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Conservation status of the threatened Iberian Peninsula narrow endemic *Antirrhinum lopesianum* Rothm. (Scrophulariaceae)

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Abstract

Antirrhinum lopesianum Rothm. is a narrow endemic of the Lusitan Duriensean biogeographical sector (central western Spain and north-eastern Portugal). The species is listed as threatened in several Spanish documents, although it does not figure as such in any Portuguese document. This paper provides a detailed study of its distribution, estimates of the sizes of its populations, the threats it faces, and its current conservation status. The total number of individuals thought to exist is only 768, distributed along the valley of the River Duero on the Spanish–Portuguese border (562, 71.2%), and in the Portuguese Sabor River valley (206, 26.8%). The main threat to the species is loss of habitat: about one third of the Iberian populations can be considered threatened; one population containing 37.6% of all these plants (289) is severely threatened. To determine the Area of Occupancy and the Extent of Occurrence, an exhaustive bibliographical survey was carried out, and herbarium specimens deposited in several institutions were revised. It is, therefore, classifiable as Critically Endangered in Portugal and Endangered in Spain.

Key words: Antirrhinum lopesianum, *area of distribution, conservation, endangered species, habitat fragmentation, Iberian Peninsula, Scrophulariaceae, stenoendemic*

Introduction

Approximately one-fifth of the native plant species of the Iberian Peninsula are threatened to some degree (VV.AA., 2000). Numerous studies show that narrow endemics are susceptible to extinction for a variety of reasons, one of the most important being the destruction of their habitat (Lande, 1988; Schemske et al., 1994; Romero et al., 2004). The Mediterranean Basin is considered one of the Earth's hotspot areas for biodiversity (e.g., Myers et al., 2000), and its rupicolous plants constitute one of the endangered groups in the Mediterranean flora, basically as a result of anthropic habitat destruction and alteration. This ecological group includes European and Mediterranean taxa such as *Antirrhinum lopesianum* Rothm., a chamaephyte which grows on calcareous substrates such as sites close to watercourses (González-Talaván et al., 2003; Amich et al., 2004). This species is endemic of the western Iberian Peninsula with a disjunct distribution in some localities of the Duero (Portugal and Spain) and Sabor Basins (Portugal) (Bernardos et al., 2004a, b).

It is widely recognized today that the primary strategy for nature conservation is the establishment and maintenance of a system or network of protected areas. The majority of the territories studied in this work belong to the Natural Park of Las Arribes del Duero (Spain) and the Natural Park of Douro International (Portugal). However, the simple presence of a species in a Protected Area is no guarantee of its conservation (Huntley, 1999; Heywood & Iriondo, 2003; Bernardos et al., 2006).

A. lopesianum has been listed as a threatened species in the Habitats Directive 92/43/EEC (Annex IV; Anonymous, 1992). In Spain it is listed in various documents (Anonymous, 1995, 2001) and in various compilatory works on threatened flora (VV.AA., 2000;

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González-Talaván et al., 2003, 2004), in which it appears as Endangered (IUCN, 2001). In Portugal, by constrast, *A. lopesianum* does not appear in any threatened checklist (e.g., Dray, 1985) nor have studies been made on its distribution and conservation status. Since Castilla y León is one of the few Spanish Autonomous Communities that has no official catalogue of protected plants (see Moreno Saiz et al., 2003), *A. lopesianum* enjoys no protection in that region, in spite of being an endangered species.

This taxon belongs to *Antirrhinum* section *Kickxiella* (Rothm.) Fern. Casas, a small group (six species) of rupicolous species that grow on calcareous or siliceous substrates, and have discontinuous and restricted distributions (Fernández-Casas, 1997) that may have originated in the climatic and topographic changes that occurred during the Pleistocene (Davis, 1951).

The aim of the present work was (i) to determine whether the species is still present in the localities where it has been cited, (ii) to survey new areas with habitats suitable for the species and thus establish its present distribution, (iii) to determine whether its numbers have fallen in any population in order to establish if its overall distribution and population sizes are in decline, and (iv) to determine the threatened category of *A. lopesianum* in Portugal and Spain.

This paper is part of a research project in which the genetic structure of the populations of *A. lopesianum* was also studied as well as determinants of reproductive success, and the main ecological features of their habitats (Bernardos et al., 2004b). The general purpose of the research was to obtain an accurate diagnosis of the status of the species through an integrated approach, and to establish the main factors that determine the viability of the population.

