**Therya Advance Access published November 24, 2023**

*THERYA, 2024, Vol. 15(X):XX-XX* DOI:10.12933/therya-24-5003 ISSN 2007-3364

# Group structure and diurnal behavior in a large colony of *Mimon cozumelae* in Yucatán, México

Kinari Romo-Hernández[1], Jorge Ortega[2], Beatriz Bolívar-Cimé[3], and M. Cristina MacSwiney G.[1]*

[1] Centro de Investigaciones Tropicales, Universidad Veracruzana, Xalapa. Veracruz, México. Email: cmacswiney@uv.mx (MCMG) kinnromo2@gmail.com (KR-H).

[2] Departamento de Zoología, Escuela Nacional de Ciencias Biológicas, Instituto Politécnico Nacional. CDMX, México. Email: artibeus2@aol.com (JO).

[3] Instituto de Investigaciones Forestales, Universidad Veracruzana, Xalapa. Veracruz, México. Email: bbolivar@uv.mx (BB-C).

* Corresponding author: https://orcid.org/0000-0002-9007-4622

The Phyllostominae is a Neotropical subfamily of bats that include species considered sensitive to habitat disturbance, but that are the poorly known. The Cozumelan Golden Bat, *Mimon cozumelae*, is a rare phyllostomine that inhabits forests and semi-deciduous tropical forests from central México to western Colombia. This study describes for the first time, the social organization and diurnal behavior of *M. cozumelae* to provide basic information about the social relationships of this elusive species. We captured and marked individuals inhabiting a cave in Yucatán, México in 2020 and 2021. Observations were carried out filming its behavior inside the cave in two seasons, breeding (March-July) and non-breeding (August-January). We constructed an ethogram and classified the observed behaviors into states and events in each season. A total of 103 individuals (47 females and 56 males) of *M. cozumelae* were captured. The sex ratio was not different from 1:1. The size of the groups did not vary throughout the seasons. The most frequent behaviors performed by *M. cozumelae* were resting, followed by flight, self-grooming, wing extension, and social grooming. The group composition most common in both seasons was multi-male, ruling out the typical formation of harems in the breeding season for this species. Copulation and maternal grooming were recorded for the first time in the reproductive season. This bat exhibits social grooming, which in theoretical terms could categorize it as a species that forms societies. This study contributes updated information regarding group size and composition, and especially diurnal behavior of *M. cozumelae*. It is suggested that this work serves as a baseline to investigate its social systems (behavioral ecology) in depth, and when carrying out conservation plans for this species.

Los Phyllostominae son una subfamilia neotropical de murciélagos que incluyen especies consideradas como sensibles a la alteración del hábitat, pero que son las pobremente conocidas. *Mimon cozumelae*, es un raro filostomino que habita en bosques y selvas tropicales semideciduos desde el centro de México hasta el oeste de Colombia. Este estudio describe por primera vez la organización social y el comportamiento diurno de *M. cozumelae* para proporcionar información básica sobre las relaciones sociales de esta especie. Capturamos y marcamos individuos que perchan una cueva en Yucatán, México en 2020 y 2021. Se realizaron observaciones filmando su comportamiento dentro de la cueva en dos temporadas, reproductiva (marzo-julio) y no reproductiva (agosto-enero). Se construyó un etograma y se clasificaron los comportamientos observados en estados y eventos en cada estación. Se capturaron un total de 103 individuos (47 hembras y 56 machos) de *M. cozumelae*. La proporción de sexos no fue diferente de 1:1. El tamaño de los grupos no varió a lo largo de las estaciones. Los comportamientos más frecuentes registrados para *M. cozumelae* fueron de descanso, seguido del vuelo, el aseo personal, la extensión de alas y el aseo social. La composición de grupo más común en ambas épocas fue la de multimachos, descartando la típica formación de harenes en época reproductiva para esta especie. La cópula y el aseo materno se registraron por primera vez en la época reproductiva. Este murciélago exhibe acicalamiento social, lo que en términos teóricos podría categorizarlo como una especie formadora de sociedades. Este estudio aporta información actualizada en cuanto a la descripción del tamaño y composición de los grupos y en especial, del comportamiento diurno de *M. cozumelae*. Se sugiere que este trabajo sirva como línea base para investigar a profundidad sobre sus sistemas sociales (ecología del comportamiento), y realizar planes de conservación para esta especie.

***Keywords:*** Cave-roosting; diurnal activities; group composition; Phyllostominae; Yucatán Peninsula.

© 2024 Asociación Mexicana de Mastozoología, www.mastozoologiamexicana.org

## Introduction

Bats are considered mammals with a high degree of sociability because they form large groups of hundreds to millions of individuals. In addition, some species of bats present social interactions considered cooperative with a social component (Wilkinson 1984; Ripperger *et al.* 2019). All behaviors carried out by bats in their daily activity, or during their life cycle, are important for the survival and reproduction of individuals, but those behaviors that imply some type of interaction between the members of a group can sometimes be more relevant, since they can reveal temporal patterns that describe the social structure of the species (Kerth *et al.* 2003). Social behavior includes the interaction of two or more individuals, and these associations can form groups that allow them to obtain benefits such as avoiding predation, preventing the spread of diseases by parasites, or obtaining energy benefits due to social thermoregulation (Kerth 2008; Cárdenas-Canales *et al.* 2022).

The groups of individuals that display social bonds and engage in cooperative behaviors and can recognize each other individually or as members of the same group, are known as bat societies (Kerth 2008). Some species that have been classified under these parameters and considered as bat societies are: *Eptesicus fuscus*, *Noctilio leporinus*, and *Rhynchonycteris naso*, belonging to different taxonomic families but showing similar social interactions (Bradbury and Vehrencamp 1977; Brooke 1997; Willis and Brigham 2004; Kerth 2008). Kerth (2008), added to this classification a sublevel within societies, which he called complex societies, but which briefly involves "complex interactions" within roosting sites. Some species of tropical bats that have been classified as complex societies are *Phyllostomus hastatus*, *Trachops cirrhosus*, and *Desmodus rotundus,* due to their social bonds and interactions displayed in their roosting sites (McCracken and Bradbury 1981; Wilkinson 1988; Wilkinson and Boughman 1998; Flores *et al.* 2020; Razik *et al.* 2022). Another aspect to consider is that these species live in roosting refuges and can change their social structure not only over time but also throughout the day (Chaverri and Kunz 2010; Wilkinson *et al.* 2019). Daytime roosts are one of the most important places for the performance of individual and social behaviors, and several reports suggest that most species interact and communicate with their conspecifics at roosting sites, presenting several complex behavioral interactions (Kerth *et al.* 2003; Chaverri and Kunz 2006; Ortega and Maldonado 2006; Prat *et al.* 2016; Carter 2021; Crisp *et al.* 2021).

