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Spatio-temporal variation of *Mocis latipes* (Guenée, 1852) (Lepidoptera: Erebidae) populations in Brazil according to meteorological factors

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Abstract: *Mocis latipes* (Guenée, 1852) (Lepidoptera: Erebidae) has been recognized as a major owlet caterpillar associated to the herbivory of gramineaceous plants across the American continent. During outbreaks, the caterpillars are capable of completely consuming preferred hosts (grasses) and, when these hosts are destroyed, they can move to adjacent non-grass plants and cause similar damage. Meteorological variable such as temperature and humidity are described as factors that affect the development and abundance of *M. latipes*. This paper aimed to describe and compare the spatial and temporal distribution of *M. latipes* in different locations in Brazil and to evaluate the influence of meteorological variables on the temporal range. A total of 12 locations were evaluated, in each collection point light traps were installed near cultivated areas. In order to understand the influence of meteorological variables on the abundance of *M. latipes*, the data were analyzed using a Generalized Linear Model according to Poisson regression. A linear regression was also used to verify the relation between the abundance and the latitude. A total of 1,985 moths were collected. The highest collections were in Amazon and Cerrado biomes. Results show that abundance was inversely related to increasing latitude and Poisson regression analysis indicated that the main meteorological variables were significantly related to abundance at each site. This study shows that due to the high preference for gramineas and the high temperature requirements (30°C), *M. latipes* is an important species in hot regions and regions with hight humidity. Furthermore, even in higher latitudes, in subtropical areas, during summer months, populations can Rapidly growth being able to cause economic damages.

Keywords: *light trap; owlet moth pest; populational variations; striped grassworm.*

Variações espaço-temporais das popupações de *Mocis latipes* (Guenée, 1852) (Lepidoptera: Erebidae) no Brasil de acordo com fatores meteorológicos.

Resumo: *Mocis latipes* (Guenée, 1852) (Lepidoptera: Erebidae) tem sido reconhecida como uma das principais espécies consumidoras de gramíneas em todo o continente americano. Durante os surtos, as lagartas são capazes de consumir completamente os hospedeiros preferenciais (gramíneas) e, quando os hospedeiros preferenciais são destruídos, podem mover-se para plantas adjacentes não gramíneas e causar danos semelhantes. Variáveis meteorológicas, como temperatura e umidade, são conhecidas por afetar o desenvolvimento e a abundância de suas populações. Este trabalho teve como objetivo descrever e comparar a distribuição espaço-temporal de *M. latipes* em diferentes localidades do Brasil e avaliar a influência de variáveis meteorológicas sobre suas variações temporais. Foram avaliados 12 locais, em cada ponto de coleta foram instaladas armadilhas luminosas próximas às áreas de cultivo. Para entender a influência das variáveis meteorológicas na abundância de *M. latipes*, os dados foram analisados pelo Modelo Linear Generalizado, empregando a regressão de Poisson. Uma regressão linear também foi utilizada para verificar a relação entre a abundância e a latitude. Um total de 1.985 mariposas foram coletadas. Os maiores números de indivíduos foram coletados nos biomas Amazônia e Cerrado. Os resultados mostram que a abundância de mariposas está inversamente relacionada ao aumento da latitude. A análise de regressão de Poisson indicou que as principais variáveis meteorológicas foram significativamente relacionadas à abundância em cada local. Este estudo mostra que devido à preferência por gramíneas em estado vegetativo e às altas exigências de temperatura (30°C), *M. latipes* é uma espécie importante em regiões quentes, especialmente nas épocas de maior umidade. Além disso, mesmo em latitudes elevadas, durante os meses de verão, as populações podem aumentar rapidamente, podendo causar danos econômicos.

Palavras-chave: *armadilha luminosa; noctuoides-praga; variações populacionais; curuquerê-dos-capinzais.*

Introduction

Mocis latipes (Guenée, 1852) (Lepidoptera: Erebidae) is an important grass pest that occurs throughout the Americas, from Canada to Argentina, Chile and Uruguay (Bethune 1869, Biezanko et al. 1957, Barth 1958, Angulo & Jana-Sáenz 1983, Pastrana 2004, Wagner et al. 2011, Alves et al. 2019). Due to the fact that *M. latipes* is widely distributed, it is common for it to receive different names across its range of distribution. For example, in North America it is called as "striped grassworm" and "striped grass looper" (Genung & Allen Jr. 1974, Reinert 1975, Koehler et al. 1977); in Central America, "falso medidor de los pastos" and "Guinea-grass moth " (Fennah 1947, Calderón et al. 1981); in Brazil "curuquerê-dos capinzais" and "lagarta-dos-capinzais" (Pigatti & Mello 1960, Cavalcante 1977, Silva et al. 1991, Correia et al. 1999), in Colombia "gusano agrimensor" (Alvarez-R & Sanchez-G 1981) and in Argentina "gusano cuarteador" (Costilla et al. 1973, Hayward 1960, Salvatore & Willink 2004, Acosta et al. 2005).

