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Combining population monitoring with habitat vulnerability to assess conservation status in populations of rare and endangered plants

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ABSTRACT

In this paper, we propose an integrative framework to assess the conservation status of rare plant populations that combines population trends with four criteria to assess habitat vulnerability. We illustrate how population trends can be studied using a presence/absence method for a species that is inappropriate for a demographic study. The four other criteria concern habitat fragmentation, the human footprint in the surrounding landscape, observed impacts on a population and elements of habitat structure and quality that may impinge on population status. Each criterion is assessed with various indicators that can be adapted to the biology and ecology of the studied species. To test the feasibility of the proposed framework, we perform a case study of a Mediterranean geophyte *Allium chamaemoly* L., a species listed for protection in France. The results show a wide range of conservation status among a regional set of populations in the study species. Variation among the indicators used to assess different criteria illustrates the importance of assessing a range of different factors and ways to combine them if population conservation status is to be objectively identified. The study of diverse criteria may allow for a more precise assessment of the causes of differences in conservation status among populations of a single species. The framework of five criteria could be adapted by modification or substitution of indicators or adaptation of thresholds among classes, and thus be applied to other species of conservation importance.

1. Introduction

A major aim of contemporary species conservation efforts is to identify the factors that impinge on the viability of populations and the quality and quantity of the habitat in which they occur. Most studies define viability as the probability of persistence of a population or the increase in numbers to a targeted level in a given time (Reed et al., 2006). Following the publication of John Harper's classic book on plant population biology (Harper, 1977) many studies have illustrated the pertinence of a demographic approach to understanding plant population dynamics (Doak, 1992; Menges, 1990; Svensson, Carlsson, Karlsson, & Nordell, 1993). Based on this approach, Schemske et al. (1994) emphasised the importance of conducting demographic studies to quantitatively assess population status and the viability of rare and endangered plant species. The authors stressed the need to correctly assess population growth rates based on individual monitoring and the identification of the life-cycle stages that may be key elements in any observed population decline. Written at a time when there was much debate concerning the relative importance of adopting an approach based on population demography, relative to a purely population genetics approach, this innovative paper stimulated much effort towards detecting population trends and their causes in rare and endangered plant populations (Andrieu et al., 2013; Fréville et al., 2004; García, 2003; Jacquemyn, Brys, Hermy, & Willems, 2007; Lehtilä, Syrjänen, Leimu, Garcia, & Ehrlén, 2006; McCauley & Ungar, 2002; Nicolè, Brzosko, & Till-Bottraud, 2005; Ulrey, Quintana-Ascencio, Kauffman, Smith, & Menges, 2016).

Although demographic studies produce a clear idea of short-term dynamics (Jacquemyn et al., 2007; Nicolè et al., 2005; Schleuning & Matthies, 2008; Vander Stelt, Fant, Masi, & Larkin, 2017), information on extinction risk and long-term viability in plant populations remain rare. Also, a lack of trends in a given study time period may not mean absence of long-term trends. A second problem is that a demographic approach requires that individuals be followed through their life cycle. However, it is often not possible to identify and follow individual plants for a variety of practical reasons. First, extremely high local density in populations with a

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patchy structure can preclude the identification of individuals and their monitoring in subsequent years (even in some rare and endangered plant populations). Second, many perennial plants are not visible above ground during most of the year and do not always reappear in a subsequent year; hence it is often not possible to be completely sure that the same genetic individual reappears in a given place in successive years. Third, in clonal plants it is usually not possible to identify and monitor genetically distinct individuals. Finally, it can be very difficult to identify and monitor seedlings when closely related species co-occur. For these reasons, for many rare and endangered species, for which management staff may require information on their conservation status, a purely demographic approach is simply not possible. Alternative approaches to studying population trends, such as the use of presence/absence data, the monitoring of adult plant numbers or numbers of flowering individuals and annual estimations of flowering and seed set may thus be necessary to provide pertinent information for rare and endangered species to have their conservation status assessed (e.g. Amat, Vargas, & Gómez, 2013; Berjano et al., 2013; Elzinga, Salzer, & Willougby, 1998; Joseph, Field, Wilcox, & Possingham, 2006).

