

# Birds and bats captured in a managed forest in Southwestern Brazilian Amazonia: Results and recommendations from a short-term study

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**Abstract.** Understanding the activity pattern and the height of capture of birds and bats can help to optimize the sampling of both groups. Our aimed was to determine the rates of capture at different times of day/night, and the overlap in the height of capture; classify the trophic guilds, and check variation in the capture rates of the birds and bats. We conducted the study in the Antimary State Forest, in March, 2017. We set mist-nets at the same location during five consecutive days, and were open between 06:00 h and 00:00 h. The birds presented a bimodal activity pattern, as well as bats. Bats were captured at higher levels than birds. Most of the birds captured were insectivores, where as most of the bats were frugivores. Neither group presented a clear pattern of variation in capture rates. Therefore, the first hours of the morning are fundamental for the capture of birds. For bats, we would recommend the captures only after 17:00 h. Mist-nets should be set at ground level for birds, whereas for bats, they should be set above a height of 0.5 m. Thus, the captures should be optimized.

**Keywords:** Bird activity; Bat activity; Activity pattern; Capture efficiency; Short-term.

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## Introduction

Birds and bats are two highly diverse vertebrate groups found in the

principal biomes of the Neotropical region (Stotz et al., 1996; Marques et al., 2013; Voigt and Kingston, 2016). In both cases, specimens can be captured using

mist-nets (Meyer et al., 2011, Marques et al., 2013). In the case of the birds, visual and auditory sampling can also be used to complete the inventory (Whitman, 2004; Blake and Loiselle, 2009; Marques et al., 2013). In bats, mist-netting is the principal sampling method (Meyer et al., 2011), although high-frequency echolocation recorders have been used increasingly in recent years to conduct acoustic surveys (Stahlschmidt and Brühl 2012). One disadvantage of the use of mist-nets is that, after a certain time in the same location, both birds and bats appear to be able to learn the location of the nets and avoid them (Esbérard, 2006; Marques et al., 2013). Even so, mist-nets are considered to be relatively effective for the inventory of both groups of vertebrates (Bernard, 2001; Johnson et al., 2011), as well as the monitoring of activity patterns (Trnka et al., 2006; Verde et al., 2018).

In general, the activity patterns of the two groups are distinct, with birds being active predominantly in the morning and afternoon periods, and bats, at night. Tropical birds tend to be active primarily during the early hours of the morning and late afternoon, in a typical bimodal pattern (Gilardi and Munn, 1998; Salina-Melgoza and Renton, 2005; Brandt and Cresswell, 2009; Dias et al., 2016). In other regions, however, the seasonal changes in day length, with shorter days in the winter and longer ones during the summer, influence bird activity patterns (Rollfinke and Yahner, 1990; Reyes-Arriagada et al., 2015; Silva et al., 2015). The climate, in particular temperature, but also rainfall, may also affect these patterns (Boyes and Perrin, 2010; Reyes-Arriagada et al., 2015). Similar variation is observed in bats (Speakman et al., 2000; Thies et al., 2006), which are predominantly nocturnal (Presley et al., 2009, Verde et al., 2018). In the Amazon region, for example, bats are active primarily during the first hours of the night, with activity then declining progressively until shortly before dawn, when foraging increases

once again, in a bimodal pattern (Bernard and Fenton, 2002; Presley et al., 2009; Verde et al., 2018).

Birds and bats forage in different forest strata (Bonter et al., 2008; Pereira et al., 2010). This is determined primarily by the availability of feeding resources and the foraging adaptations of the different species (Rosenberg, 1990; Pereira et al., 2010). Birds forage at different levels in the forest to avoid interspecific competition, and the preference for a given stratum may vary according to the trophic guild (Collins, 2015), with a similar pattern being observed in bats (Bernard, 2001; Pereira et al., 2010). Bats also present a range of behavioral, morphological, and physiological adaptations for foraging, which are observed in their foraging behavior and mold their activity patterns (Schnitzler and Kalko, 2001).

In the understory of the Amazon forest, most species of bird and bat belong to distinct guilds. Most of the bats captured in the understory are frugivores (Bernard, 2001; Pereira et al., 2010), whereas most of the birds found in this stratum are insectivores (Johnson et al., 2011). There is also little overlap in the diets of frugivorous birds and bats, given that few of the same types of fruit are exploited by the two taxa (Gorchov et al., 1995). In the case of insectivory, few prey are shared (Rydell and Speakman, 1995; Speakman et al., 2000), due in particular to the asynchronous timing of the foraging activity of bats and birds (Rydell and Speakman, 1995).

