Roosting And Mating System Of *Ectophylla Alba* In Costa Rica: Implications For Conservation.

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1. Objectives

This work was part of my graduate studies, where the general aim is to identify habitat requirements for the construction of their shelter and the roll of construction in the matting system. This is an important input in science since in most bat species (93%), the mating system is unknown.

Ectophylla alba is a species with a small distribution. There is little information regarding its matting system. It represents one of the few species in the world that builds its own shelter, which does by modifying Heliconia leaves. The construction of its shelter has been associated to their matting system since the general hypothesis for this selected bat group says that males build the shelter to attract females and mate with them.

To respond the question "who builds the tent" and to know ecological aspects of their selected habitat to build their shelter are key features. This information will be very usefully to know the conservation status of these bats, especially in the areas near rural communities where the habitat perturbation, changes in land use (forest to fields), and unsustainable use of wildlife, put in risk the conservation of healthy populations of this species.

As main objectives, I stated:

- To characterize habitat requirements on the structure of the vegetation used by *E. alba* to build its shelter.
- To document if shelter construction is associated to reproductive time in this species.
- To understand why harems are formed when offspring is born (social structure).

2. Progress in attaining these objectives

2.1 Characterization of habitat used by E. alba:

There are some studies showing that preference of specific shelters or nesting sites can be beneficial in fitness, since they protect individuals from bad weather, are breeding sites for development of the offspring, offer protection from predators and opportunities to mate (Alcock 2001). In this regard, it is known that for many species, the microclimate is an important factor that influences the selection of refuges (Hartman & Oring 2003, Kalcounis & Bringham 1998, Kerth *et al*. 2001, Sedgeley 2001, Wiebe 2001).

In bats, the ecology of shelters must be seeing as a complex physiological, behavioral interaction related to morphological adaptation. They must influence the reproductive success of individuals. Under this definition, shelters can be classified as resources, since they can limit and influence the adecuation, and are being "consumed" by their occupation (Aguirre *et al.* 2003).

Despite the importance of bats in tropical ecosystems, there is little knowledge of the shelter and behavior ecology in these systems, since most studies take place in temperate zones (Sedgeley & O'Donnell, 1999).

Specifically for *E. alba*, the preference of secondary forest over primary forest to build its shelters is know. It also shows a preference for Heliconias over other plant species, mostly *H. imbricada* and *H. pogonantha*. Plants must have a length between 0.8 m y 1.2 m (Brooke 1990) to be chosen by this bat species.

However, we must ask: Does *E. alba* use any type of secondary forest when *Heliconias* are present? Are there other requirements? We do not know much of the structure and vegetation chosen by this species.

In this study I am interested in identify the vegetation structure utilized by this species to build its shelter. To accomplish this, I measure characteristics such as canopy cover, understory cover, density of Heliconias and trees, tree diameter and their distance to the tent. My study unit is circular plots of 5m in radio where a tent is present and I repeat the same methodology in a control leaf (a Heliconia leaf with no tent).

Results and discussion

This particular part of my study started in 2006. I characterized 50 tents and 55 controls in 25.3 hectares.

Data for this section was analyzed with a Discriminant Test. The main result shows that by using all variables it was possible to separate the two groups, tents and controles, $F_{(9,92)} = 6.3779$, $p < 0.001$. With the Discriminant Test by Steps it was also possible to separate the groups, $F_{(3,98)} = 18.97$, $p < 0.001$. In addition, three variables were identified as the main ones: canopy cover, $F_{(1,98)} = 11,42$, $p<0,001$, cover higher than one meter, $F_{(1,98)} = 20,50$, $p< 0,001$, and density of Heliconias, $F_{(1,98)} = 3.44$, $p < 0,066$. There must be a high percentage of canopy cover, meaning that the secondary forest cannot be of an early stage, and that bats are using secondary forests in a mature stage. The second variable confirms this assumption. There must be an open understory, which is characteristic of a more mature forest. This may be due to mechanical limitations to access the tent in and out, or an easier way to find the tents during the same night. At last, low density of Heliconias around the tent can be seeing as a consequence from the last two. For example, with a higher canopy cover there is less light and less Heliconias. In summary, this is the fist micro habitat study that shows this species has specific needs for the construction of their tents. It shows a selection process where bats choose certain size leaves, age, height and specific habitat structure characteristics. Because of that specificity and the low abundance of suitable habitats for the presence of its shelters, *Ectophylla alba* may be much more vulnerable to extinction than the common believe

