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BIODIVERSITY OF GROUND BEETLES IN YOUNG AND OLD AGE POPLAR STANDS

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by

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A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry and environmental management.

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ABSTRACT

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Ground beetles (Coleoptera: Carabidae) are a useful bioindicator group in forests in almost every part of the world. This thesis studied the biodiversity of carabid beetles in old and young age trembling aspen (*Populus tremuloides*) stands to determine if there was a difference in species abundance and individual abundance. Six sites (three young age and three old age) in the Kenora/Rainy River district north of Nestor Falls, Ontario with a primarily poplar species composition were selected, and five pitfall traps were dug and placed in a seventy-five metre transect at each site. Samples were collected every two weeks from May 11th to August 17th, 2018 and identified to estimate species accumulation and individual abundance over a longer sampling period using EstimateS, a biodiversity estimation software. A difference in species accumulation and individual abundance over time was found between the two stand types. There was also a measured difference in the biodiversity of carabids between the two stand types. It was found that large scale disturbances such as forest harvesting had an effect on the species abundance of carabid beetles in young age poplar stands while the accumulation of biomass and familiar habitat found in old age poplar stands had an effect on the individual abundance of carabids. This data has not been documented in the mentioned district before and would provide information for future research or environment-based operations occurring in the area. This research can be used to map the distribution of carabid beetles in northwestern Ontario, specifically in the Kenora/Rainy River district.

Keywords: boreal forest, Coleoptera, Carabidae, Northwestern Ontario, trembling aspen (*Populus tremuloides*), biodiversity, abundance.

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INTRODUCTION

Northwestern Ontario is home to numerous species of insects, from forest tree defoliators to ground dwelling beetles that feed on insects and fungi. The focus of this thesis is on the latter group, referring specifically to the insect order Coleoptera, family Carabidae, also known as ground beetles. In general, these insects are viewed as being environmentally beneficial, feeding on multiple invertebrate pest insect species, as well as being predators of the seeds of some invasive weeds. On the other hand, they have been considered pests themselves at times by infesting buildings and consuming the seeds of valuable crops, such as corn (Hadley 2018). Their habitat is typically located within the top mineral soil and organic layers of forested areas, favouring areas underneath rocks, logs and other debris (Hadley 2018). They have been frequently observed in agricultural farm soils, such as orchards and other private gardens. The family Carabidae is used in North America and other regions of the world as an indicator species in most ecosystems, and they were used in this study due to their simple capture rate using pitfall traps (Boetzl et al. 2018). They are also sensitive to environmental conditions and have a generalist diet, meaning their distribution is not indicative of the distribution of their food.

Taxonomically, coleoptera are the most speciose order of insects on the planet, and their adult stage are characterized by the hardening of the forewings into elytra (Hadley 2018). In the family Carabidae, most individuals are distinguished by their diet, while others are separated morphologically. Subfamilies of the carabids are further divided into tribes, as Carl Lindroth proposed more than 50 years ago (Holliday et al. 2014). The key identifying features of all members of the family Carabidae are based primarily on segmentation of their characteristic 11 segmented filiform antennae as well as their tarsal formula, which are all segmented into groups of 5 from each set of legs (Figure 1) which arise from the thorax (Holliday et al. 2014). The elytra of the family Carabidae are the hardened forewings that display striations from the attachment of the thorax throughout the elytron (Figure 1). Furthermore, the flight wings (hindwings) of carabids are typically reduced, and most individuals are flightless, while some display polymorphism in wing length.

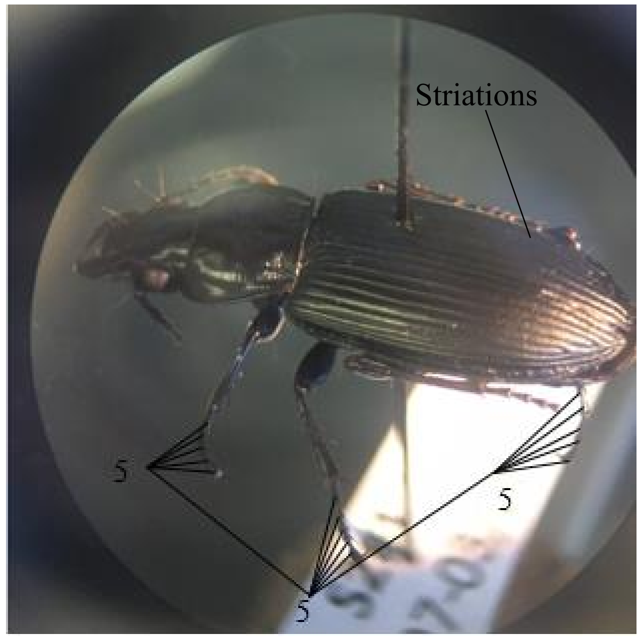

Figure 1. *Pterostichus melanarius* with tarsal formula (5-5-5) and elytra striations marked

The diet of ground beetles is mostly predaceous, feeding on ants, aphids, slugs, maggots, etc. (Hadley 2018). Some species focus on a particular food source, such as the caterpillar hunter (*Calosoma sycophanta*), while other species are generalist feeders (Riddick 2008). Some ground beetle species also exhibit phytophagous feeding tendencies, consuming seeds, shoots and pollen of plants rather than other insects.

The life cycle of ground beetles follows complete metamorphosis (egg to larva to pupa to adult), with females producing one generation of offspring annually (Holliday et al. 2014), which can consist of 30 to 600 eggs that hatch into larvae. Three larval instars are completed before pupating in the soil and finally emerging as adults shortly after. Overall, an entire life cycle can be completed within a single season, and adults can live from one to four years, and are the most active between April and October. The short life cycle of ground beetle species allows them to quickly accumulate large population numbers which lets them easily infest buildings and agricultural land (Thiele 1977), causing panic/alarm issues to humans when the beetles occur in large numbers inside buildings. While these insects do not pose a direct health threat to humans or damage property, they are a nuisance and some species will release repellent odorous secretions when disturbed, while other species can damage crop species, as mentioned above. However, carabids are widely considered to be valuable bioindicators of environmental quality and forest health.

After a disturbance in the boreal forests of Northwestern Ontario, one of the most frequently occurring successional species is trembling aspen (*Populus tremuloides* Michx). This deciduous canopy eventually leads to a thick accumulation of litter on the top layer of the forest soil, also keeping the pH of the soil less acidic than a needle covered soil layer in a coniferous forest. Furthermore, the high density of succeeding poplar stands provides a high amount of cover for understory vegetation species, as well as produce high amounts of litter from young stems (DeByle 1985). This thick litter layer, combined with high rates of decay leads to a high frequency of carabid beetles to their preferred food sources (seeds, shoots, prey insect species, etc.), along with abundant cover (fallen logs, rocks throughout the boreal shield, etc.) that provide diverse amounts and types of habitat for the ground beetles (Schier et al. 1985). In mature stands, poplar is a dieback species, giving way to more resilient and long-lived species such as cedar and white spruce (Lange et al. 2014). Those stands that don’t experience stand replacing disturbances will often deteriorate and their soil organic layer becomes thinner and more acidic. While a thinner soil layer may not provide better cover for ground beetles, the accumulated biomass of dying poplars, as well as the rocky terrain of the boreal shield can provide adequate habitat (Gustafson et al. 2003).

These clear differences in organic matter and associated cover found within stands of poplar that are young (i.e., early successional) and old (i.e., mature climax) leads to the question of whether or not there are similar differences that are traceable to the ground-dwelling insects that reside within these stands. These differences can be captured by the biodiversity measured for each stand with regards to abundance and number of species of carabids found. The use of carabid biodiversity is an important tool because it helps to illustrate the health of an ecosystem (Oehri et al. 2017). In the study described below, the biodiversity of the forest floor ecosystems in both old and young age poplar stands was evaluated by Carabid beetle species diversity and abundance of species. These measures of Carabid biodiversity in young and old age poplar stands were compared and measures from other Carabid biodiversity studies performed elsewhere in Canada and other places with similar environments were compared to attempt to explain the differences or similarities found in the collected data.

OBJECTIVE AND HYPOTHESIS

Thus, the main research question underpinning this study was: Does a difference in biodiversity occur among ground beetles inhabiting young and old poplar stands? This refers to the different amounts of/diversity of ground beetle species found among both trembling aspen stand types of two different age classes. This was, in part tested using a null hypothesis based on the individual abundance data between the two stand types, which states that there is no difference between the diversity and individual abundance of members of the family Carabidae between old age and young age *P. tremuloides* stands.

An attempt to answer this research question was initiated by conducting field studies along highway 71 in Northwestern Ontario, along a transect approximately 30 kms long, starting 90 kilometres south of Kenora, Ontario and ending about 2 kilometres north of Nestor Falls, Ontario. Using pitfall traps, as many carabid beetle specimens as possible were trapped within the summer carabid beetle activity period, beginning in May and ending in August 2018. These collected specimens were identified, and species accumulation curves were constructed and compared for each stand type, with each stand type represented by three replicate poplar stands that were classified as either young age (5-12 years) or old age (>75 years). A species accumulation curve for each stand type was constructed by the biodiversity estimation software program EstimateS. The results of this analysis will be used to infer the amount of species found in each stand type over a specified number of samples, and whether or not the carabid species found are similar in species composition and abundance across both stands.

LITERATURE REVIEW

This undergraduate thesis examines the biodiversity of ground beetles (Coleoptera: Carabidae) when sampled in two different age classes of trembling aspen forest stands. This thesis referred to the literature pertaining to the composition of the forest floors of these stands, the ecology and natural behaviour of the family Carabidae in general, and the measurements of biodiversity used to arrive at a conclusion.

The distribution of trembling aspen stands is described by Gustafson, Lietz and Wright in 2003, indicating the presence of these stands in the boreal forest region of Ontario, where the sampling for this thesis was conducted. The forest floors and their composition is further described in Schier, Shepperd, and Jones' management guidelines for trembling aspen (1985). These guidelines describe the understory vegetation found in most stands, which is used to validate the species found in the collection sites used for data collection in this thesis. In 1985, N. Debyle published an article describing the composition of forest floors in poplar stands in regard to biomass, litter layer size, and soil types, followed by Cryer and Murray (1992) who describe the soil types and areas that trembling aspen stands are typically found in. The study areas in this thesis report deal with these stands and how the amount of biomass varies between young and old age stands. This could have an effect on species biodiversity and richness of Carabid beetles, especially with the variation of ground types that occur in stands of the same age class. Three of the study areas used were sites that have recently undergone a stand replacing disturbance in the form of timber harvesting. The regenerative ability of trembling aspen following disturbances is described by Perala (1990) providing insight into the growth patterns of the young age stands and whether or not they can contribute viable habitat for Carabid beetles.

An article published by Allegro and Sciaky (2003) described the potential role of insects in the family Carabidae as bioindicators in poplar stands, meaning there is some validity to searching for Carabid beetles in forest stands dominated by trembling aspen. A study in Slovakia by Boetzl et al. (2018) was carried out analyzing the influence of canopy composition and soil properties on insects belonging to the family Carabidae. This study helps provide insight as to what sort of habitat(s) support the presence of carabid beetles, more specifically, the presence of carabids in poplar stands and the species that are present there. The accumulation of carabid species is observed in multiple environments in the prairie provinces across Canada, these environments being classified based on canopy closure (%), soil depth (cm) and exposure to sunlight (Holliday et al. 2014). The presence of these individuals in dry to fresh soil environments that possess high amounts of exposure to sunlight and moderately deep soils allows for comparison to the species found in the similarly composed young age aspen stands used for sampling. The first step to analyzing the presence of carabid beetles, however, is first identifying which species are present.

