ABSTRACT

Title of Thesis: THE MARYLAND NATIVE POLLINATOR SURVEY: COMBINING CITIZEN SCIENCE WITH A SPECIMEN COLLECTION TO DETERMINE THE FLORAL PREFERENCES OF MARYLAND'S NATIVE POLLINATORS

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This citizen science project collected data on pollinator visits to flowering plants. Participants were trained, received educational materials, and identification skills were measured with pictorial quizzes. Participants learned and retained identification skills. Bee specimens were collected to compare community composition between observational and collected specimens; community composition differed between data collection methods. The data generated in the citizen science project were used to calculate a pollinator attractiveness score (PAS) for 23 plant species using five metrics: bloom length, visitation rate, pollinator richness and evenness, and specialist value. The field season was divided into three portions: 'early', 'middle', and 'late'. In the 'early' season *Asclepias syriaca* scored highest

and *Thymus vulgaris* lowest, in the ‘middle’ season, *Asclepias incarnata* scored highest, and *Thymus citriodorus* lowest. *Symphyotrichum novae-angliae* scored highest in the late season and *Rudbeckia triloba* the lowest. PAS provides a framework for assessing the relative plant attractiveness to pollinators.

THE MARYLAND NATIVE POLLINATOR SURVEY: COMBINING CITIZEN SCIENCE WITH A SPECIMEN COLLECTION TO DETERMINE THE FLORAL PREFERENCES OF MARYLAND'S NATIVE POLLINATORS

by

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Dedication

I dedicate this work to those closest to me, who have supported me tirelessly over the past few years. Mom and dad, thank you for your endless love and encouragement throughout my academic career. Thank you for believing in me and for allowing me to pursue my dreams. I would not be where I am today without you two as my role models.

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Chapter 1: The Maryland Native Pollinator Survey: a useful method for citizen scientists to survey pollinators visiting floral resources

Abstract:

Citizen science research projects have the potential to gather large amounts of data in a quick and economical manner. Data generated by citizen science research projects can provide answers to large-scale ecological questions, and engage and enlighten citizens about the scientific method and current environmental issues. This citizen science project aims to create a method to collect accurate data on the identity of pollinators visiting specific flowers. To improve the accuracy of the citizen scientist's observations, they were trained to identify floral visitors to functional groups. Participants who attended a training session received educational materials for field identification purposes. The impact of these training sessions was evaluated using a pictorial pre- and post-quiz of native pollinators. In the first year, 2015, volunteers observed functional groups of native bees and in 2016 functional groups of butterflies were added. In year two, a follow-up training occurred where questions about data collection and pollinator identification were answered and a specimen and additional pictorial quizzes were administered. To further assess the efficacy of this data collection method, bee specimens were collected using two methods: hand-collection and bowl trapping, was conducted in the second field season. For both years, volunteers scored higher on the post-quiz than they did on the pre-quiz. The volunteers retained the identification knowledge they learned at the initial training into the follow-up training session. When the community composition of the observational data and hand-collected specimen data were compared using a PERMANOVA test, it was discovered that the community compositions were different between the two data collection methods. This difference was evaluated using a SIMPER analysis which determined that the "honey bee" and "bumble bee" functional groups were contributing the most to the community differences (17.48 and 15.43%, respectively). Despite these community differences, the observational data generated by this study can still prove useful for drawing conclusions about pollinator floral preference.

Introduction:

Citizen scientists, members of the public involved in organized research efforts (Dickinson and Bonney 2012), can generate data that can provide valuable answers to socially significant, landscape-level ecological questions by amassing large datasets that were previously labor or cost-prohibitive (Dickinson et al. 2010). While the generation of data for research purposes benefits scientists, citizens participating in informal science also benefit by improving their scientific literacy and knowledge, and as a result tend to become better environmental stewards (National Research Council et al. 2009; Bonney

2009; Crall et al. 2013; Domroese and Johnson 2017). This valuable method of data collection has become increasingly popular since Irwin *et al.* (1994) coined the phrase "citizen science" and its versatility has been further revitalized by technological advancements (Triezenberg et al. 2012; Dickinson et al. 2012).

The concept of citizen science far outdates the recent advent of this terminology; members of the public have long played an important role in collecting ecological data (Triezenberg et al. 2012; Dickinson et al. 2012). The first citizen science project in the United States began in 1880 when lighthouse keepers began recording which bird species struck their windows (Dickinson and Bonney 2012). Since then, many other successful citizen science projects on birds have evolved to include: the long-running National Audubon Society's Christmas bird counts, initiated in 1900 and continues today in the United States, Canada, and Central and South America (LeBaron 2016); the Cornell Lab of Ornithology's Project FeederWatch (Bonter 2012); and Neighborhood Nestwatch (Evans et al. 2005). Birds make high quality subjects for citizen science research as they are diurnal, charismatic, frequently encountered and already observed by many 'bird watchers' (Sullivan et al. 2009).

Aside from monitoring bird populations, citizen science has proven useful in understanding landscape-level environmental trends and in documenting population change and size, in several types of organisms including plants and insects. Project Budburst seeks to gather information on the impact climate change has on plants by using citizen scientists to monitor specific events in both native and non-native plant life cycles throughout the year (Meymaris et al. 2008; Henderson et al. 2012). In the United Kingdom, citizen scientists across the landscape monitored the pollination services

received by the fava bean, *Vicia faba* L., by assessing changes in plant yield after manipulating the pollination environment to either receive hand pollination, insect pollination, or prevent pollination by excluding insects (Birkin and Goulson 2015). The Monarch Larva Monitoring Project is a good example of the use of citizen scientists to monitor population size and trends. This project recruits citizens to monitor monarch eggs and larvae during the breeding season (Kountoupes and Oberhauser 2008). Similarly, citizen scientists in France photographed floral visitors in a variety of land-use types to determine how land-use change is affecting pollinator populations (Deguines et al. 2012).

While citizen science can collect valuable ecological data in a variety of contexts, there are some limitations to this method. First, citizen scientists are amateur naturalists and therefore are prone to making mistakes (i.e. incorrectly identifying organisms). To counteract this, volunteers are often given specific training on how to collect data for individual projects. Training sessions are intended to help improve the data quality from the start of the project. To further validate the data quality throughout the project, many citizen science projects have a mechanism in place to double check submitted data. For instance, in the Buckeye Lady Beetle Blitz (Gardiner et al. 2012), participants attended an in-person training session where they received a lady beetle identification guide, protocol guidelines and equipment for data collection. After completing a training session, participants collected and identified lady beetles. To check the accuracy of the lady beetle identifications they were verified by entomologists. Similarly, when pollinator populations were surveyed photographically in France, these photographs were checked

by trained entomologists, however, in contrast, participants in this study received no formal training ahead of time (Deguines et al. 2012).

A further challenge of working with insects in general, and pollinators specifically, is that they are often difficult to identify without extensive training. The identification of individual pollinators to the species level often requires specialized taxonomic skills (Hopkins and Freckleton 2002), to make pollinator identifications easier, functional groups, scientifically-meaningful classification of organisms that share similar characteristics within a community (Stanley 1979), can be used. Functional groups can describe organisms either based on physical characteristics (i.e. metallic coloration) or their ecological role in the environment (i.e. predator). Using functional groups simplifies the pollinator identification process for the citizen scientists.

The Xerces society, an international, nonprofit organization striving to protect and conserve invertebrates, focuses some of their current conservation effort on pollinators. In 2007, the Xerces society initiated the 'California Pollinator Project', a citizen science project monitoring bee diversity and abundance over time in Yolo County, CA (Ullmann et al. 2007). Participants in the 'California Pollinator Project' were instructed to walk transects in meadows, hedgerows, or crops, at least three times per season and record all bees visiting the reproductive parts of flowers to one of ten functional groups.

The work done by the Xerces society ultimately set the groundwork for the Maryland Native Pollinator survey, a citizen science project to monitor pollinator visitations to flowering resources. This project strives to determine if citizen scientists can collect reliable ecological data on pollinator visitation rates to floral resources. To reduce the potential for participant error, pollinators were organized into functional

groups based on visible physical characteristics. More obvious pollinators like the Monarch butterfly (*Danaus plexippus* L.) or the honey bee (*Apis mellifera* L.) are readily identified, and were not placed into a functional group. The focus of this chapter is twofold; first, to document the impact of training on citizen scientist ability to identify pollinators, and second, to quantify the accuracy of the in-field observations with a comparison to a hand-collected bee specimen collection.

Methods:

Citizen Science - Volunteer selection

In 2015 and 2016, Master Gardener coordinators were contacted to recruit participants. Master Gardeners were the target participants for this survey because they already understand the basics of the scientific process and have experience in plant identification. Therefore, Master Gardeners only needed to learn pollinator identification skills to participate in this survey.

Master Gardener groups that were contacted first had a strong member base or had independently reached out, expressing an interest in participating. Master Gardener coordinators were emailed a summary of the survey and were then asked to contact their Master Gardeners to gauge interest in the survey. If the Master Gardeners in that county expressed interest in participating, they were then included in the study for the upcoming field season. The goal was to have a total of three participating counties in the first year and six in the second year. In 2015 Prince George's, Montgomery, and Baltimore counties participated in the survey and in 2016 Baltimore, Prince George's, Baltimore city, Frederick, Allegany, and Howard counties participated.

Citizen Science – Training

Training sessions were held in-person, once per county. At the beginning of the training session information on trainee demographics was collected using a paper survey attached to the pre-quiz questionnaire (Appendix A: Demographic surveys of citizen science participants). This survey collected information on their: gender, age, race, and occupation. Prior to the start of the training session, participants were asked to provide a self-reported score of pollinator knowledge from 1-5, where 1 indicated little to no knowledge of pollinators, and 5 indicated a thorough knowledge of pollinators.

To assess if training sessions were successful in teaching potential participants to identify pollinator functional groups, pictorial quizzes were administered prior to and after the completion of each training session. The pictorial quizzes included photographs that the participants would not see during the training session. In 2015, the pictorial quiz included ten photos of bees and in 2016 the pictorial quiz included fifteen photos, seven of bees, seven of butterflies and one "other" floral visitor that participants were asked to identify to functional group. Each photo in the pictorial quiz was shown to the participants for approximately two seconds to simulate in-the-field observations.

To enhance the training sessions and aid in pollinator identification, volunteers were provided with both a monitoring guide and pocket guide (**Error! Reference source not found.**). The monitoring guide included information on the importance of pollinators, insect anatomy and defining characteristics, the individual pollinator functional groups, and how to collect and submit data. A companion Pocket Identification Guide was developed to serve as an in-field reference guide for identifying observed pollinators. The

monitoring guide, pocket guide, and data sheets were based on the 'Pennsylvania Native Bee Survey' (Ullmann et al. 2007; Donovall and vanEngelsdorp 2009).

The 2015 field season focused solely on native bee functional groups, similar to what was done in Pennsylvania (Donovall and vanEngelsdorp 2009). In 2016, improvements were made to the monitoring and pocket guides based upon feedback from the 2015 exit survey as outlined in the results. Butterfly functional groups were monitored in addition to bee functional groups in the second field season. The 2015 guides were modified to reflect this addition and the survey was appropriately renamed the 'Maryland Native Pollinator Survey'.

To properly identify different pollinators to functional groups, participants were first taught basic insect anatomy. Important insect characteristics and body part modifications were discussed (i.e. location of scopa or pollen basket in bees, the presence of wing tails in butterflies). Then, each pollinator functional group was examined in detail, highlighting their distinguishing characteristics. Because there are some insects that closely mimic certain pollinators (i.e. some wasps in the family *Chrysididae* mimic green sweat bees in the family *Halictidae*), a special emphasis was placed on teaching volunteers to differentiate similar-looking insects.

Volunteers were next taught the standardized methods for collecting data. To track volunteer data submissions throughout the field season, each participant was given a unique identification number. Participants were asked to collect observational data four times per month: twice in the morning and twice in the afternoon. These observations could take place on the same day or on different days, but were requested to occur at roughly the same time each month (e.g. the 5th and 15th of every month). Volunteers

began collecting data as soon as they received training and were instructed to collect data until the first frost in the fall, typically in late October or early November.

Participants were instructed to choose six to eight in-bloom plant species to observe pollinators on during a single observation period. When possible, these plants should include as many of the standard plant genera or species as possible. In 2015, the standard plants included: *Agastache*, *Asclepias*, Asters, *Echinacea*, *Helianthus*, *Monarda*, Oregano, and Thyme. These plants were chosen because collectively their bloom times span the field season. In 2016, *Rudbeckia* and *Solidago* were added to the standard plant list to bolster the number of late-season blooming plants. Suggestions for supplementary plant species to observe upon were also discussed during training sessions (Appendix C: List of standard and supplemental plants for participants to observe upon).

Volunteers were asked to observe each different type of plant for ten minutes and to record all the insects that visited the reproductive parts of the flowers during this time. Insects of the plant leaves, stems, or petals were not recorded. If a pollinator that was not a bee or a butterfly arrived on the flower, or if a bee or butterfly was unidentifiable, volunteers recorded this floral visitor in the 'Other' category on the data sheet and a description of the insect was included in the notes section of the data sheet.

During each individual observation period, participants completed a data sheet to record environmental conditions and pollinator observations (Appendix D: Citizen science pollinator monitoring data sheets). They recorded environmental conditions that included: the temperature (50s, 60s, 70s, 80s, 90s, 100+ °F), wind (still, light breeze, windy, gusty), and cloud cover (clear, partly cloudy, mostly cloudy, overcast). Additional blooming floral resources and significant environmental changes (i.e. new plants planted,

a large rainstorm caused erosion in the garden, etc.) were also noted. The plot size (i.e. 1/3 of an acre, 50 sq. ft., etc.) and number of individuals collecting data during the observational period were recorded. After completing an observational period, volunteers were instructed to submit their datasheets. In 2015, all data sheets were submitted via paper mail or electronically scanned and emailed. In 2016, participants also had the option to submit data via a Google form.

During the 2016 field season an additional follow-up training was held 6 to 8 weeks after the first training. All those who attended the first training were welcome to attend the follow-up training, however, generally only those who had already begun collecting data or were planning on collecting data attended. Volunteers were asked to reflect upon: how the observations were going, what was working well for them, what they were having trouble with, and any other issues surrounding the collection of data. After this guided discussion, the volunteers were walked through a very quick pictorial review of the pollinator functional groups covered in the initial training session. After this review, another pictorial post-quiz, the same one conducted in the initial training session, and a specimen quiz were proctored. The specimen quiz consisted of fourteen pinned pollinators that participants identified to functional group.

Citizen Science -Exit survey

After the end of each field seasons, participants were sent an exit survey to gather additional information about their experiences, suggestions for survey improvement, and whether participants were likely to return for another season of pollinator observations (Appendix E: Exit survey questionnaires). In 2015, only participants that collected data were given the opportunity to respond while in 2016 the survey was offered to all

volunteers who were trained. This provided feedback on the training sessions from both those who did and did not participate in the survey. The exit survey questions in 2016 were adapted from the 2015 exit survey. The open-ended questions asked in 2015 provided more insight and therefore, the 2016 exit survey included more open-ended questions. In 2016, volunteers were also asked to self-report their score of pollinator knowledge again after the field season was over.

Specimen collection

To determine how closely the observational data reflected true values, a native bee specimen collection was implemented in the 2016 field season. Bees were collected in the Master Gardener demonstration gardens in four of the counties (Allegany, Frederick, Baltimore, and Prince George's counties) where participants performed their observations every two weeks throughout the field season. The bee specimen collection took place on the same schedule. Bees were collected using two methods, hand-collection and bowl trapping. Both methods for collecting bees were conducted within the same 24-hour period for each sampling event.

Hand-collection took place on the same list of standard plant species that the Master Gardeners were instructed to observe. Bees were hand-collected on six to eight plant species per collection period both in the morning and again in the afternoon. Bees were hand-collected for ten minutes per blooming plant species. The collected bees were placed into a 50-mL Falcon™ plastic tube (Fischer Scientific, Pittsburgh, PA) filled with soapy water to kill the specimens.

A total of twenty-four bowl traps, eight of each fluorescent blue, fluorescent yellow, and white bowls, were placed throughout the Master Gardener demonstration

gardens approximately 3 meters apart (**Error! Reference source not found.**.1). The bowls were filled with a mixture of dish soap and water and left to sit for 24-hours (Droege et al. 2010). After 24-hours, the bowl traps were collected, the contents were strained through a 190-micron fine-mesh paint filter (Pro Marine Supplies, Venice, FL) and placed into a Whirl-Pak® (Nasco, Fort Atkinson, WI) for storage until processing.

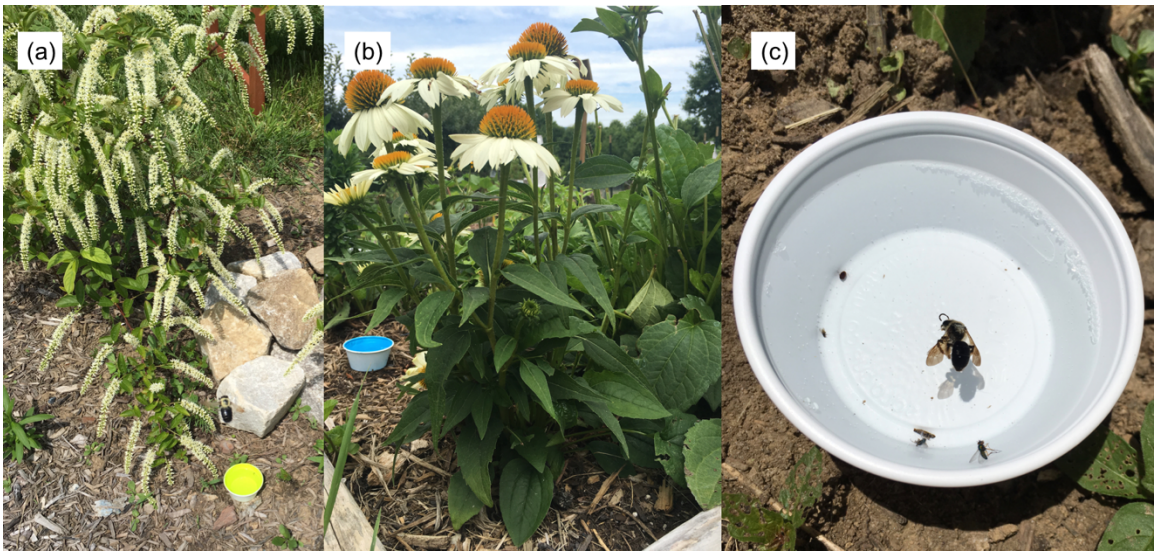


Figure 2.1: Three different colored bowls were used to collect bee species in pollinator gardens; bowls were left in the garden for 24 hours. Together, fluorescent yellow (a), fluorescent blue (b) and white (c) bowls effectively sample the entire bee community (Droege et al. 2010). Using this method to collect bees in addition to hand-collection will effectively sample the entire bee community present in an individual garden.

Hand-collecting bees directly from flower species creates records of foraging preference at the species level while bowl-trapping helps to characterize the whole bee community. It is important to use both methods together to fully sample a bee community as some larger bees, like the eastern carpenter bees (*Xylocopa virginica* L.), are big enough that they can pull themselves out of the bowl traps and avoid being collected (Droege et al. 2010). Because the bowl traps are placed in the garden for a 24-hour period, they can collect other bee species that may forage earlier or later in the day than when the hand-collection took place.

We did not collect bees that were easily identified in the field (i.e. honey bees – *A. mellifera*, or eastern carpenter bees – *X. virginica*). If there was any uncertainty about a bee's identity, it was always collected. Sometimes bees were missed in the field (i.e. the bee evaded captured) and these bees were recorded to their corresponding functional groups (i.e. "small dark bee").

Once in the lab, the soapy water was rinsed from the both the bowl trap and hand-collected specimen samples. Once rinsed, each sample was placed in a plastic Whirl-Pak® (Nasco, Fort Atkinson, WI) bag filled with enough 70% ethanol to completely cover all bees in the sample. Samples were stored at 5°C until further processing could occur.

To identify many bee species, taxonomists rely heavily on the bee's hair color or patterns. To facilitate identification, bees were removed from alcohol, washed, dried, and pinned (Sam Droege 2015). Once pinned, location labels were generated on discoverlife.org, printed on appropriate paper (acid-free, archival paper; BioQuip, Rancho Dominguez, CA), and affixed to pinned specimens. Once all specimens were pinned and labeled, they were subsequently identified. Bee identifications were confirmed or corrected by Sam Droege at the USGS Bee Inventory and Monitoring Lab in Beltsville, Maryland

Data preparation and analysis

Data submitted by participants was entered into a spreadsheet and the data was prepared prior to conducting statistical analyses. The contents of the 'other' floral visitor column, an open-ended column, with space for notes, was reviewed before data analysis and either disregarded (i.e. observation was not a pollinator: "grasshopper") or moved to

its respective functional group (i.e. “fritillaries” were moved to “brushfoot butterflies”). If a volunteer submitted fewer than four data sheets, or one complete month of observations, during a field season, their observations were not used for data analysis. This data was removed to ensure that the analyzed data came from sites with more than a few data points, providing a bigger-picture view of the pollinator populations. Because the observational data and hand-collected specimen data were not always collected on the same date, the observational and hand-collected specimen data were portioned into ten two-week periods (Table 1.1).

Table 1.3: Periods used to categorize observations and hand-collected specimens for comparison.

Period	Start date	End date
1	6/1	6/15
2	6/16	6/30
3	7/1	7/15
4	7/16	7/31
5	8/1	8/15
6	8/16	8/31
7	9/1	9/15
8	9/16	9/30
9	10/1	10/15
10	10/16	10/31

In 2015, participants were asked to record the time they started and completed observing for a given observational period, but were not asked to record when they started and completed observing on a specific plant. Therefore, when standardizing bee observations by time, it was assumed that observers spent 10 minutes per plant, as instructed in the training sessions. In 2016, participants were asked to record both the observational period and specific plant observational period start and end times. If

participants forgot to record the start or end time of their observation on a plant, it was assumed that ten minutes was spent observing this plant.

All statistical analyses were conducted in R version 3.3.2 (R Core Team 2016). When comparing the bee functional groups from the hand-collected specimen data to the observed data, only data collected from the same garden were compared.

To visually compare the changes in community composition over time between the observational and specimen collections, stacked area graphs were created (Wickham 2009). Next, the observed and hand-collected specimen data were standardized by time spent observing (bees/minute), paired by plant and period (i.e. *Asclepias* sp. in Period 3), and then were plotted by bee functional group (i.e. honey bees). The linear relationship between the data types and the associated Spearman rank correlation coefficients were calculated.

To assess the differences in community composition between data collection methods, the *adonis* function in the package *vegan* was used (Oksanen et al. 2017). The *adonis* function runs a PERMANOVA test to analyze the similarity in community composition as determined by the Bray-Curtis similarity measure. This function was utilized to compare the difference in bee community composition at the functional group level between data types (observed vs. collected), sites (counties), and to see if there was an interaction between location and data type on community composition. To determine which bee functional groups contribute the most to differences between the observed and collected community compositions, a SIMPER analysis was conducted (Oksanen et al. 2017). SIMPER analyses looks at the similarity of the percentages of each member of a community, or in this case, each bee functional group, to determine where and by what

percentage do each functional group contribute to the overall community-level differences. In Prince George's county, no observational data was submitted and therefore this data was not included in the PERMANOVA and SIMPER analyses. These analyses were only conducted the remaining three counties where both observational and specimen data were collected.

The observational data was assessed for biological accuracy and corrected when appropriate. For example, the "other metallic bees" represent bees in the genus *Osmia* which complete their life cycle in early spring (Bosch and Kemp 2000) and should not be reported after June. After corrections were made, the PERMANOVA and SIMPER analyses were recalculated.

Results:

Data preparation

In 2015, 13 locations were monitored by participants but 2 sites lacked sufficient data and so were removed from analyses. Similarly, in 2016, of the 25 sites where data was collected, 8 sites were removed.

In total, participants conducted 156 observational periods in 2015 and 316 in 2016; however, observations sometimes began earlier or continued later in the season than the hand-collected specimens were. Observational data collected outside of the 10 periods (Table 1.1) were not included in the data analysis (n=37 observations; 1.81%). There were 23 (1.12%) instances in which participants in 2016 failed to record either the start or end time of their observations on a specific plant.

In the hand-collected specimen data set, bees that were reported but not hand-collected, represent 31% (n=628) of the total number of bees. Almost half of the bees

reported but not hand-collected were the “large carpenter bees” with 4.4% (n=14) of their records coming from hand-collection events and an additional 305 records based on visual identification in the field. Honey bees and bumble bees were recorded but not hand-collected 42.6% (n=136) and 26.6% (n=134) of the time, respectively.

Citizen science - Training

In 2015, five 75-minute initial training session were conducted and 46 individuals attended (Table 1.2). Of the 46 trained participants, 21 (18 females, 3 males) submitted data at least once. The volunteers monitored native bees in 13 different locations (**Error! Reference source not found.**1.2). The average pre-training score was 37 ± 15.0%, and the post-training score averaged 55 ± 20.3%. The post-training quiz scores were higher than the pre-training quiz scores (mean improvement: 18 ± 20.0%, t_{44}=-5.966, p<0.0001; **Error! Reference source not found.**). On average, 42 volunteers self-reported their pre-training pollinator identification knowledge as 2.7± 0.98 out of 5.

	2015	**2016**
Data sheets submitted	156	316
Hours of observation	161	349.4
Number of pollinators observed	10,024	18,479
Bees	9,585	14,088
Butterflies	n/a	1,974
Other	439	2,098
Most commonly observed bees	Bumble bees (n=3,643; 36.3%)	Bumble bees (n=4,037; 21.8% of total, 28.7% of bees)
Most commonly observed butterflies	Not observed in 2015.	White & Sulphurs (n=694; 3.76% of total, 35.2% of butterflies)

Table 1.4: Citizen science observational data summary from 2015 and 2016.

		2015	2016	
		1st year participants	1st year participants	2nd year participants
Initial training	**Pre-quiz (%)**	37 ± 15.0 (n=45)	40 ± 15.7 (n=85)	64 ± 16.1 (n=11)
	Post-quiz (%)	55±20.3 (n=45)	59 ± 18.5 (n=83)	79 ± 18.0 (n=11)
	Paired t-test	t_{44} = -5.966; ***p* <0.0001**	t_{78} = -10.821; ***p* <0.0001**	t_{10} = *-5.036;* ***p* <0.0001**
Follow-up training	**Post-quiz (%)**	n/a	73 ± 16.4 (n=12)	83 ± 13.3 (n=6)
	Paired t-test	n/a	t_{10} = -1.1016; $p > 0.1$	t_5 = -0.25482; $p > 0.1$
	Specimen quiz (%)	n/a	59 ± 11.0 (n=12)	67 ± 8.7 (n=6)

Table 1.3: Participants were quizzed at the beginning and end of their training sessions with pictures of pollinators with an improvement in score demonstrating participants learning to identify pollinator functional groups. All participants in both years improved their quiz score after the training session indicating that the training sessions were successful at teaching participants to identify pollinator functional groups. Even returning participants (2nd year participants) in 2016 improved quiz scores after the initial training session, showing that participants of all previous skill levels were benefitting from the training session. In 2016 there was a follow-up training session conducted 6-8 weeks after the initial training session where participants were given another picture quiz and a quiz of pinned pollinator specimens to identify. Both first- and second-year participants scored similarly to their post-quiz score from the initial training session demonstrating that participants were able to retain the pollinator knowledge that they learned at the initial training session. First year participants averaged 59% on their specimen quiz while second year participants averaged 79%.

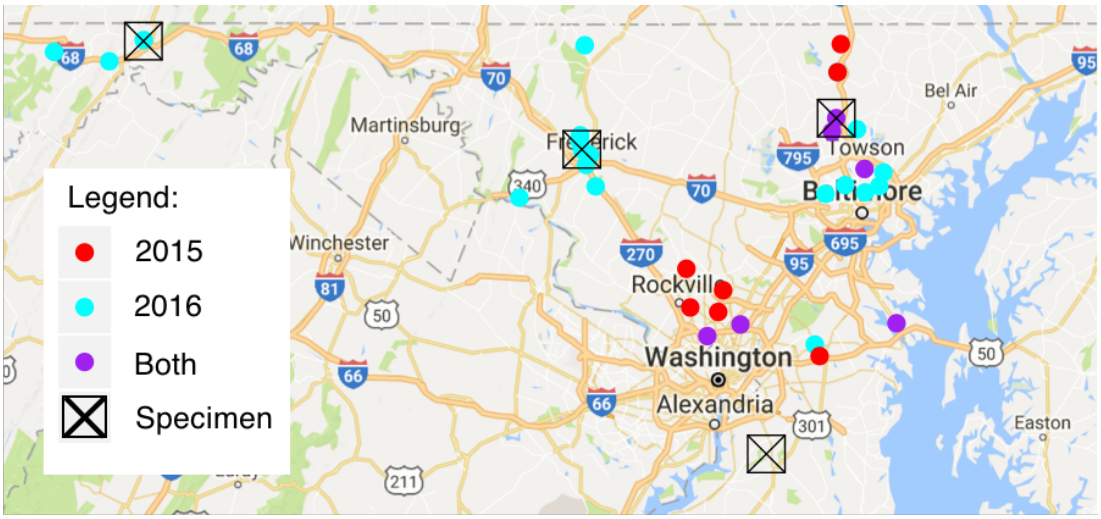


Figure 1.2: The locations where native bees and butterflies were monitored in the Maryland Native Pollinator Survey in both years. Sites that were only monitored in 2015 (n=6), are marked in red, 2016 in light blue (n=19) and sites monitored in both years are marked purple (n=6). The locations where bee specimens were collected are denoted by a black box with an "X" through it (n=4). Prince George's county did not submit observational data for their demonstration garden even though bee specimens were collected there, indicated by the specimen site lacking a corresponding field site circle of any color.

During the 2016 field season, 105 volunteers participated in one of six two-hour training sessions. Of the 105 trained participants, 28 (23 females, 5 males) submitted data (Table 1.2). The volunteers monitored either bee functional groups, butterfly functional groups or both. Most (87.8%) volunteers chose to monitor both bee and butterfly functional groups. In 2016 volunteers monitored 25 sites in seven counties (Figure 1.2). Of the six counties that hosted initial training sessions, only Howard County did not submit any observational data. Two additional counties, Garret and Montgomery, were monitored in 2016 by volunteers. Both first year and second year participants had higher post-quiz scores (first-year: 59 ± 18.5% (n=83); second-year: 79 ± 18.0% (n=11)) when compared to pre-quiz scores (first-year: 40 ± 15.7% (n=85); second year: 64 ± 16.1%

(n=11) **Error! Reference source not found.**.3). However, in 2016, the second-year participants scored higher than first-year participants in both the pre- (t_{12}=-4.6875, p<0.001) and post-quizzes (t_{13}=-3.4576, p<0.01). Collectively, 2016 participants self-reported their pre-training pollinator identification knowledge as 2.3 ± 0.87 out of 5 on average.

The secondary pictorial-quiz was administered to 28 people at the follow-up training sessions. The scores of this quiz were slightly higher, although not significantly higher, or lower than the post-quiz scores at the end of the initial training session for both first- and second-year participants (first-year: t_{10} = -1.1016, p=0.2964; second-year: t_5 = -0.25482, p=0.809; **Error! Reference source not found.**.3). The average score of specimen quiz presented to the volunteers at the follow-up training was 59 ± 11.0% (n=12) for first-year participants and 67 ± 8.7% (n=6) for second-year participants.

Citizen science – Exit survey

Six participants returned the 2015 exit survey. Most (4) volunteers found the initial training session, monitoring guide, and pocket guide helpful. When asked if they would participate again in 2016, two thirds of respondents indicated that they were likely to. Survey respondents made several suggestions to improve the survey, including a desire to have more clear and intuitive bee functional groups, more variety in the monitoring guide pictures, greater transparency about time commitment needed to participate, and better methods to record and submit data (i.e. a fillable PDF or online form).

Feedback from the 2015 participants indicated that some bee functional groups needed renaming or restructuring (Appendix F: Lists of pollinator species by functional

group). For clarity, some of the bee functional groups were renamed: the “hairy-leg bees” became the “long-horned bees”, the “green sweat bees” became the “green metallic bees”, and the “metallic hairy belly bees” became the “other metallic bees”. Participants also indicated difficulty in distinguishing the “dark bees” from the “dark hairy belly bees”. These groups were distinguished by determining where the bee carries pollen, either on the underside of their abdomen as in the “dark hairy belly bees” or in another in location. To assist with dark bee identification, in 2016, the dark bees were no longer broken up into functional groups based on where they carried pollen but by size: “large dark bees” (>1 cm) and “small dark bees” (<1 cm). If volunteers were well-versed in bee identification they had the option to still distinguish between large and small dark bees that did and did not carry pollen on the underside of their abdomen. Finally, the functional group containing kleptoparasitic bees known as the “cuckoo bees” were removed from the survey in 2016. This group of bees was rarely observed in 2015 (n=11, 0.11% of total observations) and participants reported having difficulty identifying this bee functional group as they were unsure if they could distinguish “cuckoo bees” from wasps.

Twenty-nine volunteers responded to the 2016 exit survey, 21 of which submitted data sheets during the field season. Some respondents (8), who attended one or both training sessions but did not participate in data collection indicated that they did not feel confident with their level of pollinator identification following the training sessions. When asked about the initial training session, 23 respondents found the initial training session helpful while 4 respondents either did not or did not find it sufficient for confident functional group identifications. The follow up training was evaluated by 16

respondents, 15 of which felt that the training session was helpful. Participants (27) found the monitoring guide helpful for classifying floral visitors to functional group. Most (22) indicating that they referred to it often while conducting observations and in-between observations. Similarly, 23 respondents indicated that the pocket guide was useful and was frequently used during observations. When asked about future participation, 19 of 29 respondents indicated that they were likely to participate again.

The data generated in both years of this survey can provide insights into local pollinator communities that may be useful to Master Gardeners, as they frequently give educational talks or present at outreach events. When asked if they would use the results of this survey for educational purposes, 3 of 6 respondents in 2015 indicated they would use the collected data and in 2016, 13 of 29 respondents indicated that they had an interest in using the results from this survey.

Citizen science – pollinator observations

In the 2015 field season, a total of 156 data sheets were submitted documenting 10,024 pollinator observations. This represented 161 hours of observations. Generally, as the season progressed participants spent less and less time observing floral visitors (**Error! Reference source not found.**a.). The most commonly observed group of bees were "bumble bees" (n=3,643 or 36.3% of all observations). The "other" category accounted for 439 (4.38%) of the observations and included unidentifiable bees, butterflies, moths, skippers, wasps, beetles, flies, and hummingbirds.

