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The vascular flora of Algerian and Tunisian small islands: if not biodiversity hotspots, at least biodiversity hotchpotchs?

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ABSTRACT Algerian and Tunisian coasts host more than one hundred small islands and islets, but are still poorly known. We have compiled recently published and unpublished data from "PIM initiative" (Mediterranean small island initiative) and other kind of expeditions. For each small island or archipelago we seek to establish the membership to or relationship with the regional hotspots of the Mediterranean basin and the important plant areas (IPA) of Algeria and Tunisia, thanks to species-area relationships and biogeographical analyses. Nowadays, 25 small islands are considered as botanically well-known and can be analysed. Species-area relationship follows a classical linear regression model while some islands are less rich than predicted and other ones are more rich. These richest islands can be assessed as IPA following criterion B. Some of them have been yet assessed as IPA following criterion A, especially because of presence of local or regional endemism. Each main archipelago shows biogeographical links not only with neighbour continental coasts, but also with northern coasts or big islands from the western Mediterranean, especially the Tyrrhenian complex. "Grand Cavallo" and "Petit Cavallo" islands are highlighted here as the 23rd IPA from Algeria. As biodiversity hotchpotch, each small island or archipelago should play a significant role in the conservation programs although some of them are still unexplored and a deeper taxonomical knowledge is necessary in the north-African context.

KEY WORDS Important Plant Areas; endemism; PIM initiative; protected areas; species-area relationship.

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INTRODUCTION

Mediterranean Basin is famous for its thousands of islands (more than 15,000), most of them small islands or rocky islets. Eastern Mediterranean shows more islands and islets than the Western side, nevertheless the latter includes the biggest islands like Sicily, Sardinia and Corsica. Following PIM itiniative (http://www.initiative-pim.org/) around 1100 small islands are considered in the Western Mediterranean, and 167 of them are located in front of Moroccan, Algerian or Tunisian coasts, islands beyond Gibraltar strait and beyond the Sicilian channel excluded (Fig. 1). Around one fifth are isolated islands, the others are grouped in archipelago containing from 2 to 16 islands. All are "small islands", generally uninhabited, defined here as less than 1000 ha and with at least one vascular plant (i.e. not totally submerged by waves or tide). It includes "very small islands", defined by Panitsa et al. (2006) as islands with area less than 50 hectares. Most of these small islands from Northern African coasts of the Western

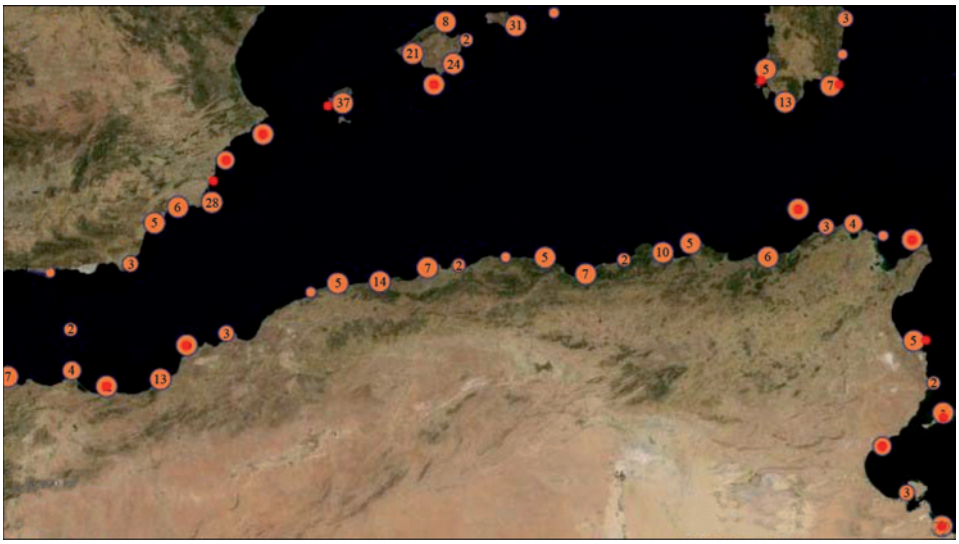

Figure 1. Screenshot centered on Algerian and Tunisan coasts after the PIM database (www.initiative-pim.org). Main archipelagos are circles spotted in red. Number of islets aggregates included within others circles are written in the circle.

Mediterranean belong to regional biodiversity hotspots like Betico-Rifean and Kabylies-Numidia-Kroumiria complexes (Médail & Quézel, 1997; Véla & Benhouhou, 2007). Their biogeographical position, often near the putative mean glacial refugia areas (Médail & Diadéma, 2009), made them probably good biodiversity refuges during glacial ages, even more because their area was considerably increased by a lower sea level. Today yet they appear as site favourable for micro-speciation (Greuter, 1995) and refuges for some rare species and/or vulnerable biota.

But why do they give us that impression? At least we can say because small islands are unfavourable for cultivated fields, urbanisation, industrialisation and other modern intensifications, they look as refuges for wilderness. Are they biodiversity hotspots (or part of them)? Are they key biodiversity areas (at least for plants)? Are they useful for conservation strategies? Answering this requests is difficult because of low knowledge of natural history for most of them, inducing difficulties to understand their biogeography (Triantis et al., 2008a), neglecting assessments of areas with conservation priorities (Nikolić et al., 2008) or erroneous conclusion following scientific field surveys (Mifsud, 2011).

In the aim of highlighting the natural history of Algerian-Tunisian small islands and their conservation values, we analyse here a compilation of published and unpublished data mainly collected by authors and collaborators during 2006-2012 PIM expeditions completed by few complementary data.

MATERIALS AND METHODS

Historical knowledge

Historical floristic investigations were very poor until the 1990s, as only six islands or archipelagos were more or less investigated:

Habibas (NW-Algeria): Maire, Wilczek & Faure in 1934 (cf. Maire & Wilczek, 1936).

Galite (NW-Tunisia): Chabrolin in 1931 (cf. Chabrolin, 1933), Bocchieri & Mossa in 1983 (cf. Bocchieri & Mossa, 1985).

Cani, Pilau, Plane (N-Tunisia): Pottier-Alapetite before her death in 1971 and most probably before Tunisian independence in 1956 (cf. Pottier-Alapetite, 1979-1981).

Zembra (NE-Tunisia): Doumet-Adamson in 1884 (cf. Doumet-Adamson, 1888); Letourneux in 1887 (cf. Bonnet & Barratte, 1896), Barratte & Cosson in 1888 (cf. Bonnet & Barratte, 1896), Labbe & Pottier-Alapetite in 1953 (cf. Labbe, 1954).

The PIM Initiative

The Mediterranean small islands Initiative (PIM initiative; www.initiative-pim.org) wants to better promote and act for the concrete management of Mediterranean islands.

