zone between land and water interact closely with aquatic habitats and, as wetland and aquatic species, are shaped both by land use and water characteristics (Wang et al. 2021; Musisi et al. 2025). Pond identity is relevant in defining plant species richness and community composition (Cannucci et al. 2025) given the interplay of multiple filtering processes, particularly local environmental filters such as physical aspects of ponds (e.g., area, depth) and physico-chemical properties of water, which influence the diversity patterns of plant species (Hrivnák et al. 2013). Plant diversity metrics can change in relation to the type of water body which can contribute uniquely and significantly to plant diversity (Bubíková and Hrivnák 2018b; Grasel et al. 2021). The observation of the ecological patterns occurring in ponds is essential to summarize the vegetation-environment relationships. Many studies on ponds have investigated the responses of plant communities to environmental drivers (Gallego et al. 2015; Fernández-Aláez et al. 2018; Sieben et al. 2021), leading to different outcomes on the most relevant drivers of plant species composition.

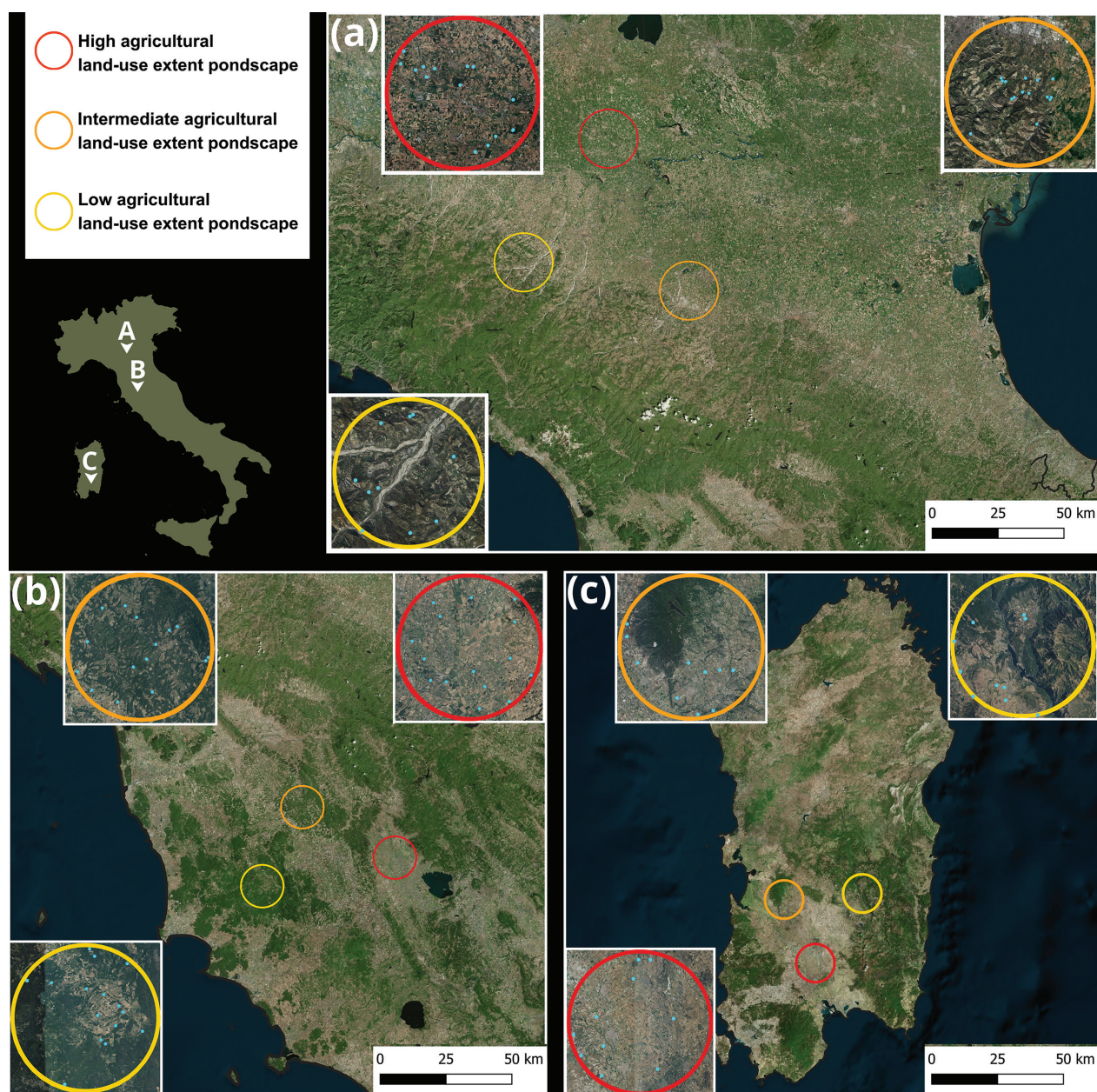
Accessible datasets are key tools for providing an overview of species and habitat distribution, and they support biodiversity conservation actions by highlighting the occurrence of species of conservation interest or alien species (Santoianni et al. 2025). Given the strong relationship between plant communities and environmental characteristics, we present the PONDY dataset: Pond vegetation data and water physico-chemical parameters. PONDY combines vegetation data of ponds with water physico-chemical parameters, thus aiming to serve as a tool to evaluate the ecological status of water bodies and to analyze how environmental conditions, related to water quality, affect species presence, abundance, and cover.

