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Coffee management and the conservation of forest bird diversity in southwestern Ethiopia

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ABSTRACT

Moist evergreen forests of southwestern Ethiopia host high levels of biodiversity and have a high economic value due to coffee production. Coffee is a native shrub that is harvested under different management systems; its production can have both beneficial and detrimental effects for biodiversity. We investigated how bird community composition and richness, and abundance of different bird groups responded to different intensities of coffee management and the landscape context. We surveyed birds at 66 points in forest habitat with different intensities of coffee management and at different distances from the forest edge. We explored community composition using detrended correspondence analysis in combination with canonical correspondence analysis and indicator species analysis, and used generalized linear mixed models to investigate the responses of different bird groups to coffee management and landscape context. Our results show that (1) despite considerable bird diversity including some endemics, species turnover in the forest was relatively low; (2) total richness and abundance of birds were not affected by management or landscape context; but (3) the richness of forest and dietary specialists increased with higher forest naturalness, and with increasing distance from the edge and amount of forest cover. These findings show that traditional shade coffee management practices can maintain a diverse suite of forest birds. To conserve forest specialists, retaining undisturbed, remote forest is particularly important, but structurally diverse locations near the forest edge can also harbour a high diversity of specialists.

1. Introduction

Tropical forest biodiversity is rapidly declining due to the conversion of forests to agriculture and the intensification of traditional agricultural systems (Wright, 2005). Between 1990 and 2010, the amount of deforested land across the wet tropics increased by 62% (Kim et al., 2015), coupled with a 40% increase in human population numbers (Edelman et al., 2014). For tropical biodiversity conservation to be successful, it needs to promote and ensure viable rural livelihoods. In this context, tropical agroecosystems and in particular shade coffee agroforests have received considerable attention, given their potential benefits for both conservation and livelihoods (Bhagwat et al., 2008; Reed et al., 2016).

Coffee is one of the world's major agricultural commodities grown in tropical areas (Jha et al., 2014) occupying an area of 10.5 million ha worldwide (FAO, 2014). The species *Coffea arabica* represents two thirds of the world's coffee market (Aerts et al., 2011), and is mostly produced in agroforests (Perfecto et al., 1996; Jha et al., 2014). To date, the vast majority of research investigating the implications of coffee production for biodiversity has focused on Latin America (Philpott et al., 2008 and references therein). However, coffee is also of particular relevance in East Africa, from where it originates (Senbeta and Denish, 2006). The Arabica coffee shrub is native to the biodiversity hotspot of wet Afromontane forests of southwestern Ethiopia, where it naturally occurs at low densities (Labouisse et al., 2008). In Ethiopia, coffee is a highly valued cash crop, with significant economic and cultural value (Petit, 2007).

Coffee in Ethiopia is traditionally grown in agroforests, under the shade of native trees but with varying degrees of management. Management can range from very little or no intervention, to the pruning and thinning of the canopy, coupled with the removal of understorey species that may compete with coffee (Aerts et al., 2011). In

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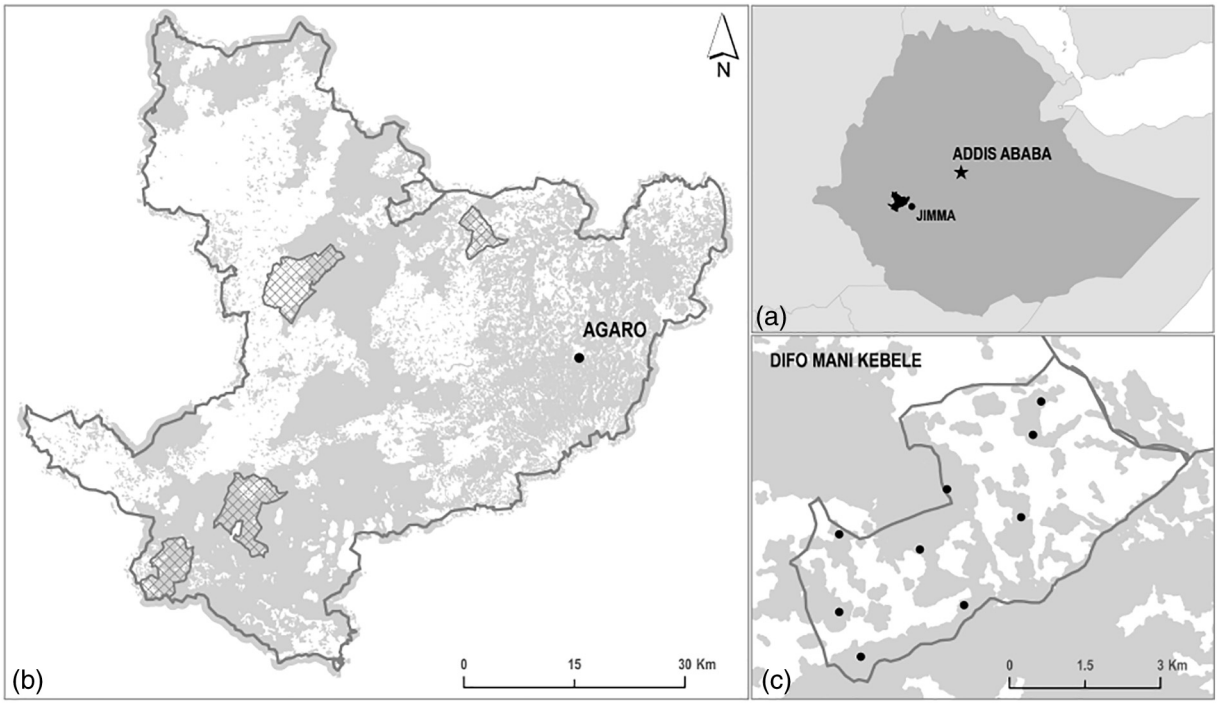

