Journal of the Lepidopterists' Society
62(2), 2008, 71-79

HAWKMOTH FAUNA OF A NORTHERN ATLANTIC RAIN FOREST REMNANT (SPHINGIDAE)

JOSÉ ARAÚJO DUARTE JÚNIOR

Programa de Pós-Graduação em Ciências Biológicas, Departamento de Sistemática e Ecologia, Universidade Federal da Paraíba, 58059-900, João Pessoa, Paraíba, Brazil; email: josejunior_lep@yahoo.com .br

AND

CLEMENS SCHLINDWEIN

Departamento de Botânica, Universidade Federal de Pernambuco, Av. Prof. Moraes Rego, s/n, Cidade Universitária, 50670-901, Recife, Pernambuco, Brazil; email: schlindw@ufpe.br

ABSTRACT. We present results of a year-long faunistic survey of Sphingidae of the Brazilian northern Atlantic rain forest. The study was undertaken between August 2003 and July 2004, at the Private Nature Reserve (RPPN) Frei Caneca in the state of Pernambuco. Hawkmoths were captured using a 250-watt mercury-vapor light trap positioned against a white wall. We recorded 379 individuals of 50 species in 19 genera. The most abundant species were *Erinnyis ello*, *E. alope*, *Neogene dynaeus* and *Protambulyx astygonus*, which accounted for 44.2% of the collected individuals. More than one individual was recorded for all but eight species. Hawkmoths abundance was lowest in the months with intense rainfall. The sphingid fauna of northeastern Brazil is compared with that of the Amazonian and southern Atlantic rain forest as well as with the adjacent caatinga, a tropical dry forest with abundant succulent plants. Species composition of Sphingidae of the northern Atlantic rain forest was most similar to that of the Amazonian forest.

Additional key words: biodiversity, biogeography, Brazil, distribution, Pernambuco, South America, survey

The Sphingidae (Bombycoidea) includes about 1200 species globally (Lemaire & Minet 1999) and 180 species in Brazil (Brown 1986). Sphingidae are cosmopolitan and show highest diversity in the tropics (Hodges 1971). In South America, surveys of Sphingidae are scarce and regional inventories are necessary to know their diversity and distribution and to elucidate their biogeographical relationships (Kitching & Cadiou 2000).

The Brazilian Atlantic rain forest, which extends along the Atlantic coast between the states of Rio Grande do Norte and Rio Grande do Sul (Rizzini 1997), is currently highly fragmented, with only 5% of its original forest remaining (Ranta *et al*. 1998, Tabarelli *et al*. 2002). The first local survey of Sphingidae in the northern part of the Atlantic rain forest revealed 23 species (Duarte & Schlindwein 2005a). In an area of *cerrado*-like savannah vegetation of the *Tabuleiro* (tropical grassland with evergreen trees and shrubs), in the northeast Brazilian state of Paraíba, Darrault & Schlindwein (2002) recorded 24 species of sphingids. In the caatinga, the hawkmoth fauna is poor, and only 14 species were recorded in an area of caatinga in Paraíba (Gusmão & Creão-Duarte 2004) and 20 in Rio Grande do Norte (Duarte & Schlindwein 2005b). This contrasts to the high diversity of Sphingidae in the Amazon basin (Motta *et al*. 1998).

The northern Atlantic rain forest is strongly influenced by the Amazonian biota (Prance 1982, Santos *et al*. 2007). The montane forests of northeast Brazil on the other hand form a refuge for several species of plants and animals, which, due to their cooler and more humid climate, differ from the arid caatinga that surrounds them (Andrade-Lima 1982). Several botanical studies in northeastern Brazil have revealed floristic disjunctions between the Amazonian forest and the north Atlantic rain forest (Andrade-Lima 1982). This is also true for many animal taxa (Bigarella *et al*. 1975, Coimbra-Filho & Câmara 1996).

In this study we determine species richness, abundance, and seasonality of Sphingidae of a preserved area of the Atlantic rain forest in Pernambuco, northeastern Brazil, and compare the sphingid fauna to that of the caatinga and Amazonian rain forest.

MATERIALS AND METHODS

Study area. The study was carried out in the Reserva Particular do Patrimônio Natural RPPN Frei Caneca (Private Nature Reserve Frei Caneca) in the municipality of Jaqueira, Pernambuco, NE-Brazil. The study site is located at 8°42'41"S and 35°50'30"W at an altitude of 500–750 m (Fig. 1). The reserve covers an area of 630.42 ha, with a mountainous relief and granite rocky outcrops. The climate is tropical, hot and humid, with a mean annual temperature of 22°C. There is a 4–5 month dry (less-humid) season between October and February and a rainy season between March and September (IBGE 1985). The mean annual rainfall,

