Fl. Medit. 25 (Special Issue): 55-64
doi: 10.7320/FlMedit25SI.055
Version of Record published online on 26 November 2015

Benito Valdés

Xenophytes in the Doñana territory (SW Spain)

Abstract

Valdés, B.: Xenophytes in the Doñana territory (SW Spain). — Fl. Medit. 25 (Special Issue): 55-64. 2015. — ISSN: 1120-4052 printed, 2240-4538 online.

The Territory of Doñana covers c. 230,000 ha mainly to the West side of the Guadalquivir river mouth. It includes the National and Natural Parks of Doñana and two other protected areas: Estero de Domingo Rubio and Laguna de las Madres, as well as the surrounding unprotected areas. A checklist published in 1980 covering the National park and part of the Natural Park listed 15 naturalized species. A checklist published in 2007 that covers the territory of Doñana, increased this number to 86. But new naturalized xenophytes have since been recorded in this territory raising the number to 99, 38 of which are native to the Old World and 61 to America. One of them, *Carpobrotus edulis*, is a harmful invader and at least two more, *Cortaderia sellowiana* and *Lantana strigocamara*, may become invaders in this area in the near future. The continuous population increase in the cities and villages around the territory, the presence of two tourist resorts within the territory (Matalascañas and Mazagón), the annual pilgrimage to El Rocio chapel and the increase in the roads net-work in the territory likely constitute the main factors responsible for this increased naturalization of introduced plants.

Key words: Alien flora, Exotic flora, Invasion pathways.

Introduction

The territory of Doñana, as defined in Valdés & al. (2010: 11), covers c. 230,000 ha mainly between the Guadalquivir river mouth and the Tinto river basin in Western Andalusia (SW Spain). The area comprises three well-characterized ecosystems: sweet and salt water marshes, stabilized sands and moving sand dunes (Castroviejo 1993; García Novo 1997).

To protect migrating birds, the Spanish Council for Scientific Research (C.S.I.C.) and the World Wildlife Fund acquired 6,794 hectares in 1964 to establish the Doñana Biological Reserve. This was gradually enlarged to form Doñana National Park (54,252 ha) and Doñana Natural Park (53,835 ha), which together were declared by UNESCO as the Doñana Biosphere Reserve in November 1980 (Pinilla 2006).

A recent floristic study of this territory (Valdés & al. 2007) indicates that the floristic richness of this territory includes 1,368 taxa (species and subspecies) of vascular plants of which 6.2% are naturalized xenophytes. But the number of xenophytes has

since increased at a rate of c. two new naturalized species per year, to complete the 99 taxa listed in this paper.

Material and methods

The basis of this study was a floristic checklist of the vascular plants of the Doñana territory (Valdés & al. 2007), along with the subsequently published papers addressing xenophytes in this territory, which will be given below.

The limits of the territory are those adopted by Valdés & al. (2007, 2011; see Fig. 1).

Results

The publication of the *Flora Vascular de Andalucía Occidental* (Valdés & al. 1987) was preceded by an appropriate study of the vascular plants of the four provinces of W Andalusia (Huelva, Córdoba Sevilla and Cadiz). The main Spanish herbaria were revised and over 80,000 gatherings were collected. The floristic knowledge of W Andalusia was

