

The potential uses of aquatic macrophytes: An initial assessment for conservation in a rural landscape

Usos potenciales de macrófitas acuáticas: evaluación inicial para la conservación en un paisaje rural

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ABSTRACT. The Argentine Pampa ecoregion is one of the largest temperate grasslands in the world, and constitutes a system in which livestock and agriculture have been generalized practices for more than a century. The Flooding Pampa is a subregion of the Argentine Pampas with countless ponds that constitute wetlands. Potential uses of aquatic macrophytes were examined in 6 ponds in order to highlight the relevance of this biological assemblage through valuing its usefulness as a resource. Plants were classified into 3 life forms and 7 use-categories. A total of 82 species (73% native) were collected. The families with the greatest numbers of species were Poaceae, Cyperaceae, and Asteraceae; and the most diverse genera were *Eleocharis* R.Br. and *Cyperus* L. The predominant life form was hygrophytes (51%), followed by helophytes (34%), and hydrophytes (15%). The largest diversity of plants was seen in Forage (61%) and Medicinal (59%) categories. Araceae, Asteraceae, and Fabaceae were found to be the most versatile families, as their component species were represented in the largest numbers of use-categories. The relationship found between the species richness of a plant family and the numbers of use-categories attributed to it, allows us to infer that greater species richness may be related to an increase in use-potential. Considering that ponds are ephemeral water bodies highly vulnerable, we would like to draw attention to the potential uses of the macrophytes as a practical and genuine way to revalue these environments, which have been historically neglected habitats by decision makers involved in biodiversity conservation.

Keywords: Flooding Pampa, helophytes, hydrophytes, hygrophytes, wetlands.

RESUMEN. La ecorregión Pampa de Argentina es una de las praderas templadas más extensas del mundo y constituye un sistema en el que la ganadería y la agricultura han sido prácticas generalizadas durante más de un siglo. La Pampa Deprimida es una subregión con innumerables cubetas que constituyen humedales. Se examinaron los usos potenciales de las macrófitas acuáticas en 6 cubetas con el fin de destacar la relevancia de este ensamble biológico a través de la valoración de su utilidad como recurso. Las plantas se clasificaron en 3 formas de vida y 7 categorías de uso. Se recolectó un total de 82 especies (73% nativas). Las familias con mayor número de especies fueron Poaceae, Cyperaceae y Asteraceae; y los géneros más diversos fueron *Eleocharis* R. Br. y *Cyperus* L. La forma de vida predominante fueron las higrófitas (51%), seguidas de las helófitas (34%) y las hidrófitas (15%). La mayor diversidad de plantas se observó en las

categorías Forrajeras (61%) y Medicinales (59%). Se determinó que Araceae, Asteraceae y Fabaceae son las familias más versátiles, ya que sus especies componentes están representadas en el mayor número de categorías de uso. La relación encontrada entre la riqueza de especies de una familia de plantas y el número de categorías de uso atribuidas a ella permite inferir que una mayor riqueza de especies puede estar relacionada con un aumento en el potencial de uso. Considerando que las cubetas son cuerpos de agua efímeros y altamente vulnerables, se propone focalizar sobre los usos potenciales de las macrófitas como una forma práctica y genuina de revalorizar estos ambientes que históricamente han sido hábitats desatendidos por los tomadores de decisiones involucrados en la conservación de la biodiversidad.

Palabras clave: Helófitas, hidrófitas, higrófitas, humedales, Pampa Deprimida

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INTRODUCTION

Wetlands are fundamental constituents of the hydrological cycle and, moreover, they are extremely productive, hold large biodiversity, and also offer many ecosystem services like food provision, flood control, water purification, waste assimilation, groundwater replenishment, climate regulation, sediment and nutrient retention, increasing the aesthetic value of the land, and providing several recreational, touristic, and sociocultural activities (Jisha & Puthur, 2022).

The Argentine Pampa ecoregion is one of the largest temperate grasslands in the world, and constitutes a system in which livestock and agriculture have been generalized practices for more than a century. However, despite the variety of environments that make up its landscape mosaic, only 0.01% of its surface (3,971 km²) is included in the Protected Natural Areas System from Argentina (Sistema de Información de Biodiversidad, Administración de Parques Nacionales, 2025). The high number of ponds in that herbaceous matrix means local communities fail to appreciate the need to care for them, endangering biodiversity and, consequently, the quality of the services they provide to the ecosystem (Maestri *et al.*, 2019). These geoforms are shallow and closed topographic depressions that result from a variety of processes such as eolian excavation and salt weathering (Ticart, 1973; Sabin &

