Universidade Federal de Minas Gerais
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Conservação e Manejo da Vida Silvestre

Biologia populacional de *Pampasatyrus glaucope boenninghauseni* e *Pampasatyrus gyrtone biezankoi*, duas borboletas ameaçadas de extinção no Brasil

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Summary

Abstract

The present study describes the population parameters, adult natural history and human impacts of two threatened butterflies subspecies, namely *Pampasatyrus glaucope boenninghauseni* and *Pampasatyrus gyrtone biezankoi*. Population biology was described based on a 2-month mark-recapture program in a site of high altitude grassland (*Campos de Altitude*) of southeastern Brazil. The daily estimated population size of *P. glaucope* males varied from 4–201 individuals and 1–231 for females and for *P. gyrtone* varied from 2–11 individuals (both sexes combined). Sex ratio of *P. glaucope* was almost 2:1, with males dominating almost all sampling period and the number of females started to increase as from half of the sample period. Average permanence time of *P. glaucope* was 7.1 days for males and 5.6 days for females, with maximum permanence of 28 days for males and 22 days for females and life expectancy of 3.8 days for males and 4.2 days for females. *P. gyrtone* maximum permanence time was 13 days for males and 10 days for females and life expectancy of 3.4 for both sexes combined. Wing size in *P. glaucope* females are greater than males but wing sizes of *P. gyrtone* are similar for both sexes. The average maximum distance traveled by *P. glaucope* was 191 m for males and 206 m for females and for *P. gyrtone* was 173 m. The average total distance traveled by *P. glaucope* was 367 m for males and 274 m for females and for *P. gyrtone* was 398 m. The average daily distance traveled by *P. glaucope* was 99.6 m for males and 91.3 m for females and for *P. gyrtone* was 112.2 m. Several impacts in the study area and surroundings were observed, such as urban expansion burnings, grazing by domestic animals and uncontrolled tourism. Both taxa share similar life traits with others threatened grassland temperate satyrids. Understanding the population patterns and human impacts on these animals can future aid conservation planning for both threatened butterflies and their natural habitat.

Key-words: Satyrinae, Pronophilina, Mark-release-recapture, movement, conservação, *Campos de Altitude*.

Resumo

O presente estudo descreve parâmetros populacionais, a história natural dos adultos e os impactos humanos de duas subespécies de borboletas ameaçadas, *Pampasatyrus glaucope boenninghauseni* e *Pampasatyrus gyrtone biezankoi*. A biologia populacional foi descrita com base num programa de marcação e recaptura totalizando 2 meses de amostragem local em campos de capim de alta altitude (*Campos de Altitude*) no sudeste do Brasil. O tamanho diário estimado da população de machos de *P. glaucope* variou de 4-201 indivíduos e 1-231 para fêmeas e para *P. gyrtone* variou de 2-11 indivíduos (ambos sexos combinados). A proporção sexual de *P. glaucope* foi de quase 2:1, com os machos dominando quase todo o período de amostragem, com o número de fêmeas aumentando a partir de metade do período de amostragem. O tempo médio de permanência de *P. glaucope* foi de 7,1 dias para machos e 5,6 dias para fêmeas, com permanência máxima de 28 dias para machos e 22 dias para fêmeas e expectativa de vida foi de 3,8 dias para machos e 4,2 dias para fêmeas. O tempo de permanência máximo de *P. gyrtone* foi de 13 dias para machos e 10 dias para fêmeas e a expectativa de vida foi de 3,4 para ambos os sexos combinados. O tamanho da asa das fêmeas de *P. glaucope* é maior do que dos machos, mas os tamanhos das asas de *P. gyrtone* são semelhantes para ambos os sexos. A média da distância máxima percorrida por *P. glaucope* foi de 191 m para machos e 206 m para fêmeas e para *P. gyrtone* foi de 173 m. A média da distância total percorrida por *P. glaucope* foi de 367 m para machos e 274 m para fêmeas e para *P. gyrtone* foi de 398 m. A média da distância diária percorrida por *P. glaucope* foi de 99,6 m para machos e 91,3 m para fêmeas e para *P. gyrtone* foi de 112,2 m. Foram observados vários impactos humanos na área de estudo e arredores, como expansão urbana, queimadas, pastoreio de animais domésticos e turismo descontrolado. Ambos os taxa compartilham traços de vida semelhantes com outros satiríneos ameaçados de campos da região temperados. Compreender os padrões da população e os impactos humanos sobre esses animais podem ajudar no futuro planejamento de conservação para ambas as borboletas ameaçadas e seu habitat natural.

Palavras-chave: Satyrinae, Pronophilina, marcação-liberação-recaptura, movimento, conservação, *Campos de Altitude*.

I - Introduction

Studies of population biology have been very significant for understanding the persistence of species in their natural environments (Tauber *et al*. 1986, Abrams *et al*. 1996, Rios *et al*. 2013). In this context, population studies of butterflies are important source of information for understanding their ecology and behavior, usually unveilling many features with a few months of fieldwork (Ehrlich 1984, Tyler *et al*. 1994, Freitas & Ramos 2001). Demographic data is fundamental to determine conservation status and the extinction risk (IUCN criteria A, C, D and E) (IUCN, 2016). Therefore, the lack of information is a critical concerning hindering our knowledge about biodiversity conservation. This concern is especially important for tropical threatened butterflies, for which very few species have information available (*e.g.* Tyler *et al.* 1994, Francini *et al*. 2005, Freitas *et al*. 2009, Beirão *et al*. 2012, Herkenhoff *et al*. 2013).

With seven species and seven subspecies, the Neotropical genus *Pampasatyrus* Hayward, 1953 (Satyrinae: Pronophilina), is widespread in open habitats of the southeastern part of South America, with one species occurring disjunctly in the Andean highlands in Peru (Zacca *et al*. 2016). Three of those subspecies are listed as 'Endangered' (EN) in the official list of endangered Brazilian fauna, namely *Pampasatyrus glaucope glaucope* (C. Felder & R. Felder, 1867), *Pampasatyrus glaucope boenninghauseni* (Foetterle, 1902) and *Pampasatyrus gyrtone biezankoi* Zacca, Pyrcz, Mielke & Casagrande 2016 (MMA, 2014, Zacca *et al*. 2016). In the summits of the Serra do Mar and Serra da Mantiqueira mountain ranges in southeastern Brazil, the high altitude grasslands (*Campos de Altitude*) harbor three subspecies of *Pampasatyrus*, including two of the endangered taxa: *P. g. boenninghauseni* and *P. gyrtone biezankoi* (Zacca *et al.* 2016). Both taxa are restricted to the open habitats above 1600 m a.s.l., where the remaining populations are threatened by recent anthropogenic

habitat conversion, including settlement, cattle ranching, agricultural expansion and frequent fires (Casagrande & Mielke 2008ab, Freitas & Marini–Filho 2011). Consequently, most of the suitable habitat remnants for these species are outside fully protected areas, making them even more vulnerable to extinction (Casagrande & Mielke 2008ab, Freitas & Marini–Filho 2011).

There is no available information on the natural history and ecology of both, *P. g. boenninghauseni* and *P. gyrtone biezankoi*, and the little available information is restricted to taxonomic and geographic distribution (Zacca *et al*. 2016). Considering that population ecology provides important source of information for subsidizing conservation actions for threatened butterflies (Freitas & Marini–Filho 2011), the aim of this study was to describe in detail the population parameters, natural history and possible impacts of the two above mentioned threatened butterflies.

