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Can artificial ecosystems enhance local biodiversity? The case of a constructed wetland in a Mediterranean urban context

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Abstract

Constructed wetlands (CW) are considered a successful tool to treat wastewater in many countries: their success is mainly assessed observing the rate of pollution reduction, but CW can also contribute to the conservation of ecosystem services. Among the many ecosystem services provided, the biodiversity of constructed wetlands has received less attention.

The EcoSistema Filtro (ESF) of the Molentargius-Saline Regional Natural Park is a constructed wetland situated in Sardinia (Italy), built to filter treated wastewater, increase habitat diversity and enhance local biodiversity. A floristic survey has been carried out yearly one year after the construction of the artificial ecosystem in 2004, observing the modification of the vascular flora composition in time. The flora of the ESF accounted for 54% of the whole Regional Park's flora; alien species amount to 12%, taxa of conservation concern are 6%. Comparing the data in the years, except for the biennium 2006/2007, we observed a continuous increase of species richness, together with an increase of endemics, species of conservation concern and alien species too. Once the endemics appeared, they remained part of the flora, showing a good persistence in the artificial wetland.

Included in a natural park, but trapped in a sprawling and fast growing urban context, this artificial ecosystem provides multiple uses, by preserving and enhancing biodiversity. This is particularly relevant considering that biodiversity can act as drivers of sustainable development in areas where most of the world's population lives and comes into direct contact with nature.

Highlights

- **Plant diversity of constructed wetlands has received little attention.**
- **The flora of the ESF accounted for 54% of the whole Regional Park's flora.**
- **Once the endemics appeared they all remained, showing persistence in the ESF habitat.**
- **Non-native species are significant, amounting to the 12% of the flora.**
- **Artificial ecosystems assure multiple uses, including enhancing local biodiversity.**

Key words: Molentargius-Saline Regional Natural Park; multi-temporal; Sardinia; vascular plants.

Introduction

Constructed wetlands (CW) are artificial wetlands designed to mimic natural wetland ecosystems, in order to filter wastewater and remove pollutants before discharge into natural water bodies (Scholz *et al*. 2007, Vymazal 2010). Several studies have demonstrated that constructed wetlands are effective for the management of municipal and agricultural wastewater and for the removal of nutrients, trace elements and microorganisms therein contained (see Scholz *et al*. 2007); for those reasons, CW are widely used as low-cost alternatives to traditional wastewater treatment worldwide (Zhang *et al*. 2014, Zhi & Ji 2012). In many countries within the Mediterranean basin, constructed wetlands have successfully reduced pollution (Masi & Martinuzzi 2007, Masi *et al*. 2000,Scholz *et al*. 2007, Vymazal 2010) and contributed to conservation of ecosystem services (Barbera *et al*. 2014, Masi & Martinuzzi 2007, Rousseau *et al*. 2008, Zhang *et al*. 2014). Among the many ecosystem services provided, the biodiversity of constructed wetlands received less attention in assessment of CW success (Hsu *et al*. 2011, Kearney *et al*. 2013). In particular, the vascular flora and rates of plant species colonization have rarely been investigated (White *et al*. 2012).

The EcoSistema Filtro (ESF, Filtering EcoSystem) is a constructed wetland inserted in a Regional Natural Park, surrounded by a densely populated urban system in the Gulf of Cagliari, southern Sardinia (Italy),completed in October 2004. Since then, there has been a constant monitoring of the vascular flora of this area that in a few years has become a reservoir of unique genetic diversity, providing ecosystem services and indirectly supporting the sustainable development of the local urban area (see Capotorti *et al*. 2013, Crane & Kinzig 2005).

The objective of this paper is to document changes and rates of change in the vascular plant flora of the artificial ecosystem since its creation, in terms of plant composition observed over the years.

2. Materials and Methods

2.1 Study area

The ESF is situated in Italy, in southern Sardinia in the Gulf of Cagliari, within the Molentargius-Saline Regional Natural Park (fig. 1; UTM WSG84 32S 513966 E, 4343085 N). The area takes up a wetland of international importance marked by the presence of outstanding biodiversity linked to its different freshwater and salt water environments (e.g. Blasi et al 2011; Marignani et al. 2014). The freshwater basins are Bellarosa Minore, Perdalonga and the ESF, while the salt water basins are Bellarosa Maggiore, Perda Bianca and the Salt Pans.

The park was established in 1999, covering a surface area of 1466.80 ha: it is included in the European Natura 2000 network (Site of Community Importance ITB040022 – Stagno di Molentargius e territori limitrofi; Special Protection Area ITB044002 – Saline di Molentargius) and in the Ramsar Convention on Wetlands (Saline di Molentargius, Ramsar site n.133). The bioclimate of the area is comprised among the Upper Thermomediterranean, Lower Dry, Euoceanic Strong and the Upper Thermomediterranean, Lower Dry, Euoceanic Weak (Canu *et al*., 2015).

From ancient times, first written information dating back to the 1st century B.C., this area has been used to collect salt for human use; only at the end of 1990's the use of the ponds ceased, due to high management costs and sanitary problems. The ESF was built to take care of the problem of wastewater and the connected sanitary problems.

2.2 Biofiltering technology: origins and characteristics of the EcoSistema Filtro

The ESF is a Free Water Surface System (FWS) covering about 37 hectares (fig. 1). The ESF receives wastewater from sewage treatment of the Is Arenas depurator, following a finishing treatment through a phyto-purification, and finally feeds the Park’s freshwater basins of Bellarosa Minore and Perdalonga with purified-quality water , in lieu of the sewage effluent which at one time fed these basins through the streams Mortu, Selargius and Is Cungiaus. The ESF performs a twofold action: it provides secondary treatment of the water coming from the Cagliari treatment plant, and it supplies and controls the water and biochemical balance of Bellarosa Minore and Perdalonga. The constructed wetland is the heart of an extensive, complex system of works carried out on the Park in the period 1990-March 2004, in the framework of the “Programme for safeguarding the coastal areas and wetlands of international importance of the Cagliari metropolitan area" (pursuant to Article 17(20), of Law Nº 67 of 11/03/1988 and Article 73(3) of Legislative Decree Nº 112 of 31/03/1998), launched by the Italian Ministry for the Environment. In 1990, at the time of the detailed design, creation of a constructed wetland represented a highly innovative solution to water treatment concerns, especially in view of the quantity of water to be treated (Qav of 300 l/s and Qmax of 400 l/s) and the size of the filtering area. The rationale for sizing the system at 37 hectares overall was based on an average pond depth of 55 cm, to treat a flow of 300 l/s, estimating a residence time of about 6 days. The net water surface area needed to meet this requirement was estimated at 27 hectares. The remaining area comprises the bank and dry land areas, which serve as nesting habitats for the bird population, and as vegetated areas for the environmental and landscape development of the system. The ESF has an average width of about 200 m and a length of 1900 m. Its long and narrow structure develops along two parallel lines (fig. 1). This solution, obtained by creating a longitudinal bank, was chosen to obtain an internal subdivision of the biofilter system, so as to circumscribe maintenance and cutting down of the reed beds to limited areas, which can be drained without compromising the system's filtering action.The two main lines of the ESF are sectioned by several transverse baffles communicating by means of sluice gates which are normally left open. This makes it possible to cut off some of the tanks (a total of 12 tanks, mean water depth 55 cm) from water circulation, achieving maximum operational flexibility, allowing variation of water residence time and hence optimising the purification action of the ESF. At the end of the two lines there is a final equalization basin that tapers until it connects with the outflow canal which conveys the water back close to the inflow point (fig. 1). This type of water treatment system uses emergent macrophytes, which are very effective water purification agents. Their action is based on the cooperative growth of macrophytes and associated bacteria, which are responsible for a good part of the degradation of organic matter (e.g. Zhi & Ji 2012). The plants remove part of the undesirable substances by direct assimilation and provide a favourable habitat for the bacteria that transform the pollutants and reduce their concentration.

The ESF has been constructed on the salty basin of Bellarosa Maggiore, a pond used in the recent past as salt evaporation pond: during the construction, all the existing vegetation were removed (see ESF 2004, fig.2).

To check for the degree of salinity of soils, in September 2005 soils samples were taken at different depth, showed an increasing level of salinity (0-15 cm: 2,8%; 15-30 cm: 7,7%; 30-50 cm: 12,7%). The amount of treated water piped in ESF increased in the years: in 2005 it was very low (Qav=30 l/s) and it increased in May 2008, letting flow an amount of water lower than the potential capacity of the treatment plant (Qav=150 l/s), with an estimated residence time of water was of 9/10 days. In September 2008 the ESF started to treat the planned quantity of water (Qav of 230-350 l/s), with an estimated residence time of water of 5/6 days. The chemical composition of ESF water varied during the seasons and the years (table 1). For example, the synthetic indicator ratio of the inorganic fraction of the nitrogen and phosphorus soluble fraction (N/P) shows a change from a condition of phosphorus limitation to nitrogen limitation.

ESF was planted in May/November 2004 with fascines of 2 m height of *Phragmites australis* (Cav.) Trin. ex Steud., which is known to play an active role in the polishing water process (Guittonny-Philippe *et al*. 2015): the density of plantation varied from 12 fascines per sqm along the banks and 1/48 sqm in the water tanks. To thicken the area where *Phragmites australis* did not grow properly, in 2005/2006 some localized interventions have been made. From 2005 to 2007, the ordinary management of ESF included the mechanical removal of plant biomass from April to November, especially in the overflow channel; after few years of testing the results of this kind of management, the practise ceased. After the construction of ESF, birds recolonized the area, showing an increasing trend of colonization and nesting (approximately 9% per year from 2005 to 2011) in line with the general trend of the park that hosts, among the others, one important colony of flamingos (*Phoenicopterus ruber roseus,* see Balkiz et al 2010).

In october 2008, the area experienced a flash flood (rain estimated 90 mm/3 hours) that provoked the breaking of the levees among salty and freshwater basins, completely mixing up the water of the salty and fresh water system and altering for a few month the whole composition of the system.

