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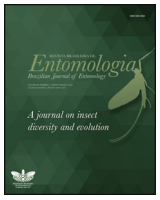

Diversity and temporal variation of brown lacewings (Neuroptera, Hemerobiidae) from Atlantic rainforest areas in southeastern Brazil

Rogéria Inês Rosa Lara[1]*, Nelson Wanderley Perioto[1], Daniell Rodrigo Rodrigues Fernandes[2]

[1]*Instituto Biológico, Laboratório de Sistemática e Bioecologia de Predadores e Parasitoides, Ribeirão Preto, SP, Brasil.*
[2]*Instituto Nacional de Pesquisas da Amazônia, Manaus, AM, Brasil.*

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ABSTRACT

A survey of the brown lacewings (Neuroptera, Hemerobiidae) was carried out with five Malaise traps/area in five areas in Atlantic rainforest of São Paulo State, Brazil, between October 2009 and December 2011. 237 specimens of Hemerobiidae were obtained belonging to 14 species and five genera: *Nusalala tessellata* (Gerstaecker, 1888) (31.6% of the total collected), *Hemerobius hernandezi* Monserrat, 1996 (26.0%), *Nusalala dispar* (Banks, 1910) (17.7%), *H. cubanus* Banks, 1930, *H. edui* Monserrat, 1991, *H. nigridorsus* Monserrat, 1996 and *H. withycombei* (Kimmins, 1928) (1.7% each), *H gaitoi* Monserrat, 1996, *Megalomus ricoi* Monserrat, 1997 and *Notiobiella cixiiformis* (Gerstaecker, 1888) (1.3% each), *Sympherobius ariasi* Penny & Monserrat, 1985 (0.9%) and, *M. impudicus* (Gerstaecker, 1888), *M. rafaeli* Penny & Monserrat, 1985 and *S. mirandus* (Navás, 1920) (0.4% each). Eighteen specimens of *Hemerobius* Linnaeus, 1758 and nine of *Megalomus* Rambur, 1842, totaling 11.4% of the collected Hemerobiidae, could not be identified at the species level. The hemerobiids were more frequent in the Parque Estadual Intervales (55.3% of the total collected) and in the Parque Estadual Morro do Diabo (23.2%), inland collection sites in the state of São Paulo, with higher abundances recorded in spring (43.9% of the total collected) and in winter (37.1%). This study extends the geographic distribution range of five species of Hemerobiidae to Brazil and three to the state of São Paulo.

Introduction

Hemerobiids (Neuroptera, Hemerobiidae) are popularly known as brown lacewings; as adults, the vast majority of their species have brown wings and bodies, except for some species of *Notiobiella* Banks, 1909, which are green in color. They are nocturnal insects and, when disturbed, exhibit a behavior known as thanatosis (New, 1975; Oswald, 1993; Garzón-Orduña et al., 2016). This family has worldwide distribution and is the third largest family of Neuroptera, with about 590 described species distributed in 28 genera (Oswald, 1993; Engel et al., 2018). In Brazil 26 species of hemerobiids are recorded in six genera (Lara and Perioto, 2016, 2021; Machado and Martins, 2022).

Some brown lacewing genera, such as *Hemerobius* Linnaeus, 1758, *Micromus* Rambur, 1842 and *Sympherobius* Banks, 1904 are almost cosmopolitan; others like *Megalomus* Rambur, 1842 (North and South America, Eurasia, and Africa) and *Notiobiella* (South and Central America, Africa, Asia, and Australia) have a large intercontinental distribution, and others, for example, *Conchopterella* Handschin, 1955, *Gayomyia* Banks, 1913, *Hemerobiella* Kimmins, 1940, *Nomerobius* Navás, 1916 and *Neosympherobius* Kimmins, 1929 (South America), and *Nusalala* Navás, 1913 (South and Central America) are restricted to a single continent (Oswald, 1993).

Hemerobiids are economically important since they are valuable as biological control agents (Stelzl and Devetak, 1999), both adults and larvae act predominantly as arboreal generalist predators of phytophagous insects mainly aphids, coccids, psyllids, mites and other soft-bodied species (Carpenter, 1940; Penny and Monserrat, 1985; Tauber et al., 2007).

There is a lack of long-term research on the frequency and seasonality of several groups of Neuropterida, among these hemerobiids, usually collected in low population density, which also makes it necessary to use different sampling methods to describe its seasonal activity (Szentkirályi, 1992, 1997; Ábrahám et al., 2003; Lara et al., 2008; Oliveira et al., 2013; Sarmiento-Cordero et al., 2021). Information about distribution patterns and diversity of hemerobiids along environmental gradients are also unusual (Cancino-López et al., 2022).

Based on the importance of brown lacewings, this study aimed to characterize the diversity and temporal variation of Hemerobiidae collected in five Atlantic rainforest localities in the São Paulo state,

* Corresponding author.
E-mail: rirlara@yahoo.com.br (R.I.R. Lara).

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Brazil. The diversity of hemerobiids between the studied areas was also compared through an altitudinal gradient and new geographical distribution records were added. Images of the studied species and maps with their geographical distribution in Neotropical region are provided.

Material and methods

Specimens of Hemerobiidae were collected with Malaise traps (model Townes, 1972) in five areas of Atlantic rainforest in São Paulo state, Brazil. Three sampled areas were located in or close to the marine coast: Estação Ecológica Juréia-Itatins (EEJI) (24°31'14.6"S / 47°12'5.7"W, 16 m above sea level (asl)), Iguape municipality, between October 2009 and March 2011; Parque Estadual da Serra do Mar - Núcleo Picinguaba (PESM/NP) (23°19'59.3"S / 44°49'57.8"W, 215 m asl), Ubatuba municipality, between November 2009 and December 2010, and Parque Estadual da Serra do Mar - Núcleo Santa Virgínia (PESM/NSV) (23º19'24.8"S / 45º05'40.1"W, 1030 m asl), São Luiz do Paraitinga municipality, between November 2009 and December 2011. The two remaining areas are located inland the state of São Paulo: Parque Estadual Morro do Diabo (PEMD) (22°36'17.0"S / 52°18'05.8"W, 350 m asl), Teodoro Sampaio municipality, between November 2009 and February 2011, and Parque Estadual Intervales (PEI) (24°16'28.0"S / 48°25'14.8"W, 880 m asl), Ribeirão Grande municipality, between October 2009 and March 2011 (Fig. 1).

