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The narrow endemic *Scrophularia valdesii* Ortega-Olivencia & Devesa (Scrophulariaceae) in the Iberian Peninsula: an evaluation of its conservation status

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Abstract. The aim of this study is to determine the conservation status of *Scrophularia valdesii* Ortega-Olivencia & Devesa, a threatened narrow endemism of the Duero Basin (central-western Spain and north-eastern Portugal, Lusitan Duriensean biogeographical sector), by using the IUCN (2001) IUCN Red List Categories and Criteria: version 3.1. IUCN Species Survival Commision. IUCN, Gland, Switzerland and Cambridge, UK. The species is listed as threatened in several Spanish compilatory works on threatened flora, such as 'The Spanish Red List of Vascular Flora' and the 'Atlas and Red Book of Threatened Vascular Flora of Spain', although it does not figure as such in any Portuguese document. Here we report detailed studies of its distribution, and assess its current conservation status with respect to this, the sizes of its populations, and the threats it faces. Our estimation 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. Fourteen populations were found, and the total members thought to exist are 161, with a highly fragmented distribution on the Spanish–Portuguese border along the valley of the River Duero. Exhaustive bibliographical and field surveys were carried out and herbarium specimens housed in several herbaria were revised in order to determine the Extent of Occurrence and the Area of Occupancy. Based on our data, the species is classifiable as Critically Endangered and Endangered in Portugal and Spain, respectively. The risk of local population extinction is high due to its typically small local population sizes and suitable conservation strategies should be developed in order to preserve the species.

Introduction

Numerous studies show that narrow endemisms are susceptible to extinction for a variety of reasons, one of the most important being the destruction of their habitats (Lande 1988; Schemske et al. 1994; Bizoux et al. 2004; Romero et al. 2004a, b). Because of that, locally endemic taxa are the first to experience the negative effect of habitat destruction or fragmentation (Cody 1986), and endemic species are used to define areas to be preserved (e.g. Rebelo 1994). The

precise evaluation of the conservation status of a particular species is a necessary condition in order to successfully prevent its extinction. An important tool for this purpose is the determination of the degree of threat (or alternatively the expectation of survival) of taxa to which a special significance is attributed. Endemic species seem to be, *prima facie*, more exposed to threats, and therefore the biological features of rare or endemic taxa have been the subject of preferential attention for biodiversity conservation programmes, in particular when threats on their habitat can be clearly identified (Lovett Doust and Lovett Doust 1995; Primack 1998; Mills and Schwartz 2005). One way of evaluating the degree of risk of a given taxon is to assign it to a standardized category of threat. The IUCN Red List Categories and Criteria (IUCN 2001) have been defined for this purpose.

A taxon is considered endemic when its area of distribution is significantly smaller than the average for taxa of the same rank (e.g. Costa 2004). These taxa face a high risk due to their low population number and limited geographic distribution, and a single disturbance on a small scale might trigger extinction. Their habitat isolation might have protected them from some biotic environmental challenges, but it may have rendered them unable to tolerate further changes (Cox 1993). Moreover, in recent times the concept of endemism has trascended the purely scientific realm to achieve geopolitical significance. Endemisms, in addition to being part of the biological heritage of a particular country, are indicators of over-localized biodiversity at the continental level (Ribera 1996).

In Spain, *Scrophularia valdesii* Ortega-Olivencia and Devesa is listed in various documents and compilatory works on threatened flora, in which it appears as Critically Endangered (VV.AA. 2000; Anonymous 2001) or Vulnerable (González-Talaván et al. 2003, 2004). In Portugal, by constrast, *S. valdesii* does not appear in any protection checklist nor studies have 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), *S. valdesii* enjoys no protection in that region and it only appears in one catalogue of Endangered Flora of Arribes del Duero Natural Park (Anonymous 2001), along with four other species. In a recent study on the endemic flora of the Duero Basin (Amich et al. 2004), *S. valdesii* was reported as one of 17 endemic taxa exclusive to the territory. It is also one of 12 species that have been proposed to the authorities of Castilla y León Autonomous Government for inclusion in an Official Catalogue of protected plants (Amich, Rico and Saldaña, pers. com.).

As a first approach, the conservation of rare endemic taxa requires an investigation into their biogeography, including geographic distribution, niche characterisation and particularly the limiting environmental factors and the impact of human factors, both past and present (Dinsdale et al. 1997; de Langhe and Norton 2004). Current knowledge of *S. valdesii* ecology and distribution is still incomplete.