Identification of individuals that belong to the family Carabidae can be found in a contribution Holliday et al. (2014) Among identifying features are the antennae, tarsal segmentation and size relationships of the head, thorax and abdomen. These features are also described by Hadley (2018), aiding in the identifying features like striated elytra. The article also describes the division of the carabid species into tribes, based on Lindroth (1961-1969), one of the most informative identification guides in this study.

This guide helped identify the species collected from the pitfall traps and also describes their biology. The second guide used for the identification of carabid species was composed by Bousquet (2014), for the government of Canada, which describes the species found in each province. The guide for Ontario ground beetles was specifically used.

Biodiversity of the carabids is analyzed following the collection and identification of the individuals. The effects the forests they are found in have on these individuals is found in a Czech Republic study (Weger et al. 2013), which used carabids as an indicator species to record changes in biodiversity that came with changes to the overstory and biomass accumulation, similar to the accumulation found in old age stands used for collection. These differences in the forest stands (age, species composition, soil depth) were found to be drivers of change in biodiversity for carabids, highlighting differences in species abundance between stands of greater litter layer depth and understory vegetation composition, among other factors (Lange et al. 2014). With these differences in stand type, there is possibility for some added edge effects, particularly in young age stands. In Hungary and the Southwestern Ukraine, a study by Gabor et al. (2006) analyzed the effects of ground beetles in fragmented habitats and matrixes. This study introduced edge preferring species and analyzed the richness and biodiversity in forested areas. While this thesis' study area does not necessarily deal with fragmented habitats, the areas are altered and can possess edge preferring species, which may or may not have an effect on the species present. The ecology and behaviour of carabids is further described by Lovei and Sunderland (1996), including their feeding and habitat preferences. These habits indicate that the carabids are found in almost all regions of the

Earth, except deserts. Furthermore, the variance in their feeding strategies indicates some adaptability for species. These feeding strategies are also described in Fournier and Loreau (2002). Collection of carabid beetles is primarily done through pitfall trapping, a minimally invasive technique that has proven successful among ground dwelling organism collection, including ants and spiders.

The use of pitfall traps is described in Boetzl et. al. (2018), where their use and design was studied, and the use of ‘simple’ traps was deemed effective in accumulating amounts of individuals. Subsequently, the results can be analyzed thoroughly, capitalizing on the feeding habits of carabids, who typically prey on vegetation consuming insects or vegetative food sources themselves, in the form of seeds or young shoots of plants. Further information about the effects of pitfall trapping on invertebrates can be found in Sherley and Stringer (2016). This helps analyze the use of the trapping method in this report, as well as how this method affects the surrounding areas/habitats of the invertebrate family of interest. The use of pitfall traps was proven to gather effective individual accumulation data over an appropriate number of samples taken and the number of replications performed. This level of accumulation can be extrapolated and further estimated through sample and indices-based computing, done by biodiversity estimation software.

The statistics program used to calculate various aspects of the biodiversity of carabids, known as EstimateS, computes expected species accumulation and individual abundance accumulation over specified sample numbers and replications (Colwell et al. 1994, 2004, 2012). These species accumulations can be extrapolated into rarefaction curves that present the data visually. The data computed can be from both sample and individual based data and is computed using Colwell's own formulas of species and individual accumulation. The input files for computing the diversity statistics of EstimateS have specific formatting requirements that vary from sample-based indices and individual-based indices. The statistical outputs are then opened in Microsoft Excel and are used to create histograms and the rarefaction curves used to compare the differences in species accumulation between the two aspen stand types (old and young).

MATERIALS AND METHODS

METHODOLOGY

An attempt to answer this research question was initiated by conducting field studies along highway 71 in Northwestern Ontario, along a transect approximately 30 kms long, starting 90 kilometres south of Kenora, Ontario and ending about 2 kilometres north of Nestor Falls, Ontario. Further information and the maps of these locations are found in Appendix V. Using pitfall traps, as many carabid beetle specimens as possible were trapped within the summer carabid beetle activity period, beginning in May 2018 and ending in August 2018. These collected specimens were identified, and species accumulation curves were constructed and compared for each stand type, with each stand type represented by three replicate poplar stands that were classified as either young age (5-12 years) or old age (>75 years). A species accumulation curve for each stand type was constructed by the biodiversity estimation software program EstimateS. The results of this analysis will be used to infer the amount of species found in each stand type over a specified number of samples, and whether or not the carabid species found are similar in species composition and abundance across both stands.

LOCATIONS OF STUDY

This study was carried out at various locations along Highway 71 in Northwestern Ontario, specifically in areas between Sioux Narrows, ON and Nestor Falls, ON. Some sites were located down the Cameron Lake Road, located North of the township of Nestor Falls. Poplar stands were selected from the Whiskey Jack forest, managed primarily by the Kenora MNR district. Pitfall traps (described below) were placed along transects within the sample sites and transects were constructed in each of 6 different stands dominated by aspen that were divided into two different age classes (old age and young age), for a total of six transects. Old age poplar stands were classified as any stand with an overstory age of ≥ 70 years and an overstory *P. tremuloides* composition of more than 75% while young poplar stands were classified as any stand with an overstory age of 5-11 years and an overstory *P. tremuloides* composition of more than 75%. The locations of each pitfall trap were recorded in UTM coordinates. These coordinates can be found in Appendix V. Aerial surveys of stands were flown by the Kenora district OMNR in 2009 and interpreted in 2018, meaning age characteristics of each poplar stand are approximately 10 years younger than the current overstory age (OAGE) of the stands (sites with an OAGE = 60 have a current age of 70 years).

STUDY SITE CHARACTERISTICS

The areas sampled are boreal in overstory species composition, with some lowland sites showing high moisture content soils mixed with some silty clay and large particle-size soils in the upland sites. Coordinates of each site can be found in Appendix V. The samples of understory vegetation found in each site are found in Table 1. Mild variation in understory vegetation was found, as stands are mostly categorized into upland and lowland mixed hardwood sites with varying moisture contents, as identified by the Ontario land classification keys (Appendix VI). For the sake of simplicity, presence of grasses is characterized by the family Poaceae, rushes by the family Juncaceae and sedges by the family Cyperaceae.

Table 1. Understory vegetation species found in 6 study sites.

Site Number	Understory vegetation species
Site 1 (Young)	Poaceae, Juncaceae, Cyperaceae*, Acer spicatum*, *Rubus idaeus*, *Dalibarda repens*
Site 2 (Young)	Poaceae, Juncaceae, *Acer spicatum*, *Cornus stolonifera, Rubus idaeus*
Site 3 (Young)	Poaceae, Juncaceae, *Cornus stolonifera, Coptis trifolia, Fragaria vesca, Rosa acicularis, Rubus idaeus, Sphagnum spp.*
Site 4 (Old)	Juncaceae, *Acer spicatum, Asarum canadense, Lycopdium annotinum, L. dendroideum, Matteuccia struthiopteris, Prunus serotina, Rubus idaeus, Sphagnum spp.*
Site 5 (Old)	Juncaceae, *Rubus idaeus, Sphagnum spp.*
Site 6 (Old)	Juncaceae, *Asarum canadense*, *Lycopodium annotinum, L. dendroideum, Rubus idaeus, Sphagnum spp., Viola renifolia*

PITFALL TRAPS

Holes for pitfall traps were dug with a trowel to a depth of 14 cm, which was ~2 cm above the lip of the trap itself. Pitfall traps are also covered with a firm foam board that was suspended at each corner with 5 cm nails to reduce effects of rainfall (Figure 2). Locations of each pitfall trap were marked with wire flags, with site and pitfall trap number marked

Figure 2. Wire flag marking pitfall trap #1 at collection site 1.

(Figure 3). Traps were filled with approximately 50 ml of propylene glycol to trap and preserve specimens. Traps were replaced every 14 days with new cups and fresh propylene glycol added. Collected pitfall traps were stored in a cool, dry environment until they were ready to be sorted in a laboratory setting.

Figure 3. Pitfall trap with cover placed overtop from collection site 6, trap #1

SAMPLING DURATION AND DESIGN

The study was carried out between May 4th, 2018 (Allowing one week for stand recovery following the disturbance of placing the pitfall traps into the ground) and August 17th, 2018 where sampling was done at 14-day intervals, for a total of 7 sample dates. With 6 total poplar sites (3 young age and 3 old age), each with 5 pitfall traps, there were 30 samples collected per replication, giving 210 total samples collected.

SAMPLE HANDLING

Following sample collections in the field, samples were sorted and identified in a laboratory. Carabid specimens were transferred from original trap cups into smaller plastic containers containing 70% ethanol to preserve specimens (Figure 4). Specimens were pinned (Figure 5),

Figure 4. Collected and sorted samples placed in ethanol cups to preserve structures for identification.

then identified to confirm membership in the family Carabidae, then keyed out further to associated subfamilies, tribes, genera and eventually species, and placed in display boxes (Appendix II). Specimens were also labeled with collection sites and dates.

Figure 5. Individual member of family Carabidae mounted with insect pin on a pinning block.

STATISTICAL ANALYSES

In order to analyze the collection data and draw conclusions about the biodiversity of the two poplar stand types, a biodiversity estimation program known as EstimateS was used (Colwell 2013). This program estimates the biodiversity of a group of organisms at a location by the accumulation of numbers of species and individuals over a specified number of samples over time, and a rarefaction curve is generated and graphed showing the accumulated number of species. The program also estimates the number of individuals that would be accumulated between the two sites over a specified amount of time. Finally, the program also performs a variety of statistics such as species diversity accumulations that includes upper and lower 95% confidence intervals and standard deviation of the amount of individuals, both collected and estimated. Biodiversity of the two stand types is also represented by beta-diversity, an index that is used to show the level of similarity or dissimilarity between two communities based on species occurrence and the number of species each community has in common.

In order to test the null hypothesis that there is no difference in carabid beetle abundances between young age and old age poplar sites, a paired, two-tailed t-test was run on the raw collection data from each stand type. The original count data was $\log_{10}$

transformed in order to minimize variances and detect differences between the two datasets. Differences were considered statistically significant at the $p = 0.025$ level of probability. This test was done to compare the results of carabid collection in one stand type (old age poplar) versus the collection of carabids in another stand type (young age poplar).

RESULTS

Following the 7 sampling periods of all 6 poplar sites, the 210 pitfall traps yielded 77 productive samples (i.e. containing carabid beetles) with 219 carabid beetles collected in total (Appendix I). The distribution of the carabid individuals was skewed with the old age and young age poplar stands accounting for 64.84% and 35.16% of the total number of individuals, respectively. The combined number of carabid individuals that were collected from each site group of 5 pitfall traps, by each collection period is displayed in stacked bar charts to show the distribution of trapped carabid individuals from each collection site. The numbers are shown in Figures 6 and 7, below.