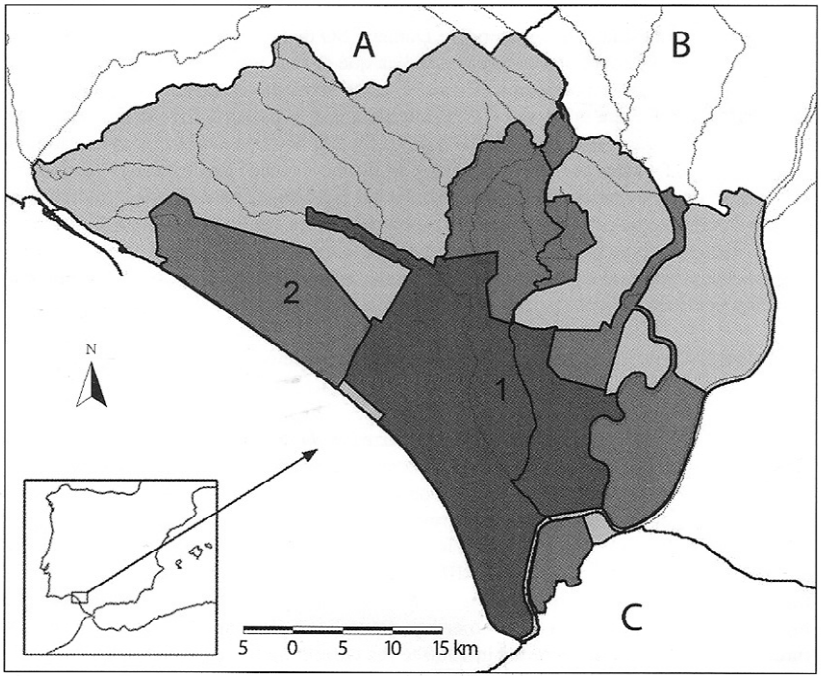

Fig. 1. Localization of the Doñana territory in the Iberian Peninsula and limits of the territory. The hydrographic network and main protected areas are indicated: 1, Doñana National Park; 2, Doñana Natural. The limits of the provinces of Huelva (A), Sevilla (B) and Cadiz (C) are added.

consequently considered to be highly accurate. Within the areas covered by the Doñana territory, 50 species were recorded as being naturalised xenophytes. But the floristic knowledge of a territory is never complete. Peinado & al (1990) recorded *Bergia capensis* L. and *Ammania coccinea* Rottb. as weeds in the rice fields of Isla Mayor, and Roales (1997) also recorded in these fields *Leptochloa uninervia* (Presl.) Hichc. & Chase. Sánchez Gullón & Rubio (1999) recorded *Chloris gayana* Kunth on roadsides near Mazagón, *Bidens pilosa* L. at the beach near the Parador Nacional (also in Mazagón) and *Diplachne fascicularis* (Lam.) Beauv. in Estero de Domingo Rubio. Medina (2003)recorded *Hydrocotyle verticillata* Thunb. in Laguna del Hondón, within the National Park, which has also been found in other parts of Doñana.

In 2005, Dana & al. (2005) mentioned *Bidens frondosus* L., *Paspalum dilatatum* Poir. and *Carpobrotus edulis* (L.) N.E. Br. as invaders in the territory of Doñana, Cobo & al. (2005) found *Ipomoea imperati* (Vahl) Griseb. in sand dunes at Matalascañas and Valdés & al. (2005a, 2005b) recorded four new naturalized taxa: *Abutilon teofrastii* Medik in the marshes of Hinojos, *Kikuyuochloa clandestinum* (Chiov.) H. Scholz (=*Pennisetum clandestinum* Chiov.) in the laguna de las Madres, not far from Mazagón, and other coastal areas of Huelva province where it starts to behave as an invader, *Galenia secunda* (L. f.) Sond. in salty areas of Monte Algaida (Cadiz province) and *Eclipta prostrata* (L.) L. in Dunas del Odiel, between Mazagón and the estuary of the rivers Tinto and Odiel.

Sánchez Gullón & al. (2006a, 2006b) recorded *Guizotia abysinica* (L. F.) Cass. within Doñana National Park, *Sporobolus indicus* (L.) R. Br. near Mazagón and *Oenothera speciosa* Nutt. also in Mazagón on coastal sand dunes and roadsides.

In 2007, seven new naturalized xenophytes were added. Fernández Zamudio & al. (2007) recorded *Cucumis myriocarpus* Naudin on roadsides and nitrified areas around Laguna de las Madres. López Albacete & al. (2007) gave *Chamaesyce maculata* (L.) Small for ruderalized areas near the Palacio de Doñana. Sánchez Gullón & al. (2007) recorded *Cyperus eragrostis* Lam. for the Doñana territory and *Chasmanthe aethyopica* (L.) N.E. Br. and Valdés & al. (2007) *Cyperus involucrata* Rottb. and *Eucaliptus camaldulensis* Dehn. This last species merits particular comment. This Australian species has been widely planted in Spain, first as an ornamental and subsequently mainly for timber, and it was never considered to be naturalized. But many seedlings produced from seeds have been observed at Dunas del Odiel, which indicates that this species has indeed become naturalized, at least in this locality.

When a checklist of the territory of Doñana was published by Valdés & al. (2007) the number of naturalized xenophytes had increase to 86, 34 of which are native to the Old World and 52 to the New World. All known previous records had been included in this checklist, but the number of naturalized xenophytes in the territory of Doñana has continue to increase.

