

DIVERSITY AND POLLINATION ECOLOGY OF SMALL FLOWER SETTLING MOTHS
WITHIN FLORIDA SANDHILL AND RELATED UPLAND COMMUNITIES

By

MONTANA ATWATER

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2011

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To my family, who always recognized and supported my passion for the natural world,
no matter how odd, and my husband with whom I share this passion

ACKNOWLEDGMENTS

I would like to acknowledge and thank my advisor, Jacqueline Miller, for her boundless dedication, guidance, and friendship. Also, the rest of my committee, Jaret Daniels and Jamie Ellis, for their helpful comments and advice. I am heartily grateful for their support and am honored to have worked with such an inspiring committee. I would also like to recognize Katy Lane and John Bremer for their efforts in the field, and in the curation of moths, Christian Salcedo for his assistance in the field and use of equipment, Jim Cuda for use of his generator, Charlie Covell, James Cuda, and Deborah Mathews Lott for their assistance in identifying moths, Walter Judd for assistance in plant identifications, Terry Lott and David Jarzen for their advice and assistance in the pollen analysis and use of the Palynology facilities, and Kent Perkins for use of herbarium specimens during the preliminary portion of the study. Lastly, I would like to thank everyone at the McGuire Center for Lepidoptera and Biodiversity for their support and use of facilities in this study.

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Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

DIVERSITY AND POLLINATION ECOLOGY OF SMALL FLOWER SETTLING MOTHS
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By

Montana Atwater

May 2011

Chair: Jacqueline Miller
Major: Entomology and Nematology

Sandhill habitat of Florida occurs on hills of well-drained soils and is considered a high priority for conservation. The purpose of this study was to investigate moth-flower interactions of small settling moths within Florida sandhill communities of the Ordway Biological Research Station (Putnam Co., FL). Objectives of this study were as follows: 1) Survey the moth communities of Ordway sandhill habitat, 2) Identify species of small flower-settling moths in Ordway sandhill habitat, and 3) Investigate whether these moths may transport pollen and/or provide pollination services for their nectar plants. The integration of both field and laboratory methods, specifically field observations of moths on flowers, inventories of moths, and various laboratory methods, were used to document these phenomena. Out of 170 observations of moths nectaring on flowers, the families Noctuidae, Geometridae, Crambidae, Pyralidae, Pterophoridae, and Gelechiidae were observed. Three behaviors were documented and categorized as hovering, settling, and fluttering. Fluttering, a behavior never documented before, was unique to two species, *Eupithecia miserulata* and *Pleuroplucha insularia* (Geometridae). Of the 27 species of plants found in bloom during the course of the study, ten flower species were observed as floral nectar sources for these moths, representing the

Families Asteraceae, Fabaceae, and Polygonaceae. In addition, of the 214 moths collected at light traps and scanned for pollen, 101 were found with pollen loads representing seven moth families and 34 genera. Eighty-one of these moths were considered small settling moths many of which were observed on flowers as well. Although this study covered a relatively small temporal scale (6 months of field observations and sampling), there was still a number of unique behaviors and natural history phenomena documented and patterns arising that could be investigated further. Overall, this project offers a valuable glimpse into the intimate associations of microlepidoptera and the plant communities upon which they depend.

CHAPTER 1 INTRODUCTION

Justifications and Background of Study

The diversity of plants and their pollinators are in decline due to a number of human induced changes to the environment such as habitat fragmentation and loss, insecticide use and the introduction of invasive species (Buchmann 1996, Kearns et al. 1998, Wagner and Van Driesche 2010). Past research of plant-pollinator interactions or services is heavily focused on agricultural landscapes, while the interaction of pollinators in naturally occurring ecosystems or plant communities has received little attention (Dixon 2009).

The study of flowers and their nectaring visitors at the community level offers a perspective more significant for ecology in that the knowledge gained can be applied directly to plant restoration, conservation, and our overall understanding of the Earth's ecosystems. For example, at the community scale, the study of insect-flower interactions can be assessed with a clearly defined spatial and temporal frame that can then provide a practical tool for the restoration of ecological processes such as pollination (Devoto et al. 2011).

Moths are extremely diverse and of great significance in other ecosystem functions such as plant herbivory and as a food source for other animals such as birds. Survival of many moth species is greatly influenced by the occurrence of their appropriate larval host plants and may be restricted further by the occurrence of specific nectar plants. Still, current plant restoration projects rarely acknowledge the significant interactions of moths with native plant communities (Spira 2001).

There are relatively few researchers who aim to document or describe nocturnal flower-insect interactions (Devoto et al. 2011). Further, moths taking nectar from flowers is a phenomenon rarely observed and documenting flower-moth interactions in the field has proven to be a formidable task. This is due to a number of factors. First, the majority of moths that nectar are small and cryptic, and second, they nectar after dusk in what we perceive as complete darkness.

During the preliminary portion of this study, I examined the mouthparts of museum specimen moths collected from Paynes Prairie State Park (Austin 2009). I hypothesized that if pollen was found on the mouthparts of moths (which it was), then there would be some kind of interactions of these moths with flowers. I also hypothesized that these moths would be found nectaring on flowers when observed in the field, in their natural settings.

The purpose of this study is to investigate moth-flower interactions of small settling moths within Florida sandhill communities. Inventories of moths (Minno 1992, Austin 2009, 2010) as well as the flora (Christman & Judd 1990, Abrahamson et al. 1984, Veno 1976) within or closely connected to Florida sandhill communities have been assessed. However, the interaction of moths with flowers within these communities has not been documented. Through this study, I was the first to conduct observations of small settling moths nectaring on flowers within sandhill plant communities.

Objectives of Study

My specific objectives include: 1) Survey the moth communities of Ordway sandhill habitat, 2) Identify species of small flower-settling moths in Ordway sandhill habitat, and 3) Investigate whether these moths may transport pollen and/or provide pollination services for their nectar plants.

Moths and Flowers: A Review

Moth-flower interactions are common and not limited to nectar-foraging and pollinator interactions. Many of the examples described in the literature are quite fascinating and involve impressive evolutionary adaptations of moths with their host plants and with the flowers they pollinate within the plant communities with which they are associated. For example, moth species of the Geometridae, and Noctuidae (e.g. *Schinia*, flower moths) oviposit on flowers of their host plant and their caterpillars feed on and often bear color patterns to mimic the flower (Habeck 1994, Treiber 1979). My study alone has confirmed that the adults also mimic and nectar on the same host plant on which they feed as caterpillars. Essentially, they utilize the flower as a host in their larval form as well as a nectar host and resting place in their adult form.

Some moths have evolved highly specialized pollinator mutualisms with their host plants as well. Examples of pollinating seed consumers include the yucca moths, (*Tegeticula* Davis and *Parategeticula* Zeller; Lepidoptera: Prodoxidae) with *Yucca* Linnaeus (Agavaceae; Pellmyr et al. 1996, Godsoe et al. 2008), and *Greya* Busck (Prodoxidae) with Saxifragaceae and Umbelliferae (Brown et al. 1997). Other examples include the senita moth, *Upiga virescens* Hulst (Pyralidae), with Cactaceae (Holland and Fleming 1999), and *Epicephala* Meyrick (Gracillariidae) in Japan with *Glachidion* J. R. Frost and G. Frost (Euphorbaceae) (Kato et al. 2003). Although these moths began as seed eating parasites, some have evolved close interdependent associations with their floral host to the point that the moth actively pollinates the flower without a nectar reward (e.g. Yucca moths; Pellmyr et al. 1996). In this case, the plant no longer produces nectar and the moth adult has reduced mouthparts (Pellmyr et al. 1996).

Apart from these highly specific studies, little is known about the interactions of moths with their floral nectar hosts. Pollination of flowers by moths (phalaenophily) is relatively understudied compared to pollination of flowers by other groups of insects. Pollinating moths can be separated into two groups based on different functional morphology, behavior, and energy requirements. The large hovering moths (e.g. Sphingidae) tend to hover above flowers and often prefer flowers with large nectar rewards to sustain their relatively high metabolic rates (Faegri and Pijl 1979, Oliviera et al. 2004). In contrast, the small settling moth groups are extremely diverse compared to the larger hovering moths yet little is known about these groups since the majority of research on moths as pollinators has focused on the Sphingidae (Schlumpberger et al. 2009, Borkowsky 2009).

What currently is known about small settling moths has been documented in Brazil (Oliviera et al. 2004), South Africa (Makholela and Manning 2006), Thailand (Tasen et al. 2009), and Japan (Okamoto et al. 2008). From these studies it is known that small settling moths of the families Noctuidae, Geometridae, and Pyralidae seek nectar from small clusters of flowers (inflorescences) (Oliviera et al. 2004). Also, flowers pollinated by settling moths are often pale in color, open in the evening, and emit dilute nectar (Okamoto et al. 2008, Makholela and Manning 2006).