In the present study, we consider the populations of *S. valdesii* in the Duero Basin and its affluents. Specifically, is this species genuinely rare, or has it simply been not studied enough? Is its Iberian distribution really well known? Is its global area declining? We also consider population size and trends with a view to assessing its resilience, and catalogue the types of threat to which it is currently subject. Our overall aim is (1) to establish the current area of distribution of this species and evaluate the size of the populations, and (2) to accurately assess its conservation status.

Material and methods

Concerning nomenclature of taxa cited in the text we have followed Flora Europaea (Tutin et al. 1964–1980) and Flora Iberica (Castroviejo et al. 1986–2003). Concerning syntaxonomy of the plant communities mentioned we follow the criteria of Rivas-Martínez et al. (2001, 2002). A Garmin e-map GPS was used to geographically locate the populations using 1×1 km coordinates.

General information on the species investigated

Diverse material of *Scrophularia* collected in the Arribes of Duero area was originally identified by Amich (1980) as *S. grandiflora* DC. subsp. *reuteri* (Daveau) I.B.K. Richardson. Later, studying material collected in the same area, Ortega Olivencia and Devesa (1991a) describe the new species *S. valdesii*. The species was first known only from three Spanish localities in the Duero Basin (Amich 1980; Sánchez Rodríguez 1988; Ortega-Olivencia and Devesa 1991a, 1993). In several studies published during the latest years, *S. valdesii* has been found in some other new localities (Ortega-Olivencia and Rodríguez Liaño 2002; Bernardos et al. 2004a, b; Marcos et al. 2004). Its taxonomic weighting seems to present no problems, and its differences with *S. reuteri* Daveau are clear (see Ortega-Olivencia and Devesa 1991a, Table 3). This taxon belongs to *Scrophularia* section *Scrophularia* subsection *Scrophularia* (Ortega-Olivencia and Devesa 1991a, 1993). The majority of the members of this subsection in the Iberian Peninsula are polyploids ($2n = 58$). This chromosome number is also found in Moroccan and Macaronesian taxa; the Iberian peninsula would therefore appear to be a centre of diversification (Ortega-Olivencia 1989; Ortega-Olivencia and Devesa 1991b).

Scrophularia valdesii (Figure 1) flowers in spring (April–May [June]) and fruits in summer (July–August [September]); insect pollinated; seeds dispersed by barochory/semachory (Amich et al. 2004), as other Iberian endemic *Scrophularia* (Melendo et al. 2003). Its chromosome number is $2n = 58$ (Ortega-Olivencia and Devesa 1991a, b).

The species grows on carbonated and siliceous rocks on the banks of the River Duero (NE Portugal and CW Spain) and along with other endemic

