Aquatic and Terrestrial Monitoring at *rare* Charitable Research Reserve

Shannon Holton
Science Horizons Intern

rare

2006

Executive Summary

In 2006, ***rare*** Charitable Research Reserve partnered with the Ecological Monitoring and Assessment Network (EMAN), in order to establish permanent aquatic and terrestrial monitoring programs on the property. Through this partnership, both a benthic biomonitoring protocol and a terrestrial salamander monitoring protocol were implemented to collect baseline data for a long term monitoring program at ***rare***.

Aquatic Monitoring

Benthic biomonitoring was undertaken on two coldwater streams on the ***rare*** property; four sites were established on Bauman Creek, and two on Cruickston Creek. Bauman Creek sites were numbered B1 to B4 and Cruickston Creek sites were numbered C1 and C2, each starting at the most downstream site and moving upstream toward the headwaters. All sites were established in order with the Ontario Stream Assessment Protocol (OSAP), consisting of a minimum forty metre reach from crossover to crossover, in order to facilitate additional monitoring opportunities in the future. The benthic monitoring program was undertaken in accordance with the Ontario Benthos Biomonitoring Network (OBBN) Protocol, as recommended by EMAN. Three transects, consisting of an upstream riffle, a pool, and a downstream riffle, were sampled at each site using the kick-and-sweep technique and a 500 um D-net. Additional variables were recorded during each sampling, including substrate type, air and water temperature, stream width and depth, and riparian community. Collected benthic samples were taken back to the lab and randomly subsampled until a minimum of 100 organisms were collected from each transect. Each organism was identified to family, input into the OBBN database, and used in various calculations in order to determine stream quality. Metrics included Total Richness, the Shannon-Weiner Index, Family Biotic Index, EPT Richness, and Percent Model Affinity, among others.

Each site was sampled twice, once in the spring and again in the fall. The highest diversity scores and water quality scores on each creek are observed on sites with higher forest cover, steeper gradients, and cobble bottoms. In the spring results site B3 and site C2 both scored the highest in terms of family richness (18 and 22), EPT index (9 and 8), and PMA (76 and 52). B4 scored slightly better than B3 in terms of FBI: 4.19 (*very good*) at B4 compared to 4.96 (*good*) at B3. In addition, B1 scored higher in the Shannon-Weiner Diversity Index than B3; 1.986 vs. 1.873. Regardless of this, B3 showed the best overall water quality on Bauman Creek according to the June results. C2 scored the highest overall for diversity with 2.146 and achieved an FBI score of 4.5 (*good*). In addition to its high scores in the other three indices mentioned, this gave it a better overall water quality rating than C1. The lowest scoring site overall from the June data was B2, which scored lowest in all indices calculated. This site is downstream of Blair Road, has 0% canopy cover, a slower gradient than its upstream counterparts, and consists of a silt dominated substrate.

The fall data analysis showed slightly different results, possibly due in part to the removal of B3 from the second sampling run. C2 again showed the highest diversity levels, with a Shannon-Wiener score of 2.763. It again showed the best overall water quality based on all metrics, with a family richness of 25 taxa, an FBI score of 4.6 (*good*), an EPT index score of 12, and a PMA of 47.5. With the removal of B3 data from the results, B4 moved into the place of highest overall water quality on Bauman Creek, with a Shannon-Wiener score of 1.966, family richness of 18 taxa, FBI score of 4.45 (*very good*), an EPT index of 8, and 38.5 PMA. The site showing lowest overall water quality in the fall sampling results was B1, the site closest to the mouth of the creek. This site scored only 1.597 for diversity, taxa richness was 13 families, an FBI score of 7.55 (*very poor*), an EPT index of 1, and 36% PMA. This site is also downstream of Blair Road, consists of primarily silt and sand substrate, and a slower gradient than the two sites upstream of Blair Road.

In addition to the biomonitoring program, quasi-monthly testing was carried out at each aquatic site for pH, conductivity, and dissolved oxygen, and water samples were taken to test for nitrates (NO3) and total phosphorus (TP). All sites showed high levels of NO3 and TP, likely as a result of agricultural chemicals being applied in the groundwater recharge zone to the south of each creek. Nothing abnormal was shown as a result of any of the other parameters measured.

Recommendations based on first year aquatic biomonitoring include continuing annual monitoring in accordance with the OBBN protocol on each of the established sites, the incorporation of additional OSAP methods at each site, regular water chemistry testing at each site, the implementation of permanent markers at the beginning and end of each site, and the cessation of chemical applications in the agricultural fields in the groundwater recharge zones to the south of the creeks.

Part B: Terrestrial Salamander Monitoring

The EMAN/Parks Canada joint protocol regarding Plethodontid salamander monitoring was implemented in Indian Woods at the 20x20 m plot IN02, which was previously established for lichen monitoring. Through donations, ***rare*** acquired 29 artificial cover objects (ACOs), which were placed in a square 10 metres outside of the 20x20 plot, at a distance of 5 m apart. Weekly monitoring began September 28th, 2006, and consisted of identifying, measuring, and counting the salamanders from under each board, while recording additional variables such as air and soil temperature, wind speed, weather conditions, and board disturbance. Monitoring took place over a five-week period, the last three of which soil moisture and temperature readings were taken under each board.

Of the 160 salamanders found over the five week period, all were red-backed salamanders (*Plethodon cinereus*) except for one individual from the blue spotted/Jefferson complex (*Ambrysoma* sp.) found on October 12. Of the red-backs found, 88.6% were of the red-back morph, while only 11.4% were of the lead-back morph. Analysis of snout to vent lengths of the red-backs appear to show at least four age classes, though more data is needed in order to confirm this. Correlations between salamander abundance and soil moisture and temperature also appear to be present, and may be supported through additional monitoring.

Recommendations based on first year Plethodontid salamander monitoring include continued annual monitoring, extended monitoring time to include additional seasons, the inclusion of additional monitoring variables during sampling, the establishment of salamander age class charting for ***rare***, the implementation of an additional salamander plot in the Hogsback area, the implementation of additional EMAN protocols on plot IN02, ending chemical applications on agricultural fields south of Indian Woods, and active forest restoration in Field 10.

Table of Contents

List of Appendices

List of Tables

List of Figures

List of Maps

1.0 Background

1.1 Ecological Monitoring

Ecological monitoring has been defined as the regular observation, measurement, and evaluation of an organism or community in order to determine the overall health of the environment in which it naturally inhabits (EMAN, 2006). Preliminary monitoring is important in order to establish a set of baseline data, which can then be used as a comparison base for any subsequent data collected. Any significant variations from the original baseline data can help to determine environmental changes or trends that are occurring in the monitored ecosystem overtime, as the result of large-scale factors including climate change, land use changes, changes in pollution levels, and habitat restoration efforts. In Canada, the Ecological Monitoring and Assessment Network is working throughout the country to make ecological monitoring more feasible for experts and citizens so ecological trends can be documented as they arise, alerting us to any significant environmental changes taking place on a local or national scale.

1.2 EMAN

The Ecological Monitoring and Assessment Network (EMAN) is a facet of Environment Canada whose primary concern is ecological monitoring in Canada. It is a network of partnerships, consisting of multiple levels of government, academic institutions, non-government organizations, industry, volunteer groups, elementary and secondary schools, and other organizations and individuals who are focussed on environmental monitoring in their community (EMAN, 2006). These groups work collaboratively to improve the effectiveness of ecological monitoring, inform local and federal decision makers, and generate a higher level of environmental awareness in Canada (EMAN, 2006).

To achieve these goals, EMAN strives to assemble a set of standardized protocols for ecological monitoring that can be used across Canada. The standardization of monitoring protocols is important in ecological monitoring to allow for the efficient comparison of data both spatially and temporally, allowing all gathered information to be as useful as possible at local, regional, national, and international scales (EMAN, 2006). EMAN is currently compiling a list of recommended protocols based on those most widely used in ecological monitoring throughout Canada and the rest of the world.

EMAN's recommended monitoring protocols range from simple techniques that the general public can implement, to more sophisticated methods requiring the expertise of trained specialists. The focus of this project includes two of the more sophisticated protocols recommended by EMAN: the monitoring of benthic macroinvertebrates in freshwater streams using the Ontario Benthos Biomonitoring Network protocol, and the monitoring of Plethodontid salamanders using a joint EMAN/Parks Canada protocol. Both protocols were implemented in 2006 at ***rare*** Charitable Research Reserve in Cambridge, Ontario (Map 1).

1.3 ***rare*** **Charitable Research Reserve**

Founded in 2001, ***rare*** Charitable Research Reserve is a non-profit organization that owns and stewards a 913-acre land reserve along the Grand River in Cambridge, Ontario (Map 1). The vision of ***rare*** involves the protection of this property in perpetuity, while at the same time providing an optimal site for ecological research and education at all levels (rare, 2006). The charity maintains a number of important habitats on the property, including headwater streams, groundwater recharge areas, winter habitat for bald eagles, provincially significant wetland, Environmentally Sensitive Policy Areas, a regionally classified Environmentally Sensitive Landscape, regionally rare alvar and cliff ecosystem and old-growth forest remnants (rare, 2006).

To uphold their vision and increase their knowledge about the ecosystems which they protect, ***rare*** developed a partnership with EMAN in the spring of 2006 to set up some permanent monitoring stations on the property using EMAN recommended protocols. Through discussions with ***rare***'s Environmental Advisory Team and EMAN advisors, it was decided that both an aquatic and a terrestrial monitoring program would be implemented, specifically using benthic macroinvertebrates and salamanders as ecological indicators.

2.0 Aquatic monitoring at *rare*

2.1 Monitoring Benthic Macroinvertebrates

It was decided that benthic macroinvertebrates would be monitored in ***rare*** streams for a number of reasons. First, benthic macroinvertebrates are ideal organisms for indicating stream health. Their abundance in most aquatic systems as well as their diverse range of species provides a critical link in most aquatic food webs (Richardson and Jackson, 2002). Macroivertebrates display a wide range of trophic roles in the ecosystem, including shredders and collectors, which break down and feed on detritus in the stream, grazers, who feed on microalgae and bacteria, parasites, which parasitize a variety of other organisms, and predators, who feed on other invertebrates (Richardson and Jackson, 2002). In addition, the large diversity in macroinvertebrate populations exhibits differing levels of tolerance to pollutants and contaminants within the aquatic system (Hart, 1999); species compositions within the system change both qualitatively and quantitatively with contaminant influx, reflecting both short and long term changes in stream quality (Lenat et al, 1980). These changes can be used to indicate water quality, habitat quality, biodiversity, and large scale changes in ecosystem functions and processes, as well as determine issues of contamination not indicated by water chemistry testing alone. Sampling data from benthic macroinvertebrates can give us a glimpse into a long term issue affecting the stream, as opposed to the instantaneous results of a water grab sample that can be influenced by the minute (Lenat et al, 1980).

There are also many technical advantages to using benthic macroinvertebrates as stream indicators. For example, their small size and relative abundance within aquatic systems make them fairly easy to sample (Rosenberg and Resh, 1993). In addition, macroinvertebrate sampling equipment is relatively inexpensive and simple to use, and there are numerous metrics available to analyse results (Rosenberg and Resh, 1993). These metrics include biotic and diversity indices, which can be used to help identify water quality issues associated with both point and non-point source pollutants, document long term changes, and summarize site survey results in a manner easily understood by both specialists and non-specialists (Resh and Jackson, 1993).

The final reason that ***rare*** made the decision to monitor benthic macroinvertebrates in two of the coldwater streams on the property was the existence of a partnership between EMAN and the Ontario Benthos Biomonitoring Network (OBBN). The OBBN is a province wide benthic biomonitoring program who, along with EMAN, provides training, equipment, support, and an online database to all participants in the program. Their mission is to "enable the assessment of aquatic ecosystem condition using benthos as primary indicators of water and habitat quality" (Jones et al, 2005). They promote standardized macroinvertebrate sampling techniques with use of site and catchment scale characteristics in order to ensure optimal comparability of benthic data throughout Ontario, all of which are compatible other provincial and national benthic biomonitoring networks, including the Canadian Aquatic Biomonitoring Network (CABIN). The OBBN's database has five purposes: it is used for storing, querying, and retrieving data for all OBBN reference and test sites, sharing reference and test site data among all OBBN partners, calculating bioassessment metrics, providing quality control checks on entered data, and providing opportunities for data sharing between similar databases like CABIN (OBBN, 2006).

2.2 Benthic biomonitoring at *rare*

The focus of the aquatic monitoring program at ***rare*** is to examine benthic macroinvertebrates from natural, coldwater stream habitats on ***rare*** land, specifically Bauman and Cruickston Creeks, using protocols laid out by EMAN and the OBBN. The long term research questions for this project include, but are not limited to the following:

- What is the ecological health of Bauman Creek and Cruickston Creek, and how do they compare to one another?
- Is the ecosystem integrity of Bauman and Cruickston Creek being maintained/improved under the management of ***rare***?
- What is the quality of the aquatic and riparian habitat on Bauman and Cruickston Creeks, and how do they compare to one another?
- Is the stream health and habitat quality of Bauman and Cruickston Creeks being improved/impacted through on-site changes in agriculture and/or due to restoration efforts being implemented on or around the creeks?
- What are the long-term ecological trends taking place within the streams at ***rare***?

2.3 Rationale

The data collected this year will provide a sound basis for a long-term monitoring framework for the creeks, allowing ***rare*** to document and assess any changes to stream health or habitat quality that may occur in the future. It will act as the base of a permanent monitoring program on the streams, in which benthic surveys would be carried out on an annual basis and results compared year to year. This program will allow ***rare*** to compare the ecological health of the streams both spatially and temporally, thereby enabling them to determine any long term trends that may be occurring in the quality of the stream due to external factors such as climate change, changes in pollution inputs, adjacent land use, or additional impacts or improvements due to any environmental management efforts by ***rare***.

The results of the annual monitoring program will provide information to ***rare***'s Environmental Advisory Team (EAT) that can be used to identify ecological problems and priority areas, update ***rare***'s Environmental Management Plan, direct future restoration and protection efforts, and improve pubic education efforts. The data will assist EAT in determining whether or not habitat quality is being maintained or improved under the current ecosystem management at ***rare***, and therefore assist them in implementing any necessary management changes by providing the necessary data to make informed decisions. Results from a long-term monitoring program could also be used to influence regional policy makers to change land use policies on adjacent land to improve local environmental quality for the benefit of all citizens in the region and within the Grand River Watershed.

2.4 Site Descriptions

The benthic monitoring program at ***rare*** consists of six sites, four of which are found on Bauman Creek, and two on Cruickston Creek (Map 2). Both streams are first order tributaries of the Grand River, and maintain coldwater status.

Bauman Creek is a coldwater stream less than 2 km in total length, draining an area of approximately 2 km^2 (ESG, 2000). The stream is forested upstream of Blair Road, where it flows through a forest known as Indian Woods, a remnant old-growth upland forest that makes up a portion of a 60 hectare area of continual mature and maturing forest (rare, 2006). North of Blair Road the riparian zone was once cleared for agriculture, leaving grasses and forbs as the dominant vegetation on Bauman'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. Fish community data collected in 1994 showed a resident brook trout population in the stream (CH2M Gore & Storrie Ltd, 1997). The creek has not been officially resampled since that time, though adult brook trout were observed in 2001 during some inventories carried out by the ***rare*** EAT (CCRR EAT, 2002), and during an undergraduate study by Sean Barfoot (Barfoot, 2003). Groundwater discharge has been cited as the main factor contributing to the coldwater fishery (ESG, 2000; CCRR EAT, 2002), and numerous groundwater seeps can be observed adjacent to Bauman Creek, especially to the south of Blair Road.

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 (Map 3). 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 and two provincially significant species of wildlife, as well as 19 locally significant species of plants and wildlife (ESG, 2000).

The benthic monitoring sites on Bauman Creek have been numbered B1 to B4, B1 being the most downstream site on the creek, and B4 the farthest upstream (Map 2). This order of numbering was used on both creeks because, under the recommendations of OBBN, the most downstream site must be sample first and the farthest upstream last, in order to avoid unnecessary disruption to any downstream sites before they are sampled.

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 is primarily 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 here, and thick with organic matter. Common species at B4 include skunk cabbage (*Symplocarpus foetidus*), yellow birch (*Betula alleghaniensis*), American Beech (*Fagus grandifolia*), and sugar maple (*Acer saccharum*).

The remaining two benthic monitoring sites are located on Cruickston Creek, which drains approximately the same sized area as Bauman Creek (ESG, 2000). The creek originates in the Hogsback wetland in the southeast corner of ***rare***'s property, and is also included in the Barrie's Lake-Bauman Creek Wetland Complex PSW. The majority of the creek is forested, except for a small area immediately south of Blair Road where Cruickston Site C1 is situated, 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 (ESG, 2000), although it is mostly underdeveloped; the channel disappears into a wetland north of Blair Road and reappears north of the Grand Trunk Trail. North of the trail the creek is intermittent, disappearing into the limestone bedrock at 43° 22' 48.8" N, 80° 20' 50.7" W, approximately 400m north of the Grand Trunk Trail. The former agricultural fields immediately east and west of site C1 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 mostly been left to naturalize on their own. Conventional agriculture is still going on in the fields to the south of the restoration area, immediately west of site C2.

