Patterns of plant invasions in the Mediterranean Biome → Basin

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1. Introduction

The introduction of alien species has altered the composition of biotas worldwide and has frequently led to biotic homogenization (Winter et al 2010)

As the pace of species introductions is increasing (Hulme et al. 2009), there is a major need to identify the species traits that are common to successful invaders and the habitat types more prone to be invaded

For sessile organisms such as plants, the vulnerability of habitats to invasion seems to follow common patterns in several regions studied:

- Human-made habitats exhibit the highest levels of plant invasions as a result of higher propagule pressure

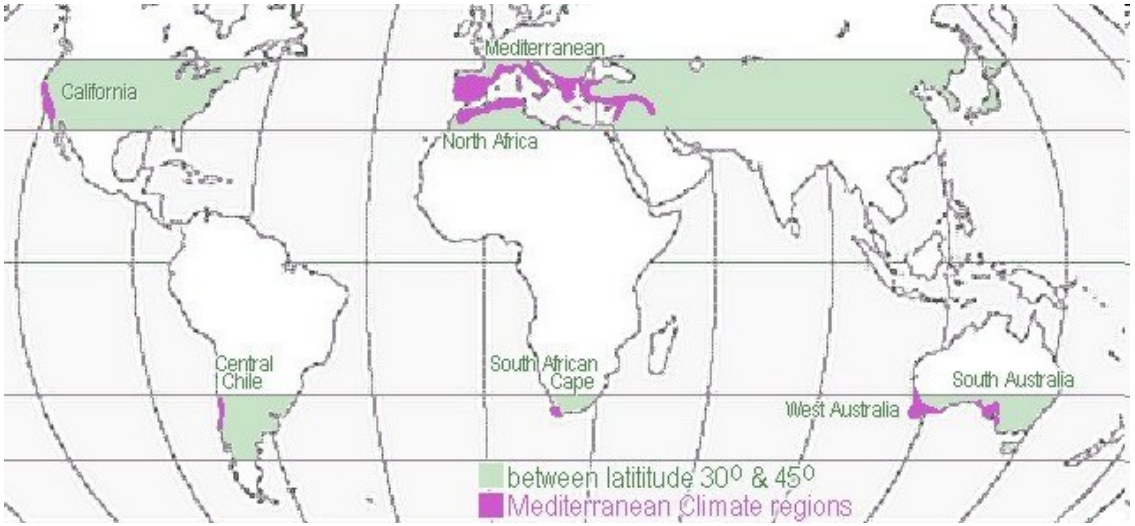
- A high proportion of alien plants are found in habitats with fertile soil, high water availability and highly disturbed

Acacia saligna saplings in sand dunes, Zakynthos

Comparisons between climatically similar regions are very informative because

- they reduce large-scale environmental variation
- they pin - point the potential consistency of habitat vulnerability to invasions (Jiménez et al. 2008, Vilà et al. 2010, Arianoutsou et al. 2010)
- similar regions may share analogous biotic peculiarities and convergent life forms

Mediterranean Climate regions (a biome)



(home of the 20 % of the world vascular plants) / high endemism – possibly threatened by alien plant species

ARIANOUTSOU M., DELIPETROU P., VILÀ M., DIMITRAKOPOULOS P.G., CELESTI-GRAPOW L., WARDELL-JOHNSON G., HENDERSON L., FUENTES N., UGARTE-MENDES E. & RUNDEL P.W. 2013. Comparative Patterns of Plant Invasions in the Mediterranean Biome. *PLOS One*. 8(11).

The aims of the study were to provide answers on:

(1) the taxonomic composition of the naturalized flora

(2) the emerging chorological patterns

(3) the life history patterns

(4) mostly invaded natural habitats

(5) homogeneity in the taxonomic composition across habitats both within a region and across regions

1a) The South African geophytic species *Oxalis pes-caprae* in Lesbos island, Greece, Mediterranean basin;
1b) The South African succulent species *Carpobrotus edulis* in California, USA;
1c) The Eurasian biennial herbs *Echium plantagineum* and *E. vulgare* in Region del Maule, Central Chile;
1d) The South African geophyte, *Watsonia meriana* var. *bulbillifera* on a granite outcrop in south-western Australia;
1e) The Mediterranean basin region herb, *Centranthus ruber* in the Cape Region, South Africa;
1f) The tall Eurasian grass, *Arundo donax* in a Californian riparian system.

Taxonomy and Chorology

5. Results

Asteraceae: the second frequent family, (except in South Africa), is the largest dicotyledonous family, also **cosmopolitan** and of **economic importance**

Amaranthaceae: family with high frequency in the Mediterranean basin → includes **grain species** and **ornamental** plants

5. Results

The only species common in all five regions are:

→ *Nicotiana glauca* (S. American)

