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BRIEF COMMUNICATION

Incipient invasion of *Galenia secunda* Sond. (Aizoaceae) in Southern Spain

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Abstract The occurrence of the carpet weed *Galenia secunda* (L. fil.) Sond. (Aizoaceae) has been reported in Southern Spain. *G. secunda* is a prostrate perennial species native to South Africa. In this paper, the current distribution of *G. secunda* and the main habitats invaded in Southern Spain, are reported. The distribution survey revealed an area of occupancy of 92 ha and an extent of occurrence of 14,250 ha for this species, thus suggesting an early stage of invasion. Since the first citation of this species in Spain (1965), our current data (2007) support a rapid spread and invasiveness of *G. secunda* as a result of an intense rate of coastal development. *G. secunda* was more often found near roads, because roads facilitate seed dispersal. *G. secunda* also appeared in other coastal natural habitats such as sand dunes, where *G. secunda* forms dense monospecific mats. Studies on its invasion potential and impacts in natural habitats are recommended and control measures should be developed to prevent future expansion.

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Introduction

Galenia secunda (L. fil.) Sond. is a prostrate perennial species native to South Africa. This taxon possesses small flowers (4 mm), and white or pink in color, with 5–6 sepals, 8–10 stamens, and 2–5 carpels (Castroviejo 1990) producing dehiscent capsules with 4–5 small (1 mm) seeds per capsule (Fig. 1). *Galenia secunda* (L. fil.) Sond. (Aizoaceae) (hereafter *Galenia*) was first cited in Spain in 1965 (Molesworth 1976). This species has an uncertain origin, as it is not used as an ornamental plant. *Galenia* has also been introduced in different parts of the world. It was found as an invasive weed in Southwestern Australia (Prescott and Venning 1984; Day 1988; Macfarlane et al. 2000). It has also been cited in West Florida (Clewell 1985; Wunderlin and Hansen 2004) and has been used as forage in Chile (Squella et al. 1986; Ovalle et al. 1993) because of its high yields and growth rates. *Galenia* belongs to the same family (Aizoaceae) as other well-known invaders such as *Carpobrotus edulis* (L.) N.E. Br. and *C. affine acinaciformis* (L.) L. Bol. (e.g., Vilà et al. 1998; Suehs et al. 2005, 2006) and *Mesembryanthemum crystallinum* L. (Vivrette and Muller 1977). Considering that taxon is among the characteristics that predispose species to become an invader (Kolar and Lodge 2001), the assessment of the invasion potential in this species is recommended. In this study, the current distribution of *Galenia* in Southern Spain was surveyed to grossly discern the degree of invasion and to explore the main habitats invaded.

Materials and methods

The study was carried out in the province of Cádiz (Southern Spain), which is the only Spanish region where *Galenia* has been found. The area has a Mediterranean climate, with a wet season from October to April (mean daily temperature: 14°C; average rainfall for the last 30 years: 507 mm) and a dry season from May to September (80 mm rainfall, mean daily temperature: 23°C). Scanning electron microscopy (SEM) micrographs of *Galenia* leaf surface, stem surface and seeds were done to illustrate the main features of this species. Airdried seeds were mounted on SEM stubs using doublestick tape. Then the seeds were goldcoated and examined with a SEM microscope (FEI Company®, model Quanta® 200).

