

The effects of morphology on feeding behavior in the family Sphingidae

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RESUMEN

El propósito de este experimento era para examinar como las características morfológicas tienen gusto de la longitud de la probóscide, peso, y se van volando el área superficial, afectan anchura de la dieta en la familia Sphingidae (orden Lepidoptera) en el bosque mojado en Monteverde, provincia de Puntarenas, Costa Rica del premontane tropical. Recogí 60 hawkmoths a partir de 11 especies entre Octubre del 18 y Noviembre del 18 del Estación Biológica de Monteverde y del Cerro Plano Jardín de Mariposas, tomando medidas morfológicas y muestras del polen de sus probóscides. No había una relación significativa entre la longitud de la probóscide y la riqueza del polen ($p = 0.9049$), ni entre la especie ($p = 0.4358$). Una correlación significativa fue considerada entre la longitud de la probóscide y el área forewing en un cociente de cerca de 1:1 ($p = 0.0083$). El peso, la probóscide, y el área forewing eran perceptiblemente diferentes entre la especie ($p < 0.0001$ para todos los parámetros). Encontré que las características morfológicas no se parecían afectar directamente riqueza del polen pero que los cambios estacionales en la abundancia de floras y una combinación de factores morfológicos y metabólicos pueden ser la causa de la diferenciación de la dieta entre la especie de la polilla del sphingid.

ABSTRACT

The purpose of this field experiment was to examine how morphological characteristics like proboscis length, weight, and wing surface area, affect diet breadth in the family Sphingidae (order Lepidoptera) in tropical premontane wet forest in Monteverde, Puntarenas province, Costa Rica. I collected 60 hawkmoths from 11 species between October 18 and November 18 from the Estación Biológica de Monteverde and the Cerro Plano Jardín de Mariposas, taking morphological measurements and pollen samples from their proboscises. There was not a significant relationship between proboscis length and pollen richness ($p = 0.9049$), nor between species ($p = 0.4358$). A significant correlation was seen between proboscis length and forewing area in a ratio of about 1:1 ($p = 0.0083$). Weight, proboscis, and forewing area were significantly different between species ($p < 0.0001$ for all parameters). I found that morphological features did not seem to directly affect pollen richness but that seasonal changes in the abundance of flowers and a combination of morphological and metabolic factors may be the cause of diet differentiation between sphingid moth species.

INTRODUCTION

Within the order Lepidoptera is a small family of about 1000 known species of moths called Sphingidae. Also known as sphinx or hawkmoths; at least 121 species are found in Costa Rica, with 73 species documented in Monteverde alone (Haber 1983). They have conically streamlined but proportionally large bodies with a pointed abdomen, a well-

developed proboscis and long, narrow forewings that dwarf the hindwings. These features make them excellent aerodynamic fliers, especially in terms of maneuverability and speed. Sphingid can actually hover; fly backward, and upside down (Haber 1983). Hawkmoths are important nocturnal pollinators of many plants in tropical ecosystems—including trees, shrubs, and epiphytes, generally preferring to feed at sweet-fragranced white tubular or brush flowers which open after sunset (Haber 1983).

The coevolution of plants and their pollinators favors specialization in feeding, with selective pressures in some sphingid species favor proboscises that match the corolla lengths of the flowers that they frequent exactly (1-20 cm) (Haber and Frankie 1989). Specialization may yield higher nectar rewards for pollinators, giving incentive for certain species to travel longer distances in search of rich flowers (Haber and Frankie 1989). Increased pollinators specificity increases efficiency, as pollen must be carried to conspecifics—helping prevent contamination from foreign pollen. This leads to pollinator syndrome, where floral morphology, color, and reward aid in a select subset of potential visitors.

Within syndromes, the effects of morphology change sometimes has other implications. For example, hummingbirds in Monteverde like the Green Hermit have long, curved bills that match the shape of the flowers on which they feed, so corolla length varies with bill length. Feinsinger (1983) states that flowers pollinated by shorter-billed birds offer less nectar reward than those adapted for pollination only by long-billed hummingbirds. Within longer bills and heavier bodies, "traplining" is the most efficient method of feeding—in which an organism travels a greater distance to locate species rich in nectar with corollas that match its bill or proboscis. Bullock and Pescador (1983) state that bumblebees with longer proboscises have been shown to pollinate long and short corollas, the opposite outcome of hummingbirds. If a similar trend occurs in the family Sphingidae, hawkmoth species with longer proboscises coupled with larger wing and body dimensions may exploit more flower species since they will be restricted from feeding at fewer flower types.

Hawkmoth flowers differ greatly—some have longer corollas that match proboscises while others support generalist-pollinated brush flowers. The outcome of specificity has been studied only to a limited degree. Because forewing size and proboscis vary together (covariation), it is believed that longer proboscis size is coupled with increased flight distance. If this is the case, sphingids may operate similarly to hummingbirds, with longer-tongued species traveling long distances in search of longer corollas for greater reward. Alternatively, they may tend to visit any flower without regard to corolla length, like bees. The result is decreased specificity with proboscis length, as they fly long distances and potentially encounter more flower types.

Based on the trends mentioned, I hypothesize that an increase in the size of sphingid's morphological characteristics like proboscis length, forewing area, and weight will lead to an increase in the number of flower types that a hawkmoth species can exploit for nectar. I will attempt to observe this trend by making morphological

measurements and sampling Sphingid proboscises for pollen richness.

MATERIALS AND METHODS

Study site—this study was conducted over a one-month period, from October 18th to November 18th, 2003 in Monteverde, Puntarenas province, Costa Rica near the Estación Biológica de Monteverde. The season in which this study took place was the end of the wet season and beginning of the windy-misty season (a two-month period that is the precursor to the dry season) (Haber et al. 2000). Monteverde is situated in the North-central portion of Costa Rica on the leeward Pacific side of the Tilarán Mountain Range, and the area where moths were collected is classified as lower-montane wet forest according to the Holdridge life zone classification system (1450-1600 m). Sphingid moths were collected at the Jardín de Mariposas and the Estación Biológica de Monteverde.

Collection Methods—Moths were attracted to collection sites via strategically placed lights. Jim Wolfe, the owner of the Jardín de Mariposas, runs a mercury vapor lamp in front of a white wall which draws moths from southwest portion of the upper valley of San Luis. At the Estación Biológica site (1560 m), 100-watt light bulbs and a black light drew specimens from the surrounding area. This method is most effective at luring individuals on moonless nights, when Sphingid are less dependent on navigation by celestial indicators and are thus more easily attracted to artificial lighting (Coop 1993).

