COMPARISONS OF GROUND-DWELLING BEETLE ASSEMBLAGES IN DIFFERENT STAND TYPES AT JACK HAGGERTY FOREST

By

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ABSTRACT

Beetles (Coleoptera) play an important role in Canada’s boreal forest as they aid in many forest processes. Ground-dwelling beetles are the focus of this study, and most of these beetles belong to the families Carabidae, Silphidae, and Staphylinidae, playing a large role in the cycling of nutrients through predation and decomposition. The study’s main objective is to determine if there is a difference in ground-dwelling beetle assemblages under different stand types. This will be determined through the analysis of species richness, species composition, and abundance under different stand types. From the Jack Haggerty Forest in Thunder Bay Ontario, data was collected from multiple stand types during the years 2022 and 2023 using pitfall traps. The data collected was analyzed using generalized linear models and non-metric multidimensional scaling through R statistical software. The results indicate that species composition was not significantly different between sites or years. Species abundance was significantly different in Pr60 compared to Pop45, Sb45 with Pr60, and Sb45 with Sb100. Species richness was only significant on a stand level between Sb100 and Pop45, Sb100 and Pr60, and finally, Sb100 and Sb45 were significantly different. The study showed the importance of the preservation of multiple stand types in an area. This idea should be implemented into forest management plans as it would increase the forest's biodiversity and in turn health and resilience.

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ACKNOWLEDGEMENTS

I would like to acknowledge my supervisor Dr. Lee for helping me throughout the entire process as he was always happy to help, especially when analyzing the data using RStudio and my second reader Dr. Wang for his recommendations and time.

INTRODUCTION

Like all insects, beetles (Coleoptera) have three distinct body parts: a head (Caput), thorax, and abdomen. What makes members of the order Coleoptera special is that they also have a protective cover for their wings called an elytron. They have a larval stage and an adult stage (Rolf G. 2016). Various species of beetles can be found across Canada with unique niches and roles they play within their associated ecosystems. Out of the over 1 million species of insects that have been discovered beetles make up around 40% (Royal Entomological Society, 2023).

Biodiversity plays a critical role in a functioning ecosystem. In general, more trophic levels and greater diversity among the trophic levels in an ecosystem increase its health (Wilsey 2000). A higher diversity among prey tends to increase resistance to predation because the odds of prey being inedible to certain predators is increased and the efficiency of specialized predators confronted is decreased (Ives et al. 2005). For predators, greater diversity can have an indirect effect on plant biomass, however, the extent of the change is extremely variable depending on the amount of omnivory and prey behavior (Thébault & Loreau 2003). Additional trophic levels can have effects on adjacent levels increasing interactions across the ecosystems producing a more complex and stronger ecosystem (Duffy, J. E., et al. 2007).

With such a vast diversity of species, it has made it inevitable that some species would be more deleterious to forests than others such as the emerald ash borer (*Agrilus planipennis*). Originally arriving in North America from Europe in the 1990s on wood packaging, the emerald ash borer has killed millions of trees in Canada (Natural Resources Canada, 2023). In the west of Canada, the mountain pine beetle (*Dendroctonus ponderosae*) has been observed to have major outbreaks leading to large areas of lodgepole pine deaths and was estimated that the total loss of pine that could have been sold was 752 million cubic meters (Natural Resources Canada, 2022). A better understanding of how forests and beetles interact and affect each other may help in minimizing tree deaths and increasing the profitability of Canada's forests as well as protection from invasive species.

Since the potential damage that beetles can cause is so high, many forest management plans have included techniques to deal with and monitor beetle activity. Forest managers can also use beetles to indicate the impacts of harvest and regeneration practices based on species composition and abundance (Pohl et al., 2007). Forest management has had an increase in interest from the general public with a keen interest in preserving biodiversity (Freedman et al. 1994). To solve this problem mixedwoods management has been presented as a solution since it increases the forest’s resistance to diseases and insect outbreaks, improves productivity, and stronger biodiversity conservation (Pretzsch 2003; Cappuccino et al. 1998).

Mixedwoods forests are areas of land that have a canopy dominated by two or more tree species where none consist of over 80% of the stand basal area (MacDonald 1995). Mixedwoods forests can consist of both broadleaf and deciduous tree species. Since multiple species co-exist in the same environment with separate niches, resources can be more efficiently used, nutrient cycling can be enhanced, and new plant sprouts can benefit from nurse crop effects (Cannell 1992: Kelty 1992: Man and Lieffers 1999). Mixed forests also allow for increased diversity of animals compared to the biological diversity found in monocultures (Hobson and Bayne 2000; Macdonald and Fenniak 2007).

OBJECTIVE

The objective of this study is to examine if there is a difference in ground-dwelling beetle assemblages among different stand types. This will be determined through the analysis of species composition, abundance, and species richness under different stand types.

HYPOTHESIS

H_0: Species composition, abundance and species richness of ground-dwelling beetles will not be significantly different among stand types.

H_1: Species composition, abundance and species richness of ground-dwelling beetles will be significantly different among stand types.

LITERATURE REVIEW

This undergraduate thesis examines the assemblages of ground-dwelling beetles (Coleoptera) in relation to different stand types supporting different dominant tree species. The literature referred to for this thesis is related to effects on the environment that the dominant tree species has on its environment and how these changes could influence the assemblages of ground-dwelling beetles under each stand type respectively. In the following paragraphs, I provide morphological and ecological information about three beetle families, i.e., Carabidae Silphidae, and Staphylinidae, as these were the most common families found in Jack Haggerty Forest using pitfall traps.

The beetle family Carabidae is extremely widespread reaching almost everywhere on earth but the arctics and some deserts. Most members of the Carabidae are predatory eating a large range of prey species (Löveï & Sunderland, 1996). Carabidae (ground beetles) prey on a large assortment of prey including caterpillars, slugs, snails, and other insects. Adults are elongated with elytra to protect their wings. They have 4 life stages: egg, larva, pupa, and adult. Eggs are laid in soil by adult females that can lay around 100 eggs in their lifetime. They live for around 2 years on average, however development from egg to adult takes months to more than a year to complete. Adults can run quickly, and many species are unable to fly as their forewings fuse and are flightless (UC IPM 2015). Members of the Carabidae have been used as indicators of the health and changes in ecosystem dynamics due to their feeding and habitat diversity such as harvesting or fires (Bennewicz & Barczak, 2020). (Carabidae can be identified by their large bean-shaped trochanters (University of Maine 2022). To avoid predators many carabid beetles, secrete a foul-smelling liquid from their bodies that deters potential attacks from predators like birds (Mahr 2020).

