Ecological Indicators 88 (2018) 205–213

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Identifying critical thresholds to guide management practices in agro-ecosystems: Insights from bird community response to an open grassland-to-forest gradient

Pedro A. Salgueiro[a,b,c,e,*], António Mira[a,b,e], João E. Rabaça[c,d,e], Sara M. Santos[a,b,e]

[a] UBC – Conservation Biology Lab, Portugal
[b] CIBIO-UE – Research Centre in Biodiversity and Genetic Resources, Pole of Évora – Research Group in Applied Ecology, Portugal
[c] LabOr – Laboratory of Ornithology, Portugal
[d] ICAAM – Institute of Mediterranean Agricultural and Environmental Sciences, Portugal
[e] Department of Biology, University of Évora. Mitra, 7002-554 – Évora, Portugal

ARTICLE INFO

Keywords:
Ecological thresholds
Bird community
Turnover patterns
Tree canopy cover gradient
Agroecosystems
Variegated landscape
Huisman-Olff-Fresco models

ABSTRACT

Landscapes are showing increased fragmentation and habitat loss due to land-use conversion and intensification, leading to species-poor and homogeneous communities. The identification of ecological thresholds above which major changes in community composition take place, may prevent the critical downfall of biodiversity while improving the effectiveness of conservation, resource management and restoration practices. In this study, we provide a new insight on how species distribute along a highly variegated agro-ecosystem in the Mediterranean region. We aim to define the thresholds of occurrence of a bird community inhabiting a tree canopy gradient, and determine the patterns of community change. We fit Huisman-Olff-Fresco models to bird occurrence data (assuming non-linear responses) to identify species-specific responses to the gradient, species richness, and turnover patterns. The tree canopy gradient is responsible for major changes in bird community likely related to the variation of the tree stratum and canopy enclosure which reflect different niche segregation opportunities. Maximum species richness was reached at 10% canopy cover while total turnover rate was higher than expected from a null model up to 10% canopy cover. Ecological thresholds can be used as indicators of specific resource limits responsible for changes in community composition and species occurrence, identifying where populations may be more sensitive. Choosing a single management scheme will invariably result in winners and losers, but optimal levels of management can be explored in order to maximize species diversity across Mediterranean agro-ecosystems.

1. Introdution

Several studies (e.g., Andrén, 1994; Mönkkönen and Reunanen, 1999; Fahrig, 2001) specify the existence of ecological thresholds to gradients of habitat alteration (the fragmentation threshold), beyond which major changes in species occupancy occur. Ecological thresholds provide an alternative to usual post-disturbance reactive tools such as endangered species legislation (Johnson, 2013) and costly restoration practices (Holl and Howarth, 2000), by establishing preventive targets on biodiversity loss to guide policy and resource management (Huggett, 2005). Moreover, it may improve the effectiveness of conservation efforts in natural resource management (Huggett, 2005), by documenting the sensitivity of species to threatening processes such as habitat loss, simplification or fragmentation (e.g., Betts et al., 2007), loss of genetic diversity (Bruggeman et al., 2010) or threat by invasive species (With, 2004). As landscapes worldwide have experienced strong changes over the last decades, caused by land-use conversion and intensification (Newbold et al., 2015), such concrete environmental tools are needed to guide policy goals aiming to prevent biodiversity loss (Balmford et al., 2003).

In agro-ecosystems these changes have been particularly noticed (Tscharntke et al., 2005), as the European Common Agricultural Policy (CAP) is triggering a shift from traditional extensive agro-forestry management to intensive agriculture and forest production areas (Jones et al., 2011). For instance, these changes have had a great impact upon the Portuguese 'montado', a characteristic large scale variegated landscape where tree cover varies gradually from presence of scattered trees to dense forest (*sensu* McIntyre and Hobbs 1999; Pinto-Correia et al.,

* Corresponding author at: UBC – Conservation Biology Lab, Portugal.
E-mail addresses: pas@uevora.pt (P.A. Salgueiro), amira@uevora.pt (A. Mira), jrabaca@uevora.pt (J.E. Rabaça), smsantos@uevora.pt (S.M. Santos).

https://doi.org/10.1016/j.ecolind.2018.01.008
Received 3 April 2017; Received in revised form 22 December 2017; Accepted 5 January 2018
1470-160X/ © 2018 Elsevier Ltd. All rights reserved.

2011) classified as High Nature Value (HNV) farmland (Andersen et al., 2003). The once structurally variegated landscape resulting from centuries of traditional human activities (e.g., agriculture, cattle grazing and forestry; Blondel et al., 2010), is changing as a result of either management intensification or land abandonment (Pinto-Correia, 2000; Plieninger and Schaar, 2008). Intensification is causing the 'montado' to disappear as a system, giving rise to a more heterogeneous landscape mosaic. Increasing crop cultivation or animal production areas with reduced tree cover are intermixed with denser and structurally complex forests resulting from land abandonment (Pinto-Correia and Mascarenhas, 1999). All these on-going changes can have strong impacts on biotic communities.

