Ecological Monitoring at *rare* Charitable Research Reserve;

2009

Jen McCarter,
Science Horizons Intern

Executive Summary

In 2006, ***rare*** Charitable Research Reserve collaborated with the Ecological Monitoring and Assessment Network (EMAN) to establish long-term monitoring programs with the ultimate goal of determining the status of ***rare***'s ecosystems and of tracking long-term trends. At that time EMAN and ***rare*** decided to initiate salamander and Benthic invertebrate monitoring on the property. Salamander monitoring was subsequently continued in 2008 and in 2009 both salamander and Benthic invertebrate monitoring were continued. In addition, in 2009 forest biodiversity monitoring plots were established.

Plethodontid Salamander Monitoring

The salamander monitoring locations monitored at ***rare*** in 2006 and 2008, Indian Woods and the Hogsback, were monitored again in 2009. Three additional artificial cover objects (ACOs) were added to Indian Woods on August 21 to fill missing ACO spaces six, seven and eight. This brought the total number of ACOs in Indian Woods to 32 while the number of ACOs in the Hogsback remained at 20.

The ACOs at both sites were monitored once weekly, following the EMAN protocol, starting August 31, 2009 and ending October 27, 2009. All salamanders found underneath ACOs were identified, measured and weighed before being released next to the ACO where they were located. Environmental variables including air and soil temperatures, soil moisture and pH, wind speed, and relative humidity were also recorded. Statistical analyses were run to determine whether any differences existed between the three years of monitoring data.

A total of 182 salamanders were observed between August 31 and October 26 in Indian Woods. All observed individuals in Indian Woods were eastern red-backed salamanders (*Plethodon cinereus)* and of those, only 7.6% were the lead-backed morph.

In the Hogsback a total of 142 salamanders were observed between September 1 and October 27. Four species were found in 2009; the most common was the eastern red-backed salamander but blue-spotted (*Ambystoma laterale*), spotted (*A. maculatum*) and four-toed (*Hemidactylium scutatum*) salamanders were also present. Compared to the observed Indian Woods population, a much larger proportion of eastern red-backed salamanders in the Hogsback (21.0%) were lead-backed morphs.

In both Indian Woods and the Hogsback, the majority of individuals observed in 2009 had snout-vent lengths in the range of 29.00-43.99mm. Individuals with snout-vent lengths greater than 44.00mm were the second most abundant group in each study plot, while individuals with snout-vent lengths less than 24.00mm, likely representing the young of the year, were the least abundant.

The three year repeated-measures analysis showed no significant differences in mean salamander abundances between monitoring years in Indian Woods. In the Hogsback, on the other hand, the second monitoring year had significantly higher observed mean salamander abundances than the first. Snout-vent lengths of eastern red-backed salamanders did not change significantly between monitoring years at either site.

Mean soil temperature had a small positive effect on mean salamander abundances at both sites, significantly so in Indian Woods but not significantly in the Hogsback. Mean soil moisture, on the other hand, had a slight negative effect on mean salamander abundances at both sites, although this relationship was only significant in the Hogsback.

Soil moisture and temperature were significantly different between the three years of monitoring in Indian Woods and between the two years of monitoring in the Hogsback. At both sites 2009 was the driest, warmest year of monitoring.

Continued yearly monitoring of ***rare*'s** salamander populations will give more strength to repeated-measures analyses such as those conducted in 2009 and will ultimately provide answers to questions regarding the ecological health and integrity of Indian Woods and the Hogsback.

Benthic Invertebrate Monitoring

The benthic monitoring program at ***rare*** consisted of eleven sites; four sites on Bauman Creek, five on Cruickston Creek (including three new sites in 2009) as well as two new sites; one in Blair Flats Wetland and one in Preston Flats Wetland.

Two sets of macro-invertebrate samples were taken from each site, one in the late spring/early summer (from May 31st to July 13th) and one in the fall (from October 7th to 10th). All sampling followed the OBBN recommended protocol. Three transects were sampled at each site; a downstream riffle, pool, and upstream riffle for creeks and three transects for wetlands running 3m from the wetland's edge into the centre. All transects were sampled using the travelling-kick-and-sweep technique and a 500µm-mesh D-net. Cruickston Creek sites C3 and C4 were also sampled using a 500µm-mesh Surber quantitative sampler. Air and water temperature, stream depth and width, water velocity, dissolved oxygen, pH, and conductivity were also measured at each site. Preserved specimens were sampled in the lab using the 'bucket sub-sampling method' until a minimum of 100 organisms were collected and identified to the OBBN 27 group level. Thirteen biotic indices were calculated for each site using total counts (the sum of the three transects/site).

A total of 22 OBBN groups were identified between all sites in both the spring and fall. In the spring, Bauman sites B1 and B2 had the highest diversity, but in the fall the site with the highest diversity was site B3. Site B4 had the highest percent of Ephemeroptera, Plecoptera and Trichoptera (EPT) of all Bauman sites in either the spring or the fall. Cruickson Creek sites C1 and C2 had the highest diversity in the spring, while sites C1, C2 and C4 all had the highest diversity in the fall. Site C1 had the highest percent EPT in the spring, while site C2 had the highest percent EPT in the fall. No wetland was consistently higher in diversity than the other. Both wetland sites had very low percent EPT in the spring and much higher percent EPT in the fall.

Benthic invertebrate monitoring should continue every two years in the future, and, when enough data is available, thorough statistical and test-site analyses should be completed. These analyses will be much more informative for evaluating the status and trends of ***rare***'s creek and wetland sites than simple evaluation of biotic indices.

Forest Biodiversity Monitoring

Indian Woods and the Cliffs and Alvars forests were selected for establishing forest biodiversity monitoring plots. Forest biodiversity monitoring plots were set-up according to the EMAN protocol in October and November 2009. Three plots containing a relatively good representation of the overall forest tree species composition and a relatively large number of trees were selected in each forest. Twenty metre square plots were then established and demarcated at each plot using steel wire pigtails for the corners and twine for the sides.

Starting at the northwest corner of each plot, trees were tagged, measured and identified in a clockwise spiral from the periphery to the centre of the quadrate. Preliminary data was mapped using biomon mapping software provided on the EMAN website, however, as not all trees were identified in the initial plot set-up, none of the recommended biotic indices (e.g. abundance, density, relative density, dominance, relative dominance etc.) were calculated.

Future work on the forest biodiversity monitoring plots should include the re-assessment of tree species identifications, measurement of tree heights, ages and degree of canopy closure, updating the data and maps on the EMAN website and calculating the biotic indices mentioned above. Additionally, the forest biodiversity monitoring plots should be re-measured every five years to monitor tree mortality and growth.

Annual decay rates monitoring plots were also established in association with Cliffs and Alvars forest biodiversity monitoring plot number one. Following EMAN's Annual Soil Humus Decay Rates protocol, 12 plots were established on November 9, 2009 by burying 48 (four/site) oven-dried, tagged and pre-weighed tongue depressors.

Annual decay rates monitoring plots will provide important information on the productivity and turnover of biomass on the forest floor. Future work on the annual decay rates monitoring plots will include the retrieval and weighing of tongue depressors in the fall of 2010 and, depending upon available resources and the success of the first monitoring year, the burying of new tongue depressors for another year (until fall 2011). If the first year of decay rates monitoring goes well, these plots could also be established at additional forest biodiversity plots in the Cliffs and Alvars forest and/or in Indian Woods.

In addition to the annual decay rates monitoring, other monitoring protocols can also be easily added to the forest biodiversity monitoring plots. These might include Shrub and Small-Tree Stratum Biodiversity, Ground Vegetation Stratum Biodiversity or Vegetation Gradient Biodiversity Monitoring Protocols available. Which, if any of these protocols should be implemented at ***rare***, of course, depends on ***rare***'s long term goals for monitoring and the available resources.

Continued ecological monitoring at ***rare*** will allow research questions regarding the trends in ecological health and integrity of ***rare***'s aquatic and terrestrial ecosystems to be fully addressed. This is especially important in light of regional changes, such as open-pit gravel mine and subdivision development, and broader issues such as climate change that are likely to affect the ecological systems ***rare*** is striving to protect. The information collected through monitoring will also be helpful as ***rare*** considers new management plans and restoration and research projects.

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1.0 – Introduction

1.1 - Ecological Monitoring

Ecological monitoring is the regular observation, measurement, and evaluation of organisms, populations or communities to detect changes in ecological systems over time (Environment Canada, 2009a). Although it would be most accurate to monitor all flora and fauna in a particular ecosystem, the cost associated with studying such a vast number of species in any given ecosystem makes this approach impractical (Welsh and Droege, 2001). Therefore, specific ecological indicator species, whose life history traits make them likely to change in abundance or presence with environmental fluctuations, are selected for monitoring (Welsh and Droege, 2001). A key component of any long-term monitoring program is baseline data, which can then be used for comparison with any subsequent data collected. Any significant variations from the original baseline data in the following years are then detectable and the root causes, i.e. climate changes, habitat loss, anthropogenic disturbance, or pollution levels, can then be identified.

1.2 – Ecological Monitoring and Assessment Network (EMAN)

Environment Canada's Ecological Monitoring and Assessment Network (EMAN) is a collaboration of federal, provincial and municipal governments, academic institutions, environmental non-government organizations, industry, volunteer groups and other citizen science groups all involved in ecological monitoring. Previously, data collected by these groups, despite large investments of time and money, were largely incompatible due to differing monitoring protocols and research agendas. The EMAN Coordinating Office (EMANCO) was developed in 1994 by Environment Canada to facilitate integrated monitoring, research and assessment through standardized protocols (Environment Canada, 2009a). With this integrated approach data collected through different monitoring initiatives can be efficiently shared and compiled into larger scale datasets (spatially and temporally) to better detect, describe and report changes in ecosystems across Canada (Environment Canada, 2009a). The monitoring protocols that were created by EMAN vary from simple community based monitoring in which the public can participate (e.g. Frog-, Ice-, Plant- or Worm-Watch) to more complex monitoring that requires trained specialists (e.g. monitoring parasites of fishes; Environment Canada, 2009a).

1.3 - Ecological Monitoring at *rare* Charitable Research Reserve

Founded in 2001, ***rare*** is a non-profit, non-government environmental organization which owns and preserves 913 acres of land along the Grand and Speed Rivers in Cambridge, Ontario (Appendix A, Figure A.1). The ***rare*** property has over 24 habitat types, including provincially significant wetlands, Environmentally Sensitive Policy areas, a regionally classified Environmentally Sensitive Landscape, a regionally rare cliffs and alvar ecosystem and remnants of an old-growth forest. ***rare***'s primary objective is to preserve its land for future generations through research, education, conservation and ecological restoration.

In keeping with their goals, ***rare*** partnered with EMAN in the spring of 2006 to establish permanent monitoring plots on the property, according to standardized EMAN protocols. ***rare***'s Environmental Advisory Committee (EAC) and EMAN advisors recommended that both aquatic and terrestrial monitoring programs be implemented. As such, in 2006 benthic invertebrates were monitored in Cruickston and Bauman creeks, plethodontid salamanders were monitored in Indian Woods and butterflies were monitored throughout the property. Plethodontid salamander monitoring continued in 2008 in Indian Woods and at an additional site in the Hogsback.

In 2009, benthic invertebrate, plethodontid salamander and butterfly monitoring continued (for more information on butterfly monitoring see the 2009 report available at ***rare***). Three new sites on Cruickston Creek and two new water bodies (Blair Flats and Preston Flats wetlands) were added to the benthic invertebrate monitoring program at ***rare*** in 2009. As well, two new monitoring protocols were implemented; six forest biodiversity plots were established (three in Indian Woods and three in the Cliffs and Alvars forest) along with one annual decay rates plot in the Cliffs and Alvars forest (Environment Canada, 2009a).

2.0 - Plethodontid Salamander Monitoring

2.1 – Introduction

Plethodontidae

The Plethodontidae are the largest salamander family in the world, with more than 200 species (Zorn *et* al., 2004; MacCulloch, 2002). Plethodontid or Lungless salamanders lack lungs, respiring entirely through their moist skin, especially through their mouth lining (Zorn *et* al., 2004; MacCulloch, 2002). In order to keep their skin moist, plethodontids live in damp environments such as beneath rotting logs, rocks, in moist rock crevices, in seepage areas, sphagnum bogs and generally around streams (MacCulloch, 2002). Some plethodontids require water for deposition of their eggs, however most species in the plethodontid group are entirely terrestrial, lay their eggs in moist places such as rotten logs, and have hatchlings that pass through the larval aquatic stage inside the egg (MacCulloch, 2002; Welsh and Droege, 2001).

A distinctive feature of salamanders in the family Plethodontidae is the nasolabial groove running from each nostril down to the upper lip (MacCulloch, 2002). This groove, which is visible only under magnification, is lined with chemoreceptors to aid in finding prey (MacCulloch, 2002).

Plethondontids are carnivorous, foraging mostly on small insects and invertebrates in the leaf litter, such as ants, termites, beetles, flies, earthworms, spiders, snails, slugs, mites, centipedes, millepedes, springtails and midges (Lannoo, 2005; Froom, 1982). Because they have such efficient metabolisms and are typically so abundant where they occur (Welsh and Droege, 2001; Burton and Likens, 1975), plethodontid salamanders play a very important role in their food webs; efficiently transferring energy from one trophic level to another (Zorn *et* al., 2004; Wyman, 1998). For example, Wyman (1998) found that experimental manipulations of plethodontid salamander abundance had a significant effect on invertebrate abundance and subsequently also affected decomposition rates on the forest floor.

Plethodontid salamanders are capable of tail autotomy and regeneration; if threatened by a predator, their tail will detach from their body along a constriction at the base of the tail (Wise and Jaeger, 1998; Froom, 1982). Predators of plethodontids include snakes, shrews, chipmunks, mice, turkeys, raccoons, foxes, and spotted salamanders (Lannoo, 2005). Plethodontids may also cannibalize the eggs or juveniles of conspecifics (Lannoo, 2005; Froom, 1982).

Plethodon cinereus

There are nine native species of plethodontids in Canada, but perhaps the most common species in eastern Canada (and at ***rare***) is the eastern red-backed salamander (*Plethodon cinereus*) (Zorn *et* al., 2004).

Eastern red-backed salamanders are elongated, flat-bodied salamanders, with large mouths, four short legs and thick toes (four on each front leg and five on each back leg) (Froom, 1982). Adult males are slightly smaller than females, averaging 73mm and 78mm in snout-vent length, respectively (Bishop, 1943).

According to Cook (1984), the red-backed salamander can be found in one of three colour morphs; the most common is the red-backed morph, where individuals have a red stripe on their back from head to tail with blackish sides and belly (Cook, 1984). The red-backed morph is believed to make up 75% of all individuals in most populations (Lamond, 1994). The second most common, though much less so than the red-backed, is the lead-backed morph, where individuals are completely blue-black in colour (Cook, 1984). The third, very rare, morph is the erythristic morph where individuals are completely red (Cook, 1984).

Eastern red-backed salamanders are commonly found in white pine, northern hemlock or deciduous forests (Cook, 1984). Not unlike most plethodontids, eastern red-backed salamanders live in moist areas, generally in or under decaying logs or stumps, leaf litter, pieces of bark or large stones (Welsh and Droege, 2001).

Eastern red-backed salamanders breed from October until December, during which time the normally territorial species can be found in breeding pairs (Ransom and Jaeger, 2006; Bishop, 1943). Eggs are inseminated in the spring and females then lay up to a dozen eggs in June or July (Lang and Jaeger, 2000; Bishop, 1943). Eggs are laid in grape-like clusters attached to the sides or roofs of small terrestrial cavities. Females guard their eggs in these cavities, and periodically turn them to prevent mildew formation, until the eggs hatch in August or early September (Zorn *et* al., 2004).

Plethodontid Salamanders as Ecological Indicators

Plethodontid salamanders are ideal indicators for detecting changes in ecosystems for a number of reasons. First, their life history and biological traits make their populations, under normal circumstances, relatively stable compared to other species (Zorn *et* al., 2004). This is because plethodontid salamanders have long life spans of ten years or more combined with low annual birth rates and low rates of mortality (Zorn *et* al., 2004). Also, on a landscape scale they are more widely distributed than aquatic species, and yet they maintain small home ranges and have high site-fidelity (Welsh and Droege, 2001). Given that plethodontid populations are typically very stable, in terms of abundance and distribution, any changes in abundance observed through monitoring are likely to reflect changes in the environment rather than changes in population distribution or abundance due to normal population cycling.

Second, physiological traits of plethodontid salamanders make them more sensitive to changes in their environment than other species. Their reliance on their moist skin for respiration makes plethodontids sensitive to environmental stressors, even more so than other 'lung possessing' amphibians, especially those influencing soil microclimate, air, water, or soil quality (Zorn *et* al., 2004).

Third, plethodontids, like most amphibians, fulfill a very important function in the forest food web. They are so efficient at metabolizing their prey that they are able to quickly achieve high population densities, equaling or surpassing the biomass of any other vertebrate group in the ecosystem (Burton and Likens, 1975) and becoming a key link in transferring energy between trophic levels (Zorn *et* al., 2004). Therefore, they are ideal to monitor as changes in plethodontid populations are likely to also reflect changes in other levels of the food web (changes in invertebrate abundance or diversity, for example).

Finally, plethodontid salamanders are logistically ideal as ecological indicators as they are easily accurately identified such that having different observers throughout long-term monitoring projects will have little impact on the quality of data collected. As well, given that they naturally seek out large logs and rocks on the forest floor for shelter, they are easily sampled using artificial cover objects (Welsh and Droege, 2001). Artificial cover objects have very little impact on ecosystems in which they are placed (as opposed to turning rocks and logs in search of salamanders), can be easily and inexpensively installed in many monitoring locations, and, if of uniform size, yield data easily comparable between locations and years.

Salamander Monitoring at *rare*

The aim of the salamander monitoring program at ***rare*** is to examine salamander populations in Indian Woods and the Hogsback through the use of artificial cover boards and protocols defined by EMAN and Parks Canada.

The general long-term research questions for this monitoring remain the same as those in 2006 and 2008 and are as follows:

- What is the current state of salamander populations at ***rare***?
- What are the long-term trends taking place as indicated by salamander populations at ***rare***?
- What is the ecological health[1] of Indian Woods and the Hogsback, and is it being maintained or improved over time?
- Is ecosystem integrity[2] of the forest being maintained or improved under ***rare*** management?
- Is either the ecological health or integrity of the two monitoring sites being affected by on-site changes in agriculture and/or restoration efforts being implemented by ***rare***?

These data will, and continue to, provide the basis for a long-term monitoring program at ***rare***. Trends observed in the salamander data will help ***rare*** determine the ecological health of Indian Woods and the Hogsback. The results from this study will also be helpful as ***rare*** considers new management plans and restoration and research projects.

This monitoring protocol can also be used in conjunction with other protocols to better assess the overall ecological health of these two sites.

1 - Ecological health can be defined, within an ecosystem management context, as, "a condition wherein [an ecosystem] has the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency[3], while meeting current and future needs of people for desired levels of values, uses, products, and services" (Styers *et* al., 2010; Twery and Gottschalk, 1996).
2 - Ecological integrity is defined by Parks Canada (2009) as, "…a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes." Further, Parks Canada defines an ecosystem as having integrity when, "…they have their native components intact, including: abiotic components (the physical elements, e.g. water, rocks), biodiversity (the composition and abundance of species and communities in an ecosystem, e.g. tundra, rainforest and grasslands represent landscape diversity; black bears, brook trout and black spruce represent species diversity) and ecosystem processes (the engines that makes ecosystem work; e.g. fire, flooding, predation)."
3 - Ecological resiliency is defined as, "the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures (defined as alternative stable states)" or, "a return time to a stable state following a perturbation." (Gunderson, 2000).

2.2 –Methods

2.2.1 - 2009 Monitoring

Monitoring Locations

The same locations monitored at ***rare*** in 2006 and 2008 were monitored again in 2009; one plot in Indian Woods and one in the Hogsback (although the Hogsback was not monitored in 2006).

Indian Woods is an old growth remnant forest located along the western edge of the ***rare*** property approximately equidistant between Blair Road to the north and Whistle Bare Road to the south (Appendix A, Figure A.2). Indian Woods contains trees up to 230 years old and is predominantly composed of red and white oak (*Quercus rubra, Q. alba*), sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), basswood (*Tilia Americana*) and white pine (*Pinus strobus*). The salamander monitoring plot is in the southeast corner of Indian Woods, approximately 100m east of the Grand Allée trail and just northeast of the large pond.

The Indian Woods plot can be accessed by parking at ***rare***'s 'South Gate', walking north along the Grand Allée trail and, where a second path merges with the main trail (a post with a blue square and white arrow is also located at this junction), heading west into the forest for approximately 100m (Appendix A, Figure A.2).

The Hogsback is located in the southeast corner of ***rare***'s property. The Hogsback is a 57-acre (42 within ***rare***'s boundary) deciduous forest and mixed swamp, dominated by the eastern white cedar (*Thuja occidentalis*). Historically, the Hogsback has been a relatively isolated area, subject to little human disturbance, however, a subdivision is now located just outside ***rare***'s eastern property line and an additional subdivision is being planned for the future just south of the Hogsback's southern edge.

The salamander monitoring plot in the Hogsback is situated just west of the creek (Cruickston) flowing through the Hogsback and approximately 100m south of the northern forest edge bordering the agricultural field (Appendix A, Figure A.2). This site can be accessed by driving through ***rare***'s 'South Gate', east along the hedgerow, stopping just before the laneway heads south, walking north and then east along the edge of the Hogsback and finally heading south into the Hogsback (over the fallen log on the fence) for approximately 50m (Appendix A, Figure A.2).

Salamander Species at *rare*

Species previously observed though salamander monitoring at ***rare*** include the eastern red-backed salamander (in Indian Woods and the Hogsback), blue-spotted (*Ambystoma laterale*) possible Jefferson's salamander (*A. jeffersonianum;* Indian Woods), and the four-toed salamander (*Hemidactylium scutatum*; Hogsback). The spotted salamander (*A. maculatum*) had also been observed on one occasion in the Hogsback (Dance, 2002). These five species are the only salamander species known to occur in the Cambridge, Ontario region (MacCulloch, 2002).

Pre-monitoring

Approximately one month prior to the commencement of monitoring all artificial cover objects were located again (for co-ordinates see Appendix A, Table A.1) and, if necessary, re-tagged and/or re-positioned flush with the substrate. Any cracks or holes in ACOs (not occupied by salamanders at the time) were also packed with soil to prevent salamanders from escaping during monitoring.

On August 21, three artificial cover objects were added to the Indian Woods plot to fill-in three empty locations (between artificial cover objects five and nine), bringing the total number of artificial cover objects to 32. The new artificial cover objects, like the pre-existing ones, were made from untreated, rough white pine boards, 5cm thick, 25cm wide and 30cm long. As well, a permanent gauge was installed in the Indian Woods pond to allow more careful observation of the pond's water levels.

Monitoring

Monitoring was conducted according to the plethodontid salamander monitoring protocol endorsed by EMAN (Zorn *et* al. 2004). The artificial cover objects in both Indian Woods (n= 32) and the Hogsback (n= 20) were checked once weekly starting August 31 and ending October 27, 2009. Each artificial cover object was lifted and the substrate beneath (as well as the underside of the board) was checked for salamanders. If more than one salamander was present they were all placed in a 'holding' container with a damp sponge. One by one the salamanders were then identified, measured and weighed. To measure salamanders, they were placed on the underside of a plastic container lid. The container, containing a snugly fitted and dampened sponge, was then place onto the lid and the closed flipped right-side up such that the belly of the salamander was visible through the lid. Once the salamander was lying relatively straight, its snout to vent and vent to tail lengths were measured using 0-150mm digital calipers. Most salamanders were weighed using a Fuzion™ Diablo digital scale (0.1-500g) however, for better accuracy very small salamanders were weighed with a Pesola spring scale (0.1-10g). All salamanders were released promptly after measuring, next to the board where they were found. Salamanders were always handled while wearing nitrile rubber gloves to avoid contamination of their highly permeable skin.

Beaufort wind and sky codes were used to record wind speed and cloud cover at the beginning of each monitoring visit. Several weather variables; mean wind speed over approximately 10 seconds, air temperature and relative humidity, were also recorded at intervals throughout each plot (i.e. at artificial cover objects 3, 7, 11, 15, 19, 23, 27 and 31 in Indian Woods and 2, 7, 12, 17 in the Hogsback) using a Kestrel 3000 pocket weather meter. Soil moisture and temperature were also recorded at each artificial cover object by inserting soil thermometer and moisture meter probes 10cm into the adjacent ground. The soil moisture meter was calibrated in water prior to each monitoring session. Finally, the precipitation for the 24hours previous to monitoring was obtained from Environment Canada's Weather Office records for the Region of Waterloo International Airport weather station (Environment Canada, 2009b).

Three soil samples were collected once, approximately half way through the monitoring season, from 10cm down beside each of the artificial cover objects where the weather variables were measured (listed above). After collection, these soil samples were air dried for approximately one week and analyzed for soil pH using a Hellige-Truog Soil Reaction tester. The three pH values for each artificial cover object were averaged.

A list of equipment required for salamander monitoring, as well as updated copies of blank field sheets are provided in Appendix B (and are also available on the ***rare*** network in the 'SALAMANDERS' folder).

2.2.2 - Comparisons Between Monitoring Years

All between-year, or repeated-measures, comparisons were done on the same number of monitoring weeks. Thus, for Indian Woods only data from the last five monitoring weeks in 2008 and 2009 were used to coincide with those weeks monitored in 2006 and, similarly, the last five weeks of 2009 Hogsback monitoring were used to coincide with the five weeks monitored in 2008.

Data from the three additional artificial cover objects (numbers 6,7,8) added to the Indian Woods monitoring plot in 2009 were removed from any between-year comparisons for an equal number of artificial cover objects (n= 29) across years.

All analyses were run in the statistical package 'SPSS 12.0 for Windows' (SPSS Inc. 1997). Test results were considered significant at p= 0.05.

Salamander Abundance

For the analysis of salamander abundance over time, all species observed were summed into one salamander count for each artificial cover object per monitoring week. Counts were not normally distributed, even after square root and natural log transformations, so non-parametric tests were used. For the three year repeated measures analysis of the Indian Woods data a Friedman's ANOVA was run. The two year repeated-measures Hogsback data was analyzed using a Wilcoxan signed rank test.

Salamander Abundance – Soil Parameter Correlation

Multiple linear regressions were used to determine the relationships between mean salamander abundance and mean soil moisture and temperature. All values were averaged over the five weeks of monitoring for each artificial cover object. Hierarchical regression methods were used; the first step contained mean soil temperature as the only predictor while the second step contained mean soil moisture as an additional parameter.

The assumptions of multiple linear regression analyses (e.g. normality and absence of collinearity among predictors) were met in all cases.

Soil Parameter Comparisons

As a follow-up to the abundance-soil parameter correlation, an additional analysis was run to determine; 1) if significant relationships between salamander abundance and either soil temperature or moisture existed, and 2) whether fluctuations in those soil parameters were significant between years. If significant differences existed between years, then they could help explain salamander abundance fluctuations from year to year.

Salamander abundance and soil moisture and temperature were averaged over the five weeks for each artificial cover object. Mean soil moisture and temperature values for Indian Woods were normally distributed. The additional assumption of sphericity was met by both mean soil moisture and temperature such that a repeated-measures ANOVA could be used.

Mean soil moisture and temperature values for the Hogsback were not normally distributed so a Wilcoxan signed-ranks test was used to compare the two years for each soil parameter.

Eastern Red-backed Salamander Snout-Vent Lengths

All species other than eastern red-backed salamanders were removed from the snout-vent length data. Snout to vent length data for both monitoring plots were non-parametric, thus, here too, Friedman's ANOVA was used to analyze the Indian Woods data and Wilcoxan signed-ranks test was used for the Hogsback. The data sets had unequal sample sizes across years but in both cases the analyses excluded unpaired data points (paired data sets equaled n= 156 and n= 40 for Indian Woods and the Hogsback, respectively).

2.3 - Results

2.3.1 - 2009 Monitoring

A summary of salamander abundances by species and date, as well as all raw salamander data, is available in Appendix C (Tables C.1 and C.2).

Total Abundance

A total of 182 salamanders were observed between August 31 and October 26 in Indian Woods (Figure 2.1A). The total abundance, which was 20 individuals on the first monitoring date, decreased the second week to 13 individuals but gradually increased over the next three weeks to 30 individuals on September 28th and peaked on October 12th with 37 individuals (Figure 2.1A).

In the Hogsback a total of 142 salamanders were observed between September 1 and October 27 (Figure 2.1B). The abundance of salamanders in the Hogsback followed a trend similar to that in Indian Woods, starting out relatively high on September 1st, decreasing for several weeks and then peaking with 20 individuals in early October before decreasing once more at the end of October (Figure 2.1B).

Species Abundance

Although in 2008 a blue-spotted/ possible Jefferson's salamander was found in Indian Woods, the only species observed in 2009 was the eastern red-backed salamander (Figure 2.1A). Of the eastern red-backed salamanders found, only 7.6% were the lead-backed morph.

In the Hogsback, a total of four species were found in 2009 (Figure 2.1B). In addition to the most common species, the eastern red-backed salamander, blue-spotted, spotted and four-toed salamanders were also present in the Hogsback. While it is possible that the blue-spotted salamander was really a Jefferson's salamander or a blue-spotted/Jefferson's hybrid, due to the absence of evidence it is reported here as a blue-spotted salamander.

Compared to the observed Indian Woods population, a much larger proportion of eastern red-backed salamanders in the Hogsback (21.0%) were lead-backed morphs.

Eastern Red-Backed Salamander Body Sizes

In both Indian Woods and the Hogsback, the majority of individuals observed in 2009 had snout-vent lengths in the range of 29.00-43.99mm (86.5% and 78.8%, respectively; Figure 2.2). Individuals with snout-vent lengths greater than 44.00mm were the second most abundant group in each study plot, while individuals with snout-vent lengths less than 24.00mm, likely representing the young of the year, were the least abundant (Figure 2.2).

Environmental Variables

Weather variables recorded during the monitoring period for both Indian Woods and the Hogsback are shown in Table 2.1.

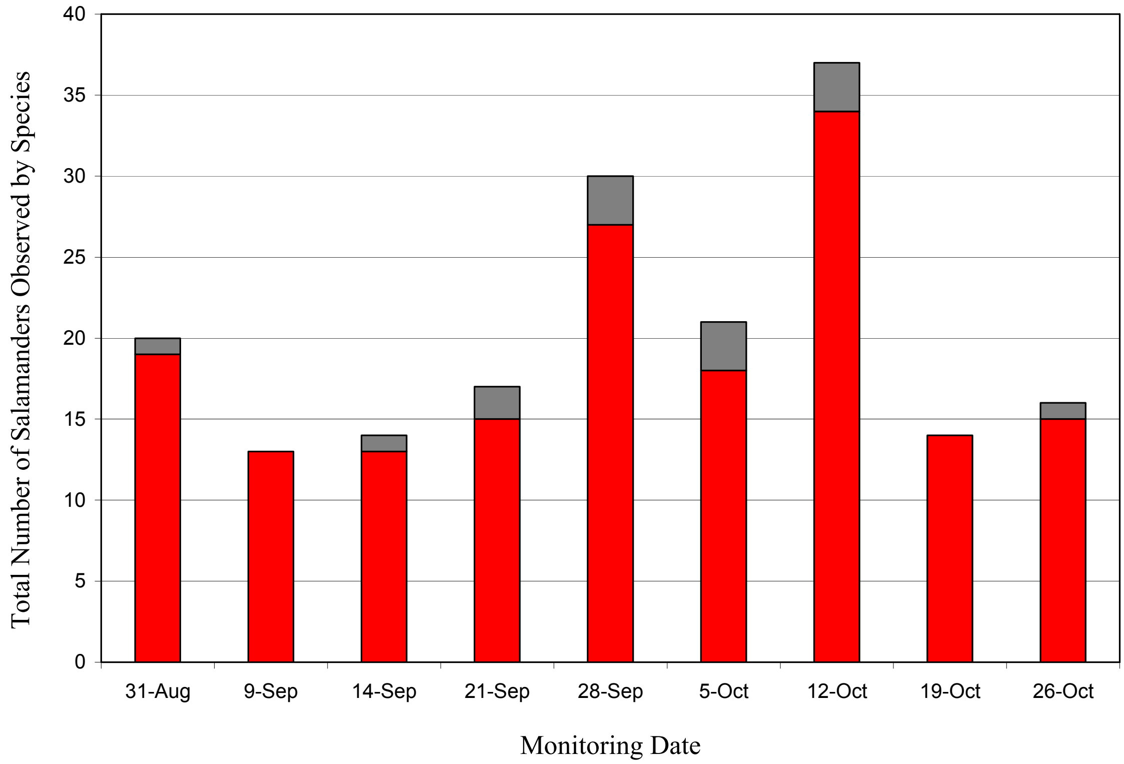
Mean soil moisture readings for both monitoring plots and the pond depth (Indian Woods only) tracked precipitation levels and followed the same general trend, with moisture levels and pond depth falling in the first weeks of September but then increasing after several rainy periods at the end of September and the beginning of October (Table 2.1, Figure 2.3). Mean soil moistures levels all decreased once more at the end of the monitoring period, although they remained higher than the lowest readings from the second (Hogsback) and third (Indian Woods) weeks of monitoring. The depth of the Indian Woods pond, on the other hand, fell from 35.5cm at the beginning of monitoring to the lowest measured depth of 16.0cm at the end of monitoring.

The north (boards 1-6) and west sides (boards 9-16) of the Indian Woods monitoring plot generally had higher mean soil moisture readings than either the south (boards 17-24) or east sides (boards 25-32; Figure 2.3A). The east side had especially low mean soil moisture readings that were consistently lower than any other side of the plot throughout the monitoring period. Similarly, the northwest side (boards 1-10) of the Hogsback monitoring plot was the moistest with consistently higher mean soil moisture content than the southeast side (boards 11-20; Figure 2.3B).

