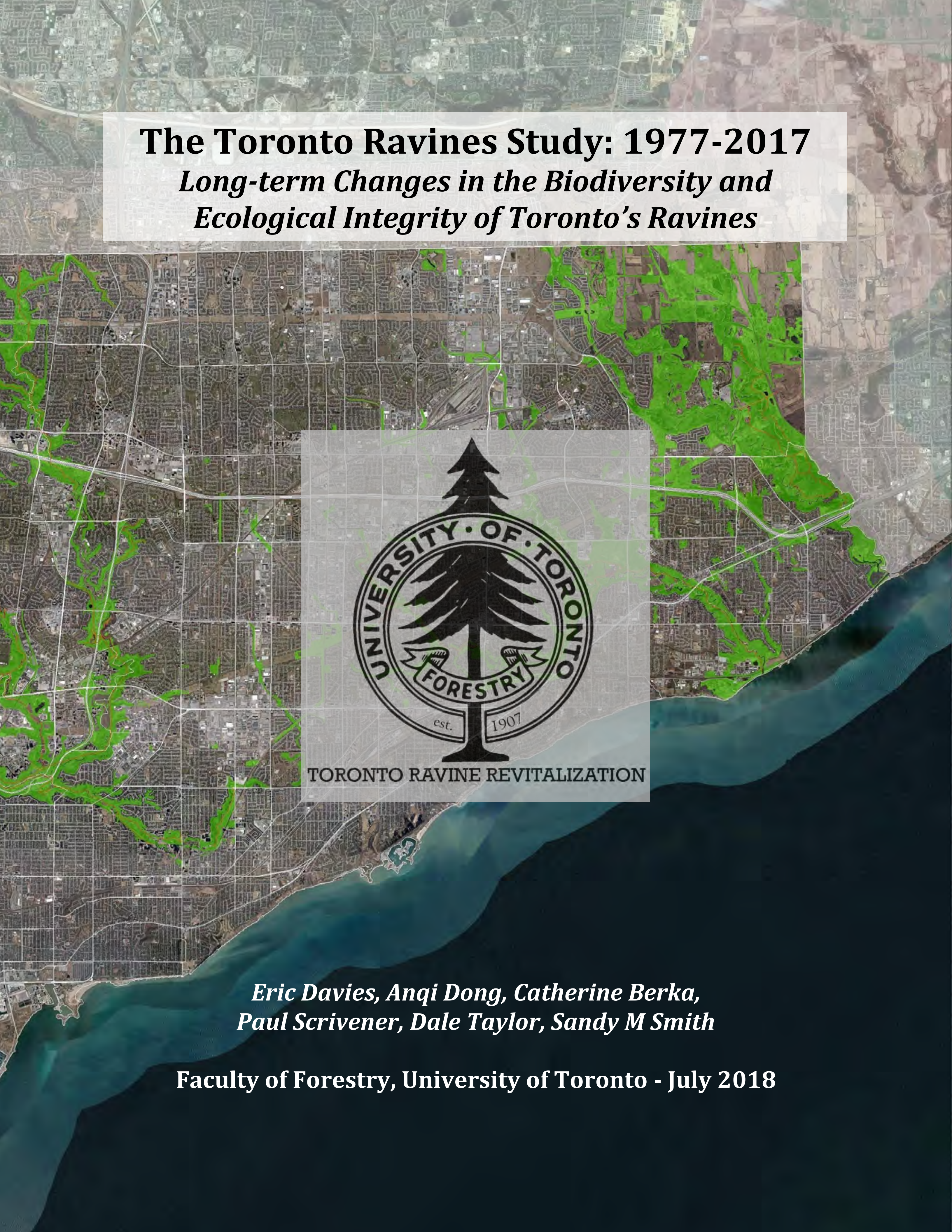

The Toronto Ravines Study: 1977-2017

Long-term Changes in the Biodiversity and Ecological Integrity of Toronto's Ravines

Eric Davies, Anqi Dong, Catherine Berka, Paul Scrivener, Dale Taylor, Sandy M Smith

Faculty of Forestry, University of Toronto - July 2018

ACKNOWLEDGEMENTS

This report would not have come into being without the work of the many individuals who dedicated endless volunteer hours to its realization. Our thanks to:

The originators of the 1977 study, our co-authors Paul Scrivener and Dale Taylor, for sticking with the project over the past 40 years, and for getting it going again. Dale and Paul provided the team with a real-life example of 'citizen science' in action, and a generational timeline to the past. They made this project an adventure for all of us. Good stewardship of the land is a lifelong affair, and Dale and Paul have exemplified that commitment beyond all expectations.

Esther McNeil for walking into the University of Toronto, Faculty of Forestry six years ago and asking: *"How can I help save the Toronto ravines?"* Esther inspired us to start working in the Toronto ravines, which ultimately led to this project, this report, and a renewed interest in ravine conservation.

Catherine Berka for jumping with two feet into this project from day one, and for providing an endless source of positivity, leadership, humour, community outreach, and every day hard work. The project would simply not be what it is today without the heart and soul of our other co-author, Catherine.

This project has benefited tremendously from the expertise, cooperation, and guidance of many people, especially in The City of Toronto, the Toronto and Region Conservation Authority, local nature groups, and countless citizens. Our most sincere appreciation to those private sponsors whose support allowed us to turn this initiative into an inspirational and useful tool for guiding the future restoration of Toronto's ravines.

Our private donors provided much more than simply funds to make this project happen – most importantly, they provided a sense of local accountability. The only meaningful deliverable required of donations is a job well done. Our team put their hearts and souls into this project for three years in the hope that the donors would see our work as such. We are sincerely grateful for this unique opportunity and hope our donors see the report as a source of pride that will inspire others to follow their lead.

The following is a partial list of those donors who provided private funding supported this initiative: Anne McConnell; Dez Capital; Jannie and Paul Mills; Manulife; Martha Rogers; Pixie and Neil Shaw; Sandra and James Pitblado; Craigellachie Holdings, Paul Scrivener, The Dalglish Family; and The Gerald Schwartz & Heather Reisman Foundation.

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UNIVERSITY OF TORONTO
FACULTY OF FORESTRY

8 July 2018

As Dean of the Faculty of Forestry and a member of the University of Toronto whose President's house sits on one of Toronto's inner ravines, I welcome the completion of this *Report of the Toronto Ravine Revitalization Study, 2015-2018*.

This work was conducted by graduate students under the supervision of academic staff in the Faculty of Forestry and guided by a steering committee of researchers, faculty members, and community ravine leaders. It was also community funded through the efforts of the Steering Committee, with the assistance of the university administration.

The study, which breaks new ground in urban forestry, has signal importance in updating a baseline study of the Rosedale ravines done in 1977, also conducted by University of Toronto graduate students under faculty supervision, and similarly funded by the community. The methodology enabled systematic and dramatic depiction of changes over time in the subject ravines.

I share the basic assumption of the study, which was also recently adopted as policy direction by the Toronto City Council, that Toronto's ravines should continue to be *"fundamentally natural areas."* The study's principle findings are unfortunately that the ravines are in long-term ecological decline. Its recommendations for action to reverse this decline deserve and require urgent attention.

I think this work is especially commendable as a model for university-community research and interaction. It shows what can be done in partnership with the public to bring university knowledge and science to important applications within our host communities.

Well done TRRS!

Professor Rob Wright,
Dean

Table of Contents

EXECUTIVE SUMMARY

The Toronto ravines are one of world's largest 'urban ecosystems'. They cover an astonishing 17% of Toronto, for a total area of over 11,000 hectares (27,000 acres). In addition to offering 2.8 million citizens the opportunity to enjoy nature, they are the primary source of habitat for Toronto's terrestrial biodiversity, and they provide billions of dollars' worth of ecosystem services. To ensure the continuation of these benefits, the ecological health of the Toronto ravines must be monitored, restored, and stewarded with a scientific framework and expertise. However, it will be the citizens of Toronto who will make this happen – its citizens, business leaders, philanthropists, and corporations, its politicians, sports legends, and rock stars – all recognizing the importance of these natural spaces and playing a vital role in bringing them back to health.

This Report, *The Toronto Ravines Study: 1977-2017,* summarizes a 3-year citizen-science effort to re-survey one of the few known historical studies of biodiversity in the Toronto ravines: *The 1977 Rosedale Ravines Study*. As summarized here, over the past 40 years the biodiversity and ecological health of Toronto's ravines has declined to a critical level and is now likely on the edge of ecological collapse. Today, invasive plants dominate large expanses of the understory, mid-story, and canopy of these ravines, and Toronto's native biodiversity is fast disappearing. Since it is the native plants that host biodiversity, ecosystem health suffers. However, if widespread, science-based action is taken soon, then it is possible that the Toronto ravines can be restored to a healthy state.

The overarching goal of *The Toronto Ravines Study: 1977-2017* is to accelerate the process of integrating 'Science' into ravine 'Policy, Practice, and Community Engagement'. We outline how the scientific frameworks of 'Adaptive Management' and 'Ecological Integrity (EI)' can be used to improve the effectiveness of ravine Policy, Practice, and Citizen Engagement by allowing for 'Evidence-Based Decision-Making'.