It participates in knowledge and protection of these micro-island areas through implementation of

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Figure 2. “Petite Habiba” and unexplored satellite islets viewed from the main island “Grande Habiba”. Figure 3. Deserted village in the sheltered bay and still inhabited semaphore on the top of the main island.

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Figure 4. “Fauchelle” and “Galiton” in the background, viewed from the main island “La Galite”. Figure 5. “La Galite” in the background, “Gallina” and “Pollastro” unexplored islets in the foreground, viewed from the top of “Gallo”.

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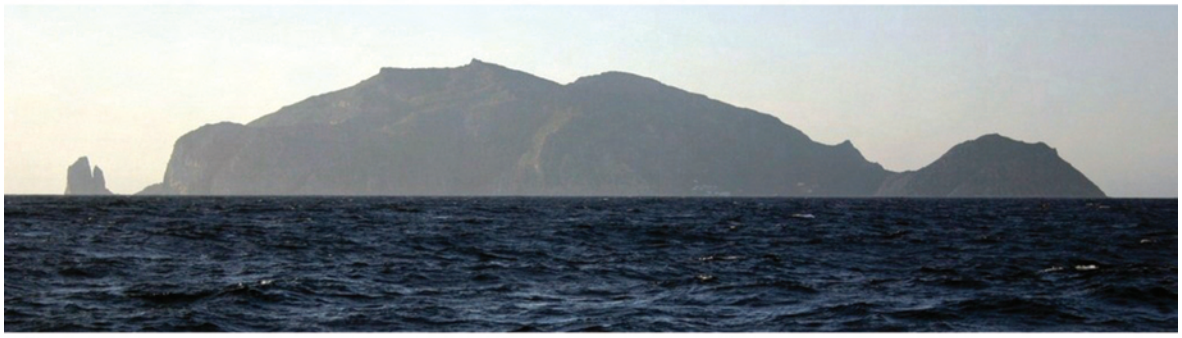

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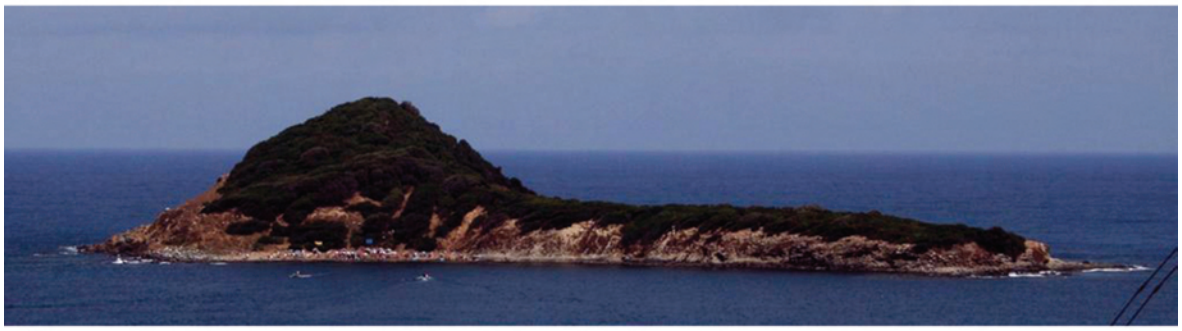

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Figure 6. N-W slope of Zembra island with its calcareous “Capo Grosso” in the background and “L’Antorcho” rocky islet on the left. Figure 7. The unexplored “Cathédrale” islet viewed from Zembra main island. Figure 8. Global view of Zembra main island with the “Cathédrale” small island on the left. Figure 9. “Les Pisans” island viewed from the Boulimate’s beach, Gouraya’s National Park, Bejaia (N Algeria). Figure 10. “Grand Cavallo” island viewed from El Aouana city, Jijel (N Algeria).

concrete actions on the field, promoting exchange of knowledge and skills between managers, naturalists and scientists from the whole Mediterranean. Since 2006, through the program named "Terra Cognita" (i.e. to better know), the PIM team organizes field expedition involving many experts. Thus, with help of Algerian CNL (Commissariat National du Littoral; http://www.matev.gov.dz/pdf/littoral/organigramme_du_cnl.pdf) and Tunisian APAL (Agence de Protection et d'Aménagement du Littoral; http://www.apal.nat.tn/), the main North-African islands have been investigated:

*Rechgoun (NW-Algeria): 2006/05.
**Habibas archipelago (NW-Algeria): 2006/05, 2007/10 (2 islands).
*Serijina (NE-Algeria) : 2008/05.
**Galite archipelago (NW-Tunisia): 2008/05, 2008/11, 2009/07 (4 islands).
**Cani archipelago (N-Tunisia): 2009/08 (3 islands).
Pilau (N-Tunisia): 2007/05.
Plane (N-Tunisia): 2007/05.
Zembra archipelago (NE-Tunisia): 2007/06, 2008/05, 2009/07, 2012/06 (2 islands).

*never explored before !
**some islets never explored…

Complementary data

Thanks to recent works on Jijel's and Bejaia's coasts in NE-Algeria (Bougaham, 2008; Hanifi-Benhamiche et al., 2011; Benhamiche-Hanifi& Moulaï, 2012; Véla et al., 2012a), flora of seven small islands from Kabylian coasts is known for the first time:

*El Euch (NE-Alg.) : 2010/03-2010/06.
*Bejaia islands (NE-Algeria): 2010/03-2010/06; 2011/06-2011/07 (3 islands).
*El Aouana islands (NE-Algeria): 2009/03; 2009/06 (3 islands).

Finally, unpublished data are available for three Algerian islet :

Vivier islet at Cap de Garde (NE-Algeria): 2002/05 ; 2003/04.
Cale Génoise islets at Cap Ténès (NW-Algeria): 2012/09.

Thus, we've got now field inventories for the Algerian-Tunisian main islands and archipelago and several of the numerous smaller ones.

IPA approach

Plantlife International (2004) proposed three main criteria for identifying important plant areas: Criterion A (significant populations of threatened species); Criterion B (exceptionally rich flora in the context); Criterion C (outstanding example of a habitat type of conservation importance). Because of missing information on habitat (types of habitats, threatened habitats) and on global plant richness (no specific data on common species) in Algeria and Tunisia, additionally to the great number of restricted-range endemic species within the whole Mediterranean hotspot, methodology to detect Important Plant Areas were partially modified by Yahi et al. (2012).

IPA were selected by presence and/or richness of "trigger species" as: globally threatened species [based on partial list from IUCN red lists as Walter & Gillett (1998) and García et al. (2010)], site-restricted endemic species (< 100 km²), high number of restricted-range species (< 5000 km²) and nationally threatened/rare species [following national floras as Battandier (1888), Battandier & Trabut (1895), Cuénod et al. (1954), Quézel & Santa (1962-1963), Pottier-Alapetite (1979-1981) and current unpublished field data] Northern Algerian and northern Tunisian territories, including small archipelagos, were respectively investigated by Yahi & Benhouhou (2011), Yahi et al. (2012) and Ghrabi Gammar (2011).