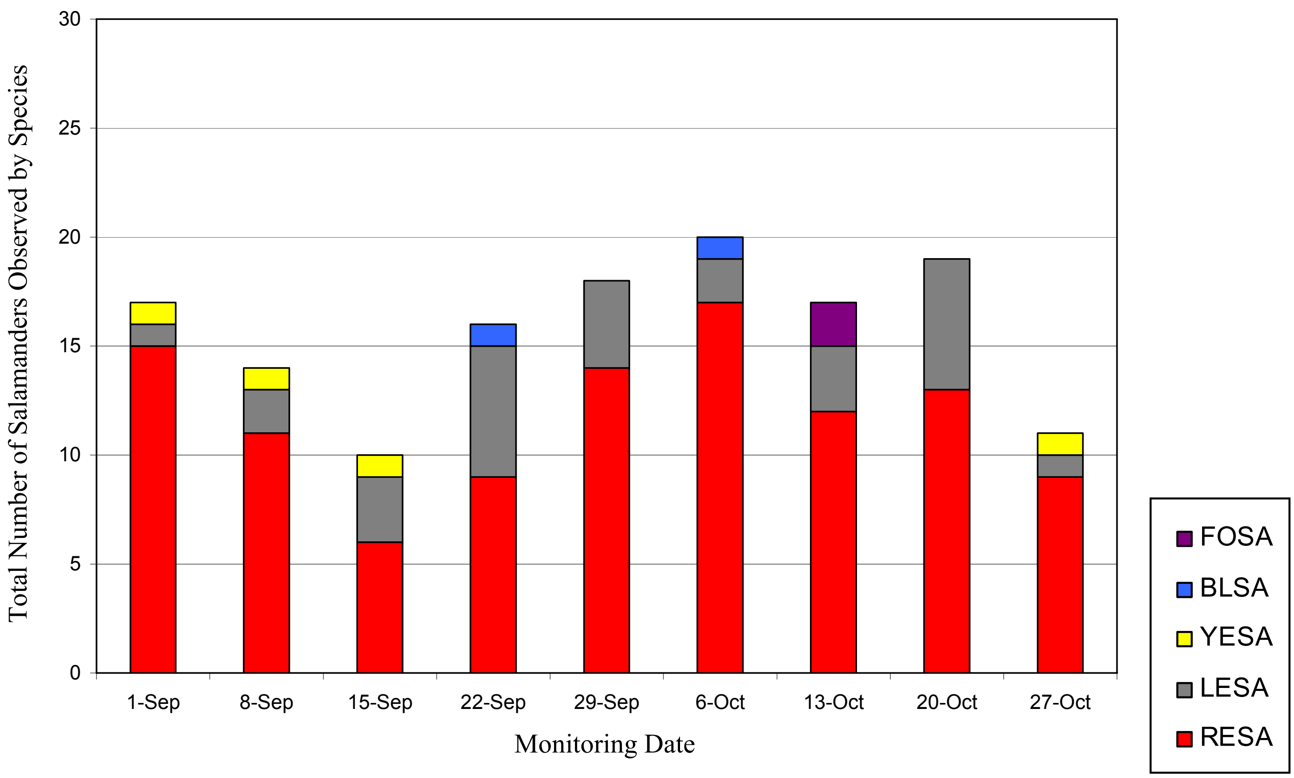
Mean soil temperatures followed the same general trend in both Indian Woods and the Hogsback; peaking in early September and then, with the exception of a second peak in the Hogsback on September 22nd, steadily decreasing to the lowest levels in mid-October (Figure 2.4). After this particularly cold period in mid-October, mean soil temperatures in both plots rose slightly once more.

The sides of each plot that had the highest mean soil moisture values also tended to have the lowest mean soil temperatures. In Indian Woods, the north and west sides of the plot were, before temperatures started dropping dramatically at the beginning of October, generally cooler than the warmer and drier south and east sides (Figure 2.4A). Similarly, the moister northwest side of the Hogsback plot was also generally cooler than the southeast side (Figure 2.4B).

Mean soil pH for Indian woods was 6.8 (ranging from 6.5 to 7.0; Figure 2.5A), while the mean pH for the Hogsback was slightly higher with an mean value of 7.6 (and ranging from 6.5 to 8.0; Figure 2.5B).

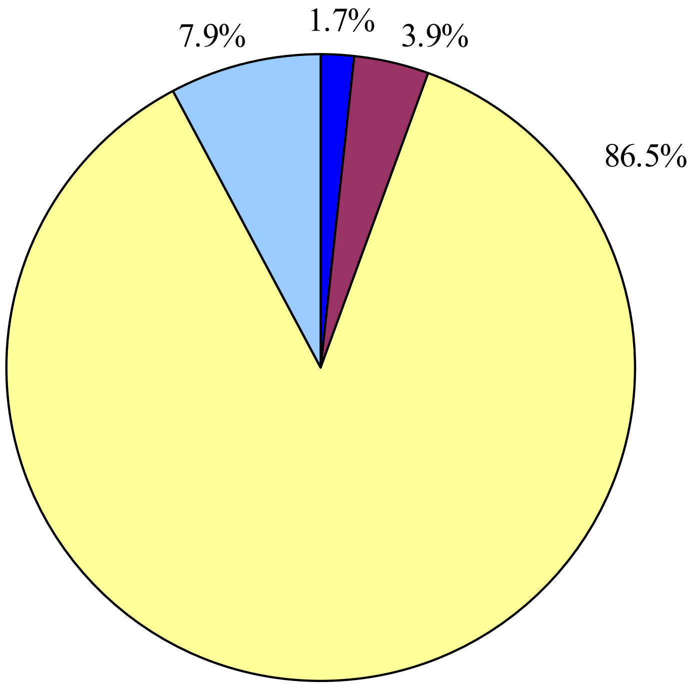


A – Indian Woods

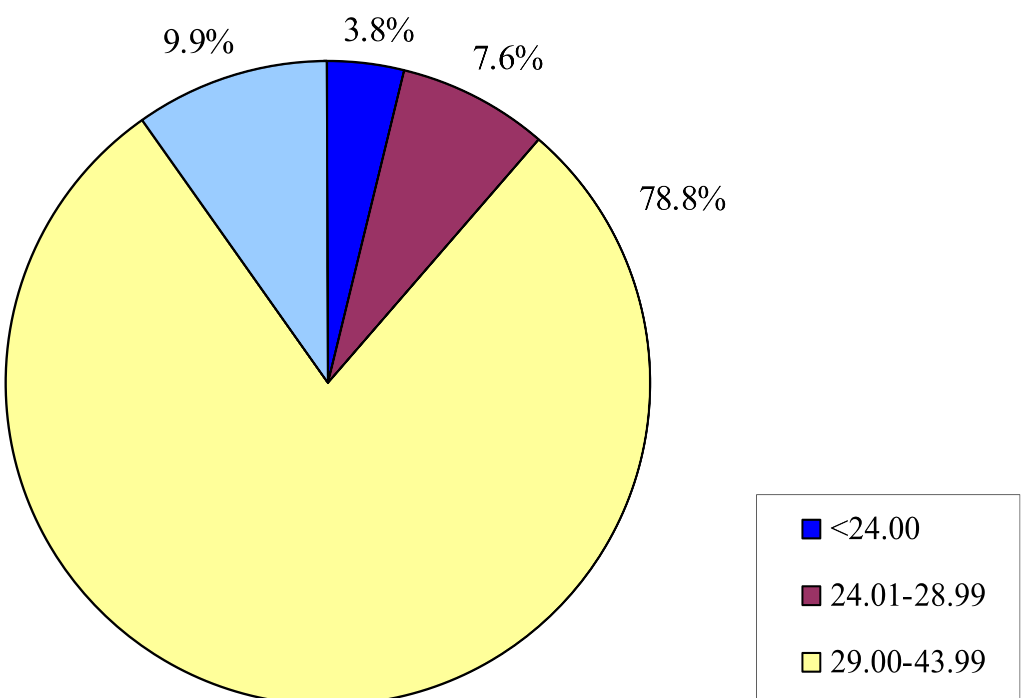


B - Hogsback

Figure 2.1. The total number of salamanders as well as the total number of individuals per species in A) Indian Woods and B) the Hogsback, over the monitoring period in 2009. (FOSA= four-toed, BLSA= blue-spotted, YESA= spotted, LESA= lead-backed morph of eastern red-backed, and RESA= eastern red-backed salamander).



A – Indian Woods



B – Hogsback

Figure 2.2. Percent of eastern red-backed salamanders in each snout-vent length class in A) Indian Woods and B) the Hogsback, in 2009

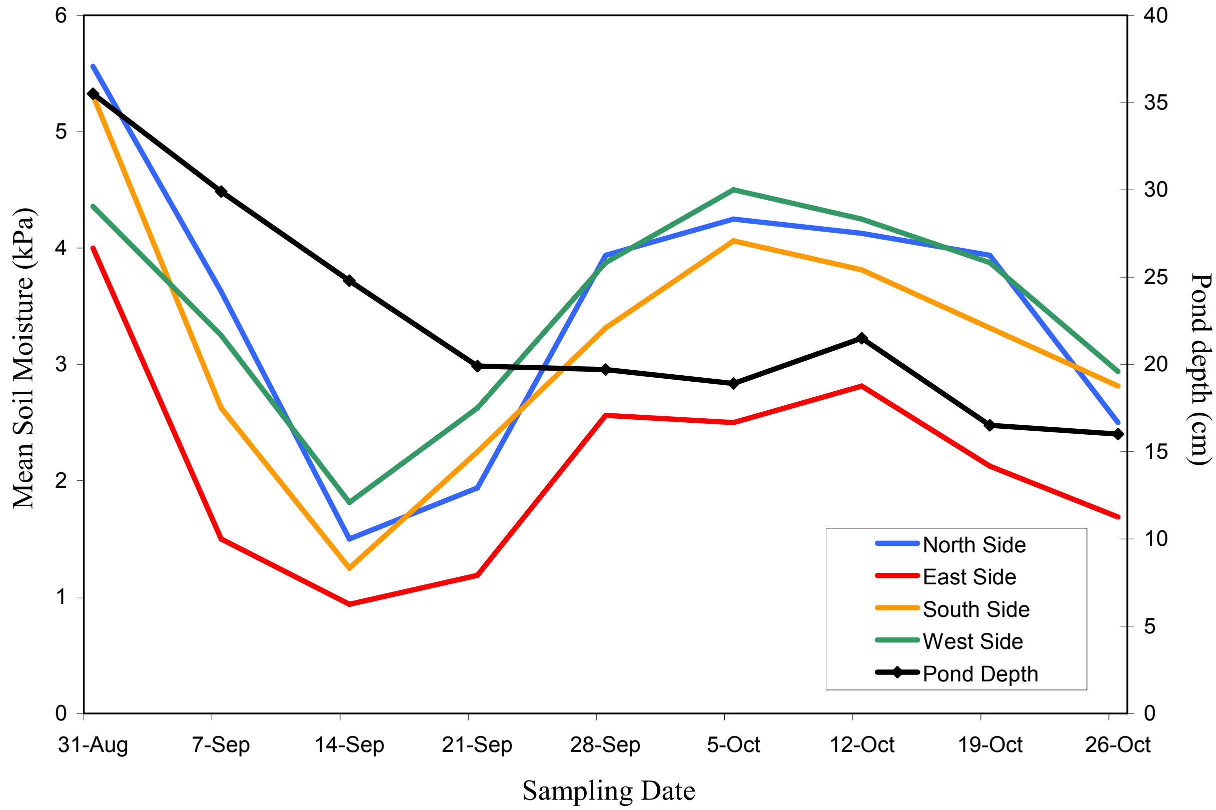
Table 2.1. The recorded weather variables for A) Indian Woods and B) the Hogsback in 2009.

A – Indian Woods

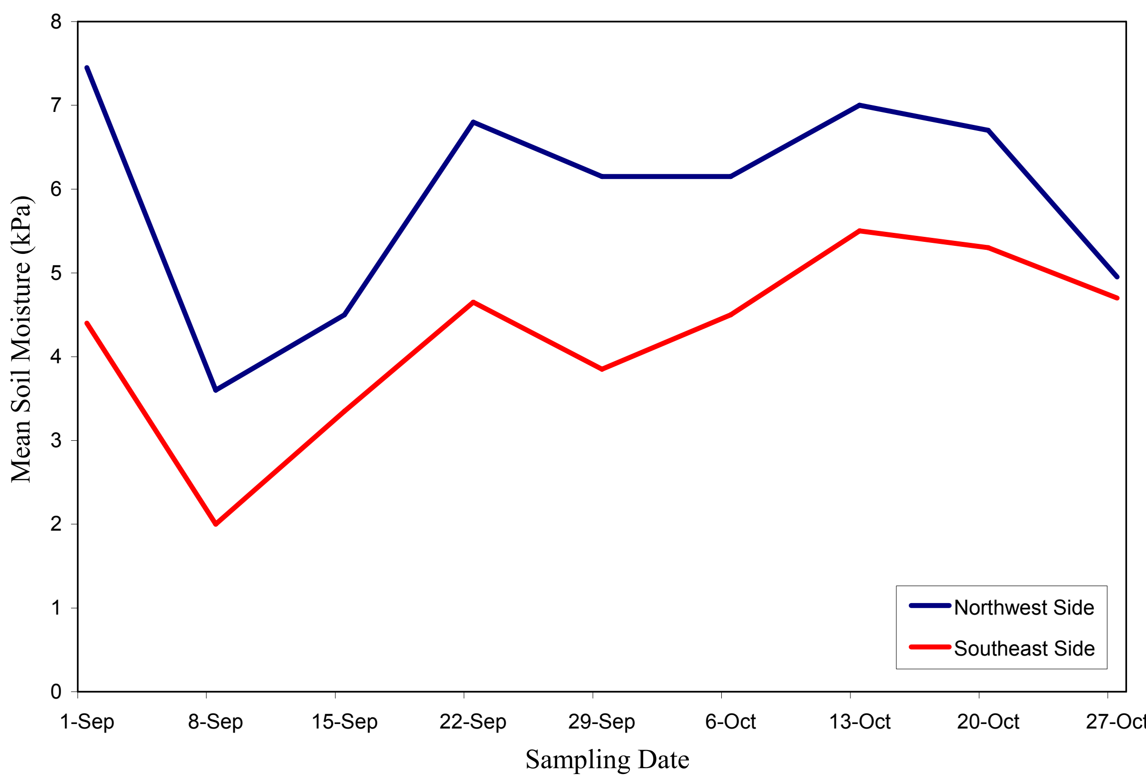
Date	Time	Observers	Beaufort: Sky Code	Beaufort: Wind Code	Mean Air Temp (˚C)	Mean Soil: Temp. (˚C)	Mean Soil: Moist. (kPa)	Precipitation (mm in previous 24 hours)
31-Aug	12:16-15:15	J. McCarter, P. Kelly	1	1	18.0	10.4	4.8	0.0
7-Sep	11:14-13:14	J. McCarter	0	1	22.4	12.8	2.8	0.0
14-Sep	11:00-13:50	J. McCarter, P. Kelly	2	2	20.7	12.1	1.4	0.0
21-Sep	10:00-12:20	J. McCarter	2, 6	0	17.8	10.4	2.0	0.5
28-Sep	12:07-14:32	J. McCarter	1	6, 7	14.1	10.0	3.4	0.5
5-Oct	10:00-12:00	J. McCarter, A. Dean	1	2, 3	11.0	6.1	3.8	1.0
12-Oct	11:30-13:30	J. McCarter	2	0	6.3	1.2	3.8	0.0
19-Oct	11:43-13:00	J. McCarter	0	3	12.4	1.0	3.3	0.0
26-Oct	12:50-14:00	J. McCarter, A. Gillespie	1	2	15.2	4.7	2.5	0.0

B – Hogsback

Date	Time	Observers	Beaufort: Sky Code	Beaufort: Wind Code	Mean Air Temp (˚C)	Mean Soil: Temp. (˚C)	Mean Soil: Moist. (kPa)	Precipitation (mm in previous 24 hours)
1-Sep	10:00-10:45	J. McCarter, A. Dean	2	3	12.0	9.4	4.8	0.0
8-Sep	10:15-11:56	J. McCarter, A. Gillespie, Katsu Tokuda, M. Crooks	2	0	21.2	12.1	2.8	0.0
15-Sep	10:30-11:30	J. McCarter, M. Lawson	0	0	21.8	11.7	3.9	0.0
22-Sep	10:00-11:30	J. McCarter, Shun Oikawa	2	0	21.2	12.1	5.7	8.5
29-Sep	10:20-11:45	J. McCarter	2	2	13.2	8.7	5.0	15.0
6-Oct	10:00-11:30	J. McCarter, J. Vassallo	2	0	11.8	5.7	5.3	1.5
13-Oct	10:30-12:00	J. McCarter, A. Dean, A. Gillespie	2	2, 3	6.6	2.6	6.3	0.0
20-Oct	10:30-12:00	J. McCarter, A. Gillespie	2	1	14.4	4.4	6.0	0.0
27-Oct	10:00-10:45	J. McCarter, A. Dean	2	3	12.0	4.3	4.8	0.0

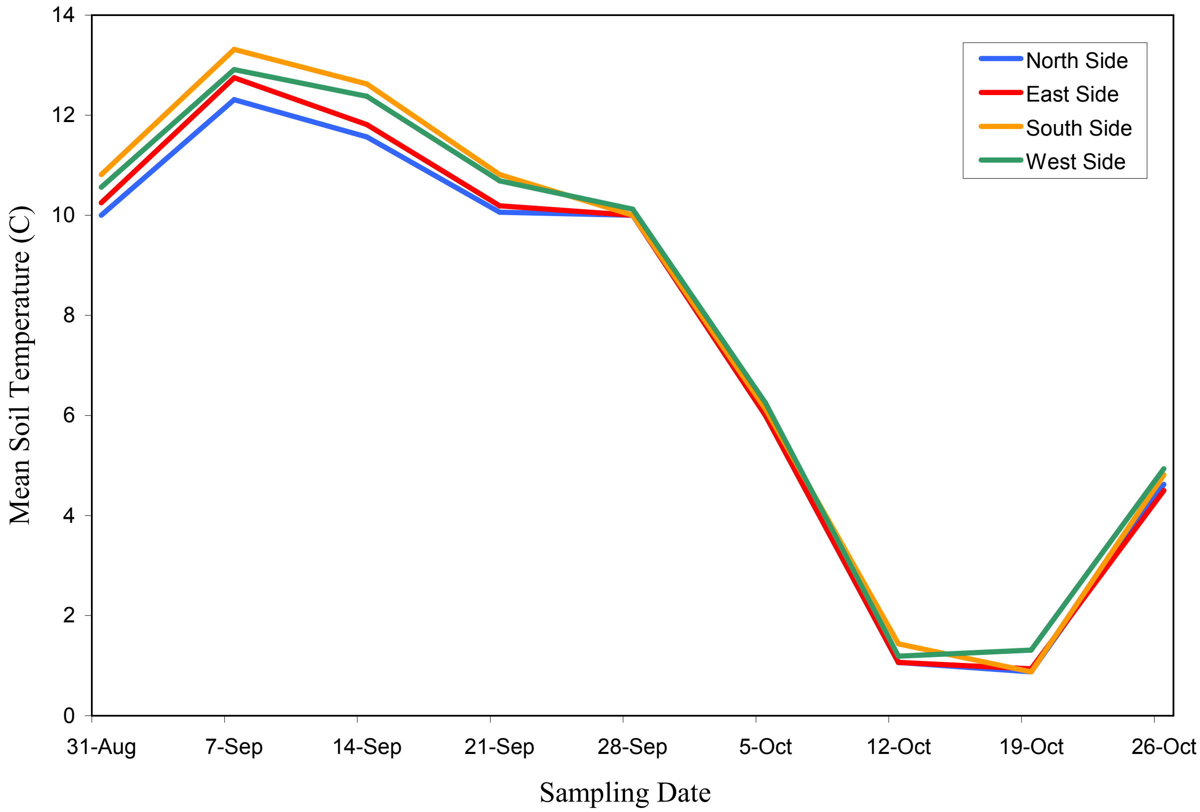


A – Indian Woods

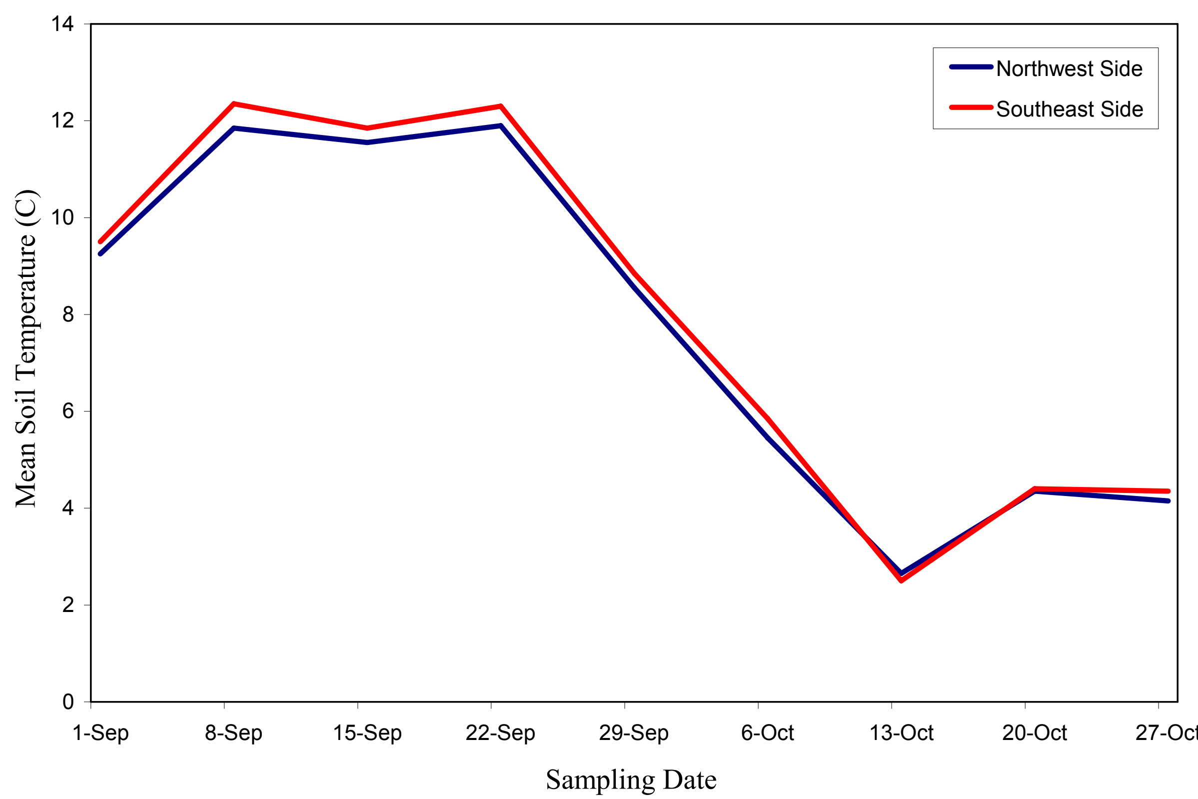


B - Hogsback

Figure 2.3. Mean soil moisture (and pond depth for Indian Woods) by monitoring date and side of the monitoring plot for A) Indian Woods and B) the Hogsback.

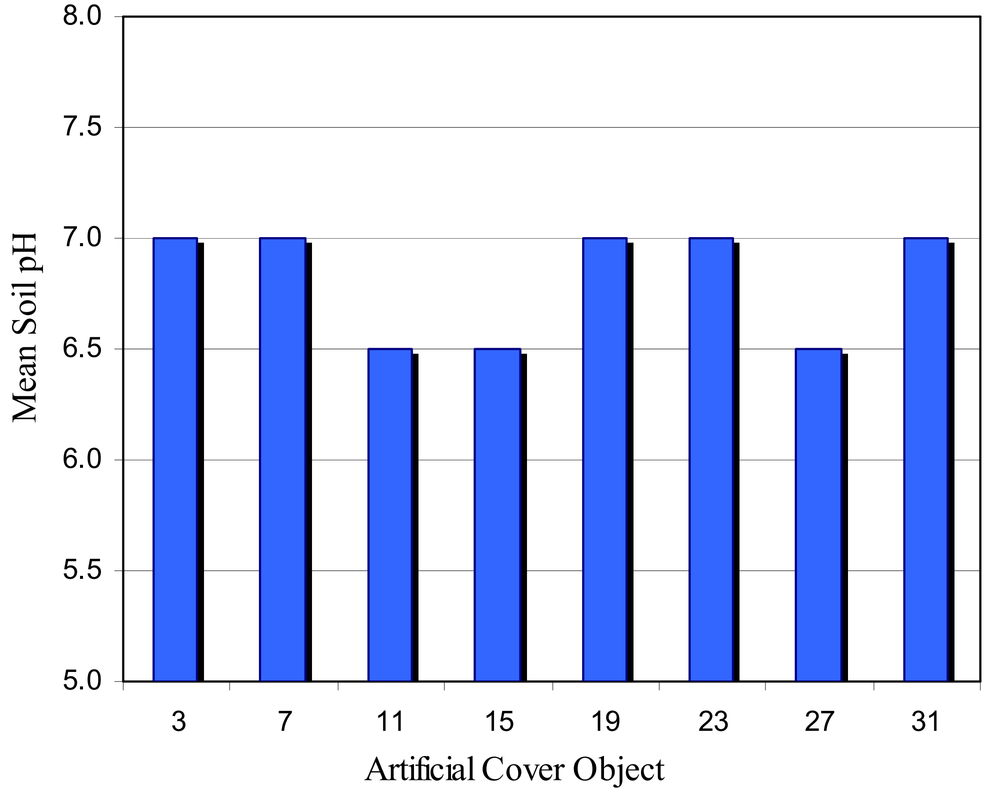


A – Indian Woods

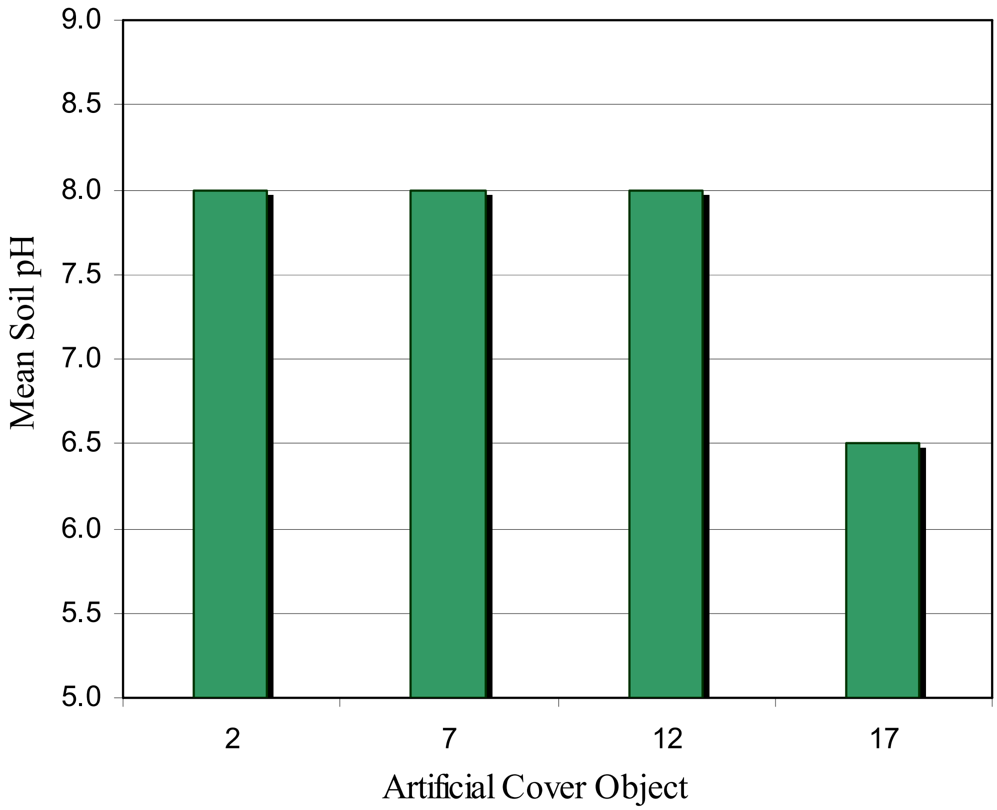


B - Hogsback

Figure 2.4. Mean soil temperature by monitoring date and side of the monitoring plot for A) Indian Woods and B) the Hogsback.



A – Indian Woods



B - Hogsback

Figure 2.5. Mean pH of soil near selected artificial cover objects in A) Indian Woods and B) the Hogsback.

2.3.2 - Comparisons between monitoring years

Salamander Abundance

There were no significant differences in mean salamander abundances between monitoring years in Indian Woods ($\chi^2_{(2)}$= 3.75, p= 0.154; Figure 2.6A). In the Hogsback, on the other had, the second monitoring year had significantly higher observed mean salamander abundances than the first (Z= -2.33, p= 0.020; Figure 2.6B).

Salamander Abundance – Soil Parameter Relationship

Mean soil temperature had a significant positive effect on mean salamander abundances in Indian Woods over the three monitoring years, although it only accounted for 5.8% of mean abundance variability (Table 2.2A, Figure 2.7A). Mean soil moisture, on the other hand, had a slight, non-significant, negative effect, accounting for only an additional 1.1% of the variability on mean salamander abundance in Indian Woods (Table 2.2A, Figure 2.7B). In the Hogsback mean soil temperature also had a positive effect on mean salamander abundance, although not a significant one (accounting for 4% of the variability in mean salamander abundance; Table 2.2B, Figure 2.7C). Mean soil moisture also had a significant negative effect on mean salamander abundance in the Hogsback, but it accounted for a much higher percent (41%) of the variability in mean salamander abundance (Table 2.2B, Figure 2.7D).

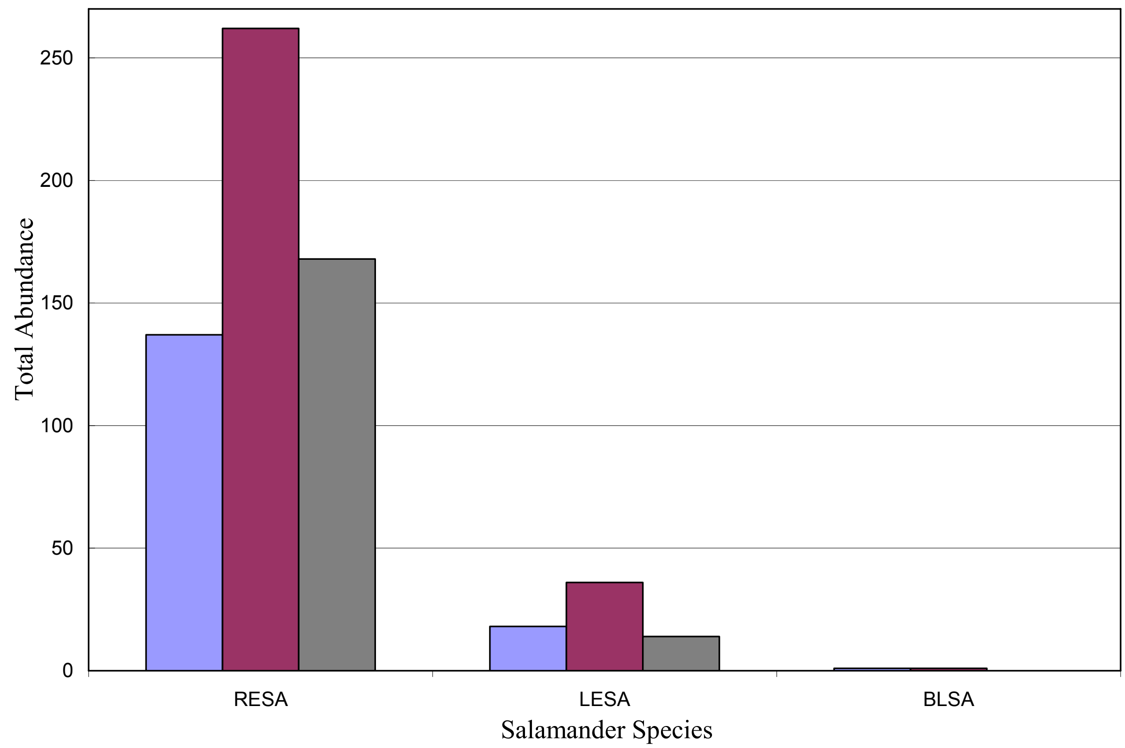
Soil Parameters Comparisons

Soil moisture measurements were significantly different between the three years of monitoring in Indian Woods ($F_{(2, 56)}$= 29.06, p< 0.001; Figure 2.8A). More specifically, year to year contrasts revealed that 2006 and 2008 ($F_{(1, 28)}$=18.21, p< 0.001) and 2008 and 2009 ($F_{(1, 28)}$= 13.41, p= 0.001) were significantly different from each other in terms of soil moisture. The same trend held for soil temperature in Indian Woods; there were significant differences in soil temperature between all years ($F_{(2, 56)}$= 2125.95, p< 0.001) with the mean soil temperatures decreasing each year (Figure 2.8B).

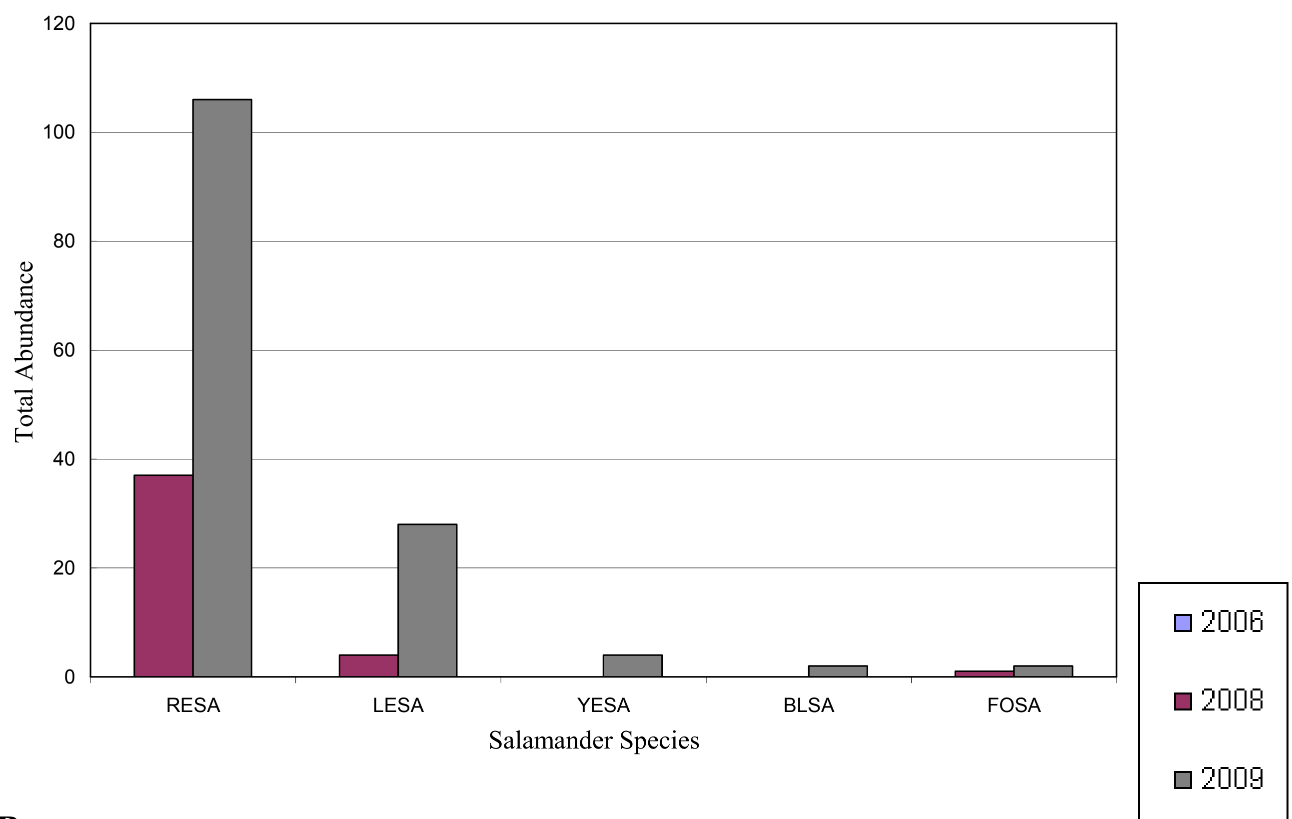
Soil measurements were significantly different between years in the Hogsback, as well, with 2009 being the drier (Z= -3.72, p< 0.001; Figure 2.9A), cooler year (Z= -3.93, p< 0.001; Figure 2.9B).

Eastern Red-backed Salamander Snout-Vent Lengths

Although there were slight differences in the percent of salamanders in each size class (Figure 2.10), overall, snout-vent lengths of eastern red-backed salamanders have not changed significantly between monitoring years in either Indian Woods ($\chi^2_{(2)}$= 5.435, p= 0.066) or the Hogsback ($z_{(1)}$= -0.632, p= 0.528).



A – Indian Woods



B - Hogsback

Figure 2.6. The total number of salamanders found in A) Indian Woods and B) the Hogsback for each year of monitoring.