Silphidae is another beetle family that was captured in the pitfall traps and used in this thesis. Silphidae also known as burying beetles, can be identified by their clubbed-shaped antennae and most species have flat black bodies (NC State University 2015). Members of the family Silphidae mostly feed on the corpses of deceased animals, but some eat fungi (NC State University 2015). They can be found in decaying organic matter such as carcasses giving them the common name carrion beetles. They drag the crops into a hole and fight until only a pair remain. They then lay eggs and the male fertilizes them before leaving the hole (Anderson, R. S. 1976). To locate their food, members of the Silphidae family use olfaction through olfactory structures called sensilla coelosphaerica located in the terminal antennal segments (Waldow 1973). When a carcass decays it releases hydrogen sulfide and some cyclic carbon compounds that the sensilla are able to pick up on (Waldow 1973). The family Silphidae can be recognized as they possess 11-segmented antennae or clavate, elytra, and tricostate. They are commonly large in size growing to around (25-35mm) and can be black mixed with red or orange in colour (Anderson 1985). The Silphidae family can be separated into two subfamilies, the Silphinae and the Nicrophorinae. The major difference between the two subfamilies is that Silphinae lay their eggs in the soil around the carcass whereas Nicrophorinae bury the small carcass before laying their eggs (Majka, 2011).

Staphylinidae, also known as rove beetles, hunt for small organisms while others feed on leaves, fungi, and flowering. Some of the organisms that they prey on include mites, nematodes, and mosquito larvae (Howard Frank, J 1999). Rove beetles are a very diverse family that are able to survive in many different microhabitats such as humus, litter, scat, nests, deadwood, and fungi (Thayer 2016, Irmler et al. 2018). Species composition has been observed to change depending on biome type and to a lesser extent local areas. Staphylinidae are sensitive to fire as they can completely change the composition to various stages of the succession cycle caused by the unevenness of the burned area. Harvesting, on the other hand, does not eliminate the beetle communities but rather alters the habitat resulting in a unique community consisting of beetles from multiple successional stages as it retains the old-growth forest beetles and allows for earlier succession species to move in (Pohl et al., 2008).

The diversity and richness of ground beetles were negatively related to soil conductivity and positively influenced by the amount of N in the soil. The dominant tree species had an indirect influence on the beetle composition and diversity by changing the soil properties by factors such as leaf litter (Vician et al., 2018). Decomposing coarse woody debris in classes 3-4 significantly increased soil carbon (+85%) and nitrogen (+49%) pools. Coarse woody debris had little to no effect on the amount of P, K, Ca, and Mg found in the soils (Wiebe et al., 2014). Beetle composition has been determined to vary under different vegetation types, most notably stands with high and low shrub cover. Higher diversity at the macrohabitat scale is important for beetle conservation. However, species composition seems to be correlated with microhabitat elements such as shrub cover and shrub species (Barton et al., 2009).

The composition of beetles and abundance have shown clear differences between old and young poplar stands. The increased amount of biomass in the older stand increased the amount of beetle habitat. The number of species caught was greater in the young poplar stand however the old poplar stand caught more individuals (Riley 2011). Different aged forest stands support different beetle communities, for example the herb stage stands would support herb specialist beetles. The type of plant communities was associated with unique beetle communities. Over 17 years the beetle communities in regrowth stands exhibited a high degree of change that was paralleled by the transformation of the stand as it matured (Heyborne et al., 2003).

METHODS

STUDY AREA

The Lakehead University Jack Haggerty Forest (Figure 1) is situated in the district of Thunder Bay 36km northwest of the city of Thunder Bay which is part of the Boreal Forest region of Canada (Rowe 1972). In 1940 the forest was first used by industry for logging for jack pine but since the horse logging didn't expose mineral soil the composition changed to more broadleaf species. In 1953 the ownership of the land was transferred from the Department of Lands and Forests to the Department of Education which would eventually become a part of Lakehead University. The forest is 1039 hectares in total and is divided into 17 blocks as it was built for a multitude of research purposes. The tree species that can be found in the LUJHF are balsam poplar (*Populus balsamifera* Linnaeus.), trembling aspen (*Populus tremuloides* Michx.), balsam fir (*Abies balsamea* (L.) Mill.), eastern white cedar (*Thuja occidentalis Linnaeus.*), tamarack (*Larix laricina* (Du Roi) K. Koch), black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), red maple (*Acer Rubrum* L.), jack pine (*Pinus banksiana* Lamb.), and black ash (*Fraxinus nigra* Marsh.). The forest stands that were observed in this thesis were black spruce, red pine, and popular dominated (Anderson 2006).

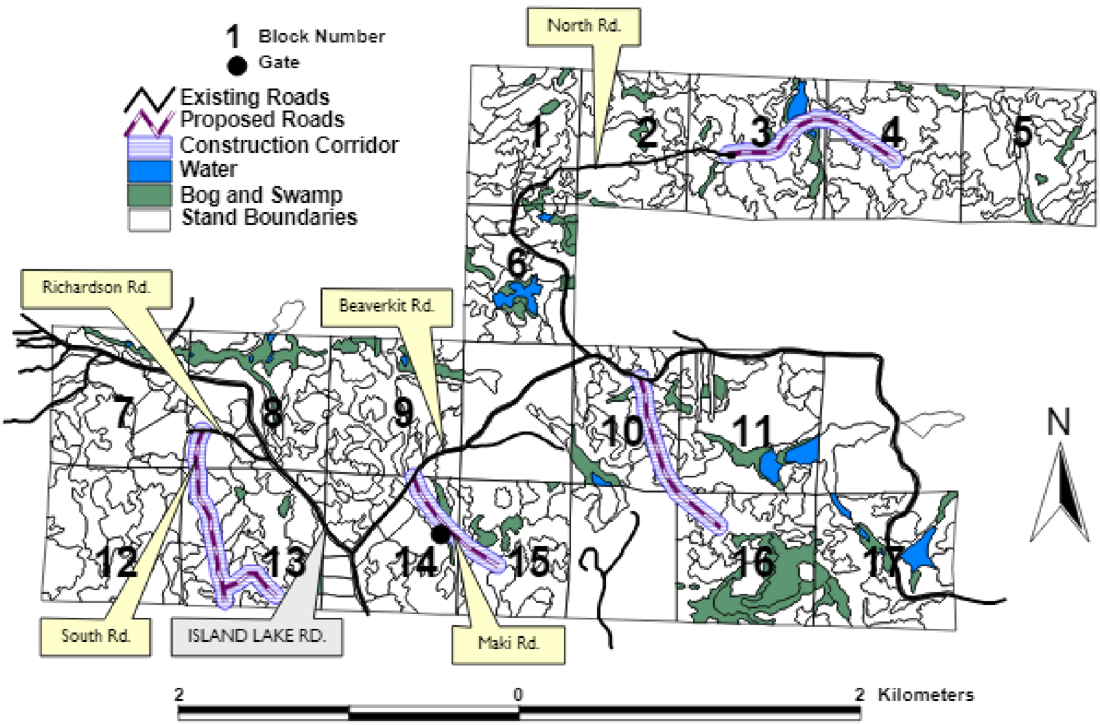

Figure 1. Map of Jack Haggerty Forest as seen from the Jack Haggerty Forest Management Plan 2006.