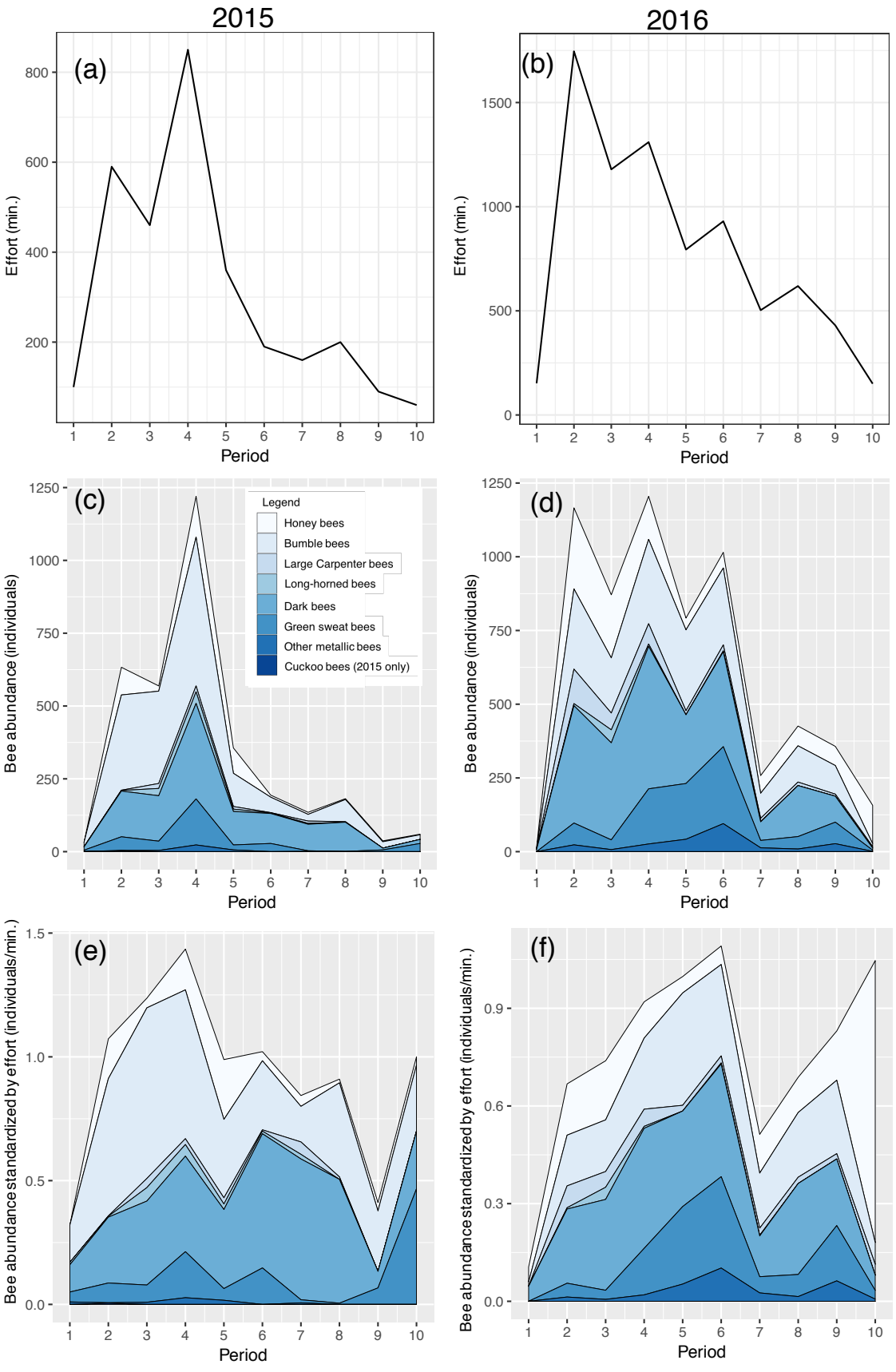

2015
2016
(a)
(b)
(c)
(d)
(e)
(f)
Effort (min.)
Period
Bee abundance (individuals)
Bee abundance standardized by effort (individuals/min.)
Legend
Honey bees
Bumble bees
Large Carpenter bees
Long-horned bees
Dark bees
Green sweat bees
Other metallic bees
Cuckoo bees (2015 only)

Figure 1.3: Participant effort, in minutes spent observing, was high at the beginning of the field season, but declined over time in both years (a. & b.). Raw bee abundances in both years decline similarly to the reduction in participant effort (c. & d.). Standardizing observations by effort (e. & f.) allows for a comparison of data over the season and between years. Even after adjusting for effort we document a steep decline in bee abundance per minute effort in period 9 (e.) and period 7 (f.).

Volunteers submitted 316 data sheets during the 2016 field season, representing 349.4 hours of observation time. As in the previous year participants spent less and less time observing flowers as the season progressed (Figure 1.3 a & b). In total, volunteers observed 18,479 pollinators including 1,974 butterflies, 14,088 bees, and 2,098 "other" pollinators. The "other" pollinator group included wasps, beetles, flies, hummingbirds, hummingbird hawk moths, and other moths. As in 2015, the "bumble bees" were the most commonly observed bee functional group with 4,037 (21.8% of total observations, 28.7% of bees observed) observations recorded. The most frequently observed butterfly functional group were the "whites and sulphur butterflies" with 694 observations reported (3.76% of total observations, 35.2% of butterfly observations).

Specimen collection

In 2016, 661 bees were collected in bowl traps and 1,276 bees were hand-collected from flowers. The collected bees represented 83 species from 27 genera (Appendix G: List of species collected in the 2016 specimen collection). Based on the records in discoverlife.org for Maryland, eight new county records, seven in Baltimore county and one in Allegany county, were created from this bee collection (**Error! Reference source not found.**

Bee species:	Bee gender:	County:
Lasioglossum versatum Robertson	female	Baltimore
Lasioglossum trigeminum Gibbs	female	Baltimore
Triepeolus remigatus Fabricius	female	Baltimore
Epeolus bifasciatus Cresson	male	Baltimore
Hylaeus mesillae Cockerell	female	Baltimore
Heriades carinata Cresson	female	Baltimore
Megachile exilis Cresson	female	Alleghany
Megachile exilis Cresson	male	Baltimore

Table 1.4: New county records of bee species collected in the 2016 specimen survey. These records come from both hand-collected and bowl trap specimens.

The community composition of bee functional groups from observational data differed from the composition of the hand-collected specimen data (PERMANOVA test df= 1, $p<0.01$). Honey bees (17.5%), bumble bees (15.4%), and small dark bees (11.8%) were responsible for most of the differences between the community composition of the two data types (hand-collected vs. observed, **Error! Reference source not found.**). Community compositions, as expected, also differed between the three sites (df=1, $p<0.001$). However, there was no interaction between data type and site (df=1, $p>0.05$). This indicates that the community composition differences between data types were the same regardless of site.

Bee functional group	Average abundance (bees/period)		Contribution to difference %
	Observations	Specimen collection	
Honey bees	28.48	14.28	17.48
Bumble bees	21.13	19.88	15.43
Small dark bees	19.70	16.64	11.84
Large dark bees	8.91	6.60	8.61
Large Carpenter bees	7.74	6.00	6.20
Green metallic bees	3.96	4.48	3.40
Other metallic bees	1.83	0.12	1.32
Long-horned bees	0.13	1.44	0.95

Table 1.5: SIMPER analysis results indicated the average abundance of each functional group of bees observed or hand-collected per two-week period (see Table 1.1) and the percentage that each functional group contributes to the community composition differences between data types (observational vs. hand-collected specimen data). Honey bees and bumble bees contributed the most to the differences between the community compositions of the observed and hand-collected data.

"Other metallic bees" were not collected at any site after period 2, however they were observed by participants in multiple sites after this time. When the "other metallic bees" after period 2 were removed, the community composition between data collection methods no longer differed (PERMANOVA test, df=1, $p>0.1$). Similarly, when observed values of large carpenter bees and bumble bees were corrected in periods 9 and 10, community composition no longer differed between data collection methods (df=1, $p>0.1$ Figure 1.4).

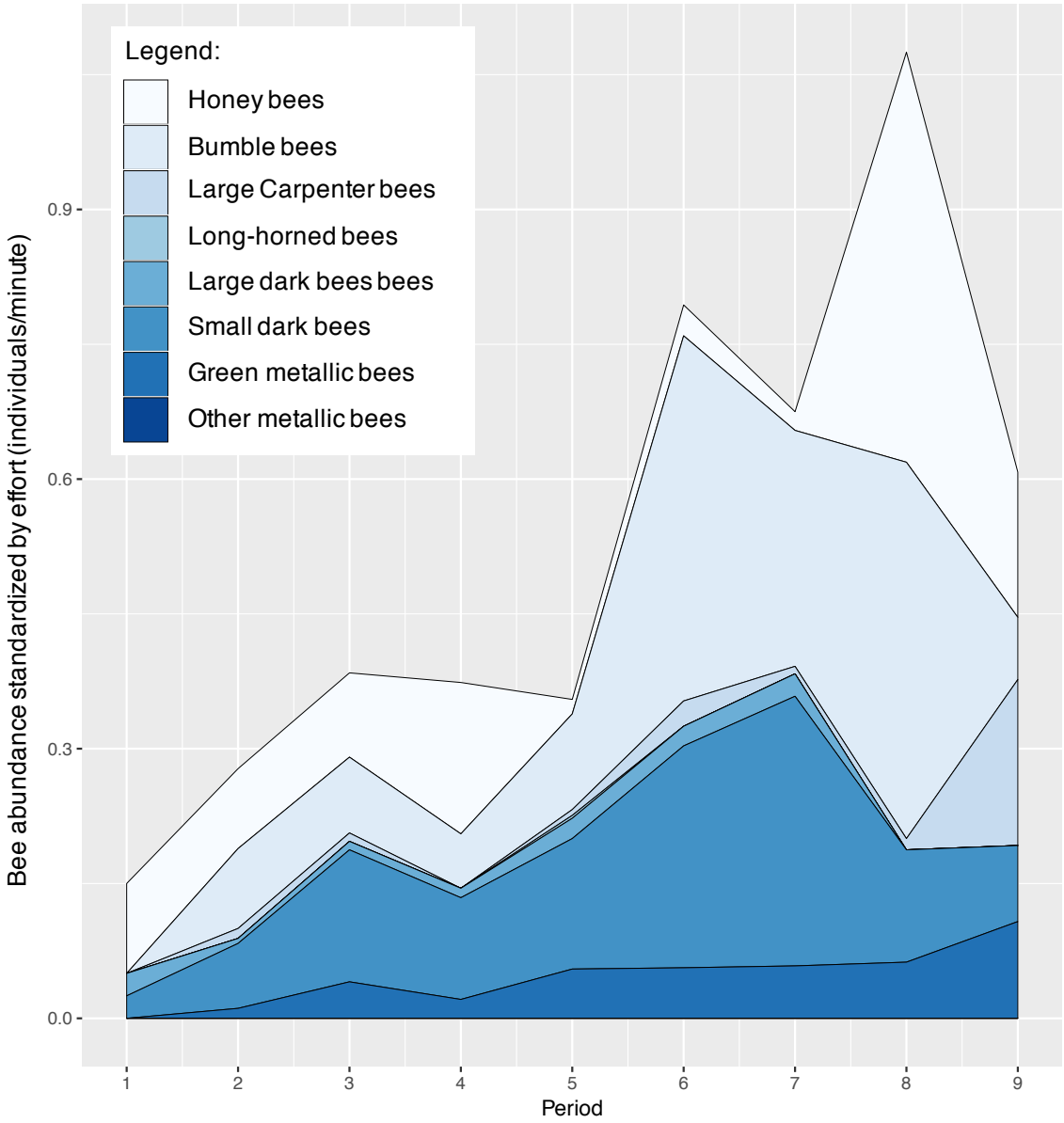


Figure 1.4: 2016 hand-collected bee specimen data standardized by effort in minutes. There is no late season decline in bees per minute as experienced in both seasons of observationally collected data. Hand-collected specimen data from period 10 is not available due to a lack of flowering resources in the monitored gardens at this time.

Strong relationships were found between the number of bees hand-collected and observed for the "honey bee" (Spearman rank coefficient: r_s= 0.617, $p<0.05$) and "bumble bee" (r_s=0.781, $p<0.05$) functional groups. The "green metallic bees", and "small dark bees" demonstrated a moderate relationship (r_s=0.550, $p<0.05$; r_s=0.474

p<0.05 , respectively) while the remaining bee functional groups demonstrated weak relationships between the observational and hand-collected specimen data ("large carpenter bees" r_s= 0.371, p<0.05; "large dark bees" r_s= NA, p>0.05; "long-horned bees" r_s= -0.039, p>0.05; "other metallic bees" r_s= -0.027, p>0.05; **Error! Reference source not found.**).

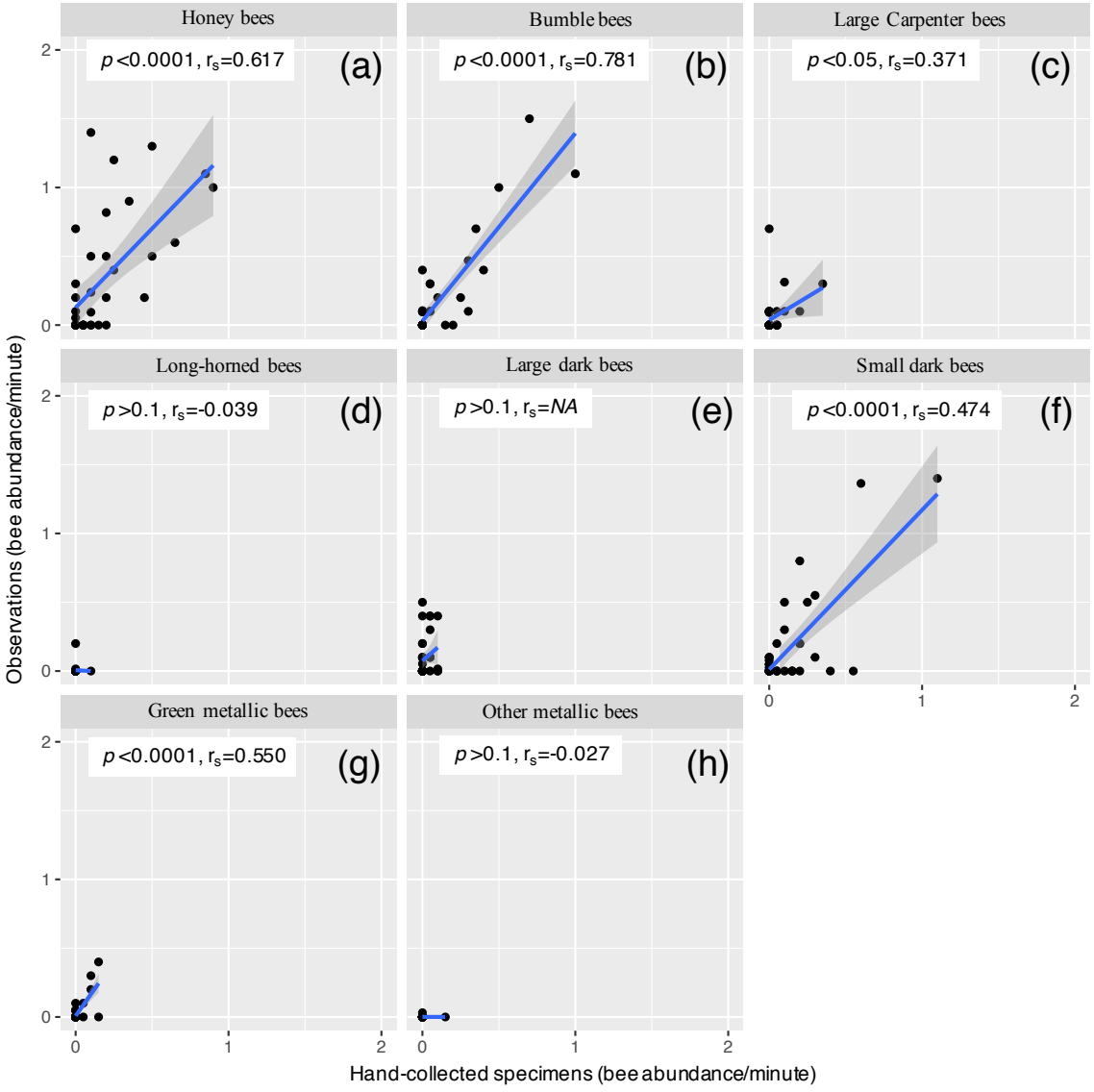


Figure 1.5: Relationships between the observed and hand-collected data collected in 2016. All data points are standardized by plant, period (see Table 1.1), and time. Data presented are from the three locations where both observational and hand-collection specimen data are available: Baltimore, Allegany and Frederick counties. Based on

Spearman rank calculations, strong relationships were found for the honey bees (a; r_s=0.617) and bumble bees (b; r_s=0.781).

Discussion

Certain bee functional groups, honey bees and bumble bees, demonstrated linear relationships between the citizen scientist observational data and the hand-collected specimen data. This is an encouraging finding as the use of citizen science to monitor pollinator communities. Pollinator communities are diverse and species-rich, and for many of these insects, little is known about their floral preferences. Citizen science has the potential to collect the information needed about pollinator community composition, floral preference, and population dynamics to fill existing knowledge gaps about pollinator biology. However, our results show that the relationships that we observe are not always strong and can improve. Ways in which we can improve our results include: additional participant training leading to better observer accuracy and corrections based on annual life cycles.

The ability of citizen scientists to properly identify floral visitors improved with training, and continued to improve with further training and experience, as indicated by an average quiz score improvement of approximately 17% over both years (Table 1.3). Others citizen science projects have documented similar findings, known as the "first-year" effect (Dickinson et al. 2010). For example, members of iSpot, an interactive online community where individuals submit and identify photos of plants or wildlife, increased their ability to correctly identify photographed organisms over time. iSpot participants also have access to online quizzes of varying difficulty to self-test and improve their identification skills ((Scanlon et al. 2014). When analyzing data from the long-term

Breeding Bird Survey data, removing data collected by first-year participants between 1966 and 1991 helped to reduce bias in population trend estimates (Kendall et al. 1996). Future use of the monitoring guide and the methods used in this project to evaluate pollinator communities may benefit by implementing a more regular self- or peer-to-peer testing and review process. For instance, online quizzes and review sessions that participants need to complete prior to bi-weekly observations.

More participants generate larger datasets, and so retaining participants for a complete field season is important (Dickinson et al. 2010). In our study, most participants who started collecting data, did so for the entire season. Even so, retaining more of the participants would have created a more spatially complete and valuable dataset. Other studies have increased retention rates by increasing communication between participants and researchers (Dickinson et al. 2012; Birkin and Goulson 2015) or by providing incentives. Successful incentives for participation incorporate rewards of either monetary value (Rogstadius et al. 2011) or intrinsic value (i.e. contributions toward scientific research (Silvertown 2009)). For instance, to encourage participation in the 2012 Great Backyard Bird Count, researchers offered "The Great Horned Owl Award", a certificate presented for participation (Dickinson et al. 2012). eBird, a citizen-based bird observation network, saw an increase in participation after a shift in the perspective of their research goals from aiming to create a scientifically valuable bird database to creating a useful resource for bird watchers (Sullivan et al. 2009).

In this survey, the participant effort declined over time, with a sudden decrease in minutes spent observing in the late summer and early fall (**Error! Reference source not found.**). Both field seasons show this trend, which may correspond to participants going

on vacation or getting busier as the academic school year begins. We did not attempt to elucidate the cause of this decline in our study, however, research to better understand the driver(s) of this trend would be beneficial. Future citizen science pollinator monitoring studies may benefit from implementing incentive strategies to better retain participation throughout the field season.

Honey bees and bumble bees correlated strongly between the observational and hand-collected specimen data, however these two groups also contributed the most to differences in community composition between data collection methods. Indicating that while participant observations did not match the hand-collected specimen data, we can still define a relationship between these data sets. It is interesting to note that some of the larger, common bees ("honey bees" and "bumble bees") were the bees contributing the most to the differences between community compositions with the observers reporting more "honey bees" and "bumble bees" than were collected. It may be that observers counted the same bee more than once, or that the removal of foraging honey bees prevented the bee from recruiting more foragers upon returning to the colony (Visscher and Seeley 1982).

Another reason for the differences detected between the observational and hand-collected specimen data, is confusion of bee functional groups. This is likely the case when it comes to "large carpenter bees" and "bumble bees" late in the field season (late-September and October). While "bumble bees" were over-reported by participants, in contrast, "large carpenter bees" were under-reported by observers (**Error! Reference source not found.**a). Large carpenter bees are abundant in the spring with fewer adults foraging during the summer months. In the fall, the large carpenter bees become

abundant again as the first-year juvenile bees first forage in search of nectar (Gerling and Hermann 1978). At this point in the year, the bumble bee colonies have produced queens and the number of foraging workers has declined, sometimes dropping to zero (Williams et al. 2014). Since “bumble bees” and “large carpenter bees” are very similar looking (**Error! Reference source not found.** c &d), it is likely that in the fall, when “bumble bees” are still frequently observed, some observers were confusing these groups of bees. If the observational data from periods 9 and 10 are corrected with the generated linear relationships, the community composition between the data collection methods no longer differ. While this result implies that late season misidentification of “large carpenter bees” and “bumble bees” contributes to the differences in community composition differences, this result should be interpreted cautiously as neither voucher specimens nor photographs exist to confirm the identity of these bees.

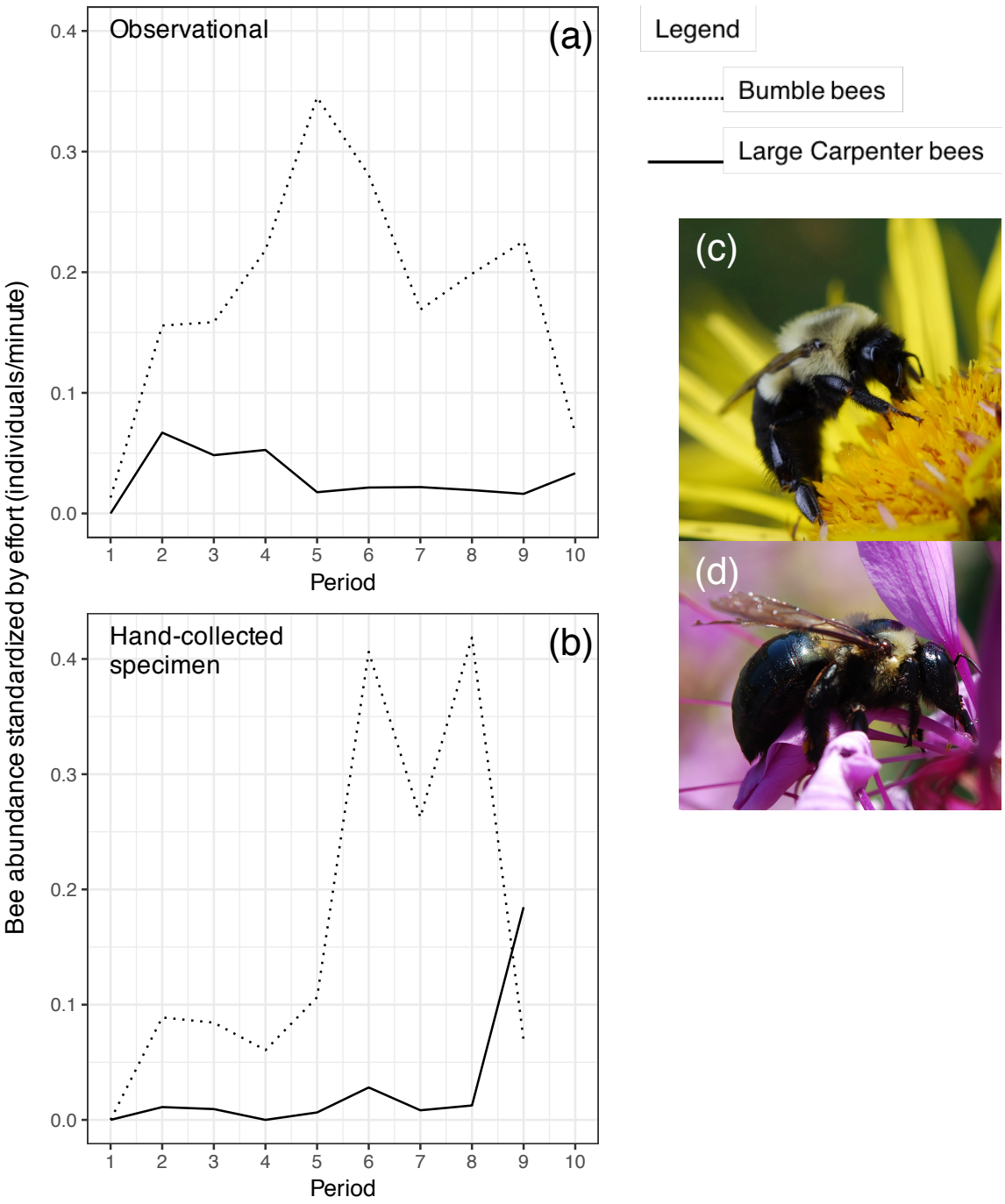


Figure 1.6: In Period 9, participants observed (a) 0.23 “bumble bees” per minute and 0.02 “large carpenter bees” per minute as opposed to the 0.07 “bumble bees” per minute and 0.18 “large carpenter bees” per minute hand-collected (b). These differences are likely due to participants misidentifying the similar-looking “bumble bees” (c) and “large carpenter bees” (d) late in the field season. In the early fall, bumble bee colonies have finished producing reproductive gynes and workers are no longer foraging to support the colony, thus bumble bee observations should decrease at this time. In contrast, juvenile large carpenter bees forage in the fall to store up energy to survive the winter months.

Hand-collected specimen data from period 10 is not available due to a lack of blooming floral resources at the monitored sites. Photos c. & d. courtesy of John Baker.

While the "other metallic bees", or bees in the genus *Osmia*, did not contribute significantly to the differences in community composition between the two groups, observers reported seeing this functional group throughout the field season, likely long after their natural annual life cycle had finished. The identification accuracy of this group of bees may increase if the study began earlier in the spring to encompass more of the *Osmia* sp. phenology, giving participants the opportunity to witness these bees foraging. While we know that the bees that participants reported seeing in this functional group late in the season were not *Osmia* sp., they cannot be confidently reclassified into another bee functional group without specimens or photos. "Other metallic bee" specimens were not hand-collected after Period 2 in June at any site. Removing the "other metallic bee" observations after June (Periods 3-10) from the PERMANOVA analysis, alters the end results: community compositions are no longer different.

Future directions

The use of the internet in citizen science projects aided in its resurgence, providing volunteers with the opportunity to instantaneously upload data while in the field (Dickinson and Bonney 2012; Scanlon et al. 2014). A native pollinator survey, like this one, could benefit from the incorporation of more technological components (e.g. an app with a compatible website for submitting and viewing data). A user-friendly app or website could more easily cater to a younger, and potentially untapped, demographic such as school children (Evans et al. 2001; Weckel et al. 2010; Tweddle et al. 2012; Hidalgo-Ruz and Thiel 2013) of participants and could expedite the data entry process.

For example, nearly 1000 school children from 39 schools documented plastic debris on Chilean beaches in the 'National Sampling of Small Plastic Debris' citizen science project (Hidalgo-Ruz and Thiel 2013). Furthermore, younger participants may have sharper eyesight, helping them to better distinguish pollinator functional groups.

While bees and butterflies are the primary pollinators, there are many other important pollinators such as beetles, moths, flies, and hummingbirds visiting flowers. Many studies that examine pollinator floral preferences focus on a small set of pollinators: bumble bees: (Patten et al. 1993), bees: (Frankie et al. 2005; Tuell et al. 2008; Williams et al. 2015), bees and syrphid flies: (Bahlai and Landis 2016), or butterflies: (Jennersten 1984; Corbet 2000; Shackleton and Ratnieks 2016), but few studies examine the entire community of pollinators at once (but see: (Corbet et al. 2001; Bartomeus et al. 2008). Pollinator communities are complex and involve many intricate interspecies relationships. These communities are altered by factors such as the introduction of invasive species (Bartomeus et al. 2008), climate change (Breed et al. 2013) and habitat loss (Fortuna and Bascompte 2006; Ricketts et al. 2008; Winfree et al. 2009). Understanding how the entire pollinator community responds to these changes can help guide conservation and restoration efforts. Expanding this study to encompass all pollinators would increase understanding about relationships between plants and pollinator communities in a variety of settings.

Chapter 2: An Assessment of the Attractiveness of Pollinator Plants Using a Combination of Citizen Science Observational and Hand-Collected Specimen Data

Abstract:

Native and managed pollinators experience stress due to habitat loss and fragmentation in response to urbanization. Despite frequent habitat fragmentation, suburban landscapes retain the potential to host a diverse native pollinator community in green spaces, conservancies, and gardens. Plantings intended to benefit pollinators have become a popular installment in many yards and managed gardens. Most gardens are planned using pre-existing pollinator garden planting lists or books. However, many of these lists are based upon the author's personal experiences and cover a broad spatial area. To create more reliable planting recommendations, a small-scale, data-driven assessment of pollinator preference is needed. This study examines the relative attractiveness of 23 plant species in Maryland (5 non-native, 18 native species) to pollinators. The data used to assess these pollinator plants was obtained from the Maryland Native Pollinator Survey in 2015 and 2016. These plants were assessed on five metrics: bloom length, visitation rates, pollinator richness and evenness, and value to specialist pollinators. Plants received a score based on the sum of these five metrics to determine their attractiveness to pollinators. Plants were divided up into three portions of the field season: 'early', 'middle', and 'late'. In the early season *Asclepias incarnata* scored highest and *Thymus vulgaris* scored the lowest. Similarly, in the 'middle' season, *Asclepias incarnata* scored highest, and *Thymus citriodorus* scored the lowest. *Symphyotrichum novae-angliae* scored highest in the late season and *Rudbeckia triloba* scored the lowest. These scores can provide a framework for assessing the relative value of pollinator plants on a smaller scale. This method can be applied to other locations to determine how the value of a pollinator plant changes throughout the landscape and over time.

Introduction:

Globally, native and managed pollinators have experienced increased stressors over the last five decades (Potts et al. 2016). A myriad of factors are responsible for these stressors including: exposure to pesticides (Scott-Dupree et al. 2009; Potts et al. 2010; Smith et al. 2014; Bernauer et al. 2015), the introduction and spread of new and possibly more virulent parasites and pathogens (Genersch et al. 2006; Colla et al. 2006; Vanbergen and The Insect Pollinators Initiative 2013; Goulson et al. 2015), a decline in habitat quality (Jennersten 1984; Curtis et al. 2015; Potts et al. 2016) and habitat loss and fragmentation due to anthropogenic factors such as urbanization or climate change (Fortuna and Bascompte 2006; Forister et al. 2010; Potts et al. 2010; Goulson et al.

2015). Pollinators provide the ecosystem service of pollination that is vital to agricultural crop, nut, and seed production (Klein et al. 2007; Potts et al. 2010; Ollerton et al. 2011). While the major agricultural pollinator is the honey bee (Calderone 2012), many native bee species also contribute to crop pollination (Vicens and Bosch 2000; Kremen et al. 2002; Winfree et al. 2007; Garibaldi et al. 2013; Gaines-Day and Gratton 2016) and are often responsible for facilitating plant reproduction in many natural systems (Wcislo and Cane 1996; Fortuna and Bascompte 2006).

Though suburban landscapes are often composed of a mosaic of land use types, they retain the potential to host a diverse native pollinator community (Smith et al. 2005, 2006; Fetridge et al. 2008; Owen 2010); often in the form of green spaces, conservancies and gardens (Salisbury et al. 2015). Similarly, hedgerows of flowers planted along agricultural fields can support pollinator and natural enemy communities by providing forage and nesting resources (Patten et al. 1993; Morandin and Kremen 2013; Williams et al. 2015). While agricultural hedgerows are valuable to many pollinators, the focus of this paper is on plantings in urban and suburban settings.

When establishing or improving existing green spaces, one may consult a book or website for guidelines and suggestions to ensure their garden will best support local pollinators. Many educational resources exist that provide lists of pollinator-friendly plants (Tallamy 2007; The Xerces Society 2011, 2016b, a; Holm 2014; Hayes 2016). However, there are some issues with many of these lists including: the spatial scale that lists are created for and that the lists are often based upon the authors personal experiences rather than on experimentally collected data.

Pollinator garden planting recommendations are often made at large, regional scales, and cover many distinct physiographic regions. This ignores microclimatic and macro-environmental differences within the region. For instance, Maryland is typically considered a part of the mid-Atlantic region along with: North Carolina, Virginia, West Virginia, Delaware, New Jersey, Pennsylvania, and Washington D.C. (Adamson et al. 2015). Yet, Maryland alone has five distinct physiographic regions including: three mountainous, a piedmont plateau, and a coastal plain region, each with their own unique biota (Reger and Cleaves 2008). Throughout these physiographic regions, the environmental conditions change and so do the accompanying flora and fauna, including pollinators. To make accurate planting recommendations for pollinators in a state like Maryland, studies that focus on smaller areas are needed.

More recently, studies have begun to use experimental data to determine which pollinator plants are the most valuable in their respective region, but these recommendations are mainly from just a few locations (i.e. Michigan (Fiedler and Landis 2007; Tuell et al. 2008; Williams et al. 2015), California, and Florida (Williams et al. 2015), Europe (Garbuzov and Ratnieks 2014, 2015; Shackleton and Ratnieks 2016)) and each paper uses a different method for assessing which plants are the most attractive to pollinators. For example, (Tuell et al. 2008) collected bee specimens and conducted observations to determine which bees were visiting the species flowers in their study. They examined floral characteristics like floral area per meter and corolla width to explain bee preference. In contrast, (Williams et al. 2015) looked at the attractiveness of pollinator-friendly plant mixes instead of specific plant species.

There are many floral traits that play a role in a flower's respective attractiveness to pollinators (i.e. quality and quantity of nectar and pollen, corolla length, color, etc. (Fenster et al. 2004). Furthermore, different pollinators are looking for particular things in a flower. For example, when considering the nutritional reward that pollinators receive from visiting a flower, most butterflies only need nectar (O'Brien et al. 2004) while bees need both nectar and the pollen (Michener 2007). And as such, pollinators will utilize different floral resources.

Often plants and pollinators have close-knit relationships, that have evolved together (Hu et al. 2008). For example, the tropical plant species *Zaluzianskya microsiphon* (Kuntze) is primarily pollinated by a long-tongued fly species. The corolla depth of this plant species varies throughout its range and similarly, the tongue length of the corresponding fly pollinator varies (Anderson and Johnson 2008). Pollinators that rely on a single or a few plant species for their food sources are considered specialists on those plant species (Waser and Ollerton 2006). However, some pollinators, like honey bees, are generalist foragers in that they will feed on many different flowers (Menzel et al. 1993). Therefore, the value of plants utilized by specialist pollinators is greater than plants only used by generalists, as their foraging range is wider (Fowler and Droege 2016). Specialists are pollinating insects that forage on a narrow set of plants. This is often at the family level, but some bees are known to further specialize on a particular plant genus (Fowler and Droege 2016).

In this study, we assessed different commonly recommended pollinator plant species for their respective attractiveness to different pollinators in Maryland. This study takes a novel approach to quantifying floral attractiveness to pollinators by combining

multiple metrics for attractiveness. We used several different metrics to grade flowering plants including bloom length, pollinator visitation rates, the richness and evenness of the pollinator communities visiting the flowers, and the value to specialist pollinators. By assessing these metrics together, we can determine which pollinator plants among those studied are the most valuable to Maryland's pollinators. Furthermore, this study improves upon exiting planting lists by making Maryland-specific, data-driven recommendations.

Methods:

Data preparation:

To assess the attractiveness of each flower species, data from the Maryland Native Pollinator Survey was used (Bernauer 2017). This project generated observational and hand-collected specimen data on which pollinators were visiting specific plant species in Maryland. For the methods of data collection, see: *Chapter 1: The Maryland Native Pollinator Survey: a useful method for citizen scientists to survey pollinators visiting floral resources* (Bernauer 2017). For the purposes of this study a plant record is a single 10-minute hand-collected specimen or observational data collection period; for the remainder of this paper observational and specimen data will no longer be separated.

Before data analysis, data was gathered at the level of individual plant species. Plant species not included in the standard plant list specified in methods section of *Chapter 1: The Maryland Native Pollinator Survey: a useful method for citizen scientists to survey pollinators visiting floral resources* were not analyzed. These plants were removed to keep the focus of this study narrow and to complement the results from *Chapter 1*. While the data collection for the Maryland Native Pollinator Survey was supposed to take place on days with optimal foraging conditions, this was not always the

case. When data was collected, the weather was also measured in three ways: the temperature (50s, 60s, 70s, 80s, 90s, 100+ °F), wind (still, light breeze, windy, gusty), and cloud cover (clear, partly cloudy, mostly cloudy, overcast). Optimal foraging conditions in this study are days in which the wind was "still" or there was a "light breeze" and the cloud cover was "clear" or "partly cloudy". Plant records that were collected on days with sub-optimal weather conditions were excluded from analyses so that the results of this study can be useful when comparing to other similar studies where data was only collected during optimal foraging conditions (Tuell et al. 2008; Isaacs et al. 2009; Williams et al. 2015).

Plants bloom at different intervals throughout the field season. To make meaningful comparisons of pollinator plant attractiveness, only plants that bloom at the same time were contrasted. The field season was portioned into three parts: the early season (May to June), mid or middle season (July to August), and late season (September through November), following the example of (Tuell et al. 2008). Plant species with fewer than five plant records per portion of the field season were removed.

Plant attractiveness metrics

We quantified five different metrics to assess plant attractiveness to pollinators: bloom length, visitation rates, pollinator richness and evenness, and specialist value. The five criteria for assessing plant attractiveness were calculated and each metric was scaled down to a maximum value of 1. Metrics were scaled so that each of the five metrics were equally important to the total score.

The first metric we assessed was bloom length (B), or a sum of the number of weeks that the plant species was in bloom. Bloom length was determined by the span of

weeks that plant records existed for a particular species and was averaged between years when the data was available. To scale down the bloom length metric, the plant's bloom length in weeks was divided by the total number of weeks in the growing season. Based on the scope of the data set from the Maryland Native Pollinator Survey, this was determined to span May 1 thru the second week in November, for a total of 29 weeks. No single species bloomed throughout the entire 29 week period, thus every plant scores less than 1 for this metric.

The visitation rate metric (V) is a measure of the number of pollinators visiting a given plant per minute. This was calculated by summing the total number of pollinators recorded on a plant divided by the time spent collecting data on said plant. The visitation rate metric was scaled down by dividing by the highest value of pollinators per minute recorded on one of the plant species analyzed in this study: 6.5.