Table 2.2. Hierarchical multiple regression results predicting mean salamander abundance for A) Indian Woods and B) the Hogsback.

A – Indian Woods

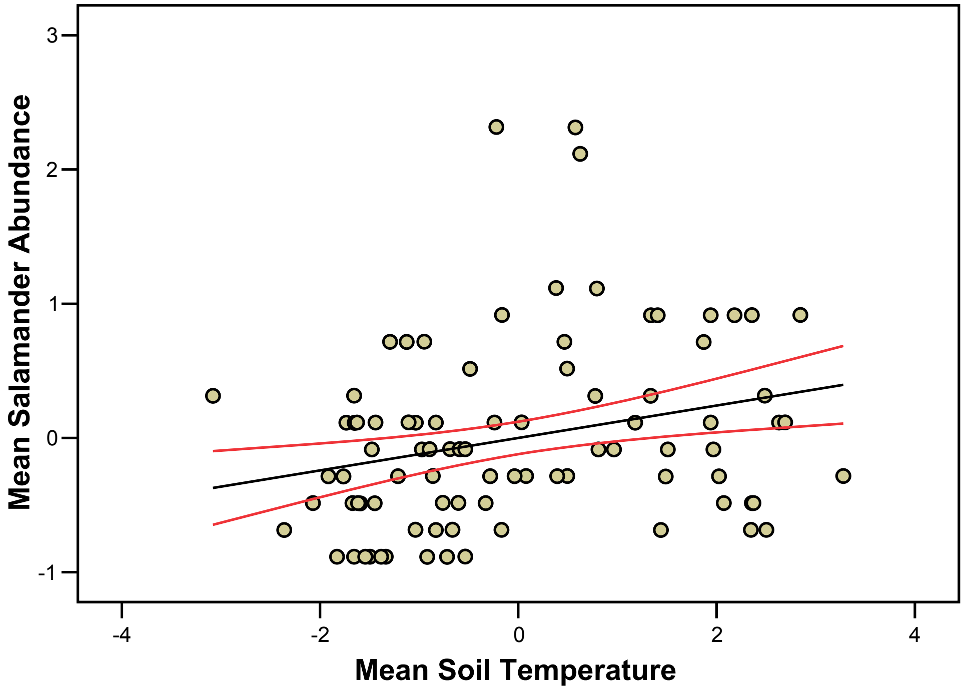
	B	**SE**	**ß**
Step 1			
Constant	0.25	0.29	
Mean Soil Temperature	0.10	0.04	0.24*
Step 2			
Constant	0.34	0.30	
Mean Soil Temperature	0.12	0.05	0.29*
Mean Soil Moisture	-0.05	0.05	-0.11

R^2 for step 1 = 0.058*; ΔR^2 for step 2 = 0.011; *p<0.05

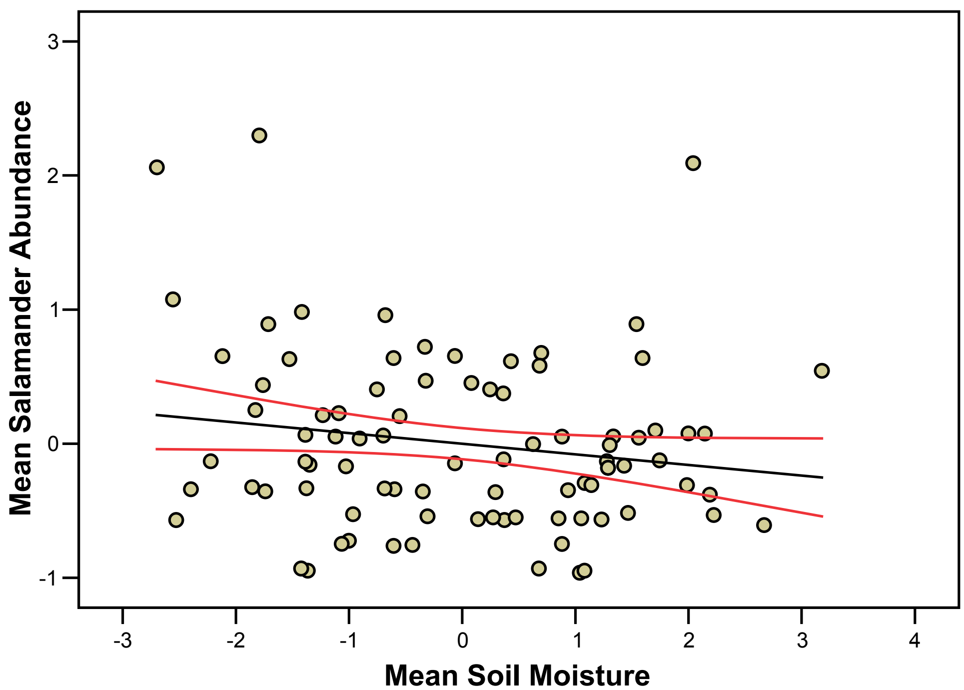
B – Hogsback

	B	**SE**	**ß**
Step 1			
Constant	3.42	0.93	
Mean Soil Temperature	-0.16	0.13	-0.2
Step 2			
Constant	4.08	0.72	
Mean Soil Temperature	0.01	0.10	0.02
Mean Soil Moisture	-0.32	0.06	-0.68*

R^2 for step 1 = 0.04; ΔR^2 for step 2 = 0.41*; *p<0.001

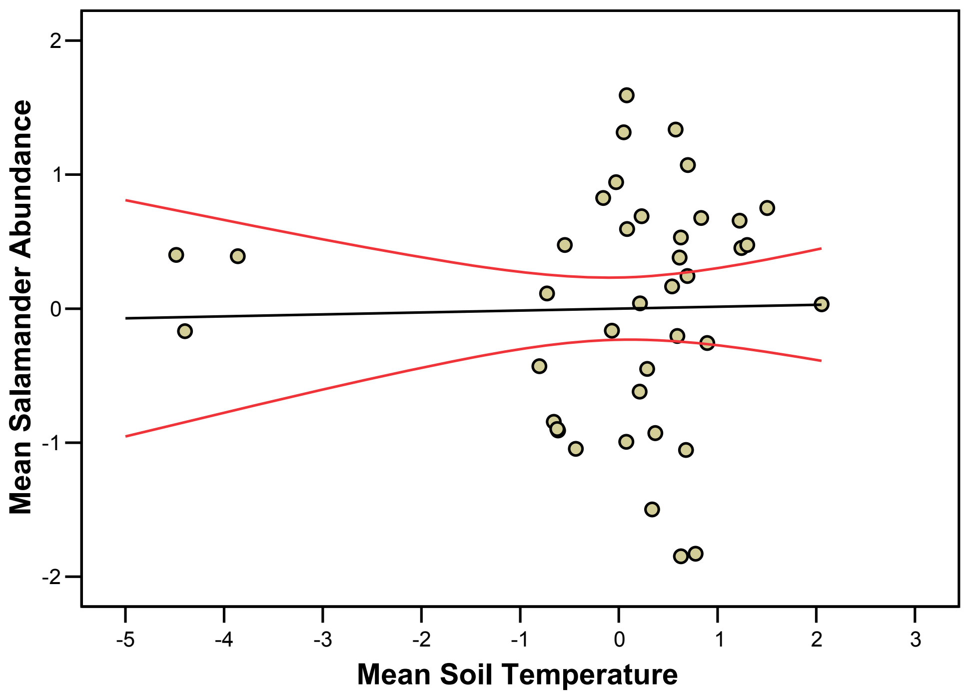


A – Mean Soil Temperature - Indian Woods

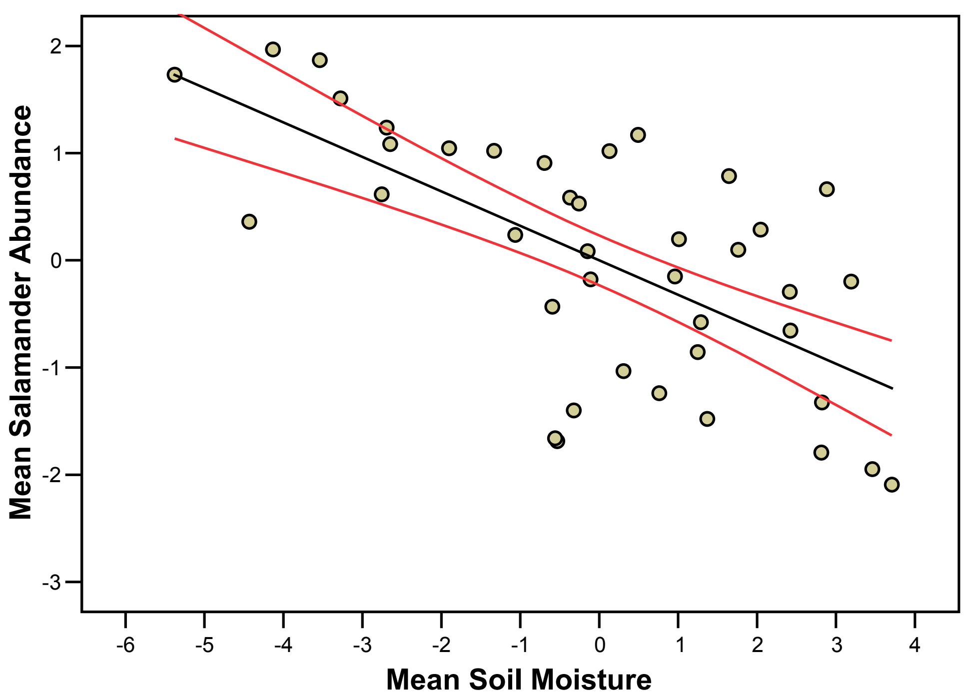


B – Mean Soil Moisture - Indian Woods

Figure 2.7. Partial regression plots for mean salamander abundance versus mean soil temperature and moisture for Indian Woods (A, B) and the Hogsback (C, D). Best fit line (black) and 95% confidence intervals (red) for the mean are shown.

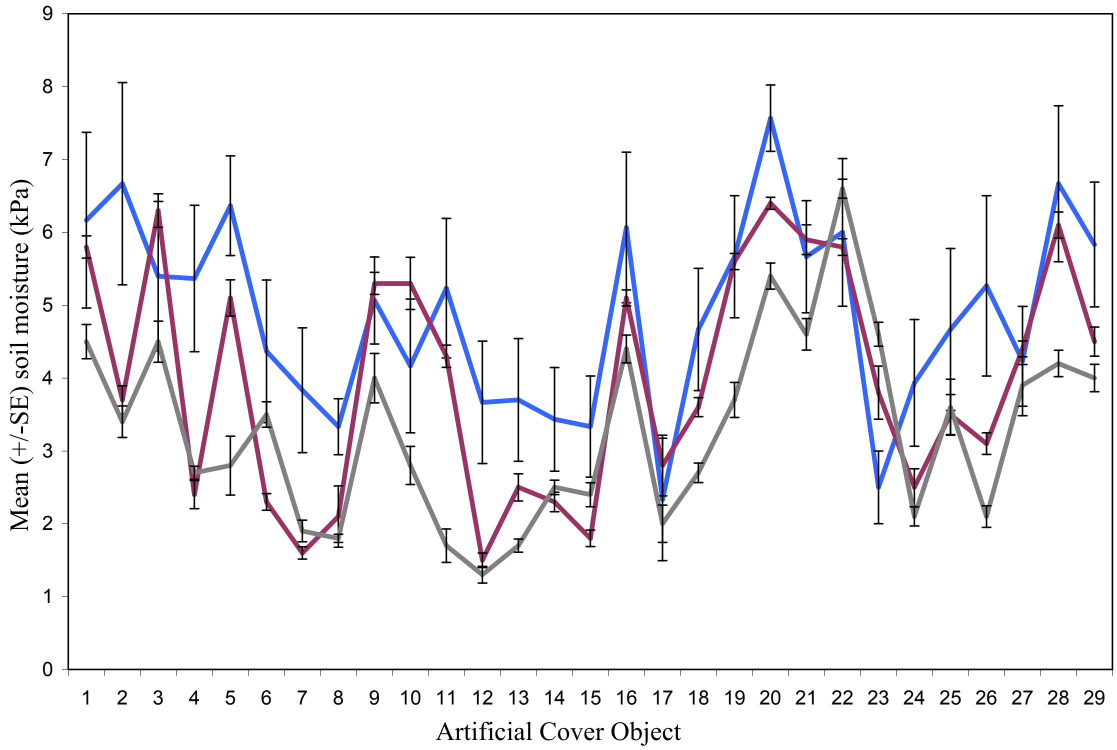


C – Mean Soil Temperature - Hogsback

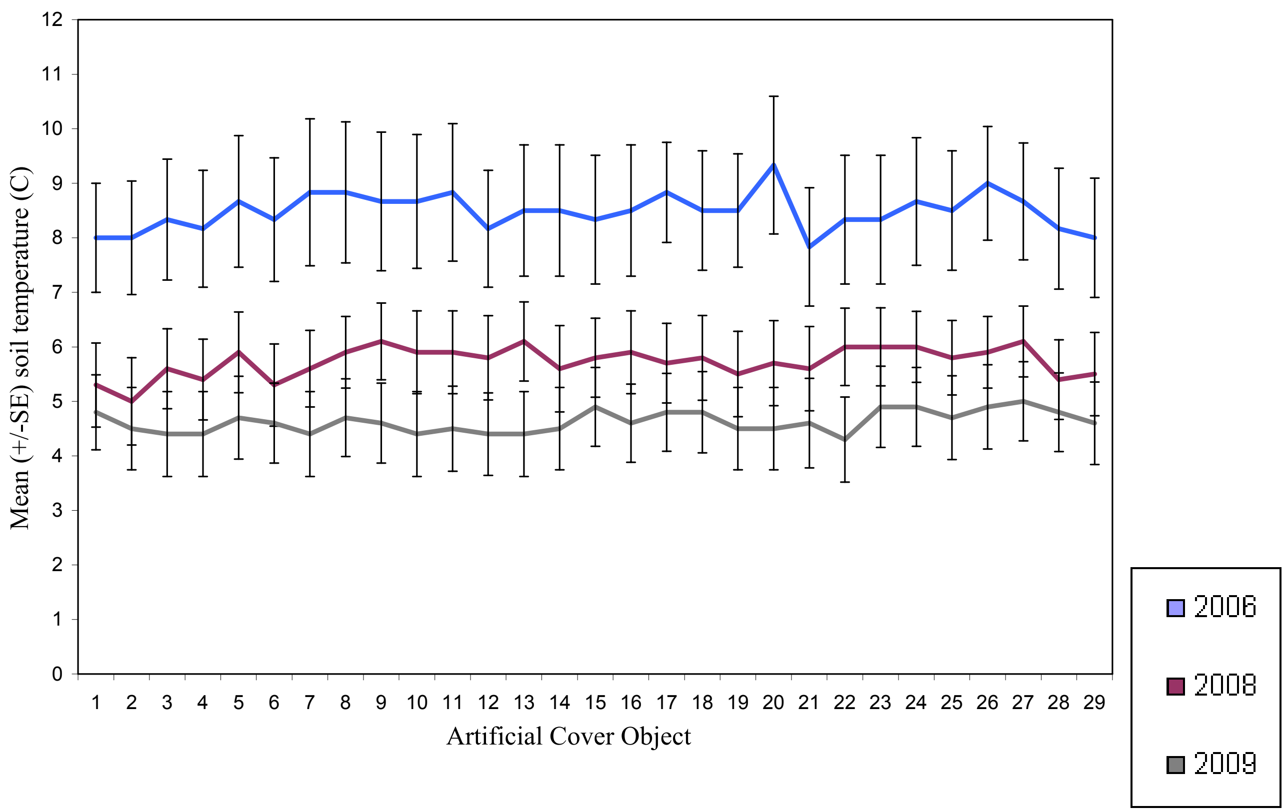


D – Mean Soil Moisture - Hogsback

Figure 2.7 (continued). Partial regression plots for mean salamander abundance versus mean soil temperature and moisture for Indian Woods (A, B) and the Hogsback (C, D). Best fit line (black) and 95% confidence intervals (red) for the mean are shown.

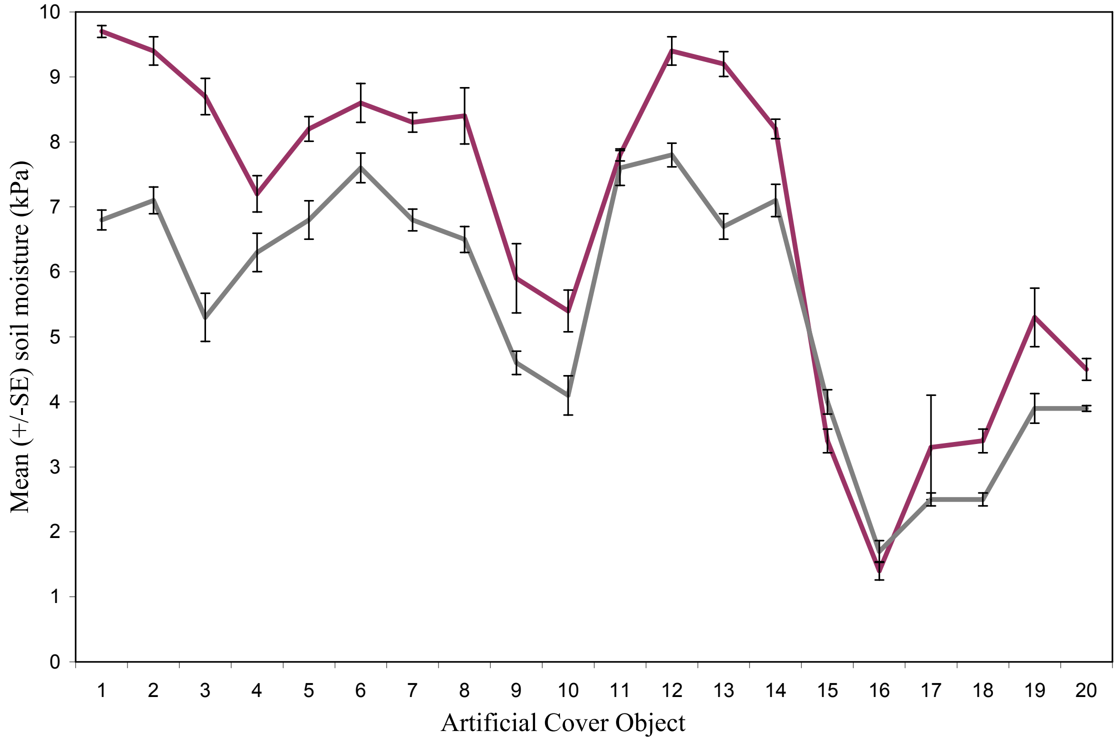


A – Soil Moisture

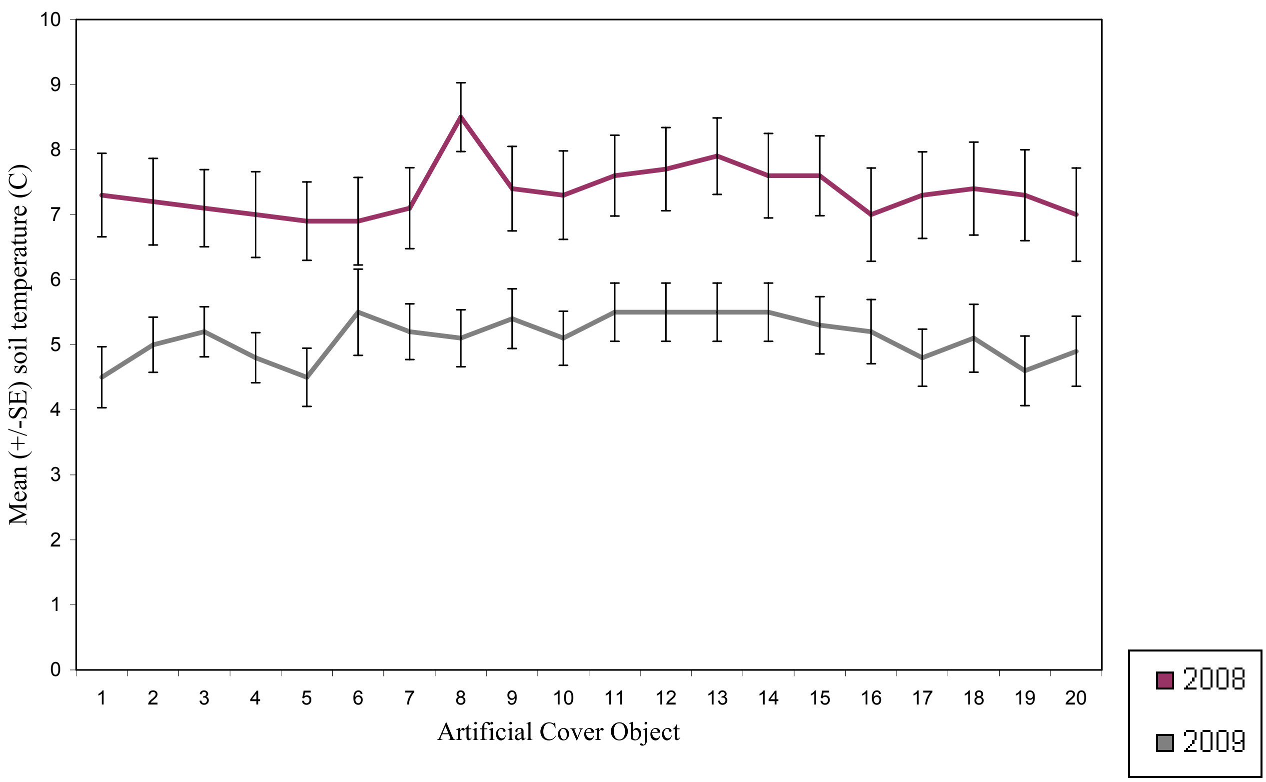


B – Soil Temperature

Figure 2.8. Mean (+/-SE) soil moisture (A) and soil temperature (B) for each artificial cover object in Indian Woods.

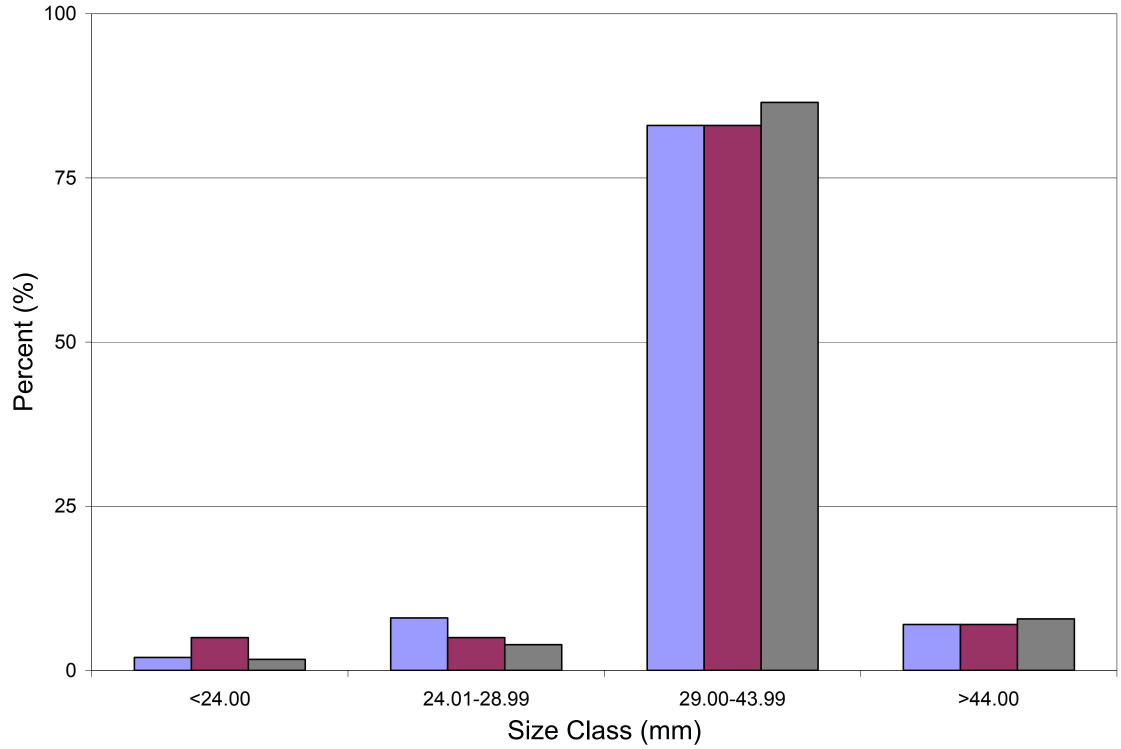


A – Soil Moisture

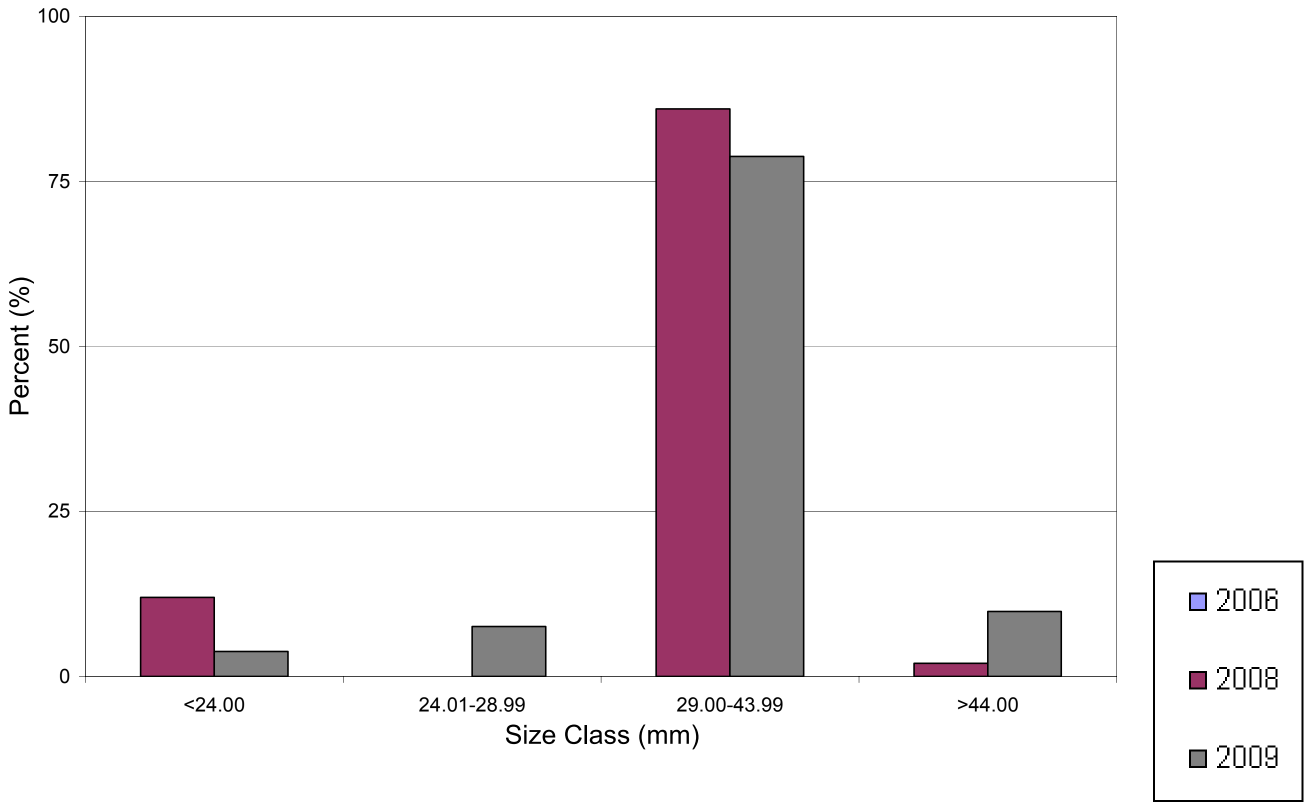


B – Soil Temperature

Figure 2.9. Mean (+/-SE) soil moisture (A) and soil temperature (B) for each artificial cover object in the Hogsback.



A – Indian Woods



B - Hogsback

Figure 2.10. The percent of eastern red-backed salamanders (both colour morphs) observed in each of the four snout-vent size classes for A) Indian Woods and B) the Hogsback.

2.4 – Discussion

2.4.1 - Comparisons between monitoring years

For the first time, since the beginning of ***rare***'s plethodontid salamander monitoring program in 2006, enough data was available to conduct between-year analyses.

Salamander Abundance

One of the primary questions to be addressed by ***rare***'s salamander monitoring regards the long-term trends as indicated by salamander populations at ***rare.*** Statistical analyses of salamander abundance data in Indian Woods over three years showed no significant differences. In the Hogsback, on the other hand, salamander abundance was higher in the second year of monitoring.

Two things should be kept in mind when considering these trends. First, the three years of data in Indian Woods were not consecutive; no data was collected in 2007. This is relevant as the drastic, although not statistically significant, increase in salamander abundance between 2006 and 2008 may have actually been more gradual.

Second, and more importantly, the significant difference between 2008 and 2009 salamander abundances in the Hogsback could represent, rather than increased abundance, increased use of the artificial cover objects by salamanders. Eastern red-backed salamanders are territorial (Ransom and Jaeger, 2006) with males and females both defending areas under rocks and logs from other individuals (Mathis, 1991). Thus as more time passed since installing the boards, more salamanders were likely to find, inhabit and defend, areas under artificial cover objects.

While it is still relatively early in this long-term monitoring initiative, and despite the two caveats discussed above, the trends in salamander populations at both sites, thus far, are encouraging; since the beginning of monitoring, neither site has experienced a significant decrease in salamander abundance.

Salamander Abundance – Soil Parameter Relationship

The trends observed in the relationships between salamander abundance and soil temperature and soil moisture were similar for both monitoring plots. In Indian Woods, soil temperature had a significant positive effect on salamander abundance and, while it was not significant, soil temperature also had a small positive effect in the Hogsback. Soil moisture, on the other hand, had a small (non-significant) negative effect in Indian Woods and a significant negative effect on salamander abundance in the Hogsback. Salamanders prefer moist micro-climates (Wyman, 1988) and are more active in cooler, moister weather (Jaeger, 1978), so it is logical that increasing temperatures would increase the number of salamanders seeking refuge under artificial cover objects. It is also logical that soil moisture would be negatively correlated with observed salamander abundance; when their environment is more moist, salamanders are more likely to be foraging and moving about on the forest floor rather than seeking refuge under artificial cover objects.

It remains enigmatic why in each monitoring plot, a different soil parameter was more influential. It could be that additional, unmeasured habitat variables were affecting these relationships. Additional data will help elucidate the true nature of the relationship between salamander abundance and soil moisture and temperature at these sites.

Soil Parameters Comparisons

In both monitoring plots the trends in mean soil parameters were the same; mean soil moisture and temperatures dropped from year to year with 2009 being the driest and coolest year since the beginning of monitoring. Although mean salamander abundance at each artificial cover object was significantly effected by mean soil temperature in Indian Woods and mean soil moisture in the Hogsback (above), these trends did not translate into overall mean salamander abundances being correlated with overall mean soil parameters at each artificial cover object. For example, while mean soil moisture had a significant negative effect on mean salamander abundance and 2009 was less moist than 2008, salamander abundance was actually much higher in 2009. Further, decreasing mean soil temperatures in Indian Woods did not cause the expected increase in mean salamander abundance. This suggests that mean salamander abundance is affected by variables other than soil moisture and temperature. For example, these data do not account for invertebrate prey abundance which could also fluctuate from year to year.

Eastern Red-backed Salamander Snout-Vent Lengths

Snout-vent lengths of eastern red-backed salamanders have not changed significantly between monitoring years in either Indian Woods or the Hogsback. It should be noted that the age-structure of salamanders observed under artificial cover objects does not necessarily reflect that of the population as a whole. For example, in their study, Marsh and Goicochea (2003), found significantly more adult salamanders under artificial cover objects compared to natural ones and gave several possible explanations for this observation (e.g. territoriality, preference of larger salamanders to dwell under larger cover objects or decreased reproductive success under artificial cover objects). Regardless of the mechanism, however, ***rare*** is building a baseline dataset of salamander abundances and measurements for comparison over time, not to extrapolate necessarily to the larger ***rare*** population. Thus, whether or not the sizes of salamanders observed under the boards are representative of the larger population, the fact that there has been very little change in those sizes from year to year suggests little has changed in the environment.

2.4.2 – Conclusion

Salamander populations on ***rare*** property do not appear to be declining, but rather the first years of monitoring indicate that they are stable in Indian Woods and either stable or potentially increasing in the Hogsback. Continued monitoring, however, will give more strength to the analyses that identified these trends. Further monitoring will also allow for the remaining, more general, research questions regarding trends in the ecological health and integrity of Indian Woods and the Hogsback as well as the effects of various landscape changes, to be addressed.

3.0 - Benthic Invertebrate Monitoring

3.1 – Introduction

Benthic Invertebrates as Indicators

Benthic invertebrates are those that inhabit the benthic zone or the lowest levels, including the sediment surface and sub-surface layers, in a body of water.

Benthic invertebrates are ideal organisms for indicating the health of aquatic ecosystems for several reasons: 1) they are ubiquitous in most aquatic systems and thus are likely to be affected by a range of perturbations occurring in a range of different habitats, 2) their taxonomic diversity means that they exhibit a variety of responses to a variety of different perturbations, 3) their sedentary nature allows researchers to locate the spatial extent of perturbations, and 4) they are critical components of their food webs such that changes affecting them are likely to cascade to other trophic levels (Merritt and Cummins, 1996; Richardson and Jackson, 2002).

Ontario Benthos Biomonitoring Network

The Ontario Benthos Biomonitoring Network (OBBN) is a province wide benthic biomonitoring program which, along with EMAN, provides training, equipment, support and an online database to program participants. Their mission is to "enable the assessment of aquatic ecosystem condition using benthos as primary indicators of water and habitat quality" (Jones *et* al., 2007). OBBN promotes standardized macroinvertebrate sampling techniques with the use of site and catchment scale characteristics in order to ensure optimal comparability of benthic data throughout Ontario and with other provincial and national benthic biomonitoring networks, including the Canadian Aquatic Biomonitoring Network (CABIN). The OBBN's database has five purposes: 1) storing, querying and retrieving data for all OBBN reference and test sites, 2) sharing reference and test site data among all OBBN participants, 3) calculating bioassessment indices, 4) providing quality control checks on entered data, and 5) providing opportunities for data sharing between similar databases like CABIN (Jones *et* al., 2007).

Benthic Invertebrate Monitoring at *rare*

The focus of the aquatic monitoring program at ***rare*** is to examine benthic invertebrates from natural, coldwater stream, specifically Bauman and Cruickston Creeks, and wetland habitats on ***rare*** property using protocols prepared by EMAN and OBBN. The long-term research questions remain the same as those initially proposed in 2006 and are as follows:

- What is the current state of ***rare's*** aquatic ecosystems, and how do they compare to one another?
- What are the long-term trends taking place within the aquatic ecosystems at ***rare***?
- Is the ecosystem integrity[2] of these aquatic ecosystems being maintained or improved under ***rare*** management?
- What is the quality of the aquatic and riparian habitat of the aquatic ecosystems on ***rare***, and how do they compare with one another?

- Is either the ecological health[1] or integrity of ***rare***'s aquatic ecosystems being affected by on-site changes in agriculture and/or restoration efforts being implemented by ***rare***?

These data will, and continue to, provide the basis for a long-term monitoring program at ***rare***. Trends observed in benthic invertebrate abundance and diversity will help ***rare*** determine the ecological health of ***rare***'s streams and wetlands. The results from this study will also be helpful as ***rare*** considers new management plans and restoration and research projects.

