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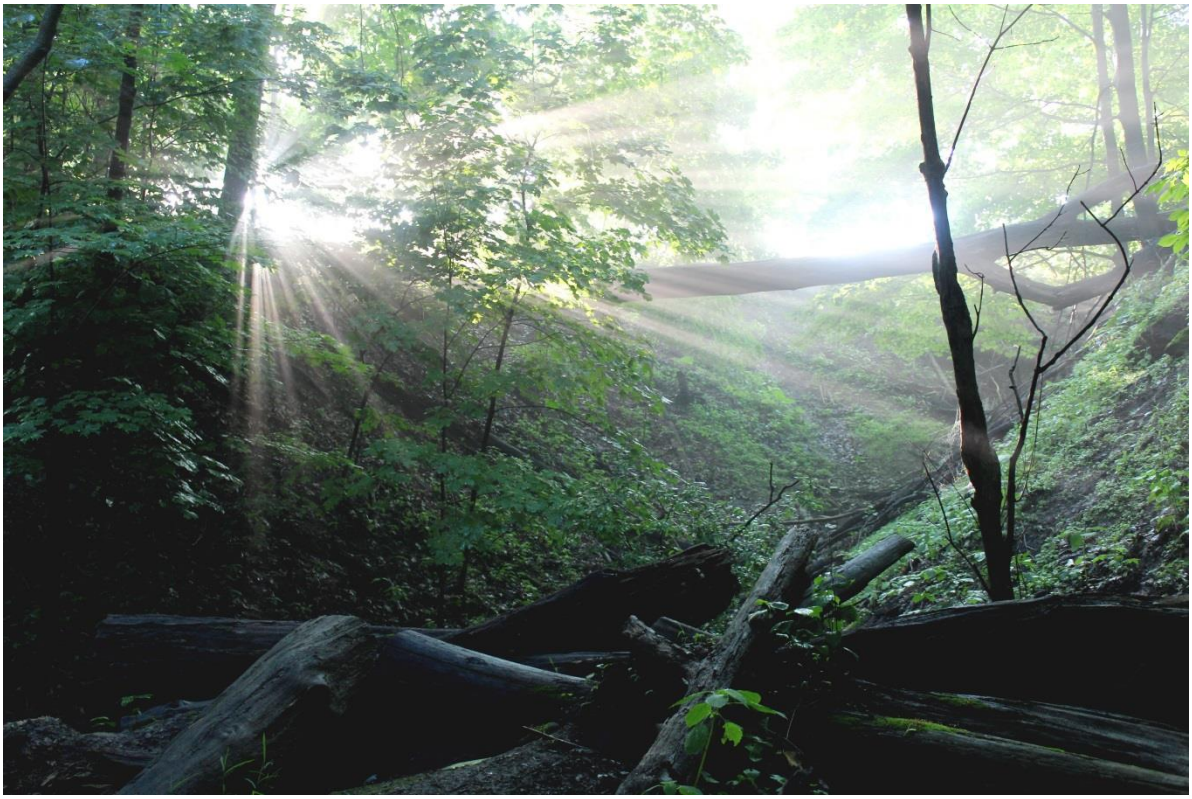
Natural Lands Department

2017 Environmental Condition of Cootes Paradise South Shore



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RBG Report # 2018-12

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Document Description

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Front cover photo of Westdale Ravine taken by Dave d'Entremont (2011).

Executive Summary

Located at the westernmost tip of Lake Ontario, and surrounded by the Niagara Escarpment, Cootes Paradise Nature Sanctuary is an important migratory bird stopover and became a formal wildlife sanctuary in 1927. This sanctuary covers over 600 hectares and features a 320-hectare river-mouth marsh, 16 creeks, and 25 kilometers of shoreline. The RBG lands surrounding Cootes Paradise Marsh can be divided into the North Shore and the South Shore, both with unique characteristics and challenges. The North Shore contains relatively large tracts of intact forest cover and is primarily surrounded by agricultural fields. Meanwhile, the South Shore consists of a much narrower strip of forest directly adjacent to a highly populated residential area. For this reason, the South Shore faces a variety of issues threatening its long-term sustainability. Some of these issues include the introduction and proliferation of non-native and potentially invasive species, dumping, bank erosion, and the creation of informal trails trampling understory and disturbing sensitive wildlife. RBG natural lands staff has established several monitoring programs including long-term forest monitoring, breeding bird surveys, marsh monitoring surveys, and a variety of smaller programs in order to better understand the implications of these problems.

Overall, long-term monitoring indicates the South Shore of Cootes Paradise has shown significant signs of decline over the past 50 years accelerating in recent years. Although canopy tree composition in forest monitoring plots has not shown substantial changes, overall forest cover appears to have declined dramatically, by approximately 34% since 1934. This indicates that roughly 22 hectares of previously forested land has lost trees and declined to woodland, savannah, or regenerating thicket. No tree thinning projects were undertaken by RBG during this period. Surveys conducted in the small tree and shrub layer over the past decade show high penetration of non-native species in the understory. A total of 6 non-native species were detected, making up 5.24% of the relative cover in this layer. The most prominent non-native species were Common Buckthorn, Glossy Buckthorn, Sweet Cherry, and Honeysuckle species. The ground vegetation layer showed the greatest signs of decline, both in terms of a loss of native species, and an increase in the dominance of non-native species. The number of non-native species detected increased from 6 species when surveys began, up to 17 species in the most recent round of surveying, making up 39% of cover in the ground vegetation layer. Native species cover decreased from 28.18% to 26.23% while non-native species cover increased from 3% to 16.8% over the course of monitoring between 2009 and 2016. Woodland Speargrass, Garlic Mustard, and Glossy Buckthorn were the most dominant non-native species in the ground layer.

Breeding bird surveys conducted on the South Shore indicate some changes in species composition over time. Yellow Warblers and Brown Creepers showed the greatest signs of decline in terms of detections. A general lack of ground nesting birds and interior forest birds suggests a lack of suitable habitat for these species on the South Shore. On top of this, European Starlings, an introduced species, have shown a dramatic increase in detections, making them the most commonly detected bird in 2017. European Starlings are likely competing with native birds for resources and nesting sites, while contributing to the spread of non-native vegetation across the property as they feed on berries from their continent of origin.

Amphibian monitoring shows that detections of frog species remain rare and have not changed substantially since surveys began in 1995. American Toad detections appear to have declined slightly in recent years; however they are still observed fairly regularly on the South Shore. Recent detections

of Wood Frogs and Western Chorus Frogs might indicate positive change in marsh conditions with ongoing restoration efforts. Green Frogs and Northern Leopard Frogs remained the most commonly detected species, being observed in 17 and 16 years of surveying respectively.

Surveys of RBG's forested property boundaries reinforced concerns of the spread of invasive species on the South Shore. Overall, approximately 150 different non-native species were detected in the surveyed forest boundary edges with the urban areas. Results suggest that maintained gardens and residential areas directly adjacent to natural areas serve as potential sources of exotic plants.

RBG staff should continue to gather data from all of the above-mentioned monitoring programs in order to better understand the challenges faced on the South Shore of Cootes Paradise. When conducting long-term forest monitoring in the future, Vegetation Sampling Protocols should be used to assess the impacted small tree and shrub layer. This method gives the best measure of dominance per species in the forest and standardizing this practice will allow for more accurate comparisons of data over time.

One of the most obvious issues on the South Shore is the proliferation of non-native species. Staff should continue with current efforts to work with partners along the edges as well as to remove invasive species from sensitive areas, such as interior forest, and around Species at Risk populations. These removals should be followed up with native species plantings, especially in areas previously dominated by non-natives or in areas with already declined canopy cover. Management techniques specific to *Poa nemoralis* (Woodland Bluegrass) should also continue to be pursued, as this species is quickly becoming one of the most concerning invasive plants on the South Shore. RBG should also consider working with the Cootes to Escarpment EcoPark System staff and local residents to provide education to landowners on the hazards associated with maintaining invasive species in gardens adjacent to natural areas and dumping yard waste.

It is also recommended that standardized salamander monitoring take place on the South Shore, including President's Pond. This will help to provide a more thorough understanding of the distribution of species that currently occur on the property. In addition, staff might consider digging new ephemeral ponds to mitigate the filling effect pre-existing ponds have seen over time.

Many of the ecosystem disturbances facing the South Shore of Cootes Paradise can be attributed to pressures from the surrounding urban environment. Off-trail use, dogs off leash, yard-waste dumping, encroachment, squatters, campfires etc. are all disturbances that are impacting the forest ecosystem. Increasing staff presence along with education and outreach initiatives with the adjacent community should reduce these impacts; however RBG should consider the feasibility of limiting public access to a lower number of more manageable main entrances and/or maintaining some form of facilities on the South Shore.

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Introduction

Royal Botanical Gardens (RBG) is a not-for-profit organization with the mission to promote the public's understanding of the relationship between the plant world, society and the environment. RBG's properties are located west of Burlington, north of Hamilton, and east of Dundas. They span approximately 1,100 hectares and consist of formal gardens and natural lands, including Lake Ontario coastal marsh, interior Carolinian forest, and talus slopes of the Niagara escarpment. RBG's natural lands are recognized as important habitat through several significant designations:

- Important Area for Reptiles and Amphibians (IMPARA)
- Class 1 and 2 wetlands
- Environmentally Sensitive Area (ESA)
- Area of Natural and Scientific Interest (ANSI)
- UNESCO World Biosphere Reserve
- Important Bird Area (IBA)

At the heart of Royal Botanical Gardens is its largest and most diverse nature sanctuary, Cootes Paradise. This sanctuary covers over 600 hectares and features a 320-hectare river-mouth marsh, 16 creeks, and 25 kilometers of shoreline. Located at the westernmost tip of Lake Ontario, and surrounded by the Niagara Escarpment, Cootes Paradise is an important migratory bird stopover and became a formal wildlife sanctuary in 1927. This sanctuary also features unique and diverse flora, consisting of Carolinian species on the uplands, and more northern species in the spring-fed shady ravines. The lands surrounding Cootes Paradise Marsh can be divided into the larger North Shore, bordered by agricultural lands and sparse residential areas, and the South Shore, a much smaller tract of land forming a narrow strip of forest between the marsh and the surrounding dense urban areas of Westdale and McMaster University in Hamilton. This report will focus on the status of the lands forming the South Shore of Cootes Paradise nature sanctuary.

The South Shore of Cootes Paradise Marsh is known for its beauty and natural heritage attractions. These factors have made the South Shore extremely popular for recreational activities including trail use, bird watching, photography, nature study, and educational programming. However, the combination of these factors along with a general proximity to urban development and subsequent encroachment has contributed to stress on this sensitive area, potentially threatening its long-term sustainability. Threats currently facing the South Shore of Cootes Paradise include the introduction and proliferation of non-native and potentially invasive species, dumping, bank erosion, and the creation of informal trails (Burtenshaw, 2010), (McPhee, 2015), (City of Hamilton, Royal Botanical Gardens, 2017). The South Shore of Cootes Paradise is also home to a variety of rare and at-risk species including plant species such as Butternut (*Juglans cinerea*), American Chestnut (*Castanea dentata*), Eastern Flowering Dogwood (*Cornus florida*), and Few-flowered Club-rush (*Trichophorum planifolium*); all of which are also threatened by the previously mentioned stressors. RBG staff has initiated several long-term monitoring studies in order to better understand how these factors influence the forests of the South Shore and the species that occupy them.

The first of these monitoring initiatives is the RBG Forest Monitoring Program. This program was started in 2008 with the goal of gathering high quality baseline forest information over the long-term, in order to identify potential threats or stressors to the terrestrial ecosystem. These data can then be used

to better guide future management decisions to help mitigate threats in an adaptive management process. There are a number of factors, both biotic and abiotic, that collectively affect the forest ecosystem negatively, including invasive species, pests and pathogens, human disturbance, and a changing climate. Forest monitoring protocols at RBG are designed to detect the change caused by any of these factors and allows RBG to react accordingly (Burtenshaw, 2010).

Since 2008, the same five forest monitoring plots on the South Shore have been surveyed every four years using Environment Canada's Ecological Monitoring and Assessment Network (EMAN). This protocol examines plant species diversity across three vertical forest layers broken down into: the canopy tree layer, the small tree and shrub layer, and the ground vegetation layer. This allows RBG staff to monitor species richness, composition, dominance, tree regeneration and tree health throughout a given forest community overtime (Burtenshaw, 2010), (Roberts-Pichette & Gillespie, 1999).

Another long term monitoring initiative conducted at RBG are breeding bird surveys. These surveys have also been conducted on the South Shore every year since 2008 in order to compliment the RBG Forest Monitoring Program. The breeding bird surveys look to accumulate long-term data on bird community composition and abundance during peak breeding season. Trends in bird population data are reflective of habitat quality since resident breeding birds are dependent on local ecosystem resources (Ellis, 2017). In other words, declines in certain bird species provide an indication that the resources or habitat that the species requires may also be in decline. This study also allows for the detection of increasing trends in bird populations, which can represent a positive rebound in a population, or the proliferation of a non-native species.

Amphibian Marsh Monitoring is another long-term monitoring program that has been conducted at RBG since 1995. The Great Lakes Marsh Monitoring Program (GLMMP) was established by Bird Studies Canada (BSC) in partnership with Environment Canada and the United States Environmental Protection Agency to assess the distribution and occurrence of amphibians across the Great Lakes Basin (Tozer, 2013). The presence or absence of amphibians is used as an indicator of marsh health, as amphibians are very sensitive to environmental stresses. RBG staff and volunteers have been collecting Marsh Monitoring Program (MMP) data from a total of seven sites along the South Shore since the program's inception to monitor any local changes in marsh health.

One main area of concern on the South Shore of Cootes Paradise is the spread of non-native and invasive species. A major pathway for the introduction of non-native species is from ornamental garden plants. This is an even bigger problem when gardens that contain these invasive plants directly border natural areas, especially forests. Most species spread by dispersed seeds, while some spread through vegetative reproduction. In both cases, the closer the plants are to the natural area, the more likely they are to spread into the adjacent natural habitat (Gavier-Pizzaro, Radeloff, Stewart, Huebner, & Keuler, 2010), (McWilliam, 2010). In order to gain a better understanding of this issue at RBG, surveys for non-native species were conducted along several forest edge property boundaries and adjacent gardens on the South Shore. Gaining an understanding of what species occur where along the edge is important because it will alert RBG staff and adjacent landowners to areas of highest concern, and allow for the most effective targeted management.

In addition to the previously mentioned large scale monitoring programs, several smaller studies have been conducted on the South Shore of Cootes Paradise including the monitoring of endangered Few-

flowered Club-rush populations (Harrison, 2015), an associated deer browse study at Few-flowered Club-rush sites (Radassao, 2013), a study of spring-ephemeral plants and the associated impacts of unofficial trails (McPhee, 2015), and an assessment of deer browse on plants at native planting events (Culbert, 2015).

This report summarizes the findings from all of the above surveys to date in an effort to best represent the current state of the South Shore of Cootes Paradise.

Methods

Long Term Forest Monitoring

There are currently fourteen permanent long-term forest monitoring plots established across RBG's nature sanctuaries. Two of these plots can be found on the escarpment properties, two can be found in the Hendrie Valley properties, five are located on the North Shore; represented by red circles in Figure 1, and five are located on the South Shore (the focus of this report); represented by green circles in Figure 1.

Forest Monitoring surveys on the South Shore were conducted within these plots in 2008, 2012, and 2016 with the exception of monitoring in the ground vegetation layer. Surveys of ground vegetation species were conducted in 2009, 2010, 2012, and 2016.

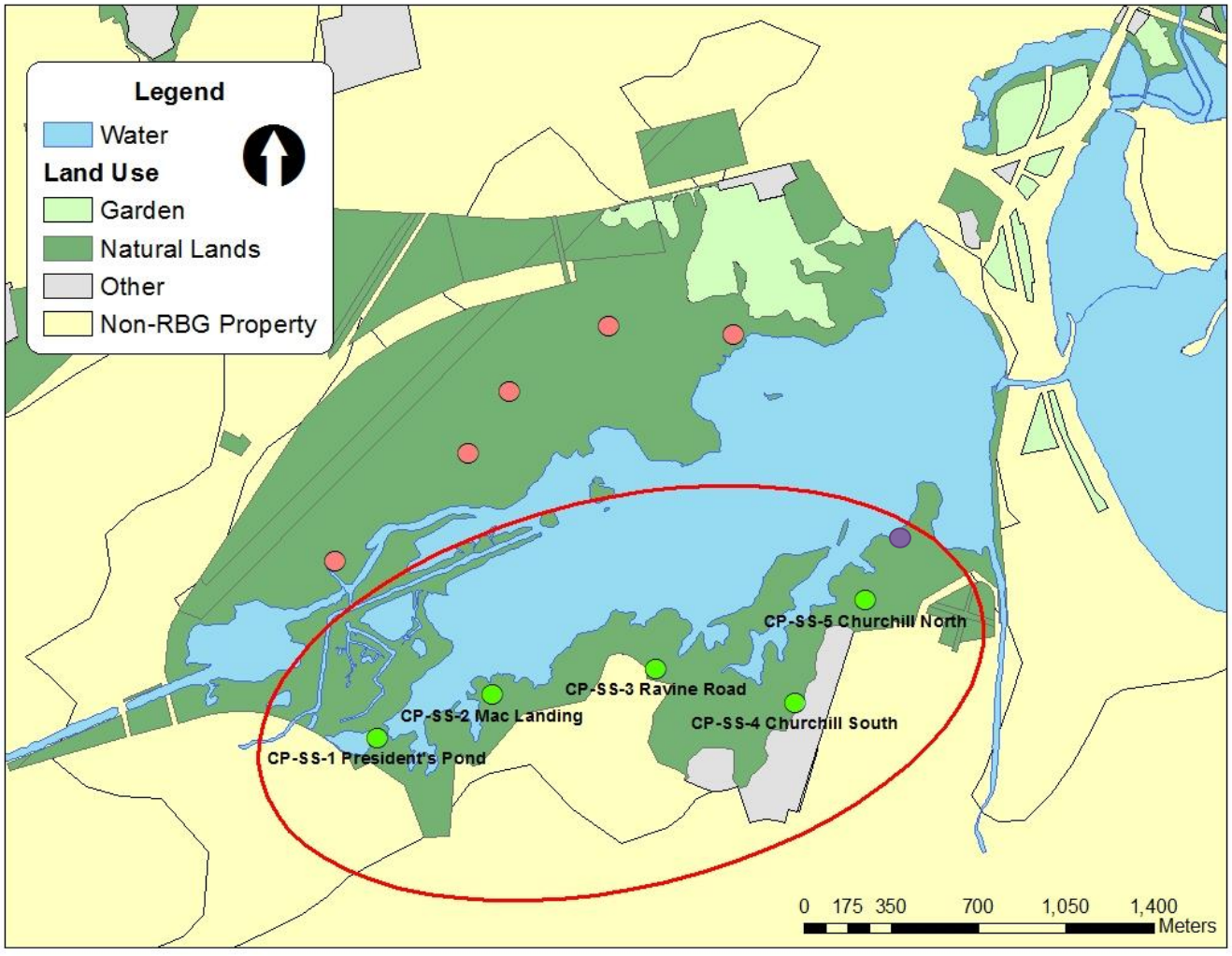

Figure 1: Locations of long-term forest monitoring plots on the South Shore of Cootes Paradise. Circled green points indicate South Shore plots, while red points indicate plots located on the North Shore of Cootes Paradise. The purple point represents the only breeding bird survey point outside of forest monitoring plots on the South Shore, located at Princess Point.

For a detailed breakdown of the methods used to conduct forest monitoring at RBG, refer to the *2009 Forest Monitoring Report* (Burtenshaw, 2010) and *Ecological Monitoring and Assessment Network: Terrestrial Vegetation Monitoring Protocols* (Roberts-Pichette & Gillespie, 1999).