For the richness metric (R), the number of pollinator functional groups recorded on a plant was counted. Floral visitors were categorized into 14 different functional groups of bees and butterflies and the maximum value a plant could score was 14. To scale down the richness metric, the number of recorded pollination functional groups was divided by 14.

A plant's evenness metric (E) was determined by Simpson's diversity index. Simpson's index (Simpson 1949) provides a measure of the evenness of the pollinator community recorded on each assessed plant. Plants that support a more even pollinator community (i.e. no single species dominates) have a higher Simpson's index making them more valuable to the pollinator community overall. Because the Simpson's diversity index has a maximum score of one, it was not further scaled down.

Lastly, the value to specialist pollinators (S) was determined for each plant at the genus or family level. A bee or butterfly is a specialist on a specific plant species if the plant either provides a larval host for butterflies and/or adult pollen and/or nectar source to at specialist bee or butterfly species. To determine the number of specialist pollinators that use a plant, two lists were used: the Central Maryland (Piedmont) list produced by the North American Butterfly Association (Gibbs et al. 1997) for butterflies and the Specialist bees of the Mid-Atlantic and Northeastern United States list (Fowler and Droege 2016) for bees. Each plant received a score between 0-3 for their value to specialist pollinators, one point was awarded for each of the following: supporting bee, adult butterfly, or larval butterfly specialists. For example, a plant that supported bee specialists but did not support adult or larval butterfly specialists would receive a score of 1. On the other hand, a plant that served as a larval host plant for a specialist butterfly and adult butterflies would score a 2. Similarly, a plant that supported larval butterflies and bee specialists would also score a 2 and so on. For a plant to score a 3, it supported specialist bees, adult butterflies, and provides a larval host plant for a specialist butterfly. The value to specialist pollinators metric was divided by three, giving a plant species a maximum score of one.

Once the metrics were calculated and scaled, they were averaged by plant species for a single portion of the field season. The averaged metrics for a plant species were summed and then divided by 5. The resulting value is a percentage, which can be converted to a final score out of 100. This final score will be known as the "pollinator attractiveness rating" or PAS for short and is illustrated in Equation (1).

(1)

$$\text{PAS} = \left(\frac{\text{B} + \text{V} + \text{R} + \text{E} + \text{S}}{5}\right) * 100$$

Data analysis:

All statistical analyses were conducted in R version 3.3.2 (R Core Team 2016). Pollination networks were constructed with the *bipartite* package (Dormann et al. 2008, 2009) to visualize the interconnectedness of plant-pollinator interactions and how they change throughout the field season.

Results:

Data preparation

The complete data set contained 2,962 plant records encompassing 210 plant species from 151 genera. After removing the plant records without species-level information available, there were 2,093 plant records remaining from 119 plant genera and 210 species. Removing the plants species not on the standard list of plants leaves 1000 plant records for 45 plant species representing 12 genera. Removing plant records with sub-optimal foraging weather yields 620 total observations, and 41 plant species from 12 genera. Plant species without five records in at least one portion of the field season were removed, leaving 542 plant records encompassing 23 species of plants in 11 genera. Eighteen of the remaining plants assessed are native to Maryland while the other five are non-natives (Table 2.1).

Season	Plant	Bloom length	Visitation rate	Richness	Evenness	Value to Specialists	Sum	Percentage	Ranking
Early	*Asclepias incarnata* L.	0.45	0.52	0.20	0.53	0.67	2.36	47.30	1
Early	*Asclepias syriaca* L.	0.38	0.36	0.21	0.59	0.67	2.20	44.06	2
Early	*Monarda fistulosa* L.	0.28	0.56	0.09	0.52	0.67	2.12	42.31	3
Early	*Asclepias tuberosa* L.	0.52	0.32	0.16	0.43	0.67	2.09	41.82	4
Early	*Echinacea purpurea* (L.) Moench	0.62	0.08	0.11	0.51	0.33	1.65	33.02	5
Early	*Monarda didyma* L.	0.28	0.16	0.12	0.47	0.33	1.36	27.21	6
Early	*Rudbeckia hirta* L.	0.59	0.16	0.09	0.04	0.33	1.21	24.11	7
Early	***Thymus citriodorus* (Pers.) Schreb.**	**0.24**	**0.32**	**0.13**	**0.43**	**0.00**	**1.12**	**22.40**	**8**
Early	***Thymus vulgaris* L.**	**0.52**	**0.12**	**0.09**	**0.25**	**0.00**	**0.98**	**19.53**	**9**
Middle	*Asclepias incarnata* L.	0.45	0.52	0.24	0.60	0.67	2.47	49.41	1
Middle	***Origanum laevigatum* Boiss.**	**0.38**	**0.88**	**0.49**	**0.70**	**0.00**	**2.45**	**48.90**	**2**
Middle	*Asclepias syriaca* L.	0.38	0.64	0.29	0.44	0.67	2.41	48.23	3
Middle	*Asclepias tuberosa* L.	0.52	0.44	0.14	0.48	0.67	2.25	44.94	4
Middle	***Origanum vulgare* L.**	**0.48**	**1.00**	**0.27**	**0.45**	**0.00**	**2.20**	**44.08**	**5**
Middle	*Echinacea purpurea* (L.) Moench	0.62	0.48	0.19	0.55	0.33	2.18	43.54	6
Middle	*Monarda fistulosa* L.	0.28	0.56	0.20	0.31	0.67	2.01	40.25	7
Middle	*Rudbeckia laciniata* L.	0.48	0.56	0.19	0.43	0.33	1.99	39.84	8
Middle	*Eurybia divaricata* (L.) G.L.Nesom	0.55	0.40	0.19	0.47	0.33	1.95	38.96	9
Middle	*Helianthus annuus* L.	0.48	0.60	0.14	0.28	0.33	1.84	36.78	10
Middle	*Rudbeckia hirta* L.	0.59	0.40	0.15	0.28	0.33	1.75	34.99	11
Middle	*Monarda didyma* L.	0.28	0.28	0.15	0.57	0.33	1.61	32.18	12
Middle	*Monarda punctata* L.	0.34	0.24	0.11	0.50	0.33	1.53	30.65	13
Middle	***Agastache foeniculum* (Pursh) Kuntze**	**0.48**	**0.40**	**0.19**	**0.46**	**0.00**	**1.53**	**30.57**	**14**
Middle	*Rudbeckia fulgida* Aiton	0.28	0.12	0.11	0.41	0.33	1.25	24.93	15
Middle	***Thymus citriodorus* (Pers.) Schreb.**	**0.24**	**0.16**	**0.11**	**0.65**	**0.00**	**1.17**	**23.31**	**16**
Late	*Symphyotrichum novae-angliae* (L.) G.L.Nesom	0.17	0.84	0.31	0.59	0.67	2.58	51.67	1
Late	*Solidago canadensis* L.	0.31	0.80	0.19	0.60	0.67	2.57	51.40	2

Season	Plant	Bloom length	Visitation rate	Richness	Evenness	Value to Specialists	Sum	Percentage	Ranking
Late	*Solidago caesia* L.	0.31	0.60	0.19	0.34	0.67	2.11	42.20	3
Late	*Rudbeckia laciniata* L.	0.48	0.44	0.24	0.57	0.33	2.06	41.24	4
Late	*Eurybia divaricata* (L.) G.L.Nesom	0.55	0.56	0.19	0.41	0.33	2.05	40.96	5
Late	*Symphyotrichum laeve* (L.) Á & D. Löve	0.34	0.52	0.24	0.50	0.33	1.94	38.82	6
Late	***Origanum laevigatum* Boiss.**	**0.38**	**0.52**	**0.31**	**0.46**	**0.00**	**1.67**	**33.33**	**7**
Late	*Solidago rugosa* Mill.	0.28	0.20	0.17	0.30	0.67	1.61	32.28	8
Late	***Agastache foeniculum* (Pursh) Kuntze**	**0.48**	**0.16**	**0.06**	**0.71**	**0.00**	**1.41**	**28.20**	**9**
Late	*Rudbeckia triloba* L.	0.21	0.04	0.04	0.50	0.33	1.12	22.32	10

Table 2.1: A ranking of the 23 plant species assessed as follows. Each plant was assessed with five different metrics that were summed and turned into a percentage. The percentage was used to rank each plant within each of the three portions of the field season. Plants that are not native to Maryland are bolded.

Plant attractiveness

Pollinator attractiveness scores (PAS) for the 23 plant species assessed in this study ranged from a low of 19.53 to a high of 51.67. The bloom length metric varied from 0.172 to 0.621, visitation rate from 0.04 to 1, richness from 0.036 to 0.486, evenness 0.04 to 0.71, and specialist value 0 to 0.667. *Thymus vulgaris* scored the lowest of all plants assessed with a PAS score of 19.53 and the overall highest-scoring pollinator plant was *Symphyotrichum novae-angliae* with a score of 51.67 (Table 2.1). Of the plants assessed in the early season, the most attractive pollinator plant was *Asclepias incarnata* (PAS = 47.30) and the least attractive of the plants assessed was *Thymus vulgaris* (PAS = 19.53). The most attractive pollinator plant in the middle season was again *Asclepias incarnata* (PAS = 49.41) and the least attractive plant was *Thymus citriodorus* (PAS =

23.31). In the late season, *Symphyotrichum novae-angliae* (PAS = 51.67) was the most attractive on the plant and *Rudbeckia triloba* (PAS = 22.32) was the least attractive.

The pollination networks for the early, middle, and late portions of the field season were generated (Figure 2.1). The early and late season pollination networks are simpler than the middle season pollination network.

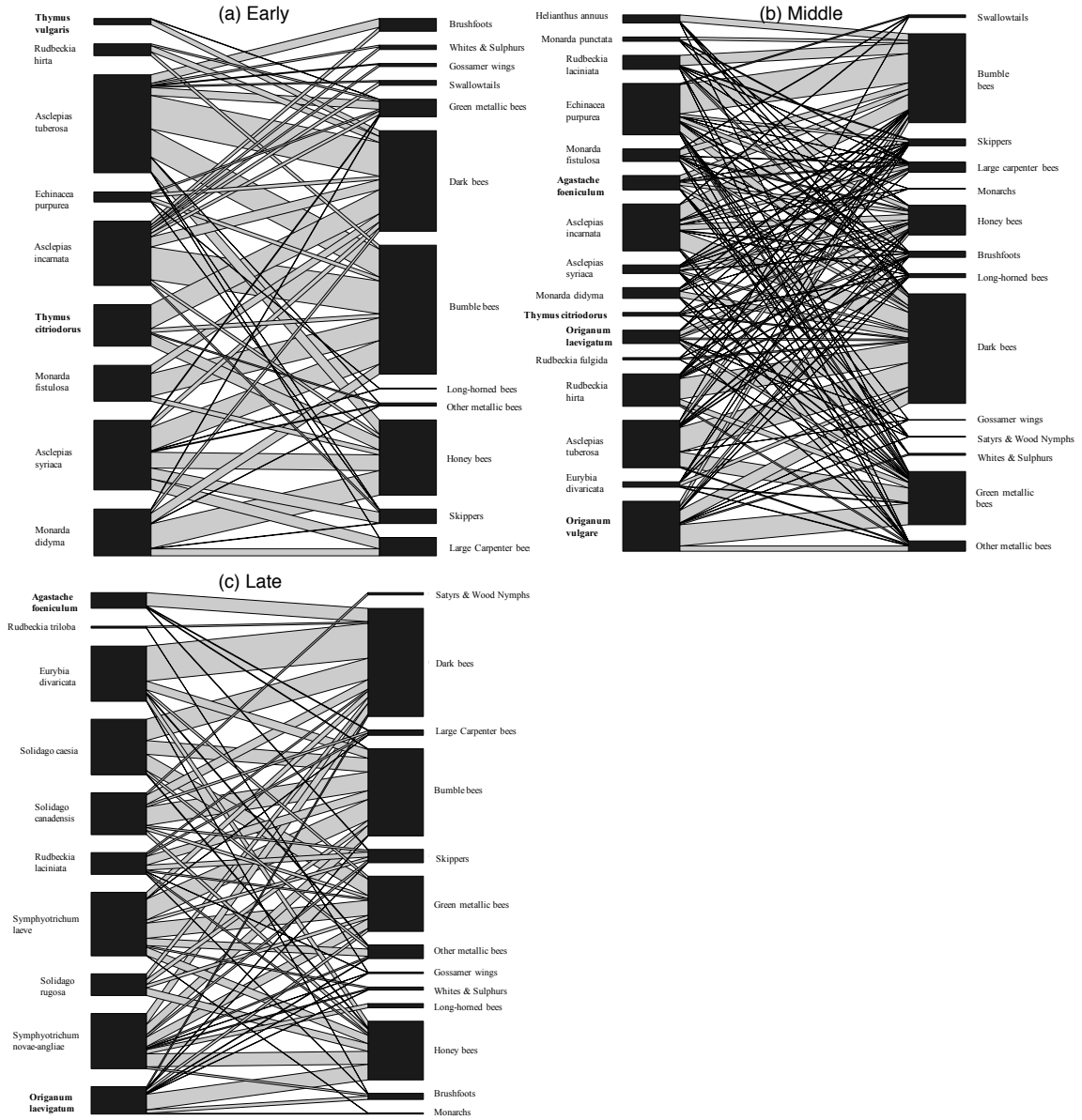


Figure 2.1: The pollinator networks constructed from the plant records used to create recommendations for the early (a), middle (b), and late (c) portions of the field season. The plant species are on the left and the pollinator functional groups are on the right. The width of the grey bars corresponds to the number of records between the plant and

pollinator; when this value is small, the grey bars become thin and may be black. Nonnative plant species are bolded.

Discussion:

This study demonstrates a useful metric to assess the value of plant species to pollinators. Because the PAS score is calculated using experimentally collected data, the results of this study are objective. While the data analyzed in this study are from Maryland, this method is not system- or location-dependent and can be applied to any number of study systems; it is not restrained to use in urban or suburban garden plantings and therefore is applicable in natural and agricultural systems. Furthermore, the PAS score can be useful for nurseries and growers to advertise high quality pollinator plants, similar to the NuVal nutritional index system often displayed in grocery stores (Katz et al. 2010).

We see that the native plants frequently outscore the non-native plants in terms of their value to pollinators. The non-native plants analyzed with this metric consistently scored in the bottom half of the plants analyzed. This could be due to specialists, evolutionary relationships, or introduced pollinator species from the plant's native range. In contrast, in the middle portion of the field season, *O. laevigatum* has a PAS score of 48.90 and ranks second of 14 in attractiveness to pollinators. In the late portion of the field season, however, *O. laevigatum* drops to a PAS score of 33.33 and ranks seventh of 10. *Origanum vulgare*, while only assessed in the middle portion of the field season, also scored relatively high, ranking fifth of 14. *Origanum* sp. accounted for two of the five non-native plant species assessed in this study. Similarly, researchers in Britain, where *Origanum* sp. are native, found that they also are beneficial to pollinator communities there (Garbuzov and Ratnieks 2014). (Razanajatovo et al. 2015) demonstrated that non-

naturalized alien plants were visited less frequently by pollinators than native or naturalized alien plants, which is generally consistent with the findings of this study. Although *Origanum* sp. do not occur in nature in Maryland, it is possible that pollinators have evolved a taste for this culinary herb in the last 200 years.

Plant-pollinator communities are dynamic and change throughout the field season. Many solitary bee species are short lived as adults, with some only foraging for a few days to weeks (Michener 2007). Bumble bee colonies, which may persist for many weeks, have dynamic needs as they shift from rearing workers to gynes (Heinrich 2004). Similarly, some butterfly species, like the Baltimore checkerspot in Maryland, only forage for approximately six weeks as adults (Durkin et al. 2013). This implies that the value of a plant species to the pollinator community may change as the pollinator community does so as well. Pollinator networks can help to visualize the changing interactions between plant and pollinator species during a field season. The pollinator networks for the early and late portion of the field season are less complex than the middle portion of the field season (Figure 2.1). As the pollinator species change throughout the season, it is likely that the value of plant species also changes. For example, *Echinacea purpurea* increased in PAS score almost ten points in the middle season as opposed to the early season.

While some of the studied plants rank quite high over two portions of the field season (i.e. *Asclepias* sp.), it is important to keep in mind that planting the highest-ranking plant and only this plant is not the best choice. Increased plant diversity has been shown to better support a more diverse pollinator community (Salisbury et al. 2015). For gardeners and garden planners to create the most valuable pollinator garden, they should

choose a variety of early, middle, and late season plants that rank highly with this metric. To ensure a high-quality habitat of continuously blooming flowers for specialist and generalist pollinators alike.

A limitation of this study is that only bee and butterfly pollinator plant preferences were assessed, however to make this metric more robust, a full assessment of the pollinating insects visiting each plant (i.e. beetles, flies, and day flying moths) should be included. While the PAS scores generated in this study are based on two years of data, the scores are likely to change with increased years of data collection. Alarcón *et al.* (2008) found that the pollinator networks varied year-to-year in a montane meadow in California, likely due to severe drought conditions during the second of three field seasons. It is reasonably to suggest that environmental conditions impact pollinator networks in other locations, and so analyzing data from multiple years can help to separate pollinator-preference from annual variation in environmental conditions.

Appendix A: Demographic surveys of citizen science participants

2015
Site ID number

Pre-training questions

Date: _____ Age: _____ Gender: _____

Race:_____ Occupation: _____

Are you a Master Gardener? Yes No

If yes, how many years have you been a Master Gardener for? _____

Which Master Gardener Group are you a part of? _____

On a scale from 1 to 5, 1 being little or no experience, 5 being lots of experience, rate how familiar you are with pollinators?: 1 2 3 4 5

Where do you plan to observe pollinators? _____

Do you have any experience working with pollinators? Yes No

If yes, please describe your experiences below:

At the end of the study you will have full access to the data collected. Do you intend to use the data or results of this study? Yes No

If yes, please explain how you intend to use this data.

Bee identification. Use the photos provided in the PowerPoint. Please categorize these bees into one of the following categories: honey bee, bumble bee, large carpenter bee, hairy leg bee, large dark bee, small dark bee, green sweat bee, metallic hairy belly bee, dark hairy belly bee, or cuckoo bee. Each choice may be used once, more than once, or not at all. Use the white ovals on the screen to determine the approximate size and shape of the bee.

1.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

2.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

3.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

4.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

5.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

6.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

7.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

8.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

9.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

10.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

Post-training questions

Site ID number

Date: _____

How interesting did you find today's training?

Very boring Boring Indifferent Interesting Very interesting

How helpful did you find today's training?

Very unhelpful Unhelpful Indifferent Helpful Very helpful

How much did you previously know about pollinators and/or native bees?

Nothing A little Some A lot

How much did you learn at today's training?

Nothing A little Some A lot

Do you have any additional questions that were not answered in today's training? If so, list them here. If you would like to be contacted with a response, please leave your email or phone number as well.

Do you have any suggestions for future training sessions? If so, write them here

Use the photos provided in the PowerPoint. Please categorize these bees into one of the following categories: honey bee, bumble bee, large carpenter bee, hairy leg bee, large dark bee, small dark bee, green sweat bee, metallic hairy belly bee, dark hairy belly bee, or cuckoo bee. Each choice may be used once, more than once, or not at all. Circle your answers below.

1.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

2.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

3.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

4.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

5.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

6.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

7.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

8.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

9.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

10.

Honey bee	Bumble bee	Large carpenter bee	Hairy leg bee	Large dark bee
Small dark bee	Green sweat bee	Metallic hairy belly bee	Dark hairy belly bee	Cuckoo bee

2016

The Pre-quizzes asked about demographic data first, then had space to record the pictorial quiz answers. The Post-quiz had the same space to record the pictorial quiz answer but did not include the questions about demographic questions.

Site ID number

Pre-Quiz
Maryland Native Pollinator Survey 2016

Date: _____ Age: _____ Gender: _____
Race:_____ Occupation: _____

- Are you: a Master Gardener? Yes No a Master Naturalist? Yes No
- If yes, how many years have you been a Master Gardener/Naturalist for? _____
- Which Master Gardener/Naturalist Group are you a part of? _____
- What garden(s) are you planning on monitoring?
- Did you participate in the 2015 Maryland Native Bee Survey? Yes No
- Rate your knowledge of pollinators on a scale from 1 to 5 (1 being little or no knowledge, 5 being very knowledgeable) 1 2 3 4 5
- Do you keep honey bees? Yes No

If yes, for how many years have you been keeping honey bees? _____

- Do you have any experience working with pollinators? Yes No
  If yes, please describe your experiences below:

Pollinator Identification

1.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

2.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

3.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
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White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

4.

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White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

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Skipper	Other		

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Skipper	Other		

7.

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Skipper	Other		

8.

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Skipper	Other		

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Skipper	Other		

10.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

11.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

12.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

13.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

14.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

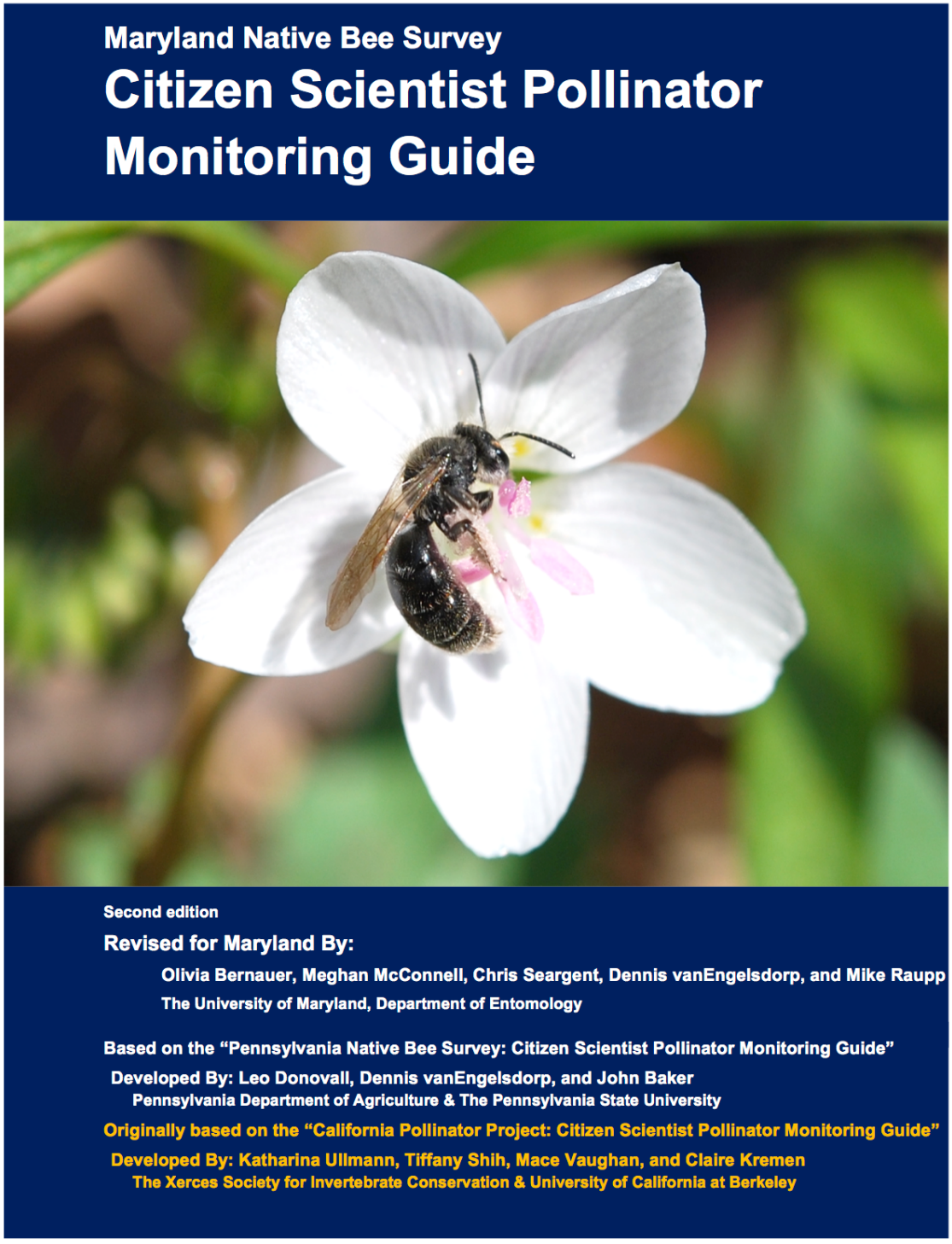
15.

Honey bee	Bumble bee	Large carpenter bee	Long-horned bee
Dark bee	Metallic bee	Swallowtail butterfly	Monarch butterfly
White or Sulphur butterfly	Gossamer wing butterfly	Satyr or Wood Nymph butterfly	Brushfoot butterfy
Skipper	Other		

Appendix B: Monitoring and Pocket Guides

2015

Monitoring guide





THE XERCES SOCIETY
FOR INVERTEBRATE CONSERVATION

Previous Editions

The Xerces Society for Invertebrate Conservation is an international, nonprofit, member-supported organization dedicated to preserving wildlife and its habitat through the conservation of invertebrates. The Society promotes protection of invertebrates and their habitat through science-based advocacy, conservation, and education projects. Its work focuses on three principal areas – endangered species, watershed health, and pollinator conservation. For more information about the Society or on becoming a member, please visit our website (www.xerces.org) or call us at (503) 232-6639.

Through its pollinator conservation program, the Society offers practical advice and technical support on habitat management for native pollinator insects.

University of California Berkeley collaborates with the Xerces Society on monitoring pollinator communities and pollination function at farm sites before and after restoration. University of California Berkeley conducts studies to calibrate the observational data collected by citizen scientists against the specimen-based data collected by scientists during standard surveys.

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Photographs

We are grateful to the many photographers who allowed us to use their wonderful photographs in this monitoring guide. The copyright for all photographs is retained by the photographers. None of the photographs may be reproduced without permission from the photographer. If you wish to get in touch with a photographer, please contact the Xerces Society.

Maryland Edition

The Maryland Native Bee Survey

The Maryland Native Bee Survey is a collaborative effort of the University of Maryland, with cooperators and volunteers from across the state. The goals of this program are to survey and monitor native bees throughout Maryland, provide opportunities and support for native pollinator research and to aide in the development of educational and outreach tools to support the conservation, restoration and protection of native pollinators, particularly in their role as support for honey bee pollination services in agricultural landscapes.

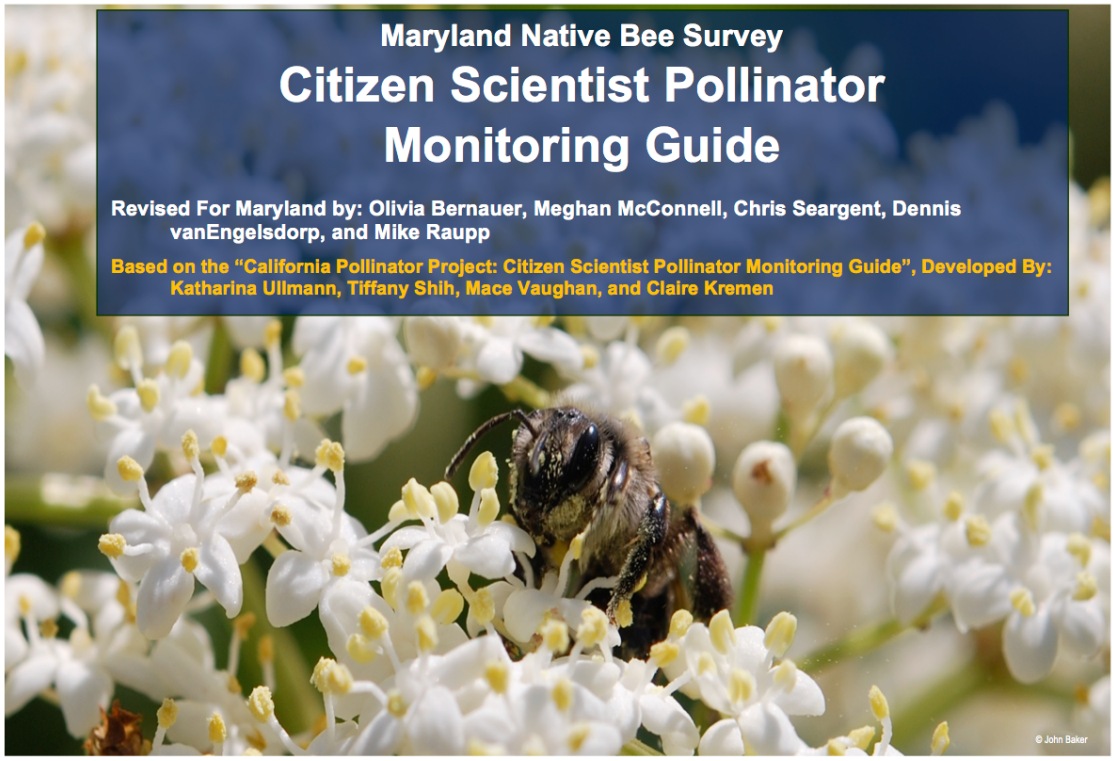
This document is a revision of the Citizen Scientist Pollinator Monitoring Protocol originally developed by the University of California at Berkeley and the Xerces Society for use in monitoring pollinator re-colonization at native vegetation restoration sites in California. This Maryland edition is a collaborative effort between the Maryland Native Bee Survey and the Maryland Master Gardener program and is intended to document floral resource use in native plantings to better inform pollinator gardening efforts.

Funding for the Maryland Native Bee Survey was provided by the United States Department of Agriculture, a United States Department of Agriculture – National Institute of Food and Agriculture grant, and from the University of Maryland.

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Front Cover

Mining bees (*Andrena* spp.) are a diverse group of pollinators that pollinate a wide range of flowering plants, including flowering trees and wildflowers. They are one of the earliest groups to begin pollinating in Maryland, gathering nectar and pollen from even the earliest spring wildflowers, like Spring Beauty (*Claytonia virginica* L.). Photograph by Leo Donovall (2009).



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Section 1

GETTING STARTED

Bees are an amazingly diverse and very important group of insects, yet they remain poorly understood. When most people hear the word "bee," a single species comes to mind, *Apis mellifera* Linnaeus (the European Honey Bee), a species that is not even native to the United States. However, in Maryland, there are more than 400 species of non-*Apis* bees (also referred to as "native", "solitary" or "wild" bees) that are extremely important pollinators of crops, garden and nursery flowers, wildflowers and trees. Conservatively, three out of every four plants on Earth depend on bees for pollination, including nearly 70% of all crop species. About one-third of a typical human diet depends directly or indirectly on insect pollination. Without insect pollinators, we would not be able to produce apples, almonds, blueberries, squash, and many other fruits, vegetables and nuts.



Bees are the most important group of insect pollinators, responsible for pollinating many different crops and wildflowers.

Since 2004, the USGS has been collecting and identifying the bee diversity of Maryland. Interest in native pollinators of Maryland began with concern over honey bee declines and the need to better understand how native pollinators could support the state's pollination demands. Interest has greatly increased as a condition termed "Colony Collapse Disorder", or "CCD", has threatened to destroy much of the Country's beekeeping industry. In partnership with the Xerces Society for Invertebrate Conservation and the University of Maryland, with funding from the United States Department of Agriculture, this project is now moving to promote pollinator education and to develop a citizen-science program designed to train others to collect the information we need to better understand and appropriately protect Maryland's diverse pollinators.



The transport of pollen between flowers is an essential function of insect pollinators.

There are an estimated 400-450 species, or kinds, of bees in Maryland. Some of these bee species can only be identified by specialists who look at traits and characteristics that are difficult to see, especially without a microscope. There are only a handful of taxonomists in North America who can accurately identify these bees to the species level! However, with a little practice and guidance, Citizen Scientists can learn to identify the most common bee species and "species-groups" (generally, sets of related species) found in the gardens, fields, and forests of Maryland. In a similar study in California, paired data collection suggests that the diversity measured by easily identifiable species and species groups correlates with the data collected by bee experts.

This Citizen Scientist Monitoring Guide was developed specifically for the purpose of training Citizen Scientists. It includes an introduction to identifying bees, in general, as well as identifying bees at a "species-group" level. The final section outlines the procedures for collecting observational data. The data generated by this project, specifically, will help gauge the value of different plants and plant communities as food resources for Maryland's bees.

How to Monitor and Observe Pollinators

There are many different species of insect pollinators, including bees, butterflies, moths, wasps, beetles and true bugs. This monitoring protocol will allow you to measure both the diversity (different kinds) and abundance (number of each kind or of all kinds) of bees that are present on the habitat you are monitoring, and how the composition of those pollinators change over time. There are many potential uses for this kind of information, including: quantifying the effectiveness of efforts to promote pollinator populations in gardens and yards; understanding the pollinator requirements of crops dependant on insect pollinators; or, simply, identifying the types of bees present on a particular habitat. This information will aid in generating guidelines on how to enhance pollinator habitat by improving or planting additional floral resources. Long term monitoring will allow us to assess how management practices are affecting local pollinator communities.

There are many ways to monitor pollinators, but most often specimens are collected or observed visiting flowers. In this program, we will not be collecting the insects, only observing them. Here, we present the necessary procedures designed to train the Citizen Scientist to:

- Select monitoring locations and collect habitat information.
- Identify pollinator species-groups.
- Record observational data on floral visitations.

Throughout the process, we will be evaluating the effectiveness of these guidelines to train Citizen Scientists to accomplish the goals outlined above. Important in this process is feedback from you, our Citizen Scientists, as you work through the material and begin to record observations. The data you collect and the feedback you provide will be important as we continue to develop a deeper understanding of our pollinators.



© Lee Donovat Pennsylvania Department of Agriculture

Monitoring of pollinators usually requires nothing more than careful observation of what the insects are doing and what they look like. By following the same procedures each time, you can begin to develop a valuable record of how insects are using your garden.

! It is sometimes difficult to tell flies, wasps, and bees apart. Furthermore, some bees look very similar to each other, but are in fact different species. Remember when identifying insects that **it is much better to identify bees accurately at a coarse taxonomic level** than to identify them inaccurately at a fine taxonomic level. When in doubt, identify only to the level you are confident, and add notes to describe the insect further, as necessary.

Observing Insects Visiting Flowers

Before you begin monitoring your property it is important to know how to make observations and how to identify floral visitors. Much of this guide focuses on the latter, but it is important to keep the following points in mind when collecting observational data on floral visitors:

- Only collect data on floral visitors.
- Look at all flower types.
- Be careful not to disturb insects visiting flowers before you get a chance to observe them well.
- Avoid sudden movements and do not stand too close to the flower you are observing.
- Insects respond to shadows passing overhead by moving away; walk so that your shadow trails you, rather than advances in front of you.
- Observe and identify insects as best you can; even noting whether a visitor is a honey bee, native bee, fly or wasp is useful information.
- Bee species can be difficult to tell apart. As we are particularly interested in monitoring native bees it is important to distinguish, at minimum, honey bees from native bees. (See the example data sheets, pages 32 and 33)

1. Remember to only observe and identify insects visiting the reproductive parts of the flower.

Pollinating insects will be collecting either pollen or nectar. It can be difficult to observe this on very small flowers. In this case, observe the floral visitor's behavior and do your best. You do not need to identify or make notes on animals sitting on petals, leaves, stems, etc., or visitors flying around the area.

2. Remember to look at all flower types.

Sometimes you need to look inside deep flowers, too. For example, in Maryland, bees may be foraging in the center of the cone-shaped flowers of squash (*Cucurbita* sp.) or bindweed (*Convolvulus arvensis*; also known as morning glory).

In addition, bees may visit flowers that are less noticeable to people – such as flowers that are quite small or green – so try not to focus on only one or a few flower types.









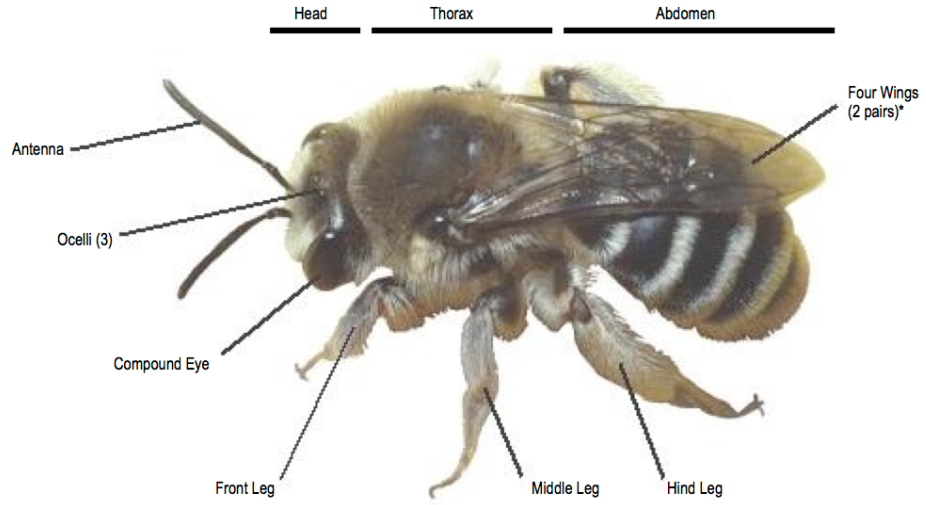
Section 2

IDENTIFYING FLORAL VISITORS

Bees, in general, are the best pollinators; they have evolved to be the most efficient pollen transporters. However, some birds, bats and other rodents, flies, wasps, butterflies, moths, beetles, and bugs visit and pollinate flowers, as well. For this reason it is important to note *all* floral visitors.

