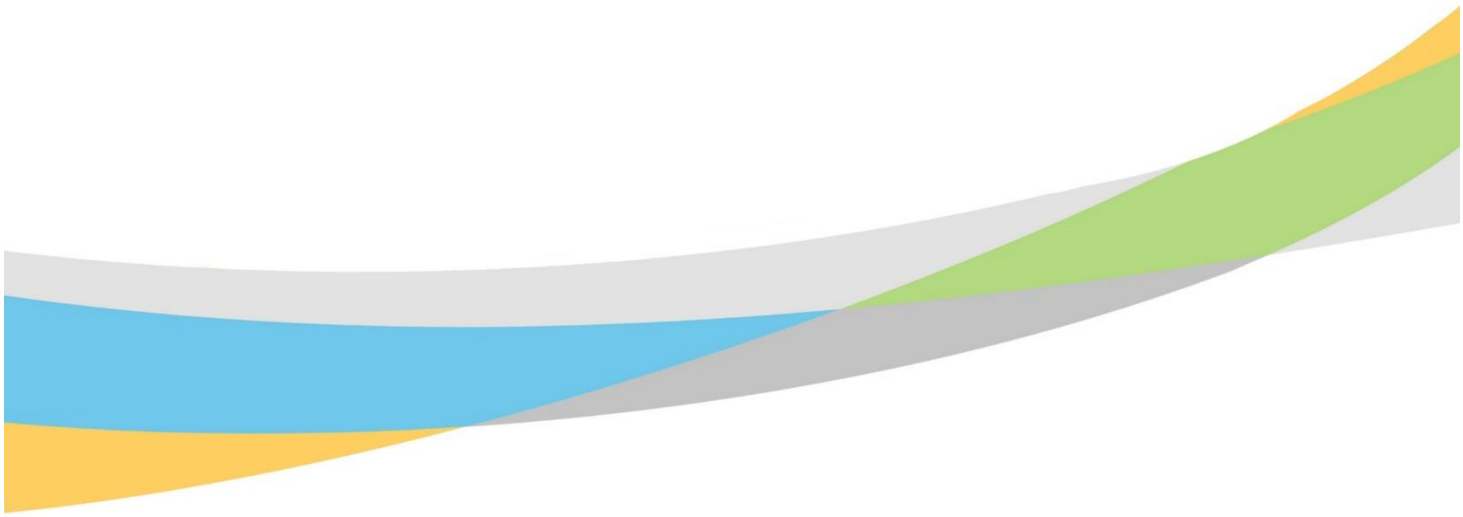


Toronto and Region Conservation Authority

Terrestrial Monitoring and Assessment of Ziplines/Ropes Courses 2013-2018

Prepared by Environmental Monitoring and Data Management

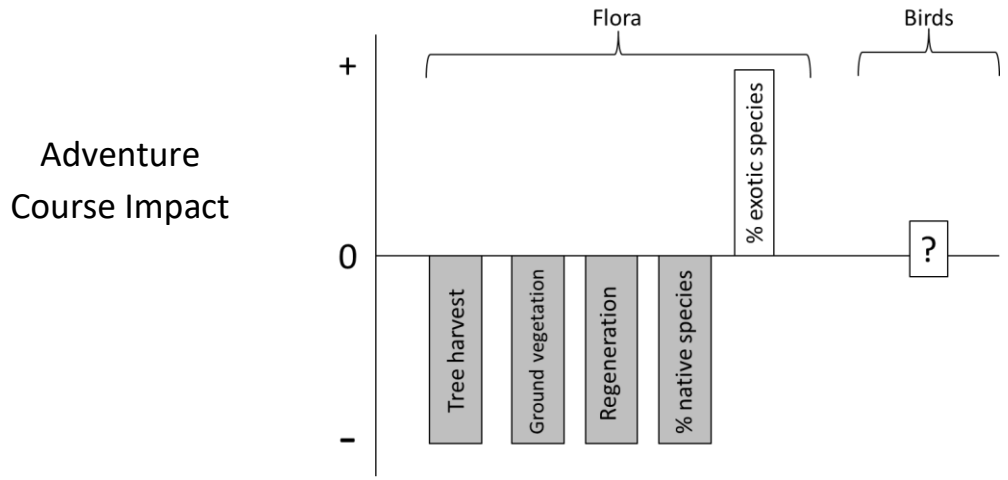
February 2019

Table of Contents

1 Executive Summary

Ziplines/ropes courses (hereafter adventure courses) were constructed at Heart Lake and Bruce's Mill Conservation Areas in 2013. The Living City Campus (Kortright Centre) in Vaughan has also been selected to potentially expand this recreational activity in the future. This report summarizes the terrestrial monitoring data collected at Heart Lake, Bruce's Mill and the Living City Campus.

The adventure course plot at Heart Lake has had large increases in the number of exotic flora species, an almost complete loss of the regeneration and ground layers along with the removal of several mature trees. The adventure course plot at Bruce's Mill has shown several impacts similar to Heart Lake including the removal of mature trees, a reduction in the extent of the regeneration layer and a complete loss of space for flora through trail creation. It is difficult to interpret bird community results at these sites since control plots were often established in larger tracts of forest which contain different bird communities than those near edges. The Living City Campus showed characteristics of a high quality forest for the region including healthy crowns, the presence of snags, many spring ephemeral species, more species of conservation concern than Heart Lake and Bruce's Mill and a forest bird community consisting of several area-sensitive species and species-at-risk. A summary of results from Heart Lake and Bruce's Mill is shown below with grey bars displayed towards the minus sign representing negative impacts and white bars displayed towards the plus sign representing positive impacts.



2 Introduction

In 2012, the Toronto and Region Conservation Authority (TRCA) approved the construction of adventure courses at Heart Lake and Bruce's Mill Conservation Areas (Figure 1). The TRCA has entered into a lease agreement with Treetop Trekking Inc. and has constructed and is currently operating these adventure courses on these properties. The course at Heart Lake was constructed and opened to the public in August 2013. The construction for the course at Bruce's Mill was completed and opened to the public June 21, 2014. The Living City Campus (Kortright Centre) in Vaughan has also been selected to potentially expand this recreational activity in the future.

Specific Objectives

The purpose of this report was to summarize the terrestrial monitoring data at existing adventure courses and to provide data on current flora and bird communities at a proposed adventure course site. The specific objectives of this study were therefore site-specific:

1. Heart Lake – compare forest bird and flora communities between the adventure course site and control sites (all post-construction data).
2. Bruce's Mill – compare forest bird and flora communities between the adventure course site and control sites pre- and post-construction.
3. The Living City Campus – provide an updated summary of baseline forest bird and flora communities both at control sites and at the proposed adventure course site.

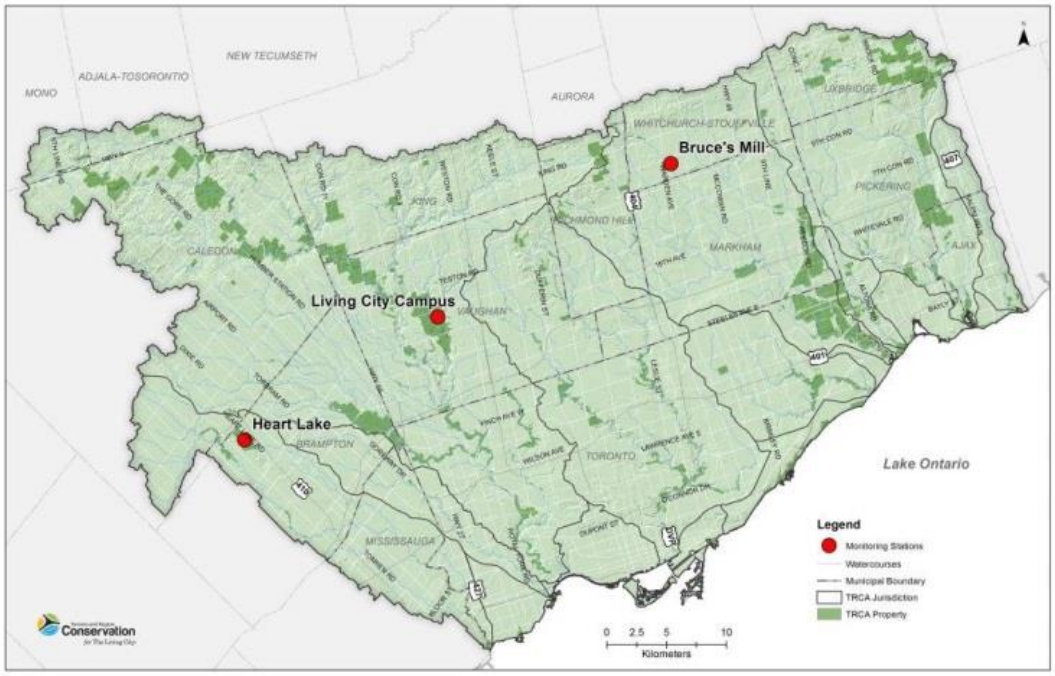


Figure 1. Locations of proposed and approved sites for adventure courses in the TRCA jurisdiction

3 Monitoring Methodology

For the purposes of this study, three main types of monitoring were conducted: bird point counts, vegetation plots and bird song recordings using song meters from Wildlife Acoustics Inc. Point counts and vegetation plots were conducted at all sites while song meters were only installed at the Living City Campus (Table 1). Each site had one forest vegetation plot in the adventure course and one plot at a control location. Similarly, each site had one point count station in the adventure course and at least three point count stations at control locations. Control locations were chosen to be in the same ELC community type as the adventure course (FOD5-1; Dry-Fresh Sugar Maple Deciduous Forest) but in areas un-impacted by adventure courses.

Table 1. Summary of monitoring type, the number of control and treatment plots and years surveyed.

Site	Monitoring type	Number of plots		2013	2014	2015	2016	2017	2018
		Control	Adventure course						
Heart Lake	Vegetation	1	1	✓	✓			✓	
	Bird point counts	3	1	✓	✓	✓	✓	✓	✓
Bruce's Mill	Vegetation	1	1	✓	✓				✓
	Bird point counts	3	1	✓	✓	✓	✓	✓	✓
Living City Campus	Vegetation	1	1	✓	✓				
	Bird point counts	4	1	✓	✓	✓	✓		
	Song meters	2	1	✓	✓				

3.1 Forest Vegetation Plots

Forest plots were set up according to standards developed by Environment Canada's Ecological Monitoring and Assessment Network (EMAN 2004a, EMAN 2004b, Roberts-Pichette and Gillespie 1999), with slight modifications. This protocol is almost identical to that used by Credit Valley Conservation in their forest vegetation plot monitoring, although there are differences in sapling assessment (CVC 2010).

Detailed information on plot set-up can be found in TRCA (2009). In summary, each forest vegetation plot consists of one 20 x 20 m square plot (i.e. 400 m^2) for monitoring tree health; and five 2 x 2 m subplots (i.e. 4 m^2) for monitoring woody regeneration (tree saplings, shrubs and woody vines). Four of the subplots are placed 1 m outside the perimeter of the 20 x 20 m tree health plot, and the fifth is located in its centre. Ground vegetation is measured in a 1 x 1 m subsection (1 m^2) of each subplot at its southwest quarter (Figure 2). Two visits are conducted per year: in the spring and in early-to-mid summer.

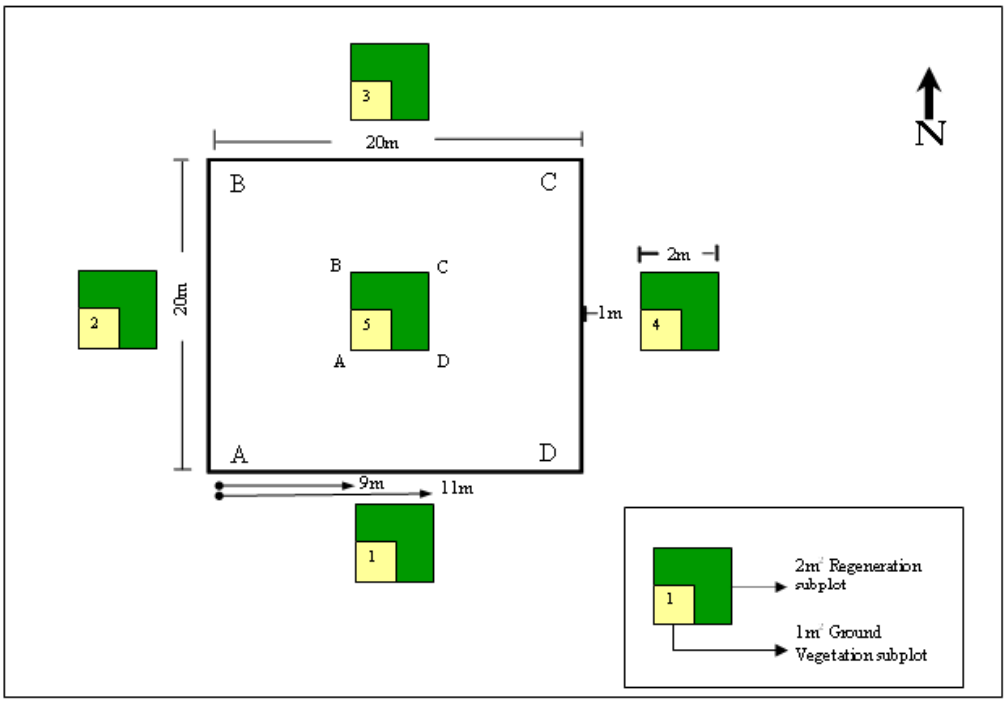


Figure 2. Forest vegetation plot design (not to scale)

Variables Monitored and Monitoring Frequency

Tree health is assessed in early-to-mid summer (late June to early August) when trees are in full leaf but prior to the onset of any late summer natural senescence. Tree health is monitored in the 400 m^2 plot. All trees >10 cm diameter at breast height (dbh) are assessed. Tree health assessment includes a variety of measures; age, tree height, tree diameter, condition, crown class, crown vigour and stem defects. A detailed summary of the measurements taken and their frequency is shown in Table 2.