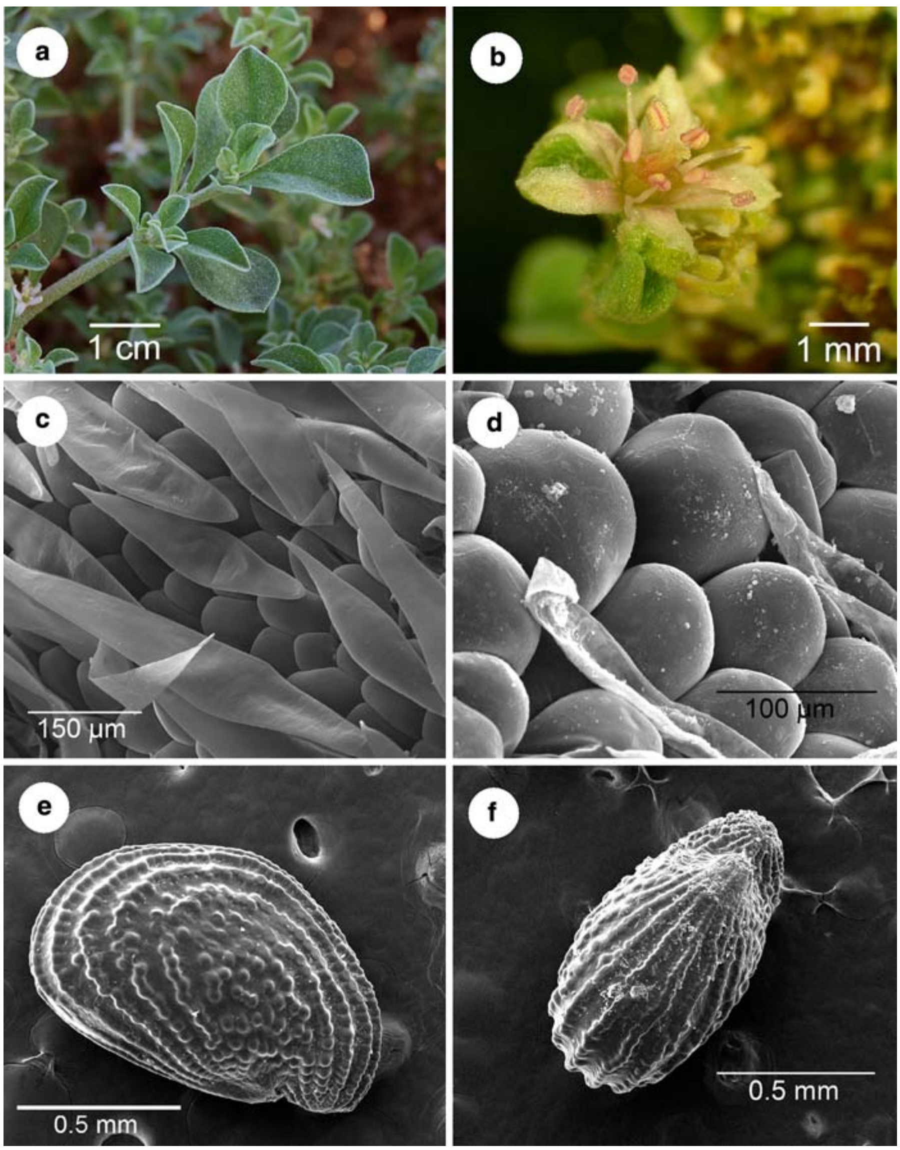

Fig. 1 Leaves (**a**) and flowers (**b**) of *Galenia secunda*. SEM micrographs showing the hairy stem surface with flat, rhomboid trichomes (**c**), the leaf surficial cells (**d**) and seeds (**e**, **f**)

Table 1 Locations and environments colonized by *Galenia secunda* in different parts of the world

Location, Country	Environment	Reference
Kruisrivier, Bloutoring, S Africa	Sandy plain with limestones with karoo vegetation	NBG Herbarium
Avondrus Farm, Touwsrivier, S Africa	Silty plain with karoo-Renosterveld vegetation	NBG Herbarium
De Hoop National Park, S Africa	Sandy-silty plains on limestone	NBG Herbarium
Sprinbok, S Africa	Sandy hills next to a dry riverine bed	NBG Herbarium
Van Rhynsdorp-Bitterfontein, S Africa	Rocky place with quarzites	NBG Herbarium
Rousevlei, S Africa	With succulent karoo vegetation	NBG Herbarium
Stillbay, S Africa	Limestone rocky crests	NBG Herbarium
Calvinia, S Africa	Inland plains	NBG Herbarium
Riversdale, S Africa	Sandy limestone soils	NBG Herbarium
Robben Island, S Africa	–	NBG Herbarium
Albany, S Africa	–	NBG Herbarium
Doringkloof, Voetpadsberg, S Africa	–	NBG Herbarium
Parden-Eiland, Cape Town, S Africa	Sand-dune in the Jakkals rivermouth	NBG Herbarium
Mosselbay, S Africa	Sandy soil with coastal vegetation	NBG Herbarium
Hartenbos rivermouth, S Africa	Sandy soils	NBG Herbarium
Cederberg, Matjiesriver Nature Reserve, S Africa	Gravel sandy soils with karoo vegetation	NBG Herbarium
Signal Hill, Cape Peninsula, S Africa	–	NBG Herbarium
Port Elisabeth, S Africa	–	NBG Herbarium
Zwartkop River, Uitenhage, S Africa	Sandy soils beside the river	NBG Herbarium
Escambia, Florida, USA	–	R. Wunderlin, pers. com.
New Jersey, USA	–	FNA Editorial Committee (1993)
Kalgoorlie, SW Australia	Inland	Macfarlane et al. (2000); Western Australia Herbarium (WAH)
Perth and Medina, W Australia	Coastal	Macfarlane et al. (2000) (WAH)
Albany, SW Australia	–	Macfarlane et al. (2000) (WAH)
Denham-Monkey Mia, W Australia	Coastal	Macfarlane et al. (2000) (WAH)
Yorke Penninsula, Wallaroo and Portwakefeld, Australia	Coastal	Transport SA (2000)
Coquimbo and Valparaiso Regions, Chile	Used for slope fixation	Squella et al. 1986; Ovalle et al. 1993
San Juan de La Arena, Asturias, N Spain	Fine sand in coastal dunes	University of Oviedo Herbarium
Cadiz, S Spain	Coastal	This study

