Original Article

POPULATION STRUCTURE OF TWO SPECIES OF *Heliconius* KLUK, 1780 BUTTERFLIES (Lepidoptera: Nymphalidae)

ESTRUTURA POPULACIONAL DE DUAS ESPÉCIES DE BORBOLETAS Heliconius *KLUK, 1780 (Lepidoptera: Nymphalidae)*

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RESUMO: As populações de *Heliconius erato phyllis* (Fabricius, 1775) e *Heliconius ethilla narcaea* Godart, 1819 foram quantificadas em uma reserva florestal de mata semi-decídual na região central do Brasil, durante o período de um ano. As subespécies apresentaram tamanho populacional similar, mas com distintos padrões. A razão sexual foi diferente entre as subespécies: *H. erato phyllis* apresentou mais fêmeas e *H. ethilla narcaea* mais machos, na maioria dos meses. Variação sazonal no tamanho dos indivíduos foi observada em ambas as populações, entretanto, a distribuição da classe etária foi diferente entre os meses e as subespécies. Assim, os resultados desse estudo demonstraram que as populações de *H. erato phyllis* e *H. ethilla narceae* apresentam semelhanças em seu tamanho, mas com propriedades e variações mensais distintas.

PALAVRAS-CHAVE: Classe etária. *Heliconius erato phyllis. Heliconius ethilla narceae.* Razão sexual. Tamanho corporal.

INTRODUCTION

The study of population biology has been an important tool for understanding the ecological stability of species in natural environments. In this sense, knowing the seasonal variations in the population structure is critical to understanding the interactions between organisms and other mechanisms, which shape the biodiversity in the most diverse ecosystems (TAUBER et al., 1986; ABRAMS et al., 1996).

Several studies have demonstrated that insect populations of are sensitive to seasonal variations (see BURSELL, 1974; TAUBER et al., 1986; BULLOCK et al., 1995) and anthropic factors (ROSEMBERG et al., 1986; HOGUE, 2009), therefore, the biology of insects is largely used in studies of environmental monitoring (see ROSENBERG et al., 1986; PRICE et al., 2011). Some species of Lepidoptera react rapidly to disturbances or changes in the environment being considered environmental bioindicators (BLAIR, 1991). Species of the Heliconiinae (Nymphalidae) are placed in this context, being significantly diverse and relatively easy to sample and identify in the tropical regions (BROWN JR, 1996; NEW, 1997; OCKINGER et al., 2006).

The body size is one of the most common features used to verify the seasonal effects from environmental changes in lepidopteran populations (BENSON et al., 1976; FORREST, 1987; RODRIGUES; MOREIRA, 2002, 2004; DI MARE; CORSEUIL, 2004; DE ANDRADE; FREITAS, 2005). The seasonal variation in individual characteristics has been considered as a key component in the life story of organisms (PETERS, 1983; BÄCHTOLD et al., 2012). Among the environmental factors that cause seasonal variation in the adult body size are temperature (JONES, 1992; KEMP, 2000), food quality (SINGER, 1984; CORRÊA et al., 2001; ELPINO-CAMPOS, 2012), photoperiod (JONES, 1992; KEMP, 2000) and competition (TAUBER et al., 1986; DENNO et al., 1995). The species of the *Heliconius* Kluk, 1780 have characteristics that favor population biology studies because they show territoriality and small population sizes, with less than 100 individuals (OLIVEIRA; ARAÚJO, 1992). Moreover, they are largely distributed in South America occurring from North to South Brazil, in Bolivia, Northeastern Argentina, and Uruguay (HOLZINGER; HOLZINGER, 1994). *Heliconius* adults settle in areas where they remain for the rest of their lives after a brief period of dispersion (MALLET, 1986). Thus, these populations are moderately sedentary units, with little movement of individuals, apparently as a result of home-range behavior (RAMOS, 1999). Such behavior can be observed in the use of specific foraging routes by individuals, who return daily to host plants that provide nectar

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pollen, place to larvae, oviposition, copulation (EHRLICH; GILBERT, 1973; CORRÊA et al., 2001; DE ANDRADE; FREITAS, 2005), and dormitories (BROWN JR, 1981). The wings of many species of this genus exhibit chromatic patterns, which made them classic models in the study of mimicry (MALLET; GILBERT, 1995; JORON, 2005). In addition, *Heliconius* species exhibit variation in population structure and body size in response to environmental conditions (BENSON et al., 1976). However, there are few studies verifying these properties of *Heliconius* populations, regardless of their broad diversity.