1 - Ecological health can be defined, within an ecosystem management context, as, "a condition wherein [an ecosystem] has the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency[3], while meeting current and future needs of people for desired levels of values, uses, products, and services" (Styers *et* al., 2010; Twery and Gottschalk, 1996).
2 - Ecological integrity is defined by Parks Canada (2009) as, "…a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes." Further, Parks Canada defines an ecosystem as having integrity when, "…they have their native components intact, including: abiotic components (the physical elements, e.g. water, rocks), biodiversity (the composition and abundance of species and communities in an ecosystem, e.g. tundra, rainforest and grasslands represent landscape diversity; black bears, brook trout and black spruce represent species diversity) and ecosystem processes (the engines that makes ecosystem work; e.g. fire, flooding, predation)."
3 - Ecological resiliency is defined as, "the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures (defined as alternative stable states)" or, "a return time to a stable state following a perturbation." (Gunderson, 2000).

3.2 – Methods

Monitoring Locations

The benthic monitoring program at ***rare*** consists of eleven sites; four sites on Bauman Creek, five sites on Cruickston Creek (including three new sites in 2009) as well as two new sites on Blair and Preston Flats Wetlands (Appendix A, Figure B.3).

The original sites selected in 2006 were chosen using a stratified random sampling technique based on habitat type and in accordance with guidelines laid out in the OBBN protocol (Jones *et* al., 2007). This was done to facilitate a wider range of future monitoring if warranted, including electrofishing and habitat assessment, which could easily be tied into the program.

Sites newly added in 2009 were selected to monitor specific environmental changes. Two of the new sites on Cruickston Creek, for example, were added to specifically monitor the health of the creek before and after the planned removal of the culvert on Springbank Lane. The third new site on Cruickston Creek was located in the Hogsback in order to better monitor changes which may occur after construction of a planned subdivision just south of the Hogsback. Finally, the two new wetland sites were added to monitoring changes at these sites as the flats undergo restoration from conventional agricultural fields to more naturalized grasslands (tall grass prairie, in the case of Blair Flats).

<u>Bauman Creek</u>

Bauman and Cruickston Creeks are both first order, coldwater, tributaries of the Grand River. Bauman Creek is less than 2km in total length and drains an area of approximately 2km^2 (Holton, 2006). The creek is forested upstream of Blair Road, where it flows through Indian Woods, a remnant old-growth forest that makes up a portion of 148 acres of continual mature and maturing forest (***rare*** Charitable Research Reserve, 2010). North of Blair Road the riparian zone was once cleared for agriculture, leaving grasses and forbs as the dominant vegetation on Baumnan's banks from the road north to the Grand River. There is also evidence that past dredging or other stream alterations have taken place in this area, likely to facilitate agricultural activities. The creek now appears to be shifting back to its original location, with water pooling west of the creek into the Blair Flats and towards what is thought to be the original creek path.

Bauman supports a resident brook trout (*Salvelinus fontinalis*) population. Brook trout were observed in 1994 (CH2M Gore & Storrie Ltd, 1997), 2001 (Holton, 2006) and again in 2003 (Barfoot, 2003). Electrofishing was also conducted in Bauman Creek in 2009, with the help of Stantec's fish biologist, Mark Pomeroy, and brook trout were once more found inhabiting Bauman Creek. A total of 53 brook trout were caught in a 50m length section of the creek, just south of Blair Road (Appendix C, Table C.3).

Bauman Creek is ideal for brook trout as it has extensive seepage on both banks and a high density of in-stream cover objects (Dance, 2002). The large volume of seepage water ensures that, while water depth if generally less than 25cm, brook trout still have suitable overwintering areas. In addition, the stream bottom has both fine and coarse gravel substrates which is suitable for spawning (Dance, 2002).

Bauman Creek is included in the Barrie's Lake-Bauman Creek Wetland Complex, which is classified as a Provincially Significant Wetland by the Ministry of Natural

Resources (Holton, 2006; Appendix A, Figure A.4). It has also been included in the designation of Environmentally Sensitive Policy Area #38, which is a locally significant biological area for wildlife and the home of two nationally endangered, two provincially, as well as 19 locally significant species of plants and animals (Holton, 2006).

The benthic monitoring sites on Bauman Creek were numbered in 2006 B1 to B4, with B1 as the most downstream site and B4 being the farthest upstream on the creek (Appendix A, Figure A.3). This order of numbering was used as, under the OBBN protocol, the most downstream sites must be sampled first in order to avoid disruption to sites prior to sampling.

Sites B1 and B2 are both located north of Blair Road, in an area formerly used for conventional agriculture. Approximately 10 acres (25%) of the field adjacent to these two sites has been removed from agricultural production since fall 2005. This area had 130 native trees and shrubs planted in the spring of 2006, and the remainder of the uncultivated area has been left to naturalize on its own. Common meadow species include goldenrods (*Solidago canadensis*), horseweed (*Erigeron canadense*), asters (*Aster* spp.), common milkweed (*Asclepias syriaca*) and meadow foxtail (*Alopecurus pratensis*). The riparian zone around site B1 has a few mature tree species providing full cover for most of the site; this includes a large black maple (*Acer nigrum*) and two large burr oaks (*Quercus macrocarpa*), along with numerous smaller Manitoba maple trees (*Acer negundo*). The banks of site B2 consist primarily of the aforementioned meadow species, primarily goldenrods and grasses. Sites B3 and B4 are both located upstream of Blair Road; site B3 is in a steeper gradient area with 100% deciduous forest cover and numerous groundwater seeps. The dominant vegetation here consists primarily of wetland species, including a thick groundcover of skunk cabbage (*Symplocarpus foetidus*), yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and some shagbark hickory (*Carya ovata*) farther upslope. The last site, B4, is in a rich, swampy area just downstream of the headwaters of Bauman Creek, and also maintains complete forest cover. The stream is much slower moving at this site, and thick with organic matter. Common species at B4 include skunk cabbage, yellow birch, American Beech, and sugar maple.

All Bauman sites can be accessed by parking at the gate where Bauman crosses Blair Road (Appendix A, Figure A.3) and walking along the creek either north (for sites B1 and B2) or south (for sites B3, B4).

<u>Cruickston Creek</u>

Cruickston Creek has approximately the same drainage area as Bauman Creek (Holton, 2006). The creek originates in the Hogsback wetland in the southeast corner of ***rare***'s property, and is also included in the provincially significant Barrie's Lake-Bauman Creek Wetland Complex (Holton, 2006; Appendix A, Figure A.4).

The majority of the creek is forested, except for a small area immediately south of Blair Road and a small area north of Blair Road before the stream channel disappears into a silver maple swamp. The total length of the creek measures 3 to 4 km (Holton, 2006), although it is mostly underdeveloped; the channel disappears into a wetland north of Blair Road and reappears north of the Grand Trunk Trail. At this point the creek is intermittent, disappearing into the bedrock of fractured solution-cavitied limestone (Wilson, 2006) at N 43° 22' 48.8" W80° 20' 50.7", approximately 400m north of the Grand Trunk Trail.

The former agricultural fields immediately east and west of the creek just south of Blair Road have undergone active restoration efforts, and approximately 156 native trees and shrubs were planted between 2005 and 2006. The entire 6 acre field to the east, along with 8 acres to the west were completely removed from agricultural production between 2004 and 2005, and have been left to naturalize. Conventional agriculture is still going on in the field west of the creek, beyond the restoration area.

There are no records of fish having occupied Cruickston Creek, and the 2009 electrofishing results were corroboratory.

The benthic monitoring sites on Cruickston Creek were not ordered sequentially as three additional sites were added in 2009 (Appendix A, Figure A.3). The farthest downstream site (C3) was still, as recommended in the OBBN protocol, sampled first and the remaining sites were sampled progressively upstream until the last, most upstream, site (C5) was sampled.

Site C3, the site farthest downstream on Cruickston Creek, is located just south of Blair Road and north of the culvert that takes the creek under Springbank Lane, whereas site C4 is located just south of the culvert.

The bank-side vegetation at site C1 is made up primarily of riverbank grape vines (*Vitis riparia*), asters, goldenrod, and grass species. The grape vines, along with the few shrubs and Manitoba maples present provide full cover for approximately 50% of this site. The gradient here is still relatively steep, providing the stream with fast flowing water over dominantly cobble bottom before the stream enters the culvert, then under Blair Road and north to the silver maple swamp.

Site C2 is located north of the Hogsback wetland (Appendix A, Figure A.3). Between C2 and the Hogsback, the stream flows rapidly under 100% forest cover. Site C2 is in a small forest clearing, where the dominant vegetation includes Joe Pye weed (*Eupatorium purpureum*), goldenrod, asters, and red-osier dogwood (*Cornus stolonifera*) for approximately 10 meters on either side of the creek, before meeting an approximately 10-20 meter band of deciduous forest adjacent to the agricultural fields. The gradient at this site is comparatively steep, with a dominantly cobble bottom. From here, Cruickston creek braids its way downhill through numerous small boulders under 100% forest cover, before emerging from the forest immediately upstream of site C1.

Finally, C5, the most upstream site, is located in the heart of the Hogsback. The Hogsback is located in the southeast corner of ***rare***’s property. The Hogsback is a 57-acre (42 within ***rare***’s boundary) deciduous forest and mixed swamp, dominated by the eastern white cedar (*Thuja occidentalis*). Historically, the Hogsback has been a relatively isolated area, subject to little human disturbance, however, a subdivision is now located just outside ***rare***’s eastern property line and an additional subdivision is being planned for development just south of the Hogsback’s southern edge.

All five Cruickston Creek sites can be accessed by parking at the gate located where Cruickston crosses Blair Road (Appendix A, Figure A.3) and walking south along the creek.

<u>Blair Flats Wetland</u>

The Blair Flats Wetland is just adjacent to the North side of Blair Road, in the Blair Flats (Appendix A, Figure A.3). Historically, the Blair Flats were farmed conventionally, however in 2005 approximately 30% of the area surrounding the wetland was set aside for restoration. In 2008, a buffer along the Grand River, was also taken out of production and left to fallow. Additionally, a long-term project conducted by researchers at University of Guelph will restore areas of the Blair Flats to tall grass prairie. The remaining farmed land on the Blair Flats is typically planted alternately with corn and soybean crops.

The Blair Flats wetland itself is a fairly large (approximately 20m wide and 100m long, Appendix A, Figure A.5), shallow wetland which in the fall supports large flocks of migrant waterfowl and, in 2009, a resident muskrat or muskrats (*Ondatra zibethicus*). Dominant macrophytes in the Blair Flats Wetland include cattail (most likely *Typha latifolia*), other sedges (which should be identified more specifically in the future) and duckweed (*Lemnoideae sp*.). Filamentous phytoplankton, or algae, fills the wetland during the summer months.

The Blair Flats Wetland site can be accessed by parking on the shoulder of Blair Road directly across from the wetland (Appendix A, Figure A.3).

<u>Preston Flats Wetland</u>

The Preston Flats Wetland is located just east of Fountain Street at the northern limit of the ***rare*** property (Appendix A, Figure A.3). The Preston Flats are adjacent to an urban area that includes residential, commercial and industrial developments. The Preston flats have been conventionally farmed for over 40 years and, like the Blair Flats, are rotated with corn and soybean crops. In 2008 two areas on the flats were taken out of production; a 100m wide strip of land along the Grand River and a small strip of land along the northern edge of the flats. The Preston Flats Wetland is fairly small (approximately 20m wide and 60m long; Appendix A, Figure A.6) and is similar to the Blair Flats Wetland in that it is also predominantly vegetated by cattail, sedges and duckweed. In addition, the Preston Flats Wetland is filled with densely growing water milfoil (*Myriophyllum sp*.) and filamentous phytoplankton. The Preston Flats Wetland is much smaller than the Blair Flats Wetland and therefore does not support the same density of waterfowl in the fall, however, it was also, in 2009 inhabited by a muskrat or muskrats.

The Preston Flats Wetland site can be accessed by parking on the shoulder of Fountain Street just beside the wetland (Appendix A, Figure A.3).

Monitoring

<u>Sampling</u>

Two sets of macro-invertebrate samples were taken from each site, one in the late spring/early summer (Cruickston Creek on May 31st, Bauman Creek on June 14th, and Blair and Preston Flats Wetlands on July 13th) and one in the fall (Cruickston Creek October 7-9th, and Bauman Creek and Blair and Preston Flats Wetlands on October 10th). All sampling followed the OBBN recommended protocol (Jones *et* al., 2007). Sample field sheets can be observed in Appendix B (and are also available on the ***rare*** network in the 'BENTHIC INVERTEBRATES' folder).

Following the OBBN protocol, three transects were sampled at each site. For creeks a 1) downstream riffle, 2) pool, and 3) upstream riffle were selected for sampling at each site. For each wetland, three transects starting at the wetland's edge and extending approximately three meters into the wetland's centre were randomly selected (Appendix A, Figures A.5 and A.6).

As mentioned, creek sites were sampled in sequence downstream to upstream in order to minimize downstream site disturbance and sample contamination. Each transect was sampled using the travelling-kick-and-sweep technique (Jones *et* al., 2007); a 500µm-mesh D-net was placed immediately downstream of the riffle or pool being sampled while the sampler then moved slowly (for approximately three minutes) across the stream, constantly kicking up the substrate. Macro-invertebrates residing in the benthos were subsequently swept downstream by the current, and trapped in the D-net.

Wetland sites were also sampled using the 500µm-mesh D-net but sampling instead followed the OBBN recommended wetland-travelling kick-and-sweep method (Jones *et* al., 2007). The sampler, starting at the end of the 3m transect, walked slowly towards the wetland shore while vigorously kicking up the substrate and continuously sweeping the D-net through the water column.

Cruickston Creek sites C3 and C4 were additionally sampled using a 500µm-mesh Surber quantitative sampler. These sites were chosen for additional sampling in order to better detect changes after the planned removal of the Springbank lane culvert (as mentioned above, C3 and C4 are on either side of the culvert). The square metal frame of the Surber sampler was placed on the creek bottom and pushed into the sediment. The net of the sampler was spread out downstream of the frame, with the open end facing upstream. The substrate inside the metal frame was then disturbed for approximately three minutes while the loosened sediment and macro-invertebrates were swept into the attached net.

After a sample was collected, the full contents of the net (D-net or Surber) were rinsed with water from the creek or wetland and carefully scooped by hand and with a plastic ladle into a large, labeled, wide-mouth plastic jar. Large sticks and rocks were removed from the sample, thoroughly rinsed over the net and replaced in the creek or wetland.

Site Characteristics

Air and water temperature, stream depth, stream width and water velocity were measured at each site. Water velocity was recorded using the timed-float technique, in which a float was dropped into the stream and timed for a distance of one meter. This was repeated three times so that an average stream velocity in meters per second could be calculated. Dissolved oxygen, pH, and conductivity were also measured using a YSI© water quality meter loaned to ***rare*** by Mark Pomeroy at Stantec©. It was first borrowed for the spring sampling and then again in October for the fall sampling, however, no water quality measurements of Blair and Preston Flats Wetlands were taken in the early summer sampling.

Processing Samples

The three samples removed from each site were stored in separate labeled, wide mouthed jars, and brought back to the office to be sorted. Due to the large number of samples collected in 2009 (11 sites x 3 samples = 33 samples), samples could not be sorted live (unlike in 2006). Samples were instead preserved with 37% formalin (adding formalin to make up approximately 10% of the sample volume).

Prior to sorting the preserved samples they were poured onto a 500µm sieve and thoroughly rinsed to remove excess sediment. The sample was then poured into a medium-sized bucket which was topped up with tap water to approximately 4.3L. The bucket's contents were stirred vigorously before a subsample was ladled into a white sorting tray. This 'bucket sub-sampling method' ensured each subsample was randomly taken from the larger sample, helping to decrease potential bias. All macro-invertebrates found in the sorting tray were removed and placed in a 70% ethanol solution. Subsequent subsamples were taken from the bucket until a minimum of 100 organisms were collected for each sample. Each organism found in the sorted sample was identified to the OBBN 27 group level using a dissecting microscope. This data was recorded on the data sheet provided by the OBBN (Appendix B, benthic invertebrate monitoring lab sheet; Jones *et* al., 2007).

Unfortunately, transects could not be re-sampled if their samples had less than 100 organisms. Due to the number of samples to be sorted, the total number of organisms in each sample was not known until several months after the original sampling date, when re-sampling was not an option.

The total volume of all subsamples was measured, as was the volume of sample remaining after all necessary subsamples were taken. This allowed for the percentage of the sample sorted to be calculated.

Calculations and Analyses

The total number of individuals observed for each OBBN group was calculated by summing the data for three transects at each site. Although the OBBN recommends calculating the mean number of organisms/group for each site, the total number of organisms/group was calculated for each site in 2006. Thus, for consistency, the total number organisms/group was used again to calculated the biotic indices in this report. The mean number of organisms/group was also calculated, however, and is available in Appendix C, Table C.4.

Biotic indices are widely used to evaluate macro-invertebrate community structure (Wallace *et* al., 1996). The biotic indices calculated for this report were: Total Number of Organisms/site (transect totals were summed), Mean Total Number of Organisms/site (averaged totals for the three transects), Taxonomic Richness (number of OBBN groups present), Number of Insect Groups, Percent of Insect Groups, Percent Oligochaeta, Percent Ephemeroptera, Plecoptera and Trichoptera (EPT), Percent Chironomidae, Dominant Taxa, Percent Dominant taxa as well as the Shannon-Weiner Index, Highest Possible Diversity and Taxomonic Evenness. The Shannon-Weiner Index was calculated using the following equation:

$$H = - \sum [p_i \text{ x } \ln(p_i)] - [(s-1)/2N]$$

Where:

H = Shannon-Weiner index

p_i = relative abundance of each species, calculated as the proportion of individuals of a given species to a total number of individuals in the community ($p_i = n_i/N$ where n_i is the number of individuals in taxonomic group i)

s = the total number of taxonomic groups observed

N = total number of all individuals (all groups)

The highest possible diversity (H_{max}) was calculated with the following equation:

$$H_{max} = \ln(s)$$

Finally, taxonomic evenness was calculated by dividing the Shannon-Weiner Index (H) by the highest possible diversity (H_{max}). Microsoft Excel was used for calculating these indices.

Higher values of diversity and percent of EPTs can be indicative of relatively undisturbed sites whereas higher percentages of typically tolerant groups such as Chironomidae or Oligochaeta can be indicative of nutrient enrichment and low dissolved oxygen levels (Merritt and Cummins, 1996; Kerans and Karr, 1994).

At the time this report was written, the 'Database' section of the OBBN website was still under construction, however eventually the website will have a index selection tool and software which will enable users to easily calculate biological indices (such as the ones mentioned above; Jones *et* al., 2007). The website will also help users select reference sites from the database and run Test Site Analyses where sites on Bauman and Cruickston creeks, for example, could be compared to similar, 'minimally impacted,' creeks from other monitoring programs (Jones *et* al., 2007, Bowman *et* al. 2003). At present, this analysis cannot be done as there are no reference sites for comparison with ***rare***'s benthic invertebrate monitoring sites.

3.3 – Results and Discussion

Benthic invertebrate monitoring site characteristics for the spring and fall are shown in Table 3.1. Total benthic invertebrate counts for all monitoring sites for spring and fall sampling are shown in Table 3.2 (mean counts for the three transects at each site are reported in Appendix C, Table C.4).

A total of 22 OBBN groups were identified between all sites in the spring (Table 3.2, A). The five OBBN groups *not* observed in ***rare***'s creeks and ponds in the spring were Coelenterata, Turbellaria, Nematoda, Lepidoptera and Culicidae. A total of 22 OBBN groups were also identified in the fall (Table 3.2, B). The five OBBN groups *not* observed in ***rare***'s creeks and ponds in the fall were Coelenterata, Turbellaria, Decapoda, Culicidae and Simuliidae.

A total of seven OBBN groups consisting of 524 individuals were identified in the quantitative sample for Cruickston site C3 in the spring, while 11 OBBN groups consisting of 552 individuals were identified in the quantitative sample for Cruickston site C4 (Table 3.3). The fall quantitative samples for both sites were very different; 10 individuals belonging to five OBBN groups were found at C3 while 56 individuals belonging to 10 OBBN groups were found at C4. Future quantitative monitoring of these sites will help to determine whether this drastic decline in abundance from the spring to the fall in 2009 represented a real trend or was due to differences in sampling methods.

In the spring, B1 and B2 had the highest diversity on Bauman Creek, each having 13 taxonomic groups present (Table 3.4). Sites C1 and C2 of Cruickston Creek also had the highest diversity, each having 14 taxonomic groups in the spring. Blair Flats wetland had comparable diversity with 14 groups while Preston Flats wetland had the highest diversity of all sites in the spring with 15 identified taxonomic groups. In the fall, Bauman Creek site B3 had the highest diversity of all the Bauman Creek sites with 14 groups. Sites C1, C2 and C4 on Cruickston Creek all had 12 taxonomic groups in the fall. Blair Flats wetland had higher diversity than the Preston Flats wetland in the fall with 14 groups compared to 12.

Cruickston Creek site C3 had consistently low diversity with 10 groups in the spring and only nine in the fall.

The dominant taxa for each site on Bauman creek in the spring were Isopoda (B1), Amphipoda (B2, B3) and Plecoptera (B4)(Table 3.4A). In the fall the dominant taxa for Bauman Creek sites were the same with the exception of site B2 where Isopoda, instead of Amphipoda was dominant taxa in the fall (Table 3.4B). The dominant taxa for each site on Cruickston Creek in the spring were Ephemeroptera (C1, C3, C4), Trichoptera (C2) and Chironomidae (C5). In the fall, the dominant taxa for Cruickston Creek sites were Trichoptera (C1, C2, C4), Oligochaeta (C3) and Isopoda (C5).

The sites with the highest percentage EPT in the spring were, for Bauman Creek, site B4 with 55.56% and, for Cruickston Creek, site C1 with 63.23% (Table 3.4A). While C1 had the highest percent EPT of all the Cruickston Creek sites, the other sites, with the exception of site C5, all had EPT percentages higher than 40%. Both wetland sites had very low (less than 2%) percent EPT in the spring. In the fall, all creek sites had lower percent EPT than in the spring. Bauman Creek site B4 was still the highest of all the Bauman sites with 50.0% (Table 3.4B). Cruickston site C1 had the second highest percent EPT in the fall with 33.47%, while site C2 had the highest percent EPT with 67.80%. On the other hand, both wetland sites had much higher percent EPT in the fall than in the spring with 9.87% and 30.65% for Blair Flats and Preston Flats wetlands, respectively.

Vegetation and substrate data collected at each site for both the spring and the fall are available in Appendix C, Table C.5.

Monitoring of benthic invertebrates at ***rare***'s creek and wetland sites should continue every two years. More in-depth surveying of the aquatic and riparian vegetation at sites C3, C4 and the two wetland sites should be conducted in the future. Biological indices for both 2006 and 2009 are shown in Table 3.5, however, these data are useful only for simple preliminary comparisons between years. As data accumulates in the future, statistical analyses will become possible, and over time (with increasing years of data) the results of these analyses will become statistically more powerful. Test Site analysis will also become possible, once the OBBN database and analysis software are available on the OBBN website (Jones *et* al., 2007). The results of statistical and test site analyses will be extremely informative in addressing the main questions motivating this ongoing research.

Table 3.1. The recorded characteristics of each benthic invertebrate monitoring site for A) spring and B) fall, 2009. Data was unavailable for cells that are blank. Spring data for the two creeks was collected by Peter Kelly, Charlotte Moore and Mark Pomeroy. Spring data for the two wetlands was collected by Charlotte Moore and Jen McCarter. Fall data was collected by Jen McCarter and, on October 9th and 10th, Janice Vassalo.

A- Spring

	Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
	1	2	3	4	1	2	3	4	5	1	1
Date	14-Jun	14-Jun	14-Jun	14-Jun	31-May	1-Jun	2-Jun	3-Jun	30-May	13-Jul	13-Jul
Number of Transects (Replicates)	3	3	3	3	3	3	3	3	3	3	3
Average Stream Width (m)	0.60	0.55	1.60	0.95						N/A	N/A
Air temp (°C)	31.4	31.4	23.6	23.6	13.0	13.0	10.0	10.0	19.4	17.5	19.0
Water Clarity	clear	clear	clear	clear	clear	clear	clear	clear	clear	clear	clear
Water Colour	none	none	none	none	none	none	none	none	none	none	none
Water temp (°C)	22.4	21.1	13.8	12.2	11.2	11.5	11.9	11.8	14.0	18.0	20.5
Dissolved oxygen (mg/L)	6.88	7.55	10.80	9.90	11.28	9.79	10.95	10.31			
pH	7.97	8.13	8.46	8.06	9.18	8.91	9.20	9.20			
Conductivity (ms/cm)	0.005	-88.7phmv	0.617	0.638	0.501	0.506	0.489	0.483			
Velocity (m/s): Transect 1	0.11	0.11	0.40	0.07	0.45	0.08	0.43	0.10	0.10	N/A	N/A
2	0.08	0.08	0.02	0.10	0.16	0.07	0.43	0.51	0.14	N/A	N/A
3	0.21	0.12	0.22	0.09	0.23	0.25	0.43	0.44	0.15	N/A	N/A
Mean Velocity	0.13	0.10	0.21	0.09	0.28	0.13	0.43	0.35	0.13	N/A	N/A
Depth (m): Transect 1	0.11	0.08	0.10	0.11	0.13	0.07	0.07	0.13	0.10	0.52	0.41
2	0.12	0.06	0.17	0.12	0.17	0.16	0.07	0.10	0.12	0.29	0.46
3	0.06	0.06	0.10	0.15	0.08	0.09	0.07	0.12	0.80	0.24	0.31
Mean Depth	0.10	0.07	0.12	0.13	0.13	0.11	0.07	0.12	0.34	0.35	0.39

Table 3.1 (continued). The recorded characteristics of each benthic invertebrate monitoring site for A) spring and B) fall, 2009. Data was unavailable for cells that are blank. Spring data for the two creeks was collected by Peter Kelly, Charlotte Moore and Mark Pomeroy. Spring data for the two wetlands was collected by Charlotte Moore and Jen McCarter. Fall data was collected by Jen McCarter and, on October 9th and 10th, Janice Vassalo.

B- Fall

	Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
	1	2	3	4	1	2	3	4	5	1	1
Date	Oct-09	Oct-09	Oct-09	Oct-09	Oct-08	Oct-09	Oct-07	Oct-08	Oct-09	Oct-10	Oct-10
Number of Transects (Replicates)	3	3	3	3	3	3	3	3	3	3	3
Average Stream Width (m)	0.4	0.7	1.5	1.0	0.5	2.0	0.9	0.5		N/A	N/A
Air temp (°C)	12.3	11.5	11.1	12.1	19.1	12.6	16.3	18.9	11.5	14.7	15.6
Water Clarity	clear	clear	clear	clear	clear	clear	clear	clear	clear	clear	clear
Water Colour	none	none	none	none	none	none	none	none	none	none	none
Water temp (°C)	8.4	8.9	9.5	10.1	10.5	10.5	9.8	10.3	10.3	13.4	13.2
Dissolved oxygen (mg/L)	7.85	9.47	11.05	10.15	10.51	9.27	10.32	10.34	4.95	5.61	1.10
pH	7.31	7.58	8.08	7.90	8.44	7.48	8.51	8.41	6.97	7.90	7.13
Conductivity (ms/cm)	0.757	0.598	0.542	0.543	0.523	0.511	0.536	0.525	0.532	0.488	0.973
Velocity (m/s): Transect 1	0.14	0.10	0.33	0.083	0.23	0.20	0.20	0.20	0.11	N/A	N/A
2	0.14	0.05	0.067	0.10	0.17	0.105	0.50	0.17	0.05	N/A	N/A
3	0.16	0.15	0.37	0.17	0.25	0.25	0.20	0.33	0.058	N/A	N/A
Mean	0.15	0.10	0.24	0.12	0.22	0.19	0.30	0.23	0.07	N/A	N/A
Depth (m): Transect 1	0.920	0.790	0.830	0.118	0.100	0.060	0.050	0.083	0.143	0.283	0.323
2	0.100	0.113	0.120	0.087	0.090	0.185	0.043	0.087	0.011	0.460	0.273
3	0.100	0.960	0.730	0.103	0.047	0.058	0.037	0.047	0.015	0.300	0.283
Mean	0.37	0.62	0.56	0.10	0.08	0.10	0.04	0.07	0.06	0.35	0.29

Table 3.2. Total benthic invertebrate counts for the Ontario Benthos Biomonitoring Network (OBBN) 27 groups for the A) spring and B) fall, 2009.

A – Spring

OBBN Group	Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
	1	2	3	4	1	2	3	4	5	1	1
Coelenterata											
Turbellaria											
Nematoda											
Oligochaeta	2	1	10	1	18	7	95	49	6	15	15
Hirudinea	1	1									5
Isopoda	103	88	3		6	17	2	3	42	2	54
Pelecypoda	45	9	1		1	7			18		7
Amphipoda	52	324	152	55		1			21	1	94
Decapoda						1					
Trombidiformes											1
Ephemeroptera	1		41	6	70	23	97	139		6	26
Anisoptera				5						7	3
Zygoptera										1	
Plecoptera		2	6	118	59	53	12	5	20	1	
Hemiptera					1		1	1		2	22
Megaloptera				3		5			5		3
Trichoptera	18	15	11	41	55	91	37	24	14		
Lepidoptera											
Coleoptera	10	3	3		10	8		11		5	14
Gastropoda	4	5			16			3		173	1
Chironomidae	66	49	43	49	26	86	29	22	83	81	76
Tabanidae	1	1			1	2		1	1		1
Culicidae											
Ceratopogonidae				1				1		1	
Tipulidae	30	2	16	16	7	8	1		1	39	
Simuliidae	4		19	2	17		43	57			
Misc. Diptera		2	3		4	1	8	1	4	11	2
Total	**337**	**502**	**308**	**297**	**291**	**310**	**325**	**317**	**215**	**345**	**324**

Table 3.2 (continued). Total benthic invertebrate counts for the Ontario Benthos Biomonitoring Network (OBBN) 27 groups for the A) spring and B) fall, 2009.

B – Fall

OBBN Group	Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
	1	2	3	4	1	2	3	4	5	1	1
Coelenterata											
Turbellaria											
Nematoda				2	14						
Oligochaeta	57	38	20	3	19	6	70	20	3	45	5
Hirudinea	5	10								1	2
Isopoda	135	140	3		11	18	43	42	38	47	42
Pelecypoda	50	53	1		2	7		3	4		
Amphipoda		2	215	16					5	1	147
Decapoda											
Trombidiformes										1	
Ephemeroptera			13	5	1	1				23	98
Anisoptera				1						3	6
Zygoptera										4	2
Plecoptera			106	29	11	33	5	8			
Hemiptera										5	4
Megaloptera	1		1	1		2		1	1		
Trichoptera	3		12	3	67	126	57	69	6		1
Lepidoptera		1					1				
Coleoptera	16	29	11	2	36	20	19	12		3	4
Gastropoda	10	50		2	45	4	5	12	5	15	
Chironomidae	1	7	4	2	13	7	16	33	18	71	11
Tabanidae	3	2	1		1				1		
Culicidae											
Ceratopogonidae			2					2	1		1
Tipulidae	6	8	9	8	16	11	25	37	1	8	
Simuliidae											
Misc. Diptera	5	3	3			1		1		6	
Total	**292**	**343**	**401**	**74**	**236**	**236**	**241**	**240**	**83**	**233**	**323**

Table 3.3. Total benthic invertebrate counts for the Ontario Benthos Biomonitoring Network (OBBN) 27 groups for the two quantitative samples collected in the spring and fall (2009) from Cruickston Creek sites three and four.

OBBN Group	Cruickston Creek 3		Cruickston Creek 4	
	Spring	Fall	Spring	Fall
Coelenterata				
Turbellaria				
Nematoda				
Oligochaeta	8	4	20	8
Hirudinea				
Isopoda		2	4	5
Pelecypoda				1
Amphipoda	4			
Decapoda				
Trombidiformes				
Ephemeroptera	236	1	212	
Anisoptera				
Zygoptera				
Plecoptera	72		64	
Hemiptera			12	
Megaloptera				
Trichoptera	104	1	40	16
Lepidoptera				1
Coleoptera	8		4	7
Gastropoda			16	1
Chironomidae	52	2	68	9
Tabanidae				
Culicidae				
Ceratopogonidae				
Tipulidae			4	7
Simuliidae	40		108	1
Misc. Diptera				
Total	**524**	**10**	**552**	**56**

Table 3.4. Indices calculated from total benthic invertebrate counts for samples from the A) spring and B) fall, 2009 (EPT = Ephemeroptera, Plecoptera and Trichoptera).

A – Spring

	Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
	1	2	3	4	1	2	3	4	5	1	1
Mean % Sample Used	19.5	11.4	53.7	69.1	29.3	61.8	21.1	35.8	100.0	22.8	29.3
Mean Total # Org	112.33	167.33	102.67	99.00	97.00	103.33	108.33	105.67	71.67	115.00	108.00
Total # Org	337	502	308	297	291	310	325	317	215	345	324
Taxon. Richness (# Groups)	13	13	12	11	14	14	10	13	11	14	15
# Insect Groups	8	7	8	9	10	9	8	10	7	10	8
% Insecta	38.58	14.74	46.10	81.14	85.91	89.35	70.15	82.65	59.53	44.64	45.37
% Oligochaeta	0.59	0.20	3.25	0.34	6.19	2.26	29.23	15.46	2.79	4.35	4.63
% EPT	5.64	3.39	18.83	55.56	63.23	53.87	44.92	53.00	15.81	2.03	8.02
% Chironomidae	19.58	9.76	13.96	16.50	8.93	27.74	8.92	6.94	38.60	23.48	23.46
Dominant Taxa	Isopoda	Amphipoda	Amphipoda	Plecoptera	Ephemeroptera	Trichoptera	Ephemeroptera	Ephemeroptera	Chironomidae	Gastropoda	Amphipoda
% Dominant Taxa	30.56	64.54	49.35	39.73	24.05	29.35	29.85	43.85	38.60	50.14	29.01
Shannon-Weiner Index	1.88	1.16	1.66	1.66	2.08	1.86	1.72	1.66	1.81	1.50	1.96
Highest possible diversity	2.56	2.56	2.48	2.40	2.64	2.64	2.30	2.56	2.40	2.64	2.71
Evenness	0.73	0.45	0.67	0.69	0.79	0.71	0.75	0.65	0.75	0.57	0.72

Table 3.4 (continued). Indices calculated from total benthic invertebrate counts for samples from the A) spring and B) fall, 2009 (EPT = Ephemeroptera, Plecoptera and Trichoptera).

