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NOTA

The body mass index is influenced by the environment in populations of *Artibeus planirostris* (Chiroptera: Phyllostomidae)?

¿El índice de masa corporal está influenciado por el ambiente en poblaciones de *Artibeus planirostris* (Chiroptera, Phyllostomidae)?

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ABSTRACT

Bats are the second most diverse taxa of mammals in the world, after rodents. Some studies have evaluated if there is a relationship between the environment and the morphology of bats because environmental conditions may have an important influence on the phenotype of the species. The aim of the present study is to evaluate the relationship between a morphological variable (body mass index - BMI) of populations of the species *Artibeus planirostris* and the environment, considering the climatic variation in two hydrographic basins of the center of the Brazilian Amazon. The proposed hypothesis suggests that the type of environment (seasonally flooded forest) as well as climatic variables (for example, periods of precipitation) present some influence on the BMI in the bat species studied, considering, in addition, the sex of the individuals. This index will be higher during the rainy season and in the high water period, in response to the high availability of resources, according to studies carried out in the same region. Four hundred bats were captured, of which 180 were males and 220 were females. Although the index seemed to show differences considering the sex of the individuals, both in the Madeira River basin (ANOVA: gl = 1, F = 6.90, P = .00) and in the Purus River (ANOVA: gl = 1, F = 3.95, P = .01), there was no significant difference between BMI and the different environments, considering the climate season. It is concluded that, in this study, no evidence was found to support the hypothesis about the influence of the environ-

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ment on BMI in populations of the bat species *Artibeus planirostris* in the middle of the Brazilian Amazon.

Keywords — Amazon, bats, flooded forest, Madeira river.

RESUMEN

Los murciélagos son el segundo grupo de mamíferos más diversos del mundo, después de los roedores. Algunos estudios han evaluado si existe alguna relación entre el ambiente y la morfología de los murciélagos, debido a que condiciones ambientales pueden tener influencia sobre el fenotipo de las especies. El objetivo del presente estudio es evaluar la relación entre una variable morfológica (Índice de Masa Corporal – IMC) en poblaciones de la especie de murciélago *Artibeus planirostris* y el ambiente, considerando la variación climática en dos cuencas hidrográficas del centro del Amazonas brasilero. La hipótesis propuesta sugiere que el tipo de ambiente (bosque estacionalmente inundable) así como variables climáticas (por ejemplo, periodos de precipitación) presentan alguna influencia sobre el IMC en la especie de murciélago estudiada, considerando, además, el sexo de los individuos. Éste será más alto durante la temporada de lluvias y en el período de aguas altas, coincidiendo con una alta disponibilidad de recursos, según estudios anteriores llevados a cabo en la región. Fueron capturados 400 murciélagos: 180 eran machos y 220, hembras. Aunque el índice pareció mostrar diferencias considerando el sexo de los individuos, tanto en la cuenca del rio Madeiras (ANOVA: gl = 1, F = 6.90, P = .00), como en el rio Purus (ANOVA: gl = 1, F = 3.95, P = .01), no hubo diferencias entre el valor del índice en los diferentes ambientes, considerando la temporada climática. Se concluye que, en este estudio no se encontró evidencias que soporten la hipótesis planteada acerca de la influencia del ambiente en el IMC en poblaciones de la especie de murciélago *Artibeus planirostris* en el centro del Amazonas brasilero.

Palabras clave — Amazonas, bosque inundable, murciélagos, río Madeira.

Bats are the second most diversified group of mammals in the world (Simmons, 2005; Fenton y Simmons, 2015), this diversity is often attributed to the type of environment, the high availability and use of resources (Fleming y Heithaus, 1981; Caras y Corine, 2005). Many studies have attempted to assess if there is a relationship between the environment and the morphology of bats, because environmental conditions can have an important influence on the phenotype of the species (Klingbeil y Willig, 2009; Lee et al., 2012; Marchán et al., 2012).

Comparative studies have shown that morphological aspects (like size) vary intra and extra specifically throughout a geographic space (Lee et al. 2012; Marchán et al., 2012). Studies such as Marchán et al. (2012) in Central and South America have found, for example, that precipitation plays an important role in the size of individuals in bats of the genus *Artibeus*, since individuals of the studied species of this genus (A. *intermediu* y *A. lituratus*) is larger in regions that are significantly rainier

than in others, the explanation for which is probably due to the greater availability of resources (for example, fruit). Likewise, other studies (Dumont y Herrel, 2003; Sztencel-Jabłonka, Jones y Bogdanowicz, 2009) propose that intra-specific variations in the morphological structure of bats may be due to changes in their diet and availability across their geographic range of distribution.