Site C2 is the farthest upstream site on Cruickston Creek, located north of the Hogsback wetland (Map 2). Between the Hogsback and the site, the stream flows rapidly under 100% forest cover. Site C2 is located in a small clearing in the forest, where the dominant vegetation includes Joe Pye Weed (*Eupatorium purpureum*), goldenrod (*Solidago* sp.), asters (*Aster* spp.), and red-osier dogwood (*Cornus stolonifera*) for approximately 10 metres on either side of the creek, before meeting an approximately 10-20 metre 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 (Map 2). The bank-side vegetation at site C1 is made up primarily of riverbank grape vines (*Vitis riparia*), asters (*Aster* spp.), goldenrod (*Solidago canadensis*), and grass species. The grape vines, along with the few shrubs and Manitoba maples (*Acer negundo*) 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 that takes it under Springbank Lane, then under Blair Road and north to the silver maple swamp.

2.5 Methodology

Two sets of macroinvertebrate samples were taken from each site, once in early summer and once in the fall, with the exception of Bauman Site B3 which was only sampled in the first set. Each sample was carried out using the recommended protocol in the OBBN manual, which can be viewed in full at http://obbn.eman-rese.ca/PartnerPages/obbn/online_resources.asp. Original field and lab notes for all 2006 aquatic sampling data are available through ***rare*** Charitable Research Reserve.

Sites were chosen using a stratified random sampling technique based on habitat type, then implemented in June. Each site was set up following the Ontario Stream Assessment Protocol (OSAP), which includes the OBBN protocol as a portion. 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 current program. Under OSAP, each sampling site involves a reach of stream measuring a minimum of 40 metres from crossover to crossover (where the thalweg crosses over the middle of the stream channel). These were measured out and marked before the samples were taken, when the sites were ground surveyed for the first time in late May/early June.

Following the OBBN, a transect was sampled at an upstream riffle, a pool, and a downstream riffle at each site within the minimum 40 m reach of the OSAP protocol; each transect was sampled using the kick and sweep technique. A 500-micrometre mesh D-net was placed immediately downstream of the riffle or pool being sampled. The sampler then moved slowly across the stream, constantly kicking up the substrate and thereby loosening any benthic macroinvertebrates residing there. The loosened organisms were subsequently swept downstream by the current, and trapped in the net. At the same time, a recorder made notes of canopy cover, substrate types, macrophytes, and other pertinent characteristics of the site. Additional measurements included air and water temperature, stream depth, hydraulic head, wetted width, and full bank width. Sample field sheets can be observed in Appendix B. Sites were sample from the farthest downstream on each creek to the farthest upstream in order to minimize downstream sample contamination.

The three samples removed from each site were kept in separate marked containers, and brought back to the office to be sorted live. Each sample was poured into a large pan and stirred vigorously before a subsample was ladled out of it and placed into a sorting tray. This ensures each subsample was randomly taken from the larger sample, helping to decrease potential bias. All macroinvertebrates found in the sorting tray were removed and placed in a 70% ethanol solution. Subsequent subsamples were taken from the main sample until a minimum of 100 organisms were collected, each marked on a tally sheet and identified to taxonomic order. The process was repeated on each of the three samples taken from the site. If less than 80 organisms were collected from an entire sample, the transect was resampled until 100 organisms can be collected. 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 required to collect the recommended 100 organisms to be calculated.

The collected organisms from each sample were later re-examined using a microscope, at which time they were identified to taxonomic family. Any difficult organisms were rechecked by Ken Dance, the Land Steward at ***rare***, or sent to Bill Morton, an aquatic taxonomy specialist if necessary. After being identified to family level, the counts from each site were input into the OBBN database. From here the data was exported to Microsoft Excel so bioassessment metrics could be calculated, as the metrics are not yet functional on the OBBN website. Metrics used for this project include Total Richness, Family Biotic Index, the Shannon-Wiener Index, Percent Model Affinity, Percent Dominant Taxon, Chironomid Abundance, EPT Richness, EPT Abundance, and Abundance of Annelid Worms. Each of these metrics assists in determining the ecological health of the stream. Full calculations are available through ***rare*** Charitable Research Reserve (Z:\rare\level5\citizen science\benthic monitoring).

In addition to the benthic sampling, chemical and physical characteristics of each site were sampled four times throughout this sampling season. A P4 Multimeter was loaned to ***rare*** by the Biology Department of the University of Waterloo for each sampling date: June 14th, July 4th, August 1st, and October 17th, 2006. The original plan was to sample once per month, but the meter was unavailable in September. The P4 meter allowed us to test for dissolved oxygen, pH, and conductivity. An aquatic thermometer was also used at each site to determine both stream and air temperature. Velocity data was recorded using the timed-float technique, in which a float is dropped into the stream and timed for a distance of one meter. This is repeated three times and an average time recorded, then used to calculate stream velocity in meters per second. On the same dates as these physical parameters were tested for, two water chemistry grab samples were taken from each site. These samples were sent to ALS Laboratories in

Waterloo, Ontario, where they were tested for nitrates (NO_3) and total phosphorus (TP) in a professional laboratory setting.

2.6 Results

Tables 1 and 2 outline the characteristics of each site that were recorded for each of the spring benthic visits (June 5 to June 28, 2006). Air and water temperatures are also shown from the fall visits (September 26 to October 17, 2006). All fall data is missing for Bauman Creek site B3, as this site was inaccessible throughout the second sampling period due to ongoing legal complications.

Table 1: Bauman and Cruickston Site Characteristics

Site	GPS Coordinates	Site Length (m)	Air Temp °C		Water Temp °C		Bank Full Width (m)
			Spring	Fall	Spring	Fall	
B1	N 43° 22' 58.1" W 80° 21' 37.2"	50.9	14	8	13	9.5	5.51
B2	N 43° 22' 58.0" W 80° 21' 50.2"	44.2	22	5	14	9	6.30
B3	N 43° 22' 51.6" W 80° 21' 0.7"	46.6	11	n/a	10	n/a	2.62
B4	N 43° 22' 36.2" W 80° 21' 5.2"	43.25	*	13.5	13	12	2.71
C1	N 43° 22' 41.9" W 80° 21' 0.9"	44.6	21	17	17	11	0.80
C2	N 43° 22' 32.2" W 80° 21' 2.9"	48.6	21	9	16	8.5	1.63

* = missing data

Table 2: Substrate types, organic matter, and riparian zone info for each site

Site	Substrate		Organic Matter						Riparian Zone	
			Woody			Detritus				
	Dominant	2nd Dominant	DSR	Pool	USR	DSR	Pool	USR	Dominant Community	% Cover
B1	Silt	Sand	present	none	none	present	abundant	present	meadow	50-74
B2	Silt	Sand	absent	absent	*	present	abundant	*	meadow	0-24
B3	Cobble	Gravel	absent	abundant	present	absent	present	absent	dec. forest	75-100
B4	Silt	Sand	abundant	abundant	abundant	abundant	abundant	abundant	dec. forest	75-100
C1	Cobble	Silt	absent	absent	present	absent	present	present	meadow	0-24
C2	Cobble	Gravel	present	absent	present	absent	present	absent	meadow	0-24

*= missing data

There were a total of 43 taxonomic family groups identified in all sites on both creeks sampled. This included insect larvae, nymphs, and adults, crustaceans, annelid worms, gastropods, flatworms, aquatic mites, and clams. Total site counts for spring and fall are summarized in tables 3 and 4 below. These totals include all organisms collected at each site from each of the three transects.

Table 3: Total benthic counts for spring sampling period

	B1	B2	B3	B4	C1	C2
Annelida: Hirudinea						
Glossiphioniidae						
Annelida: Oligochaeta						
Enchytraeidae	9	5		3	122	2
Arachnida: Acarina				4	7	17
Crustacea						
Amphipoda						
Crangonyctidae	25	214	15	59		
Isopoda						
Asellidae	44	10		1	2	6
Insecta						
Coleoptera						
Dytiscidae	2	3	2		5	2
Elmidae			5		17	14
Hydrophilidae		1				
Psephenidae						4
Diptera						
Athericidae						2
Ceratopogonidae	12	1	4			
Chironomidae	60	11	116	98	131	136
Psychodidae						1
Simuliidae			9		22	
Tabanidae	4	5	10	1		12
Tipulidae	4		21	9	20	34
Ephemeroptera						
Baetidae			110	4	6	4
Heptageniidae			2			
Leptophlebidae						
Hemiptera (Heteroptera)						
Gerridae			1			
Veliidae						4
Megaloptera						
Sialidae		2		3	1	7
Odonata						
Libellulidae				5		
Plecoptera						
Capniidae			2	1	2	
Chloroperlidae			1	9		

	B1	B2	B3	B4	C1	C2
Leuctridae				51		26
Nemouridae				1		2
Perlodidae						
Trichoptera						
Hydropsychidae					2	5
Hydroptilidae			2			
Lepidostomatidae	3		1	12	2	7
Limnephilidae	81	36	9	1	5	4
Philopotamidae			26		6	21
Rhyacophilidae			4			2
Mollusca: Bivalvia						
Sphaeriidae	40	35				
Mollusca: Gastropoda						
Lymnaeidae	4				6	1
Physidae						
Planorbidae	2	2			1	
Turbellaria: Platyhelminthes						
Planariidae						
Total Numbers:	**290**	**325**	**340**	**262**	**357**	**313**

Table 4: Total benthic counts for fall sampling period

	B1	B2	B4	C1	C2
Annelida: Hirudinea					
Glossiphioniidae	1				
Annelida: Oligochaeta					
Enchytraeidae	128	65	2	123	15
Arachnida: Acarina		1	3	32	10
Crustacea					
Amphipoda					
Crangonyctidae	3	13	95		
Isopoda					
Asellidae	10	69		9	27
Insecta					
Coleoptera					
Curculionidae					4
Dytiscidae		1			

	B1	B2	B4	C1	C2
Elmidae				30	3
Hydrophilidae				1	
Psephenidae					
Diptera					
Athericidae					
Ceratopogonidae	4	34	9	2	25
Chironomidae	89	104	83	26	38
Dixidae			1		
Ephydridae		1			
Psychodidae		3		3	10
Simuliidae				1	
Stratiomyidae					2
Tabanidae	3	2			3
Tipulidae	17	4	33	6	17
Ephemeroptera					
Baetidae		6			3
Heptageniidae					4
Leptophlebidae			1		
Hemiptera (Heteroptera)					
Gerridae					
Veliidae					
Megaloptera					
Sialidae			2	7	5
Odonata					
Libellulidae			6		
Plecoptera					
Capniidae			1	1	39
Chloroperlidae			16		5
Leuctridae			7		3
Nemouridae		2	52		7
Perlodidae					3
Trichoptera					
Hydropsychidae			2	16	35
Hydroptilidae					
Lepidostomatidae				3	2
Limnephilidae	4	1	3	12	27
Philopotamidae		1	4	1	1
Rhyacophilidae					12

	B1	B2	B4	C1	C2
Mollusca: Bivalvia					
Sphaeriidae	36			1	
Mollusca: Gastropoda					
Lymnaeidae	3	1		6	
Physidae			2	23	
Planorbidae	4			1	2
Turbellaria: Platyhelminthes					
Planariidae	1	1		9	
Total Numbers:	**303**	**309**	**322**	**313**	**302**

All nine of the metrics mentioned in the methodology section of this report were performed on the benthic data from each site using the total counts summarized above. These calculations were done separately on the summer and fall sampling data. Nominal water quality values for Family Richness, EPT Index, and Percent Model Affinity (i.e. slightly impacted, non-impacted etc.) were derived from those used in the Hudson Basin River Watch Guidance Document (cited in Suozzo, 2005), which are commonly used in New York State stream studies.

Table 5: Summer Data Table A

Site #	**Date (dd/mm/yy)**	**Shannon-Wiener Index***	**Evenness ***	**% EPT**	**% Chironomidae**	**% Annelida**	**Dominant Taxon**	**% Dominance**
B1	05/06/06	1.986	0.774	29.0	20.7	3.1	Limnephilidae	27.9
B2	05/06/06	1.251	0.503	11.1	3.4	1.5	Crangonyctidae	65.8
B3	12/06/06	1.873	0.648	46.2	34.1	0	Chironomidae	34.1
B4	15/06/06	1.807	0.652	30.2	37.4	1.1	Chironomidae	37.4
C1	19/06/06	1.765	0.623	6.4	36.7	34.2	Chironomidae	36.7
C2	28/06/06	2.146	0.694	22.7	43.5	0.6	Chironomidae	43.5

** Shannon-Weiner and Evenness calculations based on Family level identification, not species level

Table 6: Summer Data Table B

Site #	Date	Total Individuals	Family Richness	Family Richness Water Quality	Family Biotic Index	FBI Water Quality	EPT Taxa	EPT Taxa Water Quality	PMA	PMA Water Quality
B1	05/06/06	290	13	slightly impacted	5.48	Fair	2	moderately impacted	44	moderately impacted
B2	05/06/06	325	12	slightly impacted	5.76	Fairly Poor	1	moderately impacted	26	severely impacted
B3	12/06/06	340	18	non-impacted	4.96	Good	9	non-impacted	76	non-impacted
B4	15/06/06	262	16	non-impacted	4.19	Very Good	7	slightly impacted	43	moderately impacted
C1	19/06/06	357	17	non-impacted	6.93	Poor	6	slightly impacted	48	moderately impacted
C2	28/06/06	313	22	non-impacted	4.5	Good	8	non-impacted	52	slightly impacted

Table 7: Fall data Table A

Site #	Date (dd/mm/yy)	Shannon-Wiener Index*	Evenness*	% EPT	% Chironomidae	% Annelida	Dominant Taxon	% Dominance
B1	05/10/06	1.597	0.623	1.3	29.4	42.5	Enchytraeidae	42.2
B2	12/10/06	1.778	0.628	3.2	33.7	21.0	Chironomidae	33.7
B4	03/10/06	1.966	0.680	26.7	25.8	0.6	Crangonyctidae	29.5
C1	26/09/06	2.173	0.714	10.5	8.3	39.3	Enchytraeidae	39.3
C2	17/10/06	2.763	0.858	46.7	12.6	5.0	Capniidae	12.9

* Shannon-Weiner and Evenness calculations based on family level taxonomy, not species level

Table 8: Fall Data Table B

Site #	Date (dd/mm/yy)	Total Individuals	Family Richness	Family Richness Water Quality	Family Biotic Index	FBI Water Quality	EPT Taxa	EPT Taxa Water Quality	PMA	PMA Water Quality
B1	05/10/06	303	13	slightly impacted	7.55	Poor	1	moderately impacted	36	moderately impacted
B2	12/10/06	309	17	non-impacted	7.19	Fairly Poor	4	slightly impacted	38.5	moderately impacted
B4	03/10/06	322	18	non-impacted	4.45	Very Good	8	non-impacted	38.5	moderately impacted
C1	26/09/06	313	21	non-impacted	7.12	Fairly Poor	5	slightly impacted	43.5	moderately impacted
C2	17/10/06	302	25	non-impacted	4.60	Good	12	non-impacted	47.5	moderately impacted

Water chemistry results from both creeks have been compiled in two graphs: one outlining nitrate levels and the other showing total phosphorus levels for all sites. Nitrate levels showed a significant decrease in the October samples compared to the three previous, but total phosphorus levels appeared to increase at most sites. As with benthic sampling, site B3 could not be accessed in October to obtain fall water chemistry samples.

