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Bird communities in sun and shade coffee farms in Kenya

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ABSTRACT

Agricultural expansion to meet rising crop demand is one of the greatest threats to terrestrial biodiversity. Coffee, one of the most valuable trade items in tropical countries, can provide both economic livelihood and wildlife habitat. Previous work, conducted primarily on Neotropical coffee farms, indicates that birds are generally more abundant and diverse in farms with a canopy of shade trees, though regional variation exists. To date, few studies have examined birds on coffee farms in Africa, which contains 20% of the world's coffee acreage. We studied differences in the bird communities between sun and shade monoculture coffee in central Kenya, and we examined effects of vegetation on bird abundance and diversity. Sun coffee had higher species richness and abundances of all major guilds (omnivores, insectivores, and granivores), and showed low community similarity to shade. Unlike findings from the Neotropics, canopy cover appeared to have a negative influence on all guilds, while understory volume of weeds increased bird abundance and species richness with a similar magnitude as canopy cover. These differences highlight the need for further studies in the general East Africa region with a wider variety of shade coffee systems.

1. Introduction

Agriculture is one of the greatest threats to biodiversity (Foley et al., 2005, 2011; Gotelli and Ellison, 2013), especially in the tropics, where it is the leading cause of deforestation (Donald, 2004; Geist and Lambin, 2002). Agriculture, including cropland and permanent pasture, currently occupies nearly 40% of the earth's land surface (Ramankutty et al., 2008; World Bank, 2012) and production may need to increase up to 100% by 2050 to meet expected global food demand (Tilman et al., 2011). Identifying strategies to minimize the loss of biodiversity while maximizing agricultural yield is clearly one of the most pressing needs for conservation (Fischer et al., 2008).

Coffee (*Coffea* sp.) is one of the most valuable legally-traded commodities for developing countries (Donald, 2004; O'Brien and Kinnaird, 2003). Cultivated on more than 10 million hectares worldwide (FAO, 2012), typically in forested tropical regions with high biodiversity, coffee significantly influences global biodiversity (Donald, 2004; Mittermeier et al., 1998; Moguel and Toledo, 1999). Coffee is traditionally grown under a canopy of shade trees (Donald, 2004). Empirical data suggest yields may be maximized at intermediate amounts of shade (Soto-Pinto et al., 2000), but coffee is increasingly grown in full sunlight, a global trend driven in part by government incentives to promote agricultural intensification and use of agrochemicals to maximize short-term yields (Donald, 2004; Jha et al., 2014; Rice and Ward, 1996). Due to the expansion

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of sun coffee and its potential influence on tropical biodiversity, it is vital to understand the impacts of sun and shade management strategies.

Studies in the Neotropics and India suggest that bird communities in coffee are generally more diverse and abundant in shade coffee than in sun coffee, especially as cultivation intensifies (González, 1999; Gordon et al., 2007; Greenberg et al., 1997a; Petit and Petit, 2003; Wunderle and Latta, 1996). In a meta-analysis of studies in Latin America, Philpott et al. (2008) found that bird species richness tended to increase with greater habitat complexity, especially higher tree richness, tree density, canopy height, canopy cover, and canopy depth. However, coffee farms exhibit a range of variation in vegetation characteristics, making comparisons of bird communities and effects of vegetation between sun and shade inconsistent and region-specific (Anand et al., 2008; Greenberg et al., 1997b; Mas and Dietsch, 2004; Rao, 2011). Furthermore, the simple label "shade coffee" belies variation in vegetation complexity that can affect bird abundance and diversity among shaded farms (Calvo and Blake, 1998; Moguel and Toledo, 1999; Philpott et al., 2008).

Although bird diversity and abundance in coffee is well studied in the Neotropics and India (Anand et al., 2008; Donald, 2004; Komar, 2006; Philpott et al., 2008; Raman, 2006), there are few studies of bird communities on African coffee farms (Buechley et al., 2015; Gove et al., 2008). Despite the lack of focus on this region, approximately 20% of the world's 10 million hectares of coffee occur in Africa, and coffee is a leading agricultural export in the East African nations of Ethiopia, Tanzania, and Kenya (FAO, 2012). Bird communities may respond to shade and sun coffee in Africa much as they do in the Neotropics or India. However, regional species pools and the phylogeographic processes, including disturbance history, responsible for creating communities vary between Africa and the Neotropics (Handbook of the Birds of the World Alive, 2014; Jetz et al., 2012) providing an expectation that responses to agricultural disturbance may vary between the two regions.