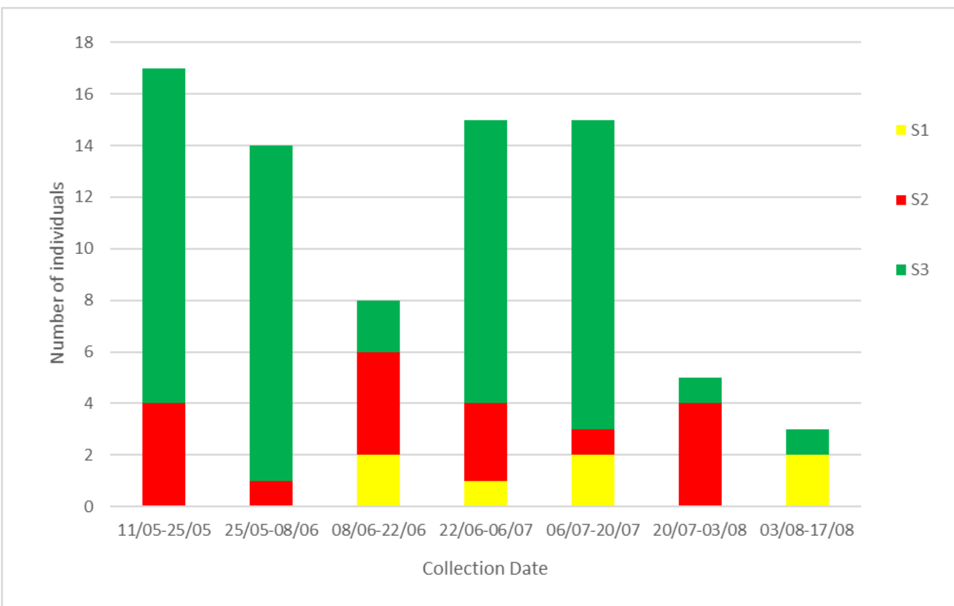

Figure 6. Stacked bar chart showing individual abundance by collection site in young age *P. tremuloides* stands.

Figure 6 shows that the distribution of carabid beetles in young age poplar stands was dominated by site 3, while site 1 did not record any collections during the first two sampling dates. Figure 7 shows the distribution of carabid individuals collected from sites 4, 5 and 6 that were representative of the old age poplar stands. These old age poplar sites accounted for 142 carabid individuals out of the total 219 collected, indicating a higher relative carabid abundance in the old age stands. Following the collection of individuals that were identified as members of the family Carabidae, the individuals were then identified down to subfamily, tribe, genus, and species using the Ground Beetles of Canada guide (Goulet and Bousquet 2014). There were 13 different carabid species identified, 11 of which were found in the young age stands and 9 found in the old age stands. The amounts of each species collected can be found in Table 2, below. Two histograms showing pooled trap collection data by collection date can be found in Appendix I

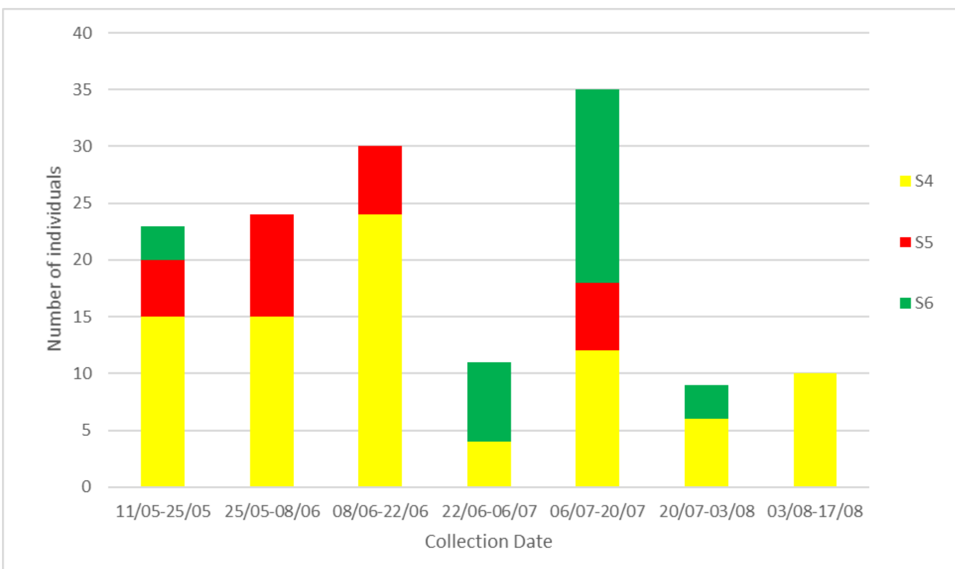

Figure 7. Stacked bar chart showing individual abundance by collection site in old age *P. tremuloides* stands.

Table 2. Amounts of individuals collected from each identified species

Identification	Total # of Individuals	# of Individuals in Old age stands	# of Individuals in Young age stands
Agonum cupripenne	1	0	1
Agonum cupreum	1	0	1
Chlaenius emarginatus	1	0	1
Diplous rugicollis	78	52	26
Lophoglossus scrutator	9	7	2
Loxandrus velocipes	5	5	0
Patrobus longiconris	15	14	1
Platynus decentis	32	21	11
Poecilus lucublandus	2	0	2
Pterostichus melanarius	41	26	15
Pterostichus permundus	2	1	1
Scaphinotus bilobus	3	3	0
Spaeroderus canadensis	29	15	14
Total	219	144	75

Table 2 shows that *Agonum cupripenne* Say*, A. cupreum* Dejean*, Chlaenius emarginatus* Say, and *Poecilus lucublanus* Say, were unique to young age poplar stands while *Loxandrus velocipes* Casey, and *Scaphinotus bilobus* Say, were unique to old age poplar stands. Following the collection of all individuals, they were mounted and placed in insect collection boxes and sorted into groups based on appearance. Identification photos of the groups of the different carabid groups are found in Appendix II. Carabids from sites 1 and 2, as well as sites 5 and 6 were grouped together in the same collection due to low numbers of individuals. The compilation of each species by collection date can be found in Appendix III.

The biodiversity estimation software known as EstimateS10 (Colwell 2013) was used to create a species rarefaction curve by accumulation through a sample-based batch input, or multiple sets of replicating sample units, the input file of which can be found in Appendix IV. The software program EstimateSWin910 was used to replicate sampling up to 50 times to show total species accumulation between young and old age poplar stands to reach an asymptote of accumulation, indicating the expected number of species present at each site. The software also estimated individual abundance across both species over time for up to 200 samples to show potential total numbers between each stand type. The species accumulation and abundance accumulation graphs are found in figures 8 and 9 below. The biodiversity statistical calculations by EstimateS can be found in Appendix IV.

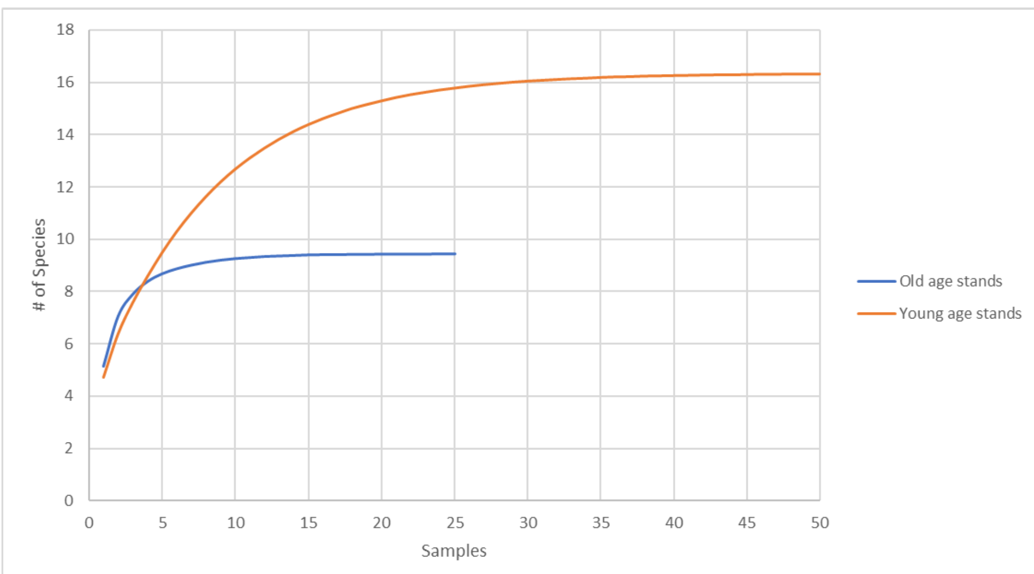

Figure 8. Smooth curve graph showing estimated species accumulation between old and young age *P. tremuloides* stands

Source: EstimateSWin910

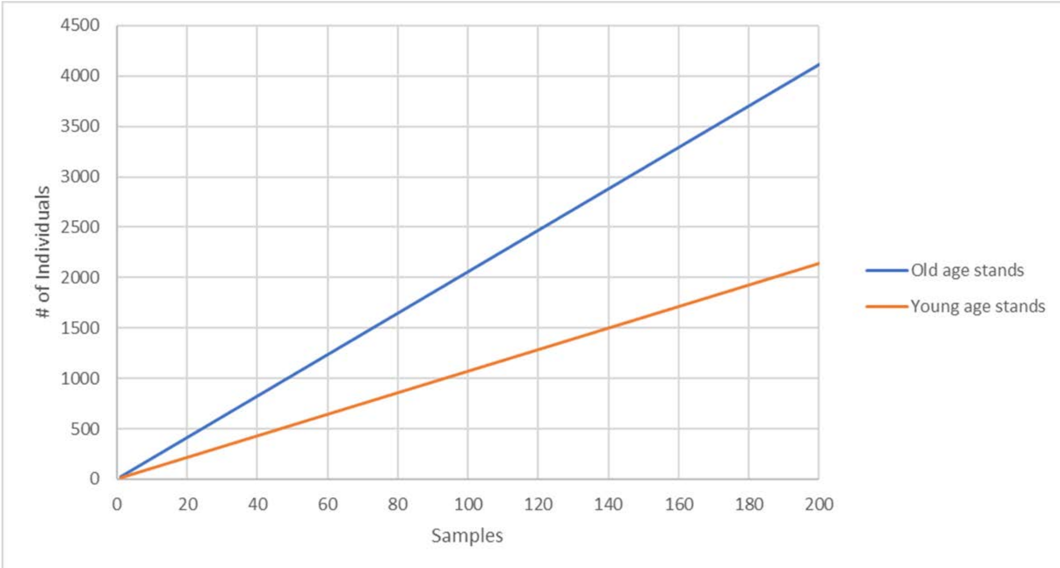

Figure 9. Smooth line graph showing estimated individual abundance accumulation over 200 samples between old and young age *P. tremuloides* stands.

Source: EstimateSWin910

Figure 8 shows that young age poplar stands would be expected to accumulate more species over time to a maximum of around 16 by the end of 50 samples, while old age poplar stands would be expected to accumulate ~9 species over the time of 25 samples, where an asymptote is reached. Figure 9 shows that old age poplar stands are expected to accumulate more individual carabid beetles over time, potentially amassing over 4000 beetles by the end of 200 samples, while young age poplar stands would be expected to have just over 2000 beetles collected after 200 samples.

The null hypothesis was that there is no significant difference in abundance of carabid beetles between young and old age *P. tremuloides* stands ($n_1 = n_2$). To test this H_o, a two-tailed t-test was run at an α-value of 0.025 in order to test the difference in both directions ($n_1 \neq n_2$) between the two stand types. The data used for the t-test, the pooled number of individuals present at each collection date for the two stand types

(Appendix I), was transformed using a $\log_{10}$ formula to reduce the amount of variance in the initial dataset (Table 3).