Florida Xeric Uplands

Florida is known for its wildlife species richness and is considered a global hotspot of diversity (Enge et al. 2002). The northern majority of the state has a subtropical climate while the southern tip is considered tropical (Enge et al. 2002). The Florida peninsular ridge contains a number of unique plant and insect communities, many of which are indigenous and/or precinctive (Frank & McCoy 1995, Deyrup 1990, Myers &

Ewel 1990). Sandhill, scrub, and xeric hammock are three main habitats associated with Florida's uplands. They occur along the peninsular ridge of Florida on hills of well-drained sandy soils. Plant communities associated with Florida's uplands are considered pyrogenic, or fire dependent (Myers & Ewel 1990). However, anthropogenic activities such as logging, overgrazing, and developmental sprawl have reduced the natural frequency of fires in Florida. Sandhill, in particular, has been degraded to only a few patches in the state (Figure 1-1). The majority of the remaining upland communities are now dependent on actively managed prescribed burning. Therefore, Florida's upland communities are considered to be under great threat and of high priority for conservation (Enge et al. 2002).

Long-term wild fire activity in Florida is related to the presence of El Niño Southern Oscillation and is primarily lightning induced or prescribed (Myers & Ewel 1990). The occurrence of particular plant communities (e.g. sandhill or scrub) depends on the frequency and intensity of these fires. Decreased fire frequency may convert sandhill communities into turkey oak barren, scrubby flatwoods, or xeric hammock. These habitats are sometimes described as an intermediary between sandhill and scrub (Givens et al. 1984, Veno 1976). Scrub is associated with an occasional occurrence of high intensity fires (Meyers & Ewel 1990). Alternatively, sandhill habitats are associated with the occurrence of more frequent (every 2-5 years), low intensity fires (Abrahamson 1984).

Habitat loss is especially a major threat to diversity of native flora and fauna, thus conservation has begun to focus more on habitat restoration and protection (Enge et al. 2002). Florida scrub and pine habitats are especially unique with high rates of

endemism (Deyrup 1990) and therefore are of special concern for conservation (MacAllister and Harper 1999). Florida sandy uplands, in particular, was converted to agricultural systems years ago during Spanish colonization and since then the remaining patches have been degraded further of their natural fire regime (Myers and Ewel 1990).

Location of Study

Fieldwork for the entire study was conducted at the Ordway Swisher Biological Research Station located in Putnam County, Florida (Figure 1-1). The Ordway is known as one of the largest expanses of remaining sandhill habitats occurring along the sand ridges in Florida (Enge et al. 2002). The University of Florida Department of Wildlife Ecology and Conservation actively manages the area with prescribed burning to maintain the natural fire regimes of the longleaf pine-wiregrass communities on the station. While sandhill is the most dominant community within the station, other communities contained in the station include baygalls, marsh lakes, xeric hammock, basin swamp, clastic upland lakes, upland mixed forest, basin marsh, and sandhill upland lakes. Although this area is rich in diversity of Florida sandhill and upland related flora and fauna, the localities of scrub at the Ordway are limited to relatively small parcels of habitat. However, there is evidence that certain scrub/upland specific insects still are found (Lamb & Justice 2005). For this reason, the Ordway is considered a valuable location for the study of all related Florida upland communities.

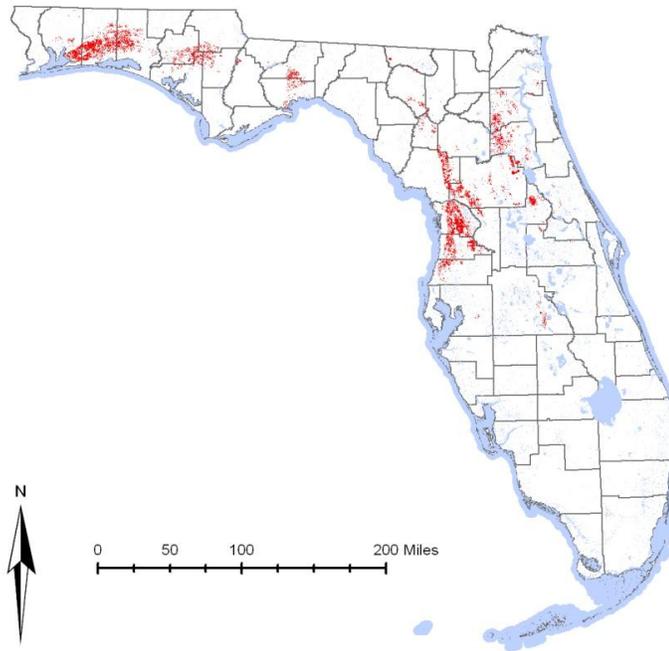


Figure 1-1. Sandhill habitat distribution or locations documented in Florida.
 (myfwc.com/media/134679/Legacy_Sandhill.pdf - 2010-11-15 - Text Version)



Figure 1-2. Ordway Swisher Biological Research Station.
 (<http://ordwayswisher.ufl.edu/about.htm>).

CHAPTER 2
PRELIMINARY SURVEY OF MOTH FAUNA OF THE ORDWAY SWISHER
BIOLOGICAL STATION

Methodology

Inventories of moths were conducted weekly on a rotating plot schedule throughout the Summer and Fall of 2010, with a total of eight plots examined (Table 2-1). These plots were selected to be within the sandhill areas of the Ordway. Majority of inventories were conducted for the first few hours after dusk. However, four visits were made in the early morning from 3am to sunrise depending on the day length. Time of visit varied depending on the length of day. Moths were collected using a light collecting sheet composed of one 40 watt ultra violet light and one 70 watt mercury vapor lamp suspended on each side of a vertical white sheet (approximately 2.0 x 2.4m). Global positioning systems (GPS) coordinates of the plot, time (duration of sample period), temperature, and wind speed were recorded for each visit. Each moth was collected into separate vials or envelopes then placed in a freezer until ready to be curated. Freezing slows the metabolism of the moth and prevents excess movement that would otherwise damage scales and wings of the moth. Vials were washed after use and reused. Specimens derived during the course of the study were curated and deposited in the McGuire Center of Lepidoptera and Biodiversity Collections, Florida Museum of Natural History.

Results

A total of 1,214 moths were collected at light traps and have been identified to family thus far. Further identifications will be made for future publications. Families of moths collected include but may not be limited to: Tineidae, Psychidae, Gracillariidae, Cosmopterigidae, Gelechiidae, Yponomeutidae, Tortricidae, Pyralidae, Limacodidae,

Megalopygidae, Lasiocampidae, Zygaenidae, Pterophoridae, Sesiidae, Geometridae, Lymantriidae, Sphingidae, Saturniidae, Cossidae, Notodontidae, Arctiidae, and Noctuidae.

Table 2-1. Global Positioning System (GPS) coordinates for all plots in the study.

Plot	Coordinates
1	N 29° 42' 52.0", W 81° 59' 49.9"
2	N 29° 41' 38.5", W 81° 57' 20.8"
3	N 29° 40' 44.6", W 81° 57' 13.0"
4	N 29° 40' 44.6", W 81° 57' 22.1"
5	N 29° 41' 38.3", W 81° 57' 56.2"
6	N 29° 41' 02.0", W 81° 59' 25.0"
7	N 29° 40' 55.7", W 82° 00' 43.5"
8	N 29° 40' 43.5", W 81° 57' 17.3"

CHAPTER 3 FLOWER NECTAR HOSTS OF MOTHS WITHIN THE SANDHILL COMMUNITY OF THE ORDWAY

To explore the interactions of moths with their floral nectar hosts, I employed an integration of both field and laboratory methods. First, direct field observations of moths on flowers were conducted in their natural habitat without manipulated settings. A second, more indirect approach also was conducted using the moths collected at a light collecting sheet (described in Chapter 2). These individuals were scanned for pollen and, if pollen was present, it was sampled for later identification and quantification. These two approaches are complimentary. However, to avoid confusion methods and results first are described separately, and then are followed with a discussion in which they are compared and contrasted further.

Observation Sessions of Moths Nectaring on Flowers

Methods

Field observation sessions were performed weekly during the moth flight period (\approx 1700 to 2400 hrs, depending on the day length) on a rotating schedule for each sample area beginning 15 July 2010 and ending 17 November 2010. Observation sessions were conducted within a 50 m diameter plot. Usually two to four observation sessions were necessary to cover the vicinity of the plot and the direction in which each observation took place was random. Each session was timed for duration up to 30 minutes. However, if no moths were observed within the first ten minutes, the session was terminated. Time, temperature, and wind speed were recorded prior to each observation session. To document plant evenness, the abundance of flowers in bloom at each plot were documented with digital photography and noted in a field notebook.

One of the major obstacles encountered was the lack of light. To compensate, I began by using both red and white field lamps but soon decided that the use of white lamps was most adequate. First, I found that the red lights were not sufficient for detailed observations. Second, no matter the color of the lamp, most moths would fly away when the beams were shined directly on them. For the majority of observations, I found using a 1-watt white LED headlamp was adequate for observations as long as I did not shine the beam directly onto the moth.