In 2008 Verloove & Sánchez Gullón (2008) recorded *Dysphania pumilio* (R. Br.) Mosyakin & Clements (*Chenopodium pumilio* R. Br.) at Matalascañas' Rocío Playa camp-site, *Eragrostis mexicana* (Hornem.) Link in Mazagón, close to the lighthouse, *Eragrostis frankii* Steud. in irrigated fields at Laguna de la Madres and *Eragrostis pectinacea* (Michx.) Nees at several ruderalized sites in Matalascañas. The following year *Spartina patens* (Ait.) Muhl. was recorded by Sánchez Gullón & Verloove (2009) in el Asperillo,

between Matalascañas and Mazagón. In 2010 *Cyperus retrorsus* Chapman was recorded in Mazagón, close to the lighthouse by Verloove & Sánchez Gullón (2010) and *Cortaderia selloana* (Schult. & Schult. f.) Asch. & Graebn. and *Lantana strigocamara* R.W. Sanders (*L. camara* auct., non L.) in Estero de Domingo Rubio by Sánchez Gullón & al (2010). In 2011 *Tragus racemosus* (L.) All. was recorded on the roadsides between Matalascañas and Mazagón (Cuesta de Maneli) by Sánchez Gullón & al (2011). *Stenotaphrum secundatum* (Walter) O. Kuntze was later recorded in Matalascañas and other localities of Huelva province by Verloove & Sánchez Gullón (2012), and Sánchez Gullón & al. (2014) added *Opuntia pilifera* F.A.C. Weber, recorded at Dunas del Odiel, and Sánchez Gullón & Galán de Mera (2014) *Lemna minuta* Kunth, a potential invader collected at Laguna de las Madres, not far from Mazagón.

Consequently, the current number of naturalized xenophytes in the Doñana territory is 99, 38 of which are native to the old World and 61 native to America, as listed in tables 1 an 2.

Table 1. Old World taxa naturalized in the Doñana territory. *Already recorded in 1980 (Rivas Martínez & al. 1980).

TAXA	ORIGING
Aizoaceae	
Carpobrotus edulis (L.) N.E. Br.	S Africa
Galenia secunda (L. f.) Sond.	S Africa
Asclepiadaceae	
*Gomphocarpus frut*icosus (L.) W.T. Aiton	S Africa
Asteraceae	
* *Arctotheca calendula* (L.) Levins	S Africa
* *Cotula coronopifolia* L.	S Africa
Guizotia abyssinica (L. F.) Cass.	S Africa
Chenopodiaceae	
Chenopodium pumilio R. Br.	Australia
Cucurbitaceae	
Cucumis myriocarpus Naudin	S Africa
Cyperaceae	
Cyperus involucratus Rottb.	Tropical Africa
Cyperus retrorsus Chapman	Old Wold tropics
Elatinaceae	
Bergia capensis L.	Old World tropics
Euphorbiaceae	
Ricinus communis L.	Tropical Africa
Fabaceae	
Medicago sativa L.	Black Sea coasts
Iridaceae	
Chasmanthe aethiopica (L.) N.E. Br.	S. Africa
Freesia refracta (Jacq.) Katt.	S. Africa
Iris albicans Lange	Yemen, Arabia
Iris germanica L.	Hybrid origin
Liliaceae	
Asparagus officinalis L.	Euro-Siberian region
Malvaceae	
Abutilon theophrastii Medik	S Asia
Moraceae	
Ficus carica L.	Mediterranean
Myrtaceae	
Eucaliptus camaldulensis Dehn.	Australia
Oxalidaceae	
* *Oxalis pes-caprae* L.	S. Africa
Poaceae	
Arundo donax L.	Asia
Chloris gayana Kunth	S Africa
* *Digitaria debilis* (Desf.) Willd.	Tropical Africa
Echinochloa colonum (L.) Link	O & N Worlds tropics
Echinochloa oryzoides (Ard.) Fritsh	C & S Asia
Ehrharta calycina Sm.	S Africa
Eragrostis curvula (Schrad.) Nees	S Africa
Panicum miliaceum L.	Asia
Pennisetum clandestinum Chiov.	Old World tropics
Sorgum halepense (L.) Pers.	Mediterranean
Sporobolus indicus (L.) R. Br.	Old World tropics
Stenotaphrum secundatum (Walter) O. Kuntze	Pantropical
Tragus racemosus (L.) All.	Tropical Africa
Scrophulariaceae	
Cymbalaria muralis P. Gaertn., B. Mey.& Scherb.	S Europe
Simaroubaceae	
Ailanthus altissima (Mill.) Swingle	China
Solanaceae	
Solanum linnaeanum Hepper & P.-M. L. Jaeger	S Africa

Table 2. New World taxa naturalized in the Doñana territory. * already recorded in 1980 (Rivas Martínez & al. 1980).