New York City (NYC)'s recent launch of its Natural Areas Conservancy provides an impressive model for Toronto to follow. For an area roughly half the size of the Toronto ravines, the NYC has budgeted $385 Million over 25 years to fund a massive science-based program to inventory, restore, and steward its natural areas. With global standards of conservancy in hand, Toronto could do the same and restore its ravines within 10-20 years, making it one of the world's greatest urban ecosystems – an outdoor Louvre of wilderness and biodiversity.

Study Achievements

Throughout the project, our team has worked in both the public and private realms, with government agencies, NGO's, and citizen groups to initiate a collaborative process to develop an 'Adaptive Management' framework that can guide the inventory, restoration, and stewardship of the Toronto ravines. The following is a list of our key efforts and achievements.

Science

- Adopted 'Adaptive Management' and 'Ecological Integrity' (EI) as the scientific frameworks for monitoring, restoring, and stewarding the Toronto ravines.
- Assembled international, national, and provincial protocols for measuring EI.
- Began developing custom protocols for monitoring, restoring, and stewarding the biodiversity and EI of the Toronto ravines.
- Re-surveyed ***The 1977 Rosedale Ravines Study*:**
  2015 - Field Survey& one Master (MFC) research project
  2016 - Field Survey& one Master (MFC) research project
  2017 - Field Survey& three Master (MFC) research projects
  2018 - Final Report: ***The Toronto Ravines Study: 1977-2017***

Our **key 'Science' finding** is the requirement for an 'Adaptive Management' framework to monitor, restore, and steward the biodiversity and 'Ecological Integrity' of the Toronto ravines. In creating this framework, we must ensure the protocol is also applicable to Policy, Practice, and Citizen Engagement.

Policy

- Conducted Policy Analysis: Integrating 'Ecological Integrity' (EI) into Toronto's ravine policy.
- Member of City of Toronto's Ravine Advisory Group.
- Made formal presentations at City of Toronto Committee Meetings (Appendix A).
- Successfully advocated for the adoption of EI as the guiding approach to implement the first principle of the City of Toronto's Ravine Strategy; *i.e.* that the ravines be maintained as *"fundamentally natural areas"*[1]

[1] *See Executive Committee Meeting EX27 item EX27.8 on September 26, 2018, available at: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2017.EX27.8*

Our **key 'Policy' finding** is the need for 'Ecological Integrity' as the guiding framework for implementing Toronto's ravine policy, as well as using 'Adaptive Management' and 'Evidence-Based Decision-Making" to direct implementation of future ravine policy.

Practice

- Started two pilot projects to field test methods for monitoring, restoring, and stewarding the 'Ecological Integrity' of the Toronto ravines. These pilot projects were collaborative efforts between UoT-Forestry, the City of Toronto, and the citizens of Toronto.

- Pilot Project 1) *Native Plant Map & Seed Bank*: Citizen-science project to map native plants and use them as a source of locally-adapted seeds for restoring the Toronto ravines.

- Pilot Project 2) *Invasive Plant Mapping & Removal*: Citizen-science project to map invasive plants and field-test methods for their removal.

Our **key 'Practice' finding** is the need for **'**Best Practice Guidelines' to monitor, restore, and steward the 'Ecological Integrity' of the Toronto ravines.

Citizen Engagement (Citizen Science)

- Conducted public events on using 'Ecological Integrity' as a guiding principal for monitoring, restoring, and stewarding the Toronto ravines.

- Worked with five Resident Associations to raise awareness, educate, and engage citizens in restoring ravine health.

- Appeared in ten Media stories (Appendix B).

- Presented ten Public talks (Appendix C).

- Led two Public walks (Appendix C).

- Received two Awards (Appendix C).

- Held a Ravine Stewardship Workshop for donors and citizens at the University of Toronto President's Residence (Appendix C).

Our **key 'Citizen' engagement finding** is that a citizen-science program should be created for monitoring, restoring, and stewarding the 'Ecological Integrity' of the Toronto ravines.

BACKGROUND

The Toronto Ravines - An Extraordinary Urban Ecosystem

Viewed from above, it is clear that Toronto has been built over, through, and around a massive ravine ecosystem. After more than 300 years of development, the Toronto ravines still cover 17% of the City, collectively totaling over 11,000 hectares, of which 40% is privately held. If you were to walk all of Toronto, 1 in 5 footsteps would fall within a ravine. This is an extraordinary ecosystem to have within any city, and it defines the ecological character of the Greater Toronto Area. It offers recreation to almost 3 million people, it generates hundreds of millions of dollars in ecosystem services every year, and it is home to a vast array of biodiversity. Given the extraordinary benefits of this ecosystem, it should be managed with the utmost care to ensure these benefits continue into the future.

However, while there is a great deal known about the non-living aspects of the Toronto ravines – their extent, ownership, and where the roads, trails, bridges, and utilities are - there is remarkably little known about their terrestrial biodiversity. Surprisingly, there are very few scientific publications on the terrestrial biodiversity of the Toronto ravines. Little scientific information exists regarding: (1) the current state of biodiversity in the Toronto ravines, (2) how it has changed over time, or (3) where it is heading into the future.

Fortunately, it is easy to answer these important questions about Toronto's terrestrial biodiversity. All that is needed is a scientific protocol to 'inventory', 'monitor', 'restore', and 'steward' the biodiversity of the Toronto ravines. Data derived from the inventory and monitoring efforts allows the determination of the most effective way to 'restore' and 'steward' the ravines. This iterative scientific process is termed 'Adaptive Management' and uses a framework discussed in more detail throughout this report.

Exploring the biodiversity of the Toronto ravines will produce many important discoveries and will provide great adventure to those who get involved. Given the massive size of the Toronto ravines, it will be essential to harness the power of 'Citizen Engagement' in order to fix them. In the future, we look forward to the Toronto ravine system becoming one of the world's most exciting and valuable 'Citizen-Science' projects.

Toronto's Indigenous People –The Origins of Land Stewardship

The Toronto ravines are the traditional lands of the Huron-Wendat, the Seneca, and the Mississaugas of the Credit River, and we acknowledge the origins of land stewardship that began with these Indigenous peoples. As ecologists interested in the conservation of biodiversity and the stewardship of ecosystems, we honour and respect this Indigenous traditional knowledge and mark its quintessential contribution to land stewardship.

We recommend John Riley's 2013 book, *The Once and Future Great Lakes Country: An Ecological History,* to readers, wherein he describes the fascinating history of Indigenous land stewardship in the Great Lakes region. This is an inspirational guide about the greater value that traditional knowledge can bring to modern land conservation and stewardship. We are dedicated to working with Indigenous people to bring this knowledge to the forefront of conservation practice in the ravines.

Looking to the future, we see the history and lessons of Indigenous land stewardship as the way forward, and as a powerful tool for learning and reconciliation.

Toronto's Faculty of Forestry - A Century of Ecosystem Science

Founded in 1907, The University of Toronto's Faculty of Forestry (UoT-Forestry) is Canada's first and longest-running forestry school. Over the past 111 years, UoT-Forestry has been at the forefront of developing scientific methods for ecosystem inventory, management, and landscape-scale conservation.

Many Canadians will be familiar with UoT-Forestry's *Trees of Canada* books that have served as Canada's official tree identification guide. This series of guides embody the ethos of forest stewardship, one that begins with tree identification, and flows through the more challenging stages of forest inventory, restoration, and stewardship. By learning tree identification, one can develop the ability to 'see' how forests ebb and flow over time, and to 'understand' how these changes produce different types of ecosystems, which host different communities of biodiversity. Ultimately, the goal of stewardship is to help guide a forest over time to ensure that the rich variety of plants and animals who call a forest home, endure.

As Aldo Leopold, Conservationist and Forester, once remarked, the goal of forestry extends beyond the production of lumber to *"...propagating owls, woodpeckers, titmice, goshawks, and other useless wildlife".*

Toronto's Faculty of Forestry exists to educate, innovate, and apply its expertise to the conservation of Canada's trees and forests. The present report, *The Toronto Ravines Study: 1977-2017,* provides one such example - envisioned by its professors, conducted by its students, and done for the City of Toronto. Being a *"City within a Forest"*, Toronto is fortunate to have one of the world's best Forestry schools – ready, willing, and able – to help inventory, restore, and steward the health of Toronto's forests and biodiversity.

The fascinating history of University of Toronto's Faculty of Forestry is told in Mark Kuhlberg's centennial book, *One Hundred Rings and Counting: Forestry Education and Forestry in Toronto and Canada, 1907-2007.*

Toronto's Citizen Science - A Century of Citizen Science

The loudest and most passionate efforts to conserve the beauty and biodiversity of the Toronto ravines has always come from its citizens, from the establishment of 'natural history clubs' in the 1920's and 1930's, to generations of outspoken citizens who have trumpeted their reverence for Toronto's nature, and rallied community and political efforts for its conservation.

The Brodie Club (1921), The Toronto Field Naturalists (1923), The Toronto Ornithological Club (1937), The Toronto Entomologists' Association (1969), and The Mycological Society of Toronto (1973), are just some of the groups that have championed the discovery of Toronto's biodiversity and the engagement of its citizens.

The biological records of these nature clubs are a treasure trove for understanding how the biodiversity of the Toronto has changed over time. However, due to the historical constraints of limited funding and the recent advent of modern database technology, many of these biological records exist today only in paper format and have yet to be consolidated or scientifically analyzed. A select group are summarized here in Appendix D.