Tropical bats of the family Phyllostomidae often form groups throughout the year, and hence are considered to be more stable groups, while sociability in temperate zone species is restricted to certain times of the year (*i. e.,* hibernation-- Bradbury and Vehrencamp 1977; Brooke 1997; McCracken and Wilkinson 2000; Kerth *et al.* 2011). Studies of sociability in bats of the subfamily Phyllostominae have been addressed to a lesser extent compared to other subfamilies of these tropical bats, mainly due to the fact that the members of this subfamily tend to form colonies of very few individuals, in addition to which their abundance in their tropical habitat is lower than that of other phyllostomids. The Cozumelan Golden Bat (*Mimon cozumelae*) it is considered rare and scarce throughout its distribution, with few reports regarding its roosting sites (Ortega and Arita 1997). Bats of this species roost principally in caves, mines, culverts, and hollow logs (Tuttle 1976), inhabiting a great variety of tropical habitats including disturbed and undisturbed sites (Fenton *et al.* 1992). The few reports on group size in *M. cozumelae* showed that the maximum number of individuals recorded to date is 15 to 20 bats, sometimes sharing the refuge with *Trachops cirrhosus* and segregating their refuge roosting sites (LaVal 1977). *M. cozumelae* is considered an opportunistic carnivorous species since it occasionally includes vertebrates in its diet, but mainly feeds on invertebrates (Ortega and Arita 1997; Gual Suárez and Medellín 2021).

We recorded data from a cave located in southeast México, in the state of Yucatán, with approximately 90 individuals of *M. cozumelae* in a single refuge, being the largest colony recorded to date. Our main goal was to investigate the social organization of this group and the behavior of *M. cozumelae* in the wild, as well as carrying out behavioral observations to provide basic information about the social relationships of this elusive species.

## Materials and methods

Our study was conducted in January 2020 and from January to June 2021, recording data during four days on each visit. In January 2020 we located the cave, established all the necessary logistics for the work, and obtained behavioral data but we could not sample during the following months due to COVID-19 restrictions. The site is located in the state of Yucatán, México, situated in the municipality of Uayma (20.7003° N, -88.2918° W), in the northeast part of the state. The cave is located within the Hacienda X'conzuk, surrounded by tropical deciduous forest and patchy areas of cropland. The site was selected during our previous visit due the continuous presence of a large colony of the Cozumelan Golden Bat (*Mimon cozumelae*).

The cave has three small simple chambers, with two small but accessible entrances. The largest chamber harbored a large colony of *Mimon cozumelae* (*ca.* 90 individuals) and included scattered individuals of *Diphylla ecaudata* (*ca.* 10 individuals) that temporarily use the roost and one or two individuals of *Micronycteris microtis*. Dimensions of the chamber were 5.70 m by 3.65 m, with an average height of 2.5 m. Individuals of the tropical porcupine (*Sphiggurus mexicanus*) and a big-eared climbing rat (*Ototylomys phyllotis*) were occasionally detected within the cave.

Captures were made in the first two visits by placing two mist nets of 3 and 6 m long, located at the entrance of the second and third chambers of the cave, in order to capture the largest number of individuals. Hand nets were also used inside the cave to capture individuals. The captured bats were kept in individual cloth bags for later processing. They were weighed, measured, sexed and their reproductive status was determined. Individuals were considered adults when presenting ossified epiphyses and subadults when having cartilaginous joints (Brunet-Rossinni and Wilkinson 2009). We corroborated this characterization by measuring body mass using a spring scale with a precision of 0.1 g, and measuring the length of the forearm with an electronic caliper with a precision of 0.1 mm. Reproductive conditions were scrotal or abdominal testes for adult males and pregnant, lactating or without signs for adult females. The reproductive or breeding season was defined as extending from April to June when > 80 % of adult females had inflamed vulva or were pregnant or lactating (Figure 1). From January to March, most adult females showed no signs of reproductive condition.

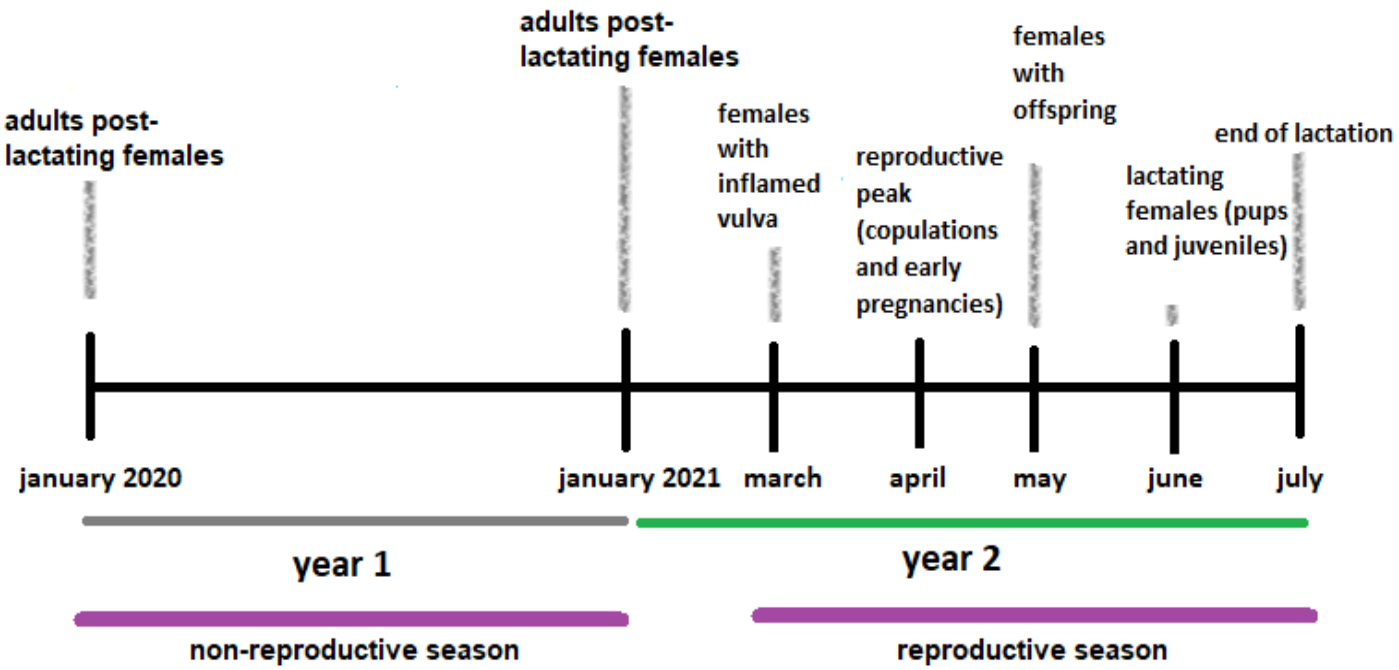


**Figure 1.** Reproductive condition of females of *Mimon cozumelae* in the Uayma refuge, during the reproductive and non-reproductive season during the two-year study. Females were captured to determine the reproductive condition. In 2020 we did not sample bats after January due to COVID-19 restrictions.