In this study, we aimed to contribute to the knowledge of population biology of two *Heliconius* subspecies describing and comparing the population biology of these subspecies, especially in relation to the population size, sex ratio, monthly variation of body size, time of residency, and distribution of age structure. Due to the similarity in life strategies between these two subspecies, we suppose to find populations with the same sizes, as well as similarities between the remaining properties.

MATERIAL AND METHODS

The study was carried out in the Parque Municipal Bosque John Kennedy (PMBJK), located in the urban perimeter of the municipality of Araguari, Minas Gerais State (48°11'19"W and 18°38'35"S). Most of the area (11.2 ha) is occupied by a seasonal semi-deciduous forest, with trees up to 25 m in height and with dense canopy, similar to the native reserves in the region. Although it is an urban forest subject to human action, this area still retains high natural floristic diversity (see ARAÚJO et al., 1997; SOUZA; ARAÚJO, 2005). The climate of this region, according to Köppen classification, is type Cwa, i.e., a humid mesothermic climate with dry winters and heavy rainfall in the summer. The average temperature is 22°C with annual rainfall of 1500 mm; with the dry season from May to September and the rainy season from October to April (ROSA, 1992).

The two subspecies of *Heliconius* monitored in this study were *Heliconius erato phyllis* (FABRICIUS, 1775) and *Heliconius ethilla narcaea* Godart, 1819. These subspecies are easily found at the PMBJK and are considered the most abundant butterfly species in the Park (PEREIRA et al., 2011). They often draw the attention of visitors by their intense wing coloration.

The observations were carried out from August 2010 to July 2011. The major pathways in the PMBJK was sampled twice weekly during the period from 9:00 to 15:00 h, time of highest butterflies activity. Adults of the *H. erato phyllis* and *H. ethilla narcaea* were captured with entomological nets and numbered with a black permanent felt-tipped pen in the underside of forewings, according to Ruszczyk and Nascimento (1999) methodology. Marked and recaptured individuals, and sex were recorded. The right forewings of captured individuals were measured (in centimeters) using a manual caliper; these measures represented the individual body size.

The estimate of population size was performed for each month, by the use of stochastic models (JOLLY, 1965, MANLY; PARR, 1968), and due to the sample size of both sexes was grouped. A Z-test (comparing means) with $P<0.05$ was used, between the two subspecies, to verify differences in the abundance of observed individuals and for the sex ratio. ANOVA ($P<0.05$) with Tukey post hoc test was used to verify possible differences in both abundance and body size of individuals over the studied months. The sex ratios (*SR*) were calculated as the number of the most abundant gender/number of the least abundant gender. The Chi-square test (χ^2) was used to verify differences in the proportion of sex ratio between the two studied subspecies during the sampling period. Frequency histograms were used to represent the distribution of age structure in each subspecies. The results from the wing length were compared between genders for each subspecies using the Student's t-test ($P<0.05$). These statistical analyses were performed using Systat version 12.0.

For analysis of age, four groups were established based on the wing color and degree of deterioration, according to Ruszczyk and Nascimento (1999): a) tenneral or newly emerged (wings relatively soft with dark shiny areas); b) new (rigid wings, perfect, and intense coloration); c) intermediate (wings with worn edges and faded colors), and d) old (wings with extremely worn edges and seriously faded colors).