The present report, *The Toronto Ravines Study: 1977-2017,* is a re-survey of one of these historical studies: *The 1977 Rosedale Ravines Study*. The goal of the original report was to show that a small group of citizens and scientists – when provided with a modest amount of funding – could produce a useful scientific report on the status of biodiversity in the Toronto ravines.

The expertise of Toronto's nature clubs, along with their treasure troves of biological records, remain well poised to play a leading role in the conservation of the Toronto ravines, through this continued, albeit expanded, practice of Citizen Science.

The Project Goal

The main goal of the present project has been, and continues to be, to integrate modern ecological science into Toronto's Ravine Policy, Practice, and Citizen Engagement in order to restore the health of its ravines and ecosystems.

The Theme - Adaptive Management

Climate change, land development, and the introduction of non-native invasive species have caused major damage to ecosystems worldwide. Consequently, the field of conservation biology has had to shift its approach from passively 'protecting' ecosystems, to actively 'restoring' and 'sustainably' managing them. Many conservation efforts and policies still focus on passive management where words such as 'protection' and 'conservation' do little to illuminate the critical nature of active forest management.

Policies aiming to conserve and protect can sometimes do more harm than good when addressing complex urban forest health issues. There are far too many external forces and variables that impact urban forests for the simple word ‘protect’ to be sufficient.

Because ecosystem threats are complex and constantly emerging, the scientific process of ‘Adaptive Management’ must be used to ensure that conservation efforts are effective and efficient. ‘Adaptive Management’ is simply a process of ‘trial and error’; *i.e.* if a method works, it is retained; if it fails, it is discarded. This iterative process ensures that the management of ecosystems improves over time – always getting better, faster, and cheaper.

There are four main components of the ‘Adaptive Management’ cycle: ‘Science’, ‘Policy’, ‘Practice’, and ‘Citizen Engagement’. The ‘Science’ improves the understanding of the ecosystem and management strategy over time. The ‘Policy’ guides it, the ‘Practice’ does it, and the ‘Citizens’ both benefit from it and contribute to it. We have used this key framework to guide our study findings and recommendations.

The Timeline - The Past, Present & Future of Toronto’s Ravines

Past: In 1977, a group of citizens teamed up with scientists at the University of Toronto and conducted the *1977 Rosedale Ravines Study*. In it, they surveyed trees, wildflowers, birds, mammals, and other biodiversity, and found that the ecological health of the Toronto ravines was poor and fast declining. Their main recommendation was to start a citywide, science-based program to monitor, restore, and steward the Toronto ravines. This never came to be. Looking back, it is easy to see why – there were simply no precedents to follow. The benefits of healthy ecosystems to people, the economy, and biodiversity had yet to be established back then. Even the term ‘biodiversity’ did not exist. However, the study helped lead to development of the City's first ravine control by-law entitled By-law 332-81 *“To Regulate and Prohibit the Destruction of Trees or Other Natural Vegetation and to Prohibit the Excavating or Other Altering of Contours Within Ravines”,* enacted May 21, 1981.[2]

Present: In June 2015, the founding members of the 1977 Study teamed up with UoT-Forestry and began a three-year process to re-survey the 1977 study sites. The current report, *The Toronto Ravines Study: 1977-2017,* summarizes these efforts and points out the widespread decline of biodiversity in the Toronto ravines over the past 40 years. We are now at the point where this ecosystem is likely on the edge of ecological collapse. Today, invasive plants dominate large expanses of the understory, mid-story, and canopy of the ravines, and native biodiversity is rapidly declining. So, while the recommendation of the 1977 Study is repeated here – to start a citywide, science-based program to monitor, restore, and steward the Toronto ravines – the urgency of this call has intensified. If we do not immediately get serious, align all our efforts with supportive City policy, then the ravines will decline beyond recovery.

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[2] *Available at: https://www.toronto.ca/legdocs/pre1998bylaws/toronto%20-%20former%20city%20of/1981-0332.pdf*

Future: New York City just approved a 25-year program totalling $385 Million to inventory, restore, and steward a natural area half the size of the Toronto ravines. Toronto could do the same – no need to re-invent the wheel. Using the now standard practices of 'Adaptive Management', 'Evidence-Based Decision-Making', and 'Ecological Integrity', we can start to work together to restore local biodiversity and eradicate the invasives that continue to erode our landscapes. Within 10-20 years, Toronto could be home to the world's greatest 'urban ecosystems' – an outdoor Louvre of wilderness, biodiversity, and recreation. They could be our constant reminder that we are a part of nature and that nature – entwined within our city streets – is part of us. Wildflowers, birds, butterflies, and thousands of other marvellous species could once again thrive in the Toronto ravines.

We hope our report inspires Torontonians to come together and start a citywide, citizen-empowered, science-based program to monitor, restore, and steward the remarkable biodiversity of the Toronto ravines.

MAIN FINDINGS

Component Studies Findings - An Ecosystem in Decline

The present report provides some of the first estimates of long-term change in the biodiversity and ecological health of the Toronto ravines. These estimates were obtained by re-surveying one of the only known historic studies of the Toronto ravines, *The 1977 Rosedale Ravines Study,* in a series of research projects. Our findings and recommendations are based on these individual components, all which can be viewed at: *https://torontoravines.org/reports/.*

Comparison of the 1977 and 2017 data clearly demonstrates a severe and widespread decline in native trees, wildflowers, birds, and mammals over the past 40 years. Our work has also shown that the Toronto ravines are experiencing rapid and widespread growth of many invasive species. Along with other non-native trees, the highly invasive Norway maple, originally planted as a street tree, has increased its canopy cover from about 10% in the 1970's to 40% in 2017. Invasive herbaceous plants – such as garlic mustard, Japanese knotweed, and dog-strangling vine (DSV) – are now present in over 95% of the forest floor surveyed.

If one were to compare such statistics to human health, it would be like finding a healthy-looking person lying on the ground, clearly unable to function. While you might not know the precise medical cause of the health condition, you would know that the person needed immediate assistance. The Toronto ravines are in a similar situation. They are showing clear signs of rapid decline at all levels of the ecosystem, and without immediate assistance, they will likely suffer irreparable damage. ***The ravines need help.***

The following is a list of the Major Findings from the five Master-level research projects that comprise the individual components of the 2017 re-survey:

1. **Low 'Ecological Integrity' in the ravine forests**

   The First Component Study completed was *"Ecological Integrity in the Park Drive Ravine: 1977 to 2015"* by Anqi Dong, 2015. A partial canopy re-survey was conducted in 2015, followed by a complete canopy re-survey in 2016. The main findings in this study were originally collected in 2015 and have been updated here using the complete dataset from 2016 (*i.e.* stats here may differ slightly from those in Dong's report).

   Historically, 73 woody species are native to Toronto, but 30 of them have now been extirpated – not actually extinct, yet locally absent in Toronto. The 1977 canopy survey found 20 native woody species across the three surveyed Rosedale ravines while 19 were found in 2016. It is clear then that the health of native tree species in the ravines has declined. Low or no evidence of regeneration was found; meanwhile increasing evidence of invasive species such as the Emerald Ash Borer and Beech Bark Disease was observed.

   Invasive tree species, especially Norway maple (*Acer platanoides* L.), were found to have increased significantly. Many areas on the ravine slopes are now populated by Norway maples whose dense shade promotes only bare soil and exposed roots underneath.

2. **Low 'Ecological Integrity' in ravine small mammal and breeding bird communities**

   The Second Component Study in our project was *"Ecological Integrity of Mammals and Birds in Toronto's Ravines"* by Alex Stepniak, 2017.

   While the complete mammal collection data in the Royal Ontario Museum reports 16 small mammal species in the Greater Toronto Area between 1866 and 2015, both the 1977 and and 2017 surveys in the Rosedale ravines showed a surprisingly low diversity of small mammals in similar areas (only three species were found in each of these two studies).

   Environment Canada's Canadian Wildlife Service lists 43 area-sensitive bird species found in the forests of Toronto. Unfortunately, both the 1977 and 2017 reports recorded only 5 area-sensitive bird species in each of the two ravine surveys.

   Out of the 118 possible native forest breeding bird species present in Toronto, the 1977 ravine study recorded only 30 species across the four Rosedale ravines surveyed, while our 2017 survey found only 31 species in similar ravine areas.

3. **Low 'Ecological Integrity' in ravine understory vegetation**

   The Third Component Study completed in our project was *"Assessing Understory Vegetation Communities as Indicators of Ecological Integrity in the Toronto Ravine System"* by Jose M. Kabigting, 2017.

   Unfortunately, because no understory vegetation data were available from the original 1977 ravine study, 1977 and 2017 results could not be compared directly. Thus, for our work, we divided sample plots into 10x10m grids in order to collect both canopy and understory vegetation and then colour-coded each grid according to the proportion of native and non-native species present. Out of the 340 grids surveyed in 2017, 63% were 'code red' with low ecological integrity (*i.e.* had less than 60% native ground cover); 30% were 'code yellow' with medium ecological integrity (60-99% native ground cover); and 7% were 'code green' with high ecological integrity (100% native ground cover).