In East Africa, bird species richness can actually be higher in mixed agriculture than forests, demonstrating the importance of agriculture to birds in this landscape (Buechley et al., 2015; Mulwa et al., 2012). Studies across a variety of agricultural land uses have found that tree density and number of indigenous trees, crop diversity, hedge volume, overall increases in structural diversity, and nearest intact forest all can influence species richness and density in East Africa (Gove et al., 2008; Mulwa et al., 2012; Naidoo, 2004; Otieno et al., 2011). This variety highlights that vegetation factors influencing bird abundance and species richness may vary between crops and habitats, emphasizing the need for coffee-specific research.

Only a small percentage of land in East Africa is protected by parks (Norton-Griffiths et al., 2010; Western et al., 2009), and effective conservation of biodiversity in this region likely needs to involve agricultural landscapes, including coffee. One way to integrate crop production and conservation is to examine the ecosystem services provided by wild species (MEA, 2005; Swift et al., 2004). In the Neotropics, pest removal services and higher coffee yields have been linked to higher bird abundance and species richness on coffee farms (Kellermann et al., 2008; Perfecto et al., 2004; Philpott et al., 2009; Van Bael et al., 2008; Railsback and Johnson, 2014), and understory insectivores and omnivores appear especially important (Greenberg et al., 2000; Johnson et al., 2010; Karp et al., 2013). Similarly, in East Africa, birds increased coffee yield by 9%, though the mechanisms remain unclear (Classen et al., 2014). We investigated the hypothesis that in central Kenya, shade coffee cultivation supports higher bird diversity and abundance than sun coffee. Specifically, we tested the predictions that: (1) shade coffee has higher abundance, species richness, and evenness than sun coffee and these communities show low similarity and (2) bird abundance and species richness correlate positively with canopy cover and other measures of farm vegetation complexity.

2. Methods

2.1. Study site

We conducted this study in Nyeri County, Kenya (elevation 1700 m), which averages 208 people/km^2, of whom 24.5% live in urban areas, primarily in the city of Nyeri (population 120,000; USAID, Kenya and Kenya Bureau of Statistics, 2012). The surrounding landscape has seen a 30%–60% increase of agricultural area from 1975 to 2000 (Brink and Eva, 2009). Locally, coffee is grown on large plantations, where practices on both shade and sun coffee farm plantations include spraying copper as a fungicide (one or two times per year), spot spraying bushes or blocks of coffee with insecticides when pest infestations occur, and either bi-yearly application of herbicides (usually during the rainy seasons, May–June and Nov–Dec) or, more rarely, manual cutting.

This research took place over two years during Dec 2012–Jan 2013 and Dec 2013–Jan 2014 on a total of 21 sites located on five individual farms. Farms were large ($>$100 ha), and multiple sites were located within each farm, each separated by $>$250 m and roads and/or hedgerows. Sites were therefore defined as sampling locations located $\geq$250 m apart, with different management conditions or histories (such as age or density of trees and frequency of herb layer cutting) from nearby sites (Fig. 1).

Observers sampled four sun coffee sites the first year, and seven sun and 10 shade sites the second year, totaling 11 sun sites (on four different farms) and 10 shade sites (on three separate farms). Seven shade sites were located on Sasini farm (210 ha), which borders Aberdares National Park and had shade trees dominated by non-native *Grevillea robusta*. The remaining three shade sites included two with shade dominated by large native *Cordia* sp. (Kihuri Farm: 19 ha) and one with a high diversity of native trees including *Albizia gummifera, Albizia schimperiana, Croton macrocarpa*, and *Bridelia micrantha* (Jungle Farm: 51 ha; Najma, 2011). Canopy cover over shade sites averaged 38%. Six sun sites were on the coffee farm at