Although some authors consider *M. latipes* as a polyphagous pest (e.g. Fonseca & Autuori 1932, Bissell 1940, Biezanko et al. 1957, 1974, Hayward 1960, Labrador 1964, Kimball 1965, Silva et al. 1968, Costilla et al. 1973, Ware 1973, Bertels 1975, Kleyla et al. 1979, Pastrana 2004, Formentini et al. 2015), the main host plants of *M. latipes* are grasses. Ogunwolu & Habeck (1975) has shown that the first to fourth instar larvae are unable to complete their life cycle in non-grassy plants. Despite that, *M. latipes* can be considered a polyphagous species because it has also been collected from non-grassy plants (Ogunwolu & Habeck 1975) or, after caterpillars completely consume grasses or when selective herbicides are used, they are able to migrate and defoliate other crops (Capinera 2005).

The importance of *M. latipes* as a pest is highlighted due to reports of population outbreaks (e.g. Watson 1933, Pugliese 1954, Capriles & Ferrer 1973, Reinert 1975, Minno & Snyder 2008) and its extensive damage to the main cultivated Poaceae, including grains, such as corn, rice, sorghum and wheat (Bodkin 1914, Hempel 1914, 1920a, 1920b, Costa 1944a, 1944b, Fonseca 1944, Bertels & Rocha 1950, Dinther 1955, Falanghe & Dias Netto 1961, Hseih 1979, Cruz 1991, Cruz & Santos 1983, Ferreira 1984, Silva & Carvalho 1986, Páliz-Sánchez & Mendonza-Mora 1999, Pitre et al. 1999, Vergara et al. 2001, Hickel et al. 2018), forage crops (Vickery 1924, Lopes 1955, 1961, Labrador 1964, Strayer 1971, Koehler et al. 1977, Calderón et al. 1981, 1982, Costa et al. 1983, Silvain 1984, Silvain & Dauthuille 1985, Miret 1986, Gibbs 1990, Milán et al. 1990, Silva et al. 1994, Jiménez et al. 1997, Teixeira & Townsend 1997, Correia et al. 1999, Piedra & Carrillo 1999, Sánchez Soto & Ortiz Garcia 1999, Alarcón et al. 2004, Fazolin et al. 2009), and sugar cane (Dine 1913, Wolcott 1921, Holloway 1933, Reiniger 1946, Queiroz 1965, Mendonça Filho 1972, Costilla et al. 1973, Guagliumi 1973, Mahadeo 1977, Planalsucar 1982, Salvatore & Willink 2004, Acosta et al. 2005, Salvatore et al. 2009, Marquez 2013).

Usually, *M. latipes* is reported as a cyclic pest (e.g. Calderón et al. 1981, Saunders et al. 1998) whose abundance is influenced by environmental factors such as humidity, precipitation and temperature (Calderón et al. 1982, Ferreira & Parra 1985, Gibbs 1990). Therefore, under favorable weather conditions and food availability, their populations increase rapidly.

Temperature and humidity are the main environmental factors that influence occurrence, distribution and complete development of *M. latipes* biological cycle. Therefore, the imbalance of these conditions directly interferes in population size (Bertels 1970, Bernardi et al. 2011). Understanding spatial and temporal distribution of pest species is important to reduce risks of Outbreaks and to develop sustainable management control (Pedigo & Rice 2009). There is a lack of studies on population dynamics of *M. latipes* in different regions in Brazil. Population outbreaks are known to occur early in the rainy season, especially in the Amazon (Teixeira & Townsend 1997, Fazolin et al. 2009). However, the factors that cause these occurrences are still unknown. Thus, this paper reports the influence of meteorological variables and latitude on spatio-temporal abundance of *M. latipes* in different regions in Brazil.

Material and Methods

1. *Moth sampling*

Mocis latipes moths were captured in systematized collections at 12 regions in Brazil (Table 1), being those regions representatives of the main Brazilian biomes and on a latitudinal range (2° North to 31° South). At each collection point, a light trap (Light Trap - Bio Controle®), adapted to Pennsylvania model (Frost 1957), was placed on a pole 3 meters from the ground. Collections were made once a month, from July 2015 to June 2016, during each novilunium repeated for five nights (repetitions). Collection methodology followed Specht et al. (2005) and Piovesan et al. (2018). Traps were placed in areas surrounded by several agricultural crops, especially cotton, soybean, corn and pastures (Table 1). Corn was the only crop presented in all regions.

