5-2023

Species diversity of Coleoptera populations in an urban garden in Chattanooga, Tennessee

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Species Diversity of Coleoptera Populations in an Urban Garden in Chattanooga, Tennessee

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Departmental Honors Thesis

The University of Tennessee at Chattanooga

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Examination Date: March 9th, 2023

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TABLE OF CONTENTS

ABSTRACT

Insects are an essential part of the function of ecosystems. The majority of entomological faunistic research has been conducted primarily in rural areas due to high diversity, space for bulky traps, and less outside influence from human activities. However, the need for time-series insect biodiversity data, in rural areas and urban areas alike, is paramount in the wake of our current sixth mass extinction event. Previous research has shown that the greater Chattanooga area is comprised of a diverse population of insects in the Coleoptera (beetles) order, and as shown in the University of Tennessee at Chattanooga's (UTC) Insect Collection. However, no systematic collection has been done in urban areas within the city limits of Chattanooga. Therefore, in order to fill this gap in data, using a Malaise trap, I collected six months (from March to September of 2022) worth of Coleoptera specimens in the urban garden situated in front of Holt Hall on the University of Tennessee at Chattanooga's campus (35°02'50.4"N, 85°17'46.7"W). This project yielded 352 individuals, with 63 morphospecies identified in 23 families (Appendix I). Out of the 23 families sampled, the families that had the highest frequency during the entire collection period included Coccinellidae (22), Staphylinidae (13), and Mordellidae (12). Ecological factors including the diets of the beetles collected and the plant composition of the garden during each collection month were used to predict why specific families were more prevalent than others.

Without establishing this baseline data, researchers will have a difficult time estimating any changes in or demonstrating progress, recovery, or destruction of Coleoptera populations in the future. The beneficial nature of this study's findings can be maximized through the yearly repetition of Coleoptera collection at this site. Further, expanding this study across more urban green spaces within Chattanooga (and Hamilton County) can give us a greater understanding of what beetles Chattanooga supports, and how time and the continuation of harmful anthropogenic activities are affecting Coleoptera populations.

INTRODUCTION

Background / Significance of Study

Insects are an essential part of the function of ecosystems. They are extremely diverse in nature and serve as food for other organisms, decompose organic matter, maintain soil integrity, are responsible for pollination, and are foundational organisms in predatory and parasitic relationships. Nearly 1.5 million insects have been discovered and described with a large percentage still left to discover. Taking this biodiversity into account, studies must be done to qualitatively describe each species and quantitatively establish how many species are present within a certain geographic area.

The majority of entomological faunistic research is conducted primarily in rural areas due to high diversity, space for bulky traps, and less outside influence from human activities. However, in recent years, studies have now explored insect fauna within urban gardens in places such as Los Angeles (Hartop et al., 2015, 2016), New York City (Matteson et al., 2008), Germany (Theodorou et al., 2020), United Kingdom (Baldock et al., 2015), and Sydney, Australia (Lequerica Tamara et al., 2021). The most notable of these studies is conducted in the UK under the umbrella of the "BioScan Project" (BIOSCAN, 2022). This ambitious project aims to identify and study the genetic diversity of 1,000,000 insects from across the UK using Malaise traps in urban and rural areas alike. After collection, researchers database the insect specimens, regardless of order, based on a genetic barcoding system using a ~658 base pair sequence from each insect's mitochondrial genome (*BIOSCAN*, 2022). This project allows for high specificity, and the ability to distinguish between insects in large families that are otherwise difficult to identify with certainty. An identically named project, although unrelated, occurs in tandem on the other side of the world. The "BioScan Project" in Los Angeles, California, however, relies on citizen scientists and their backyards to collect specimens (Hartop et al., 2016). Hartop et al.

(2016), principal researchers in this project, explain their special interest in Phoridae, a family in the order Diptera. Hartop et al. (2016) state that after a year of Malaise trap sampling from 30 different backyards across Los Angeles, the project yielded 43,651 phorids and 68 species of *Megaselia* (a genus in the family Phoridae), 43 (68%) of which were described as new to science from the BioSCAN project. This specific U.S. based Bioscan project relies on visual identification based on physical features rather than through DNA analysis of that of the UK efforts. However, both of these large-scale studies result in advancing the body of knowledge of the biodiversity of insects around the world, but also highlighting the need for urban documentation, as it just may show extremely biodiverse results, as shown by Hartop et al. (2016) in Los Angeles.

While Hartop et al. (2016) had an interest in Diptera biodiversity in urban environments, researchers such as Mattheson et al. (2008), Theodorou et al. (2020), and Baldock et al. (2015) conversely studied pollinators in New York City, Germany, and the United Kingdom, respectively. Mattheson et al. (2008) focused on describing the species richness, abundance, and ecological characteristics of bees in community gardens located in urbanized neighborhoods of the Bronx and East Harlem in New York using yellow bowl trap and hand-netting collection methods. Researchers collected a total of 1,145 individual bees which represented 54 species over the four-year collection period (Matteson et al., 2008). Mattheson et al. (2008) compared the identities of these specimens to several rural bee faunal surveys in nearby states and municipalities and determined that bee (Hymenoptera) richness of the urban gardens is less than that of surrounding rural areas. Theodorou et al. (2020), in contrast, studied the Hymenoptera, Lepidoptera, and Diptera species richness using pan-trapping and meta-barcoding methods in eastern German urban sites and neighboring rural areas. Researchers discovered that urban areas have lower species richness in the Diptera and Lepidoptera orders than the neighboring rural sites, while Hymenoptera yielded higher species richness, which does not align with Mattheson et al. (2008) findings (Theodorou et al., 2020). Further, Baldock et al. (2015) studied Hymenoptera species richness in neighboring urban and rural sites in the UK using quantified flower visiting networks. Researchers discovered that bee species richness was higher in urban areas than their rural farmland (Baldock et al., 2015). Matteson et al. (2008), Theodorou et al. (2020), and Baldock et al. (2015) highlights the unpredictable nature of urban species richness, especially when it comes to Hymenoptera, as these three research groups landed on different conclusions.

While urban insect diversity data are abundant in Hymenoptera and Diptera order, they are however, lacking in Coleoptera. In Sydney, Australia, however, Lequerica Tamara et al. (2021) studied insect composition using pan traps in three different categories of urban and rural locations including forests, urban forest remnants, and parks. This study yielded 1,400 Coleoptera specimens which were identified to 164 species/morphospecies and species richness averaged 12 species per garden, with Scarabaeidae, Mordellidae, and Chrysomelidae being the most abundant families collected (Lequerica Tamara et al., 2021). The researchers determined the species richness of beetles increased in sites where the species richness of plants was higher, irrespective of its geographical categorization (Lequerica Tamara et al., 2021).

Previous research has shown that the greater Chattanooga area is comprised of a diverse population of insects in the Coleoptera order, and as shown in the UTC Insect Collection (https://serv.biokic.asu.edu/ecdysis/collections/misc/collprofiles.php?collid=10) (Chatzimanolis et al., 2020). This database accounts for 3,454 insect specimens collected in Hamilton County (as of January 2023) and 2,497 more insect specimens from bordering counties. However, no systematic collection has been done in urban areas within the city limits of Chattanooga.

Objective

Wagner et al. (2021) in “Insect decline in the Anthropocene: Death by a thousand cuts” highlights the biology community’s common understanding and acceptance that we are currently experiencing the sixth mass extinction event, following our most recent one in the Cretaceous period occurring 66 million years ago. Terrestrial vertebrate populations, which are highly studied compared to that of insects, have recorded record losses of biodiversity with over a million species in danger of extinction over the next 50 years (Wagner et al., 2021). Authors state that we are seeing biodiversity numbers plummet due to anthropogenic factors including pollution, urbanization, introduced species via global trade, deforestation, insecticides, agricultural intensification, nitrification, increase of natural disaster frequency and intensity, and global warming (Wagner et al., 2021). Looking forward, researchers state that “there remains an urgent need for time-series data so that temporal and spatial population trends can be assessed” (Wagner et al., 2021). Therefore, the goal of this study is to collect baseline data for Coleoptera species diversity in an urban garden setting in Chattanooga. Without establishing this baseline data, researchers in the future will have a difficult time estimating any changes in populations or demonstrating progress, recovery, or destruction in the wake of this inevitable mass extinction event.