Generally, habitat diversity increase with area, then among sites with similar areas, species richness increases with habitat diversity (Kallimanis et al., 2008), it is why the lattest one is frequently used as extrapolation of the first one. On islands, species number is a function of area and number of habitats (Triantis et al., 2006), except below a threshold inducing a so-called "small island effect" (Lomolino & Weiser, 2001; Triantis et al., 2006). Below this small island effect, direct effects of area are eliminated and limited to indirect effects as the role of area on habitat diversity then the role of habitat diversity on species richness (Triantis et al., 2006).

Finally, for very small islands (Panitsa et al., 2006), plant specific richness is related with other parameters than area, like elevation (inducing itself an increasing of possible habitat diversity?), presence or absence or grazing, and non-standard factors or stochastic effects.

Nevertheless, as area remains the strongest determinant of island species numbers (Kreft et al., 2008), species-area relationships can be explored in order to show "exceptionally rich flora in the context" as an IPA indicator for islands and archipelagos ("criterion B" sensu Plantlife International 2004).

Biogeographical analysis

Taxa present on each island and archipelago are assessed from a biogeographical point of view. Regional endemism and other remarkable taxa (e.g. small islands specialised taxa) shared with neighbour areas are highlighted in order to identify biogeographical links among small islands and between small islands and continents.

RESULTS

Including PIM expeditions data, recent bibliography and unpublished data, we could say that flora is "well known" for 25 small islands or islets, 14 in Algeria and 11 in Tunisia (Table 1).

Species-area relationship

From Table 1 data, we can draw a species-area relationship for Algerian and Tunisian small islands (Fig. 11). As richness is a logarithmic function of area, richness is then a proportional function of log (area). A linear regression limited to these small islands (area between 0.4 and 732 ha) is a good approach to detect "rich" islands (richness higher than prediction) and "poor" islands (richness lower than prediction).

The best linear regression model (predicted specific richness = 70.025 log area(ha) + 15.565) obtain a R2 coefficient of determination higher as 0.6. We can also size small islands following the residual between observed and predicted species richness (Table 2). We can see fourteen islands with positive residuals, i.e. with species richness higher than predicted and thirteen islands with negative residuals, i.e. with species richness lower than predicted. Among very "poor" islands, there are very small islands as Plane and Grand-Cani (6 and 4 ha) and some bigger ones as Galiton or Rechgoun (30 and 26 ha). Among "rich" islands, La Galite is the richest and also the biggest one (732 ha).

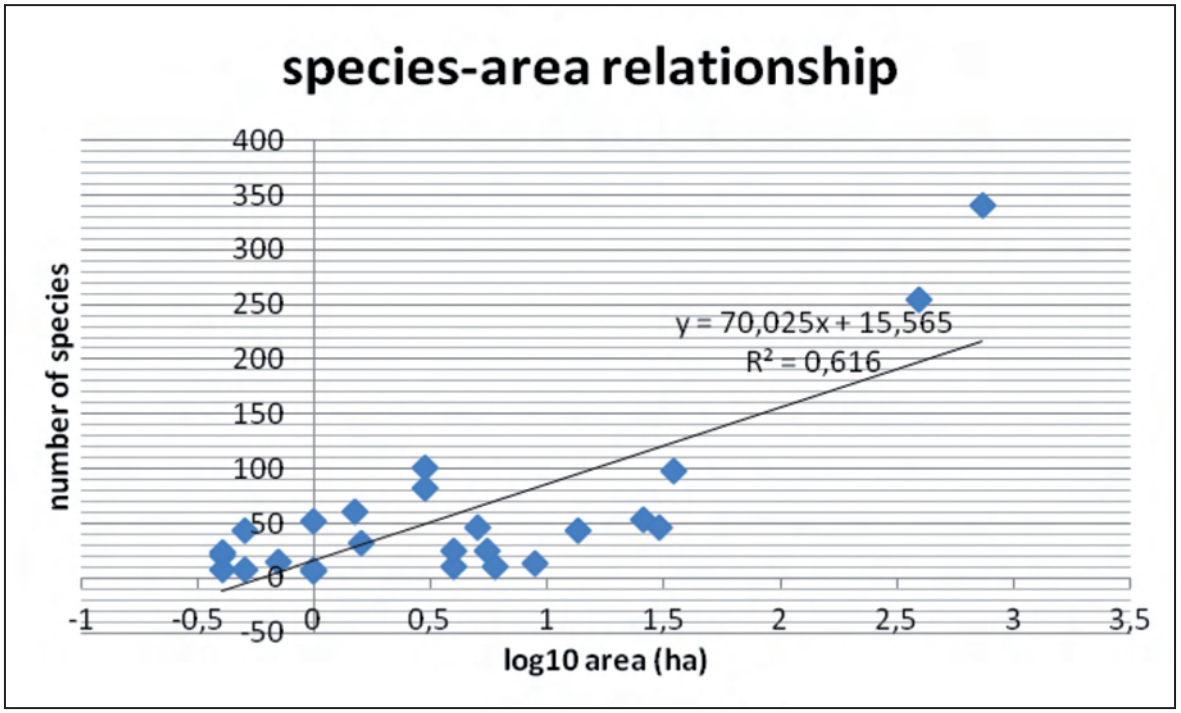

Figure 11. Species-area relationship for plants in Algerian and Tunisian small islands, following linear regression model.

