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Avian responses to reduced-impact logging in the southwestern Brazilian Amazon

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ABSTRACT

Reduced-impact logging (RIL) involves several techniques that try to minimize changes to forest structure from timber harvesting and is becoming widely adopted in Amazonia. Understanding how biodiversity will respond to RIL demands assessments that include interactions among initial site conditions, specific harvest techniques, and responses of species that can be compared across varied forest types and regions. We assessed the short-term effects of RIL on 10 avian species in logged and unlogged portions of two concessions in Acre State, Brazil. We performed 460 point-count surveys and estimated variation in occupancy using a removal model that accounts for imperfect detection. Species were selected to include birds with contrasting expected responses to logging activities. We also conducted vegetation assessments at bird sampling locations, paying particular attention to bamboo (*Guadua* spp.) structure and distribution due to its dominance in forests of the region and high importance as a habitat component for Amazonian birds. Occupancy of four species varied between RIL and unlogged areas and was highly influenced by the percentage of bamboo present. Overall, bird responses to logging was greater where percent cover of bamboo was highest and, for two species, elevated occupancy was closely associated with elevated bamboo density. Bamboo dominance did not differ between logged and unlogged areas; our analysis indicated that this may have resulted from avoidance of bamboo stands by logging crews. This potential behavior, in turn, insured that bamboo refuges were maintained within logged areas, aiding species otherwise negatively affected by logging. Our work suggested how important logger behavior can be in influencing the structure of wildlife habitat under RIL management and that bird responses to logging, both positive and negative, are strongly influenced by local forest conditions.

1. Introduction

Most logging that occurs in the tropics is not well-managed (Putz et al., 2008; Blaser et al., 2011). Historically, logging activity in tropical forests was intensive and destructive to forest functions, and it rapidly depleted target timber species. Generally known as 'conventional logging', this activity proceeded throughout the tropics with little concern for potential negative effects on forests (Putz et al., 2001). The recognition that conventional logging is largely unsustainable has led to the development of less destructive approaches for extracting timber products (Dykstra, 2002; Putz et al., 2012). One of these approaches is called reduced-impact logging (RIL) and encompasses several techniques crafted to prevent over-exploitation of target species and minimize damage to surrounding vegetation (Putz et al., 2012; West et al., 2014). RIL techniques include inventory and mapping of individual commercial trees prior to harvesting, planning of roads and skid-trails aimed at reducing impacts during extraction of trees, vine cutting prior to harvest coupled with directional felling to reduce damage to surrounding vegetation, and post-harvest assessments to evaluate whether techniques were applied effectively (adaptive management; Sabogal et al., 2000; Dykstra, 2002; Felton et al., 2006; Macpherson et al., 2012).

Reduced-impact logging has become a common approach to timber harvest in the Amazon (Zarin et al., 2007). In 2006, the Brazilian government passed a law (Law # 11,284/2006) that permits timber harvesting in public forests and dictates that this harvest must be performed sustainably, which has further increased RIL activities (Serviço Florestal Brasileiro, 2016). With the growing interest in this type of timber management, RIL will become increasingly important to the economy of the region. For

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instance, in the southwestern Amazon, the government of Acre State plans to implement and certify RIL in 15,000 km^2 of public forests (FSC, 2006). From a conservation perspective, promotion of better managed forests is important because a large proportion of tropical forest is currently being logged (Asner et al., 2009; Bicknell et al., 2015) or is expected to be logged in the future (Blaser et al., 2011; Putz et al., 2012). However, the success of RIL practices in helping guarantee conservation of biodiversity while ensuring economic sustainability will depend on several factors, including the specific techniques applied, logging intensity, harvest cycles employed, and species-specific responses to these practices (Clark et al., 2009; Burivalova et al., 2014, 2015). Although RIL tries to minimize effects on target species and vegetation, it still can cause changes to forest structure that may affect non-target species that are forest dependent, including birds (Jackson et al., 2002; Dauber et al., 2005; Felton et al., 2006). Thus, understanding how wildlife species respond to RIL is important for improving management practices (if improvements are needed) in order to establish productive operations that maintain the integrity of complex tropical ecosystems for the long term.

