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Ecobiology of haematophagous bats captured in Juruti municipality, Lower Amazonas, Pará, Brazil

Ecobiologia de morcegos hematófagos capturados no município de Juruti, Baixo Amazonas, Pará, Brasil

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ABSTRACT: Among the 1.200 species of bats belonging to the order Chiroptera, only *Diaemus youngi*, *Diphylla ecaudata,* and *Desmodus rotundus* are hematophagous, with *D. rotundus* being the most commonly found species and having the most widely studied and understood biology. This species feeds on the blood of domestic and wild birds and mammals, including humans. To understand the ecobiological characteristics of hematophagous bats in the municipality of Pará state, Brazil, bats were captured while feeding in 2013 and 2014 from solid ground and riparian regions. Over a general sampling period of 371 hours 75 individuals of *D. rotundus*—26 adult males and 49 adult females—and four adult male *D. youngi* were captured. Of these, 56 (75%) *D. rotundus* individuals were captured in solid ground regions and 19 (25%) were captured in riparian areas. *D. rotundus* often attacks cattle, horses, goats, pigs, and birds, rarely attacks dogs, and occasionally attacks people. The region's *D. rotundus* colonies were observed to consist of small groups of individuals, and *D. youngi* has low participation in animal attacks in the Juruti municipality when compared with *D. rotundus*.

KEYWORDS: haematophagous bats; ecology; Amazônia.

RESUMO: Entre as 1.200 espécies de morcegos pertencentes à ordem Chiroptera, apenas Diaemus youngi, Diphylla ecaudata e Desmodus rotundus são hematófagos, sendo D. rotundus o mais comumente encontrado e com a biologia mais estudada e compreendida. Esta espécie se alimenta do sangue de pássaros e mamíferos, incluindo humanos. Para compreender as características ecobiológicas dos morcegos hematófagos no Município de Juruti, Baixo Amazonas, Estado do Pará, Brasil, morcegos foram capturados enquanto se alimentavam em 2013 e 2014 em solo sólido e regiões ribeirinhas. Uma amostragem geral de 371 horas resultou em 75 indivíduos capturados de D. rotundus, incluindo 26 machos adultos e 49 fêmeas adultas, e 4 machos adultos de D. youngi. Destes, 56 (75%) indivíduos de D. rotundus foram capturados em regiões de solo sólido e 19 (25%) em áreas ciliares. D. rotundus frequentemente atacava bovinos, cavalos, cabras, porcos e pássaros, raramente atacava cães e ocasionalmente atacava pessoas. Observou-se que as colônias de D. rotundus da região são constituídas por pequenos grupos de indivíduos, sendo que D. youngi é uma espécie que apresenta baixa participação em ataques de animais no Município de Juruti quando comparado com D. rotundus.

PALAVRAS-CHAVE: morcegos hematófagos; ecologia; Amazônia.

INTRODUCTION

Bats belong to the order Chiroptera, which consists of two suborders: Megachiroptera, containing only the Pteropodidae family, and Microchiroptera, comprising 18 families and 168 genera. Megachiroptera are restricted to the Old World (Africa, Asia, and Oceania), whereas microchiroptera have a broad geographic distribution, including nine families occurring in the Americas (Uieda, 1992; Villa-Ramírez , 1966).

Overall, the order Chiroptera contains 1,200 species of bats, and all bats with recognized blood-feeding habits belong to the Desmodontidae subfamily of the Phyllostomatidae family. They include *Diaemus youngi*, the "white-winged vampire

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bat," *Diphylla ecaudata*, the "hairy-legged vampire bat"; and *Desmodus rotundus*, the "common vampire bat" (Arellano-Sota, 1988; Bredt, 1998; Dyce KM, Sack, 2004).

Hematophagous bats are found only in the Americas. *D. rotundus* is the most widely distributed species and can be found in North America, from Sonora and Tamaulipas in northern Mexico to Central America, and throughout South America, where its distribution reaches central Chile in western and northern Argentina, and Uruguay in the east (Arellano-Sota , 1988; Greenhall *et al*., 1983; Koopman, 1988; Uieda*, 1992*).