Since data were collected from mid-October to mid-November, the lunar cycle made a complete revolution, and I had to vary collection times to optimize collection success. Preferred times of sampling were before the rising of the moon or after its fall, especially during waning periods. Most sampling took place between the hours of 7 p.m. and 12 p.m. Rainy nights (thus, low moonlight) with weak wind were usually conducive to high numbers of Sphingid immigrants, however it proved difficult to predict when hawkmoths would be most abundant. Since these moths are nocturnal, when they reach artificial lights they tend to roost inactively as if in daylight under the illusion that they are blending with surroundings, making their capture fairly stress-free for both parties.

Pollen sampling—Pollen was collected from the proboscises of 60 moths from 11 species, using methods recommended by Haber (personal communication). Captured moths were placed in individually numbered bags to await pollen removal. This process was most successful when the moths were placed in a freezer for about 15 minutes to temporarily immobilize them, which made it easier to expose their proboscis and minimize damage caused from struggling.

Filter paper (1 cm. by 2 cm) was folded in half and dampened. I held the moth in my left hand with my thumb on top of the thorax and my index and middle fingers

supporting the undersides of its wings. Next I used a fresh insect pin to unroll the proboscis, pinning it to a surface (i.e. fingernail, Styrofoam) with the end of the tongue still hooked on the pin. With my right hand free, the proboscis was aligned between the fold of the filter paper as near to the palps as possible, running it along the entire length of the proboscis applying gentle pressure. Pieces of filter paper were then refolded and placed into a numbered envelope. Finally, the envelopes were placed in a dry box for two days to prepare the collected pollen for mounting.

Morphological measurements—Measurements of moth morphology were taken at the Estación Biológica the following day. First, using an online field guide to Sphingidae (Janzen.sas.upenn.edu), moths were identified to species. Next I measured their proboscises and calculated the area (A) of their forewings and hindwings. I treated each wing as a triangle, measuring height (h) and base (b) using the leading wing edge as the hypotenuse—and calculated with the basic formula $A = (.5)(b)(h)$. Finally, the moths were weighed using a digital scale and set outside to warm for release.

Constructing slides—I made slides by unfolding the dried swabs and locating the track of pollen/debris. After placing two drops of Permout on the slide, an insect pin was wetted slightly (tongue works fine), and run along the filter paper with the edge and tip to remove the debris. Next, I swirled the pin in the Permout and scraped it on the slide to remove what was collected; the process of scraping and swirling with the same pin was repeated until all possible debris was deposited on the slide, and no further debris could be removed from the filter paper. A cover slip was placed on the slide, and it was allowed to dry upside down with the cover slip suspended to allow the pollen to settle as near to the top as possible (this makes it easier to see mounted pollen after the slide dries by keeping it all in one layer beneath the cover slip).

Slide analyzation—A compound light microscope was used to look for pollen deposited on each of the 60 slides. The 100x eye lens was used for searching out pollen grains. After I located a possible grain or group of pollen, magnification was switched to 400x so that a sketch of the object could be made. Pollen richness was counted for each slide, but only a general notation of pollen richness (i.e. tens, hundreds, thousands, etc.) was noted to aid in morphospecies identification (Appendix 1). Once all slides had been viewed in this manner, I compiled a list of each pollen type seen, assigning a morphospecies letter (Appendix 1). This list was used in conjunction with my raw data to determine the pollen richness on each slide. Time constraints and materials were not conducive to identifying all pollen types to genera or species.

RESULTS

Body size relationships and pollen richness—No significant difference was found between *pollen richness and weight* (Simple Regression $p = 0.7521$ and $R^2 = 0.002$). The low r -squared value, indicating proximity of data points to the graphed line was extremely low, leading to a scattered plot (Figure 1). Between *pollen richness and proboscis length*, no significant difference was present (Simple Regression $p = 0.9049$ and $R^2 = 2.484E-4$) and data points were extremely scattered (Figure 2). *Pollen richness and forewing area* also did not show a significant difference (Simple Regression $p = 0.4175$ and $R^2 = 0.011$), and data points deviated greatly from the line (Figure 3). When *pollen richness and hindwing area* were compared, there was again no significant difference (Simple Regression $p = 0.3982$ and $R^2 = 0.012$) and high variation from the line (Figure 4). Finally, a regression plot was constructed with *proboscis length and forewing area*. A significant difference was observed (Simple Regression $p = 0.0083$ and $R^2 = 0.114$), and data points were considerably closer to the plotted line (Figure 5).

Next, one-way ANOVA tests were used to show significant differences between each hawkmoth species and its pollen species richness, weight, proboscis length, and forewing area (Table 1 shows abundance and means between hawkmoth species for each aforementioned parameter).

Species difference in pollen load—There was no significant difference between Spingid species for the average number of pollen species they contained (One-way ANOVA $p = 0.4538$) (Figure 6).

Species difference in weight-- A test between hawkmoth species and their mean weights showed that there was a significant difference (One-way ANOVA $p < 0.0001$) (Figure 7).

Species difference in proboscis size—A comparison of species and proboscis size showed that there was also a significant difference in proboscis length between species (One-way ANOVA $p < 0.0001$) (Figure 8).

Species difference in forewing size—finally, forewing area was also found to differ significantly between species (One-way ANOVA $p < 0.0001$) (Figure 9).

Case study of abundant species—the data from the previous one-way ANOVA tests was reused with three hawkmoth species that were most abundant in my sample—*Adhemarius dariensis* (abundance, 11), *Adhemarius gannascus* (abundance, 12), and *Xylophanes acrus* (abundance, 16). Again, I examined the categories of pollen richness, weight, proboscis length, and forewing area. The species were compared each time with the following combinations: *Adhemarius dariensis* (Ad) vs. *Adhemarius gannascus* (Ag), *Adhemarius dariensis* (Ad) vs. *Xylophanes acrus* (Xa), and *Adhemarius gannascus* (Ag) vs. *Xylophanes acrus* (Xa) (Table 3 lists their mean

differences and p-values for each combination).

