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SHORT COMMUNICATION

Small sample, substantial contribution: additions to the Honduran hawkmoth (Lepidoptera: Sphingidae) fauna based on collections from a mountainous protected area (Cusuco National Park)

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Abstract With the largest part of diversity in the world absorbed by invertebrates, ignoring invertebrates in biodiversity surveys and monitoring of areas under conservation would give a strongly incomplete image. The poor knowledge of most invertebrate taxa and their enormous diversity limits most surveys to the better-studied groups. Hawkmoths (Lepidoptera: Sphingidae) are one of the more charismatic and well-known groups among the Lepidoptera and hence a valuable group commonly used in biodiversity research. In this small-scale study, 42 museum specimens of sphingids from Cusuco National Park (Cortés, Honduras) were identified and compared to recent published accounts. This yielded three new country records and, in addition, four new regional records for the park. Some of the additions to the Honduran fauna probably result from recent taxonomic changes. However, the several contributions using a small collection of this well-studied group in an area which has attracted previous research interest, demonstrate the incomplete data availability and the necessity for more rigorous surveying. Several new records concern high altitude species, indicating the data gap in mountains. As elevation is an important determinant of sphingid community structure, sampling across an altitudinal range is recommended. This study also underpins the usefulness of a reference collection-based approach in particular, as many hawkmoth species are identified using subtle diagnostic characters.

Keywords *Adhemarius* · Biodiversity · *Eumorpha* · *Manduca* · Meso-America · *Xylophanes*

The size and attractiveness of its representatives have made the hawkmoths (Lepidoptera: Sphingidae) one of the better studied groups of lepidopterans, with monographs dating

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back to the 19th century (e.g. Druce 1881–1900; Smith 1888; Weidemeyer et al. 1903; Moss 1920) and approximately 1450 recognised species (Kitching et al. 2011). Their charismatic and conspicuous habitus, the substantial amount of information available and their importance as pollinators of many plants (see Young 1972; Haber and Frankie 1989; Darrault and Schlindwein 2002) make sphingids prime focal species in biodiversity surveys and monitoring efforts (e.g. Owen 1972; Motta et al. 1998; Darrault and Schlindwein 2002; Duarte and Schlindwein 2008; Duarte et al. 2008; Amorim et al. 2009). They have featured as target organisms in ecological research (e.g. Seifert 1974; León-Cortés et al. 1998; Marinoni et al. 1999).

Lepidoptera depend on a range of crucial habitat features for their survival, including nectar sources for adults, host plants for the larva and suitable pupation sites. Any change in the ecosystem that alters the availability of these requirements will affect a population's viability (Moss 1920; Pittaway 1993). Therefore, habitat loss and disturbance pose substantial threats to hawkmoth diversity. This sensitivity to habitat alterations together with their contribution to ecological services and high species numbers means many moth species are of particular conservation concern (Birkinshaw and Thomas 1999; Fox et al. 2011). Although hawkmoths are a relatively well-studied group, there are still major shortfalls in their taxonomy (Kitching and Cadiou 2000), geographic distribution and population density estimates, all of which are needed to evaluate rarity and hence their conservation status. There is a geographical bias on the amount of information available for this group with especially some parts of Central America largely understudied.

The recent checklist of Honduran Sphingidae listed 107 species, 33 of which were new country records (Samayoa and Cave 2008). It was composed based on museum specimens and material collected from four national parks, including Cusuco National Park (CNP) (Departamento de Cortés, Honduras). In the latter, Samayoa and Cave (2008) reported 25 sphingid species. The core zone of CNP consists of lower montane tropical rain forest, gradually transitioning to upper montane rain forest with patches of primary cloud forest at the highest point (Cerro Jilinco—2 245 m masl). We studied a small collection of 42 sphingid moths at the Oxford University Museum of Natural History (accession number OUMNH-2006-082). The insects were collected as part of the Operation Wallacea yearly biodiversity survey from May to August 2006. In contrast to "classic" mercury vapour lights, actinic light traps were used (though higher wattage, e.g. 250 or 400 W, mercury vapour lights have also been proven effective) (see Sinclair 2004; van Langevelde et al. 2011). Species were identified using D'Abrera (1986), Cadiou and Haxaire (1997), Cadiou and Hodges (1998), Kitching and Cadiou (2000), Vaglia and Haxaire (2005) and Martin et al. (2011). *Xylophanes* and *Adhemarius* were the dominant genera in terms of diversity and abundance, confirming the study of Sinclair (2004) in CNP. The present batch contained 13 species, three of which were hitherto unknown from Honduras. Another four species, previously recorded from the country, were new to the department (Cortés) and thus to CNP (Table 1). This collection also contains the second formal country record for *Adhemarius dariensis* (Rothschild and Jordan, 1916), *A. ypsilon* (Rothschild and Jordan, 1903) and *Xylophanes belti* (Druce, 1878). The other sphingids collected—*Eumorpha vitis vitis* (Linnaeus, 1758), *X. ceratomioides* Grote and Robinson 1866 and *X. germen germen* (Schaus, 1890)—have been previously reported and are widespread in Honduras.