Materials and methods

The nomenclature used for taxa cited in the text was that of Flora Iberica (Castroviejo et al., 1986–2003), except for *Scrophularia valdesii* Ortega Olivencia & Devesa in Candollea 46, 115. 1991 (= *S. grandiflora* subsp. *reuteri* sensu Amich, Anales Jard. Bot. Madrid 36, 295. 1980, non Daveau (1892). The syntaxonomy of the plant communities mentioned follows the criteria of Rivas-Martínez et al. (2001, 2002). A Garmin e-map GPS was used for geographically locating the populations using 1 × 1 km coordinates.

Characteristics and habitat of the studied species

Antirrhinum lopesianum (Figure 1) is a perennial chamaephyte with woody stems and very lanuginose leaves; corolla 22–25 mm, white, with violet stripes and white-yellowish palate; fruiting calyx 5.5–7 mm, with pedicels of 20 mm; capsule 8–8.5 mm, normally extending beyond the calyx, with many seeds. *A. lopesianum* flowers in spring (April–May) and fruits in summer (July–September); insect-pollinated; seeds dispersed by barochory/semachory (Amich et al., 2004). Its chromosome number is $2n = 16$ (Amich et al., 1989). Although many viable seeds are produced in the capsules, these plants show a strong capacity for vegetative propagation via the production of new shoots with many adventitious roots that form in the wet season. This strategy appears important for the species' biology, and explains its characteristic ''contagious-patchy'' microdistribution.

Figure 1. *Antirrhinum lopesianum*. Portugal, Bragança, Alfaião, 17 April 2004, *Amich & Bernardos* (SALA 108738). (A) flowering branch. (B) branch with fruiting calyxes and capsules. Scale bars: 1 cm.

The species grows on calcareous rocks on the banks of the River Duero (north-eastern Portugal and central western Spain) and River Sabor (north-eastern Portugal). Along with other endemic species of the central western Iberian Peninsula (i.e., *Dianthus lusitanus* Brot., *Scrophularia valdesii* Ortega-Olivencia & Devesa, *Silene coutinhoi* Rothm. & Pinto da Silva), it is a member of the highly specialized rupicolous communities of the association *Phagnalo saxatilis-Antirrhinetum lopesianii* Bernardos et al. 2004 (*Rumici indurati-Dianthion lusitani* Rivas-Martínez et al. 1973 *ex* Fuente 1986 alliance, *Phagnalo-Rumicetea indurati* (Rivas Goday & Esteve 1972) Rivas-Martínez et al. 1973 class) (Bernardos et al., 2004b).

As proposed by Moreno Saiz et al. (2003), the systematics and chorology of rare plants should be

reviewed periodically, especially of those posing taxonomic problems. *Antirrhinum lopesianum* certainly falls under this heading (Webb, 1972; Sainz Ollero & Hernández Bermejo, 1981). Our analysis confirms its clear morphological separation from the Pyrenean taxon *A. molle*, as suggested by Amich et al. (1989); Vargas et al. (2004) also indicate some morphological characters that allowed the two species to be distinguished. Its chorology and phytosociological behaviour are also clearly different: *A. molle* is characteristic of the alliance *Valeriano longiflorae-Petrocoptidion* F. Casas 1972 (*Petrocoptido pyrenaicae-Sarcocapnetea enneaphyllae* Rivas-Martínez et al., 2002 class) (Rivas-Martínez et al., 2002).

Plant material and population sizes

All the sites in the Iberian Peninsula where *A. lopesianum* has been reported (see Table I) were visited over the period 2000–2004. Other sites thought suitable for this taxon along the River Duero and its tributaries (the rivers Agueda, Côa, Huebra, Sabor, Tormes and Uces) were also surveyed. A Zodiac boat was used to help survey the Duero valley during the spring and autumn of 2003 and 2004, which allowed us to reach places that otherwise would have been impossible to explore, due to the geomorphological complexity of these territories ("*Arribes*").

Our estimate of the size of the Iberian populations was based on our own census data from those sites at which we found the species. All censuses were performed by direct counting of all potentially reproductive individuals (i.e., reproductive cluster).