Specific species difference in pollen load—for pollen richness, none of the combinations between species proved significant (One-way ANOVA $p = 0.5825$ Ad/Ag, 0.4227 Ad/Xa, and 0.1579 Ag/Xa).

Specific species difference in morphology—Two of three combinations for *weight* proved significantly different (One-way ANOVA $p = 0.0170$ Ad/Ag, $p = 0.0363$ Ad/Xa, $p = 0.6234$ Ag/Xa). *Proboscis lengths* were also significantly different in two of three species combinations, although different pairs than the previous category (One-way ANOVA $p = 0.3497$ Ad/Ag, $p < 0.0001$ Ad/Xa, $p < 0.0001$ Ag/Xa). All three pairs were significantly different *for forewing area* (One-way ANOVA $p = 0.0004$ Ad/Ag, $p = 0.0239$ Ad/Xa, $p < 0.0001$ Ag/Xa).

Pollen morphospecies trends—Morphospecies A was abundant on 30% of moths, and furthermore on those with proboscises from 1.5 to 4.6 cm in length. *Inga* (Morphospecies F) was found on 12 specimens. These are similar trends to those found by Coop (1993), seeing *Inga* pollen on 77% of his sample.

DISCUSSION

Body size relationships and difference in pollen richness—I examined pollen richness (how many different species of pollen are present) data from hawkmoth proboscises in hopes of determining that morphological characteristics influence their dietary preferences—hypothesizing that a longer proboscis size would correlate with a wider diet of flower types, but the null would prove the opposite. Although the relationship between proboscis length and pollen species richness was not statistically significant (Multiple Regression $p = 0.9049$), I found other trends that may be useful in determining how sphingids form their dietary niches.

I did not find a correlation between any of the other independent variables when they were plotted against pollen richness. That is, neither body size nor proboscis and wing length affect the amount of pollen found on an individual. It could reflect general flower use, low variability in corolla length, young moths, or early collection. Figures one through four show these trends (mostly-flat lines from which data points stray wildly).

Thus, the pollen on the proboscises of the sphingids I collected appears to be randomly distributed between the longer and shorter-proboscis individuals. Haber and Frankie (1989) had similar results, noting a lack of specificity between hawkmoths and flowers based upon tongue length and corolla tube length. They go on to say that longer-corolla flowers were visited by longer-proboscis moths, although moths of all sizes visited flowers with short corollas. My study did not identify pollen collected on proboscises to species, so I am unable to determine which corolla lengths

coincide to the pollen that I found. It seems to me from the random distribution of pollen among samples that the sphingids seem to be feeding indiscriminately on whatever flowers are blooming at the time and place where this study is taking place.

General trends of pollen richness—Morphospecies A was found on 30% sampled moths. Furthermore, it was found on proboscises ranging from 1.5 to 4.6 cm long, so I can effectively assume that it is a shorter-tubed flower since both short and long proboscis moths were visiting. I also found *Inga* polyads on 1/5 of the sample population. *Inga's* bottlebrush flower shape allows moths of many proboscis sizes to reach its nectar, and it fits the description of a Sphingid-pollinated flower due to its brush shape, white color, and pleasantly sweet smell (Haber and Frankie 1989). Coop (1993) found that 77% of moths he sampled in Monteverde at this time of year (mid/late November) contained the polyads of this plant. He determined that seasonal abundance plays a larger role than morphology in determining sphingid's diets.

These data are supported by Haber and Frankie's 1989 study, which found that sphingid abundance is closely correlated with seasonality. Numbers spike at the onset of the wet season and decline through the dry season, probably as a result of lack of vegetation to support larvae and lack of blooming flowers in the dry season (Haber and Frankie 1989). The high number of individuals that I found with a common pollen species but different proboscis lengths seems to support this data, as well.

Differences in body size and proboscis length—I found a significant difference in two important morphological feeding features: *proboscis length* and *forewing area* (Figure 5). The significance of these two features deals with the process of traplining, since a moth with more forewing area may have to carry a larger load. To support the load, they may need nectar from flowers which yield higher rewards, which in hummingbirds are known to be those that require more specialization to access (Feinsinger 1983). If similar trends hold true with sphingids, it is possible that those with longer proboscis size (which correlates with wing size) are more specialized in their feeding habits, the opposite of my original thoughts. However, seasonal abundance of flowers may not allow high-rewards to be consistently present, so feeding on non-rich flowers while traplining may be advantageous.

So body size relationships found in other sphingid communities are the same for the 11 species found in Monteverde. Therefore, cloud forests are following similar patterns as other forest types. Longer tongues generally relate to longer-winged, heavier moths. Such moths are capable of longer-distance flight, but with higher metabolic costs.

Species difference in pollen load—I found no significant difference between hawkmoth species in terms of the number of pollen morphospecies they contained (Figure 6). Within this category, none of the case study species, *Adhemarius dariensis*, *Adhemarius*

gannascus, or *Xylophanes acrus* had statistical differences, although other categories showed distinct variation (Table 2 for p-values for all parameters). In terms of weight, hawkmoth species differed significantly among species (Figure 7). This may be to reduce competition through niche partitioning.

Body size and metabolic costs—According to Bullock and Pescador body mass can be an effective indicator of metabolic costs of flight, although it can vary with feeding, egg-laying, sex, age, and larval diet. One can focus on the feeding aspect of this body mass variation as an indicator to diet. Larger moths must consume more to maintain their metabolism, so it would make sense that they would seek out high-reward flowers to minimize wasted energy hovering over resources that will not fill all of their metabolic needs. However, they may also choose to visit everything in hopes of getting more of everything. As was previously mentioned by Feinsinger (1983), and in this paper, it would thus make sense for large individuals to trapline to increase foraging efficiency. I do, however, question the selective pressures that favor comparatively small wing size to fat bodies and long tongues (i.e. genus *Manduca*), since smaller wings would be less efficient at sustaining a heavy body in search of rich flowers.

Difference in proboscis size between species—Proboscis size was also statistically different at the species level (Figure 8). This is important to avoid competition, but only if they specialize by tongue length, which the data in my study do not support. Finally, when forewing area means was compared between species there was significant difference. Figure 9 shows this trend. Outliers are mostly those in the genus *Manduca*, the largest sphingids I collected, with the longest tongues. Haber and Frankie's study (1989) supports this trend, noting that there is often a much larger ratio in these species or genera than the near one ratio present elsewhere in the Sphingidae. I feel that the differences of feeding habits between species show that morphology and seasonality affect sphingid behavior, especially in terms of metabolism and energy consumption.

