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Spatial covariance between ecosystem services and biodiversity pattern at a national scale (France)

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A B S T R A C T

We present at a national-scale estimates of spatial covariance between areas important for ecosystem services (ES) and biodiversity, at a fixed spatial scale in France. We calculated different diversity and community metrics for common bird communities: taxonomic diversity (TD), functional diversity (FD), community specialization index (CSI), trophic index (TI), phylogenetic diversity (PD) and community evolutionary distinctiveness (CED). The ES multifunctionality (ES_{MF}) was measured using a combination of ES evenness and overall ES estimator. Spatially explicit tests were used to compare the spatial patterns of ES and diversity metrics. Mixed models were used for comparisons.

We found low spatial congruence between ES and both diversity and community metrics in France. However, we detected even opposite associations between ES and each biodiversity component. Crop production was negatively associated with CED, it was positively correlated with CSI. No positive associations were found between ES_{MF} and any diversity metric, independently of farming systems. The only significant association was negative: lower values of CED were associated with hotspots of ES_{MF}. We found also a negative effect of crop production on bird CED. The conservation implication is remarkable, because conservation policies focusing solely on the economic value of ES will fail to protect overall biodiversity.

1. Introduction

Understanding the spatial distribution of environmental resources plays a fundamental role in developing successful management strategies for conserving the ecosystems (Casalegno et al., 2013). Ecosystems provide goods and services to humans and support biodiversity (Anderson et al., 2009), which has key roles at different levels of the ecosystem service (ES) hierarchy (Mace et al., 2012). For these reasons, both biodiversity and ES are important objectives in conservation planning, so maintaining biodiversity and sustaining ES supply should be more and more often incorporated into conservation project objectives (Cimon-Morin et al., 2013). However, the success in the conservation strategies addressed to protect both ES and biodiversity, depends on the extent to which biodiversity and ES can be secured under joint conservation actions. This is a rather difficult target, considering that for most people ES conservation seems more linked to human beneficiaries than biodiversity (Cimon-Morin et al., 2015). In fact, some criticisms have recently been emphasized, concerning the capacities of the strategies protecting ES to protect also biodiversity (Deliège and Neuteleers, 2014; Redford and Adams, 2009). First of all, it is necessary to understand how large the overlap is between these two conservation objects (Jax and Heink, 2015). Furthermore, new understanding can significantly speed up the process of assessing ecosystems that might be under threat, mainly in changing scenarios, like under climate change. For this reason, the identification of the link between biodiversity, landscape drivers and ES becomes an important goal, in order to maximize the synergy between biodiversity and ES in conservation planning (Bennett et al., 2015; Cimon-Morin et al., 2013; Lindenmayer

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et al., 2014; Tryjanowski et al., 2011).

1.1. ES approach

ES are by definition “benefits that people obtain from ecosystems” (Rodríguez-Ortega et al., 2014). The main types of ES are classified into provisioning, regulating and cultural services (MEA, 2005). Although several issues and weaknesses have been identified in the ES approach (Barnaud and Antona, 2014; Currie, 2011; Eppink and Popp, 2012; Morelli and Møller, 2015; Schröter et al., 2014), the concept of ES remains currently socially supported, enjoying increasing success in the scientific and political arenas. Additionally, the potential benefits of habitat conservation are higher when multiple services can be bundled together and provided by a single ecosystem (multifunctionality) (Balmford et al., 2002). Some studies (e.g. Naidoo et al., 2008) correlate the ES provision across different world ecoregions, finding only weak relationships between areas that are important for providing different services. However, the identification of these relationships is essential in order to manage multiple ES across landscapes. Indeed, enhancing of provisioning ES often leads to trade-offs between regulating and cultural ES (Raudsepp-Hearne et al., 2010). The relationships between ES can be studied by identifying which of them covary positively or negatively (Crouzat et al., 2015). The consistent associations in time and/or space between multiple ES are called “bundles” (Mouchet et al., 2014; Raudsepp-Hearne et al., 2010), and are used to establish the important areas providing ES.

However, despite the high popularity of this approach and the fact that during the last ten years many studies focused on the description of ES (Eigenbrod et al., 2010; Huang et al., 2015; Seppelt et al., 2011), methods to investigate trade-offs and synergies between ES and biodiversity have not been formalized yet, and individual studies have applied many different methods (Anderson et al., 2009; Bennett et al., 2015; Egoh et al., 2009; Gos and Lavorel, 2012; Labrière et al., 2016). Nevertheless it is still unclear precisely how the different aspects of biodiversity are related to ES, and to what extent conserving biodiversity will ensure the provision of these services. In fact, conserving biodiversity and ES could require different strategies (Egoh et al., 2009).