Lemnaceae	
Lemna minuta Kunth	T
Liliaceae	
Nothoscordum borbonicum Kunth	S A
Lythraceae	
Ammania coccinea Rottb.	T
Onagraceae	
Oenothera drummondii Hook. subsp. *drumondii*	S A
O. speciosa Nutt.	N A
O. stricta Link subsp. *stricta*	S A
Oxalidaceae	
Oxalis articulata Savigny	S A
Papaveraceae	
Eschscholzia californica Cham.	N A
Phytolaccaceae	
Phytolacca americana L.	N A
Poaceae	
Ceratochloa cathartica (Vahl) Herter	S A
Cortaderia selloana (Schult. & Schult. f.) Asch. & Graebn.	S A
Eragrostis frankii Steud.	N A
E. mexicana (Hornem.) Link	S A
E. pectinacea (Michx.) Nees	N A
Leptochloa uninervia (J. Presl.) Hitch & Chase	T
Diplachne fascicularis (Lam.) P. Beauv.	N & S A
Paspalum dilatatum Poir.	S A
**P. distichum* L.	T
P. notatum Flugge	T
**P. vaginatum* sw.	T
**Spartina densiflora* Brogn.	S A
S. patens (Ait.) Muhl.	N A
Solanaceae	
Datura inoxia Mill.	C A
D. stramonium L.	S A
Nicotiana glauca R.C. Graham	S A
Solanum eleagnifolium Cav.	S A
Umbelliferae	
Hydrocotyle verticillata Thunb.	T
Verbenaceae	
Lantana strigocamara R.W. Sanders	S A
Phvla filiformis (Schard.) Meikle	T
C. serpens (Kunth) Small	C A

Lemnaceae	
Lemna minuta Kunth	T
Liliaceae	
Nothoscordum borbonicum Kunth	S A
Lythraceae	
Ammania coccinea Rottb.	T
Onagraceae	
Oenothera drummondii Hook. subsp. *drumondii*	S A
O. speciosa Nutt.	N A
O. stricta Link subsp. *stricta*	S A
Oxalidaceae	
Oxalis articulata Savigny	S A
Papaveraceae	
Eschscholzia californica Cham.	N A
Phytolaccaceae	
Phytolacca americana L.	N A
Poaceae	
Ceratochloa cathartica (Vahl) Herter	S A
Cortaderia selloana (Schult. & Schult. f.) Asch. & Graebn.	S A
Eragrostis frankii Steud.	N A
E. mexicana (Hornem.) Link	S A
E. pectinacea (Michx.) Nees	N A
Leptochloa uninervia (J. Presl.) Hitch & Chase	T
Diplachne fascicularis (Lam.) P. Beauv.	N & S A
Paspalum dilatatum Poir.	S A
**P. distichum* L.	T
P. notatum Flugge	T
**P. vaginatum* sw.	T
**Spartina densiflora* Brogn.	S A
S. patens (Ait.) Muhl.	N A
Solanaceae	
Datura inoxia Mill.	C A
D. stramonium L.	S A
Nicotiana glauca R.C. Graham	S A
Solanum eleagnifolium Cav.	S A
Umbelliferae	
Hydrocotyle verticillata Thunb.	T
Verbenaceae	
Lantana strigocamara R.W. Sanders	S A
Phyla filiformis (Schard.) Meikle	T

Moreover, the 21 taxa listed in table 3, both from the Old and New Worlds have been detected in the territory of Dañana either as adventives or as having escaped from cultivation.

Discussion

In 1980 Rivas Martínez & al. (1980) published a study of the vegetation of Doñana. It covered the National Park and part of the Natural Park. The checklist included in this study includes 15 naturalized species. The *Flora Vascular de Andalucía Occidental* (Valdés & al. 1987) increased this number to 50. The checklist of the Doñana territory published by Valdés & al (2007) increased this number even further to 86 naturalized taxa.

Data given in tables 1 and 2 indicate that currently there are 99 naturalized taxa in the territory of Doñana, 38 of which are native to the Old World and 61 to the new World. Furthermore, 21 taxa listed in table 3 are recorded as adventitious or escaped from cultivation. The data listed in the three tables indicate that the number of xenophytes from the New World is higher that the figure for the Old World, most likely due to intense trade between Spain and America over the last five centuries.