II - Study Sites and Methods

Field work was carried out in a 12.7 ha area of highland cool-humid grass-dominated formation (*Campo de Altitude*) surrounded by forest vegetation in Campos do Jordão Municipality, São Paulo State, SE Brazil (22°43'S 45°31'W, ca. 1780 m a.s.l.) (Fig. 1 and Fig. 2 A-B). The study site is inside a residential condominium. The annual rainfall in the region is about 1.705 mm and the average annual temperature is 14.8°C (the average minimum temperature is 11°C and maximum 18°C, Cepagri 2017). The climate of the region is characterized as CWB (Subtropical highland climate, dry winter and warm summer, Köppen & Geiger 1939).

Henceforward studied subspecies *P. glaucope boenninghauseni* and *P. gyrtone biezankoi* will be namely as *P. glaucope* and *P. gyrtone*, respectively (Fig. 2 C-E).

Butterflies were collected during the entire subspecies flight-period (from February 5 to March 22, 2017, totaling 39 effective days, about 7 hours/day and 273 net-hours of sampling effort) by a mark-release-recapture (MRR) program. Butterflies were net-captured and individually numbered on the underside of both forewings with a permanent felt-tipped pen, and then released (folowing Freitas 1993, 1996, Francini 2010). Characteristics of each individual capture, including wing wear, sex, forewing length, food resources, behavior, point of capture (using GPS) and flight height, were recorded. For each individual capture occasion (including recaptured individuals), geographic coordinates data were recorded with GPS device (maximum 3 meters error), date, hour and air temperature (in the morning and in the afternoon, for average temperature of the day). During field work, some impacts in the grassland were observed. Age was estimated based on wing wear scale, divided into five categories three categories: 1) new, 2) intermediate, and 3) old (as in Freitas 1993, 1996). Age structure of *P. glaucope* was calculated (both sexes together), through the daily proportions of each category.

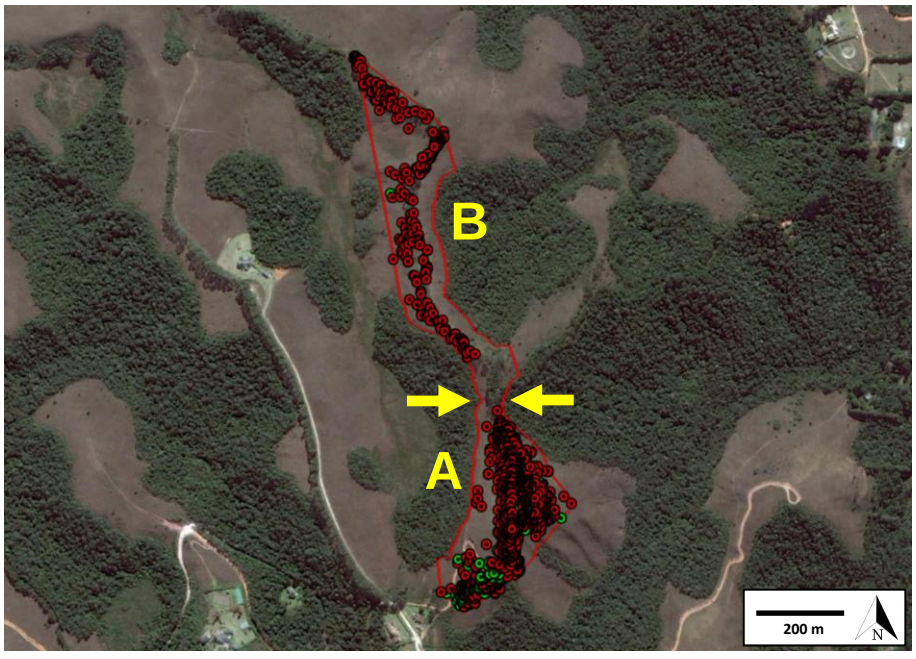

Figure 1. Studied site, Campos do Jordão, São Paulo, Brazil. Red line: total studied area; Red circles: *P. glaucope* registers; Green circles: *P. gyrtone* registers; Yellow arrows: narrowing that separate the studied site into two subareas (A and B). Source of orthophotomaps: Google Earth.