Significant declines of species are reported worldwide following landscape alteration (Billeter et al., 2008; Inger et al., 2015; Jeliazkov et al., 2016), often resulting in net changes in ecological assemblages altering community composition (Newbold et al., 2015), and in the homogenization of communities while reducing species diversity through replacement by widespread species (Clavero and Brotons, 2010; Gámez-Virués et al., 2015). In agro-ecosystems, bird community is highly shaped by the open grassland-to-forest gradient (Berg, 2002; Catarino et al., 2016; Herrera et al., 2016) and changes along the gradient result in turnovers in bird composition (Sirami et al., 2007). Some studies report that specialization (i.e., the restricted ecological niche width of a species to a given set of resources; Devictor et al., 2010) is most likely to occur at extreme ranges of landscape gradients (e.g., Clavero and Brotons, 2010), but the open structure of forests can also favor the presence of transition species (Tellería, 2001; Sanderson et al., 2009; Bonthoux et al. 2013). However, the limits of species occurrence, and where communities are most vulnerable to species loss, are still unknown. In addition, changes in habitat are also likely to affect the structure and dynamics of species assemblages by tampering with interspecific interactions (Bonthoux et al., 2013). The adoption of inappropriate and unreliable community-based approaches, that do not account for contrasting responses of individual species (Mönkkönen and Reunanen, 1999; Lindenmayer et al., 2008), have limited the insight on how community and overall biodiversity are shaped along environmental gradients (Pardini et al., 2010; Bonthoux et al., 2013). Investigating both species and community responses to landscape gradients will help to integrate both intraspecific and interspecific processes in local biodiversity patterns changing along those gradients (Lepš et al. 2011).

Here, we aim to define thresholds of occurrence of a breeding bird community inhabiting an open grassland-to-forest gradient, in a highly variegated agro-ecosystem in the Mediterranean region. We attempt to answer the questions: 'what are the ranges of tree cover most vulnerable to species loss?' and 'what ranges of tree cover best fulfill the requirements for conservation purposes?', thus providing a better understanding of how agro-ecosystems management can be optimized to meet biodiversity conservation targets. We identify patterns of community change based on ecological niche theory, where species are assumed to respond non-linearly to gradients following unimodal (Gaussian-shaped) response curves (Austin, 2007), thus avoiding common constraints of linear approaches (Swift and Hannon, 2010; Johnson, 2013). Our approach applies Huisman-Olff-Fresco models (hereafter HOF models; Huisman et al., 1993), which incorporate such species-specific response curves. We then use the cumulative changes in species distribution to define patterns of variation in community composition and identify bird assemblages by means of niche overlap. Thus, our approach integrates the (i) assessment of species-specific thresholds of occurrence based on niche width, (ii) turnover patterns where strong changes in community composition occur, and (iii) identification of species assemblages across a tree cover gradient.

2. Methods

2.1. Study area

We conducted the study in a highly variegated Mediterranean landscape (McIntyre and Hobbs, 1999) of southern Portugal, in the Évora district (centroid: 16271.45, -113395.21; EPSG: 3763-ETRS89/ Portugal TM06). The area comprises 426,000 ha, dominated by the Mediterranean savannah-like 'montado' (Pinto-Correia et al., 2011), an agro-ecosystem that includes semi-natural habitats with low intensity farming. The landscape consists of a spatially heterogeneous structure, ranging from densely wooded areas dominated by evergreen cork (*Quercus suber*) and holm oaks (*Q. rotundifolia*), to agricultural plains with scarce tree cover. The topography is generally flat, with altitude ranging between 100 and 450 m a.s.l. The climate of the region is typically Mediterranean with warm and dry summers where temperatures reach up to 40 degrees Celsius, while winters are relatively mild and wet.

2.2. Tree canopy cover gradient

Tree cover is one of the most important features in determining bird diversity in Mediterranean agro-ecosystems (Godinho and Rabaça, 2010; Catarino et al., 2016). Thus, we used the gradient of tree canopy cover as a surrogate for habitat amount (Westfall and Morin, 2012; Godinho et al., 2016). In fact, the spatial variation of open grassland to dense oak forest can represent a resource-related continuous gradient (Fischer and Lindenmayer, 2006) of basic food and shelter availability, nesting conditions, and movement ability for different bird species (Price et al., 2009). The gradient was built from aerial photography data – based on color image segmentation and using the *k*-mean algorithm, an automated method of unsupervised classification (Subbiah and Seldev, 2012). Total tree canopy cover was determined within buffers centered on each bird survey plot. The canopy cover ranged from 0 to 65%, though in further analyses we considered a maximum of ~50% due to the lack of spatial replicates at high-density cover sites and outlier removal. The gradient was extracted using Orfeo Toolbox 3.20 (Orfeo Toolbox Development Team, 2013), in QGIS 2.2 (Quantum GIS Development Team, 2013).

2.3. Bird surveys

We surveyed bird species by means of 10 min point counts (Bibby et al., 2000), with a distance limit of 100 m. A total of 152 points were carried out, covering the tree canopy gradient with spatial replicates. In order to prevent double counts, a minimum distance of 500 m between points was considered. Sampling was conducted during the 2013 breeding season from 26th April to 24th May, when there is greater bird recruitment and spatial stability. A single visit was carried out at each point at the period of highest detectability (6:00 to 11:00 a.m.; Palmeirim and Rabaça, 1994). While reducing survey effort per site, we increased the number of sites, aiming to provide statistical power and the representativeness of the study area (Loos et al., 2015). Fieldwork was conducted by one observer recording bird species that were seen or heard (Bibby et al., 2000). Fly-over individuals or aerial-feeders (e.g. barn swallow *Hirundo rustica*) were discarded from the analysis. Due to difficulty in distinguishing *Galerida cristata* and *G. theklae*, these species were pooled and analyzed together (Delgado and Moreira, 2000). Overall, we analyzed 33 species (see Supplementary Material A for details) present in > 10 sampled points (Peper et al., 2011).

2.4. Species response to tree canopy cover gradient

HOF models (Huisman et al., 1993) were used to identify species response to single gradients (Peppler-Lisbach and Kleyer, 2009; Peper et al., 2011). These consist of seven (I-VII) hierarchical models of