Feeding patterns of mosquitoes (Diptera: Culicidae) in six Brazilian environmental preservation areas

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Received 15 February 2012; Accepted 28 June 2012

ABSTRACT: Feeding patterns of mosquitoes in six Brazilian environmental preservation areas were analyzed by the precipitin technique. The mosquito populations were captured using Shannon traps during different time periods. Bird, cow, dog, horse, opossum, human, and rodent antisera diagnostic tests were employed and results were analyzed by calculating the Sørensen similarity index and using the null-model test. Of the 647 analyzed specimens, 443 reacted to the utilized antisera, of which 331 reacted to one blood source, with the most frequent being birds (49.4%); and 112 specimens reacted to two blood sources, with the most frequent combination from birds + rodents (14.3%). The feed profiles demonstrated that *Anopheles albitarsis*, *An. evansae*, *Aedes fulvus*, *Psorophora albigenu*, *Ps. albipes*, *Ps. ferox,* and *Mansonia titillans* fed predominantly on birds. The similarity index showed that in some localities *An. cruzii*, *Chagasia fajardi*, *Ae. scapularis*, *Ae. serratus*, *Haemagogus leucocelaenus, Ps. albigenu,* and *Ps. ferox* presented similar dietary habits. The null-models test indicated that species from SMSP, INP, CGNP, and THP demonstrated an aggregate pattern, while species from SONP and SBNP showed a random pattern. The mosquitoes fed predominantly on birds, but from an epidemiological standpoint, the eclectic feeding habits were found to be constant among the mosquitoes analyzed. ***Journal of Vector Ecology* 37 (2): 342-350. 2012.**

Keyword Index: Precipitin test, Culicidae, parks, Atlantic Forest, cerrado, Pantanal.

INTRODUCTION

The knowledge of mosquito feeding activity is of fundamental importance to evaluate their involvement in disease transmission, as well as to understand their biology in order to improve control efforts for certain species (Forattini et al. 1987). Interestingly, under natural conditions, the chosen food source for blood feeding is conditioned by factors in the region. In addition, the contact between the mosquito and the potential host is also influenced by multiple other factors, such as attempts to blood feed, refeeding and reaction behavior of the host (Defoliart et al. 1987).

The present study aimed to observe mosquito blood-feeding activity in different natural habitats to provide knowledge of the feed patterns of these species and how these patterns relate to the characteristics of the study area.

MATERIALS AND METHODS

Analyzed mosquito populations were taken from the following conservation areas of Brazil:

Serra dos Órgãos National Park (SONP), Rio de Janeiro, is located in the Atlantic Forest biome with vegetation phyto-physiognomy classified as lowland dense ombrophilous forest and is considered the most well preserved area of this vegetation type in the state of Rio de Janeiro and around the Atlantic Forest biome (CIDE 2004). The vegetation is rich in palm trees, epiphytes, and large trees, as well as in species diversity (Rizzini 1979). The SONP also contains a high diversity of fauna, with 462 bird, 83 mammal, 102 amphibian, 82 reptile, and six fish species having been recorded in the park (Lewinsohn 2006) (Table 1);

Serra do Mar State Park (SMSP), São Paulo, is also located in the Atlantic Forest biome, but with lowland dense ombrophilous forest vegetation cover forming in the coastal plains. To date, 1,265 vascular plant species have been recorded in the park area, with these species commonly being of newly seceding forests. Of the species registered in the Atlantic Forest, SMSP presents 53% of bird species (approximately 380 species), 39% of amphibian species (150 species), 40% of mammal species (approximately 130 species), and 23% of reptile species (approximately 60 species) (Table 1).

Serra da Bocaina National Park (SBNP), São Paulo, represents an important fragment of the Atlantic Forest domain in this study of upper montane dense ombrophilous forest vegetation cover and contains a wide diversity of vegetation types and large, continuous tracts of forest areas. The vegetation structure is composed of log and twig phanerophytes and the flora is represented by families of wide dispersion with up to 10 m in height (IBGE 1992). Forty species of non-flying mammals, as well as 294 bird species, have been listed as distributed in the Atlantic Forest of SBNP (Wege and Long 1995, Stotz et al. 1996) (Table 1).

Iguaçu National Park, Paraná (INP), which is located in the Atlantic Forest as well, is home to the largest and most important semi-deciduous forest area in the country. The INP is home to a variety of fauna. Overall data estimates there are around 800 species of butterflies, 70 species of fish, and approximately 25 species of amphibians in the park. Among reptile species, the number of species approaches 41 snake species, eight lizard species and three turtle species. Among birds, the number of species may reach 240 species, and for mammals, it is expected that the number of species reaches 50 (Table 1).

Chapada dos Guimarães National Park (CGNP), Mato Grosso, is part of the cerrado biome where various vegetation types can be found, including riparian forest, gallery forest, dry forest, savanna, classic cerrado, rough savannah (campo sujo), grassland (campo limpo), wetlands (vereda), and palms (Brasil 1982, Sano et al. 2008). The CGNP is located in the cerrado core and presents a wide variety of environments due to its variations in altitude (250 m to 800 m) and relief (hills, plateaus, and valleys). The sampling of aquatic insects covers 11 orders, with Diptera and Trichoptera being the most representative. In addition, 52 taxa of terrestrial invertebrates can be found in the park. Other records indicate at least 242 bird species in CGNP and 257 in the areas surrounding the park, as well as 76 species of mammals within and surrounding CGNP (Table 1).

Transpantaneira Highway Park (THP), Mato Grosso, is part of the Pantanal biome, with vegetation cover predominantly constituted by savanna subformations, riparian forest, and seasonally flooded fields (Campos-Filho, 1998). During the rainy season, which begins in the summer, the depressions are inundated, forming large lakes (bays) for approximately six months and having a noticeable presence of macrophytes. The system of ebbs and flows and high availability of food make the region an important site for feeding, resting, and breeding for many species. This ecosystem is considered one of the most important regions for waterfowl in the world, attracting migratory birds from the temperate region. The diversity of the fauna of the Pantanal includes around 90 species of mammals, 700 species of birds, 160 species of reptiles, 260 species of fish, and 45 species of amphibians (Table 1).