2.3 Data gathering and floristic identification

Floristic investigation was carried out during the period 2005-2013 using a mixed protocol: three squared plots (16 sqm) were surveyed every year in April/July and in September/December (8 samples per year), to cover the main flowering periods. In addition, to complete the list of species, periodic walking survey were conducted, at least one per months, collecting data on species. The samples collected were identified according to Tutin *et al*. (1964-1980, 1993) and Pignatti (1982). The nomenclature adopted is Conti *et al*. (2005) and further updates (Conti *et al*. 2007; Greuter & Raus 2007, Iamonico 2009a, 2012, Peruzzi 2010a, Costalonga 2012); other floras were also consulted such as “Flora Europaea” (Tutin *et al*. 1964-1980, 1993) and Med-Checklist (Greuter *et al*. 1984-1989, Greuter & Raab-Straube 2008). For specific groups, we consulted the monographs and the most recent taxonomic works (De Martis *et al*. 1984, Iberite 1996, 2004, Cuccuini 2002, Banfi *et al*. 2005, Valdés & Scholz 2006, Greuter *et al*. 2006, Urbani *et al*. 2007, Manns & Anderberg 2009, Iamonico 2008, 2009b, 2013, Köcke *et al*. 2010, Fuentes-Bazan *et al*. 2012). For the endemic species, we considered the works of Arrigoni *et al*. (1977-1991), the monographs on the endemic flora of Iglesiente and Sulcis (Bacchetta & Pontecorvo 2005, Bacchetta *et al*. 2007) and a recent publication on endemic flora (Peruzzi *et al*. 2014). For Author’s abbreviations we followed Brummitt & Powell (1992), as recommended by the International Code of Botanical Nomenclature (Greuter *et al*. 2000).

In the floristic list (Annex I) the systematic arrangement follows the guidelines of Peruzzi (2010b), which is based on the studies of Chase & Reveal (2009) and Haston *et al*. (2007, 2009), in accordance with the classification proposed by the Angiosperm Phylogeny Group (Stevens 2008, APG III 2009).

2.4 Data analysis

We compared the data collected across years to highlight the differences of the flora linked to the natural evolution of the artificial ecosystem (Annex II). Using the multi-temporal dataset, we analysed the changes in terms of species richness, number of species of conservation concern and number of alien species.

3. Results

3.1 The flora of ESF

The flora of ESF comprised 275 taxonomic units, including 201 specific entities, 72 subspecific taxa and 2 varieties, distributed in 25 orders, 51 families and 161 genera. The most represented families as to number of genera and of taxonomic units are *Asteraceae* (49), *Poaceae* (39), *Fabaceae* (33), *Amaranthaceae* (18) and *Caryophyllaceae* (11). In regards to the biological forms, spectrum analysis shows the marked Mediterranean nature of the area, with a prevalence of *Therophytes* (56%) indicating considerable summer aridity, by a sizeable percentage of *Hemicryptophytes* (18,8%) and *Phanerophytes* (9,1%); the presence of *Geophytes* (8,4%) indicates a certain degradation of the territory whereas the *Chamaephytes* (5,8%) are linked to the area's wind exposure. On the other hand, *Hydrophytes* are scantly represented (1,8%) in spite of the fact that it is a wetland environment.

Examination of the geographical elements confirms the Mediterranean nature of the flora: the Mediterranean component, including endemic plants, reaches 63 %. A sizable Eurasian component is present (6,5%) whereas the entities of wider distribution reach 27,6%.

Among the taxonomic units found, six are endemic (Peruzzi et al. 2014): *Euphorbia pithyusa* L. subsp. *cupanii* (Guss. ex Bertol.) Radcl.-Sm.; *Limonium dubium* (Guss.) Litard.; *Limonium retirameum* Greuter & Burdet subsp. *retirameum; Scorzoneroides muelleri* (Sch. Bip.) Greuter &

Talavera subsp. *muelleri*; *Stachys glutinosa* L.; *Tolpis virgata* (Desf.) Bertol. subsp. *grandiflora* (Ten.) Arcang.

Ten taxa (about 4%) are listed as species of conservation concern: all elements are listed in the Regional Red List (Conti *et al*. 1997) and two, *Cynomorium coccineum* L. subsp. *coccineum* and *Limonium avei* (De Not.) Brullo, are also included in the National Red List (Conti *et al*. 1992). At regional level *Limonium avei (De Not.) Brullo and Erben* and *Lupinus luteus* L. are considered endangered (EN), *Phleum arenarium* L. subsp. *caesium* H. Scholz and *Salicornia emerici* Duval-Jouve are listed as vulnerable (VU), *Marrubium alyssum* L., *Ranunculus sceleratus* L. and *Salicornia patula* Duval-Jouve are included in the low risk category (LC); moreover, *Centaurium pulchellum* (Sw.) Druce subsp. *pulchellum* and *Zannichellia palustris* L. subsp. *palustris* are data deficient (DD, *sensu* IUCN, 2001). A total of 32 species in the flora of ESF are alien. Among those, 25 are reported in the inventory of the non-native flora of Italy (Celesti-Grapow *et al*. 2009): 3 are *archaeophytes* and 17 *neophytes,* while the remaining 5 are included in the doubtful aliens, since there are no sufficient information to define their status. Considering invasiveness, fifteen species were classified as invasive and five as naturalized. In the checklist of the alien flora of Sardinia (Bacchetta *et al*. 2009, Podda *et al*. 2012a, 2012b) almost all alien taxa surveyed in ESF are reported (except *Lycium barbarum* L.): 13 belong to *archaeophytes* and 18 to *neophytes*. Most of the taxa are classified as invasive (14), six are naturalized species, a small number are defined as casual (4) and a group of 7 are cryptogenic entities, whose native or introduced status remain undefined. The biological spectrum of alien species show a prevalence of *Therophytes* (T = 46.9%) and *Phanerophytes* (P = 28.1%), followed by *Geophytes* (12.5%), *Hemicryptophytes* (9.4%) and, finally, *Chamaephytes* (3.1%). Compared to the spectrum of native flora, the alien flora is composed of fewer annual species and more shrub and tree species. The majority of species come from the Americas (34,4%) and Eurasia (21,9%), followed by species of African (9,4%) Australian (9,4%), and Tropical origin (3,1%). A consistent presence is represented by archaeophytes species belonging to the Mediterranean area (21,9%).

3.2 The changes observed in the ESF flora in the years (2005/2013)

Comparing the data through the years, except for the years 2006/2007, probably caused by the mechanical removal of the biomass conducted to manage the ESF until 2007, we observed a continuous increase of species richness, together with an increase in species of conservation concern and non-native species (figure 3, table 2, Annex II). The number of taxa increased at an annual rate of about 14% (fig. 3).

In 2006, the first endemic species *Limonium dubium* (Guss.) Litard. appeared in the constructed wetland, followed in 2007 by *Limonium retirameum* Greuter & Burdet *retirameum, Euphorbia pithyusa* L. subsp. *cupanii* (Guss. ex Bertol.) Radcl.-Sm. and *Tolpis virgata* (Desf.) Bertol. subsp. *grandiflora* (Ten.) Arcang.. In 2008/2009 *T.virgata* was not documented as present, maybe suffering from the 2008 flood event, but it was found again in 2010. After a few years the number of endemics stabilized around 6 taxa. Except in the case of *Tolpis virgata* (Desf.) Bertol. subsp. *grandiflora* (Ten.) Arcang., once the endemics appeared in the wetland they remained as part of the flora, showing high rates of persistence in the constructed wetland habitat.

Species of conservation concern showed a different behaviour: *Salicornia patula* Duval-Jouve and *Limonium avei* (De Not.) Brullo & Erben arrived in the first year and stably remained, while others like *Ranunculus sceleratus* L. and *Salicornia emerici* Duval-Jouve appeared and disappeared to show up again in the last years (2010-2013). *Zannichellia palustris* L. subsp. *palustris* sporadically appeared only in 2005 and 2008: its presence is probably linked to the availability of running fresh water in the outflow canal that was maintained by the mechanical removal of biomass.

Non-native species increased their number in the monitored years, showing a relative decrease of presence in the second year (2007), followed by an annual increasing rate of 7% (2007/2013). About 22% of these species appeared in the first year of monitoring and remained in the ESF until 2013 (*Amaranthus albus* L.; *Erigeron bonariensis* L.; *Nicotiana glauca* Graham; *Dysphania ambrosioides* (L.) Mosyakin & Clemants; *Symphyotrichum squamatum* (Spreng.) G.L. Nesom;

Glebionis coronaria (L.) Spach; *Melilotus siculus* (Turra) Steud.). A consistent group of species (25%) were sporadically present only one (6 taxa) or three times (2 taxa) in 8 years.

4. Discussion

After the construction of the ESF and planting of the reed bed, plant colonization took place following a constant and gradual increment, with the highest expansion during the first and second year. This trend is confirmed by several examples (Hsu *et al*. 2011, Shelef *et al*. 2013, White *et al*. 2012) but it cannot be considered a general behaviour of constructed wetlands (Kearney *et al*. 2013). In the period 2005-2013, the flora of the ESF accounted for 53,7% of the whole Molentargius-Saline Regional Park's flora (512 taxonomic units distributed over 364 species, 146 subspecies, 2 varieties, belonging to 71 families and 285 genera. See De Martis 2008, De Martis & Mulas 2008, De Martis & Atzeni 2009, De Martis 2011). The rich floristic composition of this peculiar environment can be attributed to its location between a freshwater basin, Bellarosa Minore, and a saline one, Bellarosa Maggiore.