To perform a correct evaluation of plant population conservation status it is also necessary that the quantification of population trends be accompanied by an assessment of the range of factors affecting the habitat in which populations occur (Armstrong & Seddon, 2008; Amat et al., 2013; Reed et al., 2006). For natural plant populations, the factors that affect their viability cover a wide range of physical and biological parameters, including abiotic habitat properties, biotic interactions (interspecific competition, herbivory and pollination), genetic features of the population (inbreeding and allele diversity of self-incompatible species) and degree of habitat connectivity and dispersal ability. Explicit descriptions of the suite of habitat characters required by a species are thus necessary (Miller & Hobbs, 2007) in terms of the natural structure of abiotic and biotic features and also their dynamics linked to natural succession or colonisation by invasive species. For this reason, assessing habitat conservation status for species conservation has long been recognised to require the use of multiple criteria (Bardat, Bensettiti, & Hindermeyer, 1997; Harding et al., 2001; Margules & Usher, 1981).

In many landscapes, habitats undergo marked ecological change due to natural dynamics within and around populations and changes in human activities and land-use practices. Habitat vulnerability must thus be assessed in terms of the risk that a population may be impacted and the degree of sensibility of populations to direct and indirect impacts (Wilson et al., 2005). The risk of impact is essentially due to the landscape context in which the populations occur in terms of the current degree of fragmentation of natural populations (reduced spatial extent, and distance and occurrence of artificial barriers among populations) and the more general risk associated with the amount of transformed land in the surrounding landscape that results from urbanisation, infrastructures, industry, etc. In addition, the "sensibility" of the habitat of a focal species to impacts can be assessed by quantifying the spatial extent of disturbance and reduced population size associated with rubbish deposition, trampling, vehicles, pipelines, and other direct and visible disturbance (Amat et al., 2013).

Quantifying the conservation status of native plant populations and their habitats is thus a challenging and in practice often difficult task. It is an important issue for conservation scientists to address because there is much practical and policy interest in the evaluation of conservation status. For example, maintaining a "favourable conservation status" of species is an essential element of the European Habitats Fauna Flora directive (CEE Council, 1992; ETC/BD, 2014) where it is defined with three components: population dynamics data which indicate long-term viability, no reduction in natural range in the foreseeable future, and a high probability that a sufficiently large habitat to maintain populations will be maintained on a long-term basis. Although there are now many practical guidelines on how to evaluate this notion of favourable conservation status (primarily for "habitats" in the sense of priority vegetation types or animal populations), a method that integrates different criteria to assess the conservation status of plant populations remains to be developed and tested.

The objective of this paper is thus to propose and test an integrative framework to assess the conservation status of populations of listed plant species based on population trends and habitat vulnerability at different spatial scales. We test the feasibility of the framework on the listed Mediterranean geophyte *Allium chamaemoly* L. in southern France. We discuss the pertinence of this framework of five criteria and how it can be adapted (by modification of indicators, thresholds among classes, etc) and applied to other species of conservation importance.

2. Material and methods

2.1. Proposed framework

We propose a framework to assess the conservation status of plant populations that combines a temporal study of population dynamics (over five years) with four other criteria that assess the degree of population fragmentation, the risk of habitat loss, sensibility to direct and indirect impacts on populations and the features of current habitat structure and composition that may affect population ecology. Along with population trends, these four criteria are noted in terms of three classes of conservation status: favourable, unfavourable-inadequate or unfavourable-bad. We examined two possible ways to combine results for different indicators to provide a single conservation status for each of the five criteria.

2.2. Study species

We test the feasibility of this framework on *Allium chamaemoly*, the dwarf garlic. This species occurs across Mediterranean Europe from Spain to Greece and in North Africa (Morocco and Algeria) (De Bolos & Vigo, 1984–2001). In southern France, populations occur in a lowland band around the Mediterranean coastline from the Spanish border to the French Riviera (Tison, Jauzein, & Michaud, 2014). The population the most distant from the coast is 63 km inland (near Narbonne) and the maximum altitude of known populations is 600 m in Provence. It occurs in a range of predominantly limestone open habitats in lowland garrigues, basaltic outcrops and rocky pastures behind coastal dunes. Flowering (inflorescences are at ground-level) is from December to March (Pavon, 2006), the species is self-compatible and even caged flowers set fruit that generally produce up to six seeds (P. Gauthier, unpublished data). This species is listed for national protection in France (Danton & Baffray, 1995) and due to its occurrence in a region where rapid population expansion and development currently occur, many sites of occurrence are threatened by construction projects. Indeed, we know of five populations in the study area that have been destroyed or impacted by construction projects in the last five years. This species has been intensively inventoried by staff of the botanical conservancy and by amateur naturalists because if it is present it can oblige modifications to construction projects due to its listed status.

2.3. Population locations

The "*SILENE*" database established and maintained by the Conservatoire Botanique National Méditerranéen de Porquerolles contains (January 2015) more than 1000 data points for the occurrence of *Allium chamaemoly* in Mediterranean France. However, because many sites are visited on repeated occasions and often by