Island (wilaya, country)	Area (ha)	Species	source
Rechgoun (Ain Temouchent, DZ)	26	54	PIM (E. Véla, unpubl.)
Grande Habiba (Oran, DZ)	35	98	PIM (Delauge & Véla, 2007); E.Véla & A. Saatkamp, unpubl.
Petite Habiba (Oran, DZ)	5.5	24	PIM (Delauge & Véla, 2007)
Cale Génoise W (Chlef, DZ)	0.4	7	D. Amari & E. Véla, unpubl.
Cale Génoise E (Chlef, DZ)	0.5	7	D. Amari & E. Véla, unpubl.
El Euch (Bejaia, DZ)	1.5	60	Benhamiche-Hanifi& Moulaï, 2012
L'Ail (Bejaia, DZ)	0.4	21	Véla et al., 2012a
Pisans (Bejaia, DZ)	1	52	Benhamiche-Hanifi& Moulaï, 2012
Sahel (Bejaia, DZ)	0.5	44	Benhamiche-Hanifi& Moulaï, 2012
Grand Cavallo (Jijel, DZ)	3	82	Benhamiche-Hanifi& Moulaï, 2012
El Aouana (Jijel, DZ)	0.4	23	Benhamiche-Hanifi& Moulaï, 2012
Petit Cavallo (Jijel, DZ)	3	101	Benhamiche-Hanifi& Moulaï, 2012
Serigina (Skikda, DZ)	1.6	32	PIM (Véla, 2008)
Vivier (Annaba, DZ)	0.7	15	E. Véla & G. de Bélair, unpubl.
Galite (Bizerte, TN)	732	340	PIM (D. Pavon et al., unpubl.)
Galiton (Bizerte, TN)	30	46	PIM (D. Pavon & M. Murracciole, unpubl.)
Fauchelle (Bizerte, TN)	13.6	43	PIM (D. Pavon & M. Murracciole, unpubl.)
Gallo (Bizerte, TN)	8.9	13	PIM (D. Pavon, unpubl.)
Grand Cani (Bizerte, TN)	4	11	PIM (M. Delaugerre et al., unpubl.)
Cani NE (Bizerte, TN)	1	6	PIM (M. Delaugerre et al., unpubl.)
Cani SW (Bizerte, TN)	1	8	PIM (M. Delaugerre et al., unpubl.)
Pilau (Bizerte, TN)	4	25	PIM (E. Véla, unpubl.)
Plane (Bizerte, TN)	6	11	PIM (E. Véla, unpubl.)
Zembra (Nabeul, TN)	389	255	PIM (E. Véla et al., unpubl.)
Zembretta (Nabeul, TN)	5	46 // 45	PIM (Serrano, 2008; Domina & Mokni, 2012)

Table 1. List of Algerian and Tunisian islands which flora is here considered “well known”.

islet	log10(area)	observed	predicted	residual
Galite	2.8645	340	216.2	123.8
Zembra	2.5899	255	196.9	58.1
Petit Cavallo	0.4771	101	49.0	52.0
Sahel	-0.3010	44	-5.5	49.5
Pisans	0	52	15,6	36.4
El Aouana	-0.3979	23	-12.3	35.3
L'Ail	-0.3979	21	-12.3	33.3
Grand Cavallo	0.4771	82	49.0	33.0
El Euch	0.1760	60	27.9	32.1
Génoise-W	-0.3979	7	-12.3	19.3
Génoise-E	-0.3010	7	-5.5	12.5
Vivier	-0.1549	15	4.7	10.3
Serigina	0.2041	32	29.9	2.1
Cani-SW	0	8	15.6	-7.6
Cani-NE	0	6	15.6	-9.6
Zembretta	0.6989	46	64.5	-18.5
Grande Habiba	1.5440	98	123.7	-25.7
Pilau	0.6020	25	57.7	-32.7
Petite Habiba	0.7403	24	67.4	-43.4
Grand-Cani	0.6020	11	57.7	-46.7
Fauchelle	1.1335	43	94.9	-51.9
Plane	0.7781	11	70.1	-59.1
Rechgoun	1.4149	54	114.6	-60.6
Gallo	0.9493	13	82.0	-69.0
Galiton	1.4771	46	119	-73

Table 2. Algerian and Tunisian islands following overage or deficit in species richness compared to standard predicted by linear regression.

Three of them, Sahel, Cavallo-S and L'Ail (the smallest ones, 0.5 ha or less) are considered rich only because their predicted richness is negative as their Log (area) is less than the origin value of the regression line. Excluding this artefact and the moderate rich Vivier and Serigina islands, we can consider six islands with a significantly high specific richness (Galite, Petit Cavallo, Zembra, Pisans, Grand Cavallo, El Euch).

Biogeographical affinities

Rechgoun and Habibas Archipelago (NW-Algeria)

The Habibas Archipelago has got a continental origin but its rocks are mainly from volcanic origin, it is without freshwater resources and is almost uninhabited. During the first half of the 20th century, a small village was built by fishermen on the main island, now abandoned and in ruins except for equipment storage. There is a lighthouse on the top (105 m) of the main island (35 ha), continuously inhabited by one keeper. Historical flora is known thanks to a previous study by Maire & Wilckzek (1936). Vascular flora is not very rich (around 100 species for the largest island) regarding to the area but remained relatively stable during 70 years in species richness and composition (Véla, 2013). It presents numerous regional endemisms shared with African and/or European continent, characterising the Alboran sea biogeographical area (Table 3).

Moreover, the "small island specialist" and Western-Mediterranean *Stachys brachyclada* De Noé is present on the main island while it is absent on the small island and on the neighboring Rechgoun island (Véla, 2013).

The island of Rechgoun contain similar flora but significantly poorer. Only three of the regional endemics are present but rare: *Anthemis chrysantha*, *Fumaria munbyi* and *Sonchus tenerrimus* subsp. *amicus* (Véla, 2013).

Kabylian-Numidian small islands (N-Algeria)

In this area, small islands are very diverse, some of them calcareous (l'ilot à l'ail, ilot Sahel), the other ones siliceous. Vascular flora is sometimes relatively poor (Vivier, Serigina) but more often very rich (Petit Cavallo, Pisans, etc.). Only one regional endemism was inventoried on ilot Sahel, *Pancratium foetidum* Pomel var. *saldense* Batt., which is a Kabylian rupicolous vicariant of the W-Algerian-Moroccan *P. foetidum* var. *foetidum*. Furthermore, the "small island specialist" and Central-Mediterranean *Allium commutatum* Guss. is present on one island, L'ilot à l'Ail at Boulimate (where it was first mentioned for Algeria, cf. Véla et al., 2012a).

La Galite Archipelago (NW-Tunisia)

This archipelago is very far from the continent (40 km). It includes a relatively big island more or less inhabited (La Galite, 732 ha) and other smaller ones whose area is varying from 8 to 30 ha. The main island, mainly granitic, hosts several intermittent seeps. Vascular flora appears to be rich but still misunknown for the largest island because of the lack of intensive researches (a cumulative of 340 species including historical and actual field observations).

It presents local and regional endemisms with Corso-Sardinian affinities and a lot of taxa exclusive for Tunisia indeed Africa (Table 4). *Bellevalia galitensis* is considered like a local endemism (Bocchieri & Mossa, 1991) and the study of the local *Limonium* "cf. *intricatum*" will certainly confirm the presence of another endemic for this archipelago. Moreover, the "small island specialist" and Central-Mediterranean *Allium commutatum* Guss. is present on La Fauchelle, a peripheric islet from the Galite Archipelago (Pavon & Véla, 2011). At least five taxa can be considered showing Corso-Sardinian affinities (during our surveys we have not seen the two last taxa mentioned by Bocchieri & Mossa, 1985):

•*Limonium* "cf. *intricatum*" = sp. nov. ? (belonging to *L. articulatum* aggr.). This interesting and understudied taxa was first mentioned on La Galite by Bocchieri & Mossa (1985, sub "*Limonium* sp.") then partially highlighted by Pavon & Véla (2011). Its strong affinity or else its identity with *L. intricatum* described from the Bizerte coast by Brullo & Erben (1989) clearly attests its belonging to the *L. articulatum* aggregate of micro-endemism from Corso-Sardinian area.