## Study area and methodology

The study area (Fig. 1) encompasses 115 permanent farmland ponds distributed across continental (Fig. 1a, b) and insular (Fig. 1c) areas of Italy. We selected permanent ponds ranging from 70 m<sup>2</sup> to 3 ha. In each area (Suppl. material 1: fig. S1a), we chose three zones, namely pondscape (interconnected pond networks in a landscape) based on the extent of agricultural land use (Suppl. material 1: fig. S1b). The percentage of agricultural land was calculated within a 10 km radius using Corine Land Cover maps (ISPRA 2018). Three pondscape, based on agricultural land-use extent, were established: low (<30% agricultural land-use extent), intermediate (30–60% agricultural land-use extent), and high (>60% agricultural land-use extent). Ponds were identified within each pondscape (Suppl. material 1: fig. S2) by extracting water bodies classified under the “Water Bodies” category (5.1.2) from the Corine Land Cover map (ISPRA 2018) using QGIS (QGIS Development Team 2023). In each pondscape, the 10 km buffer zone was divided into a 500 m × 500 m grid, which was overlaid on the extracted water bodies. From this grid, we randomly selected one pond per grid cell, using QGIS’s Random Selection tool within subsets. To overcome potential accessibility issues, the selection process was repeated three times, ensuring a minimum distance of 1 km in a straight line between selected ponds. Within each area, between 10 and 15 ponds were randomly selected (see Suppl. material 1: fig. S1c). For each pond, using the QGIS Random Points Along Lines plugin, we generated three points along the pond perimeter, setting a minimum distance of 15 m between points. In the field, in proximity of these points we positioned the plots and at each point we surveyed one aquatic plot measuring 2 m × 2 m, along with one terrestrial plot of the same size located 1 m away from the aquatic plot (Suppl. material 1: fig. S1d), thus obtaining a total of 6 plots (3 aquatic and 3 terrestrial plots) for each pond. With this sampling design, some aquatic plots resulted empty (no species recorded); these latter plots were therefore removed from the dataset due to the absence of vegetation.

