

Building relevant ecological indicators with basic data: Species and community specialization indices derived from atlas data



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ABSTRACT

Species and community specialization have become popular indicators to track the spatial and temporal changes of species and community dynamics during current global changes. However, measuring specialization requires detailed and quantitative descriptions of habitat requirements or resource use, which are difficult to obtain for many species. Here, we propose and test a new method to quantify and map the relative composition of specialist and generalist species in local plots compatible with very basic ecological data, typically used for atlases. We used co-occurrence patterns of 1090 plant species recorded in the French Mediterranean region of Languedoc-Roussillon in a systematic grid of 1225 5 × 5 km atlas cells to estimate species specialization. We then calculated the averaged specialization of each cell and tested several expected relationships of these indices. In particular, we tested the relationship between species richness and average specialization and the relationship between community specialization and landscape disturbance induced by land use. As expected from studies conducted on fine-scale data, we found that specialist species were those with more restricted distributions and occurring in richer species assemblages. We also found that community specialization was maximized at an intermediate level of landscape disturbance. These results suggest that aggregating specialization at large spatial scales provides useful species and community level indicators. Estimating specialization level with co-occurrence data is a good complementary approach to traditional estimations of diversity indices for conservation and landscape planning.

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1. Introduction

Finding the best indicator of species and community responses to landscape degradation is an ongoing challenge for ecologists. Consequently, ecological indicators based on “species diversity” are very popular; although their relevance was questioned at an early stage, when species diversity was considered a non-concept (Hurlbert, 1971). New indices (accounting for ecological, phylogenetic, or functional differences among species) have, thus, been recurrently proposed to complement species diversity metrics (Monnet et al., 2014). Developing more relevant biodiversity indicators has become, however, a scientific, political, and societal issue of great importance (Frederiksen and Gudmundsson, 2013). But rather than searching for the “best” indicator, authors have now recognized that indicators are not “good” or “bad” but that

their relevance depends on the question asked and on the data available (Feest et al., 2010).

To assess the large-scale impacts of landscape degradation on communities, ecological metrics reflecting the dynamics of “losers” versus “winners” within species assemblages were proposed as a promising approach in conservation biogeography (Devictor and Robert, 2009). In particular, the replacement rate of habitat specialist species by generalists was viewed as a direct signature of a community response to large-scale habitat degradation for animals and plants (Clavel et al., 2010; Abadie et al., 2011). In fact, it is generally expected that habitat specialists will benefit from stable and undisturbed habitats whereas, generalists should respond positively to habitat variability (Colles et al., 2009). These expectations have been widely tested and ecological indicators built upon the temporal trends of specialist species have been considered relevant official indicators of sustainable development for use at national and international levels (Gregory et al., 2005).

Ideally, the spatial or temporal replacement of specialists by generalists can be estimated using large-scale and standardized community monitoring programs (Devictor et al., 2007). With such

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data, the specialization of species and communities can be derived from the statistical relationships reflecting species distribution along habitat gradients, both monitored by standardized schemes. In practice, however, large-scale monitoring data for national or regional surveys are currently being collected for only a few groups (mostly birds, butterflies, and mammals) and are based on presence–absence data. Moreover, measuring species specialization is often impaired by the lack of high enough resolution data on habitat requirements or by the difficulty of defining habitat selection accurately (Podani and Csányi, 2010). Consequently, two main approaches have been used to quantify change in community composition following landscape disturbance: (i) at global or national scales, some authors have used crude classifications of species into specialist versus generalist groups. For instance, indicators for the state of the European avifauna rely on the average trend of some species, classified as being specialized for a given habitat type (e.g., farmland bird specialists) (Gregory et al., 2005), (ii) in contrast, others have used high-resolution data on detailed species requirements. In this case, continuous and species-specific levels of ecological specialization was derived from standardized protocols, in which habitat or resource preferences could be precisely assessed (Devictor et al., 2007; Correa and Winemiller, 2014). However, methods to estimate the specialization level of species and communities using classic ecological data (i.e., the presence or absence of species across sites) are lacking; although, they could help to track the fate of species and communities in many contexts.