DATA COLLECTION

Pitfall traps were used to collect ground-dwelling beetles in four different stand types, i.e., ~45 years old trembling aspen (Pop45), ~60 years old red pine (Pr60), ~45 years old black spruce (Sb45), and >100 years old black spruce (Sb100) stands. Pitfall traps were double 16 oz deli containers made from plastic with a diameter of 11.7cm (Figure 2). Each cup was filled with propylene glycol that kills the beetles and preserves their bodies. On the top of each cup is a 15cm x 15cm plastic cover that stops rain and fallen leaves from accumulating in the cup. A total of three pitfall traps were set in each stand type in 2022 for 43 days, and a total of four pitfall traps were set in each stand in 2023 for 13 days. Once collected the beetles were taken back to the lab and were identified with help from Dr. Lee and the use of voucher specimens provided by the Lakehead University Forest Entomology Lab.

Figure 2. Pitfall Trap used to collect beetles in the various stand types (Credit: Seung-Il Lee).

STATISTICAL ANALYSIS

The number of beetles at the end of each trial was counted and sorted into species and sorted by location of capture using a pivot table in Microsoft Excel. The data was then imported to RStudio (Posit team, 2023), and analyzed using generalized linear models (GLM) to determine the significant differences in both beetle catches and species richness between stand types. The data was also run through RStudio to examine species composition using the nonmetric multidimensional scaling (NMS). NMS is an analytical tool used to visualize differences and similarities of community structures because it transforms the data into a lower dimensional space without changing the pairwise dimensional space between the objects being examined (Kruskal, 1964). In this case, NMS allowed us to compare similarities and differences between the beetle species composition in each stand type on each year individually and both years combined. The model was also run under a stress test to validate the results of the NMS model. The stress value is recommended to be less than 20% to reliably interpret NMS results. To fix the model for this experiment the data was square rooted once and removed the data from Sb100 as it did not have enough species and individuals sampled causing errors.

RESULTS

GENERAL RESULTS

The Species composition was only significantly different between Sb45 2022, and all the other stand types expect itself in 2023. The abundance was significant between multiple stand types but not between years. Species richness among different stand types was also seen to be significant but once again was not significant between years.

SPECIES COMPOSITION

Species composition considers relative numbers of each species collected from each stand type. From the pivot tables created in Excel, nonmetric multidimensional scaling graphs were created for years combined (Figure 3) and years separated (Figure 4). Nonmetric multidimensional scaling is used for comparing the relationships between nonmetric dissimilarity data. Figure 3 showed us that there are no differences in species composition between any of the stand types. Figure 4 depicted that all stand types for both years separated were similar except for Sb45 2022 that was different from all the other stands except for the same stand in stand in 2023.

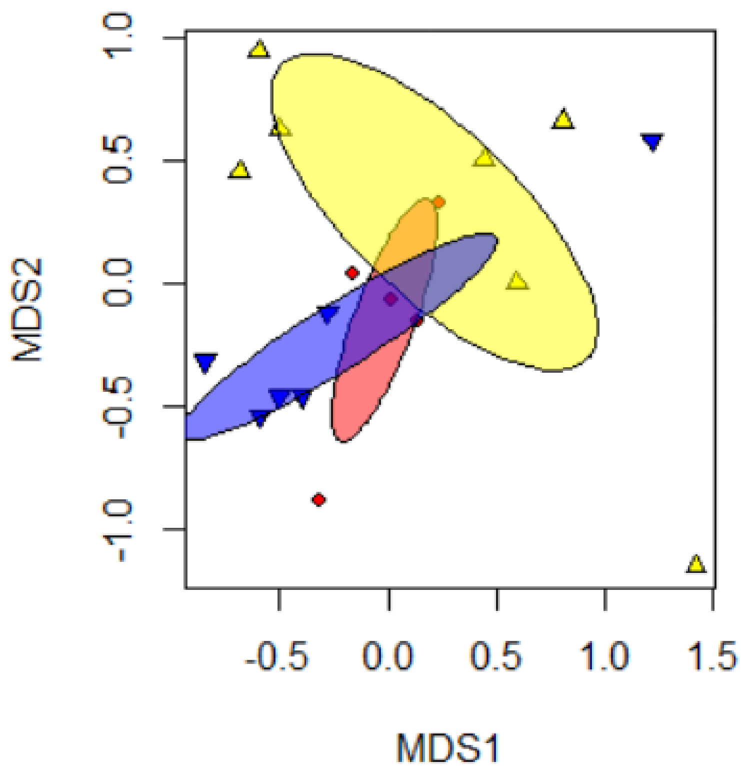

Figure 3. Similarities of species caught between Pr60 (yellow), Pop45 (red), and Sb45 (blue) with both years combined.

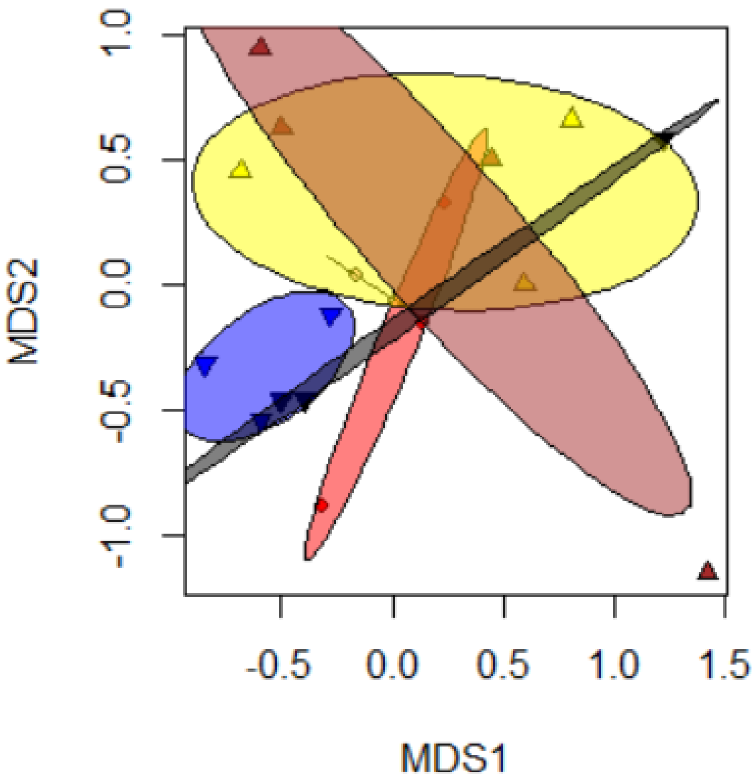

Figure 4. Similarities in beetle species found between 2022Pr60 (yellow), 2023Pr60 (dark red), 2022Pop45 (small dark line), 2023Pop45 (light red), 2022Sb45 (blue), 2023Sb45 (black) with both years separate.

