Discerning Diurnal Roost Preferences of Cavity Roosting Neotropical Bats for the Purpose of Designing Successful Artificial Bat Roosts

Angela R. Brierly [1]

[1] Department of Biological Sciences, Santa Rosa Junior College, Santa Rosa, California, USA
Corresponding emails: angela.brierly@gmail.com & info@sustainableamazon.org

Abstract

In the Neotropics bats pollinate plants, spread seeds and keep insect populations in check. However, with deforestation and selective logging, many preferred diurnal roosting sites are destroyed, which potentially lowers the concentration of colonies of certain species of bats available for pollination, propagation, and insect predation. In order to encourage and preserve the essential ecosystem services of bats, we need to understand the diurnal roosting preferences of existing bat colonies.

Introduction

The forests of the department of Madre de Díos, Peru are becoming fragmented and interspersed with a mosaic of fallow pasture and expanding agricultural plots. The fertility of many tropical soils is short -lived, and these farms can deplete the fragile soil within several years (Uhl, 1987; McGrath et al., 2001), causing farmers to abandon the now barren fields. Natural regeneration of these abandoned agricultural lands is slow due to depleted soil nutrients, increased soil temperature due to lack of plant-cover, increased seed predation, and a lack of seed dispersers in barren areas (Uhl, 1987). Lack of seed dispersal in pastureland is a main barrier to forest flora recovery in the Neotropics (Kelm et al., 2008). Bats are important pioneering species seed dispersers in the tropics (Gorchov, et al., 1993; Galindo-González, et al., 1993; Mello et al. 2011). Bats also control insect populations, which in turn might assist in the regeneration of flora. Previous studies have been conducted assessing the effectiveness of artificial bat roosts on regeneration in abandoned pastures and fields in the Neotropics, with conflicting results. One study concluded that artificial roosts in pasture increased seed input around the roost sites as compared to the control sites (Kelm et al., 2008). A conflicting two-year study concluded that artificial roosts in pastures did not accelerate forest regeneration (Reid et al., 2013), though the authors stated that this was due to bats not occupying the artificial roosts placed in pastures. The authors suspected that this may be due, in part, to a flaw in their roosts designs, i.e. that they did not take into account the roosting habits of tropical bats nor the microclimatic conditions within their roosts (Sedgeley & O'Donnell, 1999; Reid et al., 2013). Both studies included basic dimensions and materials used to construct the roosts, and they differed considerably in dimension and thermoregulatory abilities. Studies that were successful in populating artificial roosts used smaller opening to volume ratios, roughly designed them to resemble hollow tree trunks and or placed the roosts in well-shaded areas (Kelm et al., 2008). Unsuccessful artificial roost occupation occurred where the roosts were placed in insufficiently shaded areas and were built using a traditional North American bat roost design with an entirely open bottom, thus creating a larger opening to volume ratio (Reid et al., 2013).

Neotropical cavity-roosting bats prefer large trees with a diameter 50% greater than randomly sampled control trees and trees of this size comprised only <2% of the trees tested (Evelyn & Stiles, 2003). Trees of this size will become even rarer as deforestation continues, and with the loss of suitably large trees for roosting, seed dispersers and insectivores will decline as well.

The purpose of this study was to determine whether the preferred roost characteristics of Amazonian bats could be determined via a survey and comparison of occupied and unoccupied potential roosts. To do this, I measured the cavity characteristics of suitable bat cavities found in trees, logs, and standing stumps in a selectively-logged forest bordering agricultural lands with potential for reforestation. I found 20 cavities (of which five were occupied by bats) and assessed their volume, internal temperature, and other parameters. Below I present comparisons between occupied and unoccupied cavities, suggestions for proper design of neotropical bat houses, and directions for future research.

Methods

Study Area

This study was conducted at Finca Las Piedras (S 12˚ 13.502, W 069˚ 06.649), the Alliance for a Sustainable Amazon's field site near Puerto Maldonado in Madre de Díos, Peru. The site comprises a roughly 45-ha parcel of selectively-logged lowland rainforest bordered by several ha of cleared fields. Most large canopy trees, including mahogany (*Swietenia macrophylla*), Spanish cedar (*Cedrela odorata*), and ironwood (*Dipteryx micrantha*) have been removed, with only Brazil nut (*Bertholettia excelsa*) remaining common.