Identifying butterflies and moths or a spider from a bee is simple. Separating bees from wasps or flies – especially those that mimic bees or wasps – can be harder. The following pages give more information on how to identify the principle groups of pollinators and key characteristics to look for when identifying specific bee groups.

But first, let's focus on bees. To help you get to know a bee, take a look at the diagram below, on which the major body parts have been labeled. On the next page you will find more about the key characteristics of bees.



* It can be difficult to see all four wings because sometimes the wings are folded on top of each other.

A NOTE ABOUT STINGS

There is always a risk of being stung when working with and around bees (and wasps). Most bees are not aggressive and only sting if handled improperly; you will rarely be stung while simply observing bees. If, however, you happen to be stung while in the field, try to identify the type of bee (or wasp) stung you and let someone know so that they can help watch for symptoms. Most people have mild reactions to bee stings and exhibit a reaction only at the site of the sting (mild swelling, redness, itchiness and/or mild pain). Symptoms of a serious reaction include swelling elsewhere on the body, vomiting, dizziness, hoarseness, thickened or slurred speech, or difficulty breathing, and should receive prompt medical care from a physician. If you suspect you have an allergy to bee stings, consult your doctor and ask about an EpiPen®.

Identifying Bees

Key characteristics:

- Bees have **four wings** (two pair; difficult to see when folded over the body).
- Bees have **long, elbowed antennae.**
- Bees have **large, well separated eyes** with **three small eyes** (or "ocelli") **on top of the head**.
- Bees are **more robust** (i.e. rounder bodies) than wasps and flies; abdomen usually broad near thorax (vs. most wasps).
- Most bees are **hairy-bodied**, with multi-branched hairs (resemble pipe-cleaners or brushes) for carrying pollen.
- Female bees can **carry large loads of pollen**, either on their legs or on their abdomen in a "scopa".

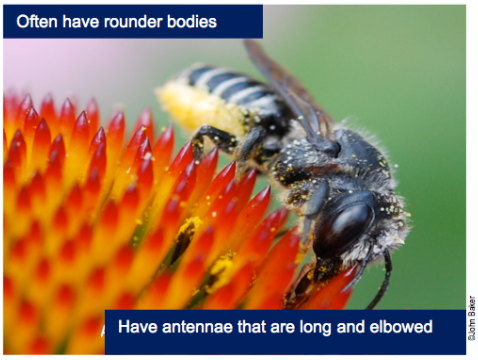
Size: Range from 2 to 25 mm (less than 1/8 inch to 1 inch) or more.

Body Color: Can be black, brown, orange, yellow, red, or metallic blue, green, or copper-colored.

Stripes: Body color (exoskeleton) or hair colors (yellow, orange, white, black or brown) can form stripes.



Bees are an incredibly diverse group of insects. Some look very "bee-like" (hairy with black-and-yellow stripes), but many are brightly colored.







! Male bees are often less hairy than female bees, often have longer antennae, and rarely carry pollen. Only females forage on flowers to collect pollen to bring back to their nests.

Non-Bees: A Quick Reference

Birds



Flies (detailed on page 10)



Wasps (detailed on page 11)



Spiders



Butterflies and Moths





Other (beetle, bug, etc.)



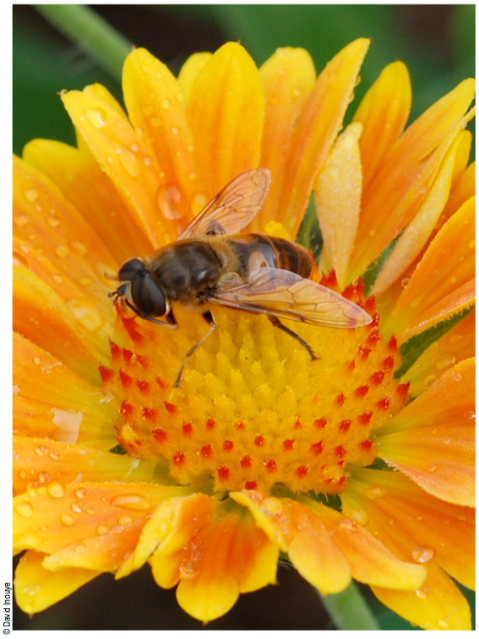


Flies vs. Bees

Key characteristics:

- Flies often have **short thick antennae** (sometimes difficult to see).
- Flies often have **large eyes near the front of their head** usually converging (coming together) on top of the head, almost touching; small eyes ("ocelli") on front of head, above antennae.
- Flies only have **two wings (one pair)**.
- Flies are usually **less hairy** than bees.
- Flies **can hover** (most bees are not able to hover).
- Flies **do not carry large loads of pollen** although some grains may stick to their bodies.

Size: Range similar to bees: tiny, small, medium, or large.
Body Color: Can be black, brown, red, orange, yellow, creamy-white or metallic blue, green or coppery.
Stripes: Can have stripes, usually from body color (exoskeleton); some look like bees (i.e. mimics)!



Some flies can be very bee-like in appearance. This is a drone fly (*Eristalis tenax*), a honey bee mimic, and like the honey bee, an introduced species from Europe.







Wasps vs. Bees

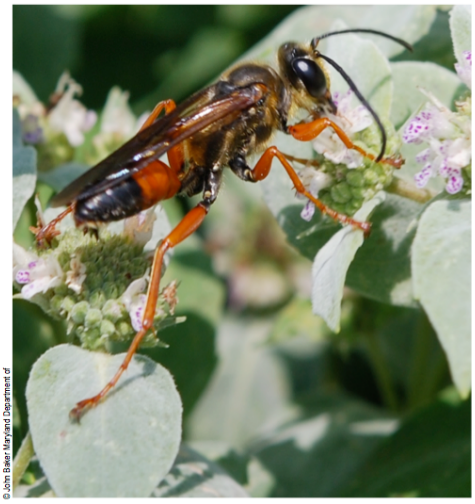
Key characteristics:

- Wasps, like bees, have **four wings** (two pairs; often folded lengthways).
- Wasps usually **narrower-bodied** than bees, with the abdomen more obviously constricted near the thorax.
- Wasps are usually **not obviously hairy**.
- Wasps are often **long-legged**.
- Wasps can have **bright markings or stripes** on their bodies (exoskeleton); stripes and marks usually not from hair patterns.
- Wasps **do not carry pollen loads**.

Size: Similar in size to bees and flies, but wasps that resemble bees are often larger.

Body Color: Can be black, brown, red, orange, yellow, pale to creamy white, or metallic green, blue or coppery.

Stripes: Can have body stripes (exoskeleton), that closely resemble a bee (close relatives often are difficult to tell from bees until seen under a microscope); stripes and markings usually not from hair patterns.



© John Baker Maryland Department of

Wasps are often described as appearing "more tough" or "more rugged" than bees.

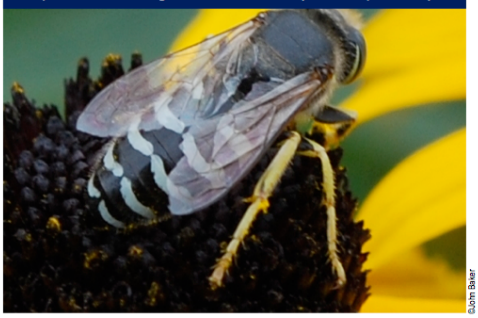
Four wings (folded lengthwise)



© John Baker Maryland Department of Agriculture

Narrower body, abdomen more constricted near thorax

Stripes and markings on exoskeleton (not hair patterns)



©John Baker

Less hairy



© John Baker Maryland Department of Agriculture

Do not carry pollen loads (some grains stuck to body)

Section 3

UNDERSTANDING BEES

Introduction

If you see that a floral visitor is carrying clumps of pollen on its body, this visitor is likely a bee. Female bees collect pollen from flowers to bring back to their nests, where they pack it into brood cells for their larvae (i.e. young bees) to feed on. For this reason, their bodies are highly adapted to be very efficient pollen transporters.

In this section, we will examine some of the characters that will help you to identify bees visiting flowers. For most bees, we will only be able to identify to a larger group (i.e., family, genus, species groupings) or to a body-type.

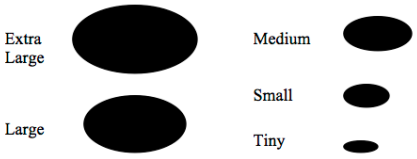
The characteristics that will be covered in this section are:

- Body size and shape
- Body coloration
- Body hair distribution
- Location of scopa
- Body stripes
- Antennal length

Bees: Body Size

The size of the bee is often a great initial separator, especially when combined with other characters.

What size is the bee?



Bees: Body Shape

Some species groups are consistent in body shape.

What shape is the bee?







Bees: Body Coloration

Color can be assigned in two ways with bees: 1) body surface (exoskeleton) color and 2) hair color. We will refer to bee color in both contexts, as necessary. In general, look at the overall color pattern to begin to make broad classifications.

What colors are present on the bee (body and hair)?

- Metallic or non-metallic
- Hair color vs. body color
- General distribution of colors (thorax, head, abdomen)

Brown



Black



Whitish stripes



Yellow



Metallic green



Metallic blue



Bees: Distribution of Hair

The pattern of hair distribution is an important tool for identification. Some bees are "fuzzy", with the entire body covered in hairs. Others are sparsely covered in hairs or hairs are covering only certain areas of the body.

Which body regions are covered in hair?

- Thorax and abdomen thickly covered
- Thorax thickly covered, abdomen sparse or in bands
- Body appears nearly hairless

Bees: Location of Scopa

The scopa, or "pollen basket", is an area of densely arranged, often highly-branched hairs that are modified for transport of the "pollen load", or packet of collected pollen. The scopa is only present on female bees and is most often located on the hind legs, resembling pipe cleaners or bottle brushes. For others, the scopa is on the underside (or bottom) of the abdomen or completely absent. If unsure, look for an area with lots of pollen packed against the body.

Where is the scopa (pollen basket) located?

- Hind legs or underside of abdomen or absent

Thorax and abdomen thickly covered



© John Baker

On the underside of its abdomen



© John Baker

Thorax thickly covered and abdomen sparse or in bands



© John Baker

On its legs



© John Baker

Appears nearly hairless



© John Baker Maryland Department of Agriculture

Scopa lacking



© John Baker

Bee: Body Stripes

Bees are often identified by the pattern of stripes, or bands, of colored hair or exoskeleton markings. The region or relationships of these stripes to one another are distinguishing features for species and species groups.

Does the bee have stripes on its body?

- Hair or exoskeleton markings
- Pattern (color, location of bands or marks)

On its thorax



© John Baker

On its abdomen



© John Baker

Bee: Antennal Length

Antennal length is important for distinguishing sex: males have longer antennae (literally, one segment longer – 12 for females, 13 for males). In general, bees have "short" antennae. However, one group is called the "long-horned" bees, because they have longer antennae than normal.

How long are the antennae?

- Long or short

Long



© John Baker

Short



© John Baker

Section 4

A Guide to the Different Groups of Bees

There are more than 400 species of bees in Maryland. This guide will help you identify some of the common bee groups you will see in your garden. The photos on this page illustrate some of the diversity of these bees.

Remember, this guide is not exhaustive, so if you observe a bee that is not does not fall into an identified species-group note the bee as "Other bee" and describe the bee thoroughly in the observational notes. Even if you can't identify the bee precisely, it is important to document that it was observed.

In particular, it is important to distinguish the honey bees, which are non-native, from the native bees. Whenever possible, attempt at minimum, to distinguish honey bees from the rest of the bee categories. So, study the "honey bee" page carefully.

Keep in mind the characteristics that will help you identify your bees (refer to Section 3: Understanding Bees, pages 12-15):

- Body size, shape and coloration
- Distribution of body hairs
- Type and pattern of stripes
- Location of scopa
- Antennal length

Honey bee



© John Baker

Metallic sweat bee



© John Baker

Bumble bee



© John Baker

Small carpenter bee



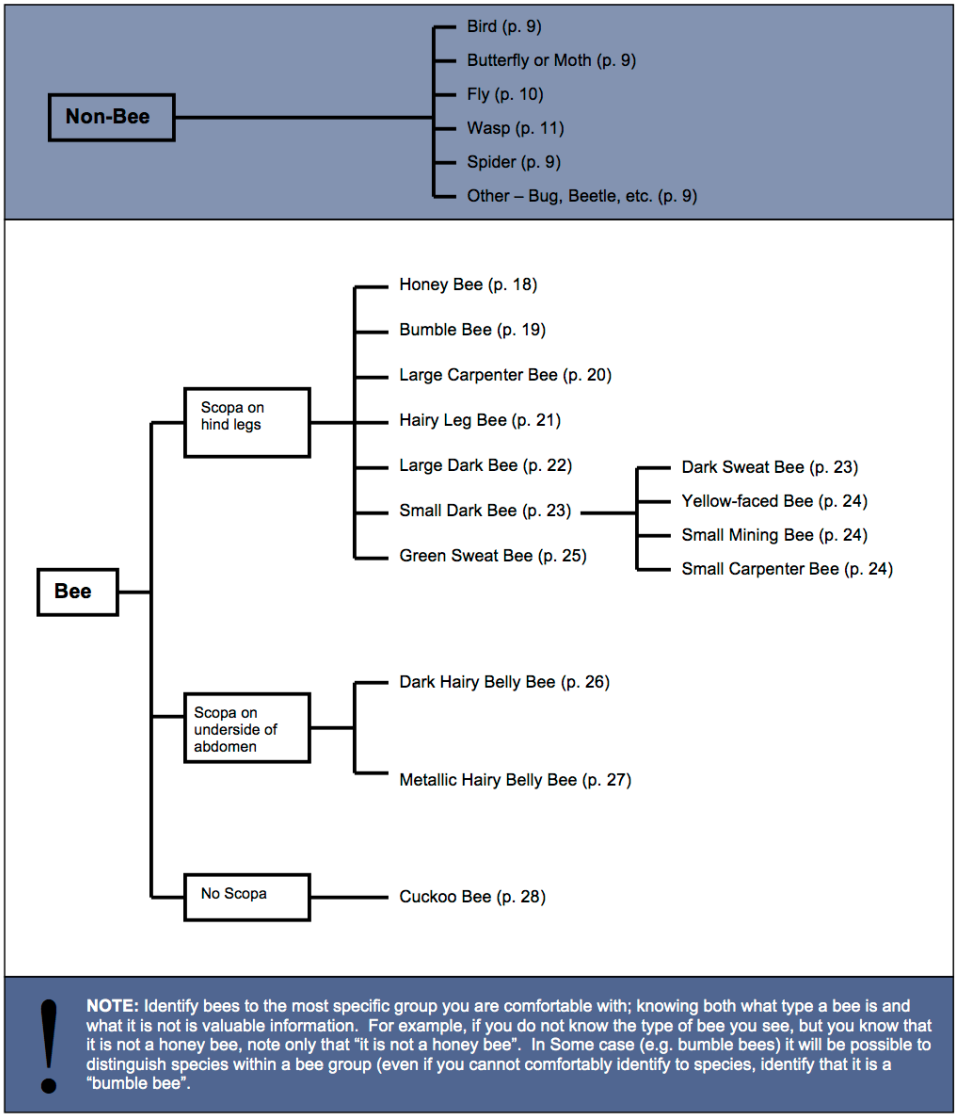
© John Baker

Leafcutter bee



© John Baker

Groups of Floral Visitors



NOTE: Identify bees to the most specific group you are comfortable with; knowing both what type a bee is and what it is not is valuable information. For example, if you do not know the type of bee you see, but you know that it is not a honey bee, note only that "it is not a honey bee". In Some case (e.g. bumble bees) it will be possible to distinguish species within a bee group (even if you cannot comfortably identify to species, identify that it is a "bumble bee".

Honey Bees

When most people hear the word "bee", it is the honey bee that comes to mind.

Key Characteristics

- **Size and Shape:** Medium to large, moderately robust.
- **Color:** Orange-brown to nearly black.
- **Hair:** Fuzzy thorax and head, legs and abdomen less hairy.
- **Stripes:** Abdomen tri-toned, with black, pale and orange-brown stripes of hair and body coloration.
- **Scopa:** Enlarged, flattened hind legs; hairless in the center.
- **Antennal Length:** Short.
- **Notes:** Makes a buzzing sound when flying; the only bee with "hairy eyes".

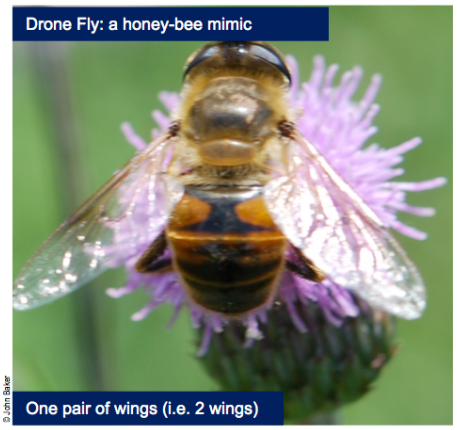
Approximate size range:



Important:
During monitoring, distinguishing between honey bees and the rest of the bee categories is the most important observation you can make.

Caution:
There are some flies and wasps that mimic honey bees. For flies: look for two wings (one pair), small antennae, big eyes, and skinny hind legs. For wasps: look for nearly hairless body with exoskeletal (body) markings rather than markings made by hair patterns.







Bumble Bees

Key Characteristics

- **Size and Shape:** Medium to very large, robust.
- **Color, Hair and Stripes:** Body black, with yellow, black, and, sometimes, orange hair stripes over thorax and abdomen.
- **Scopa:** Hind legs enlarged and flattened; hairless in center.
- **Antennal Length:** Short in females (the majority of bumble bees encountered), long in males.
- **Notes:** Make a low buzzing sound when flying; painful sting that does not linger.

Approximate size range:



Caution: There are a number of flies and other bees that mimic bumble bees. Look for a completely hairy abdomen and large hind legs, usually with short antennae.

Bombus vagans



© John Baker

Bombus griseocollis



© John Baker

Bombus perplexus



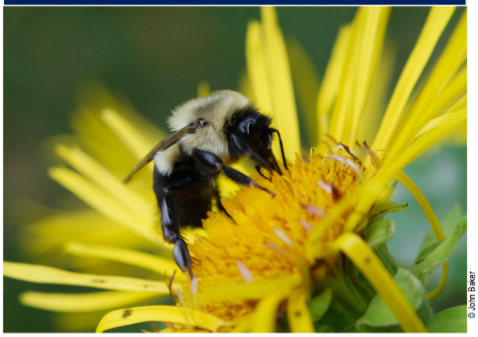
© John Baker

Bombus fervidus



© John Baker

Bombus impatiens



© John Baker

Large Carpenter Bees

Large carpenter bees look like less hairy bumble bees, with a shiny, nearly hairless abdomen.

Key Characteristics

- **Size and Shape:** Very large and robust.
- **Color and Hair:** Shiny black abdomen, thorax black with yellow/light hair; males with a yellow spot on face.
- **Stripes:** None.
- **Scopa:** Hind leg enlarged, covered with a brush of thick hair (scopa) throughout (compare with "Bumble Bees", page 19).
- **Antennal Length:** Short.
- **Notes:** Only one type (species) in Maryland: *Xylocopa virginica* (Linnaeus); often found in residential areas around exposed wood (decks, porches, trim, wood piles, etc.); males territorial (may buzz by your head); will "hover" for short period of time, "staring you down". While male carpenter bees are territorial, they cannot sting and female carpenter bees rarely sting.

Approximate size:



Comparison Note: Carpenter bees and bumble bees look very similar. Note the larger head, shiny and relatively hairless abdomen, fuzzy legs (particularly the female) and yellow spot on the face (male only). Carpenter bees nest in wood, like your deck or porch, while bumble bees nest in underground burrows and cavities.

Black, shiny abdomen (appears hairless)



© John Baker

Males with a yellow spot on the face



© John Baker Maryland Department of Agriculture

Hairy Leg Bees (Digger or Long-horned Bees)

Key Characteristics:

- **Size and Shape:** Small/medium to medium/large and robust.
- **Color and Hair:** Dark, with white to yellowish/orange hairs; thorax covered in short, dense, velvety hair.
- **Stripes:** Abdomen often with pale stripes.
- **Scopa:** On hind legs; appear as dense stands of long hair (like pipe-cleaners), usually quite prominent.
- **Antennal Length:** Generally longer than most, especially males, who have very long antennae.
- **Notes:** Some species are very quick and can visit flowers rapidly; difficult to collect.

Approximate size range:



Important:
Note key characteristics for this group when you see them visiting flowers (e.g. pollen, hairy, size/shape, color, stripes, antennae, and flight).

The legs of males will not be as hairy as the legs of females because males do not transport pollen. Additionally, in general, males in this group often have much longer antennae than females.

Can have long antennae



© John Baker

Hairy – especially on the legs and thorax of females



© John Baker

Stripes on abdomen



© John Baker

Collect dry pollen – can be all over body

Can have short antennae



© John Baker

Large Dark Bees (Mining and Plasterer Bees)

Key Characteristics

- **Size and Shape:** Small to Medium/large, relatively narrow to moderately robust.
- **Color and Hair:** Dark-bodied; most with densely hairy thorax (hairs white to pale yellow/orange) compared to abdomen, which is much less hairy
- **Stripes:** Often present on abdomen, made of pale hairs; a (rare) few with iridescent integumental (body) stripes on the abdomen.
- **Scopa:** On hind legs; often pale and short (compare with "Hairy Leg Bees", page 21).
- **Antennal Length:** Short in females, longer in males.
- **Notes:** Extremely numerous in early Spring and late Fall; possibly a valuable early season group of pollinators; some are very bumble bee-like, but have a completely hairy scopa.

Approximate size range: 

Notes:

Females have dense patches of short, pale hair (called the facial fovea) along inner margin of eye and males often have thick "beards" or "mustaches", some with yellow exoskeletal markings on face.

Mining and Plasterer Bees are some of the earliest-emerging bees in Maryland's spring. They are found on many of the early-blooming spring wildflowers and flowering trees from March through May.







Small Dark Bees (Dark Sweat Bees, Small Carpenter Bees, Yellow-faced Bees and Small Andrenid Bees)

Floral resources are visited by a large number of small dark bees, including dark sweat bees (Halictidae), yellow-faced bees (Colletidae: Hylaeinae), small carpenter bees (Apidae: Xylocopinae), and small mining bees (Andrenidae). Often, a flower patch is swarmed by these bees. The "Key Characteristics" of this section will describe any of the bees included in this group, with the small dark sweat bees as the primary example. Some distinguishing characteristics for the other species or groups of small dark bees are listed below.

Key Characteristics

- **Size and Shape:** Tiny to small/medium, moderately narrow.
- **Color:** Black to dull metallic blue, green or coppery; abdomen can be yellowish or reddish, but usually dark
- **Hair:** Body covered in pale hairs that are less noticeable, but some with large, dense patches, especially on abdomen.
- **Stripes:** Usually absent, but some have whitish to pale yellowish stripes on dark abdomen.
- **Scopa:** On hind legs; less noticeable than other bees, unless covered in pollen.
- **Antennal Length:** Short in females, longer in males.
- **Notes:** Usually the most numerous group of bees visiting flowers, and the most difficult to tell apart.

Approximate size range:



Dark Sweat Bees

Dark sweat bees are quite variable. They range in size from tiny to slightly smaller than a honey bee, are usually dark or dull metallic in coloration with few markings and are usually honey bee-shaped.



Whitish-yellow stripes on abdomen



Stripes usually absent; may sometimes have dark stripes



Medium (8 to 12 mm)



Small Dark Bees (Continued)

Yellow-faced Bees

Yellow-faced bees are similar in shape as dark sweat bees, but with white to yellow markings on face, thorax and legs. The body is much less hairy, and the scopa is absent.



© John Baker

Yellow markings on face, thorax and legs

Small Carpenter Bees

Small, or "dwarf", carpenter bees do not resemble their much larger-bodied relatives, the large carpenter bees. Small carpenter bees are entirely dull metallic green to blue-green and cylindrically shaped. The abdomen is shield-like, with a pointed tip. Males have a large pale spot on the face and broad, flat hind legs.



© John Baker

Small Mining Bees

Mining bees are often quite hairy, many with stripes of hair on the abdomen. Females have patches of pale hair on the face (called the facial fovea), and males have a hairy face, often resembling a "mustache" or "beard". Some mining bees have elaborate facial markings and yellow legs, resembling yellow-faced bees. This group is most numerous in the Spring and Fall.



© John Baker



© John Baker

Green Sweat Bees

Key Characteristics

- **Size and Shape:** Small to Medium, relatively narrow.
- **Color and Hair:** Metallic green; abdomen can be dark and/or striped; body covered in pale hairs that are less noticeable.
- **Stripes:** Usually absent, some with yellow-and-black striped abdomen.
- **Scopa:** On hind legs; less noticeable than other bees, unless covered in pollen.
- **Antennal Length:** Short in females, longer in males.
- Approximate size range: 

Notes

Relatively fast flying and numerous; most are ground nesters, but one especially numerous species nests in rotting wood, and, so, may be found in areas with a lot of woody debris.

Caution:

Some orchard bees (Megachilidae) and cuckoo wasps (chrysididae) can be metallic green. Orchard bees are more robust, duller metallic, hairier and with the scopa on the underside of the abdomen (see "Metallic Hairy Belly Bees", page 26). Cuckoo wasps tend to be more blue-green, look nearly hairless and have dark wings and will be on vegetative parts rather than flowers.

Cuckoo Wasps (Chrysididae) mimic Sweat Bees



© Rajwinder Singh Penn State University

Body nearly hairless, with dark wings

Scopa on hind legs; may be loaded with pollen



© John Baker

Males can have yellow and brown striped abdomens



© John Baker

Metallic Hairy Belly Bees (Orchard and Mason Bees)

Metallic hairy belly bees (or Orchard Bees, *Osmia* sp.) are important pollinators in fruit orchards in early Spring. They are among the first bees seen during the pollinating season.

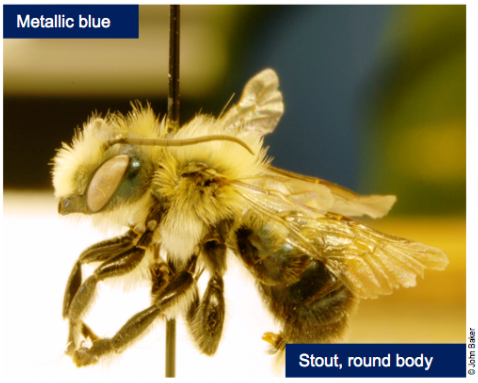
Key Characteristics

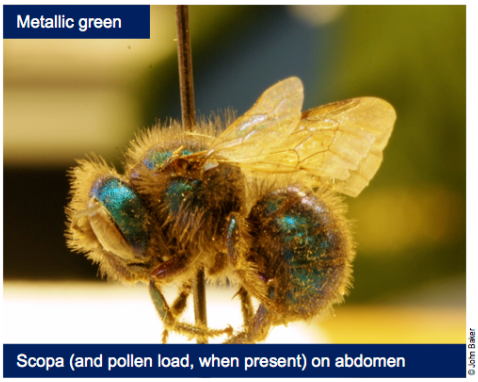
- **Size and Shape:** Small to medium/large and robust.
- **Color:** Dull to bright metallic green or blue; some very hairy and dark with coppery reflections.
- **Hair and Stripes:** Black, white or dull yellow, brownish or orange; stripes absent or faint on abdomen.
- **Scopa:** On underside of abdomen (look for pollen load).
- **Antennal Length:** Short.

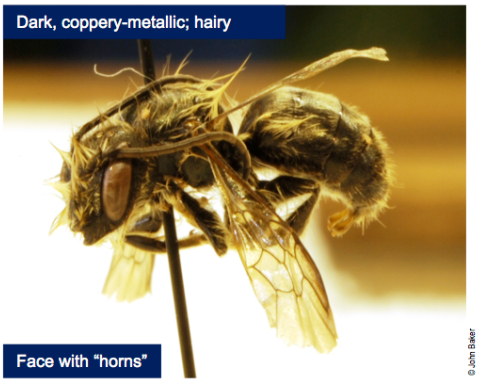
Approximate size range: 

Notes:

- Most observed in spring and early summer.
- Often called Orchard Bees (found pollinating blossoms of tree fruits) or Mason Bees (because some species gather mud and pebbles to construct nests). Others use plant materials to construct their nests.
- A few non-native (i.e. from outside of North America) species with "horns" on the face.







Dark Hairy Belly Bees (Leaf-cutter Bees)

Key Characteristics

- **Size and Shape:** Small to medium/large and very robust; a few are very large and narrow; some with abdominal projections.
- **Color:** Black or dark with coppery metallic reflections; some with bright yellow or red markings on thorax and abdomen.
- **Hair and Stripes:** Thorax and head thickly covered in white/pale to orange-colored hairs; abdomen with pale to white stripes or not striped above, with dark, pale or orange-colored hairs underneath.
- **Scopa:** Located on underside of abdomen (look for pollen).
- **Antennal Length:** Short.
- **Notes:** When visiting flowers, abdomen often flexed upward (or elevated) revealing pollen underneath.

Approximate size range:



Some with pointed abdomens or with small projections



© John Baker

Scopa on underside of abdomen



Look for pollen to find scopa

© John Baker

Often grey/white stripes on abdomen



Abdomen often flexed upward at rest

© John Baker

Some have yellow or red markings on body



© John Baker

Large, carpenter bee-like



© John Baker

Cuckoo Bees

Cuckoo bees are nest parasites: they lay their eggs in other bees' nests. Because they do not provision their own nests, they lack the pollen-carrying scopa, but adults still visit flowers to "tank up" on nectar. There are many groups of bees represented in this category, and are not separated because they are very minor pollinators.

Key Characteristics

- **Size and shape:** Tiny to medium and often narrow-bodied.
- **Color:** Body black, red, or yellowish; often wasp-like, with elaborate body markings or light-colored hair patterns.
- **Hair and Stripes:** Usually not very hairy; some with short, densely-arranged hair covering entire body.
- **Scopa:** Lack pollen carrying structures.
- **Antennal Length:** Sometimes short, often long (especially males).

Approximate size range: 

Caution: These bees tend to look very wasp-like and are often quite difficult to identify in the field – they usually need to be identified under a microscope to be sure. This is the least important group of bees, since they do not actively collect pollen and are generally not very hairy. During the day, they fly low to the ground searching for nests to parasitize. They are most often seen on the flowers, looking for nectar, in the evening when their hosts have stopped foraging and returned to their nests.

Generally, look for shorter legs, elbowed antennae, and more bee-like body stature. If still unsure, mark in the "other" category and report your suspicion of a cuckoo bee.

Cuckoo bees appear to be less hairy than other bees



Red abdomen

© John Baker

Small to medium



Wasp-like markings formed by bands of short, thick hair

© John Baker

Cuckoo bees lack a scopa (pollen-carrying hairs)



Wasp-like markings formed by markings on exoskeleton

© John Baker

Tiny



Wasp-like markings formed by clumps of short, thick hair

© John Baker

Section 5

OBSERVATIONAL DATA COLLECTION

Introduction

Documenting bee abundance and diversity is important for understanding the health of an ecosystem. Pollinators are a good measure of environmental health – changes in bee populations reflect changes in habitats and their inhabitants. Bee diversity can be affected by changing the composition of the flowering plant community. In this section, we will outline the protocols for conducting and recording observational data on floral visitors.

Observational data collection is both an active and a passive approach to measure pollinator-floral host relationships. Along with identifying who a pollinator is in a particular habitat or floral source and what day that general interaction took place, observational data on floral visitors produces specific relational information about weather, habitat, floral visitations, behavior (i.e. mating, communication, predator avoidance, etc.), flight patterns, activity schedule and interactions with other organisms. If carried out consistently, observational data can add much to our knowledge of how pollinators interact with their plant hosts.

Bee communities vary over time; while some bee groups will consistently show up during every sample year round, early season bees such as blue metallic hairy belly bees will be abundant only at certain times in the year. Also, some bee species are only active at certain times of the day. You should plan on recording observational data for your field site once per month throughout the field season (approximately April through October/early November) and at approximately regular intervals (e.g. the first Saturday, the 15th day, etc.). Observations should occur in the morning and repeated in the afternoon/early evening, as some bees are active for only a short portion of the day.

It is a good idea to be aware of the weather conditions before trying to make your observations. Bees do not like cool (temperatures below 55°F), windy (average wind speed over 5 miles per hour), or overcast skies (you should be able to see your shadow). Collect on an alternate day if conditions are not favorable, but try to remain consistent – always collect within a few days of your normal collecting date.

Included on the data sheets (pages 31-33) are places to record the habitat description, date, time and weather conditions. In addition to these habitat and environmental observations, you will also be keeping track of the bees visiting the plants in your garden. This will help us to determine the abundance and diversity of floral visitors in your managed habitat. You will be provided with datasheets to fill out for every collection period.



When done consistently and regularly, observational data can yield much valuable information about the habits of pollinators and their use of floral resources.

Materials Required:

- Identification guides (*Citizen Science Pollinator Monitoring Guide* and the companion *Pocket Guide*)
- Clipboard
- Pencil
- Observational Datasheet(s)
- First aid kit (including an Epipen or other appropriate medicine, if you are unsure of a bee allergy)

Timeline

- **Duration:** May through October or early November (ends after first hard frost).
- **Frequency of Observations:** Twice per month or more if you want, at consistent intervals – for example, the first and third Saturdays or the 10th and 20th day of the month.
- **Report Submission:** Data sheets should be mailed to the University of Maryland once per month in the pre-addressed envelopes provided.

General Sampling-Day Procedure

Initial Observations

1. For the first observational period of the year, describe: age of site (if a garden, how long it has been present), general habitat description (trees, distance to water, setting/landscape, floral and nesting resources available), etc. Drawing a crude map of the site and immediate surroundings would also be helpful. List all potential floral resources at your site (including those in bloom, those that have completed bloom and those that have yet to bloom). (See "Site Information and Initial Observations Data Sheet", page 31)
2. For the remaining observational periods, describe changes since the last visit, including the weather between observation periods (precipitation, major temperature shifts, etc.) and modifications to the landscape/habitat. Add additional floral resources missed on the initial list. (See top of "Pollinator Monitoring Data Sheet", page 32)
3. Identify and list the floral resources of your site that are currently in bloom – you will make your observations from this list. For every plant that is flowering, count the number of each that are present in the garden.

Observational Periods

1. Perform this operation twice per day: once in the morning, between 9:00 AM and noon, the other in the afternoon/early evening, between 1:00 and 5:00 PM. (see "Pollinator Monitoring Data Sheets", pages 32-33)
2. Note the time and relative temperature, windiness, and cloud cover (clear, partly cloudy, mostly cloudy with some sun and shadows, or overcast).
3. Observations:
   - Choose eight (8) plants that are in bloom. Record the number of each present in the garden.
     - Begin with the Master Gardener Pollinator Garden required plants: Oregano, Thyme, *Agastache,* Asters, *Monarda*, *Echinacea*, *Asclepias, and Helianthus*.
     - Common plants attractive to bee pollinators and native to Maryland include: Wild indigo (*Baptisia australis*), Heart-leaved Alexanders (*Zizia aptera*), Culver's root (*Veronicastrum virginicum*), and Smooth penstemon (*Penstemon digitalis*).
     - Include additional blooming plants in your garden to bring the total to at least 8 blooming plants, unless there are no other plants in bloom.
   - Using the bee guides (Section 4, A Guide to the Different Groups of Bees, pages 18-28), identify all bee species groups that arrive on the blooms. If you can't identify the bee group for sure, use the "other" category on the data sheet to record the bee's presence and list in the notes what you know (i.e., "not a honey or bumble bee").
   - This could take some time if there are many blooming flowers; multiple two-man crews could speed the process.
   - Feel free to continue observing and recording from other blooming plants in your garden – remember that we want to know how effective each floral resource is at attracting pollinators.
   - Record how many of each plant species you made your observations from (i.e. 9 out of 10).
4. At the end of the observational period, record any additional observations: behaviors of note, interactions between bees, time spent at a flower, etc.

IMPORTANT!

