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Connecting sustainable agriculture and wildlife conservation: Does shade coffee provide habitat for mammals?

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ABSTRACT

Shade coffee systems provide a refuge for biodiversity; however, research has been dominated by bird and insect studies with few studies that have focused on mammals living within coffee-dominated landscapes. Relative to other taxa studied, only 5% of the articles published on coffee and biodiversity pertain to mammals. We surveyed non-volant mammals, with an emphasis on small mammals, in 3 coffee-forest landscapes in Costa Rica with a particular focus on forest, shade coffee, and sun coffee habitats. Each of the 3 sites contained a 500- × 500-m trap grid that was sampled in 4 sessions, totaling 46 sampling nights per site. This novel approach allowed us to compare mammal abundance and richness on both a plot level and meso-landscape scale (radius 25, 50, 100, 150, 200 m). We made 976 captures (501 individuals) and detected 17 small and medium mammal species during the seven-month study period. The abundance and richness of small non-volant mammals found in the shade coffee was not significantly different that of forest habitats embedded and adjacent to coffee. Both forest and shade coffee had significantly more species and higher abundances than sun coffee habitats. Within habitats, at the plot level, higher amounts of canopy cover and lower strata vegetation (i.e., weeds, grasses, plants, and understory shrubs from 5 cm–1 m tall) significantly increased small mammal abundance and richness. Within coffee habitats (sun and shade), greater amounts of canopy cover were significantly associated with higher small mammal abundance and richness. At the meso-landscape scale, small mammal density and richness significantly decreased with increasing proportion of sun coffee within the landscape and increased as the amount of shade coffee increased. Furthermore, small mammals thrived in areas adjacent to forest patches and as the proportion of forested areas within the landscape increased. Our study indicates that while there is no substitute for native forest, shade coffee provides habitat for small non-volant mammals, particularly in comparison to sun coffee. Based on our findings, we recommend including shade trees, maintaining high amounts of canopy cover, and retaining lower strata vegetation (5 cm–1 m) within coffee farms. We also recommend preserving or reestablishing forested areas embedded within the coffee landscape to enhance small mammal diversity. Shade coffee shows promise as a conservation strategy to promote wildlife conservation and protect mammalian biodiversity.

1. Introduction

Agriculture and biodiversity conservation are often viewed as opposing forces, competing for land use and management rights. While forest reserves are crucial to conservation goals, they alone are not a sustainable solution to ensure biodiversity conservation. Recent conservation strategies focus on a broader landscape approach (Perfecto and Vandermeer, 2008) where the surrounding land use matrix is taken into account for their role in providing habitat and connectivity to biodiversity.

Coffee is an agricultural crop that is increasingly recognized as an important reservoir for biodiversity. Coffee agroforestry, or the intentional management of shade trees within coffee farms, provides habitat for wildlife (Perfecto et al., 2003; Philpott and Bichier, 2012; Williams-Guillén and Perfecto, 2010), acts as a buffer zone for forested areas and a high quality matrix that reduces edge effects (Perfecto et al., 2007), and provides biological corridors that increase connectivity between forest remnants in fragmented

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landscapes (Vandermeer and Carvajal, 2001; Steffan-Dewenter, 2002). The research in this field, however, has been dominated by bird and insect studies and little is understood about how other taxa, such as non-volant mammals, may benefit from this potential refuge (e.g., Gordon et al., 2007; Moguel and Toledo, 1999; Perfecto et al., 2003; Philpott et al., 2008a).

Over the past 4 decades, there has been a trend to move away from shade coffee towards coffee monocultures or "sun" coffee aimed at higher yields (Perfecto et al., 2005). This more intensified coffee management is accompanied by a reduction in floristic diversity and structural complexity, higher density of coffee plants, and requires higher levels of chemical inputs (Rice, 1999). Gobbi (2000) estimated that in Latin America 41% of shaded coffee has been replaced by minimally shaded or sun coffee. Coffee systems in Costa Rica exemplify this trend with approximately 60% shade coffee and 40% sun coffee (Hergoualc'h et al., 2012).

Conservation efforts to counteract this trend, such as biodiversity-friendly coffee certifications, provide financial incentives to coffee farmers to maintain or implement shaded systems for their coffee crops. The importance of conservation strategies such as these have been internationally recognized and included in the recent Convention of Biological Diversity 2020 targets which incorporate biodiversity-friendly certification programs and sustainably managed agriculture as approaches to reduce the rate of biodiversity loss (GEO BON, 2011). Approximately 40% of all coffee produced worldwide is certified by various standards (including certifications without an environmental or biodiversity focus) and the amount of certified coffee grew by 26% per year from 2008 to 2012 (Potts et al., 2014).

