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Contribution of woody habitat islands to the conservation of birds and their potential ecosystem services in an extensive Colombian rangeland

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ABSTRACT

In agricultural landscapes, patches of natural or semi-natural habitat are crucial for the survival of plant and animal populations, which in turn are essential to maintain ecosystem functioning. Species composition and diversity of trees and birds among woody habitat islands were compared in a Colombian rangeland to assess how habitat characteristics influence bird community composition, bird species traits and their potential ecosystem services. Bird and tree diversity was higher in gallery forest fragments compared to hedgerows and isolated tree islands within rangelands. Forest fragments shared over 50% of their bird and tree species with tree islands and hedgerows, yet communities differed markedly. Tree islands and hedgerows had relatively more endozoochorous and small-seeded tree species and hosted birds of forest, savanna and shrubland, while forest fragments had more synzoochorous and large-seeded tree species and primarily hosted forest birds. Hedges and tree islands contribute to the conservation of forest bird and tree biodiversity in rangeland, but gallery forests are essential for the conservation of less tolerant forest species. The savanna rangeland acts as an ecological filter between the gallery forests and the hedges and tree islands, which in turn facilitate the spillover of tolerant forest birds and their ecological functions, including tree seed dispersal, into the rangeland, and thus support regional forest conservation and restoration.

1. Introduction

Birds have important ecological functions which are essential for the provision of ecosystem services such as pollination, seed dispersal and pest control (Sekercioglu, 2006). In the tropics, habitat losses and habitat degradation, in particular in forests, are causing rapid declines in bird species, which in turn may cause reductions in ecosystem processes, services and benefits (Sekercioglu et al., 2004, 2012). In coffee agroforests, for example, reduced floristic diversity leads to reduced control of insect populations by birds and thus to crop losses (Borkhataria et al., 2012; Philpott and Bichier, 2012). In disturbed forests, altered seed dispersal patterns, for instance due to declining populations of frugivores, may influence succession, cause regime shifts in plant communities and thus modify ecosystem functioning (Farwig and Berens, 2012; McConkey et al., 2012). The conservation of birds is, therefore, essential to maintain ecosystem services delivery across a wide range of habitats including human-dominated habitats such as farmland, agroforests and rangeland (Bradbury et al., 2010; García et al., 2010).

Conservation of forest birds and their services in tropical agricultural landscapes depends on the resilience of the bird communities to disturbance (Karp et al., 2011) and on the conservation of suitable habitats of varying quality in the farmland matrix (e.g. Sekercioglu et al., 2007; Aerts et al., 2008; Gavier-Pizarro et al., 2012; Martin et al., 2012). These habitats include forest fragments, isolated trees, tree islands and linear features such as hedgerows, riparian corridors and tree-lined roads (e.g. Fischer and Lindenmayer, 2002; Manning et al., 2006; Gillies and Clair, 2008; Lentini et al., 2011). The

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extent to which these habitats are suitable for forest birds depends on their structural complexity (Haslem and Bennett, 2008) and on the resources they have to offer, including food, nesting sites, and perches.

Here, the results of a tree and bird community study from the Llanos Orientales savanna rangeland in central Colombia are presented. The objectives of the study were to assess whether differences in plant communities among isolated woody habitats in the rangeland are reflected in bird communities and their potential ecosystem services. It was hypothesized that: (1) overall tree and bird species diversity is higher in remnant forests than in other woody habitat islands; (2) tree and bird species communities differ between forests and the other habitat islands; and (3) there are direct links between tree composition, habitat characteristics, bird species and bird species traits.

2. Methods

The study was conducted in the Llanos Orientales savanna near the municipality of Granada in the Meta department in central Colombia (360–380 m asl, 3°36′ N, 73°43′ W, Fig. A.1). The Llanos Orientales or Eastern Plains is a region of wide grassy plains with meandering rivers that flow from the Andean foothills in the west to the Orinoco River in the east. The study site is located 20 km east of the Andean foothills. The main soil types are orthic ferralsols (USDA: oxisols) and plinthic acrisols (USDA: ultisols) with dystric fluvisols (USDA: fluvents) along the major rivers. Annual precipitation in the region averages 2500 mm, and drier seasons occur during January–February and July–August. The area is marked by a continuously hot climate, with a mean annual temperature of 24.8 °C and daily mean temperatures ranging between 24.0 and 25.6 °C. The natural vegetation is deciduous dry tropical forest, but most of the Llanos Orientales are covered with various types of anthropogenic savanna mainly used for cattle farming (Stevenson and Aldana, 2008). The grassy plains are interspersed with patches of natural vegetation, mainly tree islands and gallery forests along the meandering rivers. Grazing blocks are often lined with recent (<40 y old) hedgerows (Fig. A.2), consisting of trees or bushes naturally regenerating along the fences. Tree islands and hedgerows are highly appreciated by farmers as they provide services for the ranching system (e.g. to shade the cattle). The present study covered an area of approximately 400 ha which contained two continuous gallery forests with highly variable width (between 60 and 420 m wide), 200 tree islands, and 6 km of hedgerows that function as living fences (Fig. A.1). The gallery forests and the tree islands have had approximately the same area at least since 1970, while the living fences were established after 1982.