Holliday, 1995). They occur in the High Plains of the United States, the interior of southern Africa, extensive tracts of Australia, West Siberia and Manchuria, the South American Swamp, and the Pampas and Patagonia of Argentina (Goudie, 2008; Goudie & Wells, 1995). Water flows and levels in these ponds are dynamic since in summer these wetlands are dry due to the high evaporation and evapotranspiration rates, while during autumn, winter, and early spring they are filled with water. This temporal pattern of water level, or hydroperiod, is part of their ecological signature (Mitsch & Gosselink, 1993). In wetlands, hydro-sedimentological dynamics govern most of the ecological adjustment processes between organisms and the environment (Neiff, 1997); in fact, there is considerable evidence of synchronism between the occurrence of certain biotic processes (germination, growth, flowering, fruiting and seed dispersal) and the occurrence of hydrological events (Brinson, 1993). Specifically in the area under study, as in the rest of South America floodplains, permanent fluctuations of wetlands throughout an annual cycle are often confused with stress factors when the stability of the system actually depends on those recurrent changes that constitute the adaptation framework for the wide distribution of a large part of its aquatic flora (Rial, 2013). Clearly, wetlands and associated terrestrial ecosystems are also interdependent, but alterations in terrestrial ecosystems usually affect wetlands more than the reverse (National

Research Council, 1995). Thus, agricultural uses on adjacent grasslands, modify the physical, chemical, and biotic characteristics of these wetlands and, consequently, affect their functions (hydrologic, biogeochemical, and maintenance of habitat and food webs). In fact, many ponds are subject to progressive eutrophication due to human activities taking place in the region (Izaguirre *et al.*, 2022). As an example, cattle can remain in or around water for long periods of time, negatively impacting water bodies (Trimble & Mendel, 1995) by increasing nutrients through urine and fecal matter deposition, destruction of banks, soil compaction through trampling (Belsky *et al.*, 1999) and damage of aquatic vegetation.

Aquatic macrophytes are a key component of these wetlands because they contribute to the physical and biological diversity, habitat structure and ecological functioning of these systems (Hearne & Armitage, 1993; Estevez, 1998; Mainstone & Parr, 2002; Lacoul & Freedman, 2006). In addition, macrophytes are sensitive and reliable indicators of the environmental conditions (Flynn *et al.*, 2002; Schneider, 2007). In this sense, their use as indicators presents some advantages since they are relatively easy to identify, they can be monitored using satellite images, they respond more quickly to environmental changes than other organisms and, in the case of rooted plants, their immobility facilitates sampling strategies (Tagliaferro, 2020). Hence the importance of using macrophyte diversity as an indicator to conserve the biodiversity of an entire wetland (Akasaka *et al.*, 2010), and in the analysis of wetlands organization across the landscape (Malvárez, 1997).

The value of a wetland is a measure of its importance to society, hence, decisions about whether to protect wetlands or how much to spend on their protection are policy decisions based in part on the value society places on wetlands (National Research Council, 1995). As Chindamo *et al.* (2024) pointed out, the landscape as a whole must be considered the

natural unit for the management of wetlands. In a context of strong land use pressure, certain functions of the wetlands and their effects are easy to distinguish and assess (e.g. the ability to store surface water and reduce downstream flood peak), while others are more intangible to society (e.g. cycling of elements and maintenance of nutrient stocks within wetland). The latter group also includes the functions related to habitat and food web support, in which aquatic macrophytes constitute a fundamental assemblage.

In light of the importance of developing strategies for biodiversity conservation, the objective of this work is to identify the potential uses and versatility of aquatic macrophytes in Pampas wetlands as a means to revalue these historically neglected habitats and inform more effective conservation strategies.

MATERIALS AND METHODS

Study region and sampling sites selection

The Flooding Pampa is a subregion of the Argentine Pampas. It is a vast plain that occupies about 90,000 km², whose landscape is characterized by scarce topographic slopes (less than 1%), low density of drainage network, and significant development of ponds of varying size (Aragón *et al.*, 2011). Ponds are distributed across the vegetation matrix of the landscape that is, in fact, a mosaic formed by graminoid steppes and prairies with different cover and height of grasses (Vercelli, 2018; Entraigas *et al.*, 2019) that are the main livestock forage resource of the region. The advance of the agricultural-livestock frontier and urbanization in the region have deeply modified the ecosystems, where the original vegetation has been largely replaced by cultivated species, or else greatly altered by intensive grazing (Grossi *et al.*, 2013). A total of 2.7 million calves, mainly of British breeds (such as Aberdeen Angus and Hereford), are raised annually on the Flooding Pampa¹.

¹ Ministerio de Agroindustria. (2015). Caracterización de la producción bovina. Buenos Aires – Corrientes – Chaco – Formosa – La Pampa– Misiones. Serie 1. Presidencia de la Nación.

The lower basin of del Azul creek comprises an area of 3,000 km² that is part of the Flooding Pampa. It is an extremely flat area (slopes about 0.1%), and represents a geomorphological landscape with low gradient and scarce relative relief (Zárate & Mehl, 2010). Soils are alkali and/or hydromorphic and show a hard carbonate crust of variable depth and continuity that generates flooding and poor internal drainage conditions in the soil profile. The water table is near the land surface (between 0.2 and 2.5 m, (Entraigas *et al.*, 2017)), but frequently the layers composed of cemented calcium carbonate contained in their subsurface would act as physical barriers that restrict the magnitude of the interaction between the wetlands and the aquifer (Briceño *et al.*, 2025). These aeolian geoforms (currently inactive) constitute shallow water bodies (60–150 cm depth) without thermal stratification (Dangavs *et al.*, 2005), and of variable extension (from dozens of meters to 3 km in diameter). In a plan view they are relatively round in shape; their east-northeast flank is characterized by the occurrence of lunettes with a relative height of just over 1 m, indicating prevailing winds from the west-southwest during their genesis (Frenguelli, 1950; Dangavs & Reynaldi, 2008).