2. *Mocis latipes identification*

Moths were identified by comparing collected specimens against reference material from the Coleção Entomológica da Embrapa Cerrados (CPAC) and bibliographic resources (Brou Jr., 2004). After

Table 1. Geographic location, municipality, state, biome, climate (Köppen-Geiger according Beck et al., 2018) and main annual cultures, C - cotton, M - maize, S - Soybean, and P - pastures, of each light trap collecting point.

	Latitude	Longitude	Altitude (m)	Municipality	State	Biome	Climate	Cultures
1	2.695597	-61.005028	87	Alto Alegre	Roraima - RR	Amazon	Aw	C, M, S
2	-2.695596	-54.570650	114	Mojuí dos Campos	Pará - PA	Amazon	Am	M, S
3	-10.032536	-67.626908	183	Rio Branco	Acre - AC	Amazon	Af	M, S
4	-10.519042	-48.2933306	262	Porto Nacional	Tocantins - TO	Savanna	Aw	M, S
5	-11.867083	-55.600608	362	Sinop	Mato Grosso - MT	Amazon	Aw	C, M, S
6	-12.078417	-45.869111	782	Luís Eduardo Magalhães	Bahia - BA	Savanna	BSh	C, M, S
7	-15.606811	-47.745125	1169	Planaltina	Distrito Federal - DF	Savanna	Aw	M, S
8	-19.662519	-47.960878	784	Uberaba	Minas Gerais - MG	Savanna	Aw	M, S
9	-20.753231	-41.489800	120	Alegre	Espírito Santo - ES	Atlantic Forest	Cwa	M, P
10	-23.189694	-51.171861	545	Londrina	Paraná - PR	Atlantic Forest	Cfa	M, S
11	-28.230742	-52.403625	671	Passo Fundo	Rio Grande do Sul - RS	Atlantic Forest	Cfa	M, S
12	-31.351372	-54.020142	232	Bagé	Rio Grande do Sul - RS	Pampa	Cfa	M, S, P

identification, the specimens were stored in glass containers with 92.8GL ethyl alcohol, labeled with date and collecting location. Specimens were kept as voucher material in the CPAC collection and the specific abundance data were tabulated in a spreadsheet for analysis.

3. *Meteorological data*

The meteorological variables considered were the monthly average of the maximum and minimum temperatures (°C), relative humidity (%) and cumulative precipitation (mm^3/m^2/month). The data were obtained from Embrapa Cerrados, Embrapa Agrossilvipastoril, Capixaba Institute for Research, Technical Assistance and Rural Extension - Incaper and National Institute of Meteorology - INMET. Except for data obtained from INMET, all other data were collected at meteorological stations near the sample units.

4. *Statistical analysis*

To evaluate the relationship between the abundance of *M. latipes* and the latitude (Decimal Degrees - DD) used the generalized linear model (GLM) according to Poisson regression with eleven collections points established in the Southern Hemisphere (Table 1). In the same way, as abundance data considers moth count, a GLM Poisson regression was used in order to determine the conjunct influence of meteorological variables on the expected abundance of *M. latipes* at each collecting points. The analysis includes the estimates and respective significance, and the standard errors of the estimate for each collecting point and a general estimate with all points, except for Londrina, Passo Fundo and Bagé, due to the non-significance of the coefficients of the variables when studied individually. The analysis was performed on R version 3.4.0 (R Development Core Team 2017).

Results

In total, 1,985 moths of *M. latipes* were collected with greater abundance concentrated in the lower latitudes, in the Amazon and Cerrado biomes. Almost half of the insects (42.11%) were collected in Alto Alegre-RR, followed by Rio Branco-AC (13.55%) and Mojuí dos Campos-PA (11.33%) (Table 2; Figure 1). Moths were found in all sampled locations, most of the year and in 92 collections (63.88%) from the 144 collected. Disregarding the southernmost locations (Bagé, Passo Fundo and Londrina), where it is cold during the winter time, *M. latipes* were collected in 84 out of 108 events, which corresponds to more than ¾ (77.78%) of the collections.

The inverse relationship between latitude and abundance of *M. latipes* shown in Figure 1 is statistically confirmed by Poisson regression analysis (Figure 2) whose coefficients were Akaike Information Criterion - AIC 321.780; Intercept: estimate 6.194, SD 0.055, z value 113.100 ($p > 0.001$) and Latitude: estimate 0.115, SD 0.004, z value 25.930 ($p > 0.001$).

The monthly occurrence data (Table 2) indicated that, despite occurring in practically the whole year, *M. latipes* populations varied differently in each location.

Poisson regression analysis indicated for most locations that the conjunct of accumulated monthly precipitation, the monthly averages of minimum and maximum temperature and the monthly average

Table 2. Monthly abundancy of *Mocis latipes* moths collected with light traps, during five nights per novilune.