Bats were marked with a metallic ring on the forearm (Nacional de Identificación, S. A. de C. V.). The metal ring was placed on the left forearm for females and the right forearm for males, which allowed us to distinguish the sex of individuals visually and in the recordings. The handling of the individuals was carried out in accordance with the guide of the American Society of Mammalogists for the use of wild mammals in research (Sikes *et al.* 2016). This project used collection permits issued by SEMARNAT (Secretaría del Medio Ambiente y Recursos Naturales, SGPA/DGVS/9032/19) to MCMG.

For the recordings, a 4K AX33 video camera was used in Night Shot mode (Sony Inc. Japan). A fast-scanning method was implemented with the camera, which allowed us a panel exploration of the main chamber where the *M. cozumelae* individuals were found, with an intrusion into the system lasting no more than five minutes to not disturb the structure of the groups (Martin and Bateson 2007). This procedure was done twice a day (6:00 and 16:00). The scan shots were later visualized in the laboratory and with them an estimate of the group sizes and their composition could be obtained. To consider the size of the group, the number of animals observed during the panning of the fast-scanning recordings was calculated. The composition of the group was tallied according with the number of animals that had the metallic ring on the left forearm and for those that had it on the right forearm.

Once the fast-scanning recordings were completed, the camera was placed inside the cave, focusing on as many bats as possible in an open panel position. The location of the camera was kept fixed for four hours to make the focal recordings. The first 15 minutes of the recording were not measured in the results because the bats changed positions due to the cave intrusion. We established this period of time since the subsequent analysis of the focal recordings showed that the bats stop moving and stayed in stable positions after 15 minutes (Olson and Barclay 2013). Focal recordings were filmed during four hours of observation per day (6:00 to 8:00 and 16:00 to 18:00 h). These times were selected since they are critical points in which there is the possibility of greater activity in bats (two hours after returning to the shelter and two hours before the emergence).

The *ad libitum* method was used since opportunistic observations are recorded without restrictions in the measurement time in which the different activities were carried out by one or several individuals (Martin and Bateson 2007). This method is useful for the first behavioral description in a new system for the observer, or at the stage of preliminary observations. The disadvantages of this sampling are that behaviors that are easier to detect are generally recorded and others that could be included in a systematic sample are underestimated (Altmann 1974). *Ad libitum* observations were made in real time by observing them with the help of a computer (MacBook Pro, Apple). The observer was positioned with the monitoring equipment near the entrance, between the second and third chambers of the cave. For the monitoring equipment, an HDMI cable with an extension of approximately 10 meters was used, connected to the video camera (4K AX33 in Night Shot mode, Sony Inc.). The camera was placed on a tripod, with a video translator (Blackmagic Design UltraStudio Mini Recorder-Thunderbolt), and a Thunderbolt cable for computer input,

enabling the observer to mitigate the disturbance caused by being in their roost.

For the construction of the ethogram, the behavioral units defined by Muñoz-Romo (2006) were used as a reference, combined with other studies on behavior in bats (Muñoz-Romo *et al.* 2008). The observed behaviors were classified into states and events (Table 1). We measured the frequencies of the behaviors classified as events, and resting was the only state that was measured as such. Subsequently, the frequencies of each of the behaviors were recorded for each observation for each season. For non-breeding season, we analyzed recordings carried out in January 2020 and January 2021, whereas for breeding season we analyzed recordings from March to June 2021. Absolute and relative frequencies of the behaviors were obtained for each season and for sex of the performer. All analyses and graphs were carried out in RStudio version 4.1.1 and in GraphPad 9.0.1. To analyze the results of the sex ratio of bats, a binomial test was performed. To obtain the behavior accumulation curve, the number of behaviors that were observed for each field trip were considered, then they were graphed to obtain the accumulation curve. A generalized linear model was performed to analyze the behaviors that bats performed between seasons and sexes of the performer and if these behaviors differed in frequency. Normality tests (Shapiro-Wilk) were applied to all data. Mann-Whitney U tests were performed to explore statistically significant behavioral differences: 1) between sexes. 2) Between the two seasons. 3) Comparing the behavioral activities carried out after arrival of the forager, when the individual had expenditure energy, against the activities carried out in a brief period of time prior to their nocturnal departure, after resting and sleeping all day.

## Results

A total of 24 days of recordings were made in the study site in the period from January 2020 to June 2021, of which 15 days were in the non-breeding season and 13 days in the breeding season. A total of 103 individuals (47 females and 56 males) of *M. cozumelae* were captured. A total of 61 (59.23%) of the individuals were captured in the first visit (January 2020), and the rest in the January 2021. The sex ratio was not different from 1:1 ($n = 103$, $x^2 = 0.62$, $P = > 0.05$). A total of 59 individuals were marked with metal rings and were considered our study subjects. During the January 2020 visit, we noticed that metal rings on juveniles harm them, so we stopped tagging individuals in this age group.

We recorded 30 observations with the fast-scanning method, each with a duration of five minutes throughout all sampling days between the two seasons. Twelve observations were made for the breeding season and for the non-breeding season 18 observations were recorded. The size of the groups did not vary throughout the seasons, despite the fact that individuals moved during our observations. No statistically significant differences were obtained between the average size of groups observed between seasons (breeding season 1.66 ± 1.0 groups *vs.* non-breeding season 1.85 ± 1.20; $P = 0.96$, Mann-Whitney $U = 4$). However, it was observed that the highest average group size was with the presence of offspring (31.75 ± 15.77), in addition to the fact that movements between sites were reduced exponentially, leaving more structured stable groups. Within groups we observed a greater number of males than females in both the breeding and non-breeding seasons. On average, in the breeding season there were 1.67 ± 1.18 females *vs.* 3.5 ± 2.26 males. In the non-breeding season, there were 1.87 ± 0.59 females *vs.* 2.75 ± 1.87 males. Individuals roosting alone were occasionally observed, but these events were rare because most of the bats were observed in large clusters.