Table 2. Forest vegetation monitoring variables and frequency

Indicator	Variable	Details	Frequency
Tree Health	Age of Stand	Cores taken from 5 trees outside plot	Once at plot set-up
	Tree Height and Diameter	Height as measured with range-finder and diameter at breast height	At plot set-up, then every 5 years; new recruits as they appear
	Tree Status and Condition	Living/dead/damaged/leaning etc.	Annually
	Crown Class	Dominant, co-dominant, intermediate, suppressed	Annually
	Crown Vigour	Fullness of canopy, presence of dieback	Annually
	Stem Defects	Wounds, scars, seams, decay, disease, insect damage	Annually
Tree Regeneration	Stem Counts	By species in 6 height classes	Annually
	% Cover by Species	Based on all stems that originate within the subplots	Annually
Shrubs and Woody Vines	Stem Counts	By species in 6 height classes	Annually
	% Cover by Species	Based on all stems that originate within the subplots	Annually
Ground Vegetation	% Cover	Cover estimates including overhang for all species found in 1 m^2 subplot	Twice annually (spring and summer)
All Vascular Plants	Total Species Richness	All species recorded in main tree health plot plus subplots	Annually (pool both visits)
	# Native versus Exotic	Separation of species identified into native (L1-L5) and exotic (L+)	Annually
	Occurrence of Species of Regional Conservation Concern	Native species are subdivided into species of regional concern (L1-L3), species of urban concern (L4), and species not of concern (L5)	Annually

Tree regeneration and shrub assessment is done during the main early-to-mid summer visit (late June to early August). Assessments are undertaken in each of the 4 m^2 subplots and include all woody plants (including vines) that are over 16 cm in height but less than 10 cm dbh. Stem counts by 6 height classes (16-35, 36-55, 56-75, 76-95, 96-200 cm and over 2 m) are recorded for each species. In addition, surveyors obtain a percentage cover estimate based on those stems that originate within the subplot.

Tree saplings and shrubs are measured at the same time but are separated for analysis purposes because saplings represent the future tree canopy, while shrubs always remain in the understorey. Woody vines are counted with the shrubs in this baseline report but future analyses allow for their separation.

Ground vegetation assessment is conducted twice per year. The first visit in May captures spring ephemerals, while the second assessment in summer at the same time as the sapling and shrub assessment captures herbaceous species that emerge more slowly and remain visible through the growing season. Ground vegetation measurements in the 1 m^2 subplots include percentage cover of vascular plants by species and also mosses and liverworts as groups. Cover assessment includes overhanging leaves as well as stems originating from within the subsection.

Finally, a total list of all vascular plant species is taken every year for each plot. This includes all types and sizes found within the 400 m^2 tree health plot as well as the subplots. The species list yields the following information:

- Total species richness (number of species)
- Number of native versus exotic species
- Occurrence of species of regional (or urban) conservation concern (ranks L1 to L3 (L4))
- Mean coefficient of conservatism – see Masters (1997) for explanation
- Floristic Quality Index (FQI) – calculated from native species richness and mean coefficient of conservatism (TRCA 2009).

3.2 Forest Bird Stations

Forest birds were monitored using the Ontario Forest Bird Monitoring Program (FBMP) protocol designed by the Canadian Wildlife Service. This protocol was originally developed for use in large forest patches across the province where plots are generally centred at least 100 m inside the edge of the forest patch in order to target forest bird species. Despite a relatively high degree of historic forest loss and fragmentation across the region (especially in the urban zone) the majority of forest bird stations were successfully located in situations where this criterion was satisfied.

The centre of each plot is marked with a piece of rebar hammered into the ground (with the top 2-5 cm remaining above ground) in order to be able to repeat the monitoring from exactly the same location in future visits. This location is referenced using a GPS unit to ensure repeatability at that location (see Appendix 1 for the UTM coordinates of each station). The forest bird stations are monitored three times per year when it is considered optimum for recording forest bird breeding species. The first count is conducted between May 24th and June 10th; the second count is conducted no sooner than 10 days after the first visit and between the dates June 11th and June 20th; and the third count is conducted no sooner than 10 days after the second visit between the dates of June 21st and July10th. Many species that are recorded before the first week of June may still be passing through the area as migrants, therefore registering a second observation in late June or July supports the indication of a territorial and likely breeding individual. All counts are completed between 05:00 and 10:00. The second and third visits are completed at the same time of day as the first visit and an attempt will be made to maintain the same timing schedule of visits in subsequent years.

Counts are conducted in weather conditions that optimize the detection of songbird species. Ideally there should be very little to no wind, and precipitation should be at most a light rain. Overnight rainfall will also potentially have considerable impact on the ability of the recorder to hear bird song and calls since the noise from dripping trees may be enough to mask quieter species.

The FBMP requires the biologist to plot every individual bird observed and heard within a 100 m circle centred on the point station over a 10 minute period. In addition, any birds identified at distances beyond the 100 m circle are mapped at their approximate position. The count period is divided into two 5 minute segments with the observations divided between them. The following metadata are recorded on the field forms: date and start time of count period, weather conditions (wind speed and direction, cloud cover and precipitation), and observer.

For the purposes of analysis it was decided to consider only those individuals and species located within the 100 m count circle. By doing this it will be possible to diminish the effect of any variation in observer ability

over the years, the implication being that all observers should be able to effectively document any birds singing within the smaller count area. Two further data filters were imposed so as to reduce any "noise" in the analysis. All species and individuals in the swallow (*Hirundinidae)* family plus chimney swifts (*Chaetura pelagica*) were omitted. These species are exclusively aerial foragers and as such they move over very large areas in search of food. Part of the analysis will concentrate on species identified as forest-guild species in the TRCA's list of habitat-use guilds (Appendix 2).

3.3 Bird Song Recordings

Three Song Meters™ (Model SM2+) from Wildlife Acoustics Inc. were installed at the Living City Campus at three of five point count monitoring stations (stations 2, 3 and 4). The song meters were placed approximately 3.5 m off the ground and secured to tree trunks with tie-down straps (Figure 3). Trees were selected based on their proximity to the point count station and the visibility from nearby trails as vandalism and/or theft of the equipment was considered. All three of the recorders were placed within 10 m of the point count station. The song meters were programmed to record daily starting on May 28th at three specified time periods during the breeding bird season; from 05:00 to 07:30, 10:00 to 12:00 and from 23:00 to 24:00. A daily total of 5.5 hours of recordings were collected from May 28th to June 28th 2013 and May 6th to July 1st 2014.

Figure 3. Song Meters™ recording bird song activity at three stations at the Living City Campus

The song meters were visited weekly to download the data from the memory cards and to ensure that there were no issues with the devices. Recorders were set to compress the audio files in order to increase the amount of data that could be saved to each memory card. The recommended file format for field recordings of WAC0 was chosen as it is a lossless audio compression format. When audio files are selected to be compressed they are automatically stored as ".WAC" files which are the proprietary Wildlife Acoustics Audio Compression (WAAC) file format. Once files were uploaded they were converted to Waveform Audio File Format (.WAV) files using Kaleidoscope software Version 1.1.1 obtained from Wildlife Acoustics, Inc.

A free license for Raven Lite 1.0 software was obtained and downloaded from the Cornell Laboratory of Ornithology. This software allows the user to listen to bird song recordings while viewing the spectrogram that is produced by these songs (Figure 4). The spectrograms are audio signatures for each bird species. Depending on the call or song of the species a line is produced on the graph in a different pattern and frequency. For the purposes of this report, the recordings were used to add additional data to the point count surveys. A subset of sampling dates were selected based on when the majority of species present would not be migrating, represent an adequate sample size as not all recordings could be reviewed due to the amount of time required to do so, and provide the most evidence that the bird was breeding on site. The dates selected are as follows: June 10th, 11th, 12th, 17th, 20th and 28th. Two 10 minute active listening periods were selected from the 05:00 to 07:30 time period; from 05:20 to 05:30 and from 05:45 to 05:55 whereby a biologist actively listened to the recordings and documented all species heard. Two 5 minute active listening periods were selected from 23:00 to 24:00; the first at 23:20 and the second at 23:45. Outside of these set times for active listening the biologist visually scanned the spectrograms in the Raven Lite 1.0 software in order to determine additional key periods to listen to the recording. Visual cues such a change in pattern or frequency in the spectrogram was used in order to zone in on possible "new" species that were not identified in the set listening time periods. A final list of

species was produced for each station after filtering out those species suspected to be only migrating through the area rather than attempting to breed on site.

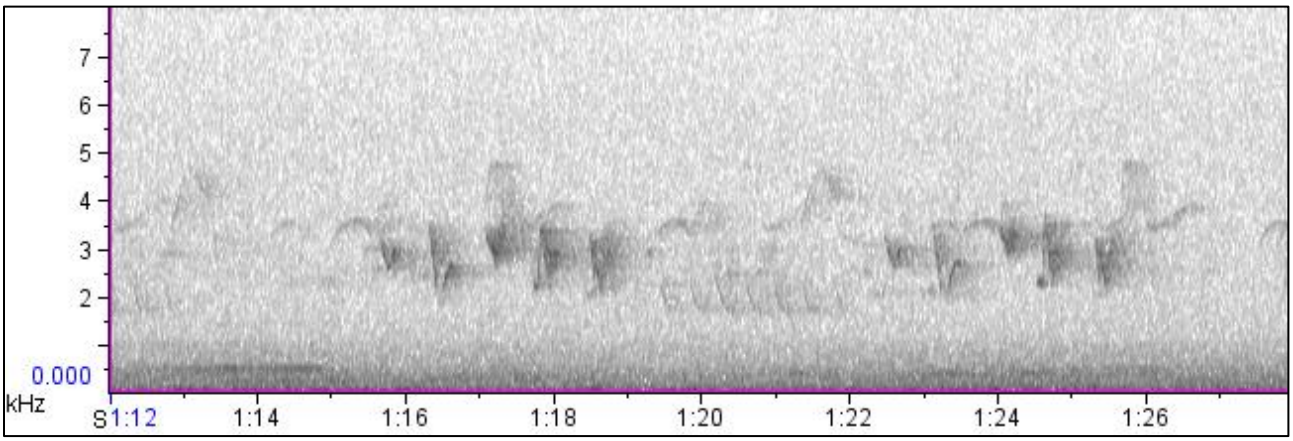


Figure 4. Example of a spectrogram produced from audio files using Raven Lite 1.0 software from Cornell Laboratory of Ornithology

4 Heart Lake

Construction of the adventure course at Heart Lake was completed and opened to visitors in August 2013. Since there are no pre-construction data, this summary will only compare results from the adventure course plot to control plots. Monitoring at this site consisted of two forest vegetation plots and four point count stations (Figure 5).

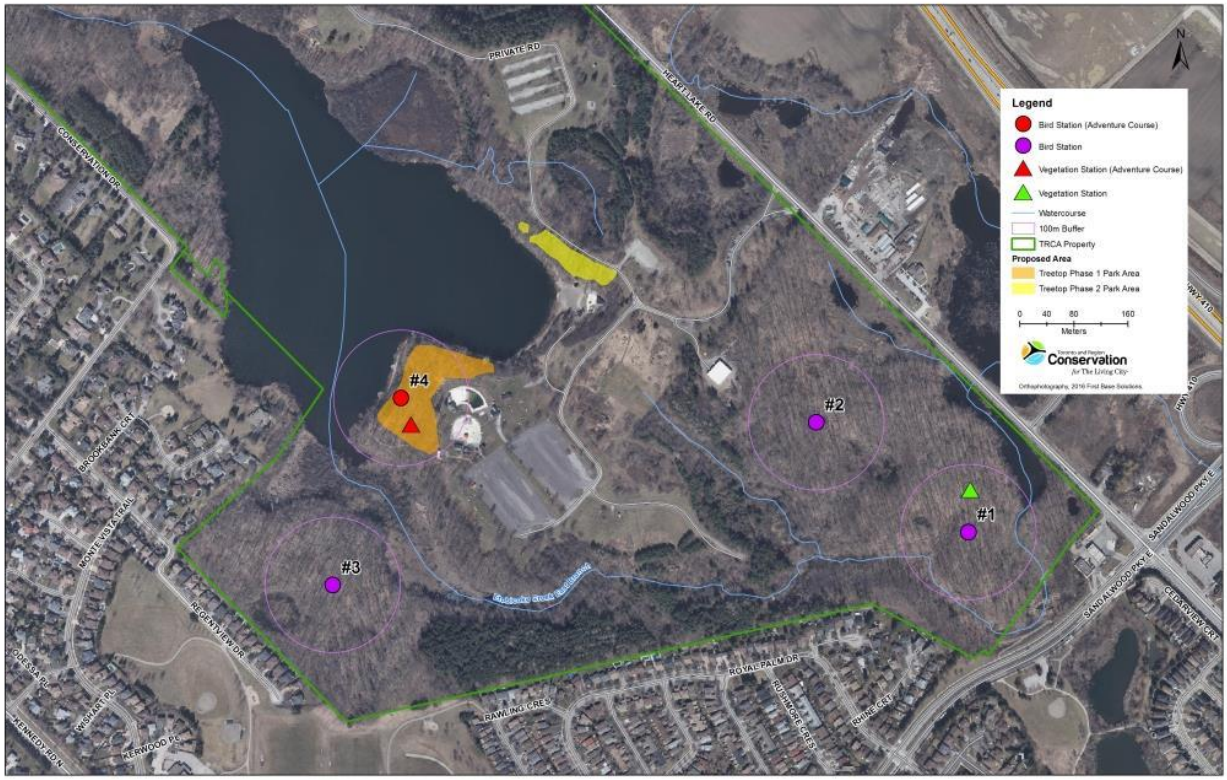


Figure 5. Bird and vegetation monitoring plots at Heart Lake

4.1 Results

4.1.1 Vegetation Plots

The adventure course and control plots are approximately 800m apart and share similar characteristics in terms of species composition, canopy structure and stand age; however, differences do exist in their sub-canopies (regeneration and ground layers). Also, the adventure course plot is approximately 20 m from the forest edge while the control plot is situated within a larger forest patch, buffering it somewhat from the surrounding matrix influence. In terms of stand disturbance, both plots are in close proximity to active trails and show evidence of light deer browse; however, the adventure course plot is in an area of high human traffic including a nearby splash pad, picnic area and parking lot.