RESULTS

Both *Heliconius* subspecies monitored in this study showed similar observed and estimated population size (Table 1 and Figure 1). Individuals of *H. erato phyllis* were more abundant than *H. ethilla narcaea* over time, however the number of observed individuals and the average number of estimated individuals through months was not different ($Z=0.737$, $P=0.461$, and $Z=1.339$, $P=0.181$, respectively). The population of *H. erato phyllis* showed abundance peak of individuals in August

2010, March and May 2011, while *H. ethilla narcaea*, showed abundance peak in August 2010, December and May 2011 (Table 1 and Figure 1).

The sex ratio of the two populations had different patterns (Table 1). Although no significant difference in sex ratio in *H. erato phyllis*, females were more abundant than males (*RS*=1.95, χ^2=12.67, *P*=0.33). This pattern was similar in almost all of the months, except for December 2010 and July 2011, when were found a greater number of males and in August 2010, when the number of males and females was similar (Table 1). An opposite pattern was evident in the *H. ethilla narcaea* population, where males were significantly more abundant than females (*RS*=2.5, χ^2=16.63, *P*=0.05). This result was observed in all months of the study, except in June and July 2011 where we found only females (Table 1).

Table 1. Number of males, females and total of individuals of *Heliconius erato phyllis* and *Heliconius ethilla narcaea,* observed from August 2010 to July 2011 in Parque Municipal Bosque John Kennedy in Araguari, Minas Gerais, Brazil.

Year	Month	*Heliconius erato phyllis* Abundance			*Heliconius ethilla narcaea* Abundance		
		♂	♀	Total	♂	♀	Total
2010	Aug	3	3	6	9	4	13
	Sep	1	2	3	2	1	3
	Oct	0	0	0	1	0	1
	Nov	0	0	0	2	0	2
	Dec	2	1	3	3	1	4
2011	Jan	1	2	3	0	0	0
	Feb	0	4	4	0	0	0
	Mar	1	8	9	0	0	0
	Apr	1	3	4	6	0	6
	May	6	10	16	8	2	8
	Jun	3	7	10	0	2	2
	Jul	3	1	4	0	2	2
Total		**21**	**41**	**62**	**31**	**12**	**43**

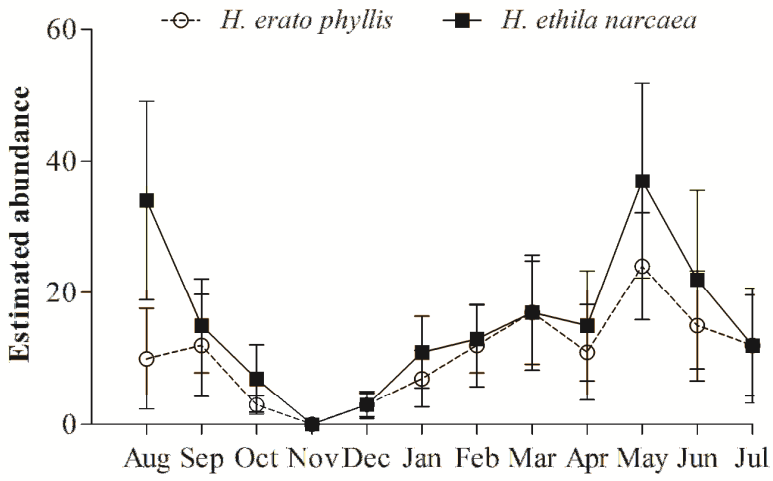

Figure 1. Estimated abundance of individuals (mean ± standard error) monthly of *Heliconius erato phyllis* and *Heliconius ethilla narcaea*, observed from August 2010 to July 2011 in Parque Municipal Bosque John Kennedy in Araguari, Minas Gerais, Brazil.

The individual body size of the two subspecies showed similar values (3.515±0.287 for *H. erato phyllis* and 3.543±0.424 for *H. ethilla narcaea* with *t*=-0.407, *P*=0.685). Likewise, the size of the male and female *H. erato phyllis* was similar (3.476±0.283 for males and 3.538±0.297 for females, with *Z*=0.799, *P*=0.428; Figure 2A). However, when comparing *H. ethilla narcaea* male and female sizes it was observed that males were larger than females (3.629±0.420 for males and

3.309±0.353 for females, t=-2.425, P<0.05; Figure 2B).