Conclusions—From the data, I devise that variation in body size does not affect diet breadth. Therefore, all moths seem to use similar resources—or they equally partition, although I did not notice this trend. In the three species with high abundance, no overlap was present for pollen load. However, there were significant differences between *Adhemarius dariensis* vs. *Adhemarius gannascus* and *Adhemarius dariensis* vs. *Xylophanes acrus* for weight. For proboscis length, both *Adhemarius dariensis* and *Adhemarius gannascus* vs. *Xylophanes acrus* had significant differences. Finally, all three species were significantly different in forewing area.

Therefore, there was high overlap for pollen richness, low overlap for weight and proboscis length, and no overlap for forewing area. Since these species all contained equally random pollen richnesses, differed greatly in weight and proboscis length, and had no overlap in forewing area, they seem to be significantly different as a group. If pollen richness is random between species and they are different

morphologically then their morphological differences must not cause a differentiation in their diets. In addition, since there was not a correlation between proboscis length and pollen richness then other factors must be causing diet differentiation in sphingids. As a result, sphingid flowers must have low specificity and are pollinated by hawkmoths in a generalist manner.

Although the mechanisms under which diets are formed in the family Sphingidae are becoming more apparent, there still does not appear to be any one answer as to how morphology affects feeding behavior. Studies must take seasonality of flowers into account when observing feeding at flowers or via examination of sampled pollen. It has been shown that seasonal abundance of flowering species can greatly alter even the powerful forces of sphingid specialization to meet their short-term food and energy needs. The question arises, how does specialization develop if flowering changes the relative proportions of available corolla lengths according to season? The answer may be contained in the fact that sphingid abundance varies with seasonal peaks in flower abundance.

Obviously, year-round studies would help provide the most complete menu of sphingid food by allowing the full blooming cycle to unfold before trends are examined. Finally, other methods of pollen collection may help to achieve more complete results, as inevitably in pollination some pollen travels elsewhere on the body, head or wings besides the tongue—but collection from these areas remains difficult until a more efficient method of pollen removal is developed.

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TABLE 1. Displays number of individuals in each species group with their mean measurements for pollen species richness (S), body weight, proboscis length, and forewing area. All 60 individuals collected in Monteverde, Costa Rica.

Species Name	# individuals	Mean Pollen S	Mean Body Weight (g)	Mean Proboscis Length	Mean Forewing Area (sq cm)
<i>Adhemarius dariensis</i>	11	0.636	0.721	2.518	4.135
<i>Adhemarius gannascus</i>	12	0.417	0.938	2.725	4.933
<i>Callionima parce</i>	2	0.500	0.681	1.600	1.870
<i>Manduca Occulta</i>	1	2.000	1.649	7.300	5.760
<i>Manduca pellenia</i>	2	0.000	1.744	10.350	5.840
<i>Manduca schausi</i>	1	1.000	3.167	6.000	5.760
<i>Protambulyx strigilis</i>	4	1.250	0.980	3.450	4.762
<i>Xylophanes Acrus</i>	16	0.938	0.898	4.150	3.678
<i>Xylophanes germen</i>	6	1.000	0.501	2.767	1.885
<i>Xylophanes hannemanni</i>	2	2.000	0.549	2.650	1.990
<i>Xylophanes neoptolemus</i>	3	0.667	0.548	3.400	2.010

TABLE 2. Mean differences and p-values (mean difference: p-value) for case study of three species with the highest abundance of individuals collected. Values are given for pollen species richness, weight, proboscis length, and forewing area.

	Pollen S: p-value	Weight (g): p-value	Proboscis Length (cm): p- value	Forewing Area (sq cm): p- value
Adhemarius dariensis (Ad)/Adhemarius gannascus (Ag)	-0.220: 0.5825	-0.217: 0.0170	-0.207: .3497	-0.797: 0.0004
Adhemarius dariensis (Ad) Xylophanes acrus (Xa)	-0.301: 0.4227	-0.177: 0.0363	-1.632: <0.0001	0.394: 0.0239
Adhemarius gannascus (Ag)/Xylophanes acrus (Xa)	-0.521: 0.1579	-0.040 0.6234	-1.425: <0.0001	0.384: <0.0001

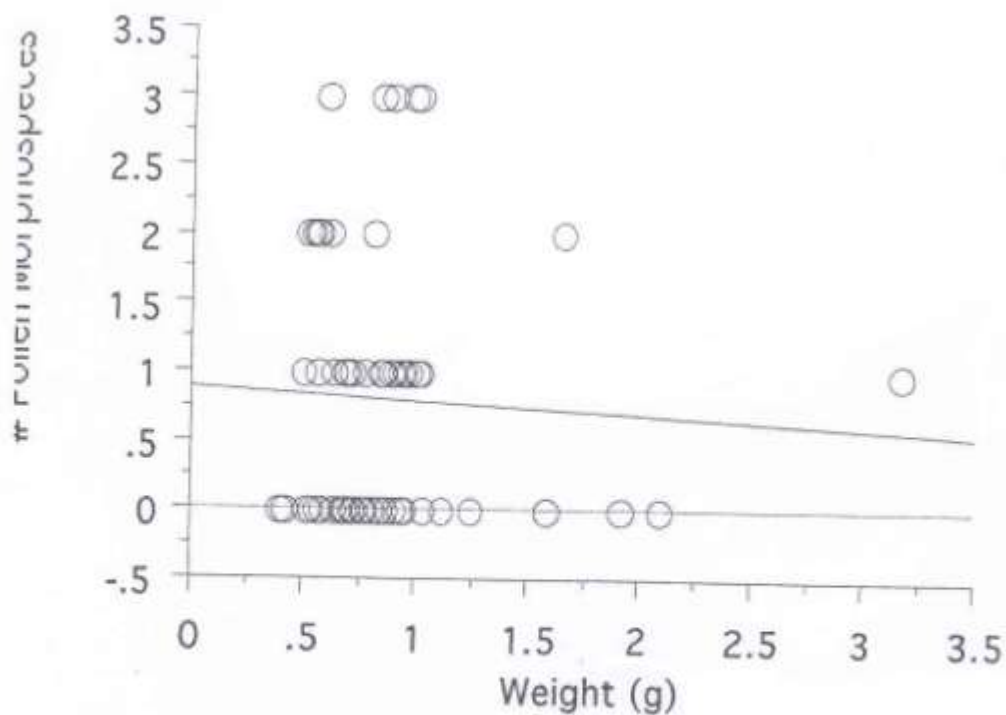


Fig. 1. Regression plot for pollen richness vs. sphingid body weight (g). No significant correlation ($p = 0.7521$). Monteverde, Costa Rica October 18-November 18.