Breeding Bird Surveys

Breeding bird surveys at RBG are conducted using passive listening point counts as described in the *Ontario Breeding Bird Atlas Guide for Participants* (Cadman M. , 2001). On the South Shore of Cootes Paradise five of the six breeding bird survey locations coincide with RBG Forest Monitoring Plots with the additional site located at Princess Point, as shown in Figure 1, represented by the purple point.

For a detailed breakdown of the methods used to conduct breeding bird surveys at RBG, refer to *Bird Monitoring Report 2016* (Ellis, 2017), and the *Atlas of the Breeding Birds of Ontario* (Cadman M. D., 2007).

Marsh Monitoring

Marsh monitoring surveys have been conducted at RBG since 1995 when the Great Lakes Marsh Monitoring Program (GLMMP) was first established. Originally, four marsh-monitoring stations were surveyed annually, however this has varied based on the availability of surveyors and variable marsh conditions such that the number of sites surveyed in a given year has ranged from one to seven.

When conducting GLMMP surveys, estimating the number of frogs calling can sometimes be difficult to determine, so a system of calling codes are used instead. A calling code 1 means individual calls do not overlap and can be discretely counted. A calling code 2 means calls of individuals sometimes overlap, but numbers can still be roughly estimated. A calling code 3 represents a full chorus, meaning the number of individual calls cannot be differentiated or accurately estimated.

For a detailed list of GLMMP methods please refer to Bird Studies Canada's *Marsh Monitoring Program Participants Handbook.*

Forest Edge Surveys

Forest edge surveys were conducted in an effort to better understand introduced species composition, abundance, and distribution along the forest boundaries of RBG's South Shore forests. A thorough understanding of the presence of non-native species in this area is important as the forest edge functions as a buffer between the sensitive forest habitat found toward the interior of the forest and the surrounding fragmented landscape. This project will also serve to provide guidance on future invasive species management initiatives by RBG, the City of Hamilton and McMaster University.

List of Equipment

- GPS
- Clipboard with data sheets, maps, and a pencil
- Camera
- Radio
- Measuring tape (to at least 10 meters)
- Field guides for species identification: Newcomb's Wildflower Guide (Newcomb, 1977), Shrubs of Ontario (Soper & Heimburger, 1982), and Trees in Canada (Farrar, 1995).
- Plastic and paper bags for vegetation sample collection
- Field herbarium press for preserving samples for lab identification

McMaster University and Churchill Park were chosen as areas to focus edge survey efforts as they both represent large tracts of disturbed landscape directly adjacent to RBG's natural lands. Surveys at McMaster were conducted in plots that measured 5 meters into the forest; while surveys at Churchill Park were conducted in plots that measured 10 meters into the forest. A study conducted on urban encroachment into natural areas found that the majority of invasive plants were concentrated within the first 6 meters of forest borders (McWilliam, 2010). Based on these findings both of the techniques used for this study would have captured the majority of problem species.

McMaster University

Non-native species inventories were conducted along the forest edge between McMaster University and RBG property from August 24th to October 18th in 2017.

Because McMaster also hosts a variety of maintained gardens, many of which are directly adjacent to natural forested edges, surveys of garden species were also conducted. Surveyors inventoried these garden areas in conjunction with adjacent forest edges in order to look for any signs of ornamental plants spreading into the natural lands.

The roughly 1400m section of forest edge between McMaster University and RBG was first divided into survey plots as shown in Figure 2 below. Satellite imagery was used to develop a sampling plan based on the unique layout of McMasters' campus. Attempts were made to maintain even lengths of survey plots however, due to the inconsistent length and layout of campus buildings, as well as the inconsistent area between buildings and where forest edges started, this was not always possible. Instead, plots were laid out in close to even lengths in conjunction with residence buildings on campus in order to facilitate easier recognition of sites by surveyors as well as RBG or University staff

conducting follow up work in response to these surveys. A full list of site names and the campus building they were associated with can be found in Appendix A.

Upon arriving at the forest edge, a 5 meter strip was measured into the forest, forming the plot. Surveyors then walked the length of the plot looking for any non-native species. If a species couldn't be identified in-field, it was collected and pressed for lab identification at a later date. If the plant had a woody stem it was counted and its location was noted on a map. If the plant was herbaceous, its presence was noted but it was not counted or mapped due to the difficulty in differentiating individuals. At the end of a round of surveying, abundance codes were assigned to all woody and herbaceous species present within the plot and this was used as the measure of dominance in a given area.

Surveyors would then assess the adjacent garden area if one was present (see Figure 2). All non-native plant species within the gardens were once again identified and recorded. Woody stems were counted and mapped, while herbaceous plants were only noted as detected. Species abundance was not measured in garden areas since they were inconsistent in size, and species were planted and maintained by staff gardeners.

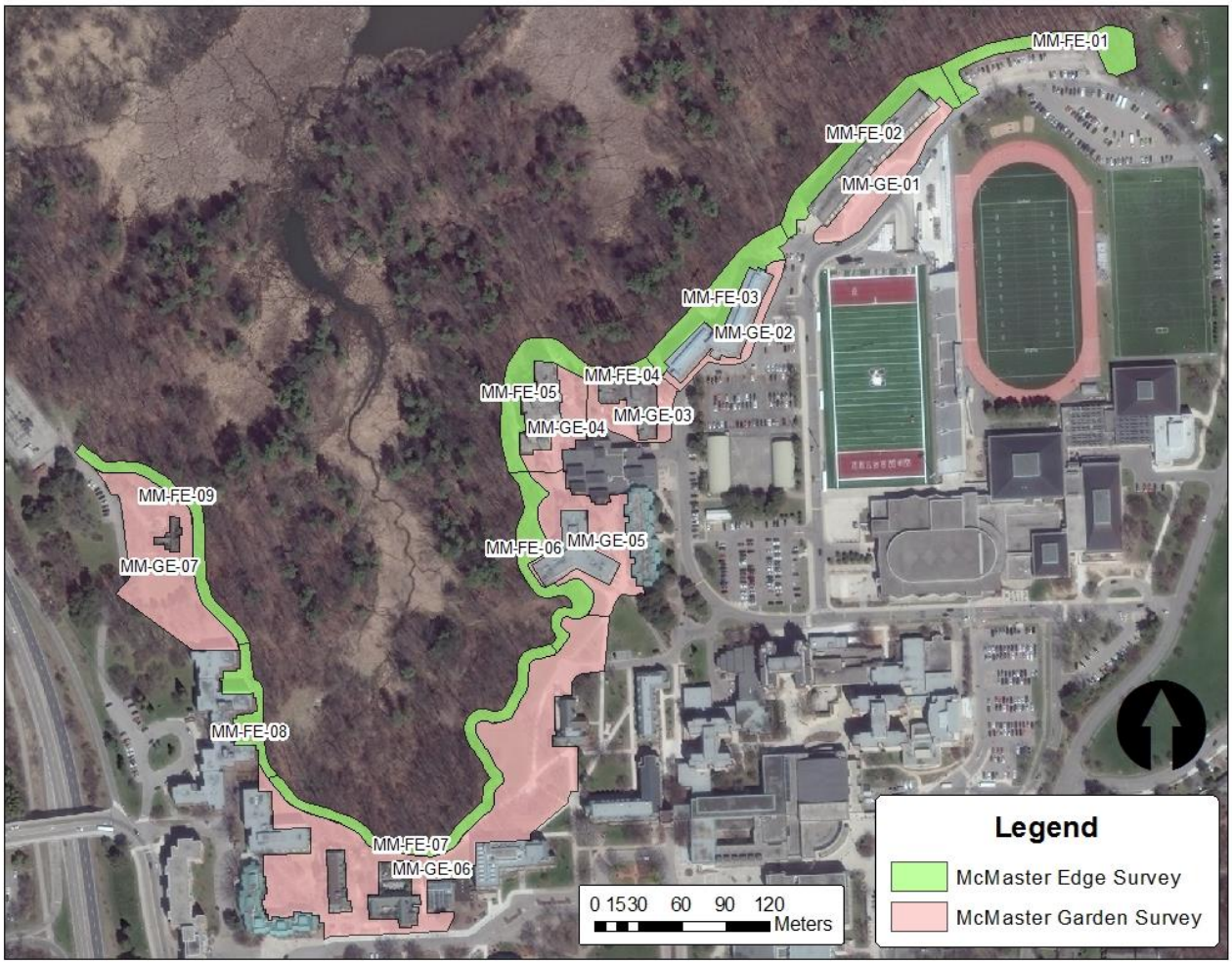

Figure 2: Overview of the forest edge and garden survey site locations between Royal Botanical Gardens and McMaster University property in Hamilton, ON.

Churchill Park

Surveys at Churchill Park were conducted on August 22nd and August 23rd in 2016, and July 27th and August 17th in 2017. These surveys covered approximately 960m of forest edge that was subdivided into five different survey areas of roughly equal length as shown in Figure 3.

At the beginning of each survey, a 10 meter wide strip was measured from the mowed park edge into the forest. Surveyors walked within the survey plots and identify any non-native species encountered. Individuals that could not be identified in-field were collected and pressed for lab identification at a later date.

Plants were once again categorized by growth form and recorded as either woody or herbaceous. Plant species with woody stems were counted while herbaceous plants were not. At the end of a plot survey, abundance codes were assigned to all species detected, just as they were for the McMaster University surveys.

Figure 3: Forest edge survey plot locations surrounding Churchill Park in Westdale, Hamilton ON.

Results

Long Term Forest Monitoring

Canopy Tree Layer

The dominant canopy tree species in 2008 was *Carya ovata* (Shagbark Hickory) with a relative abundance of 19.15%. This was followed by *Acer rubrum* (Red Maple) with a relative abundance of 15.96% and *Prunus serotina* (Black Cherry) with a relative abundance of 13.83%, (Table 1).

In subsequent surveys Shagbark Hickory, Red Maple, and Black Cherry have remained the dominant species, however the relative abundance of Black Cherry trees increased to 16.67% in 2012, tying the dominance of Shagbark Hickory. This trend was also observed in the 2016 survey, with Shagbark Hickory and Black Cherry being the most abundant trees at 17.59% of the canopy, followed by Red Maple at 13.89%. By basal area *Quercus rubra* (Red Oak) and Shagbark Hickory had the greatest coverage in 2016 at 34.78cm^2 and 31.51cm^2 respectively; more than double any other single species.

Species of least abundance have varied throughout the survey years; however *Betula papyrifera* (Paper Birch) has shown one of the greatest decreases in relative abundance. Paper Birch had a relative abundance of 4.26% in 2008, followed by 0.98% in 2012, and 0.93% in 2016. The other two species of least abundance detected in 2016 were *Catalpa speciosa* (Northern Catalpa), and *Fraxinus pennsylvanica* (Green Ash) each with a relative abundance of 0.93%.

Of the non-native species detected in the forest canopy, *Prunus avium* (Sweet Cherry), is the most abundant, and has increased in relative abundance each forest monitoring survey. Sweet Cherry's relative abundance started at 7.45% in 2008, and increased to 7.84% and 8.33% in subsequent years.

Table 1: Summaries of canopy tree density per hectare and basal area from 2008, 2012, and 2016 forest monitoring surveys, along with species richness and Shannon diversity index. Species are sorted by relative abundance. Non-native tree species are bolded.

Table 1.1: 2008 Cootes Paradise South Shore canopy tree summary

Species	Relative Abundance	Density (trees/ha)	Basal Area (cm^2)
Carya ovata	19.15%	90	27.38
Acer rubrum	15.96%	75	9.54
Prunus serotina	13.83%	65	5.66
Quercus rubra	11.70%	55	21.41
Prunus avium	**7.45%**	**35**	**0.93**
Quercus alba	6.38%	30	12.71
Betula papyrifera	4.26%	20	0.38
Fraxinus americana	4.26%	20	0.23
Pinus strobus	3.19%	15	1.53
Populus grandidentata	3.19%	15	0.34
Quercus velutina	3.19%	15	3.58
Tilia americana	3.19%	15	0.27
Sassafras albidum	2.13%	10	0.28
Tsuga canadensis	2.13%	10	0.90
Species Richness	**14**		
Shannon Diversity Index	**2.37535**		

Table 1.2: 2012 Cootes Paradise South Shore canopy tree summary

Species	Relative Abundance	Density (trees/ha)	Basal Area (cm^2)
Carya ovata	16.67%	85	27.28
Prunus serotina	16.67%	85	8.36
Acer rubrum	15.69%	80	9.21
Quercus rubra	11.76%	60	28.79
Prunus avium	**7.84%**	**40**	**1.53**
Quercus alba	5.88%	30	12.79
Populus grandidentata	3.92%	20	0.49
Fraxinus americana	2.94%	15	0.13
Pinus strobus	2.94%	15	1.45
Quercus velutina	2.94%	15	3.30
Amelanchier laevis	1.96%	10	0.05
Sassafras albidum	1.96%	10	0.31
Tilia americana	1.96%	10	0.22
Tsuga canadensis	1.96%	10	0.88
Betula papyrifera	0.98%	5	0.01
Catalpa speciosa	**0.98%**	**5**	**0.01**
Fraxinus pennsylvanica	0.98%	5	0.02
Ostrya virginiana	0.98%	5	0.01
Rhamnus cathartica	**0.98%**	**5**	**0.03**
Species Richness		**19**	
Shannon Diversity Index		**2.479154**	

Table 1.3: 2016 Cootes Paradise South Shore canopy tree summary

Species	Relative Abundance	Density (trees/ha)	Basal Area (cm^2)
Carya ovata	17.59%	95	31.51
Prunus serotina	17.59%	95	11.72
Acer rubrum	13.89%	75	7.13
Quercus rubra	12.04%	65	34.78
Prunus avium	**8.33%**	**45**	**1.84**
Fraxinus americana	4.63%	25	0.34
Quercus alba	4.63%	25	11.42
Amelanchier laevis	3.70%	20	0.22
Populus grandidentata	3.70%	20	0.57
Pinus strobus	2.78%	15	1.43
Tilia americana	2.78%	15	0.44
Quercus velutina	1.85%	10	1.84
Sassafras albidum	1.85%	10	0.33
Tsuga canadensis	1.85%	10	0.88
Betula papyrifera	0.93%	5	0.01
Catalpa speciosa	**0.93%**	**5**	**0.01**
Fraxinus pennsylvanica	0.93%	5	0.02
Species Richness		**17**	
Shannon Diversity Index		**2.426908**	

Declines in forest cover are shown in Figure 4, with red shading representing areas of declined forest cover, and green shading representing intact forest cover. This figure was created by comparing current ELC to historic aerial imagery from 1995 and 1934. Land cover that was previously forested (as observed in aerial imagery) but is now classified as woodland, savannah, or regenerating thicket was designated as declined forest.

One section of the South Shore, highlighted in Figure 4, is currently classified as woodland; this area was found to have been cleared at some point prior to 1934 (oldest aerial imagery available). This area has been excluded from the map as it represents regeneration into a woodland rather than decline from forest cover. Based on this classification, 22.01 hectares of previously forested land on the South Shore have shown canopy declines, leaving 43.36 hectares of intact forest cover. This indicates a 33.67% decrease in forest cover since 1934.

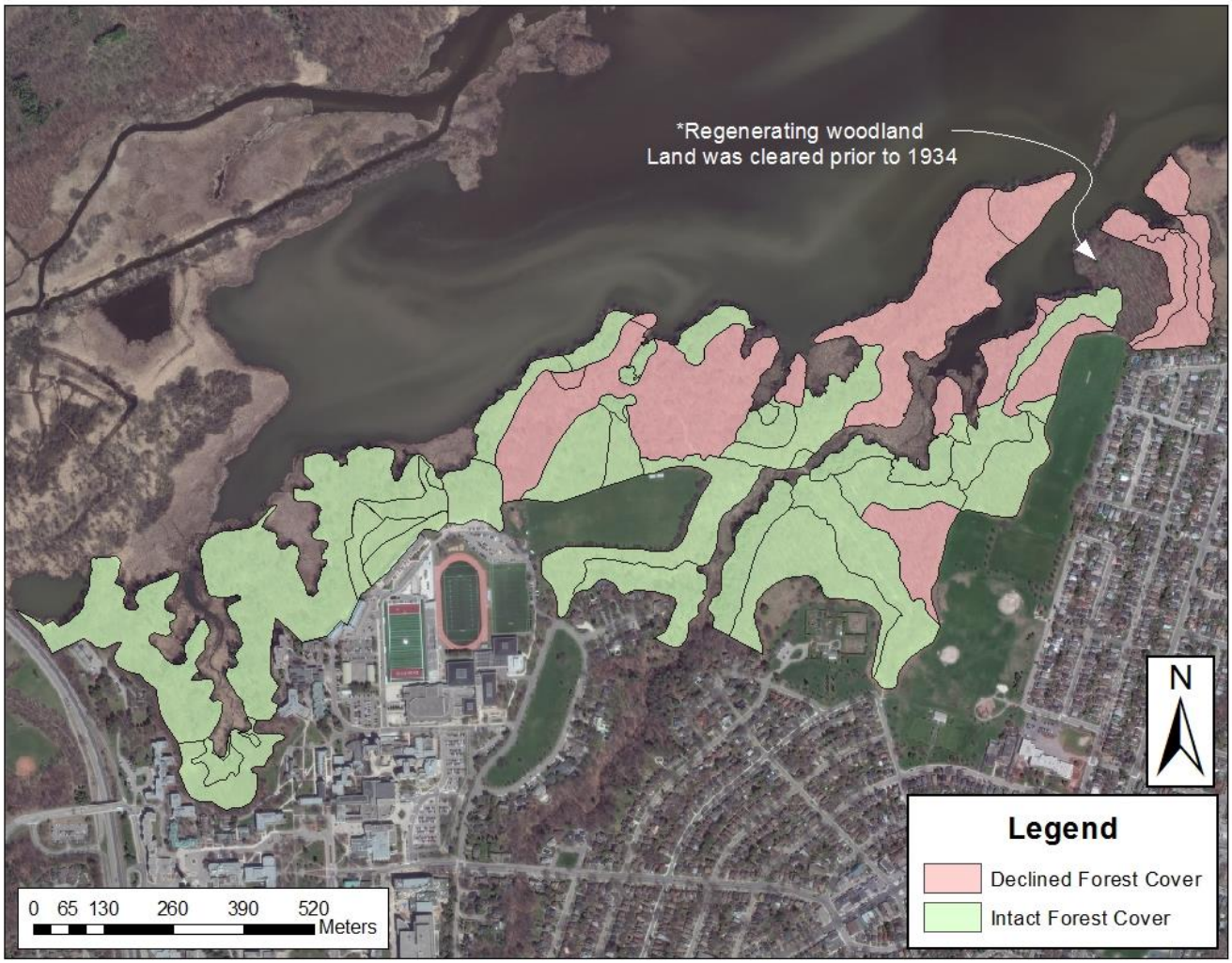

Figure 4: Current intact and declined forest cover on the South Shore of Cootes Paradise Marsh. Designations are based on current Ecological Land Classification (ELC), and historic aerial imagery (1934-1995).

Small Trees and Shrubs Layer

A total of 26 species were identified in the understory layer in 2012, with 6 of those being non-native species (Table 2). Witch-hazel was found to be the most dominant species in the shrub and small tree layer, making up 26.41% of the relative cover. White Ash and Black Cherry were the next two most dominant shrubs in the understory, with 22.73% and 9.74% relative cover respectively.

The most abundant non-native species in the 2012 understory layer was Common Buckthorn with a relative percent cover of 1.54%. This was followed by Glossy Buckthorn and Sweet Cherry with a relative percent cover of 1.08% each. Throughout all plots on the South Shore in 2012, non-native species made up 5.24% of the relative cover (Table 2).

Table 2: Summary of shrub and small tree relative abundance/cover from 2008 and 2012 forest monitoring surveys. It should be noted that 2008 surveys quantified data using the number of individuals of each species, while the 2012 surveys recorded percent cover attributed to each species.