Fig. 1. Location of (a) study area in Jimma zone, southwestern Ethiopia; (b) the five focal *kebeles* in Agaro/Jimma zone (hatched); (c) example of sampling design with survey points (black bullets) in one *kebele*. In (b) and (c) grey colour depicts woody vegetation.

the last few decades, coffee growing areas of southwestern Ethiopia have experienced both high rates of deforestation (mainly for agriculture) and a push towards the intensification of coffee production in state and privately owned plantations (Tadesse et al., 2014a). Intensification is achieved through different management practices, including the reduction of shade tree cover and diversity; an increase in coffee density; the replacement of native shade trees with faster growing exotic species; the use of agrochemicals; and the use of improved coffee varieties (Tadesse et al., 2014b). Accordingly, coffee growing has mixed effects on biodiversity conservation in southwestern Ethiopia. On the one hand, coffee production can help to reduce deforestation, because it provides a source of revenue from remnant forest, thus creating an incentive to maintain it (Philpott and Bichier, 2012; Hylander et al., 2013). On the other hand, a shift towards more intensively managed coffee plots can cause the homogenization and simplification of forest structure and diversity, with potentially negative effects on biodiversity (Aerts et al., 2011; Hundera et al., 2013).

Different species can be expected to respond in different ways to coffee management, and a mixture of positive, negative or null responses of species to coffee management practices have been reported (see Komar, 2006 and Philpott et al., 2008 and references therein). Typically, forest specialist species respond positively to systems with a high degree of naturalness, whereas generalist species tolerate more disturbed or simplified systems (Tejeda-Cruz and Sutherland, 2004). The ability of species to persist in landscapes with different degrees of coffee management will depend on a variety of factors, including: (1) species life history traits and ecological attributes (such as breeding and feeding strategies and habitat affinity) (Newbold et al., 2013); (2) site-specific conditions (such as vegetation structure and composition) (Leyequién et al., 2010); and (3) landscape context (such as landscape configuration, natural forest cover surrounding a site and distance to edge) (Tejeda-Cruz and Sutherland, 2004; Anand et al., 2008). Site-specific conditions and landscape context, in turn, can be expected to co-vary, with sites near forest edges being more disturbed and structurally different from reference sites deep within the forest (Harper et al., 2005). Both the management of coffee sites and the landscape context are thus important for biodiversity outcomes, but because they often co-vary, their separate effects remain poorly understood. Therefore, and especially in the context of rapidly changing coffee management in Ethiopia, a better understanding of the effects of landscape context and site-specific conditions is urgently needed to inform appropriate management practices.

Here, we used birds as a focal taxon. Birds play important functional roles in ecosystems, as seed dispersers, pollinators, predators and ecosystem engineers, thereby providing a direct link between biodiversity and ecosystem functions and services (Şekercioğlu, 2006). In Ethiopia, few studies have documented the effects of coffee management on bird diversity (but see Gove et al., 2008; Buechley et al., 2015; Engelen et al., 2016). Existing studies suggest that relatively intensively managed coffee systems had higher species richness than forests with more sparse coffee (Buechley et al., 2015), but that forest specialists may decline with increasing coffee density (Gove et al., 2008). Notably, to date, the value of undisturbed forest areas has not been systematically compared with locations managed at different intensities, and the effects of site-specific characteristics and landscape context remain poorly understood. To overcome these shortcomings, we investigated (*i*) how bird community composition changes along a gradient of coffee forest management; and (*ii*) how management intensification and landscape characteristics relate to the richness and abundance of different groups of birds, including functional groups and species with different range sizes.

2. Material and methods

2.1. Study area

Our study was conducted in an area of approximately 3800 km^2 in the Jimma Zone, Oromia (Fig. 1). It focused on three districts (*woredas*): Gera, Gummay and Setema. The region is undulating, with steep slopes and flat plateaus in some areas, and elevation ranges from 1900 to 3000 m above sea level. The climate is conditioned by the Inter-Tropical Convergence Zone (Schmitt et al., 2013), with 1500–2000 mm of annual rainfall (Friis et al., 1982), and a mean annual temperature of approximately 20 °C (Cheng et al., 1998). The region is part of the

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