Cusuco National Park is one of the four study sites for the extensive and year-round survey of Samayoa and Cave (2008). It is therefore surprising that the present small-scale sampling effort has yielded four additional regional records and nearly as many new country records. Some of these additions to the Honduran fauna are likely to have arisen from recent taxonomic changes, dividing up species along their geographical range (e.g. *X. cthulhu* is likely to have been identified as *X. neoptolemus*, though this species was not recorded from Cortés by Samayoa and Cave (2008)). While such cases do not represent a true increase in the sphingid diversity, it is difficult to ascertain which of the (sub)species listed by Samayoa and Cave (2008) could have accommodated the other new species first recorded here. Moreover, we would like to note that some of the specimens depicted in Samayoa and Cave (2008) represent, in our view, misidentifications (Table 2), which could have led to errors in the national and regional species lists as well (e.g. *X. hannemanni hannemanni*).

Mountain reaches and cloud forests in Meso-America are characterized by a particular fauna and flora, often with a high rate of endemism, in particular for invertebrates (Anderson and Ashe 2000). These substantial contributions to the Honduran sphingid fauna emphasize the limited knowledge we have, even of the better-studied large-bodied invertebrate groups in this region, something which has previously been highlighted for relatively well-studied beetle taxa such as Scarabaeoidea (Schuster and Cano 2006) as well as Curculionidae and Staphylinidae (Anderson and Ashe 2000). It is hard to extrapolate from the studied sphingid material a total species richness (Léon-Cortés et al. 1998). Nevertheless, substantial contributions from small collections illustrate the need for more intensive (standardized) surveys over all habitat and elevation ranges, in order to reliably predict species distributions and adequately assess other parameters needed for conservation purposes, e.g. Red List assignment (see Lewis and Senior 2011). This situation is far from unique. Recent surveys continue to provide new records and

Table 1 New species records for the state of Cortés and for Honduras

	Species	Classification	Geographical distribution	Known altitudinal range in Honduras (m)	Collection altitude (m)
New to Cortés	*Eumorpha phorbas* (Cramer, 1775)	Macroglossinae, Philampelini	MEX, GTM, BLZ, NIC, CRC, VEN, COL, SUR, FG, PER, ECU, BOL, BRA	35–185	534
	Manduca pellenia (Herrich-Schäffer, 1854)	Sphinginae, Sphingini	MEX, BLZ, GTM, NIC, CRC, PAN, COL, ECU	175–1,450	1,572
	Xylophanes anubus (Cramer, 1777)	Macroglossinae, Macroglossini	MEX to ARG	35–1,450	ca. 1,200
	X. hannemanni hannemanni Closs, 1917	Macroglossinae, Macroglossini	MEX to BOL	/	1,174–1,379
New to Honduras	*Adhemarius fulvescens* (Closs, 1915)	Smerinthinae, Ambulycini	MEX, GTM, BLZ, CRC, NIC	/	1,174–1,546
	X. staudingeri (Rothschild, 1894)	Macroglossinae, Macroglossini	MEX, SLV, GTM, NIC, CRC, PAN	/	1,656
	X. cthulhu Haxaire and Vaglia, 2008	Macroglossinae, Macroglossini	MEX, GTM, CRC	/	534

ARG Argentina, *BLZ* Belize, *BOL* Bolivia, *BRA* Brazil, *COL* Colombia, *CRC* Costa Rica, *ECU* Ecuador, *FG* French Guiana, *GTM* Guatemala, *GUY* Guyana, *MEX* Mexico, *NIC* Nicaragua, *PAN* Panama, *PER* Peru, *SLV* El Salvador, *SUR* Suriname, *VEN* Venezuela