2.1. Study design

Between July and October 2011, vegetation composition and structure, abiotic site characteristics and birds were recorded in three habitat types representing forest and additional woody habitats in the savanna matrix, i.e. (1) gallery forest; (2) tree islands; and (3) hedgerows (Fig. A.2). Using a stratified random sampling design, 20 plots were placed in the two forests, 20 plots in 20 tree islands, and 10 plots along 5 hedgerows (Fig. A.1). The plots in forests and tree islands were circular, with a radius of 11.3 m, and those along hedgerows were rectangular (4 × 100 m), with the long side parallel to the hedgerow and the hedgerow running along the centerline of the plot. All plots were 400 m^2 in size, but some tree islands were smaller. For these small patches, effective patch size was estimated from two perpendicular patch diameter measurements.

2.2. Vegetation composition, structure and traits

To determine woody species composition and stand structure, height and diameter at breast height (dbh) were measured for all woody plants with a dbh > 5 cm, including standing dead trees. Stem density (stems/ha), basal area (m^2/ha) (both corrected for effective patch size when necessary) and mean tree height (m) were calculated. Canopy cover (%) was calculated from 20 systematic measurements of canopy presence or absence using the Cajanus tube method (inner tube diameter: 0.5 cm). Grass cover (%) was calculated from Braun–Blanquet scores recorded in 10 1-m^2 subplots. In the same subplots, also the number of tree seedlings was counted. Average depth of the ectorganic horizon (mm) and soil depth (m) were calculated from five measurements at random locations within the plot. For soil depth the rod penetration method (rod diameter: 1 cm) was used. Dispersal mode (anemochorous, synzoochorous and endozoochorous) and seed size class (small: <0.5 cm width; medium: $0.5 \leq$ width ≤ 1; large: width > 1) were assigned to all recorded species (following Stevenson and Aldana, 2008) and relative frequencies were calculated for all classes.

2.3. Bird surveys and traits

Point counts were used to determine bird species abundance and count stations were at the plot centres. All 50 point count locations were surveyed four times, with at least 20 days between counts at the same point. The order in which stations were counted was randomized, but successive counts were never performed in neighbouring stations. All point counts were conducted in relatively dry weather and between 0620 and 1100 h when birds were most active. At each point, all birds seen or heard up to a 30 m radius within a 10 min period were recorded, except flyover birds. For all recorded bird species, data on average body mass, minimum and maximum number of eggs laid, preferred habitat, habitat breadth (number of major habitat types used), tolerance to disturbance, primary diet and diet breadth (number of major food sources consumed) were obtained from a world bird ecology database with standardized entries on the ecology of all bird species of the world (Sekercioglu, 2012). For numerical traits, averages per plot were calculated for the species observed in that plot. For categorical variables, the proportions for all categories were calculated for every plot (=the number of occurrences of a category in a plot divided by the number of species in the plot).

2.4. Data analysis

For plant data, α (average species richness per plot), β (= γ/α, total richness/average richness), γ (total richness per habitat type), and *Chao1* (expected species richness based on abundance data) were calculated. For birds α, β, γ and *Chao2* (expected species richness based on incidence-based data) were calculated. Mean species diversity (α) among habitat types was compared using Kruskal–Wallis one-way analysis of variance by ranks. *Chao1* and *Chao2* were calculated in EstimateS 8.2 (Colwell, 2009). Statistical tests, unless noted otherwise, were performed in IBM SPSS Statistics 20 (IBM Corp., New York, USA).

To compare community composition of birds and woody plants among the three different habitats, an indirect gradient analysis approach was adopted, with birds (presence data of species observed in at least two count stations) and woody plants (log-10 transformed basal area data of species present in at least two plots) analyzed separately. Multi-response permutation procedure tests (MRPP) were used to test for multivariate differences in community composition among habitat types. For MRPP, the Sørensen distance measure and a natural group weighting factor $n_i/\Sigma\ n_i$ were used, where n_i is the number of sample plots in each group.