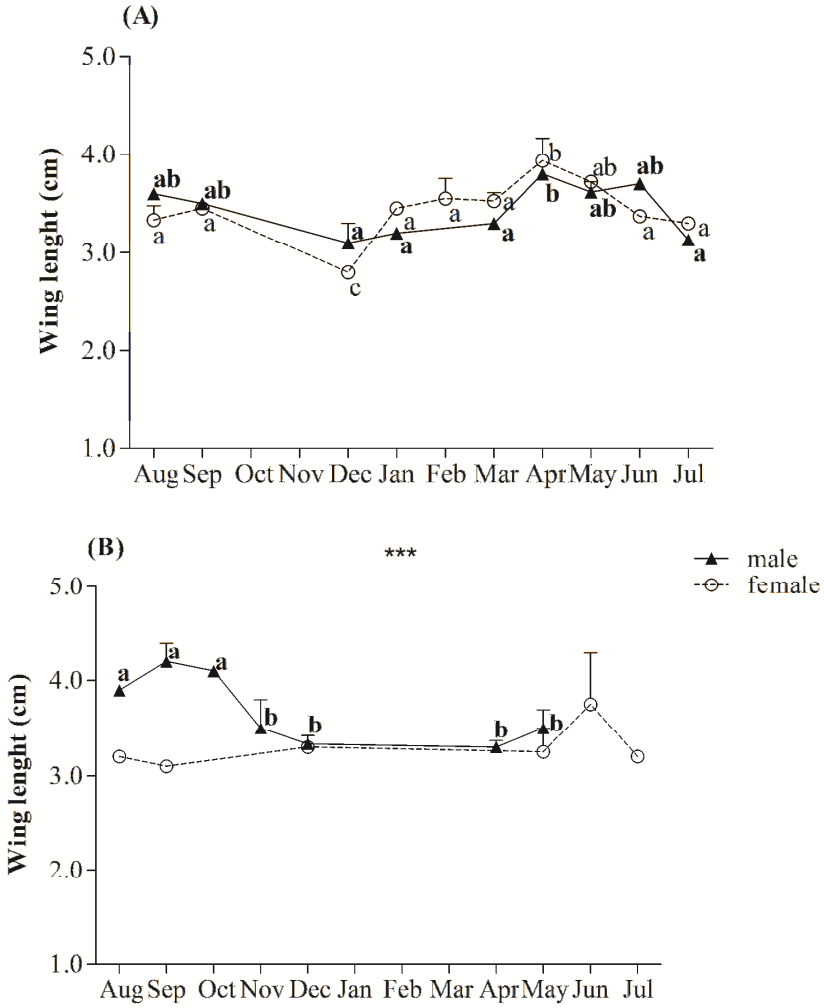

Figure 2. Wing length (cm) (mean ± standard error) of males and female of *Heliconius erato phyllis* (A) and *Heliconius ethilla narcaea* (B), observed from August 2010 to July 2011 in Parque Municipal Bosque John Kennedy in Araguari, Minas Gerais, Brazil. The asterisks mean the statistic differences in size between male and female, and letters indicate difference between moths for males (bold letters) and for female (normal letters).

Monthly variation was observed in body size between individuals of *H. erato phyllis* ($F_{[9, 52]}$=5.33, P<0.001) and also when compared between the same sexes, males ($F_{[8, 12]}$=4.011, P<0.05) and females ($F_{[9, 31]}$=3.732, P<0.05) (see Figure 2A). In *H. ethilla narcaea* population no seasonal variation of the wing size of the individuals ($F_{[8, 33]}$=1.451, P=0.213) nor in the size of the females ($F_{[5, 5]}$=0.665, P=0.667) was observed, but there was a variation in male sizes ($F_{[6, 24]}$=3.890, P<0.05) (see Figure 2B).