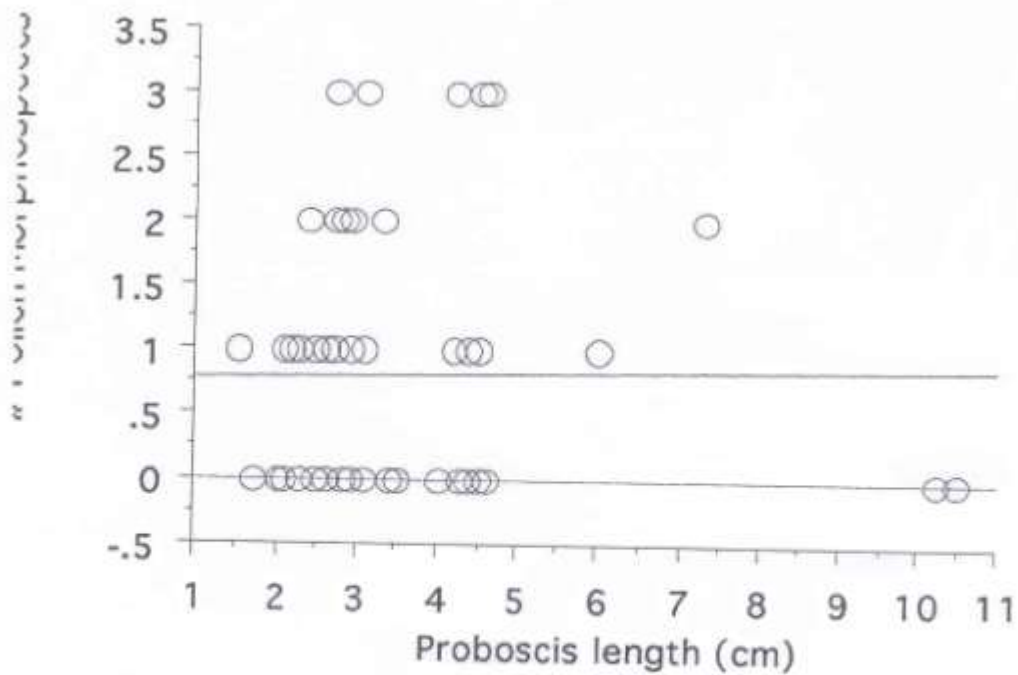


Fig 2. Regression plot for pollen richness vs. sphingid proboscis length (cm). No significant correlation ($p = 0.9049$). Monteverde, Costa Rica October 18-November 18.

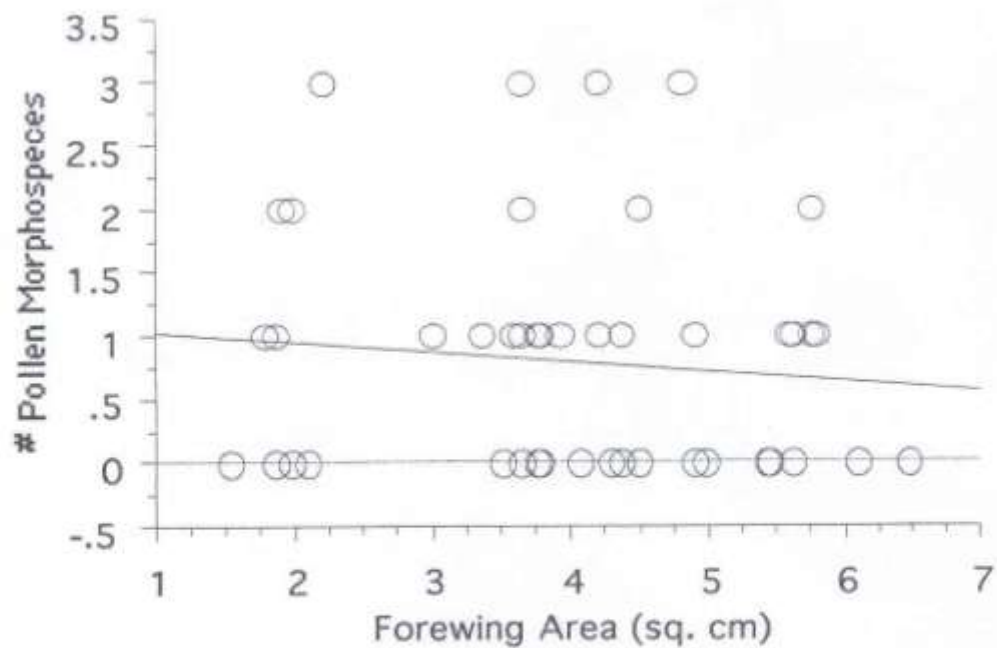


Fig. 3. Regression plot for pollen richness vs. sphingid forewing area (sq cm). No significant correlation ($p = 0.4175$). Monteverde, Costa Rica October 18-November 18.