For each moth observed on a flower, nectaring behavior, moth identification, and plant identification (at least to family) were recorded. Also, photographic documentation of moths taking nectar on flowers also was made when possible. The moth was collected when possible to prevent repeated observations of the same individuals. To prevent damage to the flower and pollen contamination, moths were collected by holding a vial directly above the moth and allowing the moth to fly up into the vial. Each moth was collected in individual vials and stored in a freezer until ready to be scanned for pollen, spread, labeled, and identified. To infer pollen transport, sampled moths were scanned visually for pollen. Whether pollen was present or not (pollen presence) as well as the location of pollen on the moth was recorded.

Scanning for pollen.

To scan a moth for pollen, the specimen first was pinned through the thorax with an appropriately sized insect pin and pinned into a small piece of foam. This stabilizes the pinned specimen in any angle needed to view pollen. The specimen then was scanned for pollen under a stereomicroscope, paying special attention to the mouthparts (Figure 3-1). These are the areas of the moth that contact the flower anthers

during observations. If the proboscis was not visible, a minuten insect pin was used to gently bend it up from the base until fully exposed.

Quantification analysis.

Pearson tests for correlation were used to test for correlation of observed frequency and floral host diversity (number of plant species they visited) of individual moths by family and genus. Logistic Regression and Chi Square analyses were applied to analyze pollen presence data, or the proportion of individuals collected with or without pollen by family and genus. Analysis of Variance tests were applied to test for differences in means of proboscis length of moths by what plant species they visited.

Results

A total of 162 moths nectaring on flowers were observed within the sandhill community of the study area. Of these observations, 134 were categorized as small settling moths representing the Families Crambidae (56 observations), Noctuidae (31), Pyralidae (24), Geometridae (19), Pterophoridae (2), and Gelechiidae (2). The other 28 observations (Noctuidae and Sphingidae) were categorized as macrolepidoptera (wing span greater than 25 mm) and therefore not included in the analysis for this study. The most frequently observed genera were *Herpetogramma* Lederer (31, Crambidae), *Hormoschista* Möschler (28, Noctuidae), *Samea* Guenée (12, Crambidae), and *Pleuroprucha* Möschler (11, Geometridae) (Table 2-1).

Out of the twenty-seven species of plants found in bloom during the course of the study, ten flower species were observed as floral nectar sources for moths, representing the Families Asteraceae (99 observations), Fabaceae (16, *Dalea pinnata* (J.F.Gmel.) Barneby), Polygonaceae (18, *Eriogonum tomentosum* Michx.), and Orobanchaceae (1, *Agalinis tenuifolia* (Vahl) Raf.).

Moths were observed nectaring on seven species of Asteraceae including *Ageratina aromatica* (Greene) Clewell & Wooten (52 Observations), *Eupatorium compositifolium* Walter (22), *Liatris tenuifolia* Nutt. (12), *Balduina angustifolia* (Pursh) B.L.Rob (4), *Pityopsis graminifolia* (Michx.) Nutt. (4), *Elephantopus* sp. Linnaeus (2) and, *Solidago odora* Aiton (1) (Figure 3-2, 3-3).

Floral diversity and frequency of observations were quantified for moth family, genera, and species and found to be correlated in all levels of taxon (all $P < 0.001$). Overall, the more frequent a moth species was observed visiting flowers, the more likely that moth species would be found on different species of flowers, or the higher their floral host diversity. For example, *Hormoschista latipalpus* (Walker; Noctuidae), with the highest observation frequency and observed floral host diversity, was observed nectaring on nine different flower species (Table 3-1, Figure 3-2, 3-3).

Out of the 134 observations of small settling moths, I was able to collect eighty-five individuals and fifty-three of these individuals were found to have pollen loads. The rate at which pollen was found on specimens varied depending on the moth family, and genus (Figure 3-4, 3-5). The frequency a moth species was observed and sampled on flowers did not mean that more specimens were found with pollen loads. There was a significant difference between the rate at which pollen was found among moth families ($P < 0.01$). For example, Geometridae and Pyralidae, which were not observed or collected as frequently, had a relatively greater proportion of total individuals found with pollen loads (Figure 3-4) compared to the Noctuidae. Further, *Hormoschista latipalpus*, while one of the most frequently observed moths, was found to have pollen loads on only two out of the fifteen specimens collected (Table 3-1, Figure 3-5).

Although there is a noticeable difference between the rate at which pollen was found within families (Figure 3-5), this was not found to be statistically significant outside of the Crambidae ($P < 0.01$). However, I suspect that with more observations, the results would begin to show statistical relevance.

Proboscis length of moths ranged from 1.0 to 7.5 mm, depending on the species. Proboscis length of moths did not vary significantly by which floral nectar host on which the moths were observed ($P = 0.064$). In other words, there flower preferences was not detected based on proboscis length.

Pollen Analysis

Methodology

Moths collected at light traps within the same time and vicinity of observation sessions were scanned for pollen (see methods above), and pollen samples were made for all moths on which pollen loads were found. Location of pollen on moth (i.e. proboscis, palpi, antennae, abdomen), number of pollen grains, pollen diversity (number of different pollen species found within a pollen sample) and pollen identification were recorded for these pollen samples.

Sampling Pollen from Moths.

Pollen loads found on moths were sampled and analyzed using the following techniques recently developed in conjunction with the Florida Museum of Natural History (FLMNH) Palynology Laboratory (Atwater and Lott, in review).

Materials. Stereo microscope (7-15x magnification), hot plate, probe with fine point (see below), glycerin gel stained with pigment (see below), glass microscope slide with cover slips, small weights (~ 40 grams), slide warmer, reflective microscope with

10-60x objectives, camera attachment and imaging software (AxioVision Rel. 4.5), pollen keys, regional identification manuals, and plant samples from the field.

Probe. Wooden dowel 14 cm long and 0.2 cm in diameter, with an embedded tip of a # 2 insect pin.

Glycerin gel with stain. Add 20 g of gelatin (Crescent Chemical Company, Cat. # 23310.02) to 70 ml boiling distilled water, once thoroughly mixed, add 60 ml glycerin (Fisher Scientific, Cat. # 633-4) and 1.2 g phenol (Fisher Scientific, Cat. # G33-4); then after crystals dissolve, add 22 drops of Safranin-O stain (Fisher Scientific, Cat. # S670-25).

Extracting pollen from specimen.

First, the stained glycerin gel was heated on a hot plate at 52°C in a water bath until it reached liquid form. Microscope slide(s) were also placed on a slide warmer. A small portion of the glycerin gel was dropped onto the microscope slide and the probe tip was dipped into the glycerin gel. The pollen was then sampled from the moth using the tip of the probe. Once the pollen adhered to the probe, it was transferred to the microscope slide into the drop of glycerin gel, covered with a cover slip, and a small weight was added on top of the cover slip (Figure 3-6). A label also was prepared for the microscope slide. The microscope slide then was left on the slide warmer long enough to enable the gel to stain the pollen (at least 24 hours). Once the gel had stained, slides were removed from the slide warmer, and the edges of the coverslip were sealed with clear fingernail polish (nitrocellulose).

Counting and analyzing pollen.

Moth pollen samples were analyzed individually using a reflective microscope at 40X (objective) and 1.25X (optivar). Pollen was located on the microscope slide and the

number of pollen grains was counted as well as pollen diversity (number of different pollen species) for each sample. When necessary, pollen was photographed a digital camera attached to the scope and imaging software (Figure 3-3). Using this image, pollen was analyzed further to confirm pollen diversity and, when possible, pollen identification.

Pollen characteristics such as shape, number and length (μm) of apertures (e.g. spines), diameter (μm), and number of furrows or spores were considered for identifications. Pollen was identified easily to family using a local pollen key (Kapp et al. 2000), and pollen identification manual (Jelks 2001). To identify pollen to genus and/or species, pollen images were matched with pollen reference images.

Since many plants from this specific plant community were not represented in local pollen libraries, I created a pollen library to use as a reference for pollen identifications. Plants in bloom throughout the study area (27 species) were photographed, collected, pressed, and identified. Pollen was sampled from the flowers and preserved on labeled microscope slides using the same techniques as described above. The pollen library created for this study was deposited into the Pollen Library (Palynology, FLMNH).

Quantification Analysis.

Analysis of variance was applied to test for differences in means of pollen counts and difference in means of pollen diversity among families and genera. Pearson correlation tests were applied to test for correlations between average pollen diversity and average number of pollen grains by genera. Logistic regression tests were used to test for differences in pollen presence among family and genera. For this analysis, only the moths more commonly collected with pollen could be used to meet the requirements of the test.

Results

Of the 1,214 moths collected and scanned for pollen, 101 were found with pollen loads representing seven families and thirty-four genera of moths. Eighty-one of these moths were considered small settling moths and analyzed for the purpose of this study. Of the 81, six families and twenty-six genera were represented (Table 3-2). Many of these were not collected commonly and therefore only found with pollen once (e.g. *Nemoria outina* Ferguson (Geometridae)). However, a repeated occurrence of pollen on a set group of moths representing the families Crambidae, Geometridae, and Noctuidae was observed. Not surprisingly, these moths were also many of the same moths commonly observed nectaring on flowers (as described above).