Table 2.1: 2008 Cootes Paradise shrub and small tree summary

Species	Average count of individuals	Relative Abundance
Grey Dogwood	196.2	40.30%
White Ash	78	16.02%
Chokecherry	69.6	14.30%
Witch Hazel	66.8	13.72%
Black Cherry	17.8	3.66%
Beaked Hazel	12.2	2.51%
Maple-leaved Viburnum	10.6	2.18%
Nannyberry	8.8	1.81%
Honeysuckle*	**5.2**	**1.07%**
Smooth Serviceberry	4.2	0.86%
Common Buckthorn*	**3**	**0.62%**
Sassafras	2.4	0.49%
Shagbark Hickory	2.2	0.45%
Hawthorn	2	0.41%
Red Oak	1.6	0.33%
Large Tooth Aspen	1.6	0.33%
Glossy Buckthorn*	**1**	**0.21%**
Elderberry	0.6	0.12%
Barberry*	**0.6**	**0.12%**
Red Maple	0.6	0.12%
Sweet Cherry*	**0.6**	**0.12%**
Ironwood	0.4	0.08%
Alternate-leaved Dogwood	0.4	0.08%
Norway Maple*	**0.2**	**0.04%**
White Mulberry*	**0.2**	**0.04%**
Species Richness	**25**	
Non-Native Richness	**7**	

Table 2.2: 2012 Cootes Paradise shrub and small tree summary

Species	Average sum of % cover	Relative % Cover
Witch-Hazel	24.4	26.41%
White Ash	21	22.73%
Black Cherry	9	9.74%
Grey Dogwood	6.2	6.71%
Nannyberry	4.62	5.00%
Shagbark Hickory	4.44	4.81%
Red Maple	4.4	4.76%
Red Oak	3	3.25%
Riverbank Grape	2.4	2.60%
Smooth Serviceberry	1.6	1.73%
Common Buckthorn*	**1.42**	**1.54%**
Eastern Hop-hornbeam	1.4	1.52%
Choke Cherry	1.22	1.32%
Glossy Buckthorn*	**1**	**1.08%**
Large-tooth Aspen	1	1.08%
Sweet Cherry*	**1**	**1.08%**
American Basswood	1	1.08%
Honeysuckle*	**1**	**1.08%**
Black Ash	0.8	0.87%
Maple-leaved Viburnum	0.42	0.45%
Catalpa*	**0.4**	**0.43%**
Alternate-leaved Dogwood	0.4	0.43%
Beaked Hazelnut	0.2	0.22%
Hawthorn sp.	0.04	0.04%
Barberry*	**0.02**	**0.02%**
Wild Red Raspberry	0.02	0.02%
Species Richness	**26**	
Non-Native Richness	**6**	

Ground Vegetation Layer

The most abundant species observed in the 2016 ground vegetation surveys was Garlic Mustard, with an average abundance of 10.05 individuals per survey plot. This was followed closely by Glossy Buckthorn and Cleavers with an average abundance of 6.95 and 6.75 individuals per plot respectively. The least abundant species observed were Morrow's Honeysuckle, American Hog-peanut, Paper Birch, Pennsylvania Sedge, Bitternut Hickory, Thistle species, Yellow Avens, Medic species, Cinquefoil species, American Basswood, Nettle species, and Maple-leaved Viburnum, all with an average abundance of 0.05 individuals per vegetation survey plot.

May-apple was found to be the most dominant ground vegetation species, based on an average 10.35% cover occupied in the ground layer. The next most dominant species was Woodland Speargrass at 9.7% per plot, followed by Avens species at 2.8%, Glossy Buckthorn at 2.4% and Cleavers at 1.65%.

Of the 77 ground vegetation species detected in the 2016 field season 17 are non-native, more than double the 6 non-native species originally detected in 2009. As shown in Table 3, the most dominant non-native species found in the ground vegetation layer were Woodland Speargrass, Glossy Buckthorn, and Garlic mustard. In total, 39% of the combined average percent cover in 2016 was attributed to non-native species.

Table 3: Summary of 2016 Cootes Paradise South Shore ground vegetation monitoring sorted by the average number of individuals per plot and by the average percent cover a given species occupied within the ground layer. (Non-native species names are bolded)

Species	Average # individuals (per m^2)	Species	Average % cover (per m^2)
Garlic Mustard	10.05	May-apple	10.35
Glossy Buckthorn	6.95	**Woodland Speargrass**	**9.7**
Cleavers	6.75	Avens species	2.775
Avens species	6.5	**Glossy Buckthorn**	**2.4**
Woodland Speargrass	5.75	Cleavers	1.65
Enchanter's Nightshade	4.6	**Garlic Mustard$_1$**	**1.55**
May-apple	4.2	Soft Agrimony	1.2
Nipplewort	3.85	**Smooth Bedstraw**	**0.775**
Soft Agrimony	3.1	White Snakeroot	0.75
Jack-in-the-pulpit	2.9	Enchanter's Nightshade	0.675
Smooth Bedstraw	2.45	White Ash	0.625
Bedstraw	2.35	Jack-in-the-pulpit	0.6
White Ash	1.9	**Nipplewort**	**0.575**
Red Maple	1.9	Woodland Strawberry	0.575
Wild Strawberry	1.85	Bedstraw	0.55
Woodland Strawberry	1.3	Wild Strawberry	0.5
White Snakeroot	1.2	Riverbank Grape	0.475
Wood Anemone	1.2	Red Maple	0.425
Smooth Serviceberry	1.1	Honeysuckle species	0.425

Black Cherry	1.05	**Common Buckthorn**	**0.4**
Yellow Trout Lily	1	Goldenrod species	0.4
Common Buckthorn	0.95	Ash species	0.35
Goldenrod species	0.9	Witch-hazel	0.3
Sedge	0.9	Sedge	0.275
Sweet Cherry	0.9	Wood Anemone	0.225
Serviceberry	0.85	Yellow Trout Lily	0.225
Running Strawberry Bush	0.65	Smooth Serviceberry	0.2
Honeysuckle species	0.6	Black Cherry	0.2
Flase Nettle	0.6	**Sweet Cherry**	**0.2**
Forget-me-not species	0.6	Flase Nettle	0.2
Riverbank Grape	0.55	**Common Dandelion**	**0.2**
Cherry species	0.55	Running Strawberry Bush	0.175
Aster species	0.5	Choke Cherry	0.175
Witch-hazel	0.45	Serviceberry	0.15
Canada Mayflower	0.4	Blue-stemmed Goldenrod	0.15
Ash species	0.35	**Common Burdock**	**0.15**
Blue-stemmed Goldenrod	0.35	Canada Mayflower	0.125
Beggarticks	0.35	Beggarticks	0.125
Canada Thistle	0.35	Buttercup species	0.125
Green Ash	0.35	**Common Speedwell**	**0.125**
Choke Cherry	0.3	Forget-me-not species	0.1
Common Burdock	0.3	Cherry species	0.1
Buttercup species	0.25	**Canada Thistle**	**0.1**
Stickseed	0.25	Stickseed	0.1
Poison Ivy	0.25	Poison Ivy	0.1
Silver Maple	0.25	Early Meadow-rue	0.1
Virginia Smartweed	0.25	Aster species	0.075
Common Dandelion	0.2	Silver Maple	0.075
Bloodroot	0.2	Virginia Smartweed	0.075
Gray Dogwood	0.2	Bloodroot	0.075
Hawthorn species	0.2	Spotted Geranium	0.075
Virginia Creeper	0.2	Highbush Cranberry	0.075
Spotted Geranium	0.15	Green Ash	0.05
Allegheny Blackberry	0.15	Gray Dogwood	0.05
Nannyberry	0.15	Hawthorn species	0.05
Violet species	0.15	Virginia Creeper	0.05
Black Nightshade	0.15	Allegheny Blackberry	0.05
Common Speedwell	0.1	Nannyberry	0.05
Early Meadow-rue	0.1	Violet species	0.05
Highbush Cranberry	0.1	Manitoba Maple	0.05
Manitoba Maple	0.1	**Common Mouse-ear Chickweed**	**0.05**
Common Mouse-ear Chickweed	0.1	Kidney-leaved Buttercup	0.05

Kidney-leaved Buttercup	0.1	Wild Red Raspbery	0.05
Wild Red Raspbery	0.1	**Morrow's Honeysuckle**	**0.05**
Raspberry species	0.1	Black Nightshade	0.025
Morrow's Honeysuckle	0.05	Raspberry species	0.025
American Hog-peanut	0.05	American Hog-peanut	0.025
Paper Birch	0.05	Paper Birch	0.025
Pennsylvania Sedge	0.05	Pennsylvania Sedge	0.025
Bitternut Hickory	0.05	Bitternut Hickory	0.025
Thistle species	0.05	Thistle species	0.025
Yellow Avens	0.05	Yellow Avens	0.025
Medick species	0.05	**Medick species**	**0.025**
Cinquefoil species	0.05	Cinquefoil species	0.025
American Basswood	0.05	American Basswood	0.025
Nettle species	0.05	Nettle species	0.025
Maple-leaved Viburnum	0.05	Maple-leaved Viburnum	0.025

Species Richness	**77**
Non-native Richness	**17**

The trends in changing ground vegetation cover are shown below, grouped by provenance; either native or non-native to southern Ontario. As shown in Figure 5, the average percent cover formed by native plants has shown a slight overall decreasing trend since ground vegetation monitoring began in 2009 ($R^2 = 0.3394$).

The trend line fitted to the non-native species average percent cover instead shows an overall positive increase over time ($R^2 = 0.9137$). This indicates that since 2009, native species cover in the ground vegetation layer has been slowly decreasing going from 28.18% in 2009 to 26.23% in 2016, while non-native species cover has been steadily increasing, from 3% in 2009 to 16.8% in 2016.

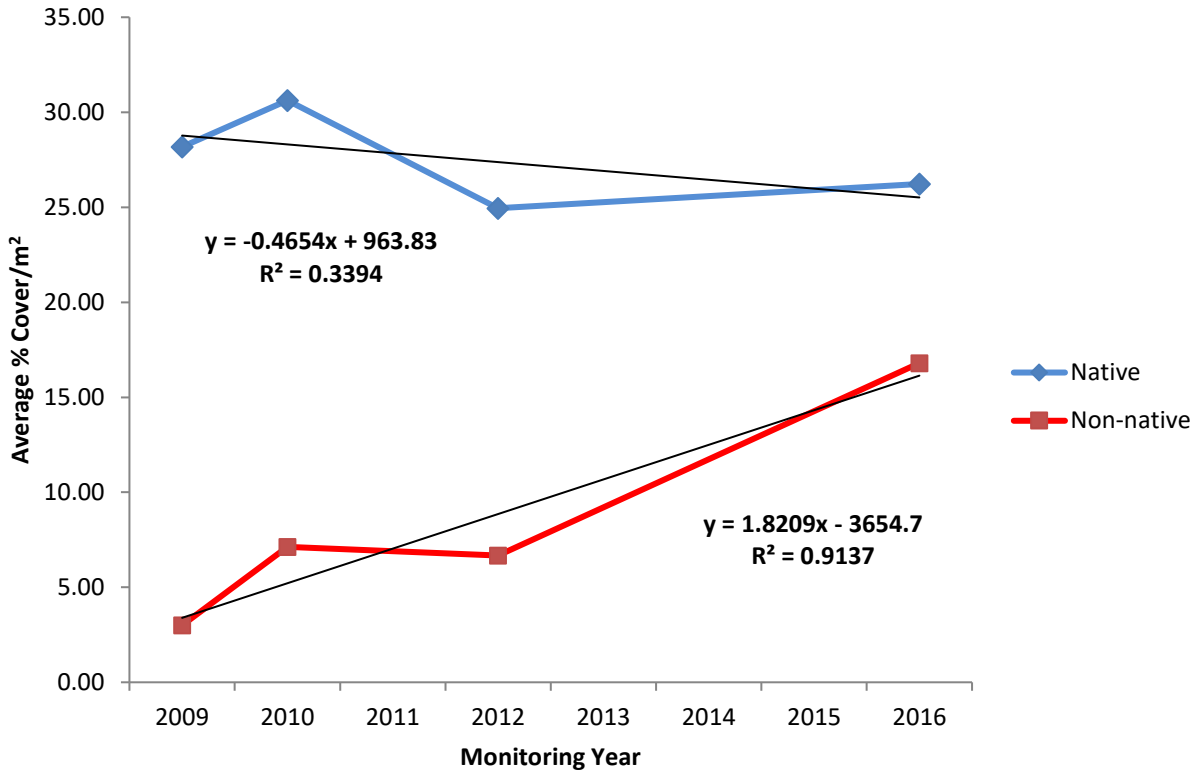

Figure 5: Trends in average percent cover per square meter of native and non-native ground vegetation species for Cootes Paradise South Shore long-term forest monitoring plots.

The cover provided by non-native species in 2016 (16.8%) can be further broken down to the proportions of cover made up by individual species. As shown in Figure 6, the largest portion of non-native species cover observed can be attributed to Woodland Speargrass, which made up 57.74% of the non-native species cover observed in 2016. This was followed by Glossy Buckthorn at 14.29% and Garlic Mustard at 9.23%. The remaining 18.75% consists of cover attributed to the 14 remaining non-native species which can be found in Table 3.

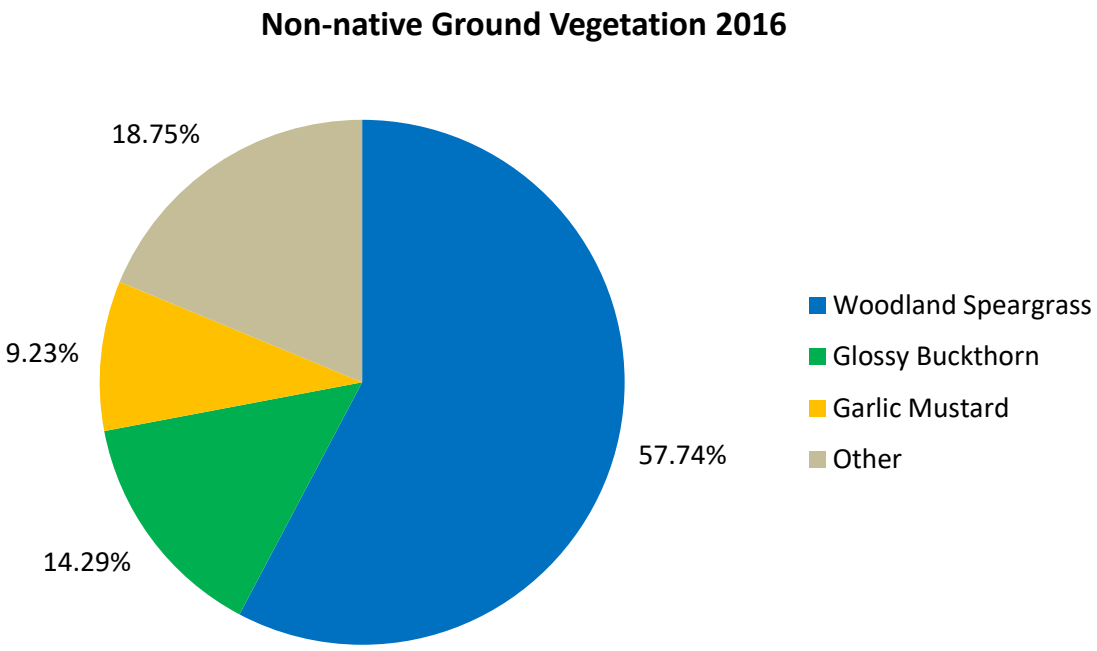

Figure 6: Non-native species composition of the 2016 ground vegetation layer of Cootes Paradise South Shore long-term forest monitoring plots.

When examined independently, it is clear that Woodland Speargrass has shown an increase in forest floor dominance within the forest monitoring plots since it was first observed in 2009. At that point the average percent cover attributed to Woodland Speargrass was only 0.05%, making it one of the lowest ranked species. Since that time average Woodland Speargrass cover increased to 0.225% in 2010, then to 0.65% in 2012, before its peak in 2016 at 9.7%.

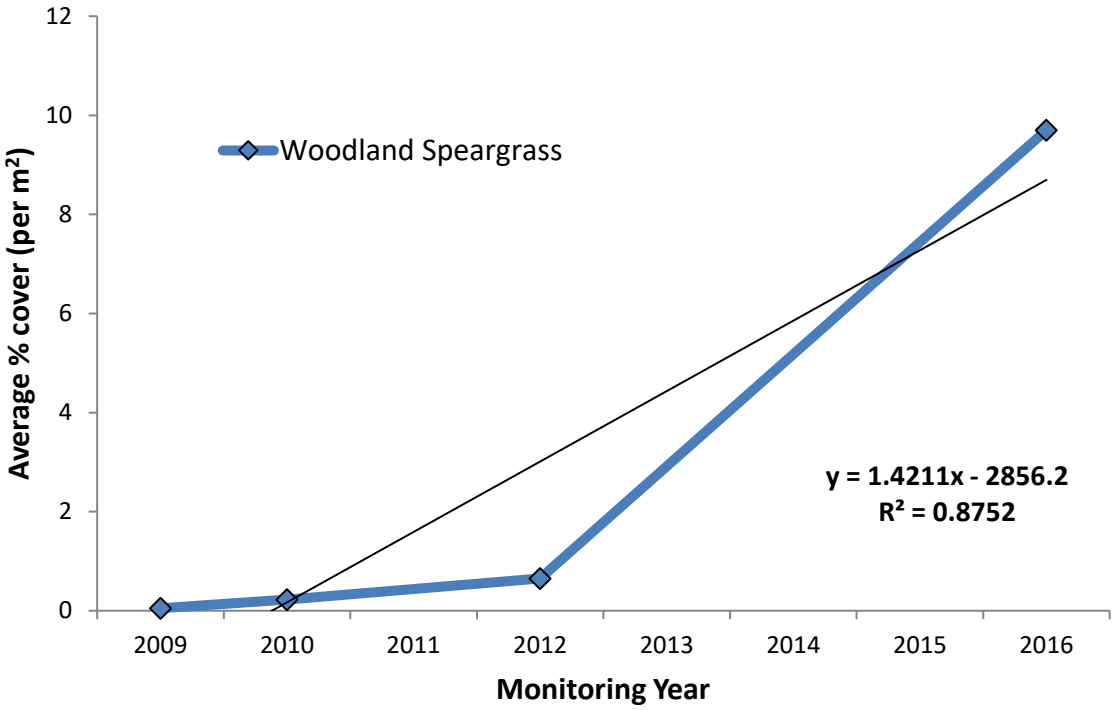

Figure 7: Average percent cover per square meter attributed to Poa nemoralis (Woodland Speargrass) in Cootes Paradise South Shore long-term forest monitoring ground vegetation plots.

Although overall trends in forest floor composition appear to remain relatively constant between 2009 and 2016, it would appear that there is a relationship between leaf litter and bare ground. This relationship was also observed in earlier forest monitoring reports (Burtenshaw, 2010). As shown in Figure 8, years with lower leaf litter cover also observe more bare ground (2009, 2012). The opposite is true for years with high leaf litter cover (2010, 2016). Moss and woody debris cover were present in all monitoring years on the South Shore, but do not appear to change dramatically between surveys. Further data collection might be required before significant trends become apparent.

The increasing trend in non-native species cover (represented by the red bars) is also apparent when examined cumulatively in Figure 8. Cover attributed to non-natives increases from 60% in 2009 to 335% in 2016.

