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THE SPHINGIDAE OF CHAJUL, CHIAPAS, MEXICO

JORGE L. LEÓN-CORTÉS
Instítuto de Ecología, UNAM, Apdo. Postal 70-275, C.P. 4510, México D.F.

AND

ALFONSO R. PESCADOR
Centro Universitario de Investigación y Desarrollo Agropecuario,
Universidad de Colima, Carretera Colima-Manzanillo Km 39,
Crucero de Tecomán, Tecomán, Colima, C. P. 28100, México

ABSTRACT. The arthropod fauna of "Selva Lacandona" is poorly studied. Though vertebrate and plant inventories are still in progress, preliminary results indicate these forests are extremely species rich. The information presented here is part of an ongoing inventory of the moth fauna of Estación de Biología Chajul. Eighty-four species of Sphingidae have been documented, and this accounts for nearly half of the fauna of this family for the entire country. Flight periods are presented for most species. Temperature data explain 52% of the variation in monthly species richness.

Additional key words: seasonal patterns, Selva Lacandona, inventory.

The "Selva Lacandona" once was a large forest covering nearly 1.3 million ha (Diechtl 1988 *in* Dirzo & Miranda 1991). However, within the last 40–50 years it has been reduced to a small fraction of its original area (Dirzo & Miranda, pers. comm.). As a conservation effort, the "Reserva de la Biósfera Montes Azules" was created within the Lacandona's forests in 1978 (Lobato 1981). It encompasses more than 300,000 ha preserving several forest types (SEDUE 1989). Today, large portions remain relatively undisturbed (Dirzo & Miranda 1991). The reserve appears to be the largest tract of northern latitude tropical rain forest (Medellín 1994). However, large portions have been severely disturbed by human activities (Rother 1990).

Though animal and plant inventories are still in progress (Dirzo, pers. comm.) preliminary surveys indicate that "Selva Lacandona" supports a rich biological diversity. For example, within the reserve Medellín (1994) found nearly 100 mammal species and Salgado-Ortiz (1993) found 300 bird species. In addition, within a 2 ha plot, roughly 900 species of flowering plants were found, and at least 200 more are expected (Ramos & Martínez 1993). Information on taxa other than vertebrates and plants is more difficult to obtain, particularly for invertebrates, which are extremely diverse. However, all taxa studied indicate that the area of Chajul supports an unusually high biological diversity. For example, De la Maza and De la Maza (1985a, 1985b) recorded 544 butterfly species within a few hectares, and Morón et al. (1985) identified 110 lamelicornian beetle (Coleoptera) species in three families.

This report is part of an ongoing inventory of the moth fauna of "Selva Lacandona." It represents samples from the forests neighboring "Estación de Biología Chajul," currently administered by Instítuto de Ecología, UNAM (EBChajul hereafter), and 160 nights of collecting over three years. We provide a relatively complete checklist of the Sphingidae for EBChajul and neighboring sites, together with information on their phenology.

MATERIALS AND METHODS

Study site. EBChajul was named after Río Chajul, and is located at the southern edge of Montes Azules Biosphere Reserve (Municipio de Ocosingo, Chiapas, México) (16°05′N, 90°56′W), a few miles north of the Guatemala border (Fig. 1). The field station is at the border of the reserve and is accessed through the Lacantún River. This river serves as a natural limit for the reserve and today virtually separates the well preserved forests from a devastated area occupied by numerous villages across the river, altogether called the "Marqués de Comillas" zone (Lobato 1981). The Lacantún has several tributaries: Lacanja, San Pedro, Tzendales, Negro, Jatate, Santo Domingo, Ixcan and Chajul. Geologically, the area is mostly middle and upper Cretaceous with Cenozoic outcroppings. Representative soils are luvisols and acrisols with a superficial lithology of sandstone, shale and clays (García 1985).