Tree Composition

Sugar maple (*Acer saccharum*) remains the dominant species in both plots. The control plot contained 13 live sugar maples, 1 sugar maple snag and 1 ironwood (*Ostrya virginiana*) that was dead and had fallen. By 2017, the tree community remained the same except that the snag fell, and two sugar maples died recently. The adventure course plot contained 9 sugar maples, 3 red oaks (*Quercus rubra*) and 1 sugar maple snag. By 2017, four trees were cut down including 2 sugar maples, 1 red oak and the sugar maple snag. There were minimal changes in crown class between 2013 and 2017 although the removal of trees from the adventure course plot likely opened the canopy.

Tree Health

Crown mortality of living trees remains low at the control plot with on average 85% (2013-2017) of trees having healthy crowns with <10% die-back. Two sugar maple trees previously reported as having broken crowns due to storm damage have subsequently died. Similar to the control plot, the adventure course plot had low crown mortality and could be considered "healthy". On average 91% of living trees evaluated at the adventure course plot had healthy crowns with <10% die-back. Three trees with light to moderate or severe crown die-back were removed sometime between 2013 and 2017. There was a higher percentage of trees with at least one defect (open wound, canker, etc.) at the adventure course plot (83%) compared to the control plot (62%) in 2013. This percentage became more similar by 2014 as several declining/hazard trees were removed at the adventure course plot (adventure course = 78%, control = 69%).

Tree health may be affected by the installation of platforms and other suspension-related infrastructure in the future because these were nailed to the trees (Figure 6). One larger platform on a tree outside the vegetation plot had a large metal nail/support (approximately 6 cm diameter) drilled into the tree trunk and sap was dripping from the tree at this wound.

Figure 6. Platform installed and sap dripping from the tree at the wound

Several trees were affected by pests/disease/fungus between 2013 and 2017 (Table 3). European gypsy moth (*Lymantria dispar*) larvae and eggs were found on 23% of trees at the control plot and 50% of trees at the adventure course plot but this outbreak appeared isolated to 2013. The higher occurrence of gypsy moth at the adventure course plot may be due to the presence of oaks in the plot, the preferred host species of gypsy moth (Hough and Pimentel 1978). One sugar maple tree at the control plot had a canker and an open wound both on the lower main stem most likely caused by the fungal pathogen *Eutypella parasitica*. Multiple trees on both plots were affected by an unknown defoliator in later years where the leaves were eaten and/or rolled. On the control plot in 2017, 67% of trees were affected by an unknown defoliator that left holes and/or rust coloration on the leaves. In addition to these more frequent occurrences, carpenter ants affected one tree at the control plot in 2017.

Table 3. Occurrence of pests/disease/fungus in forest vegetation plots at Heart Lake between 2013 and 2017

Pest/disease/fungus		Adventure course			Control		
		2013	2014	2017	2013	2014	2017
Gypsy moth	# live stems affected	6	0	0	3	0	0
	% live stems affected	50	0	0	23	0	0
Eutypella parasitica	# live stems affected	0	0	0	1	1	0
	% of live maple stems affected	0	0	0	8	8	0
Unknown defoliator	# live stems affected	0	0	6	0	1	2
	% live stems affected	0	0	67	0	8	18

Shrub and Sapling Composition

The regeneration layer at Heart Lake contained a total of eight native species ranging in L-rank from L4 to L5 (Appendix 3). These species include sugar maple, downy serviceberry (*Amelanchier arborea*), yellow birch (*Betula alleghaniensis*) (planted), chokecherry (*Prunus virginiana var. virginiana*), red oak, white ash (*Fraxinus americana*) and thicket creeper (*Parthenocissus vitacea*). Two European buckthorn (*Rhamnus cathartica*) stems were the only exotic species found in the regeneration layer and were found solely in the control plot in all years. Sugar maple dominated the regeneration layer at both plots with an average relative density of 95% and average relative cover of 97% between the two plots and across all years. The control plot had a more densely populated regeneration layer than the adventure course plot in all years (Figure 7). The large increase in 2017 can be attributed to a large number of sugar maple seedlings. Several saplings had been planted within the course in 2017 and this could contribute to regeneration in the future if they survive.

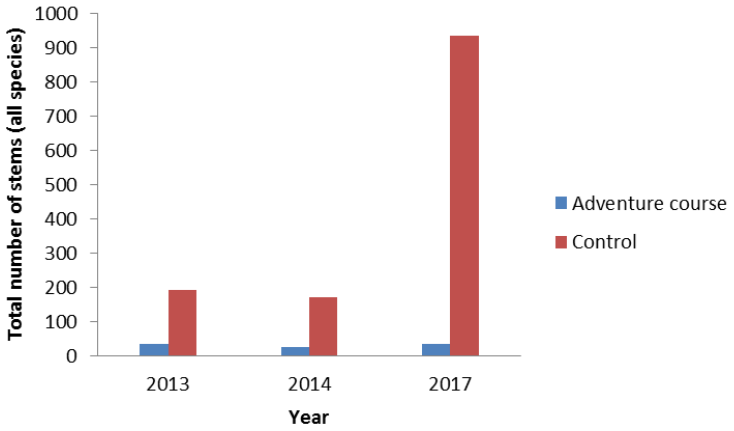


Figure 7. Total number of stems (all species) in the regeneration layer at Heart Lake

Ground Vegetation Composition

Six species were found in the control plot between 2013 and 2017; five of these were native, ranked L4-L5 (Appendix 4). The percent composition of native species was higher on the control plot compared to the adventure course plot in all years (Figure 8). The control plot contained two spring ephemeral species including blue cohosh (*Caulophyllum giganteum*) and yellow trout-lily (*Erythronium americanum ssp. americanum*) while the adventure course plot contained none. Blue cohosh provided the highest relative % cover in both 2013 (78%) and 2017 (66%); however, sugar maple seedlings provided the highest relative % cover in 2014 (86%). Garlic mustard (*Alliaria petiolata*) was the only exotic species found in the plots and increased in relative percent cover between 2013 (1.3%) and 2017 (17%) at the control plot.

Sixteen species were found in the adventure course plot between 2013 and 2017 and 9 of these were native species ranked L4-L5. Woodland spear grass (*Poa nemorlis*) provided the highest relative percent cover in all years (84% in 2013, 43% in 2014, and 73% in 2017). Of the 7 exotic species found in the plot, 3 have only appeared recently in 2017 including white clover (*Trifolium repens*), creeping thistle (*Cirsium arvense*) and common plantain (*Plantago major*). The other exotic species are not showing signs of spread. Subplot 1 was noted as being covered by mulch in 2014 and subplots 1 and 5 were completely covered with mulch in 2017 and the mulch was much thicker (Figure 9). No plants were growing in these subplots.

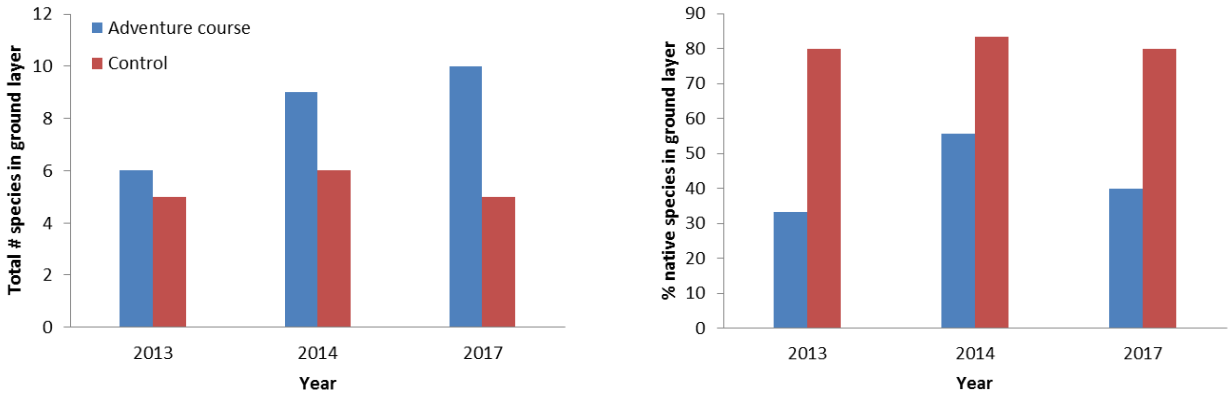


Figure 8. Total number of species and percent native species in the ground vegetation layer at Heart Lake

Figure 9. Subplots covered in wood chips/mulch

Species Richness and Floristic Quality

Thirty-one flora species were found at the control plot between 2013 and 2017 and 63 species were found at the adventure course plot between 2013 and 2017. Species richness increased between 2013 and 2017 at both the adventure course and control plots (Table 4, Appendix 5). The number of native species and exotic species increased at the adventure course plot while only the number of native species increased at the control plot. The percent exotic species at the adventure course plot changed from 33% in 2013 to 45% in 2017 while the control plot changed from 33% in 2013 to 32% in 2017. This shows that while the plots both started with a similar number of exotic species and a similar percent composition of exotic species, the magnitude of the increase by 2017 was higher at the adventure course plot.

The FQI is a measure used to assess the "quality" of a natural area. Based on the mean co-efficient of conservatism (calculated from site species lists), the FQI provides a useful measure for comparing changes in quality within and/or across site(s). Species with high CC values generally have low tolerance levels for habitat alterations whereas those with lower CC values are more adaptable and/or tolerant of disturbance.

The FQI at the adventure course plot was slightly higher than the control plot but this is likely due to the effect of the greater number of native species at the adventure course plot since it is used to calculate FQI. There was no large difference in the mean coefficient of conservatism score between plots or among years. Arrow-leaved tear-thumb (*Persicaria sagittata*) was the only species of conservation concern (L2 ranked) found at the site and it was found in the control plot.

Table 4. Heart Lake forest plot floristic quality information (2013-2017)

	Adventure course			Control		
	2013	2014	2017	2013	2014	2017
Number of Native Species	16	23	26	10	15	19
Number of Exotic Species	8	13	21	5	9	9
Percent Native Species	66.7	63.9	55.3	66.7	62.5	67.9
Percent Exotic Species	33.3	36.1	44.7	33.3	37.5	32.1
Sum of cc	58	83	82	42	57	60
Mean cc	3.6	3.6	3.2	4.2	3.8	3.2
FQI	14.5	17.3	16.1	13.3	14.7	13.8
Number of L1-L3 Species	0	0	0	0	1	0
Percent L1-L3 Species	0	0	0	0	4.2	0

4.1.2 Bird Stations

Over the 6 years of bird surveys at Heart Lake, on average 10 species were detected at the control stations and 11 species at the adventure course station. Species detected at control stations in all 6 years were eastern wood pewee (*Contopus virens*), great-crested flycatcher (*Myiarchus crinitus*), red-eyed vireo (*Vireo olivaceus*) and black-capped chickadee (*Parus atricapillus*; Appendix 6). Species detected at the adventure course station in all 6 years were American robin (*Turdus migratorius*) and red-winged blackbird (*Agelaius phoeniceus*). These species were also often the most abundant species at the control and adventure stations, respectively, although dominance often varied among years.

There were no large or consistent differences in species abundance, richness, or the number of species of conservation concern between the adventure course and control plots (Table 5). In 2013, the control plot had approximately half the abundance and richness of the adventure course plot; however, these large differences only occurred in 2013. Abundance and richness of forest-dependent birds were consistently higher at the control plot compared to the adventure course plot. This could either be due to the habitat modifications and human presence in the area or due to the control plots mainly occurring in larger forest tracts compared to the adventure course plot which is near the forest edge and near water.

Table 5. Summary of avian community assessment variables per point count at adventure course and control stations at Heart Lake (2013-2018)

Average per point count station	Adventure course					Control				
	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Abundance	13	11	14	18	15	6.3	11.3	15.3	19	17.3
Species richness	12	10	10	11	11	5	9	11.3	10.3	12
Forest-dependent abundance	3	1	2	6	4	3.7	7.3	7	7.7	8
Forest-dependent species richness	3	1	2	5	4	2.3	5.7	4.7	5	6.3
Number of L1-L3 species	0	0	1	1	0	0	0	0.3	0.7	1.7
Number of L1-L4 species	6	2	4	6	4	2.3	5.7	4.7	5.7	6.7

4.2 Summary

No pre-construction data were available for this site because it was already altered when monitoring began in 2013. The adventure course plot:

- Appears to have better tree crown health but this is only due to the removal of declining trees due to hazard tree policies.
- Was affected by similar pests as the control plot such as gypsy moth outbreaks in 2013 and an unknown defoliater in 2017.
- Had up to 27x fewer woody stems regenerating than the control plot although several saplings (10-15) were noted in 2017 as planted within and outside of the plot.
- Contained no spring ephemeral species.
- Has seen large increases in the number of exotic flora species.
- Had fewer forest-dependent bird species compared to the control stations although it remains unclear if this is due to the site alteration at the adventure course or the location of the control plots in larger tracts of forests and further away from water.

5 Bruce's Mill

Construction on the adventure course was completed and opened to visitors on June 21, 2014. Since surveys were conducted in 2013 there are pre-construction data available for comparison with post-construction data. Monitoring at this site consisted of two forest vegetation plots and four point count stations (Figure 10).

Figure 10. Bird and vegetation monitoring plots at Bruce's Mill

5.1 Results

5.1.1 Vegetation Plots

The adventure course plot is located to the south near the Maple Syrup Demonstration Area and is within 100m of the southern forest edge. The control plot is located outside of the proposed adventure course area in a larger forest patch to the north. The two plots are of similar composition, structure and age with some understorey differences.

Tree Composition

Between 2013 and 2014, the control plot contained 7 live sugar maple trees, 1 live American beech (*Fagus grandiflora*) and 2 snags including black cherry (*Prunus serotina*) and sugar maple. There were no changes in tree composition between 2013 and 2014 at the control plot; however, the American beech died between 2014 and 2018. In 2013, the adventure course plot contained 10 live sugar maple trees, 1 live American beech and 1 sugar maple snag. Between 2013 and 2014, the American beech and one sugar maple were cut down and the snag was removed. As of 2018, there were no other changes in tree status except that tree walk braces were installed to one of the living sugar maple trees (tree 11). Tree composition was affected at the site prior to monitoring with 34 trees removed to set up the adventure course including sugar maple, white ash and American beech ranging in size from 22-62 cm dbh.