The value of the flora is represented by the presence of endemic species that took advantage of the new saline and nitrogen rich habitats developed after the construction of ESF: *Euphorbia pithyusa* L. subsp. *cupanii* (Guss. ex Bertol.) Radcl.-Sm., a Tyrrhenian endemism widespread especially in nitrogen-rich, disturbed environments and in arid uncultivated terrain (Valsecchi 1980); *Limonium dubium* (Guss.) Litard., a Tyrrhenian endemism growing in coastal and subcoastal salt marsh environments (Arrigoni & Diana 1985); *Limonium retirameum* Greuter and Burdet subsp. *retirameum*, an endemism of south-eastern Sardinia, preferring coastal sandy and rocky terrain (Arrigoni & Diana 1991, Arrigoni 2005). *Scorzoneroides muelleri* (Sch. Bip.) Greuter & Talavara subsp. *muelleri*, endemic to the north Italian peninsula (Liguria not confirmed), Sicily and Sardinia (Peruzzi *et al*. 2014), preferably lives in wet and saline habitats. *Tolpis virgata* (Desf.) Bertol. subsp. *grandiflora* (Ten.) Arcang., belonging to a predominantly insular plant genus, is endemic to central-southern Italy and Sicily (Peruzzi *et al*. 2014) and according to Greuter & Raus (2007) is the only subspecies present in Sardinia. Finally, *Stachys glutinosa* L., a Tyrrhenian endemism, living from sea level up to the highest mountains, indifferent to the geological substrate, it thrives in full sun and avoids shade (Camarda 1980). This latter endemic species has been found only recently in the ESF and hence is not mentioned in earlier works on the Park (De Martis 2008, De Martis & Mulas 2008).A pattern of increasing floristic diversity over time was observed from these repeated floristic surveys of the ESF. Highlights of this pattern include observation of two elements of the flora recorded in the Red List of endangered plants recognised both at national and regional level (Conti *et al*. 1992, 1997, Pignatti *et al*. 2001, Scoppola & Spampinato 2005). Those two species are considered vulnerable at national level: *Cynomorium coccineum* L. subsp. *coccineum*, a parasitic plant living on the roots of several plants in saline or brackish coastal environments of Sicily and Sardinia and *Limonium avei* (De Not.) Brullo and Erben, a rare species with scattered distribution, which lives in lagoons and salt marshes of the western Mediterranean (Brullo 1988, Conti *et al*. 1997, Scoppola & Spampinato 2005).

The presence of non-native species in the flora of ESF is significant: this indicates that a considerable contribution to the colonization of this territory comes from surrounding areas where human activity and disturbance has led to an increase in the number of alien species (Bartomeus *et al*. 2012, De Martis 2008, De Martis & Mulas 2008) and also, probably, by the action of migratory waterbirds (García-Álvarez et al. 2015).

Alien species in 2013 amounted to the 11,6% of the flora of this study. This percentage is below the national average (13.4%, Celesti-Grapow *et al*. 2009) and higher than that indicated for Sardinia (9%, Celesti-Grapow *et al*. 2010a, Camarda *et al*. 2010). Among the non-native plants we mentioned, *Lycium barbarum* L. was recently reported for Sardinia in the areas of Assemini, Sestu and in the Bellarosa Minore (Mulas *et al*. 2008). Furthermore, we observed the occurrence of *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn., a perennial grass introduced into Europe from South America, considered as invasive worldwide (e.g. Bacchetta *et al*. 2010). This species causes a strong visual impact by altering ecosystem naturalness, by competing with native species (Herrera & Campos 2006) and by adapting easily both in natural and rural habitats (Domènech 2005); it is therefore considered a landscape modifier, like *Opuntia ficus-indica* (L.) Miller (Brundu *et al*. 2003).

The changes in the flora of the ESF reported here document a general increase of species corresponding to an increase in species of conservation concern and alien species. The increasing presence of visiting and nesting birds in the ESF surely contributed to the development of a diversified flora, as described in García-Álvarez et al. (2015) and Green & Elmberg (2014). The once exception occurred in the second year after the establishment of the constructed wetland, in this year we observed a local decrease in the general trend of increase (2006/2007): this is easily attributable to the mechanical removal of plants imposed by the ESF management procedures during the first three years: once the mechanical removal terminated, the number of species started again to increase. This is true for all the analysed categories except for the endemics: endemic taxa progressively recolonized the area in a few years, permanently finding a suitable habitat after the construction of the artificial ecosystem and showing a good fitness in human modified environments.

5. Conclusion

An updated flora of the EcoSistema Filtro is needed to inform future research on phytoremediation. Recent papers confirmed the positive performance of native macrophytes in constructed wetlands (Guittonny-Philippe *et al*. 2015, 2014). Floristic surveys conducted in the ESF from 2005-2013 have documented changes in the composition of vascular flora over time and describe the ecological differentiation and evolution of the plant communities.

The context within which the artificial ecosystem of ESF is located, its significant size and the role it plays within the natural Park, made it a unique constructed wetland of its kind in southern Europe. In fact, the ESF offers an ideal habitat for the stopover, wintering and nesting of bird species of considerable importance (e.g. Balkiz *et al*. 2010). The significance of the wetland for biodiversity conservation highlights the importance of identifying the correct balance between the need to protect and conserve wildlife and the operation and maintenance of a water treatment system located within a protected area.

Included in a natural park, but trapped in a sprawling and rapidly-growing urban context (Salvati & Morelli 2014, Zoppi & Lai 2014), the EcoSistema Filtro provides multiple uses e.g. filtering waters (Guittonny-Philippe *et al*. 2015, Shelef *et al*. 2013), carbon sequestration and stocking (Barbera *et al*. 2014, Kayranli *et al*. 2010, Mander *et al*. 2014) and preserving and enhancing local biodiversity (Hsu *et al*. 2011, Zhang *et al*. 2014, Zhi & Ji 2012). The ESF is thus an example of a constructed habitat in an urban setting that has become a key reservoir of ocal and regional biological diversity and which currently provides primary ecosystem services (e. g. Capotorti *et al*. 2013). Sites such as the ESF are thus important because they can act as drivers of sustainable development in areas in which most of the world's population now lives and comes into direct contact with nature (Crane & Kinzig 2005).

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Table 1 Data on the main characteristics of water and soil of the EcoSistema Filtro. NAV indicates that data are not available.

		2005	2007	2008	2009	2010	2011
Salinity of incoming/outgoing water (min/max, PSU)	in	1,59 – 43,4	0,73 - 2,38	0,75 – 4,39	0,68 – 3,39	NAV	NAV
	out	0,92 – 44	1,30 - 2,51	0,9 – 2,90	0,46 – 3,31	NAV	NAV
Biochemical Oxygen Demand BOD5 (mean value, mg/l)	Inflow basin	NAV	23	9,5	7,3	NAV	NAV
	outflow canal	NAV	5	10,8	12,4	NAV	NAV
O_2 concentration in the ESF water (mean value, mg/l)	-	NAV	3,18	4,08	4,32	NAV	NAV
Water temperature (min/max, °C)	Inflow basin	NAV	15-26	14-25	13-26	NAV	NAV
	outflow canal	NAV	9 – 34	6 – 34	3 – 34	NAV	NAV
N/P in the ESF water	-	NAV	1,76	1,28	2,43	2,56	2,2
Soil sampled in the ESF (min/max, mg/Kg)	N	NAV	400 – 2000	476- 3440	433- 2760	NAV	NAV
	P	NAV	300-700	189-925	193-1029	NAV	NAV

Table 2 Number of taxa, taxa of conservation concern, endemics and aliens species surveyed in the years in the constructed wetland ESF of Molentargius-Saline Regional Park. For a complete list, see annex II.

Number of	2005	2006	2007	2008	2009	2010	2011	2013	Total
Taxa	85	139	129	147	185	206	214	238	275
Conservation concern taxa	4	5	3	4	3	6	6	7	10
Endemic taxa	0	1	4	4	4	5	5	6	6
Alien taxa	11	18	14	19	22	24	26	27	32

Captions

Figure 1. The Filtering Ecosystem – ESF is surrounded by the salty basin Bellarosa maggiore and Bellarosa minore, a fresh water one. Wastewater enters from the inflow tank, reaches the last tank and leaves the ESF from the outflow canal. Arrows indicate the water direction, dotted lines the outflow canal (Source: "Molentargius" UTM WSG84 32S 513966 E, 4343085 N Google Earth March 14, 2013. November 20, 2014)

Figure 2. The evolution of the constructed wetland during the first five years after its original creation in 2004 (2004/2009). Color version of the pictures in the online version only.

Figure 3. Species richness increased over the nine years (2005-2013) in which floristic survey were conducted

