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Complementarity of rarity, specialisation and functional diversity metrics to assess community responses to environmental changes, using an example of spider communities in salt marshes

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ABSTRACT

The study of community responses to environmental changes can be enhanced by the recent development of new metrics useful in applied conservation: relative rarity, ecological specialisation and functional diversity. These different metrics have been critically assessed independently, but are rarely combined in applied conservation studies, especially for less-studied taxa such as arthropods. Here we report how these different metrics can complement each other by using the response of spider communities to environmental changes in salt marshes as an example. Sampling took place using pitfall traps in salt marshes of the Mont St Michel Bay (France) during 2004 and 2007. The sampling design was spatially replicated (3 plots per treatment and 4 traps per plot) and encompassed four habitat treatments: control, sheep grazing, cutting (annual, in summer) and invasion by the plant *Elymus athericus*. We observed contrasting responses of spider communities to the different treatments: grazing had a negative impact on both rarity and functional diversity but a positive impact on specialisation; cutting had a negative impact on the three metrics; and invasion only had a negative impact on rarity and specialisation. These contrasting responses emphasise the necessity of using different complementary community metrics in such conservation studies. Consequently, rarity-, specialisation-, and functional-based indices should be applied simultaneously more frequently, as they potentially provide additional complementary information about communities. Such complementary information is the key to better-informed conservation choices.

1. Introduction

Addressing responses of biodiversity to environmental changes at the community rather than species level present the advantage of integrating the responses of multiple species and their interactions. Responses of communities can be assessed with different facets (taxonomic, phylogenetic or functional) for which several new indices have been developed (*e.g.*, Devictor et al., 2010a; Meynard et al., 2011; Strecker et al., 2011). However, these different facets are still rarely used in applied conservation studies, particularly for less-studied taxa such as arthropods. The early methods used to assess communities in conservation studies were simple taxonomic diversity metrics such as species richness or abundance (*e.g.*, Prieto-Benítez and Méndez, 2011). However these simple metrics only reflect a fraction of the biodiversity and do not take into account the identity of species and their characteristics within and between communities, even though these aspects are crucial to assess biodiversity distribution (α,β components), conservation concerns (rarity), ecosystem functioning (functional traits) and importantly the processes implied in the impact of environmental changes on this biodiversity (biotic and functional homogenisation). Hence, species and communities were attributed values with respect to the conservation goal, for example according to their rarity, or more recently to their functional characteristics. In this study, we focus on recent methodological advances regarding three aspects: rarity, ecological specialisation and functional diversity.

Rarity primarily provides an insight into the facet of species biodiversity that is most at risk of extinction (Gaston, 1994), also with respect to the maintenance of vulnerable ecosystem functions (Mouillot et al., 2013). Different axes of rarity are usually

Abbreviations: CSI, Community Specialisation Index; FDiv, Functional Divergence Index; IRR, Index of Relative Rarity; SSI, Species Specialisation Index.

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considered: restricted abundance, restricted geographic distribution and narrow niche breadth. The study of rarity in arthropod communities has recently been improved by the proposal of new indices based on species occurrence (Leroy et al., 2012), which provide the possibility of integrating multiple spatial scales (Leroy et al., 2013). Robust metrics have also been developed to assess the average niche width, *i.e.* the specialisation of species communities (Devictor et al., 2010a). Using basic predictions from the ecological niche theory, specialist species should indeed be favoured in rather stable environments whereas generalists should be more able to thrive in disturbed habitats (Levins, 1968). In the same way, species functional traits are increasingly taken into account to provide a better assessment of the functional responses of communities to environmental changes. The study of this facet of biodiversity was improved thanks to the proposal of novel metrics which have been developed and analysed critically (Devictor et al., 2010a; Villéger et al., 2008). The loss of functional diversity was a criterion that had been overlooked initially, but is of increasing concern in biological conservation (*e.g.*, Devictor et al., 2010b).

All these distinct approaches were successfully applied on arthropod communities (*e.g.*, Leroy et al., 2013; Penone et al., 2013) to assess their responses to environmental changes. They have each been critically assessed alone, but how they complement each other in the case of applied conservation remained to be tested. In this paper, we report a case study combining different recently developed metrics (rarity, specialisation, functional diversity) to assess how they complement each other to assess the response of arthropod communities to environmental changes, by using the example of spider communities of salt marshes. The environmental changes are here the replacement of natural vegetation of salt marshes by monospecific stands of the species *Elymus athericus* (Bockelmann and Neuhaus, 1999), and two management practices likely to limit the spread of this species: annual cutting and sheep grazing. The impact of *E. athericus* will here be termed as an invasion in accordance with previous work on this species (Pétillon et al., 2005).