The study was carried out in six ponds similar in size (about 30 ha), number of input and output channels (three and one, respectively) and hydrological dynamics, located in different sectors of the lower basin of del Azul creek (Figure 1). These six sites were selected for macrophyte sampling as representative of this flat area that can be considered, as stated by Entraigas *et al.*, (2019), a wetland system. In the selected ponds, plants are distributed in an organized manner, forming division zones (like concentric rings) from the margins of the wetland to its interior (Vervoorst, 1967; Entraigas *et al.*, 2014; Vercelli, 2018). Thus, the following associations are generally identified: the “duraznillar” of *Solanum glaucophyllum* (little-branched shrub up to 1.5 m tall), followed by the “juncal” of *Schoenoplectus californicus* var. *californicus* (bulrush up to 2 m high, with knotty horizontal rhizomes), and finally the center of the pond with a floating layer formed by *Azolla filiculoides* and *Ricciocarpus natans*, or free water (depending on the depth of the water body).

Data collection

Considering the arrangement of vegetation in concentric rings, vegetation sampling was carried

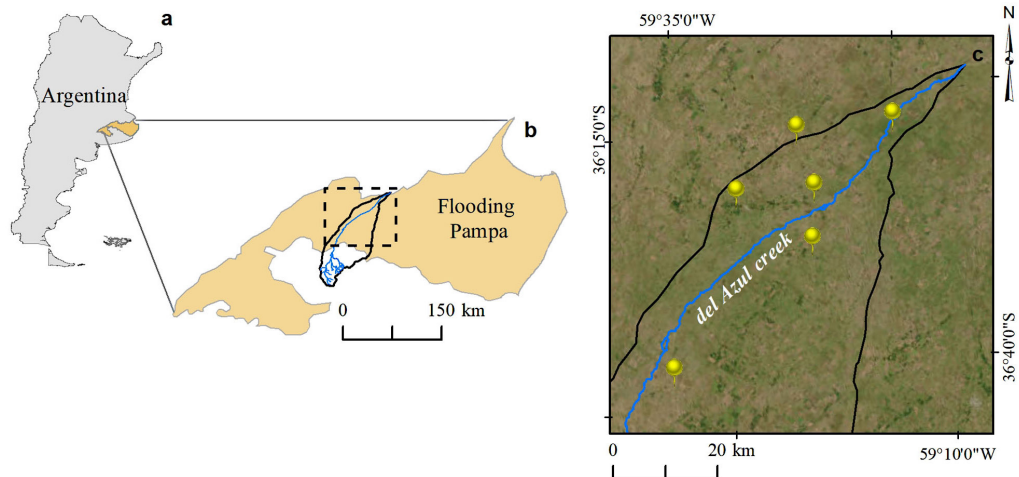


Figure 1. Study Region. (a). Location of the Flooding Pampa in Argentina; (b) location of del Azul creek basin in the Flooding Pampa (solid black line); (c) location of the selected ponds in the study area (yellow icons).

Figura 1. Región de Estudio. (a) Ubicación de la Pampa Deprimida en Argentina; (b) ubicación de la cuenca del arroyo del Azul en la Pampa Deprimida (líneas sólidas negras); (c) ubicación de las cubetas seleccionadas en el área de estudio (íconos amarillos).

out during summer by crossing each wetland following an imaginary line perpendicular to the shoreline, running from the shoreline itself to the center of the pond, where the different species found were recorded.

Specimens of each species recorded were collected and preserved in newspaper sheets, plastic bags or jars, depending on moisture content, size and consistency of collected organs. The herborization process was performed in the Laboratorio de Botánica Sistemática (Facultad de Agronomía, Universidad Nacional del Centro de la Provincia de Buenos Aires) as well as the subsequent determination using traditional flora (Cabrera, 1963; Anton & Zuloaga, 2018) and genus revisions. Later, specimens were deposited in FAA Herbarium (Thiers, 2025) and nomenclature was updated according to Flora Argentina (Anton & Zuloaga, 2018); origin of each species was extracted from the same database. With this information, the final plant list was obtained, grouped by families and large plant groups.

From the wide variety of definitions about “aquatic macrophytes”, in our study we adopted the one proposed by Weaver & Clements (Weaver & Clements, 1938): “herbaceous plants growing in water, on waterlogged land, or even in water- saturated soils”. Then, we separated the macrophytes recorded into three different life forms as proxies of functional groups: (i) hydrophytes: water-submerged plants, or those with floating leaves (Raunkiaer, 1934); (ii) helophytes: species that have aerial stems and leaves growing above the water surface and use nutrients from the sediment (Schneider *et al.*, 2018); and (iii) hygrophytes: terrestrial plants growing close to water-bodies that require high soil humidity conditions for their development (Lahitte & Hurrell, 1997).

