Wing Damage in Three Nectar-feeding Bat Species (Glossophaginae) of Lower Montane Wet Forest in Costa Rica

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ABSTRACT
Little is known about tropical bats and the damage that collects on their wing membranes over time. Likewise, it is not known whether species or gender differ in the number of scars and tears on wings. This study analyzed the wing damage of three nectar-feeding bats and found that while overall wing damage was not significantly different between gender and species, specific areas of the wing membrane were statistically different. Females generally had higher rates of wing damage to the dactylopatagium major than males (two-way ANOVA, $F = 4.21$, $p = 0.04$). Another significant difference involved pregnancy; pregnant females had a higher average number of scars on the plagiopatagium than non-pregnant females (two-way ANOVA, $F = 4.21$, $p = 0.05$). As a result of this study, it has become apparent that further research is needed to understand why and how these significant differences occur.

RESUMEN
No hay mucha información sobre los murciélagos tropicales y el daño en la membrana de sus alas con el tiempo. Además, no hay mucha información sobre las diferencias en el daño del ala entre las especies y el sexo. Esta investigación analizó el daño del ala, las cicatrices y los desgarros, de tres especies de murciélagos que se alimentan de polen y néctar. El daño del ala total no tuvo una diferencia significativa entre species y el sexo, pero partes específicas de la membrana del ala tuvieron diferencias estadísticas. Generalmente, las hembras tuvieron más daños en el quiropatagio que los machos (ANOVA de dos vías, $F = 4.21$, $p = 0.04$). Otra diferencia incluyó el embarazo; las hembras embarazadas tuvieron más daños en el plagiopatagio que las hembras que no estaban embarazadas (ANOVA de dos vías, $F = 4.21$, $p = 0.05$). Como consecuencia de esta investigación, es obvio que más investigaciones son necesarias para entender como y por qué estas diferencias significativas occurieron.

INTRODUCTION
In response to the high-energy solar input and consequent resources in the tropics, a unique nectar-feeding guild of bats has evolved. All flower-visiting bats are members of the subfamily Glossophaginae, which translates from Greek to mean “those that feed with their tongues” (Wainwright 2007). Indeed, the nectar-feeding bats have long, extensible tongues with bristles on the tip that help to extract nectar. Another defining characteristic of Glossophaginae species are short but wide wings for hovering (Wainwright 2007).

While other nectar-feeders, such as birds, utilize feathers for flight, the bat wing is something entirely different. To give structure to the wing membrane, known as the patagium, the forelimb and fingers are extremely elongated (Altringham 1996). The thumb is a claw that can be used to hold on to surroundings or a small piece of food. The membrane is constructed of muscle, nerves, and blood vessels sandwiched between two layers of skin (Llorar and Schmidt-French 1998). The blood vessels in the membrane not only transport oxygen, but assist with thermoregulation. A bat can dissipate heat through its wings and also can completely shut off blood flow to the wings via shunts in the blood vessels (Llorar and Schmidt-French 1998).

Without flight, a bat cannot feed and hence wing damage is a sizeable threat to all members in the Order Chiroptera. Glossophaginae bats face multiple dangers to their wing health including predation, cluttered and hazardous surroundings, man-made structures, and even their age. Bats in the tropics face predation from a number of raptors, including the Bat Falcon (*falco rufigularis*), the Barn Owl (*Tyto alba*), and the Great Potoo (*Nyctibius grandis*) (Chacón-Madrigal and Barrantes 2004). Nectar-feeding bats have somewhat poor echolocation abilities, due to their small noseleaves and ears, and thus cannot detect sharp objects, such as a plant's thorns, very well (Llorar and Schmidt-French 1998 and R. LaVal, 2008, pers. comm). Bats also have high rates of accidents with barbed-wire fences. The effects of age also can have an impact on wing damage. Juveniles are amateurs at flight and as such are very clumsy and thus more prone to accidents (Gelli et al. 2004). The old and pregnant are can be very awkward in flight as well (R. LaVal, 2008, pers. comm).

