Requirements of the roost used by Spix's disk-winged Bat (*Thyroptera tricolor*)

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Abstract
Thyroptera tricolor use rolled leaves of *Heliconia* spp. and *Calathea* spp. as ephemeral roosts. We study the characteristics of the roost-site by taking 13 measurements of the rolled leaves, and the vegetation composition immediately around it. Bats preferred to roost in leaves that were both narrow (small diameter in leaf mouth) and long. Also they used leaves with more abundance of closed, semi-open and open leaves of *Heliconia* sp., within a 5m radius around the leaf with bats. Probably they selected these leaves to roost because imply protection from weather conditions, and help to keep their body temperature constant. The abundance of opened leaves near the roost may keep away the bats from predators, since it could work as a long distance detector, transmitting predator's movements. More closed leaves around roost sites leaves could be an advantage because it increases the probability of finding new places for roosting the next day.
Keywords: roost places, *Heliconia sp*, Costa Rica, leaf characteristics, rolled leaf.

Introduction

Selection of roosting places by bats is influenced by several factors, such as protection against predators and weather (Timm and Lewis 1991), thermoregulation (Rodríguez-Herrera et al. 2007), and to increase the mating success (McCracken and Wilkinson 2000). Roosting places can be classified according to their duration in time, as permanent or ephemeral (Rodríguez-Herrera et al. 2007). Permanent roosts are places such as caves, natural cavities and human constructions (Rodríguez-Herrera et al. 2007). Such roost sites could be used by individuals or groups of bats for over a month and up to several years, without changing or degrading its structure (except for wood cavities). Ephemeral roosts are shorter-lived resources with duration ranging from 24 h (e.g., rolled leaves) to a month (e.g., tents) (Rodríguez-Herrera et al. 2007). Abundance of these roosting resources differs between sites, such that ephemeral roosts are often more abundant at some sites than permanent roosts (Vonhof and Fenton 2004; Rodríguez-Herrera et al. 2007).

Plant leaves are the most common ephemeral roosting resource (Rodríguez-Herrera et al. 2007). Species such as *Artibeus* spp. and *Ectophylla alba* build tents in plant leaves to roost (Rodríguez-Herrera et al. 2007), while *Thyroptera tricolor* and *Pipistrellus nanus* exclusively use rolled leaves from *Heliconia* sp., *Musa* sp., *Calathea* sp. and *Strelitzia* sp. to roost (Findley and Wilson 1974; LaVal and LaVal 1977; Simmons and Voss 1998; Wainwright 2002; Vonhof and Fenton 2004). Rolled leaves are the most ephemeral roosting resource in natural conditions (LaVal and LaVal 1977; Emmons 1990; Reid 1997). For that reason, bat species that use such resources need to change roosting places almost every day (LaVal and LaVal 1977; Emmons 1990; Reid 1997).

In Costa Rica, *T. tricolor* inhabits the lowland rainforests of the Caribbean and South Pacific coasts, as well as the middle elevation cloud forests (LaVal and Rodríguez-Herrera 2002; Wainwright 2002), using *Heliconia* spp. and *Calathea* spp. leaves for roosting (Findley and Wilson 1974; Simmons and Voss1998; Wainwright 2002; Rodríguez-Herrera et al. 2007). However, little is known about the characteristics of the leaves used to select roosting sites (but see Wilson and Findley 1977). The aim of our paper is to analyze the characteristics of leaves used by *T. tricolor*, while trying to understand the microhabitats surrounding these sites.

Material and Methods

We visited three secondary forests and forest edges in Golfito, Puntarenas province, Costa Rica: La Lechería (08º38'N, 83º11'W), La Gamba (08º39'N, 83º12'W), and Playa Cacao (08º37'N, 83º10'W). The total number of visits to each site was three, five and one, respectively, from January 15 to January 31, 2005. Each visit lasted 5 hours in the morning, in which we searched for *Heliconia* sp. and *Calathea* sp. plants along forest edges, gaps, stream borders, and secondary-forests. For every shoot identified as *Heliconia* sp. or *Calathea* sp., we looked into all rolled leaves in order to determine the presence of bats. Before checking for bats, we closed the tip of the each rolled leaf to avoid bat emergence. For each leaf, we recorded 13 measurements: leaf length, leaf bottom width (on leaf surface beginning), width of leaf mouth, leaf height (from forest floor to leaf bottom), distance to a clearing (stream rim, gap or grassland), vegetal cover immediately over the leaf (using a scale from 0 to 5, 0 = no cover, 5 = complete cover), number of closed (leaves completely rolled without space to be used by a bat), semi-open (rolled leaves with space inside) and open leaves (leaves with completely expose leaf surface) in the same plant. Moreover, we counted the closed, semi-opened and opened leaves of *Heliconia* sp. or *Calathea* sp., around the roosting site and the density of different species of *Heliconia* sp. and *Calathea* sp., which had a height above 30 cm, within a 5m radius. In case where no bats were found, we used the measures taken from the first leaf checked. These measured were conducted in each rolled leaf with bats and in the first rolled leaf that we checked per plant shoot of *Heliconia* sp. or *Calathea* sp, in shoots without bats.