## Data collection

All ponds were sampled during the peak of the growing season. Specifically, ponds in the continental areas of Italy were surveyed between June and August 2020, 2021, and 2023, those in insular Italy in late April 2024. In each plot, we recorded all the occurring species, including vascular plants and macroalgae of the Characeae family. Vascular plant species nomenclature follows the Portal to the Flora of Italy (2025). Nomenclature of Characeae follows Bazzichelli and Abdelahad (2009). In the field, together with vegetation data, we also collected physico-chemical water parameters to obtain data influencing aquatic and riparian species. Multiparametric probe (Aquaread 2000-d) was used to record several parameters at the center of each aquatic plot, between 8:00 a.m. and 3:00 p.m., including



**Figure 1.** Distribution of the sampled ponds across pondscapes (high, intermediate, and low) and the continental (a, b), and insular (c) areas of Italy.

water temperature ( $^{\circ}\text{C}$ ), depth (m), dissolved oxygen (expressed in percentage, %), pH, turbidity (NTU – Nephelometric Turbidity Unit), and electrical conductivity ( $\mu\text{S}/\text{cm}$ ). Within each plot, a water sample was collected and immediately filtered through a  $0.7\ \mu\text{m}$  glass fiber filter (GF/F, Whatman) for subsequent analyses. In the laboratory, soluble reactive phosphorus (as phosphate ion,  $\text{PO}_4^{3-}$ ;  $\mu\text{g}/\text{L}$ ) was measured spectrophotometrically following the method by Valderrama (1977). The remaining water was filtered using a  $0.2\ \mu\text{m}$  nylon membrane, and concentrations of dissolved nitrate ( $\text{NO}_3^-$ ;  $\text{mg}/\text{L}$ ) and ammonium ( $\text{NH}_4^+$ ;  $\text{mg}/\text{L}$ ) were quantified via ion chromatography (883 Basic IC plus, Metrohm, Herisau, Switzerland). Given the higher relevance of aquatic vegetation for conservation assessment compared to agricultural lands, we classified aquatic plots

to i) Annex I habitat types of 92/43/EEC Habitats Directive and ii) EUNIS habitat types (v2025-10-03; Chytrý et al. 2020). For these classifications, we used an expert-base approach and the code implemented by Bruelheide et al. (2021) in R 4.5.0 (R Core Team 2025), respectively.