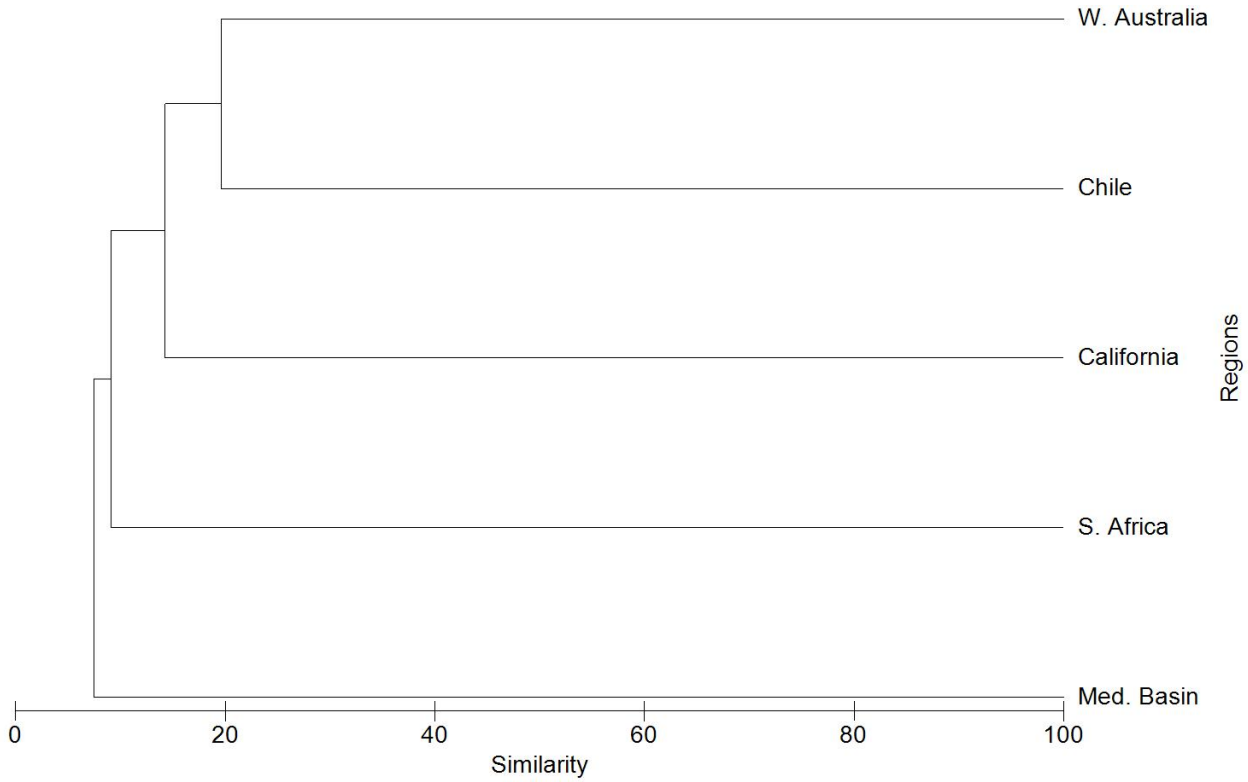
3 acacias

→ *Robinia pseudoacacia* (N. American)

→ *Acacia dealbata* (E. Australian)

→ *Acacia melanoxylon* (E. Australian)

5. ***Results***



Naturalized neophyte **species similarity** across the 5 Mediterranean regions


Datura stramonium

1) How similar is the taxonomic composition of the naturalized flora?

Species level

- Overall low taxonomic similarity among regions (<40%)
- Loose Old World - New World grouping
- Only 4 common taxa out of 1369 naturalized in all regions
- Species per area lowest in Mediterranean Basin and California
- No species-area relationship

Family level

- Higher taxonomic similarity among regions (40 - 50 %)
- Australia grouped with Old World regions
- The most frequent families are cosmopolitan and/or of economic importance e.g. Poaceae (most frequent in all regions) and Fabaceae are both cosmopolitan and the two first families in economic importance worldwide

2) Where do these naturalized alien plants come from? Are there any chorological patterns?

expected

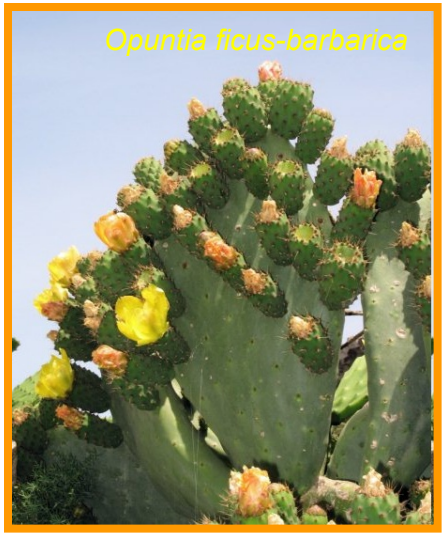
- New World taxa prominent in Old World and vice versa

but

- **Mediterranean Basin**: most aliens (55 %) originate from **America**
- **South Africa**: most aliens originate from **America** (24 %) & **Australasia** (24 %)
- **Chile**: most aliens (51 %) originate from **Eurasia**
- ***SW Australia - California***: also prominent aliens of ***American*** origin
- ***SW Australia***: prominent ***S African*** origin