Species determination was by direct observation of morphological characters based on the dichotomous keys developed by Lane and Cerqueira (1942), Lane (1953a,b), Consoli and Lourenço-de-Oliveira (1994) and Forattini (2002). Precipitin tests were performed to determine the feeding profile of mosquito species caught in Shannon traps. Mosquitoes were triturated in test tubes containing saline solution (NaCl 0.85%) at pH 7.0 and were left to stand for 12 h at 4° to 8° C. Afterwards, the specimens were centrifuged at 1,800 rpm for 5 min. For the diagnosis of ingested blood, the precipitin technique developed by Lorosa et al. (1998) was used. The following antisera with their respective titles were used: bird 1:10,000 (*Gallus gallus domesticus*); cow 1:15,000 (*Bos taurus*); dog 1:15,000 (*Canis lupus familiaris*); horse 1:15,000 (*Equus ferus caballus*); opossum 1:15,000 (*Didelphis marsupialis*); human 1:10,000 (*Homo sapiens sapiens*); and rodent 1:15,000 (*Rattus rattus*). The antisera were selected according to the local fauna and the species of mosquitoes were selected according to their epidemiological importance and availability of specimens for testing.

The similarity between the food sources of mosquito species for each area was estimated based on the presence and absence of reaction to food sources using the Sørensen Similarity Index (SI). For this analysis, the response to one food source and the response to two food sources were considered. This index was calculated by the formula:

$$SI = 2c / a + b$$

where: a = food sources of a given species in a given area "a"; b = food sources of a given species in a given area "b"; and c = common food sources of species in the different areas.

The relationship between the species occurring in each

Table 1. Parks and their respective capture locations with latitude and longitude.

Park	Location	Latitude	Longitude	Altitude
SONP	Barreira Farm	S 22°29'18.19"	W 43°00'04.91"	492 m
SMSP	Site A - Rio da Fazenda	S 23°21'42.53"	W 44°50'38.85"	3 m
	Site B - Área pantanosa	S 23°21'48.89"	W 44°49'27.71"	19 m
	Site C - Bromélias	S 23°20'48.13"	W 44°50'54.81"	13 m
	Site D - Clareira	S 23°21'45.79"	W 44°49'26.54"	12 m
SBNP	Site A - Rio Mambucaba	S 22°45'07.79"	W 44°37'02.61"	1,522 m
	Site B - Vale	S 22°45'14.50"	W 44°37'34.35"	1,425 m
	Site C - Barreirinha	S 22°45'08.85"	W 44°43'54.80"	1,642 m
INP	Site A - Poço Preto	S 25°37'31.55"	W 54°27'38.60"	22 m
	Site B - Represa	S 25°37'14.27"	W 54°28'14.02"	184 m
	Site C - Vila	S 25°37'15.54"	W 54°28'33.71"	180 m
	Site D - Cataratas	S 25°40'54.72"	W 54°26'21.21"	215 m
CGNP	Site I - Véu de Noiva	S 15°24'19.08"	W 55°50'07.06"	590 m
	Site II - Cachoeira dos Namorados	S 15°24'26.08"	W 55°49'21.08"	601 m
	Site III - Casa de Pedra	S 15°25'46.05"	W 55°50'05.04"	645 m
THP	Point 1 - Pant I	S 16°39'54.03"	W 56°47'38.02"	114 m

park with hosts of the respective areas was assessed by the test for null-models. Based on definitions by Chaves et al. (2010), we analyzed presence/absence patterns using null-models analyses to test whether mosquito foraging occurs randomly or if mosquitoes obtain blood meals only from certain host species. Each hypothesis can be respectively supported by either random, segregated patterns in which some host species were fed upon only by some mosquito species, or aggregated patterns in which some host species were fed upon by all mosquito species. The fixed-equiprobable algorithm with 5,000 randomizations was used, and simulations were carried out using the software Ecosim 7.72 (Gotelli and Entsminger 2004).

RESULTS

Of the total number of specimens captured in the six areas, 647 adult female specimens were analyzed (Table 2). Of those, 443 (68.5%) reacted and 204 (31.5%) did not react to the antisera used (Table 2). Among the positive specimens, 331 (74.7%) reacted to one blood source (Figure 1a); 164 (49.5%), or almost half, of these specimens had fed on the blood of birds and 36 (10.9%) had fed on the blood of humans (Figure 1b). Additionally, 112 (25.3%) of the positive specimens reacted to more than one blood source (Figure 1a), with the most frequent combination of blood sources being bird + rodent (14.3%), followed by opossum + rodent (13.4%), bird + horse (10.7%), and bird + human (9.8%) (Figure 1c).

Regarding the general feeding patterns of each species, *Anopheles (Nyssorhynchus) albitarsis* Lynch-Arribalzaga, 1878, *An. (Nys.) evansae* (Brethes, 1926), *Aedes (Ochlerotatus) fulvus* (Wiedmann, 1828), *Psorophora (Janthinosoma) albigenu* (Peryassú, 1908), *Ps. (Jan.) albipes* (Theobald, 1907), *Ps. (Jan.) ferox* (Von Humboldt, 1819), and *Mansonia (Mansonia) titillans* (Walker, 1848) were observed to feed on birds as the main food source in all areas that occurred, i.e., of the 15 examined species, seven proved to be ornithophilous (Figure 2).

Anopheles (Kerteszia) cruzii Dyar and Knab, 1908 was found feeding mainly on birds, birds + rodents and opossums, and *Chagasia fajardi* Lutz, 1904 was found feeding particularly on birds and humans (Figure 2).

