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Territorial behavior of the butterfly *Archonias brassolis tereas* (Godart, 1819) (Lepidoptera: Pieridae: Pierinae) in three sites in Southeastern Brazil

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Abstract
This study describes and explains aspects of male territorial behavior of the butterfly *Archonias brassolis tereas* (Pieridae). Data was collected from 2005 to 2019 in three sites at coast of São Paulo State, Brazil, near the hills of Serra do Mar. The results show that territorial behavior happens during early morning. Perched males give quick response to other flying males. The territories with the most disputed perches were those where the number of females was higher and the increase of male density in the population cause the decrease of territory length.

Keywords: Mating behavior, perching strategy, territoriality, thermoregulation

1. Introduction
In the mating of butterflies, two basic strategies have been proposed to describe the behavior of males searching for females. The first strategy is patrolling, where the males actively search for females, flying relatively long distances to found them [1, 2, 3]. The second is perching, which is based on male sitting and waiting for the female, eventually driving away other arriving competitive males. Female availability appears to be important in determining the nature of mating systems [4, 5]. Consequently, males of several butterfly species defend limited spatial areas to obtain females for mating purposes [6, 7, 8].
Density can have strong effects on selective pressures, and when male density increases the proportions of unsuccessful males in a modeled scenario of male-male competition would also increase in a sigmoidal curve still to the asymptote when all males will be unsuccessful [9]. However, density-independent factors such as severe weather put additional effects on recruitment, with consequences for the population [10]. Thermoregulation plays an important role in flight activity of butterflies [11, 12] but it will be treated in another paper.
The objective of this study was to describe aspects of the territorial behavior of the butterfly *Archonias brassolis tereas* (Pieridae) which is resident in some coastline area of the state of São Paulo, Southeastern Brazil [13].

2. Methodology
2.1 Study sites and periods of observations
The observations were made in three areas in the coast of São Paulo State, Brazil (Fig. 1 A), near the hills of Serra do Mar. VRQUI site is along a dirty road on the right bank of the Quilombo river [14] (Fig. 1 B-C VRQUI). JURUB site is another dirty road on the right bank of the Jurubatuba river that is five kilometers long, (Fig. 1 B-C JURUB). PICIN site is along another dirty road inside the Nucleon Picinguaba which is a Conservation Unit of The Parque Estadual da Serra do Mar (-23.35° and -44.85°; (Fig. 1 B PICIN). Along the three dirty roads there is secondary ruderal vegetation, growing in varying stages of succession due to continuous clearing. In these sites, different observations were made from 2005 to 2019 totaling 184 discontinuous days totaling 964 h of field effort.

2.2 Sampling procedures
Ad libitum observations of the territorial behavior of individuals of *A. b. tereas* were made during some years from 2006 to 2019 at VRQUI and on January 2006 at PICIN. Territorial mapping was made during all year of 2009 at VRQUI during July 2009 and 2010 at PICIN and

JURUB from June to September 2018 and June to August 2019. The roads at VRQUI and JURUB sites were divided into segments of approximately 1000m (Fig. 1 C) and at PICIN only one segment of 1000 m. The method of multiple marking and releasing of butterflies (MMR) was used to estimate residence times in VRQUI in 2005, 2008 and 2015. Territory mapping at JURUB during 2018-2019 was accomplished in a motor vehicle moving at a speed of 10-20 km/h and recording the position of each butterfly with a GARMIN GPS. At JURUB 30 minutes were necessary to travel the full length of the road repeating the procedure on the way back.

Distances traveled by a male within its territory were measured using a 20m measuring tape and a series of numbered flags placed 3 m apart along roadside.