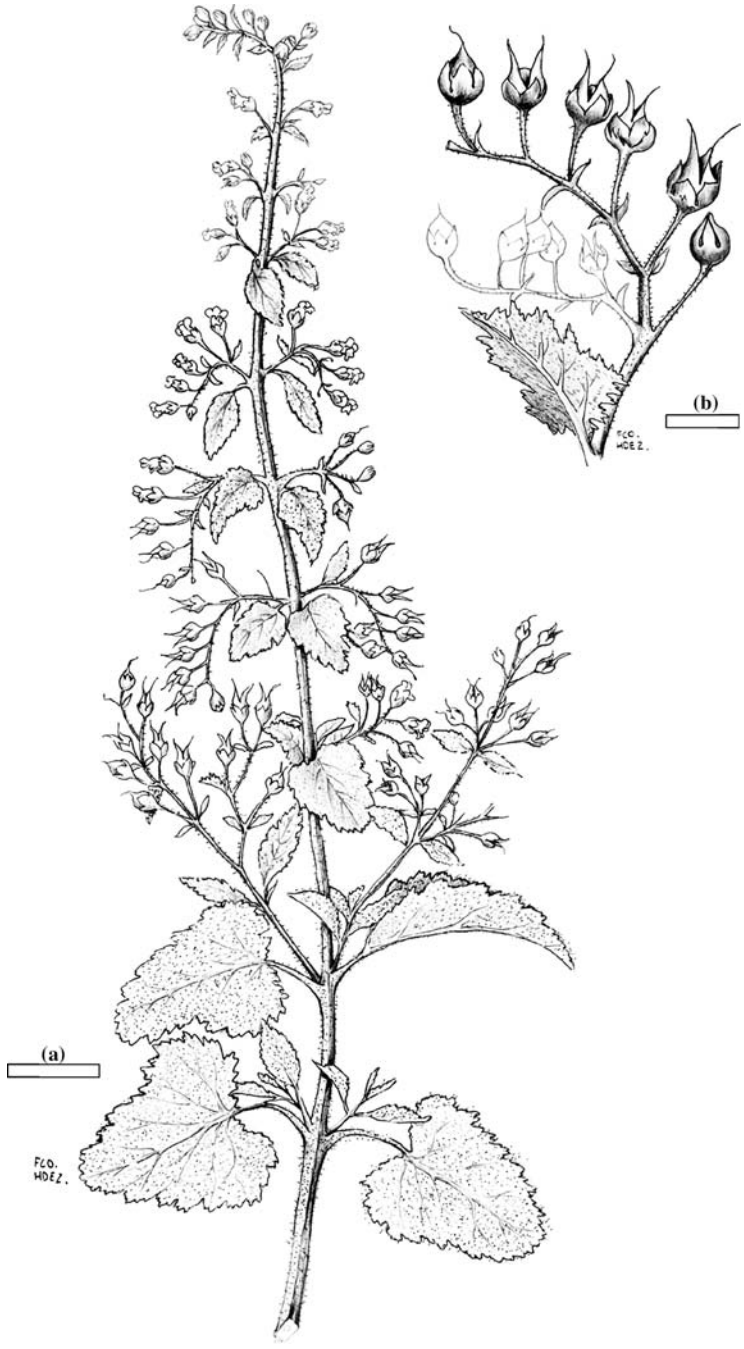

Figure 1. *Scrophularia valdesii*. Spain, Pereña, banks of the River Uces, 15.5.2001, *Amich & Bernardos s.n.* (a) Habit. Scale bars = 1 cm. (b) Branch with capsules. Scale bars = 3 cm.

species of central-western Iberian Peninsula (i.e., *Antirrhinum lopesianum* Rothm., *Dianthus lusitanus* Brot., *Rumex induratus* Boiss. & Reuter, *Silene coutinhoi* Rothm. & Pinto da Silva), it is a member of the highly specialized rupicolous communities of the alliance *Rumici indurati–Dianthion lusitani* Rivas-Martínez et al. 1973 *ex* Fuente 1986, and in several localities it forms a part of the endemic Lusitan Duriensean association *Phagnalo saxatilis–Antirrhinetum lopesianii* Bernardos et al. 2004 (Bernardos et al. 2004b). These habitats could have facilitated speciation of isolated and rare taxa. In addition, these habitats may provide an escape from competition or predation (Domínguez Lozano et al. 2003).

Study carried out and censuses

During the period 2000–2004, we visited all localities in the Iberian Peninsula in which *Scrophularia valdesii* had been reported (see Table 1), as well we also surveyed other areas thought suitable for this taxon along the River Duero and its affluents (the rivers Bemposta, Huebra, Tormes and Uces, see Figure 2). Other watercourses to the south and west, such as the Rivers Agueda, Côa and Sabor were also surveyed. A total of 37 10×10 km^2 UTM squares were visited, and the most important potential habitats were also visited in order to look for new populations. Due to the geomorphological complexity of these territories ('*Arribes*'), on several occasions during the spring and autumn of 2003 and 2004, a Zodiac boat was used to help in our surveys. This allowed us to reach places that otherwise would have been impossible to explore. Since populations have an essentially linear spatial distribution of individuals along the banks of the Rivers, neither binoculars nor telescopes nor the use of 'visual units' (e.g. García et al. 2001) were required. Censuses were performed by direct counting of all potentially reproductive individuals in all those sites at which we found the species. Our estimation of the size of the Iberian populations was based on these censuses.

When the species was detected, we recorded geographical location, habitat, and phenological data (i.e., the presence of vegetative plants, flowering stage, fruiting stage, etc.).