Pollen counts and pollen diversity of pollen loads sampled from moths varied among families ($P < 0.05$; Table 3-3), while pollen counts within the family level were similar ($P > 0.05$; Table 3-2). Pollen diversity was also similar within the family level with the exception of the Geometridae ($P < 0.05$; all other families $P > 0.05$). Pollen diversity and pollen count were found to be significantly correlated ($P < 0.001$, $R^2 = 0.2399$); meaning the more pollen grains on an individual moth, the higher the pollen diversity.

For moths included in the pollen presence data, the proportion of individuals collected at traps with and without pollen varied significantly among families ($P < 0.01$; Figure 3-6). The Geometridae were most frequently sampled with pollen. Two species in particular, *Pleuroprucha insularia* (Guenée) and *Eupithecia miserulata* Grote (both Geometridae), were sampled with pollen more than any other moth species or genera (Table 3-4, Figure 3-7). Lastly, pollen analysis among genera within each family did not vary significantly. There are patterns arising (Figure 3-7) but more samples would be needed to test accurately for variation in this case.

Asteraceae (67 samples) was the most common pollen identified in the pollen analyses. Of these samples, 25 were matched with pollen references including *Ageratina aromatica*, *Eupatorium compositifolium*, *Balduina angustifolia*, *Liatris tenuifolia*, and *Pityopsis graminifolia*. Other identifications include *Tephrosia virginiana* (Linnaeus; Fabaceae), *Agalinis tenuifolia* (Orobanchaceae), and *Eriogonum tomentosum* (Polygonaceae).

Discussion

The two approaches described (observations of moths on flowers and pollen analysis) are unique but the data resulting from them are complimentary and offer an immense amount of information regarding moth flower interactions. Twenty-seven genera of moths were sampled with pollen from light traps while 21 genera of moths were observed on flowers for a combined total of 35 genera and 37 species (Table 3-5).

Moths commonly collected and sampled with pollen from light traps often were observed on flowers as well (e.g. *Pleuroprucha*, *Herpetogramma*). However, one exception again was *Hormoschista latipalpus* (Noctuidae). This species was the most frequently observed moth on flowers but only seven individuals were collected at the light traps. Further, individuals of this species observed on flowers, as mentioned previously, rarely had pollen loads and to compliment this observation, only one out of seven *H. latipalpus* collected from light traps had pollen. These results imply that, although quite common on flowers, *H. latipalpus* may not play a significant role in pollen transport or pollination.

The majority of the moths observed on flowers were sampled with pollen loads (Figure 3-4). The Geometridae, Crambidae, and Pyralidae were observed most frequently and most often sampled with pollen (Figure 3-4). Of these moths,

Pleuroprucha (Geometridae), *Herpetogramma*, *Samea*, *Ategumia* (all Crambidae), *Ufa*, and *Phycitodes* (all Pyralidae) were observed and sampled with pollen most often. These groups also were sampled with pollen frequently in the pollen analysis of moths collected at light traps. All of this suggests that these moths function as pollen transporters and/or pollinators for their nectar plants.

The Geometridae had the greatest proportion of individuals sampled with pollen from the light traps (Figure 3-6). These results combined with the average pollen counts implies that the Geometridae (average pollen load=62; Table 3-3) function as pollen transporters and most likely pollinators for their nectar plants.

Observation sessions began July 2010; however, moths were observed nectaring only on flowers regularly from mid September 2010 until late November 2010. In addition, moths collected at light traps rarely were found with pollen until this time. There was a general paucity of flowers in bloom until mid September. This might be due to the record lack of precipitation through the months of July to December 2010 in Florida (http://www.noaanews.noaa.gov/stories2011/20110120_drought.html). The study area had very few flowers in bloom until September, after which, flowers were in bloom consistently until late November. Still, three moths collected from light traps (23 May 2010) were sampled with pollen loads. The pollen in this case was identified as *Tephrosia virginiana* (Fabaceae). This plant was the only flower found in bloom at the time and location in which these moths were collected and is also a larval host for one of the moths sampled for pollen, *Digrammia eremiata* (Guenée; Geometridae).

Table 3-1. Number of observations, observations sampled, number of flowers visited (floral diversity), and pollen presence, of all moths observed on flowers by family and genus.

Family	Genus	Individuals observed nectaring on flowers	Number of flower species visited	Individuals sampled with pollen on mouthparts	Individuals sampled without pollen on mouthparts	Individuals observed and sampled	Individuals observed but not sampled
Geometridae	<i>Pleuroprucha</i>	11	5	6	3	9	2
	<i>Eupithecia</i>	3	2	2	0	2	1
	<i>Scopula</i>	4	3	1	0	1	3
	<i>Idaea</i>	1	1	0	0	0	1
	<i>Synchlora</i>	1	1	1	0	1	0
Noctuidae	<i>Hormoschista</i>	28	9	2	13	15	13
	<i>Schinia</i>	2	2	0	1	1	1
Crambidae	<i>Argyria</i> *	2	1	0	2	2	0
	<i>Herpetogramma</i>	31	6	11	7	18	13
	<i>Spoladea</i> *	1	1	0	1	1	0
	<i>Udea</i> *	1	1	0	1	1	0
	<i>Hymenia</i> *	3	2	0	0	0	3
	<i>Ategumia</i>	6	2	6	0	6	0
	<i>Urola</i>	1	1	0	1	1	0
Pyralidae	<i>Samea</i>	12	3	6	0	6	6
	<i>Anageshna</i>	1	1	0	1	1	0
	<i>Phycitodes</i>	6	3	5	1	6	0
	<i>Ufa</i> *	10	2	5	1	6	4
	<i>Elasmopalpus</i> *	3	1	2	0	2	1
	<i>Unknown</i>	4	3	2	0	2	2
Pterophoridae	<i>Stenoptilodes</i>	2	1	2	0	2	0
Gelechiidae	<i>Isophrictis</i> *	2	1	2	0	2	0
Totals		135	10*	53	32	85	50

*Moths documented on flowers only; not sampled with pollen from light traps.

Table 3-2. Number of moth individuals with pollen, average pollen count (Mean +/- Standard error), and average pollen diversity of moths collected at traps per genus of moths.

Family	Genus	Number of individuals sampled with pollen	Average pollen count	Total number of different pollen species represented in Samples
Arctiidae	<i>Cisthene</i>	3	52	1
Crambidae	<i>Samea</i>	7	19 +/- 10.4	1
	<i>Ategumia</i>	2	7 +/- 3.5	2
	<i>Herpetogramma</i>	5	7 +/- 3.6	1
	<i>Diacme</i> *	1	1 +/- 0	1
	<i>Eudonia</i> *	2	2 +/- 0.5	1
	<i>Urola</i>	2	22 +/- 19	1
	Geometridae	<i>Synchlora</i>	2	8 +/- 5.5
<i>Digrammia</i> *		2	26 +/- 24	1
<i>Eupithecia</i>		13	112 +/- 74.5	2
<i>Pleuroprucha</i>		10	11 +/- 3.0	1
<i>Idaea</i> *		8	62 +/- 25.0	3
<i>Nemoria</i> *		1	1 +/- 0	1
<i>Scopula</i>		2	79 +/- 63.5	3
Noctuidae	<i>Metalectra</i> *	1	2 +/- 0	1
	<i>Pyrrhia</i> *	1	2 +/- 0	1
	<i>Hormoschista</i>	1	1 +/- 0	1
	<i>Afrida</i> *	2	22 +/- 4.6	1
	<i>Schinia</i>	5	278 +/- 200.3	3
Pterophoridae	<i>Stenoptilodes</i>	1	178 +/- 0	1
Pyralidae	<i>Arta</i> *	1	1 +/- 0	1
	<i>Dioryctria</i> *	1	1 +/- 0	1
	<i>Phycitodes</i>	2	20 +/- 5.5	1
	<i>Herculia</i> *	1	2 +/- 0	1
	<i>Unknown</i>	2	2 +/- 1	1
Tortricidae	<i>Choristoneura</i> *	1	3 +/- 0	1
	<i>Cydia</i> *	1	1 +/- 0	1
	<i>Sparganothis</i> *	1	8 +/- 0	1

*Moths only sampled with pollen from light traps; not observed nectaring on flowers as well.

Table 3-3. Average pollen count and pollen diversity of moths collected at traps by family.

Family	Average pollen count	Total number of pollen species
Arctiidae (3)	52 +/- 36.0	1
Geometridae (37)	57 +/- 27.1	2
Noctuidae (10)	54 +/- 104.5	2
Pterophoridae (1)	178 +/- 0	1
Pyralidae (7)	6 +/- 0.4	1
Tortricidae (3)	4 +/- 2.1	1
Crambidae (19)	28 +/- 4.0	1

Note: Number of individuals collected at traps per family is in parenthesis.

Table 3-4. Frequency of individuals collected at traps with or without pollen loads by family and genus.

