Characterizing Diurnal Roosts Used by Neotropical Bats in a Selectively Logged Forest to Improve the Construction and Implementation of Artificial Roosts

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Abstract

Bats are essential to neotropical forests because of the many ecological roles they play. Not only do they keep insect populations in check, provide vital nutrients to soil through the high levels of nitrogen and phosphorus in guano, and they also are pioneers in seed dispersal. However, selective logging in previously untouched forests is increasing the risk of many preferred diurnal roosts to be destroyed. In the recent decades, deforestation and fragmentation has dramatically changed the natural landscape throughout the region of Madre de Dios, Southeastern Peru. Therefore, the concentration of colonies in these forests might have the potential to decrease, affecting seed dispersal, propagation, and forest dynamics in consequence. This study aims to understand the diurnal roost preferences of neotropical bats to better inform about the construction and implementation of artificial roosts in conservation projects. Internal and external characteristics of roosts were analyzed. This data spurred the construction of an artificial roost, which was constructed in the field using local wood. The purpose of this construction was to replicate natural roosts to encourage bats to continue to roost in selectively logged forests for future conservation projects.

Introduction

The Madre de Dios region of the Amazon rainforest is a biodiversity hotspot that has many parts of the forest still intact. It contains some of the highest levels of species endemism and is a globally important carbon stock. The forests of the Madre de Dios department in Southeast Peru are the most vulnerable to deforestation due to practices such as gold mining, small-scale slash and burn agriculture, and logging. Due to the recent completion of the Interoceanic Highway, these practices are becoming more popular in previously untouched areas of the forest. Logging is continuing at a rapid pace, which is disrupting the habitats of animals that use economically valuable trees.

Neotropical bats are directly affected by logging in Madre de Dios due to the fact they prefer to roost far from the forest edge in large timber species. Without the availability of these roosts in the forest, bats will seek roosts elsewhere and the forests will lose a vital seed disperser. Seed dispersal is an essential factor to the regrowth of these fragmented forests. Various species of bats in neotropical forests are pioneers in seed dispersal, possibly playing an important role in the recovery of forests on abandoned agricultural land. The widespread forest fragmentation and logging in the department of Madre De Dios may prevent many bats from crossing the disturbed matrix meaning that these colonies become isolated and the population size of bats visiting these plots is reduced (Evelyn et al., 2003). The reduction in these population numbers is detrimental to regrowth of surrounding fragmented plots due to the lack of seed dispersing bats in primary forests. Certain types of neotropical frugivorous bats are only semi-tolerant to human disturbance which means they have been known to reside in selectively logged forests, but the factors that draw these bats to stay in disturbed areas are unknown. These bats' limited tendencies to work around human disturbance allow them to play a vital ecological role as seed dispersers in clearings where seed dispersal by bats often exceeds seed dispersal by birds (Gorchov et al., 1993). Nevertheless, little is known about the impacts of selectively logged forests on bats in Madre de Dios, including the species affected, as well as how populations might be enhanced to increase services such as seed dispersal that aid in forest regeneration.

There have been efforts to increase bat population in certain forests by creating artificial roosts and placing them in and around forests. Artificial roosts have been also implemented in fragmented forest regions to increase seed dispersal according to previous studies but were not successful in hosting bats (Reid et al., 2013). These studies did not account for the micro-climate, volume, and the surrounding biodiversity of the natural bat roosts that were used as a model. Therefore, the aim of this study is to understand the characteristics of natural bat roosts and their locations in a selectively logged forest in order to replicate these characteristics in an artificial roost. Studying the characteristics and locations of these bat roosts is important because bats spend large amounts of their time in their day roosts where they do activities such as rear young, rest, and mate which increases potential seed dispersal surrounding those areas. If the characteristics of these roosting sites such as the micro-climate, volume, species, and biodiversity surrounding these cavities are studied, it would allow for a better design of an artificial bat roosts and enhance reforestation efforts in the region.

Methods

Study Area

This study was conducted at Finca Las Piedras, a biological station located in a non-protected area in the department of Madre de Dios near Puerto Maldonado in Peru (lat. -12.226348°, lon. -69.112599°). The area studied consists of a 54 ha plot of forest that is considered a selectively logged forest. Brazil nut (*Bertholletia excelsa*) trees dominate the emergent canopy layer, but the forest has been stripped of other species such as Mahogany (*Swietenia macrophylla*), Cedar (*Cedrela odorata*), and Tornillo (*Cedrelinga sp*.).