2.2 Who make the tent?

Twenty-one species of bats around the world have been recorded using modified leaves as roosts, usually called "tents" (Timm, 1987; Kunz and Lumsden, 2003; Rodríguez-Herrera and Tschapka, 2005). Most tent roosting bats are members of the family of New World leaf-nosed bats (Phyllostomidae) except three pteropodids (*Balionycteris maculata*, *Cynopterus brachyotis*, *C. sphinx*) and one vespertilionid bat (*Scotophilus kuhlii*)

It has been suggested that the mating system associated with tent is polygamy, based on the defense of a resource—tents (Brooke, 1990; Balasingh *et al.*, 1995; Kunz and McCracken, 1996; Storz *et al.*, 2000; Kunz and Lumsden, 2003; Chaverri and Kunz, 2006). The main idea is that males modify leaves to create a refuge, so that females would select a male based upon some characteristics of a tent that potentially can be defended against other males (Balasingh *et al.*, 1995; Kunz and McCracken, 1996; Kunz and Lumsden, 2003).

To date, the construction of tents has only been observed in the flying fox, *Cynopterus sphinx* (Balasingh *et al.*, 1995) where males modified palm fronds. However, little information is available for all other tent-making or tent-roosting species. Using telemetry, Chaverri and Kunz (2006) observed that a male of *Artibeus watsoni* remained motionless at a site for 30 min; the following day they found the bat in a new tent where it had stayed throughout the previous night. Hence, it remains an open question how and from which sex tents are constructed. This information, however, is crucial to better understand the evolution of this complex behavior, in particular with regard to the social organization in tent-making bats.

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The study is being carried out in La Tirimbina Biological Reserve, Sarapiquí, Heredia Costa Rica (10º 24' N, 84º 07' W) where we conduct a weekly census of tents in a marked area of 7 hectares in secondary forest and 2 hectares in an old cacao plantation that had been abandoned for 20 years. During the day we check for leaves with fresh marks such as cuts along the midrib. We then observe potential activity of bats at the leaves during the night by placing a Sony HandyCam DCR-HC42 camera and an infrared light (Wildlife Engineering, model IRLamp6) at distances up to 4 m from the leaf.

Also, to evaluate the indirectly if the tent was associated to sexual selection, I counted the number of tents in good shape, new tents and bats present each week. The prediction stated was that if males built tents to attract females, the number of tents present would increase closer to the reproductive season.

Results and discussion

Production of tents did not follow the prediction on weeks 9^{th} and 32^{nd}, where females gave birth and there was not an increase in the number of tents. The production of tents is present all year round, and it does not show an increase associated to any reproductive behavior. Apparently bats are building tents any time they need them.

Fig. 1.