Table 3. Log_{10} transformed carabid abundance data between young and old age *P. tremuloides* stands

Date	Young age stands individuals present	Old age stands individuals present
11/05-25/05	1.1761	1.3802
25/05-08/06	1.1461	1.3617
08/06-22/06	0.9542	1.5051
22/06-06/07	1.1461	1.0792
06/07-20/07	1.1461	1.5315
20/07-03/08	0.7782	0.9542
03/08-17/08	0.4771	1.0000

The results of the t-test are shown in table 4 and indicate a rejection of the null hypothesis using a two-tailed t-test. This rejection indicates there is a significant difference in carabid abundance between the two stand types in this study, with collection sites in old age poplar stands having significantly more carabid abundance than collection sites in young age poplar stands.

Table 4. Results of paired two sample T-test of means at α-level 0.025.

Stats	Young age poplar stands	Old age poplar stands
Mean	0.9749	1.2589
Variance	0.0692	0.0587
Observations	7	7
Pearson Correlation	0.63163	
Hypothesized Mean Difference	0	
df	6	
t Stat	-3.45101	
P(T<=t) one-tail	0.00681	
t Critical one-tail	2.44691	
P(T<=t) two-tail	0.01362	
t Critical two-tail	2.96869	

The beta-diversity of the collected individuals was calculated using the formulas below (Tuomisto and Ruokolainen 2008) where β equals the biodiversity index, S1 equals the total number of species in old age stand types and S2 equals the total number of species in young age stand types. The variable c equals the number of species found in common between both communities and B is the biodiversity value before index calculation. This calculation yielded a biodiversity index of 0.6, represented on normalized scale of 0-1. This value indicates some dissimilarity in the diversity of young age and old age poplar stands when the two populations are being compared.

$$B = (S1 - c) + (S2 - c)$$

$$\beta = (c \times 2) \div (S1 + S2)$$

DISCUSSION

The presence of carabid beetles in both young and old age poplar stands was well documented by the use of pitfall traps, indicating there is suitability in the habitat to ground beetles that is found after many years of accumulation in an old growth stand, or after a recent stand replacing disturbance resulting in a young stand. To compare the biodiversity of the two stand types, the species accumulation curves created in Figure 8 can be interpreted to show that, over time, the young age poplar stands will have a higher number of total carabid species. Conversely, the estimations of individual abundance, performed by the EstimateS program (Colwell 2013), indicate a higher accumulation of individuals for old age stands (Figure 9) that increases exponentially over time. The biodiversity between the stand types resulted in an index value of 0.6 between the stands. Simply explained, the young age stands had 11 species of carabids present, while the old age stands had 9, for 13 total species, 7 of which were found across both stands. With a value above 0.5 on a normalized scale (0-1), there is an indication of dissimilarity between the two environments sampled.

To further indicate the differences between the two stand types, statistical analysis of the individual abundance of all collection sites was performed using a two-tailed t-test (Table 7). The results of the test rejected the null hypothesis, which stated there was no significant difference in individual abundance of carabids between young and old age *P. tremuloides* stands. Besides the differences in communities indicated by the beta diversity calculations, there are observed differences in the collection of individuals between each pitfall trap at each stand type. Based on Figure 6, site 3 was the most productive site, accounting for 68.8% of all individuals collected in the young age stands sampled. However, site 1 was absent from the collection process for the first two periods due to human interference with the pitfall traps, leading to only 7 individuals collected.

In the old age stands, collection site 4 contributed the most to the overall abundance of the three sites, accounting for 86 individuals (60.5% of total abundance). Based on the composition of the forest floors in the old age stands (soil depth, litter layer composition, old age debris) there are more instances of potential habitat for carabids in general. The presence of rock material, decaying woody debris, and accumulated leaves and needles all account for the presence of more individuals in old age stands than in the young age stands (Weger et al. 2013). The amount of individuals found in site 5 was among the least of the old age stands, which could be attributed to the slightly higher moisture regime of the soil in that site compared to the other two. The presence of ground level, vascular vegetation in old age stands (Table 1) provide food for vegetative feeders of the family Carabidae as well as opportunity for predatory species to feed on vegetative feeding species from other species (Vician et al. 2018). Another notable feature of the abundance of individuals is the seasonality, as Figures 6 and 7 illustrate a more abundant presence of carabids from late June to the end of July for both stand types. This is partially due to the increased temperatures during the hottest time of the year (Holliday et al. 2014), along with the bloom of perennial vegetation on the forest floor which attracts more vegetation feeding species.

In the young age stands, the disturbances that created the areas themselves were caused by timber harvesting, thereby creating fragmentation in the surrounding areas. Along Cameron Lake Road, there are numerous instances of such disturbance, as multiple stands were harvested and, therefore, more fragments created in forested areas along the entire road between lakes in the area. These fragments of habitat have been observed to be attractive for some carabid species, due to the suddenly altered conditions near original habitat areas of carabids (Niemela 2001). Fragmented habitats have been studied for carabid assemblages and areas of continuous habitat have yielded the fewest number of species compared to small (<0.5 ha) and large (9-21 ha) fragments (Niemela 2001).

Presence of species found in young age stands like *Patrobus longicornus, Agonum cupreum* and *Agonum cupripenne, Pterostichus melanarius* and *P. permundus,* and *Poecilus lucublandus* can be explained by the suitability of open areas with dry to fresh soils according to Holliday et al. (2014) and their report on the distribution of carabids across the prairie provinces. The dry to fresh, coarse soils were utilized by the above-mentioned species as well, and one parameter used was shade and crown closure. The low percentages of crown closure and the amount of ground level vegetation provided easier access to vertical dispersing species and are a readily available food source for colonisers of the newly formed habitats (Holliday et al. 2014). The presence of individuals in these young stands of recent disturbance can be explained by the large amounts of coarse woody debris often left behind after harvesting operations (Lange et al. 2014). These contributors to biomass accumulation provide larger amounts of habitat and feeding opportunities for multiple

Figure 10. Image of collection site #2 prior to pitfall trap placement.

species. Figure 10 illustrates this coarse woody debris and newly accumulating litter layer found in site 2, one of the young age stands used for sampling. The newly regenerating vascular vegetation on the forest floor is also a contributing factor, as new shoots and seeds are a preferred food source of some carabid species and also attract prey species for predatory carabid species (Lange et al. 2014).

Other studies have yielded similar results, as Cobb et al. (2007) noted, showing that carabid species richness increases over the short-term observation of forested areas that have undergone disturbances. The distribution of carabid species was also presented by Bousquet and Goulet (2014), which notes the presence of recorded individuals in most boreal environments. The species found in this study confirmed similar distributions as observed by Bousquet (2014), as the Northwestern boreal forest areas provide suitable soil depth and vegetation to support the presence of most identified carabid beetles.

As bioindicators, members of the family Carabidae are observed to help determine the magnitude of disturbances, and the species found in habitats following a large-scale disturbance can reflect their life strategy (Rainio and Niemela 2003). There is evidence that small bodied, generalist species with good dispersal abilities tend to increase in areas of higher disturbance, contributing to the greater number of species estimated for the young age stands. Furthermore, the number of larger bodied specialist species is known to decrease as disturbance increases, due to the poor dispersal ability of these specialists (Rainio and Niemela 2003). The disturbances of the young age stands could, in this case, be indicative of the presence of the species that were excluded from the old age stands. This also helps explain the higher abundance of individuals in the old age stands, who form aggregate communities in stands with high deciduous litter layers and large amounts of suitable habitat (Rainio and Niemela 2003).

This study was limited in its sample sizes and methods of biodiversity calculations. Using only 3 stands of each age class across a transect of roughly 40 kilometres in a boreal forest that spans more than 50 million hectares left much area unsampled and the potential to collect a larger dataset from which to extract more attractive data with less variance before transformation. Improvements to this study could be made via increased pitfall traps across more stands of similar composition and age types, assuming the researcher is looking to repeat the data collection using the same parameters. Another limitation was the sampling period used, as collections were only done during the summer months. The study could have been extended into the fall months in order to observe the potential for seasonal variance in both species collection and individual abundance. This extension would also naturally produce a much larger number of samples, which would make estimation of species accumulation more accurate, assuming the same number of runs would be used; a larger database to estimate from would lead to less “estimated” results in the short term.

This data could be used in future studies to further investigate the effects of harvest-based disturbances on the distribution of carabid species in the boreal forests of Canada. A benefit of this study was that it was the first of its kind to be done in the Kenora/Rainy River district border area. These findings could be used to add to a distribution map of carabid beetles of Northwestern Ontario and to help understand the concept of habitat loss affecting carabid species biodiversity. The idea that fragmentation leads to fewer numbers of large bodied specialist species could result in local extinctions of some species, as they are typically poor dispersers. Replication of this sampling in areas of recent disturbance will hopefully yield similar results, showing a difference in the biodiversity between two stand types that differ in age. An extension of this study could be modified to include different stand compositions as well as (or instead of) overstory age classes to observe the differences, if any, in biodiversity. Future studies could make more use of the ecosite classification system to observe whether or not there is a difference in biodiversity of stands that may have similar leading species composition or over story age, but different ground-level features.

CONCLUSION

This study on the biodiversity of ground beetles (Coleoptera: Carabidae) in old and young age poplar stands has yielded the conclusion that there is an expected difference in carabid species abundance and individual abundance at the stand level over time. The larger numbers of carabid species observed in young age poplar stands and the larger numbers of individuals in old age poplar stands is consistent with previous research and can help future studies and forest operations on the expected reactions that the environment will have following large scale disturbances. While this study only examines the biodiversity in areas that were disturbed by forest harvesting, there is uncertainty that these results can be replicated in areas that have been disturbed in other ways, such as via fire, flood, etc. at the stand level.

Considering the lack of current research in the Kenora/Rainy River district on carabid beetles, this study will prove beneficial to future operations and can help catalogue the distribution of species further north. The growing need for forest harvesting in the region and more remote locations can use information and research methods from this study to make informed decisions about forest operations by using the presence of carabid beetles as a bioindicator of forest health. The presence of certain species of carabid beetles can also be predicted to an extent, using the presence of the beetles in the study area in this study of Northwestern Ontario as a guide.

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APPENDICES

APPENDIX I

RAW COLLECTION DATA OF CARABIDAE INDIVIDUALS

Table 5. Raw collection data based on individuals for each pitfall trap at each collection date.

