

## Alien Plant Diversity in Mediterranean Wetlands: A Comparative Study within Valencian, Balearic and Sardinian Floras

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### Abstract

Although wetlands provide an important range of environmental, social and economic services, they are increasingly subjected to anthropogenic perturbations, amongst which invasion by alien plants is particularly alarming. This paper focuses on the alien flora of wetlands from three territories belonging to the western Mediterranean area: one continental (Valencian Community) and two insular (Balearic Islands and Sardinia), providing a complete checklist for the three territories and a general comparison. In total, 380 alien taxa from 89 families have been reported, being the Valencian Community the area richer in taxa (312), followed by the Balearic Islands (151) and Sardinia (134). The invasive component includes 77 taxa, of which nine are common to the three territories - and have been recognised as the most invasive ones in Mediterranean islands - and six are considered invasive worldwide (*Ailanthus altissima*, *Arundo donax*, *Cortaderia selloana*, *Oxalis pes-caprae*, *Ricinus communis* and *Eichhornia crassipes*). Multiple Correspondence Analysis (MCA) revealed that the three territories do not show statistically relevant differences in relation to the alien species present in wetlands and their characteristics. The information on the characteristics of plants in similar habitats of the same biogeographic region provides a portrait of the current dimensions of the phenomenon in Western Mediterranean wetlands and is especially useful from the management perspective: its predictive value can be applied in establishing a prioritization of control measures of those most invasive species and will help screening new introductions with invasive potential.

**Keywords:** continent; environmental impact; invasions; islands; non-native plants; water

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### Introduction

Wetlands perform various valuable ecosystem services: they recycle nutrients, purify water, recharge ground water, and provide habitat for a wide variety of flora and fauna. Simultaneously, these ecosystems are being increasingly subjected to anthropogenic perturbations (Smith *et al.*, 1999). At the global level, aquatic habitats are amongst the

environments most threatened by invasion of alien species (Barrett, 1989; Hood and Naiman, 2000; Cronk and Fennessy, 2001; DiTomaso, 2003; Ervin *et al.*, 2006; Wilby, 2007; Strayer, 2010). This susceptibility is caused by the fragility of these ecosystems, which act as vast sponges, with different levels of resilience to alterations (Carpenter and Cottingham, 1997). Disturbances have been related with the success of invasions and aquatic habitats are especially susceptible to biological invasions: flooding is a common

disturbance in wetlands and an important force continuously reshaping these habitats (Leopold *et al.*, 1964).

The percentage of the recorded introductions in wetlands is the highest in the world: Europe 25.1%, Asia 16.4%, Africa 14.7%, Oceania 14.7%, South and Central America 14.1%, Middle east 8.4%, north America 6.3% (Genovesi, 2007). During the last decade, problems associated with the spread of certain alien aquatic plant species were found to be increasing in Europe (Hussner, 2009; 2012), where 30% of alien freshwater animal and plant species negatively influence freshwater ecosystems, and 24% have an economic impact (Vila *et al.*, 2009). It is estimated that at least 260 species of plants not native to any part of Europe are established in inland waterways (Keller *et al.*, 2011). Particularly alien aquatic plants show a higher proportion of species causing impacts upon their habitats than terrestrial species (Hood and Naiman, 2000; Vila *et al.*, 2009). The actual susceptibility of European inland waters to invasions is a direct consequence of the rapid growth of transport, trade and tourism (Genovesi, 2007).

The Mediterranean Basin is one of the main biodiversity hotspots in the world and has high sensitivity to biological invasions due to biogeographic, climatic and socio-economic conditions (Myers *et al.*, 2000; Mittermeier *et al.*, 2005; Gritti *et al.*, 2006). At the same time, southern and western parts of Europe show higher number of alien aquatic plants than northern and eastern parts as a consequence of the longer growing season and mild winter temperatures (Chytrý *et al.*, 2009). Among different habitats, inland wet areas are shown to be among the most invaded environments of the Mediterranean Basin, with around 20% of alien taxa (Arianoutsou *et al.*, 2010). The vulnerability of these habitats is increased by anthropic pressure and the problem of water in these meridional regions, where the water is scarce in summer and has to be shared among different ecosystems and human exploitations (that frequently vary depending on political decisions), difficulties increased by the effect of accelerated climate change (Gitay *et al.*, 2011).

The phenomenon of biological invasions is better understood on the scale of habitat since it is at this level where many ecological processes take place (competition, inhibition, facilitation, predation, etc.) (Pino *et al.*, 2008). In addition, this scale is where most of the actions of environmental management and conservation of species are applied. There have been plenty of small-scale studies on invasions involving specific taxa on wetlands in different areas of the Mediterranean Basin (e.g. Domènech and Vila, 2008; Bacchetta *et al.*, 2010; Brundu *et al.*, 2012; Constan, 2012; Mayoral *et al.*, 2012). On the other hand, biological traits play a key role in the invasiveness of alien species, and the comparison of these traits is essential when studying alien species.