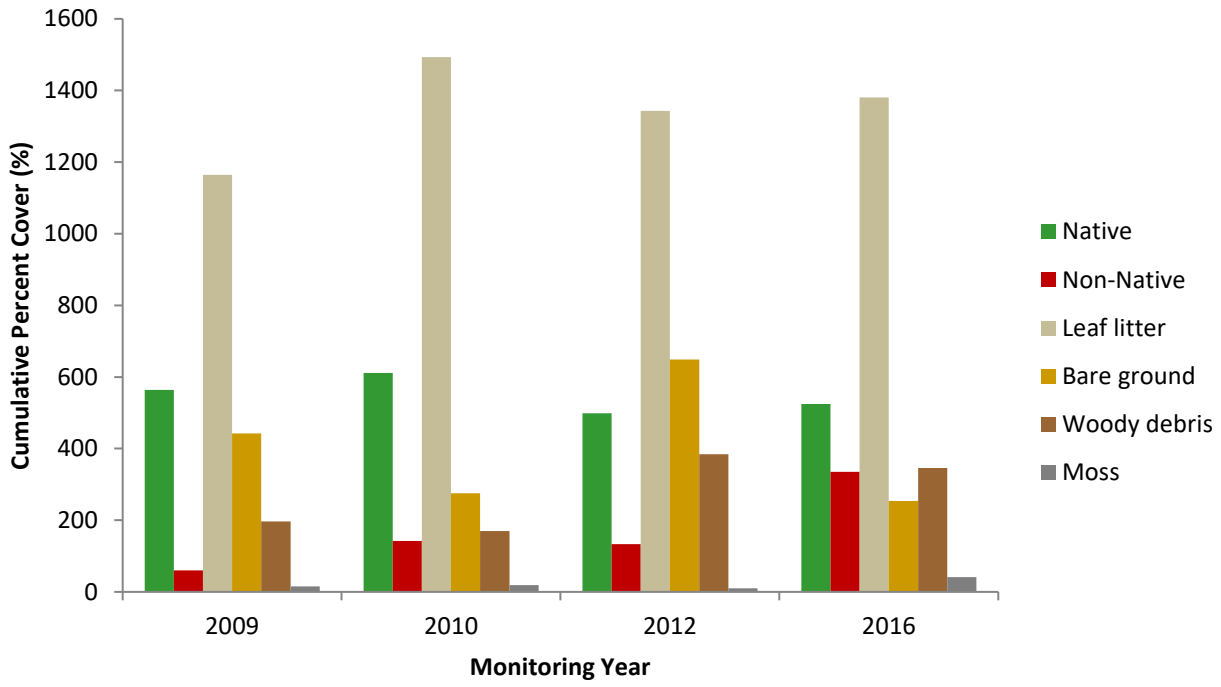

Figure 8: Average percent cover per square meter for Cootes Paradise South Shore forest floor composition from 2009 – 2016.

Breeding Bird Surveys

Overall Species Richness

As shown in Figure 9, overall trends in species richness have remained relatively stable since bird monitoring began in 2009. Fluctuations from year to year have resulted in a fitted trend line that does not display a strong linear relationship (R^2 = 0.022). It is interesting to note that the number of species detected in 2017 was 53; the highest since 2009 when 52 species were detected. Species richness for the South Shore of Cootes Paradise was lowest in 2011 when only 40 species were observed.

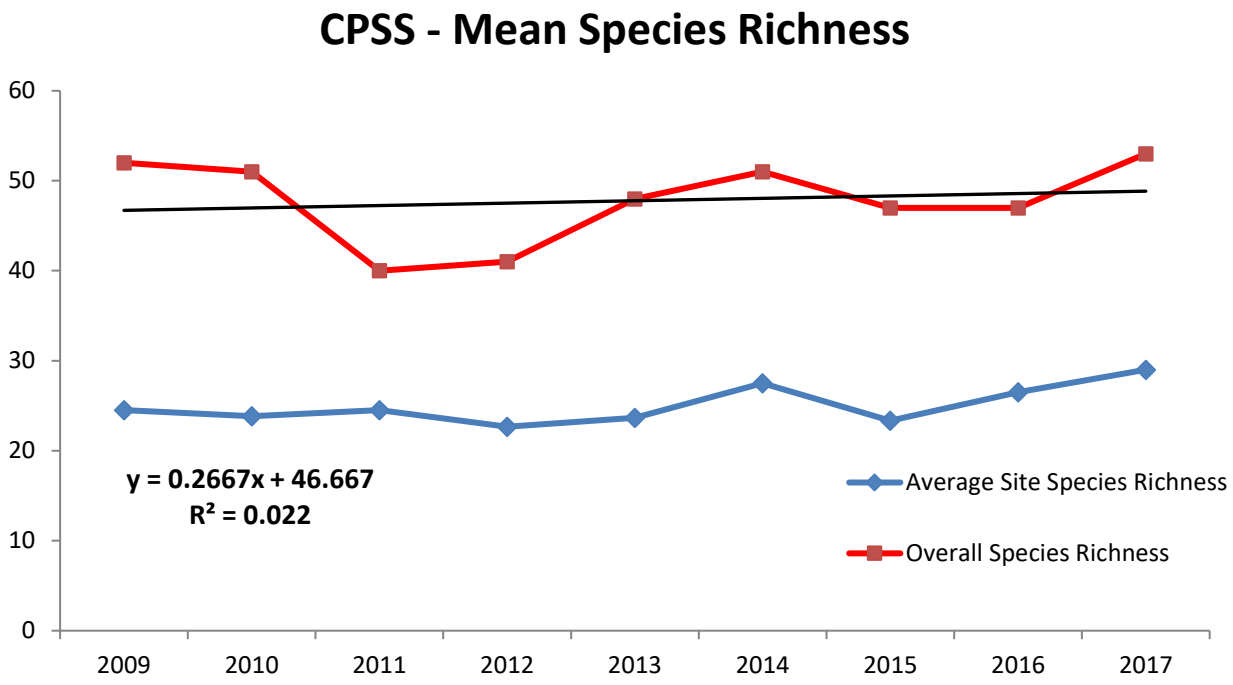

Figure 9: Trends in the species richness of birds detected both aurally and visually during breeding bird point count surveys on the South Shore of Cootes Paradise. Overall species richness represents the sum of the number of species from all sites in a given year. Average site species richness represents an average richness for any one site in a given year.

Ground-nesting Birds

The ground nesting bird species detected on the South Shore most consistently has been the Song Sparrow, which was detected every year from 2009 to 2017. The next most commonly detected ground nesting bird on the South Shore was the Belted Kingfisher; counted in six of the nine breeding bird surveys conducted on the South Shore. Kill-deer, Mourning Warbler, and Golden-winged Warbler were all detected on the South Shore during breeding bird surveys; however they were observed infrequently and do not represent consistent detections.

Table 4: Summary of ground-nesting birds detected on Royal Botanical Gardens property during breeding bird surveys. (**X**= a species that was detected on the South Shore of Cootes Paradise. **O**= species that was detected in another RBG nature sanctuary that year but not on the South Shore).

Species	# Years Detected	2009	2010	2011	2012	2013	2014	2015	2016	2017
Song Sparrow	9	X	X	X	X	X	X	X	X	X
Blue-winged Warbler	9	O	O	O	O	O	O	O	O	O
Field Sparrow	9	O	O	O	O	O	O	O	O	O
Killdeer	7	O	X	O	X	-	-	O	X	O
Eastern Towhee	7	-	O	-	O	O	O	O	O	O
Belted Kingfisher	6	X	X	-	X	X	X	-	-	X
Mourning Warbler	3	-	O	-	-	X	O	-	-	-
Ovenbird	3	O	O	O	-	-	-	-	-	-
Wild Turkey	3	-	-	-	-	O	-	-	O	O
American Woodcock	2	-	-	-	-	O	-	-	-	O
Winter Wren	2	-	-	-	-	-	-	-	O	O
Golden-winged Warbler	1	X	-	-	-	-	-	-	-	-
Clay-colored Sparrow	1	-	-	-	-	-	-	-	-	O
Common Nighthawk	1	-	-	-	-	-	-	-	O	-
Savannah Sparrow	1	-	-	-	-	-	-	-	-	O
Black-and-white Warbler	0	-	-	-	-	-	-	-	-	-
Bobolink	0	-	-	-	-	-	-	-	-	-
Brewster's/Lawrence's warbler	0	-	-	-	-	-	-	-	-	-
Canada Warbler	0	-	-	-	-	-	-	-	-	-
Eastern Meadowlark	0	-	-	-	-	-	-	-	-	-
Eastern Whip-poor-will	0	-	-	-	-	-	-	-	-	-
Grasshopper Sparrow	0	-	-	-	-	-	-	-	-	-
Hermit Thrush	0	-	-	-	-	-	-	-	-	-
Horned Lark	0	-	-	-	-	-	-	-	-	-
Louisiana Waterthrush	0	-	-	-	-	-	-	-	-	-
Nashville Warbler	0	-	-	-	-	-	-	-	-	-
Northern Harrier	0	-	-	-	-	-	-	-	-	-
Northern Waterthrush	0	-	-	-	-	-	-	-	-	-
Ruffed Grouse	0	-	-	-	-	-	-	-	-	-
Short-eared Owl	0	-	-	-	-	-	-	-	-	-
Upland Sandpiper	0	-	-	-	-	-	-	-	-	-
Veery	0	-	-	-	-	-	-	-	-	-
Vesper Sparrow	0	-	-	-	-	-	-	-	-	-
Wilson's Snipe	0	-	-	-	-	-	-	-	-	-

Interior Forest Birds

Wood Thrushes have been present the most often throughout the years of breeding bird surveys, being detected on the South Shore every year from 2009 to 2017. Pine Warbler and Hairy Woodpecker follow very closely with eight years detected respectively, while Scarlet Tanager was detected in seven of the nine survey years. Detections of Pileated Woodpecker, Brown Creeper, and Black-throated Blue Warbler have been infrequent, ranging from one to three years of detection.

Table 5: Summary of interior forest birds detected on RBG property during breeding bird surveys 2009 - 2017. (**X** = a species that was detected on the South Shore of Cootes Paradise. **O** = a species that was detected in another RBG nature sanctuary that year, but not on the South Shore).

Species	# Years Present	2009	2010	2011	2012	2013	2014	2015	2016	2017
Pine Warbler	9	X	X	O	X	X	X	X	X	X
Scarlet Tanager	9	X	X	O	O	X	X	X	X	X
Wood Thrush	9	X	X	X	X	X	X	X	X	X
Hairy Woodpecker	8	X	X	X	-	X	X	X	X	X
Pileated Woodpecker	8	X	X	O	-	O	O	X	O	O
Brown Creeper	6	X	X	X	O	-	-	-	O	O
Acadian Flycatcher	3	-	-	O	-	O	-	O	-	-
Ovenbird	3	O	O	O	-	-	-	-	-	-
Black-throated Blue Warbler	1	X	-	-	-	-	-	-	-	-
Hooded Warbler	1	O	-	-	-	-	-	-	-	-
Black-throated Green Warbler	1	-	-	-	-	-	-	-	-	O
Black and White Warbler	0	-	-	-	-	-	-	-	-	-
Blackburnian Warbler	0	-	-	-	-	-	-	-	-	-
Cerulean Warbler	0	-	-	-	-	-	-	-	-	-
Louisiana Waterthrush	0	-	-	-	-	-	-	-	-	-
Canada Warbler	0	-	-	-	-	-	-	-	-	-

Non-native Bird Species

Of the non-native bird species observed during surveys, European Starlings have shown the greatest change in detections. When bird monitoring was started on the South Shore, European Starlings were not considered a dominant species with only 5 detections in 2009. Numbers have been increasing since then, with a max count of 76 in 2016. A trend line fitted to these data clearly shows the general increase in European Starling numbers on the South Shore (R^2= 0.5662).

Detections of House Sparrow and Mute Swan have been consistently low since breeding bird surveys started. Detections of Mute Swans have slightly decreased in the last four years, while detections of House Sparrow have slightly increased in the last three years.

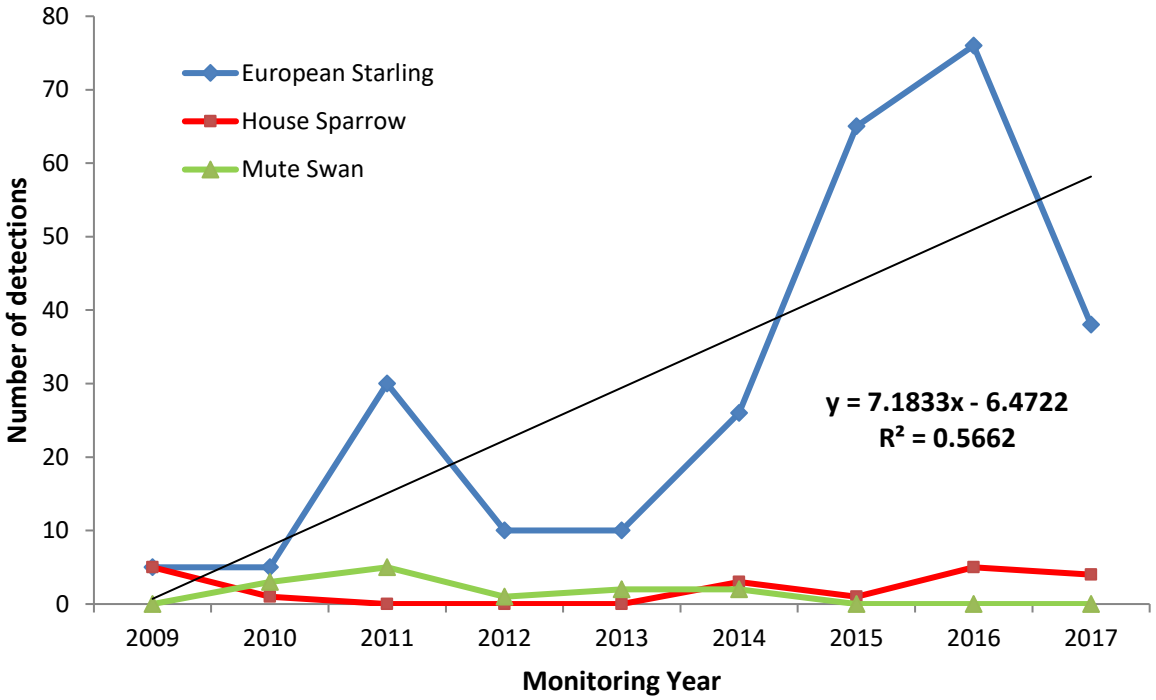

Figure 10: Trends in detection of non-native species; including European Starling, House Sparrow, and Mute Swan, from breeding bird surveys conducted on the South Shore of Cootes Paradise.

Species Declines

Yellow Warbler and Brown Creeper were two species that showed some of the greatest declines in detections per monitoring year. As shown in Figure 11, Brown Creeper detections on the South Shore all occurred prior to 2012. The highest number of detections for Brown Creeper occurred in 2009 with a value of 6 detections before declining to 2 detections in 2010 and 2011. Brown Creepers were not observed during breeding bird surveys on the South Shore in 2012 and have not been detected since.

During the first year of breeding bird surveys there were 26 detections of Yellow Warbler across the survey plots on the South Shore, making them the third most dominant bird species detected. Detections of Yellow Warblers have been declining steadily since then, down to 11 detections in 2017.

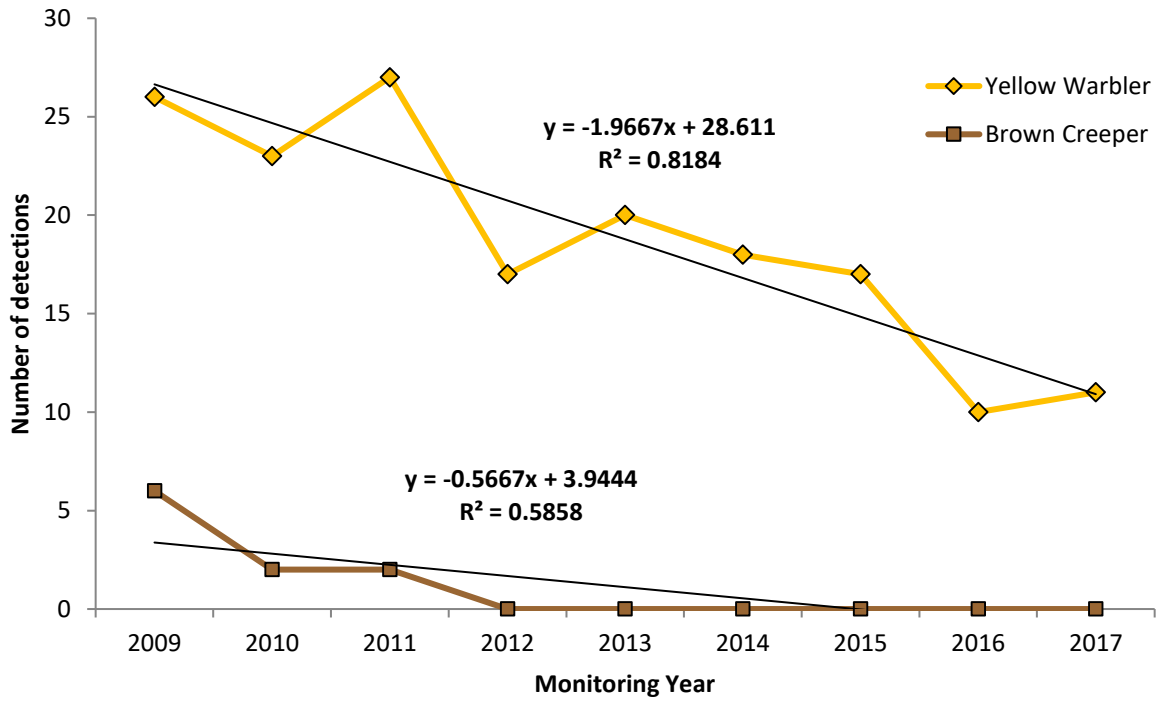

Figure 11: Trends in species detection for Yellow Warbler and Brown Creeper from breeding bird surveys conducted on the South Shore of Cootes Paradise.

Dominant Bird Species

European Starlings have shown the greatest change in dominance, transitioning from making up only 1.21% individuals in 2009, to making up 9.18% of the bird species detected in 2017; making them more dominant than any other species. European Starling dominance was at its highest in 2015 when they made up 20.7% of the birds observed.

Red-winged Blackbird and American Robin dominance do not appear to be changing substantially, with both species making up a large portion of detected birds in all years. Cedar Waxwing dominance seems to be slowly increasing overtime, while Yellow Warbler and Black-capped Chickadee appear to be declining. Yellow Warbler dominance showed the most dramatic decrease, from making up 6.30% of bird species in 2009 to making up 2.66% of bird species in 2017.

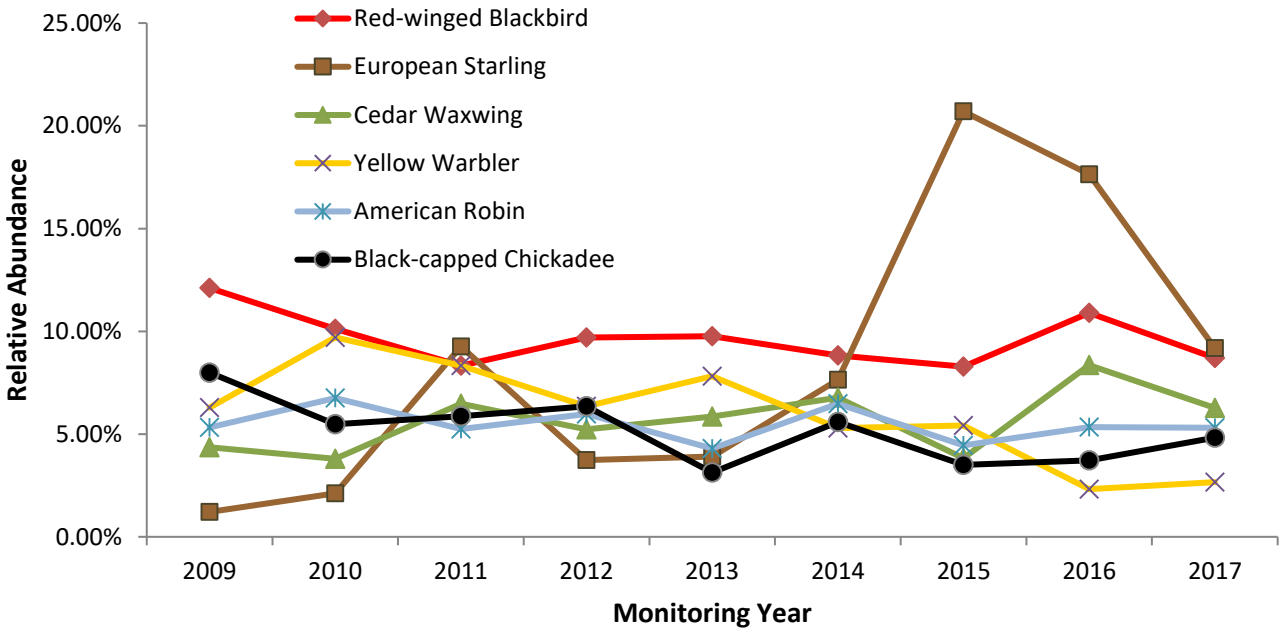

Figure 12: Trends in bird species dominance on the South Shore of Cootes Paradise over time. Species are ranked based on their calculated relative abundance for a given year. These species represent the bird species that were routinely dominant throughout monitoring surveys at RBG.