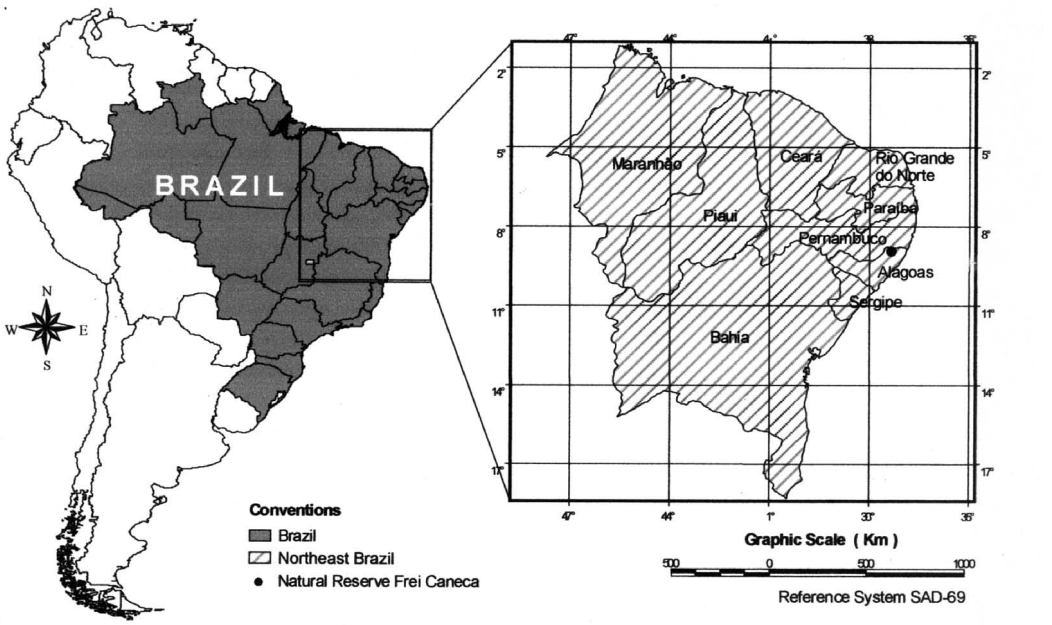

FIG. 1. Geographical location of the study site RPPN Frei Caneca in the Atlantic rain forest of Pernambuco, Brazil.

averaged over 47 years at Frei Caneca, which is 7 km from the reserve, is 1332 mm (unpublished meteorological data provided by Usina Colônia).

Sampling of Sphingidae. The survey was undertaken between August 2003 and July 2004. A 250W mercury-vapor light source, positioned against a white wall of the Reserve Station inside the park facing the forest, was used to attract moths. Specimens were collected on two consecutive new moon nights per month from 18.00h to 5.00h of the following day. Moths were killed by an injection of ethyl acetate in the posterior part of the thorax. Each specimen was then placed in an entomological envelope and prepared in the laboratory.

Moths were identified using d´Abrera (1986) and Kitching & Cadiou (2000) and the reference collection at UFPE. Specimens were deposited in the Entomological Collection of the Federal University of Pernambuco (UFPE, Recife) and the Entomological Collection of the Department of Systematics and Ecology, Federal University of Paraíba (UFPB, João Pessoa).

Three abundance criteria were established using Rabinowitz *et al*. (1986), based on the number of specimens collected per species: rare (1 to 2), common (3 to 19), and abundant (20 to 50).

Bio-Estat 2.0 (Ayres *et al*. 2000) was used to calculate Pearson's correlation coefficients (Sokal & Rohlf 1996). The data were adjusted to lognormal distributions according to the model of Preston (1948), which groups the species into frequency classes of individuals on a logarithmic scale. The program "lognorm.bas" (Ludwing & Reynolds 1988) was used, according to the equation $S(R)=S_0e^{(a^2R^2)}$, where $S(R)$ is the estimated number of species in a given octave, R is the distance in relation 1,2,3,.. (Octaves), S_0 is the estimated number of species in the modal octave, e is the natural logarithm base, and a an estimated constant calculated as $a^2 = 1/(2s)^2$, where s is the standard deviation. Dates were compared with regional inventories of Sphingidae of the Amazonian rain forest, south Atlantic rain forest and caatinga. Similarities were analyzed using NTSYS pc version 2.10t.

RESULTS

Three hundred and seventy-nine individuals, representing 50 species in 19 genera were recorded, of which 15 species are new records for northeast Brazil (Table 1). The most abundant species were *Erinnyis ello* Linnaeus 1758, *Erinnyis alope* (Drury 1773), *Neogene dynaeus* (Hübner [1825]) and *Protambulyx astygonus* (Boisduval [1875]), accounting together for 44.2% of the individuals recorded. Only 1 or 2 individuals were recorded for 17 species (Fig. 2).

From October to December, the driest months of the study period (192 mm, 6.6% of total rainfall), 170