The proportion of non-native ground cover was also recorded and found to be significantly higher at the top of the ravine slopes than at the bottom, however, no significant differences were found among high slope, low slope or bottom slope.

In our 2017 survey, 61 ground-cover plant species were found, of which 30 were non-native (50%). The coverage of native species was generally low across all the sampling plots, with some comprising only bare soil and serious erosion. Garlic mustard (*Alliaria petiolata*) and Japanese knotweed (*Fallopia japonica*) were widespread in many areas.

4. **Ravine policies need more explicit language and stronger enforcement**

The Final Component Study in our project was *"An Analysis of Toronto's Urban Ravine Policies and the Achievement of Ecological Integrity"* by John (Jack) Richard, 2017.

The City of Toronto's website hosts a number of sources on its official ravine policy. In analyzing these documents, we found an obvious lack of specificity and explicit requirements regarding ravines in the City of Toronto's Official Plan. This led to one clear recommendation to amend the current policy and include measurable criteria with specific reference to soil and groundwater contamination.

While the City's Ravine and Natural Feature Protection By-law restricts removal and damage of ravine trees and alteration of ravine landscape and grade, it does not consider one of the most critical components of ecological integrity, namely species composition. This gap in the By-law leaves a major opening for long-term ecological damage.

Recommendation was made that the recently-adopted City of Toronto Ravine Strategy require specific implementation steps and activities rather than be simply a statement of general principals and directions for the ravines.

<u>In Summary</u>, we must note that our individual study findings on the ecological health of the Toronto ravines should be taken as preliminary. Only a relatively small proportion of the actual ravines were able to be measured, and the survey itself was conducted by professional Master-level students, each over a single season.

Much more extensive sampling and analysis need to be undertaken in order to understand the long-term dynamics of this unique and fragile ecosystem. Nevertheless, because our results provide some of the only available estimates for the ecological health of the Toronto ravines, we clearly have the foundation needed to build recommendations for future ravine work.

RECOMMENDATIONS

1. Adopt 'Ecological Integrity' as the guiding principal and policy of the Toronto Ravines Strategy.

The first of the five 'guiding principles' in the Toronto Ravine Strategy is to *"Protect"* the ravines as *"fundamentally natural areas"*[3]. Thus, our first recommendation is that the City of Toronto adopt the conventional scientific framework of 'Ecological Integrity' (EI) to monitor, restore, steward, and protect the Toronto ravines.

Since first being proposed by Aldo Leopold in his 1949 book, *A Sand County Almanac*, 'Ecological Integrity' has been adopted both provincially and federally and is now globally recognized as the number one guiding principal and standard scientific framework for monitoring, restoring, and sustainably managing the world's ecosystems (Table 1).

Table 1. Application of 'Ecological Integrity' (EI) by a range of authorities.

Year	Literature	Author
1972	The Federal Water Pollution Control Act amendments	United States Environmental Protection Agency (US EPA)[4]
1981	Assessment of biotic integrity using fish communities	James Karr[5]
2000	Canada National Parks Act	Parks Canada[6]
2006	Provincial Parks and Conservation Reserves Act	Ontario[7]
2010	CANADA: National Report to the Ninth Session of the United Nations Forum on Forests	Natural Resources Canada – Canadian Forest Service[8]
2017	Toronto Ravine Strategy	City of Toronto[3]

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[3] *City of Toronto. (2017). Toronto Ravine Strategy. Retrieved from https://www.toronto.ca/wp-content/uploads/2017/10/9183-TorontoRavineStrategy.pdf*

[4] *US Environmental Protection Agency. 1972. The Federal Water Pollution Control Act Amendments PL 92-500.*

[5] *Karr, JR. 1981. Assessment of biotic integrity using fish communities. Fisheries, 6(6), 21–27.*

[6] *Minister of Justice. 2000. Canada National Parks Act.*

[7] *Ontario. 2006. Provincial Parks and Conservation Reserves Act.*

[8] *Natural Resources Canada – Can. Forest Service. (2010). CANADA: National Report to the Ninth Session of the United Nations Forum on Forests (November 2010). Retrieved from http://www.un.org/esa/forests/wp-content/uploads/2013/03/Canada.pdf*

"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community."
— Aldo Leopold, A Sand County Almanac[9]

2. Restore 'Ecological Integrity'

We have significant potential to restore the 'Ecological Integrity' of Toronto's ravines as many components of her ecological systems remain intact. Despite the extent of disturbance due to urbanization and invasive species that we have found, the ravines still preserve considerable numbers of old native trees with much of their natural seed banks. The ravine corridors also still have much of their natural soils in place, thus setting the stage for potentially effective restoration plans.

a) Increase ecological connectivity and buffers for biodiversity

The concept of connectivity is very simple: if you chop up an ecosystem into small parts that are disconnected, it cannot function. Moreover, as ecosystems are chopped up into small patches, the increased amount of 'edge' habitat causes rapid decline in overall ecosystem health – primarily through the loss of 'interior-forest species' and the invasion of 'edge species'.

Fortunately, the process of re-connecting ecosystems and rehabilitating the composition of their 'interior forest' species makes it possible to restore the health and function of ecosystems within decades.

Biodiversity hotspots as well, such as old native tree species, endangered species, and rare habitat types, all require high conservation priority. Buffer zones need to be delineated around hotspots, and surveyed regularly, not just on an *ad hoc* basis. In this way, 'Environmentally Sensitive Areas' (ESAs) can be best protected from invasion by non-native species.

b) Regenerate and reintroduce: Seed forecasting and collection

Healthy forest structure and composition are the foundation of healthy ravines. However, our re-survey of the Rosedale ravines showed no or only poor evidence of regeneration by the native plants, while invasive species such as Norway maple continue to expand their range (Dong, 2015)[10]. Native birds, small mammals, invertebrates, and other native plants are not able to establish effective populations in ecosystems dominated by these invasive species.

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[9] *Leopold A. 1949. A Sand County Almanac: And Sketches Here and There. Oxford University Press, USA.*

[10] *Dong, A. (2015). Ecological integrity in the Park Drive Ravine: 1977 to 2015. Unpublished manuscript. Retrieved from https://torontoravinesdotorg.files.wordpress.com/2016/04/anqi-dong_ecological-integrity-in-the-park-drive-ravine_1977-to-2015.pdf*

Since 2015, the TRRS team has been inventorying and mapping old, native trees across Toronto's ravine system. These heritage 'mother trees' are scattered throughout the ravines and have adapted to Toronto's climate and soil. Their seeds are the biological material needed to help re-generate a healthy, resilient urban forest in Toronto.

So far, we have only been able to inventory and map these old trees on public ravine land. Collaborations among the City, TRCA, ravine homeowners, and the TRRS team are highly recommended so privately-owned trees can be brought into the broader conservation plans.

c) Plant 'local' native species

Native plants are known to host biodiversity – most importantly, native insects – which in turn allows ecosystems to function. Insects, by eating plants, and then being eaten themselves – by birds, mammals, reptiles, amphibians etc. – allow energy to flow through ecosystems. This is the single most important aspect of ecosystem health. As E.O. Wilson, the famous biologist who coined the term 'biodiversity' in 1988 once said *"...*insects *are the little things that run the world".* Without insects, ecosystems simply fall apart.

The idea of using truly 'local' native plants is a new best practice for ecosystem restoration. The rationale behind using 'local' native plants is quite simple: local ecosystems tend to be unique in their abiotic characteristics (*e.g.* climate, soil type, etc.) as well as their biotic characteristics (*e.g.* biodiversity). The uniqueness of local systems tends to drive biodiversity to become 'locally-adapted'. For example, local adaptation means synchrony with the local climate; *i.e.* matching the 'timing' of annual life cycles such as leaf-out or flowering to that of local climate such as last and first frost. Local adaptation also works with local biotic factors, such as pollinators where some plants rely on specialized insects for pollination. Both must be locally adapted in timing to ensure matching of their respective cycles.

Given the complexity of local ecosystems, it is very dangerous to assume that non-local plants can be introduced into local ecosystems and function properly. That would be like assuming a bunch of random car parts from different makes and models could be assembled into a functioning vehicle – it would be foolish and futile. However, while using local plant stock is now widely promoted, the stock itself is not widely available. Fortunately, this new demand has driven a surge of efforts to re-tool nurseries and allow verified 'local' plant stock to be produced. Unfortunately, the supply is still years away from being able to meet the demand. Given this lack of local plant stock availability, many local conservation groups are starting to collect and propagate their own local seed, and these efforts should be greatly expanded.

The ***Toronto Ravines Study: 1977-2017*** has worked on numerous fronts to help local groups get engaged in the collection and propagation of local plants. Our major efforts have been on starting a pilot project aimed at mapping local, old-growth trees, studying their seed biology, collecting their seeds, and growing them. To date, we have mapped over 900 such trees, and grown over 10,000 seedlings. Moving forward, this pilot project will become available on a cell-phone platform to engage citizens in mapping, seed forecasting, collecting, and propagating. As citizens get engaged in the coming years, this project will have the capacity to produce hundreds of thousands of local trees per year for Toronto ravine restoration projects.

d) Rank 'invasiveness' and remove invasive species

Non-native plants are known to be poor hosts for native biodiversity, and therefore prevent ecosystems from functioning in a healthy way. The dangers of non-native plants to ecosystems are well known, and new negative effects are constantly being discovered. For example, many non-native plants toxify the soil, killing-off soil microorganisms that are essential for native plant growth and communication. Additionally, when non-native plants become invasive, they damage ecosystems by turning them into ecological deserts. Given the great complexity of ecosystems, and the tremendous damage that can be caused by non-native plants, it is best to avoid planting non-native species in natural areas, such as the Toronto ravines, or in adjacent habitats.