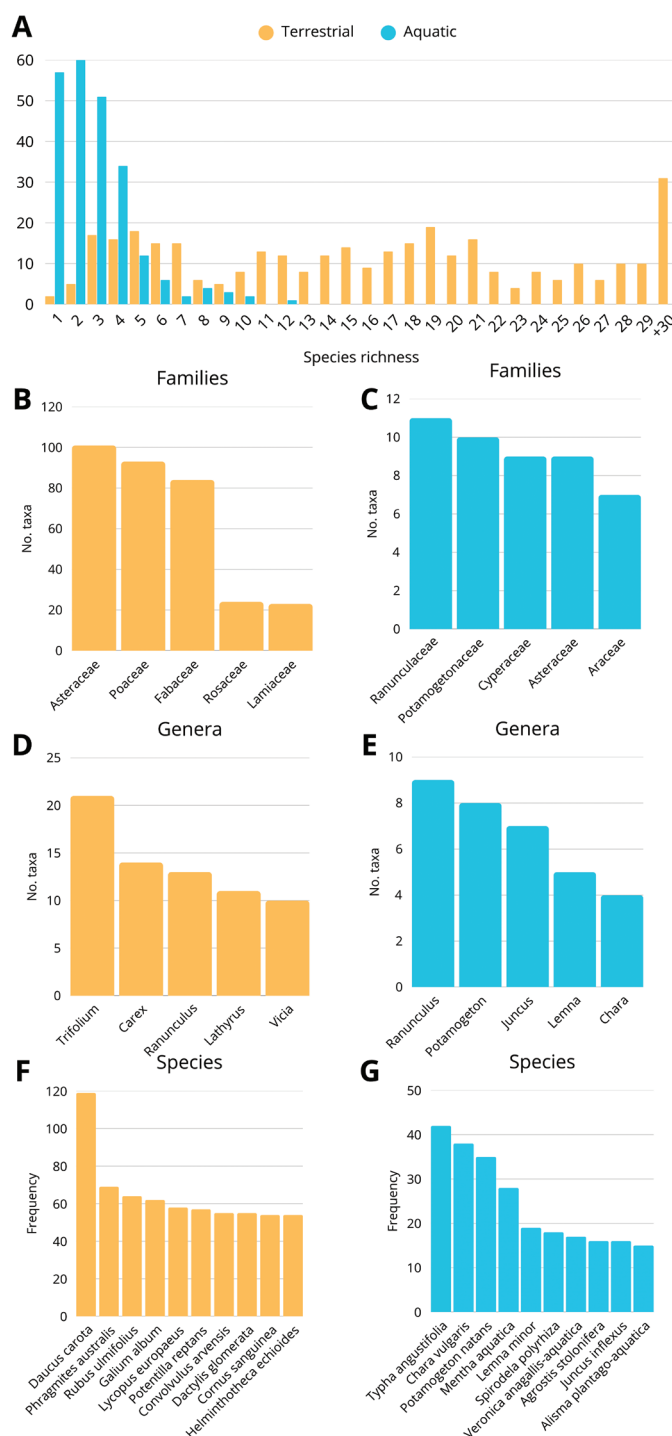
## Structure of the dataset

### Species and vegetation

The dataset includes 575 georeferenced vegetation plots (232 aquatic and 343 terrestrial) including 743 vascular plant taxa and 5 macroalgae. The species richness of plots varies between one to 40, with 443 (64.2%) plots having less

than 10 species and 121 (17.5%) plots having 20 or more taxa (Fig. 2A). The average species richness in aquatic and terrestrial plots is 2 and 16, respectively. A total of 748 taxa belonging to 364 genera and 89 families were identified. Overall, 690 taxa of 87 families were recorded in terrestrial plots and 117 taxa of 36 families were recorded in aquatic plots. Asteraceae is the largest family in terrestrial plots, with 101 species, followed by Poaceae (93 species), and Fabaceae (84 species, Fig. 2B), while Ranunculaceae is the largest family in aquatic plots, with 11 taxa, followed

by Potamogetonaceae (10 taxa), and Cyperaceae (9 taxa, Fig. 2C). *Trifolium* is the most represented genus in the terrestrial plots, with 21 species (Fig. 2D), while in aquatic plots *Ranunculus* is the genus having the highest number of species (9 species; Fig. 2E). The most frequent species in the terrestrial plots is *Daucus carota* (occurring in 17% of plots) followed by *Phragmites australis* and *Rubus ulmifolius* (Fig. 2F). *Typha angustifolia*, *Chara vulgaris*, and *Potamogeton natans* are the most frequent taxa in the aquatic plots (all occurring in at least 30% of plots; Fig. 2G).



**Figure 2.** Graphics showing species richness per plot (A), the five most frequent families in terrestrial plots (B), the five most frequent families in aquatic plots (C), the five most abundant genera in terrestrial plots (D), the five most abundant genera in aquatic plots (E), the ten most frequent taxa in terrestrial plots (F), and the ten most frequent taxa in aquatic plots (G).

The dominant life forms are Hemicryptophytes (39%) and Therophytes (37%) in terrestrial plots and Hemicryptophytes (35%) and Hydrophytes (20%) in aquatic plots. Chamaephytes are the least frequent life form in both plot types (Suppl. material 1: fig. S3). Moreover, the dataset contains a total of 10 threatened taxa of the Italian Red List (Table 1), mostly linked to the aquatic environment, highlighting the critical conservation status of plant species ecologically connected with freshwater ecosystems. More precisely, these species are mostly threatened by modification of the natural system and by agriculture and aquaculture (Orsenigo et al. 2020).