Nevertheless, information on the degree of invasion of habitats in Europe is very fragmented and heterogeneous, both in quality and geographic scale (Chytrý *et al.*, 2008; Vila *et al.*, 2008). The comparison within areas from the same biogeographic region is considered noteworthy by different authors (Crawley *et al.*, 1996; Gritti *et al.*, 2006; Podda *et al.*, 2010). Previous comparative studies have been

focused on general relationships between compatible countries or geographical spots (e.g. islands) (Crawley *et al.*, 1996; Gómez-Serrano and Mayoral, 2003; Podda *et al.*, 2010; 2011; Puddu *et al.*, 2016). However, to our knowledge, no attempt has been made to compare a single habitat type from different areas in the Mediterranean Basin.

The aim of the present study is to compare the alien flora of wetlands of islands vs. continental Mediterranean areas and to analyse the differences in biological traits of invasive species among the regions analysed. This goal is achieved from the analysis of a built checklist of the alien flora within wetlands of three western Mediterranean areas, one continental (Valencian Community) and two insular (Balearic Islands and Sardinia).

## Materials and Methods

### Study areas and habitats

The study areas are located in the western Mediterranean Basin. From a biogeographic approach, the three territories belong to the western Mediterranean sub-region of the Mediterranean region (Fig. 1), with many climatic and bioclimatic similarities. The most represented bioclimate in the three territories is the Mediterranean Pluviseasonal-Oceanic (Rivas-Martínez, 2007).

The Valencian Community (Spain) -hereafter VC- is placed on the eastern part of the Iberian Peninsula. It's a long and narrow region of 23,255 km<sup>2</sup> and a coastline of 518 km lying by the Mediterranean Sea, with 44,862 ha of wetlands.

The Balearic Islands (Spain) - hereafter BL - are located facing the Valencian Community, near the eastern coast of the Iberian Peninsula. The archipelago of the BL has a total area of 4,992 km<sup>2</sup>, and consists of five main islands: Majorca, Minorca, Ibiza, Formentera and Cabrera, and numerous minor islets, with 2,950 ha of wetlands. The perimeter of its coast has a total length of 1,428 km.

Sardinia (Italy) -hereafter SA- is the second largest island in the Mediterranean Sea (after Sicily and before Cyprus), with an area of 24,089 km<sup>2</sup>, of which 28,500 ha are occupied by wetlands. The coastline, including more than 300 islands and islets, is about 1,995 km long.

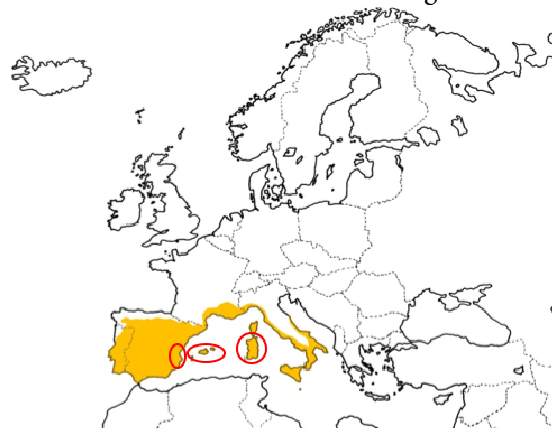


Fig. 1. Study area (ovals from left to right, Valencian Community, Balearic Islands and Sardinia) and limits of the western Mediterranean biogeographic sub-region (yellow)

Due to their transitional nature and their complex interactions, wetlands are difficult to define and demarcate accurately. In this study the term wetland is considered heterogeneous habitats, as defined in the article 1.1 of the Convention on Wetlands of International Importance (RAMSAR, 1971), including lakes and rivers, swamps and marshes, wet grasslands and peatlands and human-made sites such as ponds, rice paddies, reservoirs, and salt pans. This transitional space between land and water includes numerous and various ecosystems, characterised by an important diversity in structure and hydro-ecological functioning, with permanent or temporary, flowing or static water, including riverbeds, which in Mediterranean areas are dry great part of the year.

#### *Origin of data*

In order to collect data on alien plants of each area, the herbarium material available was consulted and implemented by unpublished data derived from our field investigations carried out during the last ten years. Furthermore, the most important bibliographic data and databases were consulted. In particular, DAISIE database (2017), and for the VC, Gómez-Serrano and Mayoral (2001) and Sanz-Elorza *et al.* (2011), for the BL, Vila and Muñoz (1999) and Moragues and Rita (2005), and for SA, Bacchetta *et al.* (2008; 2009b) and Podda *et al.* (2010; 2011; 2012).

The basis for the present study was a checklist including all the alien taxa found in wetlands of the three territories (Annex I). From a nomenclatural point of view and for the attribution of the taxa to the plant families, the on-line databases of The Plant List website (2010) and of the Med-Checklist website (Euro+Med, 2006-onwards) were followed. Concerning the validity of the plant families it was followed what is reported in the Angiosperm Phylogeny Group III (Chase and Reveal, 2009; Stevens, 2001-onwards) while for gymnosperms and pteridophytes the works of Christenhusz *et al.* (2011a, 2011b). Apart from Castroviejo S *et al.* (eds.) (1986-2017), when available, dedicated taxonomic revisions have been taken into account.

#### *Data treatment and surveying methods*

Invasive taxa were determined and ordered following the scheme proposed by Richardson *et al.* (2000), elaborated by Pysek *et al.* (2004) and reviewed according to Richardson *et al.* (2011).