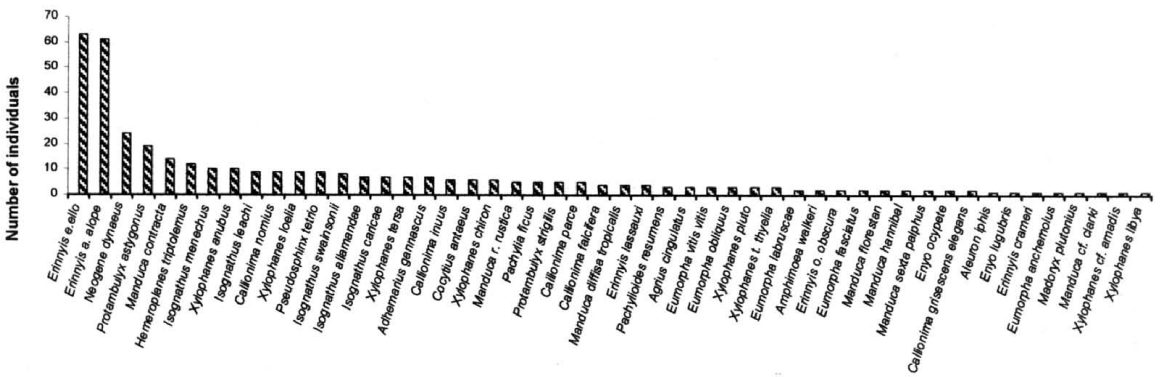

FIG. 2. Number of individuals of sphingid species recorded from August 2003 to July 2004 in the Atlantic rain forest of Frei Caneca, Pernambuco

individuals were recorded, 45% of the total. In January, the month with the highest rainfall (554 mm, 19%), only 2 individuals were recorded, *Adhemarius gannascus* (Stoll 1790) and *Protambulyx astygonus* (Boisduval [1875]). Other months with high rainfall, namely May, June and July (1120 mm, 392%) also showed low hawkmoth abundance (70 individuals, 18.5%). More than half of the species (30 individuals, 58.8%) were recorded in March (Table. 1).

The male to female sex ratio was 4:1, with 80% of captured moths being males. For almost half the species (26/50) only males were recorded. In the north Atlantic rain forest, species richness is lower in the rainy months. Pearson's correlation coefficient between rainfall 2003/2004 and abundance was -0.6813, and between rainfall 2003/2004 and species richness was -0.6741, both negative and significant (< 0,05). The species accumulation curve (Fig. 4), shows that by the fifth month of collecting 70.5% of the total number of sphingid species had been recorded and after the tenth month the number of species did not increase. The estimated number of species in the study area was 52 (Fig. 5).

DISCUSSION

The sphingid fauna of the north Atlantic rain forest shows a much higher species richness and abundance than that found in another survey, undertaken in the Atlantic rain forest, Nature Reserve of Gurjaú in Pernambuco, using the same methodology and the same sampling effort, in which only 23 species were recorded (Duarte & Schlindwein 2005a). Of these, only *Pachylia syces*, *Protambulyx eurycles*, *P. goeldii* and *Manduca brasilensis* were not recorded in the present study. The Nature Reserve, Frei Caneca is only 150 km distant from the reserve Gurjaú and is characterized by a little disturbed rain forest in a good level of conservation. The latter area is heavily fragmented, close to the metropolitan area of Recife City, surrounded and strongly impacted by sugar cane monocultures. The high number of additions to the list of the northeast Brazilian sphingid fauna (15 species) shows that the sphingid fauna of this area is still poorly known. No surveys are available for any other northeast Brazilian states (Bahia, Sergipe, Alagoas, Ceará, Piauí and Maranhão). These would most likely further increase the number of species in this region. Our study corrects earlier statements made about the apparently restricted distributions of some species, such as *Xylophanes anubus*, *Amphimoea walkeri* and *Madoryx plutonius*, which are now known to be more widespread in the neotropical region than previously thought.

The sphingid fauna of the Atlantic rain forest of Pernambuco shows no strong seasonal pattern, but we found a significant negative correlation between rainfall and both species richness and abundance, such that the rainiest months showed the lowest species richness and abundance. In Costa Rica adult sphingids were almost absent at the end of the dry season, abundant in the rainy season but scarce in October, the most humid month of the year. Abundance of Sphingidae was associated with the presence of leaves on their larval host-plants (Haber & Frankie 1989). In the south Brazilian state of Paraná, which is outside the tropics, sphingid abundance was correlated with temperature and abundance drastically diminished in winter (Marinoni *et al*. 1999). The sphingid fauna is also highly seasonal in the dry northeast Brazilian caatinga, where greatest abundance is in March at the beginning of the rainy season, when larval host-plants provide their leaves (Duarte & Schlindwein 2005b). Similar results were found in Mexico, where 77% of sphingids were recorded only in the rainy season (Gómez-Nucamendi *et al*. 2000).

TABLE 1. Species of Sphingidae recorded in the Atlantic rain forest of Frei Caneca, Pernambuco, Brazil, from August 2003 to July 2004. The abundance categories follow Rabinowitz *et al*. (1986).