The Toronto and Region Conservation Authority (TRCA) has ranked the 'nativeness' of 681 flora and fauna species within its jurisdiction using a specific *"ranking and scoring protocol"* (TRCA, 2017)[11]. In it, native species are ranked from L1 to L5, with L1 species having the highest conservation concern and L5 the lowest (*i.e.* currently not of conservation concern). All non-native species are ranked as L+, and we recommend designing similar criteria to rank 'invasiveness' in Toronto's ravines.

With a proper ecosystem-monitoring program, new invasive species can be detected and removed with relative ease. Where small patches of invasive species are found, they can be eliminated as early as possible to avoid larger environmental and financial costs. Through inventorying and mapping, the boundaries, coverage, density, *etc.* of invasive species can be used to develop optimal methods for large-scale eradication and prevent their further expansion into Environmentally Sensitive Areas (ESAs).

Unfortunately, the Toronto ravines do not currently have an ecosystem-monitoring program specifically for terrestrial invasive species, and this means that invasive plants are free to invade and grow exponentially as over the past decades. Today, there are large sections of the Toronto ravines dominated by highly invasive non-native plants - in the groundcover, mid-story, and canopy. The more prevalent these invasive species are, the more time, cost, and effort needed to remove them. With enactment of Ontario's recent Invasive Species legislation, the exponential challenge now is to meet the new mandatory requirements for their eradication on both public and private land.

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[11] *Toronto and Region Conservation Authority (TRCA). (2017). Scoring and Ranking TRCA's Vegetation Communities, Flora, and Fauna Species. Retrieved from* *https://trca.ca/app/uploads/2017/03/Ranking-Scoring-Protocol-Final.pdf*

Starting an ecosystem-monitoring project in the Toronto ravines would allow new invasive species to be detected and immediately removed before they become problematic. It would also allow the distribution and abundance of already established invasive plants to be determined, which would then allow the development of comprehensive control strategies.

> *"An evaluation mechanism is required to objectively assess whether selected management approaches are indeed conserving ecological integrity, and to provide critical evaluation and feed-back for adjustment or abandonment of the approach. Without a mechanism to assess success, the management strategy becomes untestable and largely unscientific."*
>
> — Rempel et al.[12]

3. Develop a comprehensive scientific protocol to monitor, restore, and steward the 'Ecological Integrity' of the Toronto ravines.

In September 2017, the TRRS team made its deputation at the City of Toronto Executive Committee Meeting recommending that the draft Toronto Ravine Strategy use 'Ecological Integrity' (EI) to measure and monitor ravine health. The Strategy was amended to include EI, and a biological inventory and an EI report were assured during the City Council in October 2017 (Appendix A).

Unfortunately, despite the international recognition of the concept of 'Ecological Integrity' and the complexity of addressing this in an urban environment, comprehensive protocols are still lacking in Toronto. Here, we have shown how to effectively use a very simple protocol to measure invasive understory, which builds on similar precedents in other cities. Through adaptive management, these protocols can continuously be improved.

Without a proper protocol, key issues in the ravines cannot be identified and management efforts cannot be evaluated. Such a protocol would help develop standards for remedial action - in effect, it would serve to regulate actions on various individual natural elements in the way a building code governs the human-built environment. For example, simply cutting invasive plants above-ground without dealing with their underground root system can actually accelerate their eventual spread, pointing out the need for specific recommendations and actions.

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[12] *Rempel, R. S., Naylor, B. J., Elkie, P. C., Baker, J., Churcher, J., & Gluck, M. J. (2016). An indicator system to assess ecological integrity of managed forests. Ecological Indicators, 60, 860-869.*

While the Ecological Monitoring and Assessment Network (EMAN) protocol in Canada and the Vegetation Sampling Protocol (VSP) in Ontario have both been widely used for monitoring terrestrial ecosystems, ravines need a tailored protocol to assess invasive plants specifically as well as represent their unique biotic and abiotic heterogeneity (*e.g.* conditions along the slope, high level of human disturbance, and erosion).

A well-designed ravine sampling protocol should be replicable over time across all Toronto's ravines in order to record temporal and spatial changes. Parks Canada recommends national parks produce a 5-year 'State of Reports'[13], and this is the minimum that the TRRS team also recommends for re-surveying ravine sites. Periods longer than this will likely fail to capture the real dynamics of ravine systems.

4. Change mindsets with a new vision

Ravines are Toronto's natural heritage rather than simply a pass-through of recreational paths. They are different from parks and other public greenspace. The ecosystem and passive recreational services provided by ravines should not be taken for granted. Every ravine user has the responsibility to conserve the natural state of the ravine wilderness.

a) Re-engineer law-making and enforcement

We suggest updating the Ravine and Natural Feature Protection By-law to restrict further planting of invasive species across all ravines, on both public and private land, including the buffer zones. Existing invasive species need to be controlled in both public and private property. Private landowners need to be educated regarding this responsibility. By-law revision to align with provincial invasive species legislation needs to be enforced so that the ravines can be returned to their natural healthy state.

b) Foster collaboration and partnership

Shared ownership and limited resources have always constrained ravine management. With the official release of the Toronto Ravine Strategy, formal collaboration is needed among City planners, policy makers, engineers, scientists (especially ecologists and foresters), indigenous people, NGO's, citizen scientists, philanthropists, stewardship groups, private ravine property owners, educators, and activists, *etc.* Managing the ravines involves tasks at different scales and timeframes. The aforementioned groups and individuals can play different roles in the stewardship of our urban ecosystem and all need to be engaged in a constructive way.

[13]Parks Canada. (2014). Internal Audit and Evaluation Documents: Evaluation of Parks Canada's National Parks Conservation. Retrieved from https://www.pc.gc.ca/leg/docs/pc/rpts/rve-par/89/index_e.asp

Toronto is home to tremendous cultural wealth, world-class institutions, intellectuals, artists, philanthropists, sports legends, rock stars, and 2.8 million Canadians who love nature. Over the years, the City of Toronto has worked hard to facilitate collaboration and citizen engagement by hosting public events to bring people together.

c) Create a new funding and operational model

While our Final Report was being written, New York City (NYC) launched a new Natural Areas Conservancy for revolutionizing how its urban ecosystems would be managed, funded, and enjoyed. This new initiative – from its team, to its vision, to its accomplishments – is so impressive that it literally changes the fields of urban planning and ecosystem management. The NYC plan calls for $385-million over 25 years for about half as much land as the Toronto ravines.

Our team has reviewed the NYC plan, and it has inspired us to update our vision and recommendations for the Toronto ravines and natural areas in general. Our main recommendation is to thoroughly review New York City's Natural Areas Conservancy as a model for Toronto, and then to establish a Toronto Ravine Conservancy along the lines of the NYC model.

The Faculty of Forestry at the University of Toronto collaborated with NYC in a 'Growing Green' initiative of exchange during 2014/15 and is now planning to host the NYC Natural Areas Conservancy team this fall (2018) to learn more about their experience. Their expertise would be invaluable in helping develop a similar plan for the City of Toronto's ravine ecosystems.

We extend our applause to the NYC Natural Areas Conservancy team, and to New York City as a whole for providing us with the inspiration, and most importantly, a roadmap for restoring Toronto's unique ravine forests.

TORONTO RAVINE REVITALIZATION

TRRS PARTNERS - A CITY OF COLLABORATORS

This project has benefited greatly from the wisdom, time, and efforts of many citizens, nature groups, and especially the City of Toronto. Below is a list of the many citizens who have contributed to making our ravines a better place.