Canopy Cover

The canopy at the adventure course plot was noted as being more open in 2014 compared to 2013. Some wind storm damage was noted at the control plot in 2014 but there were no comments of a direct impact on canopy cover. In 2018, canopy cover measurements were taken at both the control plot and the adventure course plot. Canopy cover was 96% at the control plot and 86% at the adventure course plot. The canopy was more open at the adventure course plot due to the removal of mature trees. The majority of trees in both plots were dominant or co-dominant with few intermediate or suppressed individuals.

Tree Health

There was no change in crown vigour between 2013 and 2014 at the control plot with 88% of living trees having healthy crowns (<10% crown mortality). The American beech was showing signs of severe decline (>50% crown mortality) in 2014 and died by 2018. After the death of this tree, all trees in the control plot as of 2018 had healthy crowns. Ninety percent of the live trees in the adventure course plot (i.e. those which had not been cut down) had healthy crowns between 2013 and 2014. By 2018, the one sugar maple that had light to moderate decline apparently improved to a healthy condition resulting in 100% of remaining trees having healthy crowns.

The adventure course plot had a higher percentage of trees with at least one defect (85%) compared to the control plot (56%) in 2013. Similar to Heart Lake, these percentages became more similar between 2013 and 2014 due to the removal of declining/hazard trees at the adventure course plot (adventure course = 67%, control = 50%). By 2018, there was no change in the number of trees that had at least one defect at the adventure course plot but there was a small decrease at the control plot to 43% due to the death of the American beech tree between 2014 and 2018.

Gypsy moth larvae and eggs were found on one tree (American beech) in the control plot, but again, only in 2013 (Table 6). This same tree was also affected by beech bark scale/disease. The American beech tree on the adventure course plot was also affected by beech bark scale/disease until it was cut down. The beech scale insect (*Cryptococcus fagisuga*) feeds on the tree leaving holes in the bark and these holes allow for invasion by the fungus *Neonectria faginata* causing small visible cankers (MNRF 2016). Two trees in the control plot had cankers suspected to be caused by the fungal pathogen, *Eutypella parasitica*.

Table 6. Occurrence of pests/disease/fungus in forest vegetation plots at Bruce's Mill between 2013 and 2018

Pest/disease/fungus		Adventure course			Control		
		2013	2014	2018	2013	2014	2018
Gypsy moth	# live stems affected	0	0	0	1	0	0
	% live stems affected	0	0	0	13	0	0
Eutypella parasitica	# live stems affected	0	0	0	2	2	2
	% of live maple stems affected	0	0	0	29	29	29
Beech bark disease/scale	# live stems affected	1	0	0	0	1	0
	% of live beech stems affected	100	0	0	0	100	0

Shrub and Sapling Composition

The regeneration layer in all plots at Bruce's Mill contained a total of seven native species ranging in L-rank from L3 to L5. These species included sugar maple, silver maple (*Acer saccharinum*), alternate-leaved dogwood (*Cornus alternifolia*), American beech, choke cherry, red-berried elder (*Sambucus racemose ssp. pubens*) and Canada yew (*Taxus canadensis*; L3). Three non-native species were found only in the control plot and included common buckthorn, wayfaring tree (*Viburnum lantana*) and European highbush cranberry (*Viburnum opulus ssp. opulus*). Sugar maple dominated the regeneration layer at both plots with an average relative density of between 85% (2014) and 96% (2018) and an average relative cover of between 82% (2014) and 96% (2018). The control plot was more densely populated than the adventure course plot in all years (Figure 11).

Vegetation was noted as trampled/crushed in subplot 1 in 2014 and subplot 4 was eliminated completely by 2018 for the creation of a trail.

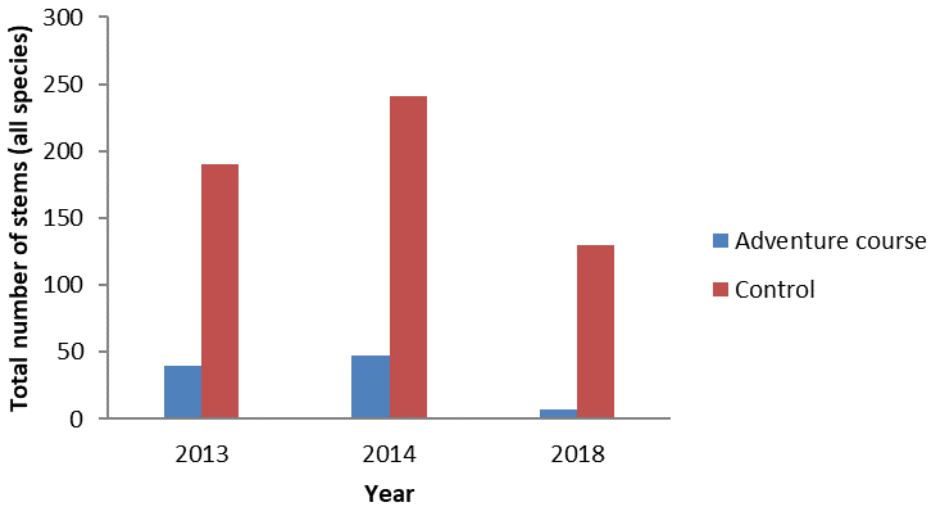


Figure 11. Total number of stems (all species) in the regeneration layer at Bruce's Mill

Ground Vegetation Composition

Fourteen species were found in the control subplots between 2013 and 2018; 10 of these were native, ranked L4-L5 (Figure 12; Appendix 4). The percent composition of native species was higher in the control plot compared to the adventure course plot in 2013, more equal between plots in 2014 then higher again in 2018. Both the control plot and the adventure course plot each contained two spring ephemeral species (control: yellow trout-lily, white trillium (*Trillium grandiflorum*); adventure course: yellow trout-lily and blue cohosh). Yellow trout-lily provided the highest relative percent cover in the control plot in 2013 (81%) and 2014 (49%); however, sugar maple had the highest relative percent cover in 2018 (53%). Dandelion (*Taraxacum officinale*) and wayfaring tree were the only two exotic species found in the control plot and had relative covers of approximately 1%.

Seventeen species were found in the adventure course plot between 2013 and 2018 and 11 of these were native species ranked L4-L5. Virginia waterleaf (*Hydrophyllum virginianum*) provided the highest relative percent cover in all three years (on average 79%). Manitoba maple (*Acer negundo*) and helleborine (*Epipactis helleborine*) were the only two exotic species found in the adventure course plot in 2013 and 2014 (<1% cover). Four new exotic species were found in 2018 including dandelion, herb Robert (*Geranium robertianum*), urban avens (*Geum urbanum*) and celandine (*Chelidonium majus*) with a total relative percent cover of approximately 7 %.

Vegetation was noted as trampled/crushed in subplot 1 in 2014 and subplot 4 was eliminated completely by 2018 for the creation of a trail. The complete removal of subplot 4 led to a loss of space for five native species previously inhabiting the subplot including sugar maple, wild leek (*Allium tricoccum*), enchanter's nightshade (*Circaea canadensis ssp. canadensis*), yellow trout-lily and Virginia waterleaf.

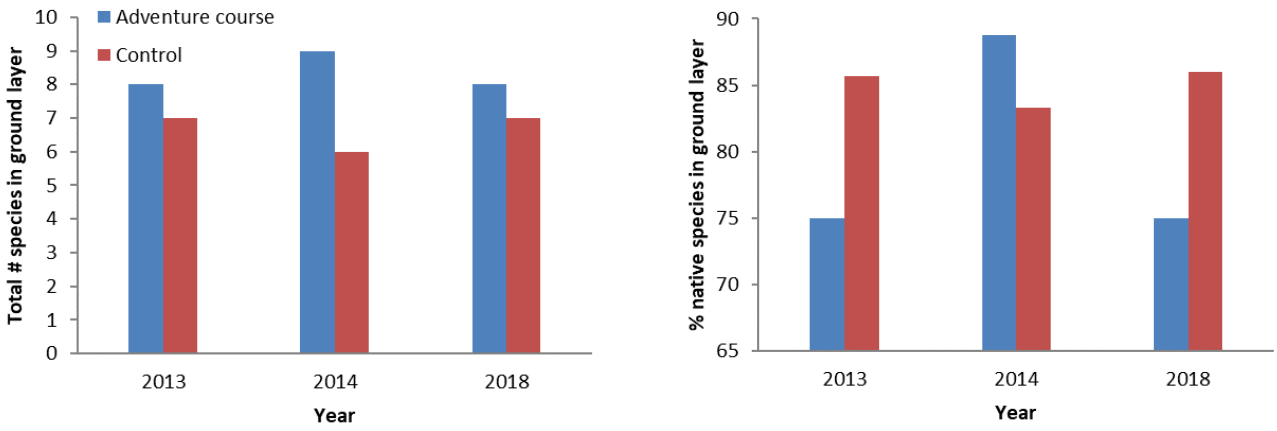


Figure 12. Total number of species and percent native species in the ground vegetation layer at Bruce's Mill

Species Richness and Floristic Quality

A total of 49 flora species were found at the control plot between 2013 and 2018 and a total of 43 species were found at the adventure course plot between 2013 and 2018 (Appendix 5). There was a relatively low annual percent composition of exotic flora species both at the adventure course plot (25%) and the control plot (19%; Table 7) compared to Heart Lake and there were no signs of increases between 2013 and 2018. The average FQI value at the adventure course plot (22.8) was slightly lower than the control plot (24.0). Canada yew was the only species of conservation concern (L3 ranked) found at the site and it was found each year only in the control plot.

Table 7. Bruce's Mill forest plot floristic quality information (2013-2018)

	Adventure course			Control		
	2013	2014	2018	2013	2014	2018
Number of Native Species	25	26	25	27	26	35
Number of Exotic Species	10	7	9	6	6	8
Percent Native Species	71.4	78.8	73.5	81.8	81.3	81.4
Percent Exotic Species	28.6	21.2	26.5	18.2	18.8	18.6
Sum of cc	113	117	115	120	114	156
Mean cc	4.5	4.5	4.6	4.4	4.4	4.5
FQI	22.6	22.9	23.0	23.1	22.4	26.4
Number of L1-L3 Species	0	0	0	1	1	1
Percent L1-L3 Species	0	0	0	3.0	3.1	2.3

5.1.2 Bird Stations

Over the 6 years of bird surveys at Bruce's Mill, both the control and adventure course stations had on average 10 species. Species detected at control stations in all six years were eastern wood pewee, red-eyed vireo, American robin, black-capped chickadee, blue jay (*Cyanocitta cristata*) and song sparrow (*Melospiza melodia*; Appendix 6). Species detected at the adventure course station in all six years were red-eyed vireo and American robin. These species were also often the most abundant species at the control and adventure stations, respectively, although dominance often varied among years.

There were no large or consistent differences in species abundance, richness, or the abundance and richness of forest-dependent birds between the adventure course and control stations (Table 8). Control stations had more species of conservation concern than the adventure course station. Mourning warbler (*Geothlypis philadelphia*) was the only species of conservation concern (ranked L3) detected at the adventure course station with one individual detected only in 2013. Several species of conservation concern were detected at the control stations including ovenbird (*Seiurus aurocapillus*; L2), winter wren (*Troglodytes hiemalis*; L3), veery (*Catharus fuscescens*; L3), black-throated green warbler (*Setophaga virens*; L3) and mourning warbler; however, these detections were isolated to control stations 1 and 4. No L1-L3 bird species were detected at control station 2 in any year.

Bruce's Mill has one year of pre-construction data (2013), one year of data which incorporates time during construction and early operation (2014) and four years of post-construction data while the course was open for visitors (2015-2018). There were no clear changes in any of the bird variables pre- and post-construction. There was a decrease in almost all variables between 2013 and 2016/2017/2018 but these decreases also occurred at control stations. The brown-headed cowbird (*Molothrus ater*), a nest parasite that lays its eggs in other species nests, was only detected at the adventure course station and only in 2015 and 2017. These

species can be transient in nature but can cause decreases in host nest productivity and are often associated with more disturbed landscapes (smaller forest fragments, open canopies: Moorman and Guynn 2001).

Table 8. Summary of avian community assessment variables per point count at adventure course and control stations at Bruce's Mill (2013-2018)

Average per point count station	Adventure course						Control					
	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Abundance	11	15	18	10	14	12	13.3	12.7	15.7	12.7	15	15
Species richness	9	9	13	8	11	7	9.7	9.7	12.7	9.3	10.3	9.7
Forest-dependent abundance	7	7	7	5	4	4	8	7.3	6.7	5.7	6	4.7
Forest-dependent species richness	6	4	7	3	3	3	5.3	4.7	5	4	4.7	3
Number of L1-L3 species	1	0	0	0	0	0	2	1	1	0.7	0.7	0
Number of L1-L4 species	6	5	7	3	3	3	5.7	6	5.7	4.7	4.7	3.3

5.2 Summary

This site had one year of pre- and several years of post-construction data. The adventure course plot:

- Had two trees removed opening the canopy compared to the control plot.
- Was affected prior to monitoring with 34 trees removed to set up the adventure course including sugar maple, white ash and American beech ranging in size from 22-62 cm dbh.
- Had up to 5x fewer woody stems regenerating than the control plot.
- Had a similar ground vegetation layer based on % composition of native species and the presence of spring ephemerals.
- Had a lower total cover of ground vegetation due to the complete loss of subplot 4 for trail creation.
- Showed no signs of increasing exotic species between 2013 and 2014, although four additional exotic species were found in 2018.
- Had fewer bird species of conservation concern although again it remains unclear if this is due to the site alteration at the adventure course or the location of the control plots in larger tracts of forests (since these differences were found in all years and not only post-construction). It is worthwhile to note that the only species of conservation concern detected at the adventure course station was found in 2013 (the only pre-construction year). There also appeared to be declines in the number of forest-dependent birds and sensitive bird species at both the control and adventure course plots.
- Had a brown-headed cowbird (a nest parasite) detected in both 2015 and 2017.