In *H. erato phyllis* population, out of a total of 62 individuals which were captured and marked, only 11 were recaptured (17.74%), three being female. However in *H. ethilla narcaea*, of the 43 individuals captured and marked only ten individuals were recaptured (23.2%), and also only three were females. The maximum time of residence in *H. ethilla narcaea* was 52 days for females and 71 for males and for *H. erato phyllis* the maximum time was 61 days for females and 84 days for males (Figure 3).

Regarding the age structure of the *H. erato phyllis* population, the intermediated group had higher percentages (Figure 4A) and tenneral individuals were not found . In August 2010 only intermediate adults were captured, while in July 2011 only old adults were found. For *H. ethilla narcaea* population, tenneral individuals were not found in any captured group, while intermediate and old individuals had the highest percentages (Figure 4B).

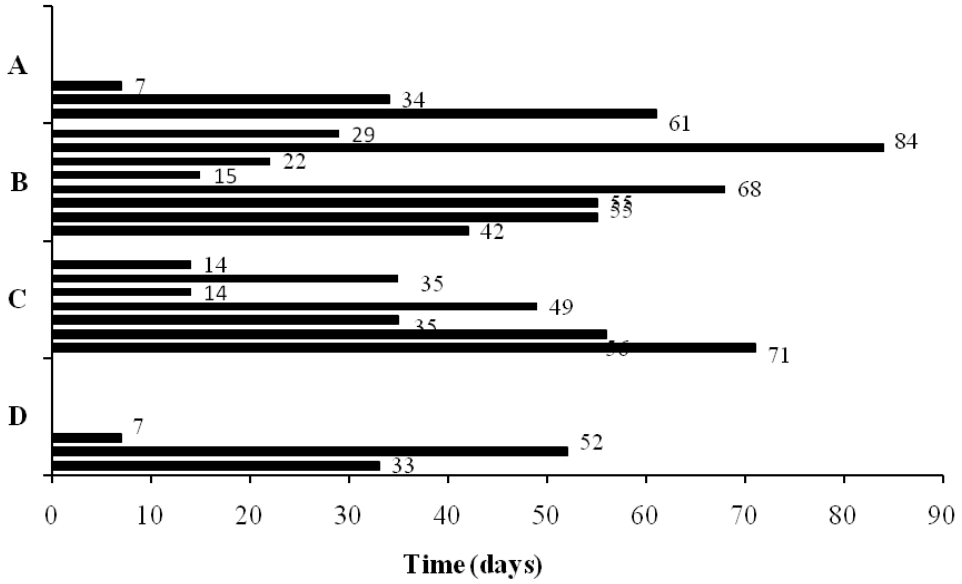

Figure 3. Residence time in days (mean ± standard error) of females (A) and males (B) of the *Heliconius erato phyllis* and female (C) and male (D) of *Heliconius ethilla narcaea*, observed from August 2010 to July 2011 in Parque Municipal Bosque John Kennedy in Araguari, Minas Gerais, Brazil.