Five Malaise traps were used to each collection site, separated from one another by 50 meters apart and operated continuously; as preservative has been used Dietrich's solution. The biological material was removed monthly, and corresponded to one sample. The surveys were authorized by the Sistema de Autorização e Informação em Biodiversidade (SISBIO), license #10632-1. The total sampling effort (trap days) was not equal in all studied areas: PESM/NSV = 3,900, PEI and EEJI = 2,700, PEMD = 2,400 and PESM/NP = 2,100.

In the laboratory, the Hemerobiidae were separated from other insects and stored in plastic vials containing 96% ethanol solution and labeled. Studied specimens were identified by the first author based on Monserrat (1984, 1996, 1997, 2000), Penny and Monserrat (1985), and Oswald (1988, 1993). Their terminalia were hot-macerated in a 10% KOH solution for about 20 minutes and subsequently immersed, for one hour, in a 10% $C_2H_4O_2$ solution for neutralization. After its study, the genital structures were preserved in glycerin in glass microvials that were stored in the plastic vials together with the respective specimens.

Observations were made using a Leica MZ9.5 stereomicroscope and a Leica DM500 optical microscope. The color images and measurements were taken using a Leica DFC295 digital camera attached to a Leica M205C APO with a Leica LED5000 HDI high diffuse dome illumination system, as well as with a Leica DFC295 digital camera attached to a Leica DM500 optical microscope, using the Leica Application Suite (LAS version 4.12.0). Focus stacking of images was done using Helicon Focus (version 5.3). The figures were prepared using Adobe Photoshop (version 11.0).

The diversity of Hemerobiidae species captured with Malaise traps in the five Atlantic rainforest studied areas was compared through rarefaction curves, obtained by bootstrapping with resampling. Bootstrap analyses were calculated using EstimateS Win9.1 software (Colwell, 2013) using 2,000 randomizations and 95% confidence intervals.

Species distributions were assembled in a dataset and incorporated into distribution maps. Geographic coordinates of the species records, if not present in labels, were taken from Google Earth software (https://www.google.com/earth/), and the maps were generated using SimpleMappr (Shorthouse, 2010).

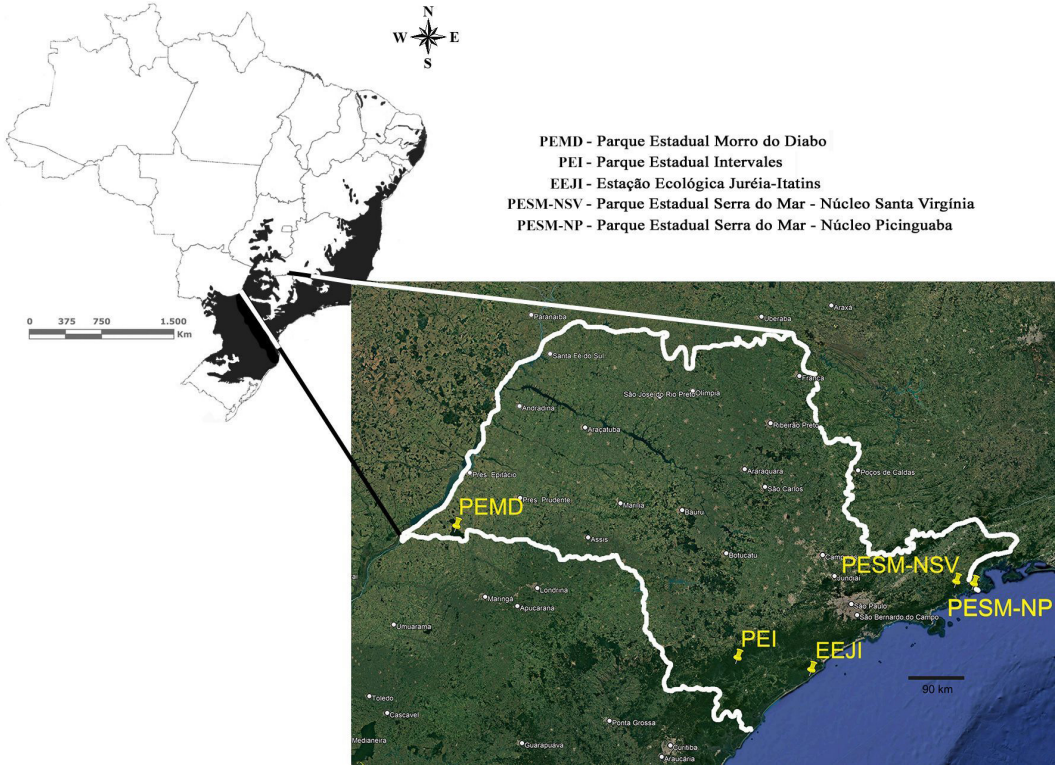


Figure 1 Map of Brazil with the original extension of the Atlantic rainforest biome in black color and map of the São Paulo state with the collection sites. PEI = Parque Estadual Intervales, PEMD = Parque Estadual Morro do Diabo, PESM/NSV = Parque Estadual da Serra do Mar, Núcleo Santa Virgínia, PESM/NP = Parque Estadual da Serra do Mar, Núcleo Picinguaba and EEJI = Estação Ecológica Juréia-Itatins. Image sources: www.wwf.org.br and Google Earth.

Histograms of species distributions along altitudinal gradient (Dambros, 2020) constructed in R (R Core Team, 2022) were used to describe the responses of individual species in relation to each sampled environment.

The following abbreviations related to the names of Brazilian states were used: AM= Amazonas, GO= Goiás, MG= Minas Gerais, PA= Pará, RS= Rio Grande do Sul and SC= Santa Catarina.

All studied specimens (voucher specimens LRRP LOTE #24-28) were deposited at Coleção Entomológica do Laboratório de Sistemática e Bioecologia de Predadores e Parasitoides of the Instituto Biológico (LRRP), Ribeirão Preto, SP, Brazil, N.W. Perioto, curator.