Results

Distribution of Scrophularia valdesii

The literature on the distribution of *Scrophularia valdesii* was reviewed. The species has been recently cited in the Portuguese province of Trás-os-Montes (Bernardos et al. 2004a; Marcos et al. 2004). The main herbaria of the central western Iberian Peninsula (BRESA, COI, HVR, PO and SALA) were also reviewed to help determine the distribution of the species (Table 1). Three new sites (one from Portugal and two from Spain, all along the banks of the River Duero) were added to those already known. The species was not found on the

Table 1. Listing of *Scrophularia valdesii* sites, with the UTM 1×1 km^2 squares, references and herbarium vouchers for each, estimated numbers of individuals in its known populations and current habitat protection and principal threats affecting.

Number of populations and localities	Source	UTM (1×1 km^2)	Altitude (m)	Number of individuals	% of total individuals	Threates (A)	Impact (B)	Voucher
1. PO: Trás-os-Montes, Freixo de Espada-à-Cinta, Quinta de Cova da Barca	Marcos et al. (2004)	29TPF8446	175	10		2	2	BRESA *s.n.*
2. PO: Trás-os-Montes, Miranda do Douro, Aldeia Nova	Marcos et al. (2004)	29TQG3102	520	8		–	–	BRESA *s.n.*
3. PO: Trás-os-Montes, Vilarinho dos Galegos	Bernardos et al. (2004a)	29TQF0169	350	4		–	–	SALA 108455
4. PO: Trás-os-Montes, Miranda do Douro, Sendim	This work	29TQF1982	400	7		–	–	SLIDE 7217
5. SPA: Salamanca, Corporario, El Rostro	Amich et al. (2004), Bernardos et al. (2004a, 2004b)	29TQF0168	350–375	11		3	2	SLIDE 4657
6. SPA: Salamanca, Aldeadávila de la Ribera	This work	29TPF9968	330–350	3		–	–	SLIDE 7223
7. SPA: Hinojosa de Duero, Puente de la Molinera	González-Talaván et al. (2003)	29TPF9044	275	16		1	2	SALA 107234
8. SPA: Salamanca, Pereña, River Uces	Amich (1980), Ortega-Olivencia and Devesa (1991a)	29TQF0366	375–400	31		1	1	MA 332848; SALA 17632, 18702
9. SPA: Salamanca, Aldeadávila de la Ribera, Aldeadávila dam	Amich (1980), Ortega-Olivencia and Devesa (1991a)	29TPF9363	330–350	3		3	3	MA 332846; SALA 15370, 15371, 15446, 18709; UNEX 6022

10. SPA: Salamanca, Saucelle, Saucelle dam	Bernardos et al. (2004a)	29TPF8446	170–190	35		3	3	SALA 88687, 107230
11. SPA: Zamora, Castro de Alcañices	Bernardos et al. (2004a)	29TQG3506	545	4		–	–	SLIDE 4667
12. SPA: Zamora, Fermoselle	(Sánchez Rodríguez 1988), Ortega-Olivencia and Rodríguez-Liaño (2002)	29TQF2074	500	–		–	–	SALA 33148
13. SPA: Zamora, Fornillos de Fermoselle	González-Talaván et al. (2003)	29TQF2382	700	27		1	1	–
14. SPA: Zamora, Pinilla de Fermoselle	This work	29TQF1881	400–425	2		–	–	SLIDE 7231
Total PO: 4				29	18			
Total SPA: 10				132	82			
Total Iberian Peninsula: 14				161	100			

Abbreviations: PO, Portugal; SPA, Spain; A, human activities; B, biotic interactions. 1: Moderate impact, 2: Severe impact, 3: Critical impact.