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Marsh Monitoring

The frog species most commonly detected on the South Shore of Cootes Paradise was the Green Frog (*Lithobates clamitans)* with a total of 17 years detected out of the 18 years marsh monitoring was conducted. This is followed very closely by the Northern Leopard Frog (*Lithobates pipiens)* with 16 years detected, and the American Toad (*Anaxyrus americanus)* with 12 years. The frog species detected the least often were Wood frogs (*Lithobates sylvaticus*) and Western Chorus-frogs (*Pseudacris triseriata*); which were only detected in two years of marsh monitoring.

Table 6: Presence of frog species detected per year from all Marsh Monitoring Program (MMP) station located on the South Shore of Cootes Paradise along with the number of stations surveyed per year and the total number of years each species was detected. The value in brackets represents the maximum calling code for that species in the given year.

Species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2006	2007	2008	2009	2010	2011	2014	2015	2016	# Years Detected
Green Frog	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (2)	X (1)		X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (2)	**17**
Northern Leopard Frog		X (1)	X (1)	X (2)	X (1)	X (1)	X (1)	X (1)	X (1)	X (1)	X (2)	X (2)	X (2)	X (1)	X (1)		X (1)	X (1)	**16**
American Toad	X (1)	X (1)	X (1)	X (1)	X (2)	X (2)	X (2)		X (2)		X (1)	X (1)		X (1)			X (1)		**12**
Spring Peeper					X (1)	X (1)		X (1)	X (1)					X (2)	X (2)				**6**
Gray Tree-frog						X (1)	X (1)		X (1)										**3**
Wood frog																X (1)	X (1)		**2**
Western Chorus-frog														X (1)		X (1)			**2**
# Stations Surveyed	**4**	**4**	**1**	**5**	**6**	**3**	**3**	**5**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	
Visits complete (3 per station)	**Yes**	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**No**	**Yes**	**Yes**	**Yes**	**Yes**	

X – Indicates the species was detected in the given year from at least one MMP station on the South Shore.

Forest Edge Surveys

McMaster University

Garlic Mustard *(Alliaria petiolata)*, Common Buckthorn *(Rhamnus cathartica)*, Japanese Barberry *(Berberis thunbergii)*, and non-native Honeysuckles *(Lonicera spp)* were the invasive species with the highest number of site occurrences along the surveyed edge. Japanese Barberry and Non-native Honeysuckle species were also found in the maintained gardens that were surveyed for non-natives, as shown in Table 7 below. A full list of the species detected in the forest edge can be found in Appendix B.

Table 7: Top twelve non-native species observed along the forested edge of the McMaster University-RBG property boundary and their abundance (D= dominant, A= abundant, O= occasional, and R= rare). Weediness values are based on the Southern Ontario Floristic Quality Assessment System (Oldham et al. 1995).

Scientific Name	Common Name	Weediness	MM-FE-01	MM-FE-02	MM-FE-03	MM-FE-04	MM-FE-05	MM-FE-06	MM-FE-07	MM-FE-09	Sites with sp. occurrence (of a total of 8)
Alliaria petiolata	Garlic Mustard	**-3**	D	D	D	A	A	A	A	D	**8**
Rhamnus cathartica	**Common Buckthorn**	**-3**	R	D	O	R	O	O	D	R	**8**
Leonurus cardiaca	Motherwort	**-1**	R	A	O	O	O	O	A	A	**8**
Berberis thunbergii	**Japanese Barberry**	**-3**	R	O	O	-	R	O	O	A	**7**
Lonicera spp.	**Honeysuckle spp.**	**-3**	R	A	O	-	O	O	A	A	**7**
Taraxacum officinale	Common Dandelion	**-2**	O	O	O	R	R	R	R	-	**7**
Circium arvense	Creeping Thistle	**-1**	A	-	O	O	O	O	A	O	**7**
Euphorbia peplus	Petty Spurge	**-1**	O	R	-	A	O	A	O	R	**7**
Daucus carrota	Queen Anne's Lace	**-3**	A	O	O	-	O	O	O	-	**6**
Lapsana communis	Nipplewort	**-2**	O	-	-	A	A	O	A	A	**6**
Acer negundo	**Manitoba Maple**	**-2**	-	R	O	R	O	A	O	-	**6**
Setaria viridis	Foxtail Grass	**-1**	A	A	O	-	-	R	O	R	**6**
	Overall non-native species richness		**32**	**32**	**31**	**15**	**29**	**46**	**48**	**23**	

Plant species with bolded names indicate those that were found both along the forest edge and in the managed garden

Japanese Barberry, Silver Grass *(Miscanthus sinensis)*, and Winged Euonymus *(Euonymus alatus)* were the non-natives detected the most often within the maintained gardens. All three of these species were also detected in the forest edge. Honeysuckles, Periwinkle *(Vinca minor)*, and Cotoneasters *(Cotoneaster spp)* are also species of note, as they were found in both the gardens and the forested edge.

Japanese Barberry was the most abundant woody garden species with a total of 93 planted stems. Cotoneasters were the next most abundant woody species found in the gardens with 60 individuals. A full list of the species detected in the McMaster gardens can be found in Appendix C.

Table 8: Top twelve non-native species observed in managed garden areas on McMaster University property. The numbers in brackets show stem count values for the given species within that site. Stem counts were only conducted for woody species. Weediness values are based on the Southern Ontario Floristic Quality Assessment System (Oldham et al. 1995).

Scientific Name	Common Name	Weediness	MM-GE-01	MM-GE-02	MM-GE-03	MM-GE-04	MM-GE-05	MM-GE-06	MM-GE-07	Sites with sp. occurrence (of a total of 7)
Berberis thunbergii	**Japanese Barberry**	**-3**	X (3)		X (2)	X (16)	X (4)	X (53)	X (15)	**6**
Miscanthus sinensis	**Chinese Silver Grass**	**-2**		X	X	X		X		**4**
Euonymus alatus	**Winged Euonymus**	**-2**	X (2)	X (6)				X (1)		**3**
Pennisetum alopecuroides	Fountain Grass	**-1**	X			X	X			**3**
Katsura sp.	Katsura	**-1**			X			X (1)	X (5)	**3**
Lonicera spp.	**Honeysuckles**	**-3**						X (1)	X (6)	**2**
Vinca minor	**Periwinkle**	**-2**					X	X		**2**
Paeonia sp.	Peony	**-1**	X	X						**2**
Hemerocallis sp.	Daylily	**-1**		X	X					**2**
Hosta sp.	Hostas	**-1**		X		X				**2**
Cotoneaster spp.	**Cotoneasters**	**-1**			X (3)			X (57)		**2**
Syringa meyeri	Dwarf Korean Lilac	**-1**		X (4)					X (4)	**2**
Overall non-native species richness			**11**	**18**	**12**	**7**	**12**	**22**	**18**	

Plant species with bolded names specify those species that were found both in the garden and along the forest edge.

Of all ornamental species detected in the gardens, Japanese Barberry was the most commonly encountered (Table 8). Japanese Barberry was also one of the most commonly encountered garden ornamentals found in the forest edge, detected in 7 of the 8 survey sites. The abundance of Japanese Barberry in forest edges was combined with the locations of planted specimens in the gardens, as well as the infestation level in surrounding forest polygons based on ecological land classification to produce the map included below (Figure 13).

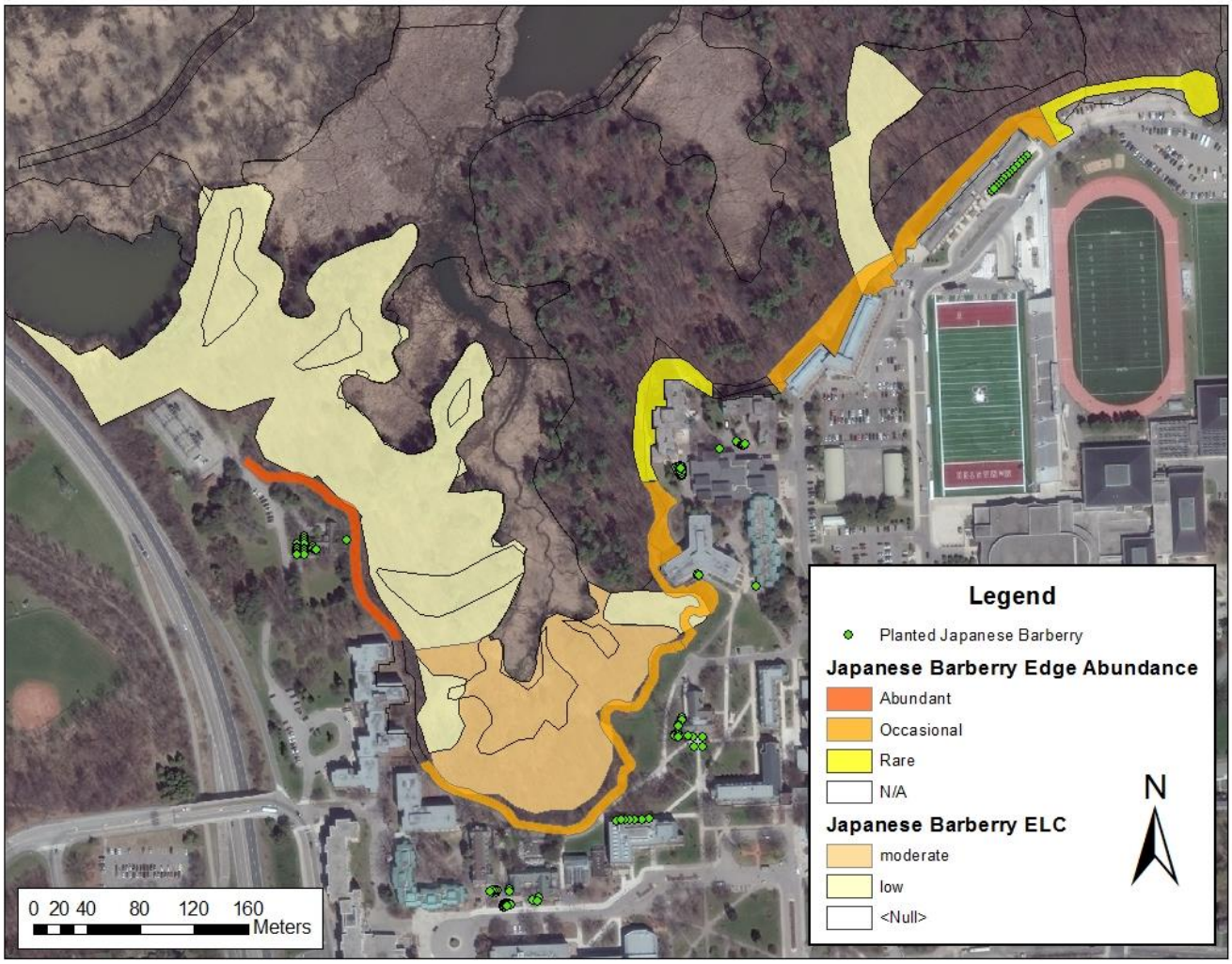

Figure 13: Distribution and abundance of Japanese Barberry (*Berberis thunbergii)* based on forest edge and garden surveys conducted along the RBG-McMaster border as well as Ecological Land Classification of the adjacent forest.

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Churchill Park

Common Buckthorn was the most dominant woody species in the forest edge surrounding Churchill Park and was found in all five survey sites. This was followed closely by *Rosa multiflora* (Multiflora rose), another woody shrub that was also found in all five survey sites. The dominant herbaceous plants detected were *Glechoma herderacea* (Creeping Charlie), *Daucus carota* (Queen Anne's Lace), *Phleum pratense* (Timothy Grass), and *Alliaria petiolata* (Garlic Mustard). A full list of the non-native species can be found in Appendix D.

Table 9: Top twelve non-native species detected along the Churchill Park forest edge survey and their abundance (D= dominant, A= abundant, O= occasional, and R= rare). Weediness values are based on the Southern Ontario Floristic Quality Assessment System (Oldham, 1995).

Scientific Name	Common Name	Weediness	CHP-FE-01	CHP-FE-02	CHP-FE-03	CHP-FE-04	CHP-FE-05	Sites with sp. occurrence (of a total of 5)
Rhamnus cathartica	Common Buckthorn	**-3**	D	D	A	D	O	**5**
Rosa multiflora	Multiflora Rose	**-3**	O	O	O	A	O	**5**
Glechoma hederacea	Creeping Charlie	**-2**	O	R	A	A	O	**5**
Daucus carota	Queen Anne's Lace	**-2**	O	O	O	O	O	**5**
Phleum pratense	Timothy Grass	**-1**	D	A	D	D	A	**5**
Alliaria petiolata	Garlic Mustard	**-3**	O	O	O	-	D	**4**
Elymus repens	Quack Grass	**-3**	O	O	O	O	-	**4**
Arctium minus	Common Burdock	**-2**	A	D	D	A	-	**4**
Rumex crispus	Curly Dock	**-2**	O	O	O	O	-	**4**
Dactylis glomerata	Orchard Grass	**-1**	D	A	-	A	A	**4**
Cirsium arvense	Canada Thistle	**-1**	O	-	O	O	A	**4**
Poa pretensis	Kentucky Bluegrass	**-1**	O	-	A	A	-	**3**
Overall non-native species richness			**32**	**27**	**21**	**25**	**59**	

Scientific Name	Common Name	Weediness	CHP-FE-01	CHP-FE-02	CHP-FE-03	CHP-FE-04	CHP-FE-05	Site Occurrence
Rhamnus cathartica	European Buckthorn	**-3**	D	D	A	D	O	**5**
Rosa multiflora	Multiflora Rose	**-3**	O	O	O	A	O	**5**
Glechoma hederacea	Creeping Charlie	**-2**	O	R	A	A	O	**5**
Daucus carota	Queen Anne's Lace	**-2**	O	O	O	O	O	**5**
Phleum pratense	Timothy Grass	**-1**	D	A	D	D	A	**5**
Alliaria petiolata	Garlic Mustard	**-3**	O	O	O		D	**4**
Elymus repens	Quack Grass	**-3**	O	O	O	O		**4**
Arctium minus	Common Burdock	**-2**	A	D	D	A		**4**
Rumex crispus	Curly Dock	**-2**	O	O	O	O		**4**
Dactylis glomerata	Orchard Grass	**-1**	D	A		A	A	**4**
Cirsium arvense	Canada Thistle	**-1**	O		O	O	A	**4**
Poa pretensis	Kentucky Bluegrass	**-1**	O		A	A		**3**
			3	2	2	2	5	
Overall Site Non-native richness			2	7	1	5	9	

Discussion

Forest Monitoring

Canopy Tree Layer

Inventories of the canopy tree layer on the South Shore of Cootes Paradise indicate species composition, dominance, and density seem to have remained relatively stable since long term forest monitoring began at RBG in 2008, showing no significant trends. Shagbark Hickory, Black Cherry, and Red Maple have remained the dominant species in the canopy within monitoring plots on the South Shore, none of which have shown substantial signs of decline or increase.

One noticeable change that has occurred in the canopy layer is that species richness increased from 14 species in 2008 to 17 species in 2016 (Table 1). The most likely explanation for this trend can be explained by the surveying protocol. In order for a tree to be included in the inventory, its stem must be greater than 10cm in diameter (Roberts-Pichette & Gillespie, 1999). Species added to the canopy layer since 2008 likely represent individuals that have grown into this stem threshold since the first round of monitoring.

Non-native species also likely played a role in changing the species richness from 2008 to 2016. Both Northern Catalpa and Common Buckthorn are non-native species that weren't detected in 2008 but were in later monitoring visits. These species also likely grew into the canopy tree diameter threshold between 2008 and 2012 or potentially occurred along the plot boundaries and were missed in the first round of surveying. It should be noted that the Common Buckthorn observed in 2012 consisted of one tree that was removed upon detection, which explains its disappearance from the 2016 forest monitoring survey. This individual was removed from the plot because Common Buckthorn is a known and managed invasive species at RBG with prolific seed production and extensive seed dispersal by wildlife (Burtenshaw, 2010). A mature tree of this size would have been a major contributor to the spread of Buckthorn in the area if left un-managed.

Sweet Cherry (*Prunus avium*) was the only non-native tree species that made up a substantial portion of the canopy layer, representing the fifth most dominant species observed with a relative abundance of 8.33% in 2016. The relative abundance of Sweet Cherry has been increasing slowly from 7.45% when it was first assessed in 2008. Although Sweet Cherries do not pose an immediate threat to forest health, they do compete with native species for canopy space. They should continue to be monitored in detail during future forest monitoring surveys, as they have shown persistence in the canopy layer and have slowly increased in abundance over time.

Although the data appear to show a decline in Paper Birch, this is not likely the case across the South Shore. Two stems from a cluster of 3 Paper Birch died in one of the monitoring plots between 2008 and 2012 (personal communication Lindsay Barr, 2018). These stems were noted to be in decline in 2008. Paper Birch abundance was low to begin with, so this small change in one plot likely caused the noticeable decrease in abundance. Paper Birch is an early successional species and it is not uncommon for them to senesce before other trees in a mature forest. No other declines of Paper Birch have been observed on the South Shore.

Although long-term forest monitoring plots indicate relatively stable canopy conditions, more concerning changes were noticed when examining historic aerial imagery in comparison to current Ecological Land Classification (ELC) of the forest. As shown in Figure 4, the proportion of intact forest cover has declined dramatically since 1934, by almost 34%. Although this is only an estimate using aerial imagery, it clearly indicates that a large portion of previously forested area has declined to woodland, savannah, or thicket on the South Shore of Cootes Paradise. This decline can likely be attributed to broad scale stressors impacting forests throughout southern Ontario, such as Emerald Ash Borer, Gypsy Moth and other native insect outbreaks (Two-lined Chestnut Borer, Fall Cankerworm, and American Plum Borer, Dutch Elm Dissease), the spread of invasive species, drought, and increased urban encroachment around property borders. It can be expected that these changes will become more noticeable within forest monitoring plots over the long term as heavily impacted species such as Ash continue to die.

Tree health surveys will also help detect more subtle changes in the canopy. These surveys, following the EMAN protocols, were completed for 2008, 2012, and 2016 however, multiple years of data (25+ years) collection is required before significant trends can be accurately displayed and interpreted.

Small Tree and Shrub Layer

It should be noted that although understory surveys were conducted in 2008 and 2012, slightly different surveying techniques were used. Forest monitoring in 2008 was conducted using Ecological Monitoring and Assessment Network (EMAN) protocols that count the number of small tree and shrub stems per species. Forest monitoring in 2012 used Vegetation Sampling Protocol (VSP) that instead records the total percent cover each species occupies within the understory layer. This means that results collected in 2008 and 2012 cannot be directly compared. Despite the inability to compare between survey years, the small tree and shrub layer data collected in 2008 and 2012 still serves as a useful baseline moving forward with long term forest monitoring, and still provides interesting information pertaining to understory composition and dominance.