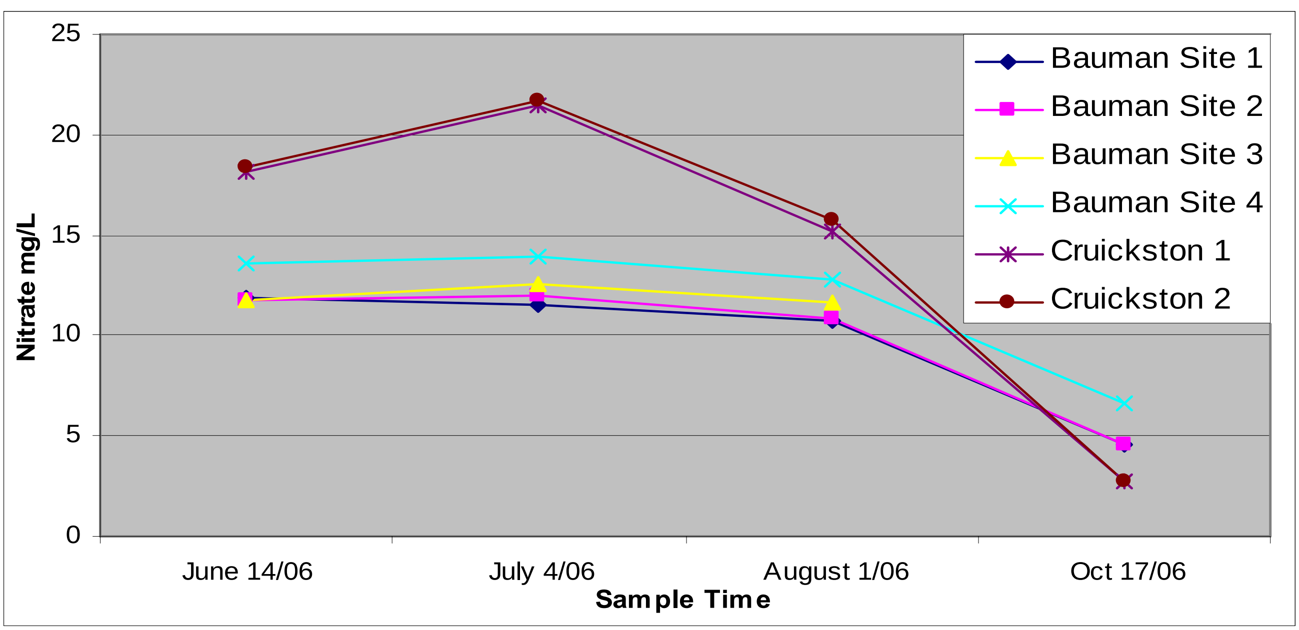


Figure 1: Water chemistry nitrate results

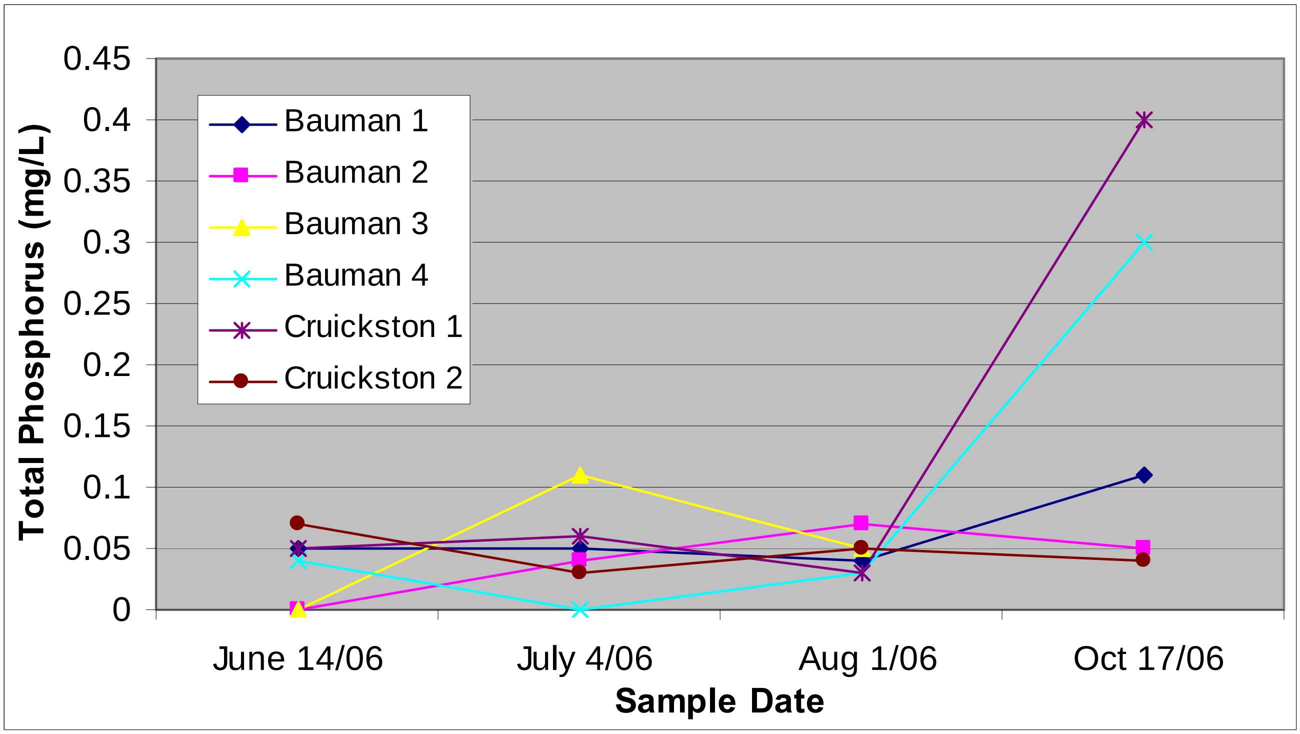


Figure 2: Water chemistry total phosphorus results

The P4 meter was used three times throughout the season to measure conductivity, pH, and dissolved oxygen (DO); July 4th, August 1st, and October 17th. On the October 17th sampling date, the DO meter was not working properly, so we were unable to obtain accurate oxygen levels for any of the sites. Overall, conductivity, pH, and DO levels stayed fairly constant for each creek between sites and sampling dates, as can be seen in tables 9 and 10.

Table 9: Bauman Creek P4 results

Date	Site #	Time	Water Temp (°C)	Stream Width (m)	Mean Depth (m)	Conductivity (µS/cm)	pH	DO (mg/L)
4-Jul-06	B1	12:54	17	1.13	0.08	1033	7.83	9.3
	B2	13:15	16	0.63	0.09	1017	7.91	12.83
	B3	13:40	15	1.6	0.05	1009	7.84	13.51
	B4	14:20	14	0.53	0.04	1022	7.37	12.3
1-Aug-06	B1	10:49	18.7	0.87	0.09	1051	7.78	8.67
	B2	11:18	18.5	0.8	0.19	1046	7.67	8.3
	B3	13:10	19	2.18	0.085	1065	7.72	9.18
	B4	14:02	18.3	1.4	0.125	1074	7.33	7.68
17-Oct-06	B1	10:32	8.5	1.15	0.105	647	7.87	n/a
	B2	11:00	8.5	1.8	0.39	526	8.06	n/a
	B4	9:30	9	3	0.18	536	7.61	n/a

Table 10: Cruickston Creek P4 results

Date	Site #	Time	Water Temp (°C)	Stream Width (m)	Mean Depth (m)	Conductivity (µS/m)	pH	DO (mg/L)
4-Jul-06	C1	11:49	20	0.48	0.03	1156	7.8	8.38
	C2	11:10	18	0.76	0.03	1117	6.6	8.72
1-Aug-06	C1	12:33	25.6	0.36	0.08	1220	7.68	5.33
	C2	12:12	22.7	1.09	0.045	1172	7.64	6.67
17-Oct-06	C1	12:19	9	0.6	0.27	480	7.18	n/a
	C2	11:41	8.5	3	0.14	450	7.16	n/a

2.7 Analysis of Benthic Results

Upon examination of the benthic results, some patterns appear to emerge. The highest diversity scores and water quality scores on each creek are observed on sites with higher forest cover, steeper gradients, and cobble bottoms. This is evident when examining the spring data results, where Bauman site B3 and Cruickston site C2 both scored the highest in terms of family richness (18 and 22), EPT index (9 and 8), and PMA (76 and 52). B4 scored slightly better than B3 in terms of FBI: 4.19 (*very good*) compared to 4.96 (*good*). This is likely due to the high abundance of stoneflies at B4, which generally have the lowest pollution tolerance rating in the FBI scoring system. In addition, B1 scored higher in the Shannon-Weiner Diversity Index than B3; 1.986 vs. 1.873. The higher the number scored in the Shannon-Wiener Index, the higher the biodiversity at the site. Regardless of this, B3 seems to show the best overall water quality in the June results for Bauman Creek. C2 scored the highest overall for diversity with 2.146 and achieved an FBI score of 4.5 (*good*). In addition to its high scores in the other three indices mentioned, this gave it a better overall water quality rating than C1. The lowest scoring site overall from the June data was B2, which scored lowest in all indices calculated. This site is downstream of Blair Road, has 0% canopy cover, a slower gradient than its upstream counterparts, and consists of a silt dominated substrate.

The fall data analysis showed slightly different results, possibly due in part to the removal of B3 from the second sampling run. C2 again showed the highest diversity levels, with a Shannon-Wiener score of 2.763. It again showed the best overall water quality based on all metrics, with a family richness of 25 taxa, an FBI score of 4.6 (*good*), an EPT index score of 12, and a PMA of 47.5. With the removal of B3 data from the results, B4 moved into the place of highest overall water quality on Bauman Creek, with a Shannon-Wiener score of 1.966, family richness of 18 taxa, FBI score of 4.45 (*very good*), an EPT index of 8, and 38.5 PMA. The site showing lowest overall water quality in the fall sampling results was B1, the site closest to the mouth of the creek. This site scored only 1.597 for diversity, had 13 different families, a score of 7.55 (*very poor*) FBI, an EPT index of 1, and 36% PMA. This site again is downstream of Blair Road, consists of primarily silt and sand substrate, and a slower gradient than the two sites upstream of Blair Road. Unlike B2, most of B1 has 100% canopy cover, but it is a small riparian zone which only covers this site, leaving the rest of Bauman Creek north of Blair Road completely open.

In 2003 Sean Barfoot, a fourth-year geography student from the University of Waterloo, completed his undergraduate thesis through an aquatic assessment of Bauman Creek. Barfoot had seven sites on the creek, between the headwaters and the mouth. As part of his aquatic assessment, two macroinvertebrate samples were taken from each site, one in March and one in September. Total richness and Family Biotic Index values from Barfoot's September data and the September/October data from this study will be compared in table 11 below. Barfoot's site 1 corresponds with B4, site 5 corresponds with B3, and site 7 corresponds with B1, but his methods were slightly different than the OBBN protocol, making it difficult to provide an accurate comparison between the sites and exemplifying the need for standardization in monitoring. This is primarily due to the limited number of organisms collected by Barfoot; total organisms collected per site ranged only from 2 to 50. This is likely the primary reason for such large differences in richness values, FBI values, and EPT taxa when compared to this year's results: water quality cannot be accurately extrapolated when sample numbers are as low as these. Full details can be found in Barfoot's 2003 report, available through the ***rare*** library.

An additional macroinvertebrate survey was carried out on Cruickston Creek in 2003 by Ken Dance. Dance sampled two sites on the creek, station 1 being in approximately the same location as C1, and station 2 being located between C1 and C2. Each station was sampled using the three-minute travelling kick technique, as recommended by the Grand River Conservation Authority before they adopted the OBBN protocol. This method is comparable to OBBN: a transect was sampled at each site in the creek, generally in a riffle. A D-net was placed immediately downstream of the transect, and the individual sampling disturbed the substrate by kicking for approximately 3 minutes, travelling from bank to bank. Organisms from the sample were subsequently counted and identified, with a goal of 200 organisms per sample (Dance, 2007). The similar methods, in addition to the comparable numbers collected, make it more feasible to compare the results between this study and the 2003 survey by Dance. The 2003 survey took place in June of that year, so results are compared in table 11 below with the June samples from this study. The comparison shows that Cruickston site C1 (Station 1) has retained similar water quality, regardless of the changes in adjacent land use. Full data can be viewed in the 2006 version of the ***rare*** Environmental Management Plan, which will be available through ***rare*** by summer, 2007.

Table 11: Comparison between 2003 and 2006 Cruickston Creek sample results

<table>
<tr><th>Sample Year</th><th>Site</th><th>Total Organisms</th><th>Richness</th><th>HBI/FBI</th><th>HBI/FBI Quality</th><th>EPT Taxa</th></tr>
<tr><td rowspan="2">Jun-03</td><td>Station 1</td><td>183</td><td>18</td><td>5.91</td><td>Fairly Poor</td><td>3</td></tr>
<tr><td>Station 2</td><td>98</td><td>22</td><td>2.89</td><td>Excellent</td><td>9</td></tr>
<tr><td rowspan="2">Jun-06</td><td>C1</td><td>357</td><td>17</td><td>6.93</td><td>Poor</td><td>6</td></tr>
<tr><td>C2</td><td>313</td><td>22</td><td>4.5</td><td>Good</td><td>8</td></tr>
</table>

The sampling results from Bauman and Cruickston Creek sites also can be compared to 2004 results from two other local streams that is are located in close proximity to the ***rare*** property. First, Schneider's Creek flows through the city of Kitchener before connecting with the Grand River less than 5 kilometres northwest of the ***rare*** property. Unlike Bauman and Cruickston Creeks, which continue to flow through mostly natural systems, Schneider's Creek has been subjected to mass alterations due to the urbanization of the city. Flowing through the western corner of Kitchener, Schneider's Creek winds its way through residential areas, parking lots, industrial areas, schoolyards, and commercial developments (Chittick, 2001). There are areas where its banks have been channelized, cemented, and tiled. It flows under roads through culverts, and has other culverts pouring urban runoff into it. It has virtually no natural riparian zone or canopy cover, and is often the recipient of garbage and shopping carts. It is essentially the classic example of a truly urban stream. It will therefore be compared to the results of Bauman and Cruickston in order to exemplify what the protection allotted to these streams have done for their ecological health and integrity.

The second local stream on which we have benthic results is Blair Creek. Blair creek is another tributary of the Grand River, situated just east of the ***rare*** property, and contains comparable habitat to both Bauman and Cruickston: it is a fast flowing, cobble bottom, coldwater stream maintaining Brook Trout habitat, which flows through fragmented riparian zone, agricultural fields, and is surrounded by an urban environment (Weatherbe and Dance, 2004). April 2004 sampling results from both Schneider's and Blair Creeks are compared with the summer 2006 results from both Bauman and Cruickston in table 12 below. Methods used were identical to those outlined above for the 2003 Cruickston survey. Full details can be viewed in the 2004 report *City-Wide Stormwater Management Plan Annual Audit Report*, compiled for the City of Kitchener by Donald G. Weatherbe Associates Inc. and Dance Environmental Inc. The 2004 study on Blair and Schneider's Creeks also involved the Hilsenhoff Biotic Index (HBI); FBI is a modified version of HBI, differing only in level of taxonomic identification (family level versus genus/species). The two indices are comparable in terms of final values, as results are not significantly different with level of identification (SWCSMH, 2006).

Table 12: Comparisons between benthic results from Bauman, Cruickston, Schneider's, and Blair Creeks

Sample Year	Site	Total Organisms	Richness	HBI/FBI	HBI/FBI Quality	EPT Taxa
Jun-06	**B1**	290	13	5.48	Fair	2
	B2	325	12	5.76	Fairly Poor	1
	B3	340	18	4.96	Good	9
	B4	262	16	4.19	Very Good	7
	C1	357	17	6.93	Poor	6
	C2	313	22	4.5	Good	8
Apr-04	**Schneider's SC2**	138	7	7.78	Poor	1
	Schneider's SC5	160	10	7.79	Poor	1
	Blair Creek	195	26	4.48	Good	9

2.8 Analysis of Water Chemistry Results

Nitrate concentrations went down steadily throughout the season on both creeks at all sites. The initial spike is concurrent with heavier fertilizer application in the spring planting season, which is likely reduced throughout the growing season (see Kaushik et al, 1981). Also, precipitation levels in late September and early October were very high (which may aid in the dilution of nitrates in the creeks.

Kaushik et al (1981) suggest that nitrates from fertilizer applications in high production agricultural systems are likely to percolate downward and into the groundwater table. The majority of land under conventional agriculture to the south and east of Cruickston and Bauman Creeks is located directly on important groundwater recharge zones (Hunter & Associates, 2004). The direction of flow of the water table aquifer would suggest that these contaminants are moving with the groundwater (Hunter & Associates, 2004) and are likely being discharged into the streams, both of which contain major areas of groundwater discharge.

The nitrate levels in both of ***rare***'s creeks spiked much higher those of Schneider's Creek and Blair Creek in the 2004 report by Weatherbe and Dance. At its highest levels, which occurred on the July 4th sampling day, Bauman Creek showed nitrate levels of 13.9 mg/L at site 4, and Cruickston reached 21.7 mg/L at site 2. The highest levels for Schneider's Creek occurred on July 6th, 2004, and reached only 2 mg/L, and Blair Creek's highest results were observed on August 16th, 2004, when nitrate levels reached 5.7 mg/L. This difference is likely a result of the intensive conventional agriculture occurring on and around ***rare*** property; agricultural inputs has been held accountable for 95% of the nitrate inputs into the Grand River watershed (Kaushik et al, 1981).

The Canadian Water Quality Guidelines list 13 mg/L as the interim limit for nitrate required to protect aquatic life in freshwater systems from direct toxic effects (Environment Canada, 2005). Bauman and Cruickston Creeks both had sites exceeding this limit in the June and July sampling sessions, when Bauman 4 measured 13.6 and 13.9 mg/L, Cruickston 1 measured 18.1 and 21.5 mg/L, and Cruickston 2 measured 18.4 and 21.7 mg/L respectively. Cruickston Creek sites again surpassed the interim limit in August, when site 1 showed nitrate levels of 15.2mg/L and site 2 measured 15.7 mg/L. The higher levels at the most upstream sites of Cruickston and Bauman Creeks (Bauman 4 and Cruickston 2) are typical, as these sites are primarily spring fed and nitrate levels are often higher in groundwater (Kaushik et al, 1981; Environment Canada, 2005). As the surface water continues downstream, uptake and denitrification by macrophytes generally result in lower concentrations in downstream sites, especially in summer months when plant productivity is highest (Kaushik et al, 1981). Levels above the interim limit do not necessarily result in adverse effects to aquatic life, as effects are reliant on site-specific factors, but these high levels warrant further investigation to determine whether any negative effects are taking place.