Besides, plants were classified into seven use-categories: Food sources, Forage, Medicinal, Ornamental, Apicultural, Remedial, Other uses. Within the “Other uses” category those uses such as construction, flavoring, coloring, fencing, basketry, were included. Information about the uses was taken from various sources (Barboza *et al.*, 2009; Dimitri & Parodi, 1987; Dimitri & Parodi, 1987; Entraigas *et al.*, 2017; Fernández Grecco & Viviani Rossi, 2011; Lahitte & Hurrell,

1998; Martelo & Lara Borero, 2012; Menone *et al.*, 2015; Rapaport *et al.*, 2009; Rossi *et al.*, 2014; Tellería, 1995; Tellería, 1996; Vercelli *et al.*, 2013; Barboza *et al.*, 2006). Finally, species were assigned according to their versatility (Sokal & Rohlf, 1995), considering three levels in terms of the number of use-categories: specialists, which are species that are included in only one use-categories; generalists, which are included within between two and three use- categories; and versatile species, which are included within more than three use-categories.

Data analysis

The Fisher test was used to determine if there are differences in the proportions of native and exotic species in terms of their life forms, and life forms in terms of their versatility (Sokal & Rolf, 1995). The Kruskal-Wallis test was applied to compare the numbers of use-categories among different life forms. The Spearman correlation coefficient was used to test any relationships between the species richness of a family and the number of use-categories attributed to that family. All statistical analyses were carried out using the software R (R Core Team, 2024).

RESULTS

A total of 82 species of macrophytes (73% of them native), distributed in 65 genera of 31 families were collected (Table 1). The families with the greatest numbers of species were Poaceae (20), Cyperaceae (12), and Asteraceae (10); and the most diverse genera with the highest number of species were *Eleocharis* R.Br. (5) and *Cyperus* L. (4). The predominant life form was hygrophytes, with 51% of the species, followed by helophytes (34%), and hydrophytes (15%). The proportions of native to exotic species in terms of their life forms differed significantly ($p = 0.0003$), with the native species being the predominant group (Table 2). If we consider only strictly aquatic life forms (hydrophytes and helophytes), the largest number of species are

Table 1. Macrophyte assemblage in the study area. Groups: L (liverworts), F (ferns), M (monocots), D (dicots). Status: N (native), E (exotic). Life forms: Hyd (hydrophyte), Hel (helophyte), Hyg (hygrophyte). Use-categories: Fos (food source), For (forage), Med (medicinal), Orn (ornamental), Api (apicultural), Rem (remedial), Oth (other uses). **Tabla 1.** Ensemble de macrófitas en el área de estudio. Grupos: L (hepáticas), F (helechos), M (monocotiledóneas), D (dicotiledóneas). Origen: N (nativa), E (exótica). Formas de vida Hyd (hidrófita), Hel (helófita), Hyg (higrófita). Categorías de uso: Fos (fuente de alimento), For (forraje), Med (medicinal), Orn (ornamental), Api (apícola), Rem (remediación), Oth (otros usos).

Family and species	Status	Life form	Use-categories
Alismataceae (M)			
<i>Sagittaria montevidensis</i> Cham. & Schtdl. subsp. <i>montevidensis</i>	N	Hel	Med, Orn, For, Api, Fos
Amaryllidaceae (M)			
<i>Nothoscordum gracile</i> (Dryand. ex Aiton) Stearn var. <i>gracile</i>	N	Hyg	Med, Orn, Api, Fos
Amaranthaceae (D)			
<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	N	Hyd	Med, For, Api, Fos
Apiaceae (D)			
<i>Eryngium ebracteatum</i> Lam.	N	Hel	Med, For
<i>Eryngium paniculatum</i> Cav. & Dombey ex F. Delaroché	N	Hyg	Med, For, Api, Fos
Araceae (M)			
<i>Lemna gibba</i> L.	N	Hyd	Med, Orn, For, Fos, Rem
<i>Spirodela intermedia</i> W. Koch	N	Hyd	Med, Orn, For, Rem
<i>Wolffia columbiana</i> H. Karst.	N	Hyd	Orn, Oth
Araliaceae (D)			
<i>Hydrocotyle bonariensis</i> Lam.	N	Hel	Med, Orn, Api
Asteraceae (D)			
<i>Ambrosia tenuifolia</i> Spreng.	N	Hyg	Med, Api
<i>Bidens laevis</i> (L.) Britton, Stern & Poggenb.	N	Hel	Orn, Api, Fos, Oth
<i>Conyza</i> sp.	N	Hyg	Med, For, Api, Fos
<i>Eclipta prostrata</i> (L.) L.	N	Hel	Med, Orn, Fos
<i>Leontodon saxatilis</i> Lam.	E	Hyg	Med, Api, Fos
<i>Mikania periplocifolia</i> Hook. & Arn.	N	Hyg	Med
<i>Soliva sessilis</i> Ruiz & Pav.	N	Hyg	Fos
<i>Symphotrichum subulatum</i> (Michx.) G.L. Nesom	N	Hyg	Med, For
<i>Taraxacum officinale</i> F.H. Wigg.	E	Hyg	Med, Api, Fos
<i>Xanthium strumarium</i> L.	N	Hel	Med, Api
Boraginaceae (D)			
<i>Heliotropium curassavicum</i> L. var. <i>curassavicum</i>	N	Hyg	Med, Api, Fos
Brassicaceae (D)			
<i>Cardamine hirsuta</i> L.	E	Hyg	Med, Fos
<i>Rorippa bonariensis</i> (Poir.) Macloskie var. <i>bonariensis</i>	N	Hel	Med
Capparaceae (D)			
<i>Tarenaya titubans</i> (Speg.) Soares Neto & Roalson	N	Hel	Orn
Ceratophyllaceae (D)			
<i>Ceratophyllum demersum</i> L.	N	Hyd	Med, Orn
Chenopodiaceae (D)			