Archaeophyte and neophyte taxa were differentiated depending on their introduction before or after 1492/1500. This variable was called "residence status". Since it is still a matter of debate if some species can be considered native or not and, in this latter case, if they are archaeophytes or neophytes (Carlton, 1996; Celesti-Grapow *et al.*, 2010), for these taxa for which such doubts still persist, we have preferred the attribution of doubtful (D). In order to differentiate the presence (as native) from the absence, those taxa present as alien in the whole territory (but not in wetlands) were stated as PA and those present as natives were stated as PN. This information is included in the checklist of Annex I but was not used for the analysis.

Life forms for taxa were determined following the classification of Raunkiaer (1934) and using the abbreviations of Pignatti (1982).

Species origin is based on geographical area or biogeographical region according to Sanz-Elorza *et al.* (2011), Moragues and Rita (2005) and Bacchetta *et al.* (2009a).

Taxa were also classified according to their intentional or not intentional anthropogenic introduction, following the considerations of the guiding principles of the Convention on Biological Diversity (CBD) and the European Strategy on Invasive Alien Species (European IAS Strategy) (Miller *et al.* 2006). Regarding introduction pathways, the categories proposed by Sanz-Elorza *et al.* (2004) and Hulme *et al.* (2008) were modified and adapted. Cultivated, ornamental or forestry taxa that do not show any degree of naturalization have not been taken into account in the present work.

Moreover, the impact of each invasive taxon was examined according to Celesti-Grapow *et al.* (2010) readapted with the identification of three broad categories according to Podda *et al.* (2011): (1) Environmental (competition and hybridisation; changes in the structure and function of the habitats; abiotic changes); (2) Economic (agricultural weeds; threatening livestock; damaging human constructions, infrastructures, monuments and archaeological remains); (3) Human health (toxic; poisonous; allergenic and armed species). The assignment of impact classes to each taxon was made at regional level and based on field data and expert-based knowledge.

#### *Data analysis*

In order to analyse the relationship among the three territories (VC, BL and SA) we used the Multiple Correspondence Analysis (hereafter MCA) (Benzécri, 1979). The initial matrix for the MCA was composed of 597 rows and 14 variables. Each row represents a taxon present in a specific territory. The considered variables are: Territory (VC, BL, and SA), Name of taxa, Type (residence status: archaeophyte and neophyte), Life form (Ph, Th, Ge, He, Hy and Ch), Taxa origin (Africa, America, Asia, Australia, South Africa, Euroasia, Europe, Mediterranean and Saharo-Arabian, Others), Status (naturalised, invasive, casual), Introduction pathways ornamental (Yes or Not), Introduction pathways agriculture (Yes or Not), Introduction pathways forestry (Yes or Not), Introduction pathways seed contaminant (Yes or Not), Introduction pathways hitchhikers (Yes or Not), Environmental impact (Yes or Not), Economic impact (Yes or Not) and Health impact (Yes or Not).

Through MCA we defined a pattern of relationships of twelve categorical variables (all those listed above except Territory and Name of taxa), describing the features that taxa can assume in a territory. We projected Territory and Name of taxa as supplementary variables on the pattern in order to analyse their positioning.

Furthermore, T-test and Chi-square test were used to analyse the dependence across all variables by twos. All analyses were performed using SPAD 7.4 software.

**Results**

A total of 380 alien taxa were recorded in the wetlands of the entire study area, distributed in 89 families and 169 genera (Annex I). Alien plants of wetlands represent the 47.1% (312 taxa) of the whole alien flora of the VC, the 42.8% (151) of the BL, and the 29.3% (134) of SA.

The highest percentages of alien taxa by families correspond to Poaceae (49 taxa, 12.9%), Asteraceae (35, 9.2%) and Fabaceae (31, 8.2%) for the territory studied as a whole. With regard to the study of families by territories, the alien flora of the VC includes 82 families, 57 the BL and 53 SA (Fig. 2).

Neophytes and archaeophytes are 77.6% (295 taxa) and 20.5% (78 taxa) of the total and seven taxa are stated as doubtful. The proportion of neophytes is of 82.4% (257 taxa) for the VC, 82.1% (124) for the BL and 73.1% (98) for SA, and of archaeophytes is of 17.6% (55) for the VC, 17.9% (27) for the BL and 26.9% (36) for SA. The invasive component represents the 17.9% for the VC (56 taxa, of which 51 are neophytes and five archaeophytes), 23.2% for the BL (35 taxa, 32 neophytes and three archaeophytes) and 18% for SA (23 taxa, 19 neophytes and four archaeophytes).