Many bird and bat species are captured only rarely or never at all in mist-nets due to a number of factors, in particular the fact that they extend to a height of 3 m, which is below the levels at which many species typically fly (Rosenberg, 1990; Bonter et al., 2008). Even when they do fly lower down, some individuals (both birds and bats) may be able to learn the location of the mist-nets (Marques et al., 2013), and some bats appear to be able detect the nets by echolocation (Duchamp et al., 2006;

Meyer et al., 2011) Many studies have shown that mist-nets that remain in a given position for a long period of time tend to become progressively ineffective for the capture of specimens (Faaborg et al., 2004; Marques et al., 2013). This indicates that individuals are memorizing the location of the nets, which allows them to avoid being captured. For this reason, most researchers will alter the position of their nets constantly, to optimize captures (Whitman, 2004; Marques et al., 2013). In this context, it is important to be able to evaluate the best possible approaches available for the sampling of the target groups, according to the objectives of the study (Marques et al., 2013), in particular during studies of limited duration. Data on daily activity patterns and the height of capture may also provide important insights into the optimal use of mist-nets for the sampling of bird and bat assemblages in the Amazon Region.

Given these objectives, the present study aimed to determine (1) the rates of capture of birds and bats during different times of day/night, (2) the degree of overlap in the height of capture of the birds and bats in the mist-nets, (3) the trophic guilds represented by the birds and bats captured, and (4) the variation in the capture rates of birds and bats among the five consecutive days of sampling. Based on the results of the study, we provide a number of recommendations for the optimization of the capture of birds and bats by mist-netting in southwestern Amazonia.

## Materials and methods

### Study site

We conducted the study in the 77,000-hectare Antimary State Forest (FEA), an area of forestry management in the State of Acre, Brazil (9° 31' 00" S, 68° 23' 00" W), in Southwestern Amazonia. The FEA is covered with open rainforest, with bamboo and palms, and dense lowland rainforest, with an

emergent canopy (Acre, 2000). The mean annual temperature in the region is between 22 °C and 33 °C, and annual precipitation is 1,600-2,750 mm (Aquino et al., 2011). The region's climate is hot and humid, with a rainy season between November and April, and a dry season from May to October (Schaefer, 2013).

### Capture method

We captured birds and bats at the site simultaneously and continuously between March 19 and 23, 2017, which includes the rainy season in the region. We used 12 mist-nets of 12 m × 2.5 m, set at ground level up to a height of 2.5 m, forming a continuous transect line. We maintained the mist-nets in the same position throughout the five days of the study period. The nets were opened at 06:00 h and closed at 00:00 h, providing a sampling effort of 216 net-hours per day. The nets were checked once per hour.

### Rate, capture variation and guild

To determine the activity pattern of the bats and birds, we calculated a capture rate ( $r_i$ ) per hour of the day/night (number of individuals captured  $m^{-2} h^{-1}$ ) as  $r_i = n_i / (a \cdot d)$ , where  $n_i$  = the number of individuals captured in hour  $i$ ,  $a$  = the area of mist-net in  $m^2$ , and  $d$  = the number of hours the nets were open (Trnka et al., 2006). We used a surveyor's tape to determine the height of capture of each specimen. The mean height of capture was calculated for each taxonomic group (birds and bats). We also registered the number of captures for each group per day, to determine the possible variation in the number of specimens captured over the duration of the study. We identified all captured specimens to species, which allowed us to determine the trophic guild of each taxon. We classified the bird guilds according to Wilman et al. (2014), and those of the bats based on Kalko (1998) and Wilman et al. (2014).