Site #	Collection dates						
	11/05-25/05	25/05-08/06	08/06-22/06	22/06-06/07	06/07-20/07	20/07-03/08	03/08-17/08
S1 #1	x	x	x	1	x	x	x
S1 #2	x	x	x	x	x	x	x
S1 #3	x	x	2	x	2	x	x
S1 #4	x	x	x	x	x	x	x
S1 #5	x	x	x	x	x	x	2
S2 #1	1	x	1	x	x	2	x
S2 #2	3	x	x	x	x	x	x
S2 #3	x	1	1	x	1	x	x
S2 #4	x	x	2	2	x	x	x
S2 #5	x	x	x	1	x	2	x
S3 #1	2	4	x	3	4	x	x
S3 #2	2	x	x	2	7	x	x
S3 #3	3	5	x	3	1	x	x
S3 #4	5	4	x	x	x	x	x
S3 #5	1	x	2	3	x	1	1
S4 #1	5	x	16	x	8	1	x
S4 #2	1	x	3	x	1	x	5
S4 #3	5	4	x	1	x	1	1
S4 #4	1	6	x	x	x	4	4
S4 #5	3	5	5	3	3	x	x
S5 #1	x	1	x	x	x	x	x
S5 #2	2	x	x	x	3	x	x
S5 #3	1	1	2	x	2	x	x
S5 #4	1	2	x	x	1	x	x
S5 #5	1	5	4	x	x	x	x
S6 #1	x	x	x	3	x	x	x
S6 #2	1	x	x	x	9	3	x
S6 #3	2	x	x	3	1	x	x
S6 #4	x	x	x	1	x	x	x
S6 #5	x	x	x	x	7	x	x

INDIVIDUAL ABUNDANCE BY COLLECTION DATE

Table 6. Pooled pitfall collection data for each collection date between old and young age stand types.

Date	Young age stands individuals present	Old age stands individuals present
11/05-25/05	15	24
25/05-08/06	14	23
08/06-22/06	9	32
22/06-06/07	14	12
06/07-20/07	14	34
20/07-03/08	6	9
03/08-17/08	3	10

POOLED COLLECTION DATA FOR TWO STAND TYPES BY COLLECTION DATE

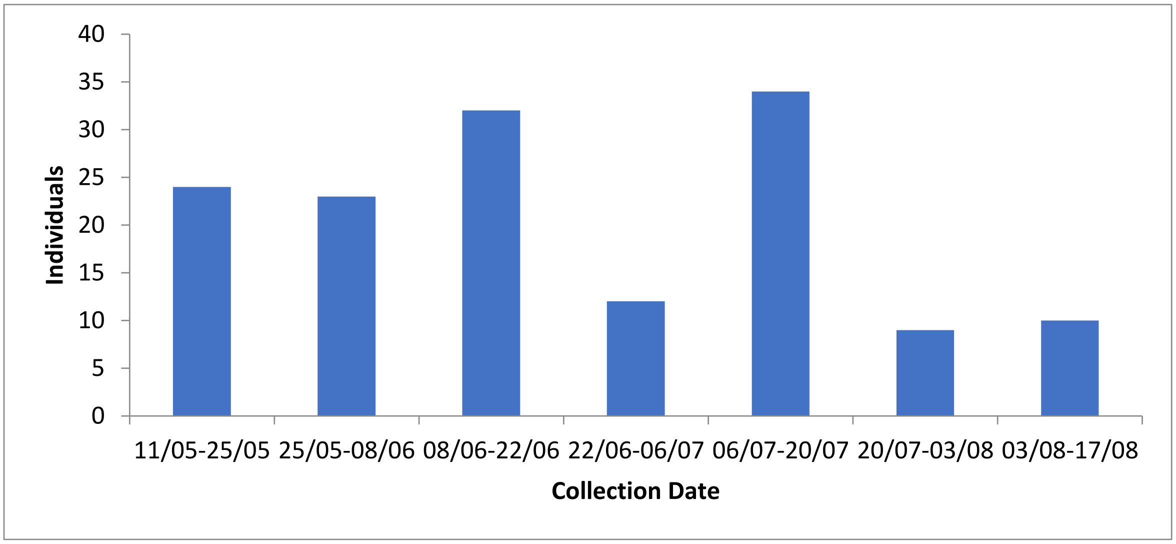

Figure 12. Histogram showing collection data of old age *P. tremuloides* stands by collection date

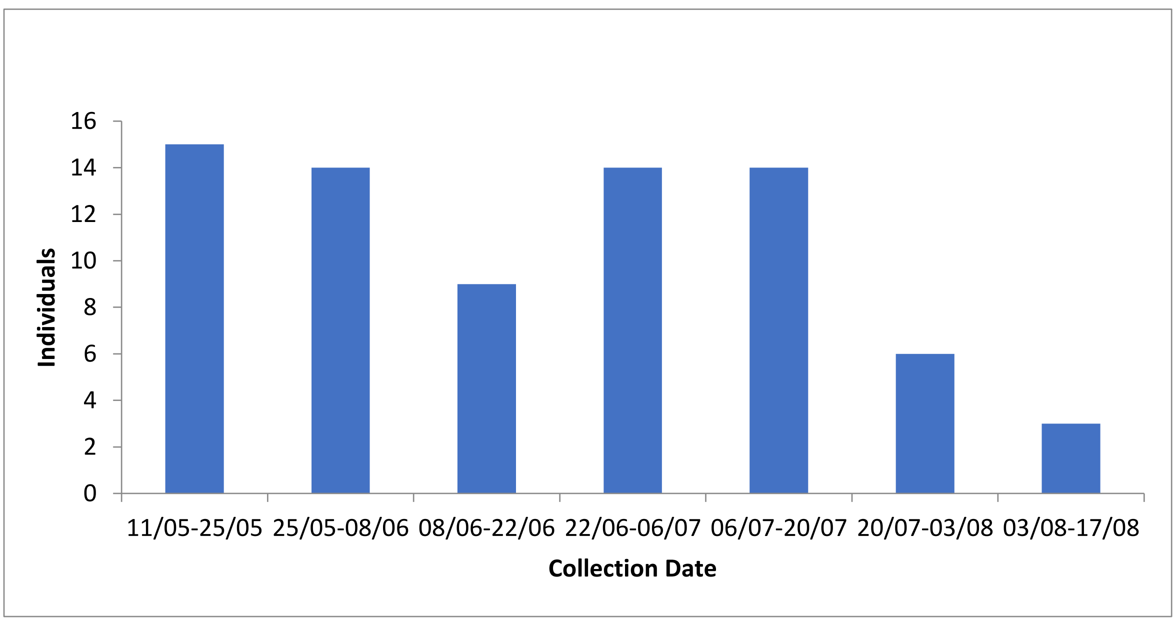

Figure 13. Histogram showing collection data of young age *P. tremuloides* stands by collection date.

APPENDIX II

MOUNTED CARABIDAE COLLECTIONS

Figure 14. Mounted collection of Carabidae members from sample sites 1 and 2

Figure 15. Mounted collection of Carabidae members from sample site 3

Figure 16. Mounted collection of Carabidae members from sample site 4

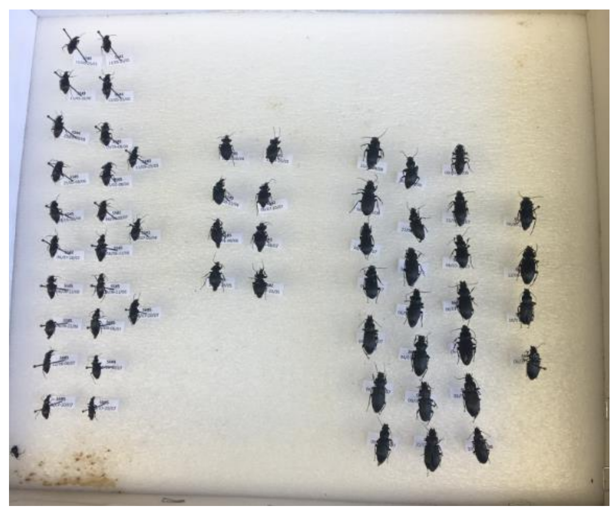

Figure 17. Mounted collection of Carabidae members from sample sites 5 and 6

MAGNIFIED INDIVIDUALS I

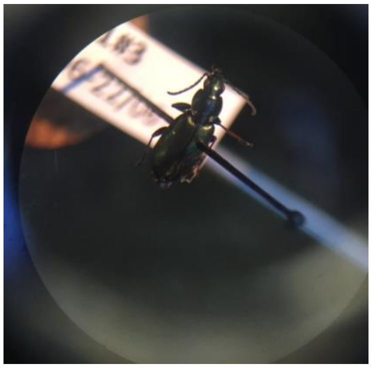

Figure 18. *Agonum cupreum*

Figure 19. *Agonum cupripenne*

Figure 20. *Chlaenius emarginatus*

Figure 21. *Diplous rugicollis*

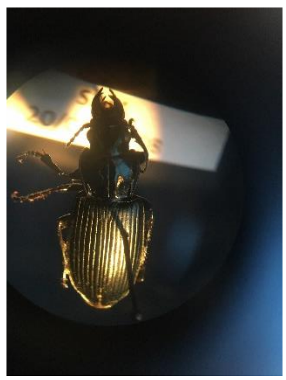

Figure 22. *Lophoglossus scrutator*

Figure 23. *Loxandrus velocipes*

Figure 24. *Patrobus longicornus*

Figure 25. *Platynus decentis*

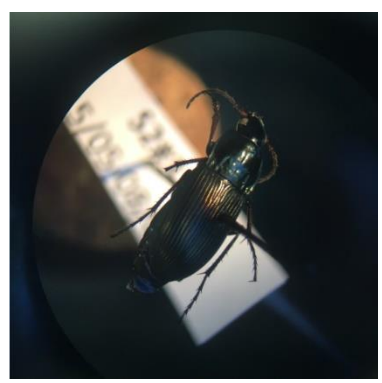

Figure 26. *Poecilus lucublandus*

Figure 27. *Pterostichus permundus*

Figure 28. *Spaeroderus canadensis*

Figure 29. *Scaphinotus bilobus*

Figure 30. All collected species, from left to right descending from the top: *Agonum cupreum, Agonum cupripenne, Patrobus longiconris, Poecilus lucublandus, Pterostichus melanarius, Scaphinotus bilobus, Spaeroderus canadensis, Chlaenius emarginatus, Pterostichus permundus, Lophoglossus scrutator, Diplous rugicollis, Loxandrus velocipes, Platynus decentis.*

APPENDIX III

SPECIES COLLECTION NUMBERS BY COLLECTION DATE FOR OLD AGE STANDS

Table 7. Raw collection data for species identified by collection date in old age *P. tremuloides* stands.

Identification	Collection Dates						
	11/05-25/05	25/05-08/06	08/06-22/06	22/06-06/07	06/07-20/07	20/07-03/08	03/08-17/08
Diplous rugicollis	12	11	21	3	4	1	0
Lophoglossus scrutator	0	0	0	1	4	1	1
Loxandrus velocipes	0	0	4	0	1	0	0
Patrobus longiconris	0	1	0	0	9	4	0
Platynus decentis	8	1	3	1	3	0	5
Pterostichus melanarius	0	4	1	5	11	2	3
Pterostichus permundus	0	0	0	0	0	0	1
Scaphinotus bilobus	0	0	0	1	1	1	0
Spaeroderus canadensis	4	6	3	1	1	0	0
Total individuals	24	23	32	12	34	9	10

SPECIES COLLECTION NUMBERS BY COLLECTION DATE FOR YOUNG AGE STANDS

Table 8. Raw collection data for species identified by collection date in young age *P. tremuloides* stands.