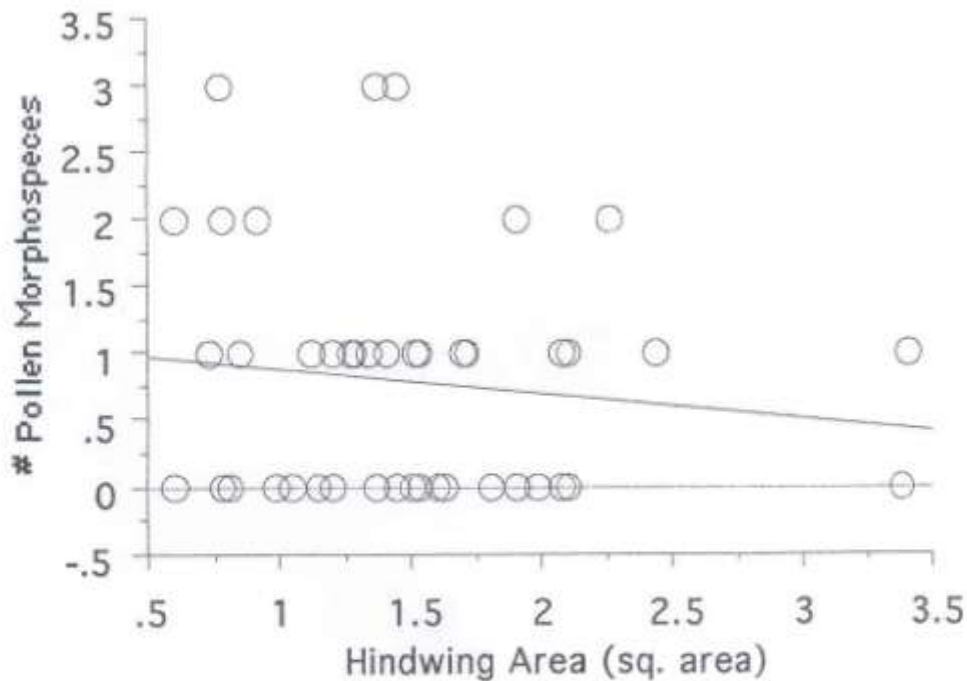


Fig. 4. Regression plot for pollen richness vs. sphingid hindwing area (sq cm). No significant correlation ($p = 0.3982$). Monteverde, Costa Rica October 18-November 18.

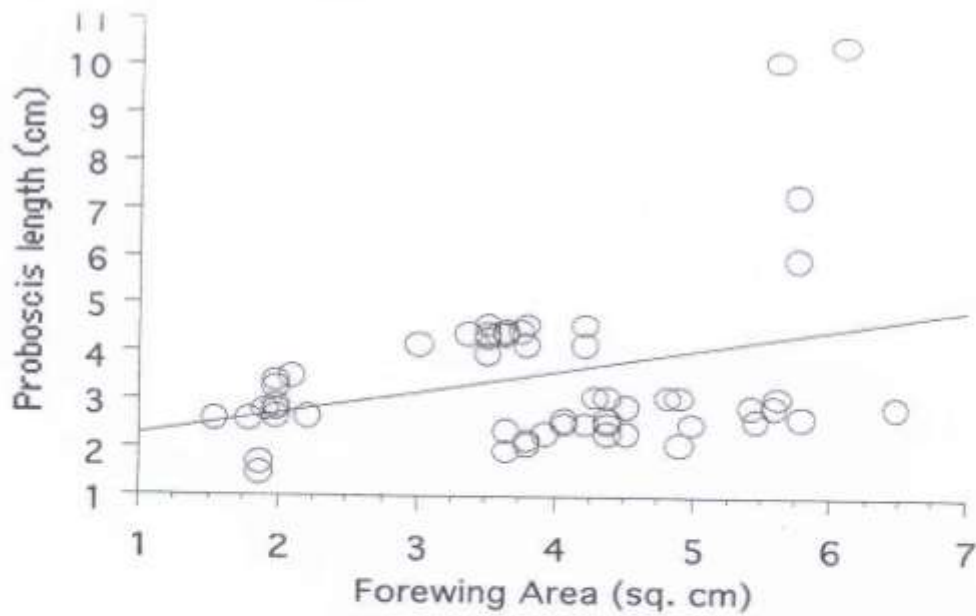


Fig 5. Regression plot for sphingid proboscis length (cm) vs. forewing area (sq cm). Significant relationship ($p = 0.0083$) seen as forewing area increases linearly with proboscis length. Outliers high above line come from individuals with very long proboscises for their wing size. Monteverde, Costa Rica October 18-November 18.

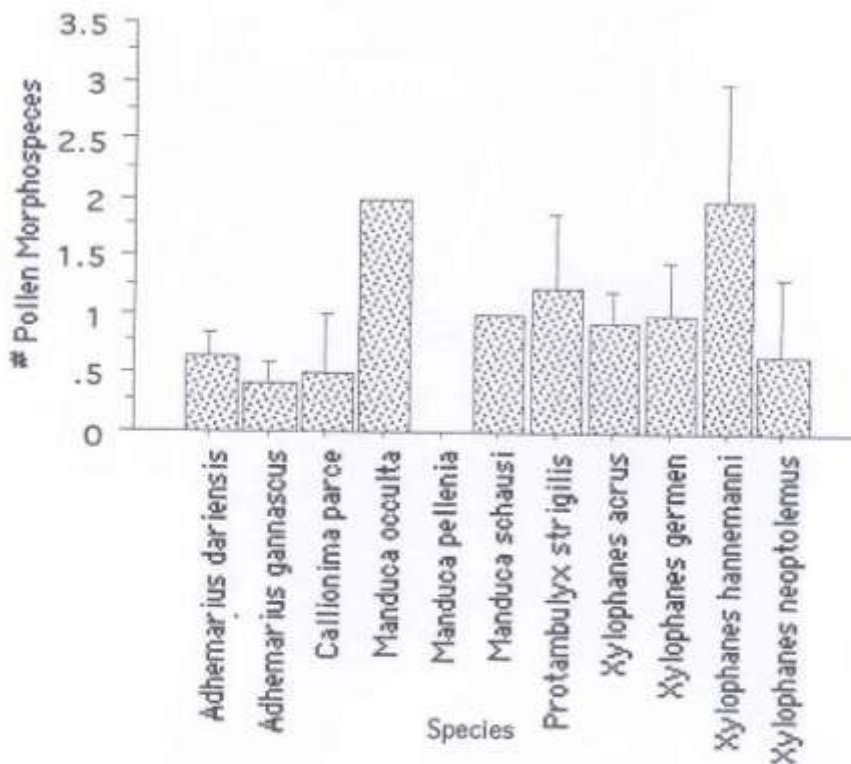


Fig 6. Interaction bar plot for mean pollen richness among 11 hawkmoth species. No significant difference ($p = 0.4538$) between species for the mean number of pollen species per individual. Monteverde, Costa Rica October 18-November 18)