A total of 79.4 hours of filming was obtained. Of the total number of hours, 55 were recorded with the *ad libitum* method and the rest were reviewed by the focal method. The 79.4 hours included the breeding season (40.4 hours) and the non-breeding season (39 hours). A total of nine behavioral activities were identified within our *ad libitum* observations. The most frequent behaviors performed by

**Table 1.** Definition of the behavioral activities most frequently observed in *Mimon cozumelae* with the *ad libitum* method.

| Behavior | Definition |
|---|---|
| Self-grooming | Grooming was recorded when an individual passed their tongue over different areas of their own body. This behavior was recorded each time an individual licked its legs up to the abdomen with short, rapid, ascending movements on the same point once or several times. Self-grooming behavior was also recorded when the individual groomed their back, head, and wings. |
| Social grooming | These behaviors can be performed between individuals of the same sex, different sex, or from an adult to a child (maternal grooming), performing the same behavior patterns described in self-grooming. |
| Flight | The individual spreads its wings, freeing the hind legs from the wall and moves in the air by repeatedly flapping its wings, the individual that ends the flight approaches to the wall and holds on to perch with hind legs (hanging). |
| Wing Extension | A roosting individual extends one or both wings in a stretching manner. |
| Resting | This behavior is recorded when an individual remains motionless on the perch site with eyes open or closed. |
| Vocalization | It is recorded when paused and continuous guttural sounds are heard, but are audible on the recording. |
| Alert | It is described when the individual is perched but moving his head from side to side in observation of what is happening inside the cave. |
| Aggression | When an individual approaches another and performs flapping behaviors, bites and short chases. |
| Copulation | Copulation behavior was recorded when the adult male mounted one female and mated for several seconds. |

*M. cozumelae* was resting, followed by flight, self-grooming, wing extension, and social grooming. The least frequent behaviors were being alert, vocalizations, aggression, and copulation; these four were not considered in our analysis due to their low frequency of occurrence. For the generalized linear model, the most frequent behaviors were considered. The analysis showed that the behaviors were statistically different between seasons, between behaviors, and in the interaction of the season (breeding versus non-breeding) with the type of behavior (behaviors $P < 0.001$, season $P < 0.001$, behavior-season $P < 0.001$). To obtain the frequencies of the behaviors of males and females in the breeding and non-breeding season, only marked individuals were considered. The behaviors with the highest frequencies were included in the analysis. The behaviors were significantly different among themselves ($P < 0.001$), between males and females ($P < 0.001$), but not in the interaction of behaviors and sex ($P < 0.001$).

We performed paired comparisons among the most frequent behaviors between sexes and breeding/non-breeding seasons (Figure 2a and 2b). Social grooming was not statistically significant between males and females ($P = 0.98$ – Figure 3), and was also similar when comparing the two seasons ($P = 0.39$). It was possible to document 22 observations of social grooming between pairs of individuals, the most frequent of which was performed by mothers towards their offspring, lasting longer than the same behavior observed among adults. Self-grooming performed by males and females was not significantly different ($P = 0.9403$). However, self-grooming was significantly lower during the reproductive season compared with the non-breeding season ($P = 0.0023$). Resting time was similar between both sexes ($P = 0.8022$). Resting time showed lower numbers during breeding season compared with non-breeding season and those numbers were statistically different ($P = 0.01$). Wing extension behavior was similar in number for both sexes and seasons and did not differ significantly ($P = 0.24$). Finally, the number of flights made by males and females to change roosting sites inside the chamber were not statistically significant between the different categories of adults ($P = 0.6395$), and were similar when both seasons were compared ($P = 0.75$). Some marked females with offspring were observed, in which the mothers made short flights inside the chamber carrying the young.

We analyzed paired comparisons among the previously described behaviors between observations made in the hours after arrival versus the hours prior to departure. Bats showed a pattern of more persistent behavioral activities during the hours prior to their nightly departure compared with activities performed at dawn after foraging. Resting behavior was consistently most frequently observed in the period after arrival compared to the period before leaving the cave ($P = 0.04$, Figure 4). Self-grooming was also a very occasional activity after arrival at the cave, compared with the frequency of occurrence observed at sunset ($P < 0.001$, Figure 4). All the other behavioral activities did not show significant values of difference between the two periods of the day.

## Discussion

This study reports the largest colony of *Mimon cozumelae* in a single refuge, with 103 individuals captured in a period of two consecutive years (2020 to 2021). It is considered that the number of individuals that have used the refuge is greater, because in the samplings carried out throughout the study individuals without marks were observed in the recordings. In general, the number of individuals observed in the cave ranged between 60 to 90. The species showed fidelity to the refuge since in all our visits, *M. cozumelae* was be found roosting at our study site. The unmarked individuals that were observed during the recordings exceed the number of the marked ones, which suggests that they come from nearby roosts, since during this study, other roosts were found nearby, one of them located approximately 2 km away. The home range for this species is unknown, so we do not know how far these individuals could move to other refuges. In other bat species such as *Tadarida brasiliensis* and *Myotis velifer*, the percentage of recaptured individuals suggested that they have low fidelity to the refuge and was attributed to the availability and proximity of other refuges (Lewis 1995). However, the individuals of *M. cozumelae* showed high fidelity to the refuge despite the proximity of other available refuges, since we

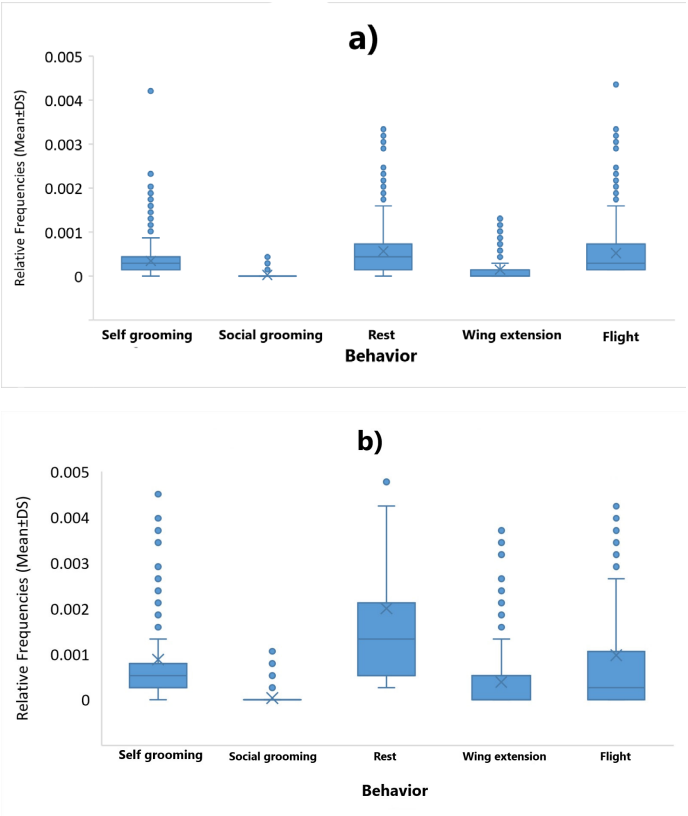


**Figure 2.** Relative frequencies of most common behaviors performed by *Mimon cozumelae* during the reproductive season, a) versus non-reproductive season b) in the cave of Uayma, Yucatán, México. For definition of each behavior see Table 1.