Haemagogus (Conopostegus) leucocelaenus (Dyar and Shannon, 1924), predominantly fed on birds, birds + horses and cows. *Aedes (Och.) scapularis* (Rondani, 1848) demonstrated eclecticism in feeding habits, feeding mostly on opossums, birds, humans, and rodents. *Aedes (Och.) serratus* (Theobald, 1901) principally fed on birds, birds + rodents, cows + horses, horses, and horses + humans. *Aedes (Protomacleaya) terrens* (Walker, 1856) fed predominately on birds, birds + rodents, cows + dogs, opossums, opossums + rodents, and humans. Finally, *Runchomyia (Runchomyia) theobaldi* (Lane and Cerqueira, 1942) principally fed on birds and opossum. *Trichoprosopon digitatum* (Rondani, 1848) showed predominance for birds + humans, horses + opossums, opossums, humans, and rodents blood sources (Figure 2).

The following species were found to present a similarity index considered acceptable (0.50 < SI <0.70) between the feeding habits in the following respective areas: *An. cruzii* in SONP x SBNP (SI = 0.50); *Hg. leucocelaenus* in INP x CGNP (SI = 0.67); *Ae. scapularis* in SONP x THP (SI = 0.57), INP x CGNP (SI = 0.50) and CGNP x THP (SI = 0.55); *Ae. serratus* in SMSP x SBNP (SI = 0.50); *Ps. albigenu* in CGNP x THP

Table 2. Absolute numbers of mosquito specie s used in precipitin tests and their respective locations of origin.

Species	SONP	SMSP	SBNP	INP	CGNP	THP	Total	NR*
An. albitarsis	-	-	-	14	-	26	40	16
An. cruzii	11	6	16	-	-	-	33	14
An. evansae	-	-	-	17	17	10	44	20
Ch. fajardi	-	-	7	21	12	-	40	15
Ae. fulvus	-	16	-	-	7	-	23	10
Ae. scapularis	22	10	-	16	22	7	77	25
Ae. serratus	-	17	10	17	-	-	44	19
Ae. terrens	6	4	5	-	-	-	15	4
Hg. leucocelaenus	8	-	15	9	-	-	32	10
Ps. albigenu	-	-	-	11	21	32	64	11
Ps. albipes	-	17	-	4	-	-	21	7
Ps. ferox	-	23	17	19	20	-	79	25
Ma. titillans	-	-	-	16	-	73	89	6
Ru. theobaldi	18	-	13	-	-	-	31	15
Tr. digitatum	10	-	-	5	-	-	15	7
Total	75	93	83	201	99	148	647	
NR*	30	38	26	52	37	21		204

*Number of non-reactive specimens.

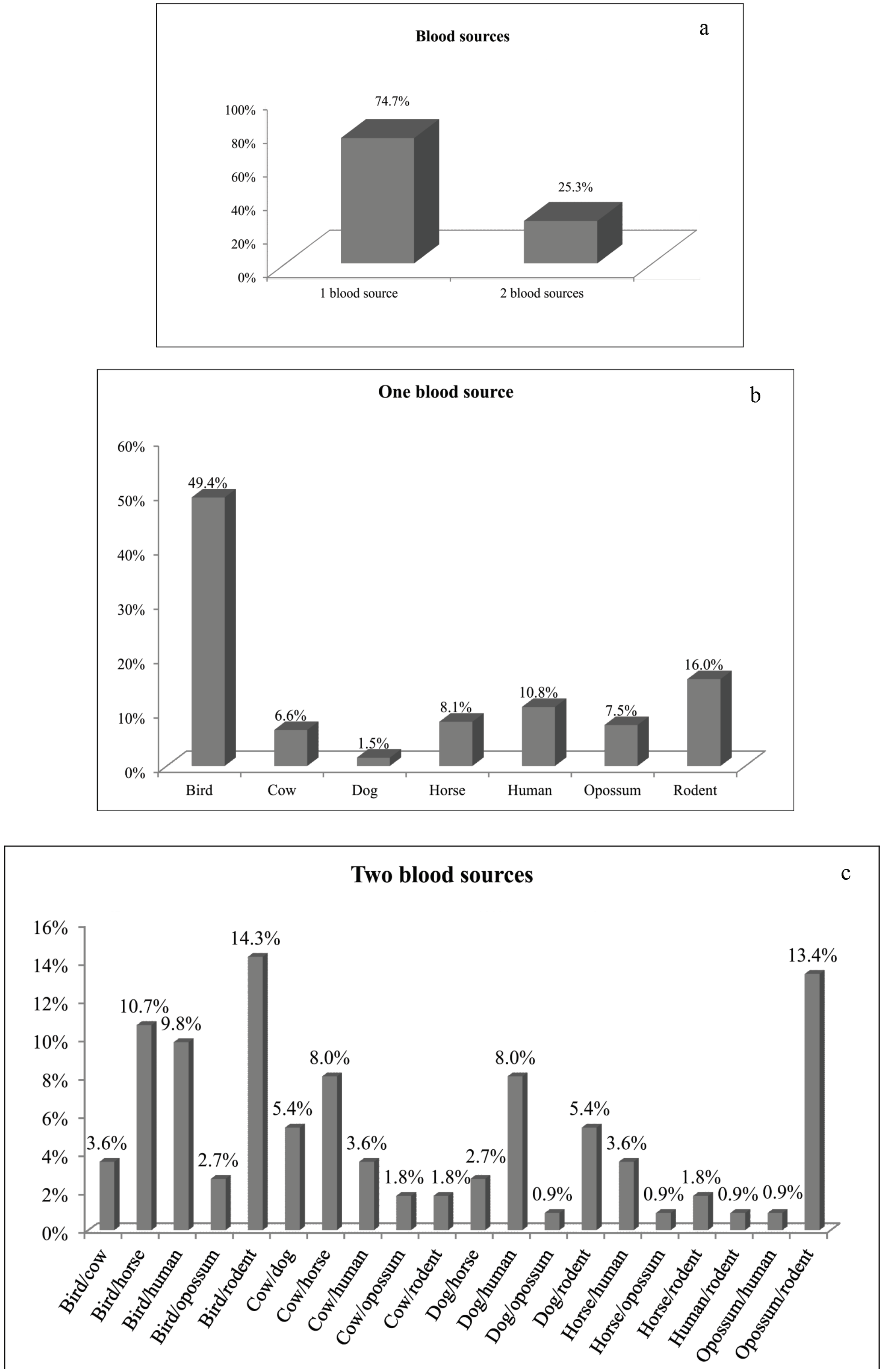

Figure 1. Identification of blood ingested by captured Culicidae females in the six study areas, considering: a) the total numbers for both one and two blood sources; b) the total numbers for one blood source; and c) the total numbers for two blood sources.