Annex I - Complete floristic list

Annex II - Complete floristic list with presence of species in the years

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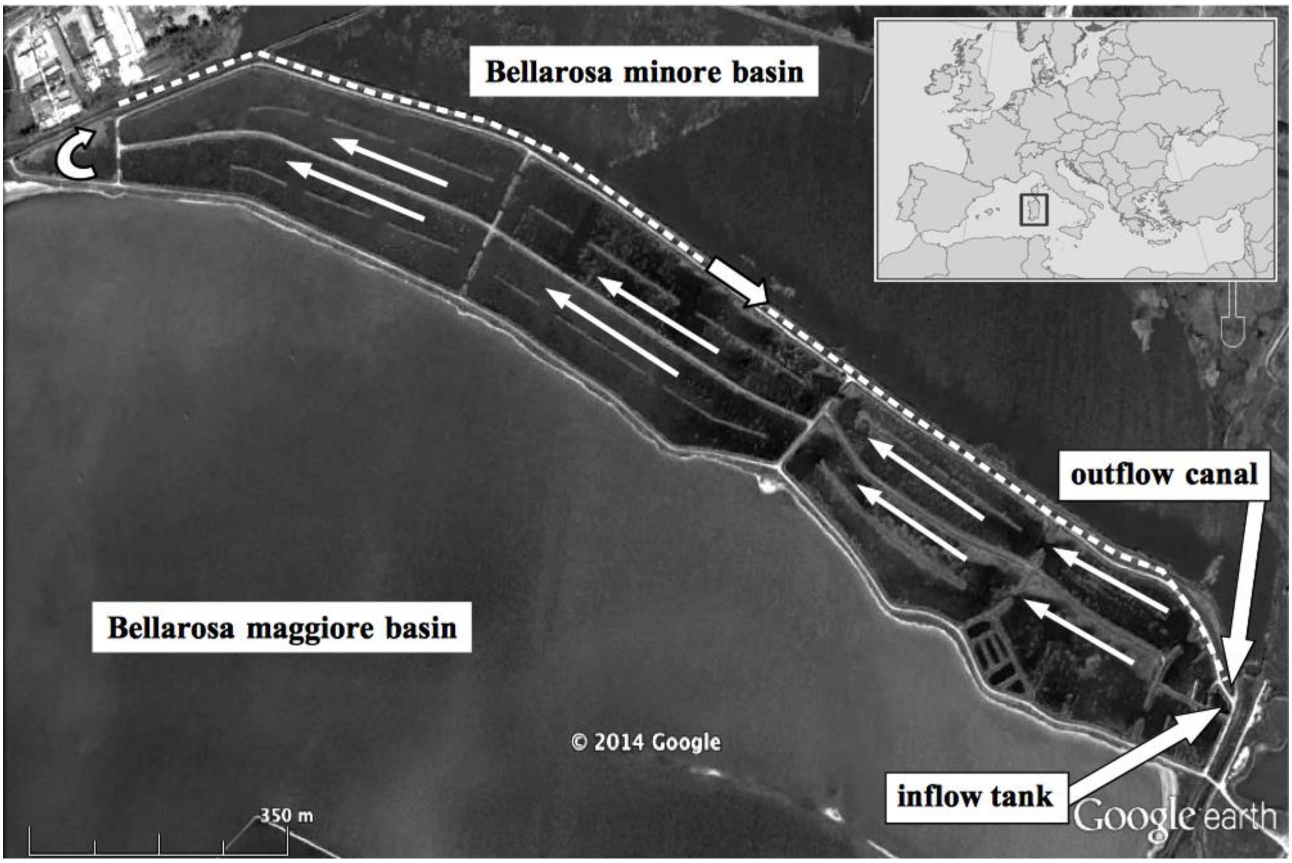
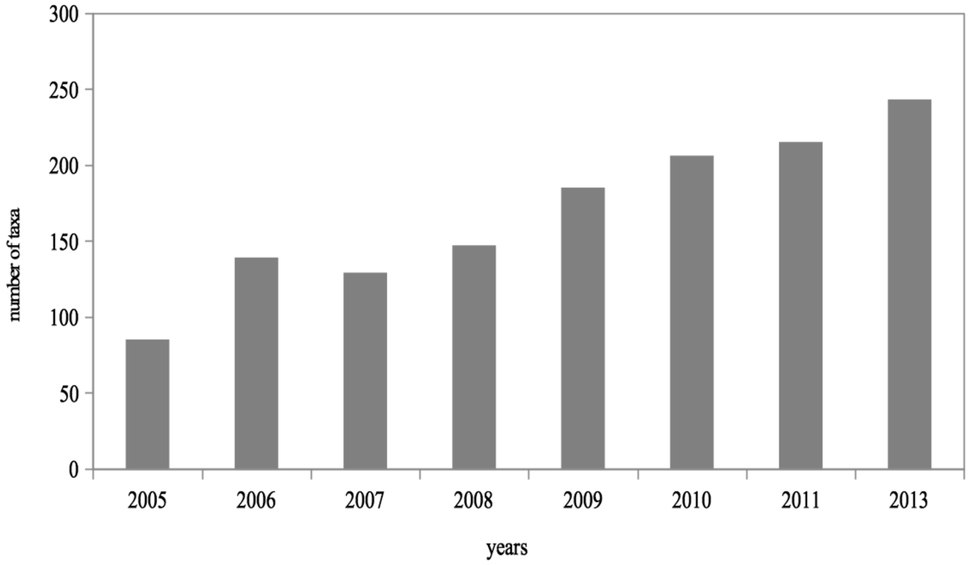

Bellarosa minore basin
outflow canal
Bellarosa maggiore basin
© 2014 Google
inflow tank
350 m
Google earth

Figure 1

Figure 2



300
250
200
150
100
50
0
number of taxa
2005
2006
2007
2008
2009
2010
2011
2013
years

Annex I - Complete floristic list

Environmental Management

Can artificial ecosystems enhance local biodiversity? The case of a constructed wetland in a Mediterranean urban context

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The *taxa* are listed in systematic order at the level of orders and families and, within those, genera, species and any infraspecific *taxa* follow the alphabetical order. For each entity we indicated the specific or sub-specific binomial followed, in order, by:

≅ biological form and sub-form, verified in the field using the classification of Raunkiaer (1934) and adopting the abbreviation of Pignatti (1982);

≅ chorotype according to Pignatti (1982). In regards to the chorology of endemic species, we adopted the geographical groups proposed by Peruzzi *et al.* (2014).

≅ non-native species, inserted in the list, are indicated with the terminology (Cas = casual; Nat = naturalized; Inv = invasive; D = doubtful) used by Celesti-Grapow *et al.* (2009, 2010a, 2010b); we furthermore consulted the works of Viegi (1993), Camarda (1998), Brundu *et al.* (2003, 2004), Camarda *et al.* (2010), Bacchetta *et al.* (2009) and Podda *et al.* (2010a, 2010b);

≅ IUCN Status for the Sardinian flora according to Conti *et al.* (1997) and, in parentheses, for the Italian flora (Conti *et al.* 1992, 1997, Pignatti *et al.* 2001, Scoppola & Spampinato 2005, Rossi *et al.* 2014). Using the latest version of the protocol IUCN (2001) and the guidelines for its application (IUCN 2010) the following categories can be found: EN = endangered, VU = vulnerable, LC = lower risk, DD = insufficient data.

ARACEAE

Arisarum vulgare O. Targ. Tozz.
G rhiz – Steno-Medit.

Lemna gibba L.
I nat – Subcosmop.

Lemna minor L.
I nat – Subcosmop.

JUNCAGINACEAE

Triglochin barrelieri Loisel.
G bulb – Steno-Medit.

POTAMOGETONACEAE
Stuckenia pectinata (L.) Börner
I rad – Subcosmop.

Zannichellia palustris L. subsp. ***palustris***
I rad – Cosmop. – DD

RUPPIACEAE

Ruppia maritima L.
I rad – Cosmop.

Asparagales

IRIDACEAE

Moraea sisyrinchium (L.) Ker Gawl.
G bulb – Steno-Medit.

XANTHORRHOEACEAE
Asphodelus fistulosus L.
H scap – Paleosubtrop.

Arecales

ARECACEAE
Washingtonia filifera (Lindl.) H. Wendl.
P caesp – Nordamer.

COMMELINIDS

Poales

TYPHACEAE
Typha angustifolia L.
G rhiz – Circumbor.

JUNCACEAE

Juncus acutus L. subsp. ***acutus***
H caesp – Euri-Medit.

Juncus hybridus Brot.
T caesp – Medit.-Atl.

Juncus maritimus Lam.
G rhiz – Subcosmop.

Juncus subulatus Forssk.
G rhiz – S-Medit.

CYPERACEAE

Bolboschoenus maritimus (L.) Palla
G rhiz – Cosmop.

Cyperus rotundus L.
G rhiz – Subcosmop. – D

Schoenoplectus lacustris (L.) Palla subsp. ***lacustris***
G rhiz – Subcosmop.

Schoenoplectus tabernaemontani (C.C. Gmel.) Palla
G rhiz – Eurosib.

Scirpoides holoschoenus (L.) Soják
G rhiz – Euri-Medit.

Anisantha madritensis (L.) Nevski
T scap – Euri-Medit.

Anisantha rubens (L.) Nevski
T scap – S-Medit.-Turan.

Anisantha sterilis(L.) Nevski

T scap – Euri-Medit.-Turan.

Arundo donax L.
G rhiz – Subcosmop. – Inv

Avena barbata Pott ex Link
T scap – Euri-Medit.-Turan.

Bromus hordeaceus L. subsp. ***hordeaceus***
T scap – Subcosmop.
Catapodium rigidum (L.) C.E. Hubb. subsp. ***rigidum***
T scap – Euri-Medit.

Cortaderia selloana (Schult. & Schult. f.) Asch. & Graebn.
H caesp – Sudamer. – Inv

Cynodon dactylon (L.) Pers.
G rhiz – Termocosmop.

Cynosurus echinatus L.
T scap – Euri-Medit.

Hordeum marinum Huds. subsp. ***marinum***
T scap – Euri-Medit.(Subatl.)

Hordeum murinum L. subsp. ***leporinum*** (Link) Arcang.
T scap – Euri-Medit.

Lagurus ovatus L. subsp. ***ovatus***
T scap – Euri-Medit.

Lamarckia aurea (L.) Moench
T scap – Steno-Medit.-Turan.

Molineriella minuta (L.) Rouy
T scap – Steno-Medit.

Ochlopoa annua (L.) H. Scholz
T scap – Cosmop.

Parapholis filiformis (Roth) C.E. Hubb.
T scap – Medit.-Atl.

Parapholis incurva (L.) C. E. Hubb.
T scap – Medit.-Atl.

Paspalum distichum L.

G rhiz – Subcosmop. – Inv

Phalaris minor Retz.
T scap – Paleosubtrop.

Phleum arenarium L. subsp. ***caesium*** H. Scholz
T scap – Medit.-Atl. – VU

Phragmites australis (Cav.) Steud. subsp. ***australis***
G rhiz – Subcosmop.

Phragmites australis (Cav.) Steud. subsp. ***chrysanthus*** (Mabille) Kerguélen
G rhiz – Subcosmop.

Piptatherum miliaceum (L.) Coss. subsp. ***thomasii*** (Duby) Freitag
H caesp – Steno-Medit.-Turan.

Polypogon maritimus Willd.
T scap – Steno-Medit.-Macarones.

Polypogon monspeliensis (L.) Desf.
T scap – Paleosubtrop.

Polypogon subspathaceus Req.
T scap – Steno-Medit.

Rostraria cristata (L.) Tzvelev subsp. ***cristata***
T caesp – Subcosmop.