The three species of hematophagous bats have several bio- logical and morphological characteristics that can be detected in the field to facilitate their quick identification (Alencar *et al*., 1994; Bredt, 1998; Burns, 1972), which were described and
used as identification keys in this study.

Among these species, *D. youngi* and *D. ecaudata* feed mostly on domestic and wild birds, and their natural history is less well known, whereas *D. rotundus* is the most studied species, feeding on the blood of birds and mammals, includ- ing humans (Greenhall *et al*., 1983; Koopman , 1988).

In general, under favorable environmental conditions, the feeding activity of hematophagous bats may occur throughout the night, starting approximately one–two hours after sun- set and ending approximately one hour before dawn (Bredt, 1998). However, the same author revealed that factors such as heavy rain and strong winds affected the feeding activity of *D. rotundus* and *D. youngi* by interfering with their flight activities.

Desmodus rotundus bats typically form harems consisting of a group of eight to 12 females and their offspring under the protection of a single dominant male (Bredt, 1998); however, colonies are usually found between 50 and 100 individuals (Greenhall *et al*., 1983). *D. youngi* and *D. ecaudata* usually form small groups of six to 10 individuals or three to 12 indi- viduals, respectively (Bredt, 1998).

The sexual maturity of *D. rotundus* is reached before the first year of life (Wilkinson , 1984). The female was polyes- trous, which allowed her to reproduce throughout the year (Burns , 1972). Gestation lasts for seven months and produces a single pup, which weighs between five and seven grams and completes its physical development in five months(Arellano-Sota, 1988; Bredt, 1998).

Diaemus youngi females have an unknown gestational period, produce only one offspring during each gestational period, and may have up to two offspring per year. In males of both species, the testes remain in the abdominal cavity until the breeding season, when they migrate into the scro- tum (Anthony, 1988; Gomes, Uieda, 2004; Ralls , 1976; Villa-Ramírez , 1966).

The goals of this study were to identify the species of hematophagous bats present in the municipality of Juruti, Mesoregion of the Lower Amazon, state of Pará, Brazil, determine their distribution in the region, describe their external morphobiometric characteristics, and identify the domestic animals they use as a food source. Moreover, this study aimed to contribute to the knowledge of the ecology of these hematophagous bat species in the region, particularly in light of reported instances of blood-feeding on animals and people inhabiting the countryside in this municipality.

MATERIAL AND METHODS

Ethics

This study obtained ethical and academic approval under protocol number 049/2013 of the Animal Ethics Committee of the Federal Rural University of the Amazon/UFRA, process number 23084.017998/2013-27. This is part of a dissertation submitted to the Postgraduate Program in Animal Health and Production in the Amazon as one of the requirements for the Master's degree in Animal Health and Production in 2014.

Kind of study

This was an observational study that included 79 bats belong- ing to two species: *D. rotundus and D. young.*

Field site

This study was carried out in the Municipality of Juruti (2° 9′ 12″ S, 56° 5′ 14″ W) (Figure 1), located in the Mesoregion of Baixo Amazonas, state of Pará, Brazil. It borders the munici- palities of Oriximiná and óbidos to the north, Santarém to the east, Aveiro to the south, Parintins and Nhamundá (in the state of Amazonas), and Faro to the west.

Nocturnal capture sessions of vampire bats were carried out for this study in 23 capture points in the same area (PC), 15 of which were located in solid ground regions and eight in river- side regions, all points were inspected daily during the period of collection, there were a total of 4 teams during the study. All the geographic coordinates were obtained by GPS (Global Positioning System).

The study was conducted over two periods, November 4th–15th, 2013 and March 18th–30th, 2014, which correspond to periods of lower and higher rainfall, respectively. Rainfall in the region is considered irregular throughout the year and the rainy periods coincide with the months of December to June and, the least rainy, with the months of July to November, with March being the one with the highest rainfall. The climate in

Source: The authors.