6 Living City Campus

There have been two proposed development phases for adventure courses at the Living City Campus. Phase 1 is located just to the west of the main building with phase 2 being an expansion both north and south of phase 1 (Figure 13). Monitoring at this site consisted of two forest vegetation plots and five point count stations. Since construction has not been approved at this site, these data represent baseline conditions.

Figure 13. Bird and vegetation monitoring plots at the Living City Campus

1.1 Results

1.1.1 Vegetation Plots

Vegetation plots are comparable in composition, structure and age and are approximately 400 m apart. Even though one vegetation plot has been established at a potential location of an adventure course, it remains undisturbed.

Tree Composition

The canopy consists entirely of sugar maple trees with a mix of crown classes ranging from dominant to supressed. There were no changes in tree condition or tree status at both the control plot and the potential adventure course plot between 2013 and 2014. The control plot continues to support nine live sugar maples and one snag while the potential adventure course plot supports nine live sugar maples and three snags.

Tree Health

There was a decline in the percent of living trees with healthy crowns at the control plot between 2013 (89%) and 2014 (67%). Two sugar maple trees changed from healthy (<10% die-back) to light to moderate decline (10-50% decline). Similar to the control plot, the potential adventure course plot also declined in the percent of living trees with healthy crowns with one sugar maple changing from healthy (<10% die-back) to light to moderate decline (10-50% decline) between 2013 and 2014. This decline could have been caused by an unknown defoliator which affected several trees and an unidentifiable black fungus on the main stem of two trees in 2014 (Table 9). This defoliator caused many leaves to be rolled and affected 67% of trees in the adventure course plot and 44% of trees in the control plot. The unknown black fungus was found on two trees in the adventure course plot in 2014 and suspected *Eutypella* canker was found on one tree in the control plot in 2014.

Forty-four percent of living trees had at least one defect in the potential adventure course plot compared to 100% of trees in the control plot in 2013. This large difference was still present in 2014 with 27% of living trees having at least one defect in the potential adventure course plot compared to 82% of trees in the control plot.

Table 9. Occurrence of pests/disease/fungus in forest vegetation plots at the Living City Campus between 2013 and 2014

Pest/disease/fungus		Adventure course		Control	
		2013	2014	2013	2014
Unknown defoliator	# live stems affected	0	6	0	4
	% live stems affected	0	67	0	44
Eutypella parasitica	# live stems affected	0	0	0	1
	% of live maple stems affected	0	0	0	11
Unknown black fungus	# live stems affected	0	2	0	0
	% live stems affected	0	22	0	0

Shrub and Sapling Composition

The regeneration layer at the Living City Campus contained two species, sugar maple and white ash, both native to the jurisdiction and ranked L5. Sugar maple was the only species found on the control plot while the potential adventure course plot had both sugar maple and white ash in approximately equal relative stem density (56% sugar maple, 44% white ash). Even though stem density was approximately equal, sugar maple again dominated the regeneration layer at both plots with on average 91% relative cover among years. Compared to both Heart Lake and Bruce's Mill where adventure courses have already been installed, the potential adventure course plot had a more densely populated regeneration layer than the control plot in all years (Figure 14).

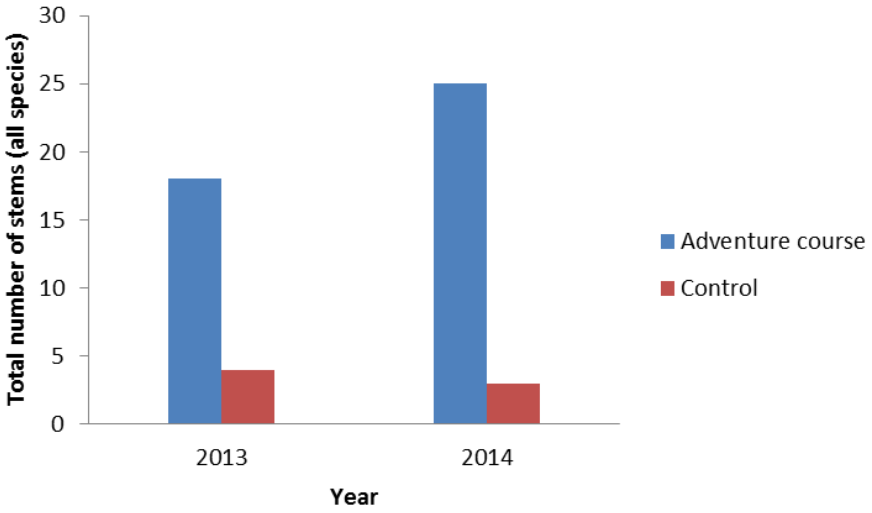


Figure 14. Total number of stems (all species) in the regeneration layer at the Living City Campus

Ground Vegetation Composition

Seven species were found in the control plot between 2013 and 2014; five of these were native, ranked L4-L5 (Figure 15; Appendix 4). The percent composition of native species was higher on the control plot compared to the potential adventure course plot in 2013 but was similar in 2014. One spring ephemeral species, yellow trout-lily, was found on the control plot and the potential adventure course plot contained four species: May-apple (*Podophyllum peltatum*), yellow trout-lily, narrow-leaved spring beauty (*Claytonia virginica*) and Canada May-flower (*Maianthemum canadense*). Jack-in-the-pulpit (*Arisaema triphyllum*) provided the highest relative percent cover in 2013 (50%); however, sugar maple seedlings provided the highest relative percent cover in 2014 (76%).

Thirteen species were found in the potential adventure course plot between 2013 and 2014 and eleven of these were native species mostly ranked L4-L5 except for narrow-leaved spring beauty which is ranked L3. In 2013, the potential adventure course plot had a more diverse distribution of relative percent covers than all other plots (i.e. control plot and Heart Lake, Bruce's Mill) with multiple species covering more than 10% including (in descending order) garlic mustard (21%), herb Robert (19%), May-apple (16%), enchanter's nightshade (11%) and Jack-in-the-pulpit (11%). In 2014, sugar maple dominated with 42% relative cover while only May-apple remained above 10% relative cover. The two exotic species in the plot (garlic mustard and herb Robert) are not showing any signs of increasing in percent cover.

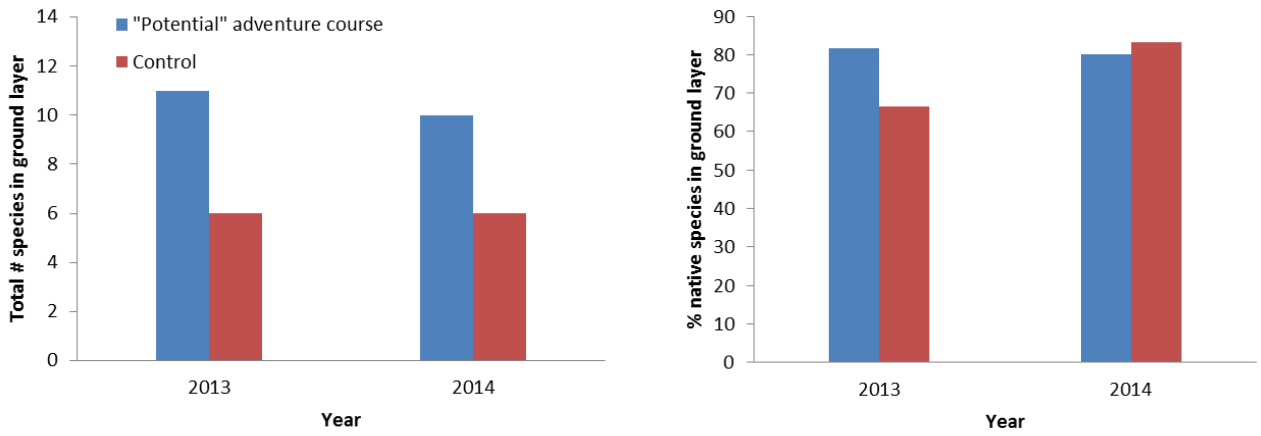


Figure 15. Total number of species and percent native species in the ground vegetation layer at the Living City Campus

Species Richness and Floristic Quality

Twenty-nine flora species were found at the control plot between 2013 and 2014 and 32 species were found at the potential adventure course plot between 2013 and 2014 (Appendix 5). The potential adventure course plot had more native species and fewer exotic species than the control plot. Although the differences were minimal, the magnitude of these differences varied by year (Table 10). These compositional differences were also reflected in the percent composition of native and exotic species.

Mean coefficient of conservation values were similar between plots although the FQI values for the potential adventure course plot were higher. This again could be due to the greater number of species in the potential adventure course plot compared to the control plot since native species richness is included in the calculation of the FQI. Since the mean coefficient of conservation values were similar, this suggests that the plots support species with similar sensitivities to habitat disturbance.

Narrow-leaved spring beauty (ranked L3) and running strawberry bush (*Euonymus obovatus*; ranked L3) were the only two species of conservation concern found in the plots. Both of these species were found in the control plot while only narrow-leaved spring beauty was found in the potential adventure course plot.

Table 10. Living City Campus forest plot floristic quality information (2013-2014)

	Potential adventure course		Control	
	2013	2014	2013	2014
Number of Native Species	25	25	15	19
Number of Exotic Species	5	4	6	8
Percent Native Species	83.3	86.2	71.4	70.4
Percent Exotic Species	16.7	13.8	28.6	29.6
Sum of cc	108	112	61	81
Mean cc	4.3	4.5	4.1	4.3
FQI	21.6	22.4	15.8	18.6
Number of L1-L3 Species	1	1	1	2
Percent L1-L3 Species	3.3	3.4	4.8	7.4

1.1.2 Bird Stations

Over the four years of bird surveys at the Living City Campus, both the control and potential adventure course stations had on average nine species. Species detected at control stations in all four years were eastern wood-pewee, pine warbler (*Setophaga pinus*), red-breasted nuthatch (*Sitta canadensis*), red-eyed vireo, American robin, black-capped chickadee and blue jay (Appendix 6). Species detected at the adventure course station in all four years were eastern wood-pewee, red-eyed vireo, American robin and black-capped chickadee. These species were also often the most abundant species at the control and adventure stations, respectively, although dominance often varied among years.

There were no large or consistent differences in species abundance, richness, or number of species of conservation concern between the potential adventure course and control plots (Table 11). The Living City Campus bird stations detected a large number of species of conservation concern. These species included ovenbird (L2), Blackburnian warbler (*Setophaga fusca*; L3), black-throated green warbler (L3), eastern towhee (*Piplio erythrophthalmus*; L3), mourning warbler (L3), pileated woodpecker (*Dryocopus pileatus*; L3), scarlet tanager (*Piranga olivacea*; L3), winter wren (L3) and wood thrush (*Hylocichla mustelina*; L3). Wood thrush and eastern wood-pewee have been listed by the federal government as threatened and of special concern, respectively. These two species are also listed by the provincial government as of special concern.

Table 11. Summary of avian community assessment variables per point count at potential adventure course and control stations at the Living City Campus (2013-2016)

Average per point count station	Adventure course				Control			
	2013	2014	2015	2016	2013	2014	2015	2016
Abundance	11	10	14	15	9.8	10.5	15.3	12.8
Species richness	10	6	8	12	8	8.8	11.5	9.5
Forest-dependent abundance	8	6	7	11	5.5	6.3	7.3	7
Forest-dependent species richness	7	3	4	9	4.8	5.3	5.3	5.3
Number of L1-L3 species	2	1	1	3	1.5	2	1.5	1
Number of L1-L4 species	7	3	4	10	4.8	5.5	6	5.5

1.1.3 Song Meters

Song meter data from 2013 and 2014 detected 14 additional species not detected during point counts (Table 12). Of these 14 species, 4 species were also detected by point counts but were excluded from analysis because they were outside the 100m radius point count area. Of the 10 species only detected using the song meter data, only one of these species was a species of conservation concern, black-billed cuckoo (*Coccyzus erythropthalmus*; ranked L3). In contrast, point count data from 2013 and 2014 detected four additional species not detected in the selected times/dates on the song meters: ovenbird (L2), winter wren (L3), warbling vireo (*Vireo gilvus*; L5), and American goldfinch (*Carduelis tristis*; L5).

Table 12. Song meter results from the adventure course and two control stations at the Living City Campus in 2013 and 2014

Common name	L-rank	Potential adventure course		Control (station 2)		Control (station 4)	
		2013	2014	2013	2014	2013	2014
black-billed cuckoo	***L3***			✓			
Blackburnian warbler	L3						✓
mourning warbler	L3				✓		
pileated woodpecker	L3	✓	✓	✓	✓	✓	✓
scarlet tanager	L3	✓	✓	✓	✓	✓	✓
wood thrush	L3	✓	✓	✓	✓	✓	✓
common yellowthroat	L4	✓		✓			
Coopers hawk	***L4***						✓
eastern wood-pewee	L4	✓	✓	✓	✓	✓	✓
great-crested flycatcher	L4	✓	✓	✓	✓	✓	✓
hairy woodpecker	L4	✓	✓	✓	✓		✓
indigo bunting	L4	✓	✓	✓		✓	✓
northern flicker	L4	✓	✓	✓	✓	✓	
pine warbler	L4	✓	✓	✓	✓	✓	✓
red-bellied woodpecker	***L4***				✓		
red-breasted nuthatch	L4	✓	✓	✓	✓	✓	✓
red-eyed vireo	L4	✓	✓	✓	✓	✓	✓
rose-breasted grosbeak	***L4***	✓		✓	✓	✓	
white-breasted nuthatch	***L4***	✓		✓	✓		
wood duck	***L4***			✓			
American crow	L5	✓	✓	✓	✓	✓	✓
American robin	L5	✓	✓	✓	✓	✓	✓
Baltimore oriole	***L5***				✓	✓	
black-capped chickadee	L5	✓	✓	✓	✓	✓	✓
blue jay	L5	✓	✓	✓	✓	✓	✓
cedar waxwing	L5		✓		✓		
chipping sparrow	***L5***					✓	
common grackle	L5						✓
downy woodpecker	***L5***			✓	✓		
eastern phoebe	***L5***	✓					
northern cardinal	L5	✓	✓	✓	✓	✓	✓
red-winged blackbird	L5	✓		✓	✓	✓	
song sparrow	L5					✓	

*species not detected during point counts are shown in ***bold***

1.2 Summary

This site has had no adventure course installed so all data represent reference conditions. Both the potential adventure course and control plots at the Living City Campus:

- Showed declines in several trees likely caused by an unknown defoliator and an unknown fungus.
- Had regeneration layers with similar stem density.
- Contained the highest number of spring ephemerals compared to all other sites (i.e. control and adventure plots at Heart Lake and Bruce's Mill).
- Had bird communities consisting of many species of conservation concern, area-sensitive species and species such as the wood thrush and eastern wood-pewee which have been listed both federally and provincially as species-at-risk.