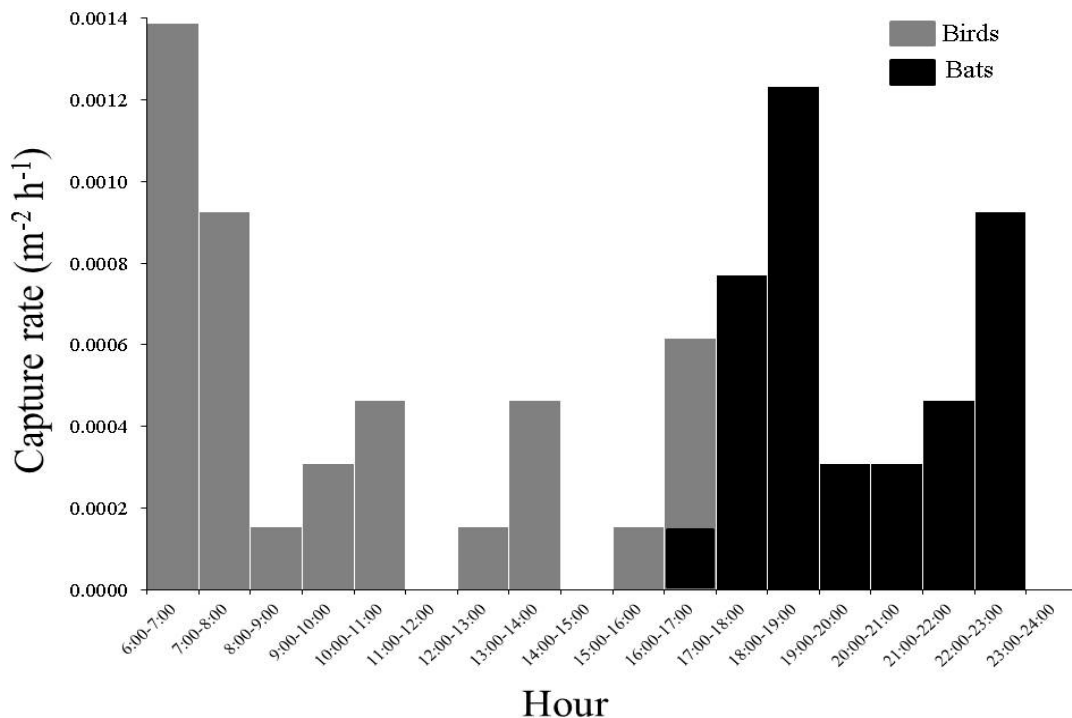
### Data analysis

We used a *t* test to verify whether birds and bats were captured at significantly different heights in the mist-nets. We ran this analysis in the *vegan* package of the R platform, version 3.0.3 (R Core Team, 2017). Confirming that the data satisfied the assumptions of normality, using the Shapiro-Wilk Test, and based on Levene's Test, the homoscedasticity of variance.

### Results

We captured 56 individuos (29 birds and 27 bats) during 1,080 net-

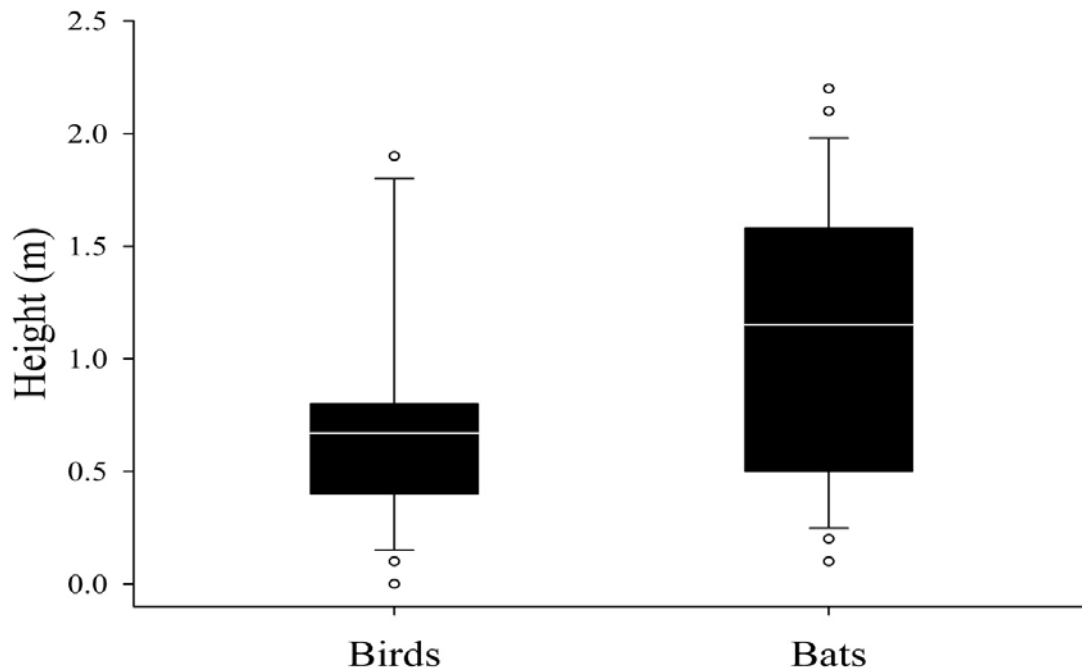
hours of sampling. The birds captured belonged to nine families, 15 genera, and 17 species (Table 1), while the bats represented two families, eight genera, and 12 species (Table 2). The hourly capture rates (Figure 1) indicated a bimodal diurnal pattern for the birds, with two principal peaks, one at 07:00 h, and the other between 14:00 h and 16:00 h. The bats also presented two major peaks in activity, at night, one at 19:00 h, and the other at 23:00 h. The only overlap between the two groups was observed at 17:00 h (Figure 1).