Experimental Design

A previous study was done in this area that examined the potential roosting sites of neotropical bats which looked at hollow logs, trees, and stumps (Brierly 2017). In order to get the most accurate data to create an artificial roost, I looked at confirmed roosting sites. These sites were confirmed through the presence of bat guano. In order to find these sites, I walked haphazardly through the 54 ha plot of land. The roosting sites are defined as any place a bat would use as shelter that protects them from rain and sunlight, but also has cavity entrances that are large enough for neotropical bats to fit through. This meant that hollow logs, stumps, and trees were ideal roosting sites. Such microhabitats were often off trail and below or above eye-level. I stopped at all potential sites but only collected data if guano was detected. Once these sites were confirmed bat roosts, I recorded the coordinates of the roost. I then proceeded to record characteristic data such as the amount of cavity entrances, height of cavity entrances from the ground, canopy coverage of the potential roost, internal temperature of the cavity versus the external temperature of the forest, the volume of the roost, the density of the surrounding vegetation, whether bats were present, and the internal complexities of the cavities. After analyzing the data collected, I sketched plans for the ideal neotropical artificial bat roost and then constructed it accordingly.

Measurements

Once I found a potential roost, the first thing I looked for was the presence of guano (bat feces). I identified guano by searching for small, dark pellets that were elongated in shape and ranged from one to three centimeters. Once the roost was confirmed, I looked for the presence of bats in that moment. I listened and looked for bats in the cavity entrances and counted each of the entrances, as well. Entrances were only counted if they were big enough for a bat to fit through. Neotropical bats are mostly fruit-eating bats which means the entrance would need to be bigger than 9.5 cm. I recorded the roost coordinates with a Garmin GPS. Afterwards, in order to be able to calculate the volume of the roost, the height and radius in centimeters of the cavity entrance was measured using a 5-meter tape measure. Due to the cylindrical nature of the roost sites, the formula I used for volume was π x height. The height was measured from one end of the cavity to the other. This means that in instances like a partially hollow log the height would end when the log stopped being hollow. I also recorded the height of the cavity entrance from the ground. This was measured from the lowest part of the cavity entrance. I also recorded canopy coverage and density of the surrounding vegetation to the cavity entrance. Both factors were measured on a 1-4 scale (1 being little to no canopy coverage/little to no surrounding vegetation and 4 being fully shaded due to canopy coverage/little cavity access due to density of vegetation). I recorded qualitative data on the internal complexities of each cavity along with their category: tree, log, or stump. I wrote descriptions about the internal surfaces such as their roughness, color, and moisture level. In order to compare the external temperature of the forest to the internal temperature of the cavity two max and min thermometers were used. One thermometer was set up 100 m into the forest at Finca Las Piedras' temperature station and the other was placed inside of a confirmed bat roost. On the same six days they were placed for 24 hours to record the maximum and minimum temperatures for that day. They were then compared to each other in order to understand the internal climate differences in bat roosts. After the quantitative data was taken, I calculated the mean values for characteristics like the number of cavity entrances, height of cavity entrances from the ground, canopy coverage of the potential roost, internal temperature of the cavity versus the external temperature of the forest, the volume of the roost, and the density of the surrounding vegetation. The results of this calculation then influenced the construction of the artificial roost.

Results

Nine confirmed roosts were surveyed within forested areas of Finca Las Piedras. Out of the nine confirmed roosting sites, seven of the roosts were in hollow logs, while the remaining two were in hollow trees.

The locations of these roosts ranged from the terra firme forest to the aguajal. All of the roosting sites were inside the forest and avoided the edge effect. Four of the roosting sites had bats present at the time of evaluation. Out of the four occupied sites, three of the roosts were hollow logs and one was a hollow tree.

The mean values were calculated for the quantitative characteristics (Table 1). During the time of the study, the maximum temperature of the forest was 25.5 C°, and the minimum was 12, with a mean of 20.71 C°. As for the roost's internal temperatures, the maximum recorded was 24 C°, the minimum was 12 C° and the average was 19.75 C°. The range of temperatures in the forest were 5.42 C°, meanwhile in the roosts the range of temperatures was 3 C° (Fig. 1).

With the mean values and the observational data collected from this study, an artificial roost was constructed. The parameters that were used to design and build the structure are also listed in Table1.

Building the Artificial Roost

According to the data collected, an artificial roost was created using materials at Finca Las Piedras (Figure 2). The roost was made from twelve 42x5x1 cm wood pieces, four 81x5x5 cm wood pieces, and eleven 81x14 cm wood panels. Using wood to construct the roost was a design choice that was made in order to mimic the microclimate of the observed roosts. Wood tends to provide enough shade and shelter from the sun that it keeps the internal climate somewhat cooler than the external climate.

Table 1: Mean Values of Quantitative Parameters of Confirmed Bat Roosts versus Current Values of Constructed Artificial Roost.