7 Conclusion

The goal of this report was to summarize terrestrial monitoring data at three TRCA properties where adventure courses either exist or have been proposed. In general, this report found that forest vegetation was negatively affected by adventure courses but the degree of impact depends on how heavily the site was altered and how much time has passed since alteration.

The adventure course at Heart Lake was constructed in 2013 and was re-surveyed for flora in 2014 and 2017 providing information five years post-construction. This plot has had large increases in the number of exotic flora species, an almost complete loss of the regeneration and ground layers along with the removal of several mature trees. The adventure course plot at Bruce's Mill has pre-construction flora data and data from five years post-construction and has shown several impacts similar to Heart Lake including the harvest of mature trees, a reduction in the extent of the regeneration layer and a loss of ground vegetation cover. It is difficult to interpret bird community results at these sites since control plots were often established in larger tracts of forest which often contain different bird communities than those near forest edges or near water.

The Living City Campus is a TRCA property that has been proposed to have an adventure course constructed and therefore represents reference conditions. This site has characteristics of a forest in very good condition for the TRCA region based on flora and bird communities. Four spring ephemeral species were found in the plots and their presence can be used as one of many indicators of forest health/integrity (Keddy and Drummond 1996). These plots also retain healthy crowns and the presence of approximately 15% snag trees providing wildlife habitat. This site had two of only four flora species of conservation concern found at all sites in all years (narrow-leaved spring beauty and running strawberry-bush). This site had a rich bird community with several area-sensitive species (those that need large forest tracts) and species of conservation concern listed at the federal, provincial and TRCA-level including one species listed federally as threatened.

Forest bird point counts and forest vegetation plot monitoring should occur again at a minimum in 2021 and at that point the monitoring data should be summarized and the monitoring plan should again be re-assessed.

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9 Appendix

Appendix 1. Monitoring plot name, plot code and UTM coordinates

Monitoring Plot Name	Northing (m)	Easting (m)
Heart Lake - Control, (FV-2)	4843397	597921
Heart Lake - Test, (FV-2A)	4843493	597094
Heart Lake – Bird Station 1	4843334	597918
Heart Lake – Bird Station 2	4843498	597695
Heart Lake – Bird Station 3	4843256	596978
Heart Lake – Bird Station 4	4843532	597079
Bruce's Mill - Test, (FV-23A)	4867091	632848
Bruce's Mill - Control, (FV-23B)	4867310	632677
Bruce's Mill - Bird Station 1	4867378	632679
Bruce's Mill - Bird Station 2	4867231	633299
Bruce's Mill - Bird Station 3	4867129	632857
Bruce's Mill - Bird Station 4	4867160	632577
Living City Campus - Test, (FV-35A)	4854139	612960
Living City Campus - Control, (FV-35B)	4854433	612908
Living City Campus – Bird Station 1	4854575	612766
Living City Campus – Bird Station 2	4854386	612935
Living City Campus – Bird Station 3	4854164	612996
Living City Campus – Bird Station 4	4853961	613168
Living City Campus – Bird Station 5	4853711	613304
Bolton Camp – Station 1	4860972	602271
Bolton Camp – Station 2	4860730	602312
Bolton Camp – Station 3	4860462	602362

Appendix 2. Nesting habitat preference for bird species

Common Name	Code	L	forest	edge	wetld	mead	gen	cav	low	mid	upr	aer	text summary
whip-poor-will	WPWI	L1											A) forest low-level nester
worm-eating warbler	WEWA	L1											A) forest low-level nester
black and white warbler	BAWW	L2											A) forest low-level nester
canada warbler	CAWA	L2											A) forest low-level nester
ruffed grouse	RUGR	L2											A) forest low-level nester
hermit thrush	HETH	L3											A) forest low-level nester
ovenbird	OVEN	L3											A) forest low-level nester
veery	VEER	L3											A) forest low-level nester
winter wren	WIWR	L3											A) forest low-level nester
hooded warbler	HOWA	L2											B) forest mid-level nester
black-throated blue warbler	BTBW	L3											B) forest mid-level nester
brown creeper	BRCR	L3											B) forest mid-level nester
magnolia warbler	MAWA	L3											B) forest mid-level nester
wood thrush	WOTH	L3											B) forest mid-level nester
red-eyed vireo	REVI	L4											C) forest upper-level nester
barred owl	BADO	L2											C) forest upper-level nester
broad-winged hawk	BWHA	L2											C) forest upper-level nester
cerulean warbler	CERW	L2											C) forest upper-level nester
merlin	MERL	L2											C) forest upper-level nester
nothern goshawk	NOGO	L2											C) forest upper-level nester
olive-sided flycatcher	OSFL	L2											C) forest upper-level nester
red-shouldered hawk	RSHA	L2											C) forest upper-level nester
Acadian flycatcher	ACFL	L3											C) forest upper-level nester
Blackburnian warbler	BLBW	L3											C) forest upper-level nester
black-throated green warbler	BTNW	L3											C) forest upper-level nester
blue-headed vireo	BHVI	L3											C) forest upper-level nester
golden-crowned kinglet	GCKI	L3											C) forest upper-level nester
long-eared owl	LEOW	L3											C) forest upper-level nester
northern saw-whet owl	NSWO	L3											C) forest upper-level nester
pileated woodpecker	PIWO	L3											C) forest upper-level nester
pine siskin	PISI	L3											C) forest upper-level nester
pine warbler	PIWA	L3											C) forest upper-level nester
ruby-crowned kinglet	RCKI	L3											C) forest upper-level nester
scarlet tanager	SCTA	L3											C) forest upper-level nester
sharp-shinned hawk	SSHA	L3											C) forest upper-level nester
white-winged crossbill	WWCR	L3											C) forest upper-level nester
wood duck	WODU	L3											C) forest upper-level nester
yellow-bellied sapsucker	YBSA	L3											C) forest upper-level nester
yellow-throated vireo	YTVI	L3											C) forest upper-level nester
blue-grey gnatcatcher	BGGN	L4											C) forest upper-level nester
Cooper's hawk	COHA	L4											C) forest upper-level nester
eastern screech-owl	EASO	L4											C) forest upper-level nester
eastern wood-pewee	EAWP	L4											C) forest upper-level nester

Common Name	Code	L	forest	edge	wetld	mead	gen	cav	low	mid	upr	aer	text summary
great-crested flycatcher	GCFL	L4											C) forest upper-level nester
hairy woodpecker	HAWO	L4											C) forest upper-level nester
red-breasted nuthatch	RBNU	L4											C) forest upper-level nester
white-breasted nuthatch	WBNU	L4											C) forest upper-level nester
blue-winged warbler	BWWA	L2											D) forest-edge low-level nester
golden-winged warbler	GWWA	L2											D) forest-edge low-level nester
American woodcock	AMWO	L3											D) forest-edge low-level nester
mourning warbler	MOWA	L3											D) forest-edge low-level nester
Nashville warbler	NAWA	L3											D) forest-edge low-level nester
white-throated sparrow	WTSP	L3											D) forest-edge low-level nester
wild turkey	WITU	L3											D) forest-edge low-level nester
ring-necked pheasant	RINP	L+											D) forest-edge low-level nester
yellow-breasted chat	YBCH	L2											E) forest-edge mid-level nester
American redstart	AMRE	L3											E) forest-edge mid-level nester
brown thrasher	BRTH	L3											E) forest-edge mid-level nester
chestnut-sided warbler	CSWA	L3											E) forest-edge mid-level nester
eastern towhee	EATO	L3											E) forest-edge mid-level nester
eastern bluebird	EABL	L4											E) forest-edge mid-level nester
indigo bunting	INBU	L4											E) forest-edge mid-level nester
rose-breasted grosbeak	RBGR	L4											E) forest-edge mid-level nester
ruby-throated hummingbird	RTHU	L4											E) forest-edge mid-level nester
downy woodpecker	DOWO	L5											E) forest-edge mid-level nester
red-headed woodpecker	RHWO	L3											F) forest-edge upper-level nester
yellow-rumped warbler	YRWA	L3											F) forest-edge upper-level nester
least flycatcher	LEFL	L4											F) forest-edge upper-level nester
purple finch	PUFI	L4											F) forest-edge upper-level nester
red-bellied woodpecker	RBWO	L4											F) forest-edge upper-level nester
American bittern	AMBI	L2											J) wetland low-level nester
American coot	AMCO	L2											J) wetland low-level nester
blue-winged teal	BWTE	L2											J) wetland low-level nester
canvasback	CANV	L2											J) wetland low-level nester
green-winged teal	AGWT	L2											J) wetland low-level nester
least bittern	LEBI	L2											J) wetland low-level nester
redhead	REDH	L2											J) wetland low-level nester
Caspian tern	CATE	L3											J) wetland low-level nester
common moorhen	COMO	L3											J) wetland low-level nester
common tern	COTE	L3											J) wetland low-level nester
great black-backed gull	GBBG	L3											J) wetland low-level nester
herring gull	HERG	L3											J) wetland low-level nester
pied-billed grebe	PBGR	L3											J) wetland low-level nester
sora	SORA	L3											J) wetland low-level nester
Virginia Rail	VIRA	L3											J) wetland low-level nester

Wilson's snipe	WISN	**L3**											J) wetland low-level nester

Common Name	**Code**	**L**	**forest**	**edge**	**wetld**	**mead**	**gen**	**cav**	**low**	**mid**	**upr**	**aer**	**text summary**
common yellowthroat	COYE	**L4**											J) wetland low-level nester
gadwall	GADW	**L4**											J) wetland low-level nester
ring-billed gull	RBGU	**L4**											J) wetland low-level nester
swamp sparrow	SWSP	**L4**											J) wetland low-level nester
Canada goose	CANG	**L5**											J) wetland low-level nester
mallard	MALL	**L5**											J) wetland low-level nester
black tern	BLTE	**LX**											J) wetland low-level nester
mute swan	MUSW	**L+**											J) wetland low-level nester
trumpeter swan	TRUS	**L+**											J) wetland low-level nester
marsh wren	MAWR	**L3**											K) wetland mid-level nester
alder flycatcher	ALFL	**L4**											K) wetland mid-level nester
black-crowned night heron	BCNH	**L3**											L) wetland upper-level nester
double-crested cormorant	DCCO	**L3**											L) wetland upper-level nester
great blue heron	GBHE	**L3**											L) wetland upper-level nester
great egret	GREG	**L3**											L) wetland upper-level nester
hooded merganser	HOME	**L3**											L) wetland upper-level nester
osprey	OSPR	**L3**											L) wetland upper-level nester
green heron	GRHE	**L4**											L) wetland upper-level nester
grasshopper sparrow	GRSP	**L2**											G) meadow low-level nester
upland sandpiper	UPSA	**L2**											G) meadow low-level nester
bobolink	BOBO	**L3**											G) meadow low-level nester
clay-coloured sparrow	CCSP	**L3**											G) meadow low-level nester
northern harrier	NOHA	**L3**											G) meadow low-level nester
sedge wren	SEWR	**L3**											G) meadow low-level nester
short-eared owl	SEOW	**L3**											G) meadow low-level nester
vesper sparrow	VESP	**L3**											G) meadow low-level nester
western meadowlark	WEME	**L3**											G) meadow low-level nester
eastern meadowlark	EAME	**L4**											G) meadow low-level nester
field sparrow	FISP	**L4**											G) meadow low-level nester
horned lark	HOLA	**L4**											G) meadow low-level nester
savannah sparrow	SAVS	**L4**											G) meadow low-level nester
spotted sandpiper	SPSA	**L4**											G) meadow low-level nester
Henslow's sparrow	HESP	**LX**											G) meadow low-level nester
willow flycatcher	WIFL	**L4**											H) meadow mid-level nester
loggerhead shrike	LOSH	**LX**											H) meadow mid-level nester
eastern kingbird	EAKI	**L4**											I) meadow upper-level nester
American black duck	ABDU	**L3**											M) generalist low-level nester
common nighthawk	CONI	**L3**											M) generalist low-level nester
killdeer	KILL	**L5**											M) generalist low-level nester
song sparrow	SOSP	**L5**											M) generalist low-level nester
black-billed cuckoo	BBCU	**L3**											N) generalist mid-level nester
yellow-billed cuckoo	YBCU	**L3**											N) generalist mid-level nester

Common Name	Code	L	forest	edge	wetld	mead	gen	cav	low	mid	upr	aer	text summary
barn swallow	BARS	**L4**											N) generalist mid-level nester
Carolina wren	CARW	**L4**											N) generalist mid-level nester
grey catbird	GRCA	**L4**											N) generalist mid-level nester
tree swallow	TRES	**L4**											N) generalist mid-level nester
American goldfinch	AMGO	**L5**											N) generalist mid-level nester
American robin	AMRO	**L5**											N) generalist mid-level nester
black-capped chickadee	BCCH	**L5**											N) generalist mid-level nester
cedar waxwing	CEDW	**L5**											N) generalist mid-level nester
chipping sparrow	CHSP	**L5**											N) generalist mid-level nester
common grackle	COGR	**L5**											N) generalist mid-level nester
eastern phoebe	EAPH	**L5**											N) generalist mid-level nester
house wren	HOWR	**L5**											N) generalist mid-level nester
mourning dove	MODO	**L5**											N) generalist mid-level nester
northern cardinal	NOCA	**L5**											N) generalist mid-level nester
northern mockingbird	NOMO	**L5**											N) generalist mid-level nester
red-winged blackbird	RWBL	**L5**											N) generalist mid-level nester
yellow warbler	YWAR	**L5**											N) generalist mid-level nester
European starling	EUST	**L+**											N) generalist mid-level nester
house finch	HOFI	**L+**											N) generalist mid-level nester
house sparrow	HOSP	**L+**											N) generalist mid-level nester
rock dove	ROPI	**L+**											N) generalist mid-level nester
American kestrel	AMKE	**L4**											O) generalist upper-level nester
chimney swift	CHSW	**L4**											O) generalist upper-level nester
cliff swallow	CLSW	**L4**											O) generalist upper-level nester
great-horned owl	GHOW	**L4**											O) generalist upper-level nester
northern flicker	NOFL	**L4**											O) generalist upper-level nester
peregrine falcon	PEFA	**L4**											O) generalist upper-level nester
American Crow	AMCR	**L5**											O) generalist upper-level nester
Baltimore oriole	BAOR	**L5**											O) generalist upper-level nester
blue jay	BLJA	**L5**											O) generalist upper-level nester
orchard oriole	OROR	**L5**											O) generalist upper-level nester
red-tailed hawk	RTHA	**L5**											O) generalist upper-level nester
warbling vireo	WAVI	**L5**											O) generalist upper-level nester
prothonotary warbler	PROW	**L2**											P) swamp mid-level nester
northern waterthrush	NOWA	**L3**											Q) swamp low-level nester
bank swallow	BANS	**L4**											special case
belted kingfisher	BEKI	**L4**											special case
northern rough-winged swallow	NRWS	**L4**											special case
purple martin	PUMA	**L4**											special case
turkey vulture	TUVU	**L4**											special case
brown-headed cowbird	BHCO	**L5**											special case

Appendix 3. Total stem counts and relative % cover found in the regeneration layer of forest plots at Heart Lake, Bruce's Mill and the Living City Campus (2013-2017).