With such risks as predation and thorny collisions, some extant of wing damage is inevitable. In most cases, the damage to the wing membrane is a small puncture wound and can take between six to eight weeks to heal (Llorar and Schmidt-French 1998). If the hole is small, the bats can still fly and feed, and given time the scar will disappear completely (R. LaVal, 2008, pers. comm.). However, holes too large will ground a bat and it is likely to starve to death. Tears, especially to the outer edges of the wing membrane, can drastically affect flight and may be irreparable. Even if large holes and tears heal, the amount of scarring left behind can have long-term effects on the bat's aerodynamics during flight.

The purpose of this study is to examine the wing damage in a sample of bats in the nectar-feeding guild. The aim of this study is to identify relationships between the amount of wing damage, species, and gender. Wing damage is defined as any visible scars, punctures, and tears. The hypothesis of this study assumes that the factors of gender and species have an affect on an individual's wing damage. I predict that amount of damage to the wing will be the same for all Glossophaginae species but different for male and females. The species will have no significant difference in wing damage because they lead such similar lives (e.g. foraging behavior and social structures). Yet, a difference between the sexes is expected because females can have differing diets from males and the added weight of pregnancy may alter their ability to avoid predation and hazardous objects. One study focusing of the reproduction of a specific Glossophaginae species, *Glossophaga commissarisi*, noted that females ate a far greater amount of insects than males (Tschapka 2005). The differences in foraging between males and females could put the females at a higher risk of wing damage because the females are chasing after their food.

Methods

STUDY SITES

This study was conducted in a hummingbird garden in Selvatura Park in Monteverde, Costa Rica, for six nights between July 24th and July 31st, 2008. Starting at approximately 6:20 p.m. mist nets were erected and remained open until 9:00 p.m. Usually, a 12 m long mist net was used, although twice a 5 m mist net was also set up. Every twenty minutes from the time the nets were up, I would inspect the nets and collect the individual bats in cloth bags. In an attempt to attract more bats near during the last three nights, I filled the birdfeeders with sugar water. The position of the nets also changed every two nights so that bats would not learn to avoid them.

Once the bats were caught, their wings were promptly inspected. By placing a flashlight underneath the wing, I was able to count the scars and current punctures in five parts of the wing membrane – the propatagium, plagiopatagium, dactylopatagium major, dactylopatagium medius, and the dactylopatagium minor (fig. 1). A scar is identifiable under the light because it appears as a pinkish discoloration, usually with a somewhat circular shape although some more linear tear scars were found. To ensure that a bat was not recorded twice, a small chunk of hair was removed from their backs. Gender and species was recorded and a note was made if a female was visibly pregnant. In order to test for possible differences in wing damage and gender and species, as well as between pregnant and non-pregnant females, two-way ANOVA tests were used.

RESULTS

In total, sixty-nine bats were mist-netted. The population was composed of three species of the nectar-feeding guild: *Anoura geoffroyi* (n = 33), *Anoura cultrata* (n = 13), and *Glossophaga commissarisi* (n = 23). The *A. geoffroyi* sample had twelve males and twenty females, the *A. cultrata* sample had four males and nine females, and the *G. commissarisi* sample had fifteen males and nine females. The *A. geoffroyi* and *A. cultrata* sample had a combination of thirteen visibly pregnant females (*A. geoffroyi* n = 9, *A. cultrata* n = 4). No pregnant females were recorded for *G. commissarisi*.

Fourteen two-way ANOVA tests were run and three of them had significant results (table 1). Although there was no difference in the number of total scars between gender and species, a specific part of the membrane did have significant differences. The dactylopatagium major data showed significant differences in gender and gender x species effects. From the corresponding graphs (figures 2 and 3) it can be generalized that females have a higher number of scars on their dactylopatagium majors and overall *A. cultrata* females had the highest number of scars on the dactylopatagium major. The last three tests reveal significant differences concerning the pregnancy status effect. It was discovered that non-pregnant females had higher averages of scars on the propatagium than pregnant females (figure 4). However, it was the pregnant females that had the higher averages of scars on plagiopatagium (figure 5). Lastly, a significant difference was found when the effect of pregnancy x species was tested; non-pregnant *A. cultrata* females had the highest average of scars on the propatagium (figure 6).