- Only record pollinators that land on flowers!
- Avoid sudden movements so that you do not disturb insects visiting flowers before you get a chance to observe them well!
- Bee species can be difficult to tell apart – if you are unsure, record what you know. At the very least, we want to know if it is not a honey bee or bumble bee!

Submitting Data Sheets

Maryland Native Bee Survey Citizen Scientist Pollinator Monitoring Project Data Sheets should be sent to the University of Maryland for processing on a routine basis, generally once per month or as part of the shipment of specimens collected from other surveys. Please call with any questions or for additional information regarding the Maryland Native Bee Survey.

Olivia Bernauer, Native Bee Survey
University of Maryland
Department of Entomology
4112 Plant Science Building
College Park, MD 20742
(301) 405 - 3799

2015 Citizen Science Pollinator Monitoring Program
Site Information and Initial Observations Data Sheet

INSTRUCTIONS: Fill the following data sheet in completely. For the site information, be as exact as possible with the address (no PO Boxes or RR numbers); use a GPS unit to gather coordinates, if possible. We will use the site information to assign location names. List the participants involved in the data collection. Be as exhaustive as possible when describing the initial observations.

SITE INFORMATION

Site Name: University of Maryland

Site Location: 1940 Regents Drive
College Park, MD 20742

County: Prince George's

Coordinates: N 38.988565, W -76.941373

Site Contact: Mary Thompson (Coordinator/Educator)

Contact Address: 422 E. Main Street
Annapolis, MD 21401
(555) 555-5555

PARTICIPANTS

Tom Smith
John Thompson
Erin Young
Mike Williams
Wanda Engel

Karen Smith
Sally Firth
Sara Engel
Sharon Thomas

INITIAL OBSERVATIONS

Site History (i.e. age, former use of land, and any additional information):
Garden is 2 years old. It had formerly been a lawn area next to a detention basin for parking lot runoff. It already contained some of the plants we have planted (Asclepias and Asters). It is surrounded by lawn that is mowed approximately twice per month

Describe the landscape, including nesting sites (bare ground, cane or hollow stems, wood piles, etc), water resources, setting (Urban/rural/ag, yard/garden/field, managed/unmanaged surroundings):
The sides of the detention pond have some bare area and stems are allowed to remain after frost. There is often very shallow standing water in one end, with a rocky bottom. There is also some bare ground along the edge of the parking lot. The setting is along the edge of a detention pond, on the edge of an urban area (Harrisburg).

List floral resources (former, current or potential) in garden/around site:
Penstemon digitalis, Aster ericoides, Chelone glabra, Helianthus spp., Asclepias tuberosa, Zizia aptera, Eupatorium spp., Trillium grandiflorum, Monarda spp., Rudbeckia spp.,

POLLINATOR MONITORING DATA SHEET **Date:** 6 / 15 /2015 **MORNING OBSERVATION PERIOD**

INSTRUCTIONS: Fill in the date and requested times, and circle the relevant weather-related information. For the "Habitat changes…" section, fill in all of the habitat changes and weather anomalies (i.e. heavy precipitation, high winds, temperature extremes, etc.) since the last time you observed bees at this site. In the table, fill in the "Floral Resource" column with the flower species you are observing (i.e. type, cultivar, etc.); for each species, count the total number of plants ("# Plants") and count the number of bees visiting each floral resource for ten (10) minutes per species; record the number of plants you actually made your bee counts from ("# Obs."). If you cannot determine which group a bee belongs to, record the bee in the "Other" column and note whether you could tell it was not a honey bee or bumble bee in the "Observational Notes" section at the bottom of the page, along with any additional comments. Please record additional blooming species at the bottom of the other side of this datasheet, under "Additional Blooming Plants".

Name: Tom Smith **Plot size:** 10 m x 20 m

Site Name: Department of Agriculture **Observation** Start Time: 9 : 00 End Time: 11 : 30

Weather: Temp: 50s / (60s) / 70s / 80s / 90s / 100+ **Wind:** Still / (Light Breeze) / Windy / Gusty **Sky:** (Clear) / Partly Cloudy / Mostly Cloudy / Overcast

Habitat changes since the last observation/collection date:
There was a lot of rain at the end of May (about 2.25 inches) - the plants really perked up. The first week of June it was very warm (highs in the low 90s), but it has cooled off this week. A lawn tractor cut down a few of the plants on one end of the garden...

Floral Resource (Genus species)	# Plants/ # Obs.	Honey Bees	Bumble Bees	Large Carpenter Bees	Hairy Leg Bees	Dark Bees	Green Sweat Bees	Metallic Hairy Belly Bees	Dark Hairy Belly Bees	Cuckoo Bees	Other - Describe in Notes
Penstemon digitalis	3 / 3	1	2	1		9	4		3		
Zizia aptera	4 / 3		4			13	8			1	
Monarda 'Fireball'	8 / 5	2	8			3	3				
Echinacea sp.	5 / 5		3		1	4	11			1	
Asclepias tuberosa	10 / 4	2	6	1		2	6		1		
Aster ericoides	20 / 11		1			11	3	1			
Helianthus annuus	6 / 3	4	4			9	8				
Rudbeckia X	12 / 9	1	2		1	8	7		1	1	

Observational Notes:
Activity increased as temperature increased.

Some of the bees were already loaded with pollen before we started. The dandelions in the grass surrounding the garden seem to be quite attractive.

Feel free to use tally marks or write the final number. If you use tallies, please write the final total for each bee species on each plant species and circle it.

POLLINATOR MONITORING DATA SHEET **Date:** 6 / 15 /2015 **AFTERNOON OBSERVATION PERIOD**

INSTRUCTIONS: Repeat the procedures from the morning observation period (reverse side of page), being sure to fill in the date and requested times and circling the relevant weather-related information. Use the same floral resources as those in the morning observation period. Again, be sure to record all bees, using the "Other" column for those that you cannot determine beyond that it is not a honey or bumble bee. At the bottom of the page, record all additional blooming plants that were not utilized during the observation periods.

Name: Tom Smith **Plot size:** 10 m x 20 m

Site Name: Department of Agriculture **Observation** Start Time: 1 : 00 End Time: 2 : 45

Weather: Temp: 50s / 60s / (70s) / 80s / 90s / 100+ **Wind** (Still) / Light Breeze / Windy / Gusty **Sky** (Clear) / Partly Cloudy / Mostly Cloudy / Overcast

Floral Resource (Genus species)	# Plants/ # Obs.	Honey Bees	Bumble Bees	Carpenter Bees	Hairy Leg Bees	Green Sweat Bees	Dark Bees	Metallic Hairy Belly Bees	Dark Hairy Belly Bees	Cuckoo Bees	Other – Describe in Notes
Penstemon digitalis	3 / 3	2	3		1	4	3		2		
Zizia aptera	4 / 4	1	1	1		2	9				1
Monarda 'Fireball'	8 / 4	1				3	11	1		1	
Echinacea sp.	5 / 3		4			2	3		2		
Asclepias tuberosa	10 / 6				1	3	13	1		1	
Aster ericoides	20 / 9	2		1		11	17				
Helianthus annuus	6 / 6	1	2			1	1	1	2	1	
Rudbeckia X	12 / 7		1			4	9		1		

Observational Notes:

One insect landed on Penstemon digitalis - I think it was a bee, but not a bumble bee or honey bee, and it wasn't metallic, either.

There were a lot of bees flying around, but not that many landed. Some of the bees seemed to be chasing others off the flowers. The carpenter bee on the thyme was chewing through the side of the flower.

Be sure to briefly describe any "other" bees (even if all you know is that it is not a honey or bumble bee).

Additional Blooming Plants:

Dandelions, Centaurea (Knapweed), Coreopsis, Sweet William, Dianthus, some Hydrangeas.

Include ALL plants that are blooming (if you can identify them), even the non-native plants.



Appendix A
THE BEES OF MARYLAND

"Honey Bees" (p. 18)
- *Apis mellifera* (European Honey Bee)

"Bumble Bees" (p. 19)
- **Bombus* spp. (Bumble Bees; 14 species)

"Large Carpenter Bees" (p. 20)
- *Xylocopa virginica* (Carpenter Bee)

"Hairy Leg Bees" (p. 21)
- *Anthophora* spp. (5 species)
- *Eucera* spp. (4 species)
- *Habropoda laboriosa* (Southeastern Blueberry Bee)
- *Melissodes* spp. (14 species)
- *Peponapis pruinosa* (Squash Bee)
- *Ptilothrix bombiformis* (Hibiscus Bee)
- *Svastra* spp. (3 species)

"Large Dark Bees" (p. 22)
- *Andrena* spp. (Mining Bees, 85 species)
- *Cemolobus ipomoeae*
- *Colletes* spp. (Plasterer and Cellophane Bees, 14 species)
- *Dieunomia* spp. (2 species)
- *Florilegus condignus*
- *Macropis* spp. (2 species)
- *Melitoma taurea*
- *Melitta* spp. (2 species)
- *Nomia* spp. (2 species)
- *Xenoglossa strenua*

"Small Dark Bees" (pp. 23-24)

"Yellow-faced Bees"
- *Calliopsis andreniformis*
- *Hylaeus* spp. (Yellow-masked Bees, 13 species)
- *Perdita* spp. (7 species)
- *Protandrena abdominalis*
- *Pseudopanurgus* spp. (6 species)

"Dark Sweat Bees"
- *Halictus* spp. (6 species)
- **Lasioglossum* spp. (77 species)

"Small Dark Bees" (pp. 23-24) *Contd.*

"Small Carpenter Bees"
- *Ceratina* spp. (Small or Dwarf Carpenter Bees, 5 species)

"Small Mining Bees"
- *Panurginus* spp. (3 species)

"Green Sweat Bees" (p. 25)
- *Agapostemon* spp. (4 species)
- *Augochlora pura*
- *Augochlorella* spp. (2 species)
- *Augochloropsis* spp. (2 species)

"Dark Hairy Belly Bees" (p. 26)
- *Anthidiellum notatum*
- *Anthidium* spp. (Wool Carder Bees, 2 species)
- *Chelostoma philadelpi*
- *Heriades* spp. (4 species)
- *Hoplitis* spp. (6 species)
- *Lithurgus chrysurus* (Mediterranean Wood-boring Bee)
- *Megachile* spp. (Resin and Leaf-cutting Bees, 23 species)
- *Paranthidium jugatorum*
- *Pseudoanthidium nanum*

"Metallic Hairy Belly Bees" (p. 27)
- *Osmia* spp. (Orchard and Mason Bees; 19 species)

"Cuckoo Bees" (p. 28)
- *Coelioxys* spp. (10 species)
- *Epeoloides pilosula*
- *Epeolus* spp. (8 species)
- *Holcopasites* spp. (3 species)
- *Nomada* spp. (32 species)
- *Sphecodes* spp. (16 species)
- *Stelis* spp. (3 species)
- *Triepeolus* spp. (10 species)

***Note:** There are a number of genera that also have cleptoparasitic, or cuckoo, bees that are not included in this list of genera. *Bombus* and *Lasioglossum* have both cleptoparasitic and non-cleptoparasitic species. Do not worry about cleptoparasitic members of these groups when counting – you are not likely going to encounter them and you are not expected to know the difference if you do see them.

Maryland Native Bee Survey

Citizen Scientist Pollinator Monitoring Guide

Pollinators are a key component of ensuring proper ecosystem health, linking natural environments with man-made and managed lands, such as parks, agricultural landscapes, and suburban and urban gardens. Although their primary objective is to feed themselves and their offspring, the work of bees, flies, beetles, butterflies and a host of other pollinators ensure that there is adequate pollination for a constant supply of fruits, vegetables, nuts and seeds. Of these, bees are generally considered to be the most important group of pollinators in North America.

Despite the great importance of these tiny organisms to our everyday lives – for, as much as one-third of our diet is the direct result of bee pollination! – surprisingly little is known about bees, outside of the honey bee, of course. We still have much to learn about the diversity and abundance of species on a local, or even regional, scale, about their nesting and foraging preferences, or about the diseases, pests and parasites that affect their health.

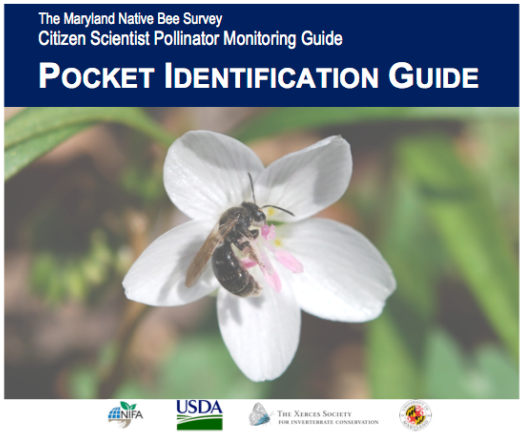
Since 2004, the USGS has been monitoring native bee diversity and abundance across the state. To date, we have identified over 400 species of bees in Maryland, but much remains to be discovered. In 2015, the Maryland Native Bee Survey, in cooperation with the Maryland Master Gardeners program, unveils the Citizen Scientist Monitoring Program, designed to equip citizen scientists with the monitoring tools necessary to identify and observe pollinators at work in our gardens. Through this effort, we hope to continue to expand our knowledge of how best to preserve, restore and protect these valuable ecological resources.



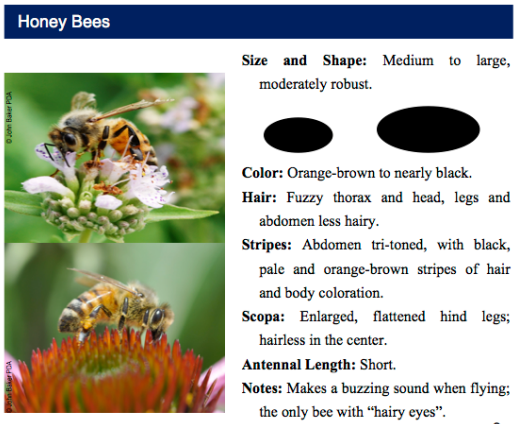
There are four species of green sweat bees belonging to the family *Agapostemon* identified from Maryland. Pictured above is *Agapostemon virescens*.

NIFA USDA THE XERCES SOCIETY FOR INVERTEBRATE CONSERVATION UNIVERSITY OF MARYLAND 1856

Pocket guide







Bumble Bees

Size and Shape: Medium to very large, robust.



Color, Hair and Stripes: Body black, with yellow, black, and, sometimes, orange hair stripes on thorax and abdomen.

Scopa: Hind legs enlarged and flattened; hairless in center.

Antennal Length: Short for females (for most bumble bees encountered), long for males.

Notes: Make a low buzzing sound when flying; painful sting that does not linger.



4

Large Carpenter Bees



Size and Shape: Very large and robust.



Color and Hair: Shiny, nearly hairless black abdomen; thorax covered in yellow/light hair; males with a yellow spot on face.

Stripes: None.

Scopa: Hind leg enlarged, completely covered in scopal hairs.

Antennal Length: Short.

Notes: Will only see one or a few at a time; only species in MD: *Xylocopa virginica*.

5

Hairy Leg Bees

Size and Shape: Small/medium to medium/large and robust.



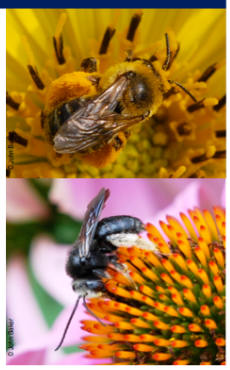
Color and Hair: Dark, with white to yellowish/orange hairs.

Stripes: Abdomen often with pale stripes.

Scopa: On hind legs; appear as dense stands of long hair (like pipe-cleaners).

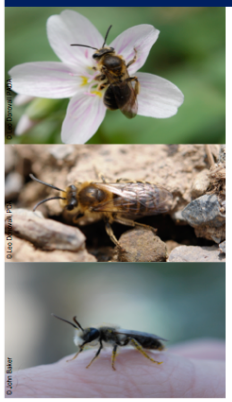
Antennal Length: Generally longer than most bees, especially males, who have very long antennae.

Notes: Very quick; difficult to collect.



6

Large Dark Bees



Size and Shape: Small to Medium/large, relatively narrow to moderately robust.



Color and Hair: Body dark, thorax covered in short, white to yellowish hairs; females with facial foveae; males with beard or mustache or yellow facial markings.

Stripes: If present, made up of pale hairs.

Scopa: On hind legs, often pale and short.

Antennal Length: Short in females, longer in males.

Notes: Can be numerous in Spring and Fall; one rare species, *Nomia nortoni*, with iridescent abdominal stripes.

7

Small Dark Bees

Size and Shape: Tiny to small/medium, moderately narrow.



Color, Hair and Stripes: Dark, often metallic; sometimes with yellow marks on face, thorax and/or legs; abdomen can be yellowish or reddish; body often dulled by short pale hairs, that can be in stripes or patches on abdomen.

Scopa: On hind legs, but can be difficult to see without pollen load.

Antennal Length: Short in females, longer in males.

Notes: Often most abundant group in the garden throughout the season.

8



Green Sweat Bees



Size and Shape: Small to Medium, relatively narrow.



Color, Hair and Stripes: Metallic green; abdomen can be dark and striped with yellow body markings or pale hairs.

Scopa: On hind legs; less noticeable than other bees, unless covered in pollen.

Antennal Length: Short in females, longer in males.

Notes: Relatively fast flying and numerous; most are ground nesters, but one especially numerous species nests in rotting wood, and, so, may be found in areas with a lot of woody debris.

9

Metallic Hairy Belly Bees

Size and Shape: Small to medium/large and robust.



Color, Hair and Stripes: Dull to bright metallic green or blue; dark, white or pale yellow to orange; stripes absent or faint on abdomen; some very hairy and dark with coppery reflections.

Scopa: On underside of abdomen (look for pollen load).

Antennal Length: Short.

Notes: Most numerous in spring; active for only a short period of time; a couple of species with short facial "horns".

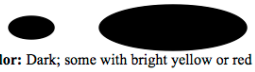


10

Dark Hairy Belly Bees



Size and Shape: Small to very large, usually robust, can be relatively narrow.



Color: Dark; some with bright yellow or red markings on thorax and abdomen.

Hair and Stripes: Thorax and head thickly covered in white/pale to orange-colored hairs; abdomen with pale to white stripes or not striped.

Scopa: On underside of abdomen, can be dark or pale to orange (look for pollen).

Antennal Length: Short.

Notes: Abdomen often flexed upward (or "elevated") when feeding.

11

Cuckoo Bees

Size and shape: Tiny to medium and often narrow-bodied.



Color: Body black, red, or yellowish; often wasp-like, with elaborate body markings or light-colored hair patterns.

Hair and Stripes: Usually not very hairy; some with short, densely-arranged hair covering entire body.

Scopa: Lack pollen carrying structures.

Antennal Length: Sometimes short, often long (especially males).

Notes: Look very wasp-like; only minor pollinators - most are nest parasites.



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2016

Monitoring guide

Maryland Native Pollinator Survey

Citizen Science Pollinator Monitoring Guide



© Olivia Bernauer

Revised for Maryland by Olivia Bernauer, Chris Seargent, Paula Shrewsbury, Mike Raupp, and Dennis vanEngelsdorp

The University of Maryland, Department of Entomology

2016, 3rd Edition



THE XERCES SOCIETY
FOR INVERTEBRATE CONSERVATION



Previous Editions

The Xerces Society for Invertebrate Conservation is an international, nonprofit, member-supported organization dedicated to preserving wildlife and its habitat through the conservation of invertebrates. The Society promotes protection of invertebrates and their habitat through science-based advocacy, conservation, and education projects. Its work focuses on three principal areas – endangered species, watershed health, and pollinator conservation. For more information about the Society or on becoming a member, please visit our website (www.xerces.org) or call us at (503) 232-6639.

Through its pollinator conservation program, the Society offers practical advice and technical support on habitat management for native pollinator insects.

University of California Berkeley collaborates with the Xerces Society on monitoring pollinator communities and pollination function at farm sites before and after restoration. University of California Berkeley conducts studies to calibrate the observational data collected by citizen scientists against the specimen-based data collected by scientists during standard surveys.

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Photographs

We are grateful to the many photographers who allowed us to use their wonderful photographs in this monitoring guide. The copyright for all photographs is retained by the photographers. None of the photographs may be reproduced without permission from the photographer. If you wish to get in touch with a photographer, please contact the Xerces Society.

Maryland Edition

The Maryland Native Pollinator Survey

The Maryland Native Bee Survey is a collaborative effort of the University of Maryland, with cooperators and volunteers from across the state. The goals of this program are to survey and monitor native pollinators throughout Maryland, provide opportunities and support for native pollinator research and to aide in the development of educational and outreach tools to support the conservation, restoration and protection of native pollinators, and to ultimately result in planting recommendations for pollinator gardens in the state of Maryland.

This document is a revision of the Citizen Scientist Pollinator Monitoring Protocol originally developed by the University of California at Berkeley and the Xerces Society for use in monitoring pollinator re-colonization at native vegetation restoration sites in California. This Maryland edition is a collaborative effort between the Maryland Native Bee Survey and the Maryland Master Gardener program and is intended to document floral resource use in native plantings to better inform pollinator gardening efforts.

A terrific job editing this document was done by Barbara Hopkins, a Master Gardener and participant in this study.

Front Cover

Bumble bees (*Bombus* spp.) are an important group of pollinators that pollinate a wide range of flowering plants, including flowering trees and wildflowers. Photograph by Olivia Bernauer (2014).

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Chapter One

Getting Started

Introduction

Insect pollinators are an amazingly diverse and very important group of insects. Conservatively, three out of every four plants on Earth depend on bees for pollination, including nearly 70% of all crop species. About one-third of a typical human's diet depends directly or indirectly on insect pollination. Without insect pollinators, we would not be able to produce apples, almonds, blueberries, squash, and many other fruits, vegetables and nuts.



© Annette Allor

Pictured above is a female Bronze Copper butterfly (Lycaena hyllus) nectaring on and likely pollinating asters in the fall.

Pollinating insects include bees, butterflies, moths, skippers, beetles, flies, true bugs and wasps. When most people hear the word "bee," a single species comes to mind, *Apis mellifera* (the European Honey Bee, pictured below), a species that is not native to the United States. In Maryland, there are more than 400 species of non-*Apis* bees (also referred to as "native", "solitary" or "wild" bees) are extremely important pollinators of crops, garden and nursery flowers, wildflowers and trees.



USGSBIML

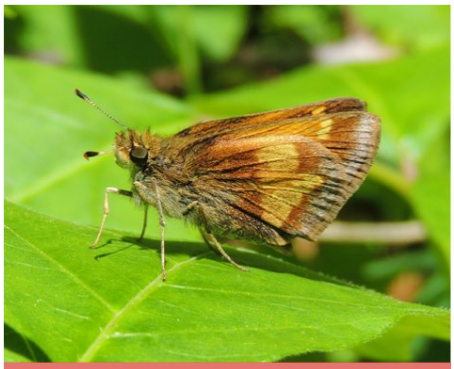
The face of a female honey bee (*Apis mellifera*), the species whose declines have helped to spark interest in native pollinators.

In addition to bees, butterflies are common flower visitors that are also important pollinators. Similar to bees, when most people hear the word "butterfly", again, a single species comes to mind, *Danaus plexippus* (The Monarch Butterfly). Monarch butterflies are a large, beautiful migratory species of butterfly whose habitat and numbers are dwindling. To date, more than 150 different species of butterflies have been documented in Maryland.

Since 2004, the USGS has been monitoring the bee diversity of Maryland. Interest in native pollinators of Maryland began with concern over honey bee declines and the need to better understand how native pollinators could support the state's pollination demands. In partnership with the

Xerces Society for Invertebrate Conservation and the University of Maryland, with funding from the United States Department of Agriculture, this aim of this citizen-science project is to establish which plants are most preferred by the Maryland's native pollinators.

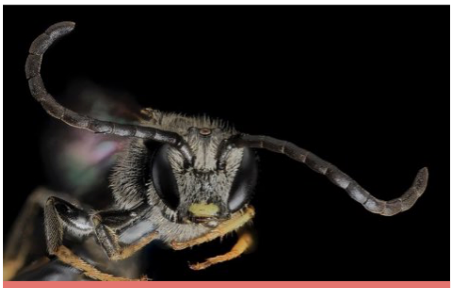
There are an estimated 400-450 species of bees and over 150 species of butterflies found in Maryland. Some of these species can only be identified by specialists who look at traits and characteristics that are difficult to see, especially without a microscope. There are only a handful of taxonomists in North America who can accurately identify these insects to the species level! However, with a little practice and guidance, Citizen Scientists can learn to identify the most common bee species and "species-groups" (generally, sets of related species) found in the gardens, fields, and forests of Maryland.



© Annette Allor

Commonly seen flying in late spring to mid-summer, the Hobomok skipper (*Poanes hobomok*) is a treat to find in the garden.

This Citizen Scientist Monitoring Guide was developed specifically for the purpose of training Citizen Scientists. It includes an introduction to identifying bees and butterflies, in general. The final section outlines the procedures for collecting observational data. The data generated by this project, specifically, will help gauge the value of different plants and plant communities as food resources for Maryland's bees and butterflies.



USGSBIML

This is a commonly found small dark bee, *Lasioglossum truncatum*, or commonly known as a dark sweat bee.

How to Monitor and Observe Pollinators

There are many different species of insect pollinators, including bees, butterflies, moths, skippers, wasps, beetles and true bugs. This monitoring protocol will allow you to measure both the diversity (different kinds) and abundance (number of each kind or of all kinds) of bees and butterflies that are present in the habitat you are monitoring, and how the composition of those pollinators change over time. There are many potential uses for this kind of information, including:

quantifying the effectiveness of efforts to promote pollinator populations in gardens and yards; understanding the pollinator requirements of crops dependent on insect pollinators; or, simply, identifying the types of bees present on a particular habitat. This information will aid in generating guidelines on how to enhance pollinator habitat by improving or planting additional floral resources. Long term monitoring will allow us to assess how management practices are affecting local pollinator communities.

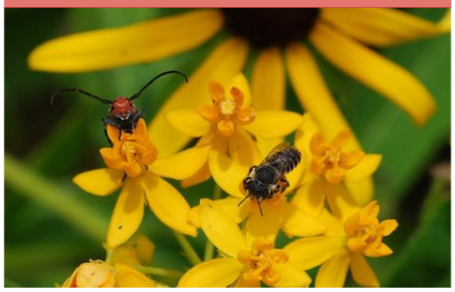
There are many ways to monitor pollinators, but most often specimens are collected or observed visiting flowers. In this study, we will be both observing and collecting some of the insects, however participants will only be responsible for observing them. Here, we present the necessary procedures designed to train the Citizen Scientist to:

- Select monitoring locations and collect habitat information.
- Identify pollinator species-groups.
- Record observational data on floral visitations.

Throughout the process, we will be evaluating the effectiveness of these guidelines to train Citizen Scientists to accomplish the goals outlined above. Important in this process is feedback from you, our Citizen Scientists, as you work through the material and begin to record observations. The data you collect and the feedback you provide will be important as we continue to develop a deeper understanding of our pollinators.

Note: It is sometimes difficult to tell flies, wasps, and bees apart. Furthermore, some bees look very similar to each other, but are in fact different species. Remember when identifying insects that **it is much better to identify bees accurately at a coarse taxonomic level** than to identify them inaccurately at a fine taxonomic level. When in doubt, identify only to the level you are confident, and add notes to describe the insect further, as necessary.

Below we see an Asclepias sp. inflorescence with a Megachilid bee and a red milkweed beetle (*Tetraopes tetrophthalmus*) simultaneously enjoying a floral meal.



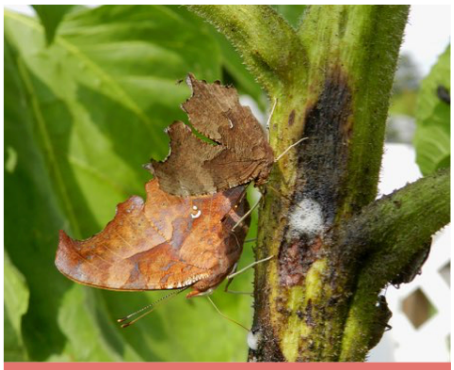
© John Baker

Observing Insects Visiting Flowers

Before you begin monitoring your property it is important to know how to make observations and how to identify floral visitors. Much of this guide focuses on the latter, but it is important to keep the following points in mind when collecting observational data on floral visitors:

- Only collect data on floral visitors. This

means, only record observations of insects on the reproductive parts of the flower, not on the petals, leaves or stems of the plant. Pollinating insects will be collecting either pollen or nectar. It can be difficult to observe this on very small flowers. In this case, observe the floral visitor's behavior and do your best. You do not need to identify or make notes on animals sitting on petals, leaves, stems, etc., or visitors flying around the area.



© Annette Allor

Above we see a Question Mark (*Polygonia interrogationis*) and Eastern comma (*Polygonia comma*) on the stem of a plant. If you see butterflies resting on plant stems, they should not be counted in this survey as they are not pollinating (i.e. on the flower itself, collecting nectar and pollen).

- Remember to look at all flower types. Sometimes you need to look inside deep flowers, too. For example, in Maryland, bees may be foraging in the center of the cone-shaped flowers of squash (*Cucurbita* sp.) or bindweed (*Convolvulus arvensis*; also known as morning glory).In addition, bees may visit flowers that are less noticeable to people – such as flowers that are quite small or green – so try not to focus on only one or a few flower types.
- Be careful not to disturb insects visiting flowers before you get a chance to observe them well. Avoid sudden movements and do not stand too close to the flower you are observing. Insects respond to shadows passing overhead by moving away; walk so that your shadow trails you, rather than advances in front of you. When collecting data, orient yourself so that your shadow is not on the flowers you are observing.
- Observe and identify insects as best you can; even noting whether a visitor is a honey bee, native bee, fly or wasp is useful information.
- Bee species can be difficult to tell apart. As we are particularly interested in monitoring native bees it is important to distinguish, at minimum, honey bees from native bees. (See the example data sheets, pages 51-54)

Chapter Two

Identifying Floral Visitors

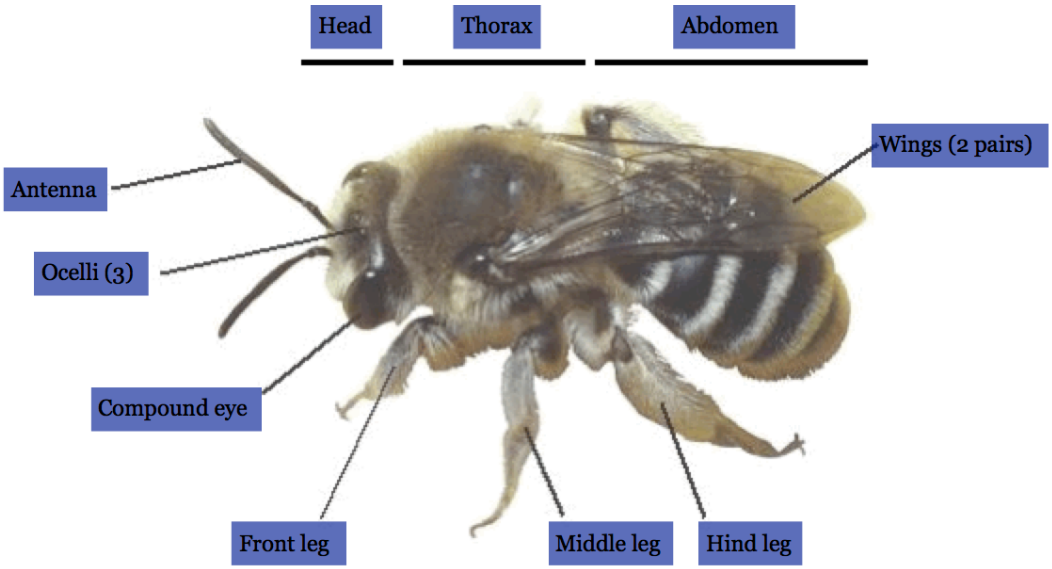
Bees, in general, are the best pollinators; they have evolved to be the most efficient pollen transporters. However, some birds, bats and other rodents, flies, wasps, butterflies, moths, beetles, and bugs visit and pollinate flowers, as well. For this reason it is important to note *all* floral visitors.

Identifying butterflies and moths or a spider from a bee is simple. Separating bees from wasps or flies – especially those that mimic bees or wasps – can be harder. The following pages give more information on how to identify the principle groups of pollinators and key characteristics to look for when identifying specific bee or butterfly groups.

First, we will focus on bees and second we will focus on butterflies.

Identifying Bees

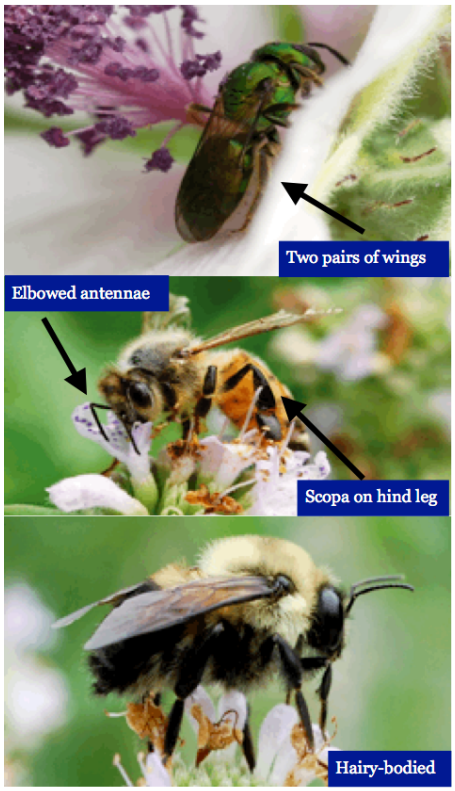
To help you get to know a bee, take a look at the diagram below, on which the major body parts have been labeled. On the next page you will find more about the key characteristics of bees.



5

Key characteristics:

- Bees have **four wings** (two pair; difficult to see when folded over the body).
- Bees have long, **elbowed antennae**. In this book, when we talk about antennal length, we are talking about the length of the female bee's antennae. You are the most likely to encounter female bees as they are major pollinators, foraging to bring pollen back to their young, while the males are not. However, if you do encounter a male bee, its antennae are likely to be longer than that of a female bee of the same species.
- Bees have large, well separated eyes with three small eyes (or "ocelli") on top of the head.
- Bees are **more robust** (i.e. rounder bodies) than wasps and flies; abdomen usually broad near thorax (vs. most wasps).
- Most bees are **hairy-bodied**, with multi-branched hairs that resemble pipe-cleaners or brushes and are designed for carrying pollen. Since male bees do not carry pollen, they are typically less hairy than female bees.





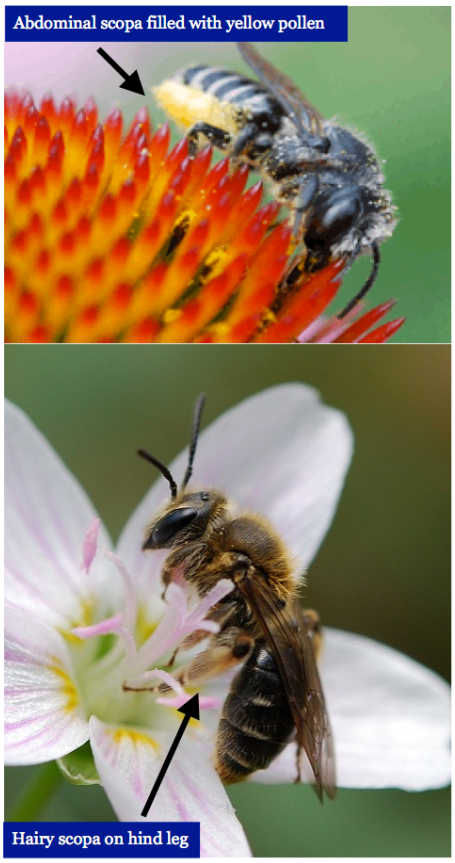
- Female bees can **carry large loads of pollen**, either on their legs or on their abdomen in a "scopa". If male bees have pollen on their bodies, it was likely accumulated by accident; they do not intentionally collect or transfer pollen.
- Many bee species exhibit **sexual dimorphism**. This means that the males and females of a single species look very different. For example, male bees are

often smaller than female bees, can have more or less hair than female bees (lacking pollen collecting hairs), or can have different colored exoskeletal markings (i.e. males of the large carpenter bee, *Xylocopa virginica,* have a distinctive white or yellow patch on their face).

Size: Range from 0.125 -1.5 inches (.2 to 3.8 cm).

Body Color: Can be black, brown, orange, yellow, red, or metallic blue, green, or copper-colored.

Stripes: Body color (exoskeleton) or hair colors (yellow, orange, white, black or brown) can form stripes.