The Rosedale Ravines Study 1977

A.	Gotfryd
Roger	Hansell
Michael	Hough
Robert	Jefferies
J.	Kaiser
R.	King
A.	Petrie
G.	Renfrey
Paul	Scrivener
Dale	Taylor
B.	Wilson

1977 Data Retrieval

Ken	Abraham
Emma	Horrigan
Susan	Jefferies

City of Toronto Staff

Norman	DeFraeye
Jessica	Iraci
Janie	Romoff
Richard	Ubbens

City of Toronto Councillors

Mayor John	Tory
Shelly	Carroll
Glenn	De Baeremaeker
Sarah	Doucette
Mary	Fragedakis
Jessica	Iraci
Josh	Matlow
Mary-Margaret	McMahon
Gord	Perks
Jaye	Robinson
Kristyn	Wong-Tam

Field Work

Anna	Almero
Andrew	Avsec
Jennifer	Baici
Lucas	Champigneulle
Rhoda	deJonge
Richard	Dickinson
Quentin	Fiers
Laetitia	Foulquier
Mary	Grunstra
William	Harding
Kaho	Hayashi
Florent	Hendrycks
Karen	Jiang
Ian	Kennedy
Professor Sally	Krigstin
Mathilde	Kropin
Leo	Lepiano
Vincent	Lepoivre
Professor Jay	Malcolm
Remi	Mauxion
Jonathan	Schurman
Emilien	Soulat
Stanley	Szwagiel
Professor Sean	Thomas
Fai	Udom
Tony	Ung

Photography

Susan	Drysdale
David	Grant
Jane	Michener

Ravine Friends

Susan Aaron
David Agro
Lloyd Alter
Craig Applegath
David Beadle
Catherine Berka
John Bossons
Barb Boysen
Linda Brett
Colleen Cirillo
Jennifer Coggen
Dana Collins
Kevan Cowcill
Paula Davies
Dawn Davis
Nancy Dengler
Richard Dickinson
Sarah Fraser
Andrew Gayman
Meric Gertler
Carla Grant
Mary Grunstra
Anne Koven
Chris Lowry
Erika Machtinger
Bryn MacPherson
Tim Mathers
Esther McNeil
Gavin Miller
Faisal Moola
Mark Peck
Peter Quinby
Jason Ramsay-Brown
Theresa Reichlin
Daniel Riley
The Sheff's
Derk Sluiter
Stephen Smith
James Somerville
Robert Spindler
Lydia Wong
Chris Woods
Joan York
Bob Yukich
Karen Yukich

Organizations

Ancient Forest Exploration & Research (AFER)
Bloor Street East Neighbourhood Association
Canadian Institute of Forestry (CIF)
Deer Park Residents Group
Downsview Park
Evergreen Brickworks
Forest Gene Conservation Association
Local Enhancement & Appreciation of Forests (LEAF)
Moore Park Resident's Association
Mount Pleasant Cemetery
Mycological Society of Toronto
Nature Area Conservancy, NYC
North American Native Plant Society (NANPS)
North Rosedale Residents' Association
Ontario Invading Species Awareness Program
Ontario Invasive Plant Council
ProtectNatureTO
Royal Ontario Museum
Somerville Nurseries
South Rosedale Residents' Association
Summerhill Resident's Association
Toronto Botanical Gardens
Toronto Entomologists' Association
Toronto Field Naturalists
Toronto Ornithological Club

Appendix A - Motions to City by TRRS

1. **Executive Committee, Meeting 27, September 26, 2017**
Source: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2017.EX27.8

Motion to Amend Item (Additional) moved by Councillor Jaye Robinson
That City Council requests the General Manager, Parks, Forestry and Recreation to consider incorporating the following in the final Toronto Ravine Strategy:

- The internationally recognized concept of "Ecological Integrity" to measure the state and health of ravines;

- Using science available at the University of Toronto's Faculty of Forestry or similar centres of research to develop baseline information and address the capacity of the City and its partners to get the work done;

- Incorporate the Ontario Invasive Species Act into the Strategy.

2. City Council, October 2, 2017
Source: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2017.EX27.8

Motion to Amend Item (Additional) moved by Councillor Glenn De Baeremaeker
That City Council direct the General Manager, Parks, Forestry and Recreation, in consultation with the Chief Planner and Executive Director, City Planning and the General Manager, Toronto Water, to report during the 2018 Ravine Strategy Implementation Plan on the funding required to create and complete a biological inventory and an ecological integrity report of Toronto's 10,500 hectares of ravine system.

3. Parks and Environment Committee, Meeting 23, November 17, 2017
Source: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2017.PE23.3

Motion to Amend Item moved by Councillor Josh Matlow
That:

- City Council requests the General Manager, Toronto Water, to expand the Yellow Creek Geomorphic Systems Master Plan Environmental Assessment to include assets beyond geomorphic systems and erosion-impacted infrastructure, as well as a long-term maintenance plan. This must include, at a minimum, an inventory and state of good repair of all existing facilities, including the trail network, an analysis of ecological integrity, and identification of the departments or agencies responsible for implementing and maintaining all planned improvements.

- City Council request the General Manager, Toronto Water, develop the Yellow Creek Geomorphic Systems Master Plan Environmental Assessment in consultation with a working group comprised of relevant community stakeholders and that this working group be formed at the earliest opportunity to inform the Environmental Assessment process for its full duration.

- City Council request the General Manager, Parks, Forestry and Recreation, use the Yellow Creek Geomorphic Systems Master Plan Environmental Assessment as a template for future ravine studies and as a costing model for what is required to bring Toronto's entire ravine system into a good state of ecological repair.

4. **Parks and Environment Committee, Meeting 29, July 12, 2018**
   Source: http://app.toronto.ca/tmmis/viewAgendaItemHistory.do?item=2018.PE29.2

   Motion to Amend Item moved by Councillor Mike Layton
   That the Parks and Environment Committee request the Chief Planner and Executive Director, City Planning to integrate “ecological integrity” as a policy, management, and scientific framework for the final recommended Biodiversity Strategy.

Appendix B - News articles and media exposure of the Toronto Ravine Revitalization Study (TRRS) team

	Media	Title	Journalist	Date
1	CBC Metro Morning	Forest ecologist Eric Davies on Toronto's oldest trees	Matt Galloway	Apr 17, 2018
2	CBC News	Toronto has big plans for its ravines but official strategy has no city funding yet	Muriel Draaisma	Oct 10, 2017
3	CBC Metro Morning	Toronto decides to inventory its ravines	Matt Galloway	Oct 3, 2017
4	CBC News	How much would an inventory of trees in Toronto's ravine system cost? City will find out	Muriel Draaisma	Oct 3, 2017
5	Metro	Meet the man on a mission to map Toronto's oldest trees	Genna Buck	Sept 18, 2017
6	Star	Life on the ravine's edge full of surprises	Patty Winsa	Oct 2, 2016
7	Metro	Researchers warn of 'very dangerous' invasive species spread around Toronto's ravines	Gilbert Ngabo	Aug 16, 2016
8	CBC Metro Morning	Forest Professor Sandy Smith on the health of Toronto’s ravines	Matt Galloway	Apr 22, 2016
9	Novae Res Urbis Toronto Edition	Ecological study of ravines: Tracking changes	Leah Wong	July 22, 2016
10	UofT News	Saving Toronto's ravines: forestry researchers track ecological changes	Noreen Ahmed-Ullah	July 20, 2016

Appendix C -Public events that the Toronto Ravine Revitalization Study (TRRS) team organized and/or participated in:

1. **Parks and Environment Committee, Meeting 29, July 12, 2018**
   Eric Davies gave deputation regarding PE29.2, A Draft Biodiversity Strategy for Toronto.

2. **Deer Park Residents Group (DPRG) AGM, June 14, 2018**
   Anqi Dong spoke about native vs invasive species in Toronto's ravines.

3. **Moore Park Residents' Association (MPRA) AGM, May 24, 2018**
   Anqi Dong and *Catherine Berka* presented on our pilot projects.

4. **City of Toronto Parks and Environment Committee, Meeting 23, November 17, 2017**
   Eric Davies and *Catherine Berka* gave deputation regarding PE23.3 Yellow Creek/Vale of Avoca emphasizing the importance of conducting inventory using Ecological Integrity as the framework *(Fig. 1a, b).*

5. **2nd Annual Ravine Symposium, Toronto Botanical Garden, November 3, 2017**
   Professor *Sandy Smith* presented on invasive species control.
   Eric Davies sat on the Seed Panel and co-led the discussion about seed conservation.

6. **Bloor East Neighbourhood Association (BENA) AGM, October 26, 2017**
   Anqi Dong and *Catherine Berka* presented on the risks and opportunities in the Rosedale ravines.

7. **Park Drive Ravine Fall Walk, October 21, 2017**
   Eric Davies led the walk and talked about tree identification and seed forecasting (*Fig.3*).

8. **City of Toronto Executive Committee, Meeting 27, September 26, 2017**
   Paul Scrivener, Anqi Dong, and *Catherine Berka* gave a deputation regarding EX27.8 Toronto Ravine Strategy *(Fig. 2a, b).* We recommended using the globally recognized concept Ecological Integrity to measure ravine health, using the knowledge and resources of University of Toronto's Faculty of Forestry, and incorporating the Ontario Invasive Species Act into the Strategy. Councilor Jaye Robinson and Councilor Mary-Margaret McMahon helped put our recommendations into a motion. The motion was carried, and the draft Strategy was amended.

9. **Ravine Stewardship Workshop, June 17, 2017**
   Eric Davies, and Professors *Sandy Smith* and *Jay Malcolm* spoke to homeowners and TRRS donors about ravine ecosystem and stewardship opportunities *(Fig. 4).*

10. **Jane's Walk in the Nordheimer Ravine, May 7, 2017**
    Eric Davies was invited by the walk leader as a guest speaker *(Fig. 5).*

11. **Park Drive Ravine Spring Walk, March 17, 2017**
    Eric Davies led the walk and talked about winter tree identification and old-growth tree conservation *(Fig. 6).*

12. **Aster Awards, Toronto Botanical Garden, November 17, 2016**
    Eric Davies won the Rising Star Award of Aster Award 2016 for his work in urban forestry and forest conservation.

13. **1st Annual Ravine Symposium, Toronto Botanical Garden, October 28, 2016**
    Eric Davies presented on ravine conservation.Anqi Dong presented the study results of TRRS.

14. **Royal Ontario Museum (ROM) Science Weekend, September 17-18, 2016**
    Jane Michener displayed our study *(Fig. 7).*

15. **Jane's Walk in the Nordheimer Ravine, May 7, 2016**
    Anqi Dong was invited by the walk leader as a guest speaker.