Salt marshes are of important conservation value because they host stenotopic species due to the constraining environmental conditions (Pétillon et al., 2011), and geographically rare species because of the restricted distribution of salt marshes in the western Palearctic (Leroy et al., 2013). In addition, salt marshes are subject to environmental changes (invasion by *E. athericus* and management) which often result in the replacement of the single dominant plant species by another (Veeneklaas et al., 2012). These changes in vegetation in turn modify the structure and composition of arthropod communities (Ford et al., 2012). The impacts of these environmental changes on salt marsh arthropods are still poorly understood, and results from scarce literature are often contradictive (*e.g.*, Rickert et al., 2012; van Klink et al., 2013). Consequently, we expected the application of distinct community metrics to provide new and complementary information, thus leading to a better understanding of how environmental changes impact communities. For that purpose, we compared the impacts of four treatments (control, invasion, cutting and grazing) on spider communities of salt marshes using community-level indices. Spiders were selected as a model group as they constitute one of the most abundant and diverse groups of arthropods in salt marshes (Pétillon et al., 2008) and for their well-known sensitivity to changes in habitat structure (*e.g.*, Marc et al., 1999).

2. Methods

2.1. Sampling design

The impacts of treatments on spider communities were investigated at two sites in the Mont-Saint-Michel Bay (NW France, 48°37′ N, 1°34′ W), 1 km apart. Four treatments were investigated: control, invasion by *E. athericus*, vegetation cutting (once a year, in July) and grazing by sheep (on average 50 sheep/ha) (Pétillon et al., 2007). Treatments are representative of the main salt-marsh habitats of the Mont St-Michel Bay (Pétillon et al., 2007), and covered all together 89% of the 4054 ha of salt marshes (*E. athericus*-invaded areas: 35%, cutting: 19%, sheep-grazing: 25%, natural vegetation: 10%, data from 2007, Valéry and Radureau, personal communication).

Spider communities were sampled between May and June in 2004 and 2007: the former with control, invasion and cutting treatments, and the latter with control, invasion and grazing treatments. The comparison between treatments was made in similar salt-marsh zones within each site and the only apparent varying factors (at the local and landscape scales) between plots were the presence/absence of management practices (cutting and grazing) or invasion by *E. athericus*.

The sampling protocol was designed to be comparable among treatments: within each site, each treatment was applied to three plots during the same sampling period. Plots had a surface area of 100 m^2 and were spaced 100 m apart. Within each plot, ground-dwelling spiders were sampled with four pitfall traps, set up regularly in a square grid and placed 10 m part, as this is the minimum distance to avoid interference between traps (Topping and Sunderland, 1992). Traps consisted of polypropylene cups (10 cm diameter, 17 cm deep) containing ethylene-glycol as a preservative. Traps were covered with a raised wooden roof to exclude the rain and were visited weekly, tides permitting (*i.e.* three times per month during May and June). To summarise, there were 36 traps per site (3 treatments × 3 plots × 4 traps) and thus a total of 72 traps for the whole sampling protocol. To verify the impacts of treatments on vegetation, percentage covers of all plant species were estimated once within a radius of 1 m around all traps.

2.2. Spider community-level indices

We calculated the average rarity, specialisation, and functional diversity of each community (pitfall trap) using species characteristics obtained from spider datasets (rarity, specialisation), and the literature (hunting strategy).

Data came from (i) the western France spider database, and (ii) the Catalogue of Spider Species from Europe and the Mediterranean Basin (both datasets were detailed in Leroy et al., 2013).

2.2.1. Multiscale Index of Rarity

For each spider species, we calculated rarity weights (w_{Mi}) according to the method described in Leroy et al. (2013) (details in Appendix A). These rarity weights integrate information on the occurrence of species at two spatial scales: the western France scale and the western Palearctic scale. Weight values range from 0 to 2. The rarer the species, the higher the weights, with species which are rare at both scales receiving higher rarity weights than species which are rare at a single scale.

The Index of Relative Rarity (I_{RR}) of each pitfall community was then calculated as the average weight of rarity of individuals of all the species of the considered community, and was subsequently normalised to values between 0 (no rare species in the community) and 1 (all individuals of the community belong to species with the maximum rarity weight):

$$I_{RR} = \frac{\left[\sum (a_i \times w_{Mi})/N\right] - w_{min}}{w_{max} - w_{min}}$$

where a_i and w_{Mi} respectively are the abundance and rarity weight of the ith species of the community; N is the total number of