**Table 1.** Threatened taxa, their statuses from the Italian Red List, and major threats (Orsenigo et al. 2020). Major threats: 1 = Residential and commercial development; 2 = Agriculture and aquaculture; 4 = Transportation and service corridors; 5 = Biological resource use; 6 = Human intrusions and disturbance; 7 = Natural system modifications; 8 = Invasive and other problematic species, genes and diseases; 9 = Pollution; and 11 = Climate change and severe weather.

| Species                                           | Status               | Major threats        |
|---------------------------------------------------|----------------------|----------------------|
| <i>Baldellia ranunculoides</i>                    | Endangered (EN)      | 1, 2, 7, 8, 9, 11    |
| <i>Butomus umbellatus</i>                         | Vulnerable (VU)      | 7, 8, 9, 11          |
| <i>Carex microcarpa</i>                           | Near Threatened (NT) | 1, 2, 7              |
| <i>Hottonia palustris</i>                         | Endangered (EN)      | 2, 5, 6, 7, 8        |
| <i>Leucojum aestivum</i> subsp. <i>aestivum</i>   | Vulnerable (VU)      | 5, 7                 |
| <i>Plagius flosculus</i>                          | Endangered (EN)      | 1, 2, 4, 7, 8        |
| <i>Ranunculus cordiger</i> subsp. <i>diffusus</i> | Endangered (EN)      | 2, 7                 |
| <i>Ranunculus ophioglossifolius</i>               | Vulnerable (VU)      | 2, 4, 6, 7, 9        |
| <i>Thelypteris palustris</i>                      | Vulnerable (VU)      | 7, 8, 9              |
| <i>Zannichellia palustris</i>                     | Near Threatened (NT) | 1, 2, 4, 7, 8, 9, 11 |

The dataset contains a total of 39 alien species, mostly found in terrestrial plots, 33 of which are categorised as invasive in Italy (Table 2).

## Habitat types

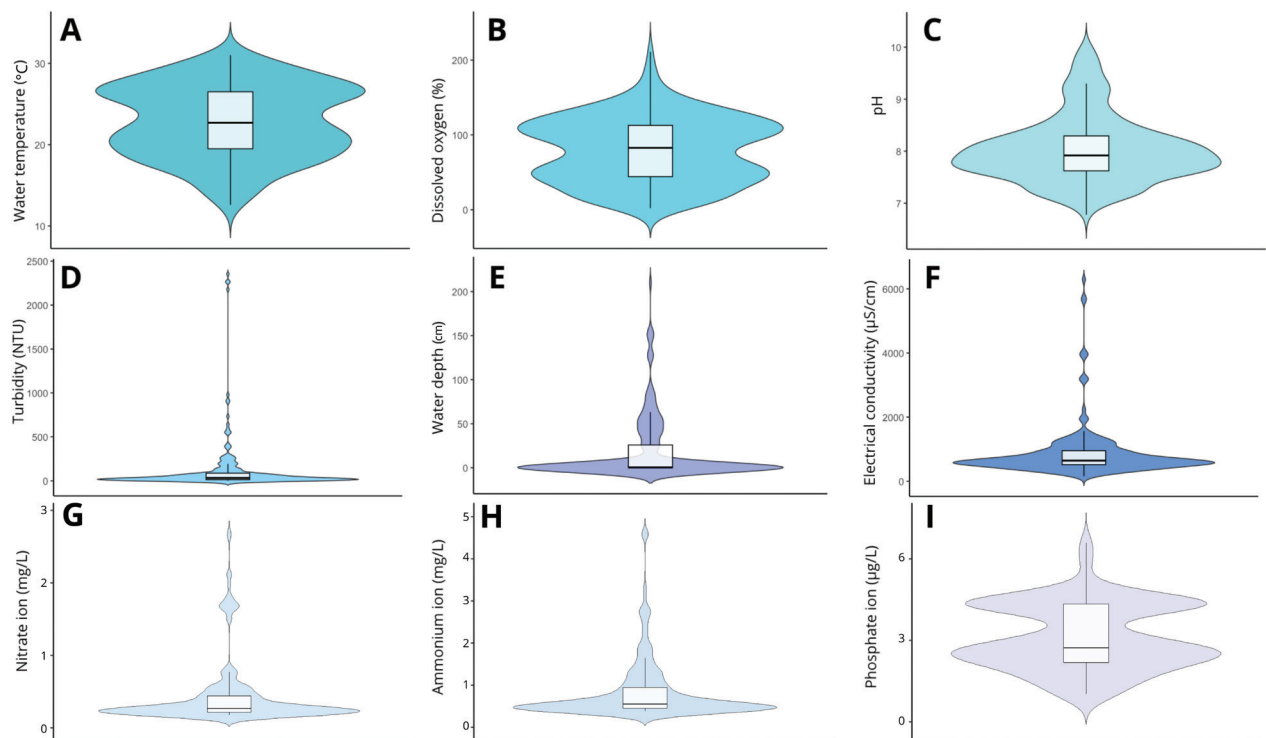
Overall, we classified 64 aquatic plots (11%) under a Habitats Directive 92/43/EEC habitat type and 275 plots (48%; based on Suppl. material 1: table S1) under a EUNIS habitat type (Table 3). More precisely, we assigned 21 plots to 92/43/EEC habitat type 3140 (Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.) and 43 plots to habitat 3150 (Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation). The conservation status of both habitats is considered unfavorable in Italy (ISPRA 2021). In particular, habitat 3140 is classified as having unfavorable conservation status in the Alpine and Continental biogeographical regions, while habitat 3150 in the Mediterranean region (ISPRA 2021). The rest of the plots (N = 511) could not be assigned to any 92/43/EEC habitat type. Moreover, 116 plots (based on Suppl. material 1: table S1) have been classified to macrohabitat type “P”