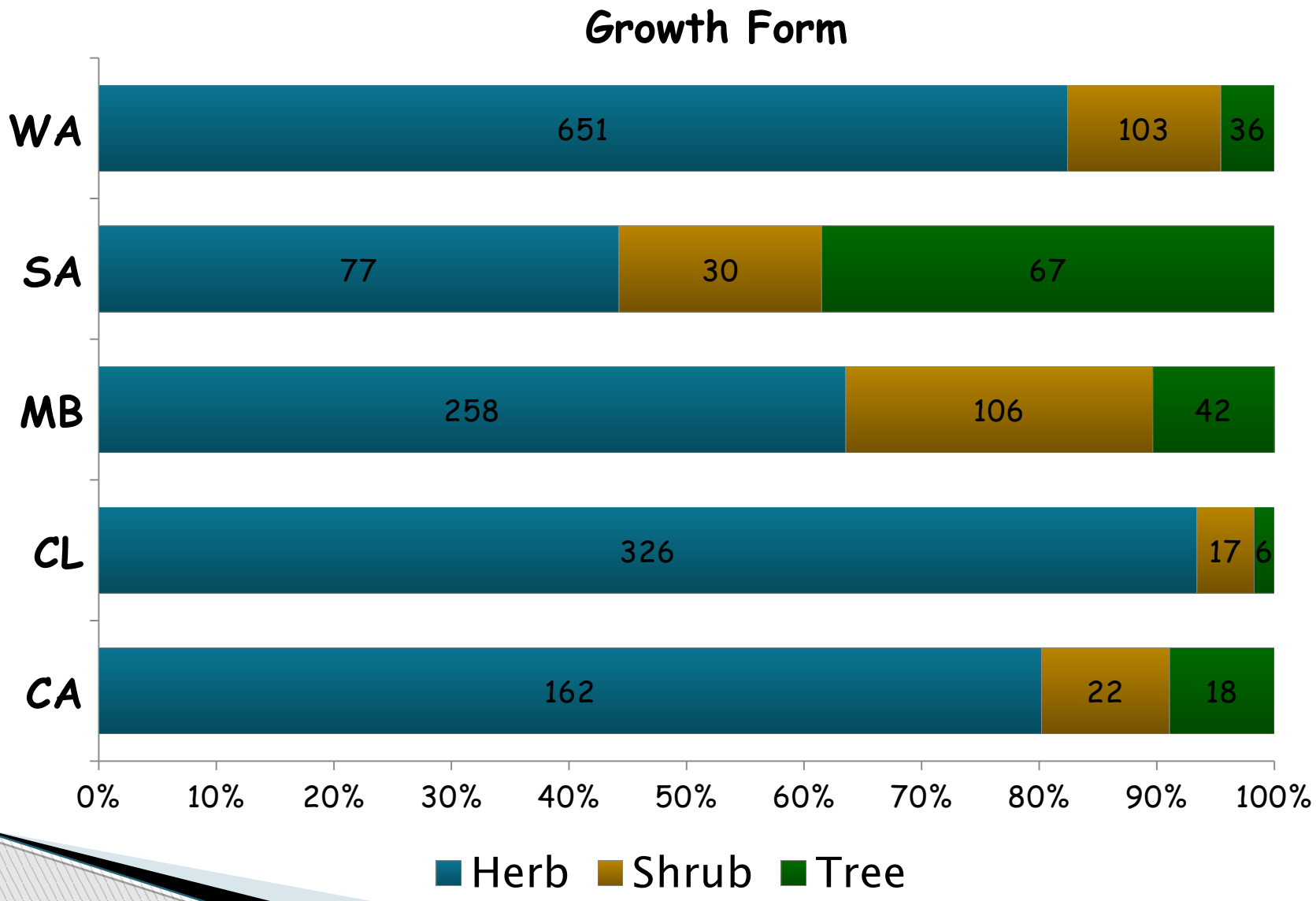
so

- Historical factors may be important for the chorological pattern

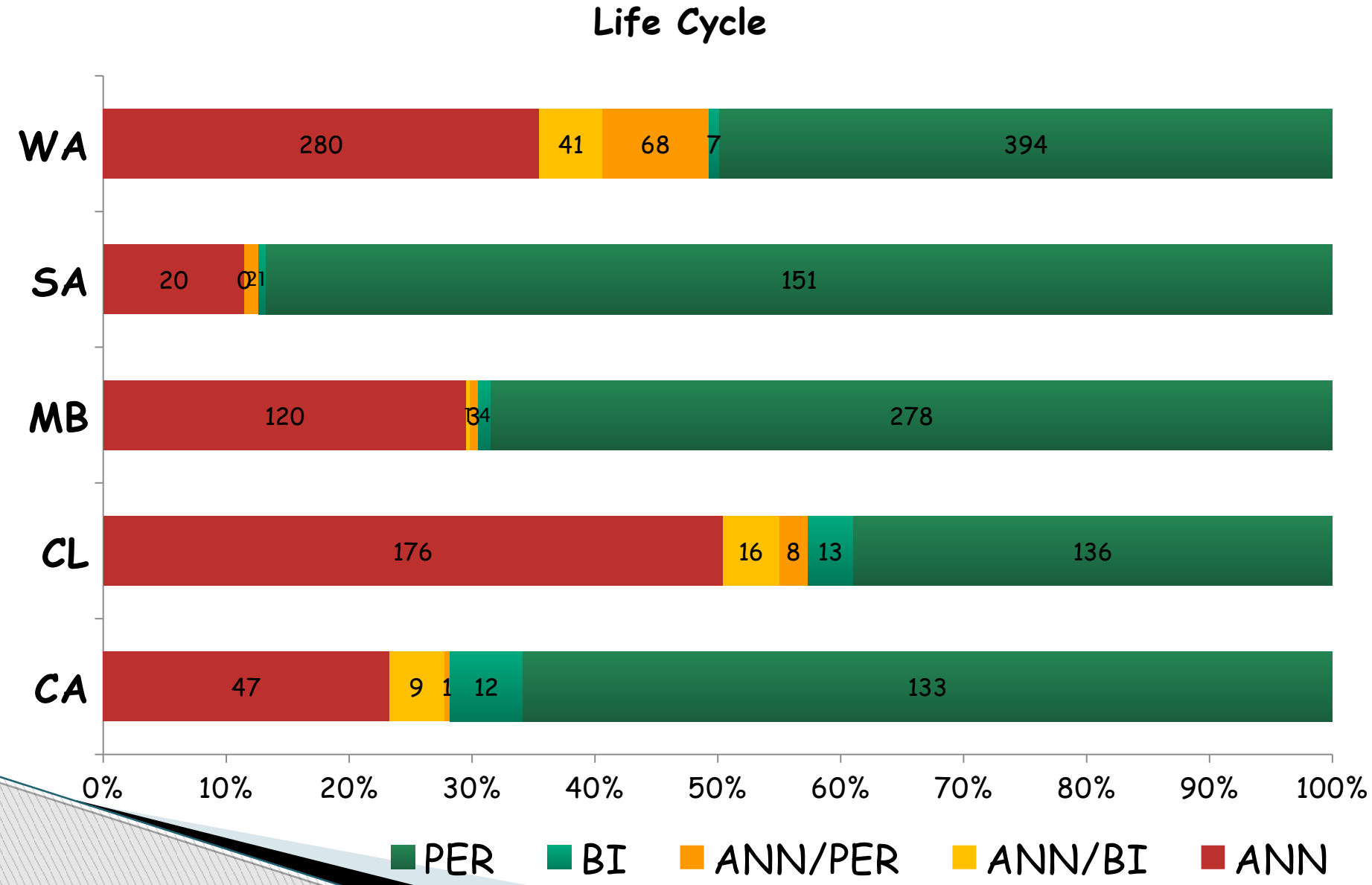


Life History Traits

