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Bat diversity of forests and open areas in a subtropical region of South Brazil

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Resumen. *El objetivo de este trabajo fue determinar la diversidad de murciélagos y su composición en áreas boscosas de diferente tamaño (680, 60 y 6.2 hectáreas) y en áreas abiertas. En 2 años de muestreos periódicos con redes de espera, fueron capturados 1111 individuos de 19 especies. En el bosque de 680 ha, fueron capturados 242 individuos, de 15 especies, mientras que en un período igual y con el mismo esfuerzo de captura fueron encontrados en áreas abiertas 399 individuos pertenecientes a sólo 6 especies. Esto muestra la influencia de la deforestación sobre la eliminación de especies. Los resultados sugieren que debe preservarse los bosques remanentes para desacelerar la desaparición de estos animales.*

Abstract. *The objective of this paper was to examine the variation in bat diversity and composition in forest areas of diferent size (680, 60, and 6.2 hectares) and in open areas of South Brazil. In two years of periodic collections with mist-nets, 1111 bats representing 19 species were captured in all sites. In the 680 ha. forest, 242 individuals belonging to 15 species were captured. In the same time period, with the same amount of effort, only 6 species, with 399 individuals were found in the open areas. This shows the influence of deforestation on the elimination of species. It can be concluded that the preservation of remaining forest is necessary to decelerate the disappearance of the animals.*

Introduction

It is known that human activities threaten habitats, and consequently, animal species. Lewin (1984) showed that the destruction of the environment has never been so massive or far reaching, occuring on a global scale in a frenzy of relentless development. Burning and deforestation drastically alter the conditions of life for animal and plant species. The situation becomes even worse when one considers that tropical forests are being destroyed by humans at the rate of 20 hectares per minute. Even in national parks of the United States, in the past few years, 42 species of mammals have become extinct (Schierholz 1991). This author explains that the probable reason for the species extinction is that parks are isolated islands of forest, damaged around their borders by human action. The damages, according to ecologists, cause deterioration of the ecosystem, failure of equilibrium, and consequently, faunal collapse. Schierholz (1991) has also shown that species extinction varies inversely with habitat size.

In the great majority of cases, because of lack of knowledge about the biology of animal groups, it is difficult to understand the effects of deforestation on them. In addition, it is not known how large an area should be to preserve species. (Diamond 1976, Simberloff and Abele 1982, Terborgh 1976, Higgs and Usler 1980, Lewin 1984, Fonseca 1991, Schierholz 1991).

In the present study, bats are the focus of interest because of their known importance in the maintenance of forests. These animals disperse the seeds of up to 25% of the trees in tropical forests (Humphrey and Bonaccorso 1979), playing an important role as well in the pollinization of at least 500 neotropical plant species (Vogel 1969). The objective of this work is to study the variation in bat diversity and composition in forested areas of diferent size and in open areas.

Materials and Methods

The county of Londrina is located in the north of the state of Parana, South Brazil, close to the Tropic of Capricorn, in an area topographically favorable for agricultural use. It is situated between 23° and 33^0 S Lat. and 51 ° and 11 ° W Long. It has humid subtropical climate with a median annual temperature of 22°C and an average rainfall between 1400 and 1600 mm. This information was obtained from the Agronomy Institute of Parana (IAPAR), based on data taken from the Meteorological Station of the Ministry of Agriculture (1978).

The sites of capture were: one in open areas (university campus), and three in the remaining forests of approximately 6.2 ha. (Regina farm), 60 ha. (Arthur Thomas Municipal Park), and 680 ha. (Mata do Godoy State Park). The university campus contains scattered native trees such as "Peroba" (*Aspidosperma polyneuron*) and fig (*Ficus luschnatiana*), and introduced trees such as the African tuliptree (*Spathodea campanulata*) and "Sibipiruna" (*Caesalpinia peltophoroides*). There are also introduced bushes and shrubs such as hibiscus (*Hibiscus* sp.), lilies (*Hyppeastrum* sp. and *Hemerocallis* sp.), as well as fruits such as "pitanga", the Surinam cherry (*Eugenia uniflora*), guava (*Psidium guayava*), and blackberry (*Morus nigra*). In the non-urbanized areas, species of the families Piperaceae, Moraceae, Cecropiaceae, and Solanaceae can be found.