Family	Genus	Pollen	No pollen	Total
Crambidae	<i>Samea</i>	7	16	23
	<i>Ategumia</i>	2	1	3
	<i>Herpetogramma</i>	5	4	9
Noctuidae	<i>Hormoschista</i>	1	6	7
	<i>Afrida</i>	2	9	11
	<i>Schinia</i>	5	1	6
Geometridae	<i>Synchlora</i>	2	2	4
	<i>Eupithecia</i>	13	5	18
	<i>Pleuroprucha</i>	10	14	24
	<i>Idaea</i>	8	20	28
	<i>Nemoria</i>	1	2	3
Totals		56	80	136

Table 3-5. All moths included in both observation and pollen analysis portions of the study.

Family	Species
Crambidae	<i>Argyria lacteella</i> (Fabricius)
	<i>Ategumia ebulialis</i> (Guenée)
	<i>Diacme elealis</i> (Walker)*
	<i>Eudonia strigilis</i> Dyar*
	<i>Herpetogramma bipunctalis</i> (Fabricius)
	<i>Herpetogramma phaeopteralis</i> (Guenée)
	<i>Hymenia perspectalis</i> (Hübner)
	<i>Samea multiplicalis</i> (Guenée)
	<i>Samea ecclesialis</i> Guenée*
	<i>Spoladea recurvalis</i> (Fabricius)
	<i>Udea rubigalis</i> (Guenée)
	<i>Urola nivalis</i> (Drury)
	Pyralidae
<i>Arta statalis</i> Grote*	
<i>Dioryctria amatella</i> (Hulst)	
<i>Dolichomia olinalis</i> (Guenée)	
<i>Elasmopalpus lignosellus</i> (Zeller)	
<i>Phycitodes reliquellus</i> (Dyar)	
Gelechiidae	<i>Ufa rubedinella</i> (Zeller)
Geometridae	<i>Isophrictis</i> sp. Meyrick*
	<i>Digrammia eremiata</i> (Guenée)
	<i>Eupithecia miserulata</i> Grote
	<i>Idaea ostentaria</i> (Walker)*
	<i>Nemoria outina</i> Ferguson
	<i>Pleuroprucha insularia</i> (Guenée)
	<i>Scopula lautaria</i> (Hübner)
	<i>Scopula umbilicata</i> (Fabricius)*
	<i>Synchlora frondaria</i> Guenée
	Noctuidae
<i>Hormoschista latipalpus</i> (Walker)*	
<i>Metalectra tantillus</i> (Grote)	
<i>Pyrrhia aurantiago</i> (Guenée)	
<i>Schinia sanguinea</i> (Geyer)	
Pterophoridae	<i>Schinia trifascia</i> (Hübner)
Pterophoridae	<i>Stenoptilodes brevipennis</i> (Zeller)
Tortricidae	<i>Choristoneura</i> sp. Lederer
	<i>Cydia</i> sp. Hübner
	<i>Sparganothis</i> sp. Hübner

* Astrisked species indicate that larval host plant is unknown.



Figure 3-1. Pollen grains on labial palpi and proboscis of *Samea ecclesialis* (Crambidae).

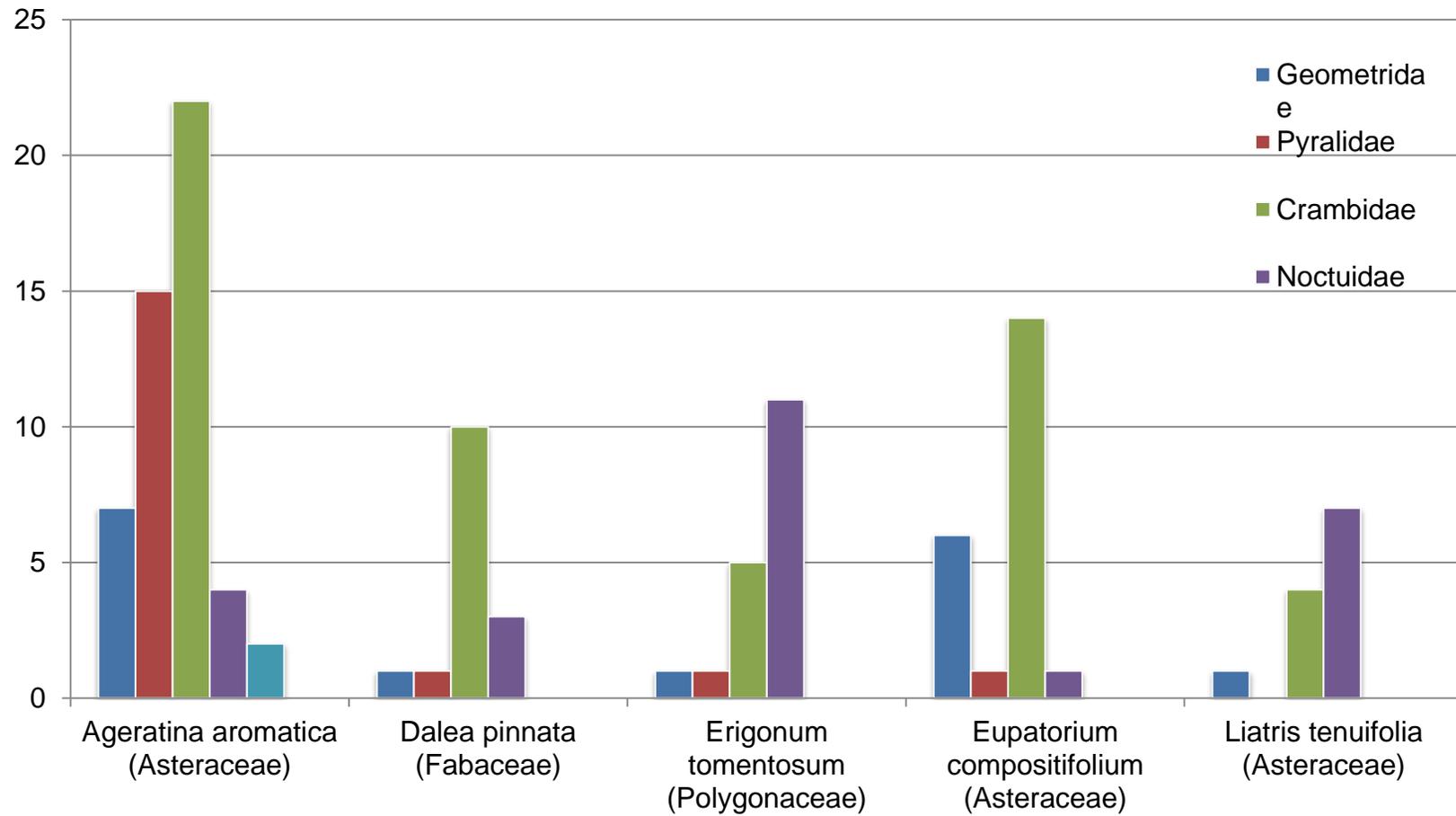


Figure 3-2. Most commonly observed floral nectar hosts (species and family) of moths and total frequency by which individual moths were observed nectaring by family.