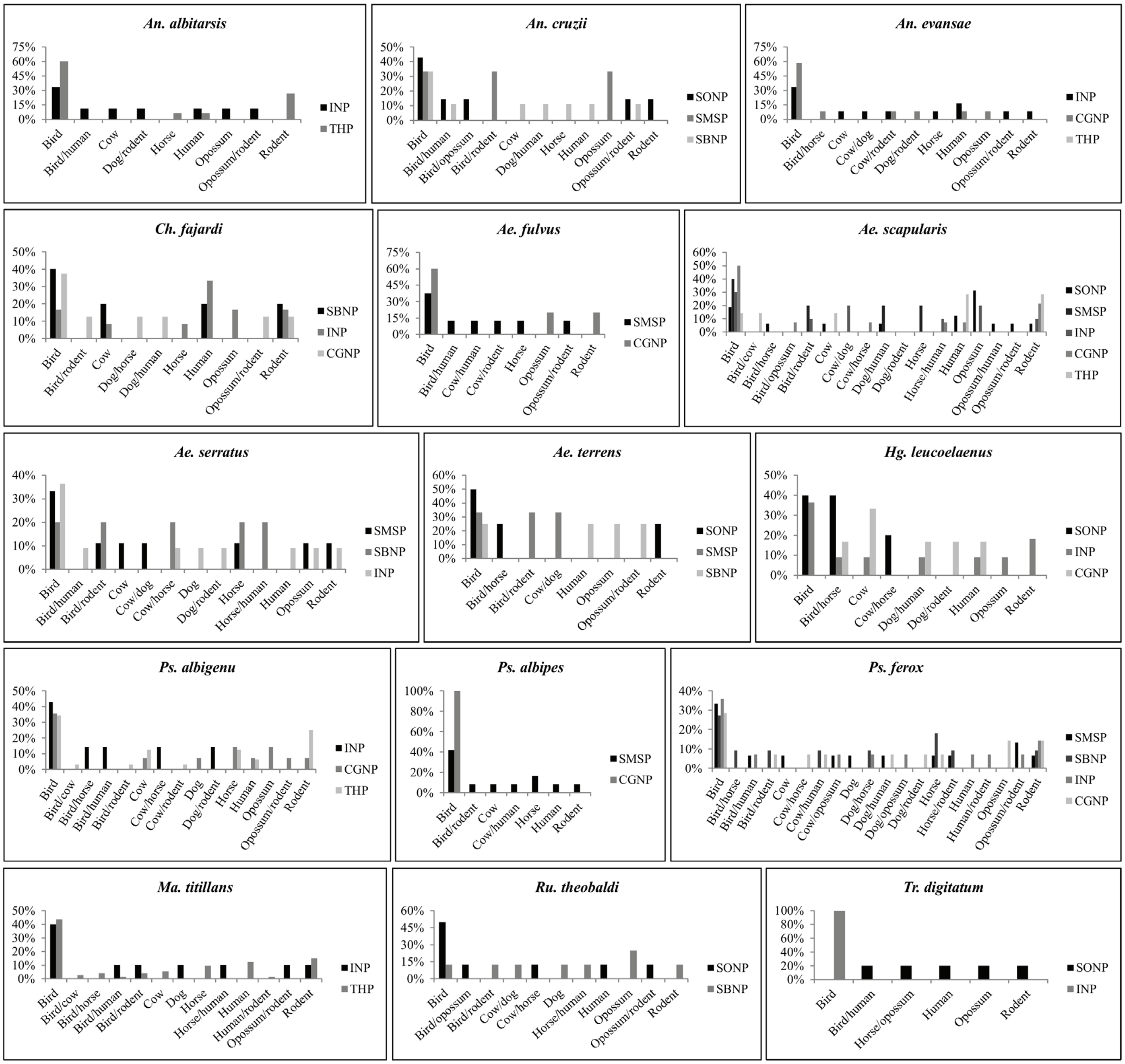

Figure 2. Mosquito species and identification of blood ingested for each of the six conservation areas studied, considering the total numbers for both one and two blood sources.

(SI = 0.63); and *Ps. ferox* in SMSP x INP (SI = 0.53). For *Ch. fajardi*, the similarity index was considered appreciable (0.70 < SI <0.90) between SBNP x INP (SI = 0.80). Moreover, the value of the index found between these two areas was the highest among the species analyzed. However, the other species did not show strong similarity between the blood sources in the areas in which they occurred.

Based on the work of Chaves et al. (2010), species of mosquitoes were analyzed according to their hosts in each site of occurrence to assess whether dietary patterns of different species in the same areas were random or structured. According to the analysis, species from SMSP, INP, CGNP, and THP presented an aggregate pattern, while the species from SONP and SBNP demonstrated a random pattern (Table 3).

DISCUSSION

Anopheles albitarsis fed predominantly on birds in both INP and in THP. However, Deane et al. (1948), Deane et al. (1949), and Lourenço-de-Oliveira and Heyden (1986) observed a high degree of zoophilia in this species, suggesting they prefer to attack animals such as equines. Lucena (1950) also reported that this species demonstrates predominance for feeding on large animals, such as cow and horses. These observations differ from what was observed in this study in the areas of INP and THP. This species occurred exclusively in areas where all the species showed aggregate patterns, indicating that this species fed principally on hosts that occurred with greater availability in each area.