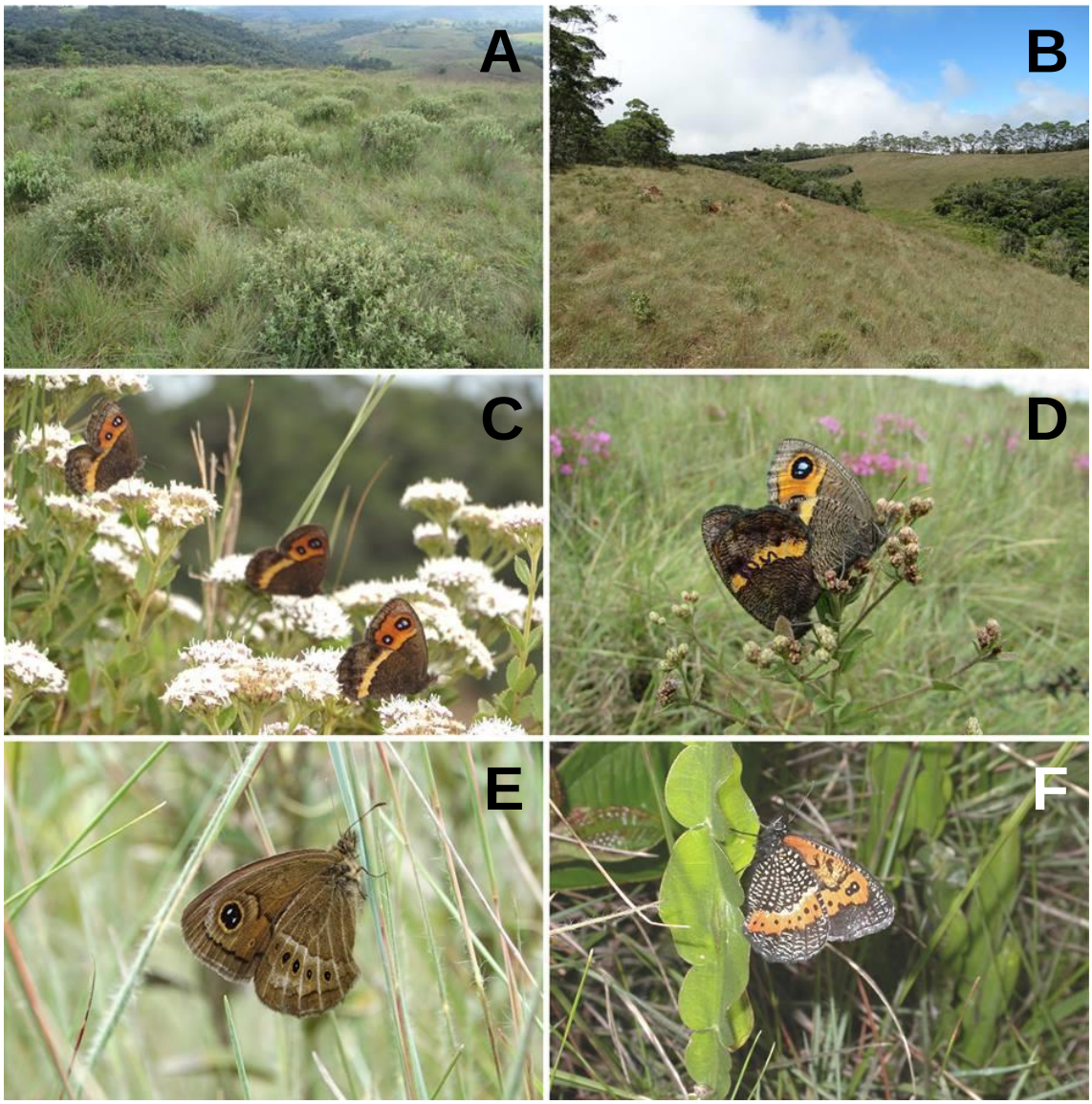

Figure 2. **A**. The *Campo de Altitude*, of subarea A; **B**. Subarea B; **C**. *P. glaucope* feeding on flowers of *Grazielia* sp. (Asteraceae); **D**. *P. glaucope* mating; **E**. *P. gyrtone;* **F**. *P. reticulata*

Population parameters were obtained by the Jolly-Seber (JS) method using the MMRWIN_2016 software (Francini 2016). Males and females were analyzed separately for *P. glaucope*; however, for *P. gyrtone* due to the low number of captured individuals, sexes were combined. Daily results were recorded as the number of individuals captured per day (NICPD), including recaptures, and the number of individuals present per day (NIPPD). To estimate NIPPD, recaptured individuals were considered to be present on all previous days since their first capture (following Freitas & Ramos 2001). Population

density was obtained as the quotiente of the total number of captured individuals by the total life area (a convex polygon encompassing all points of the captured individuals), resulting in the number of individuals per hectare (following Francini 2010).

Individual permanence (an indirect measure of individual longevity) was calculated as days elapsed between mark and last recapture (following Brussard *et al*. 1974). Survival curves follow Ehrlich & Gilbert (1973) and life expectancy follows Cook *et al*. (1967). Sex was identified by genitalia inspection and the sex ratio was calculated through the daily proportions in number of individuals captured per day (following Ramos & Freitas 1999). Forewing length of captured butterflies was measured with a caliper using forewing insertion on thorax and the tip of the wing as anatomical landmarks, for a possible sexual dimorphism.

Individual movements were obtained by using the first capture and all individuals recaptures. The following indicatives of movement were calculated: 1) maximum distance traveled (MDT), as the distance in meters between the two most distant points of each individual capture, 2) daily distance traveled (DDT), as the total distance traveled by each individual in a single day (only for recaptures in the same day), and 3) total distance traveled (TDT), as the sum of total distance traveled in meters by each individual in each recapture, from the first to the last (including those in the same day).

The individual life area was obtained by calculating the total area (in m^2) of the convex polygon based on the first capture and all recaptures (minimum of two) of each individual (including recaptures within the same day). Movements were obtained by the Google Earth using ruler tool, by connecting all recapture points plotted on map for each individual.

III - Results

1. Population Biology of *P. glaucope boenninghauseni*

1.1. Population Size

During the sample period, a total of 579 individuals were marked, being 384 males and 195 females totaling 1,847 capture events (Fig. 3). The number of individuals captured per day varied from one to 96 for males (mean = 35.1; SD = 25.87; *n* = 36 days), and from one to 30 for females (mean = 9.47; SD = 7.48; *n* = 38 days). The number of individuals present per day varied from one to 127 for males (mean = 55.9; SD = 41.79; *n* = 36 days), and from one to 37 for females (mean = 14.4; SD = 10.70; *n* = 38 days). The estimated population size by JS varied from four to 203 individuals per day for males and from one to 231 individuals per day for females (Fig. 3). The total area of occupied patches was 12.7 ha and the population density was of 30.2 individual/ha for males and 15.3 individual/ha for females.

1.2 Recaptures

Individual males were recaptured from one to 11 times (879 total recapture events), and individual females from one to 12 times (165 total recapture events); 264 males (68.8 %) and 74 females (37.9 %) were recaptured at least once (Table 1).

Table 1. Number of recaptures of *P. glaucope* and *P. gyrtone* individuals

No. of recaptures	♂ ***glaucope***	♀ ***glaucope***	♂ ***gyrtone***	♀ ***gyrtone***
1	65	42	5	-
2	48	11	4	-
3	45	6	2	1
4	45	6	4	-

5	23	5	1	1
6	14	1	1	-
7	5	1	1	-
8	9	0	1	-
9	4	1	-	-
10	5	0	-	-
11	1	0	-	-
12	0	1	-	-