Locality	2016						2017						Total	Percent
	Jul	Aug	Sep	Oct	Nov	Dez	Jan	Feb	Mar	Apr	May	Jun		(%)
Alto Alegre - RR	144	531	103	1	0	2	6	2	14	16	17	0	836	42.116
Mojuí dos Campos - PA	3	1	3	64	2	14	66	8	4	3	10	47	225	11.335
Rio Branco - AC	1	1	7	3	12	3	2	2	62	109	39	28	269	13.552
Porto Nacional - TO	3	0	0	12	17	9	4	4	32	67	7	2	157	7.909
Sinop - MT	1	1	2	3	2	2	2	0	0	0	168	8	189	9.521
Luís Eduardo Magalhães - BA	0	0	1	1	33	41	25	2	12	8	8	2	133	6.700
Planaltina - DF	0	1	0	0	22	77	1	2	0	1	3	3	110	5.542
Uberaba - MG	0	0	1	0	0	6	0	1	1	3	18	2	32	1.612
Alegre - ES	0	2	1	0	1	4	0	0	2	0	0	2	12	0.605
Londrina - PR	0	1	0	0	0	0	1	0	0	0	14	1	17	0.856
Passo Fundo - RS	0	0	0	1	0	0	1	2	0	0	0	0	4	0.202
Bagé - RS	0	0	0	0	0	0	0	0	1	0	0	0	1	0.050
Total	152	538	118	85	89	158	108	23	128	207	284	95	1985	100

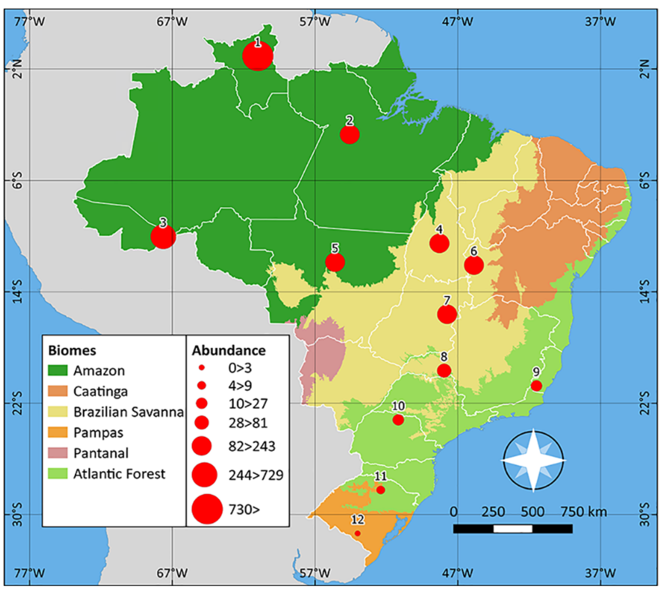

Figure 1. Variation in number (red circles) of *Mocis latipes* sampled in 12 localities of Brazil (July 2015 – June 2016). For a complete description of localities and dates, see Tables 1-2.

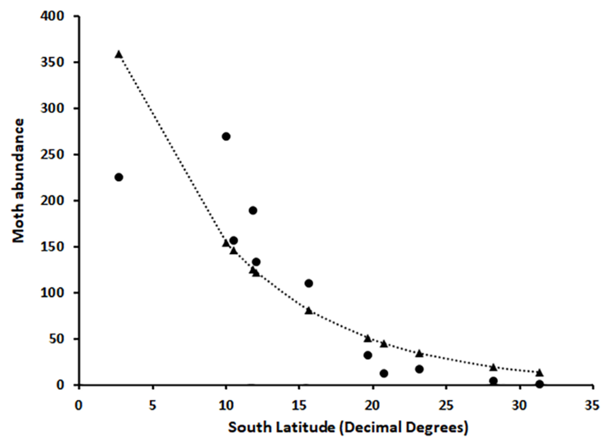

Figure 2. Representation of the observed (circles) and estimated by Poisson regression analysis (triangles) abundance of *Mocis latipes* in each collection point, according South Latitude.

of relative humidity positively influenced abundance (Table 3). As observed between monthly abundance (Table 2), the relations between the number of moths and meteorological variables varied between locations (Table 3).

