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Birds, charcoal and cattle: Bird community responses to human activities in an oak forest landscape shaped by charcoal extraction

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ABSTRACT

Oak forests around the world have been widely used to obtain firewood and produce charcoal and like other habitats have been affected by the increasing development of livestock activities. Oak forests from western Mexico are one of the five priority habitats for the conservation of birds at a continental level and are the repository of the highest number of endemic bird species in this megadiverse country. We studied how charcoal extraction and the use of oak forest for cattle grazing affect bird communities. We focused our work on oak forest patches with four different management units that include three successional stages that occur after most of the trees have been removed for charcoal production and cattle-grazing is conducted, and mature oak forest patches with little wood extraction and no cattle-grazing. We used unlimited radius point counts to survey avian communities, and compared their richness, composition, density, structure and similarity among the different management units. We found that resident bird species, summer migrants and Neotropical migrant bird species used the four management units differently. Resident bird species used all habitat units similarly. Winter migrants as a group were present in the different management units, however while some species used habitats with cattle, other species used habitats with no cattle-grazing. Finally, summer migrants used habitat units with tall trees and high values of tree and shrub richness, and tended to avoid the early successional unit. Both charcoal extraction and cattle grazing worked in synergy decreasing the species richness and the equity of the bird communities. Management strategies should include active conservation of undisturbed oak forest areas because they play an essential role to maintain resident bird species in the landscape.

1. Introduction

Oak forests are important elements of both temperate and tropical ecosystems (Abrams, 2003; Valencia, 2004). Mexico is one of the centers of diversification for the genus *Quercus* (over 160 species), with oak forests covering ~5.5% of the landscape (Rzedowski, 1978; Valencia, 2004). These ecosystems present a high floristic and physiognomic diversity, and have great ecological importance (Flores and Gerez, 1994), especially for birds, being one of the five richest habitats for avian species throughout the Neotropics, and having the largest number of endemic bird species for any given habitat in Mexico (Flores and Gerez, 1994; Stotz et al., 1996).

In addition to their ecological value, oak forests are regarded worldwide as an ecosystem with high economic importance, being used intensely for the production of wood and timber (Abrams, 2003; Valencia, 2004; McShea et al., 2007; Arriaga Cabrera et al., 2009). In developing countries like Mexico, about 80% of the wood extracted from oaks is used to obtain energy as charcoal and/or firewood (Rzedowski, 1978; Aguilar et al., 2012). As a result, in recent decades charcoal production has been one of the main causes of deforestation of large stands of oaks in this country (Rzedowski, 1978; Works and Hadley, 2004; Challenger et al., 2009). Oak forests managed for charcoal production tend to form landscapes with complex and diverse habitat mosaics. Usually they include forest fragments of different ages, which are generated by the rotation of wood cutting among forest patches (Kubo et al., 2005; García Burgos, 2007). In addition to wood extraction, other productive activities, such as cattle grazing, tend to be carried out within these charcoal producing landscapes. While this is a common practice, there is little information on the effects of these human activities on biodiversity oak forests of western Mexico.

In this study, we used bird communities as a model to understand effects of oak forest management on biodiversity. We

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compared avian communities among four management units related to the production of charcoal. We define a management unit as a forest patch that shows uniformity in land use (Zonneveld, 1989). The four management units we studied include: (a) three successional stages that occur after most of the trees have been removed for charcoal production where also cattle-grazing is conducted, and (b) ungrazed mature oak forest patches. We used this study system to determine how avian species richness, bird densities, and the structure and composition of bird communities changed in relation to habitat management for charcoal extraction and cattle grazing. We hypothesized that species richness should increase in relation to habitat structural complexity and as a response to the absence of cattle in the system. On the other hand, because disturbed/simpler habitats tend to present high quantities of a low number of food resources, bird density should be higher in the management units that are structurally simpler and used for cattle grazing activities (Winker et al., 1990; Petit et al., 1999; Dunn, 2004). We also hypothesized that the responses of resident and migratory bird species should differ in each of the management units. Resident bird species should present larger differences in their communities among management units than Neotropical migrants because they have to confront the existing habitat conditions throughout the year, while migrants can act as habitat generalists because they use different environments in different seasons (Hutto, 1989; Lynch, 1989; Levey, 1994; Smith et al., 2001).