Results

A total of 237 adult brown lacewings belonging to 14 species and five genera (*Hemerobius*, *Megalomus*, *Notiobiella*, *Nusalala* and *Sympherobius*) were obtained: *Nus. tessellata* (Gerstaecker, 1888) (representing 30.8% of the total number of adults collected), *H. hernandezi* Monserrat, 1996 (26.2%), *Nus. dispar* (Banks, 1910) (17.3%), *H. cubanus* Banks, 1930 (3.0%), *H. edui* Monserrat, 1991, *H. gaitoi* Monserrat, 1996, *H. nigridorsus* Monserrat, 1996 and *H. withycombei* (Kimmins, 1928) (1.7% each), *M. ricoi* Monserrat, 1997 and *Not. cixiiformis* (Gerstaecker, 1888) (1.3% each), *S. ariasi* Penny & Monserrat, 1985 (0.8%), and *M. impudicus* (Gerstaecker, 1888), *M. rafaeli* Penny & Monserrat, 1985 and *S. mirandus* (Navás, 1920) (0.4% each) (Table 1, Figs. 2-6). Eighteen specimens of *Hemerobius* (7.6% of the total collected) and nine of *Megalomus* (3.8%) were not identified at the species level because they were females, difficult to identify, or because they presented abdomen and/or genital structures damaged by traps or during their dissection.

The highest abundances of hemerobiids were recorded in spring (43.9% of the total collected) and in winter (37.1%) with a frequency peak in September (23.6%), late winter in the southern hemisphere (Figs. 7A, B). Hemerobiids were more frequent at PEI (55.3% of the total collected / 2,700 trap days) and PEMD (23.2% / 2,400), inland collection sites in the state of São Paulo, where the sampling effort for the capture of each specimen was 20.6 and 41.4 trap days, respectively (Figs. 1, 7C). In the sampled areas situated in or near the marine coast (PESM/NP, PESM/NSV and EEJI) were collected 21.5% of the hemerobiids.

Nusalala, the most abundant genus (49.4% of the total collected), was recorded only in PEI and PEMD, followed by *Hemerobius* (42%), the only genus collected from all sampled areas. *Megalomus* (6.1%) was registered in the PEMD, PEI and PESM/NP, *Sympherobius* (1.3%) in PEMD and PEI and, *Notiobiella* (1.3%) only in PEMD (Table 1, Fig. 9B). Five genera of Hemerobiidae were sampled in PEMD, situated inland in the state of São Paulo, while in PESM/NP and EEJI, located near the marine coast, only *Hemerobius* was captured.

The highest frequencies for *Nusalala* and *Hemerobius* were observed in winter and spring, whereas those for *Megalomus* were recorded in spring (Figs. 8A-C). All specimens of *Notiobiella* have been captured in the spring and *Sympherobius*, despite the small number of specimens collected, one in each season, was simply not captured in the fall (Fig. 8D, E). Both *Nusalala* and *Hemerobius* exhibited two clearly defined frequency peaks: *Nusalala* in September and October, and *Hemerobius* in September and November (Figs. 8A, B). *Megalomus* had the maximum frequency in February, and *Notiobiella* in November

Table 1
Seasonal abundance of the Hemerobiidae (Neuroptera) collected with Malaise traps in five areas of Atlantic rainforest at São Paulo State, Brazil, between October 2009 and December 2011.

areas of Atlantic Rainforest	seasons	*Hemerobius cubanus*	*Hemerobius edui*	*Hemerobius gaitoi*	*Hemerobius hernandezi*	*Hemerobius nigridorsus*	*Hemerobius withycombei*	*Hemerobius* sp.	*Megalomus impudicus*	*Megalomus rafaeli*	*Megalomus ricoi*	*Megalomus* sp.	*Notiobiella cixiiformis*	*Nusalala dispar*	*Nusalala tessellata*	*Sympherobius ariasi*	*Sympherobius mirandus*	total
PEI	spring			1	8		1	2			2	1		18	25		1	59
	summer				3		1	3				4		1	3			15
	autumn				1		1	1						3	5			11
	winter				4		1	2						19	20			46
PEMD	spring				4			1	1			2			10			18
	summer				1			1							2	1		5
	autumn																	0
	winter	2		1	16			1		1		2	3		8	1		35
PESM/NSV	spring	1			13			3			1							18
	summer			1	1			1										3
	autumn	3			2			2										7
	winter			1	4	2												7
PESM/NP	spring				1	2		1										4
	summer																	0
	autumn		1		1													2
	winter	1			1													2
EEJI	spring		1		1													2
	summer		1		1													2
	autumn																	0
	winter		1															1
	total	7	4	4	62	4	4	18	1	1	3	9	3	41	73	2	1	237
	%	3.0	1.7	1.7	26.2	1.7	1.7	7.6	0.4	0.4	1.3	3.8	1.3	17.3	30.8	0.8	0.4	100.0

PEI: Parque Estadual Intervales; PEMD: Parque Estadual Morro do Diabo; PESM/NSV: Parque Estadual da Serra do Mar, Núcleo Santa Virgínia; PESM/NP: Parque Estadual da Serra do Mar, Núcleo Picinguaba; EEJI: Estação Ecológica Juréia-Itatins.

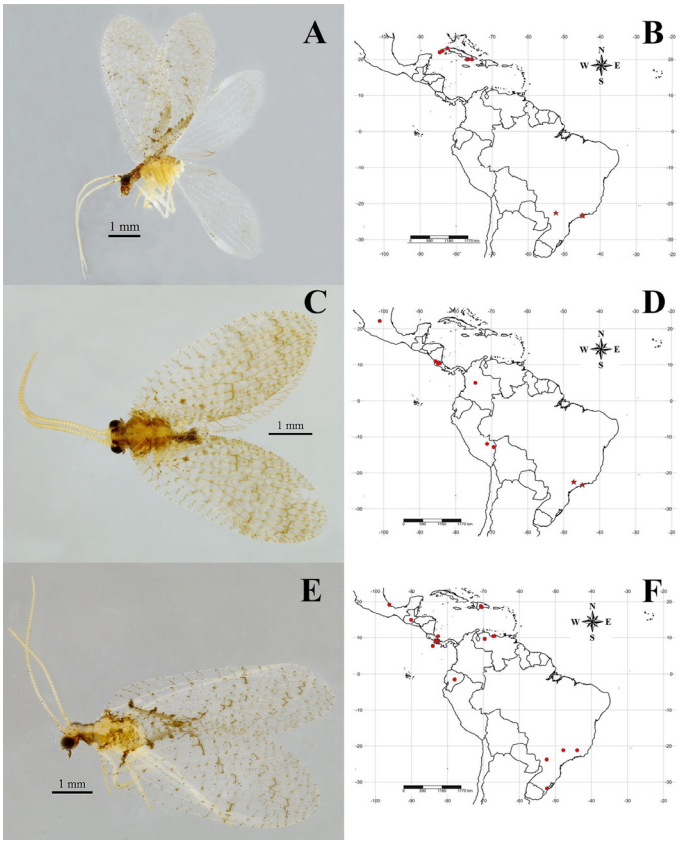


Figure 2 Habitus of collected species of *Hemerobius* Linnaeus, 1758 (Neuroptera, Hemerobiidae) and their geographical distribution in Neotropics; red circles = previous records, red stars = new records. A-B, *H. cubanus* Banks, 1930. C-D, *H. edui* Monserrat, 1991. E-F, *H. gaitoi* Monserrat, 1996.

