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Effects of Forest Fragmentation on the Colima Long-nosed Bat (*Musonycteris harrisoni*) Foraging in Tropical Dry Forest of Jalisco, Mexico[1]

ABSTRACT

We determined the effect of forest fragmentation on the nectarivorous Colima long-nosed bat (*Musonycteris harrisoni*) by observing foraging behavior of this species in disturbed and undisturbed forests on the flowers of *Ceiba grandiflora* (Bombacaceae). The study was conducted in the area of the Chamela–Cuixmala Biosphere Reserve in Jalisco, México. *Musonycteris harrisoni* was observed visiting flowers during six nights (88 visits), exclusively in undisturbed forest. This species feeds on the nectar and serves as a pollinator of *C. grandiflora*.

RESUMEN

Determinamos el efecto de la fragmentación del bosque sobre el murciélago trompudo de Harrison (*Musonycteris harrisoni*) observando el comportamiento de forrajeo de este especie en bosque perturbado y no perturbado en las flores de *Ceiba grandiflora* (Bombacaceae). Se realizó el estudio en la región de la Reserva de la Biosfera Chamela–Cuixmala en Jalisco, Mexico. Se observó *M. harrisoni* visitando flores durante seis noches (88 visitas), exclusivamente en bosque no perturbado. Esta especie se alimenta del néctar y sirve como polinizador para *C. grandiflora*.

Key words: *bat foraging; forest fragmentation; indicator species; Mexico;* Musonycteris harrisoni; *nectarivore; pollinator; tropical dry forest.*

Several studies have demonstrated that the composition and abundance of bats are negatively affected by forest fragmentation and perturbation (Fenton *et al.* 1992, Brosset *et al.* 1996, Cosson *et al.* 1999,

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Law *et al.* 1999, Medellín *et al.* 2000, Schulze *et al.* 2000), while others have demonstrated the importance of corridors that facilitate movements between fragments (Estrada *et al.* 1993). Moreover, habitat fragmentation has been identified as one of the primary elements leading to the disruption of pollinators (Kremen & Ricketts 2000), and some authors have reported that fruit set is reduced in disturbed areas, presumably because of reduced pollinator activity (Powell & Powell 1987, Sih & Baltus 1987, Jennersten 1988, Aizen & Feinsinger 1994, Cunningham 2000, Fuchs *et al.* in press). A change in pollinator activity due to forest fragmentation also has been associated with changes in mating patterns of trees, which can negatively affect the number of sires and offspring quality (Quesada *et al.* 2001, Cascante *et al.* 2002, Fuchs *et al.* in press); however, with the exception of one study on the blossom bat (*Syconycteris australis*) in Australia (Law & Lean 1999), there is a general lack of information concerning the effects of forest fragmentation on the foraging ecology of vertebrate pollinators (Kremen & Ricketts 2000). The current study was designed to identify the frequency and time spent foraging by the nectarivorous Colima long-nosed bat or banana bat (*Musonycteris harrisoni*) in disturbed areas and undisturbed forests through observations of their foraging behavior on the flowers of the tree *Ceiba grandiflora* (Bombacaceae).

Musonycteris harrisoni is endemic to the tropical dry forest in west–central Mexico and is restricted to the states of Colima, Guerrero, Jalisco, and Michoacán (Koopman 1993). This species was first described by Schaldach and McLaughlin (1960) 42 years ago. Except for taxonomic, distributional, and morphological descriptions (Winkelman 1962, Goodwin 1969, Jones & Carter 1976, 1979, Ramírez-P. *et al.* 1977, Sánchez 1978, Webster *et al.* 1982, Baker *et al.* 1989, Cifelli 1996), no information exists about the ecology of this species. *Musonycteris harrisoni* is considered a threatened species (Unión Mundial para la Naturaleza 1999), but there is no information on its demography or abundance. Based on anecdotal evidence, this species is thought to consume pollen, nectar, and insects found in banana flowers (Schaldach & McLaughlin 1960, Villa-R. 1966); however, no direct observations of its foraging behavior or diet have been reported. Furthermore, bananas are not native to the Neotropics and are patchily distributed in the region of Colima and Jalisco, occurring only where they are cultivated.