In SONP and SBNP, *An. cruzii* fed principally on birds but fed on birds, birds + rodents and opossum in SMSP. In agreement with the findings of Consoli and Lourenço-de-Oliveira (1994), this species is very eclectic and opportunistic, indiscriminately attacking humans, other mammals, birds, etc., and in this case, this species was found reacting to six unique sources and five pairs of sources. Classical studies on mosquito blood-feeding behavior have shown that some mosquitoes can be opportunistic with regard to their feeding choices (Edman 1988). The tendency of this species to be acrondendrophilic (Deane et al. 1971, Gomes et al. 1987) allowed for the majority of its contact to be with birds in some cases, and, thus, the species reacted more to this source.

Anopheles evansae also showed a greater reaction to bird antiserum in INP and CGNP (aggregate pattern). Considered to be zoophilic by Consoli and Lourenço-de-Oliveira (1994), and in the studies by Azevedo et al. (2005) on the island of São Luís, Maranhão, the animals most fed on were birds, despite also presenting a large variety of food sources.

Following Galindo and Trapido (1957), *Ch. fajardi* presented strictly zoophilic behavior. However, despite having fed mainly on birds in SBNP and CGNP, in INP this species reacted with the highest percentage to human antiserum, a result previously observed by Alencar et al. (2005a) when analyzing specimens from the same capture. This species proved to be reasonably eclectic, responding to six unique sources and four pairs of sources. In this case, since INP is one of the parks with the highest amount of public visitation, having numerous tourist attractions, this park could be considered to have a potentially higher possibility of feeding on human blood by these specimens.

Understanding the feeding profile of *Hg. leucocelaenus* is of extreme public health importance since this species is a known vector for the pathogen of yellow fever. In SONP, INP, and CGNP, there was a higher positivity for bird and bird + horse, bird, and cow antisera, respectively. Unlike what was observed by Davis (1945), who reported that this species was more attracted to primates, this attraction for birds is supported by Alencar et al. (2008), who also considered the abundance of hosts as an important influencing factor. This species has displayed a preference for the higher parts of the forest, where the transmission cycle takes place mainly at the level of the tree canopy (Forattini 1965), facilitating blood feeding on birds. However, in general, this species has proved to be eclectic, obtaining high percentages even for cows and horses. This high positivity for cow and horse antisera evident in the area of CGNP may be related to the habit of nearby livestock farmers releasing their herds during the day in these areas.

Aedes fulvus fed predominately on birds in SMSP, as well as in CGNP. These are also two areas which demonstrated an aggregate pattern. The females of this species, both as aggressive on the ground as in the tree canopy, are considered more zoophilic than anthropophilic (Consoli and Lourenço-de-Oliveira 1994).

In accordance with Forattini et al. (1987), Forattini et al. (1989), Forattini et al. (1990), Teodoro et al. (1994), Forattini (2002), Gomes et al. (2003) *Ae. scapularis* is eclectic and opportunistic regarding its choice of host, with a tendency

Table 3. Feeding patterns of different species of mosquitoes by capture location.

Area	C-score	Mean ± Variance	P < exp	P > exp	Pattern
SONP	7.867	8.259 ± 1.722	0.372	0.644	Random
SMSP	8.476	11.682 ± 2.026	0.017	0.983	Aggregate
SBNP	12.600	14.338 ± 3.531	0.178	0.828	Random
INP	13.000	17.80016 ± 1.672	0.001	0.999	Aggregate
CGNP	8.643	10.840 ± 1.467	0.048	0.954	Aggregate
THP	0.833	4.638 ± 2.389	0.006	0.996	Aggregate

to attack large mammals, including humans. Lourenço-de-Oliveira and Heyden (1986) and Mitchell et al. (1987) considered *Ae. scapularis* as a species with a wide host range. Forattini et al. (1989) states that the predominance of large mammals as the blood sources of this species is due to the abundance of these animals in the study area, a fact which also may have occurred in this study with the available hosts. On this occasion, in SMSP, INP, and CGNP, the species predominantly reacted to bird antiserum, while in SONP and in THP, the species reacted to opossum, and human and rodent antisera, respectively. The reaction to the eleven pairs of sources is of great epidemiological interest since it indicates the potential capacity for transmission of disease pathogens.

In SMSP and INP (aggregate pattern), *Ae. serratus* predominately fed on birds. Forattini et al. (1987) also observed notable ornitophilia in *Ae. serratus* specimens from Vale da Ribeira, São Paulo. However, in SBNP, there was no reaction to one specific source, confirming the assertions of Forattini et al. (1989), Forattini et al. (1990), Consoli and Lourenço-de-Oliveira (1994), and Forattini (2002), which considered this species to be very eclectic regarding its blood feeding habits. As already noted, the species of SBNP showed a random pattern with the absence of a specific host in abundance, leading to the conclusion that this species fed from several sources. *Aedes serratus* reacted to seven unique sources and six pairs of sources. In SONP, *Ae. terrens* also reacted principally to bird antiserum, but in SMSP and SBNP, predominance was not obtained by any particular source.

Ps. albigenu reacted to seven unique sources and eight pairs of sources and principally fed on bird blood in INP, CGNP, and THP (aggregate pattern). However, Forattini et al. (1987), when analyzing certain specimens of *Ps. albigenu*, verified the predominance of human blood. Presenting the same behavior, *Ps albipes* in SMSP and CGNP (aggregate pattern) and *Ps. ferox* in SMSP, INP, CGNP (aggregate patterns), and SBNP (random pattern) reacted predominately to bird antiserum. Forattini et al. (1989) observed distinct behavior by *Ps. ferox*, which reacted principally to human blood, and, in observations by Tissot and Navarro-Silva (2004) and Molaei et al. (2008), reacted to mammal blood. Although, the apparent prevalence of the mammals as hosts for this species in the studies of Molaei et al. (2008) is likely a function of deer abundance and availability in the region of the northeastern United States. In this study, females of the subgenus *Janthinossoma*, which are considered to be zoophilic and opportunistic (Consoli and Lourenço-de-Oliveira 1994), proved to be eclectic as well, with a tendency for bird blood.