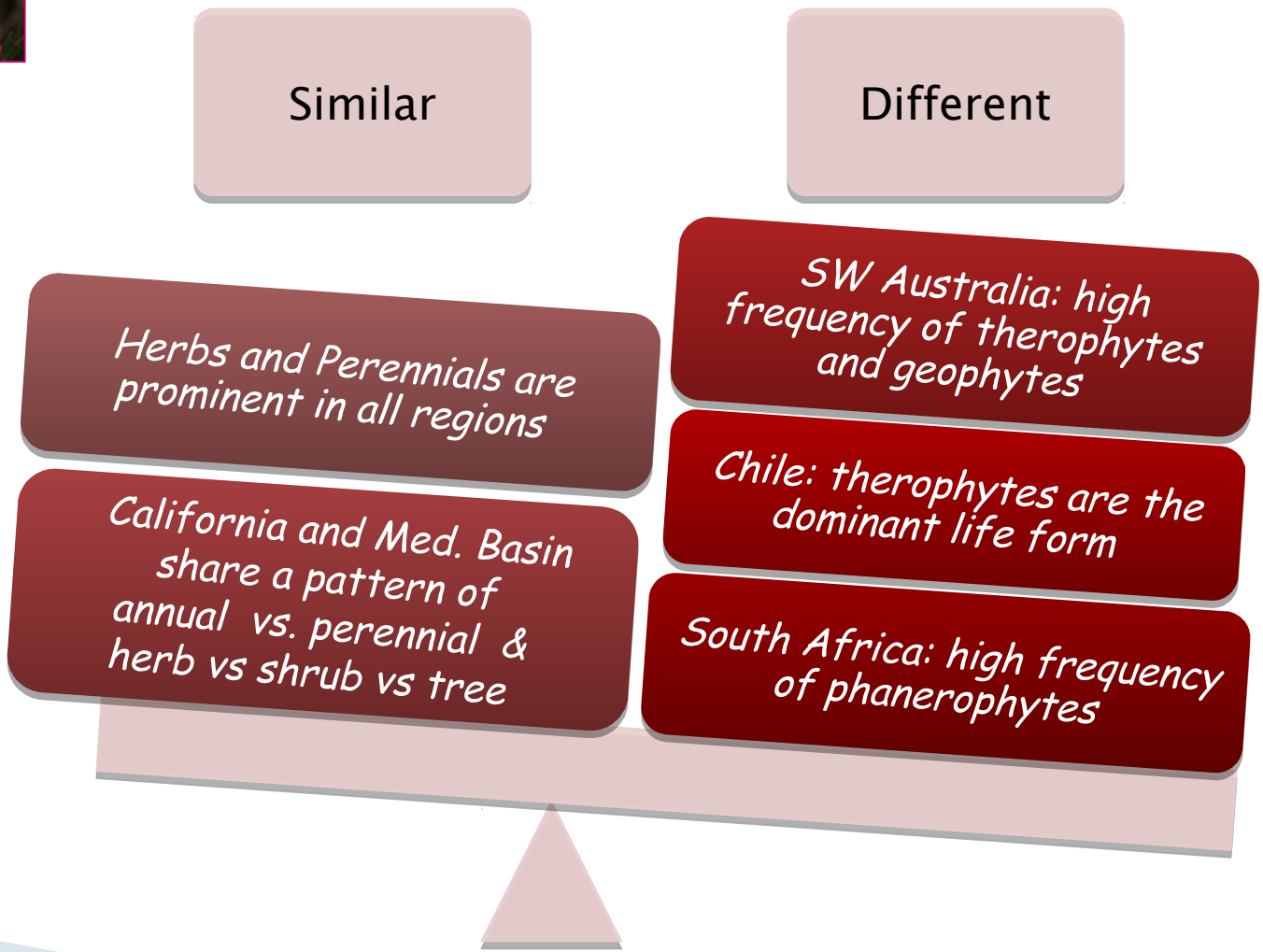
5. Results


Growth Form
WA
651
103
36
SA
77
30
67
MB
258
106
42
CL
326
17
6
CA
162
22
18
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Herb
Shrub
Tree