Leaf samples were dehydrated in an ascending series of acetones, critical-point dried, sputter-coated with gold, and examined with SEM microscope.

The distribution surveys were conducted in a total of 42 sites. Neighbour locations were separated by at least 250 m and showed different habitat features such as soil type and accompanying flora. Each site was GPS positioned and the *Galenia* coverage was measured in 10×10 m plots ($n = 3$) according to the following criteria: 1 (coverage = 1–25%), 2 (25–50%), 3 (50–75%) and 4 (>75%). The size of the site invaded was then measured on aerial images with a surface tool using Sigpac® 5.0 software from the Spanish Ministry of Agriculture. Update distribution data (June 2007) served to calculate the extent of occurrence and the area of occupancy according to IUCN criteria version 3.1 (IUCN 2001).

Results and discussion

From revision of localities given in Table 1, *Galenia* preferably colonized environments that have

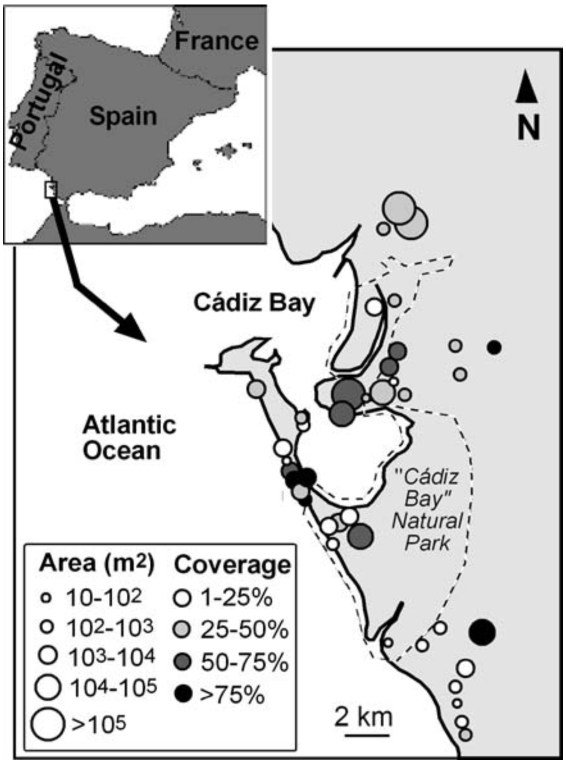

Fig. 2 *G. secunda* distribution in Southern Spain, showing the different locations. The size and color of the circles indicate the surface and the coverage of each location (see legend). The dashed line indicates the limits of the Cádiz Bay Natural Park

