Journal of Environmental Radioactivity 177 (2017) 158–164

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

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

Cuckoos vs. top predators as prime bioindicators of biodiversity in disturbed environments

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ARTICLE INFO

Article history:
Received 1 February 2017
Received in revised form
23 April 2017
Accepted 28 June 2017

Keywords:
Background radiation
Bioindicator
Cuculus spp.
Species richness hotspots
Top predators

ABSTRACT

We studied the abundance of the common cuckoo *Cuculus canorus* L. little cuckoo *Cuculus poliocephalus* L. and Asian cuckoo *Cuculus saturatus* L. and avian top predators as indicators of bird species richness (surrogate of biodiversity) in disturbed environments caused by radioactive contamination in Chernobyl, Ukraine and Fukushima, Japan, comparing their efficiency as indicators of local biodiversity hotspots.

Bird species richness and birds abundance were quantified in each sample site during the breeding seasons between 2006 and 2015 and the level of background radiation was measured at every site. The correlation between number of cuckoos, top predators, land use composition and level of background radiation with bird species richness as response variable were examined using Generalized Linear Mixed Models. The strength of correlation between species richness and abundance and the covariates obtained from the model outputs were used as measure of the efficiency of each predictor, as well as the AIC of each model. Background radiation was negatively correlated with bird species richness and bird abundance in both countries, while number of top predators and cuckoos were both positively correlated with bird species richness and abundance. However, model with number of cuckoos was more performant than model with number of avian top predators. These differences in performance supports the hypothesis that cuckoos are a largely superior bioindicator than top predators.

1. Introduction

The loss of biodiversity is of critical concern, and an increasing number of studies indicates that biodiversity plays a central role in long-term ecosystem functioning (Groombridge and Jenkins, 2002; Pereira et al., 2012). For this reason, research focused on the spatial distribution of biodiversity is necessary. Species richness provides one of the simplest univariate measures of community diversity (Magurran, 2004). However, the study of biodiversity is difficult, time consuming and costly. In many situations, the study of biodiversity can also be further complicated, as for example in areas with high levels of radiation. For this reason, considering that data on biodiversity are hard to acquire, the use of surrogates for estimates can be advantageous in ecological planning. A suitable strategy is to measure the biodiversity indirectly, using measurable attributes, as surrogates or proxies (Armon and Hänninen, 2015; Burger, 2006; Lindenmayer et al., 2014; Magurran, 2004; Mellin et al., 2011; Noss, 1990). However, studies on efficiency of such surrogates of biodiversity produce contrasting and conflicting results (Grantham et al., 2010).

One of the most emblematic examples is the case of avian top predators used as indicators of biodiversity. In fact, raptors are considered suitable bioindicators because they are umbrella species, and their distribution can mirror hotspots of biodiversity (Sergio et al., 2008b, 2006). The central ecological rationale is clear: The presence and the abundance of raptors would be spatio-temporally correlated with biodiversity, and could be assessed by ecologist as the guarantee of the occurrence of all other species positioned below the trophic level occupied by the top predator. The main reasons can be listed as follows: trophic cascade connections, facilitation of resources, dependence on ecosystem

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http://dx.doi.org/10.1016/j.jenvrad.2017.06.029
0265-931X/

productivity, occurrence of raptors mainly in areas characterized by higher landscape heterogeneity due to niche occupation and links to multiple ecosystem components (Sergio et al., 2008a, b).

However, the efficiency of top predators as biodiversity indicators is far from being demonstrated. The debate has been intense during the last decades (Cabeza et al., 2007; Roth and Weber, 2008; Sergio et al., 2008a, 2006). The use of avian top predators was strongly promoted because they are very charismatic species and thus easy to use in order to involve people in conservation projects (Sergio et al., 2008a). However, much criticism has been directed against these surrogates. The criticisms included methodological biases introduced in the sampling design that could result in overlooking a huge proportion of potential bird species present in the study area during sampling, but also other issues (Kéry et al., 2007; Roth and Weber, 2008). Cabeza et al. (2007) highlighted how the occurrence of top predators could be more related to fragmented landscapes (as anthropized environments) than to areas characterized by high biodiversity. Other reasons for suspecting the lack of accuracy of raptors as biodiversity indicators are that these birds are often generalist species, and, therefore, they can hardly be associated with areas characterized by communities composed of both generalist and specialist species, as are areas of higher diversity (Ozaki et al., 2006). Finally, we can argue that species with so large home-ranges as raptors (Newton, 2010), using feeding areas maybe far away from the breeding areas, are scarcely linked to particular sites in a territory. Thus, the extent to which top predators constitutes a valid surrogate of local biodiversity hotspots is still a question under debate.