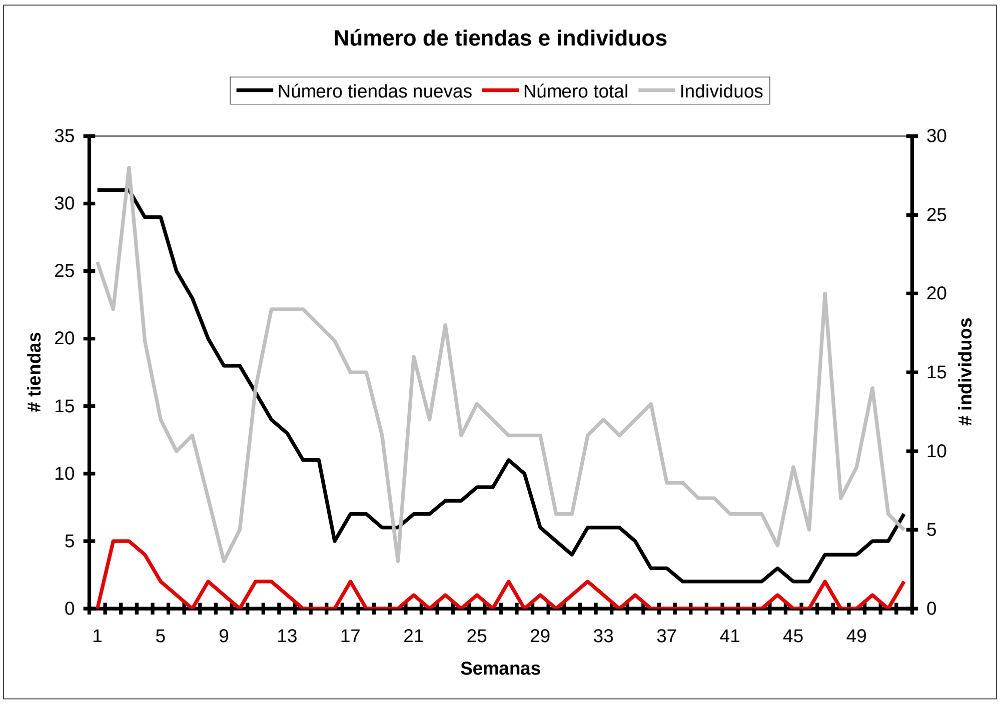

Fig. 1. Number of new tents, total number of bats in 9 hectares per week during a year of sampling.

Direct observations of the construction

I observed a female modifying *Heliconia* leaves into a tent (Fig. 2) this is the first direct observation of a phyllostomid bat constructing a tent and the first evidence that, contrary to expectation, at least in *E. alba* females contribute to tent construction. On 7 September 2005, we found a leaf of *Heliconia imbricata* with 11 cm long cuts on both sides of the central vein.

A subsequent inspection after the first half of the night revealed that the cuts had been lengthened to about 15 cm. Based on this initial observation we began filming on September 8th at 0100 h. About three hours later, at 0420 h, an adult male that we had previously marked with a band on the forearm arrived at the tent. This male stayed under the leaf for about two minutes without modifying it; then it flew around the tent for about two more minutes. The same day, we began filming at 1730 h and continued filming until 0630 h on 9 September. At 1814 h a female that we clearly identified as such because it was visibly pregnant landed on the half-built tent. The bat stayed for about five minutes, actively modifying the leaf.

My observations do not support the hypothesis that in phyllostomids only males construct tents to attract females and thus gain access for mating (Kunz and McCracken 1996, Kunz and Lumsden 2003, Chaverri and Kunz 2006).

The observations further suggest that the process of tent construction is expensive, in particular regarding the time it takes to modify the large *Heliconia* leaves. Some tents took at least one week to build, whereas in the same area some of the tents that we monitored had been constructed very fast within only two nights.

On February 2006, I filmed part of the construction of a different tent. That night two females came several times to modify the leaf. This shows the participation of various individuals in this process.

Finally in September 2006 I filmed the construction of another tent where a male was actively modifying the leave. The participation of several individuals of both sexes in the whole process tells us that the construction of the tent is costly and demands complex social interactions.

To conclude, although details of the mating system of *Ectophylla* and of most other phyllostomid tent-roosting species are still unclear, this information on *E. alba* suggests that, at least for this species, tent construction should not be seen as the main characteristic for which the females select a mate. Possibly, there are other features (e.g. vocalization repertoire, direct defense of females, etc.), which are more instrumental for the operation of sexual selection in this species.