Neophytes are mainly represented by invasive and naturalised taxa; only in Valencian wetlands casual species are dominant within the neophytes (Fig. 3). Among the 78 archaeophytes detected, only two (*Arundo donax* and *Ricinus communis*) are invasive in the three territories and four in some of them (*Acanthus mollis* subsp. *mollis*, *Sorghum halepense*, *Spartium junceum* and *Ulmus pumila*)

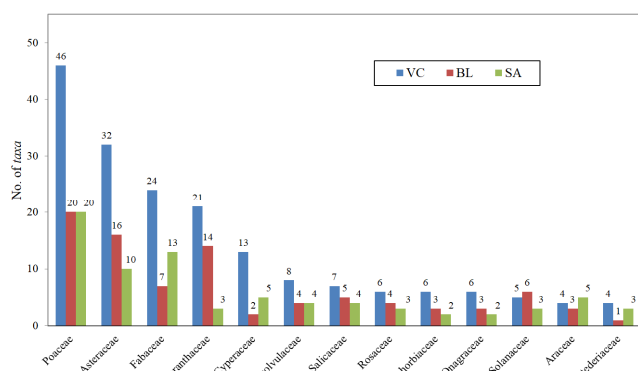
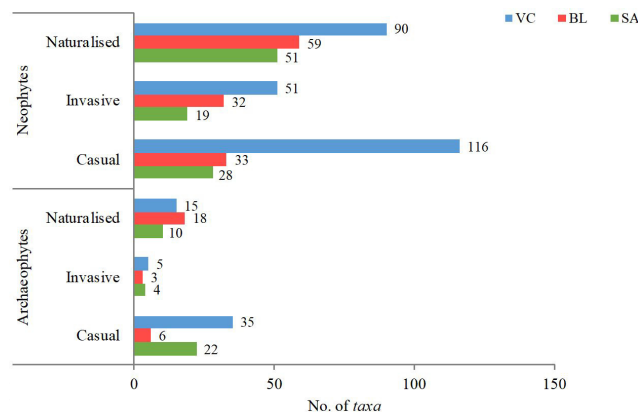


Fig. 2. Comparison of the number of taxa per family in each of the three territories



neophytes and of casual, invasive or naturalised taxa in each of the three territories

while 31 are naturalised in at least one of the three study areas. Remaining taxa (42) are casual or doubtful.

Invasive component comprehends 77 taxa, 56 are invasive in the VC, 35 in the BL and 23 in SA, among which only nine (*Ailanthus altissima*, *Arundo donax*, *Cortaderia selloana*, *Oxalis pes-caprae*, *Symphytotrichum squamatatum*, *Cyperus involuocratus*, *R. communis*, *Mirabilis jalapa*, *Eichhornia crassipes*) are common to the three regions, while 30 have invasive behaviour exclusively in the wetlands of the VC, 15 only in the BL, and four only in SA (see Annex I).

Naturalised taxa represent 33.7% for the VC (105 taxa), 51% for the BL (77), and 45.5% for SA (61), while 48.6% (151) represent the casual element in the VC, 21% (18) in the BL 25.8% (39) and 37.3% (50) in SA.

The comparison of the biological spectrum from the three territories reveals that the best represented plants are the ones that occupy the extremes in terms of duration of their life cycle, size and degree of lignification: phanerophytes are the most represented (33.4%, 127 taxa), followed by therophytes (27.1%, 103), geophytes (15.8%, 60), hemicryptophytes (13.9%, 53) and hydrophytes (18, 4.7%). Chamaephyte is the least represented life form, with 15 taxa (3.9%). Furthermore, the comparison of life forms (Fig. 4) individually for each territory reveals that phanerophytes are the most represented for the VC (31.4%), the BL (38.4%) and SA (34.3%) followed by therophytes (29.5% VC, 27.8% BL, 26.1% SA). Hydrophytes have the highest percentage in SA (4.5% VC, 1.3% BL, 7.5% SA), while chamaephytes in the BL (3.2% VC, 6.6% BL, 1.5% SA). On the other hand, geophytes account in wetlands of the VC a 17.3%, 15.9% in the BL and 17.2% in SA.

The proportion of invasive/alien taxa within each life form is higher for hydrophytes (33.3%, six taxa), followed by geophytes (28.3%, 17), therophytes (23.3%, 24), hemicryptophytes (22.6%, 12), chamaephytes (13.3%, two) and phanerophytes (10.2%, 13). In relation to the levels of significance, the proportion of hydrophytes in the invasive spectrum was higher respect to the total of taxa ( $p < 0.015$ ), while for phanerophytes the higher proportion belonged to casual taxa ( $p < 0.001$ ).

Regarding the geographical origin, the dominance of the American element (144 taxa, 37.9%), both in total and for each territory (40.4% VC, 43.7% BL, 41.8% SA) is revealed,

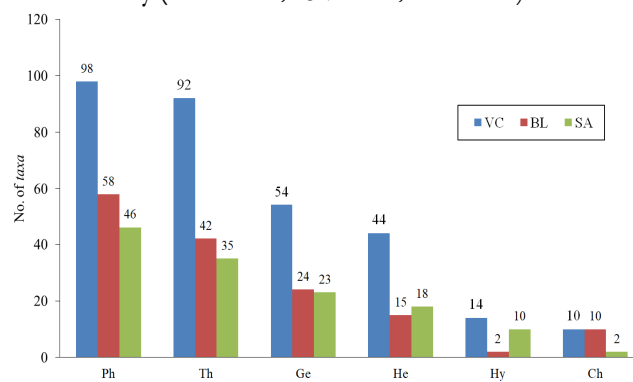


Fig. 4. Comparison of the number of taxa depending on life forms, for each of the study areas. Ph: phanerophyte, Th: therophyte, Ge: geophyte, He: hemicryptophyte, Hy: hydrophyte, Ch: chamaephyte

followed by the Asian origin (55 taxa, 14.5%; 16.7% VC, 9.9% BL, 13.4% SA), the Mediterranean (50 taxa, 13.2%; 11.9% VC, 13.9% BL, 10.4% SA) and the African (20 taxa, 5.3%; 5.1% VC; 11.3% BL, 4.5% SA) (Fig. 5). Among the American taxa, the proportion of invasive plants is higher than for all the taxa ( $p < 0.001$ ). It was also found that among American plants, both the proportion of hydrophytes ( $p < 0.001$ ) and that of therophytes ( $p < 0.012$ ) was higher than the others. The proportion of the African element in the BL was higher than in the other areas ( $p < 0.008$ ).