The closest climatic records for EBChajul are from "Estación Lacantún," 4 km downstream from the field station. These records include nearly 10 years of data, indicating a four-month dry season and an average annual rainfall of nearly 3000 mm. September has the highest rainfall (Fig. 2a). Average maximum and minimum temperatures are 34.5°C and 16.4°C respectively. The highest temperatures occur in May–June and the lowest temperatures in December–January.

Tropical rain forest is the main forest type at EBChajul (Rzedowski 1978), although other forest types are present throughout the reserve, including pines, oaks and grasslands (SEDUE 1989). In the vicinity of EBChajul are grasslands associated with the hilltops where two trees, *Brysonima crassifolia* (Malpigiaceae) and *Curatella americana* (Dilleniaceae) and several shrubby species, *Climedia* spp. (Melastomataceae), *Rourea* spp. (Connaraceae) and *Sabicea villosa* (Rubiaceae) are common. The forest canopy comprises 3 to 4 strata. The upper canopy, consisting of trees greater than 25 m in height, includes: *Licania platypus* (Chrysobalanaceae), *Virola coshnii,* (Myristicaceae), *Luehea semanii* (Tiliaceae), *Dialium guianense* (Leguminosae), *Ceiba pentandra* (Bombacaceae), *Ficus* spp. (Moraceae), and *Swietenia macrophylla* (Meliaceae). The middle canopy, consisting of trees of up to 25 m in height, includes: *Bursera simarouba* (Burseraceae), *Brosimum* spp. (Moraceae),