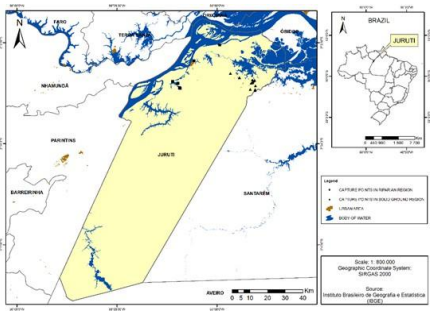


Figure 1. Map of vampire bat capture points, Juruti/PA

region Juruti is tropical, with an average annual temperature of 25.6°C, and relative humidity with values above 80% in almost all months of the year (Bernard, Fenton, 2002).

Bat capture

Desmodus rotundus and *D. youngi* were the target species used in this study were D. rotundus and D. youngi. They were captured during two time periods: one during the six days of the new moon phase in November 2013 and another during the seven days of the gibbous moon phase in March 2014. The capture points were preselected after investigating the hotspots. catches, with reports of vampire bats attacking both humans and animals.

Four teams of two to three technicians, properly trained in bat capture, were formed and distributed so that there was the greatest number of capture points per night. The bat collection sessions began around sunset (between 6 pm and 7 pm) and ended at 4 am or 5 am.

The bats were collected close to their feeding sites (corrals, corrals, pigsties, perches) and areas where oxen and buffaloes spend the night transporting carts. The bats were collected through the installation of mist nets of standard sizes of 7 x 2.5 m with 20-mm mesh and alphabetized identifiers. The mist nets were extended using metal rods fixed to the ground and were approximately 5–10 cm high.

The nets were examined regularly at 20-minute intervals for vampire bats, which were placed individually in numerically identified tobacco fabric bags (25 cm × 30 cm). Mist net data such as the capture side and capture time for each individual were recorded on the field data sheet.

Identification of the species Desmodus rotundus and Diaemus youngi

Morphological characteristics defined by Greenhall (Greenhall, 1983) and Novak (Novak, 1991) were used to identify *D. rotundus*. They described medium-sized individuals, with approximately 30 cm wingspan, long thumbs with three calluses and strong nails, a short muzzle, and a reduced nasal appendage in a horseshoe shape. Their forearm length varied between 52 and 63 mm and their body mass ranged from 25 to 40 g in adulthood.

Their body fur was usually dark brown on the back and light brown on the chest. Orange-colored, bright gold individuals can be found in certain regions and albinism has been detected in this species in Brazil (Alencar *et al*., 1994; Gomes, Uieda, 2004).

D. youngi has a forearm length ranging from 50 to 56 mm, adult weight ranging from 30 to 45 g, and bright light-brown fur color. It has two striking morphological features, white wing tips and a pair of oral glands located inside the cheeks, which release a volatile and nauseating substance (Reis *et al*., 2011).

Biometrics

The forearm of each animal was measured in millimeters using a digital caliper, and body mass (in grams) was evaluated using a digital scale with one-gram precision.

Density and sampling effort

The density of individuals (DI) was calculated in the capture effort according to the following formula: DI = total number of individuals/net.hour, where one net.hour equals 7.5 m (20 mm mesh) of open net per hour (Bredt, 1998).

All collected specimens were categorized according to sex, developmental stage was established, and reproductive conditions were examined. Sex was determined by visual examination of the external genitalia, and the developmental stage (puppy, young, or adult) was determined by the degree of ossification of the epiphysis of long bones (metacarpals and first phalanges) by visual examination of the wings under a spotlight (; Gomes, Uieda, 2004).

Abdominal palpation was performed to detect the presence of a fetus to determine whether the females were pregnant, and lactating females were detected by their size and the presence of breast milk. Females were considered reproductively active when pregnant or lactating and were considered inactive when such conditions were not observed. The reproductive development of adult males was evaluated by the presence or absence of testes in the scrotal sac because when they are reproductively active, the testicles are visible in *D. rotundus*. All data were recorded on the field data sheet.

RESULTS

In a general sampling effort of 371 net.hours (NH), 75 *D. rotundus* individuals were captured: 26 males and 49 females. Additionally, four *D. youngi* adult males were captured, indicating that they are less common. A greater individual density was obtained in the solid ground region, with 0.24 individuals/net.hour (Table 1). Fifteen (65%) of the 23 capture points were located in solid ground areas and eight (35%) were in riparian areas.