B – Fall

	Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
	1	2	3	4	1	2	3	4	5	1	1
Mean % Sample Used	87.7	100.0	61.1	100.0	96.0	70.8	90.9	83.3	100.0	100.0	51.0
Mean Total # Org	97.33	114.33	133.67	24.67	78.67	78.67	80.33	80.00	27.67	77.67	107.67
Total # Org	292	343	401	74	236	236	241	240	83	233	323
Taxon. Richness (# Groups)	12	12	14	12	12	12	9	12	11	14	12
# Insect Groups	7	6	10	8	7	8	6	8	6	8	8
% Insecta	11.99	14.58	40.40	68.92	61.44	85.17	51.04	67.92	33.73	52.79	39.32
% Oligochaeta	19.52	11.08	4.99	4.05	8.05	2.54	29.05	8.33	3.61	19.31	1.55
% EPT	1.03	0.00	32.67	50.00	33.47	67.80	25.73	32.08	7.23	9.87	30.65
% Chironomidae	0.34	2.04	1.00	2.70	5.51	2.97	6.64	13.75	21.69	30.47	3.41
Dominant Taxa	Isopoda	Isopoda	Amphipoda	Plecoptera	Trichoptera	Trichoptera	Oligochaeta	Trichoptera	Isopoda	Chironomidae	Amphipoda
% Dominant Taxa	46.23	40.82	53.62	39.19	28.39	53.39	29.05	28.75	45.78	30.47	45.51
Shannon-Weiner Index	1.60	1.78	1.43	1.89	2.05	1.62	1.81	1.98	1.70	1.95	1.45
Highest possible diversity	2.48	2.48	2.64	2.48	2.48	2.48	2.20	2.48	2.40	2.64	2.48
Evenness	0.65	0.71	0.54	0.76	0.82	0.65	0.82	0.80	0.71	0.74	0.58

Table 3.5. Indices calculated from total benthic invertebrate counts for samples from A) spring and B) fall, for 2006 (red) and the same sites in 2009 (black). Mean percent sample scooped from the total sample collected and mean total number of organisms for 2006 samples were not calculated. Bauman Creek site three could not be sampled in the fall of 2006. (EPT = Ephemeroptera, Plecoptera and Trichoptera).

A – Spring

	Bauman								Cruickston Creek			
	1		2		3		4		1		2	
	2006	2009	2006	2009	2006	2009	2006	2009	2006	2009	2006	2009
Date (d/m/y)	5-Jun	14-Jun	5-Jun	14-Jun	12-Jun	14-Jun	15-Jun	14-Jun	19-Jun	31-May	28-Jun	31-May
Mean % Sample Scooped		19.5		11.4		53.7		69.1		29.3		61.8
Mean Total # Org		112.33		167.33		102.67		99.00		97.00		103.33
Total # Org	290	337	325	502	340	308	262	297	357	291	313	310
Taxonomic Richness (# Groups)	11	13	11	13	11	12	12	11	12	14	14	14
# Insect Groups	6	8	6	7	10	8	8	9	8	10	10	9
% Insecta	57.24	38.58	18.15	14.74	95.59	46.10	74.43	81.14	61.34	85.91	91.69	89.35
% Oligochaeta	3.1	0.59	1.54	0.20	0.00	3.25	1.15	0.34	34.17	6.19	0.64	2.26
%EPT	29	5.64	11.10	3.39	46.20	18.83	30.20	55.56	6.40	63.23	22.70	53.87
%Chironomidae	20.7	19.58	3.40	9.76	34.10	13.96	37.40	16.50	36.70	8.93	43.50	27.74
Dominant Taxa	Trichoptera	Isopoda	Amphipoda	Amphipoda	Chironomidae	Amphipoda	Ceratopogonidae	Plecoptera	Chrionomidae	Ephemeroptera	Chironomidae	Trichoptera
% Dominant Taxa	28.97	30.56	65.85	64.54	34.12	49.35	37.40	39.73	36.69	24.05	43.45	29.35
Shannon-Weiner Index	1.91	1.85	1.23	1.14	1.68	1.62	1.64	1.62	1.65	2.03	1.88	1.82
Highest possible diversity	2.4	2.56	2.40	2.56	2.40	2.48	2.48	2.40	2.48	2.64	2.64	2.64
Evenness	0.8	0.72	0.51	0.44	0.70	0.65	0.66	0.68	0.67	0.77	0.71	0.69

Table 3.5. (continued) Indices calculated from total benthic invertebrate counts for samples from A) spring and B) fall, for 2006 (red) and the same sites in 2009 (black). Mean percent sample scooped from the total sample collected and mean total number of organisms for 2006 samples were not calculated. Bauman Creek site three could not be sampled in the fall of 2006. (EPT = Ephemeroptera, Plecoptera and Trichoptera).

B – Fall

	Bauman						Cruickston Creek			
	1		2		4		1		2	
	2006	2009	2006	2009	2006	2009	2006	2009	2006	2009
Date (d/m/y)	5-Oct	10-Oct	12-Oct	10-Oct	3-Oct	10-Oct	26-Sep	8-Oct	17-Oct	9-Oct
Mean % Sample Scooped		87.7		100.0		100.0		96.0		70.8
Mean Total # Org		97.33		114.33		24.67		78.67		78.67
Total # Org	303	292	309	343	322	74	313	236	302	236
Taxonomic Richness (# Groups)	12	12	15	12	13	12	14	12	14	12
# Insect Groups	5	7	9	6	9	8	8	7	10	8
% Insecta	38.61	11.99	51.46	14.58	68.32	68.92	34.82	61.44	82.12	85.17
% Oligochaeta	42.24	19.52	21.04	11.08	0.62	4.05	39.30	8.05	4.97	2.54
%EPT	1.3	1.03	3.20	0.00	26.70	50.00	10.50	33.47	46.70	67.80
%Chironomidae	29.4	0.34	33.70	2.04	25.80	2.70	8.30	5.51	12.60	2.97
Dominant Taxa	Oligochaeta	Isopoda	Chironomidae	Isopoda	Amphipoda	Plecoptera	Oligochaeta	Trichoptera	Trichoptera	Trichoptera
% Dominant Taxa	42.24	46.23	33.66	40.82	29.50	39.19	39.30	28.39	25.50	53.39
Shannon-Weiner Index	1.56	1.60	1.74	1.78	1.71	1.89	1.96	2.05	2.20	1.62
Highest possible diversity	2.48	2.48	2.71	2.48	2.56	2.48	2.64	2.48	2.64	2.48
Evenness	0.63	0.65	0.64	0.71	0.67	0.76	0.74	0.82	0.83	0.65

4.0 – Forest Biodiversity Monitoring

4.1 – Introduction

Forest Biodiversity Monitoring

Forests are important ecosystems that provide habitat for organisms and perform invaluable ecological services such as climate regulation, hydrologic regime regulation, carbon sequestration and soil conservation (Global Terrestrial Observing System, 2010). It is therefore very important to monitor the structure and composition of forests on a long-term basis to determine what is changing in forest ecosystems and, if a change is detected, to determine the rate and likely result of that change (Roberts-Pichette and Gillespie, 1999). Trees can be affected by a number of factors; many tree species are affected by the presence and abundance of animals that act as seed dispersers, changes in land-use, climate, UV-B levels and changes in chemicals or toxins in the environment (Roberts-Pichette and Gillespie, 1999). Long-term monitoring of trees in forests provides important information on tree conditions, growth rates, survival as well as forest species composition, population sizes and overall forest cover (Roberts-Pichette and Gillespie, 1999).

Forest Biodiversity Monitoring at *rare*

The focus of the terrestrial monitoring program at ***rare*** is to examine forest structure and composition using protocols prepared by EMAN. The long-term research questions are as follows:

- What is the current state of ***rare***'s forests, and how do they compare to one another?
- What are the long-term trends taking place within the forests at ***rare***?
- Is the ecosystem integrity[2] of ***rare*** forests being maintained or improved under ***rare*** management?
- Is either the ecological health[1] or integrity of ***rare*** forests being affected by on-site changes in agriculture and/or restoration efforts being implemented by ***rare***?

These data will provide the basis for a long-term monitoring program at ***rare***. Trends observed in the forest communities will help ***rare*** determine the ecological health of ***rare***'s forests. The results from this study will also be helpful as ***rare*** considers new management plans and restoration and research projects.

This monitoring protocol can also be used in conjunction with other protocols to better assess the overall ecological health of these two sites.

1 - Ecological health can be defined, within an ecosystem management context, as, "a condition wherein [an ecosystem] has the capacity across the landscape for renewal, for recovery from a wide range of disturbances, and for retention of its ecological resiliency[3], while meeting current and future needs of people for desired levels of values, uses, products, and services" (Styers *et* al., 2010; Twery and Gottschalk, 1996).
2 - Ecological integrity is defined by Parks Canada (2009) as, "…a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and

4.2 – Methods

Monitoring Locations

All forest biodiversity monitoring plot locations selected were at least 100m from the forest edge to prevent edge effects from influencing the data. Indian Woods and the Cliffs and Alvars forests were selected as they were both large enough to meet this requirement. Plots were selected to contain a fairly good representation of the overall forest tree species composition and to contain a relatively large number of trees.

Indian Woods is an old growth remnant forest located along the western edge of the ***rare*** property approximately equidistant between Blair Road to the north and Whistle Bare Road to the south (Appendix A, Figure A.7). Indian Woods contains trees up to 230 years old and is predominantly composed of red and white oak (*Quercus rubra, Q. alba*), sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), basswood (*Tilia Americana*) and white pine (*Pinus strobus*). The forest biodiversity plots are approximately in the centre of Indian Woods, 100m east of the Grand Allée trail (Appendix A, Figure A.7; for plot co-ordinates see Appendix A, Table A.3).

The first Indian Woods forest biodiversity plot can be accessed by parking at ***rare***'s 'South Gate', walking north along the Grand Allée trail and, at approximately 20m past the post with arrow sign, heading west into the forest for approximately 100m (Appendix A, Figure A.7). Plot number two is approximately 30m directly south of plot number one and similarly plot number three is approximately 30m directly south of plot number two (Appendix A, Figure A.7 and Table A.3).

The upland portion of the Cliffs and Alvars forest where the forest biodiversity plots were established is a mixed deciduous forest and swamp. Cruickston Creek disappears intermittently into the bedrock of fractured solution-cavitied limestone (Wilson, 2006) in this area north of the Grand Trunk Trail. The Cliffs and Alvars forest is predominantly composed of American beech, ash species (*Fraxinus sp*), sugar maple, black cherry (*Prunus serotina*) and ironwood (*Ostrya virginiana*).

The first Cliffs and Alvars forest biodiversity plot can be accessed by parking at the George St parking lot at the very east end of ***rare***'s property, walking northwest along the Grand Trunk Trail for approximately 800m and then heading northeast into the forest for approximately 20m (Appendix A, Figure A.7). All three forest biodiversity plots are approximately 20m apart in a line running northwest to southeast (Appendix A, Figure A.7 and Table A.3).

abundance of native species and biological communities, rates of change and supporting processes." Further, Parks Canada defines an ecosystem as having integrity when, "…they have their native components intact, including: abiotic components (the physical elements, e.g. water, rocks), biodiversity (the composition and abundance of species and communities in an ecosystem, e.g. tundra, rainforest and grasslands represent landscape diversity; black bears, brook trout and black spruce represent species diversity) and ecosystem processes (the engines that makes ecosystem work; e.g. fire, flooding, predation)."

3 - Ecological resiliency is defined as, "the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures (defined as alternative stable states)" or, "a return time to a stable state following a perturbation." (Gunderson, 2000).

Monitoring Set-up

Establishing Forest Biodiversity Plots

Forest biodiversity monitoring plots were set-up according to the EMAN protocol (Roberts-Pichette and Gillespie, 1999) in October and November 2009. Sample field sheets can be observed in Appendix B (and are also available on the ***rare*** network in the 'FOREST HEALTH' folder).

A 20 x 20m square was set up at each plot using 18" galvanized steel wire pigtails for the corners and twine for the sides. The first line was set in an east-west orientation by having one person stand in the first corner with a compass while a second person walked directly eastwards (being directed by the first person) with the tape measure until 20m away. This first line was marked with pigtails and flagging tape so that last corners could be set-up relative to the first two. Once all four corners were marked with pigtails, all four sides were re-measured to ensure the 20m lengths were accurate. The diagonals, which should have measured 28.28m, were also checked to make sure the plot was square. If any of the measurements were off, small adjustment were made until the 20 x 20m square was deemed accurate. Once the square was set-up, all the corners and sides were labeled according to the EMAN protocol (Roberts-Pichette and Gillespie, 1999; Figure 4.1).

Tagging, Measuring and Assessing Trees

Starting at the northwest corner of the plot, trees were tagged, measured and identified in a clockwise spiral from the periphery to the centre of the quadrat. Each alive and dead standing tree over 10cm diameter at breast height (DBH; or over 31.4cm circumference) was tagged and used in mapping the plot. All trees in Indian Woods were numbered with pre-numbered steel tags hung on pigtails at the base of the tree trunk. All trees in the Cliffs and Alvars plots were numbered with mark-able aluminum tags nailed to the trees at breast height. Nails were driven into the trees at a 45-degree downwards angle (to prevent water from accumulating in the tree's bark as this can make the tree vulnerable to infections). Tags were nailed to the trees in the Cliffs and Alvars plots as trees in these plots were previously tagged in this manner. All tags, whether on pigtails or nailed to the tree, were located on the north face of each tree. Pigtails and both types of aluminum tags were ordered through Commercial Solutions Inc. in Cambridge.

Multiple stems of trees were tagged given that stems split off the main trunk at or below 1.3m and stems were 10cm DBH or greater. Trees directly on the plot line were counted only if more than half the tree trunk was located within the plot.

While trees were being tagged they were also identified using 'Trees in Canada' (Farrar, 1995) and 'Trees of Ontario' (Kershaw, 2001). Tree species were identified where possible, however, not all trees could be identified as, being late October and early November, the majority of the leaves had dropped and identification from bark and branches alone was difficult. Missing tree identifications should be filled in, and other identifications should be double-checked, in the spring or summer.

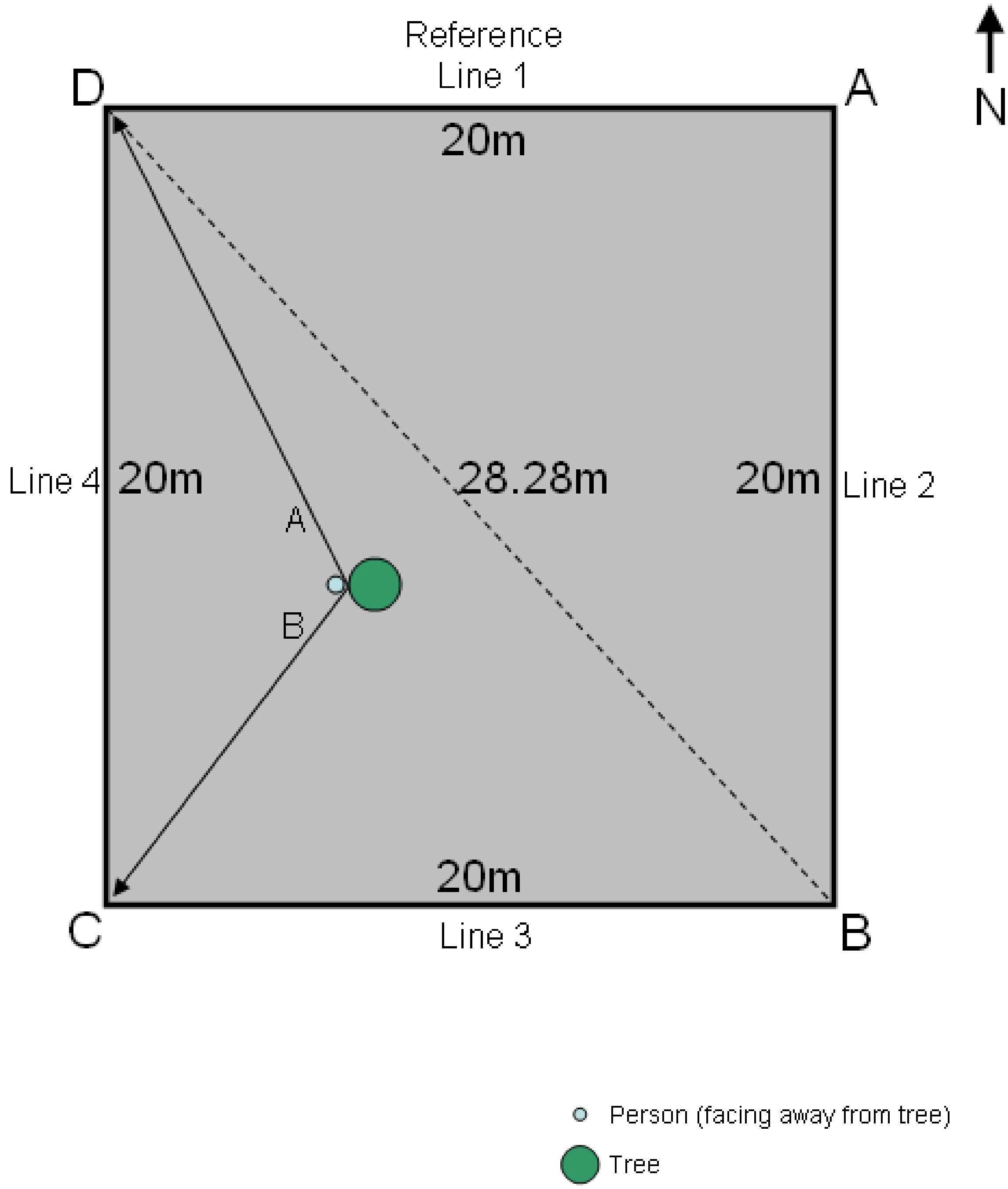


Figure 4.1. The forest biodiversity plot set-up for mapping trees (Roberts-Pichette and Gillespie, 1999).

Tree trunk diameters were calculated from the measured tree circumference using the following equation:

$$C = 2\pi\, r \qquad \text{rearranged into:} \qquad D = C/\pi$$

Where: C = circumference
π = 3.14159
r = radius
D = diameter

Tree circumference was measured by wrapping a 30m tape measure around the tree trunk at breast height (approximately 1.3m off the ground). Multiple stems, if over 10cm DBH were both measured at breast height. If the trunk was irregular (i.e. had a canker or tree branches) at breast height, then DBH was measured just above or below the irregular area and the height of the measurement was recorded.

General tree conditions were recorded using the following short forms:

Standing alive = AS
Broken alive = AB
Leaning alive = AL
Fallen/prone alive = AF
Standing alive dead top = AD
Standing dead = DS
Broken dead = DB
Leaning dead = DL
Fallen/prone dead = DF

Tree height and age were not measured in 2009. Given the appropriate equipment (e.g. a clinometer and increment borer) is purchased, these measurements could be made in the future.

<u>Tree Mapping and Analysis</u>

To map the trees within each plot each tree was measured in relation to two corners of the plot. One person stood holding the ends of two 30m tape measures against the tree trunk at breast height. Two other individuals took the tape measures and walked to the two closest corners of the plot, ensuring that 1) they were measuring a straight line directly from the tree of interest to the corner and 2) their measuring tapes were pulled taut. These two measurements became the 'A' and 'B' distances for that tree where the 'A' measurement was the line extending from the right-hand of the person standing facing away from the tree trunk and the 'B' measurement was the left-hand line (Figure 4.1).

These measurements (Cliffs and Alvars data only, as Indian Woods trees were largely un-identified) were later entered into the EMAN database so that the plots could be mapped using their online BIOMON mapping software. This software generates a map of each plot showing the exact location and DBH of each tree.

As not all trees were identified in the initial plot set-up, none of the recommended biotic indices (for example, abundance, density, relative density, dominance, relative dominance, frequency, relative frequency or importance value; Roberts-Pichette and Gillespie, 1999) were calculated. These indices should be calculated in the future when a full data set is compiled.

Annual Decay Rates Monitoring

Annual decay rates (ADR) monitoring plots were established, following EMAN's Annual Soil Humus Decay Rates protocol (Environment Canada, 2006), at Cliffs and Alvars forest biodiversity monitoring plot number one. ADR monitoring can provide valuable information about the productivity and turnover of biomass on the forest floor. These plots were established in 2009 to gather preliminary data and to determine whether this EMAN Terrestrial Monitoring protocol would be a good fit for ***rare***.

Twelve annual decay rates plots were set-up on November 9, 2009 on the corners of Cliffs and Alvars forest biodiversity monitoring plot number one (Figure 4.2). The three plots on each corner of the 20 x 20m forest plot were located on the three outside corners of 1m x 1m quadrats (the fourth corner being shared with the 20 x 20m forest plot).

Each of the twelve plots required four tongue depressors, so for the one preliminary annual decay rates plot a total of 48 tongue depressors were prepared.

A box of 500 100% birch tongue depressors was purchased from a local pharmacy. Tongue depressors for use in 2009 were first dried in an oven at approximately 70°C for 48hours and then left for another 24hours at room temperature. A 2mm hole was carefully drilled into one end of each tongue depressor and they were weighed on a Sartorius 1265MP (0.001-400g) scale to +/- 0.001g. After each tongue depressor was weighed, a pre-numbered aluminum tag was tied to it using extra-strong fishing line. Original tongue depressor weights as well as tongue-depressor tag numbers were recorded on the data sheet (Appendix B; also available on the ***rare*** network in the 'FOREST HEALTH' folder).

For each annual decay rates plot, a 1m x 1m square was measured. At each of the three outside corners of this square (see Figure 4.2) a 0.3m x 0.3m hole was dug (Figure 4.3). The material removed was kept intact in order to replace it after burying the tongue depressors. Three tongue depressors were buried at a depth of 5cm, 10cm apart from each other, by first inserting a butter knife parallel to the ground surface into the north edge of the 0.3m x 0.3m hole. The tongue depressors were then inserted into the small slits created by the butter knife with the tags left visible in the 0.3m x 0.3m hole. The fourth tongue depressor was placed underneath the leaf litter but on surface of the forest floor.

Once all four tongue depressors were in place they were strung together with another piece of extra-strong fishing line which was also strung around a flagged and labeled pigtail in the center of the hole, 10 directly south of the tongue depressors. Finally, the removed substrate material was replaced in the hole.

If rocks or trees prevented digging into the substrate at the predetermined location, the plot was moved 1m in either direction down the forest biodiversity plot line until an appropriate area was found.

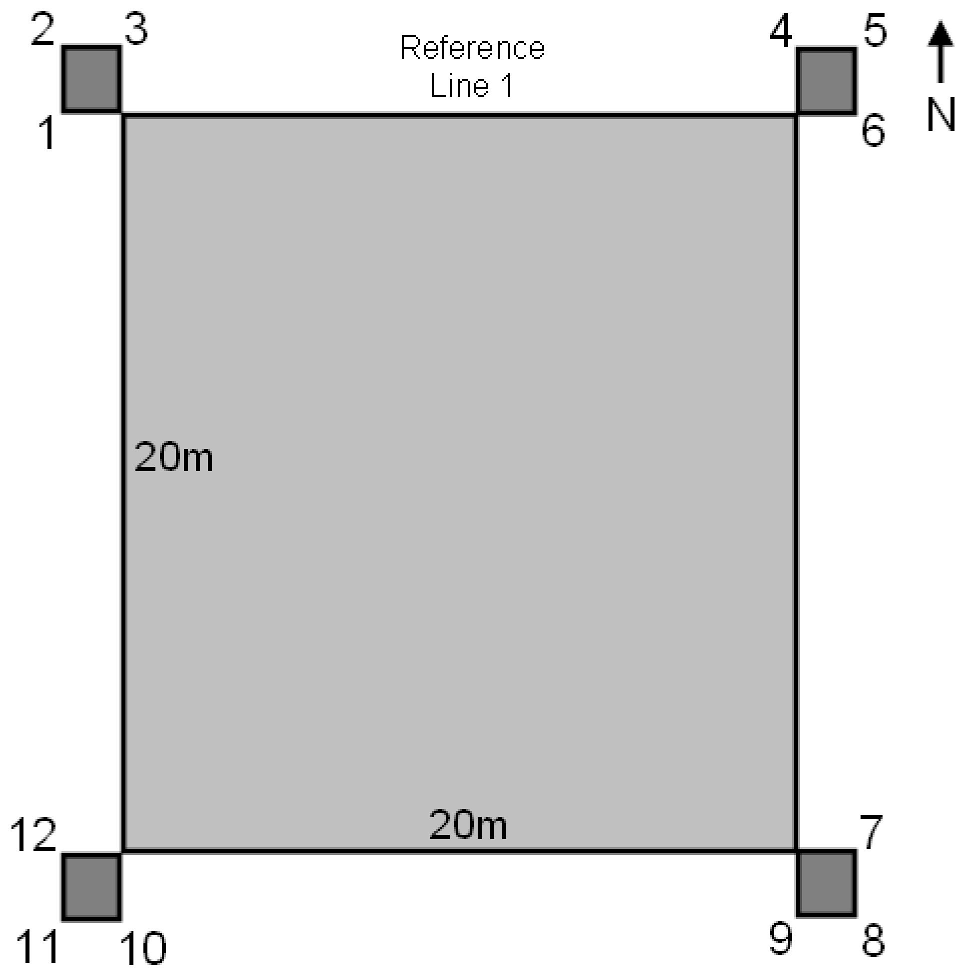


Figure 4.2. The locations of the twelve annual decay rates plots around the 20 x 20m Cliffs and Alvars forest biodiversity plot number one. The three plots on each corner of the 20 x 20m forest plot (large, light grey square) were located on three outside corners of 1m x 1m quadrates (dark squares).

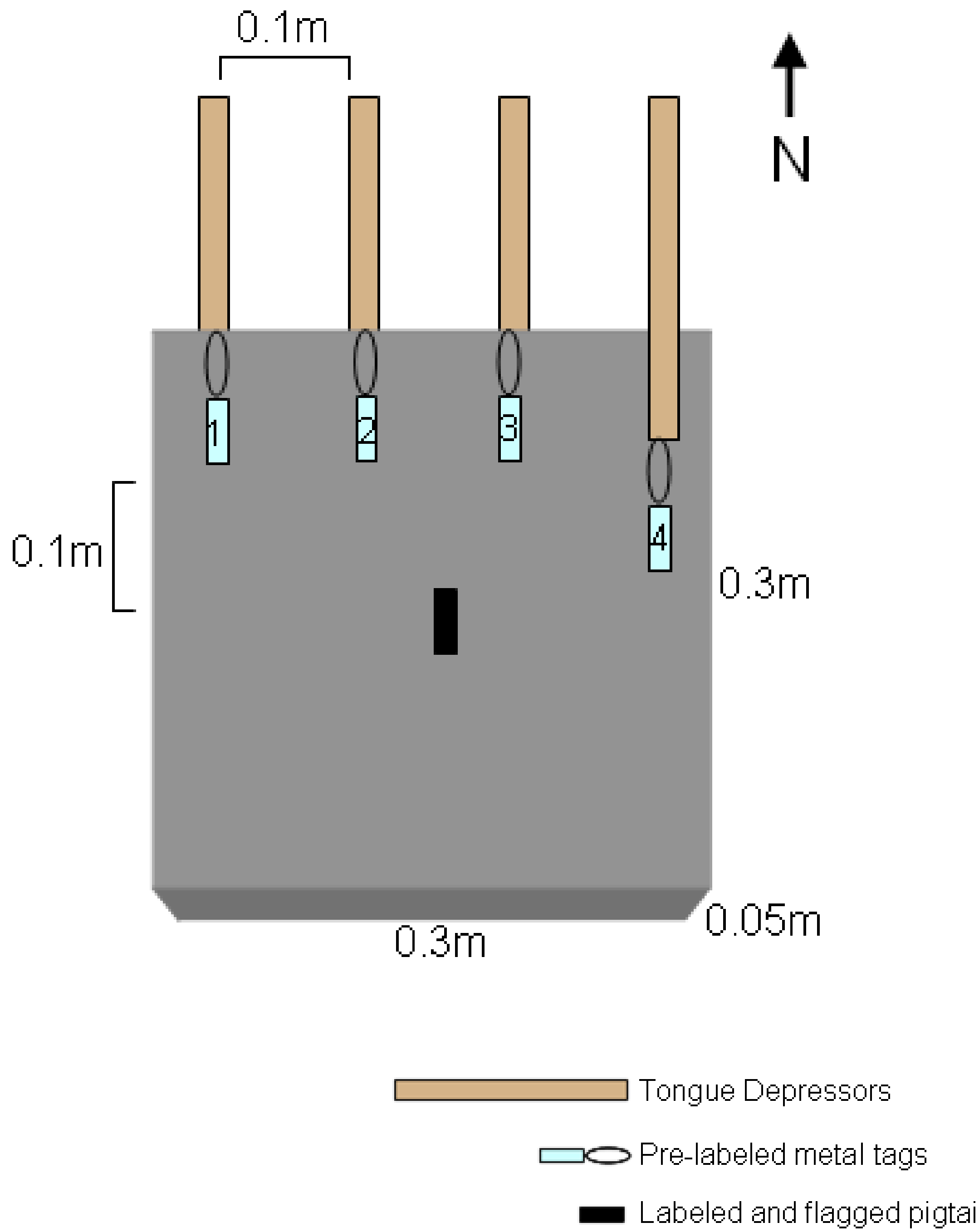


Figure 4.3. The set-up for each of the twelve annual decay rates plots. Tongue depressors one to three were buried 5cm below, but parallel to, the substrate surface while tongue depressor number four was placed on the substrate surface.

4.3 – Results and Discussion

Preliminary data for forest biodiversity monitoring plots and annual decay rates plots is available in Tables 4.1 and 4.2, respectively. Figure 4.4 shows the BIOMON mapping of Cliffs and Alvars forest biodiversity plots one, two and three (Indian Woods forest biodiversity plot wasn't mapped due to incomplete tree species data).

Future work on the forest biodiversity monitoring plots should include the re-assessment of tree species identifications as well as the measuring of tree heights, tree ages and degree of canopy closure in 2010. The data should be updated in the EMAN database and the plots mapped out using their BIOMON software. Additionally, the forest biodiversity monitoring plots should be re-measured every five years to monitor tree mortality and growth (Roberts-Pichette and Gillespie, 1999). When the plots are re-visited (Roberts-Pichette and Gillespie, 1999):

- all corner pigtails should be checked to make sure they are in place (and replaced if necessary)
- missing tree tags should be replaced
- the DBH of all numbered trees should be re-measured
- all small trees should be re-assessed to determine if their DBH is greater than 10cm, and if so, they should be tagged, identified, measured, assessed and their location should be mapped
- changes in the condition of all numbered trees should be noted
- a new plot map should be made if any changes have occurred

Future work on the annual decay rates monitoring plots will include the retrieval and weighing of tongue depressors buried in 2009 and, depending upon available resources and the success of the first monitoring year, the burying of new tongue depressors for another year (until fall 2011). If the first year of decay rates monitoring goes well, these plots could also be established at additional forest biodiversity plots in the Cliffs and Alvars forest and/or in Indian Woods.

Other monitoring protocols can also be easily added to the forest biodiversity monitoring plots. These might include Shrub and Small-Tree Stratum Biodiversity, Ground Vegetation Stratum Biodiversity or Vegetation Gradient Biodiversity Monitoring Protocols available (Roberts-Pichette and Gillespie, 1999). Which, if any of these protocols should be implemented at ***rare***, of course, depends on ***rare***'s long term goals for monitoring and the resources.

Table 4.1. Raw 2009 forest biodiversity monitoring data for A) Indian Woods Plots 1 (IW1), 2 (IW2) and 3 (IW3) and B) Cliffs and Alvars plots 1 (CA1), 2 (CA2) and 3 (CA3). The DBH or diameter at breast height was calculated from the measured circumference. Tree species were identified where possible, however, identifications should be done where missing and double checked where present, in the spring. Tree conditions are as follows: AS = alive standing, DS = dead standing, DB = dead broken. Indian Woods data was collected by Jennifer McCarter, Angela Gillespie and Andrew Dean. Cliffs and Alvars data was collected by Jennifer McCarter, Angela Gillespie, Andrew Dean and Janice Vassallo.

A - Indian Woods

Stand and Plot	Tag #	Old tag #	Common name	Species name	# Stems	Circ. (cm)	DBH (cm)	Ref Line	A distance (m)	B distance (m)	Height (m)	Tree Condition	Notes
IW1	27	-	Sugar maple	*Acer saccharum*	1	225.2	71.7	1	13.88	8.75		AS	
IW1	28	-	Sugar maple?		1	113.0	36.0	1	12.91	14.72		AS	
IW1	29	-	American beech	*Fagus grandifolia*	1	148.4	47.2	1	9.67	16.23		AS	
IW1	30	-	Sugar maple?		1	102.3	32.6	1	3.77	19.54		AS	
IW1	31	-	American beech	*Fagus grandifolia*	1	130.6	41.6	2	9.14	12		DS	
IW1	32	-	Red oak?		1	36.3	11.6	2	9.86	12.73		AS	
IW1	33	-	American beech	*Fagus grandifolia*	1	37.1	11.8	2	4.1	16.12		AS	
IW1	34	-	?		1	58.6	18.7	3	11.81	8.5		AS	
IW1	35	-	Sugar maple	*Acer saccharum*	1	248.2	79.0	4	17.5	3.02		AS	
IW1	36	-	American beech	*Fagus grandifolia*	1	32.4	10.3	4	11.65	9.43		AS	
IW1	37	-	American beech	*Fagus grandifolia*	1	46.2	14.7	4	8	12.57		AS	
IW1	38	-	Sugar maple?		1	144.8	46.1	4	8.26	12.64		AS	
IW2	15	-	American beech	*Fagus grandifolia*	1	38.2	12.2	4	2.08	18.04		AS	
IW2	16	-	American beech	*Fagus grandifolia*	1	178.4	56.8	1	11.23	8.94		DS	
IW2	17	-	?		1	97.2	30.9	1	6.83	13.65		AS	
IW2	18	-	oak?		1	85.8	27.3	2	11.68	8.45		AS	
IW2	19	-	oak?		1	111.8	35.6	3	17.25	2.92		AS	
IW2	20	-	oak?		1	79.6	25.3	3	16.44	5.91		AS	
IW2	21	-	?		1	126.2	40.2	3	12.25	9.43		AS	
IW2	22	-	oak?		1	100.2	31.9	3	7.93	12.79		AS	
IW2	23	-	American beech	*Fagus grandifolia*	1	135.4	43.1	4	14.12	6.5		AS	
IW2	24	-	oak?		1	260.6	83.0	4	10.89	9.34		AS	
IW2	25	-	?		1	105.6	33.6	4	9.8	10.58		AS	

Table 4.1. (continued) Raw 2009 forest biodiversity monitoring data for A) Indian Woods Plots 1 (IW1), 2 (IW2) and 3 (IW3) and B) Cliffs and Alvars plots 1 (CA1), 2 (CA2) and 3 (CA3). The DBH or diameter at breast height was calculated from the measured circumference. Tree species were identified where possible, however, identifications should be done where missing and double checked where present, in the spring. Tree conditions are as follows: AS = alive standing, DS = dead standing, DB = dead broken. Indian Woods data was collected by Jennifer McCarter, Angela Gillespie and Andrew Dean. Cliffs and Alvars data was collected by Jennifer McCarter, Angela Gillespie, Andrew Dean and Janice Vassallo.

IW2	26	-	?		1	114.4	36.4	3	13.62	13.51		AS	
IW3	1	-	maple?		1	100.8	32.1	1	17.37	4.19		AS	
IW3	2	-	sugar maple	*Acer saccharum*	1	35.2	11.2	1	13.6	8.05		AS	
IW3	3	-	?		1	100.0	31.8	1	10.64	9.78		AS	
IW3	4	-	?		1	69.4	22.1	1	5.96	15.45		AS	
IW3	5	-	?		1	232.6	74.0	2	13.02	7.43		DS	DBH taken from ground on higher side
IW3	6	-	?		1	74.8	23.8	2	11.87	12.06		AS	
IW3	7	-	?		1	32.4	10.3	3	11.44	9.58		AS	
IW3	8	-	?		1	107.8	34.3	3	10.47	10.31		AS	
IW3	9	-	?		1	58.6	18.7	4	13.72	9.17		AS	Broken half way up
IW3	10	-	?		1	172.4	54.9	4	11.29	12.13		AS	
IW3	11	-	?		1	138.4	44.1	4	6.6	14.69		AS	
IW3	12	-	sugar maple	*Acer saccharum*	1	42.4	13.5	4	12.25	14.4		AS	
IW3	13	-	?		1	85.0	27.1	3	12.13	12.11		DS	
IW3	14	-	?		1	142.2	45.3	3	10.54	12.89		AS	

Table 4.1. (continued) Raw 2009 forest biodiversity monitoring data for A) Indian Woods Plots 1 (IW1), 2 (IW2) and 3 (IW3) and B) Cliffs and Alvars plots 1 (CA1), 2 (CA2) and 3 (CA3). The DBH, or diameter at breast height, of each tree was calculated from the measured circumference. Tree species were identified where possible, however, missing tree species should be added and all tree species should be double checked in the spring. Tree conditions are as follows: AS = alive standing, DS = dead standing, DB = dead broken. Indian Woods data was collected by Jennifer McCarter, Angela Gillespie and Andrew Dean. Cliffs and Alvars data was collected by Jennifer McCarter, Angela Gillespie, Andrew Dean and Janice Vassallo.