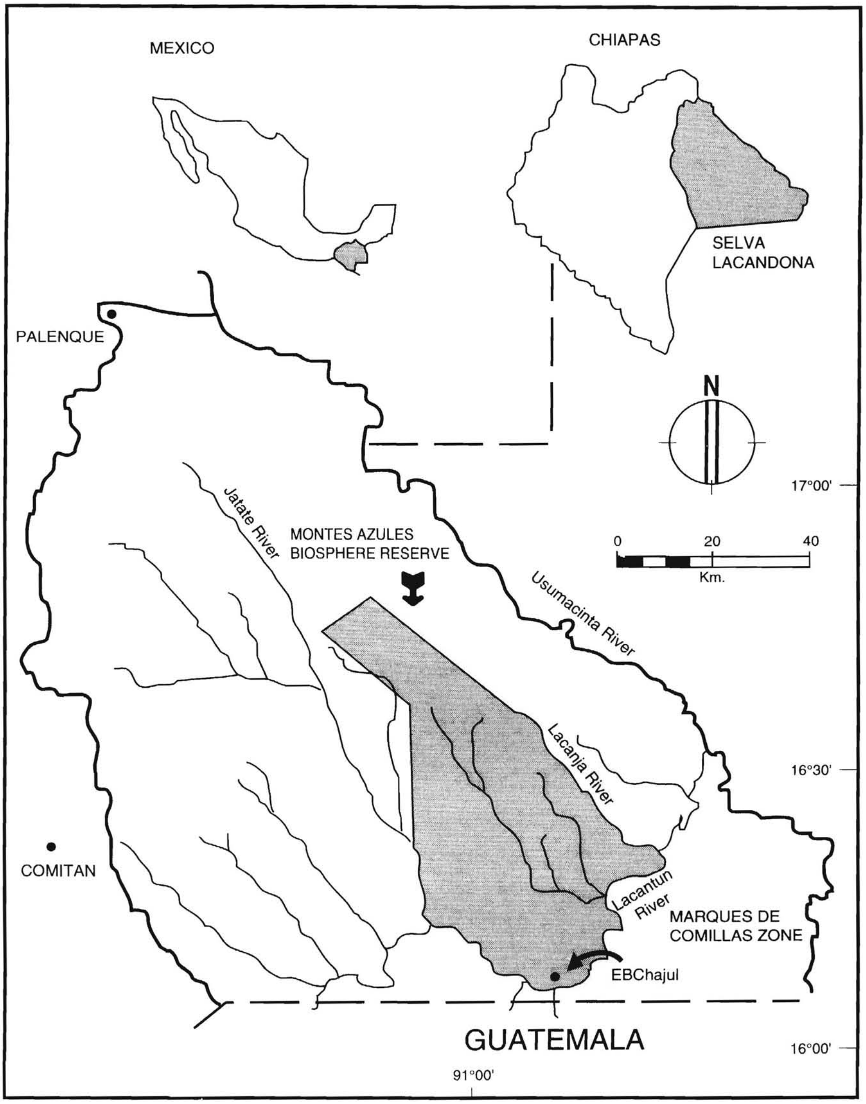

FIG. 1. Location of Estación de Biología Chajul within the Rerserva de la Biósfera Montes Azules, Chiapas, México (modified after Medellín 1994).

Zanthoxylum spp. (Rutaceae), *Pterocarpus rohrii* (Leguminosae), *Taluama mexicana* (Magnoliaceae), *Schizolubium parahybum* (Leguminosae), and *Bravaisia integuerrima* (Acanthaceae). The lower canopy, consisting of trees less than 10 m in height, includes: *Cymbopetalum penduliflorum* (Annonaceae), *Guarea glabra* (Meliaceae), *Quararibea*