Table 1. Density and sampling effort per region worked in the Municipality of Juruti/Pará in 2013 and 2014.

Capture Region	Net Hour (NH)	Density of individuals (DI)	N°. of Captured Individuals (NCI)
Solid ground	241	0,24	58
Riparian	130	0,16	21
Total	371	0,21	79

Capture of Desmodus rotundus

The biometric characteristics of *D. rotundus* captured in the municipality of Juruti showed that females are larger than males, with the mean forearm lengths being 57.14 mm (right, Standard Deviation (SD) = 1.78) and 57.23 mm (left, SD = 1.86) in males and 61.09 mm (right, SD = 1.47) and 61.10 mm (left, SD = 1.47) in females. The average weight was 27.43 g for males and 33.98 g for females.

The weights of male and female *D. rotundus* individuals in the reproductive stages were also higher. Thus, the average weight of males with scrotal testes was 28 g (SD = 2.8), while the average weight of those with abdominal testes was 27 g (SD = 3.5). In pregnant females, the average was 35.5 g (SD = 4.16), and in non-pregnant females, it was 33 g (SD = 3.8). Maximum measurements of the right and left forearms in males 61.33 cm and females 64.71 cm in both forearms.

Fifty-four (72%) of the captured *D. rotundus* individuals had dark brown coloration on the back and whitish-brown coloration on the chest (Figure 2).

Geographical distribution of Desmodus rotundus attacks

In the study region, 56 (75%) *D. rotundus* individuals were captured in a solid ground region and 19 (25%) in a riparian region (Table 2). This was due to the greater number of capture points studied in the solid ground region.

Moreover, the riparian region has fewer properties than the solid ground region studied; consequently, the number of animals that serve as prey is smaller, and therefore, there may be smaller proportions of *D. rotundus* colonies in this region.

Of the 75 captured *D. rotundus*, 26 (35%) were captured in 2013; of these, five (38%) males and four (31%) females were reproductively active. Of the 49 (65%) captured in 2014, nine (69%) males and 13 females (36%) were reproductively active (Table 3).

Two individuals with only one testicle that descended into the scrotum were captured from two properties located on solid ground. There are no reports in the literature on whether this is due to the migration of the testes from the abdomen into the scrotum occurring in a staggered fashion during the reproductive stage, or whether it is due to cryptorchidism.

Each aforementioned male was captured in a group of either five or six females, and captured *D. rotundus* individuals; 54% (n=14) of males had scrotal testes and 35% (n=17) of females were pregnant.

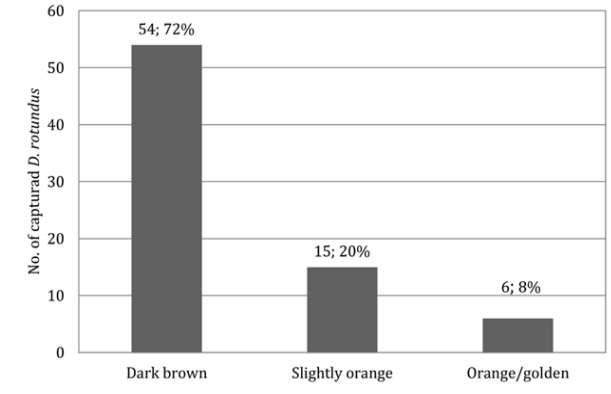


Figure 2. Proportion of *D. rotundus* captured according to coat colour.

Table 2. Number and proportion of captured *D. rotundus* males and females by capture region in the Municipality of Juruti in 2013 and 2014.

Capture region	No. of captured males (%)	No. of captured females (%)	Total (%)
Solid ground	20 (77)	36 (73)	56 (75)
Riparian	6 (23)	13 (27)	19 (25)
Total	26 (35)	49 (65)	75 (100)

Desmodus rotundus capture time

A greater number of *D. rotundus* individuals were captured between 3 and 5 AM during the first capture stage in 2013, which was held during the new moon phase. During the second capture stage in 2014, which was held during the waning moon, there was a capture peak between 9 pm and 10 pm (Figure 3).