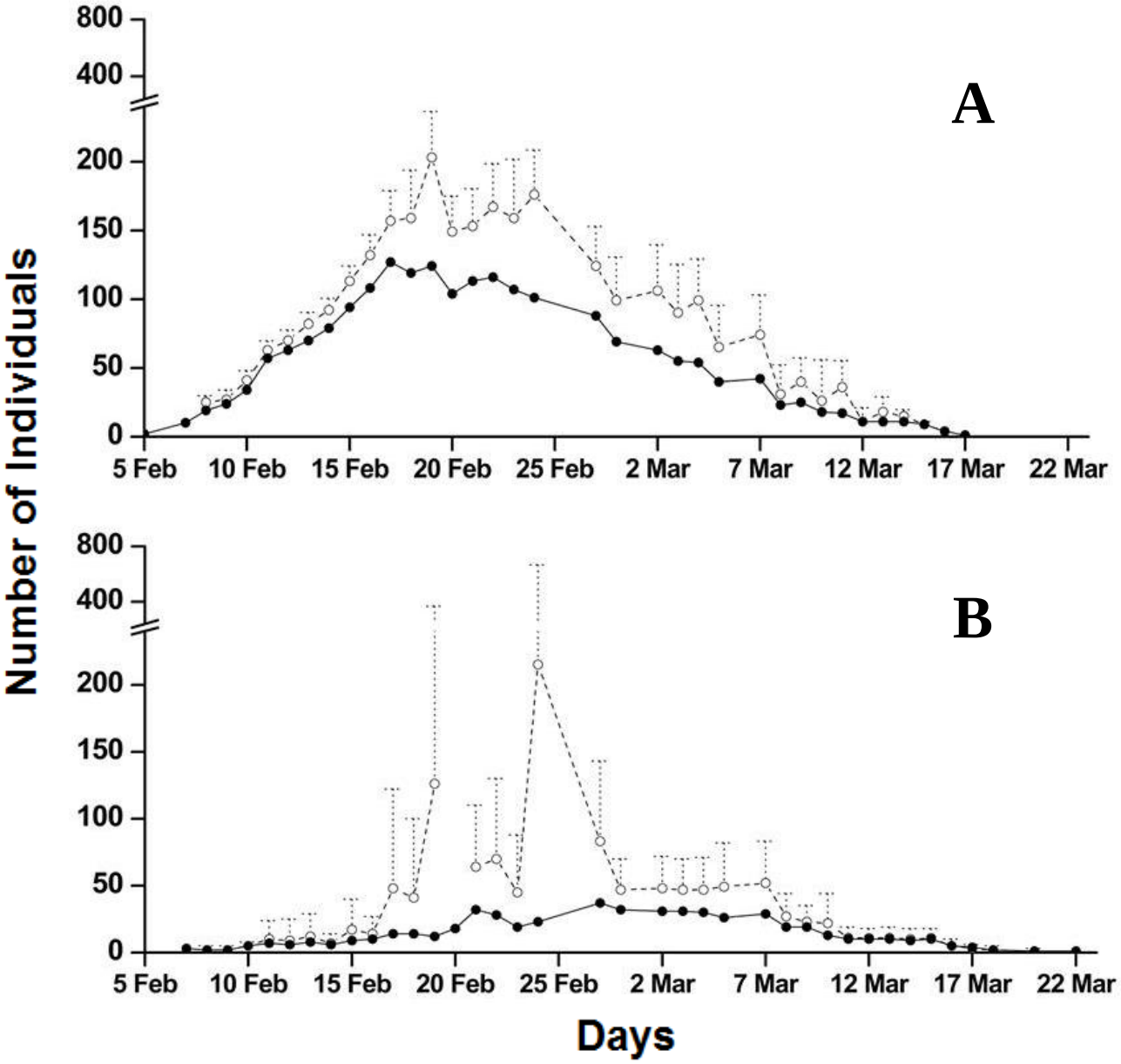

Figure 3. Number of males (A) and females (B) of *P. glaucope* from February to March (2017) in the study site in Campos do Jordão, São Paulo, Brazil. Solid circles = number of individuals present per day, open circles = estimated number, bars = 1 standard error.

1.3 Permanence Time

The permanence time (based on recaptured individuals) varied from one to 28 days for males (mean = 7.1 days; SD = 5.03; *n* = 264) and from one to 22 days for females (mean = 5.6 days; SD = 5.28; *n* = 74) (Table 2). Permanence time is different between the sexes (student *t* test; *t* = 2325; *P* = 0.022) and for males mostly of the individuals permanence were from one to eight days and from 1 to four days for females (Table 2). Life expectancy was of 3.8 days for males and 4.2 days for females. Survival curves are similar for both sexes (Kolmogorov-Smirnov test; *P* > 0.05; df = 2), approaching a type II curve (Fig. 4).

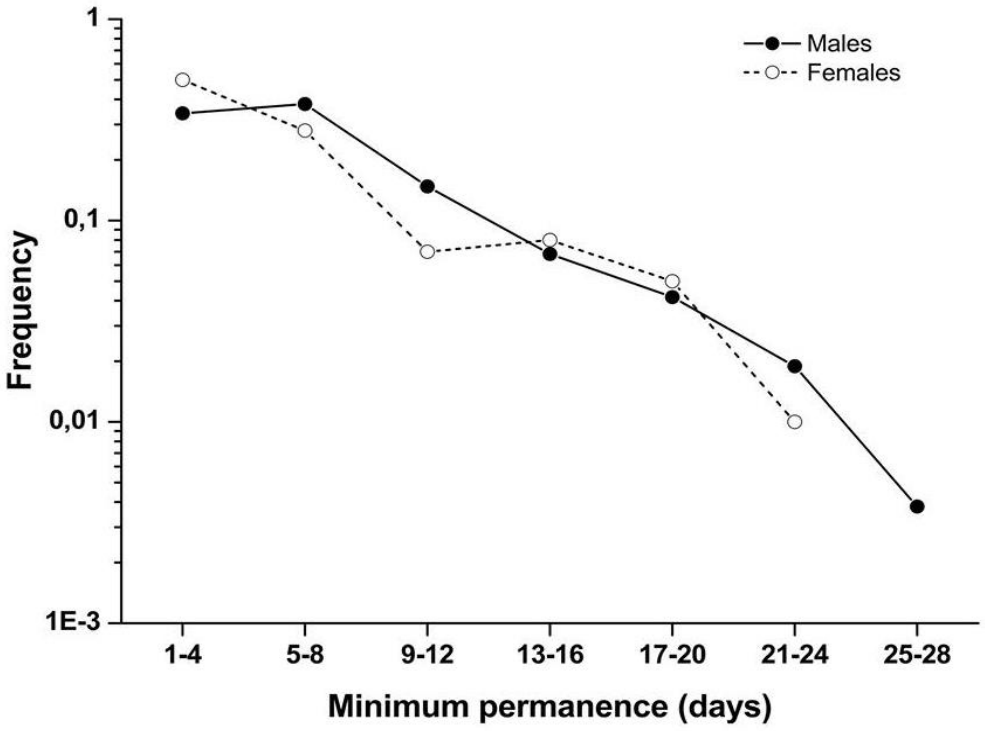

Figure 4. Survivorship curves for *P. glaucope* males and females. The frequencies of males and females are plotted on log scale against permanence categories (based on data presented on Table 2).

Table 2. Permanence of marked *P. glaucope* and *P. gyrtone.* Days elapsed between marking and last recapture represent the minimum permanence (MP) for each individual. gl = *glaucope*, gy = *gyrtone.*

MP (Days)	♂ gl	(%)	♀ gl	(%)	♂ gy	(%)	♀ gy	(%)
1-4	88	33.3	37	50.0	9	47.4	1	50
5-8	102	38.6	21	28.4	8	42.1		-
9-12	39	14.8	5	6.8	1	5.3	1	50
13-16	18	6.8	7	9.5	1	5.3	-	-
17-20	11	4.2	3	4.1	-	-	-	-
21-24	5	1.9	1	1.4	-	-	-	-
25-28	1	0.4	-	-	-	-	-	-

1.4 Sex Ratio

The sex ratio of individuals captured and marked was male biased, with 384 males and 195 females marked (1.97:1; χ^2 = 61.69; df = 1; P < 0.0001). Males were dominant almost all sampling days and females start to increase in proportion from half of the period and become exclusive at the last four sampling days (Fig. 5).

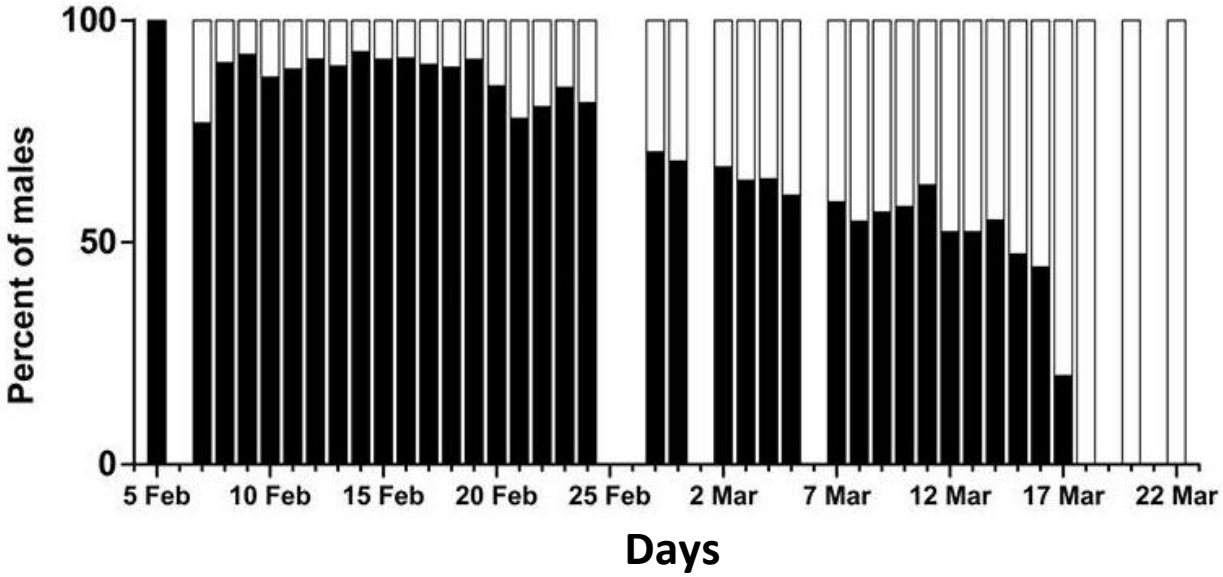

Figure 5. Sex ratio of *P. glaucope boenninghauseni* from February to March 2017 in the study site in Campos do Jordão, São Paulo, Brazil. Data presented as percent of males (black) and females (white), based on means of each day's captures.