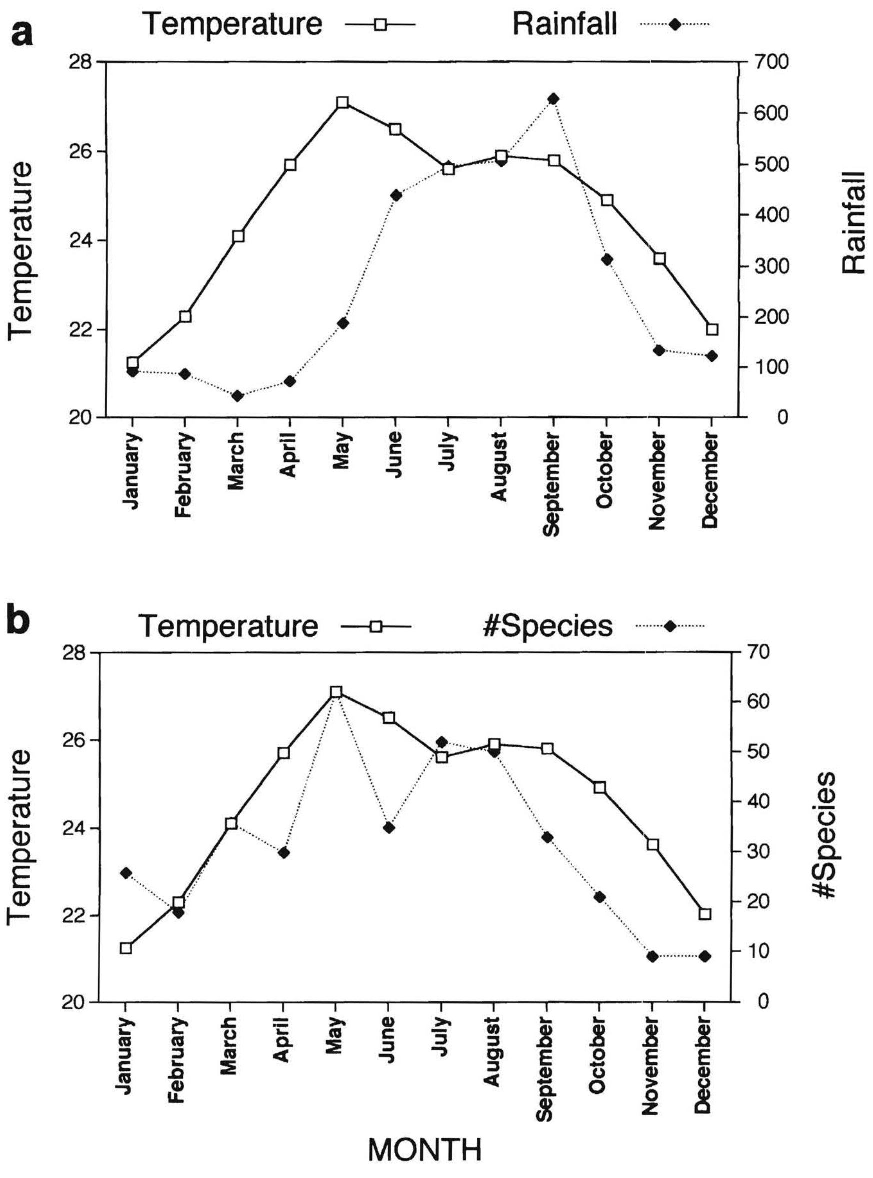

FIG. 2. **a**, Ten year (1980–1990) mean monthly temperature and mean monthly rainfall at "Lacantún" climatological station. **b**, Total number of sphinx moth species captured per month, compared to the ten year mean monthly temperature at the "Lacantún" climatological station.

funebris (Bombacaceae), *Ampelocera hottleii* (Ulmaceae), *Pachira acuatica* (Bombacaceae), *Rheedia edulis* (Guttiferae), and *Posoqueira latifolia* (Rubiaceae). In addition, there is an understory rich in palm species, including *Chamaedora tepejilote*, *Bactris* spp. and *Reinhardtia gracilis* (Ramos & Martínez 1993, G. Domínguez, pers. comm.).

Sampling protocol. The inventory effort started July 1991 and ended November 1992; additional collections occurred in January, March and July 1993. We used two 15 watt fluorescent lights powered by a car battery; both were placed 20–30 cm in front of a white sheet measuring 3 m^2. In each of two settings we used both a black-blue and a day-light bulb. Every night we collected from 1800 h to 0500–0600 h the following morning. Each month our sampling effort lasted approximately two weeks, all days spread evenly around the new moon. Sampling sites were within walking distance of EBChajul. In addition to our own records, we consulted private collections for species not captured by us.

Specimen preparation. All collected specimens were spread to facilitate identification, oven-dried and labeled for permanent storage. Hodges (1971), D'Abrera (1986) and Janzen (1984, 1986) were our main sources for identifying the collection. However, we also consulted the entomological inventory at Instituto Nacional de Biodiversidad (INBio), Costa Rica, and its curators. Specimens of the collection including Sphingidae and other moth families are currently stored at: Estación de Biología Chamela, Jalisco, Instituto de Biología, Universidad Nacional Autónoma de México; Centro Universitario de Investigación y Desarrollo Agropecuario, Universidad de Colima; El Colegio de la Frontera Sur, San Cristobal de las Casas, Chiapas. Duplicate specimens were deposited provisionally at INBio, Costa Rica.

Data analysis. We compiled information on months of capture for each species along with an analysis relating the number of species collected each month to the average monthly rainfall and temperature. As a way to check the adequacy of our inventory, we generated a species accumulation curve by plotting the number of species collected as a function of the number of nights we spent collecting. We assumed the shape of the curve can serve as a descriptive tool of sampling adequacy.

RESULTS AND DISCUSSION

We collected a total of 84 species of sphinx moths (Table 1; taxonomic arrangement follows Hodges 1971) representing nearly half the Sphingidae known from México (White et al. 1991). The species belong to 25 genera in five tribes and two subfamilies. *Xylophanes* was the most species rich genus with 16 species (19%) followed by *Manduca* with 13 species (15.5%), *Eumorpha* with 8 species (9.5%), and *Erinnyis* with 6 species (7%). Together these genera comprise 51.2% of all species at