5. Results


Life Cycle
WA
280
41
68
7
394
SA
20
0
2
1
151
MB
120
3
4
278
CL
176
16
8
13
136
CA
47
9
1
12
133
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PER
BI
ANN/PER
ANN/BI
ANN

3) Which are the growth form, life cycle, and life form patterns?



Ailanthus altissima at the riparian zone in C. Greece

Habitats

Opuntia ficus-barbarica in abandoned grazed kermes oak scrub in C. Greece

4) Which natural habitats display the highest and the lowest invasion levels?

All regions

- Highest invasion levels in *inland wetlands* and/or *grasslands*
- Lowest invasion levels in *harsh, drought stressed* habitats

Coastal

- Medium invasion levels in coastal *sands* and secondly in coastal *wetlands*, especially SW Australia, Mediterranean Basin, Chile

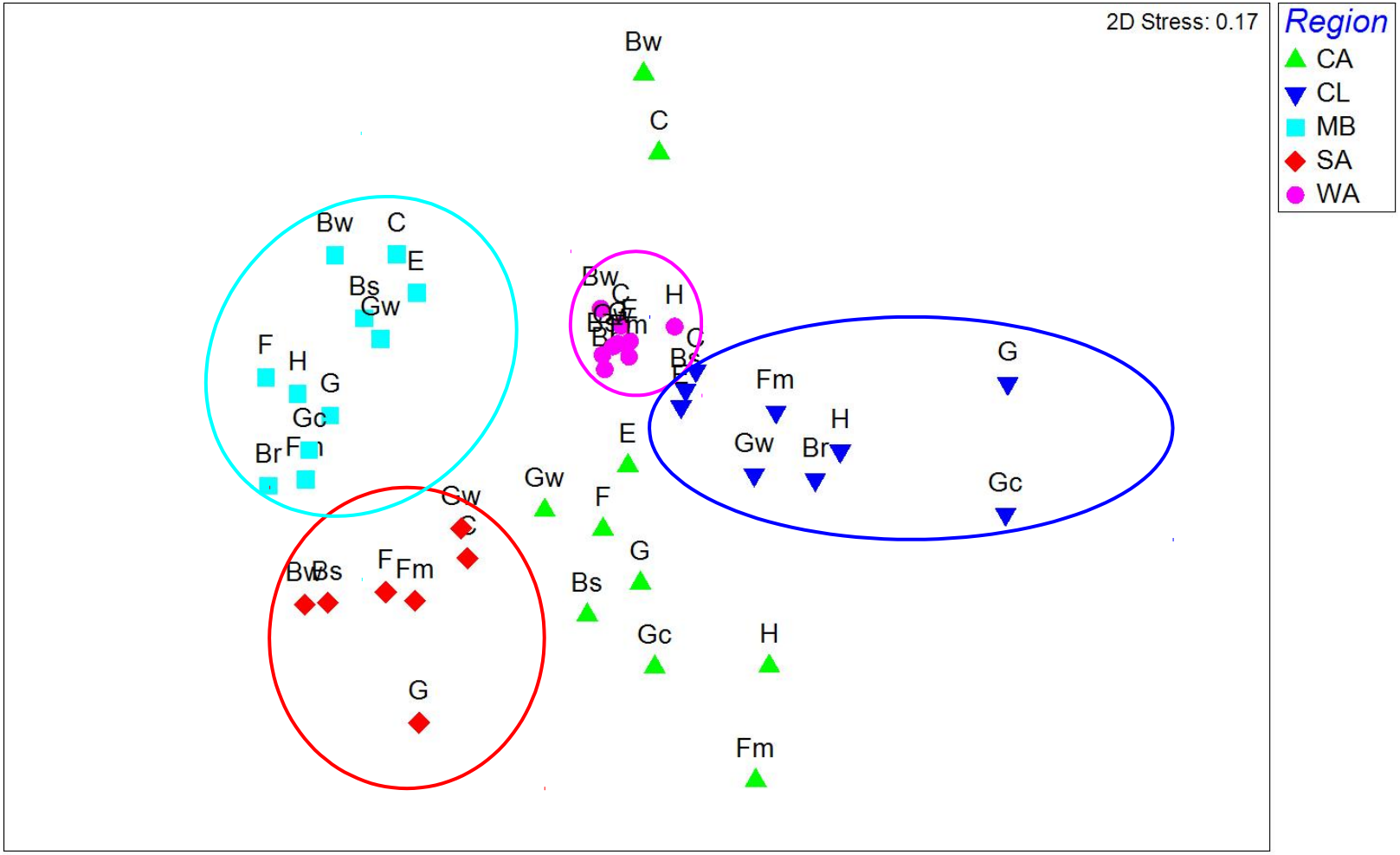
Shrub

- Medium invasion levels, except Mediterranean Basin (low levels)