1.5 Age Structure

During the 39 days of study, the age structure showed that ‘new’ individuals are dominant in the beginning of the flight period; ‘intermediate’ individuals appear in the second day and ‘old’ individuals appeared after just five days, suggesting a high decay in wing wear. The ‘new’ individuals become progressively less dominant, being replaced by the ‘intermediate’ and ‘old’ age classes, with only ‘old’ individuals sampled in the last eight days before the end of the flight period (Fig. 6).

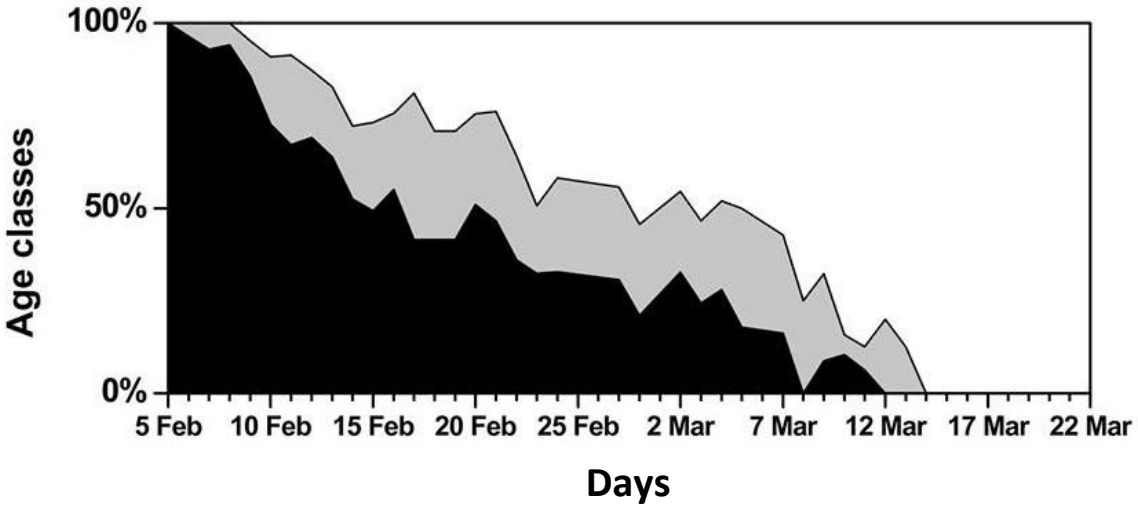

Figure 6. Age structure for *P. glaucope boenninghauseni* (both sexes) from February to March 2017 in the study site in Campos do Jordão, São Paulo, Brazil (black = new individuals, gray = intermediate, white = old).

1.6 Wing Size

The forewing length ranged from 24 to 32 mm in males and from 26 to 33 mm in females. The average forewing length of females (mean = 29.8 mm; SD = 1.55; n = 195) was bigger than that of males (mean = 28.4 mm; SD = 1.36; n = 384) (Mann–Whitney U test; U = 18951; $P < 0.0001$).

1.7 Movement

Maximum distance traveled by males and females were equal (Table 3), ranging from five meters to 1,033 m for males and from three meters to 954 m for females. Total distance traveled by males was greater than for females (Table 3), ranging from five meters to 1,928 m for males and from three m to 1,622 m for females. Daily distance traveled by males was the same of females (Table 3), ranging from three meters to 825 m for males and from three meters to 476 m for females. Life area of males and females are not significantly different (Table 3), ranging from 12 m^2 to 74,833 m^2 for males and from two m^2 to 63,362 m^2 for females.

No individual was observed entering or flying above the surrounding forests of the grassland, being restricted only to the forest edges. In the studied site there is a narrowing about 50 meters wide surrounded by forest vegetation, this bottleneck somehow separates the field studied in two subareas (Fig. 1, Fig. 2. A-B). From a total of 579 individuals, only 30 (19 males and 11 females) moved from one subarea to the other, with 24 never returning to the original subarea.

Table 3. Movement data and life area of *P. glaucope boenninghauseni* and *P. gyrtone* from February to March (2017) in the study site in Campos do Jordão, São Paulo, Brazil. Comparison between sexes was made only for *P. glaucope*, accessed by Mann–Whitney *U* test.

	Max. distance (mean ± SD)	**N**	**Test**	**Total distance (mean ± SD)**	**N**	**Test**	**Life area (mean ± SD)**	**N**	**Test**	**Daily vagility (mean ± SD)**	**N**	**Test**
glaucope ♂	191 ± 185.59	267	*U* =	367 ± 321.44	267	*U* =	5657 ± 7756.45	210	*U* =	99.6 ± 118.15	123	*U* =
glaucope ♀	206 ± 228.53	83	10328.5 ns	274 ± 317.91	83	8411.5***	8032 ± 13289.94	39	3805.5 ns	81.3 ± 96.89	27	1351 ns
gyrtone (sexes together)	173 ± 160.26	21		398 ± 324.43	21		5199 ± 10248.70	19		112.2 ± 182.92	16	

* P < 0.05; ** P < 0.01; *** P < 0.001; ns = not significant

1.8. Natural History, Behavior and Adult Resources of *P. glaucope*

P. glaucope boenninghauseni is endemic to Brazilian Southeast *Campos de Altitude*. They fly or perch beside small bushes scattered across the grasslands. This species flies in sunny days (average temperature 23,7°C, minimum 16.7°C, maximum 31.3°C), both sexes fly from 9:38 a.m. to 17:02 p.m., and they were more active between 11:00 a.m. to 12:00 p.m., with flight height varying from 0.5 m to 2.5 m above ground (average = 1.0 m; SD = 0.106; n = 1105). Adults of both sexes are usually spotted perching on grasses, quickly evading upon approach (less than 2 meters distance). Mating (Fig. 2D) was observed seven times and in six of these, females were newly emerged (against only two newly emerged males).

The quantitative behavioral repertory (a total of 1847 records) is dominated by wandering flight (n = 1105, 935 males and 170 females), followed by perching (n = 531, 375 males and 156 females), feeding on flowers (n = 193, 140 males and 53 females), and mating (n = 7 couples). The behavioral profile of males and females is different, with males much more active than females ($\chi^2 = 44.02$; df = 2; $P < 0.0001$) (Fig. 7).