Alternate to the nitrate data, the total phosphorus levels in Bauman and Cruickston Creeks stayed relatively constant in the initial three sampling dates, before peaking in the final samples. This is especially evident in Cruickston site 1 and Bauman sites 1 and 4, where levels jumped from 0.03, 0.04, and 0.03 mg/L to 0.4, 0.11, and 0.3 mg/L respectively. The rise in concentration may be attributed to the increase in water levels in the fall sampling session (table 9). Haygarth et al (2005) found that total phosphorus levels in streams generally increase with increased hydrological energy. This would include increased precipitation levels and storm events similar to those which took place before the October sampling. This rise in total phosphorus may be attributed to a "piston effect" which takes place with high precipitation levels and storm events; the increased runoff and high water levels push agricultural pollution through the catchment, starting with headwater streams like Bauman and Cruickston Creeks (Haygarth et al, 2005). As the water levels increase, organic phosphorus is released from the saturated soil first and flushed out, as it has a higher mobility rate than the inorganic phosphorus (Haygarth et al, 2005). The inorganic phosphorus is then pushed through as it is pulled from saturated soil, resulting in higher levels of total phosphorus in the stream (Haygarth et al, 2005). Fall leaf litter may be another factor contributing to the increase in total phosphorus in October levels. As fallen leaves begin to decay in the stream they release phosphorus into the water, slightly changing the phosphorus dynamics in forested streams (Howarth & Fisher, 1976). Bauman site 4 is in a deciduous forest, and receives a large number of leaves. Cruickston site 1 is just downstream of another deciduous forest, and may receive the effects from that leaf litter. Further investigation is needed to determine if this spike is a reason for concern.

Unlike nitrates, there is no interim limit for total phosphorus in the Canadian Water Quality Guidelines (Environment Canada, 2005). Instead, total phosphorus concentrations are linked to "trigger ranges", which help dictate the nutrient levels in streams (table #) (Environment Canada, 2005). Because of the wide ranges of phosphorus levels that exist in streams, further investigation is recommended if total phosphorus levels in subsequent sampling seasons rises more than 50% higher than the baseline data, or if concentrations are close to the upper limit of the trigger ranges (Environment Canada, 2005).

Table 13: CWQG trigger ranges for total phosphorus in freshwater systems

Trophic Status	Trigger Range (μg /L)	Associated Nutrient Levels
ultra-oligotrophic	<4	Deficient
oligotrophic	4 - 10	Low
mesotrophic	10 - 20	Moderate
meso-eutrophic	20 - 35	Moderately High
eutrophic	35 - 100	High
hyper-eutrophic	>100	Extremely High

Table 14: Average total phosphorus levels and related trophic status for each site

Site	Ave TP (µg/L)	Trophic Status
Bauman 1	62.5	Eutrophic
Bauman 2	47.5	Eutrophic
Bauman 3	47.5	Eutrophic
Bauman 4	100.0	Hyper-eutrophic
Bauman Cr Average	**64.4**	**Eutrophic**
Cruickston 1	135.0	Hyper-eutrophic
Cruickston 2	47.5	Eutrophic
Cruickston Cr Average	**91.3**	**Eutrophic**

The majority of both Bauman and Cruickston Creeks appear to be eutrophic systems. This means that the streams are high in nutrients (Environment Canada, 2005). Future monitoring will determine if these are normal levels of phosphorus in the creeks, and what degree of change these levels experience on an annual basis. In comparison, the 2004 data from Schneider's and Blair Creeks (Weatherbe and Dance, 2004) show that Schneider's Creek, which is a completely urbanized stream, is a eutrophic system (average 80.4 µg/L), and Blair Creek, which has more similar characteristics to both Bauman and Cruickston Creeks, is also a eutrophic system (average 36.7 µg/L).

One possible reason for the significant levels of organic pollution in Bauman and Cruickston Creek may be the chemical farm inputs being applied to the large area to the south of each creek (MAP 2). ***rare*** leases this land to a conventional farmer whose focus is primarily large scale corn and soybean crops, both of which require high chemical inputs. According to a hydrogeological survey performed on the property by Hunter and Associates in 2004, this area is an important groundwater recharge zone. Nitrate and phosphorus, both primary ingredients in synthetic fertilizers, leach downward through the soil and into the water. Some of this groundwater is then discharged into the creeks, mixing the contaminants with the surface waters and raising their levels of pollution table (Kaushik et al, 1981; Haygarth et al, 2005).

2.9 Analysis of Stream Parameter Results

2.9.1 Conductivity

Conductivity measures the ability of water to pass electrical current (US EPA, 2006); higher levels of microSeimens per centimetre (µS/cm) indicate higher conductivity. This ability is affected by the presence of inorganic solids, organic compounds, stream temperature, and local geology (US EPA, 2006).

Conductivity levels remained fairly constant in all sites throughout the season, until dropping off significantly in the fall. This is likely the result of decreased water temperatures at that time due to seasonal changes (table 10). These recorded levels could be used as baseline data, to which all future data can be compared. Any significant changes in the future could be indicative of increased pollution on new discharges into the stream. To ensure higher accuracy, future monitoring should likely take place on a more regular basis, such as weekly, biweekly, or monthly sampling dates.

2.9.2 pH

pH measures the logarithmic concentration of hydrogen (H+) and hydroxide (OH-) ions in the water, the two compounds that make up water (H+ + OH- = H2O) (US EPA, 2006). An equal concentration of these two ions results in a pH of 7.0, or neutral (US EPA, 2006). If hydrogen ions outnumber hydroxide, pH will be more acidic (less than 7.0); if hydroxide ions outnumber hydrogen, the pH will be more alkaline (higher than 7.0) (US EPA, 2006).

The largest diversity of aquatic animals generally occurs in the pH range of 6.5 to 8.0 (US EPA, 2006). All of the sites fit into this range throughout all sampling dates.

2.9.3 Dissolved Oxygen

The amount of oxygen in the water determines the amount and diversity of aquatic life that can exist in a stream. In general, faster running water dissolves more oxygen than slow or still water, and DO levels can fluctuate throughout the stream with changes in macrophyte abundance, stream flow rate, temperature, daylight hours, and time of day (US EPA, 2006).

Due to technical problems with the DO portion of the P4 meter, we were unable to obtain data for the October sampling date. Because the other two samples took place two months apart at differing times of day, it does not give us an accurate representation of dissolved oxygen levels in Cruickston or Bauman Creek. Future sampling should take place on a more regular basis. If a data logger could be obtained, the accurate data could be obtained on an hourly or daily basis, though this method is likely not feasible for a charity like ***rare***. At the very least, DO levels should take place on a weekly, biweekly, or monthly basis, with each sample taking place at the same time each date to maintain accuracy.

2.10 Recommendations Based on First Year Benthic Monitoring

There are a number of recommendations based on the data obtained in the first year of stream monitoring at ***rare***:

- Continue OBBN protocols on Bauman and Cruickston Creeks on an annual basis in order to determine any trends occurring on the waterways due to changes in management strategies, land use, restoration activities, etc.
- Incorporate the Ontario Stream Assessment Protocol (OSAP) on the established sites, which have all been implemented in line with OSAP protocol. OSAP includes additional monitoring, including habitat assessment techniques and fish inventorying via electrofishing. Both of these sections of the protocol would be especially conducive with OBBN, which is also included as a section of OSAP. These additional monitoring techniques would further assist in determining ecological trends or changes, while providing additional relevant information about the creeks to ***rare***.

- Monitor water chemistry on a more regular basis in the future to ensure a higher degree of accuracy. Testing should be done on a monthly basis at minimum, with dates and times being regulated due to the hourly fluctuations of some parameters.
- Implement permanent markers at the beginning and end of each site to ensure accurate long-term repeatability in sampling. Currently, sites are marked using wire flags, which are vulnerable to weather or animal damage, easy removed by humans, water flow, or animals, and are easily hidden by long grasses or forbs. It is recommended by EMAN that sites be marked using PVC pipe, which is much less susceptible to weathering and damage in the long term. Minimum four foot pipe lengths should be used, and placed in the ground up to two feet deep to inhibit easy removal. Two feet could be left above ground to help locate sites, with coloured outdoor paint applied to the top if needed to facilitate locating.
- End chemical pesticide and fertilizer applications in important groundwater recharge zones to the south of Bauman and Cruickston Creeks. If agricultural production is to continue on these fields, the farmer should not be permitted to apply chemicals in this area, as it appears to be having an adverse effect on the coldwater streams.

3.0 Terrestrial Monitoring at *rare*

3.1 Monitoring Plethodontid Salamanders

The second EMAN recommended protocol implemented at ***rare*** was a protocol developed jointly by EMAN and Parks Canada to monitor Plethodontid salamanders. Plethodontids are lungless salamanders that rely completely on their moist skin and the roof of their mouths for respiration (Zorn et al, 2004). They are entirely terrestrial, and make up the largest group of salamanders in the world. There are nine species of plethodontids that are native to Canada, the most common one at ***rare*** being the red-backed salamander (*Plethodon cinereus*) (Zorn et al, 2004). According to Cook (1984), the red-backed salamander can be found in one of three colour morphs; the most common is the red-back morph, where the individual has a red head stripe on its back from head to tail with blackish sides and belly (Cook, 1984). The red-back morph is believed to make up 75% of all individuals in most locations (Lamond, 1994). The second most common, though much less so than the red-back, is the lead-back morph, where the individual is completely blue-black in colour (Cook, 1984). The third possible morph, which is very rare, is the erythristic morph, which is completely red (Cook, 1984). *P. cinereus* are found throughout eastern Canada in most white pine, northern hemlock or deciduous forests (Cook, 1984). They live in damp, wooded areas, and are generally found in or under decaying logs or stumps, leaf litter, pieces of bark and large stones (Walsh and Droege, 2001).

Plethodontid salamanders are an ideal indicator group for detecting environmental change for a number of reasons. They have long life spans of ten or more years with high annual survivorship rates and low annual birth rates, allowing Plethodontids to maintain relatively stable population levels under normal circumstances (Zorn et al, 2004). In addition, Plethodontids have no aquatic habitat requirements at any stage in their life cycle, allowing them to be generally more abundant and have a higher distribution than those species that do have an aquatic larval stage (Walsh and Droege, 2001). Finally, though they are widely distributed, Plethodontids have small home ranges, generally displaying site consistency and territoriality (Walsh and Droege, 2001). These attributes increase the likelihood that an observed change in population is an indication of some stress on their habitat as opposed to a shift in their home range (Zorn et al, 2004), and negative changes are more likely to reflect significant changes in the environment as compared to other species in their habitat (Walsh and Droege, 2001). The reliance on their moist skin for respiration makes Plethodontids very sensitive to a range of environment stressors, especially those influencing microclimate, or impacting air, water, or soil quality (Zorn et al, 2004). Therefore, any event which leads to the alteration of soil moisture, sun exposure, or soil quality, including logging, development, climate change and pollution, is likely to have an adverse effect on plethodontid populations; any changes in population numbers also reflects the balance of invertebrates, leaf litter, soil moisture, pH, available burrows and debris in the ecosystem (Walsh and Droege, 2001). A benefit of this high sensitivity means that any sudden changes in populations observed through consistent monitoring may still allow for possible lead time to search for the root causes of the change, and appropriate action can be taken to reverse the problem before the associated biota are lost (Walsh and Droege, 2001).

The important role of plethodontids in forest ecosystem processes also contributes to their idealness as indicator species. Because they are so efficient at metabolizing their prey, which includes many kinds of soil invertebrates, they are able to quickly achieve high population densities (Burton and Likens, 1975). In suitable habitats, this allows them to equal or surpass the biomass of any other vertebrate group in the system (Burton and Likens, 1975). Therefore, they represent a very important function in the forest food web for the transfer of energy between trophic levels (Zorn et al, 2004).

Finally, Plethodontid salamanders make ideal indicators due to their attractiveness to monitoring projects. They are easily identified, making accurate identification possible with minimal training and allowing for changes in observers from year to year. They are also attracted to artificial cover objects, allowing for non-destructive sampling in a wide range of habitats (Binckley et al, 1997; Welsh and Droege, 2001; Marsh and Goicochea, 2003). The ability to monitor Plethodontids using non-invasive, precise, replicable techniques also allows for the incorporation of salamander monitoring with a suite of other EMAN recommended forest protocols that also relate to forest health.

3.2 Salamander monitoring at *rare*

The focus of the salamander monitoring program at ***rare*** was to examine salamander populations in Indian Woods through the use of artificial cover boards, using protocols laid out by EMAN and Parks Canada. The applicable long-term research questions for this project are as follows:

- What is the current state of salamander populations at ***rare***?
- What is the ecological health of Indian Woods, and is it being maintained or improved over time?

- Is the ecosystem integrity of the forest being maintained or improved under the management of ***rare***?
- Is forest health being improved or impacted through on-site changes in agriculture and/or due to restoration efforts being implemented nearby?
- What are the long-term trends taking place as indicated by salamander populations at ***rare***?

3.3 Rationale

The preliminary monitoring this season will allow for the collection of baseline data on the salamander populations in Indian Woods, providing the basis for a long term, annual monitoring program at ***rare***. This annual data will allow for the detection of ecological trends that may be impacting forest habitat, due to impacts such as climate change or changes in air quality, habitat quality, pollution levels or adjacent land use. This data will also allow ***rare*** to determine the ecological health and integrity of Indian Woods. This information can be used by ***rare***'s Environmental Advisory Team (EAT) for future management planning, restoration and research priorities and land use planning. Also, the feasibility of incorporating this salamander monitoring protocol with other EMAN recommended protocols will allow for the future implementation of additional protocols which will further assist in determining and monitoring the overall health of Indian Woods.

3.4 Site Description

The site used for salamander monitoring in the 2006 season in Indian Woods is plot 2 used by Nicole Weaver for lichen monitoring in 2004 (Map 4). It is located immediately northeast of a large ephemeral pond in the south west section of Indian Woods, east of the Grand Allée Trail. This site was already set up as a standard 20x20 m EMAN plot in 2004, making it easy to add the artificial cover boards needed to monitor salamanders. In addition, Indian Woods is a known habitat for red-backed salamanders, which were observed during a ground survey in October, 2001 (CCRR EAT, 2002).

Indian Woods is a rare, old-growth remnant of forest, whose dominant species include red oak (*Quercus rubra*) white oak (*Quercus alba*), sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), basswood (*Tilia americana*) and white pine (*Pinus strobus*). ***rare***'s vision for Indian Woods involves the protection and enhancement of the forest, and the charity allows only limited access for the purposes of education and research (rare, 2006). The field immediately south of the site, which slopes into the woods, was used for conventional agriculture this year, but has been removed from cultivation for the 2007 growing season. Passive restoration will take place on this field, and long term monitoring may show effects of removal; it has been hypothesized by members of the ***rare*** EAT that agricultural runoff was negatively impacting the ephemeral pond and therefore reducing the number of species that could reproduce in it each spring (Dance, 2006).

3.5 Methodology

The complete EMAN-Parks Canada protocol for monitoring Plethodotid Salamanders can be viewed online at
http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/salamanders/intro.html#toc.

Twenty nine artificial cover boards, each measuring one foot square, were donated to ***rare*** in August of 2006. W.J. Esbaugh Construction of Waterloo donated 32 boards that were one inch thick, and Michael Grealey of Kitchener donated 14 boards that were two inches thick. After a conversation with Brian Craig (2006), former Senior Science Advisor for EMAN, it was determined that the one inch boards would be nailed together to create 18 two inch boards, due to the higher decay rates of one inch boards. Three of these double boards were deemed unusable due to warping, leaving us with a total of 29 artificial cover boards of two inch thickness, the ideal thickness as recommended by EMAN. It was hoped that we would obtain three more two inch boards, but were unable to find them for the 2006 monitoring season.

The boards were placed at Lichen Plot 2 in Indian Woods according to the EMAN forest protocol (Map 4). A 20x20 meter plot, which had already been established for lichen monitoring in 2004 (Weaver, 2004) was re-marked with new posts and pink flagging tape. A second square was measured 10 meters out from the original plot boundary, along which the artificial cover boards were placed at 5 metre intervals (see Zorn et al, 2004). This method allows for the placement of 32 boards, so space was left for the missing three. Each board was tagged with an aluminium tree tag and given a unique number for monitoring, starting with board 01 in the northwest corner of the plot and continuing in a clockwise manner. The tagging code was based on the EMAN tree tagging code for forest plot monitoring, where the tags show the forest stand number, the plot number, and the tree number respectively. The numbering system on the boards shows the stand number IN, plot number 02, and board number 01 to 32 (boards 06, 07, and 08 are missing). An example of the tag coding is shown below:

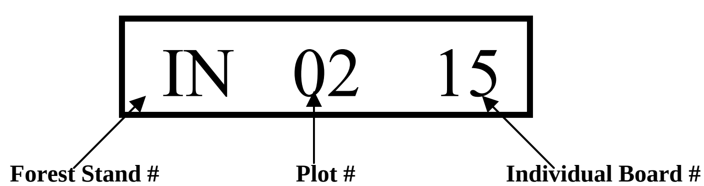


Figure 3: Example of artificial cover board tagging at *rare*

The 16 double layer boards were placed out on September 1, 2006, and the remaining boards went out on September 6, 2006. The boards were then left alone until September 28, 2006, which was the first official day of salamander monitoring at ***rare***. It was suggested by Brian Craig of EMAN that we begin salamander monitoring at this time, as the weather is cooler and wetter, which is ideal for plethodontid salamanders.