Discussion

The occurrence of *M. latipes* throughout Brazil (Figure 1) was expected due to the wide distribution previously mentioned in the bibliography (ex. Reinert 1975, Carvalho 1976, Saunders et al. 1998, Bentancourt & Scatoni 2006, Wagner et al. 2011). The simultaneous occurrence of this species in such a wide and diverse territory is correlated with several biological aspects attributed to insects presenting great geographic distribution that includes: great capacity for dispersion and migration (Ferguson et al. 1991, Brou Jr. 2004, Krauel et al. 2018, Alves et al. 2019), short life cycle with multivoltinism associated with high fertility (ex. Labrador 1964, Reinert 1975, Cruz & Santos 1983, Ferreira & Parra 1985, Silva & Carvalho 1986, Silva et al. 1991, Piedra & Carrilo 1999, Wagner et al. 2011), and polyphagy, which allows food to be obtained anywhere and at any time. In this last aspect, *M. latipes* is better classified as an oligophytophage because it develops preferentially in grasses (Ogunwolu & Habeck 1975) despite consuming other vegetables especially at the end of larval development (Hayward 1960, Labrador 1964, Kimball 1965, Silva et al. 1968, Costilla et al. 1973, Biezanko et al. 1974, Kleyla et al. 1979, Pastrana 2004, Formentini et al. 2015). Despite being an oligophagous, *M. latipes* has in its favor that grasses are vegetables that have a relatively preserved physical and chemical structure throughout evolutionary history (Kellogg 2001). Thus, this determines that *M. latipes*, like most insects associated with grasses can develop satisfactorily in most species (Tscharntke & Greiler 1995). Moreover, both annual and perennial grasses are found in almost all environments throughout the year, except for closed forest areas, deserts or very cold regions (Strömberg 2011, Dixon et al. 2014). In addition, cultivated grasses often become invasive, having additional

Table 3 . Results (AIC - Akaike Information Criterion, Intercept values - Estimate (with significance) and Standard Error -SE) obtained by the Poisson regression analysis between the monthly abundance of *Mocis latipes* moths collected in each location and the main meteorological variables (Precipitation accumulated in the month; Max. Temp - Average of monthly maximum temperature; Min. Temp - Average monthly minimum temperature and RH - average monthly relative humidity).

	Intercept	Precipitation	Max. Temp	Min. Temp.	RH
			General+ (AIC 4770.80)		
Estimate	-8.898***	0.001***	0.035ns	0.274***	0.058***
SE	0.884	0.000	0.029	0.022	0.004
			Alto Alegre (AIC 188.35)		
Estimate	34.591***	0.001ns	-0.101ns	-2.522***	0.388***
SE	3.891	0.001	0.099	0.224	0.022
			Mojuí dos Campos (AIC 210.390)		
Estimate	204.286***	0.002ns	-1.811***	-3.048*	-0.873***
SE	36.823	0.003	0.274	1.206	0.100
			Rio Branco (AIC 375.380)		
Estimate	47.646***	-0.002**	-1.204***	0.472***	-0.185***
SE	8.005	0.001	0.177	0.086	0.0417
			Porto Nacional (AIC 102.820)		
Estimate	-41.221***	-0.008***	0.350ns	0.764***	0.218***
SE	9.221	0.002	0.216	0.209	0.030
			Sinop (AIC 167.480)		
Estimate	-70.738***	-0.047***	1.028***	1.343***	0.264***
SE	8.706	0.005	0.214	.0156	0.028
			Luís Eduardo Magalhães (AIC 94.159)		
Estimate	-42.095***	0.004***	0.088ns	1.537***	0.097***
SE	8.214	0.001	0.247	0.400	0.022
			Planaltina (AIC 247.470)		
Estimate	12.475**	0.002ns	-0.609***	0.106ns	0.060**
SE	4.686	0.001	0.158	0.173	0.0197
			Uberaba (AIC 73.275)		
Estimate	-102.700**	0.001ns	3.218**	-2.711**	0.767**
SE	36.710	0.003	1.205	0.965	0.244
			Alegre (AIC 30.520)		
Estimate	-38.255*	0.014**	1.509*	-1.558*	0.254*
SE	17.735	0.005	0.682	0.615	0.116
			Londrina (22.787)		
Estimate	-523.314ns	0.088ns	16.264ns	-13.989ns	3.752ns
SE	475.690	0.063	15.000	12.609	3.348
			Passo Fundo (20.082)		
Estimate	-18.697ns	0.032ns	-0.067ns	1.417ns	-0.139ns
SE	48.558	0.038	2.287	3.657	0.697
			Bagé (AIC 12.00)		
Estimate	-223.100ns	0.191ns	13.460ns	-15.570ns	0.942ns
SE	2.182e+06	6.739e+02	6.244e+04	5.915e+04	2.018e+04

amounts of nutrients in their tissues and less physical or chemical defense structures (Tamiru et al. 2015).

The large number of specimens collected in five nights of a single month (531) in Alto Alegre - RR (Table 2) refers to the large population numbers of the species that, if under favorable environmental conditions and food availability, will determine the occurrence of outbreaks (Bodkin 1914, Watson 1933, Fennah 1947, Labrador 1964, Capriles & Ferrer 1973, Costilla et al. 1973, Hseih 1979, Calderón et al. 1981, Silvain 1984, Silvain & Dauthuille 1985, Gibbs 1990, Jiménez et al. 1997, Correia et al. 1999, Sánchez Soto & Ortiz Garcia 1999, Minno & Snyder 2008) but mainly due to its relation with higher temperatures in tropical and equatorial areas, since the optimal development temperature is 30°C (Ferreira & Parra 1985).