Males were sometimes observed chasing other butterflies, conspecific or not (other species are *Vanessa braziliensis*, *Junonia evarete*, *Moneuptychia itapeva*, *Nicolaea schausa*). The host-plant is unknown, and oviposition behavior was never observed. An individual was found with an ectoparasite mite of the genus *Leptus* (Acari: Erythraeidae). Some individuals were observed rapidly tapping the abdomen against moist soil. Besides *P. glaucope* and *P. gyrtone*, the third sympatric species (*P. reticulata*) (Fig. 1F) was observed flying fast in the hilltop of the studied site (only one male and one female).

Butterflies were observed visiting flowers of six different species of Asteraceae (Fig. 1C) and one Rubiaceae, namely *Grazielia* sp. (n = 69 records, *Chromolaena* sp. (n = 15), *Campuloclinium* sp. (n = 4), *Vernonanthura westiniana* (Less.) H. Rob (n = 2), *Heterocondylus* sp. (n = 1), *Grazielia multifida* (DC.) R.M.King & H. Rob (n = 1) (Asteraceae) and *Declieuxia cordigera* var. *angustifolia* Müll. Arg. (n = 1) (Rubiaceae).

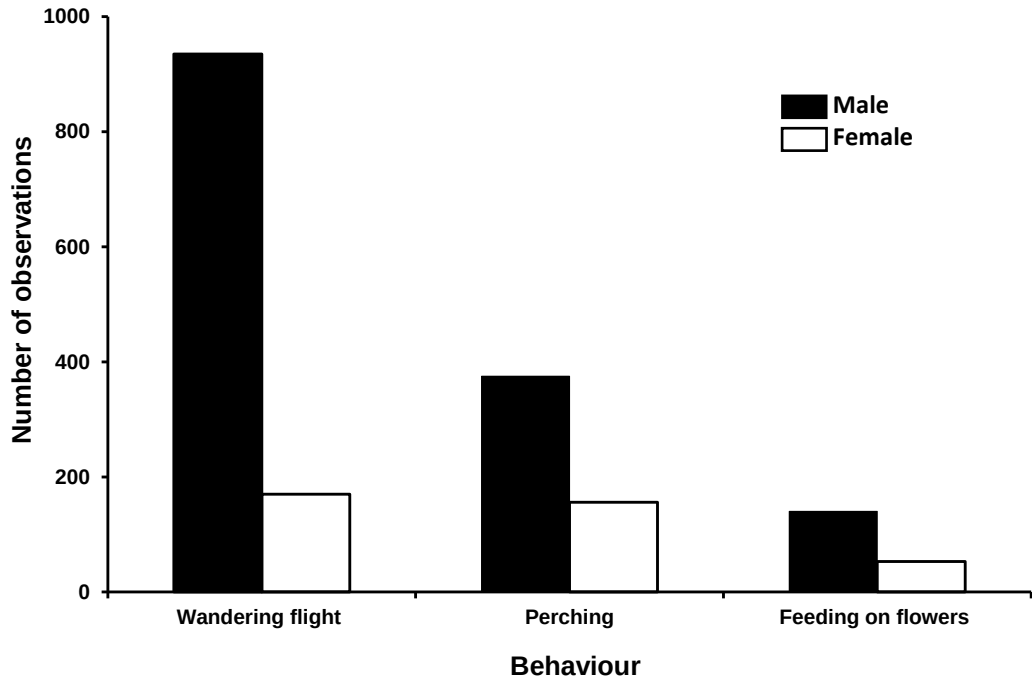

Figure 7. Different behaviors observed of *P. glaucope* in the study site in Campos do Jordão, São Paulo, Brazil

2. Population Biology of *P. gyrtone*

2.1. Population Size

During the sample period, a total of 32 individuals were marked, being 23 males and 9 females totaling 130 capture events (Fig. 8). The number of individuals captured one to eight individuals captured per day (mean = 4.0; SD = 2.19; *n* = 25 days). The number of individuals present per day varied from one to 10 (mean = 5.2; SD = 2.58; *n* = 25 d). The estimated population size by JS varied from two to 11 individuals per day

(Fig. 8). The total area of occupied patches was 6.2 ha and population density were 5.2 individual/ha.

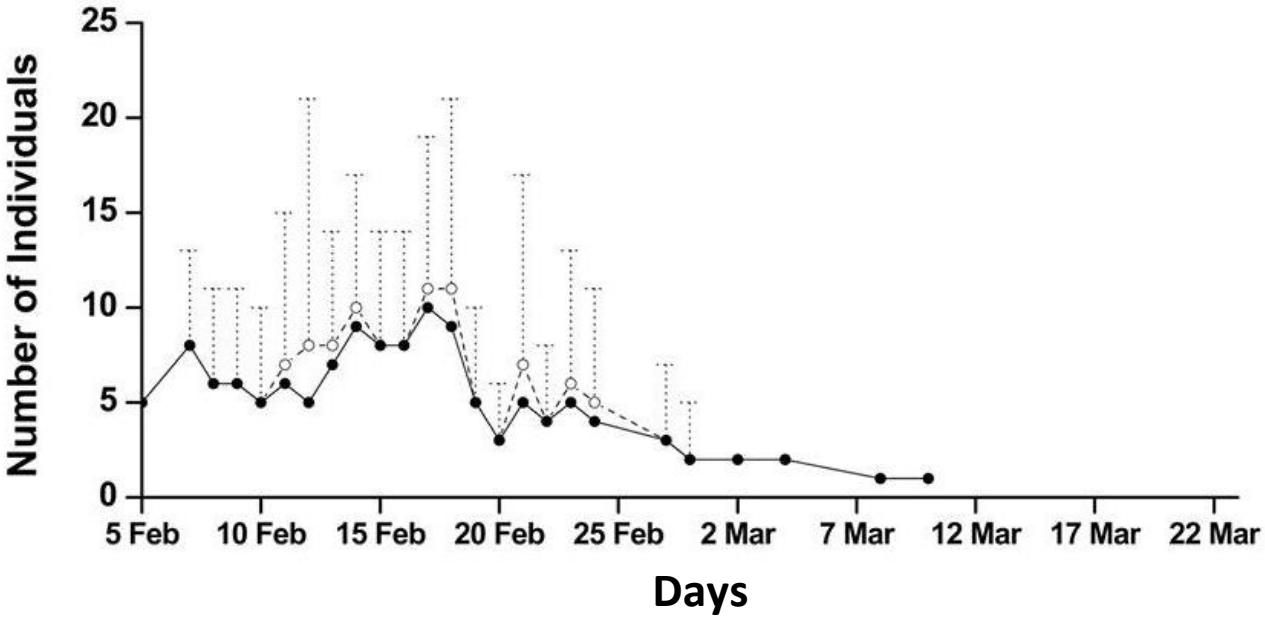

Figure 8. Number of males of *P. gyrtone* (sexes together), from February to March (2017) in the study site in Campos do Jordão, São Paulo, Brazil. Solid circles = number of individuals present per day, open circles = estimated number, bars = 1 standard error.

2.2. Recaptures

Males were recaptured from one to eight times (61 total recapture events), and two females were recaptured three and five times (8 total recapture events), 19 males (82.6 %) and two females (22.2 %) were recaptured at least once (Table 1).