DISCUSSION

The results of this study had a combination of data that both agreed and disagreed with the predictions. The first prediction, that wing damage would not differ among the species, was supported. The second prediction anticipated a significant difference between wing damage for males and females, and specifically that females would have higher wing damage. While this was not supported from evidence on overall wing damage, females had a significantly higher average number of scars on the dactylopatagium major.

There are a number of plausible reasons why the average number of scars on the dactylopatagium major was higher for females than males. The first involves the differences in lifestyles. Females hunt for insects more than males and that may present more hazards than simply foraging for flowers and fruits. Most bat species live in colonies, but the size and sex composition of these colonies varies between breeding seasons. For example, *A. geoffroyi* individuals reside either in reproductive or maternity colonies, depending on the time of year. In the reproductive colony many males are present, but after awhile they migrate and leave the females and their young in a maternity colony (Galindo et al. 2000). Maternity colonies consist of many individuals packed tightly together. Perhaps some scars are caused accidentally, if one bat scratches another as it attempts to move through the mass of the colony. When mothers with pups fly, the small pups cling to the chest of their mothers; perhaps pups scratch or puncture the inside wing of its mother when moving. However that would imply that the pregnant mothers analyzed in this study had previously been mothers, a fact that the study could not determine. Lastly, scars may arise if bats are physically aggressive to fellow colony members (R. LaVal, pers. comm.), which few biologists have ever observed. Only one or two species of bats have been observed attacking other their own colony members and nectar-feeding bats were not one of them.

The effect of pregnancy status revealed that the average number of scars on the propatagium was higher for non-pregnant females, while the average number of scars on the plagiopatagium was higher for pregnant females. This fact is difficult to explain; not enough is known about bat behavior to account for it. Age should be taken into account in this situation. This study did not record the ages of the studied bats and perhaps pregnant females have more wing damage because they are simply older than the non-pregnant, supposedly juvenile females. I have a small theory that could explain why the not pregnant females higher averages of wing damage to the propatagium. If we assume that they are indeed younger, perhaps they have more damage on the propatagium because they are inexperienced flyers and do not yet comprehend the consequences of damage to this specific part of the wing membrane. The propatagium is part of the leading edge wing flap and enough damage could drastically alter the way the air passes above and under the wing during flight (Altringham 1996). As a soon to be mother and supposedly older female, the pregnant bats may take more precautions to ensure nothing alters their aerodynamic in flight and thus jeopardizes the survival of their pups.

As a consequence of this study, a number of new questions have been unearthed. Results of wing damage lead to questions about where the scars originate. Observational studies on this are sorely needed. Furthermore, if females tend to have a higher average number of wing scars, does that correlate with higher mortality? How does the wing damage of nectar-feeding bats compare with fruit-feeding and insect-feeding bat species?

Does the area of the membrane section relate to the number of scars present? This study has merely hinted at the intricate web of interactions bats participate in and the resulting wing damage that can be obtained.

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LITERATURE CITED

Altringham, J.D. 1996. Bats: Biology and Behaviour. Oxford University Press Inc. New York, New York. pp. 63.

Chacón-Madrigal, E. and Gilbert Barrantes. 2004. Blue Crowned Motmot (*Momotus momota*) predation on a long-tongued bat (Glossophaginae). Wilson Bulletin 116: 108-110.

Galindo, C.G., Campillo, A.C., Méndez, A. S., and J. R. Pulido. 2000. Reproductive events and social organization in a colony of Anoura geoffroyi (Chiroptera: Phyllostomidae) form a temperate Mexican cave. Acta Zoo. Mex. 80: 51-68

Gelli, D., Vernier, E., and S. Romagnoli. 2004. Juvenile pathologies in European insectivorous bats. Bat Research News 45: 111.

LaVal, R.K. and B. Rodríguez-H. 2002. Murciélagos de Costa Rica. Instituto Nacional de Biodiversidad. Santo Domingo de Heredia, Costa Rica. pp. 134-157.

Llorar, A. and B. Schmidt-French. 1998. Captive Care and Medical Reference for the Rehabilitation of Insectivorous Bats. Bat World. Mineral Wells, Texas. pp. 115-119.

Tschapka, M. 2005. Reproduction of the bat *Glossophaga commissarisi* (Phyllostomidae: Glossophaginae) in the Costa Rican forest during frugivorous and nectarivorous periods. Biotropica 37: 409-415.