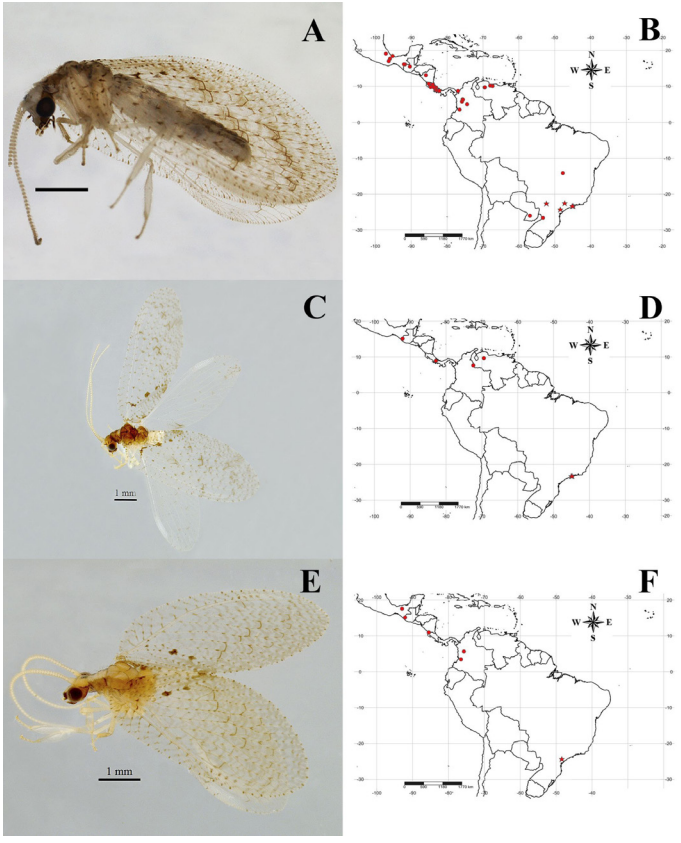


Figure 3 Habitus of collected species of *Hemerobius* Linnaeus, 1758 (Neuroptera, Hemerobiidae) and their geographical distribution in Neotropics; red circles = previous records, red stars = new records. A-B, *H. hernandezi* Monserrat, 1996. C-D, *H. nigridorsus* Monserrat, 1996. E-F, *H. withycombei* (Kimmins, 1928).

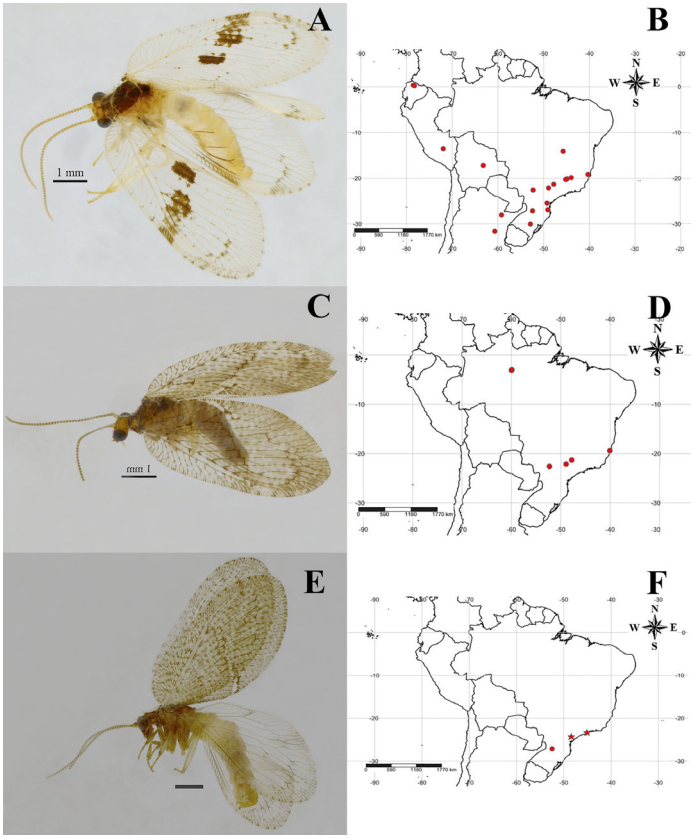


Figure 4 Habitus of collected species of *Megalomus* Rambur, 1842 (Neuroptera, Hemerobiidae) and their geographical distribution in Neotropics; red circles = previous records, red stars = new records. A-B, *M. impudicus* (Gerstaecker, 1888). C-D, *M. rafaeli* Penny & Monserrat, 1985. E-F, *M. ricoi* Monserrat, 1997.

