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Essays and Perspectives

Effects of logging on bats in tropical forests

Isai J. Castro[a,*], *Fernanda Michalski*[a,b]

[a] *Programa de Pós-Graduação em Biodiversidade Tropical, Universidade Federal do Amapá – UNIFAP, Macapá, AP, Brazil*
[b] *Instituto Pró-Carnívoros, Atibaia, SP, Brazil*

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ABSTRACT

Logging is one of the main causes of biodiversity loss in tropical forests. In the past decades there was an increase in the number of studies on the effects of logging on biodiversity, but there has been little advancement for bats, despite their ecological importance. We present a review of studies on the effects of logging on bats in tropical forests worldwide carried out in the past three decades. We aimed at answering the following questions: What is known about the effects of logging on the bat fauna of tropical forests? What are the gaps of knowledge that can be filled? We conducted a literature search of studies on the effect of logging on the bat fauna in tropical forests in the past decades. We surveyed the databases Web of Science, Google Scholar, and Scopus with different keyword combinations: "Bats OR Chiroptera", "Logging", "Selective logging", "Timber extraction", "Tropic", "Forest", and "Tropical Forest". We found 22 studies focused on Latin America and Southeast Asia. Most studies (81.8%) only compared bat richness and abundance between logged and unlogged areas, where frugivorous bats responded positively to logging, whereas gleaning animalivores bats responded negatively. Few studies (18%) tried to understand how environmental variables, such as changes in vegetation structure, affect bat diversity. We emphasize that future studies aimed at checking the effects of logging on bats should use more than one sampling method in order to obtain more representative samples. Planning should be done with more caution, in order to avoid pseudoreplication and obtain more solid results. Poorly studied regions that have intensive logging, such as the Amazon and the tropical forests of Africa, should receive more attention.

Introduction

Until 2050 the global demand for timber should triplicate due to the human population growth and the increase in the use of bioenergy, which uses the biomass as energy source (WWF, 2011). Therefore, more areas of tropical forests will be exploited, which increases the potential damage to biodiversity. Logging is one of the main causes of biodiversity loss in tropical forests (Laurance, 2007) due to impacts such

* *Corresponding author at*: Rodovia Juscelino Kubitschek, km 02, 68902-280, Universidade Federal do Amapá, Macapá, AP, Brazil.
E-mail address: isai.j.castro@gmail.com (I.J. Castro).
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as changes in forest structure, disturbance, dislodgement of animals from their habitats, gap opening, and loss of food resources (Lagan et al., 2007).

In the past decades there has been an increase in the number of studies aimed at investigating the effect of logging on the biodiversity of tropical forests, which encompassed several taxa, such as mammals, birds, beetles, and fish (Edwards et al., 2012; Politi et al., 2012). However, the results of most studies have been put into doubt for not being reliable or consistent, mainly due to errors in sampling design, such as pseudoreplication (Ramage et al., 2013). Other problems result from the lack of standardization and from poor baseline information on the study areas, such as management regime and logging period (Laufer et al., 2013).

Specifically for bats, there was little advancement in studies focused on the effect of logging, in spite of the ecological importance of these mammals. Bats are known to be important bioindicators of the status of a given habitat. Their quality as bioindicators results in part from their life history, which is one of the most diversified among mammals (Barclay and Harder, 2003; Jones et al., 2009). In addition, bats are important agents of seed dispersal and pollination, processes that are vital for the reproductive success of plants as well as for the maintenance of tropical forests, may help recover degraded (Fleming and Heithaus, 1981; Fleming and Sosa, 1994; García et al., 2000; Muscarella and Fleming, 2007) and arthropod suppression (Kunz et al., 2011; Williams-Guillen et al., 2008).