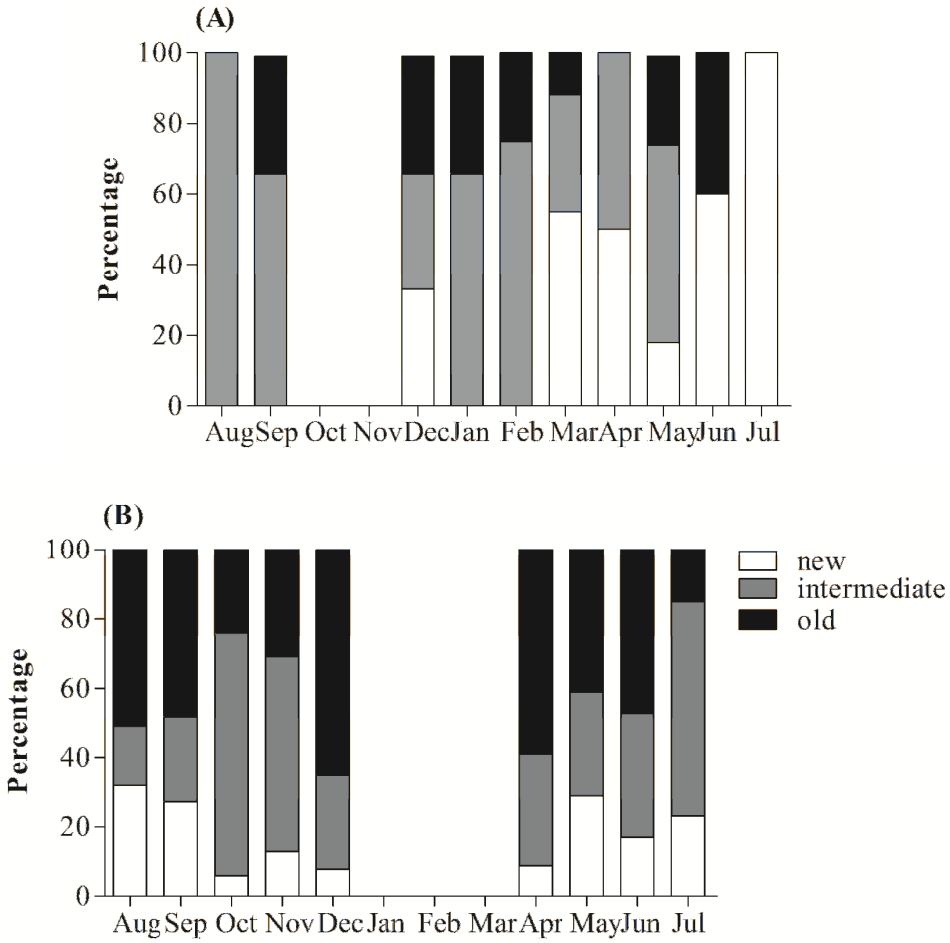

Figure 4. Distribution of adult age structure of the *Heliconius erato phyllis* (A) and *Heliconius ethilla narcaea* (B), observed from August 2010 to July 2011 in Parque Municipal Bosque John Kennedy in Araguari, Minas Gerais, Brazil.

DISCUSSION

Our results were corroborated by other studies on the population biology of *Heliconius* (RODRIGUES; MOREIRA, 2002, 2004; DE ANDRADE; FREITAS, 2005). Both *H. erato phyllis* and *H. ethilla narcaea* populations found in PMBJK are small with presented variation in sex ratio and body size of adults. According to Gilbert (1991), *Heliconius* populations are kept with low density through time. The two subspecies, sampled in the present study, had different population fluctuations with absences and abundances in distinct months. To Gilbert (1975) and Smiley (1978), the individuals abundance of the *Heliconius* populations are regulated primarily by the death of eggs and larvae, due to the deterioration or exhaustion of the host plant, attacks by predators or parasites, as well as storms or adverse weather conditions. Likewise, the availability of resources for adults, such as nectar, pollen, space and suitable nesting sites may also affect local population abundances (EHRLICH; RAVEN, 1965; BOGGS; GILBERT, 1979; CORRÊA et al., 2001). The rapid development (such as egg, larva and pupa last about four weeks, while adults have an average life expectancy of several months; see BROWN JR, 1975; GILBERT, 1976), is usually interpreted as a strategy to escape predation (BROWN JR, 1981). This propriety can be essentials for the two subspecies studied.

The sex ratio in *H. erato phyllis* was female based, while in *H. ethilla narcaea* the males were more abundant. According to Périco (1995), the deviation in sex ratio in favor of males is common in butterflies and is related to behavioral differences between sexes. Thus, the presence of higher proportion of females, although not significant, in *H. erato phyllis* observed here is uncommon in other studies of Lepidoptera (PÉRICO, 1995; DE ANDRADE; FREITAS, 2005). In our study new and intermediate individuals predominate in winter, while old and also intermediate individuals were more abundant in summer. However, dominance of specific age classes, through long periods, was not found. This result may be related to the properties of the area, which can constitute a refuge for the maintenance of populations during the colder months of the year (PÉRICO, 1995). Besides this, micro-climate of the region and the constant presence of flowers for food, as well as plant of families Passifloraceae, Asteraceae, and Rubiaceae, for adult oviposition and larval food may also influence the butterfly species.