Another bird species recently proposed as a surrogate for identifying hotspots of bird species richness is the common cuckoo *Cuculus canorus*, shown to be a reliable indicator of taxonomic and functional diversity in bird communities (Morelli et al., 2015; Tryjanowski and Morelli, 2015). The species was also found to be a good proxy for environmental characteristics in disturbed landscapes (Møller et al., 2016). The reasons behind the surrogacy of the cuckoo are completely different from the reasons behind top-predator surrogacy. While again top-predators are hypothesized indicators mainly because they are at the top of the food web, they can indicate the health of the entire trophic cascade. In contrast, cuckoo surrocagy is related to more complex and co-evolutionary mechanisms. The occurrence of this brood parasite would be related to the presence and the abundance of host species. However, the distribution of host species would be related to environmental characteristics, and also to the occurrence of other species that are not hosts of cuckoos through biotic interactions and shared niches. All these characteristics could result in areas with a greater overall number of species in a community (Møller et al., 2016; Morelli et al., 2015).

In this study, we assessed the efficiency of the abundance of cuckoos as indicator of bird species richness and bird abundance in two areas in which a major nuclear disaster has occurred recently (Fukushima, Japan and Chernobyl, Ukraine) (Møller and Mousseau, 2016), comparing the efficiency of cuckoos with the efficiency of avian top predators and radiation level in the field (a measure of environmental disturbance) as indicators of bird species richness and bird abundance in the same areas. The rationale for conducting these studies in radioactively contaminated areas is that such sites suffer from reduced abundance of many species of birds (Møller et al., 2015; Møller and Mousseau, 2007a, 2007b), and hence we should expect that such reductions in species richness and abundance should be reflected in a reduction in the number of cuckoos, if cuckoos were reliable indicators of species richness and abundance of birds. We also analyzed the relationship between background radiation and the abundance of butterflies and cuckoos, respectively, in an attempt to test if cuckoo abundance was a consequence of the abundance of butterflies that constitute the main diet of cuckoos.

2. Materials and methods

2.1. Study area and bird data collection

The breeding bird census were performed using point counts selected randomly, located at ca. 100-m intervals in forested areas west of the exclusion zone around the Fukushima Daiichi power plants in 2011–2016 (Møller et al., 2015) or in forested areas within the Chernobyl Exclusion Zone or adjacent areas, or in areas in southern Belarus around Gomel during the breeding seasons 2006–2015 (Møller et al., 2015). At least one local ornithologist participated in the censuses in Japan to confirm the identity of some bird species. The number of butterflies was assessed in the same point counts, during the bird surveys.

Point count census method was adopted because provides reliable information on relative abundance of birds (Bibby et al., 2005; Blondel et al., 1970; Møller, 1983; Voříšek et al., 2010) and insects like butterflies (Møller et al., 2015). The method is based on an observer recording for a period of 5 min all birds and other animals seen and heard. Extensive national monitoring programs for breeding and wintering birds based on point counts take place in many different countries, and this effort is part of environmental monitoring by the European Union (Voříšek et al., 2010). This method has provided highly repeatable results for birds and other animals at Chernobyl and Fukushima (Møller and Mousseau, 2011). A.P.M. conducted these standard point counts during 29 May–11 June 2006–2015 in the surroundings of Chernobyl (898 census points) and during 11–19 July 2011–2015 at Fukushima (1500 census points). Thus, one single 5-min count was recorded at each observation point in each of the study years. The fact that one person made all counts eliminates any variance in results due to inter-observer variability. There are no bird census data from Chernobyl or Fukushima before the accidents, nor to the best of our knowledge have other scientists conducted bird censuses comparable to ours in the years following the accidents (Møller et al., 2013).

We directly tested the reliability of our counts by letting two persons independently perform counts, and the degree of consistency was high for both species richness, total abundance and abundance of individual species (details reported by Møller and Mousseau, 2007a for Chernobyl; similar results exist for Fukushima: A. P. Møller and I. Nishiumi, unpublished data).

2.2. Bird species richness and environmental variables

We used a measure of biodiversity related to biological diversity of bird species in the communities and a measure related to environmental composition and disturbance in each sample site. Bird species richness was used as a biodiversity measure, because it is a basic surrogate for the more complex concept of ecological diversity (Magurran, 2004; Morelli, 2013), and because it is the most popular diversity index in ecology (Wuczyński et al., 2011; Young et al., 2013). At each site sampled, species richness was calculated as the number of bird species recorded. Furthermore, the number of cuckoos was calculated as the number of cuckoo individuals (none or common cuckoo in Chernobyl and none, little cuckoo or Asian cuckoo in Fukushima). The abundance of top predators was calculated as the total number of individuals of the following raptor species: goshawk *Accipiter gentilis*, white-tailed sea eagle *Haliaeetus albicilla*, lesser spotted eagle *Aquila pomarina*, buzzard *Buteo buteo* and kestrel *Falco tinnunculus*) for Chernobyl and the total number of individuals or species of raptors (sparrowhawk *Accipiter nisus*,