MATERIALS AND METHODS

In order to sample beetle diversity within the set geographic area, I set up a trap. The research began by setting up a commonly used insect trap called the Malaise Trap (Fig. 1). The Malaise Trap was placed in the urban garden in front of Holt Hall (35°02'50.4"N, 85°17'46.7"W) on the University of Tennessee at Chattanooga's campus and placed parallel to Holt Hall and perpendicular to Grote Hall. This trap takes advantage of insect's innate sense of flying upwards (Karlsson et al., 2018; Souza et al., 2015; Townes, 1972). The insects landed on panels E or F, the underside of D, or the posterior sides of B and C (Fig. 1). The insects then travelled upward, and inevitably fell into the collector bottle. The collector bottle was filled with a highly concentrated propylene glycol solution that killed the insects. This trap had no specificity, therefore it collected any type of insect, regardless of type, if it decided to travel inside. However, a filter was present to exclude large non-target insects such as butterflies and moths. When the collection bottle was removed, the solution of dead insects and propylene glycol solution was poured over a fine filter in order to separate the solution and the insects. The propylene glycol solution was discarded, and the remaining insects were rinsed with a steady stream of ethanol while still in the filter to ensure all solution was removed. The clean insects were then transferred into a bottle of ethanol until sorting began. We sorted out the insects that are members of the Coleoptera order and preserved the remaining insects in a separate jar with ethanol for future use within the UTC Insect Collection.

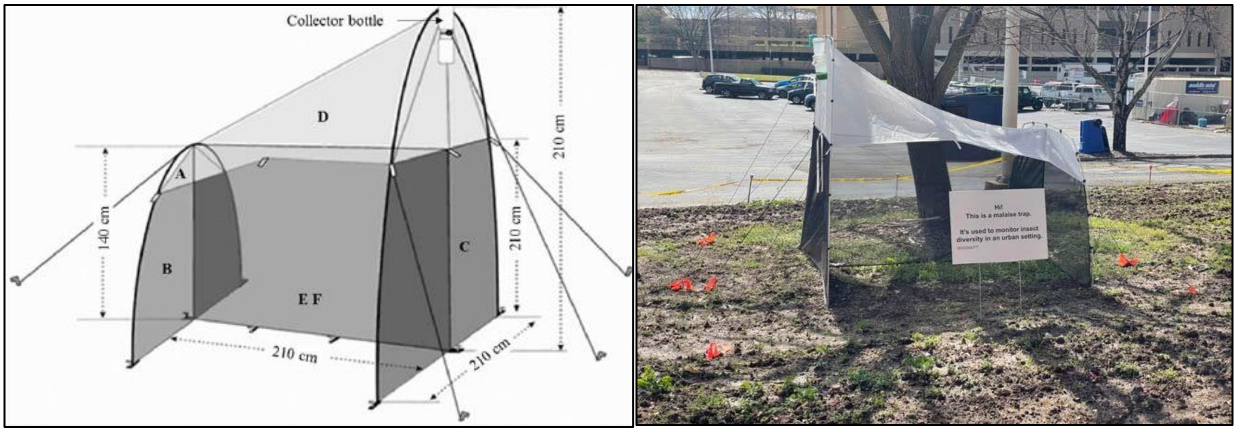
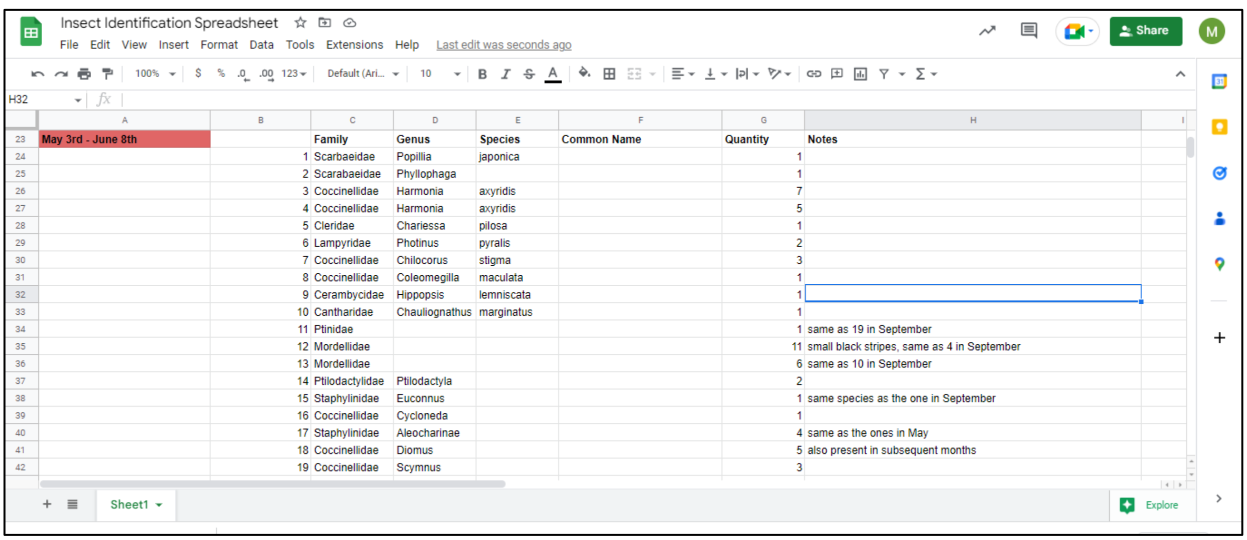


Figure 1: The dimensions and set up procedure of the Malaise Trap (Souza et al., 2015), and set up location of my Malaise trap.

Sorting began by preparing a clear glass bowl filled with a ½ inch of ethanol and subsequently pouring the jar of the months' worth of insects into the bowl, or only half depending on how large that specific month's total number of insects ended up being. I then used a stereomicroscope to examine these insects and their distinctive features such as, shape, size, color, defined body regions, the shape of wings, and antennae, and grouped them up based on common characteristic or multiple of the same specimen. Each individual insect (or groups of the same insect) was then photographed through the lens of the stereomicroscope (examples of these photographs can be found in Appendix II). Each of these digital images were uploaded to a Google Drive photo album labeled as the insect number and month it was collected in (Ex: Insect 3 – August). Each picture was first uploaded to iNaturalist first in order to try to narrow the specimen down to family or subfamily. iNaturalist is a mobile and online application where biologists and citizens scientists alike can upload pictures to a platform of any biotic thing in the environment (plants, vertebrates, invertebrates, etc.) and experts in the field and AI use the uploaded picture to identify the specimen. If iNaturalist yielded no results, I then turned to *Beetles of Eastern North America* to use the defining features to attempt to establish the taxonomy of the insect at hand. This process was repeated with every Coleoptera specimen.

After the picture was taken, uploaded to the Drive, and the specimen was identified to a meaningful level (genus or species), the details were then inputted into a master spread sheet that was separated by months on the y-axis and separated by family, genus, species, common name, quantity, and notes on the x-axis (Figure 2). After the data was inputted, each insect was then placed into individual microcentrifuge tubes labeled in permanent marker with the number corresponding to the insect number established in the photography step. Each labeled microcentrifuge tube was then placed in a tray labeled with the month of collection (Figure 3). This sorting procedure aided in quick reassessment of the specimens if needed. My director, Dr. Chatzimanolis then subsequently went through my spreadsheet while cross referencing the image database to confirm the identity of each specimen or to identify them to a more specific level (Ex: assigning a species name when I only named a genus level).



A	B	Family	Genus	Species	Common Name	Quantity	Notes
May 3rd - June 8th							
	1	Scarbaeidae	Popillia	japonica		1	
	2	Scarabaeidae	Phyllophaga			1	
	3	Coccinellidae	Harmonia	axyridis		7	
	4	Coccinellidae	Harmonia	axyridis		5	
	5	Cleridae	Chariessa	pilosa		1	
	6	Lampyridae	Photinus	pyralis		2	
	7	Coccinellidae	Chilocorus	stigma		3	
	8	Coccinellidae	Coleomegilla	maculata		1	
	9	Cerambycidae	Hippopsis	lemniscata		1	
	10	Cantharidae	Chauliognathus	marginatus		1	
	11	Ptinidae				1	same as 19 in September
	12	Mordellidae				11	small black stripes, same as 4 in September
	13	Mordellidae				6	same as 10 in September
	14	Ptilodactylidae	Ptilodactyla			2	
	15	Staphylinidae	Euconnus			1	same species as the one in September
	16	Coccinellidae	Cycloneda			1	
	17	Staphylinidae	Aleocharinae			4	same as the ones in May
	18	Coccinellidae	Diomus			5	also present in subsequent months
	19	Coccinellidae	Scymnus			3	

Figure 2: Screenshot displaying spreadsheet sorting and organization system.

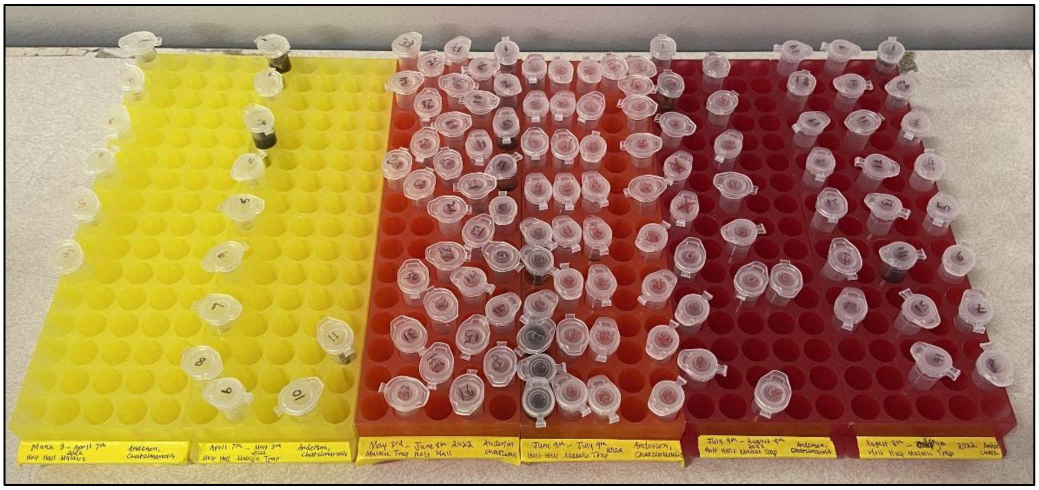


Figure 3: Image depicting individual insect sorting and storing schematic.

The collector bottle was removed, emptied, and replaced with a new concentrated propylene glycol solution once a month, beginning in March and concluding in September of 2022, for a total of six months' worth of Coleoptera population data, as shown in Figure 3.

RESULTS

Overall Occurrences of Families

In total, 352 individuals were sampled, with 63 morphospecies identified in 23 families over the six-month collection period (Appendix I). Out of the 23 families sampled, the families that had the highest number of occurrences during the entire collection period included Coccinellidae (22), Staphylinidae (13), and Mordellidae (12). Other families that had greater than five occurrences include Curculionidae (8), Elateridae (7), Chrysomelidae (6), Scarabaeidae (6), Latridiidae (6), Dermestidae (6), and Lampyridae (6). All other families not included in this list had only one occurrence during the collection period, and were not displayed in Figure 4.

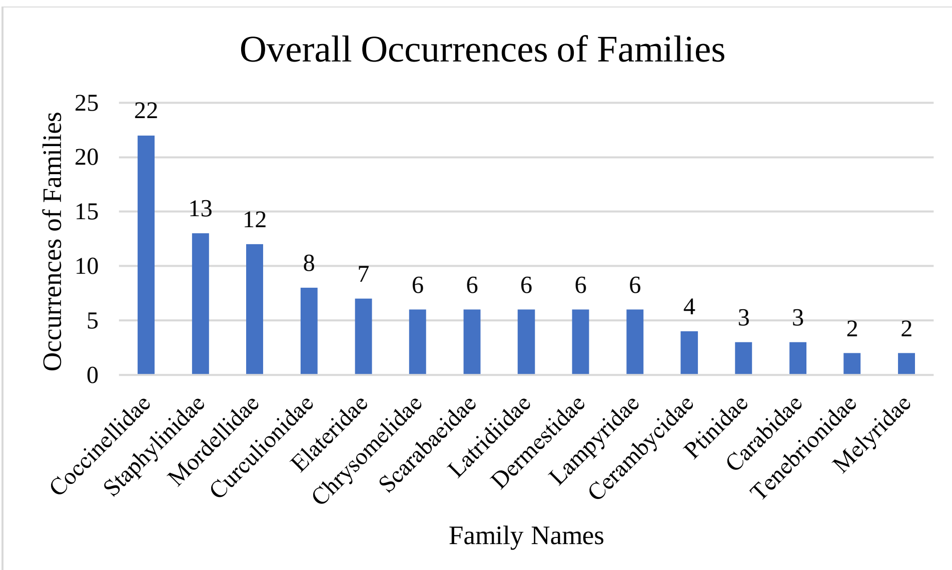


Figure 4: This figure represents the overall number of occurrences of families across all months of collection. All other families not included in this chart had only 1 occurrence over all collection months.

While Figure 4 represents the number of occurrences of families across all collection months, Table 1 indicates the number of different families collected during each month. June proves to be the most biodiverse collection month accounting for 16 different families, while April is the least biodiverse collection month accounting for only 6 different families. August experienced a decline in number of families due to a spider either blocking the entrance of the collector bottle or intercepting insects as they entered. This issue was not discovered until the third week of the four-week collection, therefore negatively affecting the number of total insects to be collected for this month. Seasonal changes are to be expected – there will be more insects in the summer months and not during the seasonal transition, especially during the colder months.

Table 1: This table represents the number of families that occurred each month of collection.

Month	**Number of families per month**
April	6
May	8
June	16
July	15
August	9
September	13

Occurrences of Families by Month

The following figures represent the occurrences of families by month. The frequency indicates the amount of distinct morphospecies within the outlined family. In April, there were a total of six families represented, with one morphospecies each in Curculionidae, Coccinellidae, Latridiidae, Chrysomelidae, Dermestidae, and Melyridae. There were no families in April that were exclusive to the April collection month.

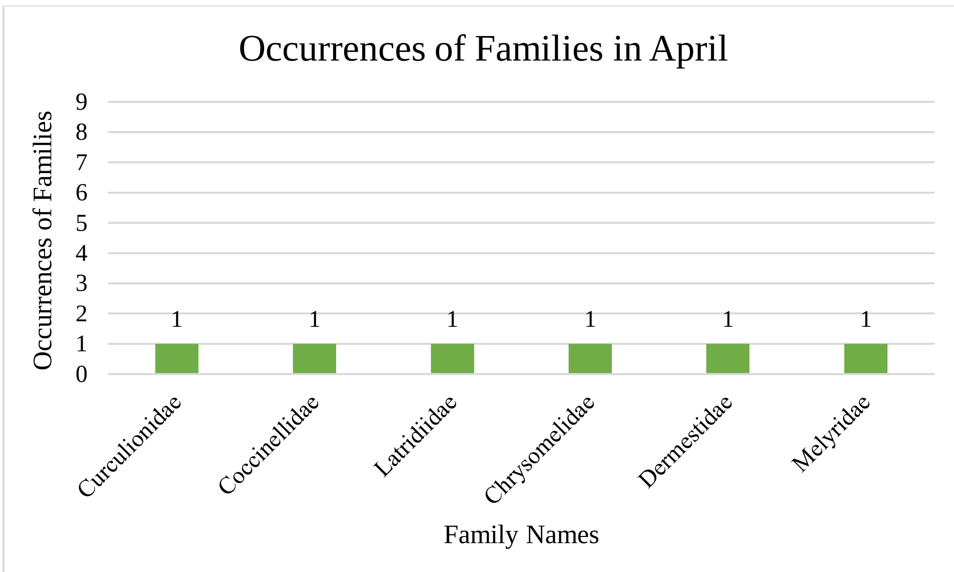


Figure 5: Overall occurrences of families across the month of April, the first month of collection.

In May, there were a total of eight families represented. Curculionidae and Staphylinidae each had two different morphospecies during the May collection period, while Cerambycidae, Coccinellidae, Dermestidae, Latridiidae, Scarabaeidae, and Scirtidae each only had one morphospecies represented. May was the only month in which a morphospecies in the family Scirtidae was collected.

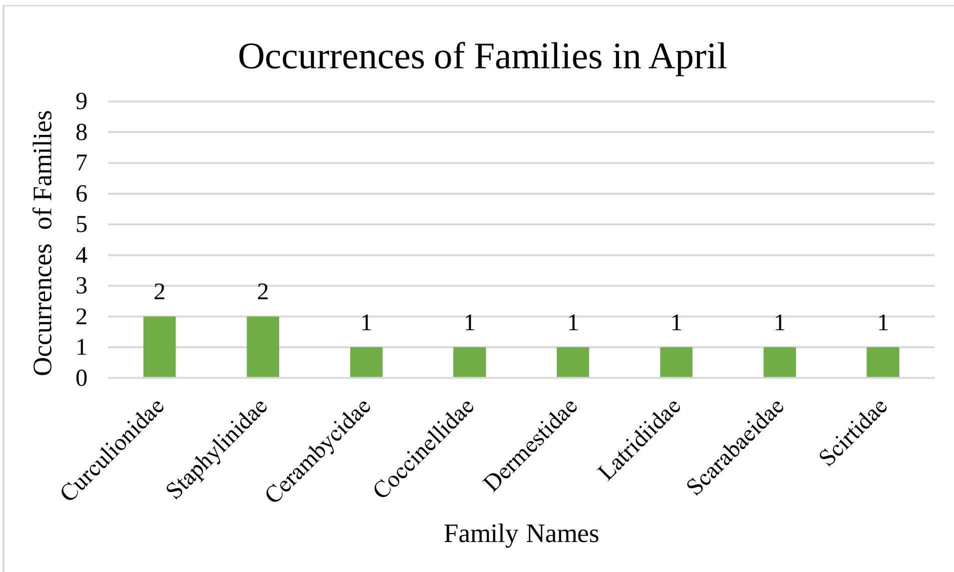


Figure 6: Overall occurrences of families across the month of May, the second month of collection.

In June, there were a total of 16 families represented, the highest number of recorded families out of all of the collection months. Coccinellidae had the highest number of morphospecies (8), while Mordellidae and Staphylinidae each had four different morphospecies during the June collection period. Further, Chrysomelidae, Lampyridae, Scarabaeidae, and Tenebrionidae each had two morphospecies, respectively. Cantharidae, Carabidae, Cerambycidae, Cleridae, Curculionidae, Dermestidae, Latridiidae, Ptilodactylidae each only had one morphospecies represented. June is the only month where a morphospecies in the families Cantharidae, Cleridae, Ptilodactylidae, and Tenebrionidae were collected.

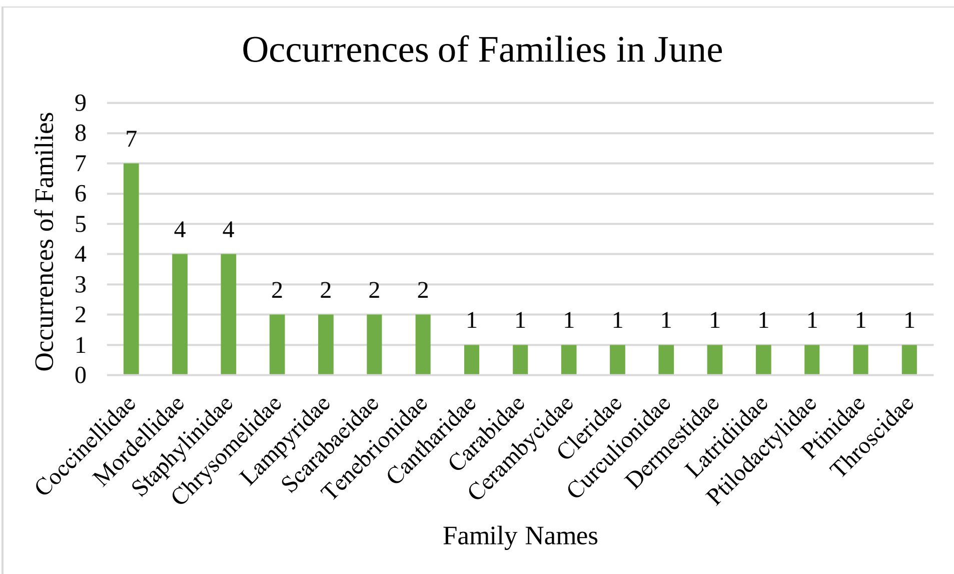


Figure 7: Overall occurrences of families across the month of June, the third month of collection.

In July, there were a total of 15 families represented, the second highest number of recorded families out of all of the collection months. Coccinellidae had the highest number of morphospecies (8), while Mordellidae and Staphylinidae each had four different morphospecies during the June collection period. Further, Chrysomelidae, Lampyridae, Scarabaeidae, and Tenebrioidae each had two morphospecies, respectively. Cantharidae, Carabidae, Cerambycidae, Cleridae, Curculionidae, Dermestidae, Latridiidae, Ptilodactylidae each only had one morphospecies represented. July is the only month where a morphospecies in the families Eucnemidae and Leiodidae were collected.

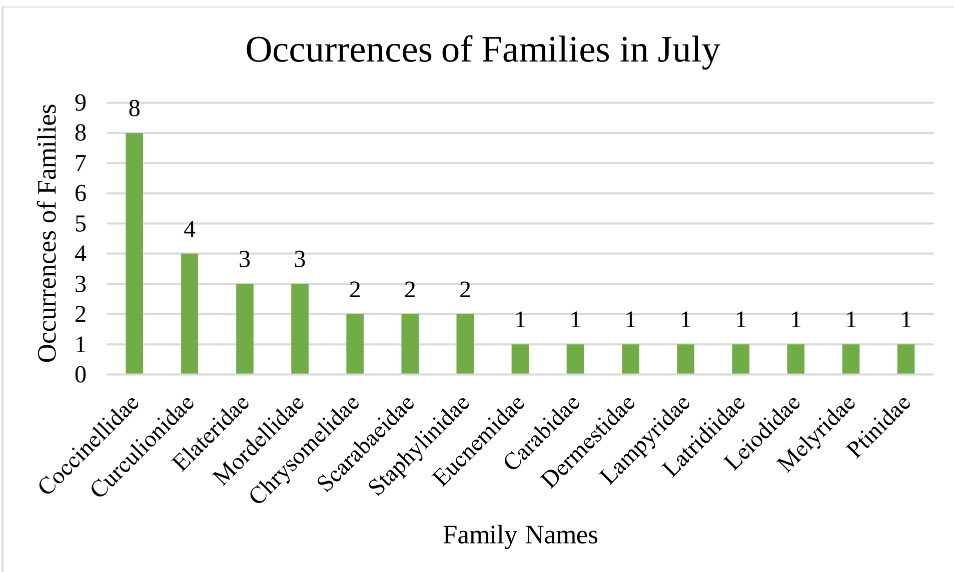


Figure 8: Overall occurrences of families across the month of July, the fourth month of collection.

In August, there were a total of 9 families represented. Coccinellidae, Elateridae, Mordellidae, and Staphylinidae all tied for the highest number of morphospecies (2). Further, Lampyridae, Cerambycidae, Dermestidae, Latridiidae, and Scarabaeidae each had only one morphospecies represented. There were no families exclusive to the collection month of August. Additionally, August experienced a decline in number of families due to a spider either blocking the entrance of the collector bottle or intercepting insects as they entered. This issue was not discovered until the third week of the four-week collection, therefore negatively impacting the total number of insects to be collected for this month.

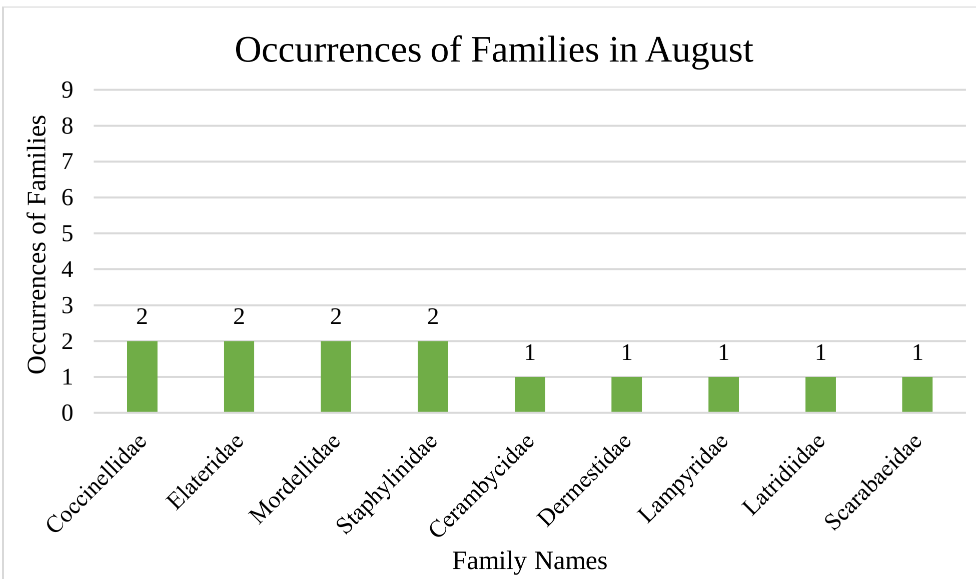


Figure 9: Overall occurrences of families across the month of August, the fifth month of collection.

In September, there were a total of 13 families represented. Mordellidae and Staphylinidae tied for the highest number of morphospecies (3). Further, Coccinellidae, Elateridae, and Lampyridae each had two morphospecies represented, while Carabidae, Cerambycidae, Chrysomelidae, Dermestidae, Latridiidae, Ptinidae, and Throscidae each had only one morphospecies represented. September is the only month in which a morphospecies in the family Mycetophagidae was collected.

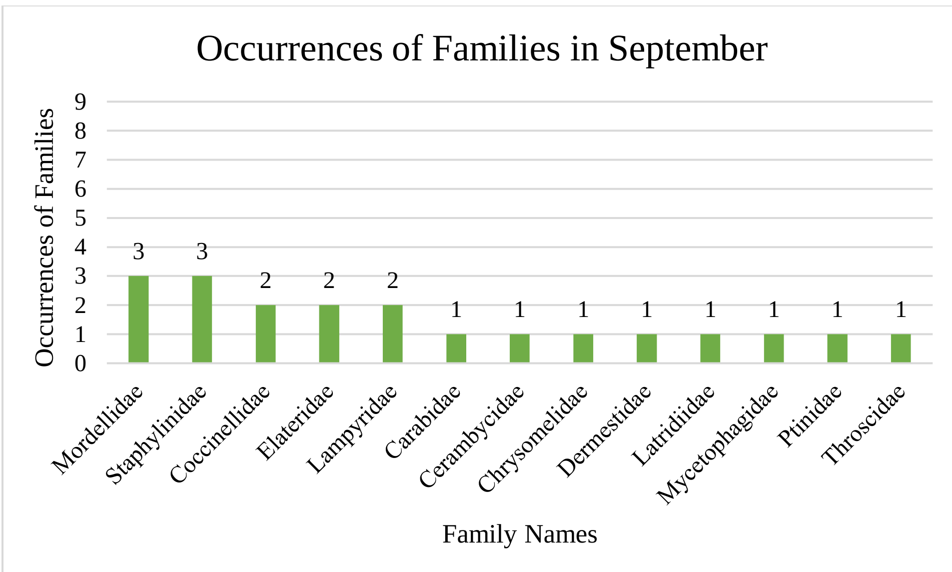


Figure 10: Overall occurrences of families across the month of September, the sixth month of collection.

Occurrences of Individuals by Month

Figure 11 displays the sum of total individuals collected during each month. July had the highest number of individuals collected (150), while April had the lowest number of individuals collected (7). Seasonal differences are expected, with the highest number of individuals collected being in the summer months. Additionally, August experienced a decline in total number individuals due to a spider either blocking the entrance of the collector bottle or intercepting insects as they entered. This issue was not discovered until the third week of the four-week collection period, therefore negatively impacting the total number of insects to be collected for this month. Seasonal changes are to be expected and are observed in Figure 11 – there will be more insects in the summer months and not during the seasonal transitions (Winter to Spring and Summer to Fall) and during the colder months.

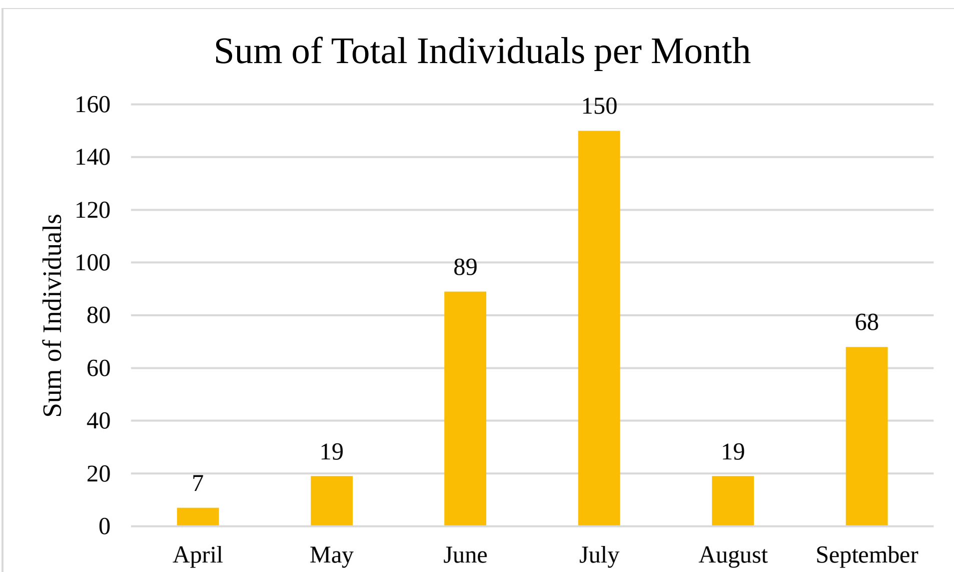


Figure 11: This figure outlines the amount of total Coleoptera individuals collected during each month.

Diversity Analysis

Diversity values were calculated using the Shannon-Weiner Diversity Index, which accounts for richness and evenness of the morphospecies present. According to this index, the most diverse month of collection was June and the least diverse was April.

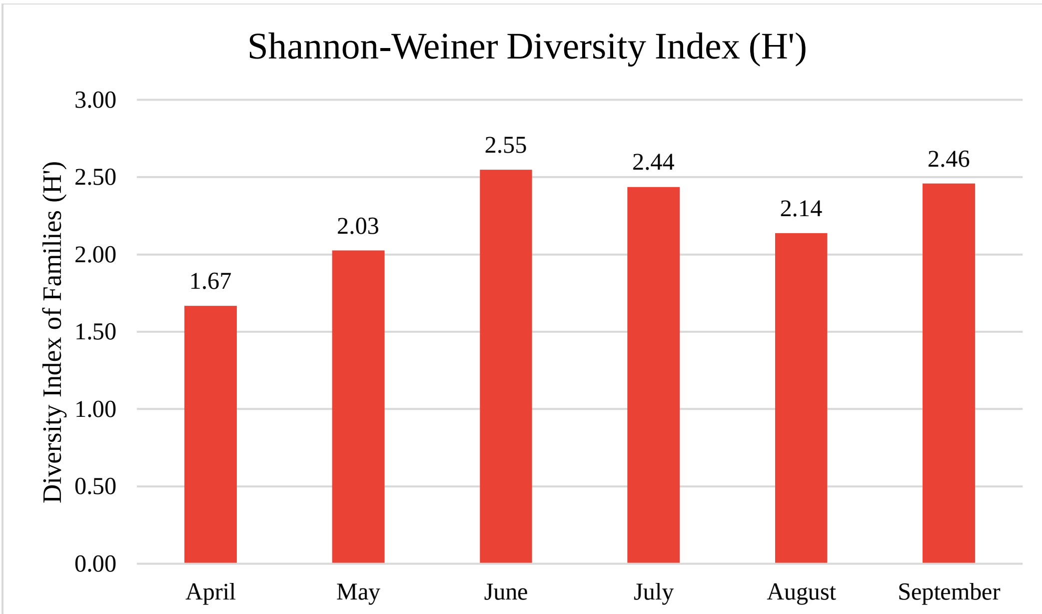


Figure 12: Diversity Values (H) according to the Shannon-Weiner Diversity Index for each of the months collected between April and September.

Figure 13 indicates the proportions of individuals by months in context of each entire collection month. For example, July has a large section of dark orange indicating morphospecies in the family Scarabaeidae. Appendix II shows that July specifically had 64 *Phyllophaga* and 12 *Popollia japonica* individuals out of the 150 total individuals collected for that month, which, combined, accounts for 50.6% of its total individuals for the month. Further, September, had 32 individuals of *Ellychnia corrusca* out of 68 total individuals collected for that month, which accounts for the large section of dark yellow indicating morphospecies in the family Lampyridae and 47.1% of its total individuals collected for that month. In May, there were seven *Harmonia axyridis* individuals out of the 19 total individuals collected for that month, accounting for 36.8%. Cross referencing the legend on the left indicating the color each family represents and Appendix II can provide more information on how the number of specific morphospecies make up the proportion of each collection month.

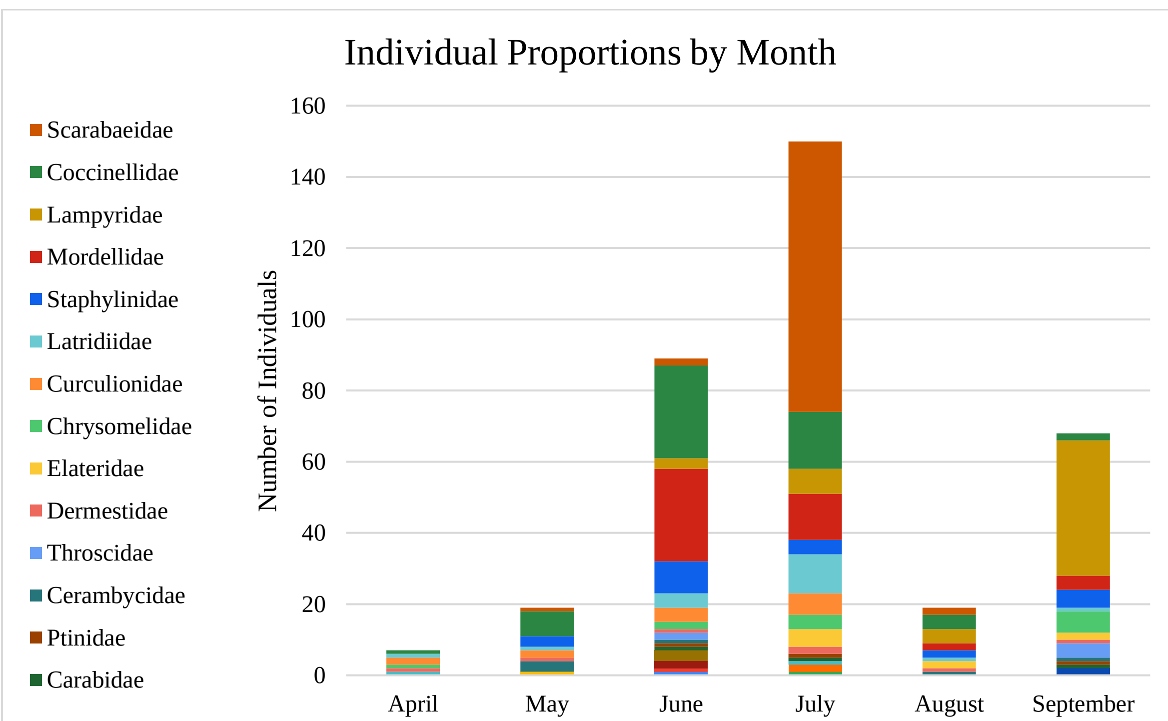


Figure 13: This figure shows the proportions of individuals by months in context of the entire collection month.

There were 63 distinct morphospecies collected, and 29 (46%) of which were recurring over subsequent months, either consecutively, not consecutively, or a combination of both. Of these 29 morphospecies that were recurring, eight morphospecies (27.5%) did not recur in consecutive months (Ex: *Neoclytus acuminatus* occurred in both May and September, but not anytime between June-August), 18 morphospecies (62.2%) recurred in consecutive months (Ex: *Diomus terminatus* occurred in all months between June and September), and three morphospecies occurred both chronologically and irregularly (Ex: *Scymnus rubricaudus* occurred in June and July, but not again until September, skipping over August completely). All other morphospecies not included in this table were only collected during one specific collection month ever recurred in subsequent months. Only one morphospecies (Latridiidae sp.1) occurred across all collection months, and only one morphospecies occurred across five out of the six collection months (Dermestidae *Cryptorhopalum*).

Table 2: This table outlines the morphospecies that were recurring over the collection months. The yellow highlighted box under a specified month means that the morphospecies was found in the collection during that month. An unhighlighted box means that the morphospecies was not found during that specified month.

Family	Genus	Species	April	May	June	July	August	September
Cerambycidae	*Neoclytus*	*acuminatus*						
Chrysomelidae	*Bassareus*							
Coccinellidae	*Chilocorus*	*stigma*						
Coccinellidae	*Coleomegilla*	*maculata*						
Coccinellidae	*Cycloneda*							
Coccinellidae	*Diomus*	*terminatus*						
Coccinellidae	*Harmonia*	*axyridis*						
Coccinellidae	*Psyllobora*							
Coccinellidae	*Scymnus*	*rubricaudus*						
Curculionidae	*Odontopus*	*calceatus*						
Dermestidae	*Cryptorhopalum*							
Elateridae	*Conoderus*	*lividus*						
Elateridae	*Hemicrepidius*	*nemnonius*						
Lampyridae	*Ellychnia*	*corrusca*						
Lampyridae	*Photinus*	*pyralis*						
Latridiidae	sp.1							
Mordellidae	sp.1							
Mordellidae	sp.2							

Mordellidae	sp.3							
Mordellidae	sp.4							
Ptinidae	sp.1							
Scarabaeidae	*Phyllophaga*							
Scarabaeidae	*Popillia*	*japonica*						
Staphylinidae	*Aleocharinae*							
Staphylinidae	*Bryoporus*							
Staphylinidae	*Coproporus*							
Staphylinidae	*Euconnus*							
Staphylinidae	*Ischnosoma*							
Throscidae	*Trixagus*	*chevrolati*						

Table 3 outlines the highest abundance of individuals collected within specified months. Only morphospecies with over six individuals during a specific month were included on this chart. *Phyllophaga* in the family Scarabaeidae in the month of July had, by far, the highest abundance with 64 individuals collected in July alone. *Ellychnia corrusca* in the family Lampyridae also had very high abundance in the month of September with 36 individuals collected in this month alone.

Table 3: This table outlines the highest frequencies of individuals collected within a specified month during the entire experiment.

Family	**Genus**	**Species**	**Month**	**Quantity**
Scarabaeidae	*Phyllophaga*		July	64
Lampyridae	*Ellychnia*	*corrusca*	September	36
Scarabaeidae	*Popillia*	*Japonica*	July	12
Latridiidae	sp.1		July	11
Mordellidae	sp.1		June	11
Coccinellidae	*Harmonia*	*axyridis*	May	7
Coccinellidae	*Harmonia*	*axyridis*	June	7
Lampyridae	*Photinus*	*carolinus*	July	7
Chrysomelidae	*Epitrix*	*fuscula*	September	6
Mordellidae	sp.3		June	6
Mordellidae	sp.2		June	6
Mordellidae	sp.4		July	6
Mordellidae	sp.2		July	6

DISCUSSION

In total, 352 individual beetles were collected. Sixty-three morphospecies were identified in 23 families (Appendix I). Out of the 23 families sampled, the families that had the highest frequency during the entire collection period included Coccinellidae (22), Staphylinidae (13), and Mordellidae (12) (Figure 4). Evans in *Beetles of Eastern North America* (2014) cites that the most commonly found beetle families are Carabidae, Staphylinidae, Scarabaeidae, Buprestidae, Elateridae, Coccinellidae, Tenebrionidae, Cerambycidae, Chrysomelidae, and Curculionidae. This project yielded specimens representing nine out of the ten families in this list (Appendix I). Out of the highest yielded families (Figure 4), only Mordellidae, Latridiidae, Dermestidae, and Lampyridae were not represented in Evans' top ten list. However, these families' natural history (they are generally found in Eastern North America) and the plant composition of the collection site can explain their high prevalence in this specific garden. Mordellidae, for example, also known as tumbling flower beetles, are attracted to sunflowers (*Helianthus annuus*), which were present in five out of the six collection months (Evans, 2014, pg. 322) (Appendix II). Latridiidae are generally either saprophagous or phytophagous, and therefore will be attracted to the garden in the broadest sense (Evans, 2014, pg. 322). Dermestidae in the genus *Cryptorhopalum* and Lampyridae in the genus *Ellychnia* feed on pollen of flowering plants and will be attracted to *Helianthus annuus* (Evans, 2014, pg. 248; pg. 234).

Four specific families, Cerambycidae (pg. 421), Chrysomelidae (pg. 450), Elateridae (pg. 216), and Mordellidae (pg. 333) are noted in literature to be specifically attracted to the three plants in the garden: *Ipomoea batatas* (Sweet Potatoes), *Vigna unguiculata* (Cowpea Beans), and *Helianthus annuus* (Sunflowers) (Evans, 2014)(Appendix II). Therefore, if Coleoptera biodiversity studies continue in subsequent years in this same urban garden, different plant composition could yield different families completely or different proportions of collected individuals. Further, Lequerica Tamara et al. (2021) found that the species richness of beetles increased in urban green spaces where the species richness of plants was higher. Therefore, increasing the number of plant species could yield higher Coleoptera biodiversity.

There were two families that were unexpected in our collection area: Scirtidae, accounting for one individual found in May and Ptilodactylidae, accounting for two individuals found in June. Scirtidae in genus *Sacodes*, also known as Marsh beetles, are typically associated with stagnant water, and as the name suggests, marshes (Evans, 2014, pg. 180-181). Ptilodactylidae in the genus *Ptilodactyla*, are usually found streamside (pg. 204-205). There are no constant water sources near our collection site. There is one storm drain about 200 yards from the trap, but only has water in it after rain showers. However, specimens in these families only occurred once, and would be of greater interest if they occurred more frequently. Further, Malaise traps lack specificity, and will intercept any flying insects if they are attracted to that specific area or insects that are simply just passing through to another destination (Karlsson et al., 2018).

In the urban green space study by Lequerica Tamara et al. (2021), researchers found that the three families of predominantly flower-feeding beetles (Scarabs, Mordellids, and Chrysomelids) represented 63% of all sampled Coleopterans, while my study yielded only 39.5% of all sampled Coleopterans (139 out of 352 individuals). This discrepancy could be due to geographical differences (this study was conducted in Sydney, Australia) in family composition and difference in sampling method (this study only utilized pan-trapping). Additionally, this study assessed biodiversity of Coleoptera, Hemiptera, Diptera, and Hymenoptera simultaneously and noted that that their specific mode of collection favored the collection of Hemiptera, Diptera, and Hymenoptera only. Malaise traps, in addition to flight-intercept traps, are the preferred method of Coleoptera collection studies (Karlsson et al., 2018; Townes, 1972), and Lequerica Tamara et al. (2021) stated that future studies should consider implementing a combination of sampling techniques (ex: pan traps, Malaise traps, and hand-netting) in order to achieve as close to a complete sample as possible.

Documenting through time-series data, as noted by Wagner et al. (2021), protecting, and supporting the biodiversity of insect populations is paramount in the face of our current mass extinction event. The beneficial nature of this studies' findings, therefore, will be maximized through the yearly repetition of Coleoptera collection at this site. Further, expanding this study across more urban green spaces within Chattanooga (and Hamilton County) can give us a greater understanding of what beetles does Chattanooga support, and how is time affecting these populations in the wake of negative anthropogenic effects.

Considerations for Future Studies

When using Malaise traps, or any traps for that matter, routine checks and monitoring of the trap itself is essential in ensuring proper functionality. Strong winds, for example, can cause the short stabilizing stakes in the ground to come up, causing the trap to lean or fall over, which can make any panels dysfunctional if insects cannot land and move upwards into the collector bottle. Additionally, the entrance to the collector bottle must also be frequently inspected to prevent spiders or other insects creating a web or home in the top. Table 1 shows the significant decrease of individuals collected during the month of August (19) from July (150) due to a spider either blocking the insects from falling into the collector bottle or capturing and consuming them upon entrance. This may be difficult to visualize from the outside due to the translucency of the collector bottle. Unscrewing the bottom of the bottle containing the propylene glycol solution, bending over, and looking directly up into the top half of the bottle is the best inspection method.

CONCLUSION

In total, over our six-month collection period using a Malaise trap, 352 individuals were collected, with 63 morphospecies identified in 23 families in our sampled urban garden in Chattanooga, Tennessee (Appendix I). Out of the 23 families sampled, the families that had the highest frequency during the entire collection period included Coccinellidae (22), Staphylinidae (13), and Mordellidae (12) (Figure 4). The highest occurrences of families were expected due to previously established geographic data and ecological characteristics of our sampled garden. Future urban garden studies within the Chattanooga and Hamilton County area could yield different results, especially in gardens with different plant species diversity. With the impending threat of mass extinction, we must continue to produce time-series data of Coleoptera populations, in rural and urban areas alike, in order to further determine not only how our actions are affecting the insect populations around us, but also what steps we can take to support their biodiversity (Wagner et al., 2021). Insects are often forgotten or understudied compared to their vertebrate counterparts, and should be studied with an equal amount of importance and urgency (Wagner et al., 2021).

ACKNOWLEDGEMENTS

There are many individuals I would like to thank for their support in completing this project. Firstly, a huge thank you to Dr. Chatzimanolis for his endless hours of helping me sort and identify insects, revising my written work, and advising me during our weekly meetings. I cannot express how thankful I am for his continual guidance, encouragement, and sharing of knowledge during this process. I would also like to thank Dr. Beasley and Dr. Craddock for being on my committee and providing valuable insights and suggestions on how I should analyze my data and improve my project as a whole. Lastly, I would like to extend a thank you to Dr. Barbosa for allowing me to place my Malaise trap in his garden for an extended period of time and giving me ecological data about the space to support my research.

BIBLIOGRAPHY

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Osgathorpe, L. M., Potts, S. G., Robertson, K. M., Scott, A. v., Stone, G. N., Vaughan, I. P., & Memmott, J. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1803). https://doi.org/10.1098/rspb.2014.2849

BIOSCAN. (2022). https://www.sanger.ac.uk/collaboration/bioscan/

Chatzimanolis, S., Cofer, Wi. G., Hightower, H. J., Roy, M. K., & Sanders, J. L. (2020). New Records of Beetles (Coleoptera) from the Tennessee Valley of Southeastern USA. *Coleopterists Bulletin*, *74*(3), 605–618. https://doi.org/10.1649/0010-065X-74.3.605

Evans, A. v. (2014). *Beetles of Eastern North America*. Princeton University Press.

Hartop, E. A., Brown, B. v., & Disney, R. H. L. (2015). Opportunity in our Ignorance: Urban Biodiversity Study Reveals 30 New Species and One New Nearctic Record for Megaselia (Diptera: Phoridae) in Los Angeles (California, USA). *Zootaxa*, *3941*(4), 451–484. https://doi.org/10.11646/zootaxa.3941.4.1

Hartop, E. A., Brown, B. v., & Disney, R. H. L. (2016). Flies from L.A., The Sequel: A further twelve new species of Megaselia (Diptera: Phoridae) from the BioSCAN Project in Los Angeles (California, USA). *Biodiversity Data Journal*, *4*(1). https://doi.org/10.3897/BDJ.4.e7756

Karlsson, D., Hartop, E., Forshage, M., Jaschhof, M., & Ronquist, F. (2018). The Swedish malaise trap project: A 15 year retrospective on a countrywide insect inventory. *Biodiversity Data Journal*, *8*. https://doi.org/10.3897/BDJ.8.e47255

Lequerica Tamara, M. E., Latty, T., Threlfall, C. G., & Hochuli, D. F. (2021). Major insect groups show distinct responses to local and regional attributes of urban green spaces. *Landscape and Urban Planning*, *216*. https://doi.org/10.1016/j.landurbplan.2021.104238

Matteson, K. C., Ascher, J. S., & Langellotto, G. A. (2008). Bee Richness and Abundance in New York City Urban Gardens. *Conservation Biology and Biodiversity*, *101*(1), 140–150. https://academic.oup.com/aesa/article/101/1/140/8467

Souza, M. M., Perillo, L. N., Barbosa, B. C., & Prezoto, F. (2015). Use of flight interception traps of Malaise type and attractive traps for social wasps record (Vespidae: Polistinae). *Sociobiology*, *62*(3), 450–456. https://doi.org/10.13102/sociobiology.v62i3.708

Theodorou, P., Radzevičiūtė, R., Lentendu, G., Kahnt, B., Husemann, M., Bleidorn, C., Settele, J., Schweiger, O., Grosse, I., Wubet, T., Murray, T. E., & Paxton, R. J. (2020). Urban areas as hotspots for bees and pollination but not a panacea for all insects. *Nature Communications*, *11*(1). https://doi.org/10.1038/s41467-020-14496-6

Townes, H. (1972). A Light-weight Malaise Trap. *Entomological News*, *83*, 239–247.

Wagner, D. L., Grames, E. M., Forister, M. L., Berenbaum, M. R., & Stopak, D. (2021). Insect decline in the Anthropocene: Death by a thousand cuts. In *Proceedings of the National Academy of Sciences of the United States of America* (Vol. 118, Issue 2). National Academy of Sciences. https://doi.org/10.1073/PNAS.2023989118

APPENDICES

APPENDIX I: Full Family, Genus, and Individual Breakdown

Table 1: Table indicating the abundance of each morphospecies under labeled headings of respective families found during each month. The number beside each morphospecies indicates the number of individuals accounted for each month. The absence of a number indicates that that specific morphospecies was not collected during that specified month. The families and morphospecies are listed in alphabetical order and do not represent any abundance pattern.

Family and Genus Breakdown	April	May	June	July	August	September	Grand Total
Cantharidae			**1**				**1**
Chauliognathus			1				1
Carabidae			**1**	**1**		**1**	**3**
Amara						1	1
Lebia			1	1			2
Cerambycidae		**3**	**1**		**1**	**1**	**6**
Hippopsis			1				1
Neoclytus		3				1	4
sp.1					1		1
Chrysomelidae	**1**		**2**	**4**		**6**	**13**
Bassareus			1	3			4
Diabrotica			1				1
Epitrix						6	6
Paria	1						1
sp.1				1			1
Cleridae			**1**				**1**
Chariessa			1				1
Coccinellidae	**1**	**7**	**26**	**16**	**4**	**2**	**56**
Brachiacantha				1			1
Chilocorus			3	1			4
Coccinella				1			1
Coleomegilla			1	1			2
Cycloneda			1	2			3
Diomus			5	5	3	1	14
Harmonia	1	7	12				20
Psyllobora			1		1		2
Scymnus			3	4		1	8
sp.1				1			1
Curculionidae	**2**	**2**	**4**	**6**			**14**
Cossonus		1					1
Odontopus		1		1			2
sp.1	2			3			5
sp.2				1			1
sp.3				1			1
Stenoscelis			4				4
Dermestidae	**1**	**1**	**1**	**2**	**1**	**1**	**7**
Cryptorhopalum		1	1	2	1	1	6
sp.1	1						1
Elateridae				**5**	**2**	**2**	**9**
Conoderus				3	1	1	5

Hemicrepidius					1	1	2
sp.1				1			1
sp.2				1			1
Eucnemidae				**2**			**2**
sp.1				2			2
Lampyridae			**3**	**7**	**4**	**38**	**52**
Ellychnia			1		4	36	41
Photinus			2	7		2	11
Latridiidae	**1**	**1**	**4**	**11**	**1**	**1**	**19**
sp.1	1	1	4	11	1	1	19
Leiodidae				**1**			**1**
Colon				1			1
Melyridae	**1**			**1**			**2**
Anthoconus	1						1
Temnopsophus				1			1
Mordellidae			**26**	**13**	**2**	**4**	**45**
sp.1			11		1	2	14
sp.2			6	6	1	1	14
sp.3			6			1	7
sp.4			3	6			9
sp.5				1			1
Mycetophagidae						**2**	**2**
sp.1						2	2
Ptilodactylidae			**2**				**2**
Ptilodactyla			2				2
Ptinidae			**1**	**1**		**1**	**3**
sp.1			1			1	2
sp.2				1			1
Scarabaeidae		**1**	**2**	**76**	**2**		**81**
Phyllophaga		1	1	64	2		68
Popillia			1	12			13
Scirtidae		**1**					**1**
Sacodes		1					1
Staphylinidae		**3**	**9**	**4**	**2**	**5**	**23**
Aleocharinae		2	4	1			7
Bryoporus					1	2	3
Coproporus		1	2				3
Euconnus			1			1	2
Ischnosoma				3	1		4
Lathrobium						2	2
Philonthus			2				2
Tenebrionidae			**3**				**3**
Alleculinae			3				3
Throscidae			**2**			**4**	**6**
Trixagus			2			4	6
Grand Total	**7**	**19**	**89**	**150**	**19**	**68**	**352**

APPENDIX II: Maps and Plant Compositions

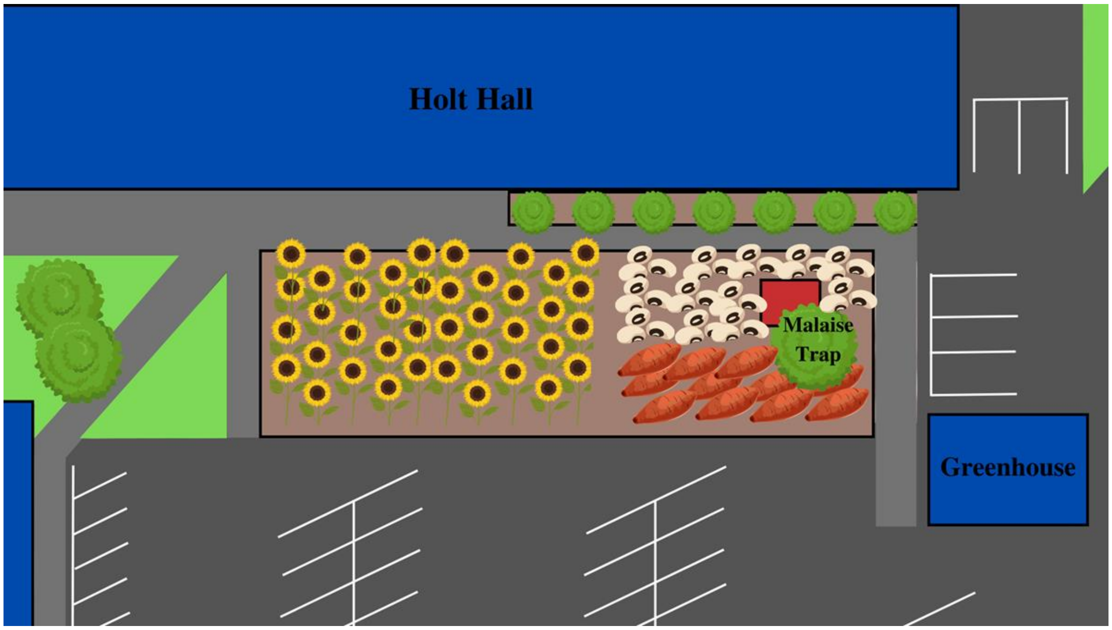


Figure 1: This figure represents the plant composition of the garden and general overview of the surroundings of the collection environment. The yellow flower graphic in the middle of the figure represents *Helianthus annuus* (sunflowers), which occupied slightly over half of the urban garden and was planted in April of 2022. The white bean graphic in the top right of the urban garden represents *Vigna unguiculata* (cowpea beans), which were planted during May of 2022. The orange sweet potato graphic in the bottom right of the garden represent *Ipomoea batatas* (sweet potatoes), which were planted during June of 2022. This plant composition remained until the completion of my study in September. The tree icons in the far left of the figure represent *Liriodendron tulipifera* (tulip trees). The row of trees lining Holt Hall are trees in the genus *Lagerstroemia* (Crepe Myrtle). The tree that the Malaise trap was placed under is a *Tilia cordata* (Littleleaf Linden).

Table 1: Planting schematic for the urban garden where insect collection took place. There were no plants planted in the garden during the month of March when the first collection month began. The highlighted sections indicate the specified plant was planted in the garden during that time period. The unhighlighted boxes indicate the specified plant was not planted in the garden during that time period.

	April	May	June	July	August	September
Helianthus annuus (sunflower)	■	■	■	■	■	■
Vigna unguiculata (cowpea bean)		■	■	■	■	■
Ipomoea batatas (sweet potato)			■	■	■	■

APPENDIX III: Photos

Appendix III provides photo examples of some of the insects collected broken down by month. This is not a complete list and does not include all 63 morphospecies collected. All photos were taken through the lens of a stereomicroscope as the beetle sits in a bowl of ethanol on the stage.

April:

Figure 1: From left to right: Curculionidae sp.1; Dermestidae sp.1; Melyridae *Anthoconus equestris*; Coccinellidae *Harmonia axyridis*

May:

Figure 2: From left to right: Scirtidae *Sacodes pulchella*; Latridiidae sp.1; Cerambycidae *Neoclytus acuminatus*; Staphylinidae *Coproporus*

June:

Figure 3: From left to right: Ptilodactylidae *Ptilodactyla*; Cantharidae *Chauliognathus marginatus*; Cerambycidae *Hippopsis lemniscate*; Chrysomelidae *Bassareus*

July:

Figure 4: From left to right: Carabidae *Lebia* sp.2; Coccinellidae *Chilocorus stigma*; Scarabaeidae *Popillia japonica*; Lampyridae *Photinus carolinus*

August:

Figure 5: From left to right: Coccinellidae *Psyllobora*; Lampyridae *Ellychnia corrusca*; Scarabaeidae *Phyllophaga*; Elateridae *Conoderus lividus*

September:

Figure 6: Throscidae *Trixagus chevrolati*; Mycetophagidae sp.1; Staphylinidae *Lathrobium*; Ptinidae sp.1

APPENDIX IV: Ecology Data

Table1: This table outlines all families collected in alphabetical order, their preferred diet, genus specific comments, and citations. All information and citations are from *Beetles of Eastern North America* (2014) by Arthur V. Evans.

Families	**Diet**	**Comments**	**Citations**
Cantharidae	Phytophagous	specifically flowers, pollen	pg. 243
Carabidae	Phytophagous	*Lebia* - attracted to light	pg. 63, 90
Cerambycidae	Phytophagous	*Hippopsis* - feed on *Helianthus*, attracted to light	pg. 388, 421
Chrysomelidae	Phytophagous	*Diabrotica* - feed on *Ipomoea batatas*	pg. 429, 450
Cleridae	Zoophagous	specifically larvae of Curculionidae and Cerambycidae	pg. 263
Coccinellidae	Zoophagous	Prey specifically on mealybugs, aphids, and scales	pg. 311
Curculionidae	Phytophagous	Dogwood, Magnolia trees	pg. 469, 474
Dermestidae	Phytophagous	*Cryptorhopalum* - feed on pollen on flowering plants	pg. 246, 248
Elateridae	Phytophagous	*Conoderus* - feed specifically on *Ipomoea batatas* and *Vigna unguiculata*	pg. 213, 216
Eucnemidae	Saprophagous		pg. 210
Lampyridae	Phytophagous	*Ellychnia* - feed on pollen and flower nectar	pg. 234-235
Latridiidae	Saprophagous, Phytophagous		pg.322
Leiodidae	Saprophagous, Phytophagous	*Colon* - feed on subterranean fungi	pg. 118
Melyridae	Phytophagous	*Temnopsophus* - prefers meadows	pg. 271, 273
Mordellidae	Phytophagous	Known as "Tumbling Flower Beetles" - attracted to *Helianthus*	pg. 333
Mycetophagidae	Saprophagous		pg. 323
Ptilodactylidae	Saprophagous	*Ptilodactyla* - larvae usually found streamside	pg. 204-205
Ptinidae	Saprophagous, Phytophagous		pg. 252
Scarabaeidae	Phytophagous	*Popillia japonica* and *Phyllophaga* considered agricultural pests, attracted to over 300 species of plants	pg. 156, 168
Scirtidae	Saprophagous, Phytophagous	*Sacodes* - larvae usually associated with aquatic plants	pg. 180-181
Staphylinidae	Zoophagous	Prey specifically on mealybugs, aphids, and scales	pg. 124
Tenebrionidae	Saprophagous, Phytophagous		pg.344
Throscidae	Saprophagous, Phytophagous		pg. 211-212