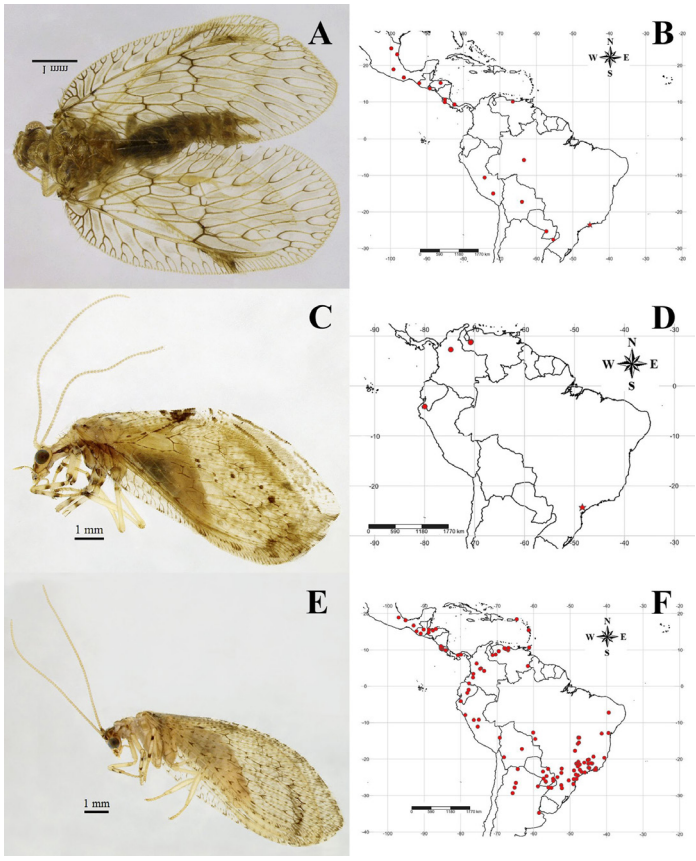


Figure 5 Habitus of collected species of *Notiobiella* Banks, 1909 and *Nusalala* Navás, 1913 (Neuroptera, Hemerobiidae) and their geographical distribution in Neotropics; red circles = previous records, red stars = new records. A-B, *Not. cixiiformis* (Gerstaecker, 1888). C-D, *Nus. dispar* (Banks, 1910). E-F, *Nus. tessellata* (Gerstaecker, 1888).

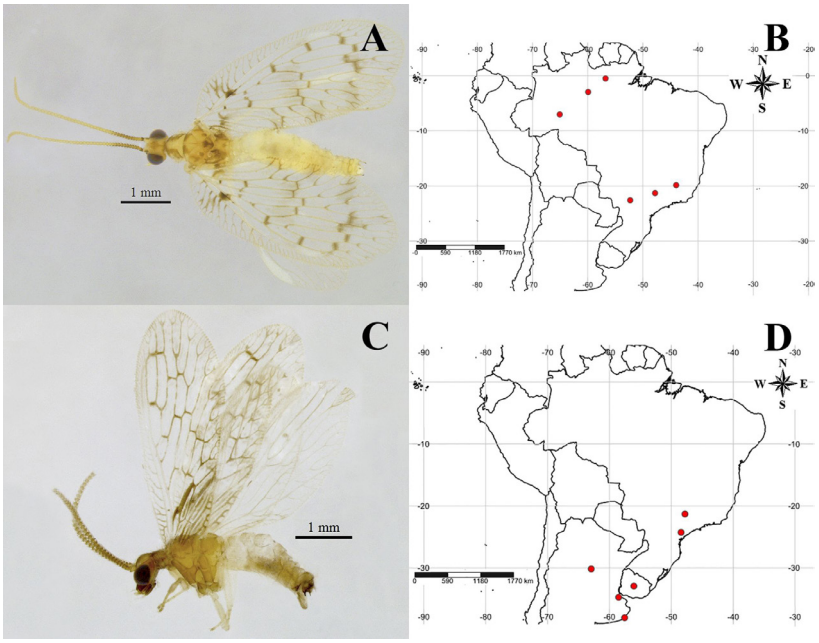


Figure 6 Habitus of collected species of *Sympherobius* Banks, 1904 (Neuroptera, Hemerobiidae) and their geographical distribution in Neotropics; red circles = previous records, red stars = new records. A-B, *S. ariasi* Penny & Monserrat, 1985. C-D, *S. mirandus* (Navás, 1920).

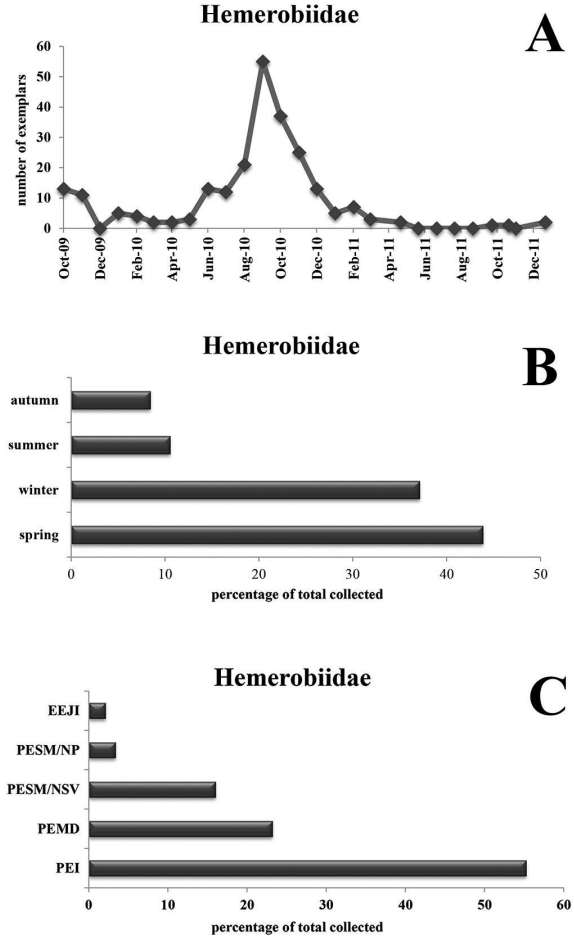


Figure 7 Hemerobiidae (Neuroptera) collected monthly in five areas of Atlantic rainforest of São Paulo State, Brazil, between October 2009 and December 2011. A, Population fluctuation. B, Seasonal abundance (percentage). C, Abundance (percentage) in each studied area. PEI = Parque Estadual Intervales, PEMD = Parque Estadual Morro do Diabo, PESM/NSV = Parque Estadual da Serra do Mar, Núcleo Santa Virgínia, PESM/NP = Parque Estadual da Serra do Mar, Núcleo Picinguaba and EEJI = Estação Ecológica Juréia-Itatins.

(Figs. 8C, D), indicating a temporal pattern of use of the environment by these predators.

The diversity of Hemerobiidae species resulting from the rarefaction curve (bootstrap curve) (Fig. 9A) showed higher values in PEMD and PEI. However, there is no evidence of stabilization indicating that more samples are needed in these areas to better estimate their diversity. At PESM/NSV the species diversity was lower than in PEI and PEMD, despite the rarefaction curve presented the asymptote at 23 samples. At PESM/NP, the rarefaction curve behavior indicates that the sampling effort used was insufficient to describe the diversity of hemerobiids species present in the ambient since there was no evidence of stabilization of the curve, and in the EEJI, the rarefaction curve reached asymptote at 14 samples, indicating that all species of hemerobiids were effectively collected.