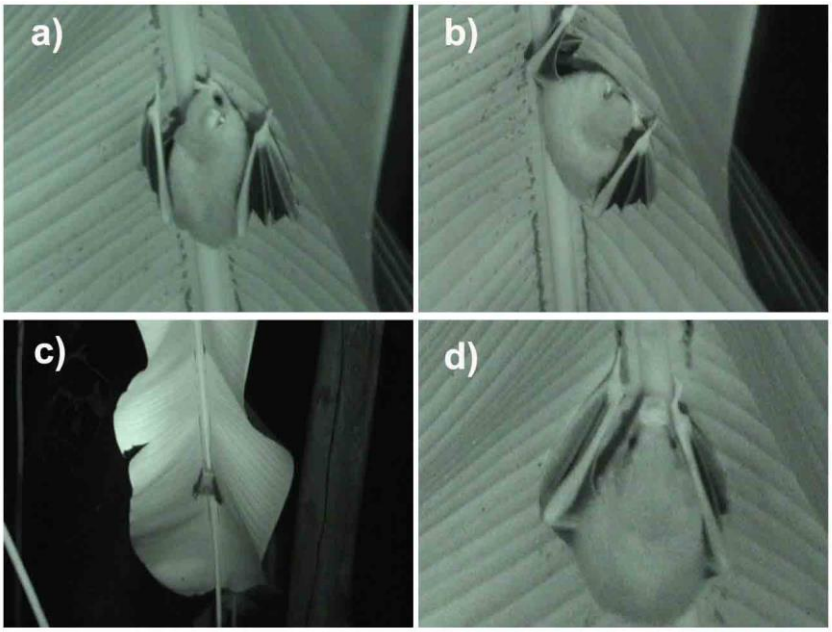

Fig. 2. a) An adult female *E. alba* using its teeth to perforate a *Heliconia* leaf along the midrib. b) Same female perforating the leaf away from the midrib. c) Female pulling down both sides of the leaf with its thumbs bending her forearms. Both sides of the leaf collapsed with the movements of the female to form the tent. d) Female using its feet and thumbs to enlarge holes created with its teeth.

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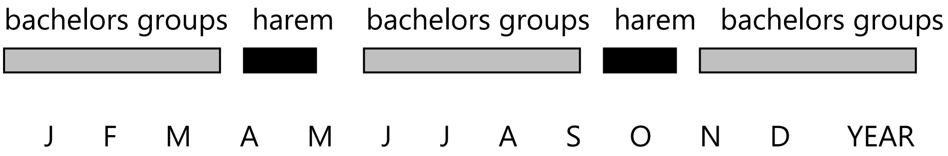
2.3 Social Structure

Based on Brooke (1990), McCraken and Wilkinson (2000) classification of the reproduction system of *E. alba* as having a bimodal cycle, being "*seasonal, single male and groups of several females*". The existing information comes from observations made on the first part of the reproductive cycle of the species (April), when Brooke (1990) registered the formation of harems at the time the pups are born (N= 4 tents), separate from groups of bachelor males (N= 2 tents). It is yet left to determine if the system classifies as a resource-defense poligyny (with the tent as a resource) or as a direct female-defense system; this is still unclear especially since there is no evidence of who is responsible for the construction of the tent.

The following figure summarizes what is known up to date about the social structure of the species.



Result and discussion

So far, my results are not consistent with the findings of Brooke (1990). It stands out that the group composition during the reproductive season is not that of a harem, as it was previously reported, for I have found that there is more than one male per group (N= 8 tents). Overall, I have studied the group composition of 38 tents (Table 1). I am also taking tissue samples for future studies, for this will help clarify the level of genetic relationship among individuals, and the reproductive success of each male.

In the contrary, stability in the groups is quite high, meaning that the majority of the members in each group stays together at least for several months independently from the reproductive season.

Table 1. Composition of groups. P= pregnant; J= juvenile; L= lacting

DATE	TENT	Total	FEMALE	BREEDING	MALE	TESTICLES SIZE
2005						
8-ag	Q_1-6	5	4(P)		2	
13-ag	J-5	4	3(p)		1	(3x3)
13-ag	C_1-6	3	1(P)		2	2(3x2)
15-ag	P-1	4	3 (1P)		1	(2x2)
12-sep	E_1-5	1	1 (P)		-	-
14-sep	Matadero	4	2 (1P)		2	
15-sept	Cormura	4	3 (2P,1L)	1	-	
26-sept	T-3	6	2 (L)	2	2	
11-oct	T_1-11	8	4 (2L)	2	2	(4x3),(5x4)
12-oct	J-3	11	5 (3)	3(1J)	3	2(4x3),(5x4)