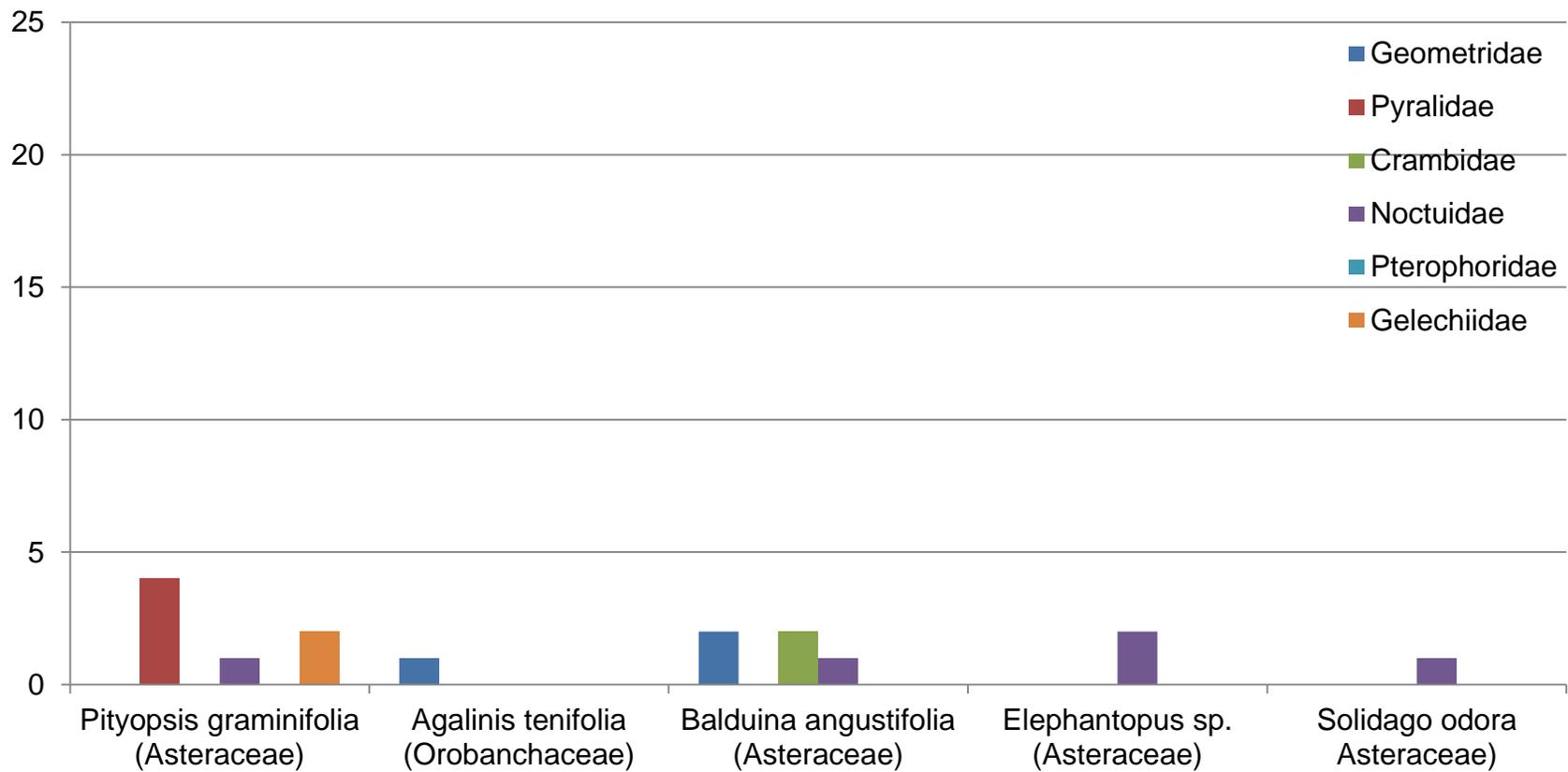


Figure 3-3. Less commonly observed floral nectar hosts of moths and total frequency by which individual moths were observed nectaring by family.

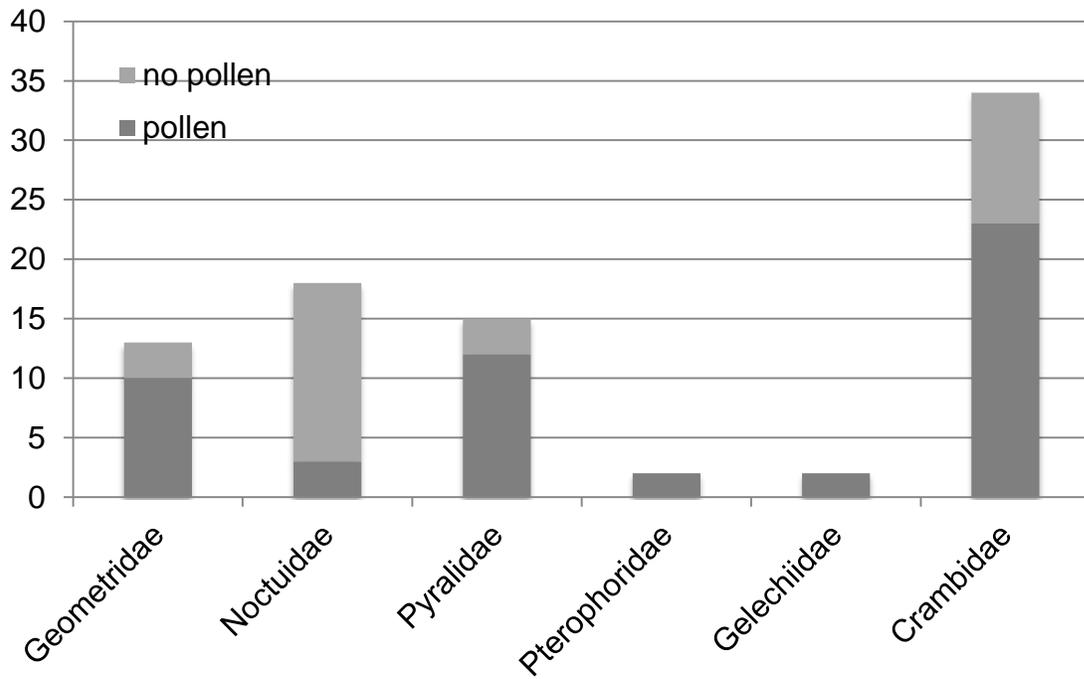


Figure 3-4. Frequency of individuals observed on flowers sampled with or without pollen loads by family

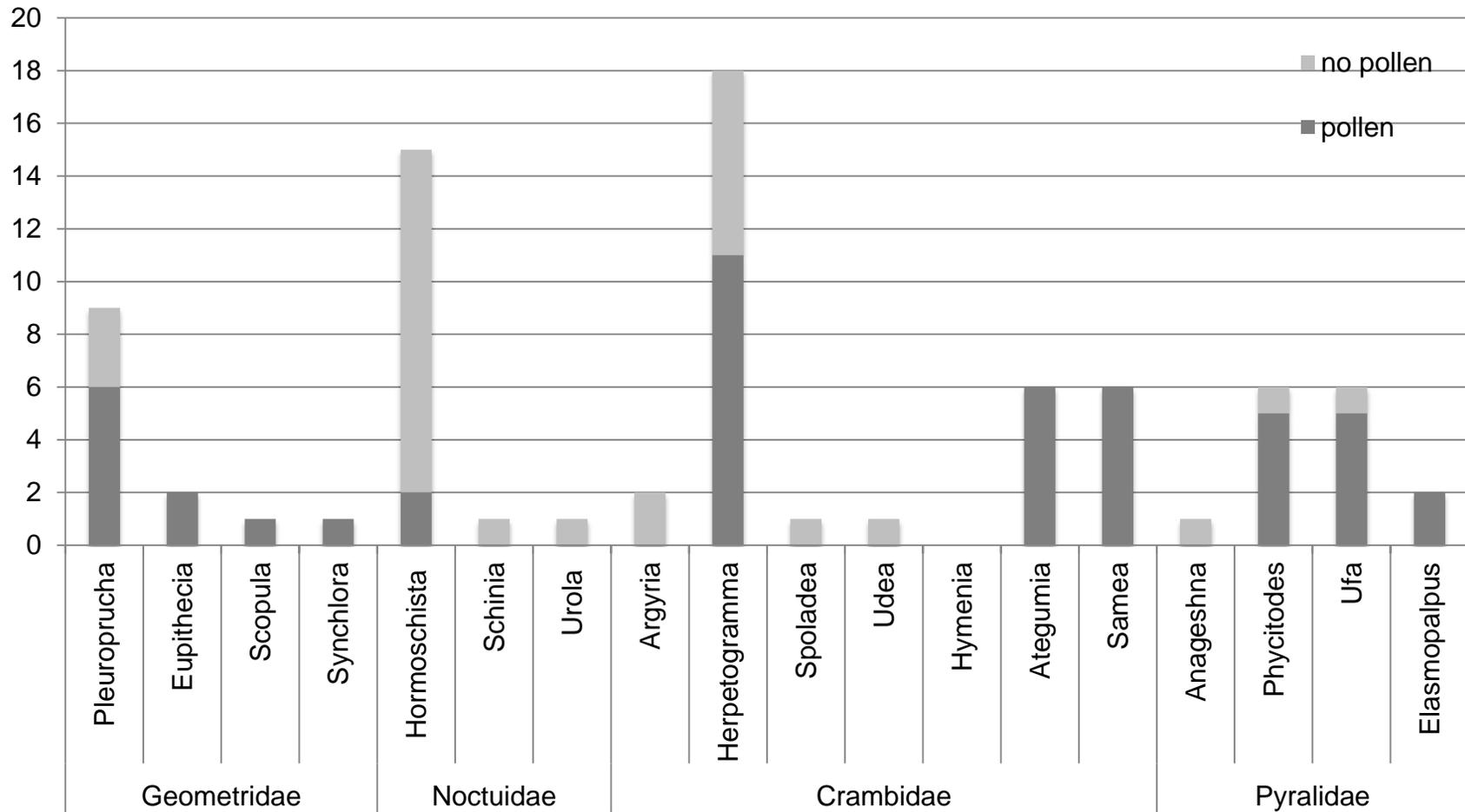


Figure 3-5. Frequency of individuals observed on flowers with or without pollen loads by family and genus.