Determining the Minimum Viable Population (MVP) is one of the most important objectives in conservation biology (e.g., Akcakaya et al., 1999). The concept of MVP depends on a series of factors such as the type of growth of the taxon, the fecundity, the asexual reproduction, the longevity of the seeds, etc. In order to simplify the evaluation of the MVP we have used guide values, following the indications offered by different authors (Mace & Lande, 1991; Given, 1994; Falk et al., 1996; Blanca & Marrero, 2003).

Results

Distribution and chorology

We first reviewed the published data on the distribution of this species and additionally revised the major

Table I. Listing of UTM 1 × 1 km^2 grid squares containing *A. lopesianum* sites, with the corresponding references and/or herbarium vouchers for each.

Population no.	UTM (1 × 1 km^2)	Altitude (m)	Localities	Source	Voucher
1	29TPG9125	460–470	PO: Trás-os-Montes, Bragança, Alfaião	Rozeira (1944), Bernardos et al. (2004b)	COI *s.n.*; SALA 108476, 108477,108738, LISU 33459, 33460
2	29TPG9225	470–480	PO: Trás-os-Montes, Bragança, Grijó de Parada	Bernardos et al. (2004a, b)	BRESA 1615, 3927; LISI *s.n.*; SALA 108474, 108475
3	29TPG91	450	PO: Trás-os-Montes, Vimioso, Argoselo, Teixo	Miranda Lopes (1926)	LISE 85713
4	29TQG0309	450–475	PO: Trás-os-Montes, Vimioso, Carçao	Bernardos et al. (2004a, b)	BRESA 2466; SALA 108472, 108473
5	29TQF2899	525	SPA: Zamora, Torregamones	Bernardos et al. (2003)	SALA 108739
6	29TQF1982	400	PO: Trás-os-Montes, Miranda do Douro, Sendim	This work	SALA 108757
7	29TQF1881	400–425	SPA: Zamora, Pinilla de Fermoselle	Bernardos et al. (2004a)	SALA 108756
8	29TQF0168	350–375	SPA: Salamanca, Corporario, El Rostro	Amich et al. (1989), Bernardos et al. (2004b)	PO 53316; SALA 45117, 45118, 45354, 84008, 108736
9	29TPF9968	330	PO: Trás-os-Montes, Mogadouro, Villarinho dos Galegos	This work	SALA 108737
10	29TPF9968	330–350	SPA: Salamanca, Aldeadávila de la Ribera	Bernardos et al. (2004a)	SALA 108448

herbaria of the central western Iberian Peninsula (BRESA [Escola Superior Agrária de Bragança, the acronym that has still not been recognized in the Index Herbariorum (Holmgren et al., 1990)], COI, HVR, LEB, LISE, LISI, LISU, PO and SALA) (Table I). In addition to the eight localities already known, two more were recorded. The total known localities are show in Figure 2. *A. lopesianum* was found to be a narrow endemic of the Lusitan Duriensean biogeographical sector (Carpetan Leonese subprovince, Mediterranean West Iberian province, according to Rivas-Martínez et al., 2002), with a small group of Portuguese populations in the high and middle areas of the Sabor Basin, and another small group in the Duero Basin where the river forms the Spanish–Portuguese border. The species' altitude range was from 325 m for the populations in the south of the Duero Depression (Aldeadávila de la Ribera and Vilarinho dos Galegos) up to 525 m for the Torregamones population in Spain. The northern and western limits of the taxon were marked by the Alfaião population in Portugal (41°45′40″ N, 6°41′55″ W), the eastern limit by the Torregamones population in the Spanish Province of Zamora (41°30′56″ N, 6°14′33″ W), and the southern limit by the Aldeadávila population in the Spanish Province of Salamanca (41°14′32″ N, 6°37′53″ W). Figure 2 shows the triangle corresponding to the Extent of Occurrence of *A. lopesianum*, which is limited by the populations at points A (Portugal: Alfaião), B (Spain: Torregamones) and C (Spain: Aldeadávila de la Ribera). This area covers some 12,500 km^2. The Area of Occupancy by the species was estimated at 29,000 m^2 (13,000 and 16,000 m^2 in Portugal and Spain, respectively), according to grid addition area (IUCN, 2001).