We found monthly variation in the body size of *H. erato phyllis*, but not between sexes. Differently, we found that *H. ethilla narcaea* showed larger males than females but without seasonal variation. In a study by Engelmann and Cardoso (2007) two species of *Heliconius* (*H. erato* and *H. melpomene*) showed periodic variations in wing size. In a review of invertebrates, Reiss (1989) concluded that females surpass the size of males only when the energy investment for reproduction is small. This strategy probably was not used for the female subspecies of the present study. Males and females exploit different food resources, because both would benefit from reduced competition for a limited supply (SELANDER, 1972). The females of some species can make a judgment of males, by selecting "capabilities" or "qualities", such as: speed, strength and / or agility (CRONIN, 1995).

A study on *H. erato phyllis* population in southern Brazil by Périco (1999) recorded maximum longevity at 176 days for females and 193 days for males, and these values were the highest observed in the field for butterflies of this subspecies. De Andrade and Freitas (2005), studying population biology of *H. erato* and *H. ethilla* observed the time of residence of the 32.6±23.93 days, with the maximum registered of 106 days. Ehrlich and Gilbert (1973) observed a *H. ethilla* male with 162 days. In their observations of *H. erato* in Rio Grande do Sul, Saalfeld and Araújo (1981) registered a female with 91 days and a male with 150, while Romanowsky et al. (1985) reported a female with 113 days and a male at 136 days. Thus, our results showed lower values for the residence time. This reduction in residence time may be related mainly to the low abundance of individuals of two populations in study area.

In many tropical and temperate regions, species face seasonal variations (KEMP, 2000). Despite this there are no significant changes in local temperatures, or total absence of seasons in tropical regions (WOLDA, 1988). Tropical environments are commonly characterized by alternating periods of drought and rainfall (BRABY, 1995), being the second subjected to the chance (JONES; RIENKS, 1987). In order to survive, the organisms, in this kind of habitats, have to use the best strategy depending on a particular space and time they are (KEMP; JONES, 2001). Thus, it is expected that tropical species occur over the year and produce little or no seasonal variation in their abundances (WOLDA, 1980). However, it is known that insects that live in tropical regions with well defined dry and rainy seasons, face significant seasonal changes

in abundances, especially in areas where the dry season is very pronounced, which may reflect on the significant decrease in their numbers (WOLDA, 1978). The annual abundance variation for the two butterfly subspecies of the present study seems to agree with this tropical pattern. These changes can occur in response to a number of factors, such as macro or micro-climatic changes, important determinants of the reproduction and survival conditions of individuals, as well as temporal variation of their food resources (WOLDA, 1988; CORRÊA et al., 2001; ELPINO-CAMPOS, 2012). Thus, the knowledge on seasonal fluctuation of the insect populations represents an important step to understanding about their interspecific interactions and also about conditions of environmental (WOLDA, 1979).

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ABSTRACT: The populations of *Heliconius erato phyllis* (Fabricius, 1775) and *Heliconius ethilla narcaea* Godart, 1819 were monitored in a semi-deciduous forest reserve in the central region of Brazil, during the one-year period. Both subspecies presented similar population size but distinct population patterns. The sex ratio was different between the subspecies: *H. erato phyllis* tending to have more females and *H. ethilla narceae* males, in most of the observations. Seasonal variation in the adult size was observed in both populations studied, however, the distribution of the adult age structure was different between over the months and subspecies. Thus, the results of this study demonstrated that populations of *H. erato phyllis* and *H. ethilla narceae* exhibit similar population size, but distinct properties and monthly variations.

KEYWORDS: Age structure. Body size. *Heliconius erato phyllis. Heliconius ethilla narceae*. Sex ratio.

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