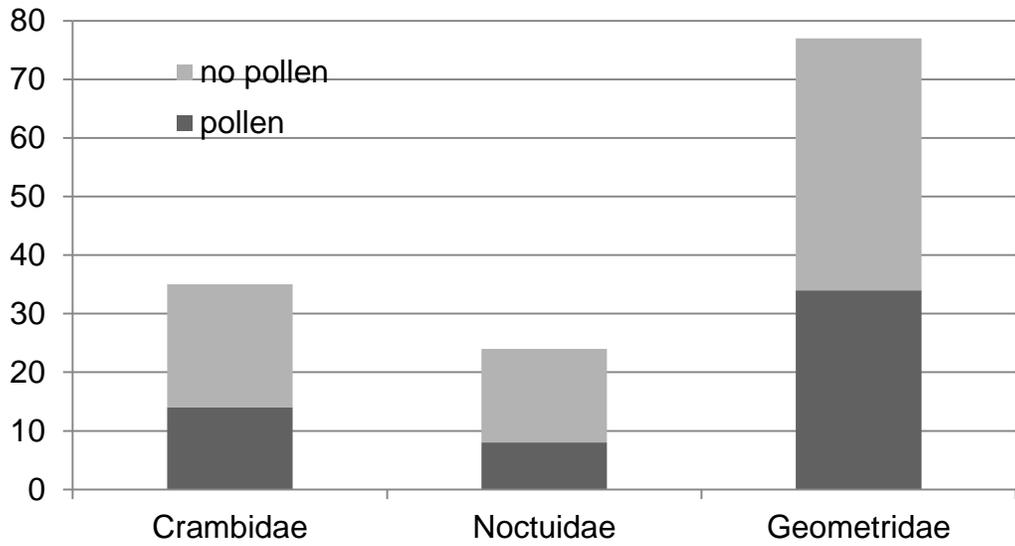


Figure 3-6. Frequency of individuals collected at traps with or without pollen loads by family.

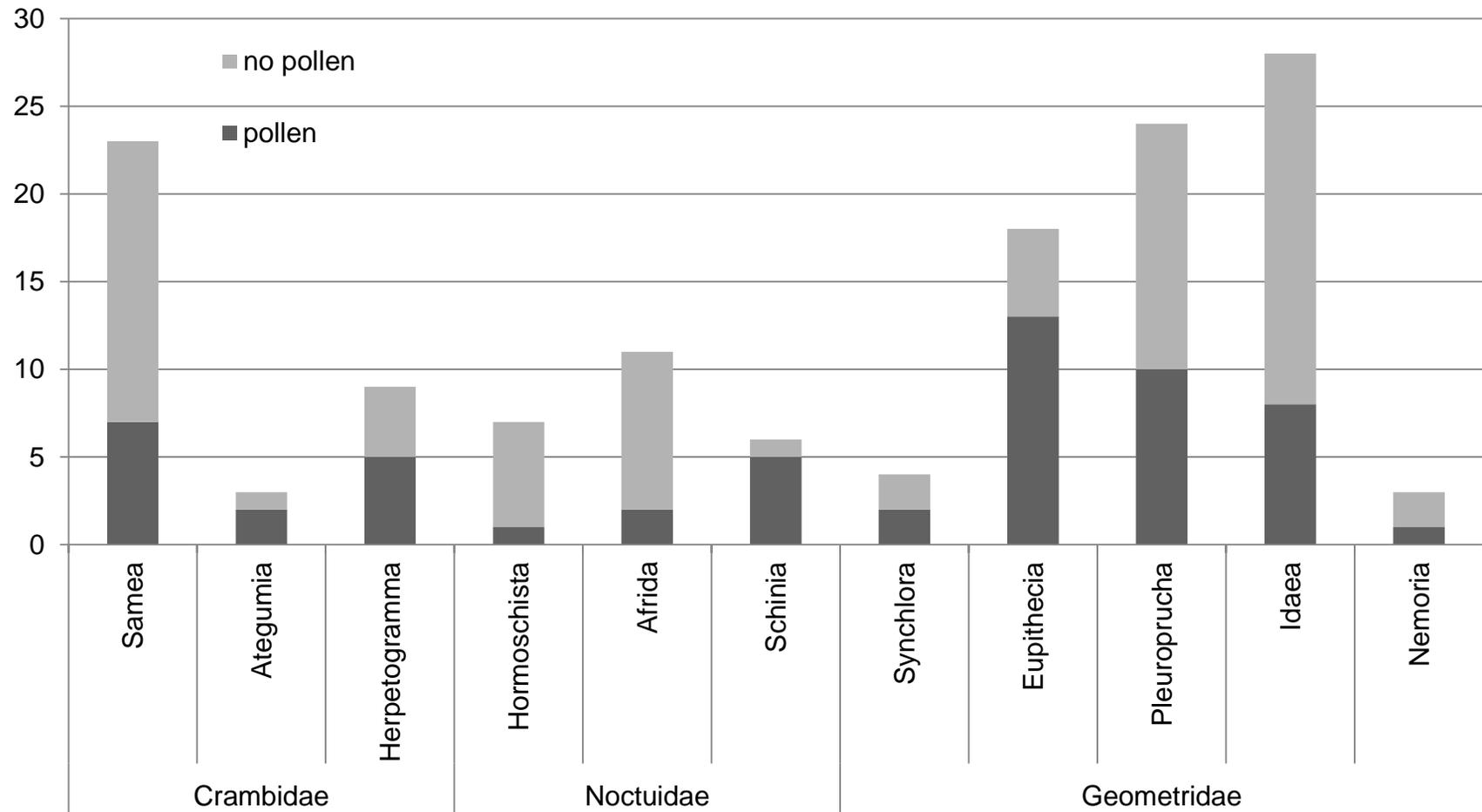


Figure 3-7. Frequency of individuals collected at light traps with or without pollen loads by family and genus.

CHAPTER 4 MOTH NECTARING BEHAVIOR AND RELATED NATURAL HISTORY PHENOMENA

Moth Nectaring Behaviors

Three nectaring behaviors were observed during the course of the study and categorized as hovering (3 observations), settling (123), and fluttering (9).

Hovering was observed by three individuals of macrolepidoptera including two unidentified Sphingidae, and one Noctuidae (*Pseudoplusia includens* (Walker)). These moths were observed hovering above flowers while reaching their proboscis down into the flower, which was often the only part of the body in contact with the flower.

The majority of moths were observed settling (Oliviera et al. 2004, Tasen et al. 2009) while nectaring (APPENDIX). These moths would settle on a flower, or a flower inflorescence, and nectar while remaining quite still. Moths typically were found nectaring upright on top of the flower; however, some were observed nectaring in a variety of angles and even upside down (Object 4-1). Once they finished nectaring on one flower, they would climb to a flower nearby or fly away to find another suitable flower. Often when on a cluster of flowers, rather than flying or walking to a nearby flower, a moth would stretch its proboscis just enough to reach the next suitable flower and even twist its head in doing so. This was observed with a few Crambidae, including *Samea* and *Herpetogramma*, and categorized as the lazy settling behavior, but only for the sake of conversation.

Fluttering, a behavior never documented before in flower settling moths, was unique to two species, *Eupithecia miserulata* and *Pleuroplucha insularia* (Geometridae). These moths would settle on flowers and nectar while beating their wings, or fluttering (Object 4-2 to 4-4). *E. miserulata* was observed fluttering in all three observations, while

P. insularia was found fluttering during six out of eleven observations. Pollen loads were found on the mouthparts (and often the ventral side of the abdomen) of all fluttering moths observed and collected from flowers, with the exception of one *P. insularia*. As mentioned in the previous chapter from the moths collected at the light traps, *E. miserulata* and *P. insularia* were sampled with pollen more than any other moths in the study (Table 3-4, Figure 3-7). These moths also had relatively high pollen counts (Table 3-2). All of these results are evidence that the fluttering behavior increases pollen collection and transport by moths.

Object 4-1. *Synclora frondaria* on *Balduina angustifolia*-20 October 2010 (.AVI 55MB)

Object 4-2. *Pleuroprucha insularia* on *Balduina angustifolia*-20 October 2010 (.MOV 20 MB)

Object 4-3. *Eupithecia miserulata* on *Eupatorium compositifolium*-1 November 2010 (.MOV 11 MB)

Object 4-4. *Pleuroprucha insularia* on *Ageratina aromatica*-17 November 2010 (.MOV 15 MB)

Flight Patterns

Flight patterns of settling and fluttering moths were similar in that they would not fly great distances at once. They would often fly a few meters at a time, land under a leaf or flower, rest a moment, then continue to fly another few meters until they reached their destination. Eventually they would find a suitable flower to nectar and I would complete the observation before sampling the moth.

Environmental Measurements

Both moths and the plants they visit for nectar are affected by environment variables such as temperature, and wind speed (Kearns and Inouye 1993). In this study, temperature and wind speed were recorded at dusk, during the observation sessions,

and before leaving a plot. Moths were observed foraging (in flight and nectaring) within temperatures ranging from 28.1°C to 16.3°C. However, once the temperatures dropped below 16°C, no moths were found during the observations or flying to the light traps. I also would like to note that once the temperatures began to drop near 16°C, the moths seemed less skittish. This was always good for the observer since it allowed for more detailed observations and better conditions for photographing the moths.

Throughout most of the study, the wind speed did not increase above 1 m/s, and did not seem to affect moth flight or foraging capabilities. One exception was in late October (28 October 2010) during a visit to the study area when there was increased wind speed (between 1 to 5 m/s) and only six moths were observed nectaring on flowers. Late October and early November was normally a very active time for moths nectaring (20 to 25 observations per night), so the decrease in observations was quite noticeable.

Although this study would not be adequate to infer any kind of flight or foraging threshold, these few observations begin to show interesting patterns and should be investigated further over a longer temporal scale. Other factors that should be investigated further include relative humidity, photoperiod, and/or soil moisture.