We used a forward step logistic regression to determine which of the 13 measures taken would explain better the bat presence in the rolled leaves, and this stepwise option exclude those highly correlated variables from the analysis. We used a t-test to compare the density of others plants of *Calathea* sp. and *Heliconia* sp. around the leaves with and without bats. All the analyses were conducted using SYSTAT 11 (Systat Software, Inc. 2004). Values reported are means ± SD.

Results

We found 14 plants with a rolled leaf with roosting bats, and 47 plants with a rolled leaf without bats at the three study sites. Thirteen bat groups were captured in *Heliconia* sp. and one group was captured in *Calathea* sp. leaves. The groups were composed of 3 to 8 bats, with a mean of 5.0 individuals per rolled leaf (±1.9). According to logistic regression (rho^2 = 0.38; χ^2 = 26.43, df = 6, P < 0.001), *T. tricolor* used in average leaves with a leaf mouth diameter of 13.17 cm, and length of 122 cm (Table 1). Also, they choose roosting places with a higher number of closed, semi-open and open leaves of *Heliconia* sp. within a 5m radius around the roosting plant, and in roosting plants with more open leaves (Table 1). The values of the other seven measures were similar in rolled leaves with or without bats (Table 1). Plant density different to *Heliconia* sp. or *Calathea* sp. around the roost was similar among leaves with (4.75 ± 4.10) and without bats (5.95 ± 6.18) (t = -0.54, df = 102, P = 0.59).

Table 1. Mean values with its respective range of measures recorded in *Heliconia* sp. and *Calathea* sp. leaves used (present) or not (absent) by *T. tricolor.*

Measures	Absent	Range	Present	Range
Focal leaf				
Long (cm)	118.53	20-200	122.13	85-165
Bottom (cm)	12.27	2-42	5.27	1.6-10
Mouth (cm)	22.79	5-37	13.17	4.5-26
Height (cm)	114.31	3-200	100.12	2-163
Covered (from 0 to 5)	4	0-5	3	0-5
Distance from nearest opening (m)	308.28	0-2000	168.35	0-600
Leaves in the same plant group				
Open	2.68	0-10	3.17	0-6
Semi-open	0.05	0-2	0.059	0-1
Close	0.03	0-1	0	0
Other plants in 5 m radius from focal leaf				
Abundance of other Heliconias	5	0-14	6.57	0-14
Close	0.88	0-5	1.82	0-9
Semi-open	0.31	0-2	0.76	0-4
Open	16.87	0-55	26.31	0-60

Discussion

Our results suggest that *T. tricolor* choose longer, smaller diameter leaves for roost sites, probably because they are more protected from weather conditions than in shorter, larger diameter leaves. Tightly rolled leaves have a greater insulating value against cold and heat. One advantage of selecting such leaves is that they could help to keep the bats body temperature constant throughout the day, as has been proposed for tent-roosting species (Kunz and Lumsden 2003; Chaverri et al. 2007). Longer leaves could allow bats to roost farther from the leaf opening thus providing a more stable microclimate. Furthermore, these types of leaves have more space inside, and thus could be used by bigger groups of bats, allowing for greater thermoregulatory efficiency. Another advantage to select longer leaves could be that in warm days they space out to keep cool.

Higher foliage density produced by the presence of other *Heliconia* sp and *Calathea* sp. plants around the roosting plant leaves influence the bat presence in rolled leaves, because can increase the bats survival. For example, the abundance of opened leaves around the rolled leaf with bats may function to help hide the bats from predators. The open leaves could also work as a long distance predator alarm, by transmitting vibrations from predator movements to the rolled leaf, allowing bats time to escape (Rodriguez-Herrera et al. 2007). Abundant semi-opened leaves around the leaf with bats can reduce the likelihood of predators identifying the correct leaf. There seems to be no external feature of occupied leaves that allow the bats to be detected from the outside (pers. obs.).

Also, *T. tricolor* probably choose a rolled leaf with closed leaves around it because this increases the probability of finding good new places for roosting the next day or throughout the day. These bats change roosting places every day since the *Heliconia* sp. leaves open rather rapidly (Findley and Wilson, 1974), hence loosing the characteristics that make them secure. Some roosting leaves could also open during the day, making the bats more vulnerable to predators like hawks and falcons (Fenton *et al*., 1994), and white-faced capuchin monkeys, raccoons or coati. Although vegetation around tubular leaves could diminish the visual detection of bats all plants different to *Heliconia* sp. and found around the roosting leave were small in height. Therefore they fail to provide any significant amount of screening.

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