A NOTE ABOUT STINGS: There is always a risk of being stung when working with and around bees (and wasps). Most bees are not aggressive and only sting if handled improperly; you will very rarely be stung while simply observing bees. If, however, you happen to be stung while in the field, try to identify the type of bee (or wasp) that stung you and let someone know so they can help watch for symptoms. Most people have mild reactions to bee stings and exhibit a reaction only at the site of the sting (mild swelling, redness, itchiness and/or mild pain). Symptoms of a serious reaction include swelling elsewhere on the body, vomiting, dizziness, hoarseness, thickened or slurred speech, or difficulty breathing, and should receive prompt medical care from a physician. If you suspect you have an allergy to bee stings, consult your doctor and ask about an EpiPen®.

Insects Easily Confused with Bees: A Quick Reference

Flies vs. Bees

Key characteristics of flies:

- Flies often have **short, thick antennae** (can be difficult to see).
- Flies often have **large eyes near the front of their head** usually converging (coming together) on top of the head, almost touching; small eyes ("ocelli") on front of head, above antennae.
- Flies only have **two wings** (one pair).
- Flies are usually **less hairy** than bees.
- Flies **can hover** (most bees are not able to hover).
- Flies **do not carry large loads of pollen** although some grains may stick to their bodies or legs.

Size: 0.125 -1.5 inches (.2 to 3.8 cm), approximately the same size range as bees.

Body Color: Can be black, brown, red, orange, yellow, creamy-white or metallic blue, green or coppery.

Stripes: Can have stripes, usually from body color (exoskeleton).

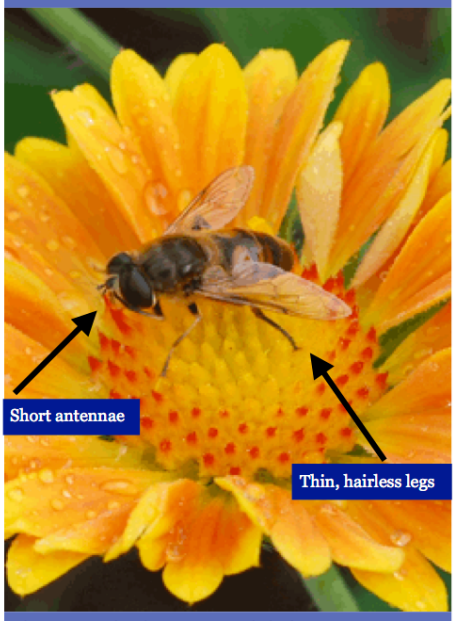


© John Baker



© John Baker

This fly is very hairy and meant to mimic a bumble bee. Its' one pair of wings is clearly visible in this photo.



© David Inouye

Above: Note the short, apparently lacking antennae on this fly. Flies do not have hairy legs, which can be seen here.

Left: This fly is set to mimic a honey bee with yellow or orange and black stripes.

Identifying butterflies

Key Characteristics:

- Butterflies have **three pairs**, or six legs.
- Butterflies have **four wings**, two pairs, that are readily visible and held vertically above their bodies while at rest. The colored patterns visible on butterfly wings are made up of many tiny, colored scales.
- Butterflies have **clubbed antennae**.
- Butterflies have long bodies; they can be slender and narrow or more robust and filled out. Butterflies have a **thorax that is broadly connected to the abdomen,** often looking like it is a complete unit. Their bodies are typically covered with short, velvety hairs.
- Butterflies **do not have specialized pollen carrying structures** like bees do. However, upon visiting flowers, butterflies can facilitate pollination by picking up pollen grains on their legs, face or body at one flower and transferring it to the next flower.
- Butterflies have sucking mouthparts (a **proboscis**) in the form of a long tube coiled underneath the head.
- Butterflies have prominent compound eyes and can have up to three simple eyes or ocelli on the top of their head, between their compound eyes.
- Butterflies often express sexual dimorphism; unlike bees, male butterflies are often larger and more brightly colored than the females.



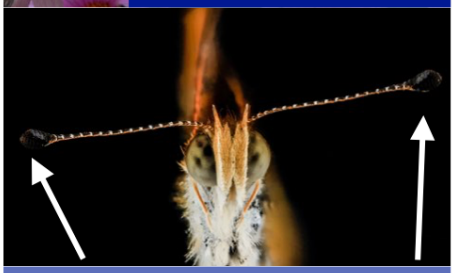
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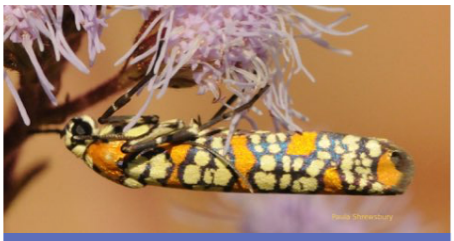
This image clearly illustrates the special clubbed antennae of butterflies.

Insects Easily Confused with Butterflies: A Quick Reference
Butterflies vs. Moths

Key characteristics of moths:

- Moths, like butterflies have **two pairs of wings**, however instead of holding them vertically over their body like butterflies do at rest, their **wings rest at their sides**.
- Butterflies have clubbed antennae, however moths have either **pointed or feathered antennae.**
- Butterflies are often brightly colored with showy patterns, moths are typically **drab and patterned with earthy colors**
- Moths have **thicker bodies** than butterflies
- Butterflies are active during the day (i.e. they are diurnal), while the majority of moths are active at night (i.e. they are nocturnal)

Some moths, like hummingbird moths, (*Hemaris* sp.), are diurnal and are often seen nectaring on flowers during the daytime. These moths are small to medium sized with thick bodies and often resemble bumble bees or hummingbirds. They often have clear wings and have a fan of hairs at the end of the abdomen.



© Paula Shrewsbury

Note the drab colors of this moth and the wings resting at the moth's sides.



© Paula Shrewsbury

The antennae of this moth are lacking the characteristic butterfly club. The thick body is also readily apparent.



© Mike Raupp

An example of a hummingbird moth (*Hemaris* sp.) visiting a flower during the day. The inner part of the wings are clear and the moth's body is thick.

11

Chapter Three

Understanding Bees

Introduction

If you see that a floral visitor is carrying clumps of pollen on its body, this visitor is likely a bee. Female bees collect pollen from flowers to bring back to their nests, where they pack it into brood cells for their larvae (i.e. young bees) to feed on. For this reason, their bodies are highly adapted to be very efficient pollen transporters.

In this section, we will examine some of the characters that will help you to identify bees visiting flowers. For most bees, we will only be able to identify to a larger group (i.e., family, genus, species groupings) or to a body-type.

The characteristics that will be covered in this section are:

- Body size and shape
- Body coloration
- Body hair distribution
- Location of scopa
- Body stripes
- Antennal length



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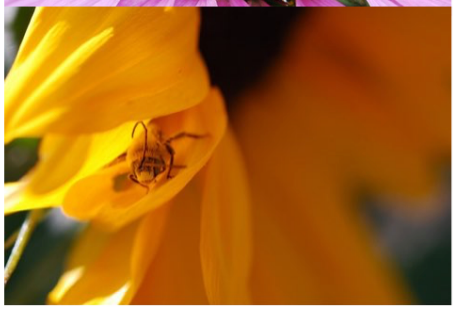


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In the photo above we see the face of *Halictus ligatus*, a small dark bee, covered in yellow pollen grains. Bees intentionally carry pollen on their scopa, either on their hind leg or under their abdomen. When bees are foraging on a particularly pollen-filled flower, they may end up with pollen everywhere, like this bee here. In the photo below there is a bumble foraging for pollen. Notice how full the pollen baskets on her hind legs are with orange pollen balls.



© John Baker



© John Baker

Body Size

The size of the bee is often a great initial separator of different bee groups. It is typically the first thing noticed when observing a bee and can be especially helpful when trying to identify bees when combined with other characters. Bees can range in size from tiny, less than an eighth of an inch to an inch or larger.

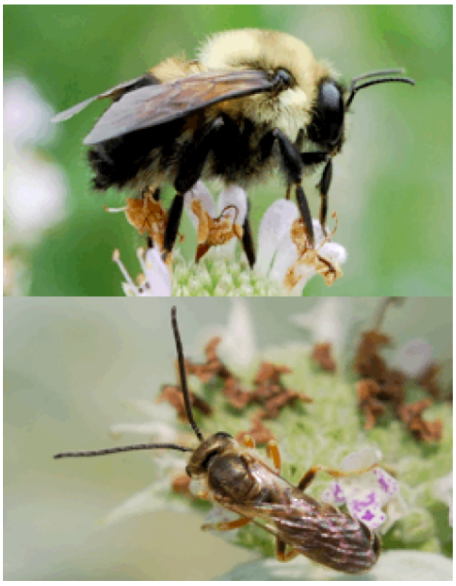
When identifying bees, determine the approximate size (large, medium, small) of the bee.

The the photo in the top right we see the very large Eastern Carpenter Bee (*Xylocopa virginica*) and in the photo below that we have an incredibly tiny *Perdita* sp. perched on an insect pin less than 0.5 mm in diameter. *Perdita* species are exceptionally tiny, typically less than 1 cm in length.



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Body shape

Some species groups are consistent in body shape. Some bees have narrower bodies, while others are more robust and stocky, like a bumble bee.

When identifying bees, determine the approximate shape of the bees (thin and narrow, or robust and stocky).

In the photos at the left, we have an example of a stocky, robust bee, the bumble bee *Bombus griseocollis*. In the lower photo we have a green sweat bee illustrating an example of a thinner, more narrow-bodied bee.

Body Coloration

Color can be assigned in two ways with bees: 1) body surface, or exoskeleton, color and 2) hair color. We will refer to bee color in both contexts, as necessary. In general, look at the overall color pattern to begin to make broad classifications.

When identifying bees, determine what colors are present on the bee (body and hair).

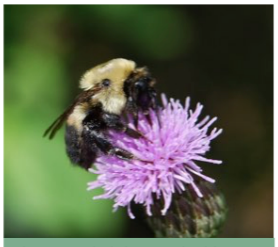
- Metallic or non-metallic
- Hair color vs. body color
- General distribution of colors (thorax, head, abdomen)



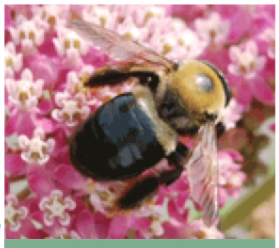
In the top photo we see a hairy yellow bumble bee (*Bombus* sp.), in the middle photo a metallic green sweat bee (*Augochlora pura*) and in the bottom photo, a black leaf cutter bee (*Megachile apicalis*)with white hairy stripes.

Distribution of Hair

The pattern of hair distribution is an important tool for identification. Some bees are "fuzzy", with the entire body covered in hairs. Others are sparsely covered in hairs or have hairs covering only certain areas of the body. When identifying bees, determine which body regions are covered in hair.



Thorax and abdomen thickly covered in hair

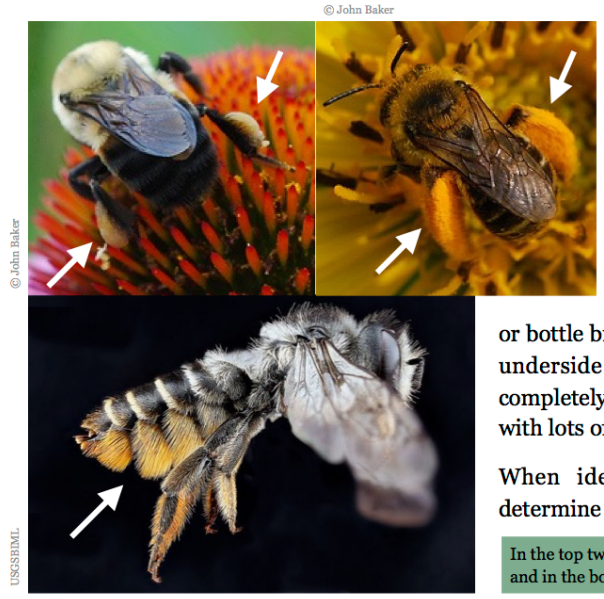


Thorax thickly covered in hair, abdomen sparse or hair in bands.



Body appears nearly hairless.

14



Bees: Location of Scopa

The **scopa**, or "pollen basket", is an area of densely arranged, often highly-branched hairs that are modified for transport of the "pollen load", or packet of collected pollen. The scopa is only present on female bees and is most often located on the hind legs, resembling pipe cleaners or bottle brushes. For others, the scopa is on the underside (or bottom) of the abdomen or completely absent. If unsure, look for an area with lots of pollen packed against the body.

When identifying bees, it is important to determine where the scopa is located.

In the top two photos we see bees with scopa on their hind legs and in the bottom photo a bee with its scopa under its abdomen.

Bees: Body Stripes

Bees are often identified by the pattern of stripes or bands of colored hair or exoskeleton markings. The region or relationships of these stripes to one another are distinguishing features for species and species groups.

When identifying bees, determine if the bee has stripes on its body (thorax, abdomen, or both).

- Hair or exoskeleton markings
- Pattern (color, location of bands or marks)

Bees: Antennal Length



The top right photo illustrates a bee, *Anthidium manicatum*, with yellow strips on its abdomen. These yellow strips are made out of exoskeleton, while the bee on the bottom has stripes made out of thin hairs.

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Antennal length is important for distinguishing sex: males have longer antennae (literally, one segment longer – 12 for females, 13 for males). In general, bees have "short" antennae. However, one group is called the "long-horned" bees, because they have longer antennae than most other bees.

When identifying bees, determine the length of the antennae.

The top left photo is an example of a bee with very long antennae, while the bee on the bottom has much shorter antennae.

16

Chapter Four

A Guide to the Different Groups of Bees

Introduction

There are more than 400 species of bees in Maryland. This guide will help you identify some of the common bee groups you will see in your garden. The photos on this page illustrate some of the diversity of these bees.

Remember, this guide is not exhaustive, so if you observe a bee that does not fall into an identified species-group note the bee as "Other bee" and either photograph or describe the bee thoroughly in the observational notes. Even if you can't identify the bee precisely, it is important to document that it was observed.

In particular, it is important to distinguish the honey bees, which are non-native, from the native bees. Whenever possible, attempt at minimum, to distinguish honey bees from the rest of the bee categories. So, study the "honey bee" page carefully.

Keep in mind the characteristics that will help you identify your bees (refer to Section 3: Understanding Bees, pages 12-16):

- Body size, shape and coloration
- Distribution of body hairs
- Type and pattern of stripes
- Location of scopa
- Antennal length

NOTE: Identify bees to the most specific group you are comfortable with; knowing both what type a bee is and what it is not is valuable information. For example, if you do not know the type of bee you see, but you know that it is not a honey bee, note only that "it is not a honey bee". In Some case (e.g. bumble bees) it will be possible to distinguish species within a bee group (even if you cannot comfortably identify to species, identify that it is a "bumble bee").

Honey Bees

One introduced species, *Apis mellifera*.

When most people hear the word "bee", it is the honey bee that comes to mind.

Key Characteristics

- **Size and Shape:** Medium to large, 0.4 to 0.6 inches (0.5-1.5 cm) in length, moderately robust.
- **Color:** Orange-brown to nearly black.
- **Hair:** Fuzzy thorax and head, legs and abdomen less hairy. The only bee with "hairy eyes."
- **Stripes:** Abdomen tri-toned, with black, pale and orange-brown stripes of hair and body coloration.
- **Scopa:** Enlarged, flattened hind legs; hairless in the center.
- **Antennal Length:** Short.

Important: While observing, distinguishing between honey bees and the rest of the bee categories is the most important observation you can make.

<u>Leg shape:</u>



<u>Body shape:</u>





© John Baker

Notice the hairs on this honey bee's eyes. She also has a small pollen ball on her hind leg. It's orange and looks like ear wax.



© Scott Bauer

These two honey bees demonstrate the variation in color of honey bees, the one on the right is pale and golden while the one on the left is much darker, almost black.



© John Baker

Above we see a honey bee foraging on a flower.

Honey bees can easily be confused with:

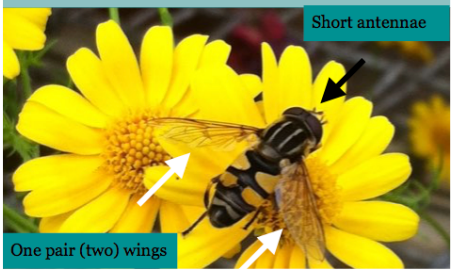
Flies:

To tell flies and honey bees apart look at the wings: a fly only has two wings (one pair), while a honey bee has four wings (two pairs). Honey bees will also have longer, elbowed antennae while flies typically have small antennae, big eyes, and skinny hind legs.



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The fly above has the same golden color as a honey bee; make sure you note the skinny, hairless legs. Flies are not meant to carry pollen like bees. In both of these pictures you can clearly see that these flies have only one pair of wings, not two like bees have. The fly below has very short antennae; they are almost impossible to see in the photograph.



© Olivia Bernauer

Wasps:

Wasps have nearly hairless bodies with exoskeletal (body) markings rather than markings made by hair patterns.Wasps have long, skinny legs, while honey bees will have hairy legs, with flattened, enlarged hind legs for collecting pollen.



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Wasps are not very hairy; they may have some short hairs like the wasp above, but they are much less hairy than honey bees are. Both of these photos demonstrate the exoskeletal stripes that make wasps easy to confuse with bees. Note that honey bees are golden-orange to black, while wasps can have red and bright yellow markings on their bodies.



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Bumble Bees

There are 14 species from the genus *Bombus* in the state of Maryland.

Key Characteristics

- **Size and Shape:** Medium to very large, robust.
- **Color, Hair and Stripes:** Body black with yellow, black, and, sometimes, orange or rusty colored hair stripes over thorax and abdomen.
- **Scopa:** Hind legs enlarged and flattened; hairless in center.
- **Antennal Length:** Short in females (the majority of bumble bees encountered), long in males.
- **Notes:** Make a low buzzing sound when flying; painful sting that does not linger.

<u>Leg shape:</u>



<u>Body shape:</u>





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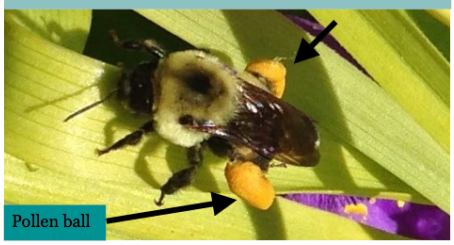
The bumble bee above, *Bombus impatiens*, is collecting nectar from this flower. If she were collecting pollen you would see a pollen ball on her shiny hind leg.



© John Baker

Above we see another bumble bee collecting nectar on a purple cone flower.

Below we see a bumble bee resting on some leaves with her pollen baskets full of orange pollen.

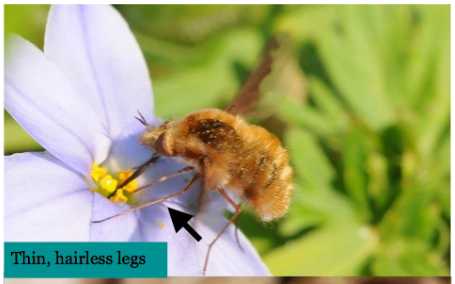


© Olivia Bernauer

Can easily be confused with:

Flies:

There are a number of flies and other bees that mimic bumble bees. Look for a completely hairy abdomen and large hind legs, usually with short antennae.



Thin, hairless legs

© Mike Raupp



One pair of wings

© John Baker

Above we see *Bombyliidae* sp. mimicking bumble bees. They have hair all over their body, but just one pair of wings. The three photos below illustrate the face of a fly (left) with very short antennae, a furry bumble bee (center) and male carpenter bee (right) with a white patch in the middle of his face. Female carpenter bees look the same, but would have black in the middle of their face instead of white.

Large carpenter bees (Xylocopa virginica):

The large carpenter bees can often be confused with bumble bees. To tell them apart, look at the abdomen. If there is hair covering the entire abdomen, then it is a bumble bee. If the abdomen is hairless and shiny, it is a large carpenter bee.

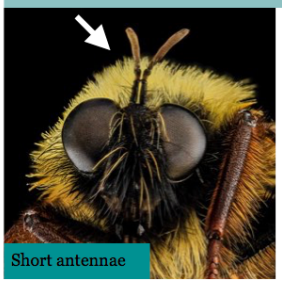


© Mike Raupp



© John Baker

In the bottom photo, notice the shiny, hairless abdomen of the carpenter bee. Bumble bees have hair covering their abdomen.

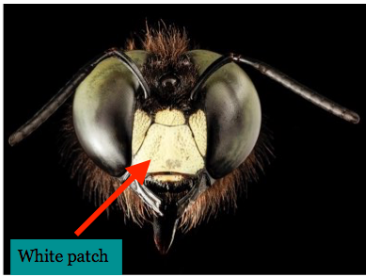


Short antennae

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White patch

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Large Carpenter Bees

One species, *Xylocopa virginica*, in Maryland.

Key Characteristics

- **Size and Shape:** Very large and robust.
- **Color, Hair and Stripes:** Shiny black abdomen, thorax black with yellow/light hair; males with a yellow spot on face.
- **Scopa:** Hind leg enlarged, covered with a brush of thick hair (scopa) throughout
- **Antennal Length**: Short.

Notes: often found in residential areas around exposed wood (decks, porches, trim, wood piles, etc.); males territorial (may buzz by your head); will "hover" for short period of time, "staring you down". While male carpenter bees are territorial, they cannot sting and female carpenter bees rarely sting.

Leg shape:



Body shape:



Can easily be confused with:

Bumble Bees (*Bombus* sp.) see pages 20 and 21 for more information.



© John Baker

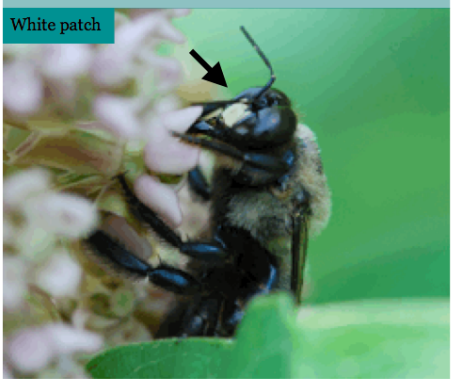
Note the shiny abdomen and furry thorax of this female carpenter bee.



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Above we see the face of a female carpenter bee. Compare this to the white patch on the male's face in the photo below.

White patch



© John Baker

Long-horned Bees

There are 29 species in this group from the following genera: *Anthophora* sp. (5 species), *Eucera* sp. (4 species), *Habropoda laboriosa*, *Melissodes* sp. (14 species), *Peponapis pruinosa*, *Ptilothrix bombiformis* and *Svastra* sp. (3 species).

Key Characteristics:

- **Size and Shape:** Small to medium to large and robust.
- **Color and Hair:** Dark, with white to yellowish/orange hairs; thorax covered in short, dense, velvety hair.
- **Stripes:** Abdomen often with pale stripes.
- **Scopa:** On hind legs; appear as dense strands of long hair (like pipe-cleaners), usually quite prominent.
- **Antennal Length:** Generally longer than most, especially males, who have very long antennae.
- **Notes:** Some species are very quick and can visit flowers rapidly.

Leg shape:



Body shape:





© John Baker

In the bees both above and below you can see the large pipe-cleaner-like scopa on their hind legs filled with yellow pollen.



© John Baker

The two bees picture above have stripes on their abdomens, while the bee below lacks stripes. Notice the very long antennae on the bee below.



© John Baker



© Leo Donovall

The bee above has a patch of hair on it's face known as a fovea. This is common in large dark bees. She also has yellow pollen coating all three pairs of legs.



© John Baker

Above we have a small carpenter bee (*Ceratina* sp.) visiting a flower.

Below we see the very tiny *Hylaeus leptocephalus* curled up. These bees are often called yellow-faced or masked bees due to the patch of lighter coloration between their eyes.



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Dark Bees

The Dark Bees are usually the most numerous group of bees visiting flowers and the most difficult to tell apart. In order to make identifying these bees easier, we present them in subgroups. When identifying a dark bee, first determine whether it is a large or small bee. Large bees are bees that are more than 0.4 inches or 1 cm long from head to tail; bees considered to be small bees are less than 0.4 inches or 1 cm in length.

Once you have determined whether the bee is large or small, determine the location of the scopa. The dark bees will either have scopa on their hind legs or on their abdomen. If you do not feel comfortable identifying the bee to this level, just record whether or not it is a large or small dark bee.



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The bee above, *Megachile texana*, is a large dark bee with an abdominal scopa. The dense patches of hair on the underside of her abdomen make up her scopa. This is where she carries pollen, not on her legs.

Large Dark Bees With Abdominal Scopa

There are 28 species in this group including: *Anthidium manicatum*, *Lithurgus chrysurus* and *Megachile* sp. (26 species). These bees are commonly known as leaf-cutter or resin bees.

Key Characteristics

- **Size and Shape:** Large and very robust; a few are narrow
- **Color:** Black or dark with coppery metallic reflections; some with bright yellow or red markings on thorax and abdomen.
- **Hair and Stripes:** Thorax and head thickly covered in white/pale to orange-colored hairs; abdomen with pale to white stripes or not striped, with dark, pale or orange-colored hairs underneath.
- **Scopa:** Located on underside of abdomen (look for pollen). In general, these bees lack hair on their legs, they do not use their legs to carry pollen.
- Antennal Length: Short.

Leg shape:



Body shape:



The bee pictured at the right is holding her abdomen upwards. This behavior is typical of bees in this group. Since they collect pollen on the underside of their abdomen, holding it upright prevents the pollen from falling off as they walk around the flower. The grey/white stripes on the abdomen seen here are a common characteristic of many bees in this group.

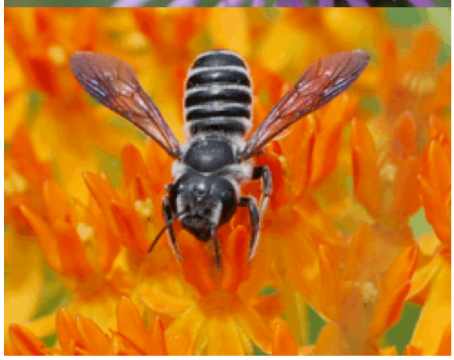


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Above is a wool carder bee, *Anthidium manicatum*, whose abdominal scopa is clearly visible. She has yellow exoskeletal stripes on her abdomen. Below we see the rusty colored *Lithurgus chyrsurus* collecting nectar.



© John Baker



© John Baker

Large Dark Bees Without Abdominal Scopa

There are 111 species in this group including: *Andrea* sp. (Mining bees, 85 species), *Cemolobus ipomoeae*, *Colletes* sp. (Plasterer and Cellophane bees, 14 species), *Dieunomia* sp. (2 species), *Florilegus condignus*, *Macropis* sp. (2 species), *Nomia* sp. (2 species), and *Xenoglossa strenua*.

Key Characteristics

- **Size and Shape:** Small to Medium/large, relatively narrow to moderately robust.
- **Color and Hair:** Dark-bodied; most with densely hairy thorax (hairs white to pale yellow/orange) compared to abdomen, which is much less hairy.
- **Stripes:** Often present on abdomen, made of pale hairs; a (rare) few with iridescent integumental (body) stripes on the abdomen.
- **Scopa:** On hind legs; often pale and short (compare with "Long Horned Bees", page XX).
- **Antennal Length:** Short in females, longer in males.



USGSBIML

The bee above has abdominal stripes due to patches of hair. Below, we can easily see the hind leg of this bee. There are short hairs all around it to collect pollen, but they are not as long as the long-horned bees.



USGSBIML

The bee below, *Cemolobus ipomoeae*, resembles a bumble bee, but lacks a very fuzzy abdomen and has hairs all throughout the scopa.



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Leg shape:



Body shape:



Notes:

- Some are very bumble bee-like, but have a completely hairy scopa.
- Mining and Plasterer Bees are some of the earliest-emerging bees in Maryland's spring. They are found on many of the early-blooming spring wildflowers and flowering trees from March through May.



©John Baker

The bee above is collecting nectar and pollen from an *Asclepias* flower. Again, we see white or gray stripes made of hair commonly on the abdomens of bees in this group.



USGSBIML

Above we have the Anthidiellum notatum, a very small bee with yellow exoskeletal markings. Many of the bees in this group look very similar to the large dark bees with abdominal scopa, the main difference being the size of the bee. Below we have Megachile exilis, showing off both her stinger and her dense patch of hair on the underside of her abdomen.



USGSBIML

Small Dark Bees With Abdominal Scopa

There are 19 species in this group including: *Anthidiellum notatum*, *Anthidium oblongatum*, *Chelostoma philadelphi*, *Heriades* sp. (4 species), *Hoplites* sp. (6 species), *Megachile* sp. (4 species), *Paranthidium jugatorum*, and *Psedoanthidium nanum*.

Key Characteristics

-**Size and Shape:** Small and very robust

-**Color:** Black or dark with coppery metallic reflections; some with bright yellow or red markings on thorax and abdomen.

-**Hair and Stripes:** Thorax and head thickly covered in white/pale to orange-colored hairs; abdomen with pale to white stripes or not striped, with dark, pale or orange-colored hairs underneath.

-**Scopa:** Located on underside of abdomen (look for pollen). In general, these bees lack hair on their legs, they do not use their legs to carry pollen.

-**Antennal Length**: Short.

Leg shape:



Body shape:



Notes: When visiting flowers, abdomen often flexed upward (or elevated) revealing pollen underneath.

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Small Dark Bees Without Abdominal Scopa

There are 119 species in this group. More information about their scientific names and groups is on the next page.

Key Characteristics

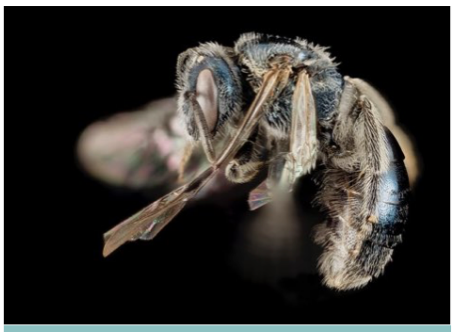
- **Size and Shape:** Tiny to small/medium, moderately narrow.
- **Color:** Black to dull metallic blue, green or coppery; abdomen can be yellowish or reddish, but usually dark
- **Hair:** Body covered in pale hairs that are less noticeable, but some with large, dense patches, especially on abdomen.
- **Stripes:** Usually absent, but some have whitish to pale yellowish stripes on dark abdomen.
- **Scopa:** On hind legs; less noticeable than other bees, unless covered in pollen.
- **Antennal Length:** Short in females, longer in males.

Leg shape:



Body shape:





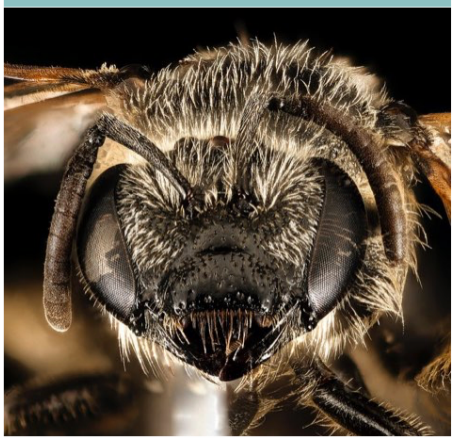
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The above bee is a dull, metallic dark blue.



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These bees carry pollen on their hind legs; you can see the orangey scopal hairs on this bee's hind legs. Below we have an up-close view of the face of one these bees.



USGSBIML

Some additional information about different small dark bees lacking abdominal scopa is provided on the next few pages. This is for your information; you do not need to know how to distinguish these groups of bees when observing.


USGSBIML

Dark Sweat Bees

Halictus sp. (6 species) and *Lasioglossom* sp. (77 species)

Dark sweat bees are quite variable. They range in size from tiny to slightly smaller than a honey bee, are usually dark or dull metallic in coloration with few markings and are usually honey bee-shaped.


USGSBIML

Yellow-faced Bees

Calliopsis andreniformis, *Hylaeus* sp. (Yellow-masked bees, 13 species), *Perdita* sp. (7 species), *Protandrena abdominal*, and *Pseudopanurgus* sp. (6 species).

Yellow-faced bees are similar in shape to dark sweat bees, but with white to yellow markings on face, thorax and legs. The body is much less hairy, and the scopa is absent.

Small Carpenter Bees

Ceratina sp. (5 species)

Small, or "dwarf", carpenter bees do not resemble their much larger-bodied relatives, the large carpenter bees. Small carpenter bees are entirely dull metallic green to blue-green and cylindrically shaped. The abdomen is shield-like, with a pointed tip. Males have a large pale spot on the face and broad, flat hind legs.


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Small Mining Bees

Panurginus sp. (3 species)

Mining bees are often quite hairy, many with stripes of hair on the abdomen. Females have patches of pale hair on the face (called the facial fovea), and males have a hairy face, often resembling a "mustache" or "beard". Some mining bees have elaborate facial markings and yellow legs, resembling yellow-faced bees. This group is most numerous in the Spring and Fall.

Metallic Bees

Some bees have shiny metallic exoskeletons. These bees are broken down into two groups: metallic green bees and all other metallic bees. The green metallic bees are green sweat bees and they can range in color from a bright blue-green to a coppery green. Some of the metallic green bees in Maryland have abdomens that are not green nor metallic but are instead colored with black and yellow stripes (*Agapostemon* sp.). The other metallic bees in Maryland can range in color from black to dark metallic blue to coppery colored.



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Above and to the right is a brilliant green bee, *Augochlora pura*, and below that, a metallic blue bee, *Osmia* sp.

Metallic Green Bees

There are 9 species in this group including: *Agapostemon* sp. (4 species), *Augochlora pura*, *Augochlorella* sp. (2 species), and *Augochloropsis* sp. (2 species). These bees are commonly known as green sweat bees.

Key Characteristics

- **Size and Shape:** Small to Medium, relatively narrow.
- **Color and Hair:** Metallic green; abdomen can be dark and/or striped; body covered in pale hairs that are difficult to notice.
- **Stripes:** Either absent, or with a yellow-and-black striped abdomen.
- **Scopa:** On hind legs; not very noticeable, unless covered in pollen.
- **Antennal Length:** Short

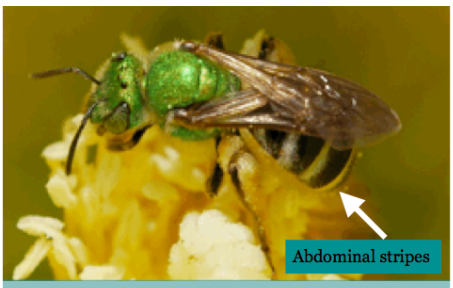
Leg shape:

Body shape:



Notes: Relatively fast flying and numerous; most are ground nesters, but one especially numerous species nests in rotting wood, and so may be found in areas with a lot of woody debris.

To the right we have *Augochloropsis metallica*. Her hind legs are covered in white pollen.



© John Baker

The bee above belongs to the genus *Agapostemon*. Bees in this genera have a metallic green head and thorax and an abdomen with black and yellow stripes.



© John Baker

This bee is covered in pollen. These green bees carry their pollen in scopa on their hind legs. This scopa is often hard to see unless it is covered with pollen like we see here. It is also common for these bees to have a coppery sheen to them like this one does.



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Metallic Green Bees can easily be confused with:

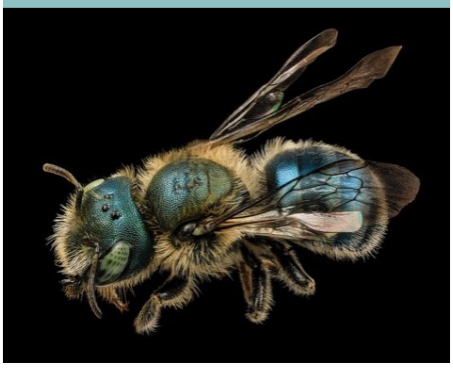
Orchard bees (*Megachilidae*):

Some orchard bees can have a metallic green hue. Look for the location of the scopa. Orchard bees will always have abdominal scopa, their legs should be relatively hairless and the underside of their abdomen should be full of dense hairs for collecting pollen. Orchard bees are often more robust than these metallic green bees and often have short hairs covering most of their body. For more information, see the Other Metallic Bee section.



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Both of these *Osmia* sp. are metallic in color with hints of green. Notice the abdominal scopa and hairy bodies these bees have, specifically a hairy thorax.



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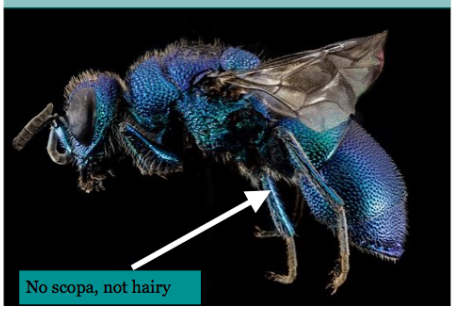
Cuckoo wasps (*Chrysididae*):

Cuckoo wasps tend to be more blue-green, look nearly hairless and have dark wings and will often be on vegetative parts of the plant resting rather than the flowers. Cuckoo wasps are not pollinators, they parasitize the nests of other bees and wasps and are only on flowers to fuel up on nectar.