Our study was designed to quantify the effect that forest fragmentation has on the foraging behavior of *M. harrisoni* and to document nectar consumption of this species. Since a few previous studies have shown that pollinators are adversely affected by forest fragmentation (review in Kremen & Ricketts 2000) we hypothesized that the presence and number of *M. harrisoni* visits would be less for flowers found on trees in disturbed habitats than for those found on trees in undisturbed forest.

The study was conducted in the central Pacific coast of Mexico within and surrounding the Chamela–Cuixmala Biosphere Reserve (*ca* 19°30'N, 105°03'W). This 13,200 ha reserve is located between Puerto Vallarta, Jalisco and Manzanillo, Colima (Ceballos & García 1995). The predominant vegetation in this area is tropical dry forest, which is characterized by a rainy season from the middle of June through October and an extended dry season from November through May. Average annual rainfall is 750 mm and the average temperature is 25°C (Bullock 1995). Two main habitats have been described in this area, upland and arroyo forest (Lott *et al.* 1987).

To examine the effects of forest fragmentation on the foraging behavior of *M. harrisoni*, the flowers of *C. grandiflora* (Bombacaceae), which are known to be visited by several nectarivorous bats (Quesada *et al.* 2001, Stoner in press, Stoner *et al.* in press), was used for observation. Foraging behavior was recorded for flowers found on trees in disturbed habitats and flowers on trees in undisturbed forest. A tree was considered to be in a disturbed habitat if it was surrounded by agricultural fields or pastures, was isolated, or had less than three reproductive conspecifics within an area of 100 × 100 m (1 ha), and was separated by more than 2 km from other conspecifics. Trees in disturbed sites were located along Highway 200 between the towns of Careyes and José Maria Morelos. Trees from undisturbed areas consisted of groups of ten or more reproductive individuals per hectare surrounded by undisturbed mature forest and were located within the Chamela–Cuixmala Biosphere Reserve. Four undisturbed populations separated from each other by at least 8 km were sampled in different watersheds within the reserve.

Ceiba grandiflora Rose (Bombacaceae) is a small tree (<12 m and 60 cm DBH [diameter at breast height]) that is only known from the tropical dry forest in the states of Jalisco and Colima, Mexico (Rose 1895). Cream-colored hermaphroditic flowers are borne at the end of branches and anthesis occurs at sunset. Flowers are perfect, actinomorphic, contain 5 petals (9.8–12.2 cm), 1 style (6–7 cm), and 5 anthers (5–6 cm). Each individual tree produces flowers over a prolonged period in the dry season from December through May.

TABLE 1. *Number of trees, flowers, and nights filmed for each habitat condition and number of nights that* M. harrisoni *was observed.*

Condition	Trees	Flowers	Nights filmed	Nights observed	Total visits
Disturbed	15	25	20	0	0
Undisturbed	19	34	30	6	88

Flowers were videotaped three to four nights each week from February through May 2001, using a Sony Digital Handycam DCR-PC 100 camcorder adapted to a Dark Invader Owl Super Gen 2 pocketscope with a laser illuminator (MSE, Inc., St. Charles, Missouri). Videotaping began at sunset before anthesis and continued for 4 hours and 30 minutes. For each flower that was filmed, the following information was collected: (1) number of visits; (2) duration of each visit; (3) frequency of contact by the bats to the flower's stigma or anthers; and (4) the form by which they arrived at the flower (hovering or landing). The number of open flowers on the tree filmed and the number of open flowers in conspecifics within a 1 ha area (100 × 100 m) of the filmed tree also were recorded. Although this may appear to be an impossible task, because the number of open flowers per tree was relatively small (1–10) and flowering occurred during the dry season when more than 80 percent of the species were leafless, it was feasible to obtain this information.