A total of 26 species were identified in the small tree and shrub layer in 2012, with the most dominant species being Witch-hazel, White Ash, Black Cherry, and Grey Dogwood. Witch-hazel and White Ash made up the most substantial portion of cover with 26.41% and 22.73% of the understory cover respectively. The above-mentioned species being dominant in forest monitoring plots is expected as all four species are commonly found in the understory of Carolinian forests in Southern Ontario (Oldham, 2017).

Of the dominant species in the small tree and shrub layer, White Ash is expected to show the greatest change in abundance in the future. The introduction of Emerald Ash Borer (EAB) has had devastating effects on all species of Ash native to southern Ontario (Murfitt, He, Yang, Mui, & Mille, 2016). A recent publication by the Botanic Gardens Conservation International (BGCI) and the International Union for Conservation of Nature (IUCN) evaluated Ash species globally and found that all species of Ash in North America are showing significant declines. They also found that White Ash seeds are only viable for an average of 2-3 years (rarely 7-8 years), and vegetative reproduction is rarely successful over long periods of time. This means that after EAB infestations take full effect there will be little to no regeneration of Ash seedlings (Barstow, et al., 2018). We have yet to see significant declines in mature White Ash in the South Shore forest monitoring plots (Table 1), however property wide Ash declines

have been extensive. Because White Ash makes up a large proportion of the understory layer on the South Shore, it can be expected that there will be major shifts in species composition and dominance once mature White Ash die and recruitment of new seedlings declines or ends completely.

Although the most dominant species detected in this layer in 2012 were native species, there were a total of 6 non-native species observed, making up a combined 5.24% of the relative cover in the understory. The non-native species encountered in the small tree and shrub layer were Common Buckthorn, Glossy Buckthorn, Sweet Cherry, non-native Honeysuckles, Northern Catalpa, and Japanese Barberry. All of these species are known non-natives with aggressive spreading habits. Due to the previously mentioned issue with monitoring techniques it is unclear whether non-native cover has changed in the understory; however, based on the known habits of the species in question and the trends observed in both the canopy layer and the ground vegetation layer, it is likely that non-native cover has increased since 2008 and would continue to do so in the future without intervention.

Ground Vegetation Layer

The ground vegetation layer showed the greatest changes over time of all the forest layers surveyed. As shown in Table 3*,* the dominant species, based on percent cover in the ground vegetation layer in 2016 were May-apple, Woodland Speargrass, Avens spp., Glossy Buckthorn, Cleavers, and Garlic Mustard. Overall, a total of 77 different species were detected. Of those, 17 were non-native, up from the 6 non-native species originally detected in long-term forest monitoring plots in 2009.

The dominance of non-native species based on percent cover has increased dramatically. Of the top 6 dominant species in 2016, 3 were non-native, making up a combined 39% of the total cover observed in the ground vegetation layer. These three non-native species were Woodland Speargrass, Glossy Buckthorn, and Garlic Mustard. As shown in Figure 5*,* the average percent cover attributed to non-native ground vegetation species has shown a substantial increase moving from 3% in 2009 to 16.8% in 2016 (R^2 = 0.9137). In contrast, the average percent cover attributed to native species has fallen, going from 30.63% at its highest point in 2010 to 26.23% in 2016 (R^2 = 0.3394). This suggests that non-native species will continue to increase in dominance throughout the ground vegetation layer and will continue to outcompete and crowd-out native species, leading to their decline.

Species in the ground vegetation layer were also assessed based on their abundance. For some species, like May-apple, individual plants occupy a large amount area by having large and broad leaf morphology. Other species, like Woodland Speargrass occupy a small amount of cover per individual as they have a small and narrow, grass-like leaf morphology. The surveying technique used can therefore have a major influence on how the results are interpreted. Although May-apple was most dominant based on cover, Garlic Mustard was actually found to have the highest abundance based on a count of individuals per square meter (Table 3)*.*

Garlic Mustard is a well-known invasive species capable of outcompeting native plants not only physically, but chemically through the release of secondary compounds with allelopathic properties (Gilliam, 2016). The fact that this species was the most abundant in the ground vegetation layer is not a good sign of overall forest health, as the above mentioned characteristics allow Garlic Mustard to quickly establish a monoculture on the forest floor (Burtenshaw, 2010). As this species continues to

increase in abundance over the years, effort should be put into continuing management, especially in sensitive areas.

Although all three of the most dominant non-natives have increased in cover since 2009, when examined in more detail it is apparent that Woodland Speargrass has seen the greatest change in the ground vegetation layer in the South Shore monitoring plots. As shown in Figure 7, Woodland Speargrass was only found to have an average percent cover of 0.05% in 2009, making it one of the least dominant species detected that year. After only 7 years, the average percent cover increased to 16.8%, making Woodland Speargrass the second most dominant ground vegetation plant in 2016. The increased dominance of Woodland Speargrass is particularly concerning because it is a species without standardized Best Management Practices that can quickly outcompete native ground cover once established, a trend already starting to be observed in forest monitoring plots (Figure 7).

This is especially concerning with regards to species at risk conservation at RBG, as the largest populations of endangered Few-flowered Club-rush are found on the South Shore. Few-flowered Club-rush is a perennial herbaceous sedge that usually occurs on the slopes of mature oak forests (Harrison, 2015), (Smith & Rothfels, 2007). RBG currently maintains the only extant population of Few-flowered Club-rush in Canada, conducting intensive monitoring and surveying work to maintain the population. During vegetation surveys around Club-rush populations in 2012, Woodland Speargrass was found at all microsites and was noted to pose a serious threat to the endangered plant (Harrison, 2015), (Smith, 2014 personal communication). Without intervention, Woodland Speargrass will almost certainly play a major role in the ongoing declines of this sensitive species.

Figure 14: Woodland Speargrass (*Poa nemoralis*) dominating the ground vegetation layer of a forested area on the South Shore of Cootes Paradise, Hamilton ON.

There is a relevant concern for the ground vegetation layer when comparing forest monitoring results of the South Shore to the North Shore. Non-native species cover increased by 13.8% on the South Shore between 2009 and 2016, whereas non-native species cover only increased by 3.7% on the North Shore between 2009 and 2017 (Barr, 2018 personal communication). It should be noted that in 2009, the average percent cover of non-native species on the South Shore was almost equal to that of the North Shore (3% vs 2.25% respectively).The obvious difference between the forest of North and the forest of the South Shore is in their shape and size. The South Shore has a greater edge-area ratio compared to the North Shore. Another major difference between areas is the adjacent land use (primarily urban on the South Shore vs. primarily rural on the North Shore).

As previously mentioned, the highly populated urban areas surrounding the South Shore have major impacts on the sensitive natural areas. As a result these areas have experienced habitat declines due to increased off-trail use, off-leash dogs damaging the understory and disturbing wildlife, bank erosion, the spread and proliferation of non-native species, and the dumping of yard waste and other debris (City of Hamilton, Royal Botanical Gardens, 2017). These issues caused by increased visitation are also likely compounded by the general lack of RBG presence on the South Shore.

At present, RBG maintains no facilities on the South Shore of Cootes Paradise, with a lack of gated entry points at trailheads. When compared to the North Shore, a significant difference in presence and security is obvious. The North Shore of Cootes Paradise features 1 main entry point with parking a parking lot (the Arboretum), 2 trail entrances without parking (Homewood, and Hopkins), and approximately 3-4 unsanctioned entrances. On the other hand, the South Shore features 2 main entrances (Princess Point, and Caleb's Walk), 8 more sanctioned trail entrances, and another 7 or more unsanctioned trail entrances. Having so many access points, official or unsanctioned, without any facilities limits RBG's ability to monitor public access, and provides increased opportunity for negligent behavior in the natural lands.

The overall trends observed in the ground vegetation layer are concerning. This forest layer had the greatest proportion of non-native species, a proportion that has increased substantially in the last 10 years. These are the observations expected for a natural system with a significant invasive species problem. When interpreting forest monitoring results one can typically make predictions for the future trends of a layer by looking at the layer below it. This is because new species, whether native or non-native, first infiltrate at the forest floor level before growing into the understory and then the canopy. Seeing increases in non-native invasive plants in the ground vegetation layer is a warning sign for negative changes throughout the forest in the future.

Breeding Bird Surveys

Overall Species Richness

The number of bird species detected during breeding bird surveys on the South Shore of Cootes Paradise has not shown any substantial changes since surveys began (Figure 9). Species richness was at its lowest in 2011 when the species count dropped to 40 from 52 in 2009. The species count does show minor fluctuations from 2013 to 2017; however it did not drop below 47 species, the average across all years. The most recent survey in 2017 actually detected the highest count to date at 53

species. Based on these observations, the number of species detected during breeding bird surveys is expected to remain relatively stable.

Ground-Nesting Birds

Ground-nesting birds (Table 4) in this case refer to those species that nest solely on or near the ground in forests, open fields, and meadow areas, excluding water birds and non-native species. Over the course of the 2017 breeding bird surveys, only two ground-nesting bird species were observed on the South Shore, Song Sparrow and Belted Kingfisher.

Of all species examined over the nine years of breeding bird surveys, Song Sparrows are the only species with consistent detections every year. Song Sparrows are known to occupy nearly any open habitat including marsh edges, overgrown fields, forest edges, and residential areas (Cornell Lab of Ornithology, 2017), (Cadman M. D., 2007). This ability to adapt to a wide variety of conditions, including heavy human disturbance likely give Song Sparrows an advantage over other ground-nesting species, as reflected in their consistent detections.

Bird species included in Table 4 that do not have detections are species that nest on or near the ground and should in theory occur at RBG based on breeding range and general habitat requirements (Cadman M. D., 2007). A lack of these species is quite apparent; of the thirty-four species included in this list only fifteen have ever been detected on RBG property, and only five of those species have been detected on the South Shore since breeding bird surveys started in 2009.

The list of ground-nesting birds used in this report was adapted from a previous breeding bird report (Ellis, 2017), however several additional species were added including Hermit Thrush, Wilson's Snipe, Belted Kingfisher, and Brewster's/Lawrence's Warbler, as all of these species meet the ground-nesting bird criteria outlined above (Cadman M. D., 2007). Additionally, some species were removed from prior editions of this list including Orange-crowned Warbler, Worm-eating Warbler, and Yellow-bellied Flycatcher. Orange-crowned Warbler and Yellow-bellied Flycatcher are both boreal forest breeders, and would not breed at Hamilton's latitude. Worm-eating Warbler breeds in the mid/southeastern United States and therefore, also would not breed at this latitude (Cadman M. D., 2007), (Cornell Lab of Ornithology, 2017). As such, earlier reports of these species during breeding season are questionable, and were not included in these analyses.

Urbanization and forest fragmentation often result in a decrease in ground-nesting bird species (Marzluff, 2001), (Newton, 2004) which are both identified issues facing the South Shore of Cootes Paradise. Although habitat loss and fragmentation pose an issue to a wide variety of birds, ground-nesting birds are particularly susceptible as increased fragmentation has been shown to increase predation rates of nests (Keyser, Hill, & Soehren, 1998), and risk of nest parasitism (Falk, Nol, & Burke, 2010). Off-leash dogs within the nature sanctuaries also likely contribute to the South Shores lack of ground nesting birds, as off-leash dogs can disturb breeding birds and destroy nests (Ellis, 2017). Similar disturbance is also likely caused by off-trail hikers. Maintaining trail closures and enforcing RBG by-laws are important measures to help reduce the impacts facing ground-nesting birds at RBG.

Interior Forest Birds

Interior forest birds in this case refer to those species that require interior forest habitat for breeding; with interior forest being defined as closed canopy forest at least 100 meters back from fields, major roads, and other anthropogenic edges; 50m back from minor roads and trails; and 25-50m back from natural edges such as cliffs or waterbodies (Lovett-Doust & Kuntz, 2001). These species often require specific habitat features such as closed canopies, large diameter trees, tall mature trees, and downed woody debris (Credit Valley Conservation Authority, 2010). The list of interior forest bird species used for this analysis was created using the above criteria as well as "*A Land Manager's Guide to Conserving Habitat for Forest Birds in Southern Ontario"* (Burke, Elliot, Falk, & Piraino, 2011) and the "*Atlas of the Breeding Birds of Ontario"* (Cadman M. D., 2007).

Detections of interior forest birds have been slightly more consistent than those of ground-nesting birds on the South Shore of Cootes Paradise, however overall numbers are still concerning. Wood Thrushes have been detected the most frequently of all species, having been observed every year since 2009. Pine Warbler and Hairy Woodpecker have also been observed regularly, being detected in eight of nine survey years respectively, while Scarlet Tanagers have been detected in seven of the nine years of surveys. The other three species of interior forest birds detected on the South Shore have been Pileated Woodpeckers, Brown Creepers, and Black-throated Blue Warblers. Observations of these species have not been consistent throughout the breeding bird surveys and range from one to three years of detection.

The consistent detections of Wood Thrush on the South Shore is an exciting finding, as they are both sensitive forest birds and are listed as a species of special concern provincially under the Endangered Species Act. Although detections of Wood Thrush have remained consistent on the South Shore of Cootes Paradise, their population throughout North America is rapidly declining. According to the *North American Breeding Bird Survey* Wood Thrush populations have declined by 62% since 1966 (Cornell Lab of Ornithology, 2017). It can therefore be expected that although Wood Thrush numbers on the South Shore appear stable now, they will likely decline in the future.

Bird species displayed in Table 5 that do not have detections are interior forest birds that could potentially nest at RBG based on their geographic range and habitat requirements but have not been observed on the property during breeding bird surveys. Of the 16 interior forest birds expected to breed at RBG, only 11 have been detected on the property, and only 7 of those species were located on the South Shore specifically.

The general lack of interior forest birds is also concerning. Interior forest birds are typically highly specific to the habitat they use. Even small changes can result in a loss of species, leading researchers and land managers to often use forest birds as indicator species, such as the Brown Creeper (Geleynse, Nol, Burke, & Elliot, 2015). This indicates that the South Shore is lacking in sufficiently isolated patches of interior forest for forest obligate species to use for breeding. This is not entirely surprising, as forest cover on the South Shore is concentrated in a very narrow strip along the shores of Cootes Paradise Marsh. The strip of forest is not only narrow; it is highly disturbed, being intersected by numerous trails, many of them unofficial, and directly adjacent to busy residential areas and a large university campus. RBG should continue to make efforts to increase the size of buffers around areas of intact forest cover through native planting events and ensuring that unofficial trails stay closed.

Ensuring there are a sufficient number of areas with little to no human disturbance is essential to maintaining forest bird biodiversity.

Non-native Bird Species

Three non-native bird species have been detected regularly during breeding bird surveys conducted on the South Shore; European Starlings, Mute Swans, and House Sparrows. Of these species, European Starlings have been most dominant by far, and have seen a drastic increase in their detections since breeding bird surveys began. As shown in Figure 10, detections of Starlings began at a maximum of 5 detections in 2009. Detections steadily increased to their peak of 76 maximum detections in 2016, before dropping back down to 38 in 2017. Despite this recent drop, European Starlings still remain the most dominant bird species detected in breeding bird surveys on the South Shore (Figure 10), and still show an overall increasing population trend. European Starlings pose a risk to native species as they are cavity-nesters and compete with native cavity-nesters such as woodpeckers, and bluebirds for suitable nesting sites (Koenig, 2003).

Starlings not only compete with native birds for habitat and resources, they also likely contribute to the spread of a variety of invasive shrubs such as Common and Glossy Buckthorn, Multiflora Rose, and Autumn Olive. Studies suggest that Starlings are one of the few bird species capable of handling the purgative properties of otherwise inedible berries, as found in species like buckthorns (Becker et al. 2013). Being frugivorous, Starlings eat the berries of these undesirable shrubs and then disperse them across the landscape (Heimpel, et al., 2010), (Howell & Blackwell, 1977). This relationship provides both European Starlings and non-native woody shrubs a potential advantage over native species, increasing the spread and density of both non-native organisms.

Another study found that Starlings actually prefer the fruits of some non-native species over native alternatives. When provided with fruits from a variety of species, Starlings preferentially ate Autumn Olive and Multiflora Rose before moving onto other foods (LaFleur, Rubega, & Elphick, 2007). A later study also found that germination rates of Oriental Bittersweet and Autumn Olive seeds were significantly improved following ingestion by European Starlings (LaFleur & Rubega, 2009). Ingested seeds were retained for an average of 30-45 minutes, providing enough time for wide dispersal. It was estimated that a Starling could theoretically transport a seed 24km in 30 minutes (LaFleur & Rubega, 2009).

Mute Swans and House Sparrows both occurred in relatively low numbers on the South Shore; however both pose a threat to native species. Like the European Starlings, House Sparrows are cavity nesters, and can out-compete some species for nesting sites. RBG should take measures to prevent House Sparrows from establishing nests in nesting boxes before spring migrants arrive (Ellis, 2017).

Mute Swans compete with native Trumpeter Swans for nesting and food resources (Environment Canada, 2015), and also pose a risk to restoration efforts at RBG, as they eat large quantities of submergent vegetation. Both Mute Swan and House Sparrow populations should continue to be monitored in order to detect any significant changes in future breeding bird surveys.

Brown Creeper Decline

Brown Creepers are small forest birds that nest behind peeling bark, often on some of the largest mature trees in a forest (Cornell Lab of Ornithology, 2017). Brown Creepers are often used as an indicator species by foresters, as they are particularly sensitive to forest disturbances (Geleynse, Nol, Burke, & Elliot, 2015).

As shown in Figure 11 and Table 5, Brown Creepers were detected in 2009, 2010, and 2011, but have since not been detected during breeding bird surveys on Cootes Paradise South Shore. Long-term trends in Brown Creeper detections have been increasing in Ontario according to the North American Breeding Bird Survey (Appendix F), indicating this decline is more localized than broad-scale. The forest on the South Shore of Cootes Paradise is highly fragmented with obvious signs of decline in mature forest cover, as previously discussed and shown in Figure 4. It is possible that these forest changes are contributing to the declines seen in breeding bird surveys. Some breeding bird plots on the South Shore are also located in forest edges or are directly adjacent to wetlands, which might also limit the chances of detecting Brown Creepers in their preferred nesting habitat even if they are present.

The general lack of Brown Creepers on the South Shore is concerning, reinforcing the indication that suitable interior forest cover is sparse and has generally been declining.

Yellow Warbler Decline

Yellow Warblers have shown the most notable decline in detections of all bird species observed on the South Shore. When breeding bird surveys started in 2009, Yellow Warblers were the third most dominant species, with a relative abundance of 6.30% and a maximum of 26 individuals detected. Since then, the number of detections and the dominance for this species has been steadily decreasing, down to a relative abundance of 2.66% and an estimated 11 individuals detected in 2017 (Figure 11 and Figure 12).

This trend was not expected, as Yellow Warblers are regarded as a common and widespread bird species in Ontario. Yellow Warblers nest in a variety of habitats, including moist deciduous thickets and disturbed/early successional habitats such as suburban yards, fields, pastures, and hydro-corridors (Cadman M. D., 2007). RBG and the surrounding area in Hamilton provide a high number of these habitat types, in fact it's the presence of these habitats and the disturbances that cause them that are thought to be limiting some of the previously discussed more sensitive species, such as interior forest and ground-nesting birds. None of the other bird species that share the Yellow Warbler's habitat requirements have shown similar signs of decline. This gives an indication that a change or deterioration in breeding habitat might not be directly responsible.

The cause for this decline on the South Shore is still unknown. Peter McLaren, author of several species accounts in the *Atlas of the Breeding Birds of Ontario,* including Yellow Warbler, had not personally noted any declines, but suggested that the Canada Breeding Bird Survey (CBBS) results did in fact show Yellow Warbler declines that mirror those observed at RBG (personal communication Peter McLaren, 2018). Both short term and long term data from CBBS do in fact show that detections of Yellow Warbler have been decreasing since the mid 1970's (Appendix E), however the overall cause of these changes are also unknown. RBG should continue to monitor changes in Yellow Warbler

detections across the property in order to help identify potential threats that might be having an impact on the Yellow Warbler population.