2.3. Permanence Time

The permanence time (based on recaptured individuals) varied from one to 13 days for males (mean = 4.7 days; SD = 3.05; *n* = 19) and four and 10 days for females (*n* = 2) (Table 2). Life expectancy was of 3.4 days (both sexes together).

2.4. Sex Ratio

The sex ratio of individuals captured and marked was male biased, with 23 males and nine females marked (2.5:1; $\chi^2 = 6.125$; df = 1; $P = 0.022$).

2.5. Wing Size

The forewing length ranged from 21 to 28 mm in males and from 23 to 27 mm in females. The average forewing length of females (mean = 24.7 mm; SD = 1.30; n = 9) was not different from males (mean = 24.5 mm; SD = 1.38; n = 23) (Mann–Whitney U test; $U = 94.5$; $P = 0.706$).

2.6. Movement

Maximum distance traveled by individuals (all information presented below is for both sexes together) ranged from 42 m to 776 m (Table 3). The total distance traveled individuals ranged from 67 m to 1,231 m (Table 3). Daily distance traveled of individuals ranged from five m to 781 m (Table 3). Life area of individuals ranged from 167 m^2 to 46,756 m^2 (Table 3). No individuals was observed entering or flying above the surroundings forests. Within a total of 32 individuals, only one changed of subarea.

2.8. Natural History, Behavior and Resources of *P. gyrtone*

P. gyrtone biezankoi lives at the same habitat kind of *P. glaucope boenninghauseni*, but in addition to Southeast it extend to South of Brasil. As *P. glaucope*, they fly or rest beside small bushes, flies in sunny days at the same temperature and both males and females fly from 9:22 a.m. to 15:45 p.m. and mostly of the individual between 10:00 a.m. to 11:00 a.m. varying in fight from 0.5 m to 2 m

above ground (average = 0.9 m; SD = 0.219; n = 89). Individuals spotted perching evade upon approach just like P. *glaucope*.

The quantitative behavioral repertory (a total of 130 records) is dominated by wandering flight flying (n = 89, 82 male and 7 female), followed by perching (n = 40; 30 males and 10 females) and feeding on flowers (n = 1). The behavioral profile of males and females is different, with males more active than females ($\chi^2 = 7.082$; df = 1; $P < 0.017$) (Fig. 9). One individual was observed visiting flowers of *Grazielia* sp. (Asteraceae). The host-plant is unknown, and oviposition behavior was never observed.

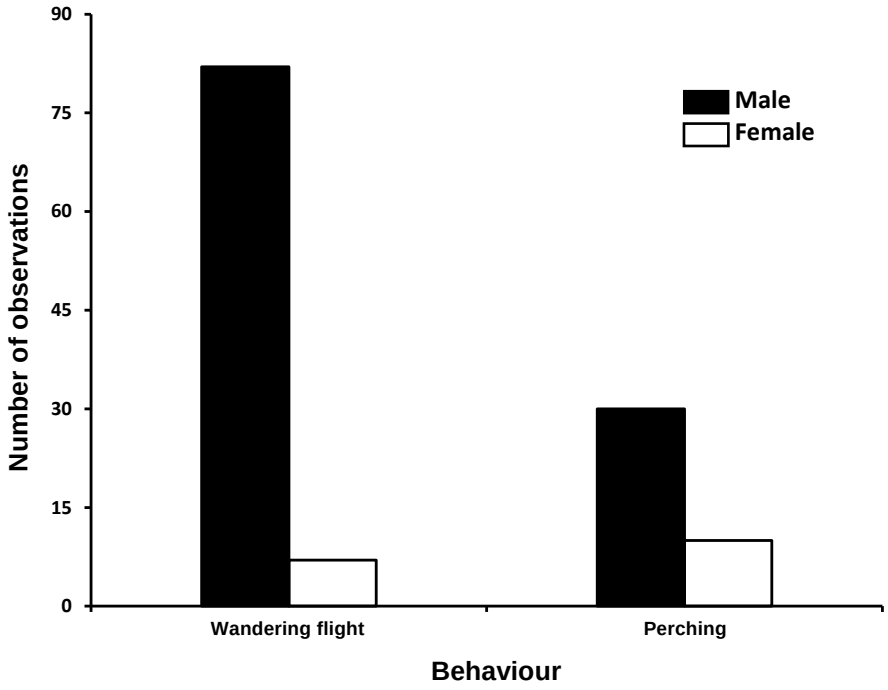

Figure 9. Differente behaviours observed of *P. gyrtone* in the study site in Campos do Jordão, São Paulo, Brazil

3. Impacts in the Study Area

During the study, we observed several impacts in the studied *Campos de Altitude*, such as urban expansion of the surroundings, because the field is inside a residential condominium that still in building new houses and its accesses (Fig. 10A).

Several plants were collect from the studied site, probably for sale. Occasionally horses were observed grazing all over the area (Fig. 10D) and also cattle in the surroundings and their traces in the site. Uncontrolled tourism is also an impact observed in the studied grassland, motorcycles and quadricycles do not follow the existing tracks and pass over the grass leaving marked paths at various locations (Fig. 10C). Fire was observed during the field work, with at least three burning occasions around the site (Fig. 10B) and several cigarette butts were found at the hilltop. In August and September of 2017, 9.2 ha (72.4 %) of the studied site was burned.

Figure 10. Impacts in the study site and surrondings, Campos do Jordão, Brazil. **A**. Construction of accesses of a future house, **B**. Antropogenic fire; **C**. Marks of a quadricycle outside trails. **D**. Horses grazzing.

IV - Discussion

4. Populational biology

Both studied butterflies present a short flight period, restricted to about two months during the austral summer, a pattern much similar to that described for temperate species of Satyrinae inhabiting similar open grassland habitats (Brussard & Ehrlich 1970, Tudor & Parkini 1979, Kuras *et al*. 2003, Szymanski *et al*. 2004, Barton & Bach 2005, Kuefler *et al*. 2008, Slamova *et al*. 2013, Konvička *et al*. 2016, Sielezniew & Nowicki 2017). Although sharing several similarities, the two studied butterfly subsprecies differ in some population parameters, including the population size, which is much larger for *P. glaucope* for which density was four times greater than *P. gyrtone*. The smaller population size of *P. gyrtone* could be only a difference of the study site, because Zacca *et al*. (2016) points out that for Pico do Itapeva (Pindamonhangaba, São Paulo) about 4.5 km away from the studied area, *P. gyrtone* is more abundant than *P. glaucope*. Thus, it is possible that population dynamics of these subspecies differ drastically among the several hilltops in the region.

Permanence between males and females of *P. glaucope* slightly differs, but when compared with *P. gyrtone*, their average and maximum is lower than that observed for *P. glaucope*, thus demonstrating that *P. gyrtone* has short lifespan. Life expectancies of *P. glaucope* and *P. gyrtone* are short (3-5 days), as those reported for other satyrids of alpine grasslands (Tudor & Parkini 1979, Čelik *et al*. 2004). Budová *et al*. (2016) found a strong relationship between butterflies' short life period and their conservation status in European butterlies were mostly of the endangerd species had short life. In this case, adult butterlies have a very narrow time window to copulate, and consequently some individuals do not have the chance to mate a partner. This could be exacerbated by protandry i.e. earlier emergence of males as compared with females,

which is typical for butterlies (Wiklund & Fagerström 1977). A negative effect of protandry for the population is that a fraction of males may not survive long enough to mate with the later-emerging females and some females will consequently died uncopulated, not laying eggs. This lost reproductive potential can significantly decrease population size and could also lead to population extinctions (Budová *et al*. 2016).