ABUNDANCE

Since the number of traps trapping and days differed between years, the catch data had to be standardized calculate the abundances. The calculated abundance helps us to get a better understanding of how many total individuals are in a given stand on average. Table 1. is a calculation from r studio that shows stand types as being significant (p = 0.0001336) in the number of beetle catches and year to be significant (p = 0.0683602).

Table 1. The calculation of significance between the standardized catches per site and year

```
Model:
StandardizedCatch^(1/4) ~ fStand + fYear
       Df Deviance    AIC scaled dev.
<none>      4.4512 11.017
fStand  3   5.8090 25.518      20.501
fYear   1   4.6474 12.339       3.322
        Pr(>Chi)
<none>
fStand 0.0001336 ***
fYear  0.0683602 .
```

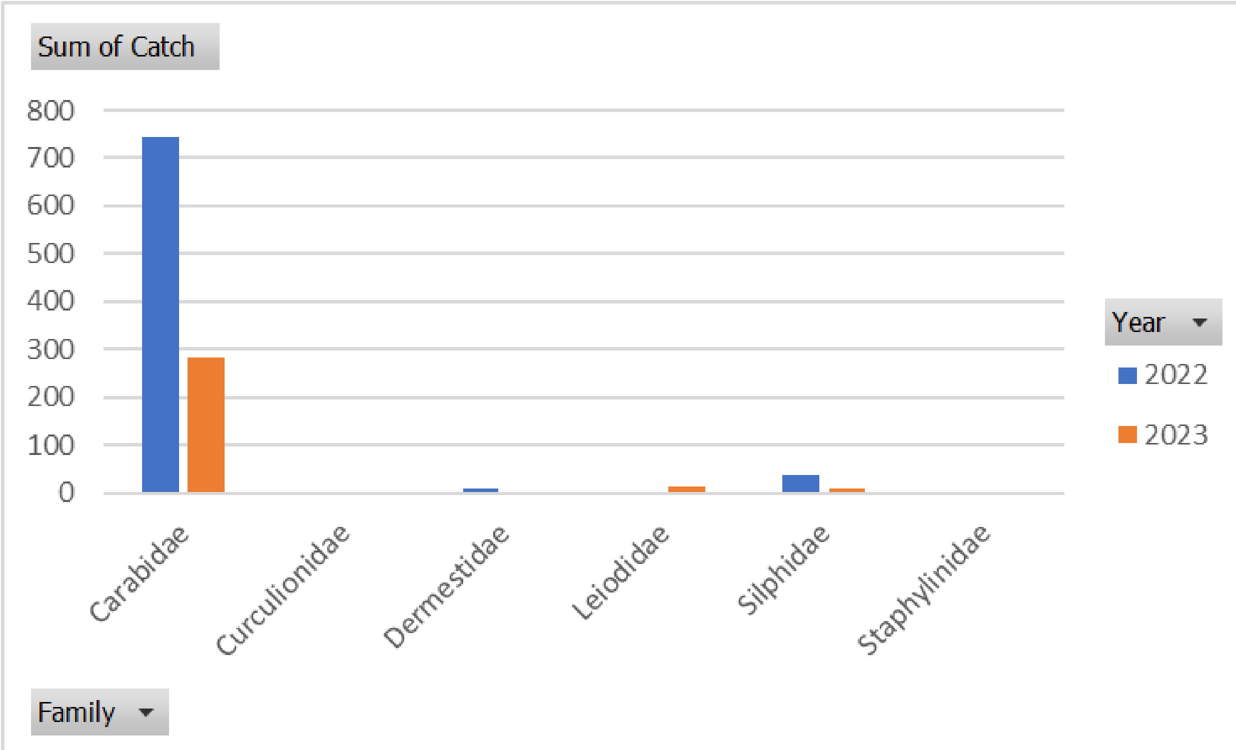

Figure 5. Number of catches in relation to families captured for each year.

Figure 5 showed that for both years Carabidae was by far the most caught family being several hundred more than the other family's catches for both years.