The monitoring protocol for salamanders involves lifting each of the boards to look for any salamanders residing below. For each salamander present, the board number, species, snout to vent length and the vent to tail length was recorded on the data sheet. All morphs were recorded as red-backed salamanders, and individual morph type was also recorded. After being measured, each salamander was removed from under the board before the board was replaced, to avoid crushing any salamanders. Each individual was then allowed to find its own way back under the board or to a different form of cover. Additional notes were taken on any observed disturbance to the boards or salamanders, as well as any other comments deemed noteworthy by the observer. Air temperature, Beaufort wind and sky codes, date, time, and observer names were also recorded each sampling date, as recommended in the protocol. Boards were checked every seven days in the same manner; sampling dates were September 28, October 5, October 12, October 19, and October 26, 2006. EMAN does not recommend sampling any more frequently than this, and additional studies have shown that sampling more than once per week results in decreased counts and increased bias (Marsh and Goicochea, 2003).

For each sampling date, specific variables were recorded, as recommended by the EMAN protocol. These included air temperature, soil temperature, Beaufort Sky Code, and Beaufort Wind Code. For the first two weeks, soil temperature was recorded using the aquatic thermometer, which was inserted 2 inches into the ground adjacent to ACO #01. This thermometer was left in the soil until the end of the sampling session, and then the temperature was recorded. In the last three weeks of sampling, ***rare*** obtained a soil thermometer. For these three sampling days, soil temperature was recorded for each ACO, which were then used to find the average soil temperature. A fifth variable recommended by EMAN is precipitation levels. Unfortunately, the local weather station, which is located at the Waterloo-Wellington Airport in Breslau, experienced technical difficulties which resulted in incomplete data for the month of October 2006. The variables recorded for each week are outlined below in table 15. Original field sheets containing all salamander monitoring data can be accessed through ***rare*** Charitable Research Reserve.

3.6 Results

Table 15: EMAN recommended variables for 5 salamander sampling days

Date	Time	Observers	Beaufort Sky Code*	Beaufort Wind Code*	Air Temp (°C)	Ave. Soil Temp (°C)	Ave. Soil Moisture Reading	Precipitation (last 24 hrs) mm
Sept 28/2006	10:10-12:05	Shannon Holton, Heather Cain	2	3	11	12	N/A	37
Oct 5/2006	12:10-14:30	Ken Dance, Shannon Holton	1	5	10.5	9.5	N/A	25.5
Oct 12/2006	11:10-13:03	Ken Dance, Shannon Holton	6	1	7	9.4	1.9**	Missing data
Oct 19/2006	9:56-11:40	Ken Dance, Shannon Holton	2	3	12	11.3	6.7	Missing data
Oct 26/2006	9:57-11:10	Ken Dance, Shannon Holton	0	0	5.5	4.7	6	Missing data

* Beaufort Sky and Wind Codes are described in Appendix #.
** Soil Moisture meter was incorrectly calibrated on Oct 12 – data not accurate.

Weekly numbers of salamanders peaked during the first three sampling days at 42, 51, and 49 individuals respectively, before crashing in the fourth week to 7 and going up slightly in the final week to 11 (figure 4). Snout-to-vent lengths, which were recorded for each salamander found, are summarized for red-backed salamanders in Figure 6. Total lengths for the red-backs are summarized in Figure 7. One salamander was found on October 12 from the blue-spotted/Jefferson complex (*Ambysoma* sp.) measured 65 mm from snout to vent, with a tail length of 86 mm, giving it a total length of 151 mm. This is more than twice the average length of all red-back salamanders found. Complete data tables, including snout to vent lengths, vent to tail lengths, and total lengths for each salamander found can be viewed in Appendix C. Original field data sheets available at ***rare*** Charitable Research Reserve.

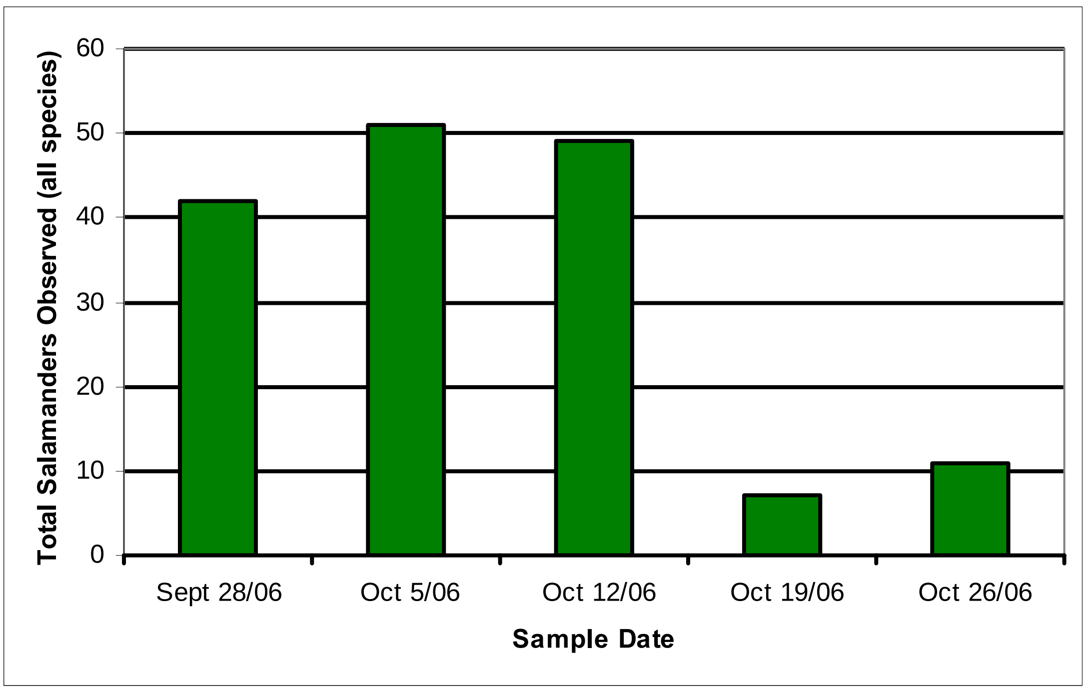


Figure 4: total numbers of salamanders found in each sampling date

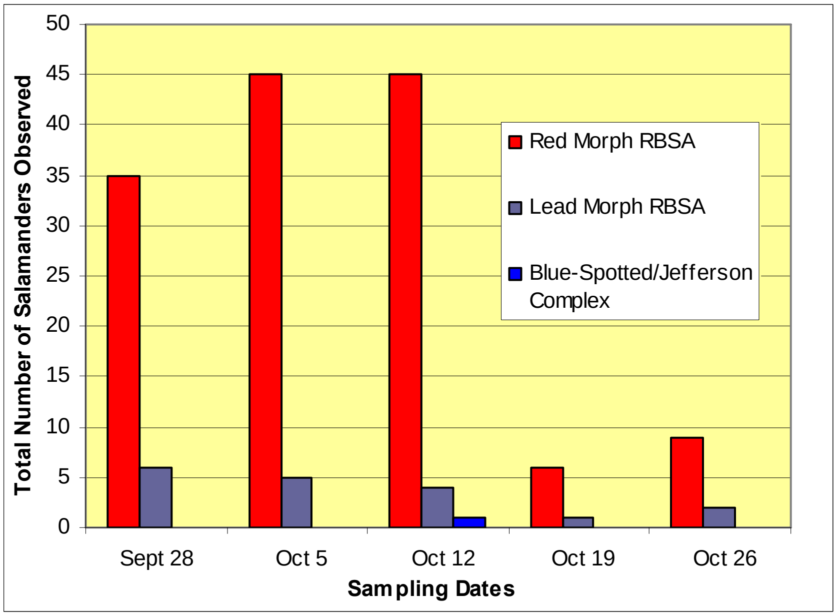


Figure 5: totals of each salamander type found per date

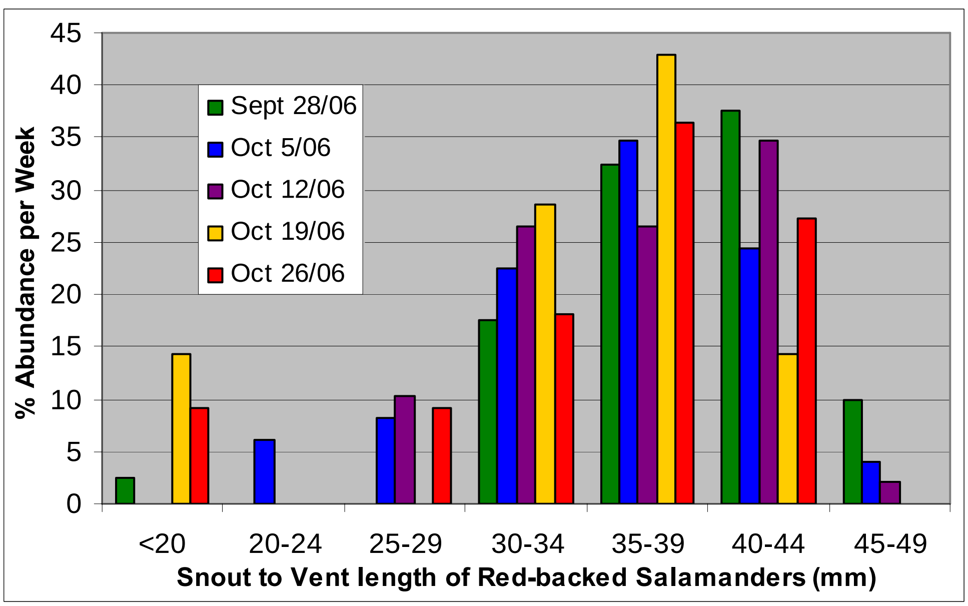


Figure 6: Summary of snout to vent lengths of Red-backed Salamanders found

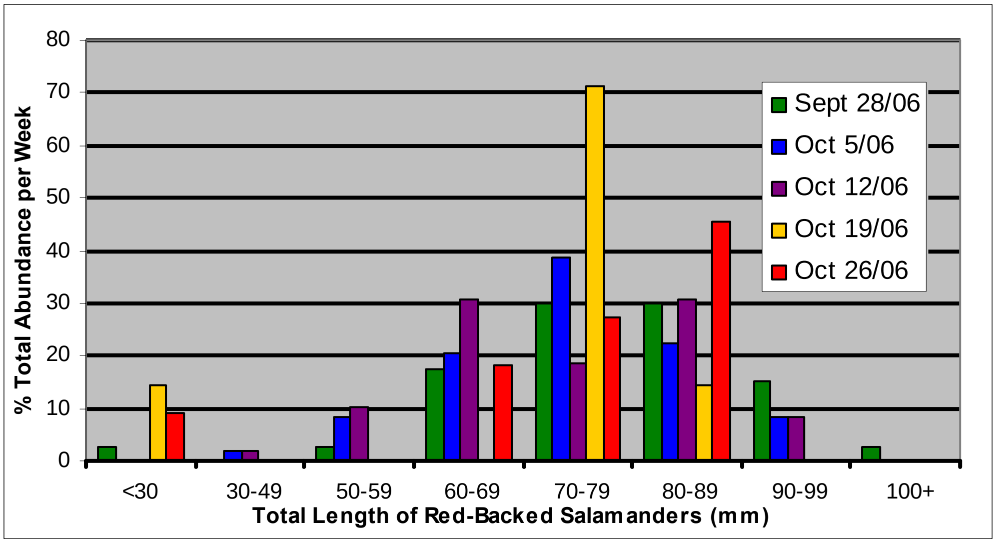


Figure 7: Summary of total lengths of Red-backed Salamanders found

For the three sampling dates from October 12th to October 26th, ***rare*** obtained both a soil moisture meter and a soil thermometer. These measurements were recorded for each of the artificial cover boards on each of these dates. Unfortunately, the soil moisture meter was not calibrated properly for the October 12th sampling date, so numbers recorded for this date are inaccurate. This problem was fixed for the remaining two sampling days, allowing us to obtain more accurate information for these dates.

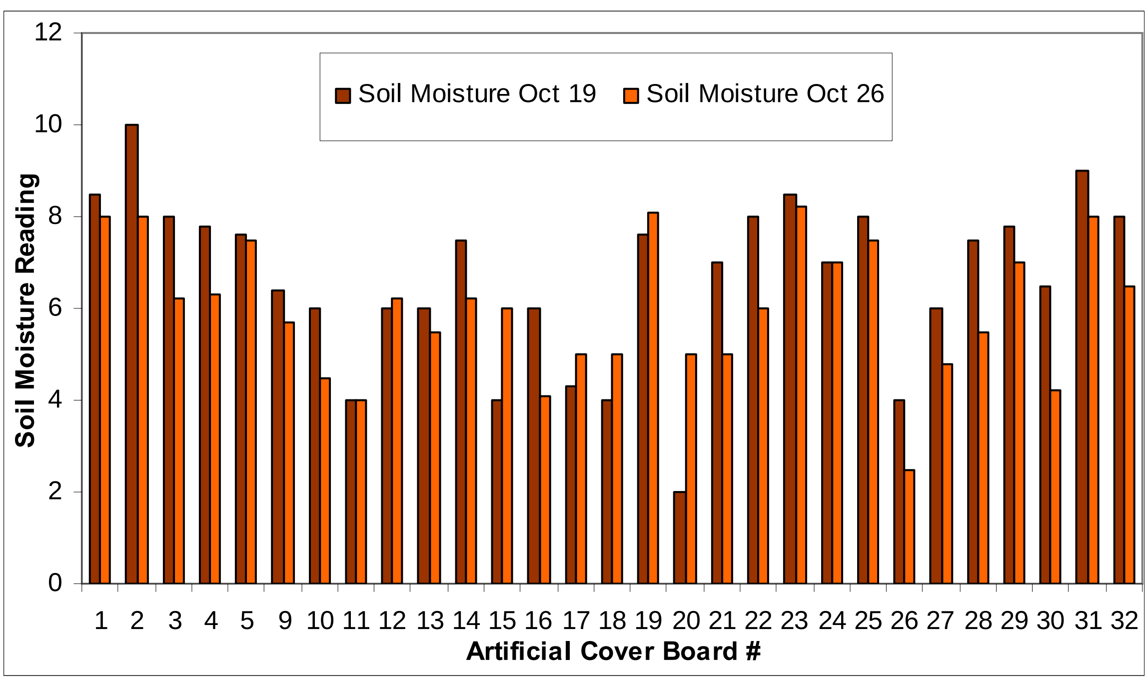


Figure 8: Soil moisture readings for October 19th and 26th for each cover board

3.7 Analysis of Salamander Results

All the 160 salamanders found under the boards were red-backed salamanders (*Plethodon cinereus*), except for one individual from the blue-spotted/Jefferson complex (*Ambysoma* sp.) found on October 12 (figure 5). Due to lack of genetic testing, we are unable to confirm whether this individual was a true blue-spotted or Jefferson salamander, or one of the various hybrids (Bogart, 2006). Of the red-backs found, 88.6% were of the red-back morph, while only 11.4% were of the lead-back morph, leaving a ratio of approximately 8 red-back morphs for each lead-back morph found under the artificial cover boards.

3.7.1 Length Comparisons

Upon examination of the snout to vent lengths of red-backed salamanders, there appears to be four to five distinct groups, or size classes (figure 6). These size classes may be related to age cohorts. The smallest size class, which could take in all individuals under 24 mm, are likely the young of the year (yoy). With each year of life the salamanders would grow larger, depending on the amount of available food source. Therefore, a second class could exist between 25 and 29 mm, which may be second year individuals. The majority of salamanders found were within a third, mid-size class, between 30 mm and 44 mm, which would likely be middle aged specimens. Very few individuals measured were greater than 44 mm, which again fits in with the age correlation hypothesis: fewer individuals would live to old age than exist at middle age due to predation, competition, and other such variables. Yearlings would be also more vulnerable to predation by larger red-backed salamanders and other species due to their size and lack of experience, which would explain the reduced number of salamanders found in the smallest size class. The collection of future data from this site may assist in the creation of an age cohort-size classification for this area, especially if a capture/recapture technique was incorporated, as growth rates for red-back salamanders tend to be dependant on local habitat (Bogart, 2006). Unfortunately, this method of monitoring may result in information that is slightly biased, as Marsh and Goicochea (2003) found that artificial cover objects appear to attract more adults Plethodontids than juveniles or yearlings when compared to natural cover objects, therefore this monitoring technique may not be ideal for population studies. More data would also lend to supporting or refuting this claim.

3.7.2 Soil Moisture

After studying the effects of clearcutting on Plethodontid salamanders for over 25 years, Ash (1997) found a positive correlation between salamander abundance and the amount of leaf litter and the moisture content of the litter and topsoil. This was observed informally, as very few salamanders were found when the site was first examined in August, when temperatures were hotter and drier, than in late September/early October when actual monitoring took place, and the weather was significantly cooler and wetter. Unfortunately, with only two days of accurate moisture data available, only a weak correlation can be observed between salamander abundance and soil moisture levels; more data is needed to confirm this apparent trend. The 2007 sampling season should include soil moisture measurements with each sampling day, ensuring the meter is properly calibrated prior to each use. Leaf litter depth measurements may also be useful in determining behavioural trends of red-back salamanders in Indian Woods.