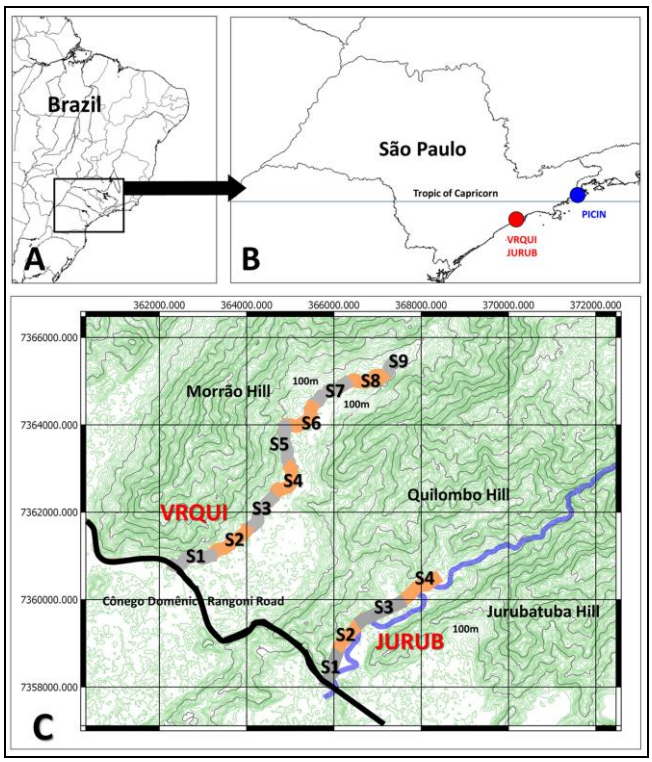

Fig 1: Localization of the study areas in (A) Brazil, and (B) in coastal area of state of São Paulo. (C) VRQUI and JURUB sites in County of Santos.

2.3 Data analysis

Appropriate tests for statistical analysis were performed using the R program v. 3.5.1 for Windows [15].

3. Results and Discussion

3.2 Male perching behavior

Males in the study areas tended to establish territories along the roads, which they then started defending. The resident male would land quickly on a perch, which is any high point where he can observe the approaching of other butterflies. These perches are branches or leaves of trees or other plants, generally not more than five meters high (range 0.50 to 7.0 m; n = 150). When any other butterfly invades his territory, the resident male rapidly flies towards it. If the intruder is another species, the male usually goes back to one of his perches. If the intruder is another conspecific male, they fight during flight in spiral flight (n = 56). These air strikes (Fig. 2) usually produce loss of wing parts. The non-resident was expulsed from the territory by the daily owner in 93% of cases (n = 67). Important to note that none of the interactions between males observed in flight resulted in their falling to the ground.

Fig 2: An air strike between two males of *A. b. tereas* during an upward spiral flight on July 26, 2018 at 09:55h. One has both right wings damaged. Photos R B Francine.

Time and horizontal distances that five territorial males traveled were quantified the by observing each other's interactions with other conspecific individuals or not. More than 84% of traveled distances were less than 9 m although in some recordings the distances were bigger (Fig. 3).

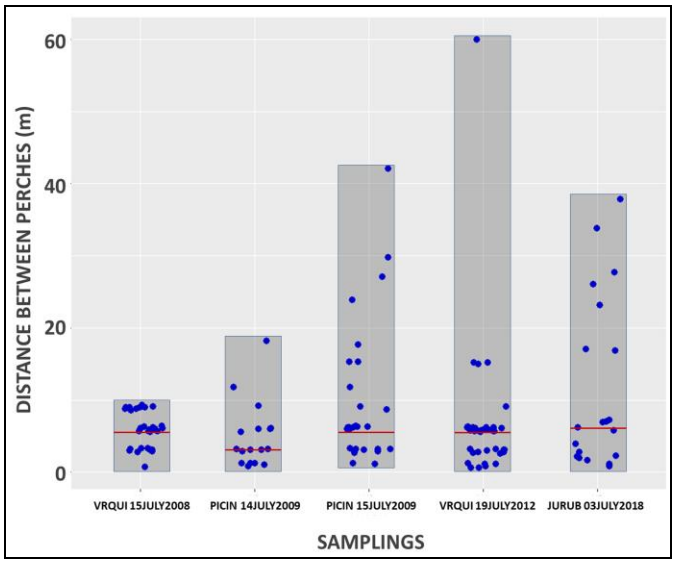

Fig 3: Distances (m) between perches of the one male butterfly *A. b. tereas* in five sites in the study area. Each point represents the distance between two landing on a perch and horizontal red line the median.