Classification follows Kitching and Cadiou (2000); distributional data are taken from Maes (1998), Samayoa and Cave (2008), Martin et al. (2011), Kitching et al. (2011), Oehlke (2011) and references therein. Note that for *X. hannemanni*, albeit tentatively mentioned for Honduras by Oehlke (2011), no detailed observations are provided by this author nor by Samayoa and Cave (2008), leading us to believe we are dealing with the first formal record of this species in the region. While *X. staudingeri* is hard to distinguish from *X. cyrene* (Druce, 1881) and species status has been under discussion (Kitching and Cadiou 2000), the pronounced green color of the specimen and the sampling altitude (see Oehlke 2011) led us to identify it as *X. staudingeri*. As neither of them has been previously recorded from Honduras, even regarding them as a species complex would mean an addition to the country's fauna

Table 2 Probable misidentifications (middle colum) and our species assignments (right) based on hawkmoth pictures in Samayoa and Cave (2008)

Lámina/plate	Probable misidentification	Our assignment
Fig. II	*Madoryx plutonius* (Hübner, 1819)	*M. plutonius dentatus* Gehlen, 1931
Fig. III	*Perigonia lusca* (Fabricius, 1777)	*P. ilus* Boisduval, 1870
Fig. IV	*Xylophanes acrus* Rothschild and Jordan, 1910	*X. cyrene* (Druce, 1881)
	X. damocrita (Druce, 1894)	*X. josephinae* Clark, 1920
Fig. V	*X. neoptolemus* (Cramer, 1780)	*X. cthulhu* Haxaire and Vaglia, 2008
	X. porcus continentalis Rothschild and Jordan, 1903	*X. hannemanni hannemanni* Closs, 1917
Fig. VI	*Eumorpha anchemolus* (Cramer, 1779)	*E. triangulum* (Rothschild and Jordan, 1903) (female)
	E. triangulum	*E. anchemolus*
Fig. VII	*Adhemarius donysa* (Druce, 1889)	*A. dariensis* (Rothschild and Jordan, 1916) (male)
	A. gannascus (Stoll, 1790)	*A. fulvescens* (Closs, 1915) (female)
Fig. VIII	*Manduca hannibal* (Cramer, 1779)	*M. hannibal mayeri* (Mooser, 1940)

Note that *Lintneria merops* (Boisduval, 1870) (assigned to *Lintneria* Butler, 1876 by Tuttle (2007)) was treated by Samayoa and Cave (2008) as *Sphinx merops*

species discoveries, even for well-studied insect and other invertebrate groups that have been proposed as useful models in biodiversity research or as of conservation importance in terms of their ecosystem function. Examples from the Neotropics include Scarabaeoidea (Schuster and Cano 2006), Drosophilidae (Medeiros and Klazcko 2004; Mata et al. 2008, 2010), Odonata (Kalkman et al. 2008) and corals (Reaka-Kudla 1997), in addition to countless smaller and less conspicuous organisms no less functionally important, e.g. endophagous mites and insects and soil-dwelling nematodes (Lewinsohn et al. 2005).

Adhemarius fulvescens and *X. staudingeri*, two of the three species reported in this study as new to Honduras, were recorded from sites at relatively high altitude, particularly *X. staudingeri*. Likewise, some of the new records for Cortés constitute confirmed altitude extensions for two species (Table 1). Despite a decline of species richness with increasing elevation (Samayoa and Cave 2008), this

demonstrates the need to include high altitude surveying in biodiversity studies, especially for sphingids since Ignatov et al. (2011) previously showed the importance of altitude as factor in sphingid community composition.

Raising entities previously considered to be geographical forms to species status might not increase local biodiversity. It does however point to the fact that populations concerned should be managed as entities that are less widely distributed than previously assumed, possibly deserving additional conservation effort. Genetic analysis would be beneficial both in terms of clarifying the species status and in order to establish the degree of genetic distinctiveness of the population particularly in light of the high proportion of endemic insects already known from CNP (Anderson and Ashe 2000; Schuster and Cano 2006). Evolutionary Significant Units (Moritz 1994) can be defined through detailed molecular analysis and used for management purposes to ensure conservation of maximal genetic diversity in a given species. Several sphingids in this study have recently undergone taxonomic reevaluation based on characters that are nearly impossible to use in the field (see e.g. Cadiou and Hodges 1998; Vaglia and Haxaire 2005), sometimes in combination with genetic data (e.g. Vaglia et al. 2008). Genital features can be useful in view of the many documented cases of intraspecific morphological variation in size or colour pattern (e.g. Brou 1994; Hundsdoerfer and Wink 2006; Schmidt 2009), in some lepidopterans possibly influenced by altitude and other environmental factors (Sullivan 2007). Hence, in order to clarify possible misidentifications, especially for "cryptic" species, further revision supported by voucher specimens deposited in accessible museum collections which can be made available for study by specialist taxonomists is strongly recommended.

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