Identification	Collection Dates						
	11/05-25/05	25/05-08/06	08/06-22/06	22/06-06/07	06/07-20/07	20/07-03/08	03/08-17/08
Agonum cupripenne	0	0	1	0	0	0	0
Agonum cupreum	0	0	1	0	0	0	0
Chlaenius emarginatus	0	0	1	0	0	0	0
Diplous rugicollis	9	5	2	4	4	1	1
Lophoglossus scrutator	0	0	0	0	1	1	0
Patrobus longiconris	0	0	0	1	0	0	0
Platynus decentis	2	2	0	3	3	0	1
Poecilus lucublandus	1	1	0	0	0	0	0
Pterostichus melanarius	1	5	0	2	5	2	0
Pterostichus permundus	0	0	1	0	0	0	0
Spaeroderus canadensis	2	1	3	4	1	2	1
Total individuals	15	14	9	14	14	6	3

APPENDIX IV

INPUT FILE FOR COMPUTING ESTIMATESWIN910 BIODIVERSITY STATISTICS

MultipleDataset	2	Carabid Biodiversity					
Old age poplar	*SampleSet*	1	1	1			
9	7						
Identification	11/05-25/05	25/05-08/06	08/06-22/06	22/06-06/07	06/07-20/07	20/07-03/08	03/08-17/08
Diplous rugicollis	12	11	21	3	4	1	0
Lophoglossus scrutator	0	0	0	1	4	1	1
Loxandrus velocipes	0	0	4	0	1	0	0
Patrobus longiconris	0	1	0	0	9	4	0
Platynus decentis	8	1	3	1	3	0	5
Pterostichus melanarius	0	4	1	5	11	2	3
Pterostichus permundus	0	0	0	0	0	0	1
Scaphinotus bilobus	0	0	0	1	1	1	0
Spaeroderus canadensis	4	6	3	1	1	0	0
Young age poplar	*SampleSet*	1	1	1			
11	7						
	11/05-25/05	25/05-08/06	08/06-22/06	22/06-06/07	06/07-20/07	20/07-03/08	03/08-17/08
Agonum cupripenne	0	0	1	0	0	0	0
Agonum cupreum	0	0	1	0	0	0	0
Chlaenius emarginatus	0	0	1	0	0	0	0
Diplous rugicollis	9	5	2	4	4	1	1
Lophoglossus scrutator	0	0	0	0	1	1	0
Patrobus longiconris	0	0	0	1	0	0	0

Figure 31. Input file data for estimation of biodiversity statistic by estimateSWin910.

Figure 31. (Continued)

Platynus decentis	2	2	0	3	3	0	1
Poecilus lucublandus	1	1	0	0	0	0	0
Pterostichus melanarius	1	5	0	2	5	2	0
Pterostichus permundus	0	0	1	0	0	0	0
Spaeroderus canadensis	2	1	3	4	1	2	1

OUTPUT STATISTICS FROM ESTIMATESWIN910

Table 9. Statistical output from EstimateS for old age *P. tremuloides* stands

Samples	Individuals (computed)	S(est)	S(est) 95% CI Lower	S(est) 95% CI Upper	S(est) SD
1	20.57	5.14	3.5	6.79	0.84
2	41.14	7.05	5.35	8.75	0.87
3	61.71	7.89	6.35	9.42	0.78
4	82.29	8.37	6.96	9.78	0.72
5	102.86	8.67	7.35	9.98	0.67
6	123.43	8.86	7.6	10.12	0.64
7	144	9	7.75	10.25	0.64
8	164.57	9.11	7.81	10.4	0.66
9	185.14	9.19	7.81	10.56	0.7
10	205.71	9.25	7.78	10.72	0.75
11	226.29	9.29	7.71	10.87	0.81
12	246.86	9.33	7.65	11.01	0.86
13	267.43	9.35	7.58	11.13	0.9
14	288	9.37	7.52	11.23	0.95
15	308.57	9.39	7.46	11.31	0.98
16	329.14	9.4	7.41	11.38	1.01
17	349.71	9.4	7.37	11.44	1.04
18	370.29	9.41	7.34	11.48	1.06
19	390.86	9.41	7.31	11.52	1.07
20	411.43	9.42	7.29	11.55	1.09
21	432	9.42	7.27	11.57	1.1
22	452.57	9.42	7.25	11.59	1.11
23	473.14	9.42	7.24	11.61	1.11
24	493.71	9.43	7.23	11.62	1.12
25	514.29	9.43	7.22	11.63	1.12
26	534.86	9.43	7.22	11.64	1.13
27	555.43	9.43	7.21	11.64	1.13
28	576	9.43	7.21	11.65	1.13
29	596.57	9.43	7.21	11.65	1.13
30	617.14	9.43	7.2	11.65	1.13
31	637.71	9.43	7.2	11.65	1.14
32	658.29	9.43	7.2	11.66	1.14
33	678.86	9.43	7.2	11.66	1.14
34	699.43	9.43	7.2	11.66	1.14
35	720	9.43	7.2	11.66	1.14
36	740.57	9.43	7.2	11.66	1.14

Table 9. (Continued)

37	761.14	9.43	7.2	11.66	1.14
38	781.71	9.43	7.2	11.66	1.14
39	802.29	9.43	7.2	11.66	1.14
40	822.86	9.43	7.2	11.66	1.14
41	843.43	9.43	7.2	11.66	1.14
42	864	9.43	7.2	11.66	1.14
43	884.57	9.43	7.2	11.66	1.14
44	905.14	9.43	7.2	11.66	1.14
45	925.71	9.43	7.2	11.66	1.14
46	946.29	9.43	7.2	11.66	1.14
47	966.86	9.43	7.2	11.66	1.14
48	987.43	9.43	7.2	11.66	1.14
49	1008	9.43	7.2	11.66	1.14
50	1028.57	9.43	7.2	11.66	1.14
51	1049.14	9.43	7.2	11.66	1.14
52	1069.71	9.43	7.2	11.66	1.14
53	1090.29	9.43	7.2	11.66	1.14
54	1110.86	9.43	7.2	11.66	1.14
55	1131.43	9.43	7.2	11.66	1.14
56	1152	9.43	7.2	11.66	1.14
57	1172.57	9.43	7.2	11.66	1.14
58	1193.14	9.43	7.2	11.66	1.14
59	1213.71	9.43	7.2	11.66	1.14
60	1234.29	9.43	7.2	11.66	1.14
61	1254.86	9.43	7.2	11.66	1.14
62	1275.43	9.43	7.2	11.66	1.14
63	1296	9.43	7.2	11.66	1.14
64	1316.57	9.43	7.2	11.66	1.14
65	1337.14	9.43	7.2	11.66	1.14
66	1357.71	9.43	7.2	11.66	1.14
67	1378.29	9.43	7.2	11.66	1.14
68	1398.86	9.43	7.2	11.66	1.14
69	1419.43	9.43	7.2	11.66	1.14
70	1440	9.43	7.2	11.66	1.14
71	1460.57	9.43	7.2	11.66	1.14
72	1481.14	9.43	7.2	11.66	1.14
73	1501.71	9.43	7.2	11.66	1.14
74	1522.29	9.43	7.2	11.66	1.14
75	1542.86	9.43	7.2	11.66	1.14
76	1563.43	9.43	7.2	11.66	1.14
77	1584	9.43	7.2	11.66	1.14

Table 9. (Continued)

78	1604.57	9.43	7.2	11.66	1.14
79	1625.14	9.43	7.2	11.66	1.14
80	1645.71	9.43	7.2	11.66	1.14
81	1666.29	9.43	7.2	11.66	1.14
82	1686.86	9.43	7.2	11.66	1.14
83	1707.43	9.43	7.2	11.66	1.14
84	1728	9.43	7.2	11.66	1.14
85	1748.57	9.43	7.2	11.66	1.14
86	1769.14	9.43	7.2	11.66	1.14
87	1789.71	9.43	7.2	11.66	1.14
88	1810.29	9.43	7.2	11.66	1.14
89	1830.86	9.43	7.2	11.66	1.14
90	1851.43	9.43	7.2	11.66	1.14
91	1872	9.43	7.2	11.66	1.14
92	1892.57	9.43	7.2	11.66	1.14
93	1913.14	9.43	7.2	11.66	1.14
94	1933.71	9.43	7.2	11.66	1.14
95	1954.29	9.43	7.2	11.66	1.14
96	1974.86	9.43	7.2	11.66	1.14
97	1995.43	9.43	7.2	11.66	1.14
98	2016	9.43	7.2	11.66	1.14
99	2036.57	9.43	7.2	11.66	1.14
100	2057.14	9.43	7.2	11.66	1.14
101	2077.71	9.43	7.2	11.66	1.14
102	2098.29	9.43	7.2	11.66	1.14
103	2118.86	9.43	7.2	11.66	1.14
104	2139.43	9.43	7.2	11.66	1.14
105	2160	9.43	7.2	11.66	1.14
106	2180.57	9.43	7.2	11.66	1.14
107	2201.14	9.43	7.2	11.66	1.14
108	2221.71	9.43	7.2	11.66	1.14
109	2242.29	9.43	7.2	11.66	1.14
110	2262.86	9.43	7.2	11.66	1.14
111	2283.43	9.43	7.2	11.66	1.14
112	2304	9.43	7.2	11.66	1.14
113	2324.57	9.43	7.2	11.66	1.14
114	2345.14	9.43	7.2	11.66	1.14
115	2365.71	9.43	7.2	11.66	1.14
116	2386.29	9.43	7.2	11.66	1.14
117	2406.86	9.43	7.2	11.66	1.14
118	2427.43	9.43	7.2	11.66	1.14
119	2448	9.43	7.2	11.66	1.14

Table 9. (Continued)

120	2468.57	9.43	7.2	11.66	1.14
121	2489.14	9.43	7.2	11.66	1.14
122	2509.71	9.43	7.2	11.66	1.14
123	2530.29	9.43	7.2	11.66	1.14
124	2550.86	9.43	7.2	11.66	1.14
125	2571.43	9.43	7.2	11.66	1.14
126	2592	9.43	7.2	11.66	1.14
127	2612.57	9.43	7.2	11.66	1.14
128	2633.14	9.43	7.2	11.66	1.14
129	2653.71	9.43	7.2	11.66	1.14
130	2674.29	9.43	7.2	11.66	1.14
131	2694.86	9.43	7.2	11.66	1.14
132	2715.43	9.43	7.2	11.66	1.14
133	2736	9.43	7.2	11.66	1.14
134	2756.57	9.43	7.2	11.66	1.14
135	2777.14	9.43	7.2	11.66	1.14
136	2797.71	9.43	7.2	11.66	1.14
137	2818.29	9.43	7.2	11.66	1.14
138	2838.86	9.43	7.2	11.66	1.14
139	2859.43	9.43	7.2	11.66	1.14
140	2880	9.43	7.2	11.66	1.14
141	2900.57	9.43	7.2	11.66	1.14
142	2921.14	9.43	7.2	11.66	1.14
143	2941.71	9.43	7.2	11.66	1.14
144	2962.29	9.43	7.2	11.66	1.14
145	2982.86	9.43	7.2	11.66	1.14
146	3003.43	9.43	7.2	11.66	1.14
147	3024	9.43	7.2	11.66	1.14
148	3044.57	9.43	7.2	11.66	1.14
149	3065.14	9.43	7.2	11.66	1.14
150	3085.71	9.43	7.2	11.66	1.14
151	3106.29	9.43	7.2	11.66	1.14
152	3126.86	9.43	7.2	11.66	1.14
153	3147.43	9.43	7.2	11.66	1.14
154	3168	9.43	7.2	11.66	1.14
155	3188.57	9.43	7.2	11.66	1.14
156	3209.14	9.43	7.2	11.66	1.14
157	3229.71	9.43	7.2	11.66	1.14
158	3250.29	9.43	7.2	11.66	1.14
159	3270.86	9.43	7.2	11.66	1.14
160	3291.43	9.43	7.2	11.66	1.14
161	3312	9.43	7.2	11.66	1.14