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<i>Oxybasis macrosperma</i> (Hook. f.)	N	Hyg	Med
S. Fuentes, Uotila & Borsch			
Cyperaceae (M)			
<i>Carex bonariensis</i> Desf. ex Poir.	N	Hyg	For
var. <i>bonariensis</i>			
<i>Cyperus corymbosus</i> Rottb. var.	N	Hel	For
<i>subnodosus</i> (Nees & Meyen) Kük.			
<i>Cyperus eragrostis</i> Lam. var.	N	Hyg	Orn, For
<i>eragrostis</i>			
<i>Cyperus reflexus</i> Vahl	N	Hyg	Med, For
<i>Cyperus meyenianus</i> Kunth	N	Hel	For
<i>Eleocharis bonariensis</i> Nees	N	Hel	Med, For
<i>Eleocharis macrostachya</i> Britton	N	Hel	For
<i>Eleocharis montevidensis</i> Kunth	N	Hel	For
<i>Eleocharis radicans</i> (Poir.) Kunth	N	Hel	For
<i>Eleocharis viridans</i> Kük. ex Osten	N	Hel	For
<i>Schoenoplectus californicus</i> (C.A.	N	Hel	Med, For, Fos, Oth
Mey.) Soják var. <i>californicus</i>			
<i>Schoenoplectus pungens</i> (Vahl)	N	Hel	For
Palla var. <i>longispicatus</i> (Britton) S.G.			
Sm.			
Fabaceae (D)			
<i>Lotus tenuis</i> Waldst. & Kit. ex	E	Hyg	For, Api
Willd.			
<i>Gleditsia triacanthos</i> L.	E	Hyg	Med, Orn, For, Api, Fos, Oth
<i>Trifolium pratense</i> L.	E	Hyg	Med, For, Api, Fos
Iridaceae (M)			
<i>Sisyrinchium platense</i> I.M.Johnst.	N	Hyg	Med, Orn, For
Juncaceae (M)			
<i>Juncus balticus</i> Willd.	N	Hel	Med, For, Oth
<i>Juncus imbricatus</i> Laharpe	N	Hyg	For
<i>Juncus microcephalus</i> Kunth	N	Hyg	For, Med
Juncaginaceae (M)			
<i>Triglochin striata</i> Ruiz & Pav.	N	Hel	Rem
Lamiaceae (D)			
<i>Mentha pulegium</i> Lam.	E	Hyg	Med, Api, Fos, Oth
Lythraceae (D)			
<i>Lythrum hyssopifolium</i> L.	E	Hyg	Med
Malvaceae (D)			
<i>Malvella leprosa</i> (Ortega) Krapov.	N	Hyg	Med, Orn, Api
Marsileaceae (F)			
<i>Marsilea ancylopoda</i> A. Braun	N	Hyd	Orn
Onagraceae (D)			
<i>Ludwigia peploides</i> (Kunth) P.H.	N	Hyd	Med, Orn, Api
Raven subsp. <i>peploides</i>			
Plantaginaceae (D)			