Taxon	Month	Rare	Common	Abundant	Male	Female	Total
Macroglossinae							
MACROGLOSSINI							
Xylophanes cf. amadis (Stoll, 1782)	Aug	x			1	0	1
Xylophanes anubus (Cramer, 1777) *	Feb-May, Jun		x		9	1	10
Xylophanes pluto (Fabricius, 1777)	Mar, Nov		x		3	0	3
Xylophanes t. tersa (Linnaeus, 1771)	Apr, May, Aug, Nov, Dec		x		5	2	7
Xylophanes chiron (Drury, 1773) *	Mar, Sep, Oct Dec			x	6	0	6
Xylophanes libya (Druce, 1878)	Sep	x			1	0	1
Xylophanes loelia (Druce,1878)	Fev, Mar-Jun, Oct		x		8	1	9
Xylophanes t. thyelia (Linnaeus, 1758) *	Mar, Oct, Dec		x		3	0	3
DILOPHONOTINI							
Aleuron iphis (Walker, 1856) *	May	x			1	0	1
Callionima falcifera (Gehlen,1943) *	Mar, Dec		x		4	0	4
Callionima grisescens elegans (Gehlen,1935)	Feb	x			1	1	2
Callionima inuus (Rothsch. & Jordan, 1903) *	Mar, May, Jun, Oct, Dec		x		4	2	6
Callionima nomius (Walker, 1856) *	Feb-Apr, May, Dec		x		8	1	9
Callionima parce (Fabricius, 1775)	Feb, Mar, May, Aug, Nov		x		4	1	5
Erinnyis a. alope (Drury, 1773)	Feb-Apr, Sep-Dec			x	50	11	61
Erinnyis crameri (Schaus, 1898)	Aug	x			1	0	1
Erinnyis e. ello (Linnaeus, 1758)	Mar-Jun, Sep-Dec			x	37	26	63
Erinnyis lassauxii (Boisduval, 1859)	Mar, May		x		4	0	4
Erinnyis o. obscura (Fabricius, 1775)	Mar	x			2	0	2
Enyo l. lugubris (Linnaeus, 1771)	Sep	x			1	0	1
Enyo ocypete (Linnaeus, 1758)	May	x			2	0	2
Hemeroplanes triptolemus (Cramer, 1779)	Feb, May, Jun, Sep, Nov, Dec		x		9	3	12
Isognathus allamandae Clark, 1920	May, Jun, Oct, Dec		x		7	0	7
Isognathus c. caricae (Linnaeus, 1758)	Feb-May, Oct, Dec		x		7	0	7
Isognathus leachii (Swainson, 1823)*	Feb -Jun, Dec		x		7	2	9
Isognathus menechus (Boisduval, [1875])	Feb-May, Sep, Dec		x		8	2	10
Isognathus swainsonii (Felder & Felder, 1862)*	Mar,Oct, Nov		x		8	0	8
Madoryx plutonius (Hübner, [1819])*	Oct	x			1	0	1
Pachylia ficus (Linnaeus, 1758)	May, Oct, Nov		x		2	3	5
Pachylioides resumens (Walker, 1856) *	May	x			2	1	3
Pseudosphinx tetrio (Linnaeus, 1771)	Feb, Mar, Sep-Dec		x		7	2	9
PHILAMPELINI							
Eumorpha anchemolus (Cramer, 1779)	Nov	x			1	0	1
Eumorpha f. fasciatus (Sulzer, 1776)	Apr, May	x			2	0	2
Eumorpha l. labruscae (Linnaeus, 1758)	May	x			0	2	2
Eumorpha obliquus (Rothsch & Jord, 1903) *	Mar, Oct, Dec		x		3	0	3
Eumorpha v. vitis (Linnaeus, 1758)	Mar, Apr	x			3	0	3

TABLE 1. Continued.

Taxon	Month	Rare	Common	Abundant	Male	Female	Total
Smerinthinae							
AMBULYCINI							
Adhemarius gannascus (Stoll, 1790)	Jan-May, Dec		x		6	1	7
Protambulyx strigilis (Linnaeus, 1771)	May, Nov, Dec		x		5	0	5
Protambulyx astygonus (Boisduval, [1875])	Jan-Mar, Oct-Dec		x		18	1	19
Sphinginae							
SPHINGINI							
Agrius cingulatus (Fabricius, 1775)	Jun, Sep	x			2	1	3
Amphimoea walkeri (Boisduval, [1875]) *	Mar, Jun	x			2	0	2
Cocytius antaeus (Drury,1773)	Mar-May, Oct		x		4	2	6
Neogene dynaeus (Hübner, [1825])	Feb-Jun, Aug-Dec			x	20	4	24
Manduca cf. clarki (Rothsch. & Jordan, 1916)	Mar	x			1	0	1
Manduca contracta (Butler, 1875) *	Feb, Mar, May, Jun		x		12	2	14
Manduca diffissa tropicalis (Rothsch. & Jord, 1903)	Mar, Sep., Oct		x		4	0	4
Manduca h. hannibal (Cramer,1779)	May, Nov	x			1	1	2
Manduca florestan (Stoll, 1782) *	Mar, Apr	x			2	0	2
Manduca r. rustica (Fabricius, 1775)	Feb, Sep, Dec		x		4	1	5
Manduca sexta paphus (Cramer, 1779)	Mar	x			1	1	2
Total					**304**	**75**	**379**

*New occurrence in northeastern Brazil

TABLE 2. Presence of sphingid species in the northern Atlantic rain forest (this study), Amazonian rain forest (Motta *et al*. 1998; Motta & Andreazze 2002), southern Atlantic rain forest (Laroca & Mielke 1975, Marinoni *et al*.1999) and caatinga (Duarte *et al*. 2001, Gusmão & Creão-Duarte 2004, Duarte & Schlindwein 2005b).