Therya Advance Access published November 24, 2023

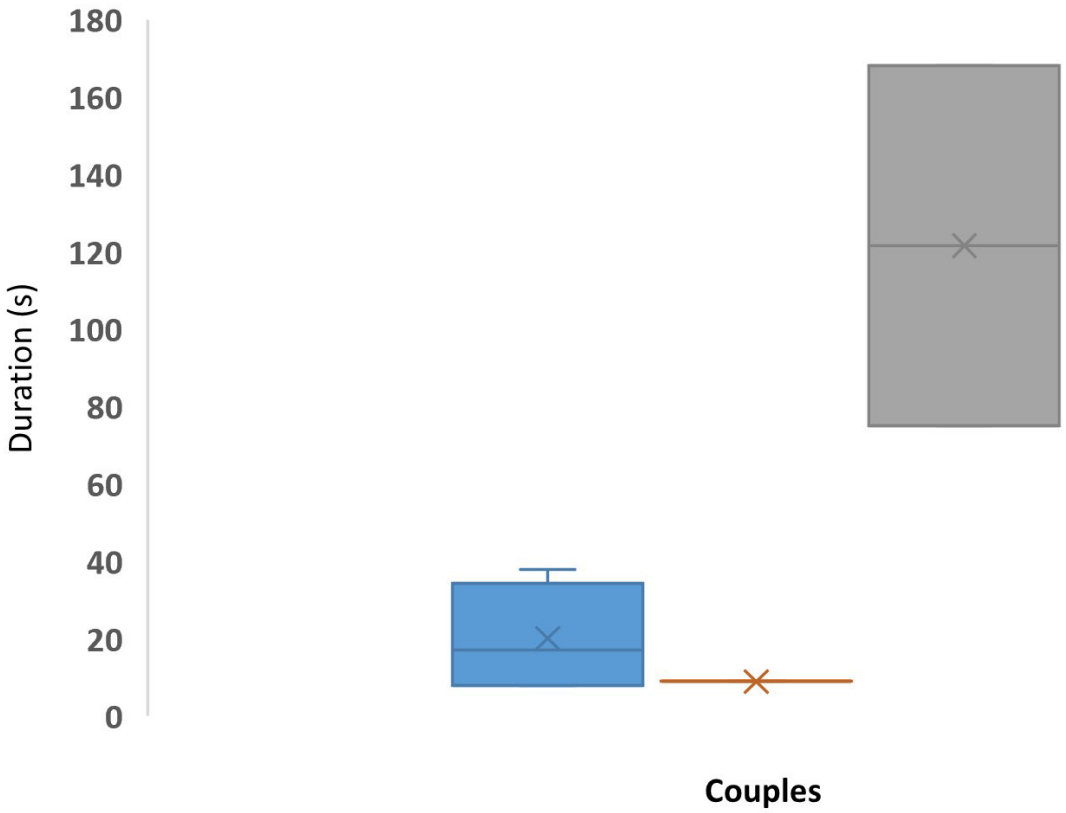


**Figure 3.** Average time spent on social grooming (s) by different observed pairs of *Mimon cozumelae* during the reproductive season (blue: male-male; orange: female-male; gray: mother-offspring).

recorded the presence of the colony in very similar numbers in every month during the study. The composition of the colony was mixed groups of adults of both sexes in the non-breeding season, adding offspring and juveniles during the reproductive season. The rearing season coincided with the dates previously reported for the species in the Yucatán Peninsula (Jones *et al.* 1973).

Opportunities to study behavioral activities in bats have been limited due to their nocturnal habits, cryptic-ity, and the difficulty in accessing their shelters (Kerth and Dechmann 2009). However, there are several studies on certain species considered common such as hematophagous bats (*Desmodus rotundus*) or pollinators (*Glossophaga mutica*), which have been studied with the use of PIT Tags (Integrated Passive Transponders), light remotes, proximity sensors, radio transmitters and infrared video recordings, combining these tools to allow more detailed studies of social behavior in bats (Ripperger *et al.* 2019, 2020; Rose *et al.* 2020). Day roosting sites are among the most important places for the performance of individual and social behaviors. Scientific reports suggest that most bat species interact and communicate with their conspecifics at perch sites (Chaverri and Kunz 2010; Prat *et al.* 2016). Self-grooming or social grooming, copulation, alloparental care, and nursing seem to occur exclusively at resting sites (Wilkinson 1984; Kerth *et al.* 2003; Chaverri and Kunz 2006; Ortega and Maldonado 2006). Studies have reported that roost attributes exert a significant influence on bat social systems (Hodgkison *et al.* 2003; Campbell *et al.* 2006; Lausen and Barclay 2006; Chaverri *et al.* 2007, 2008).

In the breeding and non-breeding seasons, the number of groups of *M. cozumelae* did not vary significantly. Our results suggest that *M. cozumelae* does not form harems in the reproductive season, since our data obtained from the composition of the groups of *M. cozumelae* included several males. Observations suggest that most of the females captured and tagged during the study left the cave, possibly to another nearby refuge, and that only a few females remained during the breeding season, which were surrounded by one or more males, which also suggests that it does not form maternity colonies. However, it is necessary to study this species in other refuges to rule out this possibility as other species of phyllostomines such as *Phyllostomus hastatus* do form harems (McCracken and Bradbury 1981). Our data and further samplings in roosting sites of *M. cozumelae* in the region show that this species has a seasonally monoestrous reproduction. Females give birth a single pup and offspring become adults by the end of August. From September to March all individuals captured in the region are adults, with no signs of reproductive activity (MCMG, personal observation).

Copulation events are difficult to register in the wild, particularly in tropical areas where roosting sites are not accessible for filming purposes, coupled with the elusive

behavior of the species. During our study, we registered a behavior that we classified as a copulation event (Supplementary Material, Video1). A female was roosting in the cave and a male arrived and positioned himself behind the female for about 15 sec. After this, both individuals adopt a face-to-face and female opened the wings in an embrace that lasted about 28 sec. After this behavior, the male flew away with a loud squeal. The whole interaction between female and male lasted about 43 sec. A couple of seconds later a male returned and positioned himself next to the female and both began to clean themselves. Although we cannot be certain, we suspect that it was the same male that returned to the visual field of the camera. Recent copulation events recorded in other phyllostomids such as *Centurio senex* had a similar duration (38 sec), although behavior between female and male of *C. senex* show different pattern as in this species females select and approach to a male for copulation (Rodríguez-Herrera *et al.* 2020).