Mediterranean and sub-desert climates. Native populations (South African) included mainly inland locations with karoo vegetation but also some coastal areas. Sandy, silty or rocky soils seem to be invariably colonized. In Southern Spain, most sites invaded are inside and surrounding the Cadiz Bay Natural Park (36°32′N, 06°10′W) (Fig. 2), which constitutes an area for wildlife conservation according to the Council Directives 92/43/EEC and 79/409/EEC. The distribution survey revealed that one-third of the invaded sites underwent the formation of dense monospecific mats (coverage $\geq$ 50%) (Fig. 2), which may involve the displacement of native flora (e.g., D'Antonio and Mahall 1991; Williams and Baruch 2000; D'Antonio and Hobbie 2005). Among the habitats invaded, most locations are associated with human-disturbed environments due to recent coastal development (urbanizations, roads, railways, etc.), representing 87.9% of the total area invaded (Fig. 3a, b). However, a number of the invaded areas belong to coastal natural habitats such as sand dunes (1.3% of the total area invaded), saline soils beside saltpans (7.0%) and occasionally pinewoods (2.6%) or scrubs (1.0% of the total area invaded) (Figs. 3b, 4). Among these habitats, dunes and degraded soils demonstrated the highest coverage (Fig. 2). *G. secunda* was more often found near roads (0–25 m) (Fig. 3d), because roads facilitate seed dispersal (Gabbard and Fowler 2007). From the net area of locations found, an area of occupancy of 91.9 ha and an extent of occurrence (not including aquatic environments) of 14,250 ha were calculated, thus suggesting an early stage of invasion. Since the first citation in 1965 (Molesworth 1976), our data support that a rapid spread and invasiveness (sensu Ricciardi and Cohen 2007) is occurring for this species, which was likely favored by the intense transformation in Southern Spain during the last two decades. Four lines of evidence suggest that *Galenia* will continue to spread throughout this region. (I) Roads and trails are known to be factors that favor non-native plant species (Spellerberg 1998). (II) There is heavy vehicle and human traffic within the extent of occurrence (CMA 2006). (III) Currently, there is a high rate of land transformation and ground disturbance. Disturbance reduces the ability of native vegetation to compete, increases the invasibility of ecosystems and increases the survival for pioneer plant invaders (e.g., Hobbs and Huenneke 1992; Lonsdale 1999; Davis et al. 2000). (IV) *Galenia* seeds are small, which is among the typical features of invasive plants (Kolar and Lodge 2001). For these reasons, control measures should be developed before this species gets out of hand and to prevent expansion to other regions with Mediterranean climates. These data support that the habitat preferences of *Galenia* are recently disturbed soils. However, because of its occurrence in other Mediterranean-climate areas and the ability to colonize coastal natural habitats such as dunes, we recommend that further studies are carried out on the invasion potential of *Galenia* and impacts provoked in native plant communities. Our data serve as a base for surveillance of the spread of *Galenia* in the future. Control measures should be developed before this species gets out of hand and to prevent expansion to other regions having a Mediterranean climate.

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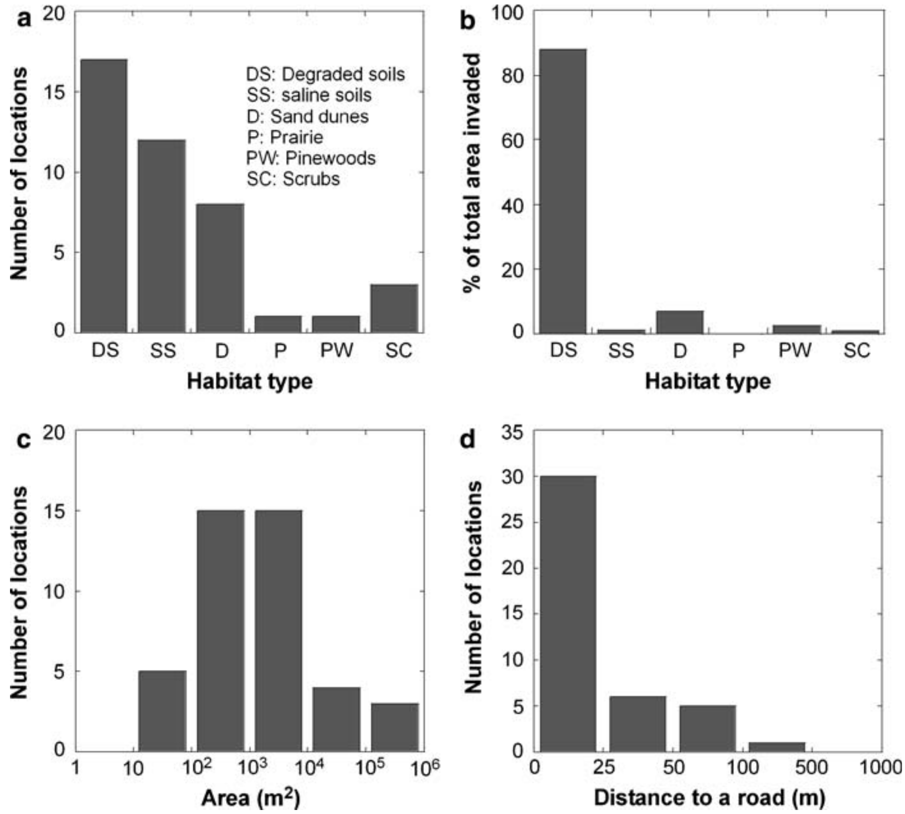

Fig. 3 Histograms showing the number of *G. secunda* locations and the percentage of total area invaded for each habitat type (**a**, **b**), the size of the area invaded and the mean distance to a road (**c**, **d**) for each location where *G. secunda* was found

Fig. 4 *G. secunda* mats colonizing disturbed areas such as degraded soils (**a**) and railway borders (**b**) and natural habitats such as dunes (**c**) and saline soils within saltpans (**d**)

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