Table 9. (Continued)

162	3332.57	9.43	7.2	11.66	1.14
163	3353.14	9.43	7.2	11.66	1.14
164	3373.71	9.43	7.2	11.66	1.14
165	3394.29	9.43	7.2	11.66	1.14
166	3414.86	9.43	7.2	11.66	1.14
167	3435.43	9.43	7.2	11.66	1.14
168	3456	9.43	7.2	11.66	1.14
169	3476.57	9.43	7.2	11.66	1.14
170	3497.14	9.43	7.2	11.66	1.14
171	3517.71	9.43	7.2	11.66	1.14
172	3538.29	9.43	7.2	11.66	1.14
173	3558.86	9.43	7.2	11.66	1.14
174	3579.43	9.43	7.2	11.66	1.14
175	3600	9.43	7.2	11.66	1.14
176	3620.57	9.43	7.2	11.66	1.14
177	3641.14	9.43	7.2	11.66	1.14
178	3661.71	9.43	7.2	11.66	1.14
179	3682.29	9.43	7.2	11.66	1.14
180	3702.86	9.43	7.2	11.66	1.14
181	3723.43	9.43	7.2	11.66	1.14
182	3744	9.43	7.2	11.66	1.14
183	3764.57	9.43	7.2	11.66	1.14
184	3785.14	9.43	7.2	11.66	1.14
185	3805.71	9.43	7.2	11.66	1.14
186	3826.29	9.43	7.2	11.66	1.14
187	3846.86	9.43	7.2	11.66	1.14
188	3867.43	9.43	7.2	11.66	1.14
189	3888	9.43	7.2	11.66	1.14
190	3908.57	9.43	7.2	11.66	1.14
191	3929.14	9.43	7.2	11.66	1.14
192	3949.71	9.43	7.2	11.66	1.14
193	3970.29	9.43	7.2	11.66	1.14
194	3990.86	9.43	7.2	11.66	1.14
195	4011.43	9.43	7.2	11.66	1.14
196	4032	9.43	7.2	11.66	1.14
197	4052.57	9.43	7.2	11.66	1.14
198	4073.14	9.43	7.2	11.66	1.14
199	4093.71	9.43	7.2	11.66	1.14
200	4114.29	9.43	7.2	11.66	1.14

Table 10. Statistical output from EstimateS for young age *P. tremuloides* stands.

Samples	Individuals (computed)	S(est)	S(est) 95% CI Lower	S(est) 95% CI Upper	S(est) SD
1	10.71	4.71	1.99	7.44	1.39
2	21.43	6.38	3.42	9.34	1.51
3	32.14	7.57	4.51	10.63	1.56
4	42.86	8.57	5.4	11.74	1.62
5	53.57	9.48	6.15	12.8	1.7
6	64.29	10.29	6.78	13.79	1.79
7	75	11	7.28	14.72	1.9
8	85.71	11.63	7.66	15.6	2.02
9	96.43	12.19	7.93	16.44	2.17
10	107.14	12.68	8.1	17.25	2.33
11	117.86	13.11	8.18	18.04	2.51
12	128.57	13.49	8.19	18.79	2.7
13	139.29	13.83	8.14	19.51	2.9
14	150	14.13	8.05	20.2	3.1
15	160.71	14.39	7.92	20.86	3.3
16	171.43	14.62	7.77	21.47	3.5
17	182.14	14.82	7.6	22.05	3.69
18	192.86	15.01	7.41	22.6	3.87
19	203.57	15.16	7.23	23.1	4.05
20	214.29	15.3	7.04	23.57	4.22
21	225	15.43	6.85	24.01	4.38
22	235.71	15.54	6.66	24.41	4.53
23	246.43	15.63	6.48	24.78	4.67
24	257.14	15.72	6.31	25.13	4.8
25	267.86	15.79	6.15	25.44	4.92
26	278.57	15.86	5.99	25.73	5.03
27	289.29	15.92	5.84	25.99	5.14
28	300	15.97	5.71	26.23	5.24
29	310.71	16.02	5.58	26.45	5.33
30	321.43	16.06	5.46	26.66	5.41
31	332.14	16.09	5.34	26.84	5.48
32	342.86	16.12	5.24	27.01	5.55
33	353.57	16.15	5.14	27.16	5.62
34	364.29	16.17	5.05	27.29	5.67
35	375	16.2	4.97	27.42	5.73
36	385.71	16.22	4.9	27.53	5.77

Table 10. (Continued)

37	396.43	16.23	4.83	27.63	5.82
38	407.14	16.25	4.77	27.73	5.86
39	417.86	16.26	4.71	27.81	5.89
40	428.57	16.27	4.65	27.89	5.93
41	439.29	16.28	4.61	27.96	5.96
42	450	16.29	4.56	28.02	5.98
43	460.71	16.3	4.52	28.07	6.01
44	471.43	16.3	4.49	28.12	6.03
45	482.14	16.31	4.45	28.17	6.05
46	492.86	16.32	4.42	28.21	6.07
47	503.57	16.32	4.4	28.25	6.08
48	514.29	16.33	4.37	28.28	6.1
49	525	16.33	4.35	28.31	6.11
50	535.71	16.33	4.33	28.34	6.12
51	546.43	16.34	4.31	28.36	6.14
52	557.14	16.34	4.29	28.38	6.14
53	567.86	16.34	4.28	28.4	6.15
54	578.57	16.34	4.27	28.42	6.16
55	589.29	16.34	4.25	28.43	6.17
56	600	16.35	4.24	28.45	6.18
57	610.71	16.35	4.23	28.46	6.18
58	621.43	16.35	4.22	28.47	6.19
59	632.14	16.35	4.22	28.48	6.19
60	642.86	16.35	4.21	28.49	6.19
61	653.57	16.35	4.2	28.5	6.2
62	664.29	16.35	4.2	28.51	6.2
63	675	16.35	4.19	28.51	6.21
64	685.71	16.35	4.19	28.52	6.21
65	696.43	16.35	4.18	28.53	6.21
66	707.14	16.35	4.18	28.53	6.21
67	717.86	16.35	4.17	28.53	6.21
68	728.57	16.35	4.17	28.54	6.22
69	739.29	16.35	4.17	28.54	6.22
70	750	16.36	4.17	28.54	6.22
71	760.71	16.36	4.16	28.55	6.22
72	771.43	16.36	4.16	28.55	6.22
73	782.14	16.36	4.16	28.55	6.22
74	792.86	16.36	4.16	28.55	6.22
75	803.57	16.36	4.16	28.56	6.22
76	814.29	16.36	4.16	28.56	6.22
77	825	16.36	4.15	28.56	6.23

Table 10. (Continued)

78	835.71	16.36	4.15	28.56	6.23
79	846.43	16.36	4.15	28.56	6.23
80	857.14	16.36	4.15	28.56	6.23
81	867.86	16.36	4.15	28.56	6.23
82	878.57	16.36	4.15	28.56	6.23
83	889.29	16.36	4.15	28.56	6.23
84	900	16.36	4.15	28.56	6.23
85	910.71	16.36	4.15	28.56	6.23
86	921.43	16.36	4.15	28.57	6.23
87	932.14	16.36	4.15	28.57	6.23
88	942.86	16.36	4.15	28.57	6.23
89	953.57	16.36	4.15	28.57	6.23
90	964.29	16.36	4.15	28.57	6.23
91	975	16.36	4.15	28.57	6.23
92	985.71	16.36	4.15	28.57	6.23
93	996.43	16.36	4.15	28.57	6.23
94	1007.14	16.36	4.15	28.57	6.23
95	1017.86	16.36	4.15	28.57	6.23
96	1028.57	16.36	4.15	28.57	6.23
97	1039.29	16.36	4.15	28.57	6.23
98	1050	16.36	4.15	28.57	6.23
99	1060.71	16.36	4.15	28.57	6.23
100	1071.43	16.36	4.15	28.57	6.23
101	1082.14	16.36	4.15	28.57	6.23
102	1092.86	16.36	4.15	28.57	6.23
103	1103.57	16.36	4.15	28.57	6.23
104	1114.29	16.36	4.15	28.57	6.23
105	1125	16.36	4.15	28.57	6.23
106	1135.71	16.36	4.15	28.57	6.23
107	1146.43	16.36	4.15	28.57	6.23
108	1157.14	16.36	4.15	28.57	6.23
109	1167.86	16.36	4.15	28.57	6.23
110	1178.57	16.36	4.14	28.57	6.23
111	1189.29	16.36	4.14	28.57	6.23
112	1200	16.36	4.14	28.57	6.23
113	1210.71	16.36	4.14	28.57	6.23
114	1221.43	16.36	4.14	28.57	6.23
115	1232.14	16.36	4.14	28.57	6.23
116	1242.86	16.36	4.14	28.57	6.23
117	1253.57	16.36	4.14	28.57	6.23
118	1264.29	16.36	4.14	28.57	6.23
119	1275	16.36	4.14	28.57	6.23

Table 10. (Continued)

120	1285.71	16.36	4.14	28.57	6.23
121	1296.43	16.36	4.14	28.57	6.23
122	1307.14	16.36	4.14	28.57	6.23
123	1317.86	16.36	4.14	28.57	6.23
124	1328.57	16.36	4.14	28.57	6.23
125	1339.29	16.36	4.14	28.57	6.23
126	1350	16.36	4.14	28.57	6.23
127	1360.71	16.36	4.14	28.57	6.23
128	1371.43	16.36	4.14	28.57	6.23
129	1382.14	16.36	4.14	28.57	6.23
130	1392.86	16.36	4.14	28.57	6.23
131	1403.57	16.36	4.14	28.57	6.23
132	1414.29	16.36	4.14	28.57	6.23
133	1425	16.36	4.14	28.57	6.23
134	1435.71	16.36	4.14	28.57	6.23
135	1446.43	16.36	4.14	28.57	6.23
136	1457.14	16.36	4.14	28.57	6.23
137	1467.86	16.36	4.14	28.57	6.23
138	1478.57	16.36	4.14	28.57	6.23
139	1489.29	16.36	4.14	28.57	6.23
140	1500	16.36	4.14	28.57	6.23
141	1510.71	16.36	4.14	28.57	6.23
142	1521.43	16.36	4.14	28.57	6.23
143	1532.14	16.36	4.14	28.57	6.23
144	1542.86	16.36	4.14	28.57	6.23
145	1553.57	16.36	4.14	28.57	6.23
146	1564.29	16.36	4.14	28.57	6.23
147	1575	16.36	4.14	28.57	6.23
148	1585.71	16.36	4.14	28.57	6.23
149	1596.43	16.36	4.14	28.57	6.23
150	1607.14	16.36	4.14	28.57	6.23
151	1617.86	16.36	4.14	28.57	6.23
152	1628.57	16.36	4.14	28.57	6.23
153	1639.29	16.36	4.14	28.57	6.23
154	1650	16.36	4.14	28.57	6.23
155	1660.71	16.36	4.14	28.57	6.23
156	1671.43	16.36	4.14	28.57	6.23
157	1682.14	16.36	4.14	28.57	6.23
158	1692.86	16.36	4.14	28.57	6.23
159	1703.57	16.36	4.14	28.57	6.23
160	1714.29	16.36	4.14	28.57	6.23
161	1725	16.36	4.14	28.57	6.23