Because they are located in the same region and exhibit the same soil type and climatic conditions, the collection sites in the forested areas display the same phyto-physionomical characteristics. This type of forest was described by Soares Silva (1990) as distinctly stratified, because height differences among species are quite large. There is an understory layer of 5 to 8 meters, as well as emergent species like *A. polyneuron, F. luschnatiana,* and *Gallesia integrifolia.* The species with the greatest number of individuals per area are: "palmito" (*Euterpe edulis*), with 138 trees per ha., and *A. polyneuron,* with 81 trees per ha. The species with the highest biomass are: *A. polyneuron* (28%), *F. luschnatiana* (9.8%), and *Crotom floribundus* (7.4%).

Of the three chosen areas, the largest (Mats do Godoy) is the last reserve of primary forest in the region. Arthur Thomas Park, the second largest, is located within the urban perimeter of the city of Londrina. This forest is seriously endangered, as it is open to public use as a leisure area, and thus cut by many paths, causing significant alteration of the flora and fauna. The forest of the Regina farm, with just 6.2 ha., is intact, bordered by areas of pasture and agriculture. Summer crops in these areas are soybean and corn, and the winter crop is wheat.

The collection method was adapted from Greenhall and Paradiso (1968), and Goodwin and Greenhall (1961). Only those bats that fly at the height of the extended nets, that is, from 0.5 to 2.0 meters above ground, were caught. Collections occurred during the first 3 hours of darkness (Reis 1984) for all areas. The first round of animal capture was determined with the aid of an ICEL Luximetro, model LD.500, in order to standardize the quantity of light during the four seasons of the year. By doing like this in all areas, an equivalent sampling effort was achieved.

Only 2 specimens of each species were killed, fixed in 10% formaldehyde, and preserved in 70% alcohol. The same bats were indentified using the keys of Viera (1942), Vizoto and Taddei (1973), and Jones and Carter (1976). Confirmation of the indentifications were carried out by Dr.. Adriano Lucio Peracchi of the Federal Rural University of Rio de Janeiro. The preserved specimens are kept in the Zoology Museum of the State University of Londrina.

Results

The site with the largest amount of forest (680 ha.) presented 15 species (Table I). The forests with smaller areas (60 and 6.2 ha.) contained 11 species each. In contrast, in the deforested area only 6 species appeared. The number of individuals collected was maximum in the open areas, the ones with lowest diversity, and did not follow a clear pattern with the size of forested areas.

Only 5 species were common to the 4 collection sites and four of them were also among the most abunfant: *A. lituratus,* which represented 63% of the number of individuals, *C. perspicillata,*

Table 1. Total number of species and individuals captured in the 4 collection areas. The number of individuals correspond to the same sampling effort for all areas. Bats of the family Molossidae were not included because they were not caught with nets.

Species	Mata Godoy	Thomas	Regina	Campus	Total	%
Micronycteris megalotis (Gray, 1842)	6	2	2		10	0.8
Phyllostomus hastatus (Pallas, 1767)		5			5	0.4
Chrotopterus auritus (Peters, 1856)	8		1		9	0.8
Anoura caudifer (E. Geoffroy, 1818)	1				1	0.09
Carollia perspicillata (Linnaeus, 1758)	58	67	9	1	135	12
Sturnira lilium (E. Geoffroy, 1810)	42	41	7	28	118	10.5
Platyrrhinus lineatus (E. Geoffroy, 1810)	1	1	2	36	40	3.5
Vampyressa pussilla (Wagner, 1843)		6			6	0.5
Chiroderma doriae Thomas, 1891			1		1	0.09
Artibeus jamaicensis Leach, 1821	13	7	1		21	1.8
Artibeus lituratus (Olfers, 1818)	96	234	51	351	712	63
Pygoderma bilabiatum (Wagner, 1843)	3	4	1	1	9	0.8
Desmodus rotundus (E. Geoffroy, 1810)			12		12	1
Myotis nigricans (Schinz, 1821)	6	14	1		21	1.8
Myotis ruber (E. Geoffroy, 1806)	3				3	0.26
Eptesicus furinalis (D'Orbigny, 1847)	1			2	3	0.5
Eptesicus diminutus Osgood, 1915	1				1	0.09
Histiotus velatus I. Geoffroy, 1824	2				2	0.17
Lasiurus borealis (Müller, 1776)	1	1			2	0.17
Total number of individuals	242	382	88	399	1111	100
Total number of species	15	11	11	6	19	100