The species richness of the hemerobiids collected in the five Atlantic rainforest areas was represented in a Venn diagram (Fig. 9B), which shows the exclusive and shared species in those areas studied. The highest richness of hemerobiids species was observed in PEMD (eight species) and PEI (seven) (Fig. 9B). *Hemerobius hernandezi* occurred at the five studied areas; *H. cubanus* and *H. gaitoi* at three and *H. edui*, *H. nigridorsus*, *Nus. tessellata* and *Megalomus ricoi* at two. *Megalomus impudicus*, *M. rafaeli*, *Not. cixiiformis* and *S. ariasi* were recorded only in PEMD and *H. withycombei*, *Nus. dispar* and *S. mirandus* only in PEI.

The areas located inland the state of São Paulo, with elevations between 350 and 880 m, recorded more than 80% of the species collected, while those located in or close to the marine coast, with elevations between 16 and 215 m, recorded less than 30% (Tab. 1, Fig. 10). The incidence of *H. edui* appears to be limited to low elevation environments, between 16 and 215 m, on the other hand, *M. ricoi*, *S. mirandus*, *Nus. dispar* and *H. withycombei* are limited to higher environments, between 880 and 1,030 m, and *H. hernandezi* showed greater environmental plasticity as their populations were observed in all extracts analyzed (Fig. 10).

This study extends for the first time the geographic distribution range of *H. cubanus* (Fig. 2A, B), *H. edui* (Fig. 2C, D), *H. nigridorsus* (Fig. 3C, D), *H. withycombei* (Fig. 3E, F), and *Nus. dispar* (Fig. 5C, D) to

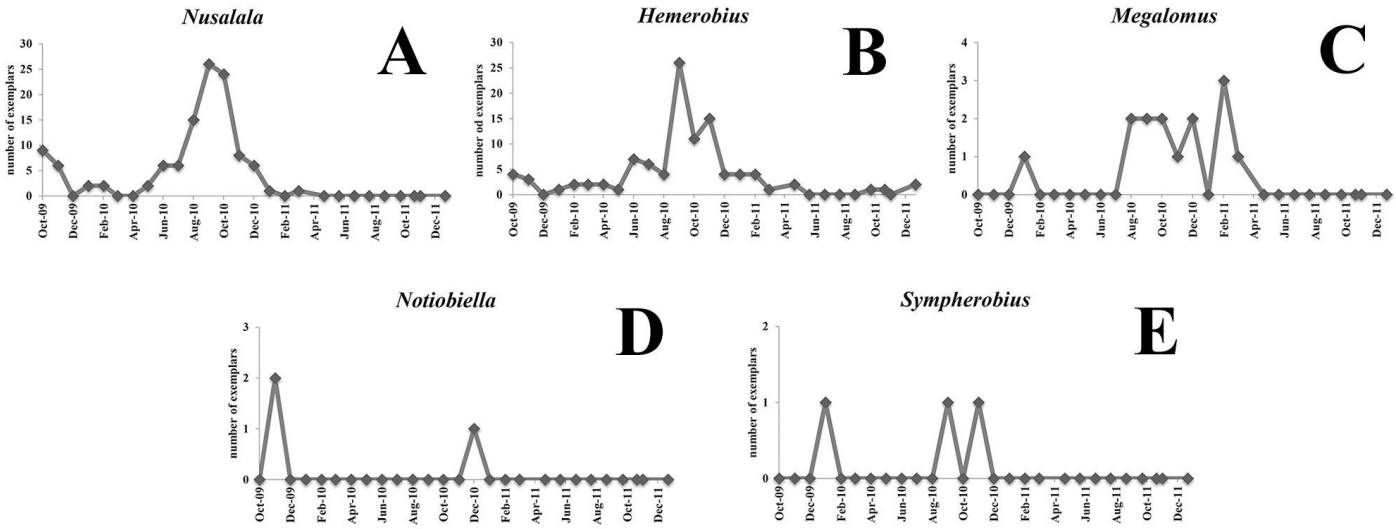
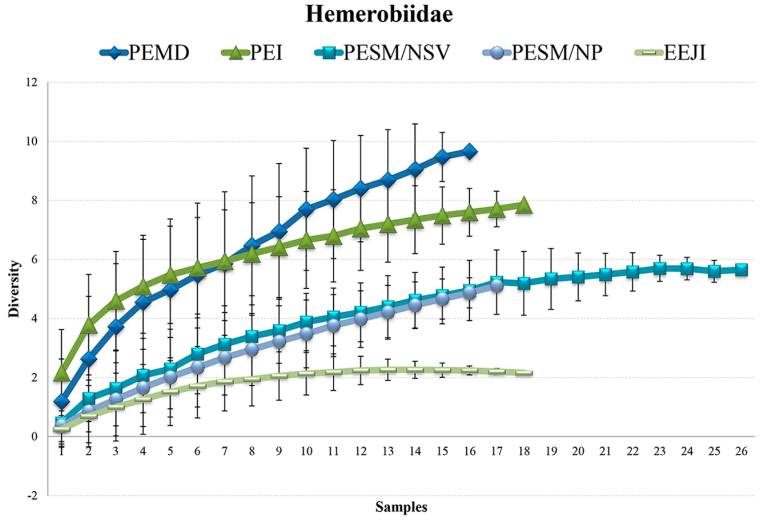
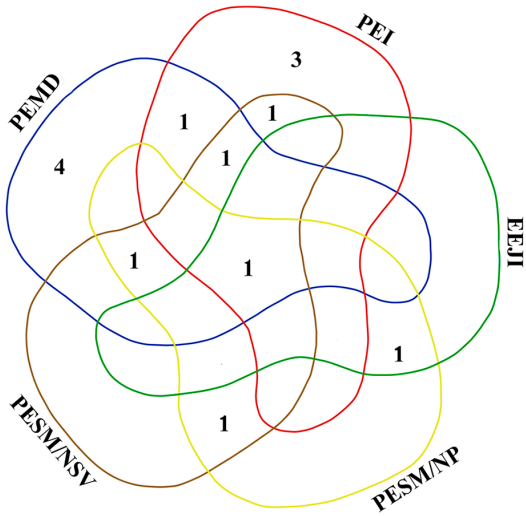


Figure 8 Genera of Hemerobiidae (Neuroptera) collected monthly with Malaise traps in five areas of Atlantic rainforest of São Paulo State, Brazil, between October 2009 and December 2011. A, *Nusalala* Navás, 1913. B, *Hemerobius* Linnaeus, 1758. C, *Megalomus* Rambur, 1842. D, *Notiobiella* Banks, 1909. E, *Sympherobius* Banks, 1904.