Wainwright, M. 2007. The Mammals of Costa Rica: A Natural Field Guide. Cornell University Press. Ithaca, New York. pp. 106-110.

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are needed to see this picture.

Figure 1. The five parts of the wing membrane analyzed for wing damage in this study. The dactylopatagium brevis was excluded because it was inconspicuous in the majority of the bats studied.

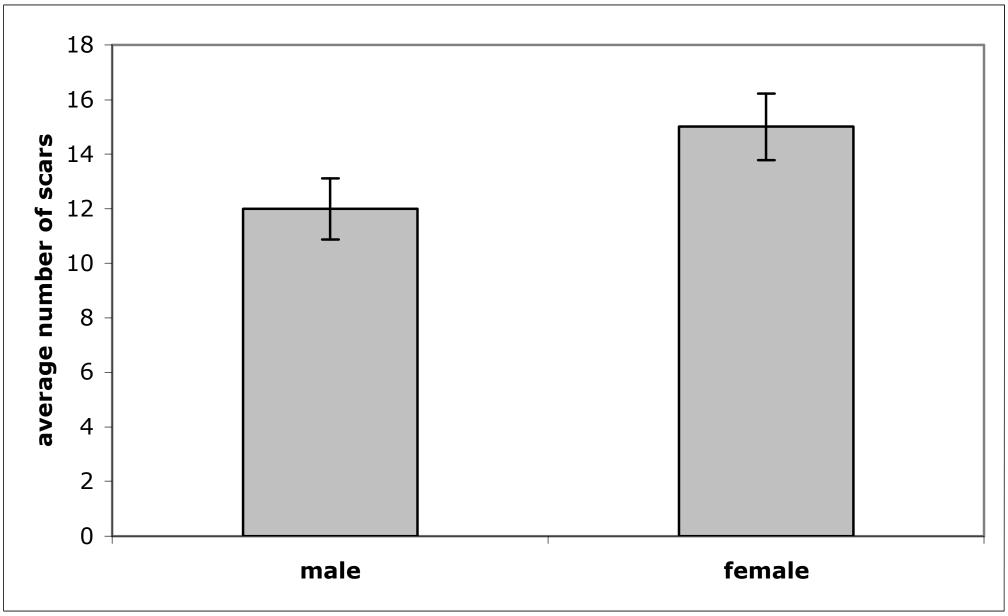

Figure 2. Male vs. female comparison of scars on the dactylopatagium major. The graph above reveals that the significant difference calculated from the two-way ANOVA test describes how, in general, females have more scars on the dactylopatagium than males. Bars represent standard error. This graph includes all three species studied.