Marsh Monitoring

Frogs

Green Frogs, Northern Leopard Frogs, and American Toads were the frog species most commonly detected on the South Shore. Of the 18 years marsh monitoring surveys that have been conducted at RBG, Green Frogs were detected in 17 years, Northern Leopard Frogs in 16 years, and American Toads in 12 years. The dominance of the above mentioned species coincide with surveys previously conducted at RBG in 1984 and 1985 that only recorded these three species on the South Shore (Royal Botanical Gardens, 1985). Information on the amphibian populations of Cootes Paradise prior to this time are vague, however in an unpublished report by Brian Pomfret (former wildlife biologist at RBG), two studies were referenced (Warren 1950) and (Brown 1928) that listed eight frog species as being historically present in Cootes Paradise Marsh. Brian Pomfret concluded that although there is a lack of data on the historic abundance of amphibians at RBG, it is assumed that amphibian populations have suffered declines relative to the degree of habitat loss. Therefore, populations of species currently present are thought to be small relative to their historic distributions (unpublished report Brian Pomfret, 2003).

Due to the nature of marsh monitoring surveys, determining an estimate of abundance for a given species is not always feasible. During a partial or full chorus, the number of individuals of a species cannot be accurately estimated, and when this is attempted, estimates are subjective to the surveyor. Frog species are instead assigned a calling code from 1 to 3 (1 representing discernable individuals, 3 being a full chorus) as a measure of relative abundance. This provides an accurate representation of species occurrence in a year, but gives a limited perspective on actual population numbers.

Green Frog and Leopard frog detections appear to be stable on the South Shore, while American Toads might be showing signs of decline in recent years. As shown in Table 6, American Toads have been detected half as often in the last nine years of surveys as they were in the first nine. GLMMP results show that overall probability of occurrence for American Toads in the Great Lakes Basin has shown fluctuations but has been relatively stable since 1995 (Tozer, 2013). If a decline is occurring at RBG, it may be fairly localized to Cootes Paradise Marsh. RBG staff should continue monitor these changes and investigate potential causes for this decline in American Toads, as this trend has not been noticed in any other frog species.

Both Wood Frogs and Western Chorus Frogs have been detected recently on the South Shore, in 2014 and 2015 for Wood Frogs and in 2010 and 2014 for Western Chorus Frogs. Neither of these species had been detected between 1995 and 2010, so this rediscovery is certainly noteworthy. However, both species were only detected in two years from one location respectively, therefore these observations do not represent well established populations. These species are likely being limited by a combination of factors including a lack of feeding and breeding territory, a lack of water clarity that limits algae growth for feeding tadpoles, and inputs of ammonia and ammonium nitrate from the sewage treatment plant in Dundas, shown to be toxic to egg survival. According to results of the GLMMP both of these species were significantly more likely to be detected in inland marshes as compared to Great Lakes coastal

marshes. Since Cootes Paradise is a Great Lakes coastal marsh, this might also help explain their relatively low occurrences.

Interestingly, Great Lakes/St. Lawrence populations of Western Chorus Frog were listed as threatened as per the Species at Risk Act in 2008. RBG property actually forms the boundary for the division of the Western Chorus frog populations and individuals detected on the South Shore technically do not fall under Species at Risk protection. However, as shown in the GLMMP results, detections of Chorus frog have been declining throughout the Great Lakes (Tozer, 2013), so any observations of this species on the South Shore are still very important.

It should be noted that survey routes, station locations, and the number of visits made to each station changed regularly throughout the 18 years that marsh monitoring has been conducted. This is reflected in the number of stations surveyed and visits completed section of Table 6. The highest number of stations surveyed in a given year was 6 in 1999, with the lowest being 1 in 1997. This should be taken into consideration when interpreting marsh-monitoring data.

Overall, the amphibian surveys indicate fairly stable marsh conditions in recent years. Although frog populations are still low compared to historic levels, detections of Green Frogs and Northern Leopard Frogs have remained stable, while the detection of Wood frogs and Western Chorus frogs might even indicate improvements in habitat quality. Even though these species are still limited in their occurrence and distribution this seems to indicate that RBG's marsh restorations efforts are having a positive impact on local populations of anurans. RBG should continue to work to eliminate Common Carp from the marsh, continue to remove invasive species, such as *Phragmites australis* and *Glyceria maxima*, and continue to plant emergent native species like Cattails and Wild Rice, all of which contribute to overall marsh health.

Salamanders

Prior to 1985, little work had been done to inventory the salamander species that occur on RBG property, even less so on the South Shore. Some of the earliest studies by Brown (1928) and Martin (1950) recorded the presence of 6 salamander species including Mudpuppy (*Necturus maculosus*), Eastern Red-backed Salamander (*Plethodon cinerus*), Spotted Salamander (*Ambystoma maculatum*), Blue-spotted Salamander (*Ambystoma laterale*), Jefferson Salamander (*Ambystoma jeffersonianum),* and Eastern Newt (*Notophthalmus viridescens*). More recent surveys conducted in 1984 (Bishop 1984), did not locate Mudpuppy, Jefferson Salamander, or Eastern Newt, although the latter was still assumed to occur on the property, as it was considered locally abundant at the time. Of the species detected in 1984 only the Red-backed Salamander was confirmed to occur on the South Shore of Cootes Paradise.

Since the mid 1980's there have been no other formal surveys on the South Shore for salamanders, however, Brain Pomfret does mention the presence of occasional Spotted Salamanders being observed on the South Shore in the Westdale area in an unpublished report on the amphibians of RBG (unpublished report Brian Pomfret, 2003). An additional informal survey was conducted by Tys Theysmeyer in the spring of 2015 to look for breeding adults in Mac Landing Inlet. Three days of trapping with two minnow traps produced one adult Spotted Salamander (personal communication Tys Theysmeyer, 2018). Red-backed and Spotted Salamanders are both assumed to still be present on the

South Shore, although exact populations and distributions are unclear. RBG staff should consider conducting formal salamander surveys to answer these questions.

Forest Edge Surveys

McMaster University

Garlic Mustard, Common Buckthorn, Japanese Barberry, and non-native Honeysuckles were the invasive species most commonly detected in the forest edge property boundary between RBG and McMaster University (Table 7). Although Motherwort was also a commonly detected non-native, it has a low weediness index value (-1) and is a lower priority than the previously mentioned known invasive species. Overall, at least 90 different non-native species were detected within the surveyed forest edge.

The composition and high abundance of Garlic Mustard, Common Buckthorn, Japanese Barberry, and Honeysuckles in the forest edge is to be expected, as all of these plants are well documented, problem species on the South Shore of Cootes Paradise (Burtenshaw, 2010). Garlic Mustard is the only herbaceous species to make the top dominant list, which can likely be attributed to its aggressive spreading nature, and release of allelopathic chemicals that inhibit the growth of other species (Gilliam, 2016), (Anderson, 2012). Common Buckthorn, Japanese Barberry, and Honeysuckles are all woody shrubs that quickly out-compete and displace native vegetation to produce thickets (Anderson, 2012). The presence of these species so close to forested properties is particularly concerning because all of these shrubs are shade tolerant, produce fruits dispersed by birds, and spread prolifically; making them very effective forest infiltrators.

Managing invasive species along forest edges is important because these edges act as a buffer between desirable forest habitat and the surrounding fragmented urban landscape. The disturbance created by the edge allows species to easily become established. If these areas aren't maintained, invasive species quickly become mature and then begin to encroach into the forest. Coordinating efforts to control these species should be easier now that their abundance and distribution along the edge is understood. These actions should take place as soon as possible as current areas of high abundance serve as a large seed source for an ongoing invasive species problem at RBG.

One major aspect of this project was to determine whether or not any populations of non-native species in the forest edge were established or are currently being augmented by specimens maintained in private gardens adjacent to RBG property. Of the problem invasive species detected in the forest edge, Japanese Barberry and Non-native Honeysuckles were two species that had the most substantial numbers of planted specimens in maintained gardens (Table 8). Common Buckthorn and Manitoba Maple were also encountered in garden areas, but in substantially lower numbers.

Japanese Barberry stood out as the species with the most likely correlation between planted individuals and those found in the forest edge. Figure 13 provides a map of Japanese Barberry abundance in survey plots, adjacent ELC polygons, and individuals detected in gardens. It is obvious that Japanese Barberry is well established in the forest edge, being found in all but two survey plots (both of which appeared to have been heavily landscaped) and has penetrated into sections of forest. This is concerning because Barberry was so prevalent in the gardens, with approximately 93 individuals detected (Table 8). Whether forest edge populations stemmed from planted individuals is tough to

determine, however the negative impact of this plant on natural systems is well documented, and maintaining such a large group of individuals directly adjacent to a natural area is likely to lead to further and increased infestations. Recommended actions would include control of Japanese Barberry found in the edge, however quick re-establishment would be likely unless individuals in adjacent gardens were removed as well.

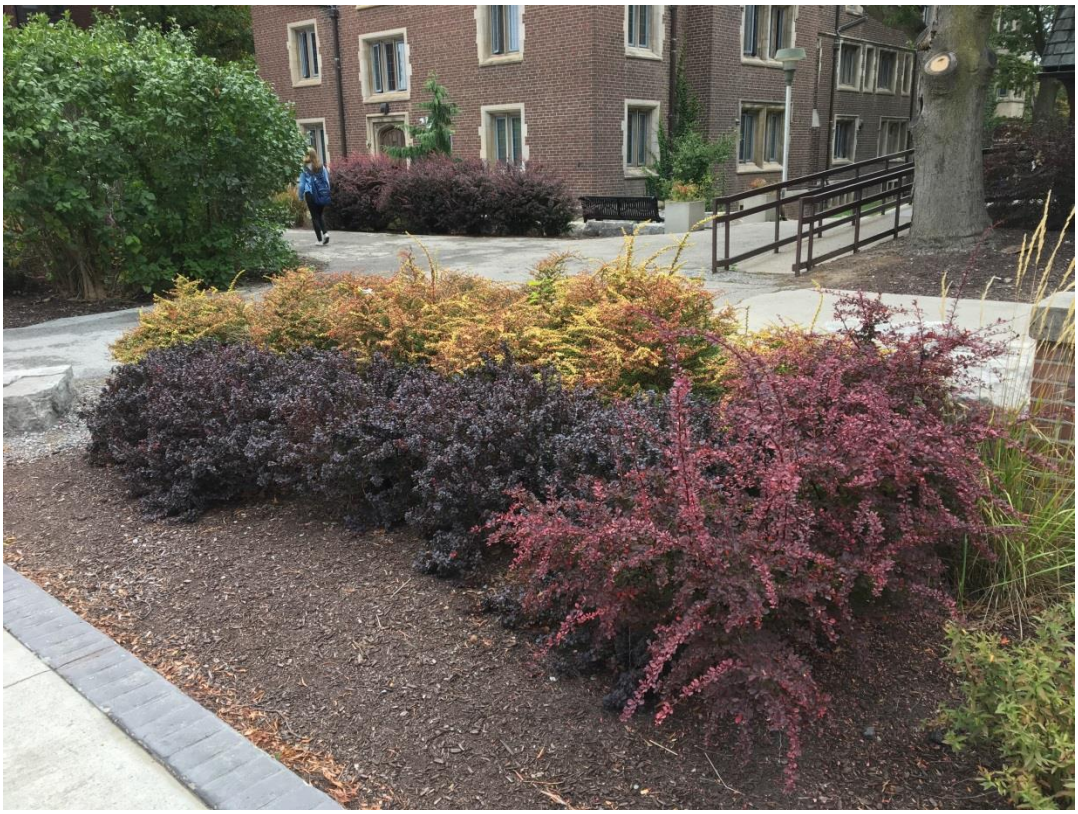

Figure 15: Varieties of Japanese Barberry (*Berberis thunbergii)* planted in a maintained garden area at McMaster University, Hamilton ON.

Several other detections of garden species were quite noteworthy. One example was *Miscanthus sinensis* (Silvergrass/Zebragrass), observed just outside of the 5m limit of survey plot MM-FE-06. This observation was included because it represents one of the first documented cases of *Miscanthus* growing spontaneously in the natural lands, adjacent to RBG property. *Miscanthus* is a known invasive grass that spreads quickly through vegetative reproduction and wind dispersed seeds, with established populations detected throughout the eastern United States and southern Ontario (OFAH/OMNR, 2012). Due to the extensive use of *Miscanthus* as an ornamental grass at McMaster University, its introduction into the natural lands is not a surprise. The closest group of planted individuals was located only 45 meters away from the plant in the natural lands. The individual clump detected in the natural lands in 2017 was treated with herbicide and had its seed heads removed. RBG staff should continue to monitor this area to detect any future spread or regrowth, as this species has the potential to become a prominent invasive species in the area.

Figure 16: a) Silvergrass (*Miscanthus sinensis*) clump growing in the natural lands and b) several varieties planted on McMaster University campus, Hamilton ON.

Winged Euonymus (*Euonymus alatus*), European Spindle Tree (*Euonymus europaeus*) and *Cotoneaster spp.* were also detected in McMaster University gardens. All three of these woody shrubs are commonly planted ornamentals that were also detected in forest edges. Winged Euonymus was found in 3 of the 7 garden areas surveyed and in 1 forest edge area, while the closely related European Spindle Tree was found in another 2 edge plots. Both species of Euonymus have been detected in the forest on the South Shore; however the proximity of these species to planted individuals indicates they likely originated from the seeds of nearby maintained plants. These species produce brightly coloured seeds that are dispersed by wildlife. Winged Euonymus is recognized by the Ontario Invasive Plant

Council and should therefore be controlled in natural areas and monitored along property boundaries to limit further spread (OFAH/OMNR, 2012).

Figure 17: An example of a *Cotoneaster* species, showing bright red berries, located in a maintained garden at McMaster University.

Cotoneaster spp. were only detected in 2 garden areas and 1 forest edge during formal surveys, but have been detected on the land surrounding McMaster during several other projects. We hoped to be able to identify whether the planted *Cotoneaster spp.* (approximately 60 individuals) at McMaster University were acting as a point source for the individuals found in the natural lands. Unfortunately, members of the *Cotoneaster* genus are very difficult to identify, and conclusions could not be drawn on exactly which species were detected in the gardens or in the edge, even after lengthy examination by several herbarium staff. However, Michael Oldham of the Natural Heritage Information Centre published a *List of the Vascular Plants of Ontario's Carolinian Zone* in which he lists *Cotoneaster divaricatus* and *Cotoneaster lucidus* as the only species to grow spontaneously in this part of Ontario (Oldham, 2017).

The specimens collected from RBG property were most closely identified to *Cotoneaster divaricatus*, in line with Michael Oldham's plant list. However, the three species of *Cotoneaster* found in maintained gardens were concluded to be different from each other and from *Cotoneaster divaricatus.* This indicates that the *Cotoneaster sp.* observed in the surrounding lands likely did not originate from the adjacent gardens at McMaster, at least not from the species located in 2017. Examples of *Cotoneaster divericatus* and *Cotoneaster horizontalis* (one of the suspected garden species) can be found in Appendix G. Further surveys of the gardens should be conducted to facilitate the collection of plant material at more appropriate times of year when identification features are most obvious, such as when the shrubs are in flower. Based on these conclusions, the *Cotoneaster sp.* located in the edge must have originated from another garden source. Because Cotoneaster also produce bright red berries, seeds could have been transported a great distance by wildlife.

A full list of the species observed in both the forest edge and gardens can be found in Appendix B. McMaster University and RBG should work together not only to develop a management plan for the invasive species located along their shared property boundary but to consider what species are planted and maintained in garden spaces. Non-native ornamentals should not be planted in areas directly adjacent to natural areas, especially those that have known invasive habits. There are a wide variety of attractive native alternatives that could serve as important learning tools for McMaster students, while serving as aesthetically pleasing garden plants that won't add to the problems in RBG's forests.

It should be noted that the edge surveys conducted in 2017 are only able to represent the composition and abundance of species at the time of surveying. RBG has already made efforts to manage invasive species along its property edges. This has included the manual and chemical removal of both herbaceous and woody species, as well as the re-planting of native plants. It can be assumed that even more abundant populations of non-native species would have been found if surveys had been conducted prior to this restoration work.

Churchill Park

The most dominant invasive species located in the forest edge surrounding Churchill Park was Common Buckthorn by far; found in every plot surveyed. As previously mentioned, Common Buckthorn is a common invasive species on RBG property so this result is not surprising. This stand of Common Buckthorn is fairly significant as it was assessed as dominant or abundant in 4 of the 5 survey plots.

Multiflora rose (*Rosa multiflora*) was the next most dominant woody shrub around Churchill Park, with occurrences in all five survey plots but with a lower average abundance than Common Buckthorn. Multiflora rose is also a known invasive plant at RBG, detected frequently through ELC conducted on the South Shore. This is another woody shrub that produces seeds dispersed by birds, allowing recruitment of new individuals far from where the parent plant originated.

Herbaceous non-natives were also numerous in the edge surrounding Churchill Park. Creeping Charlie (*Glechoma herderacea)*, Queen Anne's Lace (*Daucus carota)*, and Timothy Grass (*Phleum pratense*) were detected in all five survey plots, while Garlic Mustard was detected in four. Of these species, the abundance of Garlic Mustard is most concerning. As previously discussed, Garlic Mustard is well documented throughout RBG's nature sanctuaries, and has been shown to quickly outcompete surrounding vegetation, both physically and chemically through the release of allelopathic secondary compounds.

The forest edge survey plot with the highest number of non-native species was CHP-FE-05, with 59 species. This is almost double the number of species detected in any other plot. The most likely explanation for this difference is the proximity to residential housing. CHP-FE-05 directly backed on to a series of houses for its entire length. The boundary between these houses and RBG property usually consisted of a chain-link or wooden fence, providing little barrier for seed dispersal. This resulted in a variety of common garden plants (not all invasive), escaping into the forest. Examples included Oregano (*Origanum vulgare*), Garlic (*Allium sativum*), Lungwort (*Pulmonaria officinalis*), Pear tree (*Pyrus communis*), European Spindletree, Lesser Celendine, and European Cranberry (*Viburnum opulus opulus*). This is a major area of concern as exotic plant species from gardens pose one of the greatest threats to forest biodiversity (Gavier-Pizzaro, Radeloff, Stewart, Huebner, & Keuler, 2010).

One of the most interesting species detected in plot CHP-FE-05 were Peking Lilacs (*Syringa pekenensis*). The far west end of the plot was dominated by at least 12 mature Peking Lilacs making up the canopy, with obvious signs of regeneration with ~52 seedlings in the understory. This is not a species commonly associated with being invasive, so further investigation should be made into potential management strategies for this area.

Major restoration work is planned for Churchill Park in the coming years including invasive species removal efforts, the planting of native trees and shrubs, and the naturalization of a large parcel of currently mowed field (City of Hamilton, Royal Botanical Gardens, 2017). These efforts will help to reduce a major source of invasive species and limit further spread, and to increase the buffer around forest habitat, limiting the disturbance these areas currently experience.

Recommendations

EMAN vs. VSP Surveying Protocols for Small Tree and Shrub Monitoring

One of the most important forest layers to consider when conducting long-term forest monitoring is the small tree and shrub layer, as this component of the forest provides the most tangible insight into how tree composition will change over time. It is therefore essential that small tree and shrub surveying techniques become standardized before the next sampling event. There are two different protocols that have been used in the past and must be considered one is a provincial standard protocol known as the Vegetation Sampling Protocol (VSP) and the other is a federal standard protocol known as the Ecological Monitoring and Assessment Network (EMAN) Terrestrial Vegetation Sampling Protocol.

1. VSP, measures the percent cover attributed to each species within the small tree and shrub layer (small trees and shrubs with a height of 1m-2m) of the 20x20m plot. This technique ignores the number of stems attributed to each species and focuses on the ecological impact they have in the forest.
2. The second counts the number of stems attributed to each species as well as estimating the percent cover within a 5x5 meter small tree and shrub plot or alternatively through plots associated with tree regeneration monitoring (5 4x4m plots). This technique is time consuming because although the plots have attempted to be permanently marked, markers are being vandalized/ removed or erosion as uprooted them and it takes a lot of time to re-measure and re-mark the plots. Counting stems is also time consuming and dominance within a plot will be biased towards the species with the most stems, even if they occupy very little area.