Taxon	N-Atlantic Rainforest	Amazonian Rainforest	S-Atlantic Rainforest	Caatinga
Adhemarius gagarini (Zikan, 1935)		x		
Adhemarius gannascus (Stoll, 1790)	x	x	x	
Adhemarius palmeri (Boisduval, 1875)		x	x	
Aellopos ceculus (Cramer, 1777)		x		
Agrius cingulatus (Fabricius, 1775)	x	x	x	x
Aleuron chloroptera (Perty, 1834)		x		
Aleuron iphis (Walker, 1856)	x	x		
Aleuron n. neglectum (Rothschild & Jordan, 1903)		x		
Amphimoea walkeri (Boisduval, [1875])	x	x		
Callionima falcifera (Gehlen, 1943)	x			
Callionima grisescens elegans (Gehlen, 1935)	x			x
Callionima inuus (Rothschild & Jordan, 1903)	x	x	x	
Callionima nomius (Walker, 1856)	x	x	x	
Callionima p.pan (Cramer, 1779)		x		
Callionima parce (Fabricius, 1775)	x	x	x	x
Cocytius antaeus (Drury, 1773)	x	x	x	x
Cocytius beelzebuth (Boisduval, 1875)			x	
Cocytius duponchel (Poey, 1832)		x	x	
Cocytius lucifer (Rothschild & Jordan, 1903)			x	
Enyo g.gorgon (Cramer, 1777)		x	x	
Enyo l. lugubris (Linnaeus, 1771)	x	x	x	x
Enyo ocypete (Linnaeus, 1758)	x	x	x	
Erinnyis a. alope (Drury, 1773)	x	x	x	x
Erinnyis crameri (Schaus, 1898)	x	x	x	
Erinnyis e. ello (Linnaeus, 1758)	x	x	x	x
Erinnyis lassauxii (Boisduval, 1859)	x	x	x	x
Erinnyis o. obscura (Fabricius, 1775)	x	x	x	x
Erinnyis oenotrus (Stoll, 1780)		x	x	
Eumorpha anchemolus (Cramer, 1779)	x	x	x	
Eumorpha capronnieri (Boisduval, 1875)		x		
Eumorpha eacus (Cramer, 1780)		x		
Eumorpha f. fasciatus (Sulzer, 1776)	x	x		x
Eumorpha l. labruscae (Linnaeus, 1758)	x	x	x	x
Eumorpha obliquus (Rothschild & Jordan, 1903)	x	x	x	
Eumorpha phorbas (Cramer, 1775)		x		
Eumorpha v. vitis (Linnaeus, 1758)	x	x	x	x
Eupyrrhoglossum venustum (Rothschild & Jordan, 1903)		x		
Hemeroplanes triptolemus (Cramer, 1779)	x	x	x	
Hyles euphorbiarum (Guérin & Percheron, 1835)				x
Isognathus allamandae Clark, 1920	x	x		
Isognathus australis Clark, 1917				x
Isognathus c. caricae (Linnaeus, 1758)	x	x		
Isognathus excelsior Boisduval, 1875		x		
Isognathus leachii (Swainson, 1823)	x	x		
Isognathus m. mossi Clark, 1917		x		

TABLE 2. Continued.

Taxon	N-Atlantic Rainforest	Amazonian Rainforest	S-Atlantic Rainforest	Caatinga
Isognathus menechus (Boisduval, [1875])	x			x
Isognathus rimosus (Grote, 1865)		x		
Isognathus scyron (Stoll, 1780)		x		
Isognathus swainsonii (Felder & Felder, 1862)	x	x		
Isognathus zebra Clark, 1923		x		
Madoryx plutonius (Hübner, [1819])	x	x	x	
Manduca brasilensis Jordan, 1911	x			x
Manduca brunalba (Clark, 1929)		x		
Manduca cf. clarki (Rothschild & Jordan, 1916)	x	x		
Manduca lucetius (Cramer, 1780)		x		
Manduca contracta (Butler, 1875)	x			
Manduca d. dalica (Kirby, 1877)		x		
Manduca diffissa tropicalis (Roth. & Jordan, 1903)	x	x	x	
Manduca florestan (Stoll, 1782)	x	x	x	
Manduca h. hannibal (Cramer, 1779)	x	x	x	
Manduca l. lefeburei (Guérin, 1844)		x	x	
Manduca p. pellenia (Herrich-Schaeffer, 1854)		x	x	
Manduca r. rustica (Fabricius, 1775)	x	x	x	x
Manduca sexta paphus (Cramer, 1779)	x	x	x	x
Neococytius cluentius (Cramer, 1775)		x	x	
Neogene dynaeus (Hübner, [1827]-[1831])	x			x
Nyceryx c. continua (Walker, 1856)			x	
Orecta l. lycidas (Boisduval, 1875)			x	
Oryba kadeni (Shaufuss, 1870)		x		
Pachylia darceta Druce, 1881		x		
Pachylia ficus (Linnaeus, 1758)	x	x	x	
Pachylia syces (Hübner, [1819])	x			
Pachylioides resumens (Walker, 1856)	x	x	x	
Perigonia lusca lusca (Fabricius, 1777)				x
Perigonia pallida Rothschild & Jordan, 1903				x
Perigonia pittieri Lichy, 1962				x
Phryxus caicus (Cramer, 1777)		x		
Protambulyx astygonus (Boisduval, [1875])	x			
Protambulyx eurycles (Roth. & Jordan, 1903)	x	x		
Protambulyx goeldii (Roth. & Jordan, 1903)	x			
Protambulyx strigilis (Linnaeus, 1771)	x	x	x	x
Pseudosphinx tetrio (Linnaeus, 1771)	x	x	x	x
Xylophanes aglaor (Boisduval, 1875)			x	
Xylophanes anubus (Cramer, 1777)	x	x	x	
Xylophanes ceratomioides (Grote & Robinson, 1867)			x	
Xylophanes cf. amadis (Stoll, 1782)	x	x		
Xylophanes chiron (Drury, 1773)	x	x	x	
Xylophanes indistincta Closs, 1915			x	
Xylophanes isaon (Boisduval, 1875)			x	
Xylophanes libya (Druce, 1878)	x			
Xylophanes loelia (Druce, 1878)	x	x		
Xylophanes pluto (Fabricius, 1777)	x		x	x
Xylophanes porcus continentalis Rothschild & Jordan, 1903		x	x	
Xylophanes s. schausi (Rothschild, 1894)			x	
Xylophanes t. tersa (Linnaeus, 1771)	x	x	x	x
Xylophanes t. thyelia (Linnaeus, 1758)	x	x	x	
Xylophanes titana (Druce, 1878)			x	
Xylophanes tyndarus (Boisduval, 1875)			x	
Xylophanes xylobotes (Burmeister, 1878)			x	
Total	54	71	63	26
Species in common with the N-Atlantic Rain Forest		42 (59 %)	32 (58%)	20 (77%)