2. Methods

2.1. Study area and study sites

Our study was conducted in the Cuitzeo watershed, located in the central-northeast region of the state of Michoacán in west central Mexico (19°30′–20°05′N; 100°35′–101°30′W). The Cuitzeo watershed comprises an area of 4026 km^2 including 28 municipalities from the states of Michoacán and Guanajuato (Leal-Nares et al., 2010). The altitudinal range varies between 1830 and 3420 masl. This watershed presents high ecological diversity, including several temperate types of forests that include oak, pine, fir and mixed forests (López et al., 2001). We studied the bird communities that inhabit four management units of oak forests of *Quercus castanea* (an oak species endemic to Mexico) that are used for the production of charcoal. Locally, this is one of most abundant, widely distributed, and frequently used, oak species (Aguilar et al., 2012). The management units we sampled included an early-successional stage following intensive wood extraction for charcoal (~12 years old), which is characterized by oaks sprouting from stumps having the appearance of shrubs and a dense understory composed mostly of grasses, and free-ranging cattle. A middle-successional stage (~25 years old), in which the re-sprouting oaks have a tree structure with a height between 8 and 10 m and an understory of grasses and free-ranging cattle. And a late-successional stage (>35 years old) that presents two conditions: mature oak forest with an open understory and free-ranging cattle and ungrazed mature oak forest with a diverse shrub understory. All our sites were located at 2140–2195 masl. Our study area covered an area of approximately 30 km^2. We established 10 independent sampling units within each of the four management units. Most of the sampling points were located in plots managed by different landowners and most of the plots were separated by cattle-fences. Size of plots varied from 1.5 to 120 ha.

2.2. Bird surveys

Birds were surveyed in winter (November 2011) and summer (June 2012) to determine patterns for resident (breeding) and wintering birds (non-breeding long-distance migrants). We used unlimited radius point-counts, which were separated by at least 250 m to assure survey independence (Ralph et al., 1995, 1996; Bibby et al., 2000; MacGregor-Fors and Schondube, 2011, 2012). We sampled one point in each sampling plot, and in most cases sampling points were 400–500 m apart. We only recorded birds that were inside the management unit being sampled. Surveys were conducted for 5 min at each point-count, and all birds detected within the habitat (both visually or auditory) were counted. All surveys were conducted between sunrise and 1100 h. We used a range-finder (Bushnell; Yardage Pro Scout 6x) to measure the distance from the observer to each bird detected in our point counts. All observations were conducted by two observers that trained together, until their observations were comparable. All birds surveys were carried out under similar weather conditions (sunny open skies, low wind), to avoid changes in bird detection probabilities.

2.3. Habitat characterization

We evaluated differences in habitat structural complexity by measuring several vegetation variables in 0.19 ha circular plots (25 m radius) at the 10 point-counts within each of the four management units. We recorded: (1) the number of vegetation layers, (2) the mean height of each layer (trees, shrubs and herbs in m), (3) the percentage cover of each layer, (4) the percentage of bare soil, (5) tree diameter at breast height (DBH in cm), and (6) tree species richness (Ralph et al., 1995; Estrada et al., 1997; Bibby et al., 2000; Smith et al., 2001; MacGregor-Fors et al., 2010; MacGregor-Fors and Schondube, 2011).

2.4. Data analysis

To determine the effectiveness of our bird surveys, we compared our data to the number of species expected by the non-parametric estimator of total species richness ACE-1 for the whole area, and for each of the successional stages using SPADE (Chao and Shen, 2006). We used rarefaction curves to compare species richness values among habitats. These were computed in EstimateS 7.0 (Gotelli and Colwell, 2001; Colwell, 2005). We applied a cut-off point of 116 individuals (based on the bird abundance of the habitat with lowest avian diversity). We used the program Distance 6.0 to calculate bird densities in each management unit (Thomas et al., 2005). This software calculates the probability of detection of individuals at increasing distances from the observer and estimates the number of bird individuals that exist within a surveyed area (Buckland et al., 2001). We computed bird densities for the entire bird community of each habitat unit because Distance 6.0 estimates the number of bird individuals that exist within a surveyed area by calculating the probability of detection of individuals, and standardizing the number of detections along the concentric distances of observations (Buckland et al., 2004). This software can pool species to avoid biases resultant from differences in detection probabilities among them, or due to differences in habitat structure (Buckland et al., 2004), which could both over- or under-estimate due to the commonness/rarity of species and their differences in detection rates (Alldredge et al., 2007). We calculated the 84% confidence intervals for the mean values of species richness and bird densities of each of the management units, and these were considered statistically different with an $\alpha < 0.05$ if their confidence intervals did not overlap (Payton et al., 2003; MacGregor-Fors and Payton, 2013).

To compare the structure (dominance/evenness) of the bird communities, we used rank/abundance plots (Whittaker plots) as suggested by Magurran (2004). Rank/abundance plots are used to represent the species abundance distribution of a community.