•*Brassica insularis* s.s. (non *B. atlantic*a): in its stricto sensu, this Corso-Sardinian endemism is shared with African continent on Edough peninsula

Taxa endemic from Alboran sea (s.l.)	Presence in Europe	Presence in NW-Africa	Abundance on Habibas
Anthemis chrysantha J. Gay	SE-Spain	NW-Algeria	CC
Arenaria cerastioides (Crantz) Maire var. *oranensis* Batt.	?	NE-Mor./NW-Alg.	R
Asteriscus maritimus L. subsp. *sericeus* (Maire et Wilczek) Véla	Ø	NW-Algeria	AC
Brassica spinescens Pomel	Ø	NW-Algeria	AC
Fumaria munbyi Boiss. & Reut.	E-Spain	NW-Algeria	R
Lobularia maritima (L.) Desv. subsp. *columbretensis* R. Fern	E-Spain	Ø	R
Rostraria balansae (Coss.&Dur.) Holub	Ø	NE-Mor./NW-Alg.	AC
Silene pseudoatocion Desf. var. *oranensis* Batt.	?	NE-Mor./NW-Alg.	R
Sonchus tenerrimus subsp. *amicus* (Faure, Maire & Wilczek) Véla	Ø	Chafarinas? (sub *S. bourgeaui* Schultz Bip.?)	AC
Spergularia pycnorrhiza Batt.	Ø	NW-Algeria	AC

Table 3. Taxa endemic from the Alboran area present on Habibas archipelago (Véla 2013).

Taxa exclusive for Tunisia (*indeed Africa ; **exclusive endemism)	Biogeography	Rarity on Galite archipelago	Source
Asplenium marinum L.	Sub-Atlant.	RR	Muracciole et al. (2010)
Asplenium obovatum Viv. subsp. *obovatum*	Sub-Atlant.	RR	Pavon & Véla (2011)
***Bellevalia galitensis* Bocchieri & Mossa	N-Tunisia	R	Bocchieri & Mossa (1991); Pavon & Véla (2011)
**Bituminaria morisiana* (Pignatti & Metlesics) Greuter	Sardinia	RR?	Bocchieri & Mossa (1991)
Brassica insularis Moris [excl. *B. atlantica* (Coss.) O.E.Schulz]	Corsica, Sardinia, NE-Algeria	R	Pavon & Véla (2011)
Cheilanthes maderensis Lowe	W-Medit.-Macarones.	RR	Véla (unpubl.)
Diplotaxis viminea (L.) DC.	Europ.-Medit.	R	Pavon & Véla (2011)
Limonium cf. *intricatum* Brullo & Erben [**sp. nov. ?]	N-Tunisia	R	Pavon & Véla (2011)
Ononis minutissima L.	Medit.	RR	Pavon & Véla (2011)
**Serapias nurrica* Corrias	Tyrrhen. islands	R	Véla et al. (2012c)

Table 4. Taxa exclusive for Tunisia registered on La Galite Archipelago.

(Yahi et al., 2012) and the La Galite Archipelago (Chabrolin 1933; Pavon & Véla, 2011).

•*Serapias nurrica*: this Tyrrhenian taxa known from Corsica, Sardinia, Menorca, Sicilia and Calabria was recently discovered on La Galite island by R. Ouni (Véla et al., 2012c).

•*Hyoseris lucida* L. subsp. *taurina* (Martinoli) Peruzzi & Vangelisti is a poorly known Tyrrhenian taxa that grows in coastal cliffs of Peninsular Italia, Sardinia, Sicily, Malta and La Galite (Bocchieri & Mossa, 1985; Brullo et al., 1997; Peruzzi & Vangelisti, 2010) but also on NW-Tunisian and NE-Algerian continental coasts (Véla, unpubl.).

•*Bituminaria morisiana* is a doubtful and neglected taxa described from Sardinia and mentioned on La Galite by Bocchieri & Mossa (1985) which doesn't appear in the Euro+Med database (http://ww2.bgbm.org/EuroPlusMed/), in the African Plant Database (Dobignard & Chatelain, 2010-13) nor in the last Tunisian checklist (Le Floc'h et al., 2010).

Bizerte's coasts small islands (N-Tunisia)

In this area, small islands are relatively near (Pilau, Plane) or very distant from the continent (Cani Archipelago). Vascular flora is poor (between 6 and 25 species) and is exempted from regional endemism. Nevertheless, the "small island specialist" and Central-Mediterranean *Allium commutatum* Guss. is present on two islands of the Cani Archipelago and on Pilau island where it was first mentioned for Tunisia (cf. Le Floc'h et al., 2010).

Zembra Archipelago (NE-Tunisia)

This archipelago's comprising a relatively large island once inhabited (Zembra, 389 ha), a very small one (Zembretta, 5 ha) and some rocky islets. Floristic richness is high on the main island Zembra (about 255 species). This archipelago hosts at least one local endemism and shares eight regional endemism with Sicily and adjacent areas or with continental areas from Punic domain within or near Cap Bon (Table 5). Furthermore, two Central-Eastern Mediterranean species were recorded in Zembra where they are exclusive for Tunisia, *Sarcopoterium spinosum* (L.) Spach (Doumet-Adanson, 1888, Labbe, 1954) and *Solenopsis minuta* (L.) C.Presl (Labbe 1954 sub "*Laurentia michelii*", Domina & El Mokni, 2012).

Finally, the "small island specialist" and Central-Mediterranean *Allium commutatum* Guss. has been recently discovered on the very small island of Zembretta (cf. Domina & El Mokni, 2012).

Regional endemism (*exclusive for Tunisia; **exclusive endemism)	Biogeography	Rarity on Zembra arch.	Source
Allium cf. *lehmannii* Lojac. (= *A. obtusiflorum* DC.?)	Sicily, S-Italy? (Greece?)	RR	Pavon & Véla (2011); Domina & El Mokni (2012)
Bellevalia cf. *dolichophylla* Brullo & Miniss.	NE-Tunisia	RR	Domina & El Mokni (2012)
Brassica atlantica (Coss.) O.E.Schulz (non *B. insularis* Moris)	NE-Tunisia	R	Cosson (1883-1887)
Dianthus rupicola Biv. subsp. *hermaeensis* (Coss.) O. Bolos & Vigo	NE-Tunisia (sp: Sicily s.l. and Mallorca)	R	Cosson (1882-1890); Doumet-Adanson (1888)
**Filago lojaconoi* (Brullo) Greuter	Sicily s.l. (Linosa, Pantelleria)	R?	Domina & El Mokni (2012)
**Iberis semperflorens* L.	S-Italy, Sicily	R	Cosson (1883-1887); Doumet-Adanson (1888)
***Limonium zembrae* Pignatti	NE-Tunisia	R	Pignattii (1982)
Sixalix farinosa (Cosson) Greuter & Burdet	N-Tunisia + NE-Algeria	R	Doumet-Adanson (1888); Véla et al. (2012b)

Table 5. Narrow and regional endemism present on Zembra main island.