3.7.3 Temperature

A correlation can be observed between air and soil temperature. A slight correlation can also be observed between temperature and salamander abundance; highest salamander numbers were observed when soil temperatures were between 8 and 12 degrees and air temperatures were found within 7 and 11 degrees Celsius. Again, with only 5 weeks of data available, it is difficult to determine if this correlation is significant. Additional sampling periods throughout the year would further assist in determining any relation between salamander abundance and air and soil temperature; it would be useful to have data from additional seasons in the year so increased temperature fluctuations could be observed.

3.8 Recommendations Based on First Year Salamander Monitoring

Recommendations based on the data obtained through this year's salamander monitoring include:

- Continue to implement EMAN/Parks Canada salamander monitoring protocols in Indian Woods at plot IN02 on an annual basis in order to determine any long-term trends occurring on salamander populations due to changes in management strategies, land use, restoration activities, climatic changes etc.
- Extend monitoring season to include weekly or biweekly sampling throughout spring, summer and fall. Collected data should include air and soil temperatures, soil moisture levels, pH, and leaf litter measurements at each sampling date. This should allow for more accurate correlation data, seasonal behavioural data, and population data, giving ***rare*** a better picture of what trends are taking place regarding salamander populations and why.
- Continue relation charting between salamander size and age class, to possibly create a usable age cohort chart for the ***rare*** property. Long term size class data for this area could lead to the development of age class charting for the region. This would make an ideal post-secondary Graduate or Undergraduate level thesis project with the accumulation of data from multiple years.
- ***rare*** should obtain a scale in order to take weight measurements in addition to length, which would assist in developing age classes for red-back salamanders. Weight data is an additional variable recommended by EMAN.
- Implement an additional 20x20 m plot in the Hogsback area with salamander monitoring boards in order to obtain comparison data for salamanders and increase knowledge on ***rare***'s ecology. The Hogsback is already an area known to be suitable for salamander habitat (Dance et al, 2002), and more species with aquatic stages may be present.
- Implement additional EMAN protocols on plot IN02. Salamander monitoring and lichen monitoring have already been established with the 20x20 m plot, and additional protocols such as forest health monitoring could be easily implemented, giving ***rare*** a broader knowledge of overall ecological health and trends taking place in Indian Woods. The lichen monitoring should be also updated to ensure correct species identification and allow for proper mapping, both of which appear to be lacking in the previous project.

- Surgical scissors and a vial of ethanol solution should be taken on each salamander monitoring date to ensure proper identification of any individuals in the Blue-Spotted/Jefferson complex. Genetic testing can be performed at the University of Guelph with only a small piece of the end of the salamander's tail, which will determine for certain whether or not Jefferson salamanders are found at ***rare***. True Jefferson salamanders are considered Threatened under the Species at Risk Act (SARA) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Environment Canada, 2006). Therefore a properly identified specimen could result in increased protection measures for the property, and possible qualify ***rare*** for participation in the National Recovery Strategy for Jefferson Salamander.
- Observed salamanders could be marked in order to collect data on capture/recapture rates, giving us a more accurate picture of salamander population and behavioural trends.
- End chemical applications on the agricultural fields south of the salamander plot, to increase protection on the ephemeral pond. This is an important groundwater recharge zone (Hunter et al, 2004), and contaminated runoff may be entering the ephemeral pond. Studies have shown that ponds with increased levels of nitrates and other chemical elements associated with agricultural contamination result in reduced survival rates of amphibian eggs and larvae, including those from the blue spotted/Jefferson complex (Laposata and Dunson, 2000). The cessation of chemical use on these fields could lead to the increased reproduction capabilities of amphibians in this area, if in fact the chemical applications are negatively impacting the pond. To determine whether this is a factor, the water chemistry of the pond could be analysed multiple times throughout the year.
- The literature shows a positive correlation between salamander abundance and forest patch size, including species from both Plethodontid and Ambrysomatid families (Kolozsvary and Swihart, 1999; Guerry and Hunter, 2002; Rubbo and Kiesecker, 2005). Therefore ***rare*** should consider actively restoring the north side of field 10, which is to be removed from agricultural production after fall 2006, to a forested state. This would help to increase the overall forest area of Indian Woods, may improve the health of local salamander populations, and possibly encourage more rare species like the Jefferson salamander. Planting hedgerows on the southern side of the property between Indian Woods and the Hogsback would also provide dispersal corridors for salamanders, again encouraging additional species, including the Jefferson salamander (Rubbo and Kiesecker, 2005).

4.0 Conclusions

All of the data compiled for ***rare*** this season, for both the aquatic and the terrestrial programs, is considered baseline data. Baseline data only remains relevant if there is something with which to compare it to at a later date, allowing more concrete interpretations, recommendations, and conclusions to take place, and continually increasing the level of ecological knowledge of the site. Therefore, without a consistent benthic and salamander monitoring program, each to be continued on an annual basis, the data obtained through sampling this year would be rendered useless. Continuous monitoring is extremely important for determining and documenting any long term ecological trends or significant environmental changes that may be taking place at ***rare***. This remains true at a regional, national, or global scale, especially in the face of such significant wide scale events as global climate change, and in order to uphold ***rare***'s visions of protecting and restoring this invaluable property, improving environmental education, and supporting future generations. Among other benefits, long term data through ecological monitoring at ***rare*** could result in increased protection measures placed on the property, as well as support political paradigms regarding the environment to shift at regional, provincial, and federal levels, provide increased environmental awareness to all levels of public expertise, and support data obtained from other EMAN sites across the country. It is therefore strongly recommended that ***rare*** place the highest degree of effort possible into maintaining, improving, and expanding these monitoring programs in the years to come.

References

Ash, A.N. 1997. Disappearance and Return of Plethodontid Salamanders to Clearcut Plots in the Southern Blue Ridge Mountains. *Conservation Biology* 11: 983-989.

Barfoot, S. 2003. *Bauman Creek Study: An aquatic ecological assessment and restoration plan for a second-order southern Ontario stream*, Senior Honours Thesis, Department of Geography, University of Waterloo.

Barton, D. 1996. The use of Percent Model Affinity to assess the effects of agriculture on benthic invertebrate communities in headwater streams of southern Ontario, Canada. *Freshwater Biology* 36: 397-410

Bogart, J. 2006. Personal Communication with Ken Dance, September, 2006.

Booth, W.C., Colomb, G.G., and Williams, J.M. 1995. *The Craft of Research*. University of Chicago Press: Chicago, IL

Cairns, J. Jr. 2002. Rationale for restoration, pages 10-23 in M.R. Perrow and A.J. Davy (eds) *Handbook of Ecological Restoration Volume 1: Principles of Restoration.* Cambridge University Press, Cambridge, UK

CH2M Gore & Storrie Ltd. 1997. *Blair, Bechtel, and Bauman Creeks Subwatershed Plan.* Grand River Conservation Authority.

Chittick, S. 2001. *Schneider's Creek*. [Online] Available http://info.wlu.ca/~wwwgeog/thesis/tour1.html

Craig, B. 2006. Personal Communication, August and September, 2006.

Cruickston Charitable Research Reserve Environmental Advisory Team (CCRR EAT). 2002. Wilson, W.G. (ed) *Cruickston Park Into the Future: The Environmental Management Plan for Cruickston Charitable Research Reserve.* CCRR: Cambridge, ON.

Daigle, J-M and Havinga, D. 1996. *Restoring Nature's Place: A Guide to Naturalizing Ontario Parks and Greenspace*. Ecological Outlook Consulting and Ontario Parks Association: Schomberg, ON.

Dance, K. 2006. Personal Communication, May through December, 2006; January and February, 2007.

Dickinson, T., Metsger, D., Bull, J. and Dickinson, R. 2004. *Wildflowers of Ontario*. Royal Ontario Museum: Toronto, ON.

Donald G. Weatherbe Associates Inc. and Dance Environmental Inc. 2004. *City-Wide Stormwater Management Plan: Annual Audit Report (Year 2004)*. The Corporation of the City of Kitchener.

EGS International Inc. 2000. *Cambridge Area Route Selection Study*. [Online] Available http://www.region.waterloo.on.ca/web/region.nsf/0/3A649F6DA92F894785256AFD0074A6E2/$file/EnviroReptFigs.pdf?openelement

EMAN. 2006. *All About EMAN*. [Online] Available http://www.eman-rese.ca/eman/program/about.html

Environment Canada. 2005. *Guidelines at a Glance: Nitrate*. National Guidelines and Standards -Office: Ottawa, ON

Environment Canada. 2005b. *Guidelines at a Glance: Phosphorus*. National Guidelines and Standards Office: Ottawa, ON

Environment Canada. 2006. *Species at Risk: Jefferson Salamander* [Online] Available http://www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=642

Environment Canada, 2006b. *Daily Data Report for October 2006: Waterloo Wellington A Ontario* (Precipitation Data), [Online] Available http://www.climate.weatheroffice.ec.gc.ca/climateData/dailydata_e.html?timeframe=2&Prov=XX&StationID=32008&Year=2006&Month=10&Day=1

Guerry, A.M. and Hunter, M.L. Jr. 2002. Amphibian Distribution in a Landscape of Forests and Agriculture: an Examination of Landscape Composition and Configuration, *Conservation Biology* 16(3): 745-754.

Hart, T. 1998. Macroinvertebrate Biotic Index II. http://www.washjeff.edu/Chartiers/Chartier/mbi2.htm

Haygarth, P.M., Wood, F.L., Heathwaite, A.L., and Butler, P.J. 2005. Phosphorus dynamics observed through increasing scales in a nested headwater-to-river channel study, *Science of the Total Environment* 344: 83-106.

Hession, W.C., T.E. Johnson, D.F. Charles, R.J. Horwitz, D.A. Kreeger, B.D. Marshall, J.E. Pizzuto, and D.J. Velinsky. 2003. Ecological Benefits of Riparian Reforestation in Urban Watersheds, Pages 373-382 in M. Clar, D. Carpenter, J. Gracie, and L. Slate (eds) *Protection and Restoration of Urban and Rural Streams*. American Society of Civil Engineers, Philadelphia, Pennsylvania.

Howarth, R.N. and Fisher, S.G. 1976. Carbon, Nitrogen and Phosphorus dynamics during leaf decay in nutrient enriched stream microecosystems, *Freshwater Biology* 6(3): 221- 228

Hunter & Associates. 2004. *Regional Official Policies Plan: Cruickston Amendment Area Ecological/Hydrological Integrity*. Regional Municipality of Waterloo: Waterloo, ON.

Jones, C., Somers, K.M., Craig, B., and Reynoldson, T.B. 2005. *Ontario Benthos Biomonitoring Network Protocol Manual,* Ver. 1.0. Ontario Ministry of the Environment: Dorset, ON.

Kaushik, N.K., Robinson, J.B., Stammers, W.N., and Whiteley, H.R. 1981. Aspects of Nitrogen Transport and Transformation in Headwater Streams, pp. 113 – 139 in M.A. Lock and D.D. Williams (eds) *Perspectives in Running Water Ecology.* Plenum Press: New York

Kershaw, L. 2001. *Trees of Ontario*. Lone Pine Publishing: Edmonton, AB.

Kolozsvary, M.B. and Swihart, R.K. 1999. Habitat fragmentation and the distribution of amphibians: patch and landscape correlates in farmland, *Canadian Journal of Zoology* 77: 1288-1299

Krebs, C.J. 2001. *Ecology*, 5th Ed. Benjamin Cummings: USA

Laposata, M.M. and Dunson, W.A. 2000. Effects of Spray-Irrigated Wastewater Effluent on Temporary Pond-Breeding Amphibians, *Ecotoxicology and Environmental Safety* 46: 192-201

Lenat, D.R., L.A. Smock, and D.L. Penrose. 1980. Use of Benthic Macroinvertebrates as Indicators of Environmental Quality, Pages 97-112 in D.L. Worf (ed) *Biological Monitoring for Environmental Effects.* D.C. Heath and Company, Lexington, Massachusetts

Marsh, D.M. and Goicochea, M.A. 2003. Monitoring Terrestrial Salamanders: Biases Caused by Intense Sampling and Choice of Cover Objects, *Journal of Herpetology* 37(3): 460-466.

Merritt, R. W. and K. W. Cummins. 1996. *An Introduction to the Aquatic Insects of North America*. Kendall/Hunt Publishing Company: Dubuque, IA.

Morse, J.C. 1980. Research Suggestions – Benthic Invertebrates as Biological Indicators, Pages 113-121 in D.L. Worf (ed) *Biological Monitoring for Environmental Effects*. D.C. Heath and Company, Lexington, Massachusetts

Needham, J.G. and Needham P.R. 1962. *A Guide to the study of Fresh-Water Biology,* 5th Ed. Holden-Day Inc.: San Francisco, CA

OBBN. 2006. *Ontario Benthos Biomonitoring Network*. [Online] Available http://obbn.eman-rese.ca/PartnerPages/obbn/index.asp?lang=en-ca

Palys, T. 1997. *Research Decisions: Quantitative and Qualitative Perspectives,* 2nd Ed. Harcourt Canada Ltd.: Toronto, ON

Peckarsky, B. L., P. R. Fraissinet, M. A. Penton and D. J. Conklin, Jr. 1990. *Freshwater Macroinvertebrates of Northeastern North America*. Cornell University Press: Ithaca, NY.

Pennak, R. W. 1989. *Fresh-water Invertebrates of the United States: Protozoa to Mollusca*, 3rd Ed. John Wiley and Sons, Inc: NY

rare Charitable Research Reserve. 2006. ***rare***. [Online] Available http://www.raresites.org

Resh, V. H. and D. M. Rosenberg. 1984. *The Ecology of Aquatic Insects*. Praeger: New York.

Resh, V.H. and J.K. Jackson. 1993. Rapid Assessment Approaches to Biomonitoring Using Benthic Macroinvertebrates, Pages 195-223 in D.M. Rosenberg and V.H. Resh (eds) *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman & Hall, New York, New York.

Richardson, J.S. and M.J. Jackson. 2002. Aquatic Invertebrates, Pages 300-323 in M.R. Perrow and A.J. Davy (eds) *Handbook of Ecological Restoration Volume 1: Principles of Restoration*. Cambridge University Press, Cambridge, UK

Rosenberg, D.M. and V.H. Resh. 1993. Introduction to Freshwater Biomonitoring and Benthic Macroinvertebrates, Pages 1-9 in D.M. Rosenberg and V.H. Resh (eds) *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman & Hall, New York, New York.

Roberts-Pichette, Patricia. 1995 unpublished. *Framework For Monitoring Biodiversity Change (Species and Species Groups) Within The Ecological Monitoring And Assessment Network In Canada*. Ecological Monitoring Coordinating Office: Burlington, ON

Rubbo, M.J. and Kiesecker, J.M. 2005. Amphibian Breeding Distribution in an Urbanized Landscape, *Conservation Biology* 19(2): 504-511.

Soper, J.H. and Heimburger, M.L. 1982. *Shrubs of Ontario*. Royal Ontario Museum: Toronto, ON.

Suozzo, K. 2005. *The use of aquatic insects and benthic macroinvertebrate communities to assess water quality upstream and downstream of the Village of Stamford wastewater treatment facility*. PhD paper, Biology Candidate, SUNY Odeonta, New York.

US EPA. 2006. *Monitoring and Assessing Water Quality*. [Online] Available http://www.epa.gov/volunteer/stream/vms50.html

Voshell, J.R. Jr. 2002. *A Guide to Common Freshwater Invertebrates of North America*. McDonald and Woodward Publishing Company: Virginia.

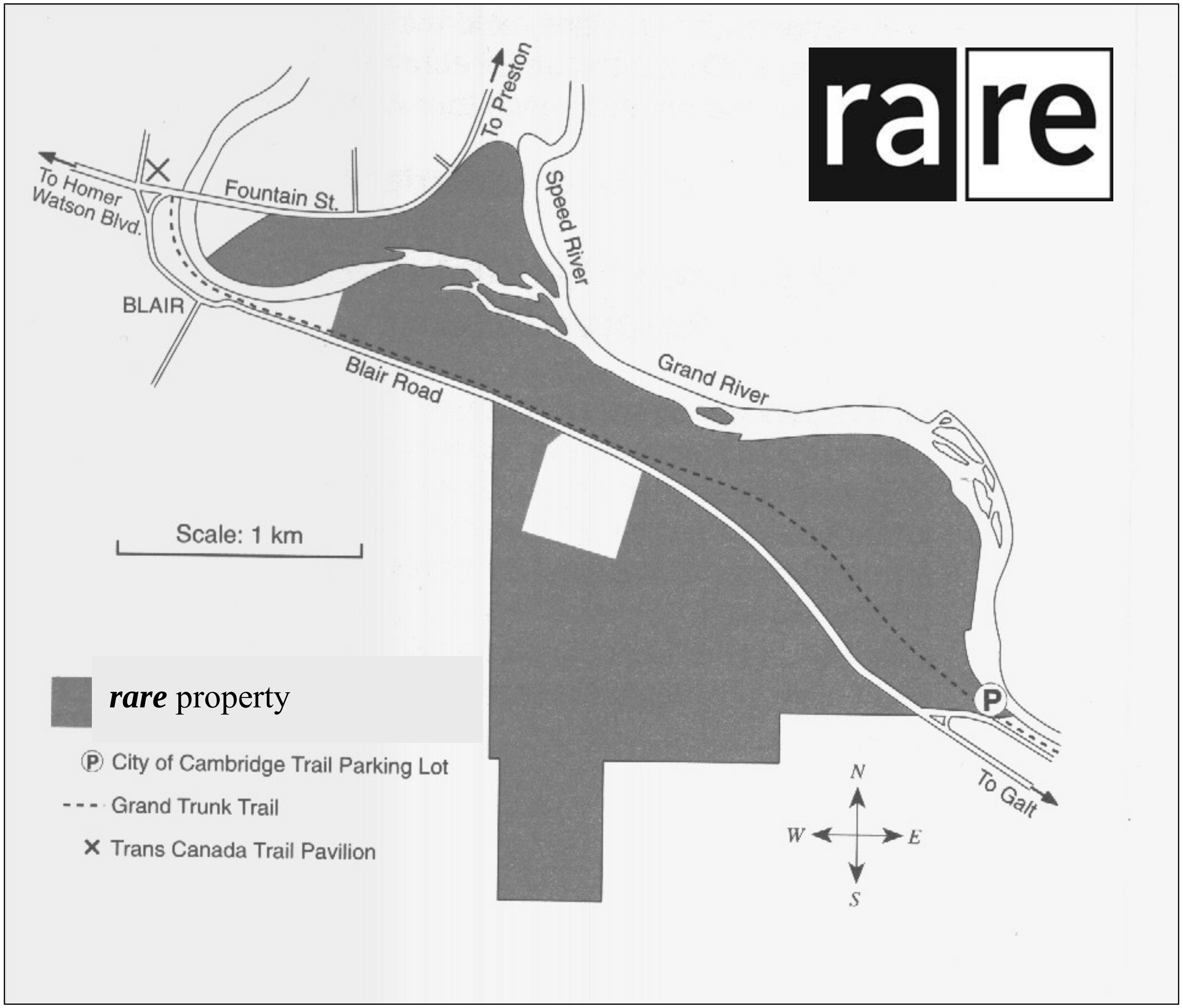
Weaver, N. 2004. *Lichen Monitoring: Cruickston Charitable Research Reserve*. Senior Honours Project, Department of Environment and Resource Studies, University of Waterloo.