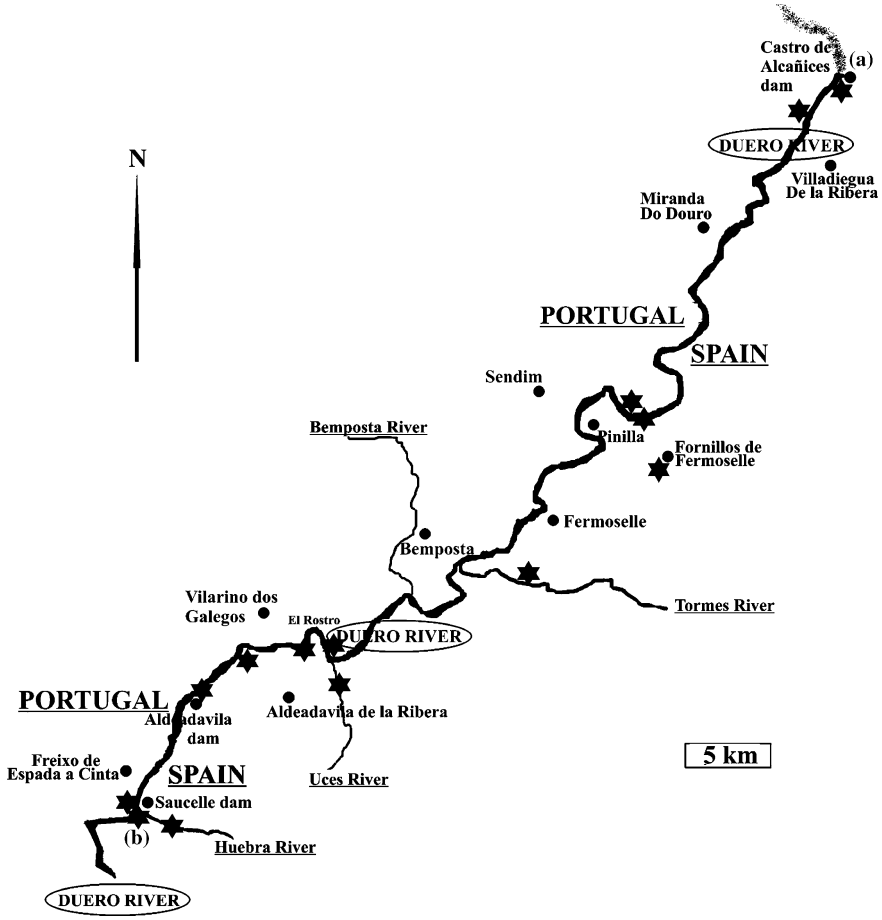

Figure 2. Extent of Occurrence (125 km^2) of *Scrophularia valdesii*, limited by points (a) (Spain: Castro de Alcañices) and (b) (Spain: Saucelle); the known populations are indicated.

banks of the Rivers Águeda, Bemposta, Côa or Sabor. The data obtained were mapped on a 10×10 km^2 UTM grid (Figure 3). *Scrophularia valdesii* was found to be a narrow endemism 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 populations in the Duero Basin where the river forms the Spanish-Portuguese border. The species' altitude range varied from 175 m for the populations in the south of the Duero Depression (Freixo de Espada-à-Cinta and Saucelle, in Portugal and Spain, respectively) up to 700 m for the Fornillos de Fermoselle population in Spain. The northern limit of the taxon was marked by the Castro de Alcañices population (41° 34′ 43″ N, 6′ 11′ 10′ W), and the southern limit by the Saucelle