Spider Predators on Flowers

Ambush spiders (Thomisidae: Araneae) were observed commonly on or near the same flower species on which moths were found nectaring. Flower dwelling predators, such as spiders, are known to prey on various flower-visiting insects (Suttle 2003) yet predator-prey associations typically are overlooked in pollinator studies (Reader et al. 2006, Suttle 2003). To investigate whether these spiders are potential predators to moths in this study, I used an aerial net to sweep net a patch of *Eriogonum tomentosum*

on which these spiders were found. This was only done once out of curiosity. I found a few spiders along with three dead moths that were potentially predated by spiders. The bodies of the moths were shrunken and only their wings remained intact.

Later in the study (3 November 2010), one observation confirmed that these spiders will ambush moths. While observing *Scopula lautaria* (Geometridae) nectaring on *Ageratina aromatica*, I noticed a spider slowly approaching the moth. The moth had stopped nectaring once the spider began moving towards it and only when the spider was directly in front of the moth did it respond with a quick backwards flight movement that only the camera was able to document (Figure 4-1). Although the spider in this observation did not catch the moth, it indicates that these spiders will ambush moths and that the moth will respond to the presence of a spider on a flower. The effects of spider predators on moth nectaring behavior and flower selection is an open topic for further research and should not be overlooked in future studies on moth pollinators.



Figure 4-1. Photo series of spider predator approaching *Scopula lautaria* (Geometridae).

CHAPTER 5 CONCLUSION

All flowers on which moths were observed nectaring and identified in pollen samples were native to Florida and in some cases have only been documented in upland habitats such as sandhill (e.g. *Ageratina aromatica*). Further, all settling moths documented are native to Florida and in some cases limited to host plants only documented in sandhill or associated upland habitat. For example, *Digrammia eremiata* (Geometridae) feeds exclusively on *Tephrosia* species (Fabaceae), a plant associated with upland pine habitats (Wunderlin and Hansen 2003).

Ageratina aromatica, *Eupatorium compositifolium*, *Liatris tenuifolia* (all Asteraceae), *Dalea pinnata* (Fabaceae), and *Eriogonum tomentosum* (Polygonaceae) were the most commonly observed floral nectar hosts of moths in this study. These plants are important nectar sources for moths in sandhill communities.

Geometridae, Crambidae, Pyralidae and Noctuidae were observed most frequently nectaring on flowers and sampled with pollen in this study. *Herpetogramma*, *Samea*, *Ategumia* (All Crambidae), *Ufa*, *Phycitodes* (Pyralidae), and *Schinia* (Noctuidae) all most likely act as pollen-transporters and pollinators for their nectar plants. Geometrid moths, particularly *Eupithecia miserulata* and *Pleuroplucha insularia* because of their unique nectaring behaviors and relatively high pollen counts, most likely play a vital role in pollination for night blooming plants in sandhill communities.

The use of the pollen analyses was a great benefit to this study. Pollen is a physical link between many plant-animal interactions and is a useful tool for pollination biologists. There are a variety of techniques developed and described for analyzing pollen of insect pollinators such as bees and beetles (Kearns and Inouye 1993), but

there has not been any specific techniques described thoroughly for pollinator studies relating to moths.

Previous researchers have explored these methods to investigate life history questions relating to Lepidopteran pollination ecology (Darwin 1885, Wiklund et al. 1979, Courtney et al. 1982, Jennerston 1984, Taseen et al. 2009), migration (Mikkola 1971, Lingren et al. 1993), and even overwintering (Berkhouson and Shapiro 1994). Many of these investigators used similar techniques to identify pollen with Scanning Electron Microscopy (SEM) and often removed the head of the specimen in order to extract the pollen. The techniques described in this study offer a less expensive and invasive alternative to using SEM to sample and identify pollen from field collected fresh or museum specimens.

Although not found to nectar on flowers, one moth collected from the light traps during this study, *Ceratophaga vicinellis* (Tineidae), is worth noting due to its unique life history associated with Florida upland pine ecosystems. The larvae of this moth feeds strictly on the keratin of dead gopher tortoise shells, *Gopherus polyphemus* (Testudinidae), and are assumed to be imperiled along with the gopher tortoise (Deyrup et al. 2005). *Ceratophaga* is the only known insect to feed on keratin and the only other known members of this genus are found in Africa where the larvae feed on the horns of water antelope (Deyrup et al. 2005). In Florida, these moths have not been found in past surveys of moths at the Archbold Biological Research Station (Uplands Co., FL) (Minno 1992) or in more recent surveys of Lepidoptera at Paynes Prairie Preserve State Park (Alachua Co., FL) (Austin 2009, 2010). The occurrence of this moth at the Ordway could be a biological indicator of well managed upland sandhill habitat. Further, after

this study, this moth is now represented in the Florida Museum of Natural History Lepidoptera Collection (McGuire Center for Lepidoptera and Biodiversity, Gainesville, FL).

Before this study, virtually nothing was known about the ecology of moths associated with sandhill communities. Still, many of the moths collected in the study have no documentation of a larval host (Table 3-5; Heppner 2003). Additional natural history studies of moths are needed to understand their life cycles and further broaden our understanding of moth-plant interactions in these communities. This is especially important since the habitat in which they are found is of high priority for conservation.

With the knowledge gained in this study, it would be useful to investigate pollination ecology of moths with host plants specific to sandhill and related pyrogenic upland communities further. These species not only are limited to these communities but also may unveil some key plant-pollinator associations. In addition, since these moths can be easily collected with light traps and much is known taxonomically about them, they could be used as bioindicators of early succession sandhill habitat for land managers, since many of them rely on host plants that are fire dependent, or are only able to grow following a fire disturbance.

Through this study, I integrated observation, taxonomy, morphology, and behavior to explore the interactions of moths as both flower visitors and potential pollinators. Although only covering a relatively small temporal scale (six months of field observations and sampling), there was still a number of unique behaviors and natural history phenomena documented and patterns arising that could be investigated further.

Overall, this project offers a valuable glimpse into the intimate associations of microlepidoptera and the plant communities on which they depend.

APPENDIX
MOTHS NECTARING ON FLOWERS

20 September 2010
Plot 5



Idaeia ostentaria (Geometridae) on *Erigonum tomentosum* (Polygonaceae). Photo courtesy of Christian Salcedo.



Hormoschista latipalpis (Noctuidae) on *E. tomentosum*. Photo courtesy of Christian Salcedo.



Urola nivalis (Crambidae) on *E. tomentosum*. Photo courtesy of Christian Salcedo.

27 September 2010
Plot 1



H. latipalpis on *Elephantopus* sp. (Asteraceae). Photo courtesy of Christian Salcedo.



Schinia sanguinea (Noctuidae) on *Liatris tenuifolia* (Asteraceae). Photo courtesy of Christian Salcedo.

6 October 2010
Plot 4



Scopula umbilicata on *L. tenuifolia*. Photo courtesy of Montana Atwater.

20 October 2010
Plot 6



Herpetogramma bipunctalis (Crambidae) on *L. tenuifolia*. Photo courtesy of Montana Atwater.

3 November 2010
Plot 4



Samea ecclesialis (Crambidae) on *Ageratina aromatica* (Asteraceae). Photo courtesy of Montana Atwater.

10 November 2010
Plot 4



Ategumia ebulealis (Crambidae) on *A. aromatica*. Photo courtesy of Montana Atwater.



Stenoptilodes brevipennis (Pterophoridae) on *A. aromatica*. Photo courtesy of Montana Atwater.



S. ecclesialis (2) on *A. aromatica*. Photo courtesy of Montana Atwater.

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BIOGRAPHICAL SKETCH

Montana Marie Atwater was born in Grand Forks, North Dakota. She spent much of her childhood in Minnesota and moved to Melbourne, Florida, when she was six. She attended Melbourne High School and graduated in 2000 while pursuing a career in ballet. Ms. Atwater soon decided to attend college and began as a Fine Arts student at Santa Fe College in Gainesville, Florida, where she was awarded the Santa Fe Fine Arts Scholarship. As an art student she expressed her fascination and respect for ecology and local flora and fauna. After receiving her Associate of Arts, she decided to pursue a career in biology and was accepted into the Department of Wildlife Ecology and Conservation at the University of Florida, where she completed an undergraduate thesis with Katie Sieving, studying predatory insects on local farms in Gainesville, Florida. She was awarded her Bachelor of Science in May 2008. During this time, she worked as a Research Assistant at the McGuire Center for Lepidoptera and Biodiversity. While at the McGuire Center, she collaborated with George Austin and Andrew Warren studying phenotypic variation of the skipper, *Atalopedes campestris* (Boisduval, Hesperiiidae). She also assisted with curating moths and created a photographic database for the inventory of moths of Paynes Prairie Preserve State Park, Alachua County, FL, led by George Austin.

Through the aforementioned activities, Ms. Atwater had developed the inspiration and foundation needed to pursue a graduate degree studying moth-plant interactions of Florida ecosystems. Following completion of her Master of Science, she will be moving to Beijing, China to join her husband, Christian Salcedo, working at the Institute of Zoology, in the Chinese Academy of Sciences, where she will be working with The Group of Lepidoptera Systematics.