Welsh, H.H. Jr. and Droege, S. 2001. A Case for Using Plethodontid Salamanders for Monitoring Biodiversity and Ecosystem Integrity of North American Forests, *Conservation Biology* 15(3): 558-569.

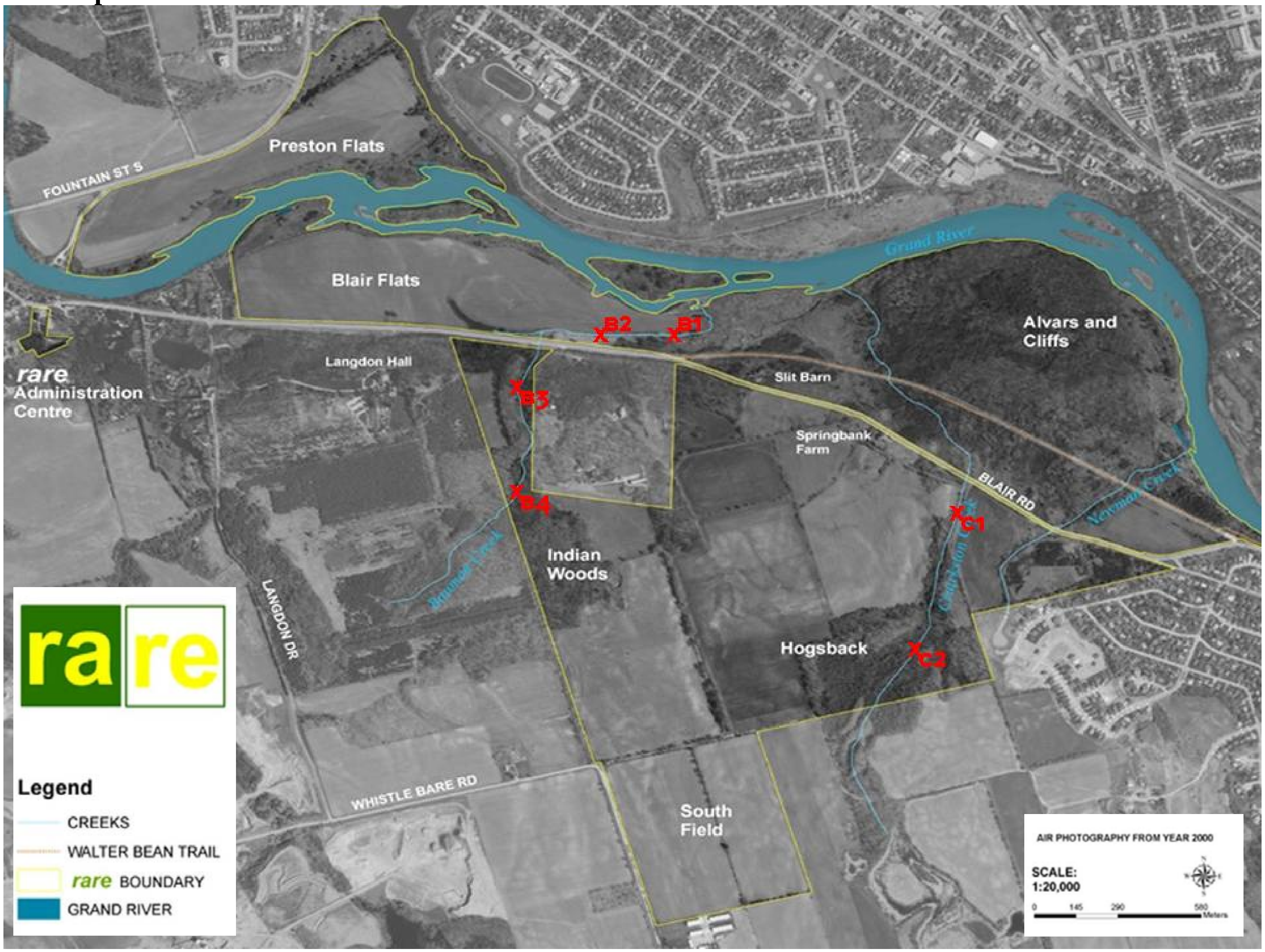
Zorn, P., Blazeski, V., and Craig, B. 2004. *Joint EMAN / Parks Canada National Monitoring Protocol for Plethodontid Salamanders*. [Online] Available http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/salamanders/

APPENDIX A: MAPS

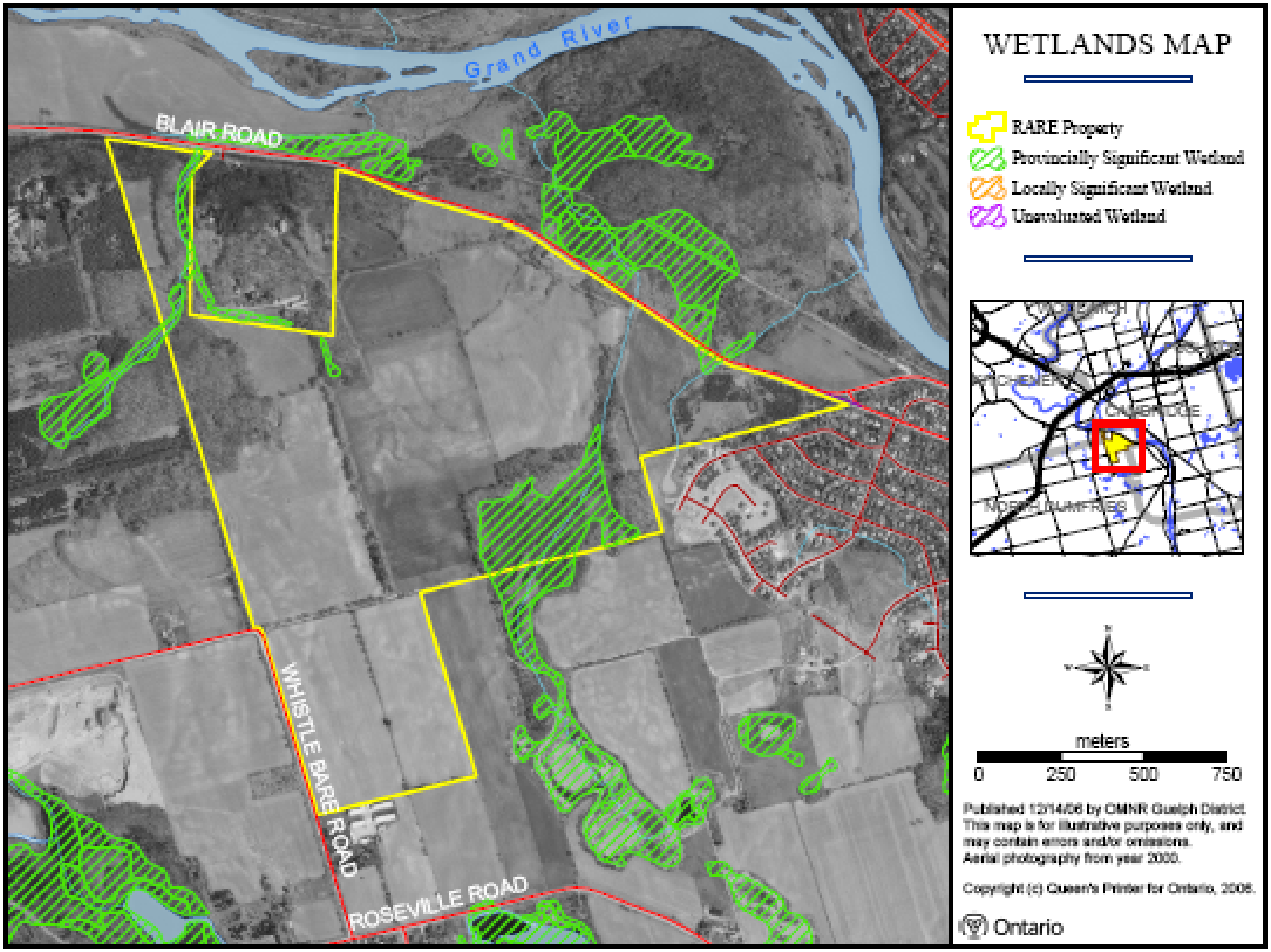
Map 1: Location of *rare* Charitable Research Reserve



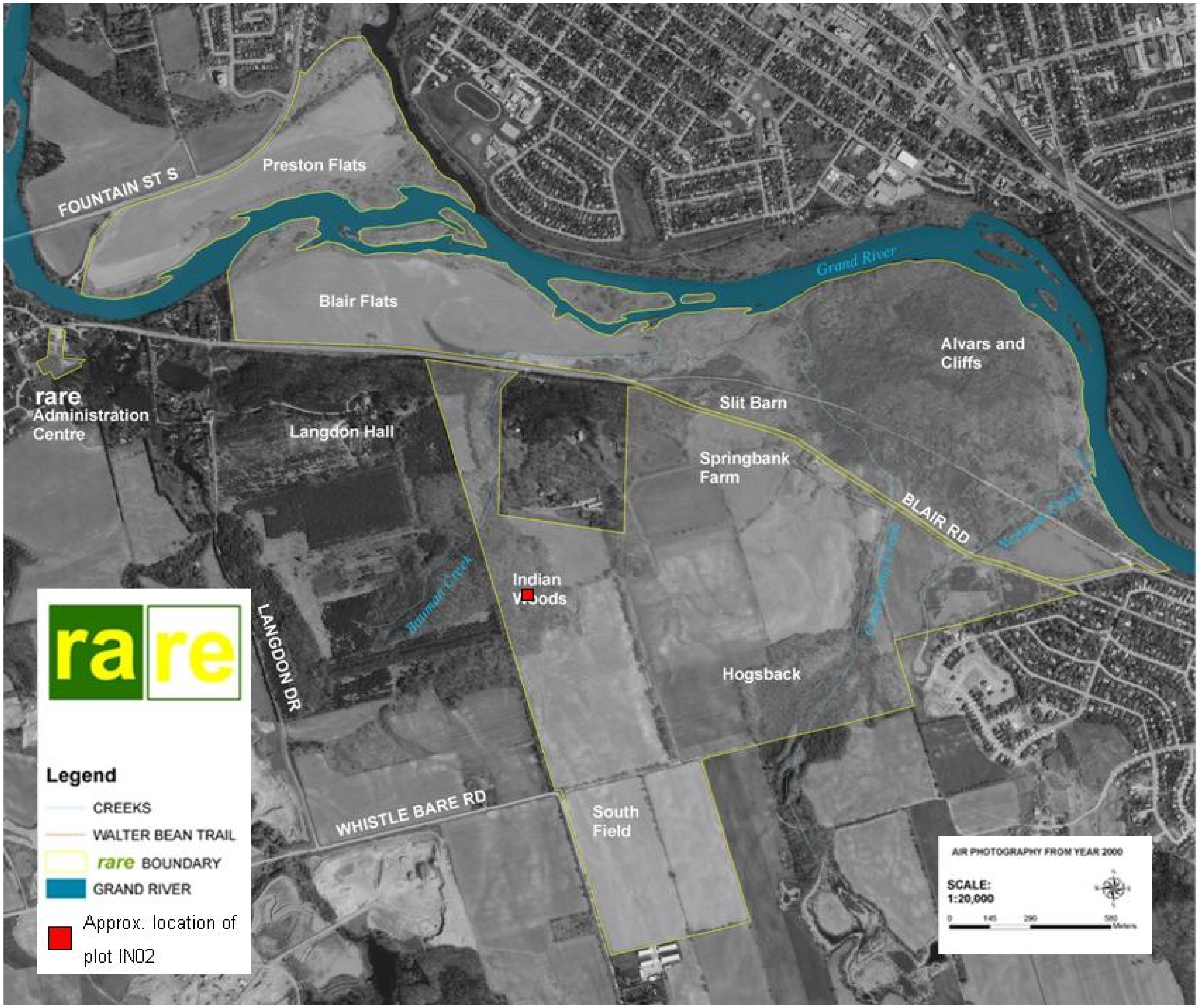
Map 2: Locations of OBBN sites at *rare*



Map 3: Provincially Significant Wetlands at *rare* (MNR, 2006)

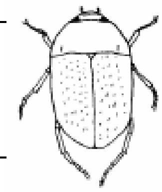


Map 4: Location of Plot IN02 – Salamander Monitoring



APPENDIX B: SAMPLE FIELD SHEETS

Ontario Benthos Biomonitoring Network Field Sheet: STREAMS



Date:	Stream name:
Time	Site #:
Agency:	Location: centroid of 3 replicates; Lat/Long or UTM
Investigators:	Elevation (m asl):
Water Quality	Datum/zone:
Water Temperature (°C):	Conductivity (uS/cm): pH:
DO (mg/l):	Alkalinity (mg/l as $CaCO_3$):

Site Description and Map

Draw a map of the site (with landmarks) and indicate areas sampled. Attach photograph (optional)

Show north arrow.

Benthos Collection Method (circle one): • Traveling Kick & Sweep • Grab Sample • Other (specify):	**Gear Type** (circle one) • D-net • Ponar • Other (specify): • Ekman • Rock Baskets **Mesh Size**: 500 micron (or specify)

Sub-samples	**Sampling distance covered (m)**	**Time (min.)**	**Max. Depth (m)**	**Wetted Width (m)**	**Max. Hydraulic Head (mm)**	**# Grabs pooled per sample**
Sample 1: Riffle (cross-over)						
Sample 2: Pool						
Sample 3: Riffle (cross-over)						

KICK AND SWEEP ONLY

GRAB SAMPLING ONLY

Substrate

Enter dominant substrate class and second dominant class for each sub-sample

	Sample 1	Sample 2	Sample 3
Dominant			
2nd Dominant			

Class	Description
1	Clay (hard pan)
2	Silt (gritty, < 0.06 mm particle diameter)
3	Sand (grainy, 0.06 - 2 mm)
4	Gravel (2 - 65 mm)
5	Cobble (65 - 250 mm)
6	Boulder (> 250 mm)
7	Bed Rock

Substrate Notes

Organic Matter-Areal Coverage

Use 1: Abundant, 2: Present, 3: Absent

	Sample 1	Sample 2	Sample 3
Woody Debris			
Detritis			

Riparian Vegetative Community

Use: 1 (None), 2 (cultivated), 3 (meadow), 4 (scrubland), 5 (forest, mainly coniferous), 6 (forest, mainly deciduous)

Zone (dist. From water's e	Left Bank	Right Bank (facing downstream)
1.5-10 m		
10-30 m		
30-100 m		

% Canopy Cover (circle one)

0-24 | 25-49
50-74 | 75-100

If instrument used, record type:

Aquatic Macrophytes and Algae (Use: 1 (Abundant), 2 (Present), 3 (Absent). Circle dominant type.