TABLE 1. Checklist of the Sphingidae of Estación de Biología Chajul. Species marked by asterisks were collected recently by other workers (J. de la Maza, personal collection), and phenological data may be incomplete. Roman numbers indicate months of the year, and each X the presence of that species in that month.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Subfamily Sphinginae												
Tribe Sphingini												
Agrius cingulata (Fabricius 1775)	X	X		X	X	X	X	X	X	X		
Cocytius antaeus Drury 1773	X	X					X	X				
Cocytius duponchel (Poey 1832)	X	X	X	X	X		X	X		X		
Neococytius cluentius (Cramer 1775)					X		X	X		X		
Manduca sexta (Linnaeus 1763)	X	X	X	X	X	X	X	X			X	
Manduca dilucida Edwards 1887					X							
Manduca occulta Rothschild & Jordan 1903	X	X	X	X	X	X	X	X	X	X		
Manduca hannibal Cramer 1779	X	X	X	X	X	X	X	X	X		X	X
Manduca pellenia (Herrich-Schaffer 1854)			X		X		X					
Manduca lefeburei (Guerin 1844)					X		X		X			
Manduca ochus (Klug 1836)			X				X	X				
Manduca rustica (Fabricius 1775)	X		X	X	X	X	X	X	X	X		
Manduca albiplaga (Walker 1856)					X	X						
Manduca muscosa (Rothschild & Jordan 1903)					X		X	X	X			
Manduca corallina (Druce 1883)	X		X		X	X						
Manduca lichenea (Burmeister 1856)									X	X		
Manduca florestan Cramer 1782				X	X	X	X	X				
Manduca lanuginosa (Edwards 1884)					X	X						
Sphinx merops Boisduval 1870			X		X		X	X	X	X		
Tribe Smerinthini												
Protambulyx xanthus Rothschild & Jordan 1906							X					
Protambulyx strigilis (Linnaeus 1771)	X		X	X	X	X	X	X	X	X		
Adhemarius gannascus (Stoll 1790)	X	X	X		X		X	X	X	X	X	X
Adhemarius ypsilon Rothschild & Jordan 1903	X	X	X	X	X	X	X	X	X	X	X	
Subfamily Macroglossinae												
Tribe Dilophonotini												
Pseudosphinx tetrio (Linnaeus 1771)	X		X	X			X	X	X	X	X	
Isognathus rimosus Grote 1865						X		X				
Erinnyis yucatana (Druce 1888)					X							
Erinnyis alope (Drury 1770)					X	X			X			X
Erinnyis lassauxi (Boisduval 1859)	X		X		X		X	X	X			
Erinnyis ello (Linnaeus 1758)	X		X		X	X	X	X				
Erinnyis oenotrus (Cramer 1782)	X		X	X	X	X	X	X	X			
Erinnyis obscura (Fabricius 1775)					X		X					
Pachylia ficus (Linnaeus 1758)				X	X		X	X				
Pachylia syces (Hübner 1822)					X		X	X				
Pachylioides resumens (Walker 1856)			X	X	X	X	X	X	X	X	X	X
Kloneus babayaga Skinner 1923*								X	X			
Hemeroplanes triptolemus (Cramer 1779)			X		X		X	X				
Hemeroplanes ornatus (Rothschild 1894)					X							
Madoryx oiclus (Cramer 1779)					X		X					X