B – Cliffs and Alvars

Stand and Plot ID	Tag #	Old tag #	Common name	Species name	# Stems	Circ. (cm)	DBH (cm)	Ref Line	A distance (m)	B distance (m)	Height (m)	Tree Condition	Notes
CA1	1	-	Sugar maple	*Acer saccharum*	1	110.2	35.1	1	15.39	4.45		AS	
CA1	2	-	Sugar maple	*Acer saccharum*	1	126.8	40.4	1	14.25	5.68		AS	
CA1	3	-	Ironwood	*Ostrya virginiana*	1	34.9	11.1	1	9.50	10.47		AS	
CA1	4	-	White ash	*Fraxinus americana*	1	90.0	28.6	1	8.05	11.91		AS	
CA1	5	-	Ironwood	*Ostrya virginiana*	1	38.2	12.2	1	5.51	14.44		AS	
CA1	6	-	Ironwood	*Ostrya virginiana*	1	38.6	12.3	1	4.03	16.16		AS	
CA1	7	-	Ironwood	*Ostrya virginiana*	1	35.4	11.3	2	17.74	3.00		AS	
CA1	8	-	American beech	*Fagus grandifolia*	1	31.1	9.9	2	17.09	4.19		AS	
CA1	9a	-	American beech	*Fagus grandifolia*	2	31.0	9.9	2	15.19	5.42		AS	
CA1	9b	-	American beech	*Fagus grandifolia*	2	36.5	11.6	2	15.00	5.55		AS	
CA1	10a	-	American beech	*Fagus grandifolia*	2	101.2	32.2	2	8.23	13.23		AS	
CA1	10b	-	American beech	*Fagus grandifolia*	2	134.4	42.8	2	8.56	13.31		AS	
CA1	11	-	American beech	*Fagus grandifolia*	1	106.1	33.8	2	2.93	17.08		AS	
CA1	12	-	Sugar maple	*Acer saccharum*	1	129.8	41.3	2	1.48	19.25		AS	
CA1	13	-	American beech	*Fagus grandifolia*	1	78.9	25.1	3	14.72	5.87		AS	
CA1	14	-	Sugar maple	*Acer saccharum*	1	53.1	16.9	3	4.20	17.83		AS	
CA1	15	-	White ash	*Fraxinus americana*	1	113.6	36.2	3	2.91	17.47		DS	
CA1	16	-	Butternut	*Juglans cinerea*	1	89.8	28.6	3	1.58	18.47		DS	
CA1	17	-	Sugar maple	*Acer saccharum*	1	32.1	10.2	3	2.05	18.31		AS	
CA1	18	-	Sugar maple	*Acer saccharum*	1	95.3	30.3	4	7.55	13.05		AS	
CA1	19	-	Black cherry	*Prunus serotina*	1	143.4	45.6	1	7.82	13.54		AS	
CA1	20	-	Sugar maple	*Acer saccharum*	1	37.8	12.0	4	14.30	11.31		AS	

Table 4.1. (continued) Raw 2009 forest biodiversity monitoring data for A) Indian Woods Plots 1 (IW1), 2 (IW2) and 3 (IW3) and B) Cliffs and Alvars plots 1 (CA1), 2 (CA2) and 3 (CA3). The DBH, or diameter at breast height, of each tree was calculated from the measured circumference. Tree species were identified where possible, however, missing tree species should be added and all tree species should be double checked in the spring. Tree conditions are as follows: AS = alive standing, DS = dead standing, DB = dead broken. Indian Woods data was collected by Jennifer McCarter, Angela Gillespie and Andrew Dean. Cliffs and Alvars data was collected by Jennifer McCarter, Angela Gillespie, Andrew Dean and Janice Vassallo.

CA1	21	-	Black cherry	*Prunus serotina*	1	69.4	22.1	4	10.19	14.80		AS	
CA1	22	-	Ironwood	*Ostrya virginiana*	1	43.9	14.0	1	10.26	11.89		AS	
CA1	23	-	Sugar maple	*Acer saccharum*	1	126.6	40.3	4	13.34	9.46		AS	
CA2	1	-	American beech	*Fagus grandifolia*	1	43.0	13.7	1	16.18	4.18		AS	
CA2	2	22	American beech	*Fagus grandifolia*	1	51.0	16.2	1	13.13	7.82		AS	
CA2	3	23	Sugar maple	*Acer saccharum*	1	66.0	21.0	1	8.59	11.78		AS	
CA2	4	-	American beech	*Fagus grandifolia*	1	42.6	13.6	1	4.75	15.15		AS	
CA2	5	-	American beech	*Fagus grandifolia*	1	215.0	68.4	1	3.71	16.23		DB	
CA2	6	25	Ironwood	*Ostrya virginiana*	1	183.2	58.3	2	15.72	4.8		DS	
CA2	7	28	Sugar maple	*Acer saccharum*	1	253.0	80.5	2	13.8	7.73		AS	splits into 2 stems above 1.3 m (one stem is dead)
CA2	8	37	Yellow birch	*Betula alleghaniensis*	1	138.4	44.1	3	11.38	10.19		AS	
CA2	9	-	Ash sp?	*?*	1	81.0	25.8	3	7.17	14.5		AS	
CA2	10	-	Ash sp?	*?*	1	139.2	44.3	3	5.67	16.68		DS	
CA2	11	8	Sugar maple	*Acer saccharum*	1	31.6	10.1	4	11.92	8.31		AS	
CA2	12	11	Ash sp?	*?*	1	42.4	13.5	4	8.09	11.64		AS	
CA2	13	16	American beech	*Fagus grandifolia*	1	49.0	15.6	4	5.16	14.67		AS	
CA2	14	17	American beech	*Fagus grandifolia*	1	32.0	10.2	4	6.06	14.48		AS	
CA2	15	18	Ironwood	*Ostrya virginiana*	1	32.0	10.2	4	15.33	6.55		AS	
CA2	16	-	Ash sp?	*?*	1	178.4	56.8	4	13.03	11.05		DS	
CA2	17	-	Sugar maple	*Acer saccharum*	1	40.0	12.7	4	13.02	7.52		AS	
CA2	18	-	Sugar maple	*Acer saccharum*	1	69.6	22.2	4	8.62	12.8		AS	
CA2	19	41	American beech	*Fagus grandifolia*	1	40.0	12.7	4	10.42	13.86		AS	
CA3	1	-	American beech	*Fagus grandifolia*	1	199.0	63.3	1	9.23	10.76		AS	
CA3	2	19	American beech	*Fagus grandifolia*	1	39.5	12.6	1	3.89	16.21		AS	

Table 4.1. (continued) Raw 2009 forest biodiversity monitoring data for A) Indian Woods Plots 1 (IW1), 2 (IW2) and 3 (IW3) and B) Cliffs and Alvars plots 1 (CA1), 2 (CA2) and 3 (CA3). The DBH, or diameter at breast height, of each tree was calculated from the measured circumference. Tree species were identified where possible, however, missing tree species should be added and all tree species should be double checked in the spring. Tree conditions are as follows: AS = alive standing, DS = dead standing, DB = dead broken. Indian Woods data was collected by Jennifer McCarter, Angela Gillespie and Andrew Dean. Cliffs and Alvars data was collected by Jennifer McCarter, Angela Gillespie, Andrew Dean and Janice Vassallo.

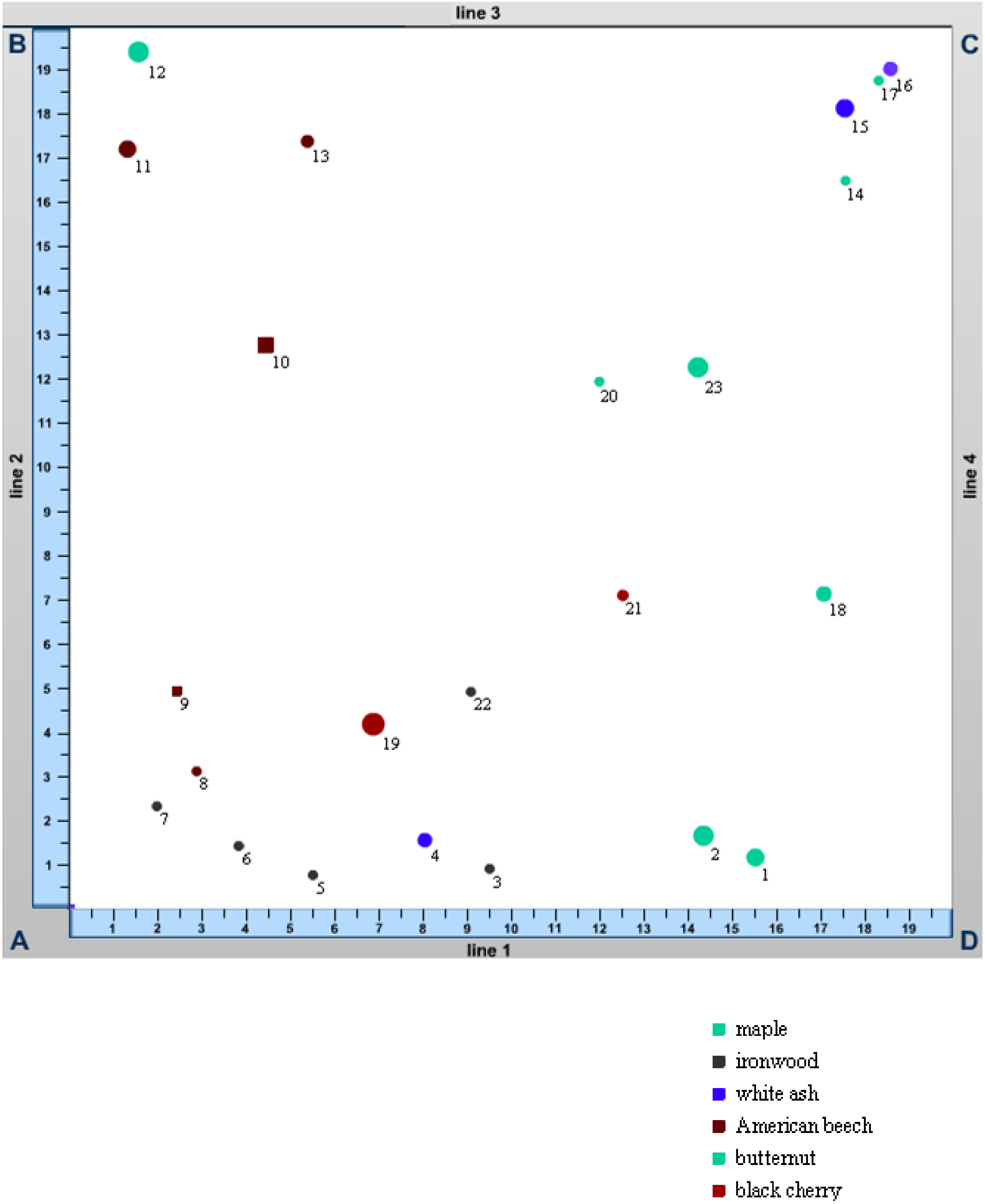
CA3	3a	-	American beech	*Fagus grandifolia*	2	195.0	62.1	2	14.04	5.99		DS	
CA3	3b		American beech	*Fagus grandifolia*	2	106.0	33.7	2	13.59	6.34		DS	
CA3	4	-	Black Cherry	*Prunus serotina*	1	41.4	13.2	2	9.88	11.21		AS	
CA3	5	-	Sugar maple	*Acer saccharum*	1	79.0	25.1	2	5.96	15.86		AS	
CA3	6	-	Black Cherry	*Prunus serotina*	1	38.2	12.2	3	13.61	6.85		AS	
CA3	7	-	Sugar Maple	*Acer saccharum*	1	77.0	24.5	3	10.2	9.76		AS	
CA3	8	-	American beech	*Fagus grandifolia*	1	183.2	58.3	3	4.52	15.79		DS	
CA3	9	-	White ash	*Fraxinus americana*	1	76.8	24.4	4	14.05	6.24		AS	
CA3	10	-	Ironwood	*Ostrya virginiana*	2	39.2	12.5	4	12.01	9.27		AS	has 2 stems, but one is <10cm DBH
CA3	11	-	Sugar maple	*Acer saccharum*	1	36.0	11.5	4	5.61	14.96		AS	
CA3	12	-	Sugar maple	*Acer saccharum*	1	32.0	10.2	1	13.08	8.26		AS	
CA3	13	31	Ironwood	*Ostrya virginiana*	1	36.0	11.5	4	12.05	12.76		AS	
CA3	14	36	American beech	*Fagus grandifolia*	1	175.6	55.9	1	9.68	14.2		AS	

Table 4.2. Raw 2009 annual decay rates data for the Cliffs and Alvars forest biodiversity monitoring plot number one. Humus depth was not measured as no soil horizons were discernable.

Forest Stand ID	Forest Biodiversity Monitoring Plot ID	ADR Station ID	Tongue Depressor (TD) Tag Number	TD Original weight (to 0.001g)	TD Placement (surface/ buried)	Humus depth (cm)	Buried depth (cm)	Date Buried (d/m/y)	Date Retrieved (d/m/y)	Decayed Weight (to 0.001g)	TD Weight Difference (to 0.001g)
CA	1	1	1	2.178	Buried		6.0	9/11/2009			
CA	1	1	2	2.477	Buried		6.0	9/11/2009			
CA	1	1	3	1.954	Buried		5.5	9/11/2009			
CA	1	1	4	2.113	Surface		0.0	9/11/2009			
CA	1	2	5	2.317	Buried		5.0	9/11/2009			
CA	1	2	6	2.367	Buried		6.0	9/11/2009			
CA	1	2	7	2.429	Buried		6.0	9/11/2009			
CA	1	2	8	2.214	Surface		0.0	9/11/2009			
CA	1	3	9	2.261	Buried		6.0	9/11/2009			
CA	1	3	10	2.029	Buried		6.0	9/11/2009			
CA	1	3	11	2.072	Buried		5.5	9/11/2009			
CA	1	3	12	2.007	Surface		0.0	9/11/2009			
CA	1	4	13	2.078	Buried		4.0	9/11/2009			
CA	1	4	14	2.132	Buried		5.0	9/11/2009			
CA	1	4	15	1.795	Buried		6.0	9/11/2009			
CA	1	4	16	2.124	Surface		0.0	9/11/2009			
CA	1	5	17	2.288	Buried		4.5	9/11/2009			
CA	1	5	18	2.358	Buried		4.5	9/11/2009			
CA	1	5	19	1.937	Buried		4.5	9/11/2009			
CA	1	5	20	2.148	Surface		0.0	9/11/2009			
CA	1	6	21	2.128	Buried		5.0	9/11/2009			
CA	1	6	22	2.296	Buried		5.0	9/11/2009			
CA	1	6	23	2.142	Buried		4.5	9/11/2009			

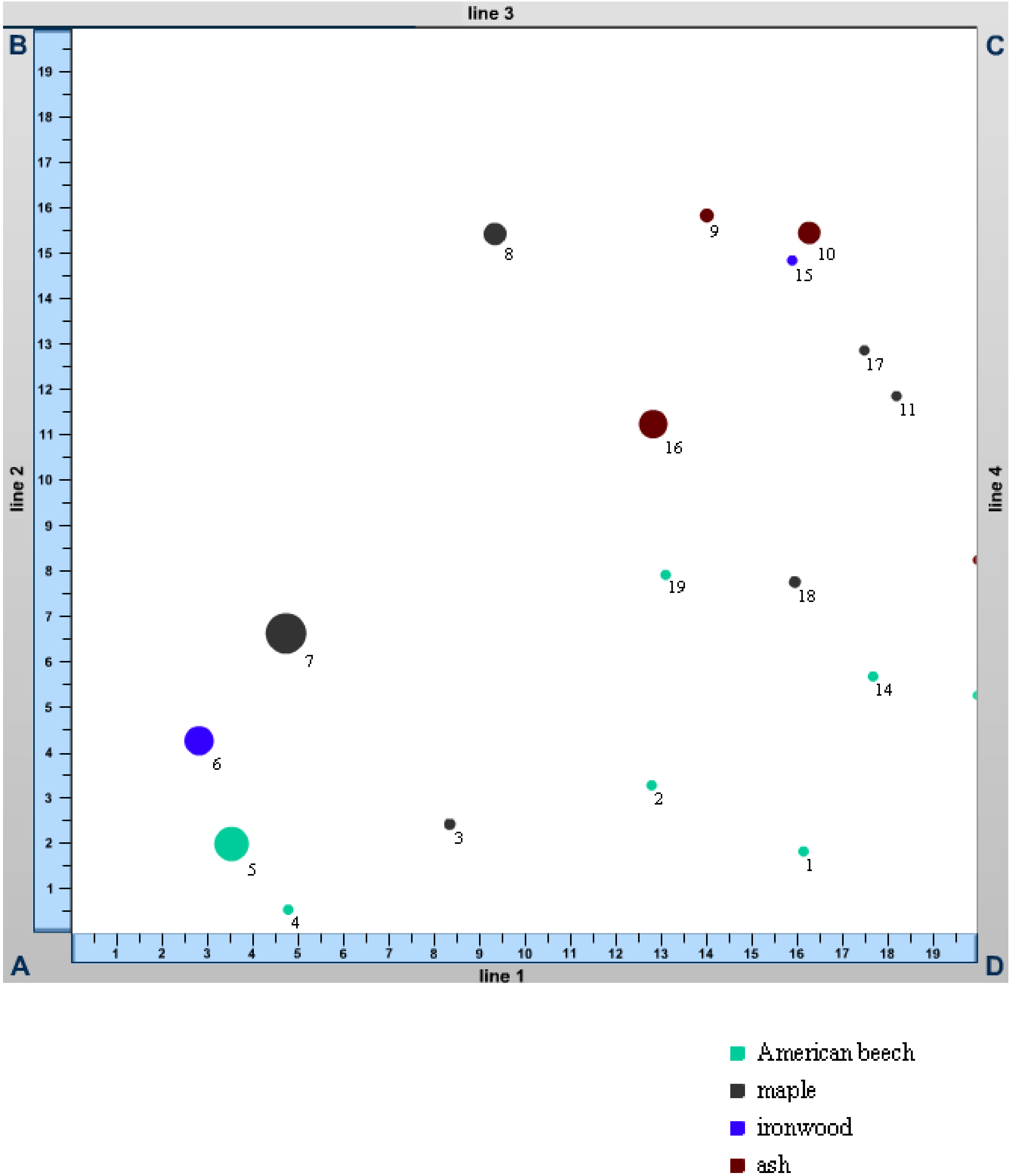
Table 4.2. (continued) Raw 2009 annual decay rates data for the Cliffs and Alvars forest biodiversity monitoring plot number one. Humus depth was not measured as no soil horizons were discernable.

CA	1	6	24	2.113	Surface		0.0	9/11/2009			
CA	1	7	25	2.241	Buried		4.5	9/11/2009			
CA	1	7	26	2.012	Buried		4.0	9/11/2009			
CA	1	7	27	1.949	Buried		4.0	9/11/2009			
CA	1	7	28	2.120	Surface		0.0	9/11/2009			
CA	1	8	29	2.188	Buried		5.0	9/11/2009			
CA	1	8	30	2.267	Buried		5.0	9/11/2009			
CA	1	8	31	2.299	Buried		5.0	9/11/2009			
CA	1	8	32	1.996	Surface		0.0	9/11/2009			
CA	1	9	33	2.135	Buried		5.0	9/11/2009			
CA	1	9	34	2.031	Buried		4.5	9/11/2009			
CA	1	9	35	2.205	Buried		5.0	9/11/2009			
CA	1	9	36	2.037	Surface		0.0	9/11/2009			
CA	1	10	37	2.515	Buried		5.0	9/11/2009			
CA	1	10	38	2.201	Buried		5.0	9/11/2009			
CA	1	10	39	2.206	Buried		4.5	9/11/2009			
CA	1	10	40	2.376	Surface		0.0	9/11/2009			
CA	1	11	41	2.087	Buried		4.0	9/11/2009			
CA	1	11	42	2.544	Buried		4.5	9/11/2009			
CA	1	11	43	2.158	Buried		4.5	9/11/2009			
CA	1	11	44	2.295	Surface		0.0	9/11/2009			
CA	1	12	45	2.202	Buried		4.5	9/11/2009			
CA	1	12	46	2.230	Buried		5.0	9/11/2009			
CA	1	12	47	2.365	Buried		5.0	9/11/2009			
CA	1	12	48	2.225	Surface		0.0	9/11/2009			



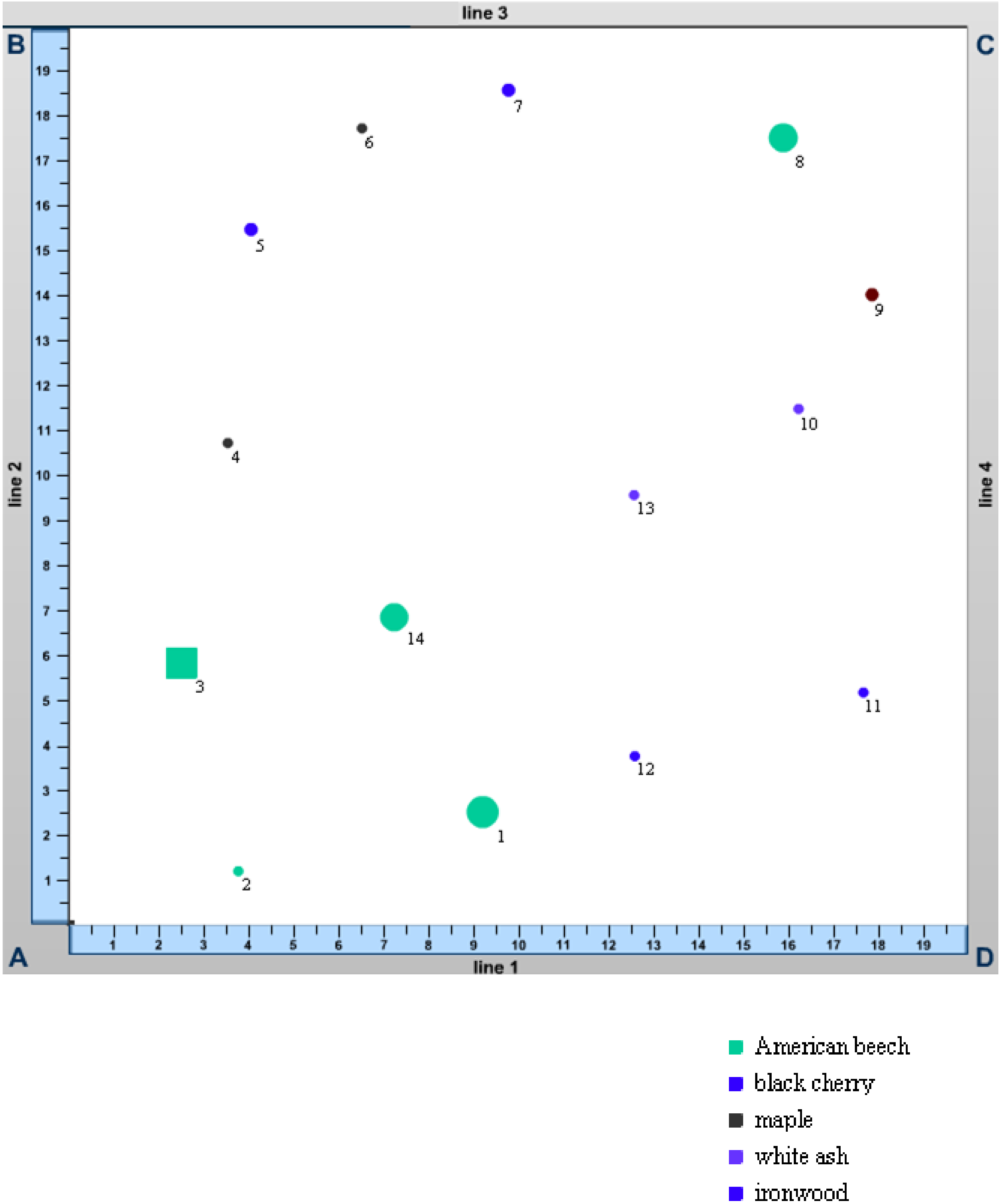
A – Cliffs and Alvars plot 1 (CA1)

Figure 4.4. Tree map for Cliffs and Alvars forest biodiversity plot number A) one (CA1), B) two (CA2), C) three (CA3) generated using EMAN online software, BIOMON. Note that line 1 faces north and square symbols represent trees with 2 stems while circles represent trees with only one stem.



B – Cliffs and Alvars plot 2 (CA2)

Figure 4.4 (continued). Tree map for Cliffs and Alvars forest biodiversity plot number A) one (CA1), B) two (CA2), C) three (CA3) generated using EMAN online software, BIOMON. Note that line 1 faces north and square symbols represent trees with 2 stems while circles represent trees with only one stem.



C – Cliffs and Alvars plot 3 (CA3)

Figure 4.4 (continued). Tree map for Cliffs and Alvars forest biodiversity plot number A) one (CA1), B) two (CA2), C) three (CA3) generated using EMAN online software, BIOMON. Note that line 1 faces north and square symbols represent trees with 2 stems while circles represent trees with only one stem

5.0 – Conclusion

In 2009 forest biodiversity monitoring plots were established on ***rare*** property, benthic invertebrate monitoring continued for the second year, and was expanded with the addition of five new sites, and salamander monitoring was continued for the third year. Statistical analyses of salamander data for the three years monitored thus far showed that no significant changes in salamander abundance have occurred in Indian Woods while abundance in the Hogsback was higher in 2009 than in 2008. Continued monitoring will lend more strength to the trends observed in ***rare***'s salamander populations as well as enabling ***rare***'s monitoring scientists to conduct in-depth analyses of the benthic invertebrate data. More generally, continued monitoring will allow for research questions regarding trends in the ecological health and integrity of ***rare***'s aquatic and terrestrial ecosystems to be fully addressed.

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Appendix A: Maps and Monitoring Plot Co-ordinates

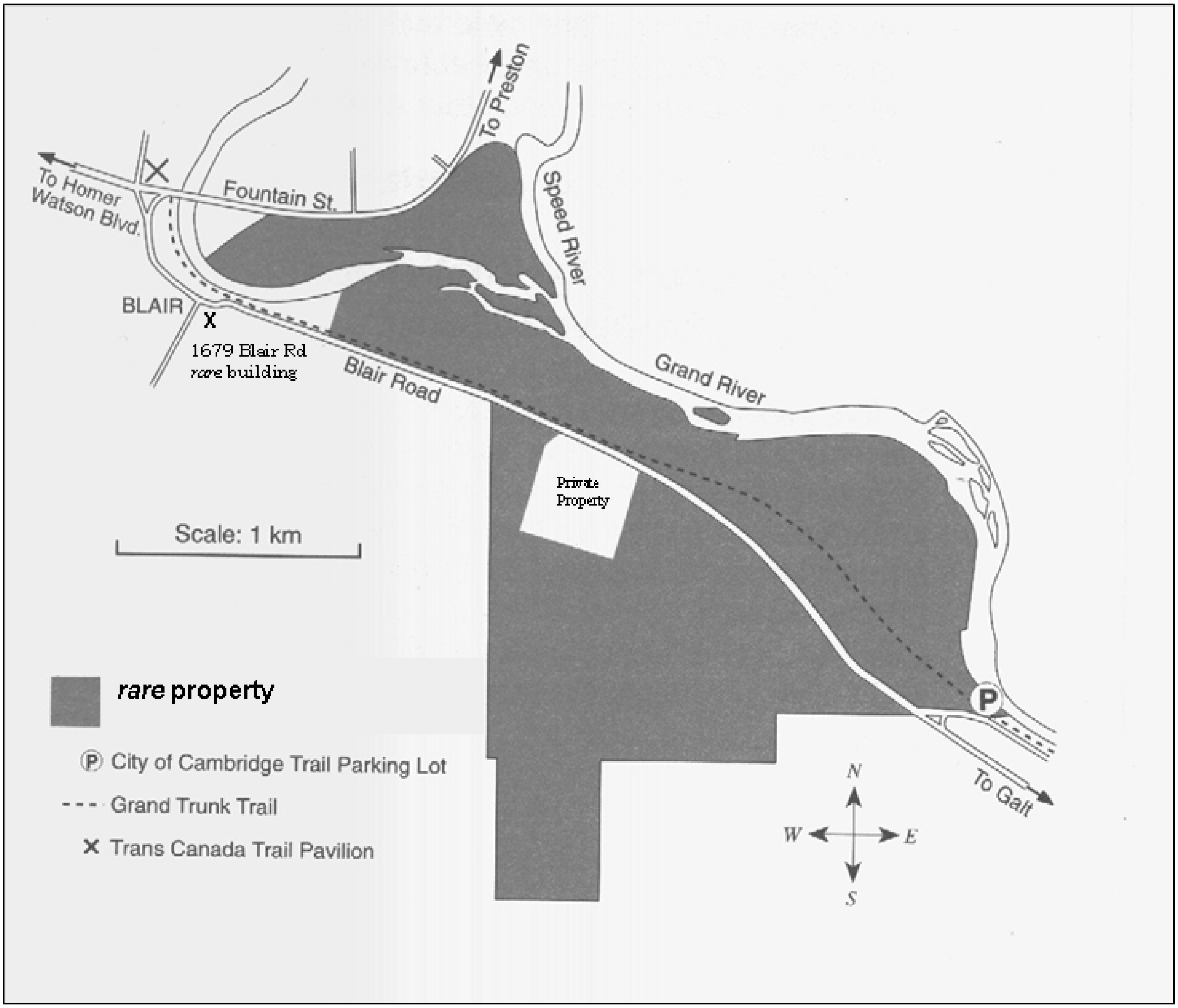


Figure A.1. Location of ***rare*** Charitable Research Reserve.

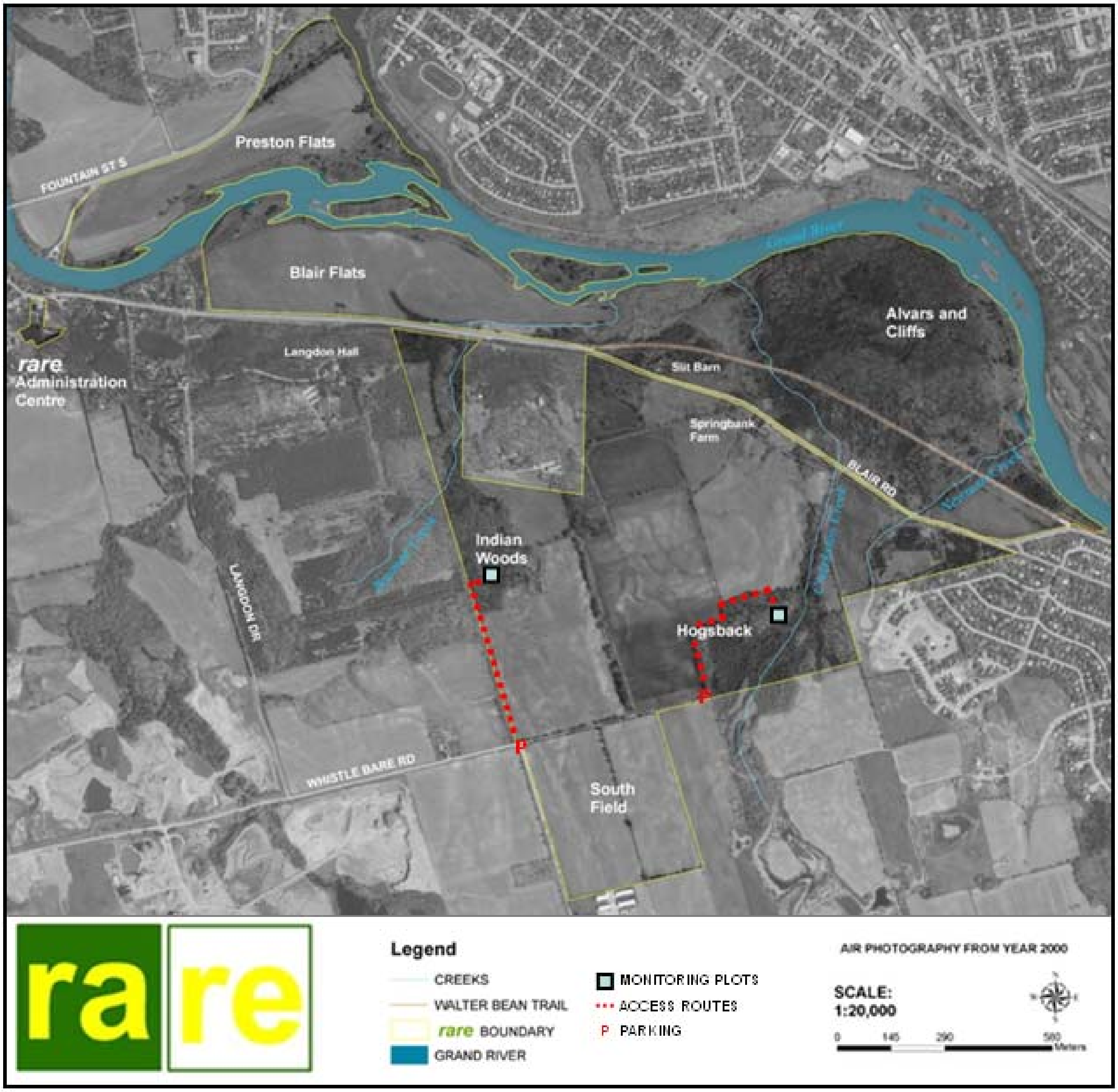


Figure A.2. Locations of the Indian Woods and Hogsback salamander monitoring plots at ***rare***.

Table A.1. Co-ordinates of artificial cover objects used for salamander monitoring in Indian Woods and the Hogsback.