© Rajwinder Singh

Both of these wasps belong to the family *Chrysididae;* the one above is more green in appearance, mimicking the metallic green bees previously discussed. The wasp below is more blue in color. You see that these insects are not hairy at all, they do not transport pollen.



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Other Metallic Bees

There are 19 *Osmia* sp. in Maryland.

Key Characteristics

- **Size and Shape:** Small to medium/large and robust.
- **Color:** Dull to bright metallic blue or green; some very hairy and dark with coppery reflections.
- **Hair and Stripes:** Black, white or dull yellow, brownish or orange; stripes absent or faint on abdomen.
- **Scopa:** On underside of abdomen (look for pollen load).
- **Antennal Length**: Short.

Leg shape:



Body shape:



Notes:

- Most observed in spring and early summer.
- Often called Orchard Bees (found pollinating blossoms of tree fruits) or Mason Bees (because some species gather mud and pebbles to construct nests). Others use plant materials to construct their nests.
- A few non-native (i.e. from outside of North America) species with "horns" on the face.

The bee to the right, *Osmia cornifrons*, is an introduced species that has become very common in the Eastern United States. This bee is not metallic and blue, but metallic and black with dense coppery hairs on its body.



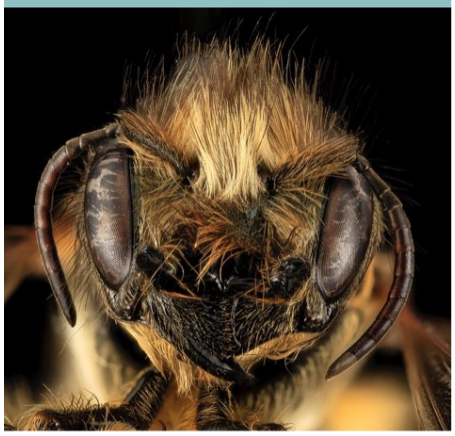
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The bee above is a beautiful metallic blue. It is easy to see the short hairs covering her thorax and head. Her hairy abdominal scopa is peeking out too.



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This bee looks very similar to a bumble bee; make sure to look for the location of the scopa. This bee has black scopal hairs.



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Chapter Five

Understanding Butterflies

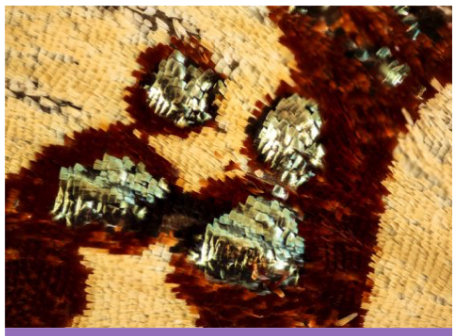
Introduction

While bees are built to carry pollen, butterflies only accidentally transport pollen from flower to flower. When we are identifying different groups of butterflies we do not look for a scopa, or pollen carrying location like we did with bees. Instead we will focus on the size of the butterfly, whether or not the butterfly has wing modifications, and the coloration and pattern of the butterfly's wings. The colors and patterns you see on butterfly wings are made by many tiny scales.

In this section, we will examine some of the characters that will help you to identify butterflies visiting flowers. For most butterflies, we will only be able to identify to a larger group (i.e., family, genus, species groupings).

The characteristics that will be covered in this section are:

- Wingspan
- Wing modifications
- Wing pattern and coloration



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The scales of this butterfly's wings are clearly visible when magnified. Some scales are metallic while others are matte. Butterfly scales come in many colors.



© Annette Allor

Above have one of the tiniest butterflies, a Gossamer wing butterfly, while below we have a swallowtail, one of the largest butterflies in Maryland.



© Annette Allor

Wingspan

The butterflies of Maryland range in size from 0.88 inches (2.24 cm) to 6.25 inches (15.88 cm). In order to identify the butterflies to different groups first look at the approximate size of the butterfly's wingspan:

- Small: 0.88 to 1.5 inches (2.24 - 3.81 cm)
- Medium: 1.5 to 2.5 inches (3.81 - 6.35 cm)
- Large: 2.5 to 6.25 inches (6.35 - 15.88cm)



© Annette Allor

Zebra swallowtails, *Protographium marcellus*, (above) can have incredibly long tails in their summer forms. Below, note the more delicate wing tails of the Gray Hairstreak, *Strymon melinus*.



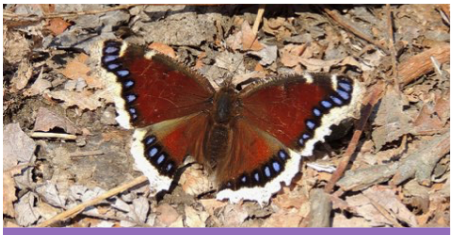
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Wing modifications

Some butterflies have tails on their hind wings. Swallowtails have particularly large tails, and this is a distinct, defining characteristic for that group of butterflies. Some Gossamer wing butterflies also have small tails resembling antennae on their hind wings too.

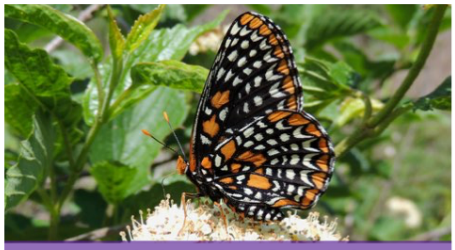
Wing pattern and coloration

Butterfly wings can take on any color of the rainbow and many of those colors are seen in Maryland's butterflies. Some butterflies can have metallic scales, but most are matte. It is common for butterflies to have stripes, checkerboard patterns, spots, eyespots, colored veins (i.e. Monarch butterflies).



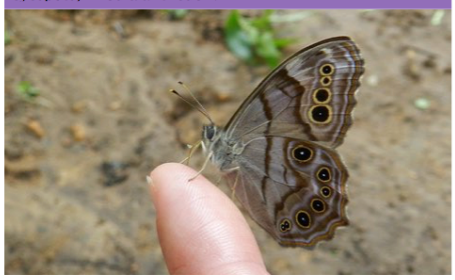
© Annette Allor

The Mourning Cloak butterfly, *Nymphalis antiopa*, has a row of blue dots lining its wings.



© Annette Allor

The Baltimore Checkerspot butterfly (*Euphydryas phaeton*) above clearly demonstrates a checkerboard pattern. Below is an example of a butterfly with many eyespots, Enodia anthedon.



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Chapter Six

A Guide to the Different Groups of Butterflies

Introduction

In the state of Maryland there are about 160 different species of butterfly. Some of these butterflies are permanent residents, others like the Gulf Fritillary (*Agraulis vanillae*) are migratory butterflies that only spend part of their lifetime in Maryland. This guide will help you identify some of the common butterfly groups in Maryland.

Remember, this guide is not exhaustive, so if you observe a butterfly that does not fall into an identified species-group note the butterfly as "Other butterfly" and either photograph or describe the butterfly thoroughly in the observational notes. Even if you can't identify the butterfly precisely, it is important to document that it was observed.

When describing the orientation of a butterfly (i.e. top or bottom) the terms **ventral** and **dorsal** will be used. A **ventral** view of a butterfly shows the underside of the wings, or the side usually visible when the wings are folded vertically over the body. The **dorsal** view shows the topside of the wings, as when they are spread open and flat.

You could add to the pictures below which is a dorsal view and which a ventral, just to clarify.

Keep in mind the characteristics that will help you identify your butterflies (refer to Chapter 5: Understanding Butterflies, pages 34-35):

- Size and wingspan
- Wing modifications
- Coloration and distinctive patterns on the wings

Swallowtail butterflies

Family *Papilionidae*

There are 8 species in this group that are found in Maryland.

- **Size and Shape:** Large with a distinctive tail on their hind wings
- **Wing span:** 2.5 - 6.25 inches (6.35 - 15.88 cm)
- **Color:** Often mostly black, yellow or white with the possibility of blue, white, orange, red or yellow spots on the wings



© Annette Allor

The ventral view of a Zebra swallowtail (*Protographium marcellus*). Note the long tail on its hind wings.



© Annette Allor

Two Pipevine Swallowtails (*Battus philenor*), a ventral to rear and dorsal view in the front butterfly.



© Annette Allor

A black swallowtail (*Papilio polyxenes*) nectaring, clubbed antennae visible Dorsal view.



© Annette Allor

The ventral view of a Spicebush swallowtail (*Papilio troilus*); note the characteristic tail on the butterfly's hind



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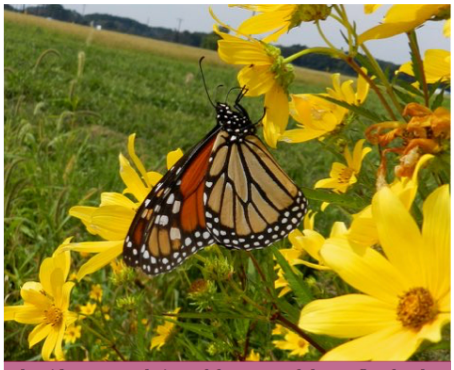
The Eastern Tiger Swallowtail (*Papilio glaucus*) is mainly yellow.

Monarch butterflies

Family *Nyphalidae*
There is only one species - *Danaus plexippus* - in this group found in Maryland.

- **Size and Shape:** Large
- **Wing span:** 3.38 - 4. 88 inches (8.6 - 12.4 cm)
- **Color:** Orange with black wing margins and veins and series of two white dots in the wing margin on the outsides of the wings

The Monarch butterfly is a migratory butterfly and travels from the United States and southern Canada in late summer or early fall to Mexico and the southern United States (e.g. California) where they overwinter in enormous aggregations.



© Annette Allor

The side or ventral view of the Monarch butterfly, clearly showing the two rows of white dots in the wing margins.



© Mike Raupp

A dorsal view of the monarch; note the orange wings and pattern of black veins



© Paula Shrewsbury

An aggregation of Monarchs overwintering on a pine tree in California.

Monarchs can easily be confused with:

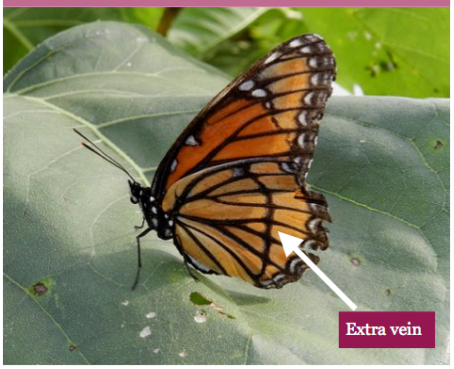
Viceroy butterfly (*Limenitis archippus*)

The Viceroy butterfly is a butterfly with orange wings, black veins and wing margins, and white spots on its wings, mimicking the Monarch butterfly. To tell these two butterflies apart, first look at the size, the Viceroy butterfly is much smaller than the Monarch butterfly with a wingspan of 2.5 - 3.38 inches (6.35 - 8.6 cm). Additionally the Viceroy butterfly has an additional black band on the hind wing. The Monarch butterfly lacks this black band.



© Annette Allor

Note the extra black band on the hindwing of the Viceroy. It can be seen from both the dorsal and ventral view of this butterfly.



© Annette Allor

Queen butterfly (*Danaus gilippus*)

The Queen butterfly like the Viceroy and Monarch butterflies is also orange with black wing margins and white spots. Again, the Queen butterfly is smaller than the Monarch with a wingspan of 2.63 - 3.88 inches (6.7 - 8.6 cm). Queen butterflies are often a darker, more rusty shade of orange than Monarchs and do not have black wing veins like Monarchs do. Queen butterflies also have more white spots scattered throughout the wings.



© Annette Allor

Note the lack of black veins on the inside of the Queen butterfly's wings and the additional white spots on both sides of the wings.



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White and Sulphur butterflies

Family *Pieridae*

There are 16 species in this group that are found in Maryland.

- **Size and Shape:** Medium
- **Wing span:** 1.4 - 2.75 inches (3.56 - 6.98 cm)
- **Color:** They are typically white, yellow or orange in color and can have black, white, pink, or orange spots or patches on their wings.

These butterflies are notorious agricultural and garden pests as caterpillars.



© Mike Raupp

Damage on a kale leaf from a caterpillar in the family *Pieridae*.



© Mike Raupp

A yellow butterfly (*Pieridae* sp.) fueling up on nectar.



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Multiple Cabbage White butterflies (*Pieris rapae*) nectaring on a thistle flower. Note the spots and dark wing tips.



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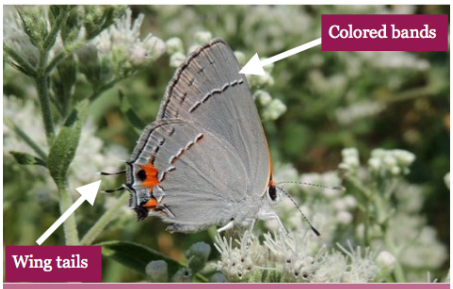
An Orange Sulphur butterfly (*Colias eurytheme*); note the pinky wing margins and variation in spots on its wings.

Gossamer wing butterflies

Family *Lycaenidae*

There are 33 species in this group that are found in Maryland.

- **Size and Shape:** Small; some of the butterflies in this group have small antenna-like tails on their hind wings.
- **Wing span:** 0.88 - 2 inches (2.24 - 5.08 cm)
- **Color:** In general, these butterflies range from orange, brown to grey on the outsides of their wings with spots or stripes in black, white, blue, orange, and/or red. Commonly, the interior of the wings are metallic blue, orange, or grey/black.



© Annette Allor

Note the tiny colored bands and spots on the wings of the Gray Hairstreak (*Strymon melinus*). The small antenna-like tails on the hind wings of some of these butterflies are clear in this photograph.



© Annette Allor

Butterflies in this group can be very small.



© Annette Allor

Here's an example of a butterfly from this group with brown outer wings, Henry's Elfin (*Callophrys henrici*)



© Annette Allor

The Spring Azure butterfly (*Celastrina ladon*) displaying white to gray outer wings and blue on the inside.



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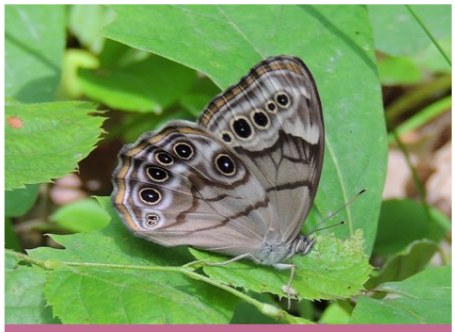
The American Copper (*Lycaena phlaeas*) displaying the bright orange color of the inside of its wings.

Satyrs and Wood Nymph butterflies

Family *Nymphalidae*

There are 7 species in this group that are found in Maryland.

- **Size and Shape:** Medium
- **Wing span:** 1.25 - 3 inches (3.18 - 7.62 cm)
- **Color:** They are drab; they are typically brown in color with a few to many eye spots on both the inside and outside of their wings.



© Annette Allor

The coloration of the Northern Pearly-eye (*Enodia anthedon*) is creamier in color with numerous large eyespots.



© Annette Allor

The Appalachian Brown (*Satyrodes appalachia*) has numerous eyespots and a light brown appearance.



© Annette Allor

Here we see both white or lighter patches and eyespots on the interior of the Common Wood Nymph's wings (*Cercyonis pegala*).



© Annette Allor

A Little Wood Satyr (*Megisto cymela*) sunning itself. Note the eyespots.



© Annette Allor

The dorsal view of the Carolina Satyr (*Hermeutychia sosybius*) lacks eyespots.

Brushfoot butterflies

Families *Nymphalidae* and *Riodinae*
There are 33 species in this group that are found in Maryland.

- **Size and Shape:** Medium to large
- **Wing span:** 1.25 - 4.44 inches (3.18 - 11.28 cm)
- **Color:** These butterflies are commonly orange, brown, black and/or white with patterns on their wings. Some have eyespots, many have a checkerboard pattern, spots, splotches of color, and/or other markings on their wings
- **Notes:**
  - This is a diverse group of butterflies.
  - Brush foot butterflies have reduced forelegs that are used to hold their wings flat while they are resting. At rest, they can look like they have only two pairs of legs.



© Annette Allor

Silver-bordered Fritillary (*Boloria selene*) showing off a busy, patterned ventral side.



© Mike Raupp

Checkerboard and other patterns in browns, oranges and black are common, like the Variegated Fritillary (*Euptoieta claudia*).



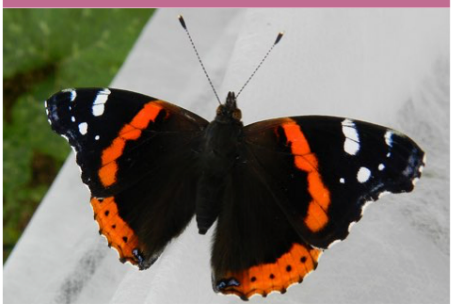
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American Lady (*Vanessa virginiensis*) has bright colors hiding under neutral patterns.



© Annette Allor

Brushfoots have a diversity of colors and patterns seen both the photos above and below.



© Annette Allor

Skippers

Family *Hersperiidae*

There are 59 species in this group that are found in Maryland.

- **Size and Shape:** Small to medium
- **Wing span:** .88 - 2.94 inches (2.24 - 7.47 cm)
- **Color:** Most skippers are **drab and dull** in color, typically brown, grey to orange with spots and strips in lighter colors.
- **Notes**:
  - Skipper's wings are typically small in proportion to their body size and at rest are held angled upwards or spread out.
  - Skippers have clubbed antennae that are hooked backwards.
  - Skippers have larger compound eyes than butterflies and moths.



© Annette Allor

This skipper's antennae are clearly visible, demonstrating the clubbed antennae that are hooked backward.



© Mike Raupp

The Silver Spotted Skipper (*Epargyreus clarus*) is a common garden visitor. This picture demonstrates a drab, brown skipper with a distinctive white blotch.



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The extra large compound eyes of skippers is clearly visible here on this orange skipper.



© Annette Allor

Skippers typically hold their wings angled out like this one.

Chapter Seven

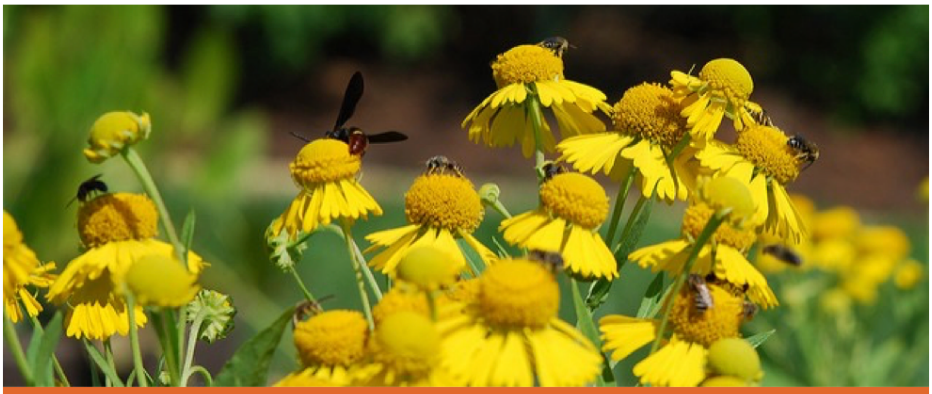
Observational Data Collection

Introduction

Documenting bee abundance and diversity is important for understanding the health of an ecosystem. Pollinators are a good measure of environmental health – changes in bee populations reflect changes in habitats and their inhabitants. Bee diversity can be affected by changing the composition of the flowering plant community. In this section, we will outline the protocols for conducting and recording observational data on floral visitors.

Observational data collection is both an active and a passive approach to measure pollinator-floral host relationships. Along with identifying who a pollinator is in a particular habitat or floral source and what day that general interaction took place, observational data on floral visitors produces specific relational information about weather, habitat, floral visitations, behavior (i.e. mating, communication, predator avoidance, etc.), flight patterns, activity schedule and interactions with other organisms. If carried out consistently, observational data can add much to our knowledge of how pollinators interact with their plant hosts.

Bee communities vary over time; while some bee groups will consistently show up during every sample year round, early season bees such as blue metallic hairy belly bees will be abundant only at certain times in the year. Also, some bee species are only active at certain times of the day. You should plan on recording observational data for your field site once per month throughout the field season (approximately April through October/early November) and at approximately regular intervals (e.g. the first Saturday, the 15th day, etc.). Observations should occur in the morning and repeated in the afternoon/early evening, as some bees are active for only a short portion of the day.



© John Baker

These flowers are covered in pollinators of all kinds. Can you spot the wasp mixed in with all the bees?

It is a good idea to be aware of the weather conditions before trying to make your observations. Bees do not like cool (temperatures below 55°F), windy (average wind speed over 5 miles per hour), or overcast skies (you should be able to see your shadow). Collect on an alternate day if conditions are not favorable, but try to remain consistent – always collect within a few days of your normal collecting date.

Included on the data sheets (Appendix A, pages XX-XX) are places to record the habitat description, date, time and weather conditions. In addition to these habitat and environmental observations, you will also be keeping track of the bees visiting the plants in your garden. This will help us to determine the abundance and diversity of floral visitors in your managed habitat. You will be provided with data sheets to fill out for every collection period.



© John Baker

It important to observe pollinators carefully and record detailed notes.

Materials Required:

- Identification guides (Citizen Science Pollinator Monitoring Guide and the companion Pocket Guide)
- Clipboard
- Pencil
- Observational Datasheet(s)
- First aid kit (including an Epipen or other appropriate medicine, if you are unsure of a bee allergy)
- A watch or other time-keeping device

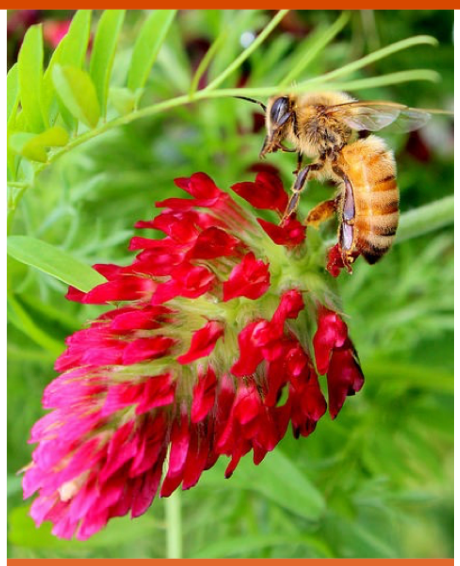
Timeline

- **Duration:** May through October or early November (ends after first hard frost).
- **Frequency of Observations:** Twice per month or more if you want, at consistent intervals – for example, the first and third Saturdays or the 10th and 20th day of the month.
- **Report Submission:** Data sheets should be mailed to the University of Maryland once per month in the pre-addressed envelopes provided.

General Sampling Day Procedure

Initial Observations

1. For the first observational period of the year, describe: age of site (if a garden, how long it has been present), general habitat description (trees, distance to water, setting/ landscape, floral and nesting resources available), etc. Drawing a crude map of the site and immediate surroundings would also be helpful. List all potential floral resources at your site (including those in bloom, those that have completed bloom and those that have yet to bloom). (See "Site Information and Initial Observations Data Sheet", page XX)



© John Baker

Here we see a golden honey bee (Apis mellifera) landing on some clover.

2. For the remaining observational periods, describe changes since the last visit, including the weather between observation periods (precipitation, major temperature shifts, etc.) and modifications to the landscape/ habitat. Add additional floral resources missed on the initial list. (See top of "Pollinator Monitoring Data Sheet", pages 51-52)

3. Identify and list the floral resources of your site that are currently in bloom – you will make your observations from this list. For every plant that is flowering, count the number of each that are present in the garden.

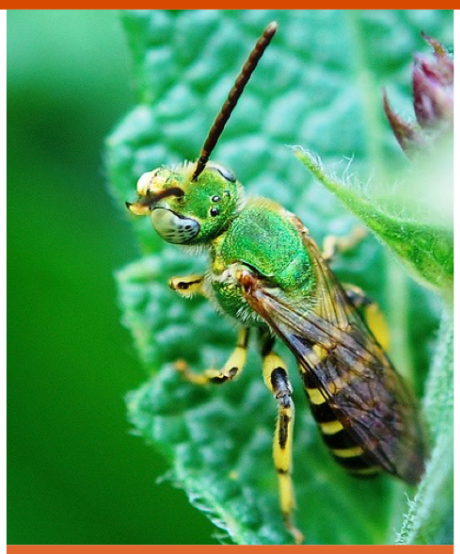
Observational Periods

1. Perform this operation twice per day: once in the morning, between 9:00 AM and noon, the other in the afternoon/early evening, between 1:00 and 5:00 PM. (see "Pollinator Monitoring Data Sheets", pages 51-54)

2. Note the time and relative temperature, windiness, and cloud cover (clear, partly cloudy, mostly cloudy with some sun and shadows, or overcast).

3. Observations:

- Choose between six and eight plants that are in bloom. Record the number or area (square footage) of each present in the garden. Record the percent of flowers in bloom in three categories: entering bloom, full bloom, and waning. Entering bloom means that the plant is just starting to come into bloom, that the majority of the plant is buds, not open flowers.



© John

This bee, an *Agapostemon* sp., is resting on a leaf, taking a break between flower visits.

Full bloom means that the majority of the flowers on the plant are open flowers. Finally waning means that the majority of the flowers on the plant are done blooming and are now dying buds.

-Begin with the Master Gardener Pollinator Garden required plants: Oregano, Thyme, *Agastache,* Asters, *Monarda, Echinacea, Asclepias, Helianthus, Rudbeckia,* and *Solidago*.

-Include additional blooming plants in your garden to bring the total to 6 blooming plants, unless there are no other plants in bloom.

-Be sure to spend 10 minutes per blooming plant species/cultivar recording the number of bees and/or butterflies in each species/group utilizing the flowers. You do not need to monitor both bees and butterflies, but are welcome to choose bees or butterflies and stick to that throughout the season.

- This could take some time if there are many blooming flowers; two-person crews could speed the process.
- Using the bee and butterfly guides provided in this manual, identify all bee and butterfly functional groups that arrive on the blooms. If you can't identify the insect to its group for sure, use the "other" category on the data sheet to record the bee or butterfly's presence and list in the notes what you know (i.e., "not a honey or bumble bee").

4. At the end of the observational period, record any additional observations: behaviors of note, interactions between bees, time spent at a flower, etc.

IMPORTANT!

- Only record pollinators that land on flowers!
- Avoid sudden movements so that you do not disturb insects visiting flowers before you get a chance to observe them well!
- Bee species can be difficult to tell apart – if you are unsure, record what you know. At the very least, we want to know if it is not a honey bee or bumble bee!

Submitting Data Sheets

Maryland Native Bee Survey Citizen Scientist Pollinator Monitoring Project Data Sheets should be sent to the University of Maryland for processing on a routine basis. They should be submitted via mail or email (addresses below). Please call or email with any questions or for additional information regarding the Maryland Native Pollinator Survey.

Olivia Bernauer, Native Pollinator Survey

University of Maryland

Department of Entomology, Rm. 4112

4291 Fieldhouse Drive

College Park, MD 20742

Phone: (608) 320 - 8388

Email for data submission: umdnps@gmail.com



© Annette Allor



© John Baker

The butterfly above is nectaring, while the bees to the right are taking shelter in a squash blossom.

Appendix A: Data sheets

The Following three data sheets will be what you use to collect data upon. Print copies will be provided to you at your initial training session.

In order to keep track of the data from each individual site, each site will be assigned a unique site number. In the 2015 survey, 4 digit ID numbers were used; this year six digit training numbers will be assigned to each site in the format XXXX16, with the 16 corresponding to this field season. The data sheets that you receive from a training session, or directly from Olivia, will already be printed with the appropriate site numbers. However, if you chose to print your own data sheets from a blank template or end up needing replacements, make sure you include your site number on the data sheet. There will is a location on each data sheet where this should go.

Initial data sheet:

On or before your first observation period, you will fill out the initial data sheet (pages 51 and 52). You will be provided with a blank copy of this data sheet complete with your site number. Please fill this out with as much detail as possible, especially the information about which plants are present in your yard. Include cultivars when applicable and if you know them. If you do not know the scientific names of the plants in the garden to species or cultivar, please include as much information as you can. If you only know the genus, a description or photo of the plant would be beneficial to submit as well. Photos can be submitted electronically at umdnps@gmail.com.

Morning and Afternoon data sheets:

On your initial and every subsequent observation period you will fill out the morning and afternoon data sheets corresponding to which time of day you are conducting your observations. Instructions on how to fill out each data sheet are included on the individual data sheet. If you have questions on how to fill out your data sheets, please contact Olivia at umdnps@gmail.com.

The more complete the data sheet, the more valuable the information is. Data sheets with blanks in the information about the weather or the time spent observing cannot be standardized the same as other data and cannot be compared as easily to other observations.

Please record temperature. If you can be exact (using your phone or the internet) that would be preferred. However, if you do not have access to this, you can estimate while in the field. Please only circle one temperature category, the one that most accurately describes your observational period.

2016 Citizen Science Pollinator Monitoring Program
Initial data sheet: Site information

Site ID number: XXXX16

Instructions: Fill the following data sheet in completely. For the site information, be as exact as possible with the address (no PO Boxes or RR numbers); use a GPS unit to gather coordinates, if possible. We will use the Site ID number (above) to assign location names. List the participants involved in the data collection. Be as exhaustive as possible when describing the initial observations.

Site Information:

Site name: _____

Site Location: _____

_____

County: _____

GPS Coordinates: _____

Site Contact: _____

Contact Address: _____

_____

Contact phone number: _____

Site History: Include the age of the site (how long has it been a garden?), former use of the land, and additional information about the site.

Describe the surrounding landscape, including bee nesting sites (bare ground, cane or hollow stems, wood piles, etc.), water resources, setting (urban/rural/agricultural, yard/ garden/field, managed/unmanaged surroundings):

2016 Citizen Science Pollinator Monitoring Program
Initial data sheet: Site information

List floral resources (former, current or potential) in garden/around site:

Trees:

Shrubs:

Herbaceous plants:

Vegetable/food plants:

Circle the following plants or genera of plants that are present in your garden:

Asters	Echinacea	Monarda	Heuchera
Asclepias	Helianthus	Thyme	Solidago
Agastache	Oregano	Rudbeckia	Coreopsis

Site ID number: _____ **Date:** _____/_____/_____

2016 Citizen Science Pollinator Monitoring Program: Morning Observation Period

Instructions: Fill in the date, garden size (approximate square footage or acreage of area devoted to flowering plants), number of participants, names can be included if desired, and start and end times of the observational period. Document the weather, record either an approximate OR actual temperature if this is possible (*you do not need to fill out both)* the level of windiness and the cloudiness. For the Habitat changes since last observation period include here any major weather events, plants that are now flowering, plants that are no longer flowering, and any changes to the landscape. Choose six plant species to observe pollinators, preferably *Aster*, *Asclepias*, *Agastache*, *Echinacea*, *Helianthus*, *Monarda*, oregano, thyme, *Rudbeckia*, and/or *Solidago*. For each plant, record its scientific name, being as specific as possible, the number of plants or the area the plants take up in the garden, the bloom status (entering bloom, full bloom, waning) and what time you begin and end observing at each plant species patch, aim for at least 10 minutes of observations per plant. Record floral visitors in the table provided, describing 'other' floral visitors in more detail in the larger space provided.

Garden size:_____ **Number of participants:**_____

Observation period start time: ____:____ am / pm **Observation period end time:** ____:____ am / pm

Weather information: **Wind:** Still / Light breeze / Windy / Occasional strong gusts **Sky:** Clear / Partly Cloudy / Mostly Cloudy / Overcast

Approximate temperature: 50-59°F / 60-69°F / 70-79°F / 80-89°F / 90-99°F / 100°F + **OR** **Actual temperature:** _____ °F

Habitat changes since last observation period:

1. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:				
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees			
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic		

2. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:				
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees			
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic		

Site ID number: _____ **Date:** _____/_____/_____

3. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

4. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

5. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

6. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

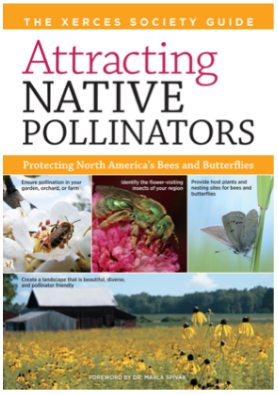
Appendix B: Additional Resources

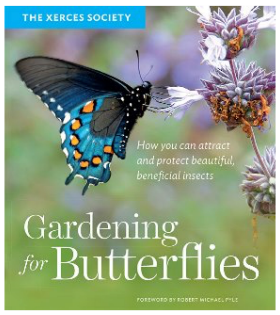
There are countless resources available on pollinators and how to best garden for them. The final section of this manual outlines a select list of some of the valuable resources available on pollinators. This list is by no means exhaustive; if you feel like it is lacking a particularly great bee, butterfly, pollinator, and/or gardening resource, send it to Olivia at olivia.bernauer@gmail.com so that it can be included in future editions of this document.

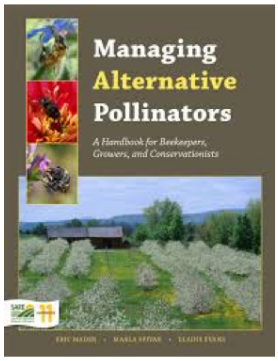
The Xerces Society

Website: www.xerces.org

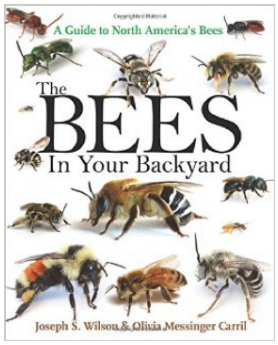
A nonprofit organization devoted to the conservation of invertebrates and their habitat, the Xerces Society devotes a lot of their time and resources to pollinator conservation. The first on their list of Programs is Pollinator Conservation. Their website is a fantastic resource to learn more about pollinators, their habitat, and what you can do to help conserve them. Online you can sign up for their Bring Back the Pollinators pledge, find out about talks that are being hosted by Xerces around the country, and find a variety of online and printable resources. In addition to their website, the Xerces Society has produced a number of additional pollinator-related publications out. Three of their most recent books on pollinators are: *Attracting Native Pollinators: Protecting North America's Bees and Butterflies; Gardening for Butterflies; Managing Alternative Pollinators: A Handbook for Beekeepers, Growers, and Conservationists.*





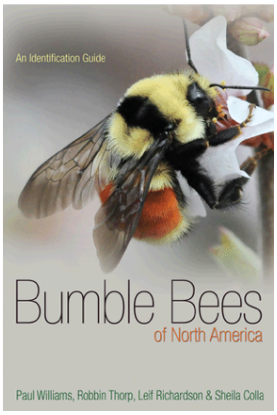


The Bees in Your Backyard: A Guide To North America's Bees



By Joseph S. Wilson & Olivia Messinger Carril
Princeton: Princeton University Press, 2015. Print.

This book contains an introduction to the approximately 4,000 species of bees found in the United States. This book is filled with lots of high quality, color photos of bees and bees on flowers. It includes information on how to tell different bees apart in the field as well as an easy to use key to tell apart the six different bee families. This is a great book for anyone interested in learning more about identifying bees to a finer taxonomic scale than used in this study.



Bumble Bees of North America: An Identification Guide

By Paul Williams, Robbin Thorp, Leif Richardson & Sheila Colla
Princeton: Princeton University Press, 2014, Print.

If you are interested in learning more about the 46 species of Bumble bees (*Bombus* sp.) found in North America, this book is for you. The book first covers an in-depth explanation of the social bumble bee life cycle including information on cuckoo bumble bees, parasitic bumble bee who do not build a nest of their own. It provides life histories, historical and contemporary ranges, and identification guides on each of these bees.

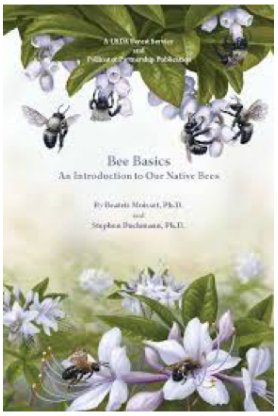
Bumble Bees of the Eastern United States



By Sheila Colla, Leif Richardson, & Paul Williams
USDA Forest Service the Pollinator Partnership

PDF available online at http://www.pollinator.org/PDFs/BumbleBeeGuide2011.pdf

A book similar to the above *Bumble Bees of North America: An Identification Guide* but with a focus on the bumble bees of the Eastern United States.