Interestingly, Fridley et al. (2007) proposed a method to estimate species specialization that only requires presence–absence data. It assumes that species co-occurring with similar species are usually those found in similar habitats and could, thus, be considered specialists. Conversely, generalists should be widely distributed across habitats and thus co-occur with many different species. In other words, for a given species, the similarity in the identity of species co-occurring with that species can be considered, according to this approach, a continuous proxy for species habitat specialization. From this assumption, and providing that co-occurrence data are available, a species specialization index (SSI) can be simply deduced for each given species using the identity of the species co-occurring with that species. This approach can be applied to any dataset providing that different species assemblages have been recorded in different locations (Abadie et al., 2011; Boulangeat et al., 2012). Using this approach, specialization was equated to niche breadth to test a specific hypothesis on the role played by competition (Manthey et al., 2011), or specific functional traits (Albert et al., 2010) in species distribution. Although originally developed for plants, this approach has also been successfully used for amphibians (Rannap et al., 2009), and fishes (Munroe et al., 2013).

This approach does not a priori tell whether ecological specialization can be relevant when measured for data collected at coarse spatial grain. Indeed, co-occurrence patterns are expected to yield different types of specialization when estimated at the quadrat, landscape, or regional scale. In this respect, although Fridley's method has been applied to various organisms in different contexts, its relevance for co-occurrence data obtained from species lists recorded across large spatial scales has not been explored (but see Boulangeat et al., 2012). Furthermore, it remains unclear whether specialization is still relevant and sensitive when defined at spatial scales different from those most likely to capture habitat selection and species interactions.

Once the specialization levels of species are estimated and are sensitive enough to habitat disturbance, the distribution of species and assemblages according to their specialization level can be investigated. In particular, specialist species are expected to be more numerous and to concentrate more individuals in less

fragmented landscapes (Devictor et al., 2007). At the community level, a community specialization index (CSI) of species assemblages can be calculated as the average of each species SSI present in the assemblage (Devictor et al., 2008). The CSI is expected to be higher for species assemblages mostly composed of specialist species. It can then be used as an interesting ecological indicator complementary to more traditional indicators based on diversity (Filippi-Codaccioni et al., 2010; Abadie et al., 2011). Mapping the CSI can thus provide a picture of spatial variation in the specialization level of communities, which can be related to independent sources of disturbance or used as a spatial guideline to identify sites of conservation interest (Devictor et al., 2008). Yet whether such a community specialization index can be used as a relevant ecological indicator with basic ecological data has never been explored.

Here, we used a large-scale co-occurrence dataset on plants to estimate a species specialization index (SSI) for each species and a community specialization index (CSI) for each grid cell. We then specifically tested several hypotheses on SSI and CSI derived from studies on specialization conducted with higher resolution data and at finer spatial resolution. In particular, we investigated (i) whether and how the species distribution was dependent on their SSI. At the assemblage level, we tested (ii) the relationship between CSI and species richness, and (iii) the relationships between these two metrics and landscape disturbance.

2. Methods

2.1. The study region

The study was carried out in the Languedoc-Roussillon region (27,376 km²) in southern France, which encompasses most of the Mediterranean region west of the Rhône valley (Fig. 1). The main landscape types occurring here are coastal landscapes with

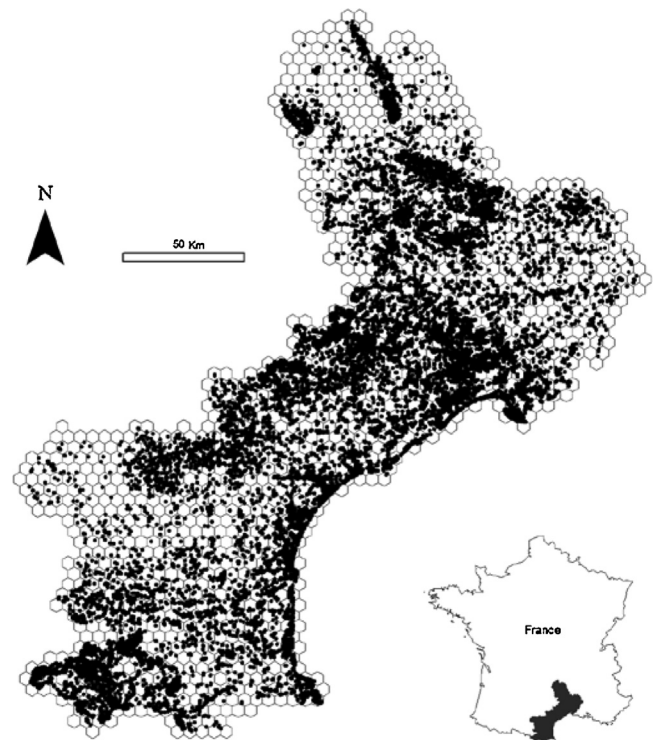


Fig. 1. The study region and the distribution of occurrence data. Each dot represents a species list recorded in the database. The grid cells of 5 × 5 km used for the aggregation are delineated.

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