1.2. Biodiversity and evolutionary components of communities

The functionality of complex ecosystems is related also to high values of taxonomic diversity, functional diversity and evolutionary history of the populations (Schulze, 1994; Tilman et al., 2014). All these components of communities can promote the system resilience and adaptive capacity, important when facing to scenarios of climate change (Freudenberger et al., 2012). Biodiversity is defined as the sum of all biotic variation, including the genetic diversity between individuals and the diversity of ecosystems (Chapin et al., 2000). Biodiversity includes multiple components and there exists different ways to measure it (Carmona et al., 2012). Species richness is the simplest way to measure taxonomic diversity in a community. However, biodiversity can also be studied in terms of phylogenetic diversity (evaluation of evolutionary distances and relationships of species) (Faith, 2002; Zupan et al., 2014) or functional diversity, which recognizes the different roles that each organism plays in the ecosystem (Duffy et al., 2007; Petchey and Gaston, 2006).

Nevertheless, studies on ES and biodiversity covariance are often focused only on partial information describing biodiversity. In particular, the most often used biodiversity measure is species richness or taxonomic diversity (Anderson et al., 2009; Egoh et al., 2009; Felipe-Lucia and Comín, 2015). However, the species richness approach is limited, because it fails to consider the ecological roles of the species inhabiting the communities (Safi et al., 2013). Functional diversity is an essential measure that links the relationships between biodiversity, ecosystem functioning and environmental constraints (Mouchet et al., 2010). Phylogenetic diversity was also proposed as an important component for nature conservation (Vane-Wright et al., 1991; Winter et al., 2013). Furthermore, evolutionary distinctiveness (ED, a measure of how isolated a species is in the phylogenetic tree) is another factor that needs to be considered in setting conservation priorities for threatened species, because it represents uniquely divergent genomes (Faith, 2008; Jetz et al., 2014).

The main goal of this study was to explore the spatial pattern of ES in France, assessing whether areas providing high levels of ES (ES hotspots) co-occur in space with high biodiversity. For this purpose, we considered different components of bird diversity (taxonomic, functional and phylogenetic diversity) as surrogates of biodiversity. More precisely, we focused on the following specific aims: (1) to map and standardize each ES proxy at a fixed spatial scale across France; (2) to calculate an aggregate estimator used as a measure of ES multifunctionality (ES_{MF}); (3) to define a rule to classify ES_{MF} outputs at a fixed spatial scale into three categories: hotspots, coldspots and moderate areas; (4) to compare the spatial covariance between each ES and ES_{MF} and different components of biodiversity; (5) to explore the potential correlations between ES and biodiversity components in different farming systems; and (6) to identify the set of ES that are spatially more congruent with each biodiversity component.

2. Methods

2.1. Proxies of provisioning, regulating and cultural ES

ES were selected on the basis of national importance, relevance to nature conservation planning, and availability of the data. In this study we used 12 proxies of ES, following the typologies from the Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013) (Table 1) provided by the Joint Research Centre, Institute for Environment and Sustainability (JRC/IES), mapped at 1 km x 1 km resolution (pixels), or estimations derived from national agricultural statistics at Small Agricultural Region (SAR) resolution (Dross et al., in press; Teillard et al., 2012). A full description of the main ES is provided in Maes et al. (2011).

All agricultural data used to calculate crop, meat and milk production were drawn from national agricultural statistics (AGRESTE, 2014). Data for crop surfaces and number of animals were taken from the 2010 agricultural census. Data on crop and animal production were taken from 2010 annual statistics. They were available only at the level of Nomenclature of Territorial Units of Statistics 3 (NUTS 3), with a mean area of 5776.8 km^2. Data were disaggregated at the SAR level, using the data for crop surfaces and animal populations. Crop yield and animal productivity were assumed to be constant within each NUTS 3 region.

2.2. Biodiversity components: diversity and community metrics

Bird data were taken from the French Breeding Bird Survey (FBBS). The FBBS is a nationwide, standardized monitoring program for which skilled volunteer ornithologists count breeding birds in randomly selected sites each spring. The sites surveyed were 2 × 2 km squares, randomly selected for each observer within a 10-km radius around a locality specified by the volunteer. In each square, the observer monitored 10 point counts (5 min each), twice per spring, with points separated by at least 300 m. Only individuals detected within a 100-m radius around the observer were considered, so that the birds reported by the observer were actually seen in the habitat. We assumed that within this fixed radius, detection probability did not widely vary across sites. Point counts were carried out each month during the 2010 breeding season (April-June). All points were visited once between 06:00 and 10:00, only during favorable weather conditions. Point counts provide highly reliable estimates of relative population density and are a standardized practical method to compare bird communities