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Influences of succession and erosion on bird communities in a South American highland wooded landscape

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ABSTRACT

In South American highland forests, domestic grazing can cause major changes in forest structure and soil quality thereby altering resources available to avian communities. However, the consequences of changes in variability in plant growth forms after disturbance are little known. Understanding forest succession effects on avifauna is critical though, given that area in secondary forests is expected to increase in the future. We sampled bird communities at 172 sample points in *Polylepis* shrublands and forests patches in Argentina. For each of these points, we calculated vegetation variables (NDVI, NDVI texture indices), landscape pattern variables (patch area and connectivity), and human disturbance variables (erosion, distances to settlements and roads), based on a Landsat 5 TM image, a local land cover map, and topography (slope and altitude) from a Digital Elevation Model. Bird communities in *Polylepis* forests included approximately twice as many species and double the abundance than those in shrublands. Species composition strongly differed between the two growth forms as well, birds that use the ground vegetation to nest and forage were less abundant in shrubland patches, air foragers were also less abundant in shrubland patches. Soil erosion, proximity to human settlements and forest isolation were the best predictors of bird richness and abundance in *Polylepis* vegetation patches. Abundance of birds that use the ground for nesting and foraging were negatively related to soil erosion. We concluded that *Polylepis* avifauna communities are primarily influenced by human impact on soils rather than by vegetation structural characteristics. *Polylepis* vegetation restoration and reduction of livestock grazing would likely reduce soil erosion rates, promote natural regeneration, increase patch connectivity and enhance microhabitat conditions for avifauna in high-altitude *Polylepis* forests and shrublands.

1. Introduction

Livestock grazing plays an important role in the dynamics of mountainous forest ecosystems in South America (Vera, 2000; Cingolani et al., 2005, 2008). Livestock grazing may be necessary to maintain ecosystem structure and function if the native wild herbivore populations are decimated or extinct or if herbivores presence is ancient in the ecosystem (Cingolani et al., 2005, 2008, 2014). However, if the ecosystem is maintained at commercially optimal stocking rates (i.e. high grazing pressure), it may be seriously affected (Cingolani et al., 2013, 2014). Large herbivore grazing alters tree survival and growth form, prevents shrublands from succeeding to forest, and may maintain grasslands in sites where forests could grow (Vera, 2000; Renison et al., 2006; Giorgis et al., 2010; Marcora et al., 2013). Overgrazing also induces soil erosion and with it loss of litter cover, seed banks, soil nutrients, water infiltration, and soil chemical properties (Renison et al., 2010; Hiltbrunner et al., 2012). This ultimately changes landscape configuration and functionality, thereby affecting available resources for native fauna and consequently faunal abundance and richness (Waltert et al., 2004).

Birds have been used as bio-indicators of land cover integrity in many ecosystems; because they provide services (e.g. seed dispersal, pest control, pollinitation) that are essential for ecosystem functioning and sustainability (Ogada et al., 2008). When distinct ecosystems, such as forests, are lost or altered, the ecological roles of birds change (Sekercioglu et al., 2004). Soil erosion adversely affects forests by modifying soil organic content, water penetrability, and vegetation cover. These changes in turn, strongly affect presence and abundance of different plant species, and aerial and

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soil invertebrates. As a result, both food availability for insectivorous birds (Molina et al., 1999; Gilroy et al., 2008; Bellis and Muriel, in press) and nesting substrates (e.g. Neave et al., 1996; Wilson et al., 2005) are reduced. This makes it important to understand the relative roles of grazing and soil erosion as causal factors of changes in bird communities in highland forest systems that are grazed, in order to inform conservation strategies (Quesada et al., 2009).

The highland forests in central Argentina is a site of international importance for bird conservation (Fjeldså, 1993; Herzog et al., 2003; Cahill and Matthysen, 2007; Lloyd and Marsden, 2008). The forest is an Important Bird Area (IBA – AR 161, *sensu* Birdlife International, 2014a) and located within an Endemic Bird Area (EBA 058, *sensu* Birdlife International, 2014b). In this region, wooded highlands (~1700–2800 m asl) are dominated by *Polylepis australis* forests. The genus *Polylepis* is endemic to South America, where it forms almost all tropical tree lines. Unfortunately, *Polylepis* forest is considered to be among the most endangered tropical and subtropical mountain ecosystems in the world (Fjeldså and Kessler, 1996; Gareca et al., 2010) and the majority of the ca. 30 species of the genus are classified as vulnerable (Toivonen et al., 2011). Currently, *Polylepis* forest remain only as scattered remnant patches of a once more continuous distribution, and are largely restricted to ravines and rocky outcrops where the impact of livestock grazing and anthropogenic burning is low (Fjeldså and Kessler, 1996; Kessler, 2002; Renison et al., 2006; Cingolani et al., 2008; Gareca et al., 2010). Mature *P. australis* forests typically are characterized by considerable volumes of standing and dead wood, a dense fern understory and presence of the *Maytenus boaria*, a shade tolerant tree species (Renison et al., 2011), but such forests are increasingly rare.