The reported sex ratio for *P. glaucope* was almost 2:1, different from that observed for many other Satyrinae from Temperate Zone that presented their sex ratio varying between 1:1 and 1.7:1 (Dowdeswell *et al*. 1949, Tudor & Parkini 1979, Čelik *et al*. 2004, Čelik *et al*. 2009, Slamova *et al*. 2013, Orvossy *et al*. 2013). Other species have some similarity for the observed in *gyrtone* 2.5:1 (*e.g*. Brakefield 1982, Lörtscher *et al*. 1997, Kuras *et al*. 2003, Szymanski *et al*. 2004). *P. glaucope* has early emergence of males up to half of the flight period and shifts more gradually for females (protandry) which is also shared with several Satyrinae species (Dowdeswell *et al*. 1949, Brussard & Ehrlich 1970, Lörtscher *et al*. 1997, Čelik *et al*. 2004, Szymanski *et al*. 2004, Slamova *et al*. 2013, Konvička *et al*. 2016, Sielezniew & Nowicki 2017). Protandry strategy can be disadvantageous as previously mentioned, but in some cases it can be advantageous for some reasons: (1) it may ensure that the few females that emerge at the beginning of the reproductive period are immediate fertilized due to the high number of males available to copulate, thus avoiding the death of virgin females (Wiklund & Fagerström 1977, Fagerström & Wiklund 1982, Zonneveld & Metz 1991, Zonneveld 1992, Čelik *et al*. 2004), (2) it may prevent inbreeding and (3) increases the chance of copula for males that survive longer periods and if this feature of longer survival is something related to their genetics, then they may benefit their offspring (Wiklund & Fagerstrsm, 1977, Bubová *et al*. 2016).

It was possible to observe certain habitat fidelity in part of both studied populations, since that some individuals were recaptured many times (up to 12 recaptures) and more than half of their individuals were recaptured at least once, this latter fact was also observed for the open fields European satyrids (Slamova *et al*. 2013, Sielezniew & Nowicki 2017).

The age structure of *P. glaucope* did not show stability between the age classes, there was a continuous decrease of the 'new' category from the beginning of the sampling, followed by the 'intermediate' class and then 'old' class. Individual in 'old' category appears five days after the beginning of the flight period, reaching almost 50% of the population in the middle of the period, and for all individuals in the last eight days. This shows that the decay of individuals age classes is fast within a few days of their flight period. Unfortunately it was not possible to observe a pattern in age structure of *P. gyrtone* due to its low number of individuals.

The length of the wings of *P. glaucope* females are bigger than that of males, presenting sexual dimorphism for this subspecies, as found by Zacca *et al*. (2016) and also observed for other satyrids (see Uehara-Prado *et al*. 2005).

The maximum and the total distance traveled shown that some individuals could reach larger distances but the pattern for most of the individual is to fly little distances. The life area of *P. glaucope* is the same for both sexes, similar that found for a North American satyrid *Neonympha mitchellii mitchellii* (Barton & Bach 2005). The narrowing that separates the studied site in two subareas, acts as a bottleneck for the individual's movement of both subspecies, as only 5% of *P. glaucope* individuals and just one individual of *P. gyrtone* could move between the two subareas, making it clear that most of the individual have their movement restricted. Thus, both studied butterflies present low movement range and high restriction to the grassland habitat,

since no individuals were observed entering or flying inside the forest patches surrounding the study area.

Behaviors were different between males and females of both studied butterflies, since that males are more active than females. Some individuals were observed striking the tip of their abdomen against the moist soil, this behavior can be carried out by females laying eggs in soil (A.V.L. Freitas personal communication, 2017).

5. Impacts and Conservation Implications

In the studied *Campos de Altitude* and the surroundings the anthropic pressure is intense. Many houses and its accesses have been built over the grassland, thus modifying the suitable habitat of the studied butterflies for ever. Horses were observed grazing freely in the field. Safford (1999) states that the impacts grazing in *Campos de altitude* were not directly studied but claim that in a long term the presence of these animals may cause negative impacts in soil, microclimate, water quality and flow and well-being to organisms, especially to endemic species of these grasslands. Unregulated tourism can also affect the habitat quality, because when passing over the grass with motorcycles and quadricycles, and they also pass over the larvae (that we suspect that lives in the grass and feed on it, as many other satyrids feeds of Poaceae) (Becalloni *et al*. 2008) or they might runover adults during the fight period. Other remarkable impact observed was the several burnings in the site and surroundings, both during the flight period of the butterflies and in subsequent visits in which almost all the studied site was burned out. Natural fire is rare in campos de altitude (Aximoff & Rodrigues 2011), and for more than a century it has been affected by antropogenic fire (Aximoff 2011, Safford 2001, Martinelli 2007). Although some members of Poaceae and Cyperaceae plant families may be adapted and resistant to fire in high altitude grasslands (Aximoff

2011, Safford 2001), butterfly adults and its immatures are not, and their population may decline sharply as result of burnings, as ocurred in one grassland for the threatened North American Satyrid *Neonympha mitchellii francisci* (Kuefler *et al*. 2008).

The studied butterflies share similar characteristics of population and habitat with other satyrids from temperate zone, and also suffer the same sort of impacts caused by human activity in their natural habitats. The satyrid butterflies *Erebia sudetica*, *Coenonympha hero*, *C. oedippus*, *Neonympha m. mitchellii* and *Neonympha mitchellii francisci* share characteristics with our studied subspecies and are also considered as threatened with extinction (Kuras *et al*. 2003, Szymanski *et al*. 2004, Barton & Bach 2005, Kuefler *et al*. 2008, Čelik *et al*. 2004, Orvossy *et al*. 2013, Sielezniew & Nowicki 2017). Thus, it is assumed that these life traits and impacts shared by these taxa could be an evidence of risk of extinction.

Although certain population patterns of *P. gyrtone* are not very clear, we believe that this subspecies may be more sensitive than *P. glaucope* of future impacts in the studied site, because it has a very small population size and a shorter permanence, so that they can be eliminated from this site by a single destructive event (*e.g*. habitat conversion to a non-natural system or fire).

Our study was able to contribute with important data on the knowledge of biology and ecology of two endangered Brazilian butterflies. This information may be of vital importance for their management, as these butterflies are included in Brazilian National Action Plan for the Conservation of Threatened Lepidoptera that establishes guidelines to be implemented for the conservation of threatened butterflies. A good example cited for these subspecies in the Action Plan is the creation need of Conservation Units of integral protection specifically for *Campos de altitude* in the range areas of the subspecies studied. The proper management of *Campos de altitude* is

very importat for the well being of the organisms that live there and for human population benefit, such as water supply. If human pressure continues at the current frequency, species restricted to these grasslands may no longer tolerate these disturbances and will only survive by strong human intervention. Proposals such as the antropic activities restriction during butterflies' reproductive period, avoidance of burnings and establishment of corridors that connect grasslands, can minimize human disturbances over populations. A long-term study is essential for assessing the extinction risk of these populations and for effective conservation strategies and planning for these subspecies and their restricted and threatened environment, the Brazilian *Campos de Altitude*.

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