Ecological Indicators 72 (2017) 565–573

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Cuckoo as indicator of high functional diversity of bird communities: A new paradigm for biodiversity surrogacy

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ARTICLE INFO

Article history:
Received 4 July 2016
Received in revised form 3 August 2016
Accepted 31 August 2016

Keywords:
Bioindicator
Citizen programs
Cuculus canorus
Evolutionary distinctiveness
Functional diversity
Taxonomic diversity
Umbrella species

ABSTRACT

We tested the hypothesis that the cuckoo may serve as an effective surrogate for different aspects of biodiversity. Six different measures of biodiversity were estimated for these three bird communities: (a) taxonomic diversity, (b) host species richness, (c) functional richness, (d) functional evenness, (e) functional divergence, and (f) evolutionary distinctiveness. Mixed models were used for studying the patterns of occurrence of the cuckoo in relation to environmental variables and biodiversity measures.

The presence of the cuckoo was positively correlated with high values of taxonomic diversity, functional richness and functional evenness, but not with functional divergence or evolutionary distinctiveness of bird communities. We demonstrate that host species represent different levels of functional diversity in bird communities, because they are broadly distributed and occupy many niches for breeding and feeding.

The implications for conservation are many: Hotspots determined by the occurrence of the cuckoo are areas with higher functional richness and evenness, also indicating high potential resilience. If host species are functionally diversified, the bird community provides higher resilience to any eventual catastrophic events. Finally, we underline how the cuckoo is a charismatic species, easy to monitor and adequate for citizen science, providing new information on the paradigm of surrogacy in ecology.

1. Introduction

Recent studies have provided strong evidence for the common cuckoo *Cuculus canorus* (hereafter cuckoo) being a prime candidate as a surrogate of bird species richness or umbrella species, useful for ecological planning and for development of conservation strategies (Morelli et al., 2015; Tryjanowski and Morelli, 2015). Umbrella species are those particularly suitable for conservation management efforts, because the protection of these species can indirectly protect many other species. The main premise is that the requirements of umbrella species encapsulate those of many co-occurring species in the community (Lambeck, 1997). In a study at a local spatial scale in Poland the efficiency of the cuckoo as a surrogate for bird species richness was 27% superior to the best performance using top predators as a surrogate (Tryjanowski and Morelli, 2015). Similar results were also found at a large spatial scale, analysing data from many European countries, highlighting that cuckoos are mainly distributed at sites with greater bird species richness (higher taxonomic diversity) than expected by chance (Morelli et al., 2015). A deep understanding of the links between cuckoo occurrence and different aspects of bird biodiversity could provide new insights into conservation. In fact action plans for biodiversity conservation and management strategies aim to integrate different aspects

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http://dx.doi.org/10.1016/j.ecolind.2016.08.059
1470-160X/

of biodiversity, including taxonomic, functional and phylogenetic components (Jetz et al., 2014; Wiens et al., 2008).

The effectiveness of biodiversity surrogates continues to be debated (Grantham et al., 2010; Marfil-Daza et al., 2013), although it is widely acknowledged that more efficient and reliable surrogates of biodiversity are needed (e.g. Caro, 2010; Sattler et al., 2014). Several advantages are associated with the use of surrogates in ecological studies, including the ability to simplify, represent, and assist in complex system management (Lindenmayer et al., 2014), and the capacity to identify and model biodiversity hotspots (Carrascal et al., 2012; Sattler et al., 2014). Finally, surrogate concepts are used in many different disciplines of environmental sciences, based on a balance among robustness, communicability, accuracy, generality, cost-effectiveness and transferability of surrogacy into praxis (Lindenmayer et al., 2015).

Functional diversity is an essential aspect of biodiversity that links species assemblages with ecosystem functioning and environmental constraints (Mouchet et al., 2010). Functional diversity can reveal species coexistence processes, the variety of roles that different organisms play in the ecosystem and assembly rules driven by functional traits (Petchey and Gaston, 2006). Phylogenetic diversity is increasingly considered in community ecology and macroecology, disciplines which recognize the value of evolutionary relationships in order to assess diversity in communities (Tucker et al., 2016).

The suitability of the cuckoo as a reliable indicator of different aspects of biodiversity could be explained by the fact that its presence mirrors species richness of its hosts and hence an important fraction of the overall bird community (Morelli et al., 2015), but also due to the relationship between host species richness and functional diversity of bird communities. Many cuckoos are known for their obligate parasitic behavior, relying on specific hosts for rearing their offspring (Erritzøe et al., 2012). Many insectivorous passerines in Europe have a coevolutionary history of interactions with the common cuckoo. These pairwise interactions possibly indicate tight co-evolution, as reflected by at least 21 specific host races having evolved in the cuckoo in Europe, each with specific mimetic eggs that to a remarkable degree resemble those of the host (Møller et al., 2011a; Yang et al., 2012).