The three bat species observed visiting *C. grandiflora* flowers were distinguished based on their relative size and body proportions in comparison to the length of the flower petals and reproductive parts. *Leptonycteris curasoae* weighs 20–30 g with a forearm measuring 46–57 mm (Nowak 1994) and *Glossophaga soricina* weighs 8–11 g with a forearm measuring 36–38 mm (Alvarez *et al.* 1991). Although *M. harrisoni* is similar in weight to *G. soricina* (12–13 g; the forearm is larger (43–49 mm; KES, pers. obs.). The most important diagnostic characteristic of this rare species is the elongated rostrum, which is more than one-half the total length of the skull and longer than the rostrum of any other related genus except for *Platalina* from South America (Nowak 1994).

In addition to night filming, we also evaluated the abundance of *M. harrisoni* in undisturbed forest using mist nets. Ground-level mist net sampling was conducted 2 days per week, for a total of 100 nights from June 2000 through June 2001, in trails and natural openings within the forest of the Chamela–Cuixmala Biosphere Reserve. Every 15 days, we sampled in designated areas within upland and arroyo forest, and the remaining sampling nights each month were randomly selected to include different areas within the reserve. One 12 m, one 9 m, and one 6 m mist net were opened for four hours beginning at dusk on each sample night. Both nocturnal videotaping and mist net sampling were conducted on nights with little moonlight due to the potential negative effect of moonlight on bat foraging activity (Morrison 1978a, b).

In 50 nights of video recording (225 hours), 25 flowers from 15 trees were filmed in disturbed areas (90 hours) and 34 flowers from 19 trees were filmed in undisturbed forest (135 hours; Table 1). *Musonycteris harrisoni* was observed visiting flowers during 6 nights in three of the four watersheds, from March through May, for a total of 88 floral visitations (Table 2). This rare nectarivorous bat was found to exclusively forage in flowers on trees in undisturbed forest. *Musonycteris harrisoni* was not observed visiting flowers on trees in disturbed areas during the 20 nights of filming. The sympatric nectarivorous species *G. soricina* and *L. curasoae* also were observed visiting the same flowers. On two nights, however, *M. harrisoni* made up more than 50 percent of the visitations (Table 1). No relationship was observed between the number of bat visits and the number of open flowers on the tree or the number of open flowers on conspecific trees within a 1 ha area (Table 1). *Musonycteris harrisoni* arrived at the flower and hovered in front of it while inserting the entire snout to drink nectar. This species was never observed consuming pollen from the anthers. The duration of each flower visit was 0.51 sec ± 0.21 SD (N = 88). In 99 percent of the visits, contact was made with the anthers; in 81 percent, contact was made with the stigma; and in 81 percent, contact was made with the stigma and anther.

During 400 hours of mist netting (1200 net hours), only two *M. harrisoni* were captured, one in upland forest and the other in arroyo forest. One nonreproductive adult female with pollen on its face from the tree *Ipomea* sp. was captured in arroyo forest in February and one nonreproductive adult female with no pollen on its body was captured in upland forest in August.

TABLE 2. *Number of bat visits per night* (i.e., *4 h 30 min of filming beginning at dusk) for each flower that was visited by* Musonycteris harrisoni, *number of visits for other bat species, number of open flowers on the tree observed, and number of open flowers on conspecific trees within a 1 ha area. All flowers that received visits from* M. harrisoni *were located in trees from continuous forest. M. h.* = M. harrisoni*; G. s.* = Glossophaga soricina*; and L. c.* = Leptonycteris curasoae.