Continúa en pág. 8

<i>Bacopa monnieri</i> (L.) Wettst.	N	Hel	Med, Orn, Api
Poaceae (M)			
<i>Aristida pallens</i> Cav.	N	Hyg	Med. For, Oth
<i>Cynodon dactylon</i> (L.) Pers. var. <i>dactylon</i>	E	Hyg	Med, Orn, for, Fos, Oth
<i>Distichlis spicata</i> (L.) Greene var. <i>spicata</i>	N	Hyg	For, Fos
<i>Echinochloa crus-galli</i> (L.) P. Beauv. var. <i>crus-galli</i>	E	Hel	For
<i>Festuca arundinacea</i> Schreb.	E	Hyg	For
<i>Glyceria multiflora</i> Steud.	N	Hel	For
<i>Helictotrichon scabrivalve</i> (Trin.) G.C. Tucker	N	Hel	For
<i>Hordeum jubatum</i> L.	E	Hel	Orn, For
<i>Lachnagrostis filiformis</i> (G. Forst.) Trin.	E	Hyg	For
<i>Leersia hexandra</i> Sw.	N	Hel	For
<i>Lolium multiflorum</i> Lam.	E	Hyg	Med, Orn, For
<i>Paspalum quadrifarium</i> Lam.	N	Hyg	Orn, For, Oth
<i>Paspalum vaginatum</i> Sw.	N	Hel	Med, For, Oth
<i>Phalaris platensis</i> Henrard ex Wacht.	N	Hyg	For
<i>Poa annua</i> L.	E	Hyg	For
<i>Poa pratensis</i> L. subsp. <i>pratensis</i>	E	Hyg	Orn, For
<i>Polypogon elongatus</i> Kunth var. <i>elongatus</i>	N	Hyg	For
<i>Polypogon monspeliensis</i> (L.) Desf.	E	Hyg	Orn, For
<i>Setaria geminata</i> (Forssk.) Veldkamp	N	Hel	For
<i>Setaria viridis</i> (L.) P. Beauv.	E	Hyg	For
Polygonaceae (D)			
<i>Polygonum hydropiperoides</i> Michx. var. <i>hydropiperoides</i>	N	Hyd	Med, Api, Fos
<i>Polygonum persicaria</i> L.	E	Hyd	Med, Api, Fos
<i>Rumex crispus</i> L.	E	Hyg	Med, Api, Fos
<i>Rumex pulcher</i> L.	E	Hyg	Med, Fos, Oth
Primulaceae (D)			
<i>Lysimachia arvensis</i> (L.) U. Manns & Anderb.	E	Hyg	Med, Api, Fos, Oth
Ranunculaceae (D)			
<i>Ranunculus apiifolius</i> Pers.	N	Hyd	Med
Ricciaceae (L)			
<i>Ricciocarpus natans</i> L.	N	Hyd	Orn, Rem
Salviniaceae (F)			
<i>Azolla filiculoides</i> Lam.	N	Hyd	Med, Orn, For, Rem
Solanaceae (D)			
<i>Solanum glaucophyllum</i> Desf.	N	Hel	Med, Orn, For, Api
Verbenaceae (D)			
<i>Phyla nodiflora</i> (L.) Greene var. <i>minor</i> (Gillies & Hook. ex Hook.) N. O'Leary & P. Peralta	N	Hyg	Med, Orn, For, Api
<i>Verbena montevidensis</i> Spreng.	N	Hyg	Med, Orn, Api

Table 2. Species richness of hydrophytes, helophytes and hygrophytes in terms of their status and use-versatility.
Tabla 2. Riqueza específica de hidrófitas, helófitas e higrófitas en términos de origen y versatilidad de uso.

	Hydrophytes	Helophytes	Hygrophytes
Native	11	26	23
Exotic	1	2	19
Specialists	2	15	12
Generalists	6	9	21
Versatile	4	4	9

monocots (22) compared to dicots (15); however, at the family level, the opposite situation occurs (monocots 5, dicots 11) (Table 1). The largest diversity of plants was seen in Forage and Medicinal categories, where they account for 61% and 59% of all the cited species, while Remedial was the less representative use (6 %) (Figure 2). The families Araceae,

Asteraceae, and Fabaceae were found to be the most versatile, as their component species were represented in the largest numbers of use- categories (6 categories each), followed by Alismataceae, Cyperaceae, and Poaceae (5 categories each) (Table 1). Regarding the life forms, the group of helophytes was the one that presented proportions in terms of their

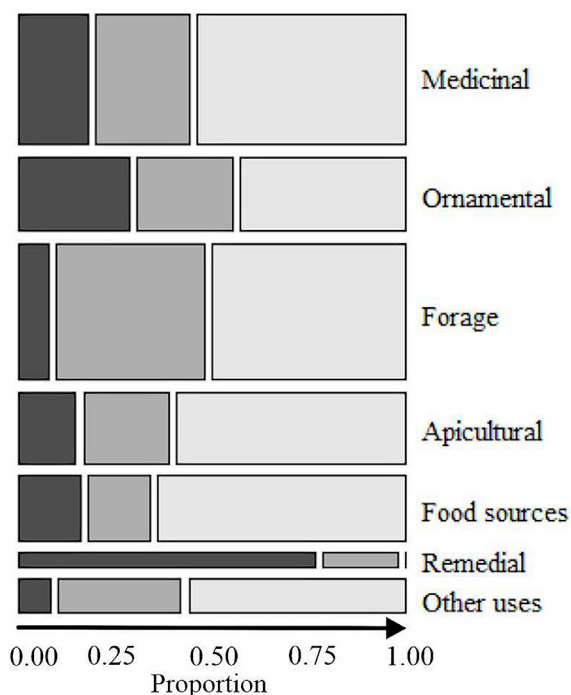


Figure 2. Mosaic plot showing the distribution in terms of use-categories and life forms of the species found in the analyzed ponds. Hydrophytes (black), helophytes (grey), hygrophytes (white).

Figura 2. Distribución proporcional de las categorías de uso y las formas de vida de las especies registradas en las cubetas seleccionadas. Hidrófitas (negro); helófitas (gris); higrófitas (blanco).

versatility that differed significantly ($p = 0.01$) (Table 2). If the analysis is performed with respect to the number of species in each use-categories, then hydrophytes are the ones that present a different distribution from the rest ($p = 0.008$) (Figure 2). In spite of the fact that hydrophytes compose only 15% of the total species registered, these plants contribute to a larger average number of use-categories (average: 2.8) in relation to helophytes (average: 1.9) and hygrophytes (average: 2.5) (Table 1). Anyway, these differences were not statistically significant ($H = 5.3$; $p = 0.07$). Regarding the relationship between the species richness of a plant family and the numbers

of use-categories attributed to it (Figure 3), it was moderate if we consider the total number of registered species ($\rho = 0.58$; $p = 0.0001$), although this relationship became stronger when native plants ($\rho = 0.62$; $p = 0.0004$) were considered separately from exotic plants ($\rho = 0.68$; $p = 0.05$).