13-oct	Roble	9	2 (L)	2	5	3(3x2),2(4x3)
13-oct	F.cacao	4	3(2 L)	1 (J)	0	
13-oct	F.cacao II	7	2 (L)	2	3	1(4x3),2(5x4)
22-oct	Ceibo	7	2 (pL)	3 (J)	2	2(4x3)
YEAR						
2006						
20-ja	U1-7	2			2	
20-ja	20-ene	10	5		5	2(3X2)1(4x3)
7-fe	J5-1	6	3		3	
23-fe	Alto	4	2(p)		2	(3.5X3)
23-fe	frente isla	7	4(p)		3	(4x3)
9-ma	ceibo 2	4	1(p)		3	(4x3)
15-ma	ceibo 2	5	2(p)		3	(4x3)
19-ma	corteza	4	2(p)		2	(4x3)
22-ma	Hans	8	6(5p)		2	(5x4)
23-ma	Osvaldo	9	7(6p)		2	(3.5x3)
27-ma	Roble	5	2(2p)		3	2(5x4) 1(4x3)
6-ap	"28feb"	5	3(3p)		2	2(5X4)
8-ap	Koopman	8	2		6	5(5x4)1(6x5)
15-may	Handley	7	2(L)*	3	2	2(5x4)
15-may	Underwood	9	5(2pL)	3(2m,1h)	1	(5x4)
20-may	Corteza	2	2(L)	2(2m)	1**	(4X3)
25-may	SSE	2	0		2	(4X3) (5X4)
29-may	STR	5	0		5	2(5X4)3(4X3)
10-ju	Escondida	5	4(postL)		1	(6X4)
5-jul	Allen	6	5(3pL,1SA)		1	(4X3)
5-jul	Casa Río	9	5(3pL,1SA)		4(2SU)	1(3X2) 1(4X3)
5-jul	Geoffroy	8	6		2	
13-jul	STR260	3	0		3	3(4X3)
28-ag	Erika	5	1(p)		4	4(4x3)

2.4 Male defense of the tent

At the time the pups are born, the testicles of adult males are indeed scrotal, which means that the females must be then receptive for mating. This leads to the conclusion that there must be a post-partum oestrus in this species. Consequently, even if the females were not selecting their mates based on their tent, because they also participate in the tent construction process themselves, it would still be possible and advantageous for the males to defend a particular tent and/or group of females. To test this hypothesis, I filmed a total of

64 hours during the reproductive season of September-October 2005, 322 hours in March-June 2006 (reproductive and non-reproductive season) and 72 hours in September-October (reproductive season) to be able to account for the time spent by both males and females in the tent during the night. My prediction is that males will spend a greater amount of time in the tent during the reproductive season than at any other period.

Result and discussion

My results from last year are presented, not including data from October 2006, are showed on Fig. 3 y 4. Here, it is evident that both males and females spend a similar amount of time at the tent. However, their activities differ, because females use the time mainly to suckle the pups, while the males have apparently no other reason for being there than being able to copulate with the females when they allow it. This can be seen as preliminary evidence for the conclusion that the males are defending the tent as a resource, and of the existence of a post-partum oestrus.

However, the presence of several males without antagonist interactions suggests another type of courtship. For example, all males hold females from their backs and leak them. This behavior is done only by males, and there is a difference in the intensity of it among them. This may have significance in courtship, as well as in social structure since males hold other males in the same way, but less common that with opposite gender.

In conclusion, we did no film any copula or male aggressions. However, interactions among males and females show different intensity in the season along the whole period. The presence of scrotal testicles in the breading season is still indirect evidence that it is the reproductive season.