The perching sites of males remained relatively constant over time, even where there were few or no nearby flowers. This could be shown during winters of 2018 and 2019 at JURUB. In this site the number of males found was bigger (> 50%) at sector S02 than in sectors S01, S03, and S04 (Fig. 4).

Perches of species of butterflies of the genus *Hamadryas*, studied by Monge-Nájera *et al.* [16] are also constant over time

in the same site. This could signify that males are defending other, non-food resources. Data from 2009 at VRQUI (Fig. 5 A) show that number of recorded males were significant correlated with number of females (Pearson's product-moment correlation r = 0.84; t = 4.16; df = 7; p = 0.004; Fig. 5 B).

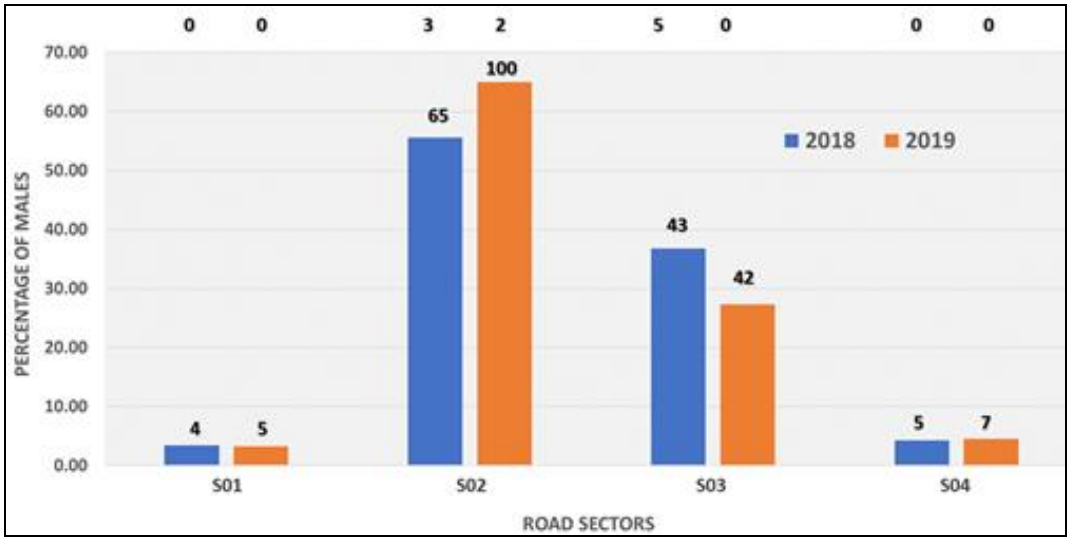

Fig 4: Percentage of males of *A. b. tereas* in the four sectors along the dirty road at JURUB during winters 2018-2019. Numbers above bars are number of males and numbers in the top, outside graph are, number of females.