Also showing an eclectic hematophagy, *Ma titillans* fed predominantly on birds in INP and THP, supporting the report of Aitken (1968), which classified the genus *Mansonia* as ornithophilic. In this case, this species was also influenced by the abundance of birds in relation to other hosts in these locations. The eclecticism observed in the reactions to six unique sources and seven pairs of sources also was consistent with Lourenço-de-Oliveira and Heyden (1986) and has been reported by Forattini (2002) as well.

Runchomyia theobaldi was observed feeding mainly on birds in SONP and on opossums in SBNP. Davis (1945) and Guimarães et al. (1987), working with animal lures, observed the opportunism of this species to feed mainly on humans. However, Consoli and Lourenço-de-Oliveira (1994) reported that this species bites humans and other mammals with a certain "timidness." Having very eclectic behavior, *Tr. digitatum* did not present any specific reaction to a food source in SONP; however, in SBNP, this species reacted exclusively to bird antiserum. According to Consoli and Lourenço-de-Oliveira (1994), this species can be found in altered environments biting humans and domestic animals, but does not prefer the blood of birds. However, in studies with animal lures, this species was found to commonly bite humans, but also to attack opossums and chickens as well (Guimarães et al. 1987). In this analysis, both *Ru. theobaldi* and *Tr. digitatum* occurred in only two places where the pattern was random and not associated with innate preferences.

This analysis has allowed for insight into the feeding patterns of certain species of Culicidae in the six study areas. Furthermore, information regarding mosquitoes which seek humans to complete their blood meal after having previously fed on other hosts, represented here by pairs of reactions to antisera, is of great epidemiological interest. The dietary eclecticism is directly linked to the potential capacity by these Culicidae to transmit infectious agents (Forattini et al. 1989).

Some species demonstrated similarity with regard to food sources in the regions under study. However, due to the eclecticism observed regarding the habit of these species, few exhibited similarity with regard to food sources in the areas in which they occurred. This eclecticism found among the species can be understood by the test results of null-models, since in each location they were associated with availability of a host.

The test for null-models indicated that the species from the parks of SMSP, INP, CGNP, and THP have aggregate patterns, in other words, the species in each of these communities share at least one host. The aggregate pattern indicates that the species are more closely related to the availability of the host than to any type of innate preference (Edman and Taylor 1968, Edman and Spielman 1988). Other authors have reported as well, that in each habitat, the feeding pattern of most species corresponded with the abundance of primary hosts (Tempelis and Washino 1967, Edman 1971, Mitchell et al. 1987, Forattini et al. 1989). In SONP and SBNP, the pattern was random, i.e., there was no specific host for any of the species. Murdoch et al. (2003) and Chaves et al. (2010) associated the random pattern in samples from only one location, as in the case of SONP, to the lower supply of resources, considered here as restricted habitats. These results demonstrate that beyond the fact that there is no preference for a particular host, the patterns are associated with availability of these hosts.

The species *An. albitarsis*, *An. evansae*, *Ae. fulvus*, *Ps. albigenu*, *Ps. albipes,* and *Ma. titillans* occurred exclusively in SMSP, INP, CGNP, and THP, which were the areas where all the species showed agreggate patterns. These results indicate these species fed exclusively on hosts that occurred with greater availability in each area. On the other hand, the species *Ru. theobaldi* and *Tr. digitatum* occurred in the only two places where the pattern was random.

In general, the mosquitoes fed predominantly on birds, which characterizes them as ornitophilic. However, when observing the description of the species in each area together with the results obtained in the null-models test, the feeding pattern of the species can be confirmed to be associated with the availability of hosts, which in the case of this study was the birds, having been abundant in all the locations studied. Moreover, in collaboration with the findings of Chaves et al. (2010), most mosquito species were able to feed on at least one common host species independently of their innate preferences. And yet, especially when compared to earlier studies, no pattern indicating an innate preference for any of the species in any of the locations was able to be observed, which also indicates the same species can feed predominantly on different hosts.

From an epidemiological point of view, the eclecticism in the feeding habits of captured mosquitoes was found to be consistent in the six study areas. Such eclecticism was favored by the diversity of wildlife used as a food source for these mosquitoes (Alencar et al. 2005b). Beyond the intrinsic capacity of each species to locate and effectively feed on a larger or smaller number of hosts, the existence of multiple extrinsic factors that influence and guide this hematophagy should be considered as well (Forattini et al. 1987). Among these factors, defensive behavior can explain site selection for bites on a given host (Walker and Edman 1985, Edman and Scott 1987, Edman 1988), which include the irritability and reactivity of hosts, birds and rodents that are more likely to interrupt the blood meal (Forattini et al. 1987). In accordance with this observation, we found the bird + rodent reaction combination to occur most frequently. Knowledge of mosquito feeding activity and dietary preferences in the areas studied allow the participation of these species in the cycle of disease transmission to be identified.

REFERENCES CITED

Aitken, T.H.G., C.B. Worth, and E.S. Tikasingh. 1968. Arbovirus studies in bush Forest, Trinidad, W.I., Setember 1959 - December 1964 III - Entomologic studies. Am. J. Trop. Med. Hyg. 17: 253-268.

Alencar, J., E.S. Lorosa, J.S. Silva, H. Gil-Santana, and A.E. Guimarães. 2005a. Fontes alimentares de *Chagasia fajardi* (Lutz, 1904) (Diptera, Culicidae) de diferentes regiões do Brasil. Rev. bras. Zoociências 7: 181-184.