Rostraria hispida (Savi) Doğan
T scap – Steno-Medit.-Sudoccid.

Sphenopus divaricatus (Gouan) Rchb.
T scap – S-Medit.-Turan.

Trachynia distachya (L.) Link
T scap – Steno-Medit.-Turan.

Trisetaria panicea (Lam.) Paunero
T scap – Steno-Medit.-Macarones.

Vulpia geniculata (L.) Link.
T caesp – Steno-Medit.-Occid.

Vulpia myuros (L.) C.C. Gmel.
T caesp – Subcosmop.

EUDICOTS

Ranunculales

PAPAVERACEAE

Fumaria capreolata L. subsp. ***capreolata***
T scap – Euri-Medit.

Fumaria parviflora Lam.
T scap – Medit.-Turan.

Papaver hybridum L.
T scap – Medit.-Turan. – D

Papaver rhoeas L. subsp. ***rhoeas***
T scap – E-Medit. – D

Papaver setigerum DC.
T scap – W-Medit. – D

RANUNCULACEAE
Delphinium gracile DC.
T scap – W-Medit.

Ranunculus sceleratus L.

FABACEAE

Acacia longifolia (Andrews) Willd.
P caesp – Australia – Nat

Acacia saligna (Labill.) H.L. Wendl.
P caesp – Australia – Inv

Anagyris foetida L.
P caesp – S-Medit.

Astragalus hamosus L.
T scap – Medit.-Turan.

Bituminaria bituminosa (L.) C.H. Stirt.
H scap – Euri-Medit.

Calicotome villosa (Poir.) Link
P caesp – Steno-Medit.

Lathyrus clymenum L.
T scap – Steno-Medit.

Lotus edulis L.
T scap – Steno-Medit.

Lotus ornithopodioides L.
T scap – Steno-Medit.

Lupinus luteus L.
T scap – W-Medit. – EN

Medicago doliata Carmign.
T scap – Steno-Medit.

Medicago praecox DC.
T scap – Steno-Medit.

Medicago rigidula (L.) All.
T scap – Euri-Medit.

Melilotus albus Medik.
T scap – Subcosmop.

Melilotus indicus (L.) All.
T scap – S-Medit.

Ononis natrix L. subsp. ***ramosissima*** (Desf.) Batt.
Ch suffr – Euri-Medit.

Ononis reclinata L.
T scap – S-Medit.-Turan.

Ononis viscosa L. subsp. ***breviflora*** (DC.) Nyman
T scap – W-Medit.

Scorpiurus muricatus L.
T scap – Steno-Medit.

Sulla capitata (Desf.) B.H. Choi & H. Ohashi
T scap – W-Medit.

Sulla coronaria (L.) Medik.
H scap – W-Medit. – Nat

Trifolium angustifolium L. subsp. ***angustifolium***
T scap – Euri-Medit.

Trifolium arvense L. subsp. ***arvense***
T scap – Paleotemp.

Trifolium campestre Schreb.
T scap – W-Paleotemp.

Trifolium lappaceum L.
T scap – Euri-Medit.

Trifolium pratense L. subsp. ***pratense***
H scap – Subcosmop.

Trifolium resupinatum L.
T rept – Paleotemp.

Trifolium scabrum L. subsp. ***scabrum***
T rept – Euri-Medit.

Rosales

URTICACEAE

Parietaria judaica L.
H scap – Euri-Medit.-Macarones.

Urtica membranacea Poir. ex Savigny
T scap - S-Medit. T scap – S-Medit.

Urtica urens L.
T scap – Subcosmop.

Cucurbitales

CUCURBITACEAE

Ecballium elaterium (L.) A. Rich.
G bulb – Euri-Medit.

ROSID I

Oxalidales

OXALIDACEAE

Oxalis pes-caprae L.
G bulb – Sudafr. – Inv

Malpighiales

EUPHORBIACEAE

Euphorbia helioscopia L. subsp. ***helioscopia***
T scap – Cosmop.

Euphorbia peplus L. T
scap – Cosmop.

Euphorbia pithyusa L. subsp. ***cupanii*** (Guss. ex Bertol.) Radcl.-Sm.
G rhiz – Endem. SIC; SAR (Corsica)

Euphorbia terracina L.
P caesp – Paleotrop. – Inv

SALICACEAE

Salix cinerea L. subsp. ***oleifolia*** Macreight
P caesp – W-Medit.-Atl.

LINACEAE

Linum strictum L. subsp. ***strictum***
T scap – Steno-Medit.

ROSID II
Geraniales

GERANIACEAE

Erodium ciconium (L.) L'Hér.
T scap – Euri-Medit.-Pontico

Erodium cicutarium (L.) L’Hér.
T scap – Euri-Medit.

Erodium moschatum (L.) L’Hér.
T scap – Euri-Medit.

Geranium molle L.
T scap – Subcosmop.

Geranium rotundifolium L.
T scap – Paleotemp.

Myrtales

ONAGRACEAE

Epilobium hirsutum L.

Malvales

MALVACEAE

Malva multiflora (Cav.) Soldano, Banfi & Galasso
T scap – Steno-Medit.

Malva olbia (L.) Alef.
P caesp – Steno-Medit.

Malva sylvestris L. subsp. ***sylvestris***
H scap – Subcosmop.

THYMELAEACEAE

Thymelaea hirsuta (L.) Endl.
NP – S-Medit.-W-Asiat.

CISTACEAE

Cistus creticus L. subsp. ***eriocephalus*** (Viv.) Greuter & Burdet
NP – Steno-Medit.

Cistus monspeliensis L.
NP – Steno-Medit.-Macarones.

Cistus salviifolius L.
NP – Steno-Medit.

Brassicales

RESEDACEAE

Reseda alba L. subsp. ***alba***
T scap – Steno-Medit.

BRASSICACEAE

Cardamine hirsuta L.
T scap – Cosmop.

Eruca vesicaria (L.) Cav.
T scap – Medit.-Turan.

Hirschfeldia incana (L.) Lagr.-Foss. subsp. ***incana***
H scap – Medit.-Macarones.

Hornungia procumbens (L.) Hayek
T scap – Subcosmop.

Sinapis arvensis L. subsp. ***arvensis***
T scap – Steno-Medit.

Sisymbrium irio L.
T scap – Paleotemp.

Sisymbrium orientale L. subsp. ***orientale***
T scap – Euri-Medit. – Nat

ASTERIDS

Caryophyllales

FRANKENIACEAE

Frankenia laevis L. subsp. ***laevis***
Ch suffr – Steno-Medit.-Centroasiat.-Sudafr.

TAMARICACEAE

Tamarix africana Poir. var. ***africana***
P caesp – W-Medit.

Tamarix arborea Ehrenb. ex Bunge
T caesp – Medit.-Asiat.

Tamarix canariensis Willd.
P caesp – Medit.-Macarones.

Tamarix parviflora DC.
Ch suffr – Endem. SIC; SAR (Corsica)

Limonium retirameum Greuter & Burdet subsp. ***retirameum***
Ch suffr – Endem. SAR

Limonium virgatum (Willd.) Fourr. Phleum
Ch suffr – Euri-Medit.

POLYGONACEAE

Polygonum aviculare L. subsp. ***aviculare***
T rept – Cosmop.

Rumex obtusifolius L. subsp. ***obtusifolius***
H scap – Subcosmop.

Rumex pulcher L. subsp. ***pulcher***
H scap – Euri-Medit.

CARYOPHYLLACEAE

Cerastium glomeratum Thuill.
T scap – Subcosmop.

Herniaria hirsuta L. subsp. ***hirsuta***
T scap – Paleotemp.

Petrorhagia velutina (Guss.) P. W. Ball & Heywood
T scap – S-Medit.

Polycarpon tetraphyllum (L.) L. subsp. ***tetraphyllum***
T scap – Euri-Medit.

Sagina apetala Ard. subsp. ***apetala***
T scap – Euri-Medit.

Silene gallica L.
T scap – Subcosmop.

Spergularia bocconei (Scheele) Asch. & Graebn.
T scap – Subcosmop.

Spergularia rubra (L.) J. & C. Presl

Stellaria media (L.) Vill. subsp. ***media***
T rept – Cosmop.
Stellaria pallida (Dumort.) Piré
T scap – Paleotemp.

AMARANTHACEAE

Amaranthus albus L.
T scap – Nordamer. – Inv

Amaranthus blitoides S. Watson
T scap – Nordamer. – Inv

Arthrocnemum macrostachyum (Moric.) Moris
Ch succ – Medit.-Macarones.

Atriplex halimus L.
P caesp – Sudafr.

Atriplex patula L.
T scap – Circumbor.

Atriplex portulacoides L.
Ch frut – Circumbor.

Atriplex prostrata DC.
T scap – Circumbor.

Beta vulgaris L. subsp. ***maritima*** (L.) Arcang.
H scap – Euri-Medit.

Chenopodium album L. subsp. ***album***
T scap – Subcosmop.

Dysphania ambrosioides (L.) Mosyakin & Clemants
T scap – Cosmop. – Inv

Oxybasis urbica (L.) S.Fuentes, Uotila & Borsch
T scap – Subcosmop.

Sarcocornia fruticosa (L.) A.J. Scott
Ch succ – Euri-Medit.-Sudafr.

Sarcocornia perennis (Mill.) A.J. Scott
Ch succ – Euri-Medit.

Suaeda maritima (L.) Dumort.
T scap – Cosmop.(alofila)

Suaeda vera J.F. Gmel.

Ch suffr – Cosmop.(alofila)

AIZOACEAE

Mesembryanthemum nodiflorum L.
T scap – S-Medit.-Sudafr. – Nat

Ericales

PRIMULACEAE

Lysimachia arvensis (L.) U. Manns & Anderb. subsp. ***arvensis***
T rept – Subcosmop.

Gentianales

RUBIACEAE

Galium aparine L.
T scap – Eurasiat.

Galium spurium L.
T scap – Eurasiat.

Rubia peregrina L. subsp. ***peregrina***
P lian – Steno-Medit.-Macarones.