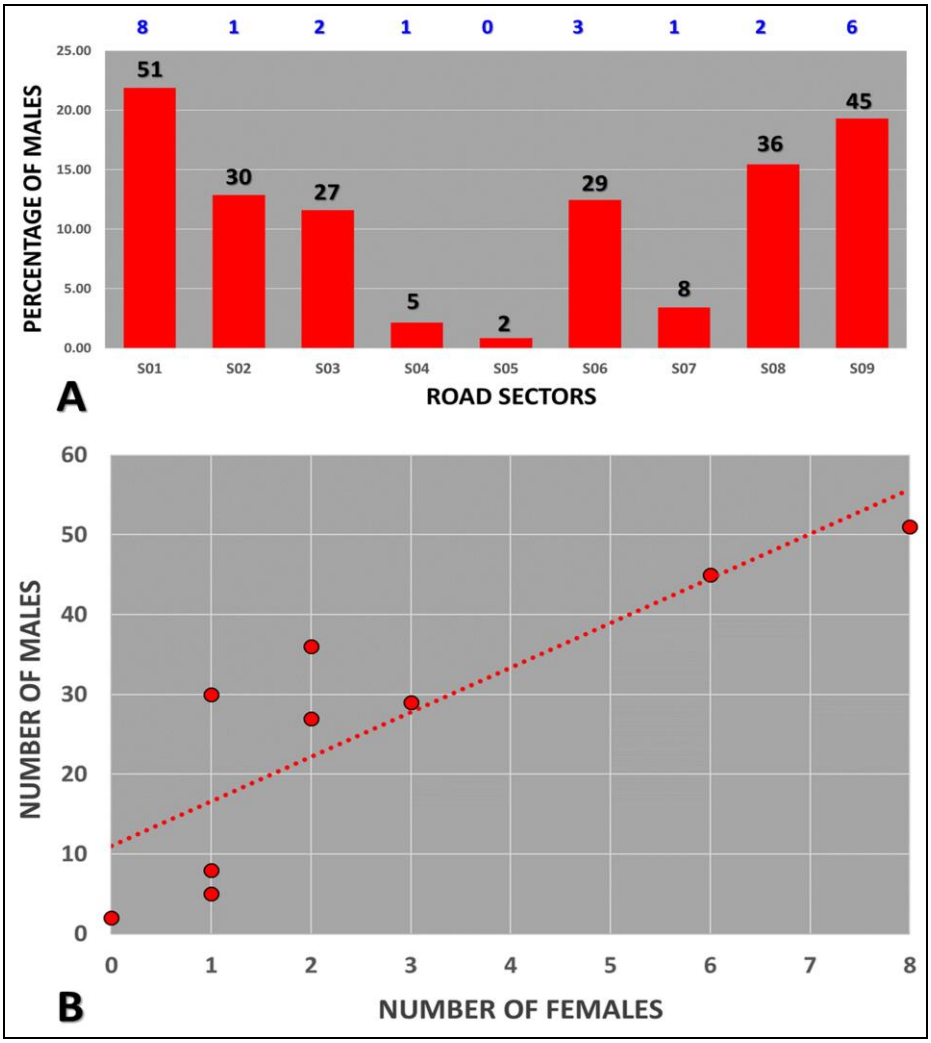

Fig 5: (A) Percentage of males of *A. b. tereas* in the nine sectors along the dirty road of VRQUI during 2009. Numbers above bars are number of males and numbers in the top, outside graph are, number of females. (B) Positive correlation between the number of females and males of *A. b. tereas* in the nine sectors along the dirty road at VRQUI site during 2009 (r = 0.84; t = 4.16; df = 7; p = 0.004).

During the winters of 2018 and 2019 the number of territories varied with each sampling (Fig. 6) as well as the distance between these territories (Fig. 7) showing a highly significant positive correlation between the number of males and the number of territories smaller than 70m ($r = 0.90$; $t = 10.066$, $df = 25$, $p < 0.0001$; Fig. 8). The greater the size of the territory, the greater the female catchment area but the greater the energy necessary for the male to defend the territory [6].