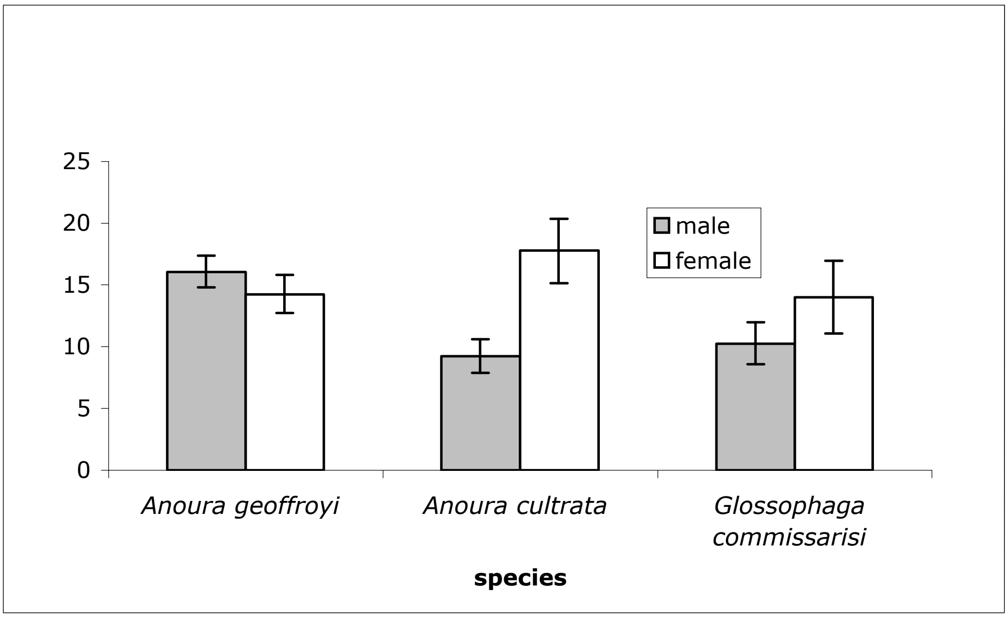

Figure 3. Average number of scars on the dactylopatagium major. This graph represents the gender differences in the scar number of the dactylopatagium major. Also noticeable is the trend in which the females of *A. cultrata* tend to have the highest average of scars on this specific part of the wing membrane. Bars represent standard error.

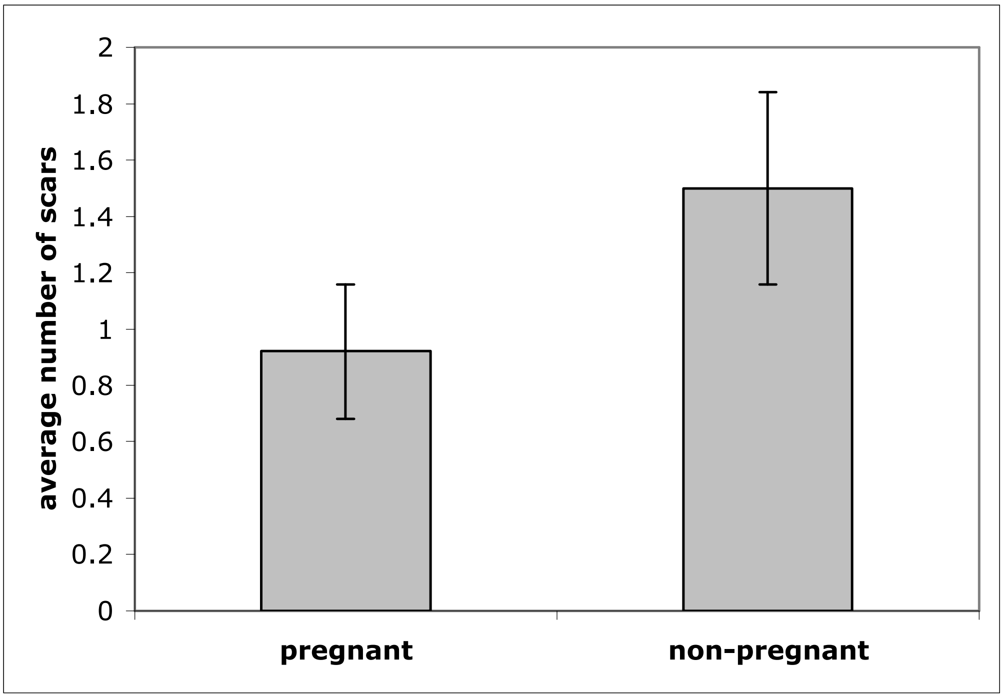

Figure 4. Comparison of scars on the propatagium of pregnant and non-pregnant females. The non-pregnant females generally had a higher number of scars on the propatagium than pregnant females. Data only included females from *A. geoffroyi* and *A. cultrata* because it was not the breeding season for *G. commissarisi*. Bars represent standard error.