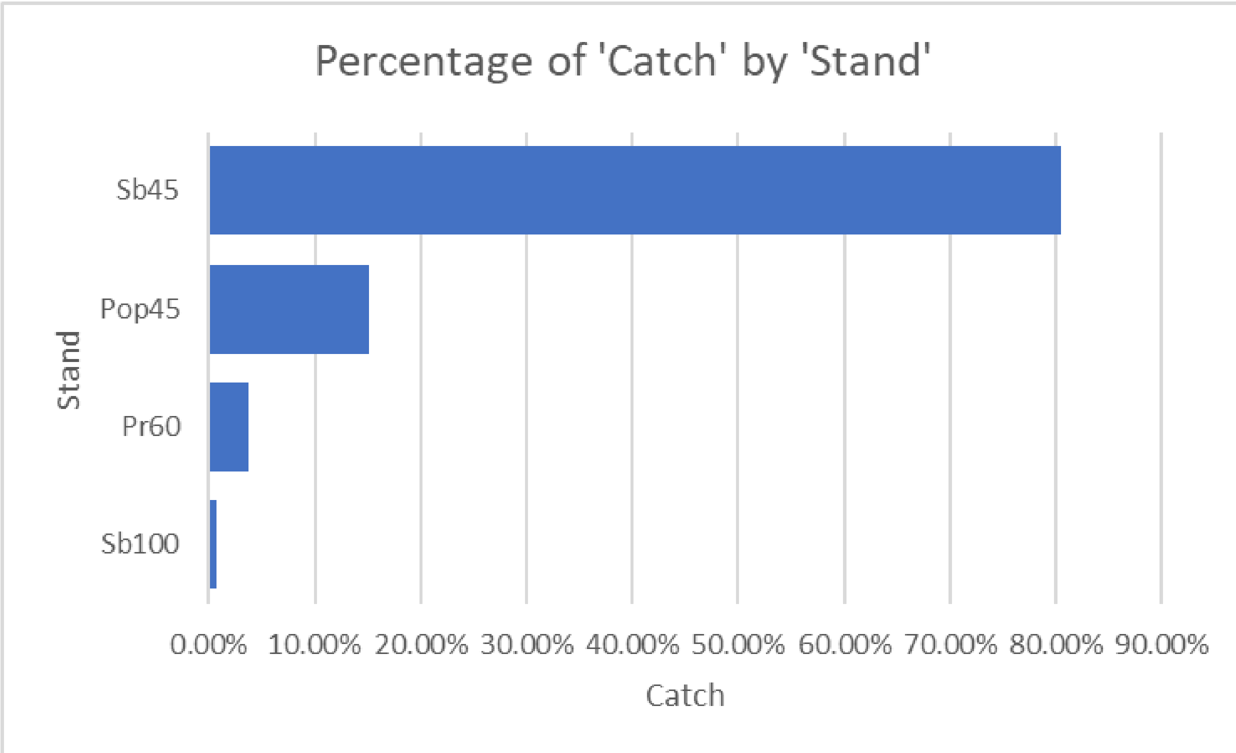

Figure 6. Percentage of total amount of beetles captured by each stand type. Abbreviations: Sb45 (~45 years old black spruce), Pop45 (~45 year old balsam poplar), Pr60 (~60 years old red pine), Sb100 (~100 years old black spruce).

Figure 6 showed that the majority of catches (over 80%) happened in Sb45, with the second most catches occurring in Pop45 (about 15%), followed by Pr60 (under 5%), and finally Sb100 (around 1%).

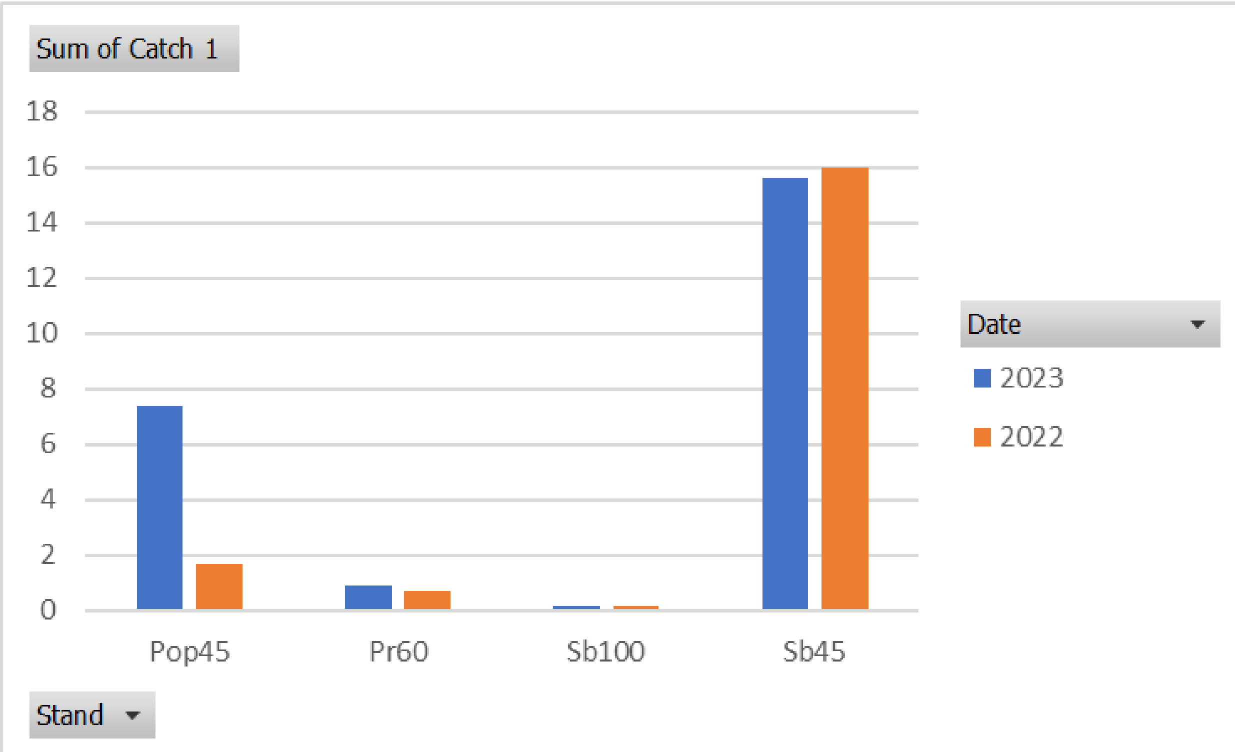

Figure 7. Standardized amount of beetle catches for each stand per day with a comparison for each year. Abbreviations: Sb45 (~45 years old black spruce), Pop45 (~45 year old balsam poplar), Pr60 (~60 years old red pine), Sb100 (~100 years old black spruce).

From Figure 7 Sb45 had the most amount of standardized catches during both years, Pop45 was second for most catches however out of all the stands it experienced the largest variation between both years, followed by Pr60 and finishing with Sb100 with little difference in standardized catches between both years.