Farmers are faced with difficult management decisions and must find a balance between controlling fungal diseases and coffee pests, managing trees and vegetation within the farms, while improving their crop yield and productivity to maintain a viable income. Shade tree composition and management within a coffee farm can vary widely (Moguel and Toledo, 1999; Philpott et al., 2008b), and the way in which it is managed has the potential to impact conservation, pest control, and plant productivity (Philpott et al., 2008b; Rice, 1999; Soto-Pinto et al., 2000). Biodiversity-friendly coffee certifications provide standards to enhance biodiversity and wildlife habitat by requiring high levels of shade cover and native vegetation complexity within the coffee farm (DeClerck and Martínez Salinas, 2011; Philpott et al., 2007; Rice, 2010; Sustainable Agriculture Network, 2010). Farmers who have obtained biodiversity coffee certifications receive a higher premium for their coffee, as well as benefit from improved health conditions with the reduction in agrochemicals, as required by most certifications, and can diversify their incomes by using shade trees as timber or sources of fruit (Méndez and Bacon, 2006).

The criteria for the biodiversity certifications mainly focus on the shade tree composition and structure and include standards such as the number of native shade tree species, percent canopy cover, and number of shade strata for both Rainforest Alliance and Smithsonian Bird Friendly certifications (Philpott et al., 2007). Most studies, on which these management protocols are based, have focused on bird and insect communities (e.g., Gordon et al., 2007; Perfecto et al., 2003; Philpott et al., 2008a). Small mammals play an important role in tropical ecosystems; however few studies are published that address non-volant mammals living in and around coffee farms (e.g., Cruz-Lara et al., 2004; Daily et al., 2003; Gallina et al., 1996, 2008). Relative to other taxa studied, only 5% of the articles published on coffee and biodiversity pertain to mammals (Web of Science, 2014). In addition to being insectivores and seed dispersers, small mammals constitute a large prey base for predatory mammals, birds, and reptiles. Alterations of these communities can have a large influence on the ecosystem and higher trophic levels that small mammals support (Klinger, 2006; Lambert et al., 2006). Small terrestrial mammals may also be sensitive to understory disturbances and therefore may be good indicators for changes in coffee farm management.

Studies on birds and insects in coffee agroforestry indicate that species richness generally decreases with an increase in management intensity and reduction of shade tree cover within the coffee farm (Gordon et al., 2007; Philpott et al., 2007, 2008a; Philpott and Bichier, 2012). Of the few studies that have been conducted with mammals and coffee agroforestry, most compare the mammal diversity among habitat types and little is known about specific habitat characteristics required by small non-volant mammal communities within coffee agroforestry. In one study on medium-sized mammals, Gallina et al. (1996) attributed high vegetation diversity within the coffee farms and habitat heterogeneity within the landscape to the high levels of mammal diversity observed. Small mammal abundances were found to increase in coffee farms with greater amounts of herbaceous ground cover and larger, mature shade trees, while small mammal species richness was found to increase with an increase in tree species richness and greater amounts of herbaceous ground cover (Caudill et al., 2014).

There is increasing evidence that both plot level and landscape characteristics may play a role in species diversity within agroforestry systems (DeClerck et al., 2010). Studies indicate that distance to forest influences the richness and composition of bird and insect communities in agroforests (Clough et al., 2009; Luck and Daily, 2003; Ricketts et al., 2001). Likewise for mammals, studies have shown that the richness increases in agroforestry systems as the distance to native forests decreases for coffee in India (Bali et al., 2007) and cocoa agroforestry in Indonesia (Weist et al., 2010).

Most mammal studies employ either small scale trap grids, typically less than 0.50 ha (e.g., Daily et al., 2013; Gordon et al., 2007; Husband et al., 2007, 2009), or line transects, usually ranging from 100 m to 1 km (e.g., Cruz-Lara et al., 2004; Rocha et al., 2011; Sáenz and Horváth, 2013), for ecological field studies. In this study, we use a combination of these two methods by creating a large scale 500-$\times$500-m trap grid encompassing sun coffee, shade coffee, and forest habitats. This novel approach allowed us to better understand the habitat use of the small mammal community both on a plot level and across these coffee-forest agricultural landscapes.

Further research is needed on the local habitat and landscape scales to guide and inform conservation strategies for the protection of biodiversity and habitat, particularly for taxa such as mammals that have not been widely studied. This study aims to determine if non-volant mammal diversity benefits from conservation efforts to increase shade levels and complexity within coffee systems and if the management protocols currently outlined in the certifications are applicable to mammals. On a plot level, we would expect that increased vegetation complexity and increased levels of shade within coffee farms would lead to higher non-volant mammalian diversity; native forests would support the highest amount of mammal abundance and diversity; and that as vegetation complexity decreases within the coffee farms, the abundance and diversity of mammals would also decrease. At a landscape scale, we would expect that the abundance and richness of non-volant mammals would increase closer to forested areas and that as the proportion of forest within a landscape increases, so does the non-volant mammal abundance and richness. Additionally, we would expect that increases in the proportion of shade coffee within the landscape would have a more positive influence on the small mammal community compared to sun coffee.

We investigated the non-volant mammal abundance and diversity, with an emphasis on small mammals, in three