Although some studies suggest that the negative effects of logging on bats in the tropical forest with some type of management are minimum (Castro-Arellano et al., 2007, 2009; Clarke et al., 2005a; Presley et al., 2008, 2009) some guilds have been affected, mainly in Latin America. Frequently, after the exploitation there has been an increase in the number of small frugivorous bats in the understory and a decrease in the number of gleaning animalivores, omnivores, and carnivore bats (Clarke et al., 2005b; Peters et al., 2006). However, studies that reported impacts of logging on bats need better planning and sampling design; most of them did not use data on changes in vegetation structure due to logging and they did not test how these changes affect the composition of the bat assemblage (Castro-Arellano et al., 2009; Presley et al., 2008, 2009).

In the present study, we conducted a review of studies on the effects of logging on bats in tropical forests worldwide carried out in the past three decades. We aimed at answering the following questions: What is known about the effects of logging on the bat fauna of tropical forests? What are the gaps of knowledge that can be filled?

Material and methods

We conducted a literature search for studies published in the past three decades (1988–2012), which assessed the effect of logging on the richness and abundance of bats in tropical forests. We surveyed the databases Web of Science, Google Scholar, and Scopus, using different keyword combinations: “Bats OR Chiroptera”, “Logging”, “Selective logging”, “Timber extraction”, “Tropic”, “Forest”, and “Tropical Forest”.

We used the following criteria to determine whether the reference was suitable for assessment: (1) studies carried out between the latitudes 23 N and 23 S, (2) studies that assessed the effects of logging on bats by comparing areas submitted to some sort of management, such as selective logging, reduced impact logging (RIL), polycyclic selective logging, and continuous selective logging with control areas. We also considered papers with sampling in logging areas, but whose objective was not to assess the effects of selective logging.

In our search we found 118 potential studies, but only 22 fit our criteria. We compiled from those papers the following information: publication year, title, location of the study site (e.g.: geographic coordinates, country), type of management (e.g.: reserve, selective logging, reduced impact logging (RIL), polycyclic selective logging, agriculture, and other types of management), size of the study area (ha) when available, exploitation period (years) since the first cut, volume of timber extracted ($m^3\,ha^{-1}$), bat sampling methods (mist nets, harp traps, active search in roosts, ultrasound detector), number of individuals collected per site, richness (number of species), trophic guilds (frugivorous, nectarivores, gleaning animalivores, aerial insectivores, omnivores, carnivores, and sanguivores), environmental and disturbance data when available, and sampling effort. As our data were normally distributed (tested with a Shapiro–Wilk test), population’s variances were equal (homoscedasticity), and independent (Zar, 1996) we used an analysis of variance (ANOVA) to test for differences in the number of capture methods used and species richness.

We used the Mann–Whitney *U*-test to compare the most abundant guilds of bats (frugivorous, nectarivores, aerial insectivores and gleaning animalivores) between logged and unlogged forests (Zar, 1996). Only abundance data for bats captured with mist nets were included in this analysis. The abundances were obtained by dividing the number of individuals captures for each trophic guild by the sampling effort for each study with data available. The mist net sampling effort obtained in the studies (Table 1) were standardized in met m^2 h (sensu Straube and Bianconi, 2002).

We used ArcGis 9.3 (ESRI, 2009) to draw the distribution map of studies (Fig. 1). To generate the map, we used the geographic coordinates provided in each study. When this information was not available, we used Google Earth to obtain approximate coordinates of the study areas, using as reference characteristics that could be easily identified in the images, such as rivers, protected areas, cities, and roads, which were mentioned in the papers.

Results

We found 22 publications about the effect of logging on bats in tropical forests, which were published in the past three decades. Most studies were carried out in the countries of Latin America (Brazil = 27%, Mexico = 9%, Venezuela = 9%, Trinidad = 9%, Guatemala = 5%) and Southeast Asia (Malaysia = 23%, Indonesia = 9%). We found only one study for the tropical forests of Africa and one for the tropical forests of Oceania (Table 1 and Fig. 1). In a temporal analysis considering the past three decades there was an increase in the number of publications. The period from 2005 to 2010 was the most