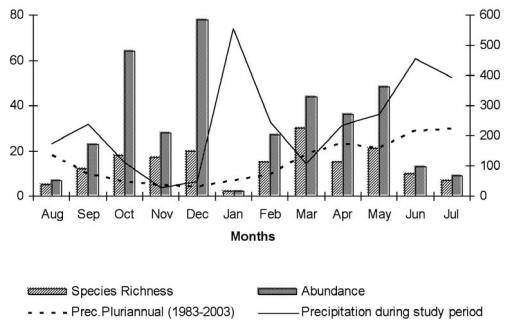

FIG. 3. Abundance and richness of sphingids, mean annual precipitation and precipitation during the study period in the Atlantic rain forest of Frei Caneca from August 2003 to July 2004.

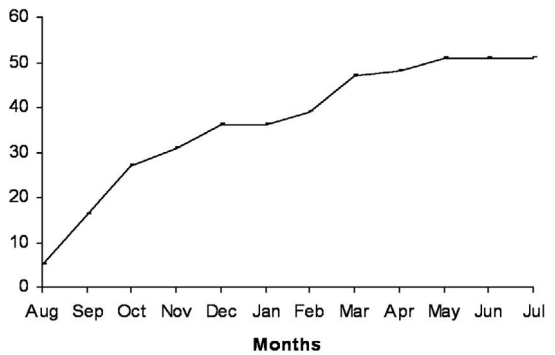

FIG. 4. Species accumulation curve of Sphingidae during the study, from August 2003 to July 2004, in the Atlantic Rain Forest of Frei Caneca.

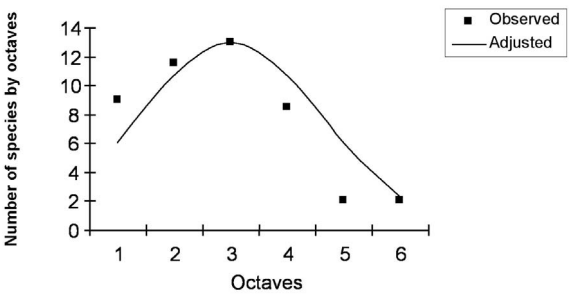

FIG. 5. Distribuition of species recorded in the Atlantic rain forest of Frei Caneca by abundance class (octaves), adjusted to a lognormal curve.

In the north Atlantic rain forest, the vegetation is not deciduous and host-plants have leaves throughout the year, a factor that probably exercises great influence on the sphingid abundance. In Pará (Amazonian region), Moss (1920) noted that periods of heavy rainfall reduced the abundance of hawkmoths, because they dislodged larvae, mainly those newly-emerged from the egg.

Callionima grisescens elegans is a sphingid subspecies endemic to northeast Brazil (Schreiber 1978), occurring abundantly in the caatinga (Duarte & Schlindwein 2005b) and tropical montane forest in Paraíba (Gusmão & Creão-Duarte 2004). In the Atlantic rain forest, only two specimens were recorded, suggesting that it is a resident species of the caatinga.

The high male to female ratio in our study follows a pattern similar to the 10:1 male to female capture ratio reported in Costa Rica by Janzen (1983). The expected male to female proportion is 1:1 (Kitching & Cadiou 2000). It appears that sampling of sphingids with light traps distorts this ratio. Janzen (1983) supposed that the two sexes could have a physiological susceptibly to light, with males showing a high mobility using light sources as reference points in finding females.