TABLE 1. continued.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Madoryx bubastus Cramer 1777					X		X					
Madoryx pluto Cramer 1779	X	X	X	X	X	X	X	X				
Callionima denticulata Schaus 1895						X						
Callionima inuus (Rothschild & Jordan 1903)				X	X	X	X	X	X			X
Callionima parce Fabricius 1775	X				X		X	X	X			
Callionima falcifera (Gehlen 1943)	X		X	X	X	X	X	X	X	X	X	
Callionima nomius (Walker 1856)					X	X	X	X	X			
Callionima neivai Oiticica 1940									X			
Aleuron carinata Walker 1856						X						
Aleuron chloroptera Boisduval 1870							X	X				
Unzela japix (Cramer 1776)								X				
Enyo lugubris (Linnaeus 1777)				X	X							
Enyo ocypete (Linnaeus 1758)			X		X		X	X		X		
Enyo gorgon (Cramer 1777)					X	X		X				
Enyo taedium (Schaus 1890)			X									
Enyo cavifer (Rothschild & Jordan 1903)								X				
Pachygonidia drucei Rothschild & Jordan 1903							X	X	X			
Perigonia lusca Fabricius 1777				X								
Aellopos ceculus (Cramer 1777)*					X		X		X			
Aellopos clavipes (Rothschild & Jordan 1903)								X				
Aellopos fadus (Cramer 1776)*										X		
Tribe Philampelini												
Eumorpha anchemola (Cramer 1780)			X	X	X		X	X	X	X		
Eumorpha triangulum Rothschild & Jordan 1903	X				X	X		X	X	X		
Eumorpha obliquus Rothschild & Jordan 1903					X							
Eumorpha satellitia Linnaeus 1771			X	X	X	X	X	X				
Eumorpha vitis (Linnaeus 1758)		X			X	X	X	X	X			
Eumorpha fasciatus (Sulzer 1776)			X									
Eumorpha labruscae (Linnaeus 1758)					X		X					
Eumorpha phorbas (Cramer 1775)			X		X		X					
Tribe Macroglosini												
Xylophanes pluto (Fabricius 1777)	X	X	X		X	X	X	X	X			
Xylophanes tyndarus (Boisduval 1875)		X	X	X	X	X	X					
Xylophanes pistacina (Boisduval 1877)			X	X	X							
Xylophanes porcus (Hubner 1829)					X							
Xylophanes ceratomioides (Grote & Robinson 1867)	X	X	X	X	X	X	X	X	X	X	X	X
Xylophanes anubus (Cramer 1777)	X	X	X	X	X	X	X	X				
Xylophanes amadis cyrene Stoll 1782					X	X						
Xylophanes belti (Druce 1878)					X		X	X				
Xylophanes chiron Drury 1770	X	X	X	X	X	X	X	X	X	X		X
Xylophanes titana Druce 1878			X					X	X			
Xylophanes tersa Drury 1770				X	X		X	X	X			
Xylophanes maculator (Boisduval 1875)				X								
Xylophanes libya (Druce 1878)	X	X	X	X	X	X	X	X	X	X		
Xylophanes neoptolemus (Stoll 1782)	X	X	X	X	X	X	X	X	X	X		X
Xylophanes thyelia Linnaeus 1758	X	X	X	X	X	X	X		X	X	X	
Xylophanes zurcheri (Druce 1894)					X	X		X				
Hyles lineata (Fabricius 1775)					X		X					