The data analysis of introduction pathways reveals that in all territories human beings introduced a great part of taxa intentionally (48.2% VC, 54.9% BL, 65.7% SA), being ornamental use the main purpose of introductions. Unintentional causes represented by the accidental introduction (hitchhikers) are the second most important pathway for the VC (27.9%) and for the BL (18.1%) while in SA, introductions promoted by seeds contamination are more frequent (23.8%). Plants intentionally introduced by agriculture show similar low percentages, while forestry represents the least frequent introduction pathway (Fig. 6). The proportion of hitchhikers is higher in the VC than in the rest of territories ( $p < 0.001$ ). Moreover, among the invasive taxa, the proportion of hitchhikers is also higher than in the rest of status ( $p < 0.003$ ).

The analysis of the negative consequences caused by invasive plants in wetlands shows that most of them

generally produce an environmental (58.9% VC, 60.3% BL, 44.2% SA) and economic (26.3% VC, 32.8% BL, 36.5% SA) impact. Human health is minimally affected (14.7% VC, 6.9% BL, 19.2% SA) (Fig. 7). The environmental impact is higher in the BL than in the other territories ( $p < 0.001$ ). Regarding the impact on health, it is higher in hydrophytes than in other biological forms ( $p < 0.001$ ), while in geophytes this proportion is higher in relation to the economic impact ( $p < 0.015$ ).

The MCA analysis (Table 1) shows that the first two factors of the pattern explain 23.80% of the inertia (i.e. variance of data). But applying Benzécri's (1979) correction formula for MCA -that amends the underestimation of the first dimension and defines the correct percentage of variance explained-, the first two factors explain 85.56% of the total variance. The graphical output has been represented in Fig. 8. Since all active variables that built the model have coordinates different from zero ( $p < 0.05$ ) at least for one of the two factors, we can state that all of them contributed to the model building. As the coordinates of the three modalities of the Territory variable cannot be considered as different from zero, they are not influenced by the two factors and consequently none can be considered as associated to any active modality or variable. In other words, the three territories (VC, BL and SA) do not present any statistically relevant difference taking into account those active modalities.

**Discussion**

The results of this study improve the knowledge of the alien flora of the wetlands from three territories belonging to the western Mediterranean area.

*Habitats*

One of the most striking aspects of the results of this study is that about half of the alien taxa found in wetlands

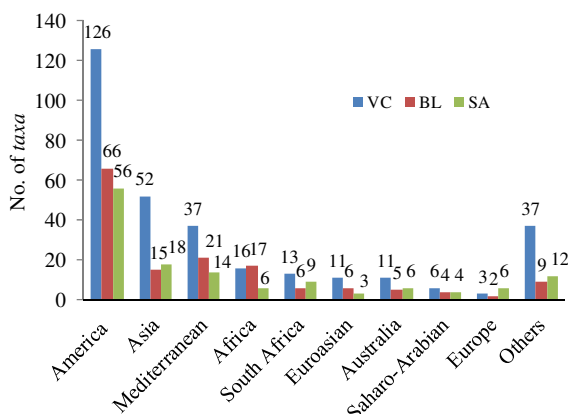


Fig. 5. Comparison of the number of taxa, depending on their geographical origin

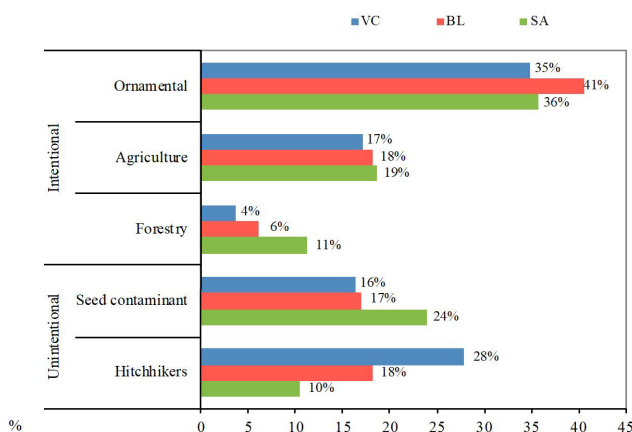


Fig. 6. Distribution of alien plants in the study areas in relation to the introduction pathways (intentional or unintentional)