This relation between greater abundance and higher temperature is in line with the significance of the negative regression between latitude and abundance found in this study (Figure 2). Indeed, despite the wide range of occurrences in the American continent, the largest number of studies that emphasize the importance of *M. latipes* as a pest refers to areas located in lower latitudes or that have climates characterized by high temperatures, especially in Central American countries and the

Caribbean (e.g. Bodkin 1914, Fennah 1947, Labrador 1964, Capriles & Ferrer 1973, Hseih 1979, Calderón et al. 1981, 1982, Silvain 1984, Silvain & Dauthuille 1985, Gibbs 1990, Jiménez et al. 1997, Teixeira & Townsend 1997, Correia et al. 1999, Sánchez Soto & Ortiz Garcia 1999, Minno & Snyder 2008). Considering the specific area of this study the greatest importance of *M. latipes* as a pest is highlighted by several studies in hot and humid regions, especially the Amazon (Silva et al. 1994, Teixeira & Townsend 1997, Fazolin et al. 2009), northeastern coast (Mendonça Filho 1972, Costa et al. 1983, Correia et al. 1999) and Southeast of Brazil (Hempel 1914, 1920a, 1920b, Fonseca 1944, Lopes 1955, 1961, Cavalcante 1977, Ferreira 1984, Cruz 1991).

Considering the higher latitudes sampled in this study (Table 2, Figure 1) it is important to note that even in places below the tropical line there are outbreaks with significant production losses, both in the Northern hemisphere (Vickery 1924, Watson 1933, Genung & Allen Jr. 1974, Ogunwolu & Habeck 1975, Reinert 1975, Koehler et al. 1977, Minno & Snyder 2008), and in the southern hemisphere, in Argentina (Costilla et al. 1973, Salvatore & Willink 2004, Acosta et al. 2005, Salvatore et al. 2009) and in Uruguay (Bentancourt & Scatoni 1996). However, the greater occurrence of *M. latipes* and outbreaks are conditioned to the hottest times of the year. This is due to the fact that, even in high latitudes, in the subtropic, during summer solstice temperatures can be high, conditioning a favorable environment to increasing the development of population, which may cause outbreaks in specific years (Cavalcanti et al. 2009). On the other hand, it should be considered, in addition to the photoperiod, that winter temperatures are close to or below the base development temperature of 13.7°C (Ferreira & Parra 1985). This determines that in addition to prolonging the life cycle, as reported in the Northern Hemisphere, to survive against adverse weather conditions, instars need to develop pupal diapause (to be confirmed in Brazil) or adults must migrate to regions where temperatures are higher, and return when local conditions become favorable to their development (ex. Ferguson et al. 1991, Brou Jr. 2004, Wagner et al. 2011).

The numbers presented in this study consist of a small sample represented by the moths caught in the range of the traps covers (estimated at 400m to *Spodoptera frugiperda* - Vilarinho et al. 2011) at just twelve points in Brazil. These samples represent only adults that survived the weather conditions and all natural enemies present during all stages and collection time. It is also not possible to associate adults with the host plants on which the caterpillars fed and developed. Despite all these limitations, the high number of adults of *M. latipes* collected in all locations (Figure 1, Table 2) highlights its importance as a key specimes in grass-insect interactions in most of Brazil (e.g. Costa 1944a, 1944b, Fonseca 1944, Pugliese 1954, Lopes 1955, 1961, Queiroz 1965, Mendonça Filho 1972, Cavalcante 1977, Planalsucar 1982, Costa et al. 1983, Ferreira 1984, Ferreira & Parra 1985, Cruz 1991, Silva et al. 1994, Teixeira & Townsend 1997, Correia et al. 1999, Fazolin et al. 2009), as well as in most countries of the American continent (e.g. Dine 1913, Bodkin 1914, Holloway 1933, Watson 1933, Fennah 1947, Dinther 1960, Guagliumi 1962, Labrador 1964, Capriles & Ferrer 1973, Costilla et al. 1973, Genung & Allen Jr. 1974, Ogunwolu & Habek 1975, Koehler et al. 1977, Mahadeo 1977, Hseih 1979, Calderón et al. 1981, 1982, Silvain 1984, Silvain & Dauthuille 1985, Miret 1986, Jiménez et al. 1997, Milán et al. 1990, Portillo et al. 1991, Saunders et al. 1998, Piedra & Carrilo 1999, Páliz-Sánchez & Mendoza-Mora 1999, Sánchez Soto & Ortiz García 1999, Pitre et al. 1999, Vergara et al. 2001, Brou Jr. 2004, Salvatore & Willink 2004, Acosta et al. 2005, Marquez 2013). Regarding the fact that it is one of the most predominant specimes, it is important to consider its role in natural ecosystems, especially in agroecosystems where there is a greater proportion or intensification of grass planting, including grains, forages, pastures and sugar cane (e.g. Labrador 1964, Koehler et al. 1977, Calderón et al. 1981, 1982, Costa et al. 1983, Cruz & Santos 1983, Ferreira 1984, Silvain 1984, Silvain & Dauthuille 1985, Miret 1986, Silva & Carvalho 1986, Gibbs 1990, Milán et al. 1990, Cruz 1991, Jiménez et al. 1997, Teixeira & Townsend 1997, Páliz-Sánchez & Mendonza-Mora 1999, Pitre et al. 1999, Vergara et al. 2001, Acosta et al. 2005, Salvatore et al. 2009, Marquez 2013, Hickel et al. 2018). Among the roles to be considered for this species, it is also considered a primary consumer, nutrient cycling promoter, food source for pests (including insects, birds and mammals), parasitoids and pathogens (Wagner et al. 2011).