Areas studied	Hemerobiidae species
PEMD	*Notiobiella cixiiformis*, *Megalomus impudicus*, *Megalomus rafaeli* and *Sympherobius ariasi*
PEI	*Hemerobius withycombei*, *Nusalala dispar* and *Sympherobius ariasi*
PESM/NSV and PESM/NP	*Hemerobius nigridorsus*
PESM/NP and EEJI	*Hemerobius edui*
PESM/NSV and PEI	*Megalomus ricoi*
PEMD and PEI	*Nusalala tessellata*
PEMD, PESM/NSV and PESM/NP	*Hemerobius cubanus*
PEMD, PEI and PESM/NSV	*Hemerobius gaitoi*
PEMD, PEI, PESM/NSV, PESM/NP and EEJI	*Hemerobius hernandezi*

Figure 9 Hemerobiidae (Neuroptera) collected with Malaise trap in five areas in the Atlantic rainforest of São Paulo state, Brazil, between October 2009 and December 2011. A, Diversity (Bootstrap). B, Venn diagram. PEI = Parque Estadual Intervales, PEMD = Parque Estadual Morro do Diabo, PESM/NSV = Parque Estadual da Serra do Mar, Núcleo Santa Virgínia, PESM/NP = Parque Estadual da Serra do Mar, Núcleo Picinguaba and EEJI = Estação Ecológica Juréia-Itatins.

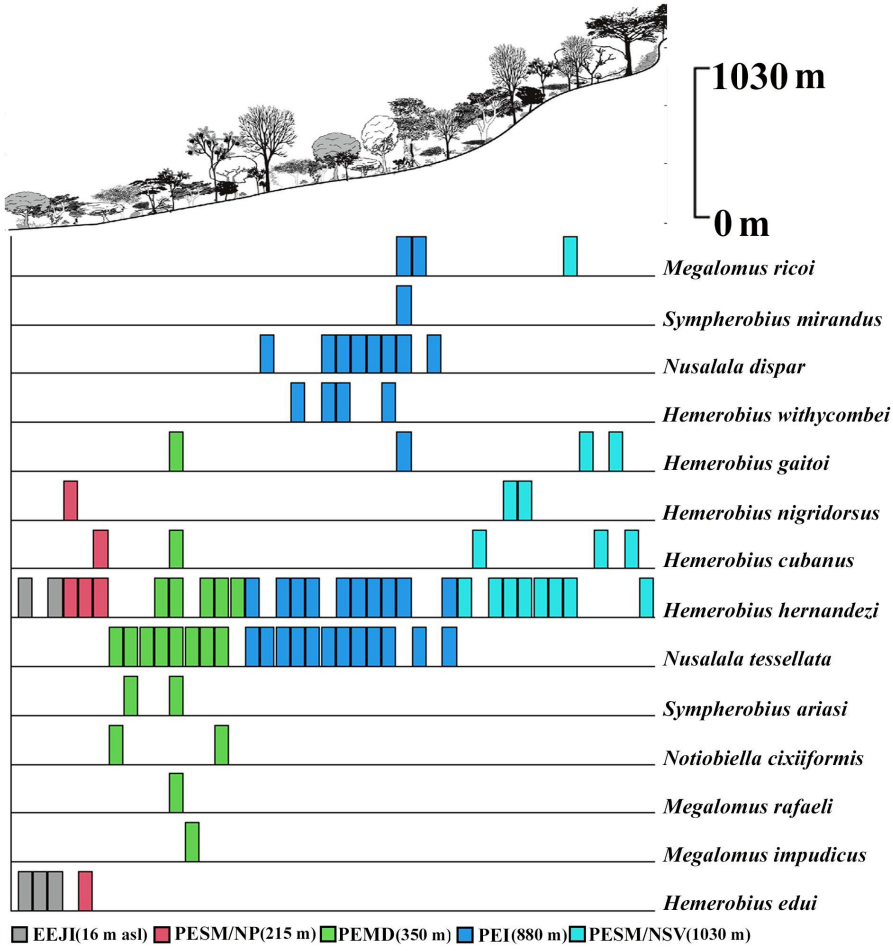


Figure 10 Species distributions of Hemerobiidae (Neuroptera) along altitudinal gradient in five areas in the Atlantic rainforest of São Paulo state, Brazil, collected between October 2009 and December 2011. asl = above sea level, PEI = Parque Estadual Intervales, PEMD = Parque Estadual Morro do Diabo, PESM/NSV = Parque Estadual da Serra do Mar, Núcleo Santa Virgínia, PESM/NP = Parque Estadual da Serra do Mar, Núcleo Picinguaba and EEJI = Estação Ecológica Juréia-Itatins.

Brazil and of *H. hernandezi* (Fig. 3A, B), *M. ricoi* (Fig. 4E, F), and *Not. cixiiformis* (Fig. 5A, B) to the state of São Paulo.

Hemerobius cubanus has been recorded in Cuba (Monserrat, 1996; Oswald, 2022); *H. edui* in Colombia, Costa Rica, Mexico and Peru (Monserrat, 1996; Oswald, 2022); *H. nigridorsus* in Costa Rica, Mexico and Venezuela (Monserrat, 1996; Cancino-López et al. 2021; Oswald, 2022); *H. withycombei* in Colombia, Costa Rica and Mexico (Monserrat, 1996; Cancino-López et al. 2021; Oswald, 2022), and *Nus. dispar* in Colombia, Ecuador and Venezuela (Monserrat, 2000; Lara and Perioto, 2016; Oswald, 2022).

Hemerobius hernandezi has previously been recorded in Brazil (GO, MG, and RS), Mexico, Guatemala, Nicaragua, Panama, Colombia, Costa Rica, Venezuela, and Paraguay (Monserrat, 1996, 1998; Silva et al., 2015; Lara and Perioto, 2016, 2021; Oswald, 2022); *M. ricoi* in Brazil (SC) (Monserrat, 1997; Lara and Perioto, 2016; Oswald, 2022), and *Not. cixiiformis* in Brazil (AM and PA), Argentina, Bolivia, Colombia, Costa Rica, El Salvador, Honduras, Mexico, Panama, Paraguay, Peru, and Venezuela (Monserrat, 1984, 1998, 2002; Lara and Perioto, 2016; Oswald, 2022).