Sherardia arvensis L.
T scap – Subcosmop.

GENTIANACEAE

Centaurium pulchellum (Sw.) Druce subsp. ***pulchellum***
T scap – Euri-Medit.

ASTERIDI

UNPLACED

Boraginales

BORAGINACEAE (unplaced)

Cerinthe major L. subsp. ***major***
T scap – Steno-Medit.

Cynoglossum creticum Mill.

H bienn – Euri-Medit.

Echium plantagineum L.
T scap – Euri-Medit.

Heliotropium europaeum L.
T scap – Euri-Medit.-Turan.

Solanales

CONVOLVULACEAE

Calystegia sepium (L.) R. Br. subsp. ***sepium***
H scand – Paleotemp.

Convolvulus althaeoides L.
H scand – Steno-Medit.(baricentro occid.)

Convolvulus arvensis L.
G rhiz – Paleotemp.

SOLANACEAE

Hyoscyamus albus L.
H bienn – Euri-Medit.

Lycium barbarum L.

Lamiales

OLEACEAE

Olea europea L. var. ***sylvestris***
Brot. P caesp – Steno-Medit. – D

PLANTAGINACEAE

Antirrhinum majus L. subsp. ***majus***
Ch frut – W-Medit. – Nat

Linaria reflexa (L.) Desf. subsp. ***reflexa***
T rept – SW-Medit.

Plantago coronopus L. subsp. ***coronopus***
T scap – Euri-Medit.

Plantago lagopus L.

T scap – Steno-Medit.

Plantago lanceolata
L. H ros – Cosmop.

Plantago macrorrhiza Poir.
H ros – W-Steno-Medit.

Plantago major L. subsp. ***major***
H ros – Subcosmop.

Plantago weldenii Rchb.
T scap – EuriMedit.

SCROPHULARIACEAE
Myoporum insulare R. Br. [COSTALONGA (2012) esclude *Myoporum tenuifolium* G. Forst. dalla flora italiana]
P caesp – Australia – Inv

Verbascum sinuatum L.
H bienn – Euri Medit.

LAMIACEAE

Lamium amplexicaule L.
T scap – Paleotemp.

Marrubium alysson L.
H scap – S-Medit. – LC

Marrubium vulgare L.
H scap – Subcosmop.

Salvia verbenaca L.
H scap – Medit.-Atl.

Stachys glutinosa L.
Ch frut – N Italian peninsula (TOS); SAR (Corsica)

VERBENACEAE

Verbena officinalis L.
H scap – Cosmop.

ASTERID II

Asterales

ASTERACEAE
Anacyclus clavatus (Desf.) Pers.
T scap – Steno-Medit.

Andryala integrifolia L.
T scap - Medit.-Occid.(Euri-)

Artemisia arborescens (Vaill.) L.
NP – S-Medit.

Calendula arvensis (Vaill.) L.
T scap – Euri-Medit.

Carduus argyroa Biv.
T scap – Steno-Medit.

Carduus pycnocephalus L. subsp. ***pycnocephalus***
H bienn – Medit.-Turan.

Carlina racemosa L.
T scap – SW-Medit.

Carthamus lanatus L. subsp. ***lanatus***
T scap – Euri-Medit.

Centaurea calcitrapa L.
T scap – Steno-Medit.

Centaurea melitensis L.
T scap – Pantrop. e Subtrop.

Chondrilla juncea L.
H scap – Euri-Medit.-S-Siber.(Subpontico)

Dittrichia graveolens (L.) Greuter
T scap – Medit.-Turan.

Dittrichia viscosa (L.) Greuter subsp. ***viscosa***
H scap – Euri-Medit.

Erigeron bonariensis L.
T scap – America tropic. – Inv

Erigeron canadensis L.

T scap – Nordamer. – Inv

Erigeron sumatrensis Retz.
T scap – America tropic. – Inv

Filago pyramidata L.
T scap – Euri-Medit.

Galactites elegans (All.) Soldano
H bienn – Steno-Medit.

Glebionis coronaria (L.) Spach
T scap – Steno-Medit. – D

Hedypnois rhagadioloides (L.) F.W. Schmidt
T scap – Steno-Medit.

Helichrysum italicum (Roth) G. Don subsp. ***microphyllum*** (Willd.) Nyman
Ch suffr - Endem.(EMO)
Helminthotheca echioides (L.) Holub
T scap – Euri-Medit.

Hypochaeris achyrophorus L.
T scap - Steno-Medit.

Hypochaeris glabra L.
T scap – Euri-Medit.

Lactuca saligna L.
T scap – Euri-Medit.-Turan.

Leontodon tuberosus L.
H ros - Steno-Medit.

Limbarda crithmoides (L.) Dumort. subsp. ***crithmoides***
Ch suffr – SW-Europ.

Mantisalca duriaei (Spach) Briq. et Cavill
T scap - Steno-Medit.

Matricaria chamomilla L.
T scap – Subcosmop. – Cas

Pallenis spinosa (L.) Cass.
H bienn - Euri-Medit.

Phagnalon rupestre (L.) DC. subsp. ***rupestre***

Ch suffr - W e S-Medit.

Phagnalon saxatile (L.) Cass.
Ch suffr - W-Medit.

Podospermum laciniatum (L.) DC.
H bienn - Paleotemp.

Reichardia picroides (L.) Roth
H scap - Steno-Medit.

Scolymus maculatus L.
T scap - S-Medit.

Scorzoneroides muelleri (Sch. Bip.) Greuter & Talavera subsp. ***muelleri***
T scap - N Italian peninsula (LIG not confirmed); SIC; SAR

Senecio leucanthemifolius Poir. subsp. ***leucanthemifolius***
T scap – Steno-Medit.

Senecio vulgaris L.
T scap – Cosmop.

Sonchus tenerrimus L.
T scap – Steno-Medit.

Symphyotrichum squamatum (Spreng.) G.L. Nesom
H scap – Neotropic. – Inv

Tolpis virgata (Desf.) Bertol. subsp. ***grandiflora*** (Ten.) Arcang.
H scap – C Italian peninsula (UMB, ABR); S Italian peninsula (PUG, CAM, BAS, CAL); SIC, SAR

Tripolium pannonicum (Jacq.) Dobrocz. subsp. ***pannonicum***
H bienn – Eurasiat.

Urospermum dalechampii (L.) F.W. Schmidt
H scap - Euri-Medit.-Centro-Occid.

Urospermum picroides (L.) Scop. ex F.W. Schmidt
T scap - Euri-Medit.

Xanthium strumarium L. subsp. ***strumarium***
T scap – Cosmop.

Dipsacales

CAPRIFOLIACEAE

Sixalix atropurpurea (L.) Greuter & Burdet subsp. ***grandiflora*** (Scop.) Soldano & F. Conti
H scap – Steno-Medit.

Apiales

APIACEAE

Ammi visnaga (L.) Lam.
T scap – Euri-Medit.

Daucus carota L. subsp. ***carota***
H bienn – Subcosmop.

Daucus carota L. subsp. ***maximus*** (Desf.) Ball
H bienn - Euri-Medit.

Daucus muricatus (L.) L.
T scap – W-Medit.

Foeniculum vulgare Mill.
H scap – Steno-Medit.

Torilis nodosa (L.) Gaertn.
T scap – Subcosmop.

Annex II - Complete floristic list with presence in the years

Environmental Management

Can artificial ecosystems enhance local biodiversity? The case of a constructed wetland in a Mediterranean urban context

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Species are listed according to their presence in the years.

TAXA	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2013**
Erigeron bonariensis L.	1	1	1	1	1	1	1	1
Amaranthus albus L.	1	1	1	1	1	1	1	1
Atriplex halimus L.	1	1	1	1	1	1	1	1
Nicotiana glauca Graham	1	1	1	1	1	1	1	1
Arthrocnemum macrostachyum (Moric.) Moris	1	1	1	1	1	1	1	1
Limonium avei (De Not.) Brullo & Erben	1	1	1	1	1	1	1	1
Beta vulgaris L. maritima (L.) Arcang.	1	1	1	1	1	1	1	1
Catapodium rigidum (L.) C.E. Hubb. rigidum	1	1	1	1	1	1	1	1
Cynosurus echinatus L.	1	1	1	1	1	1	1	1
Dittrichia viscosa (L.) Greuter viscosa	1	1	1	1	1	1	1	1
Ecballium elaterium (L.) A. Rich.	1	1	1	1	1	1	1	1
Lagurus ovatus L. ovatus	1	1	1	1	1	1	1	1
Plantago coronopus L. coronopus	1	1	1	1	1	1	1	1
Rumex pulcher L. pulcher	1	1	1	1	1	1	1	1
Sarcocornia perennis (Mill.) A.J. Scott	1	1	1	1	1	1	1	1
Trifolium angustifolium L. angustifolium	1	1	1	1	1	1	1	1
Verbascum sinuatum L.	1	1	1	1	1	1	1	1
Anacyclus clavatus (Desf.) Pers.	1	1	1	1	1	1	1	1
Euphorbia terracina L.	1	1	1	1	1	1	1	1
Glebionis coronaria (L.) Spach	1	1	1	1	1	1	1	1