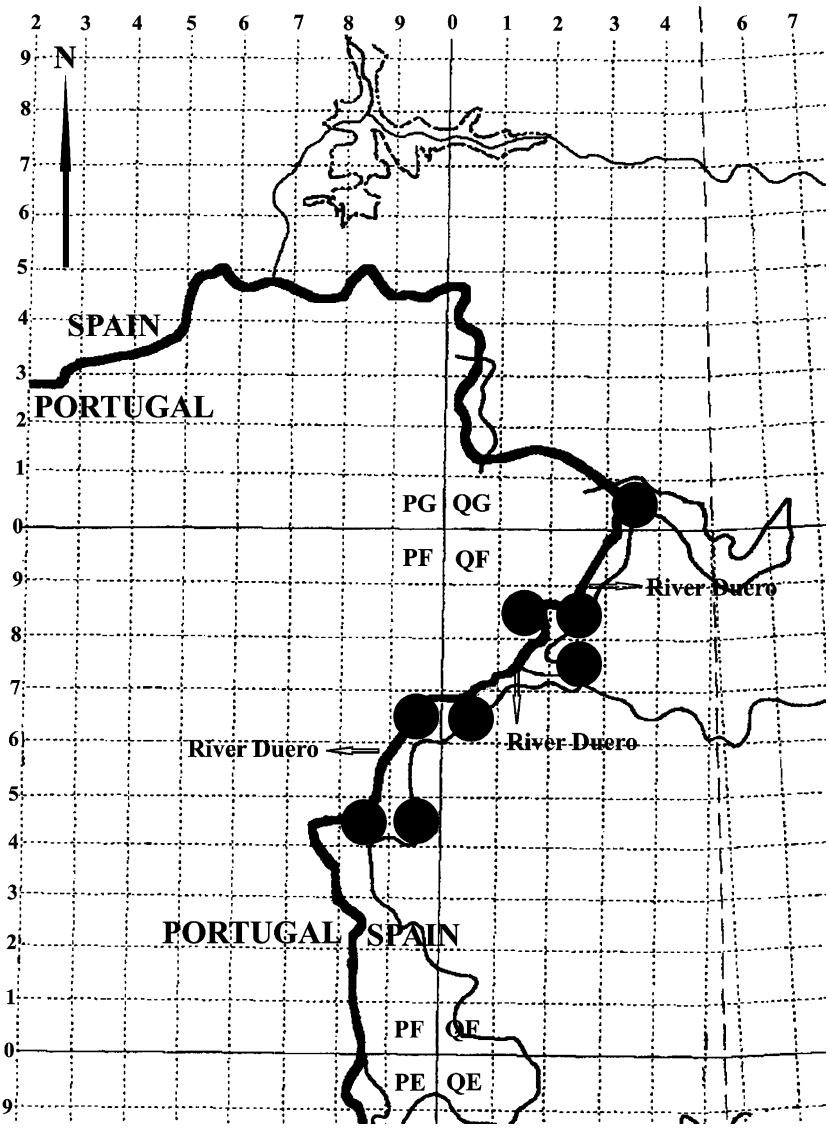

Figure 3. Grid map (10 ×10 km^2 squares UTM) showing the current area of distribution of *Scrophularia valdesii* in Iberian Peninsula.

population in the Spanish Province of Salamanca (41′ 02′ 52″ N, 6′ 48′ 02″ W). Figure 2 shows the Extent of Occurrence of *S. valdesii*, which is limited by the populations at points A (Spain: Castro de Alcañices) and B (Spain: Saucelle). This area covers nearly 125 km^2. The Area of Occupancy by the species was estimated at 1.200 m^2 (200 and 1.000 m^2 in Portugal and Spain respectively).

Estimated number of flowers, fruits and seeds

The number of flowers, fruits and seeds per capsule was counted for all the known populations; very few differences were found between populations. For populations with <10 members (7 populations) the number of flowers and fruits on all individuals were counted. In those with >10 members (6 populations) these variables were recorded for 50% of the plants. The number of flowers per plant oscillated between 20 and 315, depending on the size of the plant, with a mean of nearly 100; almost all the plants fruited normally, producing capsules. In all populations, the main factors that determined the total number of fruits produced by any given plant were the number of flowers and plant size. The relationships between size and flower production/reproductive effort have also been reported for other western Iberian rupiculous endemisms of similar ecological characteristics, such as *Dianthus lusitanus* Brot. (Ballester-Hernández et al. 2003). The mean number of seeds produced per plant was estimated around 8000, allowing us to conclude that population viability is not presently limited by seed output. Although many viable seeds are produced in the capsules, a slight number of them succeed in the germination being it affected by the rupicolous habitat in which *S. valdesii* grows.

Population size and estimated decrease

Scrophularia valdesii is distributed along the Duero River, between the Castro de Alcañices dam, in the North, and the Saucelle dam, in the south, and some of its affluents (Rivers Huebra, Tormes and Uces). To date, a total of 14 populations are known, each of them having a low number of members (see Table 1, Figure 4). The distance between these two extreme localities is approximately 100 km.

The highest density occurred in grid squares 29TPF84 and 29TQF06, with a total of 92 specimens. This region contains the majority of the members of this species in the Iberian Peninsula, with more than 56% (Figure 4) of all currently known individuals of *S. valdesii*. The area lies within Natural Park of Las Arribes del Duero/Natural Park of Douro Internacional; even so, several sites are affected by anthropic habitat degradation caused by tourist and recreational activities.