Comparison of the present short-term survey of the sphingid fauna of the northern Atlantic rain forest with those conducted in the southern Atlantic rain forest (Laroca & Mielke 1975, Marinoni *et al*. 1999), caatinga (Gusmão & Creão-duarte 2004, Duarte & Schlindwein 2005b) and the Amazonian forest (Motta *et al*. 1998; Motta & Andreazze 2002) showed that 78% (42) of the species recorded in the northeastern Atlantic rain forest also occur in the Amazonian forest, 59% (32) in the southern Atlantic rain forest, and 37% (20) in the caatinga. *Protambulyx astygonus*, *Callionima falcifera*, *Pachylia syces*, *Manduca contracta* and *Xylophanes libya* were recorded only in the northeastern Atlantic rain forest (Table 2). Nevertheless, these comparisons have to be treated with care, because the compiled species lists of all regions are results of short-term surveys.

The present study shows that the sphingid fauna of the north Atlantic rain forest is most similar to that of the Amazonian forest when compared to other regions. Several authors have demonstrated a close faunistic and floristic relationship between these two forests (Andrade-Lima 1982, Bigarella *et al*. 1975, Vanzolini 1970, Haffer 1982, Santos *et al*. 2007), which today are separated by about 1500 km. The xeromorphic caatinga forest, that occupies the gap between the rain forests, is characterized by a highly endemic flora (Queiroz *et al*. 2006). The sphingid fauna of the caatinga, however, is impoverished and formed almost exclusively from

elements of the Atlantic and the Amazonian rain forests.

ACKNOWLEDGEMENTS

We thank IBAMA for the license to work at the RPPN Frei Caneca. André Mauricio Melo Santos, Reisla Oliveira, Fernando Zanella helped with statistical support. Olaf H. H. Mielke (Federal University of Paraná, Curitiba), Catarina Motta (National Research Institute of Amazonas, INPA, Manaus) and I.J. Kitching (The Natural History Museum, London), kindly confirmed identification of specimens. This study was supported by grants from CAPES to J.A.D and CNPq to C.S.

LITERATURE CITED

ANDRADE-LIMA, D. 1982. Present-day forest refuges in northeastern Brazil. Pp. 245–251. *In* G.T. Prance (ed.). Biology diversification in the tropics, Columbia University Press. New York. 714pp.

AYRES, M., JR., D. L. AYRES, &. A. S. SANTOS. 2000. BioEstat 2.0: aplicações estatísticas nas áreas de ciências biológicas e médicas. Sociedade Civil Mamirauá e CNPq, Brasília. 272pp.

BIGARELLA, J .J., D. ANDRADE-LIMA, & P. J. RIEHS. 1975. Considerações a respeito das mudanças paleoambientais na distribuição de algumas espécies vegetais e animais no Brasil. Anais da Academia Brasileira de Ciências 47: 411– 464.

BROWN, K. S., Jr. 1986. Diversity of Brazilian Lepidoptera: History of study, methods for measurement, and use as indicator for genetic, specific and system richness. Pp. 221–253. *In* C. E. Bicudo & N. A. Menezes (eds.). Biodiversity in Brazil: a first approach. São Paulo. 326pp.

COIMBRA-FILHO, A. F, & CÂMARA, I. G. 1996. Os limites originais do bioma Mata Atlântica na Região Nordeste do Brasil. Fundação brasileira para a Conservação da Natureza. Rio de Janeiro. 86pp.

D´ABRERA, B. 1986. Sphingidae Mundi. Hawk moths of the world. Faringdon, Oxon, United Kingdom, E.W. Classey. 225pp.

DARRAULT, R. O. & C. SCHLINDWEIN. 2002. Esfingídeos (Lepidoptera, Sphingidae) no Tabuleiro Paraibano, Nordeste do Brasil: Abundância, riqueza e relação com plantas esfingófilas. Revista Brasileira de Zoologia 19 (2): 429–443.

DUARTE, A. J., JR., C. S. MOTTA & A. VARELLA-FREIRE. 2001. Sphingidae (Lepidoptera) da Estação Ecológica do Seridó, Serra Negra do Norte, Rio Grande do Norte, Brasil. Entomologia & Vectores 8(3): 341–347.

_____., Jr. & C. SCHLINDWEIN. 2005a. Riqueza, abundância e sazonalidade de Sphingidae (Lepidoptera, Heterocera) num fragmento de Mata Atlântica de Pernambuco, Brasil. Revista Brasileira de Zoologia 22(3): 662–666.

_____., JR. & C. SCHLINDWEIN. 2005b. The highly seasonal hawkmoth fauna (Lepidoptera, Sphingidae) of the caatinga of northeast Brazil: a case study in the state of Rio Grande do Norte. Journal of the Lepidopterists' Society 59(4): 212–218.

GÓMEZ-NUCAMENDI, O. L., R. W. JONES & A. MORÓN-RIOS. 2000. The Sphingidae (Heterocera) of the "El Ocote" Reserve, Chiapas, México. Journal of the Lepidopterists' Society 53(4):153–158.

GUSMÃO, M. A. B. & A. J. CREÃO-DUARTE. 2004. Diversidade e análise faunística de Sphingidae (Lepidoptera) em área de brejo e caatinga no Estado da Paraíba, Brasil. Revista Brasileira de Zoologia 21(3): 491–498.