	Mean Observed Values	Artificial Roost
Cavity Entrances	2.56	2
Height of cavity entrance from ground	85.5 cm	85 cm
Volume of Cavity	5,064,446.09 cm^3	142, 884 cm^3
Density of Vegetation	2.11	2
Canopy Coverage	2.56	3

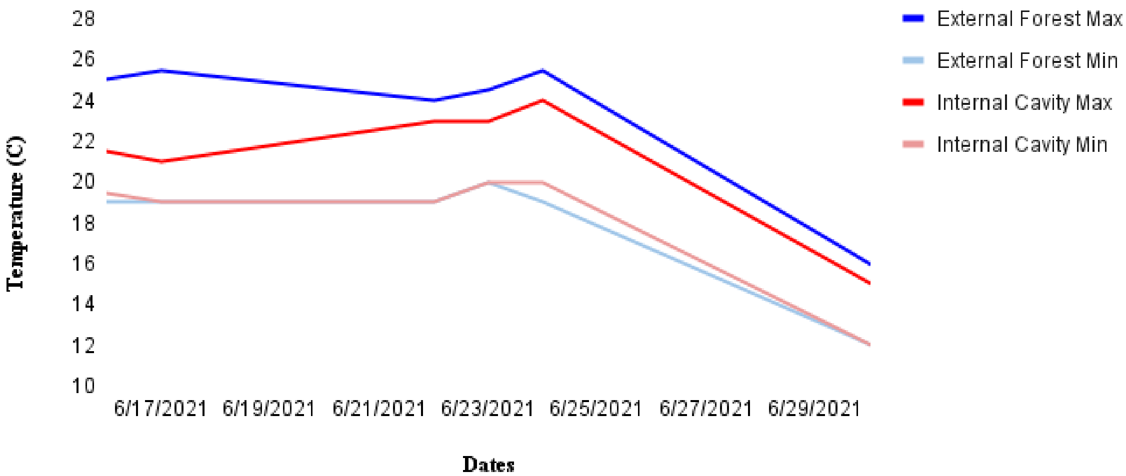

Figure 1: Comparison of the Internal Cavity Temperatures of a Neotropical Bat Roost to the External Temperatures of a Neotropical Forest

4-cm aluminum nails for pilot holes, and 4-cm aluminum screws were also used to construct the roost. The roost contains two cavity entrances, both varying in size. One is 81 x 14 cm in order to mimic the observational data of the shape of many of the cavity entrances which were long in length and short in width.

The other is 42 x 42 cm at the bottom of the artificial roost which will allow for safe access into the roost from flight. This was done because the mean average of cavity entrances that were observed was between two and three entrances. The roost also has a total volume of 142,884 cm2. The length of the first cavity entrance from the ground is 85 cm, which allows for the roost to be at a height more comfortable for flight landings. In order to mimic the rugged interior of most of the natural roosts that were observed, layered wood strips were added to the interior of the artificial roost. One alteration was made during the actual construction from the blueprints. The blueprints suggest that a support beam be used to prop up the roost, however, a beam large enough to withstand the weight of the roost was not available, so the roost was hung without a support beam instead.

Artificial Roost Installation

The location of the roost was an important factor to consider when constructing the artificial roost. From the observational data I collected, it was clear that bats chose to use hollow logs, trees, and stumps that were far from the edges of the forest. There was one exception in the data that showed one hollow log outside of a forested area with zero canopy coverage. However, for the other eight roosting sites, there was evidence that neotropical bats prefer to roost within the forest close to a water source because four out of the nine roosting sites were in the aguajal. Due to this, the artificial roost was placed at the coordinates 12*13’36’’ S 69*7’2’’ W in the aguajal forest that was near a water source, but also had a low level of vegetation density (Figure 3). The cavity entrance needed to be in a place with a low level of vegetation density because it needed to mimic roosts that gave access to the cavities with minimal conflict from

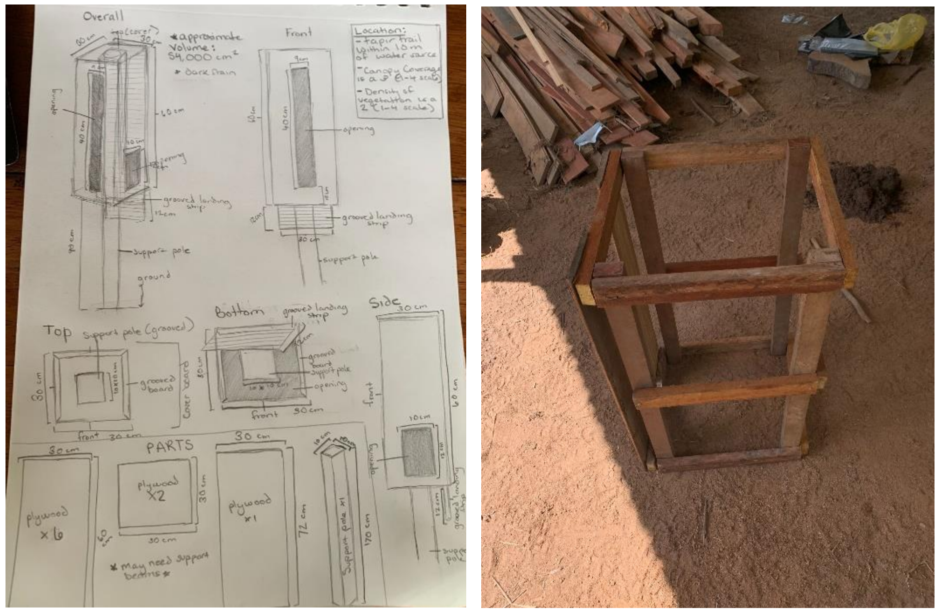

Figure 2: Original Blueprints for Construction of Artificial Roost and Beginning Framework