Discussion

According to Bozdoğan (2020), habitat types and forms can determine and influence the diversity, abundance, and distribution of Neuroptera in forests, and that some families declined in abundance with altitude. The Hemerobiidae are abundant in tropical, subtropical, and temperate environments; however, many of its species develop in xeric environments, in colder boreal zones or high elevations which generate numerous endemisms and fragmented distributions (Monserrat, 2015; Cancino-López et al., 2021). These insects are able to adapt and colonize new environments and select foraging areas based on their feeding habits, dispersal, and resource localization capacity in natural habitats (Stelzl and Devetak, 1999; McEwen et al., 2001; Duelli et al., 2002) and, as a result, are able to colonize anthropic environments, such as agricultural areas. The highest values of abundance and diversity of hemerobiids species found in areas of altitudes between 350 and 1,030 m suggest that some species have distribution restricted to higher elevations, while others have a preference for low elevations, corroborating the reports of Bozdoğan (2020) and Cancino-López et al. (2021, 2022).

In Brazil, *Nusalala* and *Hemerobius* were reported in several studies carried out in agricultural (Lara and Freitas, 2002, 2003; Lara et al., 2008, 2010, 2020; Melo et al., 2020) and wild environments (Oliveira et al., 2013; Lara and Perioto, 2021; Schuster and Machado, 2021), and in most of them, *Nusalala* was the most abundant genus. However, in all these studies, *Megalomus*, *Notiobiella* and *Sympherobius* are genera, so far, poorly represented in population surveys conducted by the authors in agroecosystems and wild environments. These results differ from those obtained by Cancino-López et al. (2021) in an altitudinal gradient at the Tacaná volcano in Mexico, where approximately 90% of the hemerobiids collected belonged to *Hemerobius.*

Lara and Perioto (2021) reported that the total sampling effort for the capture of each Hemerobiidae specimen in areas of Brazilian savanna in the state of Goiás was 91.3 trap days, about 1.5 times higher than that recorded in this study (58.2 trap days). These results may be related to the need for intense and long-term efforts for Hemerobiidae sampling. The sampling of Neuroptera was addressed by different authors, who stated that, for some groups, is required the combined use of greater and longer sampling efforts and the use of various types of traps (Szentkirályi, 1992, 1997; Ábrahám et al., 2003; Lara et al., 2008; Oliveira et al., 2013; Martins et al., 2019; Sarmiento-Cordero et al., 2021).

There are few studies worldwide on the abundance, seasonality, and diversity of Hemerobiidae, contributing to a lack of knowledge about the bioecology of this group and this information gap can be overcome through long-term investigations. Most of those studies are mainly focused on faunistic lists of a particular country or region. This is the second long-term study on the Hemerobiidae fauna in Atlantic rainforest areas in Brazil. Consequently, the results of this study can only be compared with Schuster and Machado (2021), and by similar studies conducted in other Brazilian biomes, such as the Brazilian savanna and some of its phytophysiognomies.

Schuster and Machado (2021) studied the Neuroptera in Atlantic rainforest areas in the state of Paraná, Brazil and found that Hemerobiidae was the third most abundant family, represented by three genera and seven species, with higher frequencies in summer; among them, *Hemerobius* was the most frequent genus.

In Brazil, Oliveira et al. (2013) reported that the highest frequencies of *Nusalala* in areas of Brazilian savanna and gallery forest areas in the state of Minas Gerais occurred in winter. Lara and Perioto (2021) studied the hemerobiids in areas of Brazilian savanna in the state of Goiás and found that the higher capture frequencies occurred in the fall and winter. In the state of Minas Gerais, Silva et al. (2015) reported that the highest frequencies of *Hemerobius* in semi-deciduous and riparian forests occurred in the spring and summer, while Oliveira et al. (2013) recorded these predators in late winter. Lara and Perioto (2021) collected *Hemerobius* sporadically in the mid-autumn, winter and spring. Oliveira et al. (2013) and Lara and Perioto (2021) reported higher frequencies of *Megalomus* during winter and spring. The aforementioned studies, carried out in areas of Brazilian savanna, suggest that the seasonal distribution of this group of predators is similar to that recorded for the Atlantic rainforest biome.

It should be noted that Brazil is a continental country, with a wide variety of climatic types, even when we consider the same geographic area. The above studies were performed at localities and states characterized by different climatic types according to the Köppen classification: in the Paraná (Schuster and Machado, 2021), Cfa (temperate climate, no dry season and hot summer) and Cfb (temperate climate, no dry season and cool summer) (Climate-Data.Org, 2022); in Minas Gerais (Oliveira et al., 2013; Silva et al., 2015), Aw (tropical savannah and rainy summer), Cwa (temperate, dry winter and hot summer) and Cwb (temperate, dry winter and cool summer) (*idem*); in Goiás (Lara and Perioto, 2021), Aw (*idem*) and, in this study, in São Paulo, Af (tropical equatorial), Am (tropical monsoon) and Cfa (*idem*). It is true that these climate differences strongly interfere with the temporal distribution of hemerobiids. However, there is insufficient information available to conduct more detailed analyses of its temporal distribution.

It is known that hemerobiids are usually found at low population densities and, because of this fact, their seasonal activity can only be described through long-term surveys (Szentkirályi, 1997). In the Neotropics, such studies are scarce, however the available (Lara et al., 2008; Oliveira et al., 2013; Marquez-López et al., 2020; Sarmiento-Cordero et al., 2021; Cancino-López et al., 2021, 2022) corroborate Szentkirályi's reports. Similar events occurred with some Hymenoptera families collected at low population densities and the use of Malaise traps in long-term studies was instrumental in capturing groups infrequently collected in Brazilian biomes according to the reports of Lucena et al. (2012) for the Chrysididae of the Caatinga, Versuti et al. (2014) for the Dryinidae of the Brazilian savanna, Lara and Perioto (2014) and Perioto et al. (2016) for the Monomachidae and Pelecinidae of the Atlantic rainforest, and Fernandes et al. (2017) for the Sclerogibbidae of the Amazon forest, Caatinga and Pantanal.

The present study revealed, for the first time, the simultaneous occurrence of 14 species of Hemerobiidae in areas of Atlantic rainforest in the state of São Paulo, indicating that long-term investigations in other Brazilian biomes are necessary to increase the knowledge of the diversity, frequency, and seasonality of this group of predators. Further studies are required to better understand the altitudinal distribution of hemerobiids in the studied environments.

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Conflicts of interest

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

Author contribution statement

RIRL: Contributed with the conceptualization and identification of specimens, writing, and revision of the final manuscript. NWP: Contributed with the writing, preparation of distribution maps, edition, and revision of the final manuscript. DRRF: Contributed with the analyses, writing, and revision of the final manuscript.

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