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Impacts of agricultural intensification on avian richness at multiple scales in Dry Chaco forests

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ABSTRACT

Agricultural expansion and intensification is driving rapid landscape modification in the South American Gran Chaco, affecting biodiversity at multiple spatial scales. Research on biodiversity change in modified landscapes has focused mainly on remnant habitat patches. However, the habitat quality of the matrix is increasingly recognized as a key element for planning conservation in agricultural landscapes. We employed a multi-model selection approach to test 13 hypotheses about the influence of spatial scales and structural attributes on the richness of bird assemblages and forest specialist species within matrix types at the Argentine Dry Chaco. We selected 27 cattle ranches where six structural attributes of vegetation operating at different spatial scales (plot, edge and landscape) varied independently across a matrix intensification gradient in the agricultural frontier. We found that structural attributes operating at the plot, edge and landscape scale have significant influence on overall richness, with plot-scale attributes being more important than edge and landscape-scale attributes in driving bird occurrence in the grazing matrix. Factors operating at the plot scale had the largest influence on the richness of forest specialist species in the matrix. These results suggest that planning for the long-term conservation of Dry Chaco forests avifauna should pay attention to the effects of local agricultural management. Where further cattle production intensification cannot be avoided, implementation of highly selective clearing methods can mitigate the degradation of habitat quality for birds. Where cattle production intensification has already occurred, native tree plantings on cleared areas can restore significant bird diversity.

1. Introduction

The need for conservation planning in agricultural landscapes has never been greater. Today, more than two-thirds of the ice-free global terrestrial surface is used for agriculture (Ellis and Ramankutty, 2007). Most of the recent expansion and intensification of agriculture has occurred in subtropical and tropical regions of developing countries (Rudel et al., 2009). Notably, the expansion of soybean cropping and intensification of cattle ranching in the South American Gran Chaco has driven the highest rates of tropical forest loss of the 21st century globally (Hansen et al., 2013). These land-use changes modify biodiversity through processes at multiple spatial scales, from landscape fragmentation and the formation of abrupt edges at the patch-matrix interface, to the degradation of vegetation within the matrix. Effective conservation planning in this threatened and understudied biome requires a better understanding of the relative importance of spatial scales in driving biodiversity patterns.

Modified landscapes are typically represented as mosaics of patches and corridors of native vegetation within a matrix dominated by human land-use, e.g. agriculture. As a result of this binary view, biodiversity in modified landscapes is usually measured within habitat patches and changes in biodiversity levels explained with regard to structural attributes operating at the patch scale (Fischer and Lindenmayer, 2007). However, patch-based studies may be providing an incomplete representation of biodiversity change in modified landscapes for two reasons. First, several matrix types were shown to retain biodiversity levels comparable to habitat patches (Perfecto and Vandermeer, 2010). Second, processes operating at spatial scales smaller (i.e. plot) and larger (i.e.

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landscape) than the habitat patch were shown to exert significant influence on biodiversity within patches (Cushman and McGarigal, 2004; Banks-Leite et al., 2013). We address these shortcomings by asking how structural attributes operating at multiple spatial scales influence bird species richness within matrix types found in agricultural frontier landscapes of the Argentine Dry Chaco.

Species responses to habitat modification vary according to their life history traits as these determine at what scale individuals perceive, select and use available conditions and resources. Knowledge about these differential responses is highly relevant for conservation planning for two reasons. First, changes in life history traits at the community level modify ecosystem functioning, which may have cascading effects on ecosystem services and human well-being (Díaz et al., 2011). Second, species with life history traits that confer habitat and/or diet specialization are usually those with greater sensitivity to habitat modification and therefore of higher conservation concern. In a scenario of shrinking Dry Chaco forests, the survival of forest specialist bird species largely depends on their ability to find suitable habitat in the agricultural matrix. Here we aim to answer whether the richness of forest specialist species within matrix types is affected differentially by structural attributes operating at different spatial scales, compared to the whole bird assemblage.

To answer these two questions, we will test hypotheses that explain species richness in matrix habitats by focusing on structural attributes operating either at the landscape scale (i.e. patches and the surrounding matrix), edge scale (i.e. patch-matrix interface) or plot scale (i.e. within the matrix). Among hypotheses focusing on landscape factors, the "dispersal" hypothesis proposes that species occurrence in the matrix is a function of the distance to fragments and the extent of suitable habitat in the landscape (i.e. proximity to and size of source populations, respectively, Tscharntke et al., 2012). In turn, Fahrig (2013) proposes an explanation independent of fragment size and isolation, in which species occurrence in the matrix depends on the extent of suitable habitat at the local and landscape scale ("habitat amount" hypothesis).