Macrophytes	Sample 1	Sample 2	Sample 3
Emergent			
Rooted Floating			
Submergent			
Free Floating			

Algae	Sample 1	Sample 2	Sample 3
Floating Algae			
Filaments			
Attached Algae			
Slimes or Crusts			

Stream Size/Flow

Bank Full Width (m): Discharge (m^3/s, optional, indicate method):

River Characterisation (circle one) Perennial Intermittent Unknown

Notes (esp. related to land-use, habitat, obvious stressors)

Candidate reference Site - Minimally impacted? (circle one) Yes No

General Comments

Stream Sheet-Pg. 2

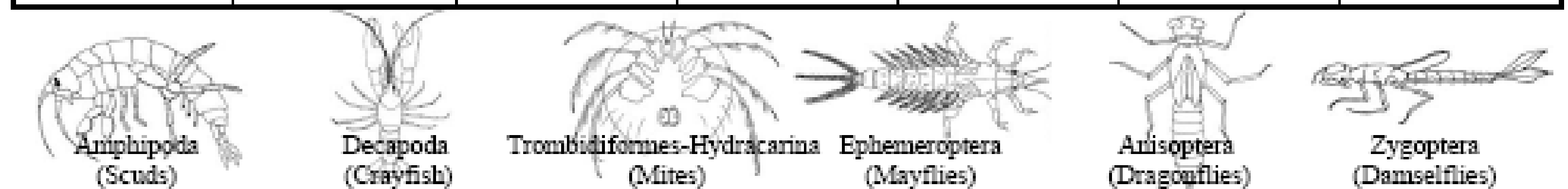
Water Body Name: ______________________ Site #: __________ Replicate #: _____ Date (mm/dd/yyyy) and Time: ______________________

Organization: __________________________ Department____________________ Address:____

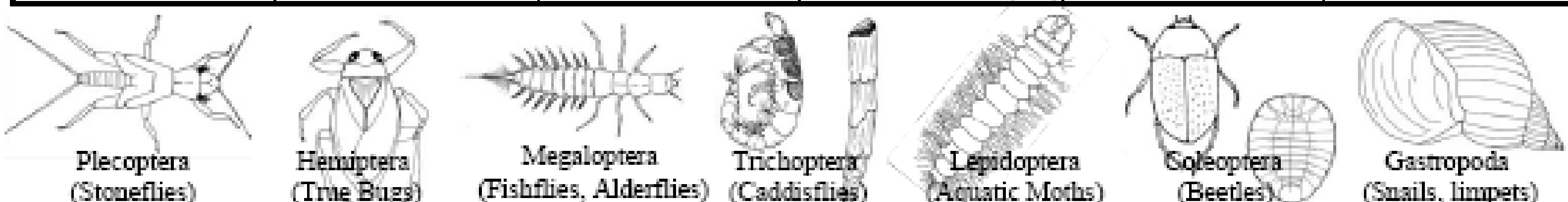
Contact: ______________ Phone: _______________ E-mail: _________________________ % picked for 100-count _____ # of vials: ________

Circle Method: (Sub-sampling) Marchant Box / Teaspoon (Location) Field / Lab (Preservation) Live / Preserved Magnification) Microscope / Unaided

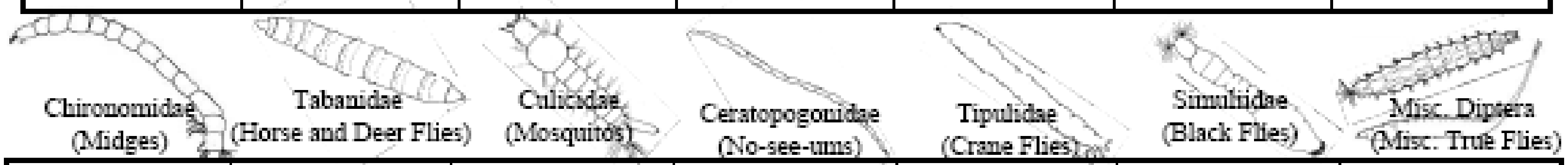
Coelenterata (Hydras)	Turbellaria (Flatworms)	Nematoda (Roundworms)	Oligochaeta (Aquatic Earthworms)	Hirudinea (Leeches)	Isopoda (Sow Bugs)	Pelecypoda (Clams)



Amphipoda (Scuds)	Decapoda (Crayfish)	Trombidiformes-Hydracarina (Mites)	Ephemeroptera (Mayflies)	Anisoptera (Dragonflies)	Zygoptera (Damselflies)



Plecoptera (Stoneflies)	Hemiptera (True Bugs)	Megaloptera (Fishflies, Alderflies)	Trichoptera (Caddisflies)	Lepidoptera (Aquatic Moths)	Coleoptera (Beetles)	Gastropoda (Snails, limpets)



Chironomidae (Midges)	Tabanidae (Horse and Deer Flies)	Culicidae (Mosquitos)	Ceratopogonidae (No-see-ums)	Tipulidae (Crane Flies)	Simuliidae (Black Flies)	Misc. Diptera (Misc. True Flies)

Salamander Monitoring Field Sheet A

Plot Name:			**Group Name**:		
UTM Easting:			**UTM Northing**:		
Observer Names:		**Date**:		**Time**:	
Precipitation in Last 24 hrs.:		**Air Temp.**:		**Soil Temp.**:	
Beaufort Sky Code:		**Beaufort Wind Code**:			
ACO Number	**Species**	**Count**	**ACO Type**	**ACO Age**	**ACO Disturb.**
Comments:					

Salamander Monitoring Field Sheet B

Plot Name:			**Group Name**:			
UTM Easting:			**UTM Northing**:			
Observer Names:			**Date**:		**Time**:	
Soil Moisture:			**Soil pH**:			
ACO No.	**Species**	**s-v Length**	**v-t Length**	**weight**	**sex**	**age class**
Comments:						

APPENDIX C: SALAMANDER DATA TABLES

Date	Time	ACO #	Species	S-V length (mm)	V-T length (mm)	Total Length (mm)	Notes
Sept 28/2006	10:10-12:05	1	Redback Salamander (*Plethodon cinereus*)	30	30	60	
		1	Redback Salamander (*Plethodon cinereus*)	45	35	80	
		2	Redback Salamander (*Plethodon cinereus*)	35	35	70	
		2	Redback Salamander (*Plethodon cinereus*)	35	30	65	
		2	Redback Salamander (*Plethodon cinereus*)	35	30	65	
		2	Redback Salamander (*Plethodon cinereus*)	43	35	78	
		2	Redback Salamander (*Plethodon cinereus*)	40	35	75	
		2	Redback Salamander (*Plethodon cinereus*)	30	40	70	
		4	Redback Salamander (*Plethodon cinereus*)	40	35	75	
		4	Redback Salamander (*Plethodon cinereus*)	-	-	-	in hole in board - unable to measure
		9	Redback Salamander (*Plethodon cinereus*)	40	35	75	
		9	Redback Salamander (*Plethodon cinereus*)	40	50	90	
		10	Redback Salamander (*Plethodon cinereus*)	35	38	73	
		11	Redback Salamander (*Plethodon cinereus*)	12	10	22	yoy lead form
		12	Redback Salamander (*Plethodon cinereus*)	35	35	70	
		12	Redback Salamander (*Plethodon cinereus*)	38	45	83	lead form
		14	Redback Salamander (*Plethodon cinereus*)	33	40	73	lead form
		16	Redback Salamander (*Plethodon cinereus*)	43	45	88	lead form
		19	Redback Salamander (*Plethodon cinereus*)	40	45	85	
		19	Redback Salamander (*Plethodon cinereus*)	40	45	85	
		20	Redback Salamander (*Plethodon cinereus*)	30	35	65	
		20	Redback Salamander (*Plethodon cinereus*)	30	30	60	

		21	Redback Salamander (*Plethodon cinereus*)	42	53	95	
		22	Redback Salamander (*Plethodon cinereus*)	45	49	94	
		23	Redback Salamander (*Plethodon cinereus*)	35	40	75	
		23	Redback Salamander (*Plethodon cinereus*)	-	-	-	escaped without measurement (lead)
		24	Redback Salamander (*Plethodon cinereus*)	40	46	86	
		25	Redback Salamander (*Plethodon cinereus*)	38	50	88	
		25	Redback Salamander (*Plethodon cinereus*)	43	47	90	
		26	Redback Salamander (*Plethodon cinereus*)	35	25	60	stubby tail
		27	Redback Salamander (*Plethodon cinereus*)	35	42	77	
		28	Redback Salamander (*Plethodon cinereus*)	37	48	85	
		28	Redback Salamander (*Plethodon cinereus*)	40	51	91	
		29	Redback Salamander (*Plethodon cinereus*)	37	40	77	
		29	Redback Salamander (*Plethodon cinereus*)	36	44	80	
		30	Redback Salamander (*Plethodon cinereus*)	42	47	89	
		30	Redback Salamander (*Plethodon cinereus*)	40	43	83	
		30	Redback Salamander (*Plethodon cinereus*)	47	55	102	
		30	Redback Salamander (*Plethodon cinereus*)	42	44	86	
		32	Redback Salamander (*Plethodon cinereus*)	32	26	58	
		32	Redback Salamander (*Plethodon cinereus*)	31	35	66	
		32	Redback Salamander (*Plethodon cinereus*)	47	49	96	lead form
Oct 5/2006	12:10-14:30	1	Redback Salamander (Plethodon cinereus)	42	37	79	
		1	Redback Salamander (Plethodon cinereus)	36	38	74	
		1	Redback Salamander (Plethodon cinereus)	34	48	82	
		1	Redback Salamander (Plethodon cinereus)	41	53	94	

2	Redback Salamander (Plethodon cinereus)	32	30	62	
2	Redback Salamander (Plethodon cinereus)	45	40	85	
2	Redback Salamander (Plethodon cinereus)	40	36	76	
2	Redback Salamander (Plethodon cinereus)	39	42	81	
2	Redback Salamander (Plethodon cinereus)	42	48	90	
2	Redback Salamander (Plethodon cinereus)	26	28	54	
2	Redback Salamander (Plethodon cinereus)	47	46	93	lead form
2	Redback Salamander (Plethodon cinereus)	41	41	82	
3	Redback Salamander (Plethodon cinereus)	40	41	81	
4	Redback Salamander (Plethodon cinereus)	-	-	-	in hole in board - unable to measure (lead)
5	Redback Salamander (Plethodon cinereus)	33	33	66	
5	Redback Salamander (Plethodon cinereus)	34	36	70	
5	Redback Salamander (Plethodon cinereus)	36	40	76	
9	Redback Salamander (Plethodon cinereus)	40	37	77	
9	Redback Salamander (Plethodon cinereus)	42	50	92	
10	Redback Salamander (Plethodon cinereus)	38	40	78	lead form
10	Redback Salamander (Plethodon cinereus)	24	30	54	
11	Redback Salamander (Plethodon cinereus)	30	32	62	
11	Redback Salamander (Plethodon cinereus)	31	40	71	
11	Redback Salamander (Plethodon cinereus)	35	39	74	
12	Redback Salamander (Plethodon cinereus)	36	32	68	
12	Redback Salamander (Plethodon cinereus)	38	46	84	lead form
13	Redback Salamander (Plethodon cinereus)	38	42	80	
14	Redback Salamander (Plethodon cinereus)	26	34	60	
18	Redback Salamander (Plethodon cinereus)	21	24	45	

		19	Redback Salamander (Plethodon cinereus)	35	37	72	
		19	Redback Salamander (Plethodon cinereus)	31	32	63	lead form
		20	Redback Salamander (Plethodon cinereus)	35	39	74	
		21	Redback Salamander (Plethodon cinereus)	34	40	74	
		24	Redback Salamander (Plethodon cinereus)	39	41	80	
		24	Redback Salamander (Plethodon cinereus)	24	34	58	
		24	Redback Salamander (Plethodon cinereus)	39	32	71	
		25	Redback Salamander (Plethodon cinereus)	33	37	70	
		25	Redback Salamander (Plethodon cinereus)	28	32	60	
		26	Redback Salamander (Plethodon cinereus)	26	31	57	
		26	Redback Salamander (Plethodon cinereus)	41	27	68	
		26	Redback Salamander (Plethodon cinereus)	36	36	72	
		27	Redback Salamander (Plethodon cinereus)	42	44	86	
		29	Redback Salamander (Plethodon cinereus)	36	34	70	
		29	Redback Salamander (Plethodon cinereus)	37	38	75	
		30	Redback Salamander (Plethodon cinereus)	42	43	85	
		30	Redback Salamander (Plethodon cinereus)	37	41	78	
		31	Redback Salamander (Plethodon cinereus)	41	40	81	
		31	Redback Salamander (Plethodon cinereus)	31	35	66	
		31	Redback Salamander (Plethodon cinereus)	37	41	78	
		32	Redback Salamander (Plethodon cinereus)	32	34	66	
Oct 12/2006	11:10-13:03	1	Redback Salamander (Plethodon cinereus)	30	39	69	
		1	Redback Salamander (Plethodon cinereus)	30	38	68	
		1	Redback Salamander (Plethodon cinereus)	26	33	59	very thin lead form

2	Redback Salamander (Plethodon cinereus)	30	39	69	
2	Redback Salamander (Plethodon cinereus)	25	32	57	lead form
4	Redback Salamander (Plethodon cinereus)	40	39	79	
4	Redback Salamander (Plethodon cinereus)	30	38	68	
4	Redback Salamander (Plethodon cinereus)	31	38	69	
5	Redback Salamander (Plethodon cinereus)	36	34	70	
5	Redback Salamander (Plethodon cinereus)	42	42	84	
5	Redback Salamander (Plethodon cinereus)	34	20	54	stubby tail
5	Redback Salamander (Plethodon cinereus)	27	40	67	
9	Redback Salamander (Plethodon cinereus)	30	26	56	
9	Redback Salamander (Plethodon cinereus)	41	41	82	
9	Redback Salamander (Plethodon cinereus)	25	32	57	
10	Redback Salamander (Plethodon cinereus)	35	39	74	
10	Redback Salamander (Plethodon cinereus)	30	31	61	
11	Redback Salamander (Plethodon cinereus)	40	41	81	
11	Redback Salamander (Plethodon cinereus)	32	36	68	
11	Redback Salamander (Plethodon cinereus)	37	50	87	
11	Redback Salamander (Plethodon cinereus)	35	37	72	
11	Redback Salamander (Plethodon cinereus)	30	36	66	
13	Redback Salamander (Plethodon cinereus)	46	48	94	
14	Redback Salamander (Plethodon cinereus)	38	42	80	
15	Redback Salamander (Plethodon cinereus)	29	31	60	
15	Redback Salamander (Plethodon cinereus)	41	45	86	
16	Redback Salamander (Plethodon cinereus)	32	28	60	
17	Redback Salamander (Plethodon cinereus)	42	25	67	stubby tail

		19	Redback Salamander (Plethodon cinereus)	42	46	88		
		21	Redback Salamander (Plethodon cinereus)	41	44	85	lead form	
		21	Redback Salamander (Plethodon cinereus)	40	48	88	lead form	
		21	Redback Salamander (Plethodon cinereus)	35	46	81		
		22	Redback Salamander (Plethodon cinereus)	42	49	91		
		23	Redback Salamander (Plethodon cinereus)	30	30	60		
		23	Redback Salamander (Plethodon cinereus)	37	28	65		
		24	Redback Salamander (Plethodon cinereus)	36	42	78		
		26	Redback Salamander (Plethodon cinereus)	40	4	44	tail has been removed	
		27	Redback Salamander (Plethodon cinereus)	38	48	86		
		27	Blue Spotted/Jefferson Complex (Ambysoma sp)	65	86	151		74.12179487
		28	Redback Salamander (Plethodon cinereus)	41	44	85		
		28	Redback Salamander (Plethodon cinereus)	40	43	83		
		28	Redback Salamander (Plethodon cinereus)	37	42	79		
		29	Redback Salamander (Plethodon cinereus)	42	45	87		
		29	Redback Salamander (Plethodon cinereus)	36	42	78		
		29	Redback Salamander (Plethodon cinereus)	42	53	95		
		30	Redback Salamander (Plethodon cinereus)	43	48	91		
		30	Redback Salamander (Plethodon cinereus)	33	32	65		
		31	Redback Salamander (Plethodon cinereus)	38	34	72		
		31	Redback Salamander (Plethodon cinereus)	36	41	77		
		31	Redback Salamander (Plethodon cinereus)	41	40	81		
Oct 19/2006	9:56-11:40	4	Redback Salamander (Plethodon cinereus)	34	38	72		

		4	Redback Salamander (Plethodon cinereus)	35	36	71	
		5	Redback Salamander (Plethodon cinereus)	36	39	75	lead form
		9	Redback Salamander (Plethodon cinereus)	10	3	13	yoy
		22	Redback Salamander (Plethodon cinereus)	35	41	76	
		29	Redback Salamander (Plethodon cinereus)	34	37	71	
		30	Redback Salamander (Plethodon cinereus)	40	46	86	
Oct 26/2006	9:57-11:10	1	Redback Salamander (Plethodon cinereus)	26	34	60	
		4	Redback Salamander (Plethodon cinereus)	35	36	71	
		5	Redback Salamander (Plethodon cinereus)	41	48	89	
		19	Redback Salamander (Plethodon cinereus)	33	34	67	lead form
		22	Redback Salamander (Plethodon cinereus)	40	38	78	
		27	Redback Salamander (Plethodon cinereus)	33	39	72	
		27	Redback Salamander (Plethodon cinereus)	38	46	84	lead form
		28	Redback Salamander (Plethodon cinereus)	18	9	27	yoy
		28	Redback Salamander (Plethodon cinereus)	35	46	81	
		28	Redback Salamander (Plethodon cinereus)	35	50	85	
		29	Redback Salamander (Plethodon cinereus)	41	42	83	

Original 2006 field data available at ***rare* Charitable Research Reserve**