Scientific name	Common name	L-rank	Total number of stems >16cm																Relative % cover													
			Heart Lake						Bruce's Mill						Living City Campus				Heart Lake						Bruce's Mill						Living City Campus			
			Adventure course			Control			Adventure course			Control			Potential adventure course		Control		Adventure course			Control			Adventure course			Control			Potential adventure course		Control	
			2013	2014	2017	2013	2014	2017	2013	2014	2018	2013	2014	2018	2013	2014	2013	2014	2013	2014	2017	2013	2014	2017	2013	2014	2018	2013	2014	2018	2013	2014	2013	2014
Taxus canadensis	Canada yew	L3										1	1															<1	<1					
Acer saccharinum	silver maple	L4								7																4.8								
Amelanchier arborea	downy serviceberry	L4			3																1.3												
Betula alleghaniensis	yellow birch	L4			1																<1												
Fagus grandifolia	American beech	L4										2	3	2														6.8	1.9	4.5				
Quercus rubra	red oak	L4	1	1	1														1.8	<1	<1													
Acer saccharum ssp. saccharum	sugar maple	L5	33	24	28	189	162	928	39	39	7	169	209	118	10	14	4	3	98.2	99.4	96.8	98.4	93.9	97.3	93.3	81.0	100.0	75.3	82.4	91.9	81.4	83.1	100	100
Cornus alternifolia	alternate-leaved dogwood	L5							1	1		12	19	3											6.7	14.3		15.7	12.9	<1				
Fraxinus americana	white ash	L5				2	4	2							8	11						1.1	4.4	2.0							18.6	16.9		
Parthenocissus vitacea	thicket creeper	L5					3	2															<1	<1										
Prunus virginiana var. virginiana	choke cherry	L5			1							2	3	2							<1							<1	<1	1.1				
Sambucus racemosa ssp. pubens	red-berried elder	L5										1	1	1														<1	<1	<1				
Rhamnus cathartica	common buckthorn	L+				2	2	2				1	2	1								<1	1.1	<1				<1	<1	<1				
Viburnum lantana	wayfaring tree	L+										1	1	1														<1	<1	<1				
Viburnum opulus ssp. opulus	European highbush cranberry	L+										1	2	2														<1	<1	<1				

Appendix 4. Ground vegetation flora species occurrence and relative % cover found in forest plots at Heart Lake, Bruce's Mill and the Living City Campus (2013-2017).

Scientific name	Common name	L-rank	Number of quadrats																Relative % cover													
			Heart Lake						Bruce's Mill						Living City Campus				Heart Lake						Bruce's Mill						Living City Campus			
			Adventure course			Control			Adventure course			Control			Adventure course		Control		Adventure course			Control			Adventure course			Control			Adventure course		Control	
			2013	2014	2017	2013	2014	2017	2013	2014	2018	2013	2014	2018	2013	2014	2013	2014	2013	2014	2017	2013	2014	2017	2013	2014	2018	2013	2014	2018	2013	2014	2013	2014
Claytonia virginica	narrow-leaved spring beauty	L3													1																2.6			
Allium tricoccum	wild leek	L4							2	2	1														<1	<1	5.5							
Betula papyrifera	paper birch	L4			1																2.3													
Caulophyllum giganteum	long-styled blue cohosh	L4				1	1	1					1	2								77.7	12.7	64.9					1.3	3.5				
Maianthemum canadense	Canada May-flower	L4													1															1.3				
Quercus rubra	red oak	L4		1																4.8													
Trillium grandiflorum	white trillium	L4							1	1															<1	<1								
Tsuga canadensis	eastern hemlock	L4		1	1									2		3				4.8	2.3						1.4			2.9			
Acer saccharinum	silver maple	L4												1													4.2						
Acer saccharum ssp. saccharum	sugar maple	L5	1	4		5	5	5	4	5	5	5	5	5	3	5	5	5	3.1	19.0		19.1	86.0	14.9	2.6	4.5	6.6	13.0	30.3	52.8	3.9	41.2	20.5	76.4
Arisaema triphyllum	Jack-in-the-pulpit	L5		1		1	1	1				4	4	3	3	2	4	4		4.8		<1	<1	<1				5.3	14.5	4.9	10.4	4.9	48.7	9.0
Circaea canadensis ssp. canadensis	enchanter's nightshade	L5								1					1	1										<1					10.4	7.8		
Cornus alternifolia	alternate-leaved dogwood	L5							1	1				1											<1	<1				<1				
Erythronium americanum ssp. americanum	yellow trout-lily	L5					1		5	5	4	4	4	4	2	5	2	5					<1		13.1	7.7	5.5	79.8	46.1	27.8	5.2	8.8	7.7	7.9
Fraxinus americana	white ash	L5										1			5	4	5	3										<1			9.1	4.9	15.4	3.4
Geum canadense	white avens	L5			1																2.3													
Hackelia virginiana	Virginia stickseed	L5									1			1		1											2.2			<1		1.0		
Hydrophyllum virginianum	Virginia waterleaf	L5							4	4	4														82.6	86.4	69.2							
Impatiens capensis	orange touch-me-not	L5				2	2	2						1								1.3	<1	2.6						2.8				
Maianthemum racemosum ssp. racemosum	false Solomon's seal	L5										1	2	1	1													<1	6.6	<1	1.3			
Podophyllum peltatum	May-apple	L5													1	1															15.6	11.8		
Prunus virginiana var. virginiana	choke cherry	L5	1																3.1															
Solidago altissima	tall goldenrod	L5			2					1	1										4.5					<1	3.3							
Vitis riparia	riverbank grape	L5		2							1	1						2		9.5							<1	<1						2.2
Bidens frondosa	common beggar's-tick	L5									1																<1							
Alliaria petiolata	garlic mustard	L+	2	1		2	3	3							2	2	1	1	6.3	4.8		1.3	<1	16.7							22.1	10.8	5.1	1.1
Cirsium arvense	creeping thistle	L+			1																2.3													
Epipactis helleborine	helleborine	L+	1	1	1				1								1		3.1	4.8	2.3				<1								2.6	
Plantago major	common plantain	L+			1																2.3													
Poa nemoralis	woodland spear grass	L+	3	4	2														81.3	42.9	72.7													
Taraxacum officinale	dandelion	L+	1	1	2						4	1		1					3.1	4.8	4.5						2.8	<1		<1				
Trifolium repens	white clover	L+			2																4.5													
Viburnum lantana	wayfaring tree	L+											1																1.3					
Geum urbanum	urban avens	L+									2																2.8							
Chelidonium majus	celandine	L+									1																<1							
Acer negundo	Manitoba maple	L+?							1	1															<1	<1								
Geranium robertianum	herb Robert	L+?									1				1	1											<1				18.2	5.9		

Appendix 5. List of flora species found in forest plots at Heart Lake, Bruce's Mill and the Living City Campus (2013-2017).

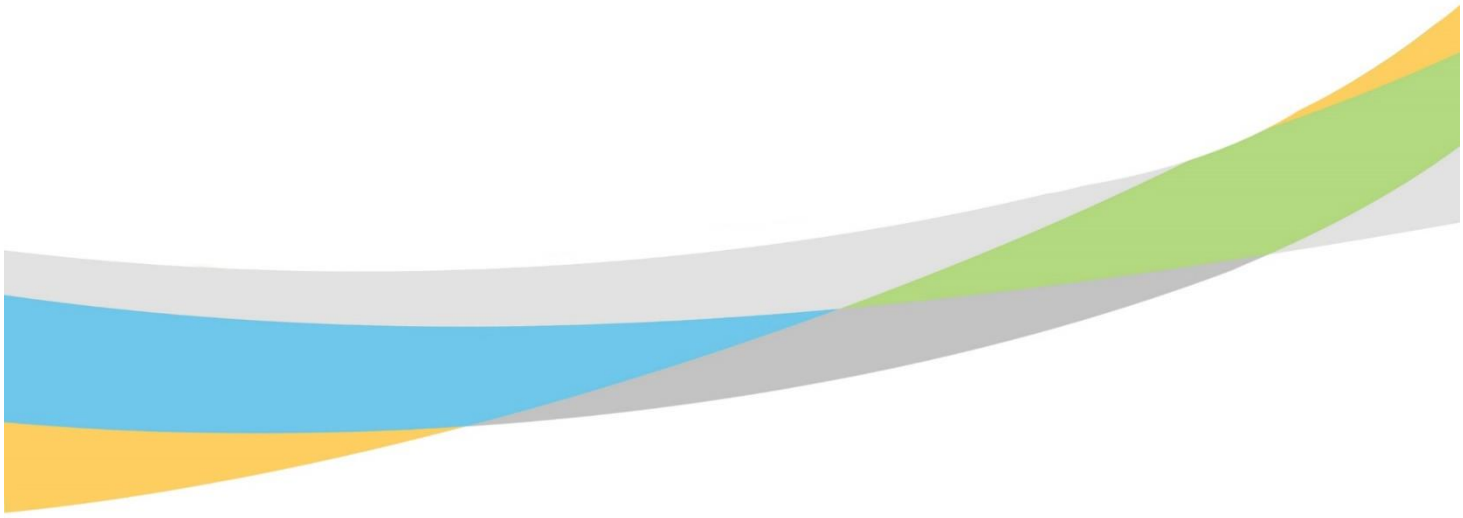
Scientific name	Common name	L-rank (2017)	Co-efficient of Conservatism	Plant type	Heart Lake						Bruce's Mill						Living City Campus			
					Adventure course			Control			Adventure course			Control			Potential adventure course		Control	
					2013	2014	2017	2013	2014	2017	2013	2014	2018	2013	2014	2018	2013	2014	2013	2014
Total number of species			Total number of species		24	36	47	15	24	27	35	33	34	33	32	43	30	29	21	27
Persicaria sagittata	arrow-leaved tear-thumb	L2	5	FO					x											
Claytonia virginica	narrow-leaved spring beauty	L3	5	FO													x	x		x
Euonymus obovatus	running strawberry-bush	L3	6	SH															x	x
Taxus canadensis	Canada yew	L3	7	SH										x	x	x				
Acer rubrum	red maple	L4	4	TR	x	x														
Acer saccharinum	silver maple	L4	5	TR								x				x				
Actaea pachypoda	white baneberry	L4	6	FO							x	x	x	x		x				
Allium tricoccum	wild leek	L4	7	FO							x	x	x				x	x		x
Amelanchier arborea	downy serviceberry	L4	5	SH			x													
Amelanchier laevis	smooth serviceberry	L4	5	SH		x														
Betula alleghaniensis	yellow birch	L4	6	TR			x													
Betula papyrifera	paper birch	L4	2	TR			x													
Cardamine diphylla	broad-leaved toothwort	L4	7	FO							x	x	x							
Carya cordiformis	bitternut hickory	L4	6	TR									x				x	x	x	x
Caulophyllum giganteum	long-styled blue cohosh	L4	6	FO				x	x	x	x	x	x	x	x	x	x	x		x
Cornus rugosa	round-leaved dogwood	L4	6	SH		x														
Fagus grandifolia	American beech	L4	6	TR							x	x	x	x	x	x				x
Lactuca biennis	tall blue lettuce	L4	6	FO												x				
Maianthemum canadense	Canada May-flower	L4	5	FO										x	x	x	x			
Polygonatum pubescens	downy Solomon's seal	L4	5	FO												x				
Quercus macrocarpa	bur oak	L4	5	TR										x	x	x				
Quercus rubra	red oak	L4	6	TR	x	x	x		x	x										
Trillium erectum	red trillium	L4	6	FO							x	x		x	x	x				
Trillium grandiflorum	white trillium	L4	5	FO							x	x	x	x	x	x	x	x		
Tsuga canadensis	eastern hemlock	L4	7	TR		x	x						x	x		x		x		
Acer saccharum ssp. saccharum	sugar maple	L5	4	TR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Actaea rubra ssp. rubra	red baneberry	L5	5	FO										x	x	x				
Arisaema triphyllum	Jack-in-the-pulpit	L5	5	FO		x		x	x	x	x	x	x	x	x	x	x	x	x	x
Asclepias syriaca	common milkweed	L5	0	FO			x													
Bidens frondosa	common beggar's-ticks	L5	3	FO					x				x			x				
Carex arctata	nodding wood sedge	L5	5	SE												x				
Carex pedunculata	early-flowering sedge	L5	5	SE													x	x		
Carex rosea	curly-styled sedge	L5	5	SE													x	x		
Circaea canadensis ssp. canadensis	enchanter's nightshade	L5	3	FO			x			x	x	x	x	x	x	x	x	x	x	x
Cornus alternifolia	alternate-leaved dogwood	L5	6	SH	x		x				x	x	x	x	x	x			x	x
Cornus foemina ssp. racemosa	grey dogwood	L5	2	SH			x													
Cornus stolonifera	red osier dogwood	L5	2	SH						x										
Dryopteris carthusiana	spinulose wood fern	L5	5	FE													x	x	x	x
Echinocystis lobata	wild cucumber	L5	3	VI										x						
Epilobium coloratum	purple-leaved willow-herb	L5	3	FO			x													
Erigeron annuus	daisy fleabane	L5	0	FO			x													
Erigeron philadelphicus var. philadelphicus	Philadelphia fleabane	L5	1	FO		x	x													
Erythronium americanum ssp. americanum	yellow trout-lily	L5	5	FO				x	x	x	x	x	x	x	x	x	x	x	x	x
Fragaria virginiana ssp. virginiana	common wild strawberry	L5	2	FO			x													
Fraxinus americana	white ash	L5	4	TR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Galium aparine	cleavers	L5	4	FO															x	x
Galium triflorum	sweet-scented bedstraw	L5	4	FO											x					
Geum canadense	white avens	L5	3	FO		x	x										x	x		
Glyceria striata	fowl manna grass	L5	3	GR										x	x	x				
Hackelia virginiana	Virginia stickseed	L5	5	FO				x	x		x	x	x			x	x	x	x	
Hydrophyllum virginianum	Virginia waterleaf	L5	6	FO							x	x	x			x				
Impatiens capensis	orange touch-me-not	L5	4	FO	x			x	x	x	x	x	x	x	x	x				
Juglans nigra	black walnut	L5	5	TR							x	x								
Juncus tenuis	path rush	L5	0	RU		x														
Maianthemum racemosum ssp. racemosum	false Solomon's seal	L5	4	FO	x	x					x	x	x	x	x	x	x	x		
Ostrya virginiana	ironwood	L5	4	TR				x	x	x							x	x		
Oxalis stricta	common yellow wood-sorrel	L5	0	FO	x	x														
Parthenocissus vitacea	thicket creeper	L5	3	VW	x	x	x	x	x	x						x				
Phryma leptostachya	lopseed	L5	6	FO									x		x					
Podophyllum peltatum	May-apple	L5	5	FO													x	x		
Prunella vulgaris ssp. lanceolata	heal-all (native)	L5	5	FO	x	x	x													
Prunus serotina	black cherry	L5	3	TR						x				x	x	x			x	x
Prunus virginiana var. virginiana	choke cherry	L5	2	SH	x	x	x	x	x	x		x	x	x	x	x			x	
Ranunculus abortivus	kidney-leaved buttercup	L5	2	FO	x	x									x	x	x	x	x	x