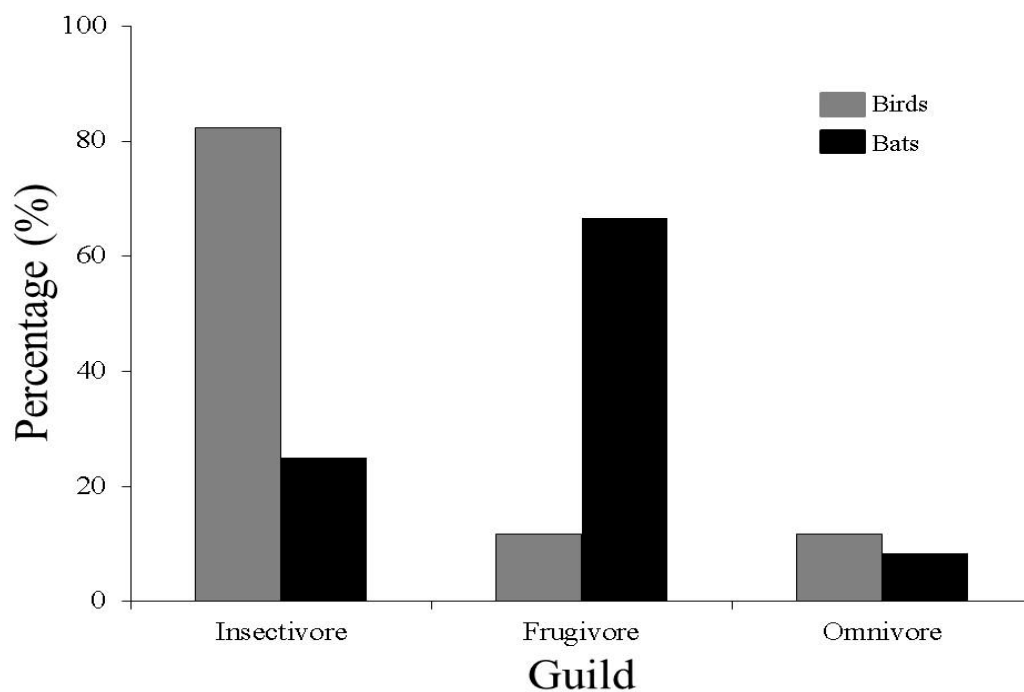
**Figure 1.** Capture rates per hour of the day/night of the birds and bats trapped in mist nets on five consecutive days in an area of forestry management in Southwestern Amazonia.

On average, the birds were captured at a mean height of 0.67 m (SD = 0.53 m) (Figure 2), whereas bats were captured at a height of 1.15 m (SD = 0.60 m), with a significant difference being found between the two means ( $t = -3.13$ ,  $P = 0.003$ ). Insectivorous birds were collected more

frequently than insectivorous bats (Figure 3), whereas frugivorous bats predominated. Two omnivorous birds, *Geotrygon montana* (Linnaeus, 1758) and *Cyanoloxia rothschildii* (Bartlett, 1890), and one bat, *Phyostomus elongatus* (É. Geoffroy, 1810), were also collected (Figure 3).