Under ideal circumstances, using both monitoring protocols would be best. This would allow for comparisons to be made to both the 2008 and 2012 surveys and would not bias analyses. However, this might be unrealistic based on resource and time restraints. If only one technique is able to be used in the next round of surveying the authors recommend the Vegetation Sampling Protocols used in 2012. Estimating the area occupied is not only faster than counting individual stems, it provides a direct measure of the ecological impact a given species is having in the forest, i.e. the area occupied within that layer. This technique also provides a finer level of detail over time. Changes in cover could be detected year to year that wouldn't be picked up when only looking at the number of stems present.

Management of Woodland Speargrass

One of the most interesting yet concerning results to come from forest monitoring on the South Shore was the proliferation of Woodland Speargrass in the ground vegetation layer. As previously discussed, this non-native species has shown the greatest increase in cover on the forest floor. Woodland Speargrass threatens a wide variety of native vegetation including the endangered Few-flowered Club-rush populations. Because this species does not have formal Best Management Practices, one important recommendation would be to consider strategies to manage this quickly spreading invasive grass.

A formal study has been proposed by RBG Natural Lands and Science staff planned to begin in 2018, trialing several different Woodland Speargrass control techniques. These strategies must be effective against the Woodland Speargrass yet low impact so as not to damage surrounding plants. A series of 5 control activities are planned for the study including cutting, pulling, freezing, burning, and herbicide application. Further details of the study will become available following successful approval and commencement of trials, but this is a step in the right direction for invasive species management at RBG and provides hope for dealing with this new problem species.

Invasive Edge Species

RBG should consider working with homeowners in the area surrounding Churchill Park, particularly the area that backs on to CHP-FE-05. Part of the restoration work planned for Churchill Park involves replanting a former cricket field located right beside CHP-FE-05. Minimizing the risk of exotic species spreading into this newly restored area would be ideal. This would be an excellent opportunity to partner with the Cootes to Escarpment Ecopark System staff and local residents to educate landowners on responsible garden and yard maintenance practices in areas adjacent to natural lands. Starting a discussion about the threat exotic garden species pose to natural areas would help residents make more informed planting and waste disposal decisions in their gardens, reducing the impact they currently have. This project would coincide well with management plans and outreach initiatives already in place through the Cootes to Escarpment Ecopark system.

South Shore Forest Restoration

RBG currently has Forest Management Goals in place to work towards improving property wide forest habitat. These goals are imbedded into the Churchill Park masterplan currently being implemented. Aiming to achieve these goals throughout the South Shore would help to mitigate the declines that have been observed. The Forest Management Goals are as follows:

1. Defragment the forest area that was reduced to the ravine slopes, increasing interior forest area and reducing the amount of forest edge through strategic reforestation;
2. Encourage people to stay on the trails through various means of communication and create trail destination points that contain and focus visitors.
3. Increase forest's resilience to disturbances by enhancing the forest edge by removing invasive species and planting native species
4. Control invasive species, especially in the interior forest and critical forest habitat for species at risk;

5. Plant native species in areas where there is a high amount of disturbance (ex. where a number of ash have died);

In order to achieve goals 1 and 3 on the South Shore it is recommended that reforestation efforts be made around forest edges to increase interior forest area. Extending these forest boundaries will decrease the forest-edge ratio and provide more suitable habitat for interior species. Maintaining forest edges is essential to improving overall forest health as these edges act as buffers, reducing the impact of outside stressors, such as invasive species and encroachment on the more sensitive interior habitat. These efforts are already underway with the planned restoration work at Churchill Park as per the Churchill Park Management Plan (City of Hamilton, Royal Botanical Gardens, 2017), but should be continued in other areas wherever possible.

In working towards accomplishment of goal 4, invasive species should be removed from identified problem areas, such as management of Woodland Speargrass, the control of invasive species along problem border areas (ex. Parkview drive, McMaster University), around Species at Risk populations, and within the interior forests. These strategies are already outlined and identified as priorities in the Buckthorn and Honeysuckle management plans and site specific plans for Species at Risk on the property, such as in the Few-flowered Club-rush (Harrison, 2015). The removal of invasive species in these targeted areas would help to improve overall forest health and reduce competition for desirable native species.

Another area of improvement would be to focus on reforesting areas with declined canopy cover. In meeting goal 5, effort should be made to plant native species in sections of forest that have seen major die backs and don't have strong natural recruitment in the ground layer or shrub layer. One example would be areas where Ash trees have died. As previously mentioned, Ash are not expected to be able to recover very successfully from the effects of Emerald Ash Borer, so areas that were previously ash dominated will need to be replanted. This not only replaces forest cover in the long term, it reduces the chance that non-native species will take advantage of the canopy openings and spread. The map presented in Figure 4 should be used as a guideline to target replanting efforts in sections of declined forest.

Ecosystem disturbance on the South Shore of Cootes Paradise can be attributed to pressures from the surrounding urban environment. Off-trail use, dogs of leash, yard-waste dumping, encroachment, squatting, campfires etc. are all disturbances that are impacting the forest ecosystem. Increasing staff presence along with education and outreach initiatives with the adjacent community should reduce these impacts and address goal 2; however RBG should consider the feasibility of limiting public access to a lower number of more manageable main entrances and/or maintaining some form of facilities on the South Shore.

Salamander Monitoring and Habitat Restoration

Although evidence points to declines in salamander populations from what they would have been historically, RBG staff should conduct formal surveys to provide a more thorough understanding of salamander populations and distribution on the South Shore of Cootes. Many of the ponds found on the South Shore that may have once hosted populations of salamanders have since been filled in by erosion, reducing their ability to be used by breeding adults. One recommendation would be to look at areas that might benefit from the digging of additional ephemeral ponds to mitigate the filling effect

observed over the past 80+ years. An additional recommendation would be to focus surveying efforts on Presidents Pond, located in the Spencer Creek Floodplain along Cootes Drive in Hamilton. The recent addition of a wildlife barrier along the roadway and planned restoration work for the pond is hoped to improve the success of reptiles and amphibians in the area. Knowing exactly what species currently occupy the pond, salamanders included, would be useful in establishing a baseline for measuring the success of the previously mentioned mitigation efforts.

Conclusion

The South Shore of Cootes Paradise faces a variety of recognized threats that have led to signs of decline. It is the collection of long-term data that allows RBG to identify and make the changes necessary to mitigate these negative effects, and while the current data provides some insight into these issues it is essential that this monitoring continues into the future. The longer data is collected, the more robust the dataset becomes and the more accurately it can be used to assess trends. The long-term monitoring programs at RBG represent powerful tools in guiding management decisions in the future and being able to adapt them to best support these goals is essential.

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Appendix A

Forest edge and associated garden survey site names, both formal survey names and local campus feature names, as well as the date surveyed and surveyors present are provided. (KV=Kyle Vincent, CB=Corey Burt, CK= Claire Kemp, MM=Mara McChaffie, ED= Earleen Dover, and NN= Nicole Nolan.)

Forest Edge Site ID	Garden Site ID	Local Name	Date Surveyed	Surveyors
MM-FE-01	-	Miller's grove	08/24/2017	KV,CB
MM-FE-02	MM-GE-01	Les Prince hall	08/24/2017	KV,CB
MM-FE-03	MM-GE-02	Hedden hall	08/24/2017	KV,CB
MM-FE-04	MM-GE-03	Woodstock hall	08/29/2017	KV,CB,CK,MM,ED
MM-FE-05	MM-GE-04	Brandon hall	08/29/2017	KV,CB,CK,MM,ED
MM-FE-06	MM-GE-05	Whidden hall	09/20/2017	KV,CB
MM-FE-07	MM-GE-06	Faculty hollow	09/27/2017	KV,CB,NN
MM-FE-08	-	Bates residence	09/27/2017	KV,CB,NN
MM-FE-09	MM-GE-07	President's house	10/18/2017	KV,CB,NN

Appendix B

Full list of non-native plant species detected in the forest edge surrounding McMaster University, Hamilton ON. Site occurrences are based on a total of 8 edge sites as shown in *Figure 2.* Weediness values are based on the Southern Ontario Floristic Quality Assessment System (Oldham et al. 1995).

Species	Weediness	Sites with Species Occurrence
Garlic Mustard	-3	8
Common Buckthorn	-3	8
Motherwort	-1	8
Japanese Barberry	-3	7
Honeysuckles	-3	7
Creeping Thistle	-1	7
Common Dandelion	-2	7
Petty Spurge	-1	7
Multiflora Rose	-3	6
Queen Anne's Lace	-3	6
Nipplewort	-2	6
Burdock	-1	6
Lady's Thumb Smartweed	-1	6
Manitoba Maple	-1	6
Foxtail Grass	-1	6
St. John's Wort	-3	5
Woodland Spear Grass	-3	5
Dame's Rocket	-3	5
Reed Canary Grass	-2	5
Catnip	-2	5
Common Plantain	-1	5
Orchard Grass	-1	5
Black Medick	-1	5
Norway Maple	-3	4
Mullein	-1	4

Bull Thistle	-1	4
Barnyard Grass	-1	4
Heal-All	-1	4
Glossy Buckthorn	-3	3
Curly Dock	-2	3
Crab Grass	-1	3
Kentucky Blue Grass	-1	3
Bitter Dock	-1	3
Common Sowthistle	-1	3
Deptford Pink	-1	3
Creeping Charlie	-1	3
White Mulberry	-3	2
European Spindle Tree	-2	2
Common Speedwell	-2	2
Sweet Cherry	-2	2
Bittersweet Nightshade	-2	2
Annual Fleabane	-2	2
Hedge Maple	-1	2
Amur Cork Tree	-1	2
Tree Of Heaven	-1	2
Field Sow Thistle	-1	2
Lamb's Ears	-1	2
Toadflax	-1	2
Catalpa	-1	2
Lamb's Quarters	-1	2
Alfalfa	-1	2
Cleavers	-1	2
Winter Creeper	-1	2
Teasel	-3	1
Tree Lilac	-2	1
Common Burdock	-2	1
Red Clover	-2	1
Common Privet	-2	1
Coltsfoot	-2	1
Common Nipplewort	-2	1
Japanese Tree Lilac	-2	1
Prickly Sow Thistle	-1	1
Oxe Eye Daisy	-1	1
Horse Chestnut	-1	1
Winged Euonymus	-1	1
Black Nightshade	-1	1
English Oak	-1	1
Pear	-1	1
Katsura	-1	1
English Plantain	-1	1
Bromus Inermis	-1	1
Chickory	-1	1
Cornelian Cherry	-1	1
Oregon Grape	-1	1
Cotoneaster	-1	1
Pachysandra	-1	1

Firethorn sp.?	-1	1
Manna Grass	-1	1
Couch Grass	-1	1
Apple	-1	1
Mouse Ear Chickweed	-1	1
Hawkweed	-1	1
Galinsoga sp.	-1	1
Dog-Strangling Vine	-1	1
Canada Fleabane	-1	1
English Hawthorne	-1	1
Canada Thistle	-1	1
White Poplar	-1	1
Colts Foot	-1	1
Boston Ivy	-1	1

Appendix C

Full list of non-native plant species detected in the maintained gardens at McMaster University, Hamilton ON. Site occurrences are based on a total of 7 garden sites as shown in *Figure 2.* Weediness values are based on the Southern Ontario Floristic Quality Assessment System (Oldham et al. 1995).

Species	Weediness	Sites with Species Occurrence
Japanese Barberry	-3	6
Miscanthus	-2	4
Boston Ivy	-1	4
Katsura	-1	4
Winged Euonymus	-2	3
Dwarf Korean Lilac	-1	3
Forsythia	-1	3
Fountain Grass	-1	3
Boxwood	-3	2
White Mulberry	-3	2
Perrywinkle	-2	2
Norway Spruce	-1	2
Magnolia	-1	2
Rose of Sharon	-1	2
Bridal Wreath	-1	2
Cotoneaster sp.	-1	2
Peony (Herbaceous)	-1	2
Day Lillies	-1	2
Purpleleaf Sand Cherry	-1	2
Ginko	-1	2
Honeysuckle	-1	2
Hosta	-1	2
Norway Maple	-3	1
European Yew	-3	1

Mountain Ash	-2	1
European Spindle Tree	-2	1
Rose Sp. 3	-1	1
Pachysandra	-1	1
Winter Creeper	-1	1
False Cypress	-1	1
River Birch	-1	1
Feather Reed Grass	-1	1
Sweet-scented Bedstraw	-1	1
Firethorn?	-1	1
Cherry Sp.	-1	1
Doublefile Viburnum	-1	1
Clematis	-1	1
Rose Sp. 1	-1	1
Foxtail Barley	-1	1
Spirea	-1	1
Climbing Hydrangea	-1	1
European Larch	-1	1
Hedge Maple	-1	1
Zebra Grass	-1	1
Colarado Blue Spruce	-1	1
Oregon Grape	-1	1
Austrian Pine	-1	1
Dogwood Sp.	-1	1
Colorado Blue Spruce	-1	1
Douglas Fir	-1	1
Japanese Maple	-1	1
Blue Spruce	-1	1
Common Plantain	-1	1
Rose Sp. 2	-1	1
Lamb's Ears	-1	1
Sandcherry	-1	1
Cornelian Cherry	-1	1
Squash	-1	1
Beauty Bush	-1	1
Vetch Sp.	-1	1
Mugo Pine	-1	1
Yew	-1	1
Blood-twig Dogwood	-1	1
Old-fashioned Weigela	-1	1

Appendix D

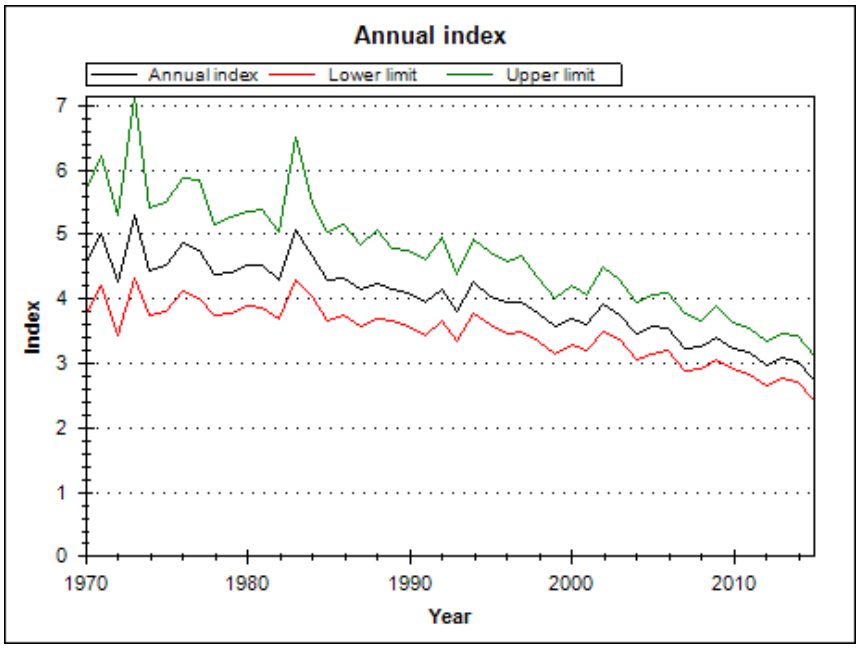
Full list of non-native plant species detected in the forest edge surrounding Churchill Park in Hamilton ON. Site occurrences are based on a total of 5 sites as shown in *Figure 3.*

Species	Site Occurrences	Species	Site Occurrences
European Buckthorn	5	Redtop	1
Multiflora Rose	5	Dog Strangling Vine	1
Honeysuckles	5	English Ivy	1
Creeping Charlie	5	Field Sowthistle	1
Queen Anne's Lace	5	Purple Loosestrife	1
Timothy Grass	5	Foxtail Grass	1
Garlic Mustard	4	Smooth Brome	1
Canada Thistle	4	Garlic	1
Common Burdock	4	Couch Grass	1
Common Plantain	4	Bell Flowers	1
Orchard Grass	4	Ox Tongue	1
Quack Grass	4	Goutweed	1
Wood Sorrel	4	Common Dandelion	1
Curly Dock	4	Greater Celandine	1
Teasel	3	Salsify	1
Woodland Spear Grass	3	Heal-All	1
Dandelion	3	Sweet Woodruff	1
Kentucky Bluegrass	3	Japanese Knotweed	1
Manitoba Maple	3	Unknown Rush	1
White Mulberry	3	Kentucky Blue Grass	1
Red Clover	2	Curly Dock	1
Cow Vetch	2	Alsike Clover	1
Lamb's-quarters	2	Oregano	1
Bittersweet Nightshade	2	Knotweed	1
Chicory	2	Periwinkle	1
Bull Thistle	2	Burdock	1
Bittercress	2	Bitter Dock	1
English Plantain	2	Leafy Spurge	1
Mugwort	2	Dog-strangling Vine	1
Catalpa	2	Lilly Of The Valley	1
Rose-Of-Sharon	2	Reed Canary Grass	1
Hawthorn	2	Lungwort	1
Japanese Barberry	2	Shining Bedstraw	1
Crab Apple	1	Moneywort	1
White Poplar	1	St. John's-wort	1

Trumpet Vine	1	Moneywort	1
European Alder	1	Common Mullein	1
Apple Tree	1	Day Lilly	1
European Spindle-Tree	1	Allium sp.	1
Boxwood	1	Mullein	1
Forsythia	1	Common Speedwell	1
European Cranberry	1	Narrowleaf Plantain	1
Peking Lilac	1	Yellow Archangel	1
Norway Maple	1	Nipplewort	1
Pear Tree	1	Oat	1
Common Privet	1		

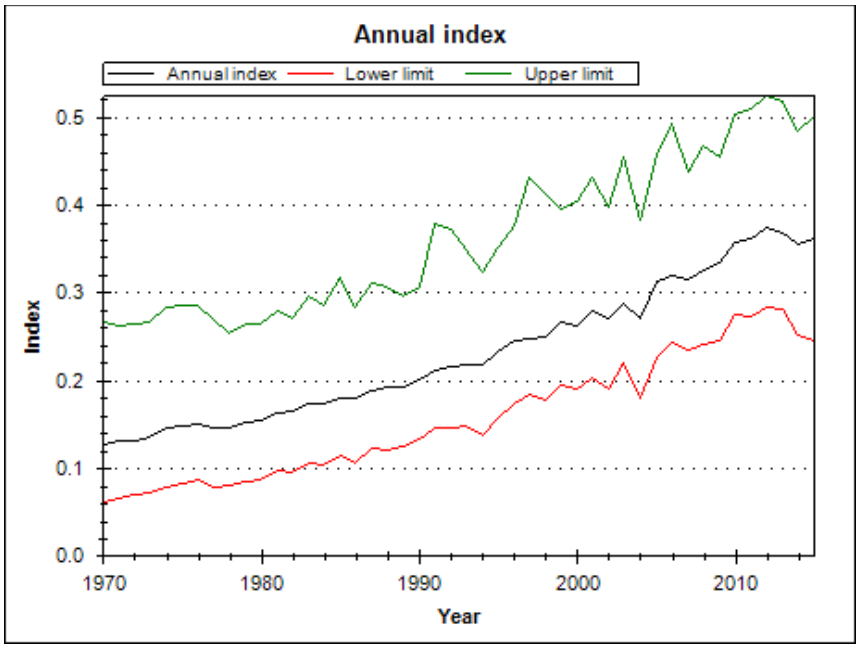
Appendix E

Long-term trends of Yellow Warbler detections in Ontario. Sourced from the North American Breeding Bird Survey.



Appendix F

Long-term trends in Brown Creeper detection in Ontario. Sourced from the North American Breeding Bird Survey



Appendix G

Herbarium vouchers of Cotoneaster species. A) Suspected *Cotoneaster divericatus.* B) Suspected *Cotoneaster horizontalis.* Both species encountered during edge and garden surveys around McMaster University.