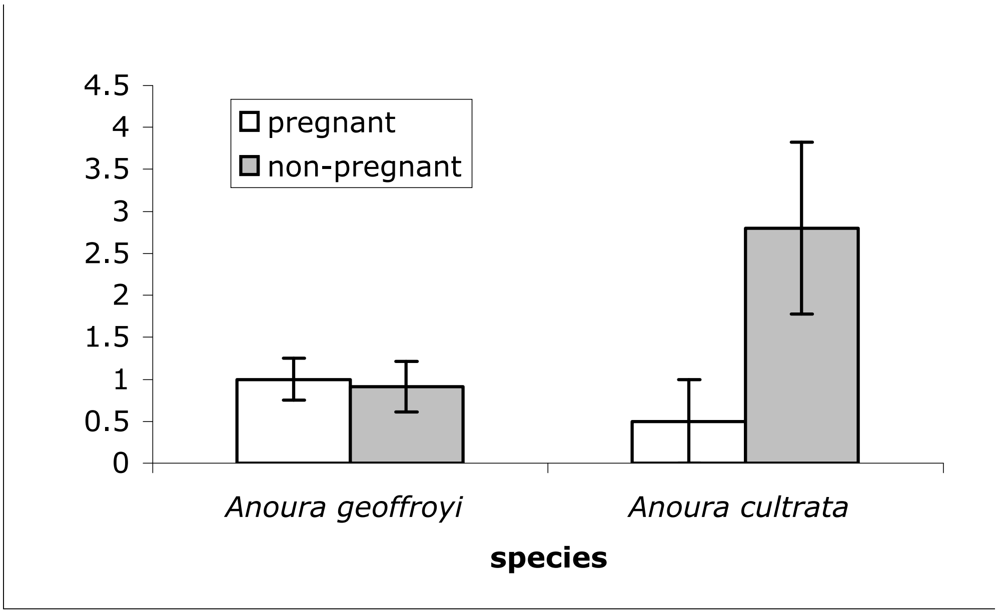

Figure 5. Comparison of scars of propatagiums of pregnant and non-pregnant females between *A. geroffroyi* and *A. cultrata*. This graph demonstrates the significant difference of scarring on the propatagium of pregnant and non-pregnant females but also includes species. Bars represent standard error.

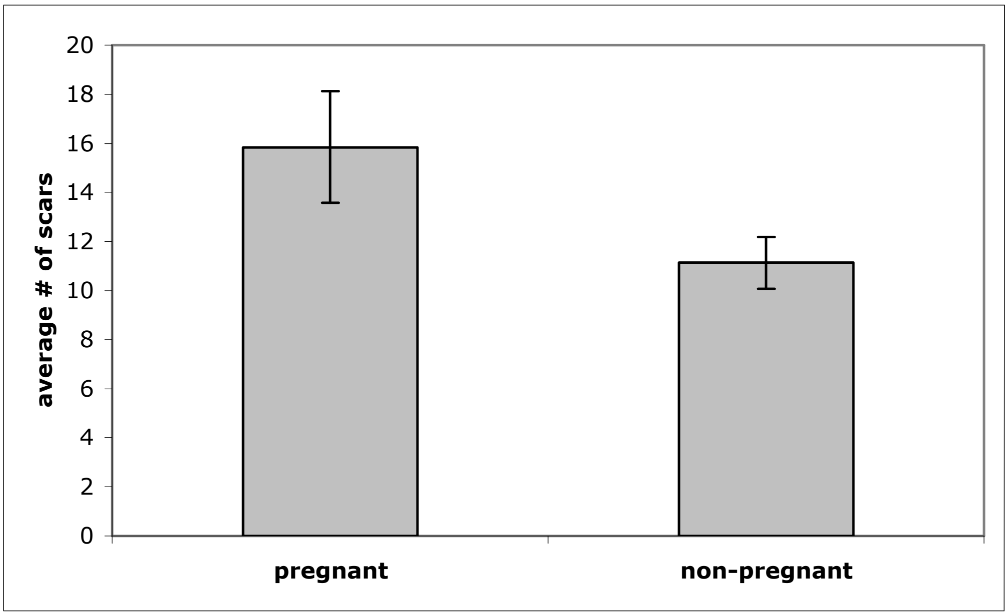

Figure 6. Comparison on scars on the plagiopatagium of pregnant and non-pregnant females. In general, pregnant females had the higher average number of scars. Bars represent standard error.

Table 1.The two-way ANOVA results for the five tests with significant results. Pregnancy status was based on whether or not the female was visibly pregnant or not.

Section of Wing Membrane	Effect	DF	F Ratio	p value
Dactylopagatium major	Gender	1	4.21	0.04
	Gender x Species	2	3.10	0.05
Propatagium	Pregnancy Status	1	4.26	0.05
	Species x Pregnancy Status	1	6.06	0.02
Plagiopatagium	Pregnancy Status	1	4.21	0.05