Rigorous biodiversity assessments in megadiverse tropical forests, whether managed or undisturbed, is both challenging and fundamental for safeguarding global resources. Birds are a useful group to study because they are highly mobile and readily respond to a broad range of habitat alterations, including local changes in forest structure and large-scale fragmentation of habitat caused by logging roads (Johns, 1997; Whitman et al., 1998; Gibson et al., 2011; Goodale et al., 2014). However, several limitations on quantitative rigor must be addressed in study design. First, many Amazonian bird species are rare and difficult to detect, making whole community surveys difficult. Second, RIL is expected to reduce the effects of logging on biodiversity, including birds, when compared to conventional logging (Putz et al., 2012; Bicknell et al., 2015; Burivalova et al., 2015), thus making RIL impacts more difficult to detect. Nonetheless, a number of fairly common bird species that are detectable in surveys fall into all three possible response groups for density or occupancy (increase, decrease, no change). Understory-insectivores (often dependent on forest undergrowth affected by logging), canopy-frugivores (often reliant on large fruiting trees that are logged), and species adapted to forest interior should exhibit negative responses to RIL (Wunderle et al., 2006a; Felton et al., 2008a; Burivalova et al., 2015). Other species may benefit from RIL (e.g. omnivores, due to increase in their food availability, and species associated with secondary forests); a third set of species may also be unresponsive, at least in the short-term (Azevedo-Ramos et al., 2006; Felton et al., 2008a; Burivalova et al., 2015). In addition to species traits, a number of predictors of the three kinds of responses include time since logging, logging intensity, scale of logging concessions compared to species territory sizes, and silvicultural treatments (Clark et al., 2009; Burivalova et al., 2014, 2015).

Third, in some regions, forest bird assessments must account for the effects of relatively high dominance of bamboo. The southwestern Amazon, where this study took place, has at least 161,500 km^2 of forests that are dominated by bamboo (genus *Guadua*; de Carvalho et al., 2013) and in Acre State, bamboo is present in over 50% of the forests (Acre, 2000). Bamboo stands are very dynamic as these species (*Guadua* spp.) benefit from disturbance and can respond to natural or human disturbances to forest structure (Burman and Filgueiras, 1993; Rockwell et al., 2014). In turn, bamboo strongly influences avian community structure because a variety of bamboo-specialist and non-specialist species use bamboo stands (Rother et al., 2013). Despite these important differences, the effects of RIL on forests and wildlife in bamboo-dominated forests has not been well studied (but see Rockwell et al., 2007, 2014; Rockwell and Kainer, 2015). We tested for avian species responses to RIL in the southwestern Brazilian Amazon (Acre State) with the aim to produce useful information for designing optimal forestry strategies for this region. We hypothesized that RIL would influence the occupancy of bird species (i.e., probability of occurence) positively or negatively, dependent on species traits, but that this response would be mediated by realized effects of logging on vegetation structure (Mason and Thiollay, 2001), especially bamboo. Although the avian species we assessed are not bamboo specialists, many of these species are known to use bamboo habitat (Guilherme and Santos, 2009; Harvey et al., 2014).

2. Material and methods

2.1. Study sites

We conducted our study in two logging concessions in Acre state in southwestern Brazilian Amazonia: Fazenda Cerejeira (6427 ha) and Fazenda São Jorge (5400 ha; Fig. 1). Here, we refer to 'sites' as the two logging concessions and logged and unlogged areas as the treatments across the concessions. The unlogged areas were also part of the concessions but had not yet been logged. The study region has an annual average temperature of 25 °C and precipitation of 2041 mm (Acre, 2006). Five major forest types occur: (1) open forest (i.e., open canopy) with low density of bamboo (*Guadua* spp.); (2) open forest with dominance of bamboo; (3) open forest with palms; (4) open forest with presence of palms and bamboo; and (5) dense forest (i.e., dense canopy; Acre, 2006).

Logging activities were performed in both sites by the same company, using the same RIL strategy and basic techniques (i.e., mapping of trees to be harvested; mapping of areas to avoid logging, such as riparian forests and areas with slopes >45 degrees; planned logging roads and skid-trails, vine cutting prior to logging, and directional felling; Sabogal et al., 2000). However, the two sites differed in various ways. Fazenda São Jorge was certified by the Forest Stewardship Council, with logging intensity of 25–30 $m^3\ ha^{-1}$, and logging in this site occurred 24–36 months before our study. Fazenda Cerejeira is a non-certified operation, with logging intensity of 10–15 $m^3\ ha^{-1}$. Logging in this site occurred 12 months prior to our study. Despite the differences between sites, we focused on comparing treatments (logged and unlogged areas) within both sites rather than comparing differences between logging sites. Differences between our study sites were likely to add significant variability, which in turn would make detection of logging effects more difficult. However, by including both sites and comparing logged and unlogged areas across the two sites, this study captured the range of both initial site conditions and logging intensity typically seen in this region.

2.2. Study design

To assess the effects of RIL on avian species, we used a cross-sectional comparative design. We compared populations of bird species in logged and unlogged areas and measured vegetation variables known to be both important to birds and likely to be affected by logging. Vegetation assessments allowed us to characterize local variation in forest structure among sites and to identify heterogeneity in intensity of actual logging effort throughout the areas open to logging.

2.3. Selection of avian species

Prior to sampling, we reviewed the bird species that occur in the study region in order to pre-select a set of species that would include those most likely to be sensitive to RIL; by 'sensitive' we mean species that would either increase or decrease in response