Monitoring Plot	Artificial Cover Object	Latitude and Longitude	UTM (zone 17T)
Indian Woods	1	N 43˚ 22.534' W 80˚ 21.925'	551408E 4802718N
	9	N 43˚ 22.533' W 80˚ 21.900'	448558E 4802716N
	17	N 43˚ 22.516' W 80˚ 21.894'	551450E 4802685N
	25	N 43˚ 22.514' W 80˚ 21.923'	551411E 4802681N
Hogsback	1	N 43˚ 22.399' W 80˚ 21.212'	552372E 4802475N
	8	N 43˚ 22.383' W 80˚ 21.222'	552359E 4802446N
	11	N 43˚ 22.374' W 80˚ 21.214'	552370E 4802429N
	18	N 43˚ 22.393' W 80˚ 21.205'	552382E 4802464N

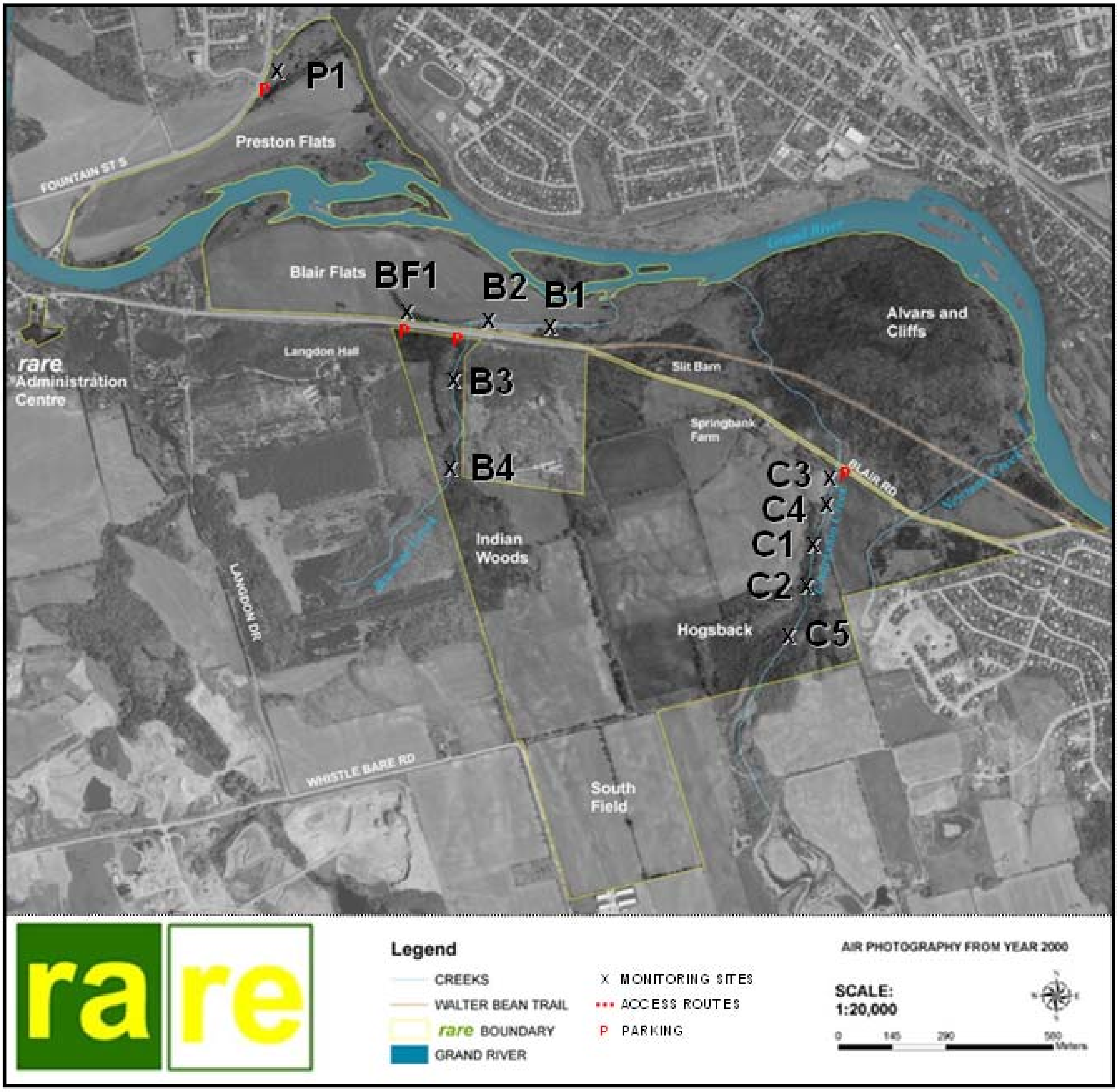


Figure A.3. Locations of the Benthic invertebrate sampling sites at ***rare***.

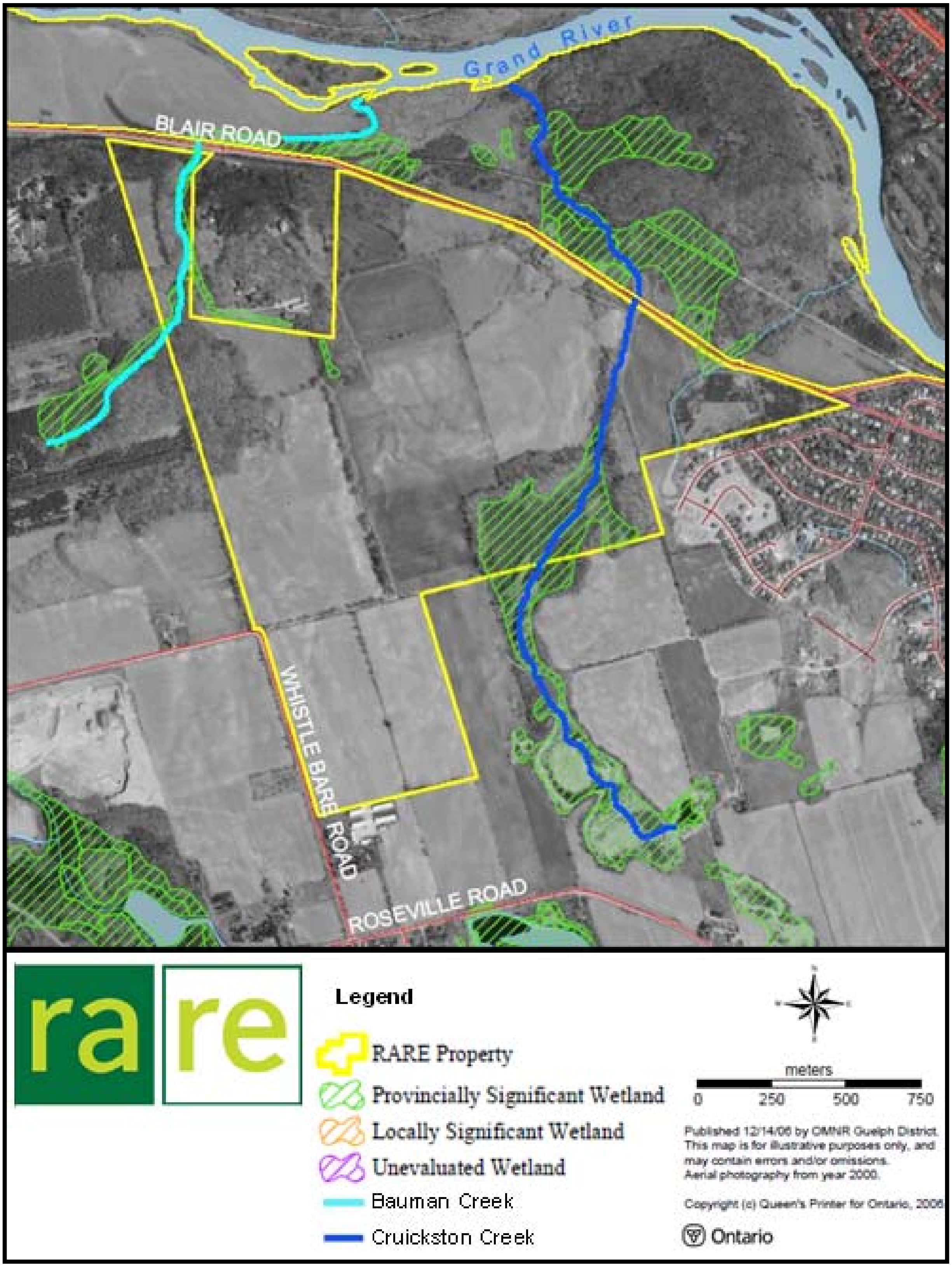


Figure A.4. Provincially significant wetlands in relation to Bauman and Cruickston creeks at ***rare*** (Holton, 2006).

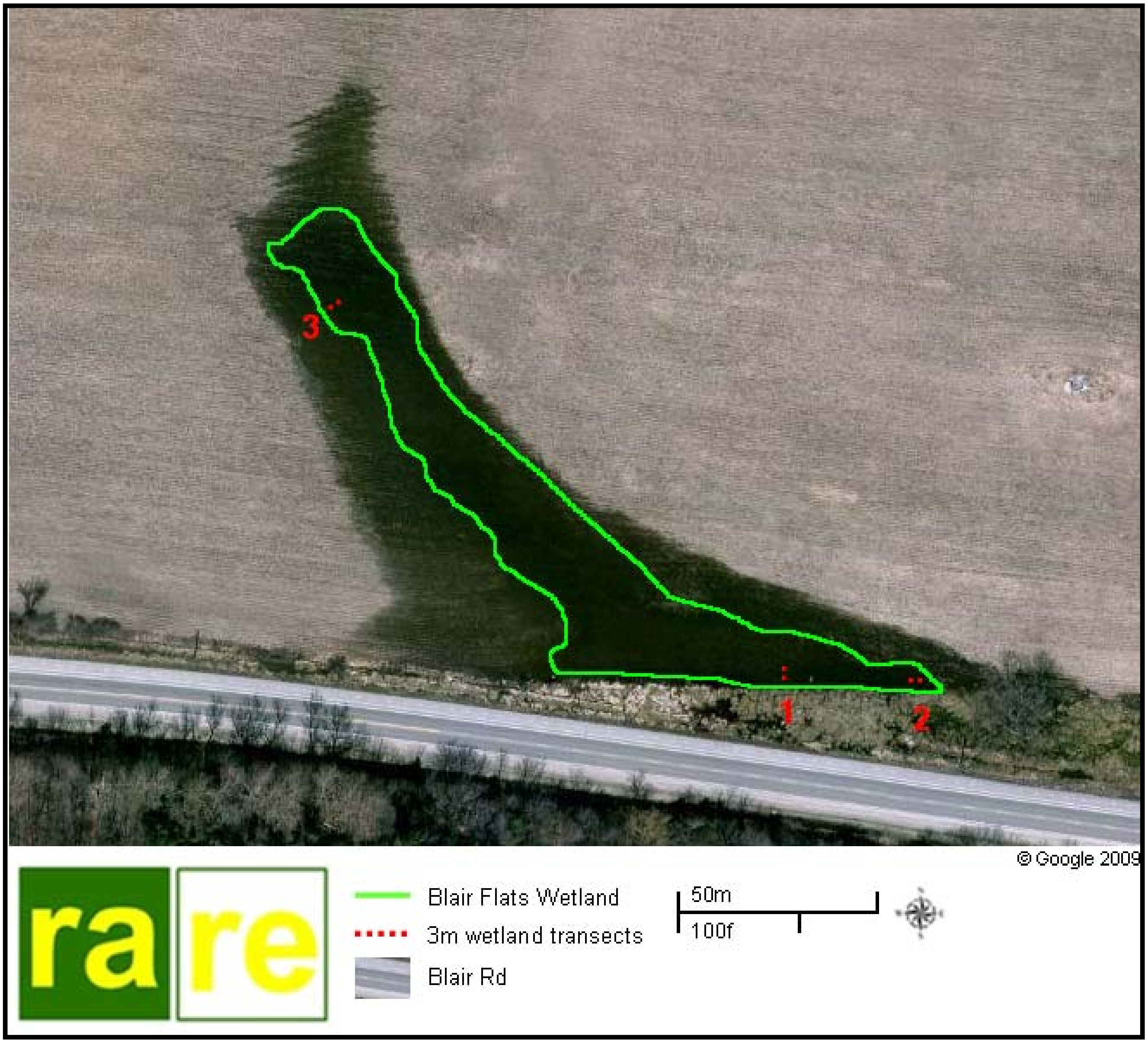


Figure A.5. Location of Blair Flats Wetland benthic invertebrate sampling transects in 2009.

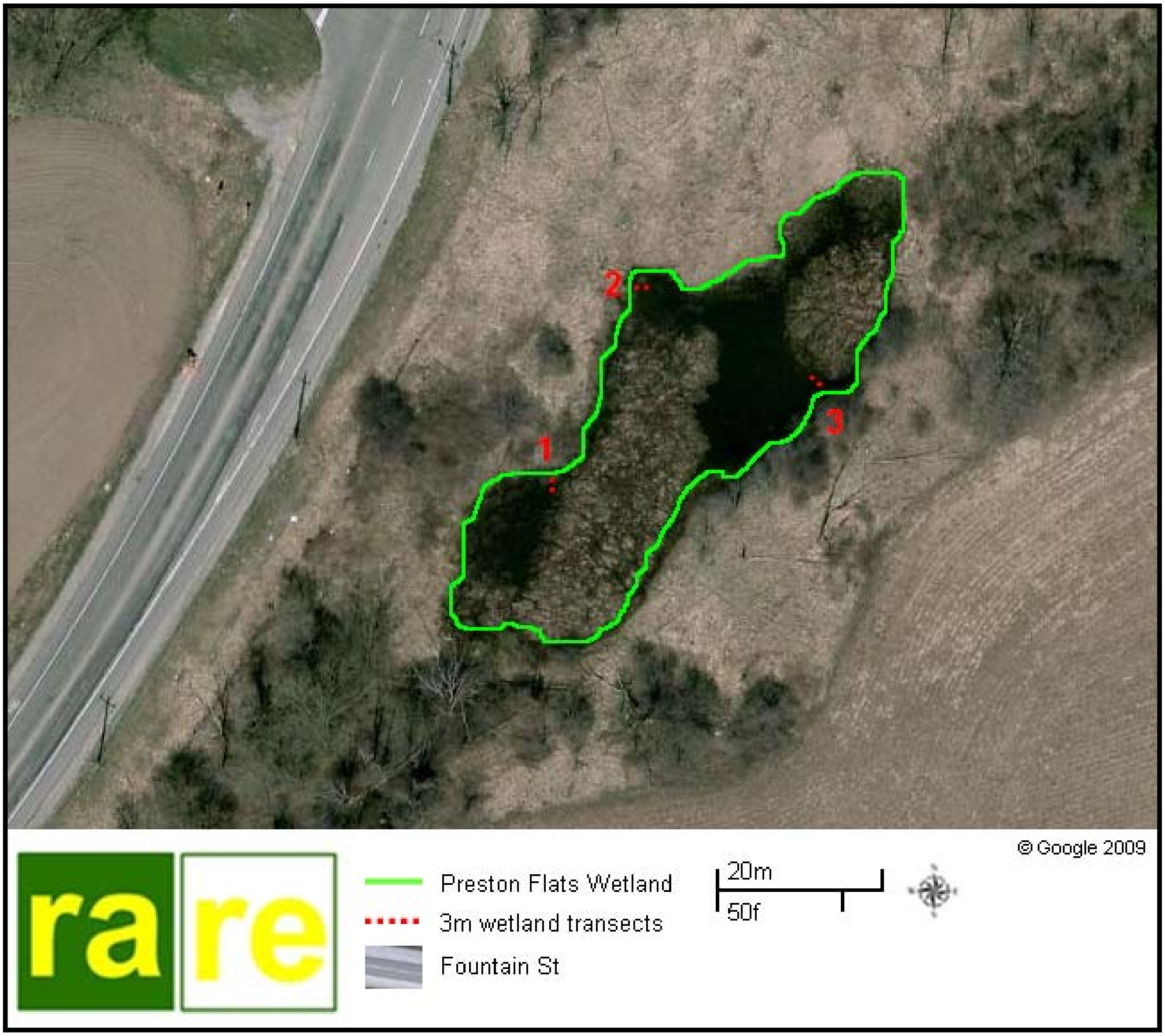


Figure A.6. Location of Preston Flats Wetland benthic invertebrate sampling transects in 2009.

Table A.2. Co-ordinates of the Benthic invertebrate sampling sites at ***rare***.

Water body (code)	Monitoring Site	Latitude and Longitude	UTM (zone 17T)
Preston Flats Wetland (P)	P1	N 43° 23' 17.91" W 80° 22' 30.17"	0550617E 4804127N
Blair Flats Wetland (BF)	BF1	N 43° 22' 51.17" W 80° 22' 7.11"	0551142E 4803306N
Cruickston Creek (C)	C1	N 43° 22’ 38.84” W 80° 21’ 0.49”	0552644E 4802937N
	C2	N 43° 22’ 26.51” W 80° 21’ 4.76”	0552551E 4802556N
	C3	N 43° 22’ 40.77” W 80° 20’ 58.6”	0552686E 4802997N
	C4	N 43° 22’ 40.35” W 80° 20’ 59.23”	0552672E 4802984N
	C5	N 43° 22’21.09” W 80° 38.51.11”	0552459E 4802388N
Baumann Creek (B)	B1	N 43° 22’ 58.1” W 80° 21’ 37.2”	0551671E 4803517N
	B2	N 43° 22’ 58.0” W 80° 21’ 50.2”	0551517E 4803515N
	B3	N 43° 22’57.86” W 80° 38.96”	0551293E 4803309N
	B4	N 43° 22’57.88” W 80° 38.17”	0551183E 4802852N

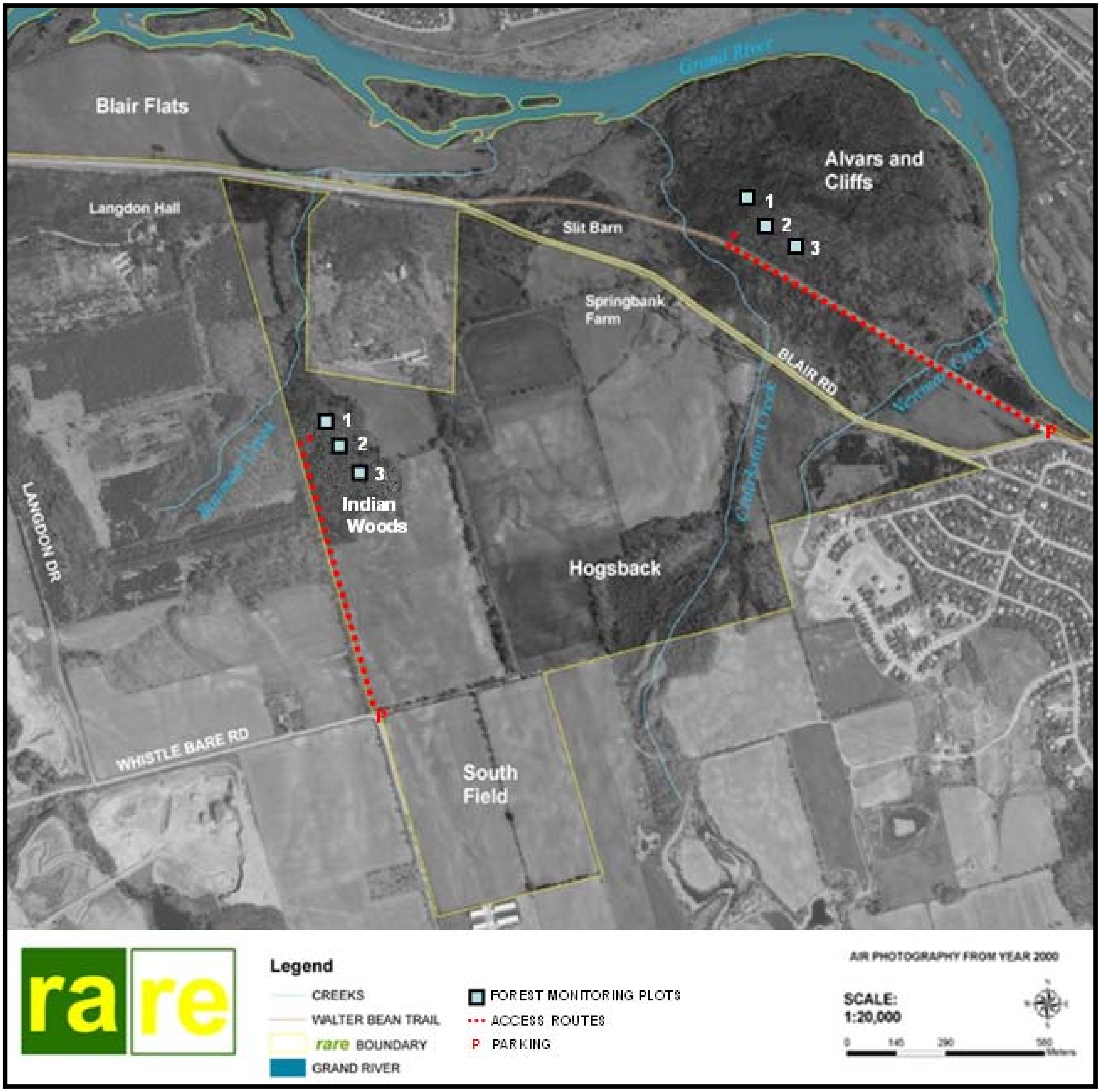


Figure A.7. Location of Indian Woods and Cliffs and Alvars forest biodiversity monitoring plots.

Table A.3. Co-ordinates of the forest biodiversity monitoring plots at ***rare***. Co-ordinates were taken at all corners of each plot (this data is stored in the ***rare*** GPS), but the co-ordinates reported here are for the north-west corner of each plot.

Forest (code)	Monitoring Site	Latitude and Longitude	UTM (zone 17T)
Indian Woods	1	N 43° 22' 27.27" W 80° 21' 51.45"	0551500E 4802571N
	2	N 43° 22' 26.12" W 80° 21' 56.08"	0551396E 4802535N
	3	N 43° 22' 23.62" W 80° 21' 54.78"	0551426E 4802458N
Cliffs and Alvars	1	N 43° 22' 46.3" W 80° 21' 1.34"	0552623E 4803167N
	2	N 43° 22' 44.64" W 80° 21' 0.21"	0552649E 4803116N
	3	N 43° 22' 43.72" W 80° 20' 57.91"	0552701E 4803088N

Appendix B: Equipment Lists and Data Sheets

Salamander monitoring equipment list:

- Clip board
- Field sheets (A and B)
- Blank paper
- Writing utensils (several sharpened pencils and a permanent marker)
- Nitrile gloves
- Kestrel 3000 pocket weather station
- Soil moisture meter
- Soil thermometer
- Digital calipers
- Fabric tape measure
- Clear ruler
- Digital scale
- Pesola spring scale
- Clear plastic bags (i.e. small re-sealable sandwich bags)
- Measuring container (small container with tightly fitted, moist sponge and clear lid)
- Holding container (larger container with several moist sponges)
- Extra Damp sponges
- Extra water
- Binoculars (to read pond depth in Indian Woods)
- Flagging tape
- Florescent safety vest (for safety in the fall)
- GPS
- Camera
- Utility knife

<u>Soil pH Testing:</u>

- Small containers (three for each weather ACO: 24 for Indian Woods, 12 for the Hogsback)
- Labels for containers
- Garden trowel
- Small ladel/probe (to transfer soil to sample containers)
- Nitrile gloves
- Soil pH testing kit

Salamander monitoring field sheet A (note that the number of rows should be adjusted for monitoring):

Field Data Sheet A							
Plot Name:				Group Name: rare Charitable Research Reserve			
Observer Name(s):							
Pond depth (Indian Woods):				Date:			Time:
Precip. (last 24hrs):			Beaufort Sky Code:			Beaufort Wind Code:	
ACO Number	Species	Count	ACO: Type	Age	Soil: Temp	Moisture	ACO Disturbance
Additional Comments:							

Salamander monitoring field sheet B (note that the number of rows should be adjusted for monitoring):

Field Data Sheet B							
Plot Name:					Group Name: rare Charitable Research Reserve		
Observer Name(s):							
Pond depth (mm; Indian Woods):					Date:		Time:
Precip.(mm in last 24hrs):			Beaufort Sky Code:			Beaufort Wind Code:	
ACO Number	Cumulative Number of Salamanders	Species	Length (mm) S-V	V-T	Total	Weight (g)	Comments
Additional Comments:							

Weather Variables:

	North Perimeter		East Perimeter		South Perimeter		West Perimeter	
ACO Number:								
Wind Speed (mph)								
Relative Humidity (%)								
Air Temp (°C)								

Benthic invertebrate monitoring equipment list:

Sample Collection:

- Clip board
- Benthic invertebrate monitoring field sheets
- Blank paper
- Writing utensils (several sharpened pencils and a permanent marker)
- OBBN manual
- 500µm mesh D-net
- 1 large bucket (5 gallon)
- 500µm sieve
- Rinse bottle
- Ladel
- Chest waders
- Kestrel 3000 pocket weather station
- Thermometer
- Clear ruler
- Metre stick
- Stop-watch
- Wide-mouth sample bottles
- Permanent markers and masking tape (for labeling bottles)
- Flagging tape
- Florescent safety vest (for safety in the fall)
- GPS
- Camera
- Utility knife

Sample Processing:

- Benthic invertebrate monitoring lab sheets
- Formeldyhyde
- Ethanol alcohol (diluted to 70%)
- Small funnels
- Nitrile gloves and safety glasses
- Fan
- Extra light sources
- 500µm sieve
- Medium bucket (for "bucket" sub-sampling method)
- Ladel
- White sorting trays
- Rinse bottle
- Forceps (fine- and large-tipped)
- Waste water bucket
- Petri dishes
- Dissection microscope
- Taxonomic keys/ OBBN manual
- Vials for preserving samples (if they're to be kept)
- Permanent markers and masking tape (for labeling vials)

Benthic invertebrate monitoring field sheet (front):

Stantec

Benthic Sample Collection Form

Project Number: ____________ Station ID: ____________

'roject Manager: ____________ Date (yyyymmdd): ____________

Project Name: ____________

Descriptive Location: ____________

____

UTM coordinates: ________ easting ________ northing zone: ____ datum: ____

Sampling Method: ____________

Number of Replicates: ____________ Sampling Duration (minutes) (if applicable): ____________

Supporting Samples Collected (circle if applicable): water sediment TOC sediment grain size other: ________

Estimated Average Stream Width (m): ________ Water Clarity/Colour: ________

***In-Situ* Supporting Measurements** (measured at water/sediment interface)

Water Temperature: ____________ Dissolved Oxygen: ____________

Air Temperature: ____________ pH: ____________

Time: ____________ Conductivity: ____________

Replicate 1 (all observations pertain to individual grabs)

Number of Jars: ____________

Depth (m): ____________

Water Velocity (m/s): ____________

Macrophytes:	none	sparse	common	abundant
Algae:	none	sparse	common	abundant

Substrate description/odour: ____________

____

Replicate 2 (all observations pertain to individual grabs)

Number of Jars: ____________

Depth (m): ____________

Water Velocity (m/s): ____________

Macrophytes:	none	sparse	common	abundant
Algae:	none	sparse	common	abundant

Substrate description/Odour: ____________

____

Replicate 3 (all observations pertain to individual grabs)

Number of Jars: ____________

Depth (m): ____________

Water Velocity (m/s): ____________

Macrophytes:	none	sparse	common	abundant
Algae:	none	sparse	common	abundant

Substrate description/Odour: ____________

____

Field Staff: ____________

____

____

(station diagram on back)

Benthic invertebrate monitoring field sheet (back):

Stantec

Station Diagram:

(include North Arrow, Flow Direction and Road Names if applicable)

Field Staff: ______________________________ Notes By: ____________________

____

Other Notes:

____

____

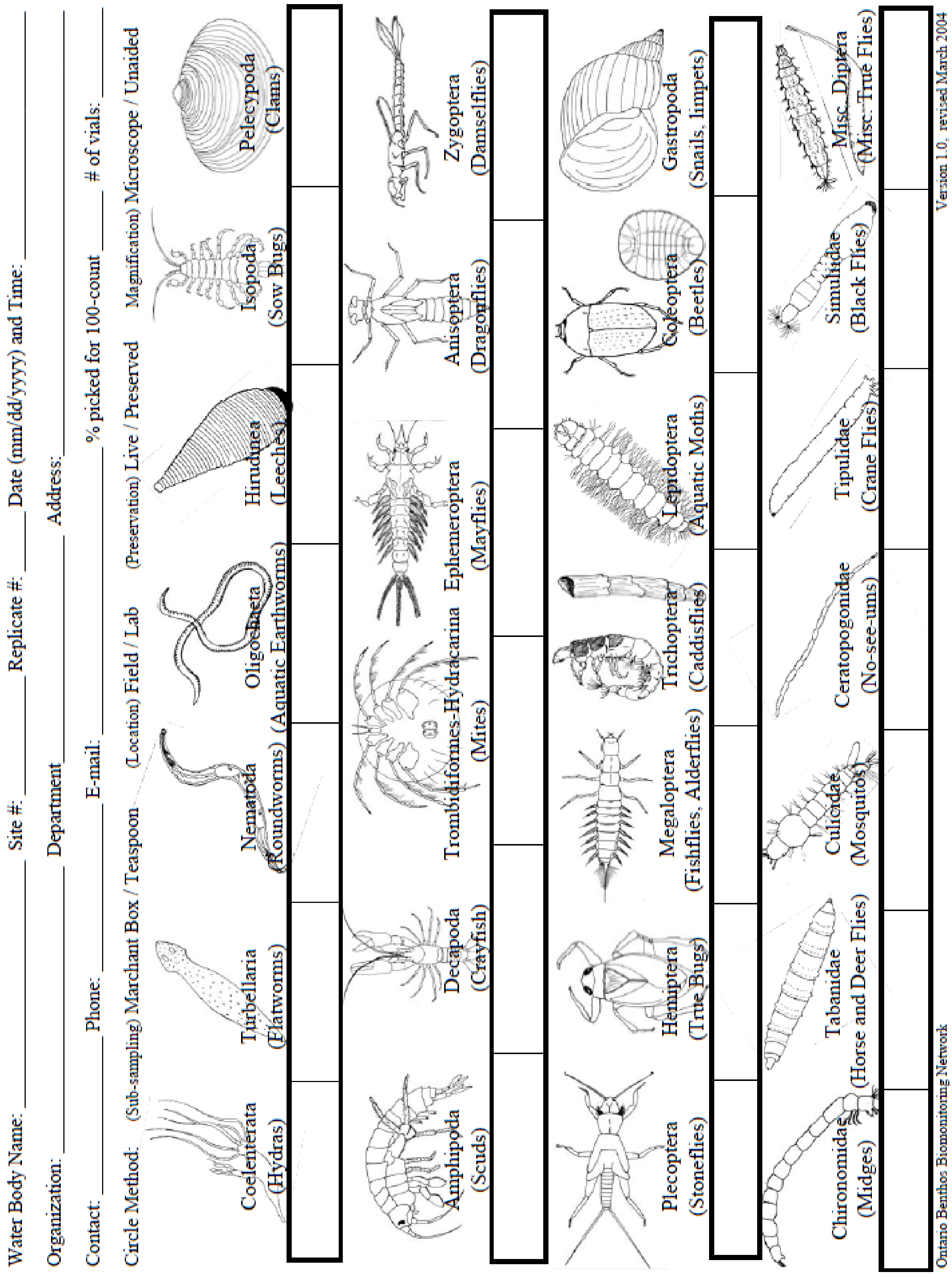
____

____

Quality Control: This form is complete (__) & legible (__). QA/QC by: (signature) ____________

______________________________ (station diagram on back)

Benthic invertebrate monitoring lab sheet (Jones *et al.*, 2007):



Electro-fishing record and catch results field sheet:

Stantec

Page ___ of ___

Stantec Consulting Ltd - Electrofishing Record and Catch Results

Project Number ____________________ Station Number ____________________

Project Name ____________________ Pass No. (if applicable) ____________________

Project manager ____________________ Date (yyyymmdd): ____________________

Descriptive Location ____________________

____

UTM coordinates ____________ easting ____________ northing zone ______

Fishing Method (circle one): Backpack Boat Unit Model/Make ____________

Sampling Method (circle one): even habitat transect spot

Effort (Electrofishing Seconds): ________ Number of Netters: ________ Number of Anodes: ________

Settings

Frequency (Hz) ________ Voltage (volts) ______ Current (Amps) ______ Power (Watts) ______

Station Information

Length of Stream Surveyed (m) ____________________

Station Characteristics: Width (m): Range ________ Average: ________

Depth (m): Range ________ Average: ________

Water Clarity/Colour: ____________ Water Velocity if Measured (m/s): ________

Temperature (°C) ________ Conductivity (uS/cm) ________

pH ________ Dissolved Oxygen (mg/L) ________

Catch Data

Species	Number of Fish	Species	Number of Fish

Fish Measurements on Separate Sheet? Y/N

Field Staff: ____________________ Notes By: ____________________

____

(Station Diagram on Back)

Forest biodiversity monitoring equipment list:

Tree mapping:

- Clip board
- Forest biodiversity monitoring field sheets
- Blank paper
- Writing utensils (several sharpened pencils and a permanent marker)
- Two 30.5m tape measures
- Tree identification manual
- Binoculars
- GPS
- Compass
- Twine
- Flagging tape
- Permanent markers
- Extra pre-labelled metal tags, hammer, nails
- Extra 18" galvanized steel wire pigtails
- Florescent safety vest (for safety in the fall)
- Camera
- Utility knife

Forest biodiversity monitoring canopy-tree sample field sheet:

CANOPY-TREE SAMPLE: FIELD DATA SHEET (1-ha. plot or 20 m x 20 m stand-alone quadrats). Stand name.. Date..

Stand location (lat. & long.) ....Hectare plot and quadrat nº.........................OR Stand-alone quadrat nº........... Av. stand height..

Identification manual................................ Observer(s)..

Tag #	Species name	Number of stems	dbh (cm)	Line (1,2,3,4)	A distance (m)	B distance (m)	Height (m)	Condition	Notes

Forest biodiversity monitoring canopy-tree summary field sheet:

CANOPY-TREE SAMPLE: SUMMARY SHEET. Stand name.. Date...

Stand location (lat. & long.).. Number of 1-ha plots .... OR Number of 20 m x 20 m stand-alone quadrats ....

Sample area (m^2).................. Average canopy height .... Data processor(s)..