Rest is one of the behaviors that lasts the longest in bats, and one of its functions is to conserve energy. Measuring this behavior can be confusingly complicated because when the organism is immobile it is difficult to differentiate whether it is completely sleeping or just inactive. The amount of time bats spends sleeping varies by day and between species but it has been recorded that some cave species can spend more than three quarters of their time resting (Fleming *et al.* 1998; Hengjan *et al.* 2017). Our observations indicated that not all individuals rested at the same time, at least one individual remained active, usually the individual separated from the group. This suggests that a certain level of vigilance may be necessary for bats to successfully occupy roosts (Muñoz-Romo 2006). Although the individuals of *M. cozumelae* were inactive most of the diurnal rest time, this was an interrupted phenomenon since the individuals did not sleep continuously for more than 20 minutes. This observation has also been reported for the fruit bat *Artibeus lituratus* (Muñoz-Romo 2006).

Flight in bats is part of locomotion and is one of the behaviors that is difficult to record, since it is necessary to use radio telemetry or light remote sensors to track individuals (Ripperger *et al.* 2020). In cave bats, this activity is possible to record in frequencies of short periods within the refuge, which is spotted when individuals change social groups (Ortega *et al.* 2010). Prior to flight, stretching of the wings could contribute not only to maintaining the optimal condition of the flight muscles and joints, but also to avoid hypothermia that could occur during rest periods in cold climates (Kunz 1982). In *M. cozumelae* short flights were observed inside the refuge near dusk and dawn. Particularly, at dusk a few individuals were observed leaving the roost for shorts periods and returning, which probably help to identify the exact moment of emergence for the rest of the group, which come out one by one every few seconds or minutes. The whole group left the roost 30 minutes after this initial recognition flights carried out by a few individuals.

Self-grooming performed by bats also has a personal hygiene character and this behavior is the most common behavior reported in bats (Fleming *et al.* 1998). In the case

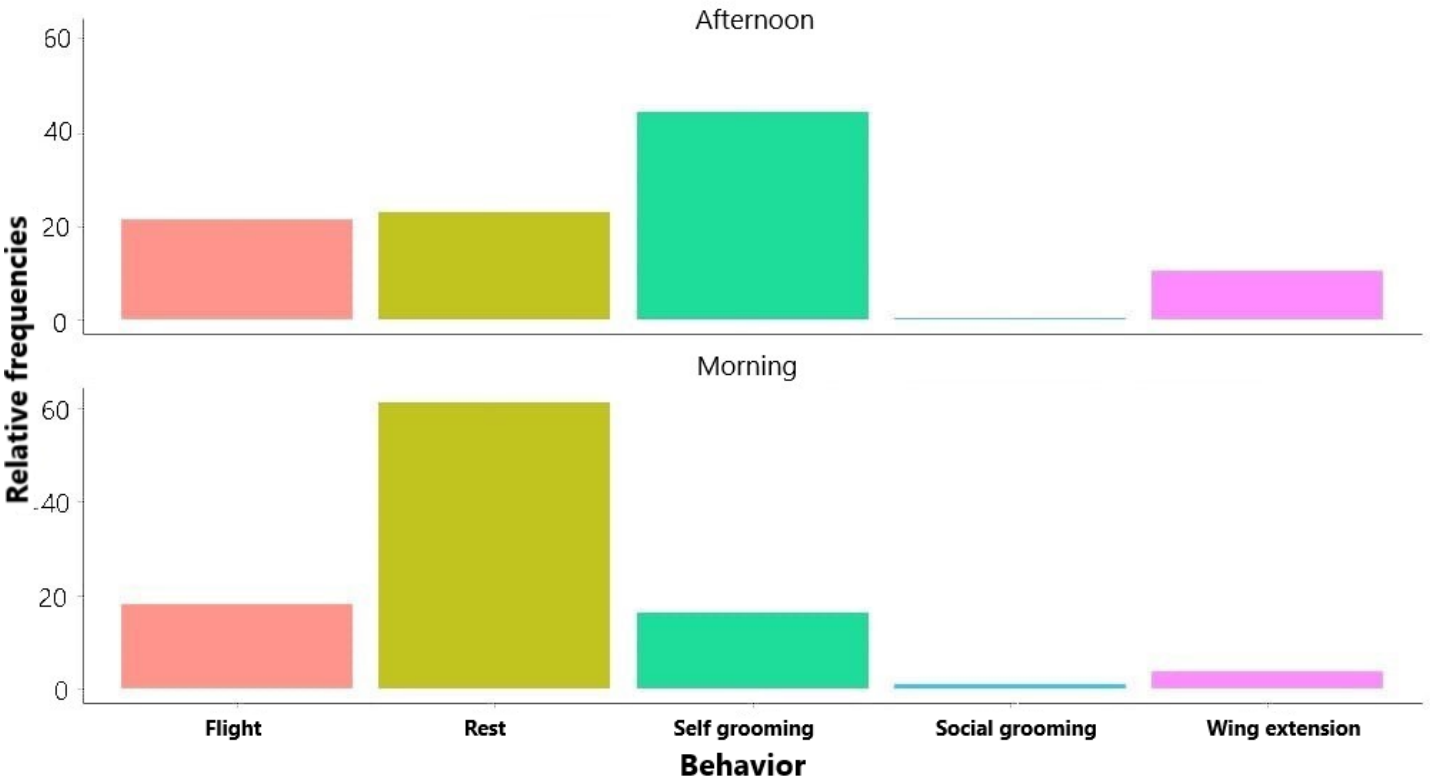


**Figure 4.** Relative frequencies of the most common behavioral activities observed during the morning versus the afternoon. For definition of each behavior see Table 1.

of social grooming, the vampire bat (*D. rotundus*) is a species that spends a lot of time in this behavior compared to other bat species (Carter and Leffer 2015; Rathinakumar *et al.* 2017). However, the social grooming performed by the vampire bat is not always intended to help another individual because sometimes its response to their own need (Carter and Leffer 2015). Social grooming might be a consequence of licking a groupmate to gather sensory information, also a bat might preen due to the needs of the recipient (Narizano and Carter 2020). In maternal grooming it might be expected that mothers' grooming towards young offspring might be more recipient-driven (attuned to offspring's needs) compared to offspring's grooming towards mothers, which might be more recipient-based in the need of the offspring (Narizano and Carter 2020). In the case of *M. cozumelae*, maternal grooming was recorded, and in the case of one pup, grooming was carried out not only by the mother, but also by another unmarked individual. We were unable to determine whether this individual was a male or another female. Further investigations are needed to document whether this behavior is frequent in the species.