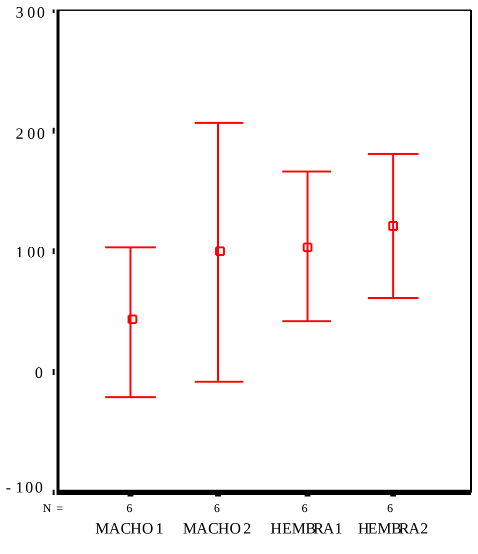


Fig. 3. Mean time of males and females per night in the tent ("mating season"). Total 64 hours of night film.

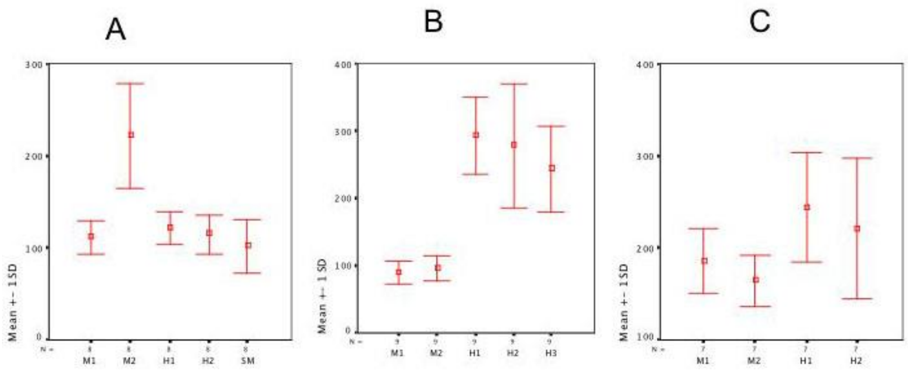


Fig. 4. A. Mean time of males and females per night in the tent, before "mating season" . B "mating season", C after "mating season". Total 322 hours of night film. March-June 2006.

3. Particular challenges faced and solutions adopted

There have been few changes incorporated into the project. One of the main obstacles I had to deal with was the high precipitation of the region (Sarapiqui, Costa Rica), which receives an average of 4500 mm of rain per year! This affected the filming in the beginning, so I was forced to adjust the equipment for functioning under these conditions. Another problem was the localization of the individuals, because this is not an abundant species. However, I have been able to capture and mark 75 individuals so far. Finally, I had to design a device that would allow me to capture the individuals and manipulate them easily, without injuring them or destroying the tent. This device is shown on the attached photograph, and it consists of a horizontal sac of transparent cloth.

4. Changes to your project arising during the year / 18 months

The main challenge I was confronted with was a change in the dates programmed to gather the data. I was forced to stay in Mexico longer than expected and could travel to Costa Rica until the middle of 2005 to start the project. However, I anyways have planned to finish gathering data this year and proceed with the remaining data analysis.

5. Expenditure budget

We did not have problems with the budget requested to Rufford Small Grants. It was sufficient to cover all the travel expenses, food, material, and equipment.

6. Where next?

I am currently taking data in Costa Rica and I hope to finish my Ph.D. in Mexico by the end of 2007. From the moment I made the decision of pursuing a post-graduate degree, I had the clear goal in my mind of returning to my home country, Costa Rica, to get involved again in an institution that allows me to continue my research on mammals. Moreover, I find it of vital importance to form students that work on the collection of data that enables us to make adequate decisions regarding the conservation of tropical forests, so this is something I also plan to get involved with in the following years.

7. How will this take your forward?

I had previous experience with research projects developed in the Brazilian Amazon, Mexico and Costa Rica, but this project has undoubtedly directed me to build my knowledge on behavioral ecology, a field of study that is seldom addressed with bats. For this reason, the feeling of conducting a project with a novel approach, which can aid in the better understanding of the biology of several species is very gratifying. As a product of this effort, I have projected the publication of 3 scientific articles on internationally reviewed journals; however, I also expect this information to help us generate material for environmental education within our program with children of rural areas of Costa Rica.

This challenge has definitely made me ratify that this is what I like to do, and the products of this study, including my doctorate degree, will promote my establishment as a researcher, both

Seeing bats with a mirror.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