As indicated above, of the four Portuguese populations, one is reported here for the first time and the remaining three have been very recently reported (see Table 1). Of the ten Spanish populations, two are reported here for the first time, five have been cited recently (number 5, 7, 10, 11 and 13) and only three (numbers 8, 9 and 12) have been known for years. Thus, an estimate can only be ventured for three Spanish populations (Pereña, Aldeadávila Dam and Saucelle Dam) with respect to recent changes in the number of their members. All three populations have seen a reduction in their numbers over the period 1992–2004. Though this was not very significant for the Pereña and Saucelle

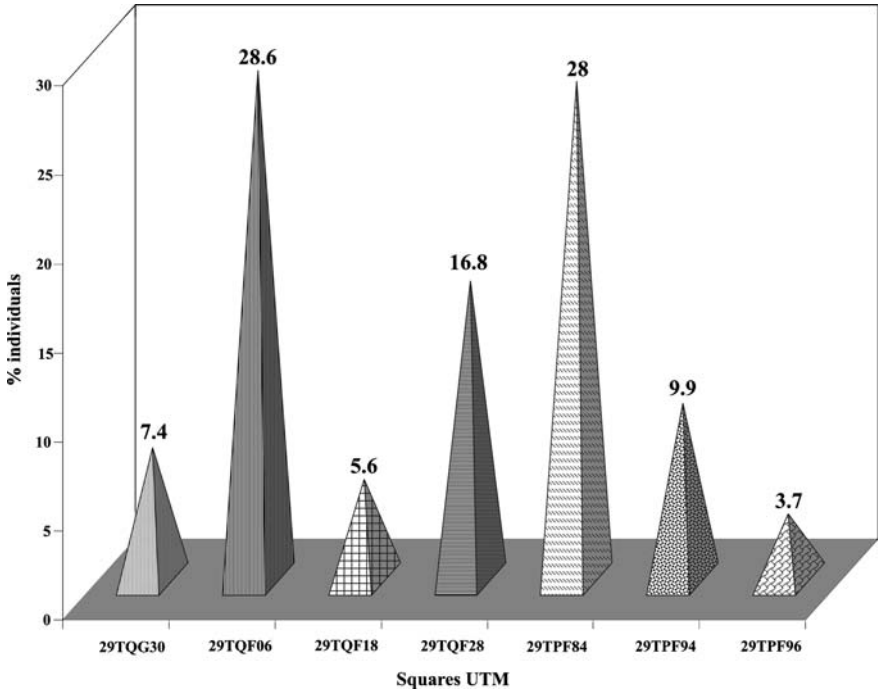

Figure 4. Percentages of the total Iberian populations of *Scrophularia valdesii* within each of the main UTM 10×10 km^2 grid squares.

Dam populations (nearly 16%) (Table 2), the Aldeadávila Dam population lost 90% of its members.

Discussion and conclusions

A plant can be considered as rare because of its small habitat and geographic range, specialization or low population density (Rabinowitz 1981; Olivieri and Vitalis 2001). *Scrophularia valdesii* is a narrow-range endemism of the Duero Basin (Lusitan Duriensean biogeographical sector), ecologically specialized,

Table 2. Estimated reduction in the number of individuals of the populations of Pereña (number 8), Aldeadávila dam (number 9) and Saucelle dam (number 10) from 1992 to 2004.

Years	Populations and number of individuals		
	Pereña	Aldeadávila	Saucelle
1992	37	31	42
2004	31	3	35
% reduction	16.22	90.32	16.66

and with a low number of individuals in its reduced number of populations. This places *S. valdesii* in the second classification group of Fiedler and Ahouse (1992), and most endangered plant species are predisposed to threat by virtue of those characteristics (Kruckeberg and Rabinowitz 1985; Morse 1996).

That is why accurate data on the distribution of a plant species are also of key importance in conservation biology. One of the aims of this work was to determine whether the species is still present in the localities where it has been cited, to survey new areas with habitats ideal for the species and thus establish its true distribution. This allowed us to confirm the species to still be present in all of its previously reported sites, with the exception of population number 12, and to record three new localities.

The Minimum Viable Population (MVP) (Mace and Lande 1991; Given 1994; Falk et al. 1996; Blanca and Marrero 2003) for this taxon (a perennial species growing in climatic habitats, life span <25 years) is estimated to be around 150–200 individuals. Since all Portuguese and Spanish populations were smaller than the MVP (see Table 1), it might be concluded that the distribution of *S. valdesii* is very highly fragmented in the Iberian Peninsula, and one third of its populations, even including some that enjoy protected status, and also the one that has a bigger number of members (35 members, population number 10), are currently very threatened.