Night activity patterns, mainly foraging behaviors, showed a peak of activity around midnight for insect gleaning bats (Lee and McCracken 2001; Berková and Zukal 2009). Bats expend a great deal of energy at night because they carry out a great number of activities to find their food. Nocturnal activities are closely correlated with the time of year, reproductive activity and even the age of the bat, so that in times of food scarcity, the search effort is greater (Lee and McCracken 2001). It is common to observe that many species of bats return to their roosting site at dawn, after having carried out intense foraging activities. We found that *M. cozumelae* return to the roost site at dawn, but that a large amount of time after arrival is devoted to resting, which contrasts with the increased activity in the time span before setting out to forage in the evening.

Finally, it is important to mention that *M. cozumelae* seems to be a species sensitive to disturbance as our observations showed that after several days visiting the cave, individuals tend to move to another roosting site. However, all individuals of *M. cozumelae* returned to the site two to three weeks after. The movement of individuals in a colony of bats due to the presence of researchers has been reported for other species of bats such as the vespertilionid *Corynorhinus rafinesquii* in which after a few days after young bats were marked, the mothers took their offspring and moved to a nearby refuge, but after a few days they returned to the initial roosting site (Pearson *et al.* 1952). Another species with a similar behavior is *C. mexicanus*, which abandoned its refuge near Pachuca, Hidalgo, México, after this site started to be visited by tourists (Aguilar, M. personal communication).

In general, it had been previously reported that phyllostomines are particularly sensitive group to disturbance of their environments (Fenton *et al.* 1992). This study contributes with updated information regarding the description of the size and composition of groups and, especially diurnal behavior of *M. cozumelae*. It is suggested that this work may serve as background to consider both for works that delve into the subject of social systems (behavioral ecology), and when carrying out conservation plans for this species, due to the alterations that are changing its habitat, with the potential megaprojects that are currently being developed in the Yucatán Peninsula.

## Acknowledgments

First author would like to thank Consejo Nacional de Ciencia y Tecnología, México, for its financial support with master's degree scholarship number 977727 and Centro de Investigaciones Tropicales, Universidad Veracruzana for the field's work financial support. We also like to thank IDEA WILD for the grant for equipment. We thank Dr. G. Chaverri for her comments and suggestions on the thesis that derived this manuscript. We thank the colleagues, students and local guides that helped with the fieldwork and the authorities of the Cuxtal Reserve and landowners that granted the permit to sample in their sites.

## Literature cited

**Altmann, J**. 1974. Observational study of behavior: Sampling methods. Behaviour 49:227–266.

**Berková, H., and J. Zukal**. 2009. Flight activity of bats at the entrance of a natural cave. Acta Chiropterologica 8:187-195.

**Bradbury, J. W, and S. L. Vehrencamp**. 1977. Social organization and foraging in emballonurid bats: IV Parental investment patterns. Behavioral Ecology and Sociobiology 2:19–29.

**Brooke, A. P**. 1997. Social organization and foraging behaviour of the fishing bat, *Noctilio leporinus* (Chiroptera: Noctilionidae). Ethology 103:421–436.

**Brunet-Rossinni, A. K., and G. S. Wilkinson**. 2009. Methods for age estimation and the study of senescence in bats. Pp. 315-325, *in* Ecological and behavioral methods for the study of bats (Kunz, T. H., and S. Parsons, eds). The Johns Hopkins University Press. Baltimore, U.S.A.

**Campbell, P., *et al.***. 2006. Comparative roosting ecology of *Cynopterus* (Chiroptera: Pteropodidae) Fruit Bats in Peninsular Malaysia. Biotropica 38:725–734.

**Cárdenas-Canales, E. M., *et al.***. 2022. Social effects of rabies infections in male vampire bats (*Desmodus rotundus*). Biology Letters 18: 20220298

**Carter, G. G**. 2021. Co-option and the evolution of food sharing in vampire bats. Ethology 127:837-849.

**Carter, G. G., and L. Leffer**. 2015. Social grooming in bats: are vampire bats exceptional? Plos One 10:e0138430.

**Chaverri, G., and T. H. Kunz**. 2006. Reproductive biology and postnatal development in the tent-making bat *Artibeus watsoni* (Chiroptera: Phyllostomidae). Journal of Zoology 270:650–656.

**Chaverri, G., and T. H. Kunz**. 2010. Ecological determinants of social systems: Perspectives on the functional role of roosting ecology in the social behavior of tent-roosting bats. Pp. 275-318, *in* Advances in the Study of Behavior (Brockmann, H. J., C. T. Snowdon, and T. Roper, eds). Elsevier. Amsterdam, Netherlands.

**Chaverri, G., *et al*.** 2007. Ecological Correlates of roost fidelity in the Tent-Making Bat *Artibeus watsoni*. Ethology 113:598–605.

**Chaverri, G., C. Schneider, and T. H. Kunz**. 2008. Mating system of the tent-making bat *Artibeus watsoni* (Chiroptera: Phyllostomidae). Journal of Mammalogy 89:1361–1371.

**Crisp, R. J., J. N. Brent, and G. Carter**. 2021. Social dominance and cooperation in female vampire bats. Royal Society Open Science 8:210266.

**Fenton, M. B., *et al*.** 1992. Phyllostomid bats (Chiroptera: Phyllostomidae) as indicators of habitat disruption in the Neotropics. Biotropica 24:440-446.

**Fleming, T. H., A. A. Nelson, and V. M. Dalton**. 1998. Roosting behavior of the Lesser Long-Nosed bat, *Leptonycteris curasoae*. Journal of Mammalogy 79:147-155.

**Flores, V., *et al*.** 2020. Social structure and relatedness in the fringe-lipped bat (*Trachops cirrhosus*). Royal Society Open Science 7:192256.

**Gual Suárez, F., and R. A. Medellin**. 2021. We eat meat: a review of carnivory in bats. Mammal Review 51:540–58.

**Hengjan, Y., *et al*.** 2017. Diurnal behavior and activity budget of the golden-crowned flying fox (*Acerodon jubatus*) in the Subic bay forest reserve area, the Philippines. The Journal of Veterinary Medical Science 79:1667-1674.

**Hodgkison, R., *et al*.** 2003. Roosting ecology and social organization of the spotted-winged fruit bat, *Balionycteris maculata* (Chiroptera: Pteropodidae), in a Malaysian lowland dipterocarp forest. Journal of Tropical Ecology:667–676.

**Jones, J. K. Jr., J. D. Smith, and H. H. Genoways**. 1973. Annotated checklist of mammals of the Yucatán Peninsula, Mexico. I. Chiroptera. Occasional Papers, The Museum Texas Tech University 13:1-31.