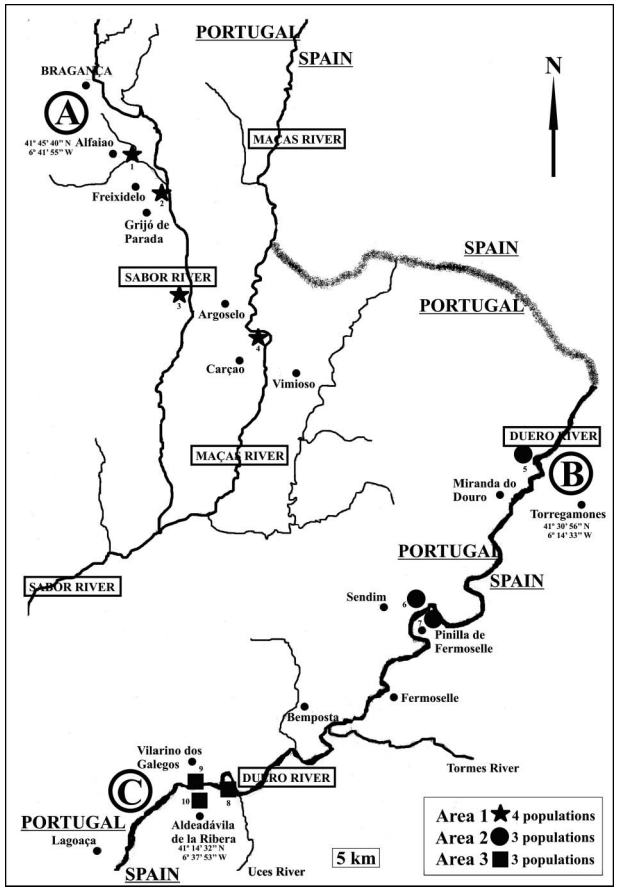

Figure 2. Map showing the current area of distribution of *Antirrhinum lopesianum* in the central western Iberian Peninsula. The Extent of Occurrence (12,500 km^2) is limited by points (A) Alfaião, Portugal, (B) Torregamones, Spain and (C) Aldeadávila de la Ribera, Spain. Scale bars: 5 km.

Population size and trends

The populations showed an essentially linear spatial distribution of individuals along the banks of the rivers. The localities where *A. lopesianum* was found can be grouped into three well-differentiated areas (see Figure 2). Area 1 (Portugal: North of Trás-os-Montes) is located in the depression of the River Sabor and the mid-depression of the River Maças, and is composed of four populations (Table II) – one not confirmed – separated by an average of 17.5 km (56, 53 and 97 individuals, respectively). Areas 2 and 3 lie on the banks of the River Duero where it forms the Spanish–Portuguese border, the former in the northern zone between the villages of Torregamones and Pinilla de Fermoselle/Sendim, the latter further to the south between Corporario and Aldeadávila de la Ribera/Vilarinho dos Galegos. The distance between these two areas is approximately 29.5 km. Area 2 comprises three populations separated by a maximum distance of 15 km and contains 13, 21 and 93 individuals, respectively. Area 3 includes three populations situated on either side of the River Duero and with 289, 57 and 89 individuals, respectively.

The highest density occurred in grid squares 29TPF9968 and 29TQF0168, and corresponded to area 3 (a total of 435 specimens). The region containing the majority of the members of this species was the Duero depression, with more than 56% (see Table II) of the current Iberian populations of *A. lopesianum*. This territory lies within Las Arribes del Duero Natural Park/ Douro Internacional Natural Park; even so, several sites are affected by anthropic habitat degradation caused by recreational and tourist activities. In contrast, the sites located in the north of the Trás-os-Montes region (which comprises about 26.8% of total members of the Iberian populations, see Table II), and that enjoy no protected status, are not excessively affected by human activities.

Three of the four Spanish populations have been cited recently (number 5, Bernardos et al., 2003; numbers 7 and 10, Bernardos et al., 2004a; see Table I).

Table II. Estimated numbers of individuals of *A. lopesianum* in its known population areas, and current habitat protection and principal threats. Abbreviations: PO: Portugal; SPA: Spain; A: human activities; B: biotic interactions. 1: Moderate impact; 2: Severe impact; 3: Critical impact.