Fragmentation processes could be particularly serious when rare plants have low-density distribution and/or poor recolonisation and establishment and their effects are difficult to appreciate in the short term (Domínguez Lozano et al. 2003). Such high fragmentation can lead to several problems. Small populations are also more prone to demographic, environmental and genetic stochasticity, such as Allee and edge effects (Lande 1988, 1998). In plants, Allee effects (Allee et al. 1949) mainly involve difficulties in fertilisation when populations become small and their densities reduced (Oostermeijer et al. 2000; Hackney and MacGraw 2001). Simulation studies (Menges 1991, 1992; Lande 1993, 1998) have shown that demographic stochasticity is important in very small populations ($N < 50$), and *S. valdesii* has all the populations with less than 50 members (between 2 and 35). That means that they are clearly exposed to a higher probability of extinction. In addition, many studies on the genetic variation in several plant species suggest that small populations generally have less variation than large ones (Oostermeijer et al. 2000, 2003).

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. The close relationship between habitat and species highlights human alteration of environments as one of the key elements in the threat of the Iberian rare plants (Domínguez Lozano et al. 2003). Rarity in itself is not synonymous with extinction threats (de Langhe and Norton 2004), but because of their limited geographical and ecological extension, rare endemic taxa are more prone to be driven to extinction by anthropogenic habitat destruction. Moreover, the increase in tourism and outdoor recreational activities has recently been considered as a new major threat to biodiversity

worldwide (Christ et al. 2003). Population number 5, the fifth in number of individuals (11), 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, 9 and 10: 48 members, 30% of total) are under threat because of the enlargement of dams and their proximity to roads and agricultural tracks.

The species is also threatened by a series of intrinsic factors (i.e., competition from other plant communities), reported important in other threatened taxa (see Svensson and 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 (population numbers 1, 5, 9 and 10), a large increase in the anthropisation of the habitat was observed, along with the introduction of semi-shade-loving, nitrophilous plant communities belonging to the association *Chelidonio majoris-Smyrnietum olusatri* Amigo & Romero 1997 (Bernardos et al. 2004a) plus several deciduous shrubby mesophytic plant communities belonging to the alliance *Pruno-Rubion ulmifolii* O. Bolòs 1954 ('zarzales'). These may eventually prevent the development of the phytocenosis to which *Scrophularia valdesii* belongs (*Rumici indurati–Dianthion lusitani*), and lead to a reduction in the size of its populations (see Table 2).

Although elasticity and perturbation analyses were not performed, seed survival in the seed bank could make a major contribution to the long-term persistence of *S. valdesii*. Future research should focus on understanding the factors affecting seed survival and germination.

Current conservation status of Scrophularia valdesii

Insufficient historical data exist 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, as well as the modification and anthropisation of its habitat, suggest *Scrophularia valdesii* should be considered a rare and threatened species. Considering the field observations and the pressure factors that act detrimentally on the plant populations under study, we conclude that the Extents of Occurrence and Area of Occupancy decrease in tight correlation with the alteration of their natural environment, and a significant reduction in population sizes can be anticipated in the near future.

In Portugal, *S. valdesii* can be defined as Critically Endangered in terms of IUCN criteria (IUCN 2001), i.e., (a) it has an area of occupancy of <10 km^2, it is severely fragmented and the number of mature individuals is declining, (b) it has no populations larger than 50 individuals, and (c) only 29 mature individuals are known.

In Spain, the current status of the species can be defined as Endangered by IUCN criteria, i.e., (a) area of occupancy of <500 km^2, it is severely fragmented and shows a declining number of mature individuals, (b) it has no populations of over 50 individuals, and (c) only 132 mature individuals are known.

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 (i.e., number of individuals, reduction, decline, fragmentation) correspond to the regional population (IUCN 2003). However, since no significant immigration of propagules capable of reproducing in the region was recorded, and in agreement with the conceptual scheme of the procedure for assigning an IUCN Red List Category at the Regional level (IUCN 2003), no change in its preliminary categorisation is required.

The present study provides some interesting insights into the threats faced by *S. valdesii*. Further work is needed on the flowering phenology, plant size, breeding system, and genetic structure of the populations of this species in order to assess the main factors affecting female reproductive success and to identify existing or potential threats to the viability of its populations. Studies of this kind have previously supplied important data for other species (see Torres et al. 2002).

With respect to conservation of the species, goals need to be set and intervention methods decided upon (i.e., population reinforcement, translocation, restoration) (Maunder 1992; Brown 1994). Unfortunately, plant conservation demands a combination of social, economic and scientific interests (Grizzle 1994; Schemske et al. 1994) that, at present, are not always compatible (Domínguez Lozano et al. 2003).

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