In another set of studies, the suitability of the matrix as bird habitat depends on the distance to a structurally complex vegetation edge ("edge effects" hypothesis) or just on how similar is the matrix and patch vegetation at the nearest edge ("edge contrast" hypothesis). The latter asserts that the more similar the vegetation is across the nearest edge, the more likely it will be to find forest specialist species in the matrix (Zurita et al., 2012). This effect occurs because species encounter suitable conditions to disperse, available resources and/or a favorable abiotic environment in the matrix (Driscoll et al., 2013). However, this effect is predicted to change with distance from the edge to the interior of the matrix as conditions, resources and the abiotic environment may become less suitable as species permeate into the matrix ("proximity to edge" hypotheses).

Finally, the intensity of disturbances caused by agricultural management at the plot scale is receiving increasing attention as a factor influencing species retention in the matrix (Kennedy et al., 2010). Managing the land for agriculture often involves the simplification of the structure of native vegetation to favor the growth of crops and pastures. Hence, agricultural management practices increase the intensity of disturbances (e.g. vegetation clearing, plant regrowth suppression) and affect the suitability of the matrix for native species. Here we found relatively high support for the "disturbance" hypothesis, indicating that processes operating within the matrix (i.e. plot scale) have a strong influence on bird species occurrence in matrix types of Dry Chaco agricultural frontier landscapes. This effect was more pronounced for forest specialist species, suggesting that planning for the long-term conservation of Dry Chaco forests avifauna should pay attention to the effects of local agricultural management.

2. Methods

2.1. Study site

The study area corresponds to the upper portion of the Bermejo–Pilcomayo Interfluve (Salta province, Argentina), a tract of dryland of ca. 2 Mha between the Pilcomayo and Bermejo rivers (Fig. 1). The Bermejo–Pilcomayo Interfluve is delimited to the west by the eastern foot of the Andes range (elevation 500–380 m, annual rainfall 1000–800 mm) and extends to the east over the Dry Chaco plains (elevation 380–240 m, annual rainfall 800–500 mm). It is covered by xerophytic semi-deciduous forests dominated by red quebracho (*Schinopsis quebracho-colorado*) and white quebracho (*Aspidosperma quebracho-blanco*) and to a lesser degree by palo blanco (*Calycophyllum multiflorum*) and palo amarillo (*Phyllostylon rhamnoides*) in humid areas, and by palo santo (*Bulnesia sarmientoi*) and *Prosopis spp*. in drier areas. Deforestation from 1977 to 2008 has produced more than 1.5 million ha of cleared areas in Salta province (26% of its area) and 116,200 ha in the Bermejo-Pilcomayo Interfluve (Paruelo et al., 2011). In the Argentine Chaco, annual deforestation rates for the period 2002–2008 ranged between 1.5 and 2.5%, surpassing Latin America (0.51%) and global deforestation rates (0.2%) (Seghezzo et al., 2011).

2.2. Matrix gradient and structural attributes

A matrix intensification gradient was identified in the study area comprising four types of cattle ranching systems of increasing land-use intensity: very-low (VLIS), low (LISS), intermediate (IISS) and high (HIPS). Twenty-seven cattle ranches were selected and six sampling points were located within the grazing matrix in each cattle ranch (see Section 2.3). Six structural attributes were assessed in each of the 162 sampling points (Fig. 2). Each attribute varied independently across the matrix intensification gradient due to differences among cattle production systems in: (i) type of vegetation clearing method used to increase forage productivity; (ii) location within the agricultural frontier, and (iii) size of grazing plots. Two of the structural attributes influenced habitat quality for birds at the plot scale (i.e. plot tree cover and plot vegetation complexity), two of them operated at the edge scale (i.e. distance to edge and edge vegetation complexity) and the remaining two captured landscape-scale effects (i.e. distance to forest and landscape forest cover). The definition and assessment of the six structural attributes was as follows:

- *Plot tree cover (PTC):* land area covered by the arboreal strata in the grazing matrix, expressed as percentage of the sampling point area (0.2 ha). Tree cover at each sampling point was assessed via ocular estimation using a vertical tube. PTC was expressed as the quotient between zenith observations intercepted by the arboreal strata and total observations (25 per sampling point) multiplied by 100.
- *Plot vegetation complexity (PVC):* number of vertical strata of vegetation at the grazing matrix. Six strata were identified (bare soil [BS], herbaceous [H], shrub [SH, 1–3 m], lower arboreal [LA, 3–5 m], middle arboreal [MA, 5–10 m] and higher arboreal [HA, >10 m]), and seven levels of plot complexity were defined based on combinations of vegetation strata (Table 1).
- *Edge vegetation complexity (EVC):* number of vertical strata of vegetation at the edge of the nearest forest patch (definition of strata and complexity level as for PVC).
- *Distance to edge (DE):* linear distance between the center of the grazing matrix (sampling point) and the nearest area where the vertical complexity of vegetation increases or decreases by 2 or