Cluster, country no. and UTM	Population no.	No. individuals	% total population	% total individuals	Habitat protection	Threats/impact	
						A	B
Area 1 (PO)							
29TPG9125	1	56	11.1	7.3	No protection	No	No
29TPG9225	1	53	11.1	6.9	No protection	1	2
29TPG91	1 (No confirmed)	–	–	–	No protection	–	–
29TQG0309	1	97	11.1	12.6	No protection	1	2
Area 2 (PO & SPA)							
29TQF2899	1	13	11.1	1.7	Natural Park	No	No
29TQF1982	1	21	11.1	2.7	Natural Park	No	No
29TQF1881	1	93	11.1	12.1	Natural Park	No	No
Area 3 (PO & SPA)							
29TQF0168	1	289	11.1	37.6	Natural Park	3	2
29TPF9968	2	57 + 89	22.2	19.0	Natural Park	No	No
Total PO	5	284	55.5	37	–	–	–
Total SPA	4	484	44.4	63	–	–	–
Total Iberian Peninsula	9	768	100	100	–	–	–

Of the six Portuguese populations, two are reported here for the first time (Table I). Of the remaining four populations we only have data from one of them. Therefore, we can only provide an estimate of the recent changes in the number of *A. lopesianum* plants for two populations, one Spanish (number 8, Corporario) and one Portuguese (number 4, Carçao). Both of them have seen a fall in their numbers over the period 1990 – 2004, although this reduction in numbers of individuals has not been statistically significant (4% and 7.6%, respectively) (Figure 3).

The MVP for this taxon is estimated to be around 100 – 150 individuals, according to the criteria previously indicated and to the characteristics of *A. lopesianum*: perennial species, growing in climax habitats, and having a lifespan of 25 – 50 years.

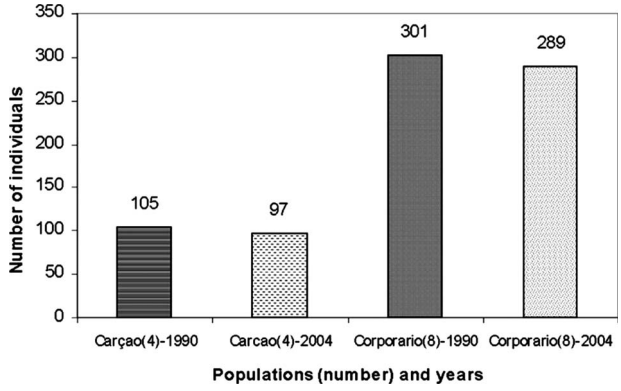

Figure 3. Estimated reduction in the number of individuals of the populations of Carçao (number 4) and Corporario (number 8) from 1990 to 2004.

Discussion

Accurate data on the distribution of a plant species are of key importance in conservation biology. Erroneous distribution assessments frequently lead to incorrect evaluation of conservation status (Valdés et al., 2000). One of the aims of this work was to obtain a better knowledge of the distribution of this species; thus, field studies were undertaken throughout the area of its distribution. This allowed us to confirm the presence of the species in all of its previously reported sites, except for the 'locus classicus' of *A. lopesianum* – population number 3 –, and to record two new sites.

The MVP for this taxon is estimated to be around 100 – 150 individuals. Since the Portuguese populations are smaller than the MVP (see Table II), it might be concluded that their distribution is very highly fragmented (see Blanca & Marrero, 2003). In Spain, more than 60% of the members of this species were concentrated in only three populations larger than the MVP (see Table II); its fragmentation in Spain is, therefore, high (see Blanca & Marrero, 2003). Thus, although the populations are geographically scattered, and might even show quite an ample genetic diversity – as indicated for other members of the genus whose distribution is equally restricted (see Torres et al., 2003) – although there are few data on this topic (Mateu-Andrés, 1999; Bernardos et al., unpub. data), one third of its populations, even including some that enjoy protected status, are currently threatened. A draft conservation policy for *A. lopesianum* might be based on the conservation of natural habitats by reducing human presence and decreasing recreational pressures, and on the reinforcement of some natural populations by introducing new individuals in the mother populations.

Such high fragmentation can lead to several problems. Many studies suggest that small populations generally have less variation than large ones (Oostermeijer et al., 2003). It is related with population size and also with inbreeding. Though the estimated mean number of seeds produced per plant is high (726), suggesting that population viability is not presently limited by seed output, inbreeding phenomena are common in small isolated populations (Oostermeijer et al., 2003), and not all seed may be viable or be able to develop a healthy new plant; seeds have less efficiency in these cases. Due to the habitat of *A. lopesianum* (rocky cliff), the majority of produced seeds may fall, and we should consider this phenomenon as an emigration. All these circumstances suggest that the number of seeds produced is not enough to maintain the population.