Species name	Abundance	Density	Basal Area	Dominance	Frequency	Relative Density	Relative Frequency	Relative Dominance	Importance Value	Notes

Forest biodiversity annual decay rates (ADR) monitoring equipment list:

Pre-weighing tongue depressors:

- 100% natural birch, oven dried, tongue depressors (4 tongue depressors/ADR site x 12 sites/forest biodiversity monitoring plot = 48 tongue depressors/plot)
- Drill with 2mm drill bit
- Sartorius 1265MP (0.001-400g) scale
- Extra strong fishing wire
- Pre-labelled metal tags
- Forest annual decay rates (ADR) data sheet

Burying tongue depressors:

- Permanent markers
- Dried, pre-weighed and tagged 100% natural birch tongue depressors
- Clip board
- Forest annual decay rates (ADR) data sheet
- Writing utensils (several sharpened pencils and a permanent marker)
- 18” galvanized steel wire pigtails
- Flagging tape
- Shovel and small garden trowel
- Butter knife
- Ruler
- Meter stick (or 1m^2 quadrate)
- Compass
- GPS
- Florescent safety vest (for safety in the fall)
- Camera
- Utility knife

Forest annual decay rates (ADR) data sheet (note that the last three columns are filled out one year after burying the tongue depressors):

Forest Stand ID	Forest Biodiversity Monitoring Plot ID	ADR Station ID	Tongue Depressor (TD) Tag Number	TD Original weight (to 0.001g)	TD Placement (surface/ buried)	Humus depth (cm)	Buried depth (cm)	Date Buried (d/m/y)	Date Retrieved (d/m/y)	TD Decayed Weight (to 0.001g)	TD Weight Difference (to 0.001g)

Appendix C: 2009 Monitoring Data Summaries and Raw Data

Table C.1. Summary of salamanders found in A) Indian Woods and B) the Hogsback in 2009 (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

A – Indian Woods

Date	Total Salamanders Found					DATE TOTAL
	RESA	*LESA*	*YESA*	*BLSA*	*FOSA*	
31-Aug-09	19	1	0	0	0	20
7-Sep-09	13	0	0	0	0	13
14-Sep-09	13	1	0	0	0	14
21-Sep-09	15	2	0	0	0	17
28-Sep-09	27	3	0	0	0	30
5-Oct-09	18	3	0	0	0	21
12-Oct-09	34	3	0	0	0	37
19-Oct-09	14	0	0	0	0	14
26-Oct-09	15	1	0	0	0	16
TOTAL	168	14	0	0	0	182

B – Hogsback

Date	Total Salamanders Found					DATE TOTAL
	RESA	*LESA*	*YESA*	*BLSA*	*FOSA*	
1-Sep-09	15	1	1	0	0	17
8-Sep-09	11	2	1	0	0	14
15-Sep-09	6	3	1	0	0	10
22-Sep-09	9	6	0	1	0	16
29-Sep-09	14	4	0	0	0	18
6-Oct-09	17	2	0	1	0	20
13-Oct-09	12	3	0	0	2	17
20-Oct-09	13	6	0	0	0	19
27-Oct-09	9	1	1	0	0	11
TOTAL	106	28	4	2	2	142

Table C.2. Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

A – Indian Woods

ACO#	Species	Cumulative Number (per date)	Lengths (mm)			Weight (g)	Comments
			Snout-Vent	Vent-Tail	Total		
Indian Woods - Week 1 (31-Aug-2009, 12:16-15:15):							
4	RESA	1	31.17	26.40	57.57	0.55	
4	LESA	2	29.81	30.47	60.28	0.60	
10	RESA	3	40.27	40.67	80.94	1.15	
10	RESA	4	29.83	31.80	61.63	0.60	
10	RESA	5	29.73	28.91	58.64	0.45	
11	RESA	6	46.16	48.20	94.36	1.55	blotchy colouring
11	RESA	7	43.99	45.47	89.46	1.45	
14	RESA	8	40.93	45.97	86.90	1.25	
14	RESA	9	38.36	41.00	79.36	0.90	
15	RESA	10	40.70	39.80	80.50	1.20	
16	RESA	11	38.86	32.88	71.74	0.80	
17	RESA	12	40.83	38.89	79.72	0.85	
18	RESA	13	-	-	0.00	-	in ACO crack
22	RESA	14	31.39	29.88	61.27	0.60	
24	RESA	15	39.03	35.19	74.22	1.00	
25	RESA	16	43.12	29.91	73.03	1.15	
26	RESA	17	36.86	34.49	71.35	1.00	
27	RESA	18	29.04	27.99	57.03	0.50	
29	RESA	19	36.68	42.27	78.95	0.95	flushed out of hole
32	RESA	20	40.63	45.65	86.28	1.45	
Indian Woods – Week 2 (07-Sep-2009, 11:14-13:14):							
2	RESA	1	29.77	24.84	54.61	0.50	
4	RESA	2	30.21	28.56	58.77	0.50	ants under board
6	RESA	3	38.14	39.67	77.81	0.80	
10	RESA	4	29.59	30.11	59.70	0.50	
11	RESA	5	31.88	29.70	61.58	0.50	
11	RESA	6	48.20	48.15	96.35	1.80	dark - blotchy tail
11	RESA	7	41.70	45.79	87.49	1.50	
12	RESA	8	37.90	41.62	79.52	0.90	
17	RESA	9	42.80	36.03	78.83	1.00	
21	RESA	10	21.49	20.76	42.25	0.30	
21	RESA	11	29.28	26.63	55.91	0.40	
25	RESA	12	39.71	35.96	75.67	0.90	
32	RESA	13	41.39	43.31	84.70	1.40	

Table C.2. (continued) Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Indian Woods – Week 3 (14-Sep-2009, 11:00-13:50):

2	RESA	1	25.93	22.79	48.72	0.30	
2	RESA	2	30.11	8.93	39.04	0.40	lost tail recently
7	LESA	3	27.15	24.71	51.86	0.40	
8	RESA	4	27.44	23.23	50.67	0.40	
8	RESA	5	37.32	29.94	67.26	1.00	
10	RESA	6	35.30	35.43	70.73	0.70	
13	RESA	7	33.29	33.47	66.76	0.60	mostly leadbacked but has some red spots
14	RESA	8	37.76	46.90	84.66	0.70	
17	RESA	9	41.74	36.38	78.12	1.10	
20	RESA	10	30.92	26.32	57.24	0.50	
25	RESA	11	39.35	38.28	77.63	0.90	
27	RESA	12	39.32	33.19	72.51	1.10	
31	RESA	13	30.94	31.36	62.30	0.60	
32	RESA	14	41.06	43.81	84.87	1.50	

Indian Woods – Week 4 (21-Sep-2009, 10:00-12:20):

1	RESA	1	36.33	32.84	69.17	0.90	
2	RESA	2	37.81	38.03	75.84	0.80	
6	LESA	3	39.46	35.23	74.69	1.00	
7	RESA	4	28.63	22.28	50.91	0.40	
7	RESA	5	39.99	44.14	84.13	0.80	
13	RESA	6	40.22	36.52	76.74	0.90	
13	RESA	7	30.69	34.08	64.77	0.30	very dark colouring, red blotches
17	RESA	8	88.42	88.42	176.84	1.10	tip of tail regenerating
18	RESA	9	48.50	38.18	86.68	0.70	
21	RESA	10	42.24	32.17	74.41	1.00	tip of tail regenerating
24	RESA	11	40.87	44.87	85.74	1.30	
24	RESA	12	42.96	36.12	79.08	1.10	
25	RESA	13	38.57	36.75	75.32	1.00	
25	RESA	14	39.41	35.05	74.46	0.90	
25	LESA	15	-	-	0.00	-	down hole
31	RESA	16	-	-	0.00	-	down hole
31	RESA	17	30.35	31.74	62.09	0.50	

Indian Woods – Week 5 (28-Sep-2009, 12:07-14:32):

1	RESA	1	40.20	39.01	79.21	0.80	
3	LESA	2	25.34	25.43	50.77	0.30	
4	RESA	3	43.06	41.27	84.33	1.10	
6	RESA	4	40.33	41.04	81.37	1.00	
7	RESA	5	42.32	44.66	86.98	1.20	
7	RESA	6	32.48	32.36	64.84	0.60	
7	RESA	7	37.72	32.84	70.56	0.70	

Table C.2. (continued) Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Indian Woods – Week 5 (continued):

7	RESA	8	36.61	38.01	74.62	0.90	
7	RESA	9	37.94	32.89	70.83	1.10	
7	LESA	10	28.31	25.04	53.35	0.40	
8	RESA	11	37.62	37.81	75.43	1.00	
9	RESA	12	39.37	39.06	78.43	1.00	
9	LESA	13	49.27	47.17	96.44	1.90	
10	RESA	14	39.06	42.88	81.94	1.10	
10	RESA	15	46.12	47.17	93.29	1.30	
14	RESA	16	37.05	30.10	67.15	0.70	
15	RESA	17	41.35	40.00	81.35	1.20	
15	RESA	18	40.34	44.22	84.56	1.30	
16	RESA	19	38.32	43.48	81.80	1.00	
16	RESA	20	45.53	47.29	92.82	1.20	
17	RESA	21	43.49	37.44	80.93	1.30	
18	RESA	22	39.84	34.35	74.19	0.90	
23	RESA	23	40.55	37.73	78.28	0.90	
25	RESA	24	38.86	31.80	70.66	1.10	
25	RESA	25	44.72	42.79	87.51	1.20	
26	RESA	26	30.85	31.49	62.34	0.60	
26	RESA	27	-	-	-	-	down hole
29	RESA	28	37.71	39.96	77.67	0.85	
32	RESA	29	43.33	44.95	88.28	1.70	
32	RESA	30	40.42	36.41	76.83	1.25	

Indian Woods – Week 6 (05-Oct-2009, 10:00-12:00):

3	RESA	1	39.23	36.16	75.39	1.10	
4	RESA	2	43.43	42.77	86.20	1.20	
4	RESA	3	37.75	35.33	73.08	0.90	
6	LESA	4	39.28	44.28	83.56	1.20	
7	LESA	5	28.73	24.73	53.46	0.50	
7	RESA	6	42.35	44.18	86.53	1.20	light white patch under torso
7	RESA	7	38.05	37.49	75.54	1.10	
8	RESA	8	29.28	24.63	53.91	0.50	
8	RESA	9	38.07	38.20	76.27	0.90	
9	RESA	10	44.19	38.87	83.06	1.50	
9	RESA	11	39.61	40.50	80.11	0.90	
10	LESA	12	34.77	37.46	72.23	0.80	
10	RESA	13	39.11	41.90	81.01	1.10	
15	RESA	14	40.66	42.25	82.91	1.30	
16	RESA	15	35.80	33.32	69.12	0.70	garter snake under ACO
22	RESA	16	37.79	36.46	74.25	1.10	
24	RESA	17	39.42	39.07	78.49	1.00	
25	RESA	18	40.97	40.64	81.61	0.90	short tail –possibly regen.

Table C.2. (continued) Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Indian Woods – Week 6 (continued)

30	RESA	19	37.00	39.00	76.00	0.90	used ruler
32	RESA	20	33.00	31.00	64.00	0.50	used ruler
32	RESA	21	41.00	32.00	73.00	1.20	used ruler

Indian Woods – Week 7 (12-Oct-2009, 11:30-13:30):

4	RESA	1	35.05	29.44	64.49	0.80	
4	RESA	2	42.28	40.17	82.45	1.30	
4	RESA	3	41.07	39.97	81.04	1.10	
5	RESA	4	12.27	8.87	21.14	0.05	
6	RESA	5	39.13	39.13	78.26	1.30	
6	RESA	6	40.67	27.78	68.45	1.10	
6	RESA	7	44.52	44.11	88.63	1.50	
7	RESA	8	39.53	43.69	83.22	1.40	
7	RESA	9	41.51	45.93	87.44	1.60	
7	LESA	10	36.59	32.71	69.30	0.80	
7	LESA	11	46.46	38.04	84.50	1.60	
7	RESA	12	37.62	36.14	73.76	0.90	missing left eye
7	RESA	13	39.65	40.69	80.34	1.00	
7	RESA	14	32.08	31.49	63.57	0.60	
7	RESA	15	37.24	38.90	76.14	1.10	
7	RESA	16	30.91	27.45	58.36	0.50	
7	RESA	17	30.24	32.36	62.60	0.60	
7	RESA	18	39.90	45.44	85.34	1.20	
7	RESA	19	34.01	37.20	71.21	0.80	
7	RESA	20	40.05	29.31	69.36	0.90	
7	LESA	21	37.74	43.34	81.08	1.00	
8	RESA	22	39.25	35.44	74.69	1.20	
10	RESA	23	41.44	42.31	83.75	1.30	
11	RESA	24	40.72	39.70	80.42	1.50	
14	RESA	25	38.02	41.87	79.89	1.20	
17	RESA	26	39.41	44.39	83.80	1.00	
17	RESA	27	39.58	34.70	74.28	1.00	
20	RESA	28	35.01	33.25	68.26	0.80	
20	RESA	29	40.09	43.53	83.62	1.20	
21	RESA	30	16.58	13.48	30.06	0.15	brown snake
22	RESA	31	43.18	31.36	74.54	1.20	
24	RESA	32	38.15	39.90	78.05	1.00	
25	RESA	33	38.39	40.13	78.52	1.00	
25	RESA	34	38.74	45.19	83.93	1.30	
29	RESA	35	41.10	39.25	80.35	1.20	
30	RESA	36	42.15	43.22	85.37	1.70	
30	RESA	37	32.49	37.32	69.81	0.90	

Table C.2. (continued) Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Indian Woods Week 8 (19-Oct-2009, 11:43-13:00):

4	RESA	1	44.15	42.06	86.21	1.40	really large/fat
7	RESA	2	37.76	40.56	78.32	0.90	
7	RESA	3	33.70	37.73	71.43	0.70	
10	RESA	4	40.99	41.74	82.73	1.30	
21	RESA	5	43.86	44.00	87.86	0.90	long tail
21	RESA	6	35.40	33.44	68.84	0.80	
22	RESA	7	41.92	36.04	77.96	1.20	
22	RESA	8	42.05	42.89	84.94	0.80	
24	RESA	9	39.23	41.57	80.80	1.00	
25	RESA	10	41.39	46.22	87.61	1.50	
29	RESA	11	33.60	35.96	69.56	0.70	
29	RESA	12	37.46	37.74	75.20	0.90	
32	RESA	13	42.29	34.68	76.97	1.30	
32	RESA	14	37.77	33.45	71.22	0.90	

Indian Woods Week 9 (26-Oct-2009, 12:50-14:00):

1	RESA	1	40.22	37.29	77.51	1.30	
4	RESA	2	38.07	36.05	74.12	0.80	
6	RESA	3	43.94	43.17	87.11	1.50	
7	RESA	4	37.93	37.01	74.94	1.00	
7	LESA	5	37.64	41.83	79.47	0.90	
9	RESA	6	36.12	40.89	77.01	0.90	
10	RESA	7	33.46	29.81	63.27	0.70	
10	RESA	8	40.60	37.95	78.55	1.20	
11	RESA	9	44.27	42.72	86.99	1.00	
15	RESA	10	37.89	35.31	73.20	0.90	
17	RESA	11	45.61	43.53	89.14	1.40	
17	RESA	12	42.22	42.87	85.09	1.20	
20	RESA	13	42.29	44.12	86.41	1.30	
20	RESA	14	41.88	29.70	71.58	1.20	
21	RESA	15	38.49	44.79	83.28	1.40	
22	RESA	16	40.81	32.00	72.81	1.10	

Table C.2 (continued). Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

B – Hogsback

ACO#	Species	Cumulative Number (per date)	Lengths (mm)			Weight (g)	Comments
			Snout-Vent	Vent-Tail	Total		
Hogsback - Week 1 (01-Sep-2009, 10:52-12:20):							
7	RESA	1	39.17	38.22	77.39	1.05	
8	RESA	2	-	-	-	-	down a hole
9	RESA	3	44.78	39.87	84.65	1.20	
10	RESA	4	27.30	25.43	52.73	0.35	
10	RESA	5	31.28	29.35	60.63	0.45	
11	YESA	6	68.57	79.33	147.9	>10	
11	RESA	7	-	-	-	-	down a hole
12	RESA	8	29.69	26.63	56.32	0.45	
14	RESA	9	27.43	23.84	51.27	0.55	
14	RESA	10	38.93	28.80	67.73	0.90	
15	RESA	11	27.79	24.96	52.75	0.50	
15	RESA	12	40.88	46.88	87.76	1.40	
15	RESA	13	34.28	35.57	69.85	0.60	
17	LESA	14	40.41	43.34	83.75	1.40	
19	RESA	15	38.24	41.40	79.64	1.00	
20	RESA	16	41.14	38.19	79.33	1.45	
20	RESA	17	30.34	32.32	62.66	0.50	
Hogsback - Week 2 (08-Sep-2009, 10:15-11:56):							
4	RESA	1	34.13	35.47	69.6	0.60	
7	RESA	2	35.77	39.65	75.42	1.20	
8	RESA	3	36.33	33.67	70	0.90	
9	RESA	4	42.59	47.85	90.44	1.70	down a hole
10	RESA	5	46.04	45.39	91.43	1.40	
11	YESA	6	75.09	82.42	157.5	17.80	
12	RESA	7	28.81	30.52	59.33	0.40	
13	LESA	8	25.96	27.65	53.61	0.40	
14	RESA	9	32.73	25.95	58.68	0.60	
14	RESA	10	38.80	32.87	71.67	0.90	
15	RESA	11	32.42	24.49	56.91	0.40	
15	RESA	12	33.06	32.70	65.76	0.60	
17	LESA	13	41.73	45.96	87.69	1.50	
17	RESA	14	30.50	35.58	66.08	0.50	

Table C.2 (continued). Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Hogsback - Week 3 (15-Sep-2009, 10:30-11:30):

4	RESA	1	33.85	35.32	69.17	0.70	
6	LESA	2	38.13	27.92	66.05	0.70	
11	YESA	3	67.59	81.42	149.01	17.5	
12	RESA	4	18.13	20.60	38.73	0.40	
14	RESA	5	36.05	32.65	68.7	0.90	
15	RESA	6	34.51	38.41	72.92	0.70	
15	RESA	7	33.00	33.91	66.91	0.60	
15	RESA	8	31.37	26.93	58.3	0.40	
17	LESA	9	44.37	44.36	88.73	1.30	
18	LESA	10	37.85	43.29	81.14	0.70	

Hogsback - Week 4 (22-Sep-2009, 10:00-11:30):

1	RESA	1	39.29	41.8	81.09	0.90	
2	RESA	2	29.36	28.86	58.22	0.40	
6	LESA	3	36.76	29.21	65.97	0.80	
7	LESA	4	38.36	41.42	79.78	0.80	
8	RESA	5	38.00	38.52	76.52	1.20	
11	RESA	6	41.44	51.20	92.64	1.50	
12	RESA	7	27.34	29.27	56.61	0.50	
13	RESA	8	37.52	38.29	75.81	0.80	
14	BLSA	9	52.26	49.36	101.62	5.40	
14	LESA	10	40.97	37.65	78.62	1.20	
14	RESA	11	42.07	46.03	88.1	1.20	
14	LESA	12	38.63	36.27	74.9	0.80	
15	RESA	13	39.97	47.71	87.68	1.10	
17	LESA	14	41.62	41.84	83.46	1.40	
17	RESA	15	38.18	37.59	75.77	0.90	
18	LESA	16	30.40	28.52	58.92	0.50	

Hogsback - Week 5 (29-Sep-2009, 10:20-11:45):

1	RESA	1	32.19	26.4	58.59	0.80	
1	RESA	2	38.61	35.77	74.38	0.90	
5	LESA	3	43.73	41.05	84.78	1.30	left eye missing, bleeding
6	RESA	4	46.54	39.94	86.48	1.40	really fat
8	RESA	5	35.80	35.49	71.29	0.80	
9	RESA	6	27.74	29.84	57.58	0.50	
9	LESA	7	38.43	42.02	80.45	1.00	
9	RESA	8	44.42	42.05	86.47	1.60	
10	RESA	9	29.23	30.00	59.23	0.50	
10	RESA	10	33.59	30.25	63.84	0.70	
13	RESA	11	38.09	39.10	77.19	0.80	
14	RESA	12	31.03	31.56	62.59	0.60	
14	LESA	13	42.27	40.22	82.49	1.00	
16	RESA	14	36.61	32.46	69.07	0.90	

Table C.2 (continued). Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Hogsback - Week 5 (continued)

16	RESA	15	42.19	46.63	88.82	1.10	
17	RESA	16	36.45	41.04	77.49	0.90	
17	LESA	17	47.14	44.42	91.56	1.50	
17	RESA	18	38.00	36.58	74.58	0.90	

Hogsback - Week 6 (06-Oct-2009, 10:00-11:30):

1	RESA	1	30.85	26.02	56.87	0.50	
3	BLSA	2	51.48	41.81	93.29	5.20	
4	RESA	3	30.38	30.47	60.85	0.60	
8	RESA	4	40.79	43.04	83.83	1.10	sharp edges below each nare - possibly male?
8	RESA	5	43.51	45.06	88.57	1.50	no sharp edges - female?
9	RESA	6	45.61	41.51	87.12	1.70	fat
9	RESA	7	41.45	40.27	81.72	1.20	
9	LESA	8	40.04	43.98	84.02	1.10	
10	RESA	9	48.27	44.63	92.9	1.40	
10	RESA	10	35.76	29.88	65.64	0.70	
10	RESA	11	29.29	29.08	58.37	0.60	eating a worm
11	RESA	12	28.70	28.47	57.17	0.60	
12	RESA	13	31.37	31.47	62.84	0.50	
13	RESA	14	40.75	40.75	81.5	1.20	blunt tail - end of regen.?
14	LESA	15	41.32	40.16	81.48	1.40	
15	RESA	16	39.58	36.80	76.38	1.00	
15	RESA	17	32.15	29.58	61.73	0.50	
16	RESA	18	33.21	35.67	68.88	0.70	
17	RESA	19	39.92	39.92	79.84	1.00	
17	RESA	20	38.26	35.99	74.25	1.00	

Hogsback - Week 7 (13-Oct-2009, 10:30-12:00):

8	RESA	1	37.78	37.38	75.16	1.10	
9	RESA	2	28.48	35.46	63.94	0.80	
9	RESA	3	30.02	31.36	61.38	0.60	
10	FOSA	4	17.41	14.82	32.23	0.20	white belly with black spots
10	FOSA	5	26.61	32.38	58.99	0.40	white belly with black spots
10	RESA	6	31.29	29.48	60.77	0.40	
10	RESA	7	44.90	47.12	92.02	1.30	
10	LESA	8	39.51	23.34	62.85	0.80	
13	LESA	9	40.89	35.02	75.91	1.10	
13	LESA	10	39.66	40.66	80.32	1.20	
13	RESA	11	39.03	38.60	77.63	1.10	
15	RESA	12	43.22	52.14	95.36	1.70	
15	RESA	13	45.64	42.33	87.97	1.00	

Table C.2 (continued). Raw 2009 Salamander Monitoring Field Data for A) Indian Woods and B) the Hogsback (RESA= eastern red-backed salamander, LESA= lead-backed morph of eastern red-backed, YESA= spotted, BLSA= blue-spotted and FOSA= four-toed).

Hogsback - Week 7 (continued)

15	RESA	14	15.53	9.77	25.30	0.10	
16	RESA	15	16.15	10.93	27.08	0.10	
16	RESA	16	27.14	22.82	49.96	0.50	
17	RESA	17	41.41	35.11	76.52	1.10	

Hogsback - Week 8 (20-Oct-2009, 10:30-12:00):

1	RESA	1	41.51	37.48	78.99	1.20	
1	RESA	2	40.68	28.7	69.38	0.50	
5	RESA	3	16.48	11.6	28.08	0.05	
9	RESA	4	44.15	42.37	86.52	1.50	
9	LESA	5	32.98	32.86	65.84	0.60	
10	RESA	6	36.56	36.63	73.19	0.80	
12	RESA	7	30.89	26.74	57.63	0.50	
14	LESA	8	41.84	38.74	80.58	1.10	
14	LESA	9	33.07	35.30	68.37	0.50	
15	LESA	10	31.06	33.27	64.33	0.50	
15	RESA	11	32.52	36.41	68.93	0.60	
15	RESA	12	34.55	33.75	68.3	0.70	
16	LESA	13	14.81	9.10	23.91	0.10	
16	RESA	14	42.49	49.61	92.1	1.30	
17	LESA	15	30.00	31.53	61.53	0.50	
18	RESA	16	39.53	42.94	82.47	0.80	
18	RESA	17	32.89	30.26	63.15	0.50	
19	RESA	18	47.46	48.58	96.04	1.40	
19	RESA	19	41.22	39.61	80.83	1.20	

Hogsback - Week 9 (27-Oct-2009, 10:00-10:45):

1	RESA	1	32.21	30.71	62.92	0.7	
5	RESA	2	31.41	33.04	64.45	0.7	
5	RESA	3	41.37	45.96	87.33	1.0	
6	RESA	4	41.46	44.09	85.55	1.2	
10	RESA	5	40.79	46.48	87.27	1.4	
13	RESA	6	40.36	40.79	81.15	1.1	
14	LESA	7	39.13	42.12	81.25	1.2	
15	RESA	8	31.74	32.08	63.82	0.5	
17	RESA	9	42.91	42.41	85.32	1.2	
19	RESA	10	44.93	48.96	93.89	1.4	
20	YESA	11	26.26	28.03	54.29	1.3	

Table C.3. Raw 2009 electro-fishing catch results for Baumann Creek, Site B3.

Date	Pass Number	Species	# Fish (cumulative)	Total Tail Length (mm)	Forked Tail Length (mm)
25-Sep	1	Brook Trout	1	70	68
25-Sep	1	Brook Trout	2	73	71
25-Sep	1	Brook Trout	3	81	79
25-Sep	1	Brook Trout	4	71	69
25-Sep	1	Brook Trout	5	82	80
25-Sep	1	Brook Trout	6	74	72
25-Sep	1	Brook Trout	7	79	76
25-Sep	1	Brook Trout	8	80	77
25-Sep	1	Brook Trout	9	72	69
25-Sep	1	Brook Trout	10	72	70
25-Sep	1	Brook Trout	11	84	80
25-Sep	1	Brook Trout	12	82	80
25-Sep	1	Brook Trout	13	145	140
25-Sep	1	Brook Trout	14	66	64
25-Sep	1	Brook Trout	15	66	64
25-Sep	1	Brook Trout	16	71	69
25-Sep	1	Brook Trout	17	70	68
25-Sep	1	Brook Trout	18	82	80
25-Sep	1	Brook Trout	19	144	140
25-Sep	1	Brook Trout	20	153	150
25-Sep	1	Brook Trout	21	134	131
25-Sep	1	Brook Trout	22	143	140
25-Sep	1	Brook Trout	23	121	120
25-Sep	1	Brook Trout	24	60	59
25-Sep	1	Brook Trout	25	72	71
25-Sep	1	Brook Trout	26	61	60
25-Sep	2	Brook Trout	27	280	276
25-Sep	2	Brook Trout	28	132	130
25-Sep	2	Brook Trout	29	81	79
25-Sep	2	Brook Trout	30	78	77
25-Sep	2	Brook Trout	31	63	61
25-Sep	2	Brook Trout	32	70	68
25-Sep	2	Brook Trout	33	76	74
25-Sep	2	Brook Trout	34	78	76
25-Sep	2	Brook Trout	35	72	71
25-Sep	2	Brook Trout	36	70	68
25-Sep	2	Brook Trout	37	78	76
25-Sep	2	Brook Trout	38	70	68
25-Sep	2	Brook Trout	39	68	66
25-Sep	2	Brook Trout	40	76	74
25-Sep	2	Brook Trout	41	62	60

Table C.3. (continued) Raw 2009 electro-fishing catch results for Baumann Creek, Site B3.

25-Sep	3	Brook Trout	42	198	198
25-Sep	3	Brook Trout	43	148	146
25-Sep	3	Brook Trout	44	154	152
25-Sep	3	Brook Trout	45	142	139
25-Sep	3	Brook Trout	46	72	70
25-Sep	3	Brook Trout	47	68	66
25-Sep	3	Brook Trout	48	96	93
25-Sep	3	Brook Trout	49	78	76
25-Sep	3	Brook Trout	50	58	56
25-Sep	3	Brook Trout	51	78	75
25-Sep	3	Brook Trout	52	64	63
25-Sep	3	Brook Trout	53	65	63

Table C.4. Mean benthic invertebrate counts for the Ontario Benthos Biomonitoring Network (OBBN) 27 groups for the A) spring and B) fall, 2009.

A – Spring

OBBN Group	Bauman Creek				Cruickston Creek					Blair Flats Wet-land	Preston Flats Wet-land
	1	2	3	4	1	2	3	4	5	1	1
Coelenterata											
Turbellaria											
Nematoda											
Oligochaeta	0.67	0.33	3.33	0.33	6.00	2.33	31.67	16.33	2.00	5.00	5.00
Hirudinea	0.33	0.33									1.67
Isopoda	34.33	29.33	1.00		2.00	5.67	0.67	1.00	14.00	0.67	18.00
Pelecypoda	15.00	3.00	0.33		0.33	2.33			6.00		2.33
Amphipoda	17.33	108.00	50.67	18.33		0.33			7.00	0.33	31.33
Decapoda						0.33					
Trombidiformes											0.33
Ephemeroptera	0.33		13.67	2.00	23.33	7.67	32.33	46.33		2.00	8.67
Anisoptera				1.67						2.33	1.00
Zygoptera										0.33	
Plecoptera		0.67	2.00	39.33	19.67	17.67	4.00	1.67	6.67	0.33	
Hemiptera					0.33		0.33	0.33		0.67	7.33
Megaloptera				1.00		1.67			1.67		1.00
Trichoptera	6.00	5.00	3.67	13.67	18.33	30.33	12.33	8.00	4.67		
Lepidoptera											
Coleoptera	3.33	1.00	1.00		3.33	2.67		3.67		1.67	4.67
Gastropoda	1.33	1.67			5.33			1.00		57.67	0.33
Chironomidae	22.00	16.33	14.33	16.33	8.67	28.67	9.67	7.33	27.67	27.00	25.33
Tabanidae	0.33	0.33			0.33	0.67		0.33	0.33		0.33
Culicidae											
Ceratopogonidae				0.33				0.33		0.33	
Tipulidae	10.00	0.67	5.33	5.33	2.33	2.67	0.33		0.33	13.00	
Simuliidae	1.33		6.33	0.67	5.67		14.33	19.00			
Misc. Diptera		0.67	1.00		1.33	0.33	2.67	0.33	1.33	3.67	0.67
Total	**112.33**	**167.33**	**102.67**	**99.00**	**97.00**	**103.33**	**108.33**	**105.67**	**71.67**	**115.00**	**108.00**

Table C.4 (continued). Mean benthic invertebrate counts for the Ontario Benthos Biomonitoring Network (OBBN) 27 groups for the A) spring and B) fall, 2009.

B – Fall

OBBN Group	Bauman Creek				Cruickston Creek					Blair Flats Wet-land	Preston Flats Wet-land
	1	2	3	4	1	2	3	4	5	1	1
Coelenterata											
Turbellaria											
Nematoda				0.67	4.67						
Oligochaeta	19.00	12.67	6.67	1.00	6.33	2.00	23.33	6.67	1.00	15.00	1.67
Hirudinea	1.67	3.33								0.33	0.67
Isopoda	45.00	46.67	1.00		3.67	6.00	14.33	14.00	12.67	15.67	14.00
Pelecypoda	16.67	17.67	0.33		0.67	2.33		1.00	1.33		
Amphipoda		0.67	71.67	5.33					1.67	0.33	49.00
Decapoda											
Trombidiformes										0.33	
Ephemeroptera			4.33	1.67	0.33	0.33				7.67	32.67
Anisoptera				0.33						1.00	2.00
Zygoptera										1.33	0.67
Plecoptera			35.33	9.67	3.67	11.00	1.67	2.67			
Hemiptera										1.67	1.33
Megaloptera	0.33		0.33	0.33		0.67		0.33	0.33		
Trichoptera	1.00		4.00	1.00	22.33	42.00	19.00	23.00	2.00		0.33
Lepidoptera		0.33	0.00				0.33				
Coleoptera	5.33	9.67	3.67	0.67	12.00	6.67	6.33	4.00		1.00	1.33
Gastropoda	3.33	16.67		0.67	15.00	1.33	1.67	4.00	1.67	5.00	
Chironomidae	0.33	2.33	1.33	0.67	4.33	2.33	5.33	11.00	6.00	23.67	3.67
Tabanidae	1.00	0.67	0.33		0.33				0.33		
Culicidae											
Ceratopogonidae			0.67					0.67	0.33		0.33
Tipulidae	2.00	2.67	3.00	2.67	5.33	3.67	8.33	12.33	0.33	2.67	
Simuliidae											
Misc. Diptera	1.67	1.00	1.00			0.33		0.33		2.00	
Total	**97.33**	**114.33**	**133.67**	**24.67**	**78.67**	**78.67**	**80.33**	**80.00**	**27.67**	**77.67**	**107.67**

Table C.5. Vegetation and sediment data for all benthic invertebrate monitoring sites for the A) spring and B) fall, 2009. Substrate composition was not recorded for either of the wetlands as the view was obstructed by vegetation.

A – Spring

		Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
Transect:		**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**1**
Date		14-Jun	14-Jun	14-Jun	14-Jun	31-May	1-Jun	2-Jun	3-Jun	30-May	13-Jul	13-Jul
Macrophytes	**1**	sparse	common	sparse	none	none	none	none	none	none	abundant	abundant
	2	sparse	sparse	sparse	sparse	none		none	none	none	common	abundant
	3	common	common	none	none	none	sparse	none	none	none	common	abundant
Algae	**1**	none	none	sparse	sparse	sparse	none	sparse	sparse	none	abundant	abundant
	2	none	none	sparse	none	sparse		sparse	sparse	none	abundant	abundant
	3	none	none	common	none	sparse	sparse	sparse	sparse	none	abundant	abundant
Substrate	**1**	100% silt	100% silt	10%boulder, 40% cobble, 30% gravel, 20% sand	80% silt, 20% woody debris	10% boulder, 45% cobble, 10% gravel, 10% sand	40% cobble, 25% sand, 17.5% detritus, 17.5% silt	50% cobble, 30% gravel, 20% sand	30% cobble, 30% gravel, 30% sand, 10% silt	30% woody debris, 70% silt		
	2	100% silt	100% silt	10% cobble, 40% gravel, 30% sand, 20% silt	90% silt, 10% woody debris	10% boulder, 20% cobble, 40% gravel, 20% sand, 10% clay	20% cobble, 20% gravel, 20% woody, 10% sand, 30% silt,	50% cobble, 30% gravel, 20% sand	20% boulder, 20% cobble, 20% gravel, 30% sand, 10% silt	15% woody debris, 85% silt		
	3	100% silt	100% silt	15%boulder, 40% cobble, 25% gravel, 20% sand	80% silt, 20% woody debris	10% boulder, 45% gravel, 15% cobble, 25% sand, 5% clay	40% cobble, 30% gravel, 15% sand, 5% woody, 10% silt	50% cobble, 30% gravel, 20% sand	30% cobble, 20% gravel, 15% sand, 35% clay	10% woody debris, 90% silt		

Table C.5 (continued). Vegetation and sediment data for all benthic invertebrate monitoring sites for the A) spring and B) fall, 2009. Substrate composition was not recorded for either of the wetlands as the view was obstructed by vegetation.

B – Fall

		Bauman Creek				Cruickston Creek					Blair Flats Wetland	Preston Flats Wetland
Transect:		**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**	**1**	**1**
Date		9-Oct	9-Oct	9-Oct	9-Oct	8-Oct	9-Oct	7-Oct	8-Oct	9-Oct	10-Oct	10-Oct
Macrophytes	**1**	sparse	common	sparse	none	none	none	none	none	none	abundant	abundant
	2	sparse	sparse	sparse	sparse	none		none	none	none	common	abundant
	3	common	common	none	none	none	sparse	none	none	none	common	abundant
Algae	**1**	none	none	sparse	sparse	sparse	none	sparse	sparse	none	abundant	abundant
	2	none	none	sparse	none	sparse		sparse	sparse	none	abundant	abundant
	3	none	none	common	none	sparse	sparse	sparse	sparse	none	abundant	abundant
Substrate	**1**	100% silt	100% silt	10% boulder, 40% cobble, 30% gravel, 20% sand	80% silt, 20% woody debris	10% boulder, 45% cobble, 10% gravel, 10% sand	40% cobble, 25% sand, 17.5% detritus, 17.5% silt	50% cobble, 30% gravel, 20% sand	30% cobble, 30% gravel, 30% sand, 10% silt	30% woody debris, 70% silt		
	2	100% silt	100% silt	10% cobble, 40% gravel, 30% sand, 20% silt	90% silt, 10% woody debris	10% boulder, 20% cobble, 40% gravel, 20% sand, 10% clay	20% cobble, 20% gravel, 20% woody, 10% sand, 30% silt,	50% cobble, 30% gravel, 20% sand	20% boulder, 20% cobble, 20% gravel, 30% sand, 10% silt	15% woody debris, 85% silt		
	3	100% silt	100% silt	15% boulder, 40% cobble, 25% gravel, 20% sand	80% silt, 20% woody debris	10% boulder, 45% gravel, 15% cobble, 25% sand, 5% clay	40% cobble, 30% gravel, 15% sand, 5% woody, 10% silt	50% cobble, 30% gravel, 20% sand	30% cobble, 20% gravel, 15% sand, 35% clay	10% woody debris, 90% silt		