Alencar, J., E.S. Lorosa, J.S. Silva, C.M. Lopes, and A.E. Guimarães. 2005b. Observations on feeding patterns among mosquitoes (Diptera: Culicidae) in the Pantanal, MT, Brazil. Neotrop. Entomol. 34: 681-687.

Alencar, J., C.B. Marcondes, N.M. Serra-Freire, E.S. Lorosa, J.B. Pacheco, and A.E. Guimarães. 2008. Feeding Patterns of *Haemagogus capricornii* and *Haemagogus leucocelaenus* (Diptera: Culicidae) in two Brazil States (Rio de Janeiro and Goiás). J. Med. Entomol. 45: 873-876.

Azevedo, P.C.B., G.C. Vasconcelos, J.A.C. Mendonça, J.A.B. Maioba, F.O.P. Dias, G.B. Sousa, A.S. Pereira, E.M.L. Silva, L.M. Andrade, R.S. Fonteles, J.L.P. Moraes, G.A. Amorim, E.S. Lorosa, R.V. Rocha, and J.M.M. Rebêlo. 2005. Identificação de fontes alimentares sanguíneas de espécies do gênero *Anopheles* (Diptera: Culicidae) da Ilha de são Luís-MA, Brasil. Anais do VII Congresso de ecologia do Brasil, Caxambú, MG.

Brasil. 1982. Projeto RADAMBRASIL. Folha SD.21 Cuiabá: geologia, geomorfologia, pedologia, vegetação e uso potencial da terra. Ministério das Minas e Energia, Departamento Nacional de Produção Mineral, Rio de Janeiro. 544 pp.

Campos-Filho, L.V. 1998. Projeto PRODEAGRO-FEMA/MT. As atividades artesanais tradicionais de Poconé-MT. "Plano Diretor de Mineração de Poconé-MT". Sub Componente Sócio Econômico: B2-regularização e Racionalização de Atividades Mineradoras. Cuiabá, 81 pp.

Chaves, L.F., L.C. Harrington, C.L. Keogh, A.M. Nguyen, and U.D. Kitron. 2010. Blood feeding patterns of mosquitoes: random or structured? Front. Zool. 7: 1-11.

CIDE. 2004. *IQM-Verde II: Índice de Qualidade Ambiental dos municípios do Estado do Rio de Janeiro*. Fundação Centro de Informações e Dados do Rio de Janeiro.

Consoli, R.A.G.B. and R. Lourenço-de-Oliveira. 1994. *Principais Mosquitos de Importância Sanitária no Brasil*. Editora Fiocruz, Rio de Janeiro, 228 pp.

Davis, D.E. 1945. A comparison of mosquitoes captured with avian bait and with human bait. Proc. Entomol. Soc. Wash. 47: 252-256.

Deane, L.M., O.R. Causey, and M.P. Deane. 1948. Notas sobre a distribuição e a biologia dos anofelinos das regiões nordestina e amazônica do Brasil. Rev. Ser. Esp. de Saúde Pública 1: 827-965.

Deane, L.M., M.P. Deane, J.A. Ferreira-Neto, and F.B. Almeida. 1971. On the transmission of simian malaria in Brazil. Rev. Inst. Med. Trop. 13: 311-319.

Deane, L.M., C.S. Vernin, and R.G. Damasceno. 1949. Avaliação das preferências alimentares das fêmeas de *Anopheles darlingi* e *Anopheles aquasalis* em Belém, Pará, por meio de provas de precipitina. Rev. Serv. Esp. Saúde Públ. 2: 793-808.

DeFoliart, G.R., P.R. Grimstad, and D.M. Watts. 1987. Advances in mosquito-borne arbovirus/vector research. Ann. Rev. Entomol. 32: 497-505.

Edman, J.D. 1971. Host-Feeding Patterns of Florida Mosquitoes I. *Aedes*, *Anopheles*, *Coquillettidia*, *Mansonia*, and *Psorophora*. J. Med. Entomol. 8: 687-695.

Edman, J.D. 1988. Disease control through manipulation of vector-host interaction: some historical and evolutionary perspectives. In: Scott T.W., and J. Grumstrup-Scott. The Role of vector-host interactions in disease transmission. Entomological Society of America, Landover, Maryland, 43-50.

Edman, J.D. and D.J. Taylor. 1968. *Culex nigripalpus* - Seasonal Shift in Bird-Mammal Feeding Ratio in a Mosquito Vector of Human Encephalitis. Science 161: 67-68.

Edman, J.D. and T.W. Scott. 1987. Host defensive behavior and the feeding success of mosquitoes. Insect Sci. Appl. 8: 617-622.

Edman, J.D. and A. Spielman. 1988. Blood-feeding by vectors: physiology, ecology, behavior, and vertebrate defense. In: T.P. Monath (ed.) *The Arboviruses: Epidemiology and Ecology*, CRC Press. Boca Raton, Florida. 1: 153-189.

Forattini, O.P. 1965. *Entomologia Médica*. 3º Volume, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, 416 pp.

Forattini, O.P. 2002. *Culicidologia Médica*. 2º Volume: Identificação, Biologia, Epidemiologia. Editora da Universidade de São Paulo, São Paulo, 860 pp.

Forattini, O.P., A.C. Gomes, D. Natal, I. Kakitani, and D. Marucci. 1987. Preferências alimentares de mosquitos Culicidae no Vale da Ribeira, São Paulo, Brasil. Rev. Saúde Pública 21: 171-187.

Forattini, O.P., A.C. Gomes, D. Natal, I. Kakitani, and D. Marucci. 1989. Preferências alimentares e domiciliação de mosquitos Culicidae no Vale do Ribeira, São Paulo, Brasil, com especial referência a *Aedes scapularis* e a *Culex (Melanoconion)*. Rev. Saúde Pública 23: 9-19.

Forattini, O.P., A.C. Gomes, J.L.F. Santos, I. Kakitani, and D. Marucci. 1990. Frequência ao ambiente humano e dispersão de mosquitos Culicidae em área adjacente à mata Atlântica primitiva da planície. Rev. Saúde Pública 24: 101-107.