Forest

- Not Riparian: Low invasion levels, except SW Australia evergreen forest (high levels)
- Riparian: High invasion levels except Chile (medium levels)

Species assemblages among the invaded habitats in each region



Habitats are classified per region and not by type

Habitats all regions

- **Highest homogeneity in inland wetland - riparian forests and in grasslands** - evergreen forest
- Medium homogeneity in coastal sands, harsh habitats and tall shrub
- Low homogeneity in habitat groups with few species

Habitats per region

- Species assemblages are more homogeneous among different habitats in the same region than among the same habitat in different regions
- There is a loose Old World to New World grouping
- **Highest homogeneity among habitats of SW Australia**
- **Lowest homogeneity among habitats of California**

Growth Forms

- **All growth forms occur in all habitats**
- **Herbs are dominant in all habitats except low open shrub and conifer forest**
- **Most of the herbaceous species (> 60%) occur in inland wetlands & grasslands**
- **Almost all the tree species occur in riparian woodlands**

Multiple Habitats

- **Most aliens invade multiple habitats**
- 60 % of aliens occur in > 1 habitats, 30 % occur in 4–11 habitats in all regions
- Multiple habitat invasion is more frequent in SW Australia

5) How homogeneous is the alien flora composition across habitats both within a region and across regions?

6. Overall Conclusions

Low taxonomic similarity

Loose Old World – New World grouping (taxonomy, chorology, species assemblages in habitats per region)

Herbs and Perennials are the dominant life traits

Multiple habitat invasion is common

Hogenization is higher among different habitats in each region than among regions

SW Australia exhibits by far the highest degree of invasion and homogenization

High stress and less disturbed habitats, especially drought stressed, have the lowest frequency of invasion

Low stres and highly disturbed habitats have the highest frequency of invasion and homogenization

ARIANOUTSOU M., DELIPETROU P., CELESTI-GRAPOW L., BASNOU C., BAZOS I., KOKKORIS Y., BLASI C. & VILÀ M 2010. Comparing naturalized alien plants and recipient habitats across an east-west gradient in the Mediterranean Basin. *Journal of Biogeography,* 37(9), 1811-1823.

Table 1 Total number of naturalized neophytes per country for each of the four Mediterranean countries studied (a) and totalled for all the countries studied (c); and number of shared naturalized neophytes (plants occurring in more than one of the four countries) per country (b).

	(a) Total per country				(b) Shared				(c) Total
Species	Cyprus	Greece	Italy	Spain	Cyprus	Greece	Italy	Spain	All
Families	51	47	96	87	45 (88)*	46 (98)	79 (82)	78 (90)	117
Genera	100	92	262	243	65 (65)	80 (87)	154 (59)	153 (63)	416
Species	127	125	463	398	63 (50)	94 (75)	198 (43)	193 (48)	782
Native species	1612[1]	5855[2]	6611[3]	7920[4]					
Area km^2	9251	132,700	293,805	491,310					

[1]Hadjikyriakou (1997); [2]Strid & Tan (1997), Tan & Iatrou (2001); [3]Conti *et al.* (2005); [4]Bueno *et al.* (1995).
*Numbers in brackets are the percentages of shared families, genera and species.

ARIANOUTSOU M., BAZOS I., DELIPETROU P. & Y. KOKKORIS 2010. The alien flora of Greece: taxonomy, life traits and habitat preferences. *Biological Invasions*, 12(10), 3525-3549.

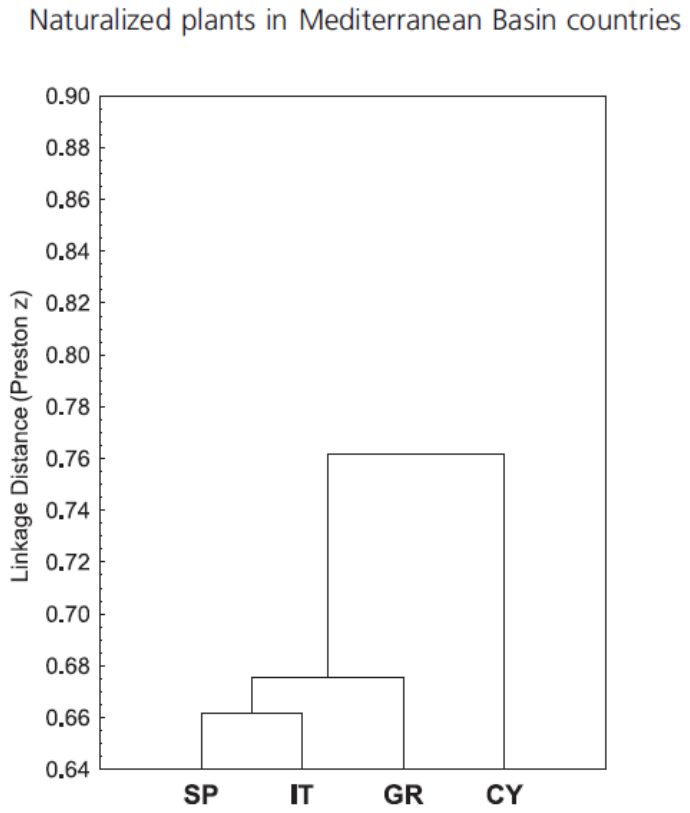


Figure 1 Floristic similarity between the four Mediterranean Basin countries studied on the basis of the naturalized plant species. SP, Spain; IT, Italy; GR, Greece; CY, Cyprus.