16. **Fred G. Jackson Prize, 2015**
    Anqi Dong's ravine canopy resurvey project received the Fred G. Jackson Prize for the best research project of the year.

See following pages for event photos.

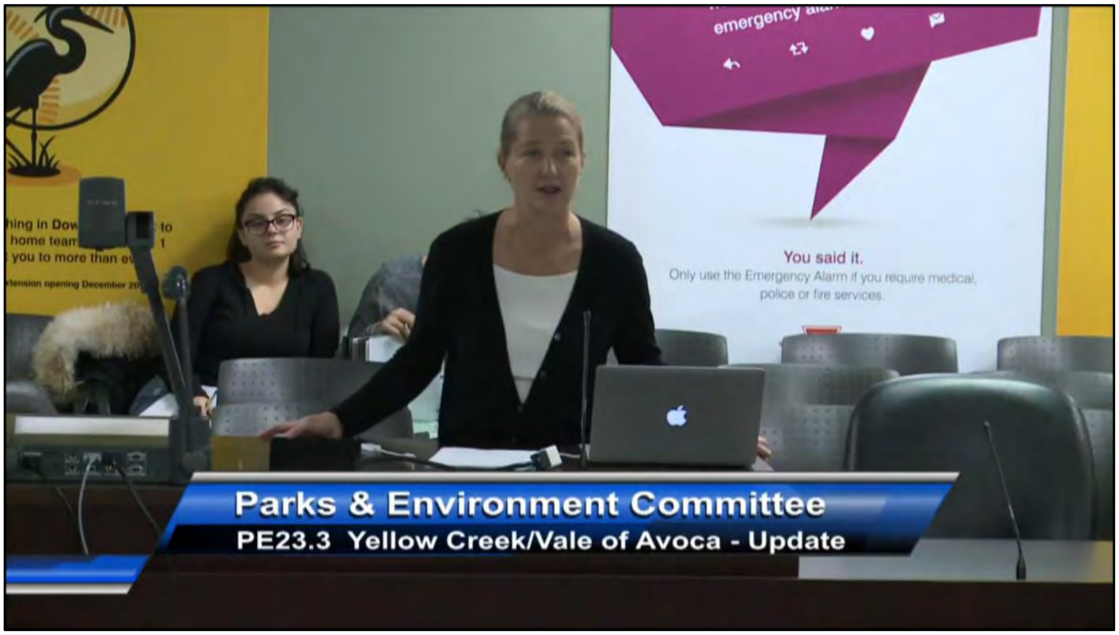

Figure 1a. Catherine Berka (right) presented at the City of Toronto Parks and Environment Committee, Meeting 23, November 17, 2017 ***(Credit: City of Toronto)***
Image retrieved from https://www.youtube.com/watch?v=DNpOmS8pgbo

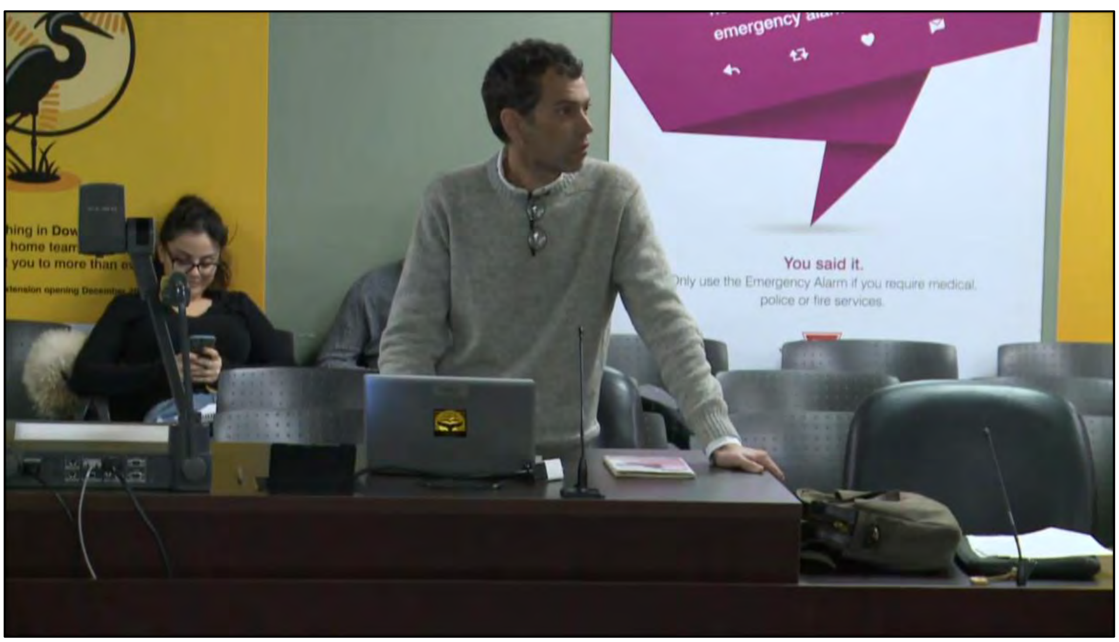

Figure 1b. Eric Davies (right) presented at the City of Toronto Parks and Environment Committee, Meeting 23, November 17, 2017 ***(Credit: City of Toronto)***
Image retrieved from https://www.youtube.com/watch?v=DNpOmS8pgbo

Figure 2a. Catherine Berka (left), Paul Scrivener (middle), and Anqi Dong (right) giving deputation at the City of Toronto Parks and Environment Committee, Meeting 23, November 17, 2017 ***(Credit: City of Toronto)***
Image retrieved from https://www.youtube.com/watch?v=jQYZkCjcfZk

Figure 2b. Catherine Berka (right), Paul Scrivener (middle), and Anqi Dong (left) giving deputationat the City of Toronto Parks and Environment Committee, Meeting 23, November 17, 2017 ***(Credit: City of Toronto)***
Image retrieved from https://www.youtube.com/watch?v=jQYZkCjcfZk

Figure 3. Eric Davies (beside the tree in the centre) Park Drive Ravine Fall Walk, October 21, 2017 ***(Photo credit: Jane Michener)***

Figure 4. Ravine Stewardship Workshop, June 17, 2017 ***(Photo: Jane Michener)***

Figure 5.Eric Davies (left) speaking at the annual Jane's Walk in the Nordheimer Ravine, May 7, 2017 ***(Photo credit: Anqi Dong)***

Figure 6. Eric Davies (left) leading the Park Drive Ravine Spring Walk, March 17, 2017 ***(Photo credit: Alex Stepniak)***

Figure 7. Royal Ontario Museum (ROM) Science Weekend, September 17-18, 2016
(Photo credit: Jane Michener)

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TORONTO RAVINE REVITALIZATION

Appendix D– Historic ecological studies in the Toronto ravines (*Tables 1, 2; L. Wong**)

		Ravine												
Theme	**Threats**	Chatsworth 1973[1]	Glen Stewart 1973[2]	Moore Park 1973[2] & 1977[7]	Vale of Avoca 1973[2]	Brookbanks 1974[3]	Chapman Creek 1975[4]	Wigmore Park 1975[5]	Park Drive 1976[6] & 1977[7]	Burke 1977[8]	Rosedale 1977[7]	Sunnybrook 1978[9]	Cedarvale 1980[10]	**Totals**
Hydrology	Bank erosion	■	■		■		■			■		■		6
	High silt burden	■					■	■	■	■	■	■		7
	Flooding					■	■	■		■	■	■	■	7
	Gabion basket collapse					■			■	■				3
	Pollution (chemical)	■				■	■	■	■	■		■		7
	Pollution (physical)	■				■		■						3
	Algal growth	■							■					2
Slope / Soil	Erosion/Landslides	■	■	■	■			■	■	■	■	■		9
	Bare/Compact soil			■	■						■	■		4
	Poor quality soil					■				■	■		■	4
Vege-tation	Invasive plants	■ *	■	■	■	■ *	■ *	■	■	■	■	■	■	12
	Lack of understory			■	■				■		■			4
	Lack of tree regeneration												■	1
	Conifer decline			■		■			■	■	■		■	6
User misuse & overuse	Foot-traffic		■		■	■	■			■				5
	Bicycles & Motorbikes		■				■					■		3
	Littering	■		■			■			■		■	■	6
	Children cutting branches	■					■							2

(Table 1 continues on the next page)

Theme	Threats	Chatsworth 1973[1]	Glen Stewart 1973[2]	Moore Park 1973[2] & 1977[7]	Vale of Avoca 1973[2]	Brookbanks 1974[3]	Chapman Creek 1975[4]	Wigmore Park 1975[5]	Park Drive 1976[6] & 1977[7]	Burke 19778	Rosedale 1977[7]	Sunnybrook 1978[9]	Cedarvale 1980[10]	Totals
		Ravine												
Private land-owners	Construction on slopes						■		■				■	3
	Garden escapees								■		■	■		3
	Birdfeeders attract squirrels						■							1
Other	Domestic cats					■		■	■				■	4
	Over-mowing	■						■						2
	Salt-drift									■	■	■		3
	Totals	10	5	6	6	9	11	8	11	12	10	11	8	