The four *D. youngi* captures occurred during the waning moon period, and the time varied between 7 pm and 2 am.

Desmodus rotundus aggression target species of D. rotundus.

The results showed that *D. rotundus* routinely feeds on the blood of domestic animal species commonly found in Juruti/Pará municipality in both solid ground and riparian areas.

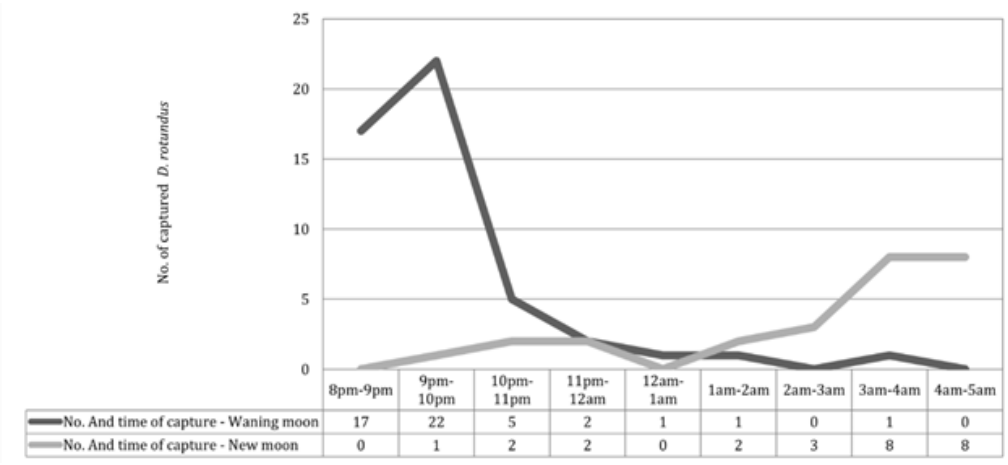
Despite the higher capture records in places where cattle stayed overnight (Figure 4), when there were other species in addition to cattle, signs of aggression by *D. rotundus* and bat captures were more frequent in buffaloes, horses, goats, pigs, and birds; however, this was not necessarily the case.

Thus, on one of the properties where there were several horses and cattle in close proximity, only one horse was a

Table 3. Number and proportion of captured *D. rotundus* males and females by capture period, sex and reproductive status in the Municipality of Juruti/Pará in 2013 and 2014.

Year of capture	Sex		Reproductive state
	M(%)*	F(%)*	NPF(%)*
2013	13/50	13/50	set/69
2014	13/27	36/73	23/64
Total	26/35	49/65	32/65

*NPF: non-pregnant female.



	8pm-9pm	9pm-10pm	10pm-11pm	11pm-12am	12am-1am	1am-2am	2am-3am	3am-4am	4am-5am
No. And time of capture - Waning moon	17	22	5	2	1	1	0	1	0
No. And time of capture - New moon	0	1	2	2	0	2	3	8	8

Figure 3. *Desmodus rotundus* number and capture time in the waning moon and new moon phases.