HAFFER, J. 1982. General aspects of the Refuge Theory. Pp. 6–24. *In* G. T. Prance (ed.). Biological diversification in the tropics. Columbia University Press, New York. 714pp.

HABER, W. A. & G. W. FRANKIE. 1989. A tropical hawk-moth community: Costa Rican dry forest Sphingidae. Biotropica 21(2):155–172.

HODGES, R. W. 1971. Sphingidae. The moths of America north of Mexico, volume 21. E. W. Classey and R.B.D. Publications, London. 158pp.

IBGE. 1985. Atlas nacional do Brasil. IBGE, Rio de Janeiro.

JANZEN, D. H. 1983. Costa Rica natural history. Univ. Chicago Press, Chicago. 816pp.

KITCHING, I. J. & J.-M. CADIOU. 2000. Hawkmoths of the world: an annotated and illustrated revisionary checklist (Lepidoptera: Sphingidae). Cornell University Press, Ithaca, New York. 227pp.

LAROCA, S. & O. H. H. MIELKE. 1975. Ensaios sobre ecologia de comunidades em Sphingidae na Serra do Mar, Paraná, Brasil. (Lepidoptera). Revista Brasileira de Biologia 35(1): 1–19.

LEMAIRE, C. & J. MINET. 1999. The Bombycoidea and their relatives. Pp. 321–353. *In* De Gruyter (ed.). Lepidoptera: moths and butterflies. 1. Evolution, systematics, and biogeography. Part 35. Handbook of zoology. IV, Berlin, New York. 576pp.

LUDWING, J. A. & J. F. REYNOLDS. 1988. Statistical ecology. New York: John Wiley, 337pp.

MARINONI, R. C., R. R. C. DUTRA & O. H. H. MIELKE. 1999. Levantamento da fauna entomológica no Estado do Paraná. IV. Sphingidae (Lepidoptera). Diversidade alfa e estrutura de comunidade. Revista Brasileira de Zoologia 16(2): 223–240.

MOSS, A. M. 1920. Sphingidae of Para. Brazil. Early stages, food plants, habits, etc. Novitates. Zoological 27: 334–357.

MOTTA, C. S., F. J. AGUILERA-PERALTA & R. ANDREAZZE. 1998. Aspectos da Esfingofauna (Lepidoptera: Sphingidae), em área de terra firme, no Estado do Amazonas, Brasil. Acta Amazonica 28(1): 75–92.

_____. & R. Andreazze. 2002. Sphingidae (Lepidoptera) de Querari, São Gabriel da Cachoeira, Amazonas, Brasil. Entomologia & Vetores 9(3): 329–337.

PRANCE, G. T. 1982. Forest refuges: evidences from woody angiosperms. Pp. 137–159. *In* G. T. Prance (ed.). Biological diversification in the tropics. Columbia University Press, New York. 714pp.

PRESTON, F. W. 1948. The commonness and rarity of species. Ecology 29: 254–283.

QUEIROZ, L. P., A. A. CONCEIÇÃO & A. M. GIULIETTI. 2006. Nordeste semi-árido: caracterização geral e lista das fanerógamas. Pp. 15–364. *In* A. M. Giulietti, A. A. Conceição & L. P. Queiroz (eds.), Diversidade e caracterização das fanerógamas do semiárido brasileiro. Recife, Associação Plantas do Nordeste, Vol. 1. 488pp.

RABINOWITZ, D., S. CAIRNS & T. DILLON. 1986. Seven forms of rarity and their frequency in the flora of the British Isles. Pp. 205–217. *In* M. E. Soulé (ed.). Conservation biology: The science of scarcity and diversity. Sinauer, Sunderland, Massachusetts. 584pp.

RANTA, P., T. BLOM, J. NIEMELA., E. JOENSUU & M. SIITONEN. 1998. The fragment rain forest of Brazil: size, shape and distribution of forest fragment. Biodiversity & Conservation 7(3): 385–403.

RIZZINI, C. T. 1997. Tratado de fitogeografia do Brasil. Âmbito cultural Edição Ltda, Rio de Janeiro, Brasil. 747pp.

SANTOS, A. M. M., D. R. CAVALCANTI., J. M. S. CARDOSO & M. TABARELLI. 2007. Biogeographical relationships among tropical forests in north-eastern Brazil. Journal of Biogeography 34: 437–446.

SCHREIBER, H. 1978. Dispersal centres of Sphingidae (Lepidoptera) in the neotropical region. Biogeographica. 10: 195pp.

SOKAL, R. R. & F. J. ROHLF. 1996. Biometry. Freeman & Company, New York. 887pp.

TABARELLI, M., J. F. MARINS & J. M. C. SILVA. 2002. La biodiversidad brasileña. Investigation y Ciencia 308: 42–49.

VANZOLINI, P. E. 1970. Zoologia sistemática, Geografia e a origem das espécies. Universidade. S. Paulo. Instituto Geográfico. Séries teses e Monografias 3: 1–56.

Received for publication 29 September 2005; revised and accepted 20 December 2007.