Table 3 Naturalized plant species shared by Spain, Italy, Greece and Cyprus.

Species	Family
Agave americana	Agavaceae
Ailanthus altissima	Simaroubaceae
Amaranthus albus	Amaranthaceae
Amaranthus blitoides	Amaranthaceae
Amaranthus hybridus	Amaranthaceae
Amaranthus retroflexus	Amaranthaceae
Amaranthus viridis	Amaranthaceae
Aptenia cordifolia	Aizoaceae
Asclepias fruticosa	Apocynaceae
Aster squamatus	Asteraceae
Carpobrotus edulis	Aizoaceae
Chenopodium ambrosioides	Amaranthaceae
Conyza bonariensis	Asteraceae
Conyza canadensis	Asteraceae
Conyza sumatrensis	Asteraceae
Cuscuta campestris	Convolvulaceae
Datura stramonium	Solanaceae
Echinochloa colona	Poaceae
Eucalyptus camaldulensis	Myrtaceae
Mirabilis jalapa	Nyctaginaceae
Nicotiana glauca	Solanaceae
Oxalis pes-caprae	Oxalidaceae
Paspalum distichum	Poaceae
Phalaris canariensis	Poaceae
Phytolacca americana	Phytolaccaceae
Robinia pseudoacacia	Fabaceae
Solanum elaeagnifolium	Solanaceae
Tagetes minuta	Asteraceae
Xanthium strumarium subsp. *italicum*	Asteraceae
Xanthium spinosum	Asteraceae

Table 4 Number of naturalized plant species (percentages in brackets) classified according to growth forms in each of the four countries of the Mediterranean Basin studied.

	Number (%) of naturalized plant species				
Growth form	Cyprus	Greece	Italy	Spain	All*
Grass	13 (10)	17 (13)	48 (11)	60 (15)	96 (13)
Herb	55 (42)	75 (60)	253 (56)	196 (49)	402 (52)
Subshrub/Shrub	27 (21)	19 (15)	100 (22)	72 (18)	159 (21)
Tree	31 (24)	9 (7)	37 (8)	49 (12)	88 (11)
Vine	1 (1)	5 (4)	10 (2)	21 (5)	22 (3)

*Total number of naturalized plant species for all four countries.

Table 6 Number of naturalized plant species (percentages in brackets) classified according to life cycle in each of the four Mediterranean countries studied.

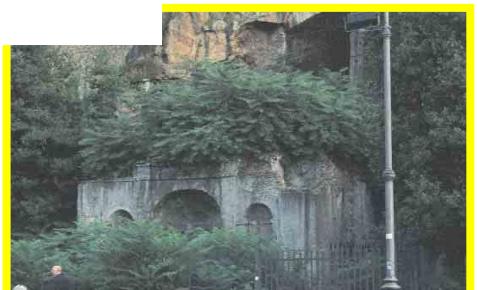
	Number (%) of naturalized plant species				
Life cycle	Cyprus	Greece	Italy	Spain	All*
Annual	45 (35)	59 (47)	131 (29)	119 (29)	221 (29)
Annual/perennial and annual/biennial	0 (0)	1 (1)	3 (1)	1 (0)	9 (1)
Biennial	0 (0)	1 (1)	12 (3)	1 (0)	9 (1)
Biennial/perennial	0 (0)	1 (1)	1 (0)	0 (0)	4 (1)
Perennial	82 (65)	63 (50)	301 (67)	280 (70)	524 (68)

*Total number of naturalized plant species for all four countries.

Table 7 Number and percentages (in brackets) of naturalized plant species in each habitat group.

		Number (%) of naturalized plant species							
		Cyprus		Greece		Italy		Spain	
Habitat group		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Natural habitats									
B1	Coastal sand and shingle	8 (6)	3 (2)	38 (18)	7 (3)	27 (9)		40 (11)	3 (1)
B2	Coastal rocks	4 (3)		12 (6)		8 (3)		8 (2)	
B3	Coastal wetland		3 (2)		11 (5)				41 (11)
C	Inland water bodies – fens, bogs		41 (33)		50 (23)		187 (65)		21 (5)
E	Grassland	1 (1)	9 (7)	12 (6)	13 (6)	5 (2)		14 (4)	9 (2)
F1	Shrub – maquis	7 (6)		8 (4)		6 (2)		5 (1)	
F2	Shrub – garrigue	10 (8)		5 (2)		1 (0)		3 (1)	
F3	Shrub – phrygana	2 (2)		5 (2)					
F4	Shrub – riparian		1 (1)		12 (6)				85 (23)
G1	Forest – riparian		11 (9)		18 (8)		41 (14)		68 (18)
G2	Forest deciduous			2 (1)				16 (4)	
G3	Forest – broadleaved evergreen	3 (2)		4 (2)				16 (4)	
G4	Forest – coniferous	18 (14)		5 (2)				15 (4)	
H	Rocks/screes	4 (3)		11 (5)		13 (5)		25 (7)	
Total		57 (46)	68 (54)	103 (48)	111 (52)	60 (21)	228 (79)	150 (39)	227 (61)
Artificial habitats									
E1	Grassland (ruderal, disturbed)	4 (1)		26 (8)		22 (2)	1 (0)	163 (28)	
I1	Cultivations	68 (23)		62 (18)		167 (16)		51 (9)	
I2	Gardens/parks	47 (16)		33 (10)		121 (11)		27 (5)	
IFG	Woody cultivations	42 (14)		34 (10)		8 (1)		2 (0)	
IG	Tree plantation	9 (3)				22 (2)			
J	Constructed/inhabited	39 (13)	13 (4)	36 (11)	11 (3)	541 (51)	40 (4)	22 (4)	
Jro	Road networks	69 (23)		68 (20)		136 (13)		131 (23)	
Jwa	Walls	5 (2)		35 (10)				16 (3)	
Jwp	Waste places	5 (2)		29 (9)				138 (24)	
Total		288 (96)	13 (4)	322 (96)	13 (4)	1017 (96)	41 (4)	550 (95)	28 (5)