with 12 %, *S. lilium*, with 10.5 %, and *P. lineatus,* with 3.5 %. Of the 19 species collected, 12 species each represented less than 1 % of the total number of bats caught. Of these 12, 10 were only captured in forest areas, and 4 only in the 680 ha. forest. In contrast, 4 of the 6 species captured in the deforested areas were among the most common.

Figure 1 reveals that, except for the Regina farm, the sampling effort measured as sampling time, has been enough to detect all species at each habitat. No new species have been caught in 6 months at Mata do Godoy Park, in 8 months at Arthur Thomas Park, and in 9 months at the university campus.

Discussion

There exists a minimium area for forests below which the existence of a given species is not possible (Simberloff and Abele, 1976). It is important to have some notion of this minimum area in order to be able to preserve the principal characteristics of the ecosystem, maintaining biological integrity and the greatest number of species possible (Schaffer 1981 and Diamond 1976).

Lewin (1984) confirms that species may become globally extinct as result of deforestation. This explains why in northern Parana, where little forested area remains, many species may have already

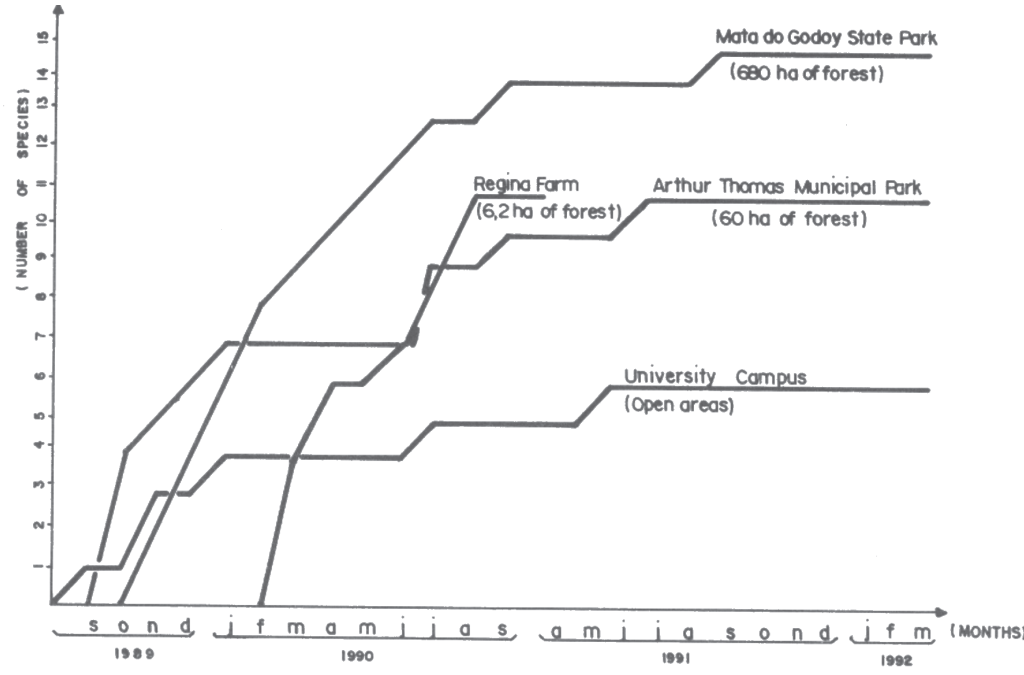

Figure 1. Evolution of the number of species captured during the collection period in the four study areas.

disappeared due to great decreases in their habitat size. Our results suggest that out of the 19 species collected only 4 would not have serious survival problems: *A. lituratus, C. pespicillata, S. lilium,* and *P.lineatus.* These appeared in all 4 collection stations and in different environments, demonstrating their high adaptive potential. The 15 remaining species had their populations reduced to less than 1.8 %, and 11 of them represented less than 1 % of the total population each.