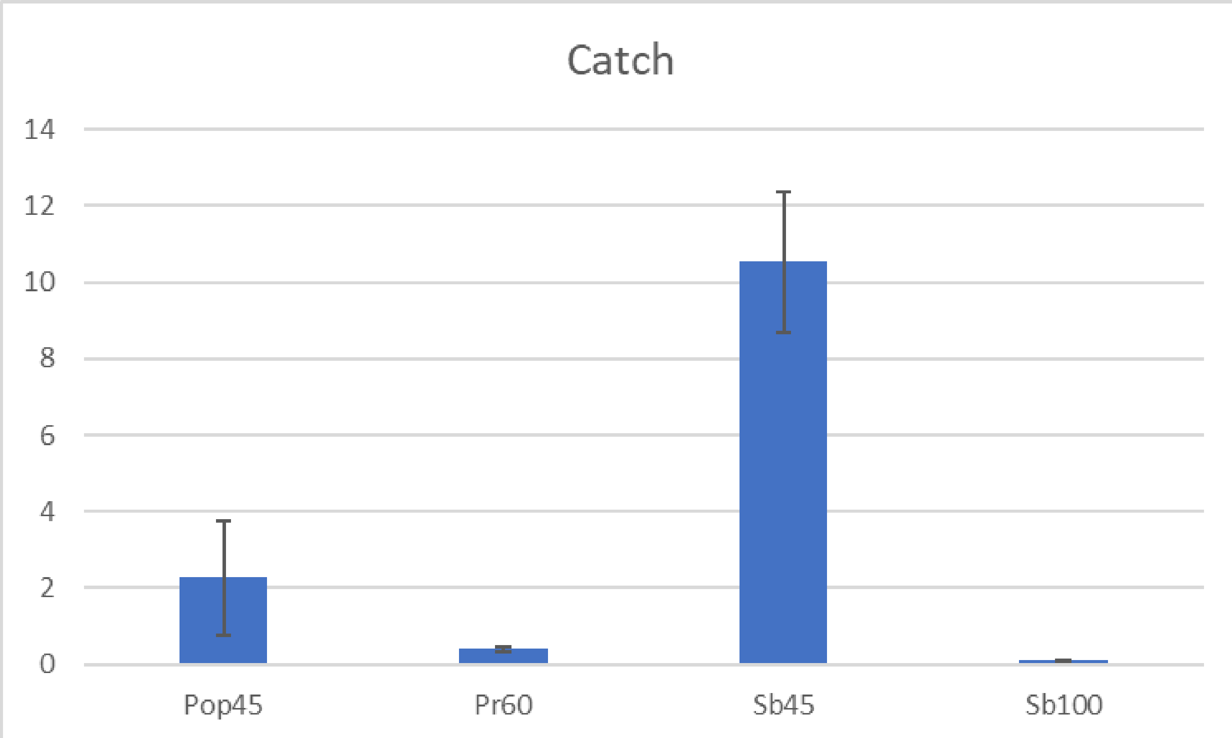

Figure 8. Standardized amount of beetle catches for each stand with standard error bars. Abbreviations: Sb45 (~45 years old black spruce), Pop45 (~45 year old balsam poplar), Pr60 (~60 years old red pine), Sb100 (~100 years old black spruce).

Table 2. Multiple comparisons of the standardized catches between different stand types.

```
Linear Hypotheses:
                   Estimate Std. Error
Pr60 - Pop45 == 0  -0.19414    0.07608
Sb100 - Pop45 == 0 -0.21134    0.12501
Sb45 - Pop45 == 0   0.11809    0.07188
Sb100 - Pr60 == 0  -0.01720    0.12501
Sb45 - Pr60 == 0    0.31224    0.07188
Sb45 - Sb100 == 0   0.32943    0.12250
                   z value Pr(>|z|)
Pr60 - Pop45 == 0   -2.552   0.0491 *
Sb100 - Pop45 == 0  -1.691   0.3172
Sb45 - Pop45 == 0    1.643   0.3430
Sb100 - Pr60 == 0   -0.138   0.9990
Sb45 - Pr60 == 0     4.344   <0.001 ***
Sb45 - Sb100 == 0    2.689   0.0338 *
```

The standardized beetle catches for both years combined (Figure 8) determined that Sb45 had the most amount of standardized catches with the other stand types have much less in the order of Pop45, then Pr60 and lastly Sb100 with the least amount of standardized catches. As seen in Table 2, it was determined that standardized catches in Pr60 were significantly lower than those in Pop45 ($p = 0.0491$), and Sb45 ($p < 0.001$). Standardized catches in Sb45 were significantly higher than those in Sb100 ($p = 0.0338$).

SPECIES RICHNESS

Species richness is the number of species found in a given area. Based on the initial model, there was no interaction of species richness between stand types and years (Table 3). Calculations shown in Table 4 showed that species richness was not significantly different between years ($p = 0.118329$) but was significantly different among stand types ($p = 0.001565$). Sb100 and Pop45, Sb100 and Pr60, and finally Sb100 and Sb45 were found to be significantly different (Table 5). The species richness between stands can be observed in Figure 9 as well as standard error bars where it is clear that the species richness is much lower in Sb100 compared to all the other stands.

Table 3. The significance of Stand types and Year on species richness.

```
Model:
Richness^(1/2) ~ Year * Stand
           Df Deviance    AIC scaled dev. Pr(>Chi)
<none>          2.6531 33.896
Year:Stand  3   2.7325 28.545     0.64913   0.8851
```

Table 4. The significance of Stand types and Year separately on species richness.

```
Model:
Richness^(1/2) ~ Year + fStand
       Df Deviance    AIC scaled dev.
<none>      2.7325 28.545
Year    1   3.0529 28.985      2.4393
fStand  3   5.4820 37.863     15.3173
       Pr(>Chi)
<none>
Year   0.118329
fStand 0.001565 **
```

Table 5. Multiple comparisons of species richness among different stand types.

```
Fit: glm(formula = Richness^(1/2) ~ Year + fStand, family = "gaussian",
    data = `speciesrichness.(1)`)

Linear Hypotheses:
                    Estimate Std. Error z value Pr(>|z|)
Pr60 - Pop45 == 0   -0.26833    0.23481  -1.143   0.6618
Sb100 - Pop45 == 0  -0.93367    0.26950  -3.464   0.0028 **
Sb45 - Pop45 == 0    0.05809    0.24338   0.239   0.9952
Sb100 - Pr60 == 0   -0.66534    0.25159  -2.645   0.0405 *
Sb45 - Pr60 == 0     0.32642    0.22339   1.461   0.4598
Sb45 - Sb100 == 0    0.99176    0.25879   3.832   <0.001 ***
```