Hedypnois rhagadioloides (L.) F.W. Schmidt	1	1	1	1	1	1	1	1
Lotus ornithopodioides L.	1	1	1	1	1	1	1	1
Plantago lagopus L.	1	1	1	1	1	1	1	1
Senecio leucanthemifolius Poir. leucanthemifolius	1	1	1	1	1	1	1	1
Sixalix atropurpurea (L.) Greuter & Burdet grandiflora (Scop.) Soldano & F. Conti	1	1	1	1	1	1	1	1
Sonchus tenerrimus L.	1	1	1	1	1	1	1	1
Trisetaria panicea (Lam.) Maire	1	1	1	1	1	1	1	1
Dittrichia graveolens (L.) Greuter	1	1	1	1	1	1	1	1
Piptatherum miliaceum (L.) Coss. thomasii (Duby) Freitag	1	1	1	1	1	1	1	1
Avena barbata Pott ex Link	1	1	1	1	1	1	1	1
Epilobium hirsutum L.	1	1	1	1	1	1	1	1
Trifolium arvense L. arvense	1	1	1	1	1	1	1	1
Trifolium campestre Schreb.	1	1	1	1	1	1	1	1
Tripolium pannonicum (Jacq.) Dobrocz. pannonicum	1	1	1	1	1	1	1	1
Parapholis filiformis (Roth) C.E. Hubb.	1	1	1	1	1	1	1	1
Parapholis incurva (L.) C. E. Hubb.	1	1	1	1	1	1	1	1
Salicornia patula Duval-Jouve	1	1	1	1	1	1	1	1
Hordeum marinum Huds. marinum	1	1	1	1	1	1	1	1
Dysphania ambrosioides (L.) Mosyakin & Clemants	1	1	1	1	1	1	1	1
Senecio vulgaris L.	1	1	1	1	1	1	1	1
Solanum nigrum L.	1	1	1	1	1	1	1	1
Suaeda maritima (L.) Dumort.	1	1	1	1	1	1	1	1
Suaeda vera J.F. Gmel.	1	1	1	1	1	1	1	1
Cynodon dactylon (L.) Pers.	1	1	1	1	1	1	1	1
Spergularia salina J. & C. Presl	1	1	1	1	1	1	1	1
Lysimachia arvensis (L.) U. Manns & Anderb. arvensis	1	1	1	1	1	1	1	1
Chenopodium album L. album	1	1	1	1	1	1	1	1
Daucus carota L. carota	1	1	1	1	1	1	1	1
Phragmites australis (Cav.) Trin. ex Steud. australis	1	1	1	1	1	1	1	1
Phragmites australis (Cav.) Trin. ex Steud. chrysanthus (Mabille) Soják	1	1	1	1	1	1	1	1

Rumex obtusifolius L. obtusifolius	1	1	1	1	1	1	1	1
Silene gallica L.	1	1	1	1	1	1	1	1
Sonchus oleraceus L.	1	1	1	1	1	1	1	1
Spergularia bocconei (Scheele) Graebn.	1	1	1	1	1	1	1	1
Centaurea melitensis L.	1	1	1	1	1	1	1	1
Symphyotrichum squamatum (Spreng.) G.L. Nesom	1	1	1	1	1	1	1	1
Lolium rigidum Gaudin rigidum	1	1	1	1	1	1	1	1
Polypogon monspeliensis (L.) Desf.	1	1	1	1	1	1	1	1
Sarcocornia fruticosa (L.) A.J. Scott	1	1	1	1	1	1	1	1
Asparagus stipularis Forssk.	1	1	1	1	1	1	1	1
Melilotus siculus (Turra) Steud.	1	1	1	1	1	1	1	1
Melilotus sulcatus Desf.	1	1	1	1	1	1	1	1
Sphenopus divaricatus (Gouan) Rchb.	1	1	1	1	1	1	1	1
Erigeron sumatrensis Retz.	0	1	1	1	1	1	1	1
Limonium dubium (Guss.) Litard.	0	1	1	1	1	1	1	1
Hirschfeldia incana (L.) Lagr.-Foss. incana	0	1	1	1	1	1	1	1
Tamarix parviflora DC.	0	1	1	1	1	1	1	1
Diplotaxis erucoides (L.) DC. erucoides	0	1	1	1	1	1	1	1
Sulla coronaria (L.) Medik.	0	1	1	1	1	1	1	1
Tamarix africana Poir. var. africana	0	1	1	1	1	1	1	1
Erodium cicutarium (L.) L'Hér.	0	1	1	1	1	1	1	1
Limonium virgatum (Willd.) Fourr.	0	1	1	1	1	1	1	1
Plantago weldenii Rchb.	0	1	1	1	1	1	1	1
Polycarpon tetraphyllum (L.) L. tetraphyllum	0	1	1	1	1	1	1	1
Trifolium stellatum L.	0	1	1	1	1	1	1	1
Cerinthe major L. major	0	1	1	1	1	1	1	1
Galactites elegans (All.) Soldano	0	1	1	1	1	1	1	1
Lotus edulis L.	0	1	1	1	1	1	1	1
Malva olbia (L.) Alef.	0	1	1	1	1	1	1	1
Reseda alba L. alba	0	1	1	1	1	1	1	1
Scorpiurus muricatus L.	0	1	1	1	1	1	1	1
Sinapis arvensis L. arvensis	0	1	1	1	1	1	1	1
Thapsia garganica L.	0	1	1	1	1	1	1	1

Polypogon maritimus Willd.	0	1	1	1	1	1	1	1
Carduus pycnocephalus L. pycnocephalus	0	1	1	1	1	1	1	1
Eruca vesicaria (L.) Cav.	0	1	1	1	1	1	1	1
Convolvulus arvensis L.	0	1	1	1	1	1	1	1
Herniaria hirsuta L. hirsuta	0	1	1	1	1	1	1	1
Sisymbrium irio L.	0	1	1	1	1	1	1	1
Galium spurium L.	0	1	1	1	1	1	1	1
Limbarda crithmoides (L.) Dumort. crithmoides	0	1	1	1	1	1	1	1
Atriplex portulacoides L.	0	1	1	1	1	1	1	1
Atriplex prostrata Boucher ex DC.	0	1	1	1	1	1	1	1
Typha angustifolia L.	0	1	1	1	1	1	1	1
Bolboschoenus maritimus (L.) Palla	0	1	1	1	1	1	1	1
Erigeron canadensis L.	0	1	1	1	1	1	1	1
Plantago lanceolata L.	0	1	1	1	1	1	1	1
Stellaria media (L.) Vill. media	0	1	1	1	1	1	1	1
Malva sylvestris L. sylvestris	0	1	1	1	1	1	1	1
Marrubium vulgare L.	0	1	1	1	1	1	1	1
Asphodelus fistulosus L.	0	1	1	1	1	1	1	1
Ononis reclinata L.	0	1	1	1	1	1	1	1
Thymelaea hirsuta (L.) Endl.	0	1	1	1	1	1	1	1
Acacia longifolia (Andrews) Willd.	0	0	1	1	1	1	1	1
Oxalis pes-caprae L.	0	0	1	1	1	1	1	1
Limonium retirameum Greuter & Burdet retirameum	0	0	1	1	1	1	1	1
Euphorbia pithyusa L. cupanii (Guss. ex Bertol.) Radcl.-Sm.	0	0	1	1	1	1	1	1
Antirrhinum majus L. majus	0	0	1	1	1	1	1	1
Calicotome villosa (Poir.) Link	0	0	1	1	1	1	1	1
Carduus argyroa Biv.	0	0	1	1	1	1	1	1
Polypogon subspathaceus Req.	0	1	1	1	0	1	1	1
Salix cinerea subsp. oleifolia Macreight	0	0	1	1	1	1	1	1
Lemna minor L.	0	0	1	1	1	1	1	1
Vicia sativa L. nigra (L.) Ehrh.	0	0	1	1	1	1	1	1
Juncus subulatus Forssk.	0	0	1	1	1	1	1	1

Myoporum insulare R. Br.	0	0	0	1	1	1	1	1
Lycium barbarum L.	0	0	0	1	1	1	1	1
Cortaderia selloana (Schult.) Asch. & Graebn.	0	0	0	1	1	1	1	1
Stachys glutinosa L.	0	0	0	1	1	1	1	1
Papaver rhoeas L. rhoeas	1	1	0	0	0	1	1	1
Carlina racemosa L.	0	0	0	1	1	1	1	1
Salicornia emerici Duval-Jouve	0	1	1	0	0	1	1	1
Bituminaria bituminosa (L.) C.H. Stirt.	0	0	0	1	1	1	1	1
Helminthotheca echioides (L.) Holub	0	0	0	1	1	1	1	1
Juncus acutus L. acutus	1	1	0	0	0	1	1	1
Ononis natrix L. ramosissima (Desf.) Batt.	0	0	0	1	1	1	1	1
Carlina corymbosa L.	0	0	0	1	1	1	1	1
Cistus creticus L. eriocephalus (Viv.) Greuter & Burdet	0	0	0	1	1	1	1	1
Cistus salviifolius L.	0	0	0	1	1	1	1	1
Cistus monspeliensis L.	0	0	0	1	1	1	1	1
Echium sabulicola Pomel sabulicola	0	1	1	1	1	1		
Geranium rotundifolium L.	0	0	1	0	1	1	1	1
Ruppia marittima L.	1	1	1	1	0	0	1	0
Arundo donax L.	0	0	0	1	1	1	1	1
Cerastium glomeratum Thuill.	0	0	0	1	1	1	1	1
Lemna gibba L.	1	1	1	1	1	0	0	0
Plantago major L. major	0	0	0	1	1	1	1	1
Stuckenia pectinata (L.) Börner	0	0	1	1	1	1	1	0
Rostraria cristata (L.) Tzvelev cristata	0	0	0	1	1	1	1	1
Ricinus communis L.	0	0	0	1	1	1	1	1
Phalaris minor Retz.	0	0	0	1	1	1	1	1
Artemisia arborescens (Vaill.) L.	0	0	0	1	1	1	1	1
Foeniculum vulgare Mill.	0	0	0	1	1	1	1	1
Mesembryanthemum nodiflorum L.	1	1	0	0	0	1	1	1
Anisantha rubens (L.) Nevski	0	0	0	1	1	1	1	1
Frankenia laevis L. laevis	0	0	0	1	1	1	1	1
Diplotaxis tenuifolia (L.) DC.	0	0	0	1	1	1	1	1
Amaranthus blitoides S. Watson	1	1	0	0	0	0	1	1