**Kerth, G**. 2008. Causes and consequences of sociality in bats. BioScience 58:737–746.

**Kerth, G., *et al*.** 2003. Social interactions among wild female Bechstein's bats (*Myotis bechsteinii*) living in a maternity colony. Acta Ethologica 5:107–114.

**Kerth, G., and D. K. Dechmann**. 2009. Field-based observations and experimental studies of bat behavior. Pp. 393-406, *in* Ecological and behavioral methods for the study of bats (Kunz, T. H., and S. Parsons, eds.). Johns Hopkins University Press. Baltimore, U.S.A.

**Kerth, G., N. Perony, and F. Schweitzer**. 2011. Bats are able to maintain long-term social relationships despite the high fission–fusion dynamics of their groups. Proceedings of the Royal Society B: Biological Sciences 278:2761–2767.

**Kunz, T. H**. 1982. Roosting ecology of bats. Pp. 1-55, *in* Ecology of bats (Kunz, T.H., ed.). Plenum Pres. New York, U.S.A.

**LaVal, R. K**. 1977. Notes on some Costa Rican bats. Brenesia 10/11:77–83.

**Lausen, C. L., and R.M. Barclay**. 2006. Benefits of living in a building: Big brown bats (*Eptesicus fuscus*) in rocks versus buildings. Journal of Mammalogy 87:362–370.

**Lee, Y.-F., and G. F. McCracken**. 2001. Timing and variation in the emergence and return of Mexican free-tailed bats, *Tadarida brasiliensis mexicana*. Zoological Studies 40:309-316.

**Lewis, S. E.** 1995. Roost fidelity of bats: A review. Journal of Mammalogy 76:481–496.

**Martin, P., and P. Bateson**. 2007. Measuring Behaviour: An introductory guide. Cambridge University Press. Cambridge, U. K.

**McCracken, G. F., and J. W. Bradbury**. 1981. Social organization and kinship in the polygynous bat *Phyllostomus hastatus*. Behavioral Ecology and Sociobiology 8:11–34.

**McCracken, G. F., and G. S. Wilkinson**. 2000. Bat mating systems. Pp. 321-362, *in* Reproductive Biology of Bats (Crichton, E. G., and P. H. Krutzsch, eds). Academic Press, Massachusetts, U.S.A.

**Muñoz-Romo, M**. 2006. Ethogram and diurnal activities of a colony of *Artibeus lituratus* (Phyllostomidae: Stenodermatinae). Acta Chiropterologica 8:231–238.

**Muñoz-Romo, M., E. A. Herrera, and T. H. Kunz**. 2008. Roosting behavior and group stability of the big fruit-eating bat *Artibeus lituratus* (Chiroptera: Phyllostomidae). Mammalian Biology 73:214–221.

**Narizano, H., and G. Carter**. 2020. Do vampire bats groom others based on need? Behavioral Ecology 31:107-113.

**Olson, C. R., and R. M. R. Barclay**. 2013. Concurrent changes in group size and roost use by reproductive female little brown bats (*Myotis lucifugus*). Canadian Journal of Zoology 91:149–155.

**Ortega, J., and H. T. Arita**. 1997. *Mimon bennettii*. Mammalian Species 549:1–3.

**Ortega, J., and J. E. Maldonado**. 2006. Female interactions in harem groups of the Jamaican fruit-eating bat, *Artibeus jamaicensis* (Chiroptera: Phyllostomidae). Acta Chiropterologica 8:485–495.

**Ortega, J., *et al*.** 2010. Estructura social y composición temporal en una colonia de *Nyctinomops laticaudatus* (Chiroptera: Molossidae). Revista Mexicana de Biodiversidad 81:853-862.

**Pearson, O. P., M. P. Koford, and A. K. Pearson**. 1952. Reproduction of the lump-nosed bat (*Corynorhinus rafinesquei*) in California. Journal of Mammalogy 33:273–320.

**Prat, Y., M. Taub, and Y. Yovel**. 2016. Everyday bat vocalizations contain information about emitter, addressee, context, and behavior. Scientific Reports 6:1–10.

**Rathinakumar, A., *et al*.** 2017. Social grooming among Indian short-nosed fruit bats. Behaviour 154:37–63.

**Razik, I., B. Brown, and G. Carter**. 2022. Forced proximity promotes the formation of enduring cooperative relationships in vampire bats. Biology Letters 18:20220056.

**Ripperger, S. P., *et al*.** 2019.Vampire bats that cooperate in the lab maintain their social networks in the wild. Current Biology 29:4139–4144.

**Ripperger, S.P., *et al*.** 2020. Thinking small: Next-generation sensor networks close the size gap in vertebrate biology. Plos Biology 18:e3000655.

**Rodríguez-Herrera, B., *et al*.** 2020. The masked seducers: Lek courtship behavior in the wrinkle-faced bat *Centurio senex* (Phyllostomidae). Plos One 15:e0241063.

**Rose, A., M. Tschapka, and M. Knörnschild.** 2020. Visits at artificial RFID flowers demonstrate that juvenile flower-visiting bats perform foraging flights apart from their mothers. Mammalian Biology 100:463-471.

**Sikes, R. S., and the Animal Care and Use Committee of the American Society of Mammalogists.** 2016. Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97:663–88.

**Tuttle, M.** 1976. Collecting techniques. Pp. 7-56, *in* Biology of the bats of the New World family Phyllostomidae. Part II (Baker R. J., J. K. Jones Jr., and D. C. Carter, eds). Special Publications The Museum Texas Tech University Press. Texas, U.S.A.

**Therya Advance Access published November 24, 2023**

**Wilkinson, G. S.** 1984. Reciprocal food sharing in the vampire bat. Nature 308:81–184.

**Wilkinson, G. S.** 1988. Reciprocal altruism in bats and other mammals. Ethology and Sociobiology 9:85–100.

**Wilkinson, G. S., and J. W. Boughman**. 1998. Social calls coordinate foraging in greater spear-nosed bats. Animal Behaviour 55:337–350.

**Wilkinson, G.S., *et al***. 2019. Kinship, association, and social complexity in bats. Behavioral Ecology and Sociobiology 73:1-15.

**Willis, C. K. R. and R. M. Brigham**. 2004. Roost switching, roost sharing and social cohesion: Forest-dwelling big brown bats, *Eptesicus fuscus*, conform to the fission–fusion model. Animal Behaviour 68:495–505.

*Associated editor: Robert Owen*
*Submitted: July 7, 2023; Reviewed: September 4, 2023*
*Accepted: October 10, 2023; Published on line: XX xx, 2023*

## Supplementary material

Video1. Copulation event of *Mimon cozumelae* in the Yucatán, México: https://doi.org/10.5281/zenodo.7178551.

**Therya Advance Access published November 24, 2023**