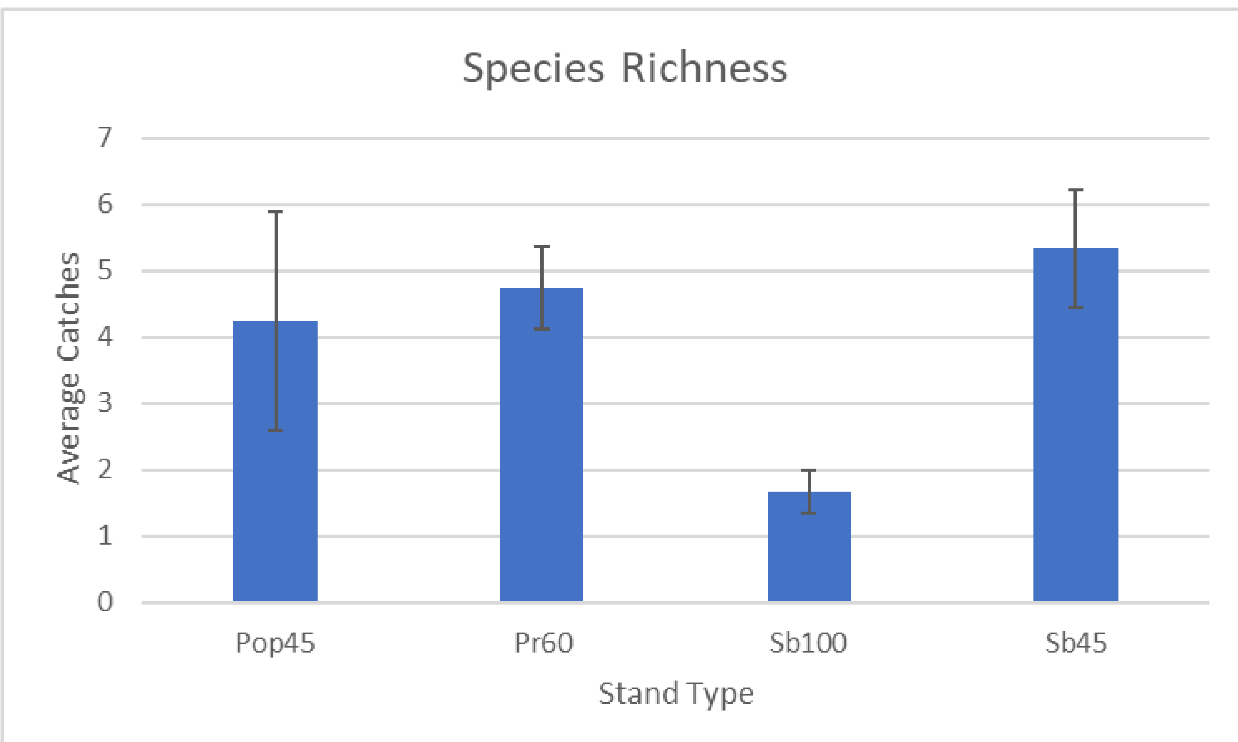

Figure 9. Species richness between stand types with standard error bars.

DISCUSSION

During the data analysis, the significance between the two years was also analyzed for any significant differences between species composition, abundance, and species richness with no significant differences found between any of them (Figure 3, Table 1, Table 3, and Table 4). The non-significant results between years could be caused by a lack of data as the life history of beetles allows them to change their population numbers drastically within only a few generations. This is because ground-dwelling beetle adults can live for multiple years as breeding adults, and some can breed multiple broods in a single year (Loreau 1985). Beetle populations like a lot of insects, can change or even reach outbreak levels depending on certain variables such as resource availability and abundance such as an increase in food and favorable habitat (Parks Canada Agency 2022). With only two years of data collection, the conditions may not have changed enough to cause the population to change and even if there was some sort of change the observed population may not have changed due to lag time (Gohli 2024).

The reasons the species composition between the stands were very similar (Figure 3 and Figure 4) can be caused due to the fact that the Jack Haggerty Forest is not extremely large, nor does it possess any geological features that would block the access of one stand type from the others (Anderson 2006). It seems that beetle species composition shows a strong correlation with plants' functional traits (Pakeman &

Stockan 2014). However even if the beetles did not use a certain stand type as habitat, the relatively close proximity to other stand types allows the relatively undesirable habitat to be used to travel between the stands in search of more suitable stand types (California Department of Fish and Wildlife 2023) explaining why the composition remained so similar between stand types. Another potential reason why the species composition remained similar between stand types is because almost all the species caught were part of the family Carabidae, Silphidae, or Staphylinidae all have the similar food sources (live or dead organisms) meaning the likelihood of them seeking the same habitat types would be high. A similar study also found that Carabidae species composition was not significantly different between deciduous stands and mixed wood forests but found that spruce stands did contain fewer species and individuals (Pearce 2003).

Species abundance between stands was significant between Pr60 and Pop45, Sb45 and Pr60, and finally between Sb45 and Sb100 (table 2) with the most abundant catches in Sb45 followed by Pop45, then Pr60, and ending with Sb100 (Figure 8). The species abundances may have been lower in the older conifer stands (Pr60 and Sb100) because of the effects that the overstory has on the soil. The soils under coniferous species are more acidic and have more aluminum than the soils found under the broadleaf species influencing the species composition of the understory species with the effects on the topsoil reaching 0-10 cm deep (Augusto, L. et al. 2003). Since ground beetles live in the understory, the vegetation is the dominant habitat. Understory vegetation from trembling aspen can survive in the black spruce stand however mosses and other ericaceous plants found under the black spruce stands were not able to survive under the trembling aspen as they slowly invaded by aspen understory species (Rodríguez-Rodríguez et al., 2023). The increased amount of understory vegetation biodiversity increases the amount of animal species found in the understory (Simonetti et al., 2013) meaning that increased understory vegetation creates not only a more suitable habitat for the ground-dwelling beetles but also provides more food for them since previously mentioned the families observed are almost exclusively predators with a few decomposers. It was interesting to see that the black spruce stand at 45 years old was significantly different from the black spruce stand at 100 years old. One possible explanation for this would be that older spruce stands have been observed to have more acidic soil limiting growth and what species are able to establish (Alriksson et al., 1995). One possible explanation for Sb45 holding just over 80% of the overall catches (Figure 6) is that the young spruce stand may have a lower amount of canopy cover, about 25%-50% than the broadleaf poplar stands, about 25%-90% (Janet 2014). The lower canopy cover would let more light into the understory increasing the species diversity of plants and animals soon after. This combined with the lower acidification may be why it hosts more beetles than any other stand by such a significant amount.

The species richness among the stand types was significant between the black spruce stand at 100 years old with every other stand type (Table 5). The old black spruce stand had a significantly lower species richness compared to the others (Figure 9). At about 100 years old it is most likely in the climax phase of succession where the canopy has a dominant species and other species or juveniles of the dominant species fill the gaps where possible, for example after a tree is blown over (Petrokas 2020). Once black spruce reaches the climax phase the species richness may decrease as the vegetation transitions from a diverse mix of herbaceous and shrub species to almost entirely sphagnum moss (Cavard 2011; Lecomte 2005). With the limited food selection, many prey species would be more inclined to spend more time in other stand types and as a result would cause the species richness of the ground beetles to dramatically decrease in the Sb100 stand.

As a side note, it is also important to acknowledge what could be done better in similar experiments and what could be added to gain a better understanding of the relationships between beetle assemblages, years, and stand types. Next time I would collect data across multiple summer months till the snow falls for ideally up to 10 years to allow the populations to respond to any time lags from any disturbances. To further our understanding on the relationships between beetles and stand types, I would recommend the collection of data on the understory vegetation for each stand and similar ground conditions that would influence the understory.

CONCLUSION

The results seen in beetle species composition, abundance, and species richness lead to the conclusion that beetles can be used as bioindicators for disturbances and overall biodiversity (Rainio 2003) and could be included in forest management plans to monitor the well-being and state of the forest. The differences seen between different stand types also solidify the idea that forests should be managed to promote multiple stands within the forest as having various stand types dominated by different tree types promotes biodiversity and resilience (Cacard 2011). Management should also attempt to keep stands at different ages/stages of succession even stands of the same species.