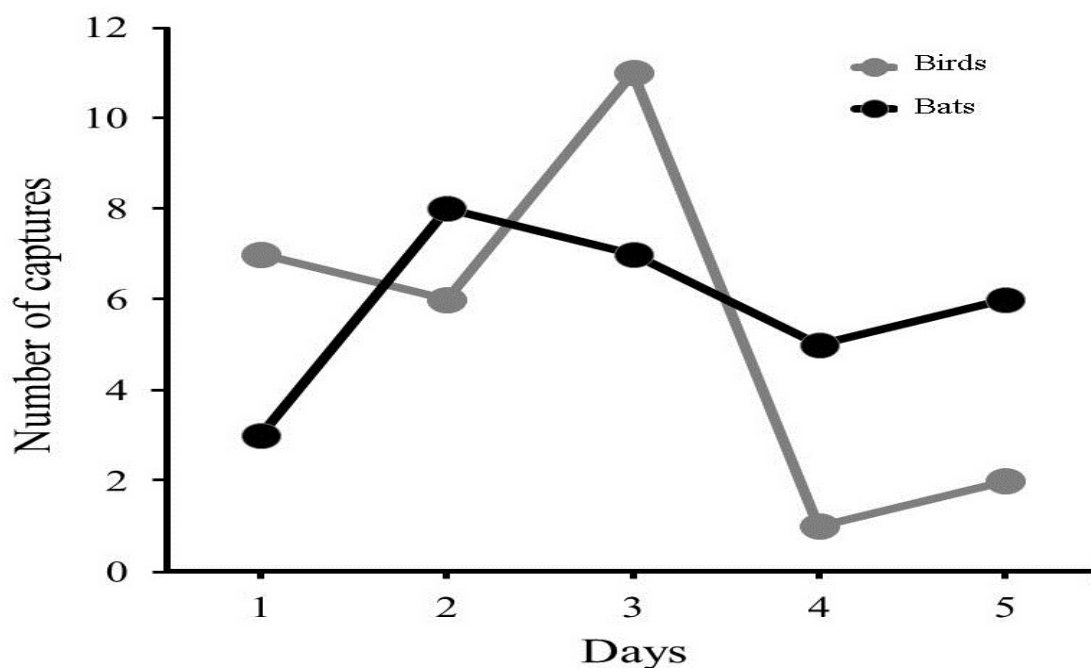
**Figure 2.** Box plots of the height at which the birds and bats were captured in the present study in an area of managed forestry in southwestern Brazilian Amazonia. The boxes represent 50% of the data collected for each group, between the 25th and 75th percentiles, with the mean indicated by the horizontal midline, and the whiskers, the 10th and 90th percentiles (standard deviation). Outliers are shown as circles. The nets extended from ground level to a height of 2.5 m.



**Figure 3.** Contribution (percentage) of the different trophic guilds of birds and bats captured in the present study in an area of managed forest in Southwestern Brazilian Amazonia.

No systematic variation was observed among days in the capture of birds or bats (Figure 4). In both groups, the number of specimens collected on the first day was relatively low, then peaking on the second (bats) or third (birds)

days. In the bats, the number of captures remained virtually constant after the second day, whereas in the birds, there was an abrupt decline on the third day, followed by a slight increase.



**Figure 4.** Number of birds and bats captured on each of the five consecutive days of mist-netting in a managed forest in southwestern Amazonia.

**Table 1.** Bird species captured in an area of forestry management in the Antimary State Forest in Acre, Brazil.

Order	Family	Subfamily	Species	TG	N
<b>COLUMBIFORMES Latham, 1790</b>					
<b>COLUMBIDAE Leach, 1820</b>					
			<i>Geotrygon montana</i> (Linnaeus, 1758)	OM	1
<b>PASSERIFORMES Linnaeus, 1758</b>					
<b>TYRANNI Wetmore and Miller, 1926</b>					
<b>THAMNOPHILIDA Patterson, 1987</b>					
<b>THAMNOPHILIDAE Swainson, 1824</b>					

Table 1. Continued.