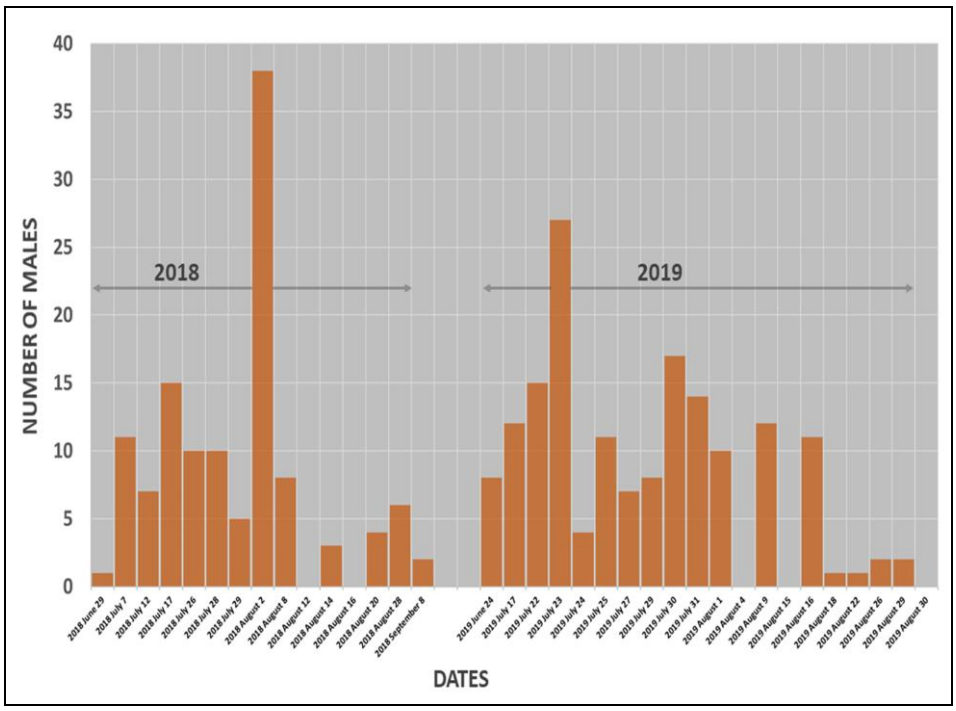

Fig 6: Number of males of *A. b. tereas* during winters 2018-2019 along the dirty road at JURUB showing that the number of male forming territories vary along time, probably dependent to number emerging and weather conditions.

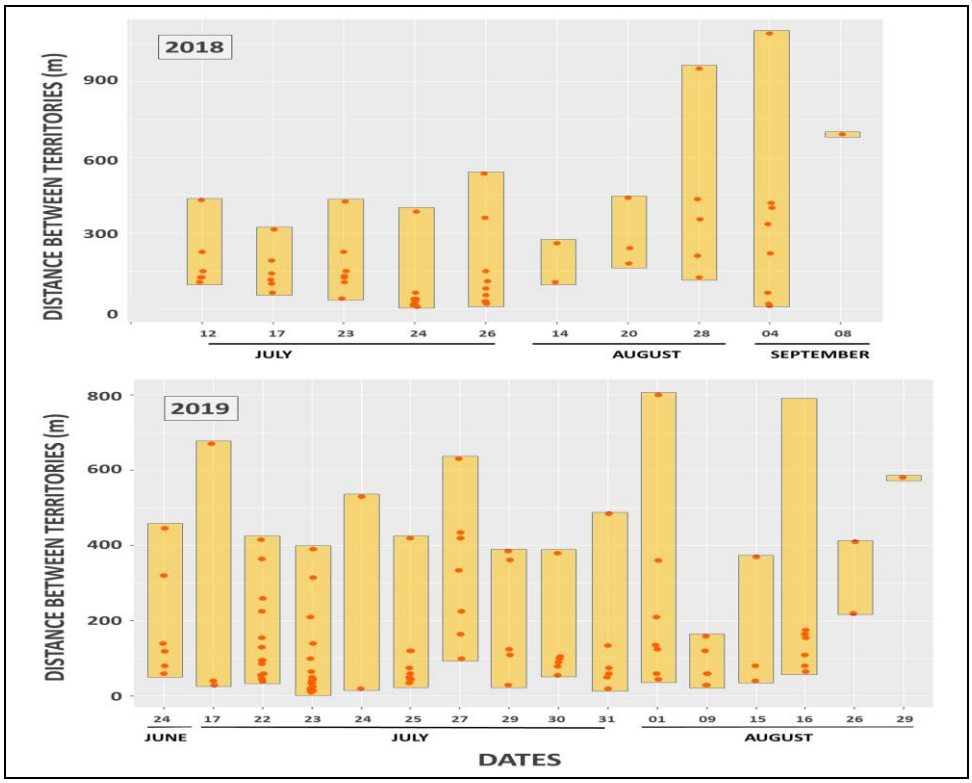

Fig 7: Distance between territories in JURUB in winter 2018 and 2019.