This determines that some morphological characteristics may be more advantageous than others (under certain conditions), which constitutes a very important aspect for the survival of the species (Lee et al., 2012; Marchán et al., 2012).

Artibeus planirostris (Spix, 1823) is a species of bat belonging to the family Phyllostomidae, subfamily Stenodermatinae, and is exclusive to the Neotropical region (Simmons, 2005). It is predominantly frugivorous (Bonnacorso, 1979) and one of the most frequently captured in Neotropical forests (Durán y Canchila, 2015, Pereira et al., 2010), characteristics that make it a very convenient study model.

The aim of this study was to evaluate if the Body Mass Index (BMI) is related to the environment where two populations of *A. planirostris* inhabit, also considering the climatic season (rain, dry).

The proposed hypothesis suggests that the type of environment (seasonally flooded forest) as well as climatic variables (for example, periods of precipitation) present some influence on the BMI in the bat species studied, considering, in addition, the sex of the individuals. This index will present its highest values during the rainy season and in the high water period (for example, in Várzea), possibly responding to greater availability of resources (Pereira et al., 2009).

Two hydrographic basins were selected for the study, located in the Brazilian Central Amazon (figure 1). The sampling points at both sites (Purus and Madeira) were separated by more than 500 kilometers in a straight line: The first, **Purus River** situated near of the Piagaçu-Purus Sustainable Development Reserve in Manaus (Amazonas) (4°14’ S, 62°16’ W) and also a mosaic of non-flooded forest (Terra firme) and seasonally flooded forest (Várzea). These floods can last up to six months and reach heights up to 6 meters high, sometimes reaching a maximum level of 10 m (Pereira et al., 2010). In the area, the average annual rainfall is 2600 mm, with the rainiest months between February-June and the driest from July-October (Haugaasen y Peres, 2006).

The second basin corresponds to the **Madeira River** in the area of the municipalities of Jaci Paraná (9°17’ S, 64°26’ W) and Porto Velho (8°49’ S, 63°56’ W), in the state of Rondónia. This river is the main tributary of the Amazon River, being responsible for 15% of its volume (Goulding et al., 2003). The annual rainfall varies between 1700 and 2000 mm, with the rainiest periods from November to April, and the driest from June to September. The type of vegetation is dense tropical forest (Veloso et al., 1991).

The climatic season was only taken into account for the points of the Madeira river and for those of Terra firme on the Purus river, since both are not seasonally flooded, unlike Várzea.

To capture *A. planirostris* individuals, ten mist nets (12 x 2.5 meters) were used in open areas at the understory level, for four consecutive nights (from 18:00 to 00:00 horas), between the months of June and September 2008, October-November