The main reason for this increasing number of naturalized xenophytes appears to involve the increase in population in the villages surrounding the territory (see table 4) as well as the presence of two tourist resorts within the territory, the subsequent increase in gardening and agricultural activities (mainly strawberry and rice fields) and the continuous growth of the roads network, as indicated in Fig. 2, a fact that very much facilitates mobility in the territory of Doñana.

Data included in table 4 indicate that from 1981, when 15 xenophytes were recorded (Rivas Martínez & al. 1980) to 2013, the population of the area almost doubled, and this figure shows a big increase in summer in two important tourist resorts: Mazagón and

Table 3. Old and New Worlds taxa that are adventitious or have escaped from cultivation in the Doñana territory.

Asclepiadaceae	
Asclepias curassavica L.	Tropics of America
Asteraceae	
Gaillardia aristata Pursh	N America
Brassicaceae	
Brassica juncea (L.) Czern	Asia
Brassica napus L.	?
Brassica oleracea	Atlantic Europe
Raphanus sativus L.	E Mediterranean
Caryophyllaceae	
Silene pseudoatocion Desf.	Ibero-Maghrebian
Cistaceae	
Cistus populifolius L.	Iberian Peninsula [Fr.]
Cyperaceae	
Cyperus aggregatus (Willd.) Endl.	America
Cyperus croceus Vahl	C & S America
Kyllinga brevifolia Rottb.	America
Fabaceae	
Lupinus albus L.	Balcans?
Linaceae	
Linum usitatissimum L.	Cult.
Onagraceae	
Oenothera affinis Cambess.	S. America
Oenothera glazioviana Micheli	Cult. hybrid
Poaceae	
Axonopus fissifolius (Raddi) Kullm.	Tropics of America
Pennisetum ciliare (L.) Link	Old World tropics
Zoysia matrella (L.) Merr.	Tropics of Asia
Scrophulariaceae	
Linaria maroccana Hook.	Morocco
Vitaceae	
Vitis vinifera L. subsp. *vinifera*	SW Asia

Table 4. Permanent population in cities and villages inside and around the Doñana territory from 1900 to 2013 (Anonymous 1902, 1932, 1962, 2015; INE 1981, 1991, 2000, 2010). *No available data.

	1900	1930	1960	1981	1991	2000	2010	2013
Almonte	6917	8287	11538	12959	16350	17444	22204	22964
Bollullos del Condado	7922	8881	10947	11862	12465	12822	13959	14394
Bonares	3928	4848	4783	4815	4900	5122	6145	6282
Hinojos	2058	2660	3278	3130	3434	3556	3926	3904
Isla Mayor	*	*	*	*	*	6057	5930	5948
Lucena del Puerto	1456	1658	1703	1870	2049	2237	2659	2600
Moguer	8455	7051	7222	10004	12193	14389	20040	21209
Palos de la Frontera	1621	2201	2540	5901	7335	7115	9167	10196
Pilas	4251	5755	8604	9835	10503	11289	13509	14058
Rociana del Condado	4291	5705	6016	5777	6095	6292	7362	7673
Villamanrique de la Condesa	3079	3154	3392	3225	3460	3805	4162	4359
TOTAL	43978	50200	60023	69378	78784	90128	109063	113587