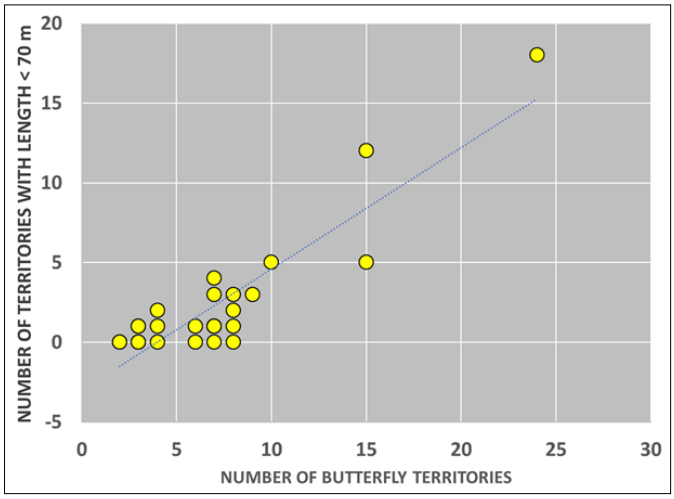

Fig 8: Positive correlation between number of butterfly territories and number of territories with length < 70 m in JURUB in winter 2018 and 2019 ((r = 0.90; t = 10.066, df = 25, p < 0.0001).

3.4 Residence in the population

During MMR of 2015 114 butterflies were marked being 80 males and 34 females (X^2 = 18.561; p < 0.0001). Only 14 males (17.5%) and 4 females (11.8%) were recaptured. Maximum residence time (MRT) of males was 29 days and females 20 days but residence time of male and females were not significant different (Wilcoxon rank sum test with continuity correction W = 47, p = 0.05). The MRT of this species at VRQUI was 30 days and other 17 species of nectarivore butterflies ranged from 6 to 120 days [17]. Male biased sex-ratios in butterflies were known for butterflies in temperate and tropical areas [18, 19, 20].

3.5 Distribution of perches in space and time

At VRQUI (n = 150) and JURUB (n = 289) the perches of males were in open areas with at least 80% of the sky visible as we can see in the at main territory at sector S02 at JURUB on 2018-2019 (Fig. 9). Topographic determinants of habitat quality of the butterfly *Euphydryas editha* were studied indicating that solar radiation is a key factor [21]. The height of the branches (mainly leaves of plants) are lower than other perching butterfly species. At VRQUI, the perches of males of *Eueides pavana* [14] and *E. aliphera* (RBF; unpublished data) are tallest at heights more than 10 meters high.