Date	Species			F1/tree	F1/ha[a]
	M. h.	G. s.	L. c.		
9 March	23	22	1	4	6
13 March	9	37	0	1	1
16 March	5	4	23	1	3
20 March	46	13	26	5	4
22 March	4	12	18	1	0
18 May	1	3	1	2	0
Total	88	91	69		

[a] Not including open flowers on the filmed tree.

Our study demonstrated for the first time that forest fragmentation negatively affects the foraging behavior of a bat pollinator in the Neotropics. We found that the bat endemic to the tropical dry forest of Mexico, *M. harrisoni*, is limited to forage in undisturbed forest. In contrast, the sympatric nectarivore *G. soricina* has been reported to forage and fly in disturbed areas (Lemke 1984, 1985) and *L. curasoae* is known to migrate latitudinally (Cockrum 1991), presumably passing through and foraging in fragmented landscapes. *Musonycteris harrisoni* apparently differs from these other nectarivorous bats by its being restricted to forage in undisturbed forest.

Our study is the first to describe the feeding activity of *M. harrisoni* under natural conditions. A phylogenetic study of the family Phyllostomidae based on morphological, chromosomal, and biochemical data concluded that *M. harrisoni* is part of the Glossophagini tribe (Baker *et al.* 1989). It has been assumed that this bat is nectarivorous like other species of this taxon. In addition, a comparative study of the mandibular and dental morphology of a sample of New World leaf-nose bats (Phyllostomidae) suggested that the shape of the dental arcade of *M. harrisoni* is comparable to the long, slender snout of nectar-feeding specialists (Cifelli 1996); however, no previous empirical evidence has demonstrated the feeding ecology of *M. harrisoni*. Our data indicate that this species feeds on the nectar and serves as a pollinator of *C. grandiflora*.

Our data from mist netting suggest that *M. harrisoni* is a rare bat (*i.e.,* only two individuals captured in 1200 net hours) in this area; however, more extensive mist netting needs to be conducted to determine if *M. harrisoni* is flying higher than ground level, thus accounting for its very low capture rate in our study. The nectarivorous bat *L. curasoae* is rarely captured in ground-level mist nets at Chamela even when it is quite abundant (Stoner in press). In addition, abundance of *M. harrisoni* should also be evaluated by searching potential roost sites. Since this species is present in the region at least from February through August, coinciding with the period in which the *L. curasoae* population in the Chamela region is lowest (Stoner *et al.* in press), this nectarivore may be an important pollinator for many other species in the tropical dry forest of this region. It has been documented that other nectarivorous bats use more than 20 species of trees and shrubs as nectar resources (and likely serve as pollinators) in the tropical dry forest in the Chamela area (Stoner in press, Stoner *et al.* in press), and it is likely that *M. harrisoni* utilizes many of these species as well.

Although the concept of indicator species (species sensitive to habitat degradation or contamination) has been widely debated (Meffe & Carroll 1994), the fact that *M. harrisoni* is endemic to the area and only found foraging in undisturbed forest suggests that this species may be an appropriate indicator species of the tropical dry forest ecosystem in this region of Mexico. The presence of *M. harrisoni* likely indicates an undisturbed ecosystem; however, the absence of this species does not necessarily indicate a disturbed habitat without extensive sampling (*i.e.,* due to low abundance). Future studies should evaluate nocturnal activity of *M. harrisoni* to determine if foraging activity of this species occurs later at night, thus accounting for the low abundance observed in the nocturnal filming and mist netting (which occurred for 4 hours and 30 minutes after sunset).

The tropical dry forest in Jalisco, Mexico has been identified as a critical geographical region for the conservation of biodiversity based largely on number of endemic species and species richness (Ceballos & García 1995); however, few empirical ecological studies have provided evidence that demonstrates species interactions. To develop a conservation strategy for the protection of dry forests in Mexico, it is important to identify and understand species interactions that contribute to the maintenance of this endangered ecosystem. Our study is the first step in identifying the role of *M. harrisoni* as a pollinator in this endangered ecosystem.

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