Table 1. Matrix showing factors that threaten the environmental health of 12 ravines in the City of Toronto. Red boxes indicate presence. The year surveyed is indicated *(some were surveyed more than once by different authors).* Asterisks denote surveys where plants considered invasive by the Ontario Invasive Plant Council (OIPC) were not mentioned. *1) Cranmer-Byng, J., Hamilton E. and Hilts, S. 1973. Toronto Field Naturalists' Ravine Survey: Study No. One Chatsworth Ravine. Toronto Field Naturalists' Club; 2) Wainio, A., Price, G., Jew, K., Hamiwka, W., Wilson, L. and West, P. 1973. General Biological Survey of Three Ravines Within the City of Toronto: Moore Park Ravine, Vale of Avoca, Glen Stewart Ravine. General Foods Limited [Ministry of Natural Resources]; 3) Cruickshank, B. and Parker, B. Toronto Field Naturalists' Ravine Survey: Study No. Two Brookbanks Ravine. Toronto Field Naturalists' Club; 4) E, C. and Goodwin J.E., 1975. Toronto Field Naturalists' Ravine Survey: Study No. Three Chapman Creek Ravine, Etobicoke. Toronto Field Naturalists' Club; 5) Kelly, D. and Greenbaum, A., 1975. Toronto Field Naturalists' Ravine Survey: Study No. Four Wigmore Park Ravine. Toronto Field Naturalists' Club; 6) Taylor, D. and Scrivner, P., 1976. Toronto Field Naturalists' Ravine Survey: Study No. Five The Park Drive Ravine Rosedale. Toronto Field Naturalists' Club; 7) Gotfryd, A., Kaiser, J., King, R., Petrie, A., Renfrey, G. and Wilson, B. 1977. A quantitative ecological study of Toronto ravines 1977: Rosedale Ravine, Park Drive Ravine, Moore Park Ravine, Burke Brook Ravine. University of Toronto; 8) Cranmer-Byng, J., Cunningham, R. and Hamilton, E. Toronto Field Naturalists' Ravine Survey: Study No. Six Burke Ravine. Toronto Field Naturalists' Club; 9) Banville, D. and Cardini, L. 1978. Toronto Field Naturalists' Ravine Survey: Study No. Eight Est Don River Valley 1974-1978: Sunnybrook Park to Rosedale Golf and Country Club. Toronto Field Naturalists' Club; and 10) Gotfryd, A. and Smith, P. 1980. Cedarvale Ravine: An Ecological and Human Use Study. Toronto, Ontario Ministry of the Environment.*

Table 2. Matrix showing plants considered invasive by the Ontario Invasive Plant Council *(Credit Valley Conservation 2010*). Red boxes indicate presence.

Invasive Plant	Ravine: Chatsworth 1973	Glen Stewart 1973	Moore Park 1973 & 1977	Vale of Avoca 1973	Brookbanks 1974	Chapman Creek 1975	Wigmore Park 1975	Park Drive 1976 & 1977	Burke 1977	Rosedale 1977	Sunnybrook 1978	Cedarvale 1980	Totals
Norway Maple *Acer platanoides*	■	■	■	■				■	■	■	■	■	9
European spindletree *Euonymus europaeus*									■				1
Non-native bush honeysuckles *Lonicera* spp.	■		■		■	■		■	■	■	■	■	9
Common & glossy buckthorn *Rhamnus cathartica & R. frangula*	■		■	■				■	■		■	■	7
Dog-strangling vine *Cynanchum rossicum & C. nigrum*					■		■		■	■	■		5
Garlic mustard *Alliaria petiolate*	■	■	■	■				■	■	■	■	■	9
Japanese knotweed *Polygonum cuspidatum*		■		■				■	■	■	■	■	7
Goutweed *Aegopodium podagraria*			■	■				■		■		■	5
English ivy *Hedera helix*		■	■										2
Periwinkle *Vinca minor*		■	■	■								■	4
Totals	4	5	7	6	2	1	1	6	7	6	6	7	

***Source:** Wong, Lydia. 2018. Restoring Toronto's Ravines: a management tool for system-wide approaches. Undergrad paper to Sandy M Smith.

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TORONTO RAVINE REVITALIZATION

Map credit: *Mary Grunstra*
Map data: *City of Toronto*
Source: *ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community*

Ecological Integrity in the Park Drive Ravine: 1977 to 2015

A Report for FOR3008 Capstone Project in Forest Conservation

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Table of Contents

Tables and Figures

Abstract

Ecological integrity is an important concept in ecosystem management. It is a measure of ecosystem health, and the abundance and functionality of native species are the key components. The main objective of this study is to obtain estimates of the ecosystem health of the Park Drive Ravine, Toronto, Ontario, Canada through the lens of ecosystem health. A comprehensive survey was conducted in the Park Drive Ravine in 1977, and a canopy resurvey was conducted in 2015. Results indicated a degraded ecological integrity in this ravine – the relative contribution of native species has decreased with no or little evidence of regeneration, but the relative contribution of non-native species, especially Norway maple (*Acer platanoides* L.) has increased with lots of regeneration. Ash species (*Fraxinus spp.*) and American beech (*Fagus grandifolia* Ehrh.) used to be two of the dominant species in this ravine in 1977, but their populations have largely declined due to the massive infestation of emerald ash borer and beech bark disease. As the ravine canopy loses these major contributors and other native species, the population of Norway maple will further expand and severely degrade the ecological integrity. In order to restore the ravine ecosystem, long-term monitoring of various taxonomic groups in the ravines is recommended, and collaboration among various stakeholders is critical.

Introduction

Ecological integrity has been an important concept in ecosystem management for decades. It emerged when Aldo Leopold wrote in his well-known book A Sand County Almanac that “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community” (Leopold, 1949, pp. 224-225). In 1972, the US Environmental Protection Agency (EPA) established The Federal Water Pollution Control Act Amendments with the objective being “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters” (EPA, 1972). In 1981, Dr. James Karr developed the Index of Biotic Integrity (IBI) to measure the quality of water resources. In 2000, the Canada National Parks Act was established, and ecological integrity was considered as the first priority in national park management (Minister of Justice, 2000). The act defined ecological integrity as “a condition that is determined to be characteristic of its natural region and likely to persist, including…abundance of native species…and supporting processes” (Minister of Justice, 2000). In 2006, the Provincial Parks and Conservation Reserves Act (PPCRA) was established, and ecological integrity was considered as the first priority in the management of provincial parks and conservation reserves (Ontario, 2006). This provincial act defined ecological integrity as “a condition in which…the composition and abundance of native species…are characteristic of their natural regions and…ecosystem processes are unimpeded” (Ontario, 2006). In 2015, the Toronto Ravine Strategy is being developed by Parks, Forestry and Recreation, City Planning, and Toronto Water in consultation with Economic Development and Culture, the Toronto and Region Conservation Authority (TRCA), stakeholders, and the public, and one of the targets of this strategy is to protect the ecological integrity in Toronto’s ravines (City of Toronto, 2015).

Urban natural areas provide various ecosystem services such as erosion control, pollution mitigation, microclimate regulation, and improvement of physical and mental health of urban residents (Bolund and Hunhammar, 1999). However, as the remnant natural areas within urban boundaries keep being disturbed and threatened by human activities, the quality of ecosystem services they provide are degrading due to a loss of biodiversity and the introduction of non-native species (Wilson, 1988). For example, as a result of urbanization since 1982, 180 native plant species have disappeared from the forests of Munich, Germany (Pauleit and Oppermann, 2002). Recently, McCune and Vellend (2013) resurveyed 184 vegetation plots on southern Vancouver Island and found that urbanization had resulted in double the number of non-native species lost compared to the late 1960s. Another recent analysis by Dolan (2015) compared tree inventory data from 1820 to that in 2008 and showed that 35 out of 40 pre-settlement tree species (including both native and non-native ones) could still be found in present-day remnant natural areas of Indianapolis. Indiana. He also found that the frequency and size of different species had changed significantly over that time, and that 18 new non-native species had been introduced. In particular, the frequency of American beech and oak species were found to have decreased while that of sugar maple (*Acer saccharum* Marshall) and elm species (*Ulmus spp.*) had increased.

The few studies carried out in urban naturalized areas reveal an interesting phenomenon – not all tree species are negatively impacted by human activities. While urbanization eliminates certain species from their native geographic ranges, it facilitates the introduction of others. Species that benefit from disturbance and expand their populations are considered *'winners'* while those whose populations are reduced are termed *'losers'* (McKinney and Lockwood, 1999). *'Winners'* and *'losers'* are not randomly distributed among taxa – some life history traits promote population expansion (*e.g.* fast growth) while others accelerate extinction (low fecundity) (McKinney, 1997). Generally, there are only a few *'winners'* but lots of *'losers'* (McKinney and Lockwood, 1999). For example, in Dolan's study (2015) above, sugar maple and elm species were the *'winners'* while American beech and oak species were the *'losers'*.

Ravines are terrestrial landscapes dissected by a stream or river that result in small valleys each comprised of two steep slopes on either side (Bates and Jackson, 1984, pp. 419). Ravine systems are one of the most distinguishing landscapes in Toronto and are characterized by an extensive network of river corridors within undeveloped urban forest areas. As such, they represent biodiversity hotspots for this large urban metropolis. Moreover, each ravