Temporal and Stand Effects on Lepidoptera and Coleoptera Defoliators in the Eastern Hardwood Forest Ecosystem

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Abstract:

Diversity is linked to the functioning of an ecosystem. In a forest ecosystem, insects are major contributors to diversity and health of the environment. While invasive defoliators can be harmful to the forest ecosystem, native defoliators contribute to the health of the forest by promoting the natural state of flux and tree succession. The goal of this study was to investigate the native defoliators in the orders Lepidoptera and Coleoptera in an Eastern Hardwood forest and what factors contribute to their community structure. This was performed through the use of active search for insects, Lindgren funnel trapping, and Malaise trapping on five different Eastern hardwood forest sites. Malaise trapping indicated an increase over time in total morphospecies abundance (12.6 ± 5.85 morphospecies, $t = 4.81$, $df = 4$, $p = 0.00429$) and in specifically Lepidoptera morphospecies abundance (10.5 ± 6.02 morphospecies, $t = 3.79$, $df = 4$, $p = 0.00962$). Active search indicated an increase in species abundance due to temporal differences ($F = 36.70$, $df = 1, 23$; p-value = 3.47e-06) but not based on differences between research sites ($F = 0.76$; $df = 1, 23$; p-value = 0.785). The most abundant family of Coleoptera was Curculionidae. There was no overall abundance of a single Lepidoptera family. The lack of community difference due to site characteristics did not agree with previous research though this may have been due to site homogeneity. The consistency of Curculionidae sighting and high diversity of Lepidoptera families was expected for a healthy forest ecosystem.

Introduction:

Diversity is an important factor in the functioning of an ecosystem. A greater diversity is linked to greater productivity, niche differentiation, resistance to invasion, and stability of an ecosystem (Tilman 1999). In a forest ecosystem, insects are a major source of species diversity (Stork 1988). Insects serve numerous roles in a forest ecosystem and contribute to the overall health and functioning of the forest. The healthiest forests support the greatest insect diversity by providing many ecological niches, who in turn provide benefits to the forest such as resistance to insect outbreaks, contributions to plant diversity, and nutrient cycling through decomposition (Schowalter 2017). Insect diversity is affected by numerous aspects of the forest. The diversity of insect communities is benefitted by an increase in the diversity of trees in a forest, though the loss of a single-species forest stand can be detrimental for those species specialized to the stand (Rohr at al. 2009).

The relationship between Coleopteran communities and diversity is complex in nature. Beetle species represent 65% of the ground-dwelling insect species within the eastern hardwood forest type (Gibbs et al. 2007), but the nature of their diversity is unclear. Total forest productivity does not appear to be related to beetle species richness but is positively correlated with the total abundance of beetles in the forest (Similä et al. 2002). There appears to be little effect on diversity by topographic characteristics of forest sites with the exception of sites that have recently faced external damage such as tornadoes (Gibbs et al. 2007). Wildflower diversity, however, may be a predictor of beetle species diversity (Frank et al. 2012).

Lepidopterans play an important role in the forest ecosystem. Lepidopterans are tied to the well-being of the forest, with moths serving as indicator species of forest health (Orr et al. 2000). They can also be indicators of the health of other orders, such as Lepidopteran diversity correlating with Hymenoptera species richness (Kerr et al. 2019). In a forest, Lepidopterans can fill numerous niches, including negative roles such as defoliators or as components of the trophic structure. Caterpillars are a large part of the diets of birds, which keeps the caterpillar populations within forests low and acts as a major agent of natural selection on caterpillars (Holmes et al. 1979).

The factors affecting Lepidoptera species diversity within a forest change in importance based on the level the scale perspective. Within a forest stand, the factors of the plants in the forest are predictors of diversity. The host diversity affects the diversity of caterpillars in an environment (Ostaff and Quiring 2000). The ground cover also affects Lepidopteran communities at the level of the stand, with a single-species plant cover limiting Lepidopteran diversity (Hanula and Horn 2011). Within landscapes, the individual plant species diversity is less important than factors such as the isolation of the area from other forests, the history of human influence on the area, and the floristic turnover of the region (Usher and Keiller 1998; Summerville et al. 2006). At the level of the landscape, tree diversity and heterogenous plant communities support greater Lepidopteran species richness (Essens and Hernández-Stefanoni 2013; Hammond and Miller1998).

Defoliation is one role of forest insects. The natural state of the forest is one of flux; with cycles of defoliation and regrowth (Wickman 1992). While there are cases of severe defoliation causing great damage to the forest such as the invasive gypsy moth, native defoliators play a natural role in the forest ecosystem by promoting succession of the forest through tree death and by acting as part of the food web (Haack 1993). Two major sources of defoliation in the Eastern Hardwood Forests are Lepidopteran larvae and Coleoptera. Coleoptera also cause damage to by feeding on tree phloem, such as bark beetles.

Defoliator outbreaks do pose a threat to the forest ecosystem. Outbreaks are often complex, with at least four different trajectories an outbreak can take due to the various forest variables (Meiges et al. 2011). After a large defoliation event, the rate of foliation returns to a standard rate within five years of the infestation (Wickman et al.) Forest management may be factor promoting the frequency of defoliator outbreaks. The prevention of fire within a forest promotes non-adapted tree species which increases the susceptibility of the forest to an outbreak of a defoliating species (Schowalter 2008).

In this study, the communities of insects within an Eastern Hardwood Forest system were analyzed, with a focus on defoliating Lepidopterans and Coleopterans. The goal of the study is to determine the species contributing to defoliation within the ecosystem and determine how the frequency and distribution of insects change over the course of one season with an emphasis on defoliators.

Methods:

<u>Site Selection</u>

Research sites were chosen from the University of Notre Dame Environmental Research Center (UNDERC, 46°13'41.1"N 89°31'24.9"W). This study location represents a mostly aspen-dominated second growth forest (UNDERC East). This site, as a preserved research site, is currently undisturbed by logging or other forest management. Five sites were chosen within the study location (Figure 1). The sites were selected as representations of different Eastern Hardwood forests types. Sites were chosen in late May and consist of plots that are 20 meters in diameter. Within each site, information about dominant tree species and understory composition was recorded.

Lindgren Funnel Trapping

Lindgren funnels were used in order to gather data on beetles within the plots. One Lindgren funnel trap was placed at each site around 1.3 meters in height, suspended between trees in the vicinity of any coniferous trees found within the plots. Ethanol was used as an attractant for the traps. Traps were retrieved and processed after six nights.

Malaise Trapping

Two methods of temporal collecting were used: active search and Malaise trapping. Malaise traps were deployed twice for each plot. Bioquip traps were fitted for dry collecting. Collection by the traps lasted for three continuous nights for each site, and the traps were rotated between the sites. The second round of collecting took place approximately 21 days after the first round, with the traps placed in the same location within the plot in other to maximize consistency. The second-round traps utilized ethanol as an attractant and kill agent. Insects located on the trap but not within the collecting jar were also noted but not collected. A paired t-test was run in order to determine if there was a significant increase in the number of morphospecies found between the temporal samples across all five sites. A second paired t-test was run to determine if there is a significant increase in the number of Lepidoptera morphospecies between temporal samples.

Active Search

Active search protocol was to search for caterpillars and beetles on the plots. Each site was searched for 10 total person-minutes per sample. Samples requiring lab identification were collected, while field identifiable species were noted but not collected. This protocol was performed once a week for five weeks over the course of the summer in order to gain temporal information. ANOVA tests were utilized to determine if there was a significant difference in species abundance between sites or between weeks of the experiment.

Results:

Lindgren Funnel Trapping

Lindgren Funnel traps were baited with ethanol and placed on each experimental plot for six nights before being collected. Each trap was checked thoroughly for any insects that had been collected in the ethanol. Four out of the five traps collected insects. Although Lindgren funnel traps were developed to preferentially attract Coleoptera, the orders collected included Coleoptera, Diptera, Hymenoptera, and Lepidoptera (Table 1). The insects were identified to family and family abundance by site was recorded (Figure 2). The families of Coleoptera were sorted by frequency in order to determine the diversity of beetles across the sites (Figure 3), with Scolytidae making up the highest frequency of families located.

Malaise Traps

Malaise traps were placed on each plot twice twenty-one days apart. The samples were taken over three nights and analyzed. Each insect was identified to family and grouped by morphospecies. The frequency of morphospecies within each family was recorded for each sample (Table 2). The majority of morphospecies in each sample came from the orders Diptera, Lepidoptera, Hymenoptera, and Coleoptera; though Hemiptera, Odonata, and Orthoptera were also collected. Lepidoptera morphospecies were identified, though it was often difficult to identify Lepidoptera to family due to damage to the wings obscuring wing venation. The percentage of morphospecies in each sample consisting of each order showed a consistent majority of Diptera morphospecies in each sample (Figure 4). The total number of morphospecies for each sample was recorded and a paired t-test was run on the difference of total morphospecies counts between sample dates on each site. There was a significant average increase of 12.6 ± 5.85 morphospecies between the first and second sample dates ($t = 4.81$, $df = 4$, $p = 0.00429$). A second paired t-test was run on the number of Lepidoptera morphospecies between temporal samples across all five sites. There was a significant average increase of 10.5 ± 6.02 Lepidoptera morphospecies between the first and second sample dates ($t = 3.79$, $df = 4$, $p = 0.00962$).

<u>Active Search</u>

Active search for lepidoptera and coleoptera was performed across five sites for five weeks over the course of the summer. All specimens were identified to family and recorded (Table 3). The total number of species found was recorded by order and there was a general increasing trend in number of species over the course of the experiment (Figure 5). Lepidopteran families collected included Tortricidae, Lasiocampidae, Erebidae, Geometridae, and unknown families, of which Tortricidae made up over half of all encounters (Figure 6). Coleoptera families included Curculionidae, Elateridae, Carabidae, Coccinelidae, Cerambycidae, and unknown species (Figure 7). Curculionidae made up the majority of coleopteran encounters. The family

Coccinellidae was found on three separate weeks but only at one location. ANOVA tests were run on both morphospecies located per site and morphospecies located per week. Site was not found to be a significant factor determining morphospecies abundance ($F = 0.76$; df = 1, 23; p-value = 0.785). Week was found to be significant in determining morphospecies abundance ($F = 36.70$, df = 1, 23; p-value = 3.47e-06).

Discussion:

This experiment investigated the prominent defoliators within the Eastern Hardwood forests and gained insight into the temporal distribution of defoliators throughout the season. It was determined through active search of the forests that the species abundance of Coleoptera and Lepidoptera species is impacted by temporal factors and not by the characteristics of the site on which it resides. This disagrees with previous research on Lepidoptera which supports the idea that forest community structure is impacted by characteristics of the stand such as heterogenous plant community, host species, and tree diversity (Essens and Hernández-Stefanoni 2013; Ostaff and Quiring 2000; Hammond and Miller 1998). Coleopteran research, on the other hand, has drawn a less clear conclusion with conflicting studies. Past studies suggest both that plant diversity is an important determinant of community structure and that stand characteristics have only weak correlation with species diversity (Frank et al.2012; Similä et al. 2002). This may, however, be due to homogeneity of the chosen sites. The five sites were chosen within a relatively small and controlled geographic area so each site shared the same management and natural history. Four of the five sites were aspen-dominated. While two of the five sites contained numbers of coniferous trees, their numbers may not have been great enough to have an impact. Regeneration was fairly consistent across the five sites. While these factors did create a controlled experiment allowing temporal data be assessed, the high similarity may have masked influences of stand characteristics due to their homogeneity.

An increase in diversity due to temporal effects were shown both by the active search and by Malaise trapping. Active search was performed over the period of May 30th to July 15th, which represents a large period of the summer when insects would be expected to be active and abundant. Malaise trapping was performed at the same site 21 days apart, beginning in mid-June and into mid-July. High temperatures and weather were fairly consistent across the sites during this period. The cause of this increase in morphospecies may be due to delayed emergence to ensure activity during the warmest points of the year or to allow for complete foliation before emergence of defoliating species. There was a notable significant increase of Lepidopteran morphospecies between the first and second round of Malaise trapping. This may be due to the need of these species to have ample foliation during their caterpillar stage, thus delaying their metamorphosis to adults until after there has significant foliation over a long period of time.

The most abundant families of Coleoptera was noted to be Curculionidae, which was found consistently as a majority and across sites by Lindgren Funnel traps, Malaise traps, and active search. This family, made up the true weevils, are mostly plant eaters. Recently the family was widened to contain the former family Scolytinae, the bark beetles. The overwhelming presence of this family across the sites and consistence across weeks signifies that this is an important species for the forest. The natural state of the forest is one of periods of flux, with defoliator and other tree-harming species contributing to the forest by promoting succession of trees within the forest (Wickman 1992; Haack 1993). The high presence of this family contributes to the succession rate of the forest its overall health, and can be suggested to be healthy for the forest ecosystem, though it may also be problematic depending on the species or if species are unchecked and overabundant.

The most abundant family of Lepidoptera was not as available due to the difficulty in identifying Malaise trap specimens to family as these specimens often had torn up or missing wings which obscured venation required for identification. There appeared to be a large diversity of morphospecies with large morphological differences, suggesting a high rate of diversity for Lepidoptera as a whole. As high Lepidoptera diversity is an indicator of forest health, this too suggests that the forest stand the five sites are a part of to be healthy ecosystem (Orr et al. 2000). It is notable that, in Malaise trapping, there were no overwhelmingly common species. Lepidoptera communities as a whole have been suggested to be made up of a majority of rare species with no highly abundant majority species (Barbosa et al. 2000). This was supported by this experiment. The communities appear to be diverse within a forest ecosystem.

There are ways that this experiment could have been improved upon that would have clarified results. First of all, sites could be chosen that have higher between-site plant and tree species diversity to further investigate whether or not forest stand characteristics impacted Lepidopteran and Coleopteran communities. The sites chosen may have been too similar to reveal any differences at the acuity of the research performed. Secondly, more data points could be gathered over a greater duration of the summer season. The research was limited both in time and equipment. This limited how often traps could be placed on sites and active search could be performed. A better research scenario would have been to place Malaise traps on all sites for the duration of the summer, checking them periodically on a consistent schedule, but as only two traps were available this was not possible. Other methods also could have been utilized in active search such as branch beating which would have resulted in more observations of caterpillars and beetles within the stands.

Future experimentation on the subject are suggested in order to better understand the impact of native defoliators upon a site. The majority of defoliator research is on outbreak species and not on the less common species (Barbosa et al. 2000). Defoliators are ecosystem regulators in their natural state and are important for the health of the forest. (Haack 1993). Future investigation on the impacts of individual species or families upon forest defoliation could be performed following methods outlined in other research (Clancy 1993). Furthermore, while this study was able to assess species abundance, it was unable to reach the acuity necessary to fully study species diversity. Diversity is linked to the functioning of an ecosystem and thus a greater understanding of a site's diversity would lead to great information about the health and productivity of that ecosystem (Tilman 1999).

Insects represent a highly diverse aspect of the forest ecosystem, filling both positive and negative ecological niches and contributing to the overall functioning of the forest (Stork 1988). It is important to understand the insect community in an understanding of overall forest health and characteristics in order to gain a deeper understanding of the forest ecosystem as a whole.

Tables:

Table 1: Families found through Lindgen Funnel trapping by order.

Site	Coleoptera	Hymenoptera	Diptera	Lepidoptera
1	Carabidae Erotylidae		Culicidae	
2				
3	Scolytidae	Unknown		
4	Elateridae Scolytidae Curculionidae Cerambycidae	Formicidae	Culicidae Unknown	
5	Elateridae Scolytidae Scarabidae			Noctuidae Geometridae

Table 2: Morphospecies identified by family and order collected by Malaise trapping.

Order	**Family**	**Site 1**		**Site 2**		**Site 3**		**Site 4**		**Site 5**	
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Coleoptera	Carabidae		1							1	
	Cerambycidae						1		1		
	Chrysomelidae							1			
	Curculionidae		2		1				2	1	1
	Elateridae					1					1
	Endomychidae		1								
	Scolytidae						1				
	Staphylinidae				1						
	Unknowns		1		1						
	Total	**0**	**5**	**0**	**3**	**1**	**2**	**1**	**3**	**2**	**2**
Diptera	Anthomyiidae				1						
	Asilidae	1	1						1		1
	Bombyliidae						1		1		
	Calliphoridae						1				
	Chironomidae	1		7							
	Culicidae	1		6	4		5	6	5	4	7

	Empididae				2		1	3		2	
	Lonchopteridae									1	
	Muscidae		4	2	5		5	2	4	4	4
	Ottidae									1	
	Phoridae		1				1	2			1
	Rhagionidae	1									
	Tabanidae	2	5	3	4	3	5	8	4	7	6
	Therevidae									1	
	Tipulidae	2	2	2	2	2	1	2	2	4	3
	Unknowns	2		3	8	15	8	6	5	7	8
	Total	**10**	**13**	**23**	**26**	**20**	**28**	**29**	**22**	**31**	**30**
Hemiptera	Largidae								1		
	Pentatomidae					1					
	Unknown Heteropteran										1
	Unknown Planthopper						1				1
	Total	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**2**
Hymenoptera	Bracionidae			1	1						
	Formicidae			1			1				
	Sphecidae		2				1		1	1	
	Tiphiidae		2		1						
	Vespidae		2		2	1	1	1	1	2	1

	Unknown							1			
	Total	**0**	**6**	**2**	**4**	**1**	**3**	**2**	**2**	**3**	**1**
Lepidoptera	Erebidae				1				1		
	Geometridae	1		1							
	Hesperiidae	1						1		1	
	Noctuidae				1		2				
	Notodontidae				1						
	Nymphalidae				1						1
	Papillionidae				1						
	Unknown		2		5		10	1	15	4	19
	Total	**2**	**2**	**1**	**10**	**0**	**12**	**2**	**16**	**5**	**20**
Odonota	Lestidae						1				
	Total	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**
Orthoptera	Acrididae						1				
	Total	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**

Table 3: Families found by active search over five sites and five collection dates. All collections took place in the year 2019. An order name in italics is used to signify that the specimen could not be identified to family.

Site	30-May	10-Jun	15-Jun	9-Jul	15-Jul
1	N/A	Curculionidae	Curculionidae	Geometridae Curculionidae Sphingidae Tortricidae	Curculionidae Tortricidae *Lepidoptera*
2	N/A	Lasiocampidae Curculionidae	Tortricidae	Tortricidae	Geometridae Curculionidae Tortricidae
3	N/A	Erebidae Curculionidae	Elateridae Lasiocampidae	Carabidae Tortricidae *Coleoptera*	Geometridae Curculionidae Cerambycidae Tortricidae Elateridae
4	N/A	Curculionidae	Curculionidae Elateridae Tortricidae	Tortricidae Curculionidae	Tortricidae *Lepidoptera*
5	N/A	Curculionidae	Elateridae Coccinellidae	Coccinellidae *2 Coleoptera* *Lepidoptera*	Coccinellidae Tortricidae *Coleoptera*

Figures:

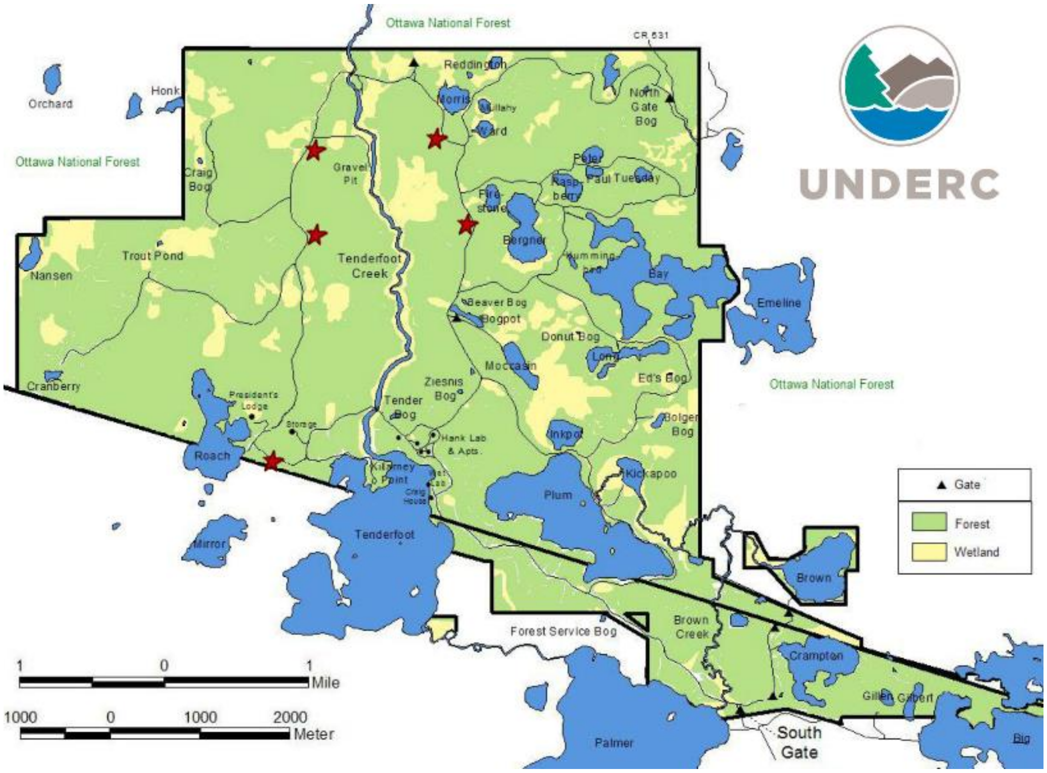

Figure 1: Map of the five plots chosen on the UNDERC property (UNDERC East). The selected plots are marked with red stars.

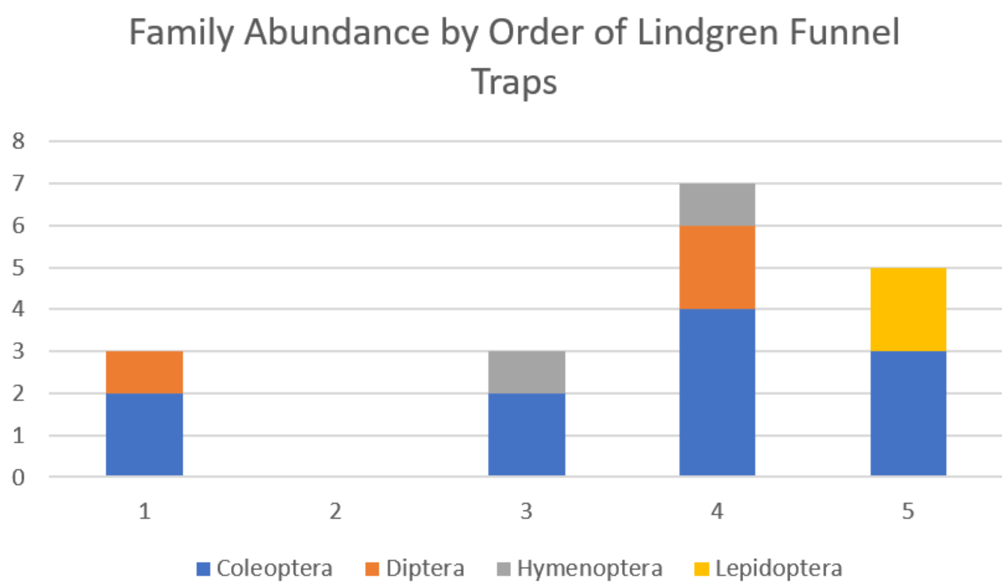

Figure 2: The family abundance by order across the five sites collected by Lindgren Funnel Traps. One sample contained no insects.

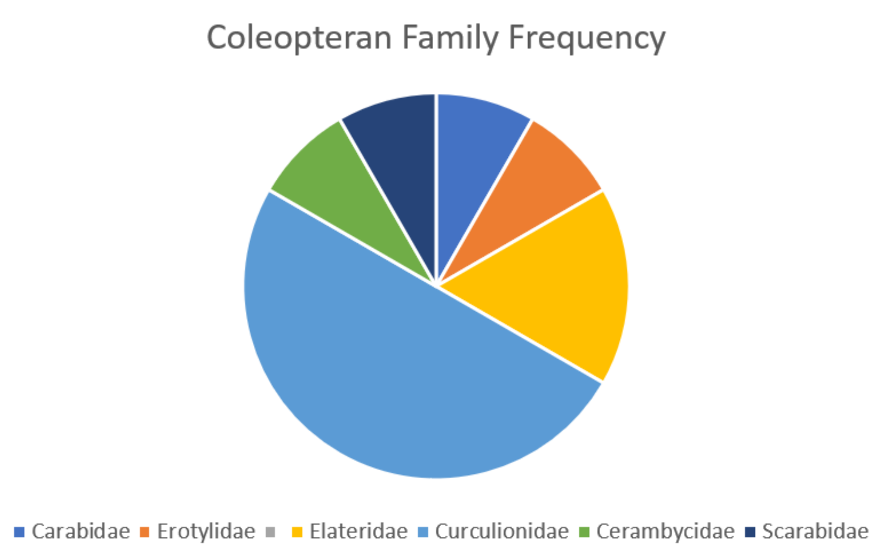

Figure 3: The frequency of Coleopteran families caught in Lindgren Funnel Traps.

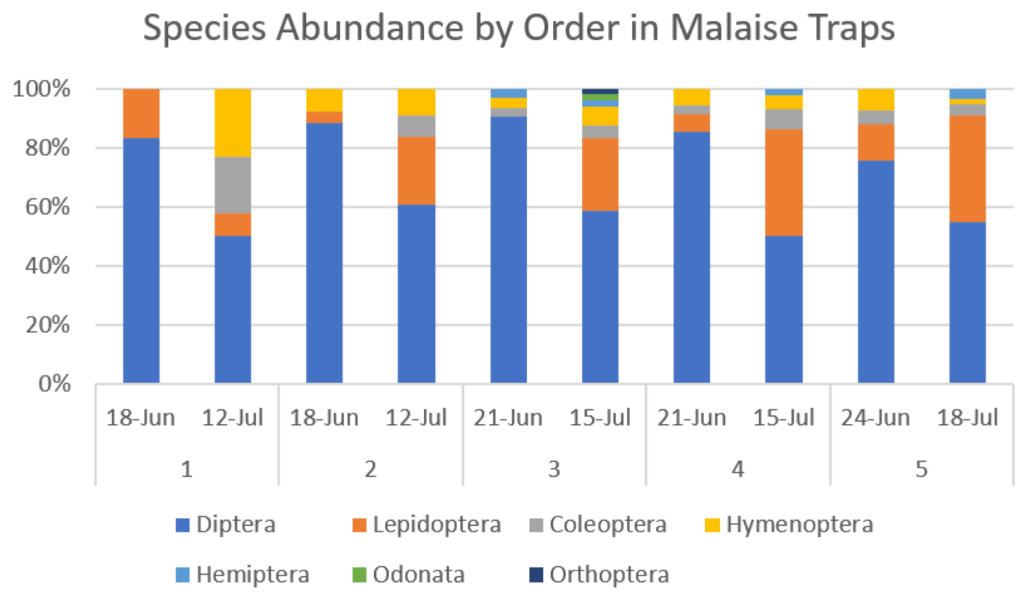

Figure 4: The percentage of species in each Malaise trap sample by order. In all samples the order Diptera made up the majority of species within the sample.

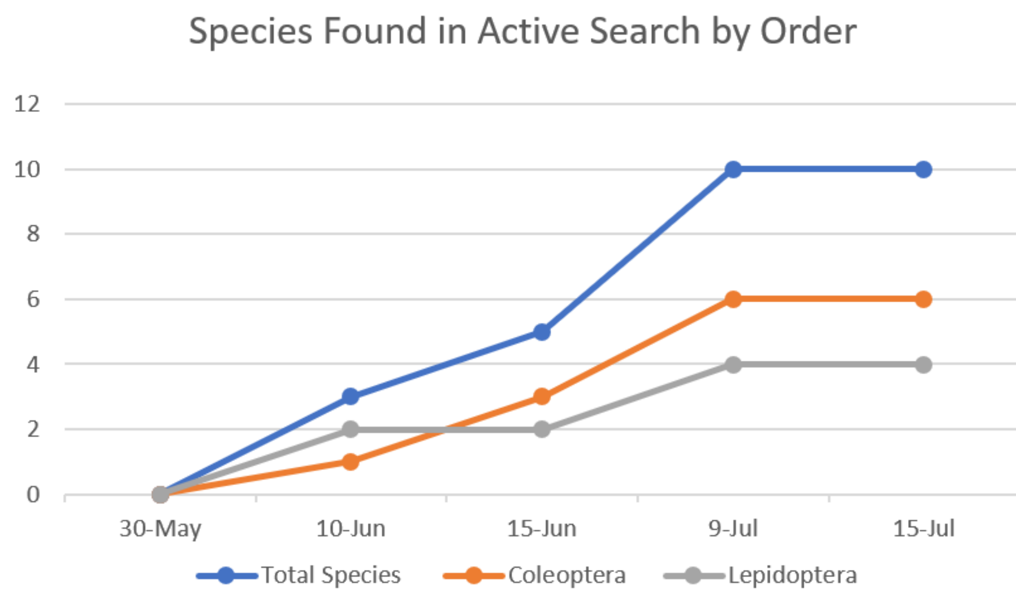

Figure 5: The abundance of morphospecies found in active search by order and in total.

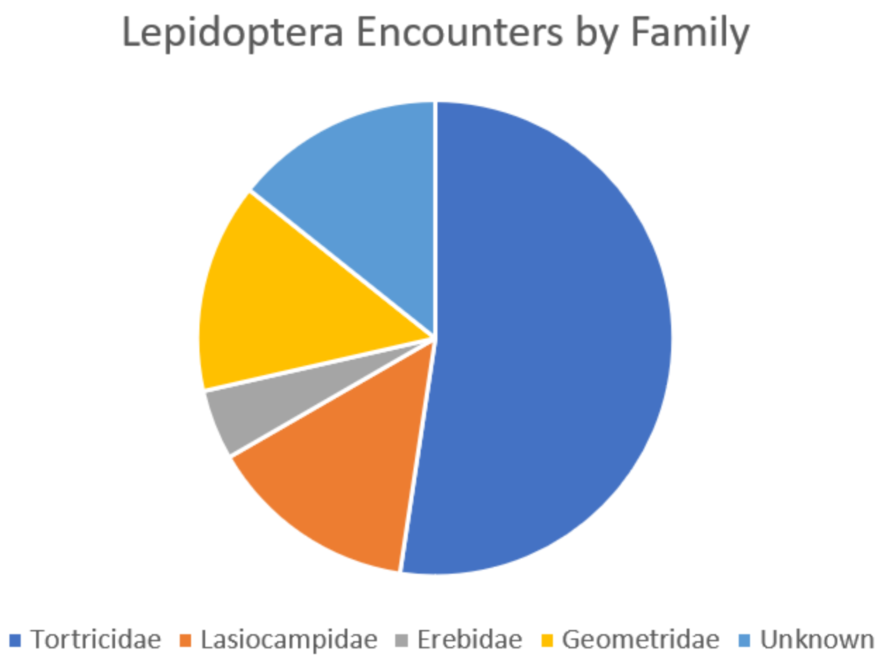

Figure 6: The proportion of total Lepidopteran encounters during active search by family.

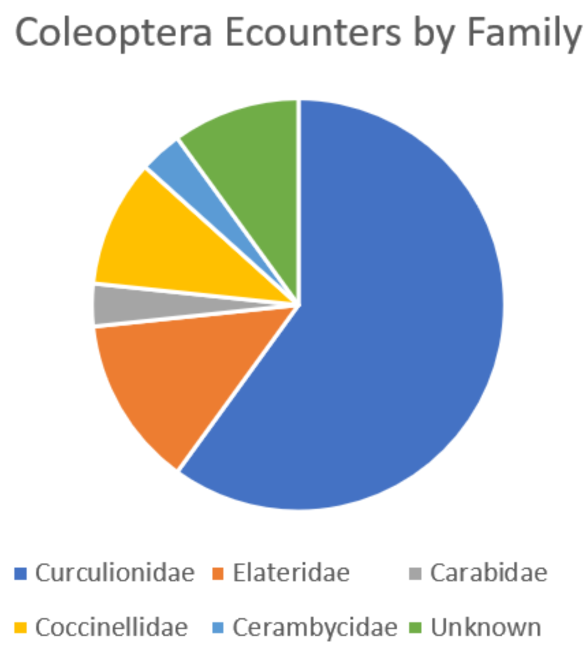

Figure 7: The proportion of Coleoptera encounters during active search by family.

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Raw Data

Data 1: Active search raw data

30-May	No collections from any site				
10-Jun	Site 1 Curcilionidae	Site 2 Lasiocampidae (forest tent) Curcilionidae	Site 3 Erebidea, Lymantriinae (tussock moth) Curcilionidae	Site 4 Curcilionidae	Site 5 Curcilionidae *Tenthredinidae (sawfly)*
11-Jun	Site 1 Curcilionidae	Site 2 Lasiocampidae (forest tent) Curcilionidae	Site 3 Curcilionidae	Site 4 Curcilionidae	Site 5 Curcilionidae
15-Jun	Site 1 Curcilionidae *Unknown pupa*	Site 2 *Unknown grub* Tortricidae (leaf roller, 1)	Site 3 Elateridae (click beetles) Lasiocampidae (forest tent)	Site 4 Curcilionidae Elateridae (click beetles) Tortricidae (leaf roller, 1) *Unknown Grub*	Site 5 Elateriidae (click beetles) Coccinellidae
9-Jul	Site 1 Geometridae Curcilionidae Sphingidae (adult) Torticidae (7)	Site 2 *Unknown pupal case* Torticidae (3)	Site 3 Carabidae Beetle larva Torticidae (3)	Site 4 Torticidae (1) Curcilionidae (2)	Site 5 Unknown caterpillar Coccinellidae 2 beetle larvae
15-Jul	Site 1 Unknown caterpillar Curculionidae Torticidae (3)	Site 2 Geometridae Curculionidae Torticidae (7)	Site 3 Geometridae Curculionidae (2 species) Cerambycidae Torticidae (17) Elateridae	Site 4 Unknown caterpillar Torticidae (12)	Site 5 Beetle larvae Coccinellidae Torticidae (19)

Data 2: Lindgren Funnel raw data

SITE 1	TOTAL: 3				
	Diptera: 1	Culicidae (1 species, 2)			
	Coleoptera: 2	Carabidae (1 species, 1)	Erotylidae (1 species, 2)		
SITE 2	TOTAL: 0				
SITE 3	TOTAL: 3				
	Hymenoptera: 1	1 Unknown			
	Coleoptera: 2	Curculionidae: Scolytidae (2 species, 1 each)			
SITE 4	TOTAL: 7				
	Diptera: 2	Culicidae (1 species, 1)	1 species of unknown midge, 3		
	Coleoptera: 4	Elateridae (1 species, 2)	Curculionidae: Scolytidae (1 species, 1)	Curculionidae (1 species, 1)	Cerambycidae (1 species, 1)
	Hymenoptera: 1	Formicidae (1 species, 1)			
SITE 5	TOTAL: 5				
	Lepidoptera: 2	Noctuidae (1 species, 1)	Geometridae (1 species, 1, caterpillar)		
	Coleoptera: 3	Elateridae (1 species, 2)	Curculionidae: Scolytidae (1 species, 1)	Scarabidae (1 species, 1)	

Data 3a: Malaise trap raw data Sites 1-3

Site 1	18-Jun	TOTAL SPECIES RICHNESS: 12 Dipterans: 10 Lepidopterans: 2	Tipulidae (crane flies, 2 species, 1 and 1) Hesperiidae (1 species, genus *Poanas*, 1)	Tabanidae (horse and deer, 2 species, 6 and 2) Geometride (1 species, 1)	Rhagionidae (1 species, 2)	Culicidae (1 species, 1)	Asilidae (1 species, 1)	Chironomidae (1 species, 1)	2 Unknown		
Site 1	12-Jul	TOTAL SPECIES RICHNESS: 26 Dipterans: 13 Coleopterans: 5 Lepidopterans: 2 Hymenopterans: 6	Tipulidae (2 species, 1 and 1) Endomychidae (1 species, 1) 2 species of unknown moth (3 and 1) Vespidae (2 species, 4 and 1)	Tabanidae (5 species, 3, 19, 5, 25, 33) Curculionidae (2 species, 19 and 1) Sphecidae (2 species, 1 and 1)	Muscidae (4 species, 2, 1, 2, 6) Carabidae (1 species, 1) Tiphiidae (2 species, 1 and 1)	Asilidae (1 species, 1) 1 unknown	Phoridae (1 species, 1)				
Site 2	18-Jun	TOTAL SPECIES RICHNESS: 26 Dipterans: 23 Lepidopterans: 1 Hymenoptera: 2	Tipulidae (2 species, 1 and 1) Geometridae (1 species, 1) Formicidae (1 species, 1)	Tabanidae (3 species, 1 each) Bracionidae (1 species, 1)	Culicidae (6 Species, 6, 3, 11, 1, 1, 1)	Muscidae (2 species, 1 each)	Chironomidae (7 species, unknown	3 Unknowns			
Site 2	12-Jul	TOTAL SPECIES RICHNESS: 44 Dipterans: 26 Lepidopterans: 10 Hymenopterans: 4 Coleopterans: 3	Tipulidae (2 species, 2 and 2) Papillionidae (1 speciess, 1, Papilio genus) Vespidae (2 species, 1 each) Curculionidae (1 species, 2)	Culidicidae (4 species, 5, 2, 2, 1) Nymphalidae (1 species, 1) Bracionidae (1 species, 1) Staphylinidae (1 species, 2)	Muscidae (5 species, 1, 10, 2, 2, 5) Notodontidae (1 species, 1) Tiphiidae (1 species, 1) 1 unknown (1)	Tabanidae (4 species, 9, 6, 20, 1 Erebidae (1 species, 1)	Empididae (2 species, 10, 5) Noctuidae (1 species, 1)	Anthomyiidae (1 species, 2) Unknown (5 species, 20, 2, 2, 1, 1)	8 Unknown		
Site 3	21-Jun	TOTAL SPECIES RICHNESS: 23 Dipterans: 20 Hymenopterans: 1 Heteropterans: 1 Coleopterans: 1	NOTE: Majority of sample flies are torn up, making them impossible to ID Tipulidae (2 species, 6 and 1) Vespidae (1 species, 2) Stinkbug (1 species, 1) Elateridae (1 species, 1)	Tabanidae (3 species, 11, 11, and 2)	Many unknown~15 (sample impossible to identifiy)						
Site 3	15-Jul	TOTAL SPECIES RICHNESS: 48 Dipterans: 28 Hymenopterans: 3 Lepidopterans: 12 Coleopterans: 2 Hemipterans: 1 Orthopterans: 1 Odonata: 1	Tipulidae (1 species, 1) Formicidae (1 species, 1) Noctuidae (2 species, 1 each) Curculionidae: Scolytinae (1 species, 1) Planthopper (1 species, 3) Acrididae (1 species, 2) Lestidae (1 species, 2)	Phoridae (1 species, 4) Vespidae (1 species, 4) 10 unknowns Cerambycidae (1 species, 1)	Tabinidae (5 species, 1, 5, 6, 9, 65) Sphecidae (1 species, 1)	Culicidae (5 species)	Muscidae (5 species, 2, 5, 9, 1, 3)	Calliphoridae (1 species, 1)	Bombyliidae (1 species, 1)	Empididae (1 speces, 1)	8 unknowns

Data 3b: Malaise trap raw data Site 4 and 5

Site 4	21-Jun	TOTAL SPECIES RICHNESS: 34 Dipterans: 29 Hymenopterans: 2 Lepidopterans: 2 Coleopterans: 1	Tipulidae (2 species, 2 and 8) Vespidae (1 speices, 1) Hesperiidae (1 species, 6) Chrysomelidae (1 species, 1)	Tabanidae (8 species, 1, 1 ,2, 7, 7, 1, 15, 128) 1 Unknown Unknown moth	Culicidae (6 species, 1 each)	Empididae (3 speices, 3, 1, 3)	Phoridae (2 species, 1 and 1)	Muscidae (2 speices, 1 and 1)	6 Unknowns		
Site 4	15-Jul	TOTAL SPECIES RICHNESS: 44 Dipterans: 22 Lepidoptera: 16 Hymenopterans: 2 Coleopterans: 3 Hemipterans: 1	Tabanidae (4 species 5, 6, 115) 15 unknowns Vespidae (1 species, 5) Cerambycidae (1 species, 1) Largidae (1 species, 1)	Muscidae (4 species, 1, 2, 1, 1) Erebidae (1 species, capterpillar) Sphecidae (1 species, 1) Curculionidae (2 species, 1 and 3)	Tipulidae (2 species, 1 and 3)	Asilidae (1 species, 1)	Bombyliidae (1 species, 1)	Culicidae (5 species)	5 Unknowns		
Site 5	24-Jun	TOTAL SPECIES RICHNESS: 41 Dipterans: 31 Hymenopterans: 3 Lepidopterans: 5 Coleopterans: 2	Tipulidae (4 species, 1, 2, 3, and 1) Vespidae (2 species, 1 and 1) Hesperiidae (1 species, 1) Curcilionidae (1 species, 1)	Culicidae (4 species, 4, 5, 2, 2) Sphecidae (1 species, 1) 4 distinct but unknown moths Carabidae (1 species, 1)	Tabanidae (7 Species, 1, 2, 2, 32, 49, 27, 54)	Ottidae (1 species, 1)	Empididae (2 species, 2, 5)	Muscidae (4 speices, 3, 12, 2, 1, 4,)	Lonchopteridae (1 species, 5)	Therevidae (1 species, 3)	7 Unknowns
Site 5	18-Jul	TOTAL SPECIES RICHESS: 54 Dipterans: 30 Hymenoptera: 1 Coleoptera: 2 Hemiptera: 2 Lepidoptera: 20	Culcidae (7 species) Vespidae (1 species, 2) Curculionidae (1 species, 1) Leafhopper (1 species, 3) Nymphalidae (1 species, 1)	Tipulidae (3 species) Elateridae (1 species, 1) Heteropteran (1 species, 1) 19 Unknown moths	Tabanidae (6 species, 5, 1, 1, 2, 19, lots)	Muscidae (4 species, 3, 1, 2, 1)	Phoridae (1 species, 1)	Asilidae (1 species, 1)	8 unknowns		