**Table 2.** The alien species present in this dataset and their associated status (Portal to the Flora of Italy 2025) in Italy, as well as their distribution in aquatic or terrestrial plots. Plant species are ordered alphabetically.

| Species                            | Neophyte/<br>Archaeophyte | Status      | Plot        |
|------------------------------------|---------------------------|-------------|-------------|
| <i>Acalypha virginica</i>          | Neophyte                  | Invasive    | Terrestrial |
| <i>Acer negundo</i>                | Neophyte                  | Invasive    | Terrestrial |
| <i>Amaranthus blitoides</i>        | Neophyte                  | Invasive    | Terrestrial |
| <i>Amaranthus cruentus</i>         | Neophyte                  | Invasive    | Terrestrial |
| <i>Amaranthus retroflexus</i>      | Neophyte                  | Invasive    | Terrestrial |
| <i>Amorpha fruticosa</i>           | Neophyte                  | Invasive    | Terrestrial |
| <i>Arundo donax</i>                | Archaeophyte              | Invasive    | Terrestrial |
| <i>Avena strigosa</i>              | Neophyte                  | Casual      | Terrestrial |
| <i>Bidens connata</i>              | Neophyte                  | Invasive    | Terrestrial |
| <i>Bidens frondosa</i>             | Neophyte                  | Invasive    | Aquatic     |
| <i>Cyperus strigosus</i>           | Neophyte                  | Invasive    | Terrestrial |
| <i>Erigeron annuus</i>             | Neophyte                  | Invasive    | Terrestrial |
| <i>Erigeron bonariensis</i>        | Neophyte                  | Invasive    | Terrestrial |
| <i>Erigeron canadensis</i>         | Neophyte                  | Invasive    | Terrestrial |
| <i>Erigeron sumatrensis</i>        | Neophyte                  | Invasive    | Terrestrial |
| <i>Eucalyptus camaldulensis</i>    | Neophyte                  | Invasive    | Terrestrial |
| <i>Euphorbia humifusa</i>          | Neophyte                  | Naturalized | Terrestrial |
| <i>Galinsoga parviflora</i>        | Neophyte                  | Invasive    | Terrestrial |
| <i>Hesperocyparis arizonica</i>    | Neophyte                  | Naturalized | Terrestrial |
| <i>Humulus japonicus</i>           | Neophyte                  | Invasive    | Terrestrial |
| <i>Lemma aequinoctialis</i>        | Neophyte                  | Naturalized | Aquatic     |
| <i>Lemma minuta</i>                | Neophyte                  | Invasive    | Aquatic     |
| <i>Lindernia dubia</i>             | Neophyte                  | Invasive    | Aquatic     |
| <i>Ludwigia hexapetala</i>         | Neophyte                  | Invasive    | Aquatic     |
| <i>Oenothera stueckii</i>          | Neophyte                  | Invasive    | Terrestrial |
| <i>Oxalis pes-caprae</i>           | Neophyte                  | Invasive    | Terrestrial |