In relation to the natural enemy organisms of *M. latipes*, there are studies about the relationship of a countless number of species associated with their natural biological control (predators, parasitoids and pathogens), in different stages of development, in different countries of the American Continent (e.g. Sauer 1946, Silva et al. 1968, Lopes 1969, Gonçalves & Gonçalves 1974a, 1974b, Genung et al. 1976, Guimarães 1977, De Santis 1979, 1989, Lourenção et al. 1982, Collins & Watson 1983, King & Saunders 1984, Hall 1985, Santos 1989, Rogers et al. 1990a, 1990b, Galán & Rodríguez 1991, Cave 1992, Rogers & Marti Jr. 1993, Whitaker Jr. et al. 2007, Rolfe et al. 2014). These studies mention that the action of several natural enemies is important when analyzing the abundance data of *M. latipes* in any area of its distribution. As shown for other owlet moths (Pereira et al. 2018), their population levels are maintained, at least most of the time, by the action of natural enemies. This might be related to the different population levels, between locations and in different months presented in this study (Table 2).

In relation to ecological balance promoted by the association and the presence of natural enemies, it is important to note that throughout the American continent *M. latipes* occurs in conjunction with other owlet moths associated with grasses, including congeneric species (Babayan et al. 1975, Ogunwolu & Habek 1975, Koehler et al. 1977, Brou Jr. 2004) and, specially, *S. frugiperda* (J.E. Smith) (e.g. Fonseca 1944, Pugliese 1954, Lopes 1955, 1961, Guagliumi 1962, Queiroz 1965, Mahadeo 1977, Hseih 1979, Calderón et al. 1981, Costa et al. 1983, Silvain 1984, Silvain & Dauthuille 1985, Portillo et al. 1991, Páliz-Sánchez & Mendoza-Mora 1999, Pitre et al. 1999, Sánchez Soto & Ortiz Garcia 1999, Fazolin et al. 2009) forming species complexes. *Spodoptera frugiperda* is a polyphagous species (Montezano et al. 2018) with high biotic potential (Montezano et al. 2019a, 2019b) and, as in this study (Table 2, fig. 1) it was collected in all the locations presented here (Piovesan et al. 2018). It is important that *M. latipes* and other owlet moths, including *S. frugiperda* share the same predators, pathogens, also egg, larvae and pupae parasitoids (Silva et al. 1968, Rogers & Marti Jr. 1993, Camera et al. 2010). This determines that the presence of *M. latipes*, even in low populations, allows the maintenance of populations of different groups of natural enemies in natural ecosystems and agroecosystems. Thus, the occurrence of immature *M. latipes* allows the maintenance of a wide range of natural enemies, it is essential for the maintenance of natural biological control over time, for the entire species complex.

The significant relationship between the abundance of *M. latipes* with at least one of the meteorological variables (Table 3), in practically all Brazilian territory except in the three most southern locations (Figure 1) reinforces the strong association between population variations and climatic conditions mentioned in several studies (e.g. Bertels 1970, Genung & Allen Jr. 1974, Babayan et al. 1975, Calderón et al. 1981, Gibbs 1990, Jiménez et al. 1997, Pitre et al. 1999, Salvatore & Willink 2004, Fazolin et al. 2009, Hickel et al. 2018). The relationship between population variations and climatic conditions, is evidenced by the large number of moths collected in rainy months (July, August and September), in Alto Alegre, RR, located in the Northern Hemisphere (Table 2) while all the other places are located in the Southern Hemisphere, these same months correspond to winter time (dry or cold), with very low population levels. Indeed, studies always relate the highest population levels with warm months, preferably during the rainy season in the Northern Hemisphere (Bodkin 1914, Vickery 1924, Watson 1933, Fennah 1947, Capriles & Ferrer 1973, Calderón et al. 1981, Gibbs 1990, Minno & Snyder 2008) as in the Southern Hemisphere (Lopes 1955, Costilla et al. 1973, Carvalho 1976, Lourenção et al. 1982, Teixeira & Townsend 1997, Correia et al. 1999, Salvatore & Willink 2004, Acosta et al. 2005).