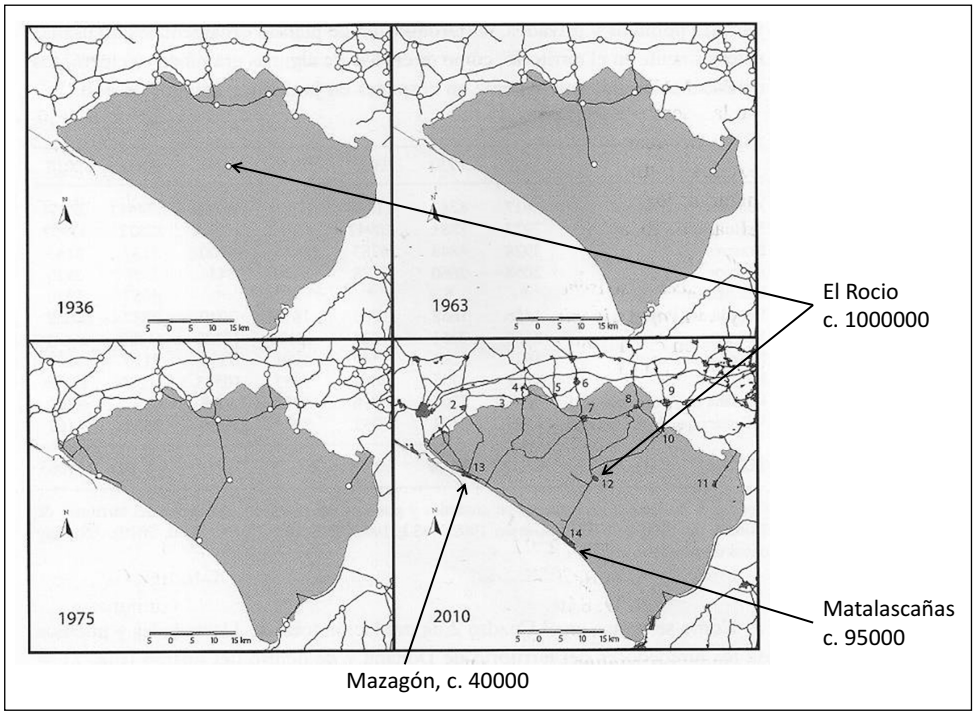

Fig. 2. Roads network in the Doñana territory from 1936 to 2010 (Spanish Instituto Geográfico and Instituto Geográfico y Catastral).

Matalascañas. It is estimated that in Mazagón (n. 13 in Fig. 2) the summer population may exceed 40,000 people and in Matalascañas (n. 14 in Fig. 2) 100,000 during July and August. But the village of El Rocío must be included. El Rocío, right in the middle of the Doñana territory (n. 12 in Fig, 2), concentrates over one million people for one week, during a famous pilgrimage which takes place in May. More than 100 brotherhoods arrive in El Rocío on foot, or by horse or horse and cart from the main cities and from many villages in Andalusia, following old unpaved roads.

Gardening constitutes an important activity for plant introduction and many naturalized species found in the territory of Doñana in the last two decades were recorded in Matalascañas (*Ipomoea imperati*, *Dysphania pumilio*, *Eragrostis pectinacea*, *Stenotaphrum secundatum*), Mazagón (*Sporobolus indicus*, *Eragrostis mexicana*, *Cyperus retrorsus*) and the Parador Nacional (*Bidens pilosa*). *Diplachne fascicularis*, *Cortaderia selloana* and *Lantana strigocamara*, recorded in Estero de Domingo Rubio, may have escaped from the gardens of the neighbouring Technical University of La Rábida.

Agricultural practices within and around the territory of Doñana is another factor responsible for the introduction of xenophytes in the area. The presence in the area of la Laguna de las Madres of *Kikuyuochloa clandestina*, *Cucumis myriocarpus* and *Eragrostis frankii*, at least, could be related to the extensive strawberry fields in the vicinity, and *Bergia capensis*, *Ammania coccinea* and *Leptochloa uninervia* are indeed weeds from the rice fields.

Roads are excellent pathways for penetration of exotic plants (Brisson & al. 2010; Gelbard & Belnap 2003; Harrison & al. 2002; Mortensen & al. 2009). This has been confirmed in the Doñana territory, where some species, both exotic and native, spread along the roads. The gradual growth of the roads network in the territory may have contributed to this alarming increase in naturalized xenophytes, as an increase occurs in nitrogen deposition due to human and animal activity, particularly along the roads (Forman & Alexander 1998), while nitrogen enrichment also results from burning petrol derivatives (Pasari & al. 2011). This increase can favor the establishment and propagation of exotic plants (Dukes & Mooney 1999). Indeed, many naturalized species behave as nitrophylous and ruderal ones, as is the case, for instance, of the species of *Amaranthus*, *Erygeron*, *Xanthium*, *Solanum* and *Eragrostis*. *Tragus racemosus*, *Chloris gayana*, *Oenothera speciosa* and *Cucumis myriocarpus* were recorded in this habitat as being new to the territory.

Unfortunately, the naturalization of exotic plants in the territory of Doñana is an ongoing process, as many other xenophytes have already become naturalized in some coastal areas in the provinces of Huelva and Cadiz (for references see Valdés & al. 2011) and their introduction into the Doñana territory is only a matter of time. Furthermore, some of those already recorded as adventives in the territory will, undoubtedly become established in the near future.

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Address of the author:
Benito Valdés,
Departamento de Biología Vegetal y Ecología, Universidad de Sevilla, Avda Reina Mercedes, s/n, 41012, Sevilla, Spain. E-mail: bvaldes@us.es