Order	Family	Subfamily	Species	TG	N
<b>THAMNOPHILINAE Swainson, 1824</b>					
			<i>Epinecrophylla haematonota</i> (Sclater, 1857)	IN	4
			<i>Thamnomanes ardesiacus</i> (Sclater and Salvin, 1867)	IN	1
			<i>Thamnomanes schistogynus</i> Hellmayr, 1911	IN	2
			<i>Sciaphylax hemimelaena</i> (Sclater, 1857)	IN	1
			<i>Cercomacroides nigrescens</i> (Cabanis and Heine, 1859)	IN	1
			<i>Willisornis poecilinotus</i> (Cabanis, 1847)	IN	2
			<i>Oneillornis salvini</i> (Berlepsch, 1901)	IN	1
<b>DENDROCOLAPTIDAE Gray, 1840</b>					
<b>SITTASOMINAE Ridgway, 1911</b>					
			<i>Dendrocincla fuliginosa</i> (Vieillot, 1818)	IN	5
<b>DENDROCOLAPTINAE Gray, 1840</b>					
			<i>Glyphorhynchus spirurus</i> (Vieillot, 1819)	IN	1
			<i>Xiphorhynchus ocellatus</i> (Spix, 1824)	IN	2
			<i>Xiphorhynchus elegans</i> (Pelzeln, 1868)	IN	2
<b>XENOPIDAE Bonaparte, 1854</b>					
			<i>Xenops tenuirostris</i> Pelzeln, 1859	IN	1
<b>TYRANNIDA Wetmore and Miller, 1926</b>					
<b>PIPRIDAE Rafinesque, 1815</b>					
<b>PIPRINAE Rafinesque, 1815</b>					
			<i>Lepidothrix coronata</i> (Spix, 1825)	FR	1
<b>ONYCHORHYNCHIDAE Tello, Moyle, Marchese and Cracraft, 2009</b>					
			<i>Onychorhynchus coronatus</i> (Statius Muller, 1776)	IN	1
<b>TROGLODYTIDAE Swainson, 1831</b>					
			<i>Microcerculus marginatus</i> (Sclater, 1855)	IN	2
<b>CARDINALIDAE Ridgway, 1901</b>					
			<i>Cyanoloxia rothschildii</i> (Bartlett, 1890)	OM	1

TG = Trophic Guild; N = Number of individuals captured; FR = Frugivore; OM = Omnivore, IN = Insectivore.

**Table 2.** Bat species captured in an area of forestry management in the Antimary State Forest in Acre, Brazil.

Family Subfamily Species	TG	N
<b>PHYLLOSTOMIDAE</b> Gray, 1825		
<b>CAROLLINAE</b> Miller, 1924		
<i>Carollia brevicauda</i> (Schinz, 1821)	FR	2
<i>Carollia perspicillata</i> (Linnaeus, 1758)	FR	5
<b>RHINOPHYLLINAE</b> Baker et al., 2016		
<i>Rhinophylla fischeriae</i> Carter, 1966	FR	1
<i>Rhinophylla pumilio</i> Peters, 1865	FR	4
<b>PHYLLOSTOMINAE</b> Gray, 1825		
<i>Lophostoma silvicola</i> d'Orbigny, 1836	IN	2
<i>Phyllostomus elongatus</i> (É. Geoffroy, 1810)	OM	2
<i>Tonatia saurophila</i> Koopman and Williams, 1951	IN	3
<b>STENODERMATINAE</b> Gervais, 1856		
<i>Artibeus lituratus</i> (Olfers, 1818)	FR	3
<i>Artibeus obscurus</i> (Schinz, 1821)	FR	1
<i>Artibeus planirostris</i> (Spix, 1823)	FR	1
<i>Dermanura cinereus</i> (Gervais, 1856)	FR	2
<b>THYROPTERIDAE</b> Spix, 1823		
<i>Tyroptera tricolor</i> Spix, 1823	IN	1

TG = Trophic Guild, N = Number of individuals captured. FR = Frugivore, OM = Omnivore, IN = Insectivore.

## Discussion

During the five days of the study period, it was possible to verify the daily activity pattern of the birds, which presented a well-defined bimodal distribution (Figure 1). Activity peaked during the first two hours of the morning, followed by a lesser peak prior to sunset. A similar bimodal activity pattern has been observed in birds in many other tropical regions (Gilardi and Munn, 1998; Salina-Melgoza and Renton,

2005; Brandt and Cresswell, 2009; Dias et al., 2016), as well as in the Northern hemisphere, for example, in Slovakia (Trnka et al., 2006).

In the bats, the nocturnal activity recorded up to midnight also presented what appeared to be a bimodal pattern, with one peak at the beginning of the night, and the other, near midnight (Figure 1). Other studies in the Amazon region have shown that bat activity tends to peak at the beginning and end of the night (Bernard and Fenton, 2002; Verde



et al., 2018), when the whole nocturnal period is monitored. Capture rates may also be influenced by other factors, such as the type of habitat (Lövei et al., 2001), climatic conditions (Thies et al., 2006), and even the avoidance of moonlight (Mello et al., 2013), in the specific case of non-insectivorous bats, for these that foraging just after the sunset is adaptive (Appel et al., 2017). Given this, we would recommend comparing the activity pattern of bats in preserved and managed forests during the whole nocturnal period, to verify possible differences among habitats.