Linaria reflexa (L.) Desf. reflexa	0	0	0	0	1	1	1	1
Ononis viscosa L. breviflora (DC.) Nyman	1	1	0	0	0	0	1	1
Anisantha madritensis (L.) Nevski	0	0	0	0	1	1	1	1
Calendula arvensis (Vaill.) L.	0	0	0	0	1	1	1	1
Filago pyramidata L.	1	0	0	0	0	1	1	1
Fumaria capreolata L. capreolata	0	0	0	0	1	1	1	1
Hordeum murinum L. leporinum (Link) Arcang.	0	0	0	0	1	1	1	1
Hyoscyamus albus L.	0	1	0	0	0	1	1	1
Medicago rigidula (L.) All.	1	0	0	0	0	1	1	1
Schenkia spicata (L.) G. Mans.	0	1	0	0	0	1	1	1
Trifolium scabrum L. scabrum	1	0	0	0	0	1	1	1
Parietaria judaica L.	0	0	0	0	1	1	1	1
Arisarum vulgare Targ. Tozz.	0	0	0	0	1	1	1	1
Asparagus acutifolius L.	0	0	0	0	1	1	1	1
Lathyrus clymenum L.	0	1	0	0	1	1	1	0
Malva multiflora (Cav.) Soldano, Banfi & Galasso	1	1	0	0	0	0	1	1
Molineriella minuta (L.) Rouy	0	0	0	0	1	1	1	1
Olea europea L. var. sylvestris Brot.	0	0	0	0	1	1	1	1
Pistacia lentiscus L.	0	0	0	0	1	1	1	1
Stipa capensis Thunb.	0	0	0	0	1	1	1	1
Tolpis virgata (Desf.) Bertol. grandiflora	0	0	1	0	0	1	1	1
Trifolium spumosum L.	0	0	0	0	1	1	1	1
Rubia peregrina L. peregrina	0	0	0	0	1	1	1	1
Astragalus hamosus L.	0	1	1	0	0	0	1	1
Fumaria parviflora Lam.	0	0	0	0	1	1	1	1
Trachynia distachya (L.) Link	0	0	0	0	1	1	1	1
Heliotropium europaeum L.	1	0	0	0	0	1	1	1
Lactuca saligna L.	0	1	0	1	1	1		
Mercurialis annua L.	0	0	0	0	1	1	1	1
Ranunculus sceleratus L.	1	0	0	0	0	1	1	1
Galium aparine L.	0	0	0	0	1	1	1	1
Phleum arenarium L. caesium H. Scholz	0	1	0	0	0	1	1	1
Salvia verbenaca L.	0	0	0	0	1	1	1	1

Cardamine hirsuta L.	0	0	0	0	1	1	1	1
Euphorbia helioscopia L. helioscopia	0	0	0	0	1	1	1	1
Euphorbia peplus L.	0	0	0	0	1	1	1	1
Ochlopoa annua (L.) H. Scholz	0	0	0	0	1	1	1	1
Polygonum aviculare L. aviculare	1	0	0	0	0	1	1	1
Cyperus rotundus L.	0	0	0	0	1	1	1	1
Juncus maritimus Lam.	0	0	1	1	1	1	0	0
Melilotus indicus (L.) All.	0	0	0	0	1	1	1	1
Sonchus asper (L.) Hill asper	0	0	0	0	1	1	1	1
Spergularia rubra (L.) J. & C. Presl	1	0	0	0	0	1	1	1
Torilis nodosa (L.) Gaertn.	0	0	0	0	1	1	1	1
Trifolium pratense L. pratense	0	0	0	0	1	1	1	1
Urtica urens L.	0	0	0	0	1	1	1	1
Vulpia myuros (L.) C.C. Gmel.	0	0	0	0	1	1	1	1
Anagyris foetida L.	0	0	0	0	1	1	1	1
Marrubium alysson L.	0	0	0	1	1	1	1	0
Daucus muricatus (L.) L.	0	0	0	0	1	1	1	0
Delphinium gracile DC.	0	0	0	1	0	1	1	0
Ammi visnaga (L.) Lam.	1	1	1	0	0	0	0	0
Erodium moschatum (L.) L'Hér.	0	0	0	0	1	0	1	1
Scirpoides holoschoenus (L.) Soják	0	0	0	0	0	1	1	1
Sisymbrium orientale L. orientale	0	1	0	0	0	0	1	1
Trifolium lappaceum L.	1	0	0	0	0	1	1	0
Linum strictum L. strictum	0	0	0	0	0	1	1	1
Moraea sisyrinchium (L.) Ker-Gawl.	0	1	0	0	0	0	1	1
Plantago macrorrhiza Poir.	0	1	0	0	0	0	1	1
Lamarckia aurea (L.) Moench	0	0	0	0	0	1	1	1
Stellaria pallida (Dumort.) Crép.	0	0	0	0	1	1	1	0
Juncus hybridus Brot.	1	1	0	0	0	1	0	0
Oxybasis urbica (L.) S. Fuentes, Uotila & Borsch	0	1	0	0	0	0	1	1
Geranium molle L.	0	0	0	0	1	1	1	0
Matricaria chamomilla L.	0	0	0	0	1	1	1	0
Sherardia arvensis L.	0	0	0	0	0	1	1	1

Sulla capitata (Desf.) B.H. Choi & H. Ohashi	0	0	1	0	0	1	0	0
Carthamus lanatus L. lanatus	1	1	0	0	0	0	0	0
Asphodelus ramosus L. ramosus	0	0	0	0	1	1	0	0
Medicago praecox DC.	0	1	0	0	0	0	0	1
Calystegia sepium (L.) R. Br. sepium	0	0	0	0	1	1	0	0
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	0	1	1	0	0	0	0	0
Zannichellia palustris L. palustris	1	0	0	1	0	0	0	0
Hornungia procumbens (L.) Hayek	0	1	0	0	0	1	0	0
Schoenoplectus lacustris (L.) Palla	0	1	1	0	0	0	0	0
Atriplex patula L.	0	0	0	0	0	0	1	1
Carlina lanata L.	0	0	0	0	0	0	1	1
Helichrysum italicum (Roth) G. Don subsp. microphyllum (Willd.) Nyman	0	0	0	0	0	0	1	1
Lolium perenne L.	0	0	0	0	0	0	1	1
Urospermum dalechampii (L.) F.W. Schmidt	0	0	0	0	0	0	1	1
Urtica membranacea Poir. ex Savigny	0	0	0	0	0	0	1	1
Papaver setigerum DC.	0	1	0	0	0	0	0	0
Hypochaeris glabra L.	0	1	0	0	0	0	0	0
Sagina apetala Ard. apetala	0	0	0	0	1	0	0	0
Medicago doliata Carmign.	0	1	0	0	0	0	0	0
Triglochin bulbosum L. barrelieri (Loisel.) Rouy	0	1	0	0	0	0	0	0
Cynomorium coccineum L. coccineum	0	1	0	0	0	0	0	0
Papaver hybridum L.	0	1	0	0	0	0	0	0
Lamium amplexicaule L.	0	0	0	0	1	0	0	0
Trifolium resupinatum L.	1	0	0	0	0	0	0	0
Salicornia dolichostachya Moss	0	0	1	0	0	0	0	0
Xanthium strumarium L. strumarium	1	0	0	0	0	0	0	0
Melilotus albus Medik.	0	1	0	0	0	0	0	0
Paspalum distichum L.	0	1	0	0	0	0	0	0
Acacia saligna (Labill.) H.L. Wendl.	0	0	0	0	0	0	0	1
Achnatherum bromoides (L.) P. Beauv.	0	0	0	0	0	0	0	1
Andryala integrifolia L.	0	0	0	0	0	0	0	1
Anisantha sterilis (L.) Nevski	0	0	0	0	0	0	0	1

Ballota nigra L. subsp. uncinata (Fiori & Bég.) Patzak	0	0	0	0	0	0	0	1
Bromus hordeaceus L. subsp. hordeaceus	0	0	0	0	0	0	0	1
Centaurea calcitrapa L.	0	0	0	0	0	0	0	1
Centaurium pulchellum (Sw.) Druce subsp. pulchellum	0	0	0	0	0	0	0	1
Chondrilla juncea L.	0	0	0	0	0	0	0	1
Convolvulus althaeoides L.	0	0	0	0	0	0	0	1
Cynoglossum creticum Mill.	0	0	0	0	0	0	0	1
Daucus carota L. subsp. maximus (Desf.) Ball	0	0	0	0	0	0	0	1
Erodium ciconium (L.) L'Hér.	0	0	0	0	0	0	0	1
Hypochaeris achyrophorus L.	0	0	0	0	0	0	0	1
Leontodon tuberosus L.	0	0	0	0	0	0	0	1
Lupinus luteus L.	0	0	0	0	0	0	0	1
Mantisalca duriaei (Spach) Briq. et Cavill	0	0	0	0	0	0	0	1
Melica ciliata L. subsp. magnolii (Gren & Godr.) Husn.	0	0	0	0	0	0	0	1
Pallenis spinosa (L.) Cass.	0	0	0	0	0	0	0	1
Petrorhagia velutina (Guss.) P. W. Ball & Heywood	0	0	0	0	0	0	0	1
Phagnalon rupestre (L.) DC. subsp. rupestre	0	0	0	0	0	0	0	1
Phagnalon saxatile (L.) Cass.	0	0	0	0	0	0	0	1
Podospermum laciniatum (L.) DC.	0	0	0	0	0	0	0	1
Reichardia picroides (L.) Roth	0	0	0	0	0	0	0	1
Rostraria hispida (Savi) Doğan	0	0	0	0	0	0	0	1
Scolymus maculatus L.	0	0	0	0	0	0	0	1
Scorzoneroides muelleri (Sch. Bip.) Greuter & Talaverasubsp. muelleri	0	0	0	0	0	0	0	1
Tamarix arborea Ehrenb. ex Bunge	0	0	0	0	0	0	0	1
Tamarix canariensis Willd.	0	0	0	0	0	0	0	1
Urospermum picroides (L.) Scop. ex F.W. Schmidt	0	0	0	0	0	0	0	1
Verbena officinalis L.	0	0	0	0	0	0	0	1
Vulpia geniculata (L.) Link.	0	0	0	0	0	0	0	1
Washingtonia filifera (Lindl.) H. Wendl.	0	0	0	0	0	0	0	1