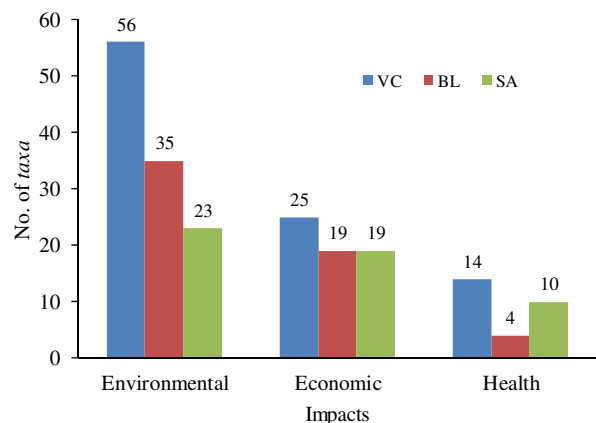


Fig. 7. Distribution of invasive alien plant species in the study areas in relation to the impacts they cause

Table 1. Inertia explained by the first five factors

Factors	F1	F2	F3	F4	F5
Inertia (%)	13.55	10.25	8.27	5.93	4.99
% Accumulated inertia	13.55	23.80	32.07	38.00	42.99
After Benzécri's correction					
Inertia (%)	60.23	25.43	11.50	2.12	0.47
% Accumulated inertia	60.23	85.56	97.07	99.18	99.65

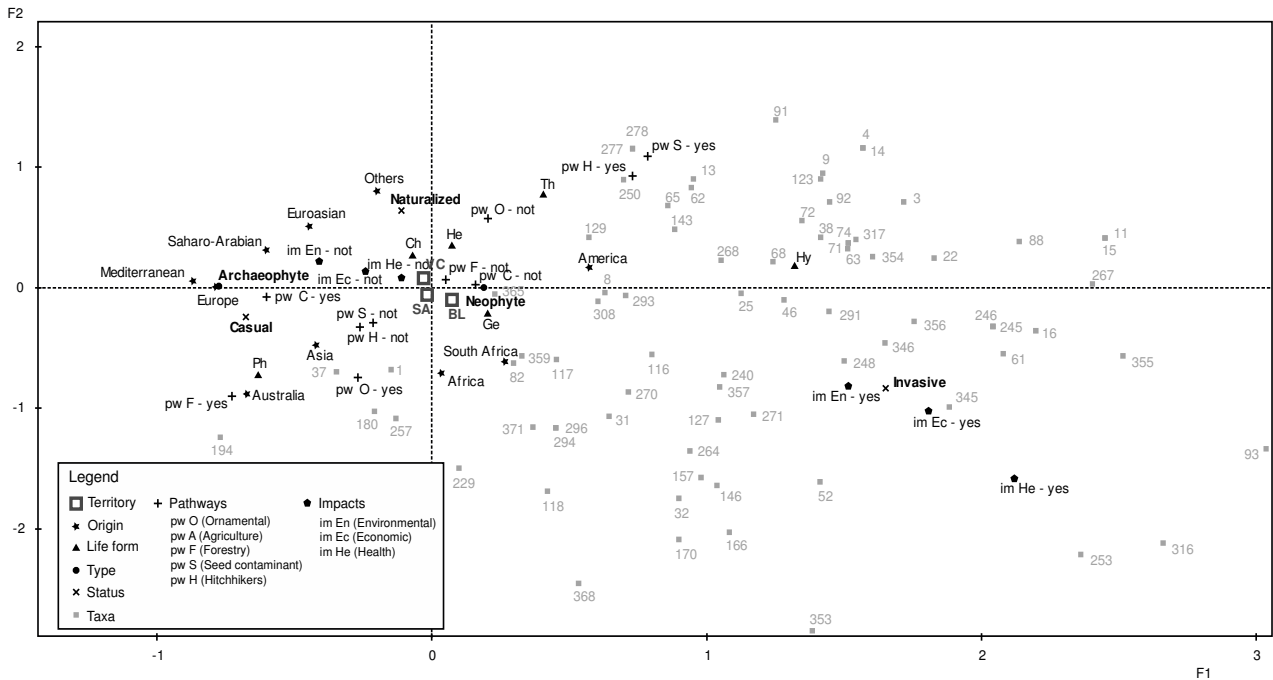


Fig. 8. Map of the MCA where categories are displayed on the first two axes (F1 and F2)

are from terrestrial habitats. Nevertheless, they inhabit ecosystems that are not a priori propitious to them, taking advantage of the seasonality of the presence of water in many Mediterranean wetlands or small spaces with acceptable conditions for their installation. This circumstance has to be taken into account since the evolution of many wetlands -as a consequence of changes in land uses- promotes the drainage and drying of portions and even entire wetlands. This is in synergy with the increase of the periods of drought as a consequence of the accelerated climatic change (Meehl and Tebali, 2004). If this trend of change in land use and climate change remains active, terrestrial alien plants (which appear sporadically and tangentially in wetlands) will increase their surface and become environmental problems of the first order in wetlands.

*Islands versus mainland*

Although it has been demonstrated that islands are invaded more frequently than the mainland (Lonsdale, 1999; Daehler, 2006), our data are not conclusive in this regard. While the mainland (VC) is the richest in absolute values, the BL have a relative richness (relative to the surface in wet areas) much higher than the other two zones. In contrast, SA is the territory with a lower degree of invasion in both absolute and relative terms. Thus, our results suggest that the BL are particularly affected by the problem of alien species in wetlands, but it is on the mainland (VC) where more exotic species arrive and establish.