surrounding vegetation. The lowest cavity entrance was placed at a height of 90 centimeters to ensure that the roost had enough height from the ground to welcome bats in flight. The artificial roost was hung instead of propped up on a support beam so it could be tested in various locations if the location selected after this study did not come out to be successful. This was done by sliding a rope through the back openings on the roost and then tying the ropes around the tree.

Discussion

The data collected in natural roosts allowed me to replicate them into an artificial roost made with local wood. Most roosts have at least two to three cavity entrances and are located almost a meter off of the ground (85.5 cm). No generalizations can be made about volume because the variation found was high.

The lowest volume observed was 120, 000 cm^3 and the highest was 29,549,175.2 cm^3 Variation observed could be due to the nature of hollow logs, stumps, and trees. It was also observed that the density of vegetation surrounding the cavity entrances was very sparse. On a 1-4 density scale, the mean value was 2.11. This suggests that bats prefer an entrance that requires minimal conflict to access. Canopy coverage was also measured on a 1-4 scale, and the data collected supported the idea that neotropical bats prefered to roost in shaded areas far from the forest’s edge.

Evaluation of Roost

One challenge the project faced was a time crunch due to the lack of tools at the beginning of the project. The scale of this project was considerable due to the amount of man-hours (approximately 35) it took to collect data and build the roost itself. Therefore, time and effort are major considerations for a project like this which means planning for the gathering of materials and the building itself is necessary. The length of this study did not allow for a thorough evaluation of the implementation of the artificial roost. Structurally, it was quite sound with little movement from outside pressures. However, it is unknown how it will stand up against day-to-day neotropical events such as *friajes*, tree falls, bouts of rain, and damage from termites. Wood has not been known to withstand damage as well as structures built out of PVC, metal, and other plastics. However, wood does meet the internal climate requirements that natural bat roosts provide which are that neotropical bat roosts have lower maximum temperatures and higher minimum temperatures. At this point it is also unknown as to whether or not neotropical bats will take to using the structure as a diurnal roost. The data that was collected supports the idea that a structure that follows the characteristic trend of naturally occurring roosts will be a safe and natural space for bats to roost.

Figure 3: Finished construction of artificial roost in selected location

Future Work

In order to monitor the success of this artificial roost, the contents of bat guano in the roost, on the roost, and surrounding the roost should be looked for on a day-to-day basis. Most likely, two to three weeks will be needed to accurately measure whether or not bats are choosing to roost in the structure, and after that, the location may need to be reconsidered to a location that has an altered level of canopy coverage, density of vegetation, or a closer proximity to water. Maintenance will be needed as parts of the structure start to decay due to things like water damage, and the inspections for this maintenance should be done once before the dry season and once before the wet season. For future studies, in the case of a successful roost, I would suggest a further examination of the internal roosting habits of neotropical bats which could be studied using video cameras and how the placement of this roost affects seed dispersal of fruit producing plants. Overall, little is known about neotropical bats activity patterns and behavior, and the addition of this roost to Finca Las Piedras has the potential to be a useful tool to the research opportunities surrounding bats in the Madre de Dios region of Peru.

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Literature Cited

Brierly, A. R. *Discerning Diurnal Roost Preferences of Cavity Roosting Neotropical Bats for the Purpose of Designing Successful Artificial Bat Roosts*. Alliance for a Sustainable Amazon, 2017.

Evelyn, M.J et al. Roosting Requirements of Two Frugivorous Bats (*Sturnira lilium* and *Artibeus intermedius*) in Fragmented Neotropical Forest. *Biotropica*, 2003. 405-418.

Gorchov, D.L, et al. The Role of Seed Dispersal in the Natural Regeneration of Rain Forest after Strip-Cutting in the Peruvian Amazon. *Vegetatio*, 1993. 339– 349.

López-Baucells, Adrià et al. *Field Guide to Amazonian Bats*. Instituto Nacional de Pesquisas da Amazônia, 2016. 3-173.

Reid, J. et al. Artificial bat roosts did not accelerate forest regeneration in abandoned pastures in southern Costa Rica. *Biological Conservation*, 2013. 9-16.