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APPENDIX

Table 6. Data collected from the field used to calculate all of the results of this thesis.

Year	Date	Days	Trap	Location	Site	Stand	Order	Family	Species	Catch	StandardizedCatch	Sorted by	Identified by
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Carabus nemoralis	3	0.069767442		
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Pterostichus coracinus	1	0.023255814		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Pterostichus melanarius	19	0.441860465		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Synuchus impunctatus	2	0.046511628		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Silphidae	Nicrophorus defodiens	7	0.162790698		
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop3	Pop45	Coleoptera	Carabidae	Pterostichus coracinus	5	0.11627907		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop3	Pop45	Coleoptera	Carabidae	Pterostichus melanarius	27	0.627906977		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop3	Pop45	Coleoptera	Carabidae	Carabus granulatus	1	0.023255814		
2022	20220720_0831	43	Pitfall	Jack Haggerty	Pop3	Pop45	Coleoptera	Silphidae	Nicrophorus defodiens	6	0.139534884		
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM1JH	Pr60	Coleoptera	Carabidae	Pterostichus melanarius	4	0.093023256		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM1JH	Pr60	Coleoptera	Carabidae	Synuchus impunctatus	5	0.11627907		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM1JH	Pr60	Coleoptera	Silphidae	Nicrophorus defodiens	4	0.093023256		
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM1JH	Pr60	Coleoptera	Staphylinidae	Philonthus cyanipennis	1	0.023255814		
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Carabidae	Carabus nemoralis	3	0.069767442		
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Silphidae	Nicrophorus defodiens	1	0.023255814		
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Carabidae	Pterostichus coracinus	2	0.046511628		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Carabidae	Pterostichus melanarius	4	0.093023256		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Staphylinidae	Quedius labradorensis	2	0.046511628		
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM3JH	Pr60	Coleoptera	Carabidae	Pterostichus coracinus	2	0.046511628		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM3JH	Pr60	Coleoptera	Carabidae	Pterostichus melanarius	1	0.023255814		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	PrM3JH	Pr60	Coleoptera	Staphylinidae	Ontholestes cingularis	1	0.023255814		
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbO1	Sb100	Coleoptera	Carabidae	Pterostichus coracinus	2	0.046511628		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbO3	Sb100	Coleoptera	Carabidae	Pterostichus coracinus	2	0.046511628		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbO3	Sb100	Coleoptera	Carabidae	Pterostichus melanarius	2	0.046511628		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM1	Sb45	Coleoptera	Carabidae	Pterostichus coracinus	16	0.372093023		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM1	Sb45	Coleoptera	Carabidae	Pterostichus melanarius	284	6.604651163		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM1	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	49	1.139534884		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM1	Sb45	Coleoptera	Silphidae	Nicrophorus defodiens	11	0.255813953		
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	3	0.069767442		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Pterostichus coracinus	3	0.069767442		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Pterostichus melanarius	49	1.139534884		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Silphidae	Nicrophorus defodiens	7	0.162790698		
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	8	0.186046512		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Carabus nemoralis	1	0.023255814		
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	4	0.093023256		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Pterostichus melanarius	224	5.209302326		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Pterostichus coracinus	18	0.418604651		AC
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Dermestidae	Dermestes lardarius	9	0.209302326		
2022	20220720_0831	43	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Silphidae	Nicrophorus defodiens	1	0.023255814		
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop1	Pop45	Coleoptera	Carabidae	Pterostichus melanarius	9	0.692307692	Kelly	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop1	Pop45	Coleoptera	Carabidae	Pterostichus coracinus	5	0.384615385	Kelly	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Pterostichus melanarius	28	2.153846154	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Pterostichus coracinus	5	0.384615385	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Carabus nemoralis	19	1.461538462	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Silphidae	Nicrophorus defodiens	1	0.076923077	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Synuchus impunctatus	6	0.461538462	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Carabidae	Sphaeroderus nitidicollis	1	0.076923077	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Staphylinidae	Tachinus sp.	2	0.153846154	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Leiodidae	Catops sp.	14	1.076923077	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop2	Pop45	Coleoptera	Staphylinidae	Acidota sp.	1	0.076923077	Eli	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop4	Pop45	Coleoptera	Carabidae	Pterostichus melanarius	4	0.307692308	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	Pop4	Pop45	Coleoptera	Carabidae	Pterostichus coracinus	1	0.076923077	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM1JH	Pr60	Coleoptera	Carabidae	Carabus nemoralis	1	0.076923077	Ruichen	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM1JH	Pr60	Coleoptera	Carabidae	Pterostichus pensylvanicus	1	0.076923077	Ruichen	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Carabidae	Pterostichus melanarius	1	0.076923077	Kelly	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM2JH	Pr60	Coleoptera	Carabidae	Pterostichus coracinus	1	0.076923077	Kelly	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM3JH	Pr60	Coleoptera	Carabidae	Pterostichus melanarius	3	0.230769231	Sam	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM3JH	Pr60	Coleoptera	Carabidae	Sphaeroderus nitidicollis	1	0.076923077	Sam	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM3JH	Pr60	Coleoptera	Carabidae	Synuchus impunctatus	1	0.076923077	Sam	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM4JH	Pr60	Coleoptera	Curculionidae	Curculionidae sp.2	1	0.076923077	Kelly	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM4JH	Pr60	Coleoptera	Carabidae	Pterostichus melanarius	1	0.076923077	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	PrM4JH	Pr60	Coleoptera	Carabidae	Synuchus impunctatus	1	0.076923077	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbO1	Sb100	Coleoptera	Carabidae	Synuchus impunctatus	1	0.076923077	Jessie	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbO2	Sb100	Coleoptera	Carabidae	Platynus decentis	1	0.076923077	Sam	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM1	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	3	0.230769231	Jessie	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM1	Sb45	Coleoptera	Carabidae	Pterostichus melanarius	61	4.692307692	Jessie	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Pterostichus melanarius	56	4.307692308	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Pterostichus coracinus	6	0.461538462	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	3	0.230769231	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Carabidae	Carabus nemoralis	1	0.076923077	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM2	Sb45	Coleoptera	Silphidae	Nicrophorus defodiens	4	0.307692308	Ratna	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Synuchus impunctatus	9	0.692307692	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Silphidae	Nicrophorus defodiens	6	0.461538462	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Carabus nemoralis	1	0.076923077	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Pterostichus adstrictus	1	0.076923077	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Pterostichus melanarius	51	3.923076923	Veronica	
2023	20230816_29	13	Pitfall	Jack Haggerty	SbM3	Sb45	Coleoptera	Carabidae	Pterostichus coracinus	1	0.076923077	Veronica	