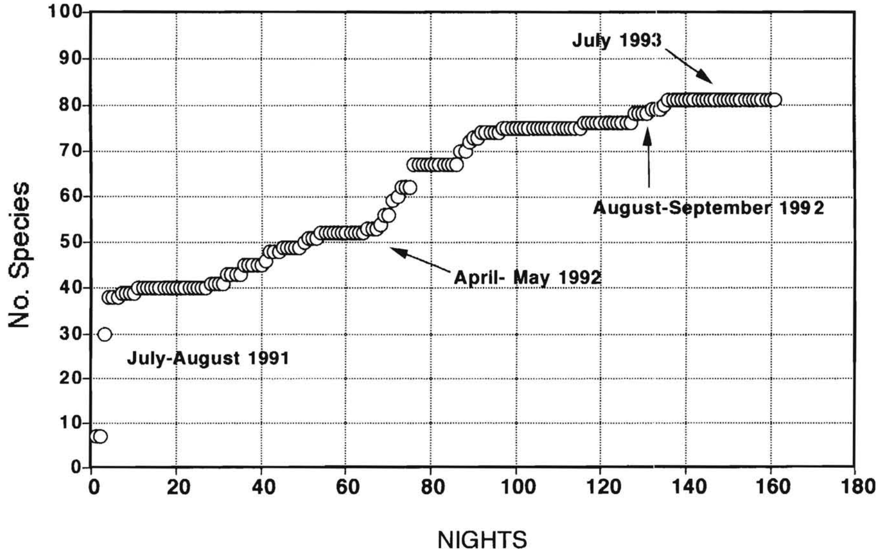

Fig. 3. Sphinx moth species accumulation curve at EBChajul compared to the number of nights of field work.

EBChajul. This pattern appears to be a common feature among sphingid assemblages in tropical forests across tropical America (León-Cortés & Pescador, unpubl. data).

Our sampling effort included 161 nights representing more than 1600 hours of field work. Of the 84 species, 81 were captured by us; 3 additional species had been found in previous years (J. De la Maza, personal collection). Within the first three months after the beginning of the rainy season 87.6% of the total number of species was caught (cf. May–July; Fig. 3, Table 1). However, 62 (76.5%) of all was present in May, the month when the rainy season begins (Fig. 2a, Table 1).

Fifteen species (17.6%) were collected at EBChajul for nine or more months during the year. However, rainfall in May apparently cued the emergence of 24 (28%) sphingid species (Table 1). In addition, photoperiod and/or temperature also appeared to have a strong effect on the phenology of many species; 20 (23.5%) initiated their flying season in March–April, when temperature is rising, two months before the onset of the rainy season (Fig. 2a, Table 1). This pattern (Fig. 2b) suggested a correlation between sphnix moth monthly richness and mean monthly temperature. A regression analysis of species richness versus temperature (log-log scale) indicated that 52.4% of sphingid monthly richness variability was explained by temperature ($MS_{err} = 145.85$, $df = 10$, $F = 11.01$, $p < 0.01$; $\ln(S) = -124.275 + 6.352 \times \ln(\text{temperature})$). In contrast, rainfall, even when it had a major influence on the start of the flying season for many species in May, apparently had no other effect on subsequent dates.

These patterns are only an approximation of the actual phenologies of the sphingid fauna of EBChajul. Janzen (1983, 1986) has stressed that captures at light sources are only a partial view of sphingid populations. One of the reasons for this is that we do not completely understand why insects are attracted to light (see Janzen 1984 for a review). For example, some species (commonly captured at lights) may be found in large numbers in the forest while foraging for nectar and pollen without reaching the lights (Janzen 1983, Pescador, unpubl. data). Most sphingids collected at lights are in good condition, suggesting they reach the lights soon after emergence (Janzen 1983, 1984).

The shape of the species accumulation curve suggests we collected nearly all the Sphingidae at EBChajul that are attracted to light (Fig. 3). However, given the proximity of EBChajul to Central America and its similarity in floral composition, Janzen (pers. comm.) suggests the following species probably will be added to our list: *Cocytius beelzebuth* (Boisduval), *C. lucifer* (Rothschild & Jordan), *Unzela pronoe* (Druce), *Nycerpx coffeae* (Walker), *N. tacita* (Druce), *Eupyrrhoglossum sagra* (Poey). Moreover, J. M. Cadiou (pers. comm.), who has extensive knowledge of the Sphingidae in the neotropics, suggests that we could expect 12 additional species in this area. Therefore, based on the intensity of our collecting we assume that nearly all the breeding species in the vicinity of EBChajul have been documented. However, a larger effort should be made to explore the rest of the reserve.

A comparison with other published checklists of Sphingidae in the neotropics, particularly in Mexico, is clearly possible. We abstain from doing so here because the results of this study indicate that variation in sampling effort has a substantial effect on the size of a checklist. Variation in sampling effort may be accounted for in various ways, however, those analyses are still in progress (León-Cortés, unpubl. data).

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