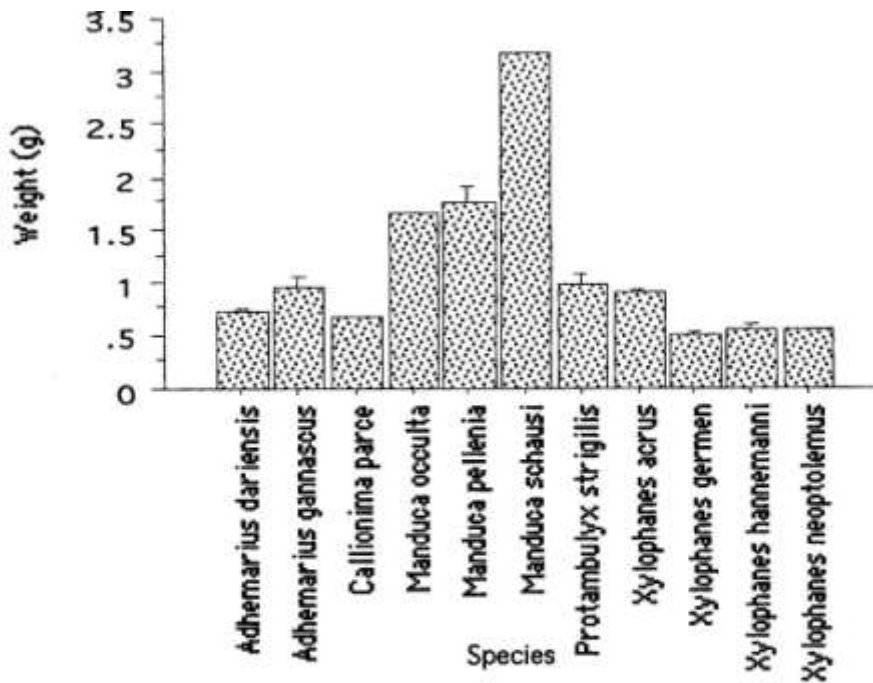


Fig 7. Interaction bar plot for mean weight (g) among 11 hawkmoth species. Significant difference present ($p < 0.0001$) between species for average weight (g). Monteverde, Costa Rica October 18-November 18).

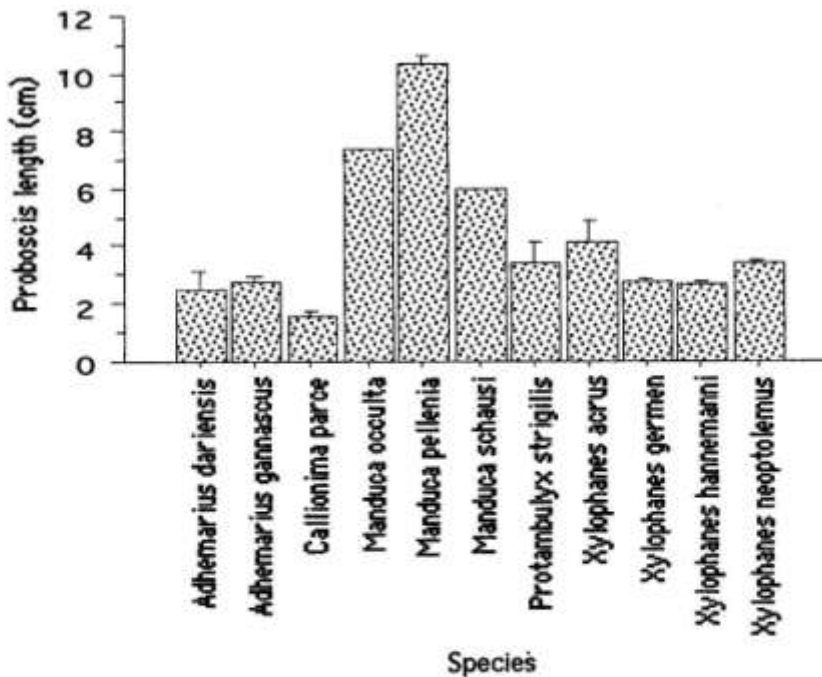


Fig 8. Interaction bar plot for mean proboscis length (cm) among 11 species of hawkmoths. Significant difference ($p < 0.0001$) between species for average proboscis length. Monteverde, Costa Rica October 18-November 18).

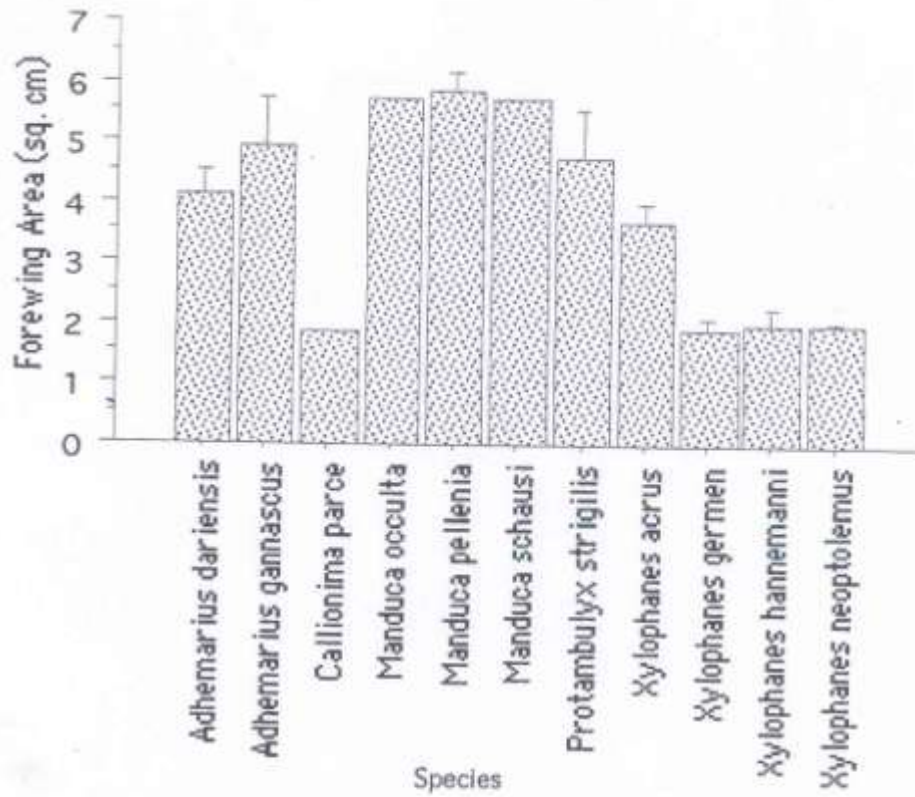













Fig 9. Interaction bar plot for mean forewing area (sq cm) between 11 hawkmoth species. Significant difference ($p < 0.0001$) for average area of forewings between species. Monteverde, Costa Rica October 18-November 18.