Table 10. (Continued)

162	1735.71	16.36	4.14	28.57	6.23
163	1746.43	16.36	4.14	28.57	6.23
164	1757.14	16.36	4.14	28.57	6.23
165	1767.86	16.36	4.14	28.57	6.23
166	1778.57	16.36	4.14	28.57	6.23
167	1789.29	16.36	4.14	28.57	6.23
168	1800	16.36	4.14	28.57	6.23
169	1810.71	16.36	4.14	28.57	6.23
170	1821.43	16.36	4.14	28.57	6.23
171	1832.14	16.36	4.14	28.57	6.23
172	1842.86	16.36	4.14	28.57	6.23
173	1853.57	16.36	4.14	28.57	6.23
174	1864.29	16.36	4.14	28.57	6.23
175	1875	16.36	4.14	28.57	6.23
176	1885.71	16.36	4.14	28.57	6.23
177	1896.43	16.36	4.14	28.57	6.23
178	1907.14	16.36	4.14	28.57	6.23
179	1917.86	16.36	4.14	28.57	6.23
180	1928.57	16.36	4.14	28.57	6.23
181	1939.29	16.36	4.14	28.57	6.23
182	1950	16.36	4.14	28.57	6.23
183	1960.71	16.36	4.14	28.57	6.23
184	1971.43	16.36	4.14	28.57	6.23
185	1982.14	16.36	4.14	28.57	6.23
186	1992.86	16.36	4.14	28.57	6.23
187	2003.57	16.36	4.14	28.57	6.23
188	2014.29	16.36	4.14	28.57	6.23
189	2025	16.36	4.14	28.57	6.23
190	2035.71	16.36	4.14	28.57	6.23
191	2046.43	16.36	4.14	28.57	6.23
192	2057.14	16.36	4.14	28.57	6.23
193	2067.86	16.36	4.14	28.57	6.23
194	2078.57	16.36	4.14	28.57	6.23
195	2089.29	16.36	4.14	28.57	6.23
196	2100	16.36	4.14	28.57	6.23
197	2110.71	16.36	4.14	28.57	6.23
198	2121.43	16.36	4.14	28.57	6.23
199	2132.14	16.36	4.14	28.57	6.23
200	2142.86	16.36	4.14	28.57	6.23

APPENDIX V

COLLECTION SITE LOCATIONS AND DATA

Table 11. UTM coordinates of each pitfall trap used for collection

Site Number	UTM Coordinates
S1 #1	15 431056E 5464301N
S1 #2	15 432054E 5464286N
S1 #3	15 431052E 5464274N
S1 #4	15 431046E 5464261N
S1 #5	15 431046E 5464246N
S2 #1	15 437144E 5465139N
S2 #2	15 437154E 5465147N
S2 #3	15 437162E 5465160N
S2 #4	15 437163E 5465177N
S2 #5	15 437171E 5465182N
S3 #1	15 429939E 5449237N
S3 #2	15 429918E 5449239N
S3 #3	15 429900E 5449242N
S3 #4	15 429885E 5449244N
S3 #5	15 429868E 5449243N
S4 #1	15 427587E 5462683N
S4 #2	15 427602E 5462676N
S4 #3	15 427616E 5462665N
S4 #4	15 427631E 5462662N
S4 #5	15 427640E 5462652N
S5 #1	15 429759E 5465540N
S5 #2	15 429757E 5465552N
S5 #3	15 429749E 5465571N
S5 #4	15 429745E 5465589N
S5 #5	15 429739E 5465604N
S6 #1	15 431406E 5448554N
S6 #2	15 431396E 5448568N
S6 #3	15 431386E 5448582N
S6 #4	15 431369E 5448585N
S6 #5	15 431354E 5448597N

MAPPED SITE LOCATIONS

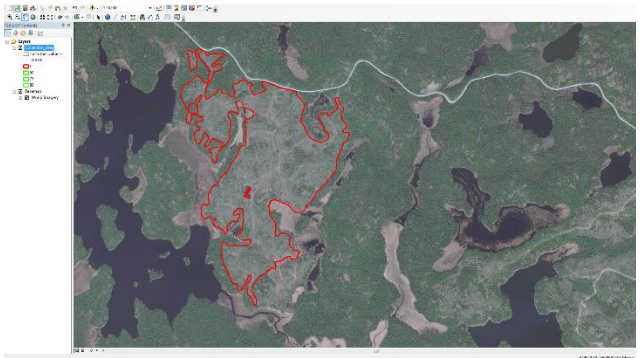

Figure 32. ArcGIS display showing site 1, approximately 2 kilometres down Cameron Lake Road, North of Nestor Falls, ON.

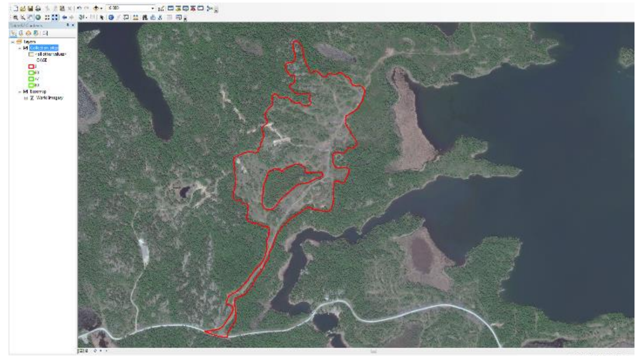

Figure 33. ArcGIS display showing site 2, approximately 9 kilometres down Cameron Lake Road, North of Nestor Falls, ON.

Figure 34. ArcGIS display showing site 3, 1 kilometre down Young's Road, North of Nestor Falls, ON.

Figure 35. ArcGIS display showing site 4, approximately 1 kilometre down Cameron Lake Road, North of Nestor Falls, ON.

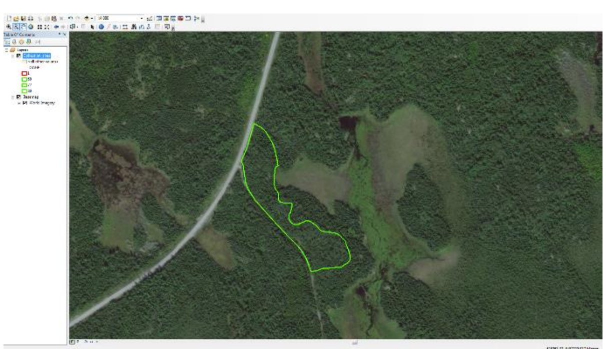

Figure 36. ArcGIS display showing site 5, approximately 18 kilometres North of Nestor Falls, ON.

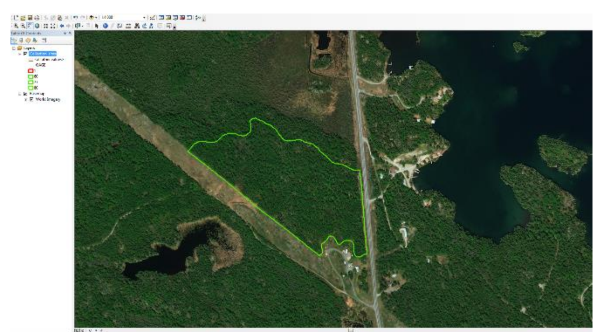

Figure 37. ArcGIS display showing site 6, approximately 5 kilometres North of Nestor Falls, ON.

GROUND LEVEL PHOTOS OF COLLECTION SITE 1

Figure 38. Overview of collection site 1 on Cameron Lake Road.

Figure 39. Pitfall trap #1 in site 1 on Cameron Lake Road.

Figure 40. Pitfall trap #2 in site 1 on Cameron Lake Road.

Figure 41. Pitfall trap #3 in site 1 on Cameron Lake Road.

Figure 42. Pitfall trap #4 in site 1 on Cameron Lake Road.

Figure 43. Pitfall trap #5 in site 1 on Cameron Lake Road.

GROUND LEVEL PHOTOS OF COLLECTION SITE 2

Figure 44. Overview of collection site 2 on Cameron Lake Road.

Figure 45. Pitfall trap #1 in site 2 on Cameron Lake Road.

Figure 46. Pitfall trap #2 in site 2 on Cameron Lake Road.

Figure 47. Pitfall trap #3 in site 2 on Cameron Lake Road.

Figure 48. Pitfall trap #4 in site 2 on Cameron Lake Road.

Figure 49. Pitfall trap #5 in site 2 on Cameron Lake Road.

GROUND LEVEL PHOTOS OF COLLECTION SITE 3

Figure 50. Overview of collection site 3 on Young's Road, North of Nestor Falls, ON.

Figure 51. Pitfall trap #1 in site 3 on Young's Road.

Figure 52. Pitfall trap #2 in site 3 on Young's Road.

Figure 53. Pitfall trap #3 in site 3 on Young's Road.

Figure 54. Pitfall trap #4 in site 3 on Young's Road.

Figure 55. Pitfall trap #5 in site 3 on Young's Road.

GROUND LEVEL PHOTOS OF COLLECTION SITE 4

Figure 56. Overview of collection site 4 approximately 1 km down Cameron Lake Road

Figure 57. Pitfall trap #1 in collection site 4 on Cameron Lake Road

Figure 58. Pitfall trap #2 in collection site 4 on Cameron Lake Road

Figure 59. Pitfall trap #3 in collection site 4 on Cameron Lake Road

Figure 60. Pitfall trap #4 in collection site 4 on Cameron Lake Road

Figure 61. Pitfall trap #5 in collection site 4 on Cameron Lake Road

GROUND LEVEL PHOTOS OF COLLECTION SITE 5

Figure 62. Overview of collection site 5 approximately 18 km down Highway 71, North of Nestor Falls, ON

Figure 63. Pitfall trap #1 in collection site 5 off Highway 71.

Figure 64. Pitfall trap #2 in collection site 5 off Highway 71.

Figure 65. Pitfall trap #3 in collection site 5 off Highway 71.

Figure 66. Pitfall trap #4 in collection site 5 off Highway 71.

Figure 67. Pitfall trap #5 in collection site 5 off Highway 71.

GROUND LEVEL PHOTOS OF COLLECTION SITE 6

Figure 68. Overview of collection site 6 approximately 3 km down Highway 71, North of Nestor Falls, ON

Figure 69. Pitfall trap #1 in collection site 6 off Highway 71.

Figure 70. Pitfall trap #2 in collection site 6 off Highway 71.

Figure 71. Pitfall trap #3 in collection site 6 off Highway 71.

Figure 72. Pitfall trap #4 in collection site 6 off Highway 71.

Figure 73. Pitfall trap #5 in collection site 6 off Highway 71.

ECOSITE LAND CLASSIFICIATION FOR COLLECTION SITES

Table 12. Ecosite land classification of each collection site

Site Number	Ecosite Number	Ecosite name
S1	ES055	Dry to Fresh, Coarse: Aspen - Birch Hardwood
S2	ES055	Dry to Fresh, Coarse: Aspen - Birch Hardwood
S3	ES088	Fresh, Clayey: Aspen - Birch Hardwood
S4	ES119	Moist, Fine: Aspen - Birch Hardwood
S5	ES119	Moist, Fine: Aspen - Birch Hardwood
S6	ES119	Moist, Fine: Aspen - Birch Hardwood