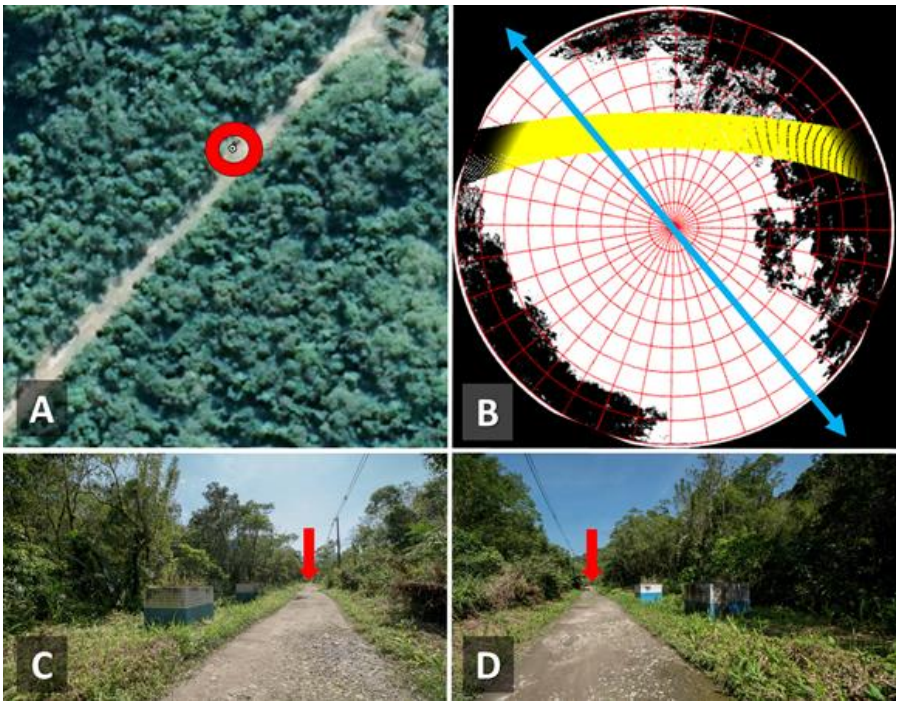

Fig 9: Main territory at JURUB. (A) Satellite view of the main territory in the sector S2 at coordinates: -23.873505° and -46.313110°. (B) Fisheye view of the central point of the main territory showing site openness of 68.28% and total transmitted solar radiation = 4.89 MJ/m^2/day (80.96%). The yellow patch indicates the sun trail during winter rising at left (east) and falling at right (west). Blue line indicates the direction of road at this point. Geographic north at top. (C) View from main territory towards SABESP dam. The red arrow indicates the beginning of the territory. (D) View of the main territory towards the Cônego Domênico Rangoni highway. The red arrow indicates the end of the territory. Photos R B Francine.

Although the territorial strategy of *A. b. tereas* could be considered as energy economic because male stays more than 50% of time landed it is a hybrid between a strict perching tactics (e. g., as in some *Adelpha* species, unpublished data) and a territorial patrolling found in male of *Actinote* species [22, 23]. *Brylla*, *discrepans*, and *zikani*, unpublished data) which spent more than 50% of territorial budget flying. The distribution of receptive females is unlikely to be random, therefore, the locations defended by territorial males should be related to a high probability of receptive females meeting [24]. The consequence is that males of territorial butterfly species should defend areas associated with female oviposition sites [6, 25, 26, 27, 28] or female food resources [29, 30]. Males of *A. b. tereas* defend sites with well-defined topographic or physical structures that are devoid of obvious resources but function as easily identifiable landmarks. This behavior was recorded for territorial males of several other butterfly species [31, 32, 33, 34, 35, 36, 37].

The increase of the number of males decreasing the distance between territories is expected by one of the hypotheses of intraspecific competition that advocates that increasing density should promote the reduction of the distance between

conspecific individuals [38]. Baker [39] argues that territorial behavior seems likely to evolve when some requirement, in this case females, is obtained in greater quantity as a result of staying a certain length of time in one suitable area rather than spending some of that time in voluntary displacement from area to area and when the quantity of this requirement is further increased by defending the area against competing individuals. He also argues that male territories are likely to be found in species in which some requirement of the female (e.g., feeding or oviposition sites) occurs in relatively concentrated areas and less likely to be found in species in which female requirements are diffusely scattered through the environment [6]. One model state that short duration of fertilizable female availability may lead to low male choosiness, less complex mate recognition systems with short courtship [40]. Also, mating takes precedence over obtaining other resources as food and males tend to aggregate in scramble competition swarms where operational sex-ratio is very male biased as showed by our results. Therefore, these results with *A. b. tereas*, are in accordance with this model and mating system can be classified as being type of resource defense polygyny [41].

4. Conclusions

1) Males are strong attracted by spots where females have high probability to be present.
2) Territories are time dependent, being formed only at early morning.
3) Increase of male density in the population cause decrease of territory length.

5. Acknowledgements

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