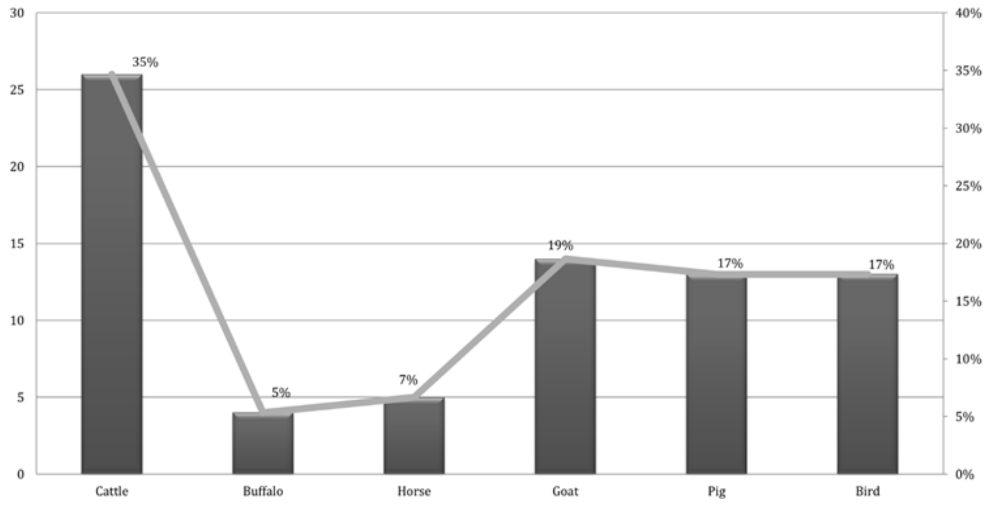


Figure 4. Livestock served as bait for capturing *D. rotundus*.

routine target of *D. rotundus* individuals, which were captured on mist nets set up between the horse and the cattle corral where the bats moved after feeding on the horse.

The bats that fed on the horse moved toward the cattle in the adjacent corral, possibly attacking them. More *D. rotundus* were also captured with a mist net on the side opposite the corral.

Properties in the municipality of Juruti, which have small livestock—such as goats, pigs, and domestic and wild birds—usually for subsistence activities, are frequent targets of bat attacks, even when cattle are within the property.

The most frequent location of wounds caused by hematophagous bats on their prey was the neck region, and other areas are listed on switchboard 1. Signs of haematophagia in birds were observed only in the physical structures of their perches.

To prevent hematophagous bat attacks on small livestock, most capture points use fishing nets that are placed around animal shelters; however, hematophagous bats find gaps to enter these shelters. A "scarecrow" was used in only one property where attacks on goats were frequent, but without the desired effects.

Therefore, investigations into reports of animals attacked by hematophagous bats have observed that dogs are rarely attacked and that these attacks occur more often when there is an absence of other animals that are often targeted by hematophagous bats.

Only one property located in a solid ground region reported a case of aggression by a hematophagous bat in an adult woman in 2014, in a location where there were frequent aggression reports in cattle living nearby.

Capture of bats was not possible (PC1) when these cattle were used as bait; however, *D. rotundus* individuals that attacked birds and cattle were captured approximately 780 m away, in a straight line from this property, in PC2.

In general, the possibility of hematophagous bat attacks in humans is influenced by the presence of livestock at the disposal of bats. According to historical reports obtained

from cattle owners in the Juruti/Pará region, attacks by hematophagous bats on animals vary seasonally. This may be due to increased rainfall in the region at certain times of the year, which affects some areas by causing rivers to overflow and flood pastures. This makes them unusable for the herd and forces owners to transfer their cattle to better grazing areas above the rivers.

This may change the prey demand for *D. rotundus*, which will attack the remaining species, such as birds, or will follow relocated cattle during times of flooding. Thus, *D. rotundus* were found at night.

With the herd's relocation, many aggression cases cease to exist or are reduced at some capture points but continue to occur at the targeted capture points; however, because there is a seemingly distinct monitoring of conditions concerning the aggression of animals between headquarters and secondary capture points, there is an impression that the attacks no longer exist in that herd.

For example, animals from one property, which had reported sporadic aggression towards cattle, were relocated approximately 2 km away by boat because of the flood; however, the property was located 500 m in a straight line from the headquarters, and therefore, continuity of attacks was found.

Capture of *Diaemus youngi*

The four captured male *D. youngi* individuals had a mean forearm length of 52.71 mm (right) and 52.71 mm (left), with an average weight of 35 g (swichboard 2), which corresponds to values found in the literature as described by Bredt (5) and Reis (16); all of the captured males had scrotal testes. However, data regarding the reproductive period of this species are limited.

In the solid ground area, two *D. youngi* individuals were captured in mist nets near the cart oxen. However, approximately 30 m from where these oxens stayed overnight, the bird perches were covered with straw and unsealed wooden sides.

Two *D. rotundus* were also obtained during this capture session next to these animals, which had marks of aggression from the bats. Blood traces were not detected when the bird perch was inspected and bird examination was not possible.

Therefore, *D. youngi* may have crossed the perch but had to fly close to the cattle.