Polylepis shrubland is an early stage on the successional path to *Polylepis* forests. *Polylepis* shrubland is maintained in shrub form by browsing and by frequent anthropogenic fires in the majority of the species' range (Cabido and Acosta, 1985; Fjeldså and Kessler, 1996; Renison et al., 2006; Cingolani et al., 2008; Giorgis et al., 2010; Marcora et al., 2013) and is often accompanied by widespread soil erosion (Renison et al., 2006; Cingolani et al., 2008; Gareca et al., 2010; Toivonen et al., 2011). The structure of shrub and tree forms of *Polylepis*, and resources available for avifauna, differ considerably (Teich et al., 2005; Cingolani et al., 2008). In *Polylepis* shrublands, grazing pressure is higher and erosion is more active (Cingolani et al., 2004). Moreover, lower overstory, tree basal area and vertical complexity (Renison et al., 2011), combined with the reduction of associated vines, ferns and other understory plants, affects nesting and foraging resources available to avian *Polylepis* specialists (Fjeldså, 1993). However there is no information about the conservation value of *Polylepis* shrubland for native birds. Conversion of *Polylepis* forest to shrubland has, to date, been linked with changes in avifauna distribution and habitat availability only at the scale of individual patches of forests (e.g. Fjeldså and Kessler, 1996; Kessler et al., 2001; Herzog et al., 2003; Cahill and Matthysen, 2007; Lloyd and Marsden, 2008, 2011; Bellis et al., 2009, 2014; Tinoco et al., 2013), and no studies have addressed the combined influence of changes in vegetation structure (defined as variability in plant growth forms) and extensive soil erosion on the bird community.

Our goal was to evaluate relationships between vegetation structure (measured as variability of above-ground biomass), soil erosion, and spatial arrangement of *Polylepis* patches and characteristics of bird communities. Unlike previous studies on *Polylepis* birds that used only vegetation data at the local or point scale, we considered information at broad and fine scales simultaneously using texture measures, an effective tool for characterizing vegetation from remotely sensed data. Texture variables are indexes related to both between-vegetation patches and within-vegetation patches structures (Bellis et al., 2008; St Louis et al., 2009), and have been successfully used to model birds in different environments such as savannas (Wood et al., 2013), forests (Culbert et al., 2012; Wood et al., 2013), grasslands (Bellis et al., 2008), and desert scrub ecosystems (St-Louis et al., 2009). Recent studies showed that image textures were better predictors of avian richness than field-measured vegetation structure (Wood et al., 2013), and could be used to map species richness over larger areas, such as *Polylepis* forests, where limited access make it difficult to measure traditional forest variables in the field.

In this study we addressed the following questions: (1) Are there differences in bird species richness and assemblage structure between *Polylepis* forests and shrublands? (2) What are the main vegetation attributes associated with these bird communities? (3) Does bird assemblage structure within *Polylepis* forest and shrubland have implications for vegetation management and conservation strategies?

2. Methods

2.1. Study area

Our study was conducted in the upper vegetation belt of the Sierras Grandes of Córdoba (Central Argentina, 1,700–2,800 masl, 31°34′S, 64°50′W; 124,700 ha), in "Quebrada del Condorito" National Park (26,000 ha) and two adjacent designated water reserves (National 12,000 and Provincial 117,000 ha). Vegetation consisted of a mosaic of tussock grasslands, *P. australis* woodlands and shrublands, grazing lawns, granite outcrops and eroded areas with exposed rock surfaces (Cingolani et al., 2004). The first humans settled in the area about 8000 years ago and altered the environment by using fire for hunting (Berberián, 1999; Pastor, 2000). Since early European settlements (~400 years ago) *Polylepis* forests have been affected by logging and fire to create grazing grounds for horses, sheep, goats, and cattle (Díaz et al., 1994). In 1997, "Quebrada del Condorito" National Park and the water reserves were created to reduce soil erosion and protect vegetation in order to maintain water-holding capacity. However, the water reserves are under private ownership, traditional livestock practices continue, and soil erosion remains a severe problem in most of the area (Cingolani et al., 2008; Renison et al., 2010).

Forests (characterized by tree-form *Polylepis*) currently occupy 2.5% (3157 ha) of our study area (Cingolani et al., 2008). In Sierras Grandes of Córdoba, *P. australis* attains a height of up to 14 m and lives up to 120 years (Suárez et al., 2008; Renison et al., 2011). The rare patches of mature *P. australis* possess several attributes found nowhere else in these mountain ecosystems, such as a relatively high volume of standing and down dead wood (19.5 m^3/ha on average), a dense fern understory (up to 30% cover), many fungus species, overstory of approximately 72%, and presence of many *Maytenus boaria*, a rare shade-tolerant tree species (Renison et al., 2011).

Shrublands dominated by *Polylepis* occupy 9.4% (11,674 ha) of the area and are mixed with grasslands and rocky outcrops, both natural and resulting from erosion. Shrublands show different degrees of disturbance, and usually have overstory of ⩽23%, little standing or down dead wood (<3 m^3/ha), low fern cover (<7%), few *Maytenus boaria* trees (<6 individuals/ha), an average shrub height of ⩽5 m, and an average age ~47 years (Renison et al., 2011).

2.2. Bird Surveys

Bird data were collected during two breeding seasons (January 18 to March 19 2006, and October 20 2007 to March 30 2008) when bird species richness peaks due to presence of both migrant