Morphospec

APPENDIX I

- 1  Look Different depending on view
- Transparent, slightly Golden edges... Sometimes have lines within.
- 2  Brown/Red up or Down Heart
- 3  Brown to tan, like, fairly tiny
0 - few Dark lines
- 4  Disc/egg-like. Golden. Turn spike-like projections
- 5  Ref like - top. Golden, No markings or lines
- 6  always clustered. Sometimes w/ Dark spots.
- 7  Dark edges, heart only in center (golden)
*Near hexagonal
- 8  kidney-shaped. Very Grb, Near Black on edges
- 9  Transparent, little edge.
- 10  hexagonal & Gloss-like. Dark Circle in Middle
- 11  Teardrop-like. Dark at top, Golden within.

~~12~~
L (12)



Very fine, smooth treatment

M (13)



clear

Large, fine, porous H. yellow/white
- flat perforations w/ tiny openings between.

N (14)



Green/yellow Rim, transparent Center part.

Ind.Num.	Species name	Weight (g)	Proboscis length (cm)	Forewing area (sq cm)	Hindwing area (sq cm)	Num Pollen Morphosp	Morposp types
1	Adhemarius dariensis	0.691	2.1	4.90	1.33	1	a
2	Xylophanes hannemanni	0.598	2.7	2.19	0.77	3	b,c,d,
3	Adhemarius gannascus	1.111	2.6	5.44	1.81	0	
4	Adhemarius gannascus	0.999	2.9	5.58	2.10	1	a
5	Adhemarius gannascus	0.697	2.6	4.06	1.98	0	
6	Adhemarius dariensis	0.615	2.4	3.63	1.90	2	l,e
7	Xylophanes germen	0.405	2.8	1.96	1.90	0	
8	Adhemarius dariensis	0.803	2.5	4.35	1.60	0	
9	Xylophanes acrus	0.933	4.4	3.57	1.52	1	a
10	Protambulyx strigillis	0.848	3.1	4.80	1.36	3	a,f,g,
11	Adhemarius gannascus	0.767	3.1	4.35	1.80	0	
12	Protambulyx strigillis	0.865	3.1	5.60	1.28	1	f
13	Callionima parce	0.681	1.7	1.87	0.80	0	
14	Xylophanes acrus	0.808	4.0	3.50	1.14	0	
15	Xylophanes germen	0.541	2.8	1.98	0.98	0	
16	Xylophanes germen	0.414	2.6	1.52	0.60	0	
17	Xylophanes germen	0.573	2.7	1.98	0.78	2	a,c
18	Adhemarius gannascus	0.878	2.9	5.43	2.10	0	
19	Xylophanes neoptolemus	0.584	3.5	2.07	0.78	0	
20	Adhemarius gannascus	0.838	2.5	4.96	1.80	0	
21	Xylophanes neoptolemus	0.524	3.4	1.98	0.78	0	
22	Xylophanes acrus	0.772	4.4	3.36	1.19	1	a
23	Protambulyx strigillis	0.955	4.5	3.75	1.20	1	h
24	Xylophanes acrus	0.771	3.1	4.29	0.98	0	
25	Adhemarius dariensis	0.911	4.5	3.75	1.36	0	
26	Xylophanes acrus	0.569	2.0	3.64	1.20	0	
27	Xylophanes acrus	0.997	4.6	4.20	1.44	3	a,c,i
28	Xylophanes acrus	0.884	4.5	3.75	1.20	1	j
29	Manduca pellenia	1.581	10.5	6.08	2.07	0	
30	Protambulyx strigillis	1.250	3.1	4.90	1.36	0	
31	Xylophanes neoptolemus	0.537	3.3	1.98	0.78	2	a,f
32	Adhemarius dariensis	0.728	2.3	4.50	1.36	0	
33	Manduca schausi	3.167	6.0	5.76	2.07	1	f
34	Xylophanes germen	0.523	2.9	1.98	0.91	2	f,k,
35	Callionima parce	0.681	1.5	1.87	0.85	1	a
36	Xylophanes acrus	0.895	4.5	3.64	1.36	3	a,f,l
37	Manduca occulta	1.649	7.3	5.76	2.25	2	c,l
38	Xylophanes acrus	0.900	4.4	3.64	1.40	1	f
39	Xylophanes acrus	0.932	4.3	3.50	1.04	0	
40	Xylophanes acrus	1.022	4.2	3.00	1.11	1	a
41	Xylophanes acrus	0.934	4.4	3.50	1.50	0	
42	Adhemarius gannascus	0.814	2.9	4.50	1.90	2	f,m
43	Adhemarius gannascus	0.889	2.7	5.78	2.43	1	n
44	Xylophanes acrus	1.041	4.6	3.77	1.62	0	
45	Xylophanes germen	0.550	2.8	1.89	0.60	2	a,c
46	Manduca pellenia	1.906	10.2	5.60	2.10	0	
47	Adhemarius gannascus	2.098	2.9	6.48	3.38	0	
48	Adhemarius gannascus	0.777	2.5	4.20	1.71	1	f
49	Xylophanes acrus	0.948	4.6	3.51	1.20	0	
50	Xylophanes acrus	0.975	4.2	3.78	1.26	1	a
51	Adhemarius dariensis	0.845	2.5	4.19	1.70	1	a
52	Adhemarius dariensis	0.717	2.5	4.35	1.70	1	f
53	Adhemarius gannascus	0.665	2.6	4.35	1.45	0	
54	Adhemarius gannascus	0.718	2.5	4.06	1.53	0	
55	Adhemarius dariensis	0.780	2.3	4.35	1.45	0	
56	Adhemarius dariensis	0.638	2.2	3.77	1.53	1	a
57	Xylophanes acrus	0.986	4.2	4.20	1.36	3	a,f,l
58	Xylophanes hannemanni	0.501	2.6	1.79	0.72	1	a
59	Adhemarius dariensis	0.573	2.3	3.92	3.40	1	a
60	Adhemarius dariensis	0.628	2.1	3.78	1.20	0	
*****	Averages	0.881	3.4	3.78	1.44	0.8	