Experimental Design

I surveyed Finca Las Piedras for potential roosting cavities haphazardly, by walking existing trails and off-trail through areas without trails, checking all large trees, logs, and stumps for cavities at or below eye-level. Previous studies conducted cavity surveys that were limited to only tree trunks that were along roadsides, forest remnant edges and within forest remnants (Breviglieri & Uieda, 2014), via indiscriminate mist-netting and radio-telemetry of both foliage and cavity roosting species (Evelyn & Stiles, 2003) or via line-transects (Kelm et al., 2008). Previous studies success rate of finding occupied roosts ranged from eight roosts (Breviglieri & Uieda, 2014), to 32 roosts (Evelyn & Stiles, 2003). A potential roost was defined as a cavity that is protected from rain and direct sunlight, with an opening large enough for a bat to fly through that leads to a cavity large enough to house >1 bat. When a cavity was located the DBH, internal and external temperatures, surface area of the opening, number of openings, height of each opening from the ground, internal volume, wall thickness, canopy cover, and opening foliage cover were recorded, and the presence or absence of bats was noted.

Measurements

The DBH of each tree was recorded,

with buttressed trees, stumps and logs being measured 11cm above the buttress where possible. Where not possible, a photograph was taken of an object of known height next to the tree, and diameter determined with this reference. In the event of a fallen log, the DBH was estimated with the existing surface accessible. Light and ease-of-flight were measured on a 0-4 scale for foliage surrounding the cavity opening and the canopy was measured as an average of percent cover as viewed through a 9.5x5cm viewing cylinder at 5m in each cardinal direction (NSEW and over the origin) from the cavity opening. The number of openings to the cavity were recorded, their location on the tree, (i.e. trunk, branch, buttress, etc.) and the cardinal direction the opening faced was recorded. The internal temperature was taken using an animal husbandry thermometer after ten minutes in the cavity. The external air temperature was also taken along with the time of day and weather conditions. I measured the height from the ground to the bottom of the opening, the height of the tallest and shortest portion of the opening and the width of the widest and narrowest portion of the opening to gather accurate data regarding opening shape and size. A rough drawing was made of the opening and cavity while in the field. The internal dimensions were measured by inserting a tape measure into the cavity, or along the length of a log, to assess depth, width, and height, and thickness of the walls.

Determination of occupancy

Bat occupancy was determined by visual observation of the bats. In the cavities where the number of bats was indeterminate due to an inability to visually see inside entire cavity clearly, an estimate of colony size was noted. The presence of guano was recorded, as well as physical descriptions of the bats and notes on their behavior.

Results

Twenty potential roost cavities were surveyed along the Aguajal trail and the forested area at Finca las Piedras for non-foliage roosting bats. Of the 20 cavities studied, 12 were in logs, 6 were in standing trees and 2 were in standing stumps. Of the total cavities, 5 were occupied by one or more bats, and 15 were found to be unoccupied at the time of observation. One occupied cavity was located in a standing tree, and the remaining four occupied cavities were located in logs. None of the stumps studied were found to be occupied.

Mean values of occupied and unoccupied cavities were calculated for total opening surface area, height of the opening from the ground, of the cavity, number of openings to the cavity, and internal temperature for both occupied and unoccupied cavities are. Values are listed in Table 1.

There was a significant difference between mean values of the number of openings in occupied and unoccupied cavities (two-sample t-test, $t = 4.5985$, $df = 6.271$, $p = 0.003$), with the occupied cavities having the higher mean value of openings (Tab. 1).

No significant difference was found between occupied and unoccupied cavities for the difference between internal temperature and external temperature, (Welch two-sample t-test, $t = -1.3712$, $df = 16.366$, $p = 0.18$), the opening surface area (Welch two-sample t-test, $t = 2.3692$, $df = 4.7923$, $p = 0.06$), the opening height from the ground (Welch two-sample t-test, $t = -0.29515$, $df = 11.568$, $p = 0.77$), the internal volume (Welch two-sample t-

Table 1: Mean values of parameters of occupied and unoccupied cavities

Occupied	Unoccupied
Opening Size (cm^2)= 1217.8	Opening Size (cm^2)= 4068.5
Volume of Cavity (cm^3)= 39064600	Volume of Cavity (cm^3)= 2294799
Height Opening off Ground (cm)= 26.04	Height Opening off Ground (cm)= 30.98
Number of Openings= 2.6	Number of Openings= 1.33
Internal Temperature (C˚)= 23.06	Internal Temperature (C˚)= 23.87

test, t = 2.2042, df = 4.0513, p = 0.09), the percentage of canopy cover at the openings (Welch two-sample t-test, t = -1.0014, df = 6.4771, p = 0.35), nor the surface area of the openings (Welch two-sample t-test, t = 1.5212, df = 11.879, p = 0.15).