| <i>Panicum capillare</i>           | Neophyte                  | Invasive    | Terrestrial |
| <i>Panicum dichotomiflorum</i>     | Neophyte                  | Invasive    | Terrestrial |
| <i>Parthenocissus quinquefolia</i> | Neophyte                  | Invasive    | Terrestrial |
| <i>Paspalum distichum</i>          | Neophyte                  | Invasive    | Aquatic     |
| <i>Sicyos angulatus</i>            | Neophyte                  | Invasive    | Terrestrial |
| <i>Solidago gigantea</i>           | Neophyte                  | Invasive    | Terrestrial |
| <i>Sorghum halepense</i>           | Archaeophyte              | Invasive    | Terrestrial |
| <i>Symphyotrichum lanceolatum</i>  | Neophyte                  | Invasive    | Terrestrial |
| <i>Symphyotrichum squamatum</i>    | Neophyte                  | Invasive    | Aquatic     |
| <i>Trifolium alexandrinum</i>      | Neophyte                  | Naturalized | Terrestrial |
| <i>Verbena bonariensis</i>         | Neophyte                  | Naturalized | Terrestrial |
| <i>Veronica persica</i>            | Neophyte                  | Invasive    | Terrestrial |
| <i>Xanthium spinosum</i>           | Neophyte                  | Invasive    | Terrestrial |

**Table 3.** Classification of the vegetation plots according to EUNIS habitat types. Only habitats occurring in more than 3% of plots classified in the given habitat are reported. The complete table is provided in Suppl. material 1: table S1.

| EUNIS                                           | No.<br>plots | Percentage |
|-------------------------------------------------|--------------|------------|
| Fresh-water small pleustophyte vegetation (P3b) | 32           | 5.6        |
| Fresh-water submerged vegetation (P3d)          | 18           | 3.1        |
| Fresh-water nymphaeid vegetation (P3e)          | 24           | 4.2        |
| Stonewort vegetation (P3h)                      | 39           | 6.8        |
| Tall-helophyte bed (Q51)                        | 96           | 16.7       |
| Helophyte beds (Qb)                             | 36           | 6.3        |



**Figure 3.** Violin plots of physico-chemical water parameters measured for each aquatic plot. Water temperature (A), dissolved oxygen (B), pH (C), turbidity (D), water depth (E), electrical conductivity (F), nitrate ion (G), ammonium ion (H), and phosphate ion (I).

(Inland waters) and related sublevels of EUNIS classification, while 159 plots (based on Suppl. material 1: table S1) to macrohabitat type “Q” (Wetlands) and related sublevels.

### Physico-chemical water parameters

The dataset includes key parameters describing physical aspects, water chemistry, and trophic indicators (Fig. 3). The summary of the physico-chemical water parameters recorded in the study ponds, including mean, standard deviation (SD), minimum (Min), and maximum (Max) values is reported in Suppl. material 1: table S2.