Hotspot areas

At global level (Myers et al., 2000; Mittermeier et al., 2004), biodiversity hotspots are delimited by exceptional botanical and zoological richness and endemism rate on large areas as major mountain ranges (Himalayas, Caucasus, Andes, etc.), major tropical islands and archipelagos (Madagascar, Sundaland, New-Caledonia, etc.) or major Mediterranean biomes (California, Cape region, Mediterranean Basin, etc.).

As part of the Mediterranean basin, small islands like biggest ones are including within the global Mediterranean hotspot. At regional level (Médail & Quézel, 1997; Véla & Benhouhou, 2007), plant biodiversity hotspot within the Mediterranean basin are delimited by semi-empiric data as specific richness for 10,000 km² and endemism/subendemism rate within areas as high mountains (Atlas, Lebanon…), collision chains (Betico-Rifean arc, Taurus, Kabylies…), big islands (Tyrrhenian islands, Creta, Cyprus…) or oceanic archipelagos (Canaries and Madeira). Themselves, small islands are not sufficient territories (<< 10,000 km²) to host high specific richness (> 2000 sp.) and endemism rate (> 10 %). But most of them are located near to the coast and could be included within regional hotspots:

- Peripheral islets satellites from Corsica, Sardinia, Sicily and the Balearic can be included within The Tyrrhenian Island hotspot area;

- Small islands near northern and southern coasts of the Alboran sea (like Habibas archipelago in NW-Algeria) can be included within the Betico-Rifean hotspot area;

- Small islands near the Kabylian and Numidian coasts of NE-Algeria and NW-Tunisia (like Bejaia's, Jijel's, Skikda's and Annaba's small islands) can be included within the Kabylian-Numidian-Kroumirian hotspot area;

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Figures 12-14. Species exclusive for Tunisia, as example of the hotchpotch phenomenon. Fig. 12. *Sarcopoterium spinosum* on Zembra island (N-E Tunisia). Fig. 13. *Cheilanthes maderensis* on La Galite is "new" for Tunisia.Fig. 14. *Ononis minutissima* on La Galite (N-W Tunisia).

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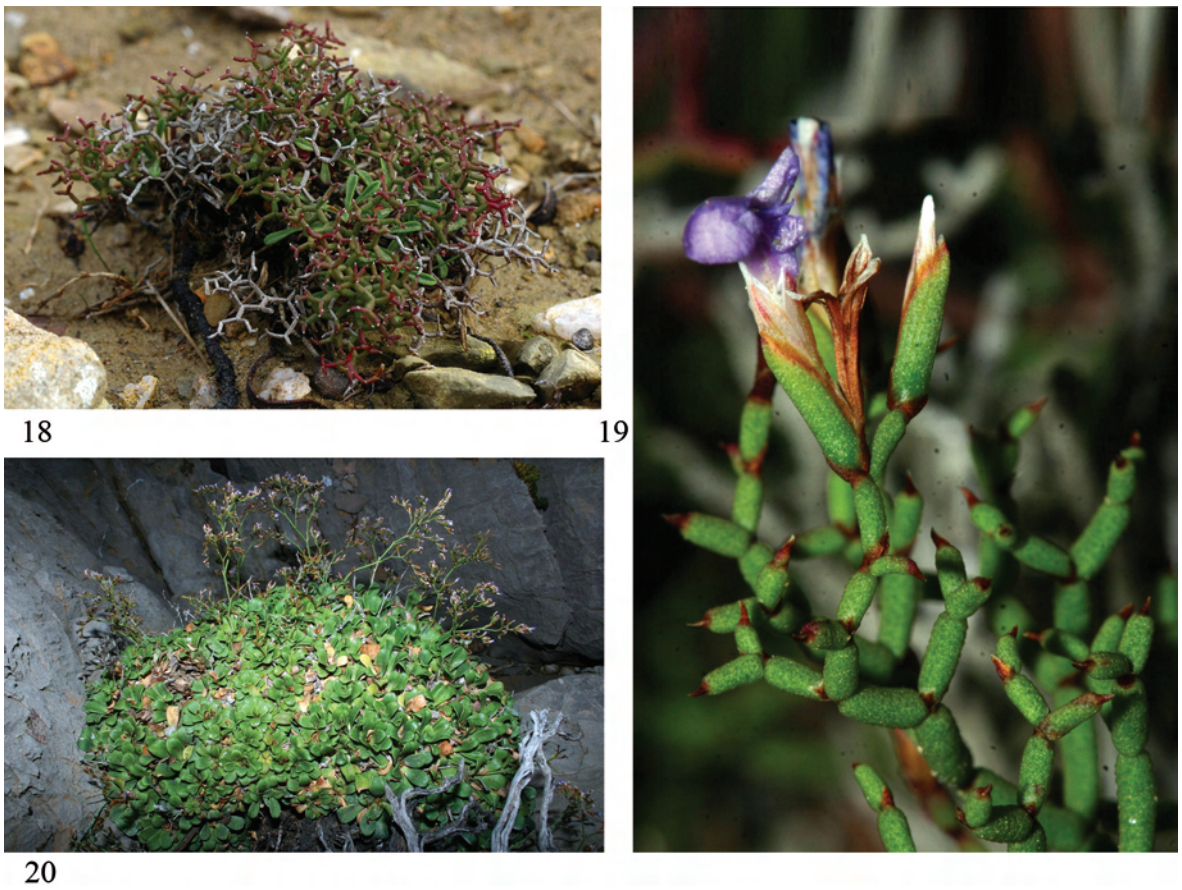
Figures 15-17. Irreplaceability characterised by “small islands specialist” species. Figure 15. *Fumaria munbyi* on Rechgoun island, Ain Temouchent (N-W Algeria). Figure 16. *Stachys brachyclada* on Habibas main island, Oran (N-W Algeria). Figure 17. *Allium commutatum* on “Ilot à l’Ail” near Boulimate’s beach, Bejaia, (N Algeria).



Figures 18-20. Irreplaceability characterised by micro-speciation of narrow endemism. Figures 18, 19. *Limonium* cf. *intricatum* (possibly not described species) on La Galite island (N-W Tunisia). Figure 20. *Limonium zembrae* on Zembra (N-E Tunisia).

- All the numerous small islands of Dalmatian coasts are de facto part of the putative hotspot area suggested by Nikolić et al. (2008);

- Most of the numerous small islands of Grecian territories could be more or less included within the related hotspot areas as Peloponnese, Crete and Taurus.