Percentages are calculated on the basis of the total number of occurrences in natural or artificial habitats and in wet or dry habitats. A species may occur in more than one habitat group. Symbols in habitat groups correspond to the EUNIS classification system level 1.



Opuntia ficus-barbarica

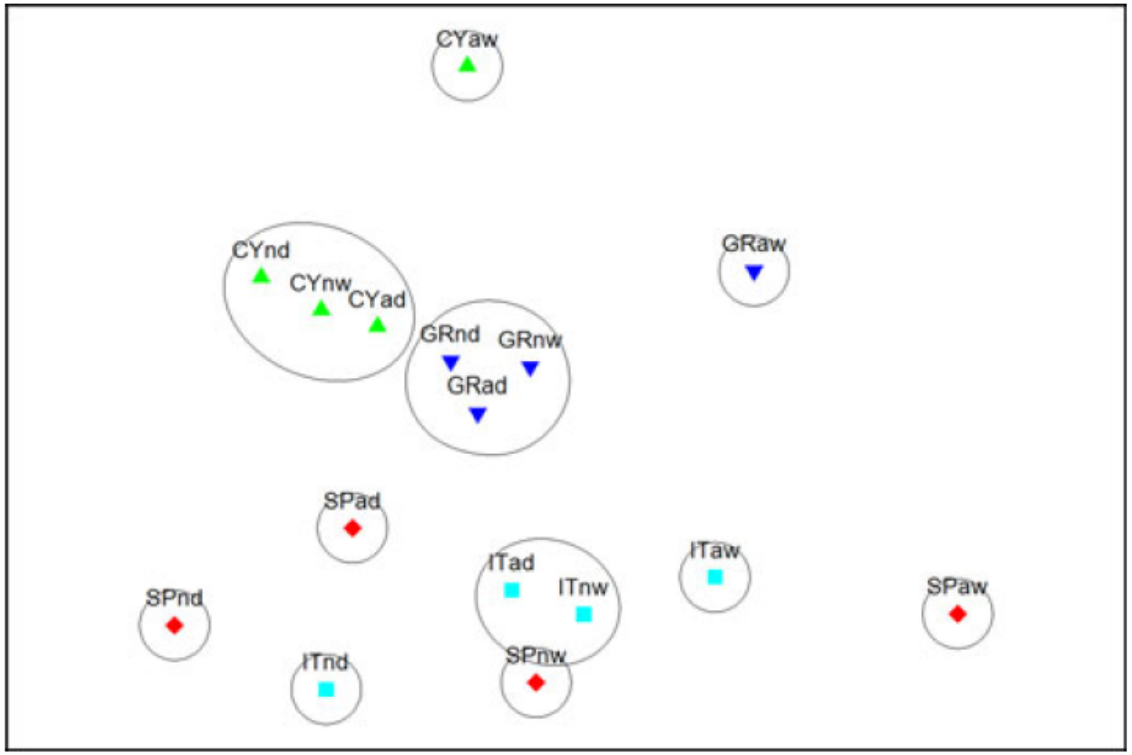


Figure 2 Diagram of the two-dimensional non-metric multi-dimensional scaling ordination performed on the naturalized plant species observed across the habitat categories identified in the four Mediterranean countries studied, pooled into four groups: artificial (a), natural (n), dry (d), wet (w). ◆ SP, Spain; ■ IT, Italy; ▼ GR, Greece; ▲ CY, Cyprus. Contours indicate habitats that are similar at the 25% similarity level.

Although the Mediterranean Basin has been proposed by Lambdon *et al.* (2008b) as one biogeographical zone that may be considered quite distinct from the other European zones in view of the homogenization of the naturalized plant species within the latter (figure 7 in Lambdon *et al.*, 2008b), it should be borne in mind that the Mediterranean countries are placed along an east–west gradient as well as a precipitation gradient. Our study confirms this trend, with the western part being represented by Spain and Italy and the eastern part being represented by Greece and Cyprus.

Thank you

Main conclusions The floristic similarity of naturalized neophytes between the four countries is low, although the overall analysis indicates that the western group (Italy–Spain) is separated from the eastern group (Greece–Cyprus). Similar patterns emerged regarding the life-history traits and recipient habitats. The artificial habitats and the natural wet habitats are those that are invaded most and display the greatest homogenization in all four countries. Coastal habitats display a lower degree of homogenization but a high frequency of aliens. Dry shrubs and rocky habitats display a lower degree of homogenization and a low frequency of aliens.