In addition, smaller populations are more prone to demographic, environmental and genetic stochasticity as well as Allee and edge effects (e.g., Lande, 1988, 1998). Allee effects (Allee et al., 1949) for plants mainly involve the difficulty of the ovules being fertilized when populations become small and density decreases (Oostermeijer et al., 2000; Hackney & MacGraw, 2001). Simulation studies (Menges, 1991, 1992; Lande, 1993, 1998) have shown that demographic stochasticity is only relevant in very small populations ($N < 50$), and *A. lopesianum* has five populations (55.5% of the total) with < 50, or between 50 and 57, old members.

Along with the problems that this high fragmentation raises, another important threat to the survival of the species is the impact of human activity on several of its populations. Population number 8, the largest (289 individuals), is seriously threatened by the development of the surrounding area, which includes the laying of an artificial beach on the banks of the Duero, new roads and paths, and the construction of picnic sites. Other populations (numbers 1 and 4) are under threat because they are close to roads and agricultural tracks.

The species is also threatened by a series of intrinsic factors, such as the enormous difficulty it faces in reproduction by seed and biotic interactions, which have been reported as important in other threatened taxa (see Svensson & Carlsson, 2004). These factors need to be taken into account in the design of conservation strategies. At the sites of the populations most affected by human activity, we observed a large increase in the anthropization of the habitat, and the introduction of semi-shaded nitrophilous plant communities belonging to the alliances *Galio-Alliarion petiolatae* Oberdorfer & Lohmeyer in Oberdorfer et al. 1967 and *Pruno-Rubion ulmifolii* O. Bolòs 1954. These eventually prevent the development of the phytocenosis to which *A. lopesianum* belongs (*Phagnalo saxatilis-Antirrhinetum lopesianii*), with the consequent reduction in the size of its populations (see Figure 3).

A. lopesianum is an interesting example of a transborder (Portugal and Spain) narrow species, and conservation responsibilities should be shared between both conservation administrations. This is very important in order to elaborate conservation programmes (Thompson, 2005). Though both countries are under the same legislation (Habitats Directive 92/43/EEC, Anonymous, 1992), the species has a different threatened status (see Introduction), which raises limitations to effective species conservation.

We consider that adopting legal measures of protection (as has been proposed to the Castilla y León Autonomous Government), and creating several IPAs in the territories where *A. lopesianum* grows, are immediate actions that should be taken.

Conclusions

We have insufficient historical data to precisely quantify the population decline suffered by the species, but the high fragmentation of its populations, which are few in number and rather small, suggest that *A. lopesianum* is a rare and threatened species.

The current status of *A. lopesianum* in Portugal can be defined as Critically Endangered based on IUCN criteria (IUCN, 2001), i.e., area of occupancy less than 10 km^2, severely fragmented, number of mature individuals declining, and only 284 mature individuals in total: CR B2ab(v).

The current status of *A. lopesianum* in Spain can be defined as Endangered by IUCN criteria, i.e., area of occupancy less than 500 km^2, severely fragmented, declining number of mature individuals, less than 2,500 mature individuals in total, with only one population with more than 250 individuals: EN B2ab(v); C2a(i); D.

In this step, the IUCN Red List Criteria are applied to the regional population of the taxon, and all the data used in this initial assessment belong to the regional population (IUCN, 2003). However, because we have not observed any significant immigration of propagules capable of reproducing in the region, and according to the conceptual scheme of the procedure for assigning an IUCN Red List Category at the Regional level (IUCN, 2003), it would not be necessary to change the preliminary categorization.

Our study provides some insights into the factors that threaten *A. lopesianum*. Work is needed on the flowering phenology, plant size, and breeding system of the species in order to assess the main factors affecting female reproductive success. Studies of this kind have previously supplied important data in this respect (see Torres et al., 2002).

The goals, intensity and methods of intervention (i.e., population reinforcement, translocation, restoration) should be carefully determined (Maunder, 1992; Brown, 1994). Proposals have already been made to the authorities of the Arribes del Duero (Spain) and Douro International (Portugal) Natural Parks. Close collaboration and coordination between both authorities would be desirable, since the case of *Antirrhinum lopesianum* is a clear example of a transborder species, with a narrow distribution in both countries.

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