## Conclusions

The information present in the PONDY dataset strengthens the knowledge of pond plant diversity along insular and continental Italy. This dataset, which provides comprehensive data on plant species, community composition, habitat types, and physico-chemical water parameters, is important for understanding the plant diversity hosted in these freshwater systems and studying its relationship with physico-chemical water parameters. This dataset can be the base for future studies on the relationships between plant communities and environmental conditions and can be used for developing predictive models for species distribution based on chemical parameters. Furthermore, in the future, the dataset might be expanded with functional trait data to provide an assessment of functional composition of plant communities in relation to water chemistry. Additionally, it can

contribute to define conservation status of lentic systems by assessing conservation indices, similarly to the ECELS index used in Catalonia (Sala et al. 2004), based on water characteristics, land use, and vegetation status aspects.

### Data availability

The vegetation plot data are available in the CircumMed database (GIVD: EU-00-026 - CircumMed database <https://www.givd.info/ID/EU-00-026>).

### Author contributions

SC and RB collected the data in the field with contributions from CA, EF, TF, and FM. SC, CA, RB, and SM designed the sampling plan. SC and RB identified vascular plant species with contributions from FM and TF. TF identified Charophyceae species. ADV performed the chemical analysis in the laboratory. SC and RB assembled the dataset with contribution from LS. FC performed the semi-automatic habitat EUNIS classification. SC did the analyses. SC led the writing with contributions from GB. SC prepared the figures with contributions from GB. CA and GB supervised the research. All authors critically revised the manuscript and approved the final version.

### Competing interests

The authors declare that no competing interests exist.

## Acknowledgements

Silvia Cannucci, Emanuele Fanfarillo, Claudia Angiolini, Simona Maccherini, and Gianmaria Bonari were funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU; Award Number: Project code CN\_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP B63C22000650007, Project title “National Biodiversity Future Center - NBFC”. Rossano Bolpagni benefited from the equipment and framework of the COMP-R Initiative, funded by the ‘Departments of Excellence’ program of the Italian Ministry for University and Research (MUR, 2023–2027) and is partially funded under the NRRP, Mission 4 Component 2 Investment 1.4, funded by the European Union – NextGenerationEU; Call for tender: Project code CN\_00000033, CUP B63C22000650007, Project title “National Biodiversity Future Center - NBFC”, Cascading grant call by Spoke 3 “Assessing and monitoring terrestrial and freshwater biodiversity and its evolution: from taxonomy to genomics and citizen science”, Project title “development of the Italian MACrophytes Database (iMAD)”. Alice Dalla Vecchia is currently funded by a MSCA-Global-2023 fellowship DIVE IN “Predicting DIVERsity of INvasive aquatic plants” (GA No. 101147317).

We thank Giovanni Riviaccio for the logistics and Jacopo Cristoni for his contribution to sampling and characterization of ponds.

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## Supplementary material 1

### Suppl. figures and tables

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Data type: docx

Explanation note: **figure S1**: Spatial representation of the sampling design followed, spanning (a) the regions, (b) the selection of ponds, (c) the selection of ponds, and (d) the localisation of vegetation plots (2 m × 2 m) within each pond. A = aquatic plot, T = terrestrial plot. **figure S2**: Examples of ponds of the three ponds: (a) High agricultural land-use extent pond (Monastir, Sud Sardegna, Italy); (b) Low agricultural land-use extent pond (Montieri, Grosseto, Italy); (c) Intermediate agricultural land-use extent pond (San Venzio, Modena, Italy). Photo credits: (a, b) S. Cannucci; (c) R. Bolpagni. **figure S3**: Number of different life forms for both the terrestrial and aquatic plots. **table S1**: Classification of the vegetation plots according to EUNIS habitat types. **table S2**: Summary statistics of environmental parameters measured across the plots of the studied ponds.

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Link: <https://doi.org/10.3897/ved.176891.suppl1>