*Plant families*

Concerning families, the presence of Cyperaceae, Salicaceae, Onagraceae and Pontederiaceae within the richest (considered apart from Poaceae, Asteraceae and Fabaceae, which are typically most represented in the Mediterranean context) (Sanz-Elorza et al., 2004), reveals

that the exotic flora of wetlands in the western Mediterranean context is largely represented by specialised taxa of wet ecosystems. Poaceae are mostly represented by therophytic and hemicryptophytic weeds that colonise temporary flooded areas (e.g. temporary ponds, riverbeds), while Fabaceae almost completely include phanerophytes that occupy riparian habitats (Aguar and Ferreira, 2013).

*Neophytes versus archaeophytes*

Major differences within the three territories were found in the neophyte component, while differences in archaeophytes were minimal. These results agree with those obtained in some recent comparative studies within the total and invasive floras of the BL and SA (Podda et al., 2010; 2011). Moreover, with the exception of some taxa from Cyperaceae (*Cyperus glaber*, *C. michelianus*, *Schoenoplectus mucronatus*) and *A. donax*, alien taxa introduced before 1492/1500 detected in the wetlands of the study area are ubiquitous and adapted to occupy a wide range of habitats.

*Invasive taxa*

Among the nine taxa that show invasive status in all territories, six of them are considered invasive worldwide (*A. altissima*, *A. donax*, *C. selloana*, *O. pes-caprae*, *R. communis*, *E. crassipes*) (CABI, 2013) and three in Europe (*A. altissima*, *C. selloana*, *O. pes-caprae*) (DAISIE, 2014) while all taxa (included *S. squamatum*) have been recognised as the most invasive ones in Mediterranean islands (Lloret et al., 2004; Hulme et al., 2008).

*Life forms*

The comparison of life form data from wetlands with those of the whole alien flora shows very similar data for the three territories. The highest percentages in all territories are

obtained by phanerophytes, results that broadly agree with those observed in other Mediterranean alien floras, where introduction pathways are mostly intentional, showing the ornamental introductions for gardening superiority over the rest (Gómez-Serrano and Mayoral, 2003; Sanz-Elorza *et al.*, 2004; Podda *et al.*, 2010; Sanz-Elorza *et al.*, 2011). It is found that for the whole of the alien flora of the VC, phanerophytes represent 37% of the total and therophytes 24% (Sanz-Elorza *et al.*, 2011) and for SA, phanerophytes 40%, and therophytes 30%, while for the BL, therophytes are more frequent (34%), followed closely by phanerophytes (32%) (Podda *et al.*, 2010). The slightly lower percentages of phanerophytes and therophytes for wetlands in comparison with the whole alien flora can be explained by the particularly noteworthy higher percentage of hydrophytes in wetlands in the studied territories.

Hydrophytes are represented by few taxa, although the proportion in wetlands is higher than when considering all the alien taxa of the territories. In addition, hydrophytes show a higher percentage between invasive species than the other life forms. And most important of all is the fact that 1/3 of them are invasive in almost one of the study areas and are evaluated as noxious for species and ecosystems worldwide: *Azolla filiculoides*, *E. crassipes*, *Hydrocotyle ranunculoides*, *Lemna minuta*, *Heteranthera limosa* and *Salvinia* genus resulted the most spread invasive hydrophytic taxa. *Egeria densa*, *Vallisneria spiralis*, *Lemna paucicostata*, *L. valdiviana* and other taxa from *Heteranthera* genus, are present in almost one site and, due to their noticeable capacity to naturalise, found also in other areas, also of Mediterranean climate. From our point of view, the monitoring of casual/naturalised populations of the hydrophytes is of high priority, as the great number of imported aquatic plant species into Europe continues to be an on-going threat for European freshwater ecosystems (Hussner, 2009).

Many woody plants have been recognised as major invasive species with serious impacts on diversity and functioning of invaded ecosystems (e.g. Richardson, 1998; Pysek *et al.*, 2014; Richardson *et al.*, 2014). In this sense, it has to be taken into account the significant occurrence of bushy and woody species in western Mediterranean wetlands, justified in part by the high susceptibility of riverine habitats to biological invasions (Vila *et al.*, 2008; Costa *et al.*, 2011; Aguiar and Ferreira, 2013). Actually, all phanerophytic species detected in the three study areas specifically occur in riparian ecosystems. Nevertheless, barely 23 taxa (20%) are typical riparian species (*Nerium oleander*, *Elaeagnus angustifolia*, and *Alnus*, *Populus*, *Salix*, *Tamarix*, *Vitis* genus) occurring in riverine habitats only, while all remaining taxa are ubiquitous that occur in a great variety of habitats. In fact, phanerophytic species behaving as invasive are *A. altissima*, *Asclepias fruticosa*, *Lantana camara*, *Lonicera japonica*, *Pittosporum tobira* and *R. communis*, that inhabit a wide range of environments and have been evaluated as the most invasive species (Weber, 2003).

The low occurrence of invasive therophytes is justified by the specialization of this biological form in arid environments (Sarris and Coutias, 2014): wet habitats are not favourable for annual terrestrial species that are not

adapted to resist tide fluctuations, flooding phenomena and asphyxiated soils. For the same reason, in the study area almost all therophytic species invade seasonally dry wetlands as astatic lagoons and temporary ponds, and the dry bed and riverbanks of intermittently flowing streams and rivers (e.g. *Amaranthus*, *Bidens*, *Chenopodium*, *Datura*, *Xanthium* genus).