Biotic interactions affect the spatial distribution of species via mechanisms such as predation, competition, resource-consumer interactions, host-parasite interactions, mutualism, and facilitation (Wisz et al., 2013). For this reason, co-evolutionary considerations may provide insights into the causes of the distribution of biodiversity (Thompson, 2005). Different host races of parasitic cuckoos can be considered a specific kind of intraspecific biodiversity as reflected by their genetic and behavioural distinctiveness. This is reflected by different host races of cuckoos laying their eggs at different times of the year, and cuckoos reproducing at a similar, but narrower subset of dates as their possible hosts (Fossøy et al., 2012; Møller et al., 2011a). These observations are consistent with expectations for reproductive character displacement reflecting the outcome of competition among host races of cuckoos for access to host nests.

In the present study, we test the hypothesis that the cuckoo may serve as an effective surrogate for different components of biodiversity. First, we tested the relationship between cuckoo occurrence and taxonomic diversity, functional diversity and evolutionary distinctiveness of bird communities in three European countries. Second, we investigated the functional diversity components and phylogeny of the potential host bird communities. In particular, we investigated the following hypothesis: (a) host species are broadly distributed across a gradient of functional diversity, reflecting the functional diversity of the entire bird community, and (b) host species are broadly distributed across the tree of life of the bird phylogeny, reflecting any difference in terms of evolutionary distinctiveness of bird communities.

2. Methods

2.1. Study area, bird data collection and environmental variables

Fieldwork was performed at 472 sample sites selected randomly in three European countries (Ukraine, Poland and Denmark) (Table 1). The sample sites in Ukraine were mainly distributed on forested, secondarily forested areas and meadows of a total of 2000 km^2 in the Chernobyl Exclusion Zone and outside this area ranging from Bobor, Dytiatki and Pisky to Ivankov with an uncontaminated control area around Voronkov. The sample sites in western Poland (centroid 51.73N, 17.49E) were mainly distributed on farmlands of a total of 3000 km^2. The sample sites in Denmark (centroid 57.23N, 09.91E) were mainly distributed in landscapes characterized by farmlands and meadows of a total of 800 km^2.

Data on bird species were collected using standardized breeding bird point counts, carried out during the 2015 breeding seasons (April–June). All points were visited once between 06:00 and 10:00 for 5 min, only during favourable weather conditions without rain or strong wind. Point counts provide highly reliable estimates of relative population density, and constitute a standardized method for comparing bird communities among habitats and temporal scales (Bibby et al., 1992).

All diurnal bird species detected visually and acoustically in a radious of 100 m from the observer were recorded. The areas visited were classified on the basis of the dominant land use types, using the following catagories: meadows, forests, marsh/rivers, urban and agricultural land compiled during the field work. All sample sites were also classified on the basis of the type of soil, using the follow catagories: organic, sand, clay soil (see Garnier-Laplace et al. (2015) for a detailed explanation).

2.2. Biodiversity measures and evolutionary distinctiveness

In this study we used six different measures of biodiversity: two related to taxonomic diversity, three related to functional diversity and one related to phylogenetic uniqueness. Overall bird species richness (BSR) was used as a measure of taxonomic diversity (Magurran, 2004) in all countries. Species richness was expressed as the number of recorded bird species at each sample site. Host species richness (HSR) was calculated as the sum of all host bird species present at each sample site, considering the host species for common cuckoo listed in Møller et al. (2011b) and Wesołowski and Mokwa (2013).

Functional diversity indices were calculated for each bird community. The biodiversity metrics based on species-trait approaches are focused on functional aspects of biodiversity, and constitute an additional tool to the traditional taxonomic approach (de Bello et al., 2010). In this study, functional diversity indices were calculated using the avian niche traits provided by Pearman et al. (2014), based on traits related to feeding and breeding ecology, considering this information adequate for characterizing bird communities. The trait table consists of 52 variables that describe the niche of each bird species, including variables across (1) food types (13 variables), (2) behaviours used for acquiring food (9 variables), (3) substrate from which food is taken (9 variables), (4) period of day during which a species forages actively (3 variables), and (5) nesting habitats (18 variables) (Pearman et al., 2014). All variables are binomial (scored as either 0 or 1).

In order to avoid the issues related to the strong positive correlation between the most used functional diversity indices and species richness in sample sites, multidimensional FD indices were pro-