DISCUSSION

The identification of representative species of liverworts, ferns, monocots and dicots confirms what was asserted by Rejmankova (2011), i.e. wetland macrophytes comprise a taxonomically

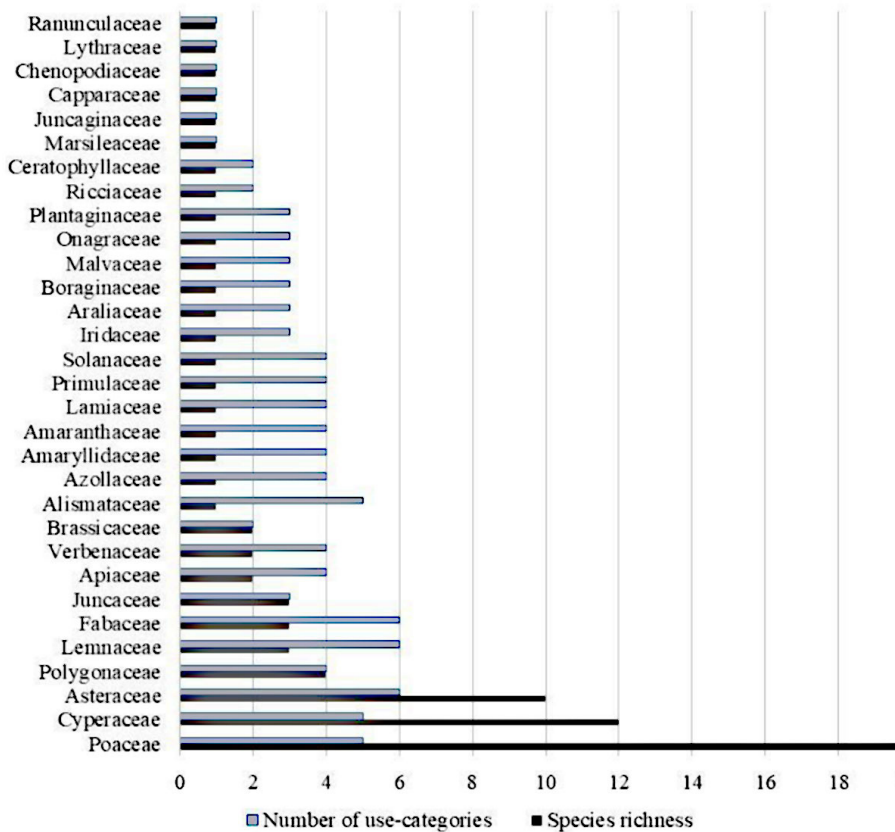


Figure 3. Relationship between the species richness and the numbers of use-categories in each registered plant family.
Figura 3. Relación entre la riqueza específica y el número de categorías de uso en cada familia botánica registrada.

highly diverse group of plants. Like any typical natural grassland growing in the Flooding Pampa of Argentina, the great representativeness of Poaceae family stands out (Matteucci, 2012; Entraigas *et al.*, 2017; Vercelli & Entraigas, 2021) and Cyperaceae family also makes an important contribution due to the wetland condition of the analyzed environment. At the same time, it should be noted that Ricciaceae, Salviniaceae, Araceae, Alismataceae, Juncaginaceae and Ceratophyllaceae families are exclusive to these environments in the region, since they are not represented in the surrounding grasslands. It is also important to emphasize that native species maintained their prominence in these grasslands, as they represented over 73% of the species found along the sampling campaign. Comparing with other studies carried out in the region, this representativeness of the natives is slightly higher than that found in natural grasslands (67%, Entraigas *et al.*, 2019; Vercelli & Entraigas, 2021) and slightly lower than that recorded in wetlands (82%, Scaramuzzino *et al.*, 2010) and water courses (86%, Scaramuzzino *et al.*, 2019)). These discrepancies may be due to genuine differences between the environments, or it can be a reflection of the anthropic pressure to which they are exposed (the higher anthropic pressure, the lower percentage of native species), or perhaps partly due to the variation in sampling effort.

In our research, considering only strictly aquatic life forms, monocots were the group with the largest number of species. These results agree with those obtained by Schmidt-Mumm (1998) in Colombia, Sena Kafer *et al.* (2011) in Brazil, Jocu *et al.* (2018) in the Argentinian Patagonia, and this dominance of monocotyledonous species could be explained by their complex and profuse rhizome system that significantly expands their colonization capacity (Cronk & Fennessy, 2001). Macrophyte assemblages are composed of species with different life forms and many of them have great potential to be used by man in various aspects. Among the identified use-categories, Forage and Medicinal were the most represented at the species level, and even though hydrophytes compose only 15%