Feeding on the blood of birds was observed on the branches of a tree (mango tree, *Mangifera indica*) by *D. youngi* at another solid ground property. The tree was located adjacent to the sheepfold and six *D. rotundus* were captured. Some animals confined to this sheepfold showed signs of blood feeding by bats. Two additional *D. youngi* individuals were captured from different riparian areas. One was captured in nets set up around the perches as previously described, and a *D. rotundus* male was also captured.

Diaemus youngi individuals were captured in nets armed only on one side of the second property, in which a horse that exhibited signs of attack by bats was located; however, there were perches of birds in tree branches close to the animals. Another *D. rotundus* individual was also captured during the same session, but it was interrupted by the onset of rain.

DISCUSSIONS

Female *D. rotundus* individuals that were larger than males were also found in studies performed in colonies in northeast Brazil and São Paulo (Alencar *et al*., 1994; Arellano-Sota, 1988; Bredt , 1998; Novak , 1991). Having *D. rotundus* females and males of different sizes is a consequence of adaptive selection, in which larger females are better able to produce viable offspring than smaller ones. In addition, females would require a higher load capacity to compensate for the weight gained during pregnancy and to carry their offspring in the first months after birth, whereas males are subject to selection that does not require larger wings (Bredt , 1998; Dyce *et al*., 2004; Wilkinson , 1984).

Uieda (1992) reported that the highest frequency of individuals had dark brown coats on the back and whitish-brown coats on the chest, as identified in this study.

The late capture of *D. rotundus* during the new moon may indicate that the species of livestock used for blood feeding was a secondary source of food at that time because there was no moonlight throughout the night. Flores-Crespo (1976), Uieda (2008), Erkert (1982), and Uieda (1993) have described the influence of the lunar cycle on the activity of the species identified in this study. The factor that favored a greater number of captures in the early hours during the waning moon phase was that the darkest period occurred at these times, although many of the livestock used as bait were usually in places that offered protection for hematophagous bats from wind and moonlight, such as piggeries, covered sheepfolds, and pens close to the vegetation cover. However, in some sessions, capture was unsuccessful when strong winds foretelling rain began.

Pereira *et al*. (2010), Uieda (2008), and Bredt (1998) described the anatomical areas commonly affected by hematophagous bats, which were also observed in this study.

Although *D. rotundus* bats feed on cattle due to their wide availability in the environment, goats and horses are the species of choice (Uieda,1996). Furthermore, according to the authors, the species is sensitive to how it selects its prey and chooses targets that are docile. The authors also states that the choice of prey by hematophagous bats depends directly upon their availability to the predator ("the preferred animal is the most accessible"). Dogs are not usually prey for these bats, especially dogs that do not rest at night, because bats must be very careful when approaching active dogs.

According to Uieda (1996), *D. rotundus* individuals spend most of their time exploring their living areas and finding potential alternative food sources when their main prey source is lost because of relocation or herd sales, as well as performing other social interactions.

In general, the attacks remain the same in animals, even with a change in location, and monitoring the number of attacks occurs more often when the herd spends the night at property headquarters. In addition, younger cattle were more frequently targets of hematophagous bats than adults. Turner (1975) and Sazima (1978) described the behavior of *D. rotundus* relative to their more docile prey.

CONCLUSIONS

The work conducted in the municipality of Juruti showed that the morphobiometric characteristics of captured *D. rotundus* were within the ranges reported in the literature, with the presence of females that were larger than males and blood-feeding activity occurring in a wide area of that municipality.

Blood feeding by *D. rotundus* was more frequent in cattle, buffaloes, horses, goats, pigs, and birds; rare in dogs; and occasionally in people, whether in solid ground or riparian areas.

Moreover, the *D. rotundus* of the region belongs to a small group of individuals. *D. youngi* showed lower aggression than *D. rotundus*, and despite the small number of captured individuals, their size did not differ from that found in other studies of the species.

The *D. rotundus* feeding activity schedule was observed to be influenced by moonlight; this is not different from what is already known about the species' behavior, where they favor food sources in areas of trees, shadows, and shelters where livestock animals spend the night.

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