Discussion

I found no significant difference between occupied and unoccupied cavities in any parameter except the number of openings (p = 0.15). Occupied cavities had an average of 2.6 openings, while unoccupied cavities averaged 1.33 openings. Opening surface area of occupied cavities averaged 1217.8 cm^2 while unoccupied cavity opening size averaged 4068.5 cm^2. Even with this result the observed trend was for occupied cavities to have a larger interior volume and smaller openings than unoccupied logs. This would benefit from further research. Though no significance was found between the internal temperatures of occupied and unoccupied cavities, I believe that internal microclimate warrants further study and that a shaded, thermally insulated roost would be preferable.

In future studies, I recommend that the internal and external cavity temperatures of the occupied or occupied and unoccupied logs should be taken between 1:00-4:00pm, during the hottest time of the day, as this is when the insulation properties of the cavities would be most apparent, and perhaps show significance. The current study took temperatures between 8:00am-1:10pm, and perhaps this influenced the significance of the temperature differences. I also recommend recording the latitude and longitude of every cavity studied, not just the occupied cavities, in order to conduct follow-up observations. Further research into possible significance of volume and opening area is advised. This study would mainly benefit from a

Table 2: Summary data with mean values

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> summary(CavityData)
    CAVITY     OCCUPIED         TSL123        NUMOPEN        OPENSIZE            HEIGHT
 C-001  : 1   Min.   :0.00   Min.   :1.0   Min.   :1.00   Min.   :   58.1   Min.   :  0.00
 C-002  : 1   1st Qu.:0.00   1st Qu.:1.0   1st Qu.:1.00   1st Qu.: 1255.8   1st Qu.:  0.00
 C-003  : 1   Median :0.00   Median :3.0   Median :1.50   Median : 2331.4   Median : 19.70
 C-004  : 1   Mean   :0.25   Mean   :2.3   Mean   :1.65   Mean   : 6230.9   Mean   : 29.75
 C-005  : 1   3rd Qu.:0.25   3rd Qu.:3.0   3rd Qu.:2.00   3rd Qu.:10186.8   3rd Qu.: 33.77
 C-006  : 1   Max.   :1.00   Max.   :3.0   Max.   :3.00   Max.   :20104.0   Max.   :154.90
 (Other):14
     VOLUME              INTTEMP         OUTTEMP        DIFFTEMP      CANOPY        FOLIAGE
 Min.   :    1560   Min.   :20.00   Min.   :23.0   (4.00) :5   Min.   :40.0   Min.   :0.00
 1st Qu.:   72500   1st Qu.:23.25   1st Qu.:26.0   (2.00) :4   1st Qu.:59.0   1st Qu.:0.75
 Median :  811000   Median :24.00   Median :27.0   (3.00) :3   Median :63.0   Median :2.00
 Mean   :11487250   Mean   :23.66   Mean   :26.7   (2.50) :2   Mean   :63.4   Mean   :1.50
 3rd Qu.:10032500   3rd Qu.:24.50   3rd Qu.:28.0   #VALUE!:1   3rd Qu.:70.5   3rd Qu.:2.00
 Max.   :95300000   Max.   :27.00   Max.   :29.0   (1.50) :1   Max.   :80.0   Max.   :3.00
                    NA's   :1       NA's   :1      (Other):4
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larger sample size, especially of occupied roosts, as having only 20 subjects, 5 of which were occupied, is too few to obtain meaningful results. In order to increase relevant sample size, I suggest conducting nocturnal surveys using nylon mist netting of trails, roads, treefalls and streams then using radiotelemetry to locate day roost sites of select cavity roosting bats.

Based on my study, I believe ideal roosts for neotropical bats should have multiple openings, enough physical height/space sufficient for bats to launch into flight from, a roomy interior space, a cool consistent interior microclimate and an entrance and exit that is clear of foliage.

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