Galindo, P. and H. Trapido. 1957. Forest mosquitoes associated with sylvan yellow fever in Nicarágua. Amer. J. Trop. Med. Hyg. 6: 145-152.

Gomes, A.C., O.P. Forattini, and D. Natal. 1987. Composição e atividade de mosquitos Culicidae. Emprego de armadilha CDC no Vale do Ribeira, Estado de São Paulo, Brasil. Rev. Saúde Pública 21: 363-370.

Gomes, A.C., N.N. Silva, G.R.A.M. Marques, and M. Brito. 2003. Host-feeding patterns of potential human disease vectors in the Paraíba Valley region, State of São Paulo, Brazil. J. Vector Ecol. 28: 74-78.

Gotelli, N.J. and G.L. Entsminger. 2004. EcoSim: Null models software for ecology. Version 7. Acquired Intelligence Inc. and Kesey-Bear. Jericho, VT 05465.

Guimarães, A.E., M. Arlé, and R.N.M. Machado. 1987. Mosquitos no Parque Nacional da Serra dos Órgãos, Estado do Rio de Janeiro, Brasil. IV- Preferência Alimentar. Mem. Inst. Oswaldo Cruz 82: 277-285.

IBGE - Fundação Instituto Brasileiro de Geografia e Estatística. 1992. *Manual Técnico da Vegetação Brasileira. Séries Manuais Técnicos em Geociências*. Fundação Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro, Rio de Janeiro. 94 pp.

Lane, J. and N.L. Cerqueira. 1942. Os Sabetíneos da América. Arch. Zool. Est. São Paulo 3: 473-849.

Lane, J. 1953a. *Neotropical Culicidae*. 1º Volume. Editora Universidade de São Paulo, São Paulo, 548 pp.

Lane, J. 1953b. *Neotropical Culicidae*. 2º Volume. Editora Universidade de São Paulo, São Paulo, 1112 pp.

Lewinsohn, T.M. 2006. *Avaliação do Estado do Conhecimento da Biodiversidade Brasileira*. 2º Volume. Ministério do Meio Ambiente, Brasília. 269 pp.

Lorosa, E.S., S.M. Andrade, S.M. Santos, and C.A. Pereira. 1998. Estudo das fontes alimentares através da reação de precipitina e grau de infectividade em *Triatoma rubrofasciata* (De Geer, 1973) coletados na Ilha de São Luiz, Maranhão. Entomol. Vect. 5: 241-250.

Lourenço-de-Oliveira, R. and R. Heyden. 1986. Alguns aspectos da ecologia dos mosquitos (Diptera: Culicidae) de uma área de planície (Granjas Calábria) em Jacarepaguá, Rio de Janeiro. IV- Preferências alimentares quanto ao hospedeiro e frequência domiciliar. Mem. Inst. Oswaldo Cruz 81: 15-27.

Lucena, D.T. 1950. Hábitos domiciliares do *Anopheles tarsimaculatus* Goeldi, 1905. Rev. Bras. Malariol. D. Trop. 2: 239-260.

Mitchell, C.J., T.P. Monath, M.S. Sabattini, H.A. Christensen, R.F Darsie Jr., W.L. Jakob, and J.F. Daffner. 1987. Host-feeding patterns of Argentine mosquitoes (Diptera: Culicidae) collected during and after an epizootic of western equine encephalitis. J. Med. Entomol. 24: 260-267.

Molaei, G., T.C. Andreadis, P.M. Armstrong, and M. Diuk-Wasser. 2008. Host-feeding patterns of potential mosquito vectors in Connecticut, USA: Molecular Analysis of Bloodmeals from 23 species of *Aedes*, *Anopheles*, *Culex*, *Coquillettidia*, *Psorophora*, and *Uranotaenia*. J. Med. Entomol. 45: 1143-1151.

Murdoch, W.M., C.J. Briggs, and R.M. Nisbet. 2003. *Consumer-Resource Dynamics*. Princeton University Press, Princeton, 456 pp.

Rizzini, C.T. 1979. *Tratado de Fitogeografia do Brasil - Aspectos Sociológicos e Florísticos*. Editora HUCITEC/EDUSP, São Paulo, São Paulo. 374 pp.

Sano, S.M., S.P. Almeida, and J.F. Ribeiro. 2008. *Cerrado: Ecologia e Flora.* 1º Volume. Embrapa Informação Tecnológica, Brasília, DF.

Stotz, D.F., J.W. Fitzpatrick, T.A. Parker III, and D.K. Moskovits. 1996. *Neotropical Birds: Ecology and Conservation*. University of Chicago Press, Chicago. 502 pp.

Tempelis, C.H. and R.K. Washino. 1967. Host-feeding patterns of *Culex tarsalis* in the Sacramento Valley, California, with notes on other species. J. Med. Entomol. 4: 315-318.

Teodoro, U., A.L.F. Guilherme, A.L. Lozovei, F.V. Salvia, A.A. Sampaio, R.P. Spinosa, M.E.M.C. Ferreira, O.C. Barbosa, and E.M. Lima. 1994. Mosquitos de ambientes peri e extradomiciliares na região sul do Brasil. Rev. Saúde Pública 28: 107-115.

Tissot, A.C. and M.A. Navarro-Silva. 2004. Preferência por hospedeiro e estratificação de Culicidae (Diptera) em área de remanescente florestal do Parque Regional do Iguaçu, Curitiba, Paraná, Brasil. Rev. Bras. Zool. 21: 877-886.

Walker, E.D. and J.D. Edman. 1985. Feeding-site selection and blood-feeding behavior of *Aedes triseriatus* (Diptera, Culicidae) on rodent (Sciuridae) hosts. J. Med. Entomol. 22: 287-294.

Wege, D.C. and A.J. Long. 1995. Key areas for threatened birds in the neotropics. Birdlife Conservation Series, Cambridge 5: 75-80.