Appendix 5 (cont'd). List of flora species found in forest plots at Heart Lake, Bruce's Mill and the Living City Campus (2013-2017).

Scientific name	Common name	L-rank (2017)	Co-efficient of Conservatism	Plant type	Heart Lake						Bruce's Mill						Living City Campus			
					Adventure course			Control			Adventure course			Control			Potential adventure course		Control	
					2013	2014	2017	2013	2014	2017	2013	2014	2018	2013	2014	2018	2013	2014	2013	2014
Ranunculus recurvatus var. recurvatus	hooked buttercup	L5	4	FO											x	x				
Ribes americanum	wild black currant	L5	4	SH							x	x								
Ribes cynosbati	prickly gooseberry	L5	4	SH							x	x								
Rubus allegheniensis	common blackberry	L5	2	SH						x										
Rubus idaeus ssp. strigosus	wild red raspberry	L5	0	SH			x			x							x			
Rubus occidentalis	wild black raspberry	L5	2	SH														x		
Sambucus racemosa ssp. pubens	red-berried elder	L5	5	SH			x							x	x	x	x	x		
Sanguinaria canadensis	bloodroot	L5	5	FO													x	x		
Solidago altissima	tall goldenrod	L5	1	FO			x		x	x	x	x	x	x		x			x	x
Solidago caesia	blue-stemmed goldenrod	L5	5	FO	x	x	x										x	x		
Solidago flexicaulis	zig-zag goldenrod	L5	6	FO	x	x														
Solidago gigantea	late goldenrod	L5	4	FO		x	x													
Symphyotrichum lanceolatum var. lanceolatum	panicled aster	L5	3	FO		x	x			x	x									
Symphyotrichum lateriflorum var. lateriflorum	calico aster	L5	3	FO	x															
Tilia americana	basswood	L5	4	TR		x					x	x	x							
Ulmus americana	white elm	L5	3	TR							x	x	x							x
Viola pubescens var. pubescens	downy yellow violet	L5	5	FO										x	x					
Viola pubescens var. scabriuscula	smooth yellow violet	L5	5	FO										x		x				
Vitis riparia	riverbank grape	L5	0	VW	x	x	x		x	x	x	x	x	x	x	x	x	x		x
Acer platanoides	Norway maple	L+		TR			x				x									
Aesculus glabra	Ohio buckeye	L+		TR			x													
Alliaria petiolata	garlic mustard	L+		FO	x	x	x	x	x	x	x	x					x	x	x	x
Arctium minus	common burdock	L+		FO	x	x	x	x	x	x				x	x	x				
Cerastium fontanum	mouse-ear chickweed	L+		FO			x													
Chelidonium majus	celandine	L+		FO							x		x			x				
Chenopodium album	lamb's quarters	L+		FO									x							
Cirsium arvense	creeping thistle	L+		FO			x													
Cynanchum rossicum	dog-strangling vine	L+		VI				x	x	x							x			
Epipactis helleborine	helleborine	L+		FO	x	x	x				x		x	x			x	x	x	x
Geum urbanum	urban avens	L+		FO	x	x	x			x	x	x	x							
Lactuca serriola	prickly lettuce	L+		FO			x		x											
Lonicera x bella	shrub honeysuckle	L+		SH		x			x	x					x					
Malus pumila	apple	L+		TR			x		x	x						x				
Medicago lupulina	black medick	L+		FO		x	x													
Plantago major	common plantain	L+		FO	x	x	x													
Poa nemoralis	woodland spear grass	L+		GR	x	x	x													
Polygonum aviculare ssp. aviculare	prostrate knotweed	L+		FO			x													
Rhamnus cathartica	common buckthorn	L+		SH			x	x	x	x	x	x	x	x	x	x			x	x
Rosa multiflora	multiflora rose	L+		SH		x														x
Solanum dulcamara	bittersweet nightshade	L+		VW	x	x	x	x	x	x						x			x	x
Solanum nigrum	black nightshade	L+		FO			x													
Sonchus asper	spiny sow-thistle	L+		FO			x													
Sonchus spp.	sow-thistle spp.	L+		FO		x														
Taraxacum officinale	dandelion	L+		FO	x	x	x		x	x	x	x	x	x	x	x	x			
Trifolium pratense	red clover	L+		FO		x														
Trifolium repens	white clover	L+		FO			x													
Viburnum lantana	wayfaring tree	L+		SH							x	x	x	x	x	x				
Viburnum opulus ssp. opulus	European highbush cranberry	L+		SH							x	x		x	x	x			x	x
Acer negundo	Manitoba maple	L+?		TR			x				x	x	x					x	x	x
Geranium robertianum	herb Robert	L+?		FO									x				x	x		x

Appendix 6. Average avian abundance by species, site, station type and year

Species name	Nesting guild	L-rank	Bolton Camp										Bruce's Mill												Heart Lake												Living City Campus									
			Control					Potential adventure course					Control						Adventure course						Control						Adventure course						Control					Potential adventure course				
			2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
ovenbird	forest low-level nester	L2											1																								1									
American redstart	forest-edge mid-level nester	L3																											1	1																
Blackburnian warbler	forest upper-level nester	L3																																				1								
black-throated green warbler	forest upper-level nester	L3											1																																1	
brown creeper	forest mid-level nester	L3																											1																
chestnut-sided warbler	forest-edge mid-level nester	L3																											1																
eastern towhee	forest-edge mid-level nester	L3																																									1				
great blue heron	wetland upper-level nester	L3																															1												
mourning warbler	forest-edge low-level nester	L3	1					1					0.5	1		0.5	0.5		1																								1				
pileated woodpecker	forest upper-level nester	L3																										1	1	1				1		2				0.5	0.5		1			1	
scarlet tanager	forest upper-level nester	L3																																			1	0.75				1					
veery	forest low-level nester	L3											1		1														1																
winter wren	forest low-level nester	L3											1	1	1	1	1																				1								
wood thrush	forest mid-level nester	L3	1																								0.5	0.5									1	1.5	1.25			2	1	2	
belted kingfisher	special case	L4																															1												
blue-gray gnatcatcher	forest upper-level nester	L4												1							1					1		1																
common yellowthroat	wetland low-level nester	L4	1										0.5	1	2	0.5										0.5		0.5	0.5		1									1				
eastern kingbird	meadow upper-level nester	L4													1																													
eastern wood-pewee	forest upper-level nester	L4											1.67	1.67	0.33	1	1.33	1	1	1	1	1			0.33	1.33	1.33	1.33	1.33	2	1			1		1	1.25	1	0.75	0.5		1	1	1	1	
field sparrow	meadow low-level nester	L4	1																																									
gray catbird	generalist mid-level nester	L4	1											1		1		1								1		1												1	1				
great crested flycatcher	forest upper-level nester	L4	1					1					0.67	1.33	1.33	0.33		2	1		1			1	0.33	0.67	0.33	0.67	0.67			1				1				0.33	0.67		1			1	
great horned owl	generalist upper-level nester	L4																																							1				
hairy woodpecker	forest upper-level nester	L4	1										0.5				1								0.5	0.5	0.5			1.5				1		1							1				
indigo bunting	forest-edge mid-level nester	L4	3					1					2		1	2	1	1	1	2	1																			0.5		0.5					
northern flicker	generalist upper-level nester	L4						1							1	1				1							0.5	0.5	1.5	1	2			1						0.5	0.5	0.5					
pine warbler	forest upper-level nester	L4																																			0.75	1	0.5	0.75		1		1	1	
red-bellied woodpecker	forest-edge upper-level nester	L4															1					1	1						1	1				2											
red-breasted nuthatch	forest upper-level nester	L4													1	1			1		1				0.33	0.67	0.67	0.67						1	1			0.67	0.33	0.67	0.67					1	
red-eyed vireo	forest mid-level nester	L4	3					4					2.33	2.67	2.33	2.33	1.67	2	2	3	1	3	2	2	2.33	2.33	3	2.67	2	2.33	1			1	1		1.5	1.75	2.25	1.75		2	3	4	2	
rose-breasted grosbeak	forest-edge mid-level nester	L4	1.5											0.5	0.5		0.5	1			1								1						1					0.5	1					1	
ruby-throated hummingbird	forest-edge mid-level nester	L4																				1				1	0.5				1														
swamp sparrow	wetland low-level nester	L4																									1																	
turkey vulture	special case	L4																										1																
white-breasted nuthatch	forest upper-level nester	L4															1						1	1					2	1				1											
wood duck	forest upper-level nester	L4																																							0.5	0.5				
American crow	generalist upper-level nester	L5						2					0.33	0.33	0.33	1.67		2		2		1		1				1.5	1									0.33	0.33	0.67					
American goldfinch	generalist mid-level nester	L5													0.67		1.67	3	1		3		2	3	0.33	0.67	1.33		0.33		1			3	1			0.33	0.67					
American robin	generalist mid-level nester	L5	1					1					1	0.33	0.67	0.67	3	1	2	2	3	1	1	3	0.33		0.67	1	2.33	1	1	1	2	4	3	1	1.25	0.75	1.5	1.5		1	1	1	2	
Baltimore oriole	generalist upper-level nester	L5												1		1	1											1		1		1		1						2				
black-capped chickadee	generalist mid-level nester	L5	1.5					1					1.33	1	1.33	0.33	1	1			1	1	1		1	1.33	1.33	2	2.33	1.33	1	1	1	3	1		1.5	0.5	1.75	1.5		1	2	2	1	
blue jay	generalist upper-level nester	L5	1										0.67	0.67	1	1	0.67	1					2		0.5	1	1		0.5	1							1	1.25	1.25	1		1	1	3		
brown-headed cowbird	special case	L5																			1		1																		1				
Canada goose	wetland low-level nester	L5																														1												
cedar waxwing	generalist mid-level nester	L5											0.5	0.5	0.5		0.5			1			1				1		0.5	3						1		2	1						
chipping sparrow	generalist mid-level nester	L5																													1				1									
common grackle	generalist mid-level nester	L5	1					1					0.33	0.33	0.67		0.33	1									0.5		1	1.33			1		1	1		0.33	1						
downy woodpecker	forest-edge mid-level nester	L5	1												1	0.5										0.67	0.67	1	0.67	1									0.5	0.5					
eastern phoebe	generalist mid-level nester	L5																										1																
house wren	generalist mid-level nester	L5												1		1	1				1		1									2												
mourning dove	generalist mid-level nester	L5	1												1																														
northern cardinal	generalist mid-level nester	L5											0.67		0.67	0.33	0.67	1.67				1		1					1	2		1	2	1		2	0.33	0.33	0.67						
red-tailed hawk	generalist upper-level nester	L5																								1	2			1														
red-winged blackbird	generalist mid-level nester	L5	1												0.5	0.5		1.5							0.33	0.33	1.67	0.33		1.5	1	1	3	2	1	2									
song sparrow	generalist low-level nester	L5											0.5	0.5	1	1	1	1.5	1	2	2	1	1		0.33		0.33	0.33	0.33			1							1						
warbling vireo	generalist upper-level nester	L5																												1			1	0	1	1	1							
yellow warbler	generalist mid-level nester	L5																										1		1					1									



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