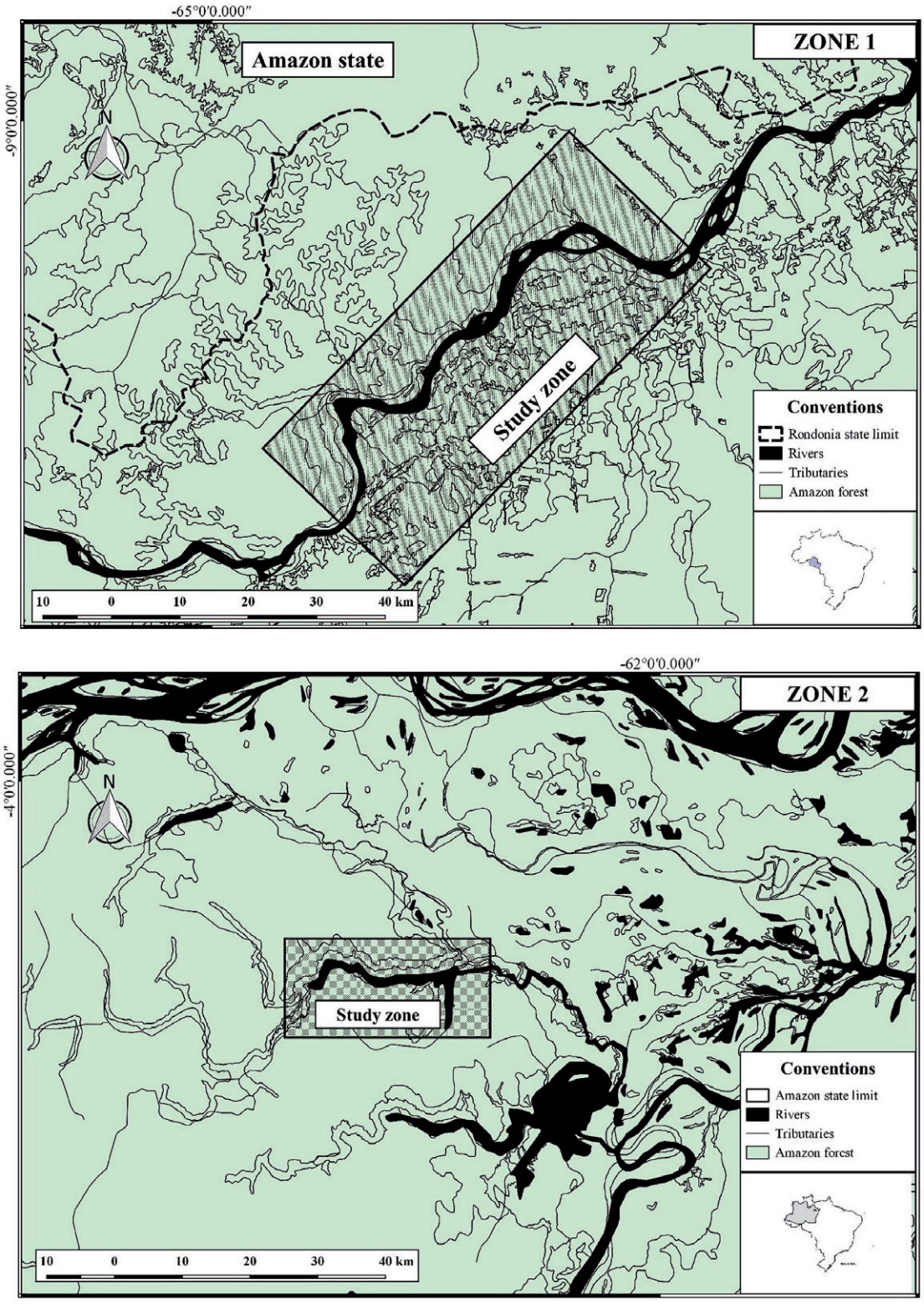

Figure 1. Map with the location of the two hydrographic basins in the Brazilian Central Amazon. Zone 1 = Purus River basin, Zone 2 = Madeira River basin. Source: Author.

2009 and March 2010. For a total of 40 nights of sampling for each site (Purus and Madeira), thus obtaining a sampling effort of 240 hours/nets/site. In Várzea during the flood season, the nets were located in non-flooded areas within the forest. The individuals were captured, sexed and measured with a calibrator (precision 0.05 mm) and weighed using a Pesola (60-100 grams).

The species *A. planirostris* is easily distinguishable because of their medium-size, ears shorter than the head, and lower lip with three large warts in the center. Swallow with serrated edge, dorsal color dark ash and almost indistinguishable facial lines; wings attached to the metatarsus and interfemoral membrane stuck to the calcar (Muñoz, 2001) (figure 2).

Figure 2. Individual of *A. planirostris*. Photo by courtesy of Setsuo Tahara.

Body Mass Index (BMI) taken as the relationship between weight (P) and forearm length (AB) (Lacki et al., 2015),

$$BMI = P / AB,$$

For the populations the mean BMI was calculated for each river basin with their respective 95% confidence interval. Subsequently, an Analysis of Variance was carried out to evaluate the relationship between the BMI and each type of environment: Terra Firme (non-flooding ecosystem) and Várzea (seasonally flooding ecosystem). In addition, the climatic season (rainy and dry periods) was considered. These analyzes were developed on the R v. 3.4.0 platform (R Core Team 2017). To make the graphs, the "ggplot2" package was used for the aforementioned platform (Wickham, 2009).

Four hundred individuals of *A. planirostris* were captured, among which 180 were males and 220 females. The largest number of individuals were from the Purus River (n = 226). The basin of the Madeira River during the rainy season was the one that recorded the highest frequency of captures (n = 126), while, in the Purus River, Várzea during the flood period presented 76 individuals (table 1).

Overall, no significant differences were found between the BMI for the two hydrographic basins (Purus = 1.20 ± 0.004 and Madeira 1.15 ± 0.005, df= 1; F= 2.37; P = 0.1). In the same way, no differences were recorded between the BMI in the different environments (Várzea and Terra firme), considering the climatic season (table 2) (figure 3).

Table 1. Abundance of individuals of *A. planirostris* in the two hydrographic basins of the Brazilian Central Amazon.

Tabla 1. Abundancia de individuos de *A. planirostris* en las dos cuencas hidrográficas de la Amazonía central brasileña.