Even if Galite and Zembra Archipelagos have got biogeographical affinities with Corso-Sardinian and Sicilian areas respectively (cf. supra), it seems imprudent to include them empirically within the Tyrrhenian hotspot area without further investigations. In order to explore richness and endemism at a lower level than the hotspot one, IPA methodology will be helpful.

IPA assessment in Algeria and Tunisia

In Algeria, Yahi & Benhouhou (2011) and Yahi et al. (2012) have assigned 22 IPA whose only one is insular, the Habibas Archipelago. But several islets located near the coast could be included de facto in some littoral IPA (Traras mountains, Oran's hills, Cap Ténès, Chenoua mountain, Gouraya national park, Taza national park, Edough peninsula and El Kala national park).

As an example, among the islets with well-known flora, the three islands of Bejaia "Ilot à l'Ail", "Ile des Pisans" and "Ilot Sahel" (Benhamiche-Hanifi& Moulaï, 2012; Véla et al., 2012a), because of their geographical proximity and ecological similarity with continental coasts make them as part of the Gouraya's IPA:

- Boulimate's "Ilot à l'Ail" hosts the main Algerian population of *Allium commutatum*, a rare, fragmented and range-edge species not known elsewhere in this IPA;

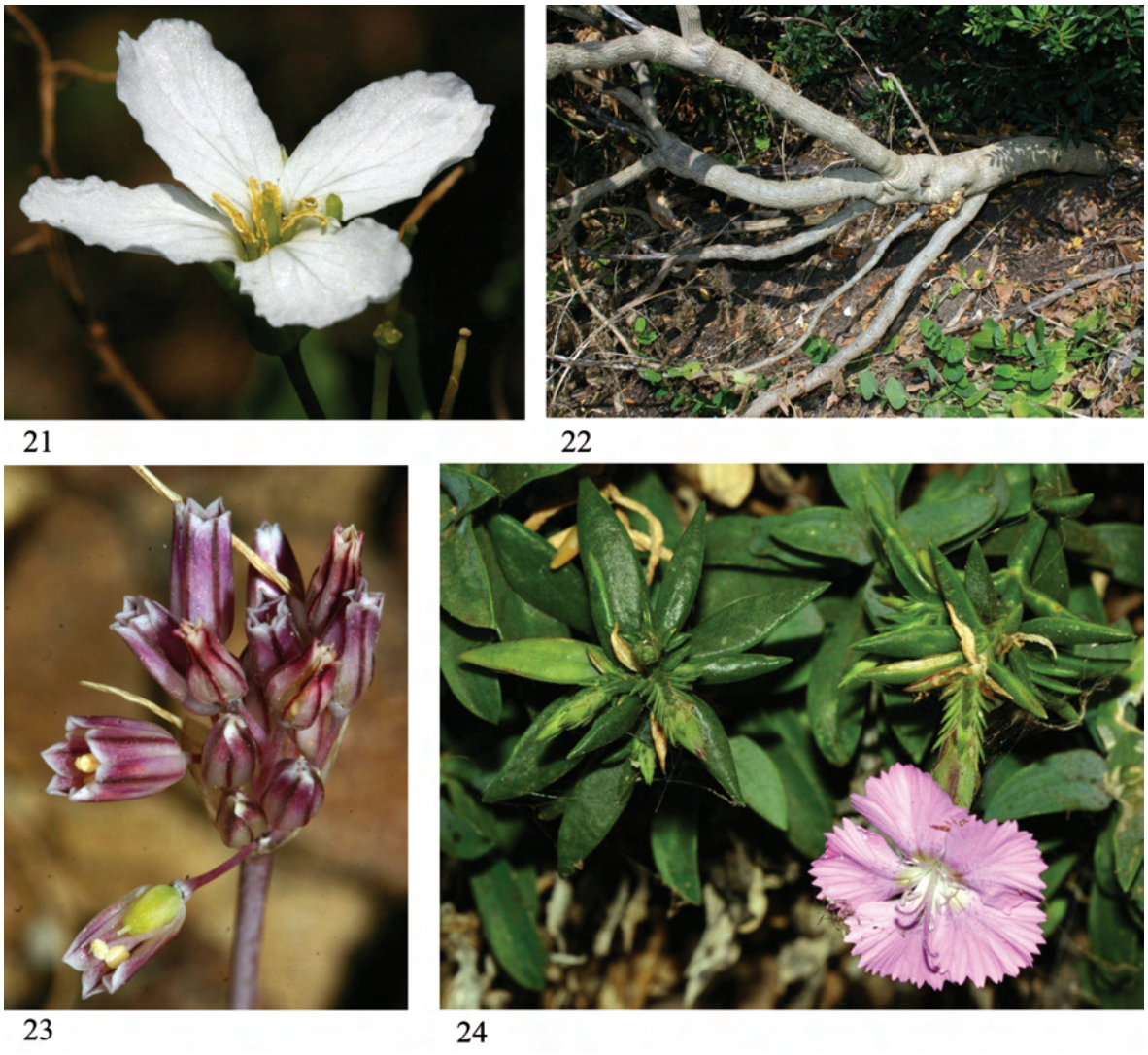
- "Ilot Sahel" hosts the site-restricted endemism

Pancratium foetidum var. *saldense*, the restricted-range Algerian endemism *Sedum multiceps* and the Algerian-Tunisian endemism *Sedum pubescens*.

- "Iles des Pisans" is one of the six richest small islands regarding to the species-area relation. This exceptional rich flora in the context met the island with the criterion B and is an IPA indicator.

Other islands recently studied like El Aouana islands "Grand Cavallo" and "Petit Cavallo" (Bougaham, 2008; Hanifi-Benhamiche et al., 2011; Benhamiche-Hanifi& Moulaï, 2012) are remarkable following the presence of the restricted-range Algerian endemism *Aristolochia longa* subsp. *fontanesii* and *Genista numidica*. Furthermore, with a high specific richness (respectively 101 and 82 plant species for an area of only 3 hectares each one), among the richest islands studied here, these archipelago could be assigned as an autonomous IPA.

In Tunisia, Ghrabi Gammar (2011) has assigned 24 IPA whose two are insular, the Galite Archipelago and the Zembra Archipelago. A third IPA (Sidi Ali el-Mekki), restricted to the littoral, is de facto including the interesting island "Ile Pilau" which hosts one of the three Tunisian populations of *Allium commutatum* (Pavon & Véla, 2011).