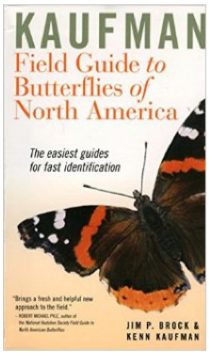
Bee Basics - An Introduction to Our Native Bees

By Beatriz Moisset & Steven Buchmann
USDA Forest Service and the Pollinator Partnership

PDF available online at http://www.pollinator.org/PDFs/BeeBasicsBook.pdf

This is a short booklet available for purchase or as a free PDF download that is full of beautiful illustrations of the bees of North America. It discusses the life styles of different native bees, the foraging needs of bees, and highlights some of the commonly found bees and their floral preferences. A great, visually pleasing introduction to bees.

Butterflies of North America



By Jim P. Brock & Kenn Kaufman
New York, N.Y: Houghton Mifflin Harcourt, 2006. Print.

This guide is super easy to use and will help you identify the butterflies of North America. It describes important characters to look for when identifying butterflies and shows how to identify each species. It includes distribution maps of each butterfly and images of both the larval and adult forms of most butterflies. This book is a convenient size for taking in the field.



Maryland Butterflies: A photographic resource of the butterflies of Maryland

By Annette Alor
Website: http://www.marylandbutterflies.com

Annette has done an incredible job of photographically documenting all of the butterflies and skippers found in Maryland. She has a list of each of the species found in Maryland and photos of each butterfly along with additional information about their distributions and preferred host plants. If you are interested in identifying butterflies in Maryland, this is a great place to start. Annette is the source of the vast majority of the butterfly photos in this document.

Pocket guide

Maryland Native Pollinator Survey

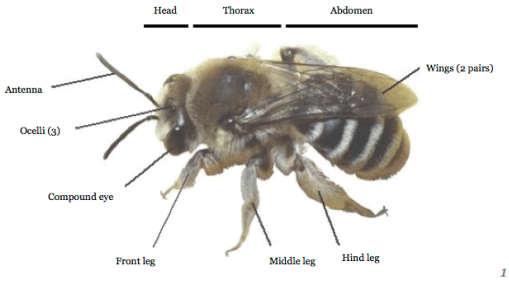
Citizen Science Pollinator Pocket Guide



Revised for Maryland by Olivia Bernauer, Chris Seargent, Paula Shrewsbury, Mike Raupp, and Dennis vanEngelsdorp.
The University of Maryland, Department of Entomology. 2016, 1st Edition.

Bees

Below is a labeled diagram of the basic anatomy of a bee, refer here if you need a refresher on bee body parts. For more information visit pages 6 and 7 in the Monitoring Guide.

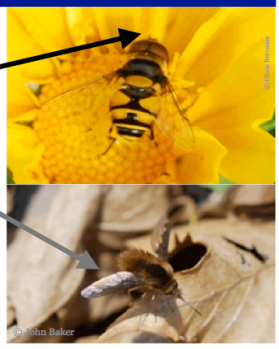


1

Bees vs. Flies

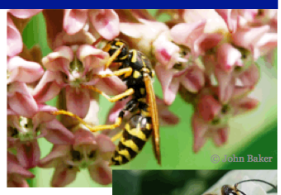
Key Characteristics of flies:

- **Flies have thick, short, hard to see antennae**
- Flies have large eyes
- Flies do not carry large loads of pollen
- **Flies only have two wings (one pair)**
- Can have stripes, usually from exoskeleton, not hair
- Can be black, brown, red, orange, yellow, creamy-white, or metallic blue, green or coppery



2

Bees vs. Wasps





© John Baker

Key Characteristics of wasps:

- Wasps, like bees, have four wings (two pairs)
- Wasps are typically **narrow bodied** with a pinched in 'waist'. **Wasps are not very hairy**
- Wasps do not intentionally collect pollen
- **Wasps often have long, thin legs**
- Wasps can have body strips that are similar to colors and patterns seen on bees, but these stripes are on the exoskeleton, not from hair

3

Honey bees

Apis mellifera



© Scott Bauer

Key Characteristics:

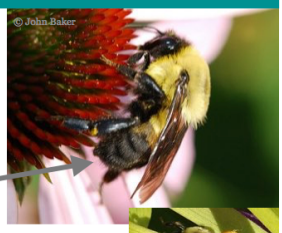
- Medium to large
- Orange-brown to nearly black
- **Hairy thorax and head**, abdomen less hairy
- Abdomen tri-toned with black, pale and orange-brown strips
- Scopa on hind legs, enlarged flattened, hairless in center

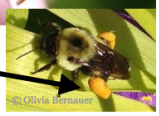
Commonly confused with flies and wasps, see pages 18 and 19 in the Monitoring Guide for more information.

4

Bumble bees

14 Bombus sp.





Key Characteristics:

- Medium to very large and robust
- Body black with black, yellow and sometimes orange hairy stripes, **very hairy**
- Scopa on hind leg, enlarged, flatted and hairless in center, pollen packed into balls

Commonly confused with carpenter bees (*Xylocopa virginica*) and flies see page 6 in the Pocket guide and pages 20 - 22 in the Monitoring guide for more information.

5

Large Carpenter bees

Xylocopa virginica



Key Characteristics:

- Large and robust
- **Shiny black abdomen**
- Thorax black with yellow or light hair
- Scopa on hind leg, enlarged, flattened, and hairy throughout
- Males with white patch on face

Commonly confused with bumble bees (*Bombus* sp.) see page 5 in the Pocket guide and pages 20 - 22 in the Monitoring guide for more information.

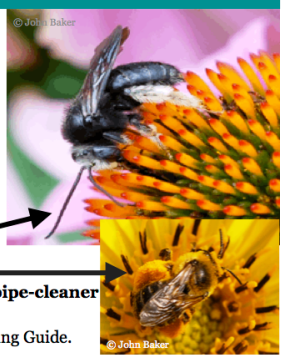
6

Long-horned bees

29 species from six genera

Key Characteristics:

- Small to medium-large and robust
- Dark with white to yellow/ orange hairs, thorax densely covered in hairs. Abdomen often with pale stripes.
- **Long antennae**
- **Scopa on hind legs, made up of dense hairs, pipe-cleaner** prominent



More info on pg. 23 in Monitoring Guide.

7

Dark bees

The Dark Bees are usually the most numerous group of bees visiting flowers, and the most difficult to tell apart. In order to make identifying these bees easier, they have been broken down into subgroups.

- When identifying a Dark bee, first determine whether it is a **large or small bee**. Bees that are considered to be large bees are bees that are more than .4 inches or 1 cm long from head to tail, bees considered to be small bees are less than .4 inches or 1 cm in length.
- Once you have determined whether the bee is large or small, **if you feel comfortable further identifying the bee, determine the location of the scopa**. The dark bees will either have scopa on their hind legs or on their abdomen.

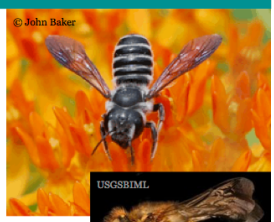
8

Large dark bees: with abdominal scopa

28 species in 3 genera

Key Characteristics:

- Large and very robust
- Black or dark with coppery metallic reflections. Can have other exoskeletal colorations.
- Thorax and head very hairy, abdomen with pale to white strips of hair
- **Scopa on underside of abdomen, legs not hairy.**





More information on Dark bees on pg. 24-30 in Monitoring Guide.

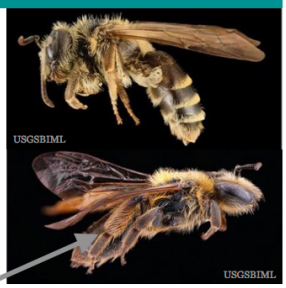
9

Large dark bees: without abdominal scopa

111 species in 8 genera

Key Characteristics:

- Small to medium/large, relatively narrow
- **Dark bodied** with pale hairs, dense on thorax, strips relatively rare, made of hair or exoskeleton
- **Scopa on hind legs, often made of short, pale hairs.**



More information on Dark bees on pg. 24-30 in Monitoring Guide.

10

Small dark bees: with abdominal scopa

19 species in 8 genera

Key Characteristics:

- Small and very robust
- Black or dark with coppery metallic reflections. Can have other exoskeletal colorations.
- Thorax and head very hairy, abdomen with pale to white strips of hair
- **Scopa on underside of abdomen, legs not hairy.**

More information on Dark bees on pg. 24-30 in Monitoring Guide.



11

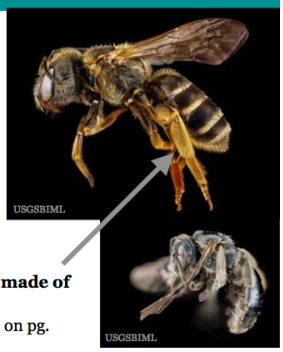
Small dark bees: without abdominal scopa

119 species in many genera

Key Characteristics:

- Tiny to small/medium, relatively narrow
- **Dark bodied** with pale hairs, dense on thorax, strips relatively rare, made of hair or exoskeleton
- **Scopa on hind legs, often made of short, pale hairs**.

More information on Dark bees on pg. 24-30 in Monitoring Guide.



12

Metallic Bees

Some bees have shiny metallic exoskeletons. These bees are broken down into two groups:

- Metallic green bees: The green metallic bees can range in color from a bright, blue green to a coppery green.
- All other metallic bees: The other metallic bees in Maryland can range in color from black to dark metallic blue to coppery colored. It is important to distinguish these two groups of metallic bees when collecting data.

For more information on metallic bees, see pages 30-33 in the Monitoring Guide.



13

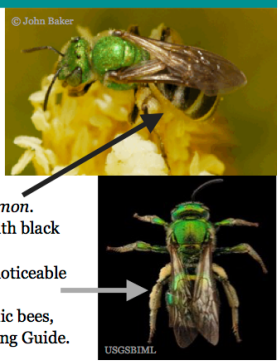
Metallic bees: Green metallic bees

9 species in 4 genera

Key Characteristics:

- Small to medium, relatively narrow
- **Metallic green** head thorax and abdomen, except in the genus *Agapostemon*. These bees have abdomens with black and yellow stripes.
- Scopa on hind legs, not very noticeable unless covered in pollen.

For more information on metallic bees, see pages 30-33 in the Monitoring Guide.



14

Metallic bees: Other metallic bees

19 *Osmia* sp.

Key Characteristics:

- Small to medium/large and robust
- **Dull to bright metallic blue**, some very hairy and dark with copper reflections
- **Scopa on underside of abdomen**
- Black, white or dull hair on thorax and head, stripes on abdomen absent or faint.

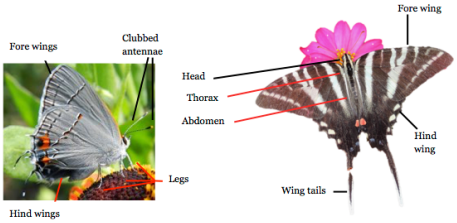
For more information on metallic bees, see pages 30-33 in the Monitoring Guide.



15

Butterflies

Below is a labeled diagram of the basic anatomy of a butterfly, refer here if you need a refresher on bee body parts. For more information visit page 10 in the Monitoring Guide.

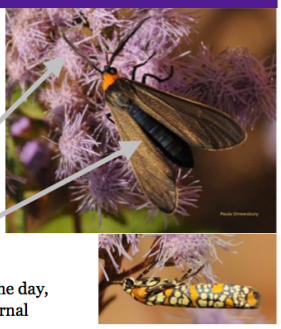


16

Buterflies vs. Moths

Key Characteristics of Moths:

- Moths have two pairs of wings and **at rest hold them at their sides**
- Moths have **pointed or feathery antennae**
- **Moths are more drab**, and less patterned than butterflies
- Moths have **thicker bodies** than butterflies
- Butterflies are active during the day, while moths are mostly nocturnal



17

Swallowtail butterflies

8 *Papilionidae* sp.

Key Characteristics:

- Large butterflies with **a distinctive tail on their hind wings.**
- Wing span: 2.5 - 6.25 inches (6.35 - 15.88 cm)
- Often mostly black, yellow or white with the possibility of blue, white, orange, red or yellow spots on the wings

See Page 37 in the Monitoring Guide for more information.



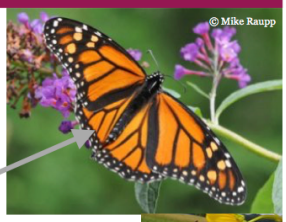
18

Monarch butterflies

Danaus plexippus

Key Characteristics:

- Large butterflies
- Wing span: 3.38 - 4. 88 inches (8.6 - 12.4 cm)
- Color**: Orange with black wing margins and veins and series of two white dots in the wing margin on the outsides of the wings**





Can commonly be confused with Viceroy or Queen butterflies. See pages 38 and 39 in the Monitoring Guide for more information.

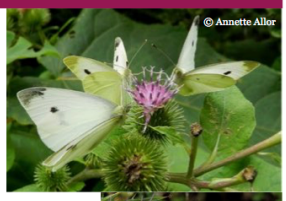
10

White and Sulphur butterflies

16 *Pieridae* sp.

Key Characteristics:

- Medium butterflies
- Wing span: 1.4 - 2.75 inches (3.56 - 6.98 cm)
- They are typically white, yellow or orange in color and can have black, white, pink, or orange spots or patches on their wings.





These butterflies are commonly agricultural pests. More information can be found on page 40 in the Monitoring Guide.

20

Gossamer wing butterflies

33 Lycaenidae sp.

- Small butterflies, often with small antenna-like tails on their hind wings.
- Wing span: 0.88 - 2 inches (2.24 - 5.08 cm)
- In general, these butterflies range from **orange, brown to grey on the outsides of their wings with spots or strips in black, white, blue, orange, and/or red. Commonly, the interior of the wings are metallic blue, orange, or grey/black**.





More info on page 41 in the Monitoring Guide.

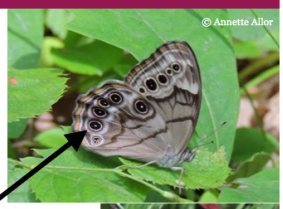
21

Satyrs and Wood Nymph butterflies

7 *Nymphalidae* sp.

Key Characteristics

- Medium sized butterflies
- Wing span: 1.25 - 3 inches (3.18 - 7.62 cm)
- They are **drab**; they are typically brown in color with a few to many **eye spots** on both the inside and outside of their wings.





See page 42 in the Monitoring Guide for more information.

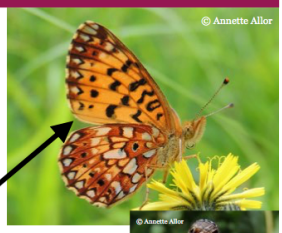
22

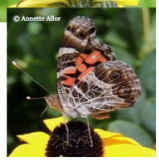
Brushfoot butterflies

33 *Nymphalidae* sp. and *Riodinae* sp.

Key Characteristics:

- Medium to large butterflies
- Wing span: 1.25 - 4.44 inches (3.18 - 11.28 cm)
- These butterflies are commonly **orange, brown, black and/or white with patterns on their wings**. Some have eyespots, many have a checkerboard pattern, spots, splotches of color, and/or other markings on their wings





More info on pg. 43 in the Monitoring Guide.

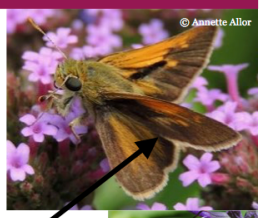
23

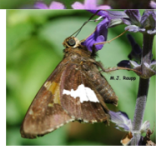
Skippers

59 *Hesperiidae* sp.

Key Characteristics:

- Small to medium
- Wing span: .88 - 2.94 inches (2.24 - 7.47 cm)
- Most skippers are **drab and dull** in color, typically brown, grey to orange with spots and strips in lighter colors.
- Skippers wings are typically held **angled outward at rest** and have **clubbed antennae that are hooked backward**.





More information on page 44 in the Monitoring Guide.

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Appendix C: List of standard and supplemental plants for participants to observe upon

List of plants to monitor

Maryland Native Pollinator Survey

*** Please note that this list is NOT exhaustive, its purpose is to serve as suggestions of possible plants to monitor. ***

Standard plants:

- Asters:
  - *Eurybia divaricata*
  - *Symphyotrichum novae-angliae*
- *Asclepias* spp.
  - *Asclepias tuberosa*
  - *Asclepias syriaca*
  - *Asclepias incarnata*
- *Agastache* spp.
  - *Agastache foeniculum*
- *Echinacea* spp.
  - *Echinacea purpurea*
- *Helianthus*
  - *Helianthus annuus*
  - *Helianthus divaricatus*
- *Monarda* spp.
  - *Monarda fitsulosa*
  - *Monarda didyma*
  - *Monarda punctata*
- Oregano
- Thyme
  - *Thymus serpyllum*
  - *Thymus citriodorus*
- *Rudbeckia* spp. (**2016 addition**)
  - *Rudbeckia hirta*
  - *Rudbeckia laciniata*
- *Solidago* spp. (**2016 addition**)
  - *Solidago caesia*
  - *Solidago canadensis*
  -

Additional plants:

- *Baptisia australis*
- *Penstemon* spp.
  - *Penstemon digitalis*
  - *Penstemon smalii*
- *Veronicastrum virginicum*
- *Pycnanthemum* spp.
  - *Pycnanthemum muticum*
  - *Pycnanthemum tenuifolium*
- *Vernonia noveboracensis*
- *Helenium autumnale*
- *Eupatorium/Eutrochium dubium*
- *Eupatorium/Eutrochium dubium* 'Baby Joe'/'Little Joe'
- *Coreopsis* spp.
  - *Coreopsis verticillata*
- *Zizia* spp.
  - *Zizia aptera*
  - *Zizia aurea*
- *Sedum* spp.

Appendix D: Citizen science pollinator monitoring data sheets

2015

The following is an example of the data sheet provided to observers in 2015. The only difference in the morning and afternoon datasheets was the word "MORNING" in the upper right corner. Each set of data sheets provided to observers also included their unique site ID number.

POLLINATOR MONITORING DATA SHEET **Date:** ____/____/2015 **MORNING OBSERVATION PERIOD**

INSTRUCTIONS: Fill in the date and requested times, and circle the relevant weather-related information. For the "Habitat changes…" section, fill in all of the habitat changes and weather anomalies (i.e. heavy precipitation, high winds, temperature extremes, etc.) since the last time you observed bees at this site. In the table, fill in the "Floral Resource" column with the flower species you are observing (i.e. type, cultivar, etc.); for each species, count the total number of plants ("# Plants") and count the number of bees visiting each floral resource for ten (10) minutes per species; record the number of plants you actually made your bee counts from ("# Obs."). If you cannot determine which group a bee belongs to, record the bee in the "Other" column and note whether you could tell it was not a honey bee or bumble bee in the "Observational Notes" section at the bottom of the page, along with any additional comments. Please record additional blooming species at the bottom of the other side of this datasheet, under "Additional Blooming Plants".

Name: _____ **Plot size:** _____

Site Name: _____ **Observation** Start Time: ____:____ End Time: ____:____

Weather: Temp: 50s / 60s / 70s / 80s / 90s / 100+ **Wind:** Still / Light Breeze / Windy / Gusty **Sky:** Clear / Partly Cloudy / Mostly Cloudy / Overcast

Habitat changes since the last observation/collection date:

Floral Resource (Genus species)	# Plants/ # Obs.	Honey Bees	Bumble Bees	Large Carpenter Bees	Hairy Leg Bees	Dark Bees	Green Sweat Bees	Metallic Hairy Belly Bees	Dark Hairy Belly Bees	Cuckoo Bees	Other - Describe in Notes

Observational Notes:

2016

Below is an example of the front page of a data sheet for the 2016 field season. The data sheets are a little different looking than the 2015 data sheets as they needed to also include space for the butterfly functional groups. The back side of the data sheet is on the next page.

Site ID number: 02021

Date: ____/____/____

Maryland Native Pollinator Survey 2016

Instructions: Fill in the date, garden size (approximate square footage or acreage of area devoted to flowering plants), number of participants, names can be included if desired, and start and end times of the observational period. Document the weather, record either an approximate OR actual temperature if this is possible (*you do not need to fill out both)* the level of windiness and the cloudiness. For the Habitat changes since last observation period include here any major weather events, plants that are now flowering, plants that are no longer flowering, and any changes to the landscape. Choose six plant species to observe pollinators, preferably *Aster, Asclepias, Agastache, Echinacea, Helianthus, Monarda*, oregano, thyme, *Rudbeckia,* and/or *Solidago*. For each plant, record its scientific name, being as specific as possible, the number of plants or the area the plants take up in the garden, the bloom status (entering bloom, full bloom, waning) and what time you begin and end observing at each plant species patch, aim for at least 10 minutes of observations per plant. Record floral visitors in the table provided, describing 'other' floral visitors in more detail in the larger space provided.

Garden size:_____ **Number of participants:**_____

Observation period start time: ____:____ am / pm **Observation period end time:** ____:____ am / pm

Weather information: **Wind**: Still / Light breeze / Windy / Occasional strong gusts **Sky**: Clear / Partly Cloudy / Mostly Cloudy / Overcast

Approximate temperature: 50-59°F / 60-69°F / 70-79°F / 80-89°F / 90-99°F / 100°F + **OR Actual temperature:** _____ °F

Habitat changes since last observation period:

1. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status**: Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:

Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees	
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic

2. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status**: Entering Bloom / Full Bloom / Waning

Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:

Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees	
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic

Site ID number: 02021 **Date:** _____/_____/_____

3. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning
Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

4. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning
Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

5. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning
Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

6. **Plant name:** _____ **Number of plants or area:** _____ **Bloom status:** Entering Bloom / Full Bloom / Waning
Start time for observations on plant #1. : ___:___ am / pm **End time for observations on plant #1.** : ___:___ am / pm

Swallowtails	Monarchs	Whites and Sulphurs	Gossamers	Satyrs and Wood Nymphs	Brushfoots	Skippers	Other:			
Honey bees	Bumble bees	Large carpenter bees	Long-horned bees	Large dark bees		Small dark bees		Metallic bees		
				Abdominal scopa	No abd. scopa	Abdominal scopa	No abd. scopa	Green metallic	Other metallic	

Appendix E: Exit survey questionnaires

2015

Maryland Native Plant Survey: Exit survey

Starred (*) questions were mandatory for participants to answer.

1. * How helpful was the native bee training you received in Spring or Early summer?
    a. Very helpful
    b. Helpful
    c. Neutral
    d. Not helpful
    e. Very unhelpful
    f. NA, did not attend training
2. * How helpful was the Monitoring Guide when you were observing native bees? (The larger of the two booklets given out)
    a. Very helpful
    b. Helpful
    c. Neutral
    d. Not helpful
    e. Very unhelpful
3. * How helpful was the Pocket Guide when you were observing native bees? (The smaller of the two booklets given out)
    a. Very helpful
    b. Helpful
    c. Neutral
    d. Not helpful
    e. Very unhelpful
4. * Do you have any suggestions for improvement of the Monitoring Guide? (The larger of the two booklets given out)
5. * Do you have any suggestions for improvement of the Pocket Guide? (The smaller of the two booklets given out)
6. * Do you have any overall suggestions or comments to improve this study in future years?
7. * How likely are you to participate in this study again next year? (Next year's study will include native bees, and butterflies)
    a. Very likely
    b. Likely
    c. Not likely
    d. Unlikely
8. * Do you plan to use the data or results from the survey for anything?
    a. Yes
    b. No
9. * If you plan on using the data or results from this survey, what do you plant to use them for?

2016

2016 Maryland Native Pollinator Survey: Exit survey

This questionnaire has some final questions about the 2016 Maryland Native Pollinator survey. If you attended a training but did not actually collect and submit data, please still fill this out! Responses are anonymous, so please be complete and honest. Thank you so much for taking the time to complete this survey and for participating in my pollinator survey!

Starred (*) questions were mandatory for participants to answer.

1. * Did you participate in the 2015 Maryland Native Bee survey?
    a. Yes
    b. No
2. * Did you attend an initial training session (in May or June of 2016)?
    a. Yes
    b. No
3. If you attended an initial training session, did you find it to be useful? Why or Why not? What could have been improved?
4. * Did you attend a follow-up training session (in July or August of 2016)?
    a. Yes
    b. No
5. If you attended a follow-up training session, did you find it to be useful? Why or why not? What could have been improved?
6. * Did you submit data either electronically or via paper mail for the 2016 Native Pollinator Survey?
    a. Yes
    b. No
7. If you submitted data electronically, what were your thoughts on that system? Did you like that option? Did it work well? Was it hard to use? What could be improved?
8. * Now that the 2016 Native Pollinator Survey is over with, please rate your knowledge of pollinators on a scale from 1 to 5 (1 being little to no knowledge of pollinators, 5 being very knowledgeable).
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
9. * Please tell me something you learned about pollinators after participating in the 2016 Native Pollinator Survey.
10. * Now think about the Monitoring guide you received. How helpful was the Monitoring guide when you were observing pollinators? Did you refer to it after the initial training session?
11. Do you have suggestions for improvement of the Monitoring Guide? If so, what are they?

12. * Now think about the Pocket guide you received. How helpful was the Pocket guide when you were observing pollinators? Did you refer to it after the initial training session?
13. Do you have suggestions for improvement of the Pocket Guide? If so, what are they?
14. Do you have any suggestions or comments to improve the study in future years? If so, what are they?
15. * How likely are you to participate in this study again next year?
    a. Very likely
    b. Likely
    c. Neutral/unsure
    d. Not likely
    e. Unlikely
16. If you had access to the results of this survey, would you use them for anything? (i.e. a pollinator talk)
    a. Yes
    b. No
    c. Maybe
17. * If you collected data for the 2016 Native Pollinator Survey, have you already submitted all of your data sheets?
    a. Yes
    b. No
    c. No, did not participate/collect data

Appendix F: Lists of pollinator species by functional group

2015

Functional group		Bee scientific names	Common names
"Honey bees"		*Apis mellifera*	European honey bee
"Bumble bees"		*Bombus* species (14 species)	Bumble bees
"Large Carpenter bees"		*Xylocopa virginica*	Eastern carpenter bee
"Large Dark bees"		*Andrena* species (85 species)	Mining bees
		Cemolobus ipomoeae	
		Colletes species (14 species)	Plasterer and Cellophane bees
		Dieunomia species (2 species)	
		Florilegus condignus	
		Macropis species (2 species)	
		Melitoma taurea	
		Melitta species (2 species)	
		Nomia species (2 species)	
		Xenoglossa strenua	
“Small Dark bees”	"Yellow-faced bees"	*Calliopsis andreniformis*	
		Hylaeus species (13 species)	Yellow-masked bees
		Perdita species (7 species)	
		Protandrena abdominalis	
		Pseudopanurgus species (6 species)	
	"Dark Sweat bees"	*Halictus* species (6 species)	
		Lasioglossum species (77 species)	
	"Small Carpenter bees"	*Ceratina* species (5 species)	Small or Dwarf Carpenter bees
	"Small Mining bees"	*Panurginus* species (3 species)	

"Green Sweat bees"	*Agapostemon* species (4 species)	
	Augochlora pura	
	Augochlorella species (2 species)	
	Augochloropsis species (2 species)	
"Dark Hairy Belly bees"	*Anthidiellum notatum*	
	Anthidium species (2 species)	Wool Carder Bees
	Chelostoma philadelphi	
	Heraides species (4 species)	
	Hoplitis species (6 species)	
	Lithurgus chrysurus	Medierranean Wood-boring bee
	Megachile species (23 species)	Resin and Leaf-cutting bees
	Paranthidium jugatorum	
	Pseduanthidium nanum	
"Metallic Hairy Belly Bees"	*Osmia* species (19 species)	Orchard and Mason bees
"Cuckoo Bees"	*Coelioxys* species (10 species)	
	Epeoloides pilosula	
	Epeolus species (8 species)	
	Holcopasites species (3 species)	
	Nomada species (32 species)	
	Sphecodes species (16 species)	
	Stelis species (3 species)	
	Triepeolus species (10 species)	

2016

Functional group		Bee scientific names	Common names
"Honey bees"		*Apis mellifera*	European honey bee
"Bumble bees"		*Bombus* species (14 species)	Bumble bees
"Large Carpenter bees"		*Xylocopa virginica*	Eastern carpenter bee
"Large Dark bees"	**with abdominal scopa**	*Anthidium manicatum*	Wool carder bee
		Lithurgus chrysurus	Medierranean Wood-boring bee
		Megachile species (26 species)	Resin and Leaf-cutting bees
	without abdominal scopa	*Andrena* species (85 species)	Mining bees
		Cemolobus ipomoeae	
		Colletes species (14 species)	Plasterer and Cellophane bees
		Dieunomia species (2 species)	
		Florilegus condignus	
		Macropis species (2 species)	
		Melitoma taurea	
		Melitta species (2 species)	
		Nomia species (2 species)	
		Xenoglossa strenua	
“Small Dark bees”	**with abdonminal scopa**	*Anthidiellum notatum*	
		Anthidium oblongatum	Wool Carder bees
		Chelostoma philadelphi	
		Heraides species (4 species)	
		Hoplitis species (6 species)	
		Megachile species (4 species)	
		Paranthidium jugatorum	
		Pseduanthidium nanum	

"Small Dark bees"	**without abdominal scopa**	"Yellow-faced bees"	*Calliopsis andreniformis*	
			Hylaeus species (13 species)	Yellow-masked bees
			Perdita species (7 species)	
			Protandrena abdominalis	
			Pseudopanurgus species (6 species)	
		"Dark Sweat bees"	*Halictus* species (6 species)	
			Lasioglossum species (77 species)	
		"Small Carpenter bees"	*Ceratina* species (5 species)	Small or Dwarf Carpenter bees
		"Small Mining bees"	*Panurginus* species (3 species)	
Metallic bees	**Metallic green bees**		*Agapostemon* species (4 species)	
			Augochlora pura	
			Augochlorella species (2 species)	
			Augochloropsis species (2 species)	
	Other metallic bees		*Osmia* species (19 species)	Orchard and Mason bees

Appendix G: List of species collected in the 2016 specimen collection

Bee species	Baltimore		Frederick		Prince George's		Allegany	
	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection
Agapostemon texanus Cresson	1	0	0	0	0	0	0	0
Agapostemon virescens Fabricius	23	5	6	0	20	0	3	0
Andrena alleghaniensis Viereck	0	1	0	0	0	0	0	0
Andrena crataegi Robertson	0	2	0	0	0	0	0	0
Andrena cressonii Robertson	0	57	0	0	0	0	0	0
Andrena forbsii Robertson	0	2	0	0	0	0	0	0
Andrena hippotes Robertson	0	1	0	0	0	0	0	0
Andrena illini Bouseman and LaBerge	0	4	0	0	0	0	0	0
Andrena imitatrix Cresson */morrisonella* Viereck	0	3	0	0	0	0	0	0
Andrena nasonii Robertson	0	19	0	1	3	0	0	0
Andrena nuda Robertson	0	1	0	0	0	0	0	0
Andrena perplexa Smith	1	23	0	0	0	0	0	0
Andrena personata Robertson	0	1	0	0	0	0	0	0
Andrena robertsonii Dalla Torre	0	11	0	0	0	0	0	0
Andrena spp.	0	1	0	0	0	0	0	0
Andrena vicina Smith	0	29	0	0	0	0	0	1
Anthidium manicatum L.	0	0	0	6	0	0	0	5
Anthidium oblongatum Illiger	2	0	0	1	1	0	2	0

Bee species	Baltimore		Frederick		Prince George's		Allegany	
	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection
Apis mellifera L.	13	132	4	6	0	1	3	24
Augochlora pura Say	2	6	0	0	11	1	1	1
Augochlorella aurata Smith	27	37	7	20	13	9	1	3
Augochloropsis metallica metallica Fabricius	0	3	0	1	0	0	0	0
Bombus bimaculatus Cresson	0	24	1	0	0	6	1	3
Bombus fervidus Fabricius	0	1	0	0	0	0	0	0
Bombus griseocollis De Geer	0	53	0	3	0	0	0	18
Bombus impatiens Cresson	87	182	0	37	0	4	0	9
Bombus perplexus Cresson	0	16	0	0	0	0	0	0
Bombus spp.	0	3	0	0	0	0	0	0
Calliopsis andreniformis Smith	9	0	2	0	3	0	2	1
Ceratina calcarata Robertson	2	3	3	2	0	5	1	7
Ceratina dupla Say	0	2	0	4	0	4	0	0
Ceratina mikmaqi Rehan and Sheffield	5	1	4	4	11	9	1	0
Ceratina spp.	2	3	0	1	1	5	0	0
Ceratina strenua Smith	15	4	7	12	69	23	3	1
Coelioxys sayi Robertson	0	3	0	0	0	2	0	0
Colletes latitarsis Robertson	0	0	0	0	0	0	0	2
Colletes thoracicus Smith	0	1	0	0	0	0	0	0
Epeolus bifasciatus Cresson	0	3	0	0	0	0	0	0

Bee species	Baltimore		Frederick		Prince George's		Allegany	
	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection
Halictus confusus Smith	4	3	0	1	10	4	0	1
Halictus ligatus Say/*poeyi* Lepeletier	10	71	6	38	13	34	5	10
Halictus parallelus Say	0	0	0	0	1	0	0	0
Heriades carinata Cresson	0	4	1	0	0	0	0	0
Hoplitis pilosifrons Cresson	1	0	0	0	0	0	0	0
Hoplitis spp.	0	0	0	0	0	0	1	0
Hylaeus affinis Smith/*modestus* Say	3	2	2	12	0	2	0	0
Hylaeus mesillae Cockerell	3	3	0	1	0	0	0	0
Hylaeus modestus Say	0	0	0	1	0	0	0	0
Lasioglossum admirandum Sandhouse	0	0	0	0	1	1	0	0
Lasioglossum apocyni Mitchell	0	0	0	0	0	0	4	7
Lasioglossum bruneri Crawford	0	1	1	0	10	0	0	0
Lasioglossum callidum Sandhouse	5	3	1	0	0	0	0	0
Lasioglossum coreopsis Robertson	0	0	0	0	1	0	0	0
Lasioglossum cressonii Robertson	0	0	2	0	0	0	0	0
Lasioglossum ephialtum Gibbs	0	1	0	0	0	0	0	0
Lasioglossum fuscipenne Smith	0	0	0	0	1	0	0	0
Lasioglossum hitchensi Gibbs	36	22	10	6	27	3	10	4
Lasioglossum illinoense Robertson	2	0	1	1	0	0	1	0
Lasioglossum imitatum Smith	0	6	2	9	17	12	0	1
Lasioglossum leucocomum Lovell	0	0	0	0	2	0	0	0

Bee species	Baltimore		Frederick		Prince George's		Allegany	
	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection
Lasioglossum pilosum Smith	8	4	1	0	21	0	0	0
Lasioglossum platyparium Robertson	3	0	1	1	1	0	0	0
Lasioglossum spp.	9	6	2	4	5	9	2	0
Lasioglossum tegulare Robertson	7	1	5	0	6	2	1	1
Lasioglossum trigeminum Gibbs	42	9	8	3	7	1	1	0
Lasioglossum versatum Robertson	12	3	0	0	0	0	1	0
Lasioglossum weemsi Mitchell	3	2	1	0	2	0	0	0
Lasioglossum zephyrum Smith	0	0	1	0	0	0	0	0
Megachile brevis Say	0	0	1	0	1	0	0	0
Megachile campanulae Robertson	0	0	0	0	0	1	0	0
Megachile exilis Cresson	0	3	0	0	0	0	0	1
Megachile frugalis Cresson	1	0	0	0	0	0	0	1
Megachile inimica Cresson	0	0	0	2	0	0	0	0
Megachile mendica Cresson	0	5	0	0	1	2	0	2
Megachile pugnata Say	0	0	0	0	0	0	0	1
Megachile rotundata Fabricius	0	1	0	0	0	0	0	1
Megachile sculpturalis Smith	0	1	0	2	1	0	0	1
Melissodes bimaculata Lepeletier	0	0	0	2	0	0	0	0
Melissodes denticulata Smith	0	15	0	0	0	0	2	0
Melissodes spp.	0	0	0	14	0	0	0	0
Melissodes tepaneca Cresson	0	1	0	1	0	0	2	0
Melissodes trinodis Robertson	0	5	0	0	0	0	0	0

Bee species	Baltimore		Frederick		Prince George's		Allegany	
	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection	Bowl trap	Hand collection
Nomada pygmaea Cresson	0	0	0	0	0	0	0	0
Osmia caerulescens L.	0	0	0	0	1	0	0	0
Osmia pumila Cresson	0	0	0	0	0	0	0	1
Peponapis pruinosa Say	0	0	0	0	0	0	1	2
Ptilothrix bombiformis Cresson	0	0	0	0	3	0	0	0
Stelis lateralis Cresson	1	0	0	0	2	0	1	0
Triepeolus remigatus Fabricius	0	1	0	0	0	0	0	0
Xylocopa virginica L.	0	2	2	0	0	0	0	0

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