Basin	Local	Male	Female	Total
Purus River	Várzea (Flooded)	27	49	76
	Várzea (Not-flooded)	19	17	36
	Terra firme (Rain)	29	31	60
	Terra firme (Dry)	26	28	54
Madeira River	Rainy season	22	18	40
	Dry season	57	77	134

Table 2. Body mass index for the bat populations in the two hydrographic basins of the Brazilian Central Amazon. * p< 0.05, ** p< 0.01.

Tabla 2. Índice de masa corporal de las poblaciones de murciélagos en las dos cuencas hidrográficas de la Amazonía central brasileña. * p <0,05, ** p <0,01.

Basin	Local	Male	Female
Purus River	Várzea (Flooded)	1.19 (±0.001)	1.16 (±0.001)
	Várzea (Not-flooded)	1.23 (±0.002)	1.13 (±0.002)*
	Terra firme (Rain)	1.26 (±0.001)	1.19 (±0.001)
	Terra firme (Dry)	1.22 (±0.001)	1.18 (±0.001)
Madeira River	Rainy season	1.12 (±0.001)	1.11 (±0.002)
	Dry season	1.22 (±0.002)	1.11 (±0.001)**

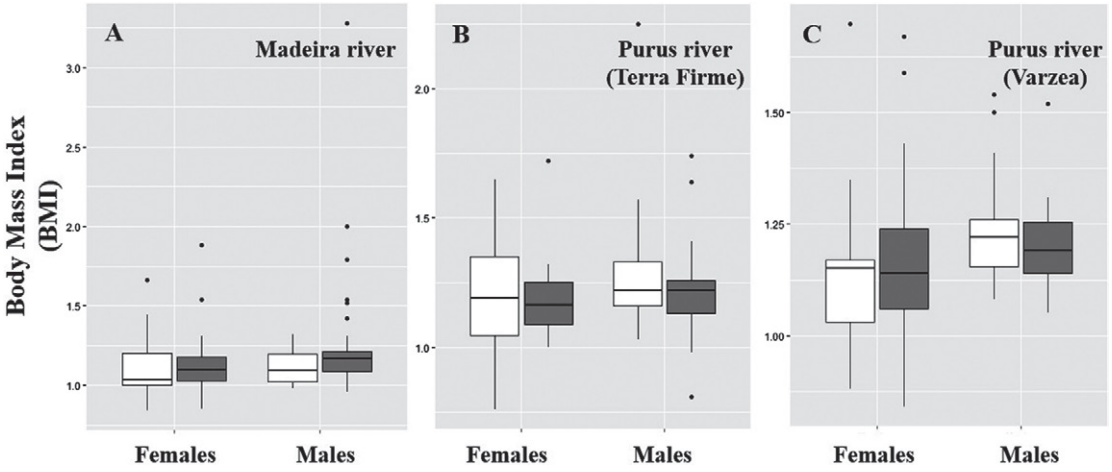

Figure 3. Boxplot chart of Body Mass Index (BMI) considering the sex, the type of environment and the climatic season in the two hydrographic basins of the Brazilian Central Amazon. In A and B, the white squares = rainy season, black squares = dry season, in C, white squares = Várzea not flooded, black squares = Várzea flooded.

The proposed hypothesis was not confirmed. The type of environment did not favor the BMI, which could be because this species is well known for being adaptable to changes in its habitat (Durán y Canchila, 2015), that is why they are found in great abundance. This could also explain the lack of relationship between the climate season and the BMI; therefore, the hypothesis is not supported.

However, in almost all the locations there were higher frequency of captures in rains and in the flood season, coinciding with a greater availability of resources for these seasons, according to a study conducted by Pereira et al., (2010) in the same region.

In the populations of the Madeira River basin, only significant difference was found during the dry season between the BMI according to sex (gl = 1, F = 6.90, P = .00), while in the Purus river basin, it was in Várzea during the non-flooded period where there were differences (gl = 1, F = 3.95, P = .04) (table 2). In both cases, males presented higher BMI than females.

Previous studies in other bat species have found that females had significantly higher BMI values than males (Speakman y Racey, 1985), in contrast to what was recorded in this study on *A. planirostris*, which may be due to their morphology, where males are larger than females (Hollis, 2005).

In this study, no evidence was found to support the hypothesis raised. The BMI in the species *A. planirostris* is not influenced by the climatic season in the study area and during the sampling periods, being this a highly adaptable species with general habits. In seasons of scarcity of its main resource (the fruits), it consumes other food items that appear in greater abundance, such as insects and floral parts (Bonnacorso, 1979). However, sex did show an influence; males recorded higher BMI than females.

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PARTICIPATION

The only author of the paper, Adrián Alonso Durán, made the entire study

CONFLICTS OF INTEREST

The author guarantees that there is no conflict of interest of any kind.

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