Regarding the different numbers of moths collected each month, in each location (Table 2) besides the climatic characteristics (Cavalcanti et al. 2009), biogeographic and phytophysiognomic variations should also be considered (Heppner 1991). Although *M. latipes* is an oligophytophagous species with a preference for grasses (ex. Ogunwolu & Habeck 1975, Wagner et al. 2011), in each location the moths were able to choose to lay eggs on plants arranged as a space-time mosaic containing different native and/or cultivated species that served as food for their larvae.

The *M. latipes* abundance spatial variations described in this study, combined with the knowledge of its great dispersion capacity, including migration (ex. Barth 1958, Ferguson et al. 1991, Wagner et al. 2011, Alves et al. 2019) point to the need for studies related to the molecular characterization of populations in order to allow assessments of local populations, migration routes and/or gene flow as done for other owlet moths (e.g. Palma et al. 2015, Nagoshi et al. 2017). This information is extremely important to assess whether the occurrence of population outbreaks of this species is related only to the fast reproduction of local populations or whether it involves dispersion or migration events. Thus, it should be noted that even in Southmost areas, where the abundance of *M. latipes* was extremely low, there are several registers of its occurrence (ex. Tarragó et al. 1975, Link 1977, Specht & Corseuil 2002, Specht et al. 2004, 2005, Zenker et al. 2010) indicating that the species was present in more than 50% of weekly collections between July 1994 and June 1995 (Specht & Corseuil, 2002). Furthermore, further to the South, Bentancourt & Scatoni (2006) relate sporadic population outbreaks of this species in Uruguay, noting that, even at greater latitudes, the occurence of this species is relatively constant with increases in population linked to favorable conditions to its development. Especially in these places it is questioned whether the presence of the species is due to a local population or as a result of migration as described for the Northern Hemisphere (Brou Jr. 2004, Wagner et al. 2011).

The results of this study as well as most previous publications (ex. Carvalho 1976, Lourenção et al. 1982, Fazolin et al. 2009, Bentancourt & Scatoni 1996, Saunders et al. 1998, Wagner et al. 2011) indicates that *M. latipes*, besides having a wide distribution, it has low population levels during most of the year, with sporadic population outbreaks during favorable weather conditions, food availability and inadequate cultural management. Therefore, it must be considered that agricultural occupation has modified most of the ecosystems where the effect of seasonal variations on native host plants is minimized by cultivating grasses that serve as alternative hosts more resistant to drought in the savanna and to the cold in greater latitudes. These plants can serve as a green bridge between the most favorable seasons to the development of *M. latipes* and other insects (Favetti et al. 2017). Considering grasses as host plants, it must be taken into consideration that *M. latipes* has food available both in open native environments and in the most diverse combinations of forage, grain and sugar production. In addition to these plants directly related to production, other crops should be considered for soil protection and biomass production to be incorporated in crop rotation systems (Dias et al. 2016, Favetti et al. 2017), integrated crop-livestock systems (Vilela et al. 2011) and even when introduced grasses become pests occupying most ecosystems for most of the year (Minno & Snyder 2008).

Even though this study shows an inverse relationship between latitude and *M. latipes* abundance along with other meteorological variables, it should be considered that abiotic factors are conditional to species development, and not necessarily associated with the decrease of abundance. Therefore, additional hypotheses need to be tested considering specific abundance and environmental factors. One example is the high abundance of *M. latipes* in tropical areas, it can be related to favorable conditions, while that in subtropical regions only summer months present favorable conditions. On the other hand, areas presenting favorable conditions all year long also provide a high number of natural enemies. Thus, due to the large number of variables related to *M. latipes* itself (which includes developmental biology in different conditions, the ability to diapause, migrate, defend against natural enemies) and biotic factors associated with each location (availability of different host plants native or cultivated, presence and abundance of natural enemies, interspecific competition) cause the associations established between population levels, latitude and environmental factors to be explored continuously. A better understanding of these associations will allow a more accurate understanding of the effects of local environmental variations and global climate changes on insect populations, pests or not.

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Vander C. M. Claudino: Substantial contribution in the concept and design of the study; contribution to data collection; data analysis and interpretation; manuscript preparation and critical revision, adding intelectual content. Alexandre Specht: Substantial contribution in the concept and design of the study; contribution to data collection; data analysis and interpretation; manuscript preparation and critical revision, adding intelectual content.

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Pedro R. Martins: Contribution to data analysis and interpretation; manuscript preparation and critical revision; Fernando A.M. Silva: Contribution to data collection; data analysis and interpretation; manuscript preparation and critical revision.

Juaci V. Malaquias**:** Substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; manuscript preparation and critical revision.

Conflict of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

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