Capture heights were significantly different between birds and bats (Figure 2), with birds typically being captured at heights of around 0.5 m above the ground, and bats a meter higher. This may be related, in part, to the differences in feeding guilds between the two groups, given that the majority of the birds we captured were insectivores (Figure 3), a pattern expected in Amazonian forests (Terborgh et al., 1990; Johnson et al., 2011). Some resources, such as fruit, can be scarce in the understory (Gentry and Emmons, 1987), supporting only a reduced diversity of frugivores (Johnson et al., 2011), with frugivorous birds being captured more rarely in the understory. The predominance of frugivorous bats was also expected for an Amazonian forest in the understory (Bernard, 2001; Rex et al., 2011). When fruit is available, it is normally found in the upper crowns of the understory shrubs and trees (Gentry and Emmons, 1987), which would account for the almost complete absence of bats captured at heights of below 0.5 m.

The number of individuals captured varied considerably among days, for both birds and bats. The number of individuals of either group captured during a given session may vary according to four principal factors: (1) High levels of rainfall, which typically reduce foraging activity in both birds (O'Connor and Hicks, 1980) and bats

(Erickson and West, 2002). (2) Temperature. In Southwestern Amazonia, between May and June, cold fronts derived from polar air masses reduce ambient temperatures to approximately 10 °C (Acre, 2000; Duarte, 2007). These events are known locally as the *friagem* (cold snaps). While these events last only a few days, they may result in a considerable reduction in the activity of birds and mammals within the forest. (3) Learning and detection of mist-net. Birds and bats can learn the location of nets and bats can detect them by echolocation (Marques et al., 2013; Duchamp et al., 2006; Meyer et al., 2011) (4) Mixed bands and army ants (birds only). Heterospecific bands of birds that associate with army ants involve large numbers of individuals moving through the forest in a coordinated manner (Oniki and Willis, 1972; Willis and Oniki, 1978), which may result in a considerable increase in the number of individuals captured on a given day. In the absence of this phenomenon, capture rates return to normal. (5) Avoidance of moonlight (non-insectivorous bats only). During nights with brighter moonlight, the number of bats in activity decreases considerably due to the increase in the risk of predation (Appel et al. 2017).

## Conclusions

Based on this evidence, we suggest the following recommendations.

Timing of captures: The optimal time of day for the capture of birds within the forest of southwestern Amazonia was the first three hours of daylight. In studies of birds, we recommend that the nets are closed prior to 17:00 h to avoid capturing bats, and in studies of bats, the nets should be opened only after 17:00 h, to avoid capturing birds.

Net height: To capture understory birds, we recommend setting the nets at ground level. However, setting mist-nets at heights of less than 0.5 m is ineffective for the capture of bats. In

order to optimize the capture potential of the nets for bats, the nets should be set at heights of above 0.5 m.

Mist-net: Stay for many days in the same site or to change every three or five days: The benefits of shifting the site of the mist-nets will depend on the objectives of the study, although other factors that may interfere in capture rates, such as rainfall (for both birds and bats) and the moon phase (for bats), should also be taken into account. During rainy periods, the nets should be managed for longer periods in the same site, to optimize the capture of birds and bats, whereas during drier periods (low precipitation), five consecutive days is the maximum period recommended. This is because, during periods with low levels of precipitation, birds (O'Connor and Hicks, 1980) and bats (Erickson and West, 2002) are more active overall, which increases the probability of capture. The only exception in the study region would be during the cold snaps (*sensu* Parmenter, 1976), when both birds and bats may become less active. We would thus not recommend setting the nets during these events. In the specific case of the bats, on nights with more moonlight, we would recommend setting the nets only until moonrise, or not at all. On moonlit nights, bat capture rates may decrease drastically (Mello et al., 2013). By following these simple recommendations, researchers can obtain optimal mist-netting results for birds and bats in Amazonian forest environments, considering the pay-off between costs (sampling effort) and benefits (capture rates).

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## Conflict of interest

The authors declare that they have no conflict of interest.

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