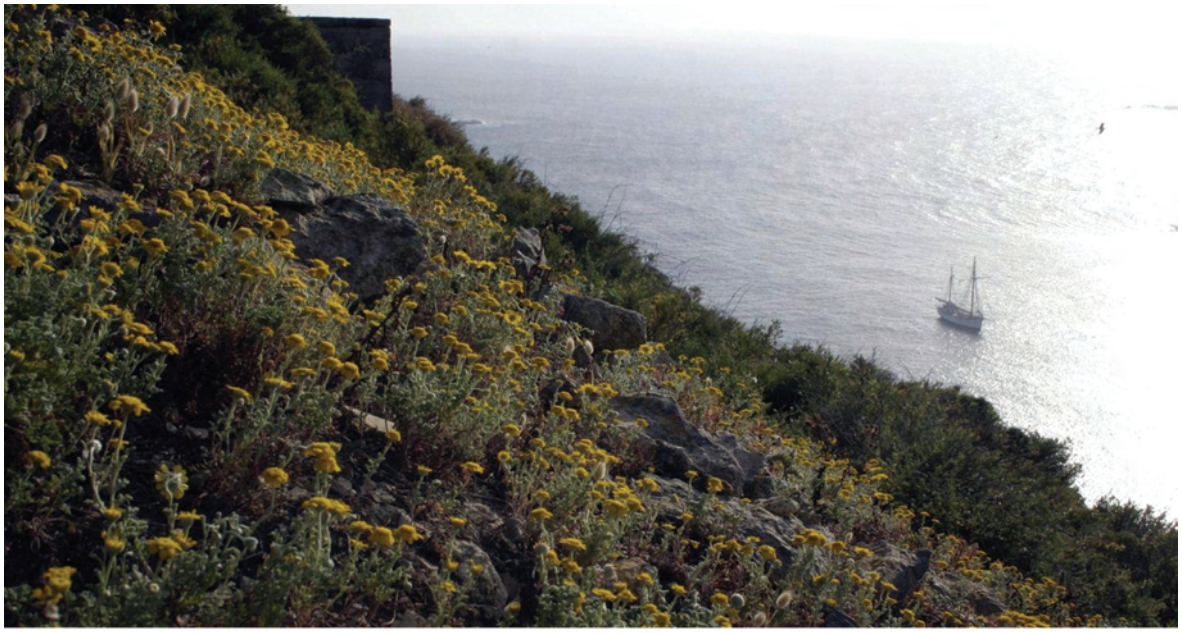


Figures 21-24. Biogeographical affinities of Zembra (N-E Tunisia) as revealed by shared endemism. Figs. 21-22. *Brassica atlantica* (≠ *B. insularis* s.s.?), endemism shared with Cap Bon peninsula (N-E Tunisia). Fig. 22. *Allium* cf. *lehmanii*, endemism shared with Sicily. Fig. 23. *Dianthus rupicola* subsp. *hermaensis*, endemism shared with Cap Bon (subspecies) or Sicily and Mallorca (species).

DISCUSSION

Contrarily to the biggest islands of the whole Mediterranean, small islands or archipelago are not considered as regional hotspot themselves, certainly due to their very low area insufficient to allow the in situ speciation (Lomolino & Weiser, 2001) and keep them poor in exclusive endemism (Triantis et al., 2008b). Nevertheless they are sharing regional endemism with neighbour areas like big islands or continent. In contrast their can host specialised species absent from continent because of higher competition or they can share species with far countries which are not present on the neighbouring areas.

Finally, each islet, island or archipelago host an original combination of native and exotic flora and can be assimilate as biodiversity hotchpotchs. As an example, Sicilian Strait is a barrier to dispersal and gene flow which may be crossed by natural or anthropogenic long-distance dispersal overseas, assisted by sea-level oscillations during the Pleistocene (Lo Presti & Oberprieler, 2011). In the previous studies, examples of "significant populations of threatened species" were satisfying criterion A for IPA



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Figures 25-27. Biogeographical affinities of Habibas (N-W Algeria) as revealed by shared endemism. Figure 25. *Anthemis chrysantha*, endemism shared with Murcian coasts (S-E Spain). Figure 26. *Asteriscus maritimus* subsp. *sericeus*. Figure 27. *Brassica spinescens* (right), endemism shared with Oran's coasts (N-W Algeria).

assessment. But fortunately, criterion B can be tested here because of a good knowledge of the specific richness on these small sites. The main ones archipelago as Zembra (main island ≈ 400 ha, 4 islands) and La Galite (main island ≈ 700 ha, 6 islands) have been easily assessed as important plant areas (IPA) following criterion A (Radford et al., 2011). For the smaller ones, like Habibas Archipelago (main island 35 ha, 4 islands), number of species is relatively low but can contain some local rarities like regional endemism (i.e. "restricted-range species"), range edge, or specialised habitat species and permitted to asses following criterion A (Yahi et al., 2012).

Because they are most often devoid of local endemism (i.e. "site-restricted endemic species") and depleted in regional endemism, other "very small island" (less than 50 hectares, often even less) were not recognized as IPA following criterion A.

Nevertheless, thanks to our richness data by island, we can now size island based on species-area residuals. It follows that specific richness is abnormally high (residual > 30 species) for six islands. The two main islands (La Galite; Zembra) belonging to the two main archipelagos has been yet assessed as IPA following criterion A (Radford et al., 2011), and can now be re-affirmed with criterion B. One very small islands (Pisans) belonging to a coastal archipelago is considered here naturally included within the continental Gouraya's IPA. Two other very small islands (Grand-Cavallo and Petit-Cavallo) forming a coastal archipelago near El Aouana city should be proposed following criterion B as a new IPA, ie the 23rd of Algeria (cf. Yahi & Benhouhou 2011; 2012). Continental areas facing the archipelago (Cap Noir, Grand Phare…) are known for their floristic richness as hosting the rare *Silene sedoides* Poir. and *Limonium* aff. *minutum* (L.) Kuntze (Quézel & Pons, 1954) and probably belong to this same IPA.

Finally, the last very small island classified here as very "rich" (El Euch) is located near the coast between Bejaia and Azzefoun but we need additional investigation, particularly on the continental coasts, in order to assess it as a probable IPA (or not?).

Then, with better knowledge of the flora and vegetation of each island or islet, managers can make priorities for conservation and protection against insidious threats like exotic invasive plants, introduced animals, local extinction, touristic activities and many others. Nevertheless, deeper taxonomic investigations will be useful to complete biodiversity comprehension while field survey are needed to understand impact of environmental change on biodiversity and ecosystems services.

If not exactly hotspots, but at least hotchpotchs and/or key biodiversity areas for plants, north African small islands appear to be good refugia for current biodiversity conservation. They are until now relatively difficult to access for local population and show often better conservation status than continent touristic/urbanistic areas. Furthermore they can host not necessarily local endemism but at least specialised species intolerant to competition against the continental flora (e.g. *Allium commutatum*, *Fumaria munbyi*, *Stachys brachyclada*, etc.).

Nevertheless, legal protection status as National Park or Protected Marine Areas appears to be usefull to maintain this level of conservation and to develop long term management plan.

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