It is clear that population size should differ among species, as should the area needed to maintain a population that is large or sufficiently immune to rapid extinction. It has been shown that in this study, 52% of the species were only found in forests. Four of those, *A. caudifer, M. ruber, E. diminutus,* and *H. velatus,* were collected only at Mata do Godoy State Park, with 680 ha. of primary forest. Odum (1975) and Fonseca (1991) explain this fact by saying that with the increase in forest area there is an increase in habitat size, leading to an increase in the number of available niches. This permits the existence of a greater number of species.

An alarming fact occured in the deforested area, where of the 6 species collected, 4 were among the most common, representing 89% of the total number of bats. Not a single rare species was found there. Gilpin and Diamond (1980) have shown that a 100% increase in the size of forest area raised by 25% the number of species. Terborg (1976) also showed that a 250 km^2 area loses 4% of its species in a century, but a 5000 km^2 area loses only 0.5%.

In adition to the minimum forest area, other factors also determine species number, such as, border effect. Forests possess a very isolated ecosystem, with shadows and moisture. When a piece of forest is exposed to direct wind and rain, drastic climatic changes increase the impact even more than might be foressen (Lewin 1984, Lovejoy et al 1984). This provokes the invasion of new plants that considerably transform the forest's periphery. This new vegetation in turn provokes changes in the animal populations. In the specific case of bats, the borders are invaded by Solanaceae, Piperaceae, and Cecropiaceae, which serve as food source for the most common species. Consequently, these species take the place of the rarer and more sensitive species.

Often a smaller area will present better quality habitats than a larger area containing habitats of lower quality or few critical habitats (Zimmerman and Bierrgaard 1986). For example, the untouched

6.2 ha. forest at the Regina farm presented the same number of species (11) as the 60 ha. forest at Arthur Thomas Park. The latter, in addition to containing altered forest, experiences intensive movement of visitors on its various paths, creating an intense border effect. On the order hand, the periphery of the Regina farm contains cattle, which favor the appearance of yet another species, the vampire *Desmodus rotundus.* In addition, we believe the total number of species of the Regina farm has not yet been reached, because only 2 months have gone by with no new species appearing in our collections, while at A. Thomas Park, 8 months have passed with no new species being found.

It is known that, although the remaining areas of forest are few in northern Parana, even small refuges must be preserved as much as possible. It should be kept in mind that small refuges lose principally species requiring mature habitats and retain those with great adaptive potential, due to greater amount of peripheral vegetation that favors common species (Diamond 1976, Simberloff and Abele 1976).

Another aspect to consider is that large forested areas favor the existence of animals at the end of the food chain, such as predators. Obviously, these predators alter the composition of the community, eating the common species and thereby increasing the total number of species. Our 6 year experience in the Amazon allowed us to observe the presence of cats, snakes, and owls in sewer pipes where more numerous bat species took refuge, such as *C. perspicillata.* These same predators diminish or disappear in small forests (Fonseca 1991).

Higgs (1981) affirms that biological understanding of the distribution and requirements of the habitats and species to be preserved is vital for application in biogeography studies of forest islands. For this reason, intensive field studies are needed in order to develop guidelines for Chiroptera preservation. In these years of collections, it has been found that *A. literatus, C. perspicillata,* and *S. lilium* are species which, due to their high adaptive capabilities, can eliminate rarer and more sensitive species. It was verified that species like *M. megalotis, A. caudifer, C. auritus, E. dorianus, C. doriae, M. ruber, H. velatus;* and *L. borealis* were rarely caught (none exceeding 2 specimens). In addition, *A. caudifer, M. ruber, E. diminutus,* and *H. velatus* were only collected in the 680 ha. forest. It should be remembered that insectivorous bats, with their refined system, are less often captured in nets (Handley 1967).

It is clear, as Terborg (1976) says, that the principal objective is rational conservation, and that it should be done in a way that preserves viable populations of as many species as possible that inhabit existing protected areas. For this reason, some large reserves should be preserved. However, considering the actual situation of the forests of southern Brazil, we must preserve what exists, because little still remains. Almost everything here has been destroyed without the knowledge and consent of authorities and concerned citizens.

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