of the total species registered, these plants contribute to a larger average number of use-categories. In fact, Remedial use-category is almost exclusive to this life-form due to the filtering and water purification capacity of species such as *R. natans*, *A. filiculoides*, *Lemna gibba* L. and *Spirodela intermedia* W. Koch. In the same sense, the moderate relationship found between the species richness of a plant family and the numbers of use-categories attributed to it, which is stronger for native plants, suggests that maintaining higher native macrophyte diversity could be directly translated into a broader spectrum of ecological functions and potential uses. This interpretation reinforces the argument for protecting rich native communities as a conservation strategy, which agrees with management and conservation policies based on ethnobotanical studies (de Albuquerque *et al.*, 2008). As Dalle and Potvin (2004) state, the use-frequency of a given plant species is influenced by ecological, cultural and historical factors. Moreover, it is important to take into account that in the region in which this study was carried out there is no strong tradition regarding the use of these plants (except Forage and Apicultural uses, which occur naturally, that is, without carrying out harvesting tasks or any type of treatment).

Similarly to what happened in other regions dominated by grasslands, the implementation of agroecosystems in the Argentine pampas have substantially modified their structure and functioning (Viglizzo *et al.*, 2001). This is due, in large part, to the fact that many of the decisions that are adopted in relation to the management of agroecosystems are carried out without taking into account the ecological impacts associated with these transformations. This issue is further aggravated by the fact that, specifically in the Flooding Pampa, there is currently no federal protected area dedicated to the conservation of this type of landscape (Bilenca & Miñarro, 2004), since the only national park in this region is located close to the sea coast. In this sense, it is important to highlight that macrophyte assemblages are one of the most sensitive biological communities to

assess anthropogenic impacts (Buosi & Sfriso, 2017). The presence of species such as *Lolium multiflorum* Lam., *Festuca arundinacea* Schreb., *Lotus tenuis* Waldst. & Kit. ex Willd. and *Trifolium pratense* L. on the shorelines is due to the fact that the native grassland community is often replaced with these exotic and more productive grass species to increase the forage supply for livestock (Colabelli & Miñón, 1993; Jacobo *et al.*, 2000). In the specific case of *Gleditsia triacanthos* L., it is a deciduous, exotic and invasive tree species, with several characteristics that favor its rapid expansion: high resistance to drought and salinity, high growth rate (60 cm/year), clonal and sexual reproduction, short juvenile period, high seed production and the almost total absence of pests and associated diseases that affect it (Marco & Páez, 2000). One of the main dispersal agents is cattle, since animals ingest the seeds and partially digest their seed coat, which favors their subsequent germination (Blair, 1990). Likewise, feces containing the seeds fertilize the soil, and this contributes to the development of seeds and adult plants (Leggieri, 2010). These wetlands are within livestock raising areas, strongly associated with pasture grasses, so these examples are indicative of the anthropogenic influence on the native flora composition of these aquatic environments. However, it is noteworthy that although wetlands seem to be especially vulnerable to invasions and invasive plants affect their biodiversity (Zedler & Kercher, 2004), in this case, on the contrary, native species that have become extinct at the regional level in other places of southeastern South America are preserved, such as *Cyperus corymbosus* Rottb. var. *subnodosus* (Nees & Meyen) Kük. and *Paspalum quadrifarium* Lam. (Guerrero, 2018). As mentioned in the objective of this paper, an initial approach is presented here for generating conservation strategies, although the extent to which anthropogenic pressures affect the structure of macrophytes assemblage in terms of their life forms and versatility remains to be answered. A preliminary analysis of macrophyte diversity constitutes a first step towards the design and implementation of specific

environmental policies to ensure the sustainable use of resources. As Vercelli and Entraigas (2025) propose that a quantitative analysis of wetland macrosystems using interdisciplinary approaches is required, considering the interactions between anthropogenic disturbances, hydrological dynamics, and ecological responses. This will allow us to determine the natural management units and, within these, the appropriate proportion of wetlands to be protected while also maintaining for the sustainable agricultural-livestock production and the long-term maintenance of water resources.

Final considerations

The lower basin of del Azul creek functions as an extensive floodplain that constitutes a wetland system where water is a major force modeling the mosaic of plant communities and, at the same time, it plays an important role shaping the landscape. Current conservation policy is certainly failing to preserve much of the biodiversity and ecosystem services supported by wetland landscapes like this. Aquatic macrophyte habitats often represent the most diversified, productive and heterogeneous portions of water bodies (Chambers *et al.*, 2007), consequently management strategies using macrophytes are based on the general concept that these plants increase habitat complexity, which, in turn, brings benefits for the aquatic and semi-aquatic biota (Thomaz & Cunha, 2010). Taking these considerations into account and, furthermore, considering that ponds are ephemeral water bodies highly vulnerable (due to their shallow water, small surface area, and the intensive livestock and agricultural modifications of its habitat), we would like to draw attention to the potential uses of the macrophytes as a practical and genuine way to revalue these environments that have been historically neglected habitats by decision makers involved in biodiversity conservation.

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CRediT Contribution Statement

IE: Conceptualization, Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Software, Supervision, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing. **NV:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – Original Draft, Writing – Review & Editing. **RS:** Data Curation, Investigation, Resources, Supervision, Validation, Writing – Review & Editing. **CD:** Data Curation, Investigation, Supervision, Writing – Review & Editing.

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