



## Demographic vulnerability in cliff-dwelling *Sonchus* species endemic to the western Mediterranean

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### Abstract

Species of *Sonchus* section *Pustulati* (*Sonchus masguindalii*, *Sonchus fragilis* and *Sonchus pustulatus*) constitute a group of endemic cliff plants in the Mediterranean region, restricted to narrow non-overlapping areas within the Baetic–Rifan hotspot of plant species diversity. *S. pustulatus* occurs both in SE Spain and N Africa, whereas the other related species are exclusive to N Africa. We characterized all the extant populations of *Sonchus* species (section *Pustulati*) in 2008 by recording population size, demographic structure and reproductive success, and we estimated the population trends for the critically endangered Spanish *S. pustulatus* by repeating censuses in 2013. We also calculated the stochastic population growth rate ( $\lambda_S$ ) and modelled future viability (PVA) of one of the Spanish *S. pustulatus* populations by using matrix models derived from detailed demographic monitoring over a six-year period (2003–2008).

Population sizes ranged between 100 and 22,000 reproductive individuals. In spite of differences in plant size, population protection and anthropogenic disturbance, the life history stage structure of all populations was similar and characterized by a low abundance of seedlings and juveniles, suggesting low recruitment. The population growth rate of Spanish *S. pustulatus* populations ranged between 0.91 and 1.01, and the matrix model showed significant population decline ( $\lambda_S = 0.9042$ ; 95% CI: 0.9041–0.9043). The PVA projected that this population would shrink to a few individuals in approximately forty years under present conditions. Since high temperatures and drought negatively affected the dynamics of this population, ongoing climatic change will jeopardize its future persistence.

### Zusammenfassung

Die *Sonchus*-Arten der Sektion *Pustulati* (*Sonchus masguindalii*, *S. fragilis* und *S. pustulatus*) bilden eine Gruppe endemischer Felspflanzen in der Mittelmeerregion, die auf kleine, nicht überlappende Gebiete im Betikum/Rif-Hotspot der Pflanzendiversität beschränkt sind. *S. pustulatus* kommt sowohl in Südost-Spanien als auch Nordafrika vor, während die anderen Arten der Gruppe nur in Nordafrika auftreten. Wir beschrieben alle bestehenden Populationen der Sektion *Pustulati*, indem wir im Jahre 2008 Populationsgröße, demographische Struktur und Reproduktionserfolg erfassten, und wir bestimmten die Populationsentwicklung für die kritisch gefährdete spanische *S. pustulatus*, indem wir die Erhebungen 2013 wiederholten. Wir berechneten auch die stochastische Populationswachstumsrate ( $\lambda_S$ ) und modellierten die zukünftige Überlebenswahrscheinlichkeit (PVA) für eine der spanischen Populationen, auf der Basis von Matrix-Modellen für detaillierte demographische Erhebungen über einen sechsjährigen Zeitraum (2003–2008).

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Die Populationsgrößen variierten zwischen 100 und 22,000 reproduktiven Individuen. Trotz Unterschieden in der Pflanzengröße, im Schutzstatus und bei anthropogenen Störungen war die Altersstruktur in allen Populationen ähnlich und charakterisiert durch geringe Abundanzen von Sämlingen und Jungpflanzen, was auf geringe Rekrutierung hinweist. Die Wachstumsraten der spanischen *S. pustulatus*-Populationen rangierten zwischen 0.91 und 1.01, und das Matrix-Modell zeigte eine signifikante Populationsabnahme ( $\lambda_S = 0.9042$ ; 95% CI: 0.9041–0.9043). Die PVA ergab, dass diese Population bei gleich bleibenden Bedingungen in ungefähr 40 Jahren auf wenige Individuen zusammenschrumpfen wird. Da hohe Temperaturen und Trockenheit die Entwicklung dieser Population negativ beeinflussen, wird der gegenwärtige Klimawandel ihr Fortbestehen gefährden.

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## Introduction

For the conservation of rare or endangered species, a demographic approach to species management is of critical importance (Schemske et al. 1994). Detailed demographic characterization in terms of population number, size and structure across the distribution range of a species offers an accurate picture of its current conservation status. Population monitoring can reveal both temporal trends and the most critical life stages for the population growth rate (Horvitz & Schemske 1995), but this is more time and resource consuming, and is therefore often restricted to the most critically endangered species (Heywood & Iriondo 2003). The study of both the current status and the dynamics of populations are necessary to assess actual and potential threats and devise appropriate management strategies.

Long-term monitoring programmes are uncommon because of the need to maintain monitoring structures and funding in the long run. This becomes even more difficult in the case of cliff-dwelling species due to their difficult access. Consequently, our knowledge about the conservation and biology of cliff plants is greatly limited (Larson, Matthes, & Kelly 2005), despite the fact that rocky habitats harbour many rare and endangered plants with narrow distributions; particularly in the Mediterranean region (Thompson 2005). Cliffs are highly fragmented, and offer very particular ecological environments that make life difficult, such as scarce microsite availability for plant establishment. However, competition in these habitats is also lower, and adapted organisms have a lower probability of suffering anthropogenic disturbances.

Although limited, studies on the populations and dynamics of cliff-dwelling plants suggest that local persistence is high (Lavergne, Thompson, Garnier, & Debussche 2004; Thompson 2005), they are extraordinarily long-lived (Larson et al. 2000; García, Guzman, & Goñi 2002), and their population sizes are unusually stable (Morris & Doak 1998; Picó & Riba 2002; García 2003).

In this study, we examine the demography of a small group of related plants that constitute the subgenus *Sonchus* section *Pustulati* (Asteraceae): *Sonchus pustulatus* Willk., *S. fragilis* Ball, and *S. masquindalii* Pau and Font Quer (Boulos 1973; Kim, Lee, & Mejías 2007). These narrow endemics are

restricted to small areas of the western Mediterranean Basin (Boulos 1973) on both sides of the Alboran Sea (Fig. 1) and tend to be located on rocky cliffs at low altitudes. All three species are found in North Africa, where they are considered to be very rare (Fennane & Ibn Tatroo 1998). *S. pustulatus* also occurs in the SE Iberian Peninsula, where it is categorized as “critically endangered” (Cueto et al. 2003). Phylogenetic and phylogeographic data suggest that these taxa are relicts of the late Tertiary period (Silva 2014). Their restricted and disjunct distribution seems to be related to old geological events of large biogeographic impact: the Messinian Salinity Crisis (during which North Africa and the Iberian Peninsula were connected by land), and the subsequent Zanclean reflooding of the Mediterranean basin (by which Africa and the Iberian Peninsula were separated).

The principal goal of this study was to assess the current conservation status and future risk of extinction for these cliff-dwelling species and their vulnerability to ongoing climate change. For that purpose, we undertook extensive fieldwork to analyse the overall demographic situation of the clade, and modelled the dynamics of one of the Iberian populations in detail. We focused on the following specific objectives: (1) to accurately define the boundaries of the distribution range of the species after visiting all known populations and potentially suitable habitats; (2) to estimate extent of occurrence of each taxon, as well as area of occupancy, size, structure, and reproductive success of all extant populations; (3) to analyze temporal trends in the three Spanish populations of *S. pustulatus*, and to model the viability (PVA) of the *a priori* most endangered population by matrix models. Our results will help in assessing the conservation status and vulnerability of a group of cliff-dwelling species of high biogeographic and conservation value.

## Materials and methods

### Plant species

The subgenus *Sonchus* section *Pustulati* includes three species: *Sonchus pustulatus*, *S. fragilis* and *S. masquindalii*.

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