#### Comparison among territories

It should be noted that some of the species included in the checklist are not usually mentioned in wetlands but have been found in at least one of the three territories (e.g. *Cupressus sempervirens* in the BL as naturalised, *Castanea sativa* in the VC and SA as casual, *Ligustrum lucidum* in the VC and the BL as naturalised, *Poncirus trifoliata* in the VC as casual). The ecological niche shift of these and other taxa should be followed carefully in order to monitor changes in the coming years.

Some species present on the island wetlands are also living in the VC lands, but only recorded as invaders for dry ecosystems (e.g. *Antirrhinum majus* or *Prunus dulcis*, herein only referred for the BL, or *Senecio inaequidens*, reported for SA). Additionally, some of the species reported for one or both islands but absent as wetland invaders in the VC, really match the condition of being native to the continent, e.g. *Acer campestre*, *Rubus idaeus*, *Trachelium caeruleum*, *Glinus lotoides*, *N. oleander*, *Corylus avellana*, etc.

On the other hand, the trend of the VC to hold herbaceous neophytes, often not shared by the BL and/or SA, could also come from its higher interconnection with other mainland territories, which act as source of new invasive plant species. The VC is connected by roads and train with the remainder European regions, and simultaneously acts as a major industrial and commercial node in Spain -Valencia city is the third main city of Spain-, mainly for agriculture and horticulture, so its availability to receive and host new weeds is really relevant, if compared with the other two territories here analysed. A good example could be given with *Diospyros lotus*, an aggressive invader of the Valencian wetlands, absent in SA and the BL. The main reason for its presence in the VC is that it was used during decades for grafting the Persimmon tree (*Diospyros kaki*), one of the main agricultural productions at local level. *D. lotus* sprouts from roots after the abandonment of persimmon crops, producing small fleshy fruits which host small seeds dispersed by birds (SENB-CIEF, 2011). Future studies could include the parameter "interconnection of the territory" to help explain the behaviour of alien taxa in different territories.

Despite the two reasons explained above, no absolute rules can be found, and lots of exceptions impede the establishment of clear territorial or behavioural groups in the graphics. Some of these exceptions can be apparently explained by external reasons, such as the degree of competitiveness and the invasion speed of each taxon, the local horticulturist preferences, etc. For instance, the presence of species in SA which are absent in the BL or the VC, such as *Phacelia tanacetifolia* or *Dactyloctenium aegyptium*, only represents an early invasion in that territory, for two species which could easily invade the other two territories within a few years (Laguna *et al.*, 2009). The lack of some very aggressive invaders in a concrete territory - e.g.

*Ludwigia grandiflora* for SA, *Salvinia molesta* for BL, etc. - is only a question of hazard and time.

#### Introduction pathways

Regarding introduction pathways, ornamental use is the main cause of introduction, based on the use of plants from areas with similar climates (Hulme *et al.*, 2008). Furthermore, ornamental trade is considered as the major pathway of aquatic plant introduction within the different continents and climatic regions and thus into Europe (Brunel, 2009; Hussner, 2009). It should also be noted that introductions promoted by agriculture or unintentional introduction of seeds as contaminants are more frequent in SA than in the VC and the BL.

#### Impact

In the three territories, all invasive plants may cause impact on the environment because of fierce competition with native species, often causing their disappearance and modifying the function and structure of their habitats. The six invasive species common in the three territories, which are a threat not only for the environment, but also for economic activities and human health are *A. donax*, *C. selloana*, *R. communis*, *A. altissima*, *O. pes-caprae* and *E. crassipes*, considered also invasive worldwide (CABI 2013). Among the exclusively aquatic species such as *E. crassipes* (VC, BL and SA), *A. filiculoides* (VC and SA), *L. grandiflora* (VC and BL), *Ludwigia repens* and *H. limosa* (BL), it should be emphasised that the impact is also socio-economic (Sala *et al.*, 2000; Genovesi, 2007). In addition, the study showed that health impact by hydrophytes is higher than by other biological forms, which emphasises the danger of these species.

The information compiled on the invasive plants present in the wetlands of the western Mediterranean provides a snapshot of the current dimensions of the phenomenon and will be useful for managers, in order to prevent the introduction of species that are considered invasive in similar regions. From the management perspective, the predictive value of the floristic researches that enable information sharing is essential and will be of special value when little information is available on the invader's characteristics, arrival date or spatial extent. Before control or eradication alternatives can be considered, information on the behaviour of some species in similar habitats of the same biogeographic region will prove especially useful (Sanz-Elorza *et al.*, 2004; Keller and Perrings, 2011; Hussner, 2012; Aguiar and Ferreira, 2013).

#### Conclusions

The comparative analyses presented in this paper shows the similarities and differences in wetlands alien plant diversity between three areas from western Mediterranean, one continental (Valencian Community - Spain -) and two insular (Balearic Islands - Spain - and Sardinia - Italy -). An updated checklist is provided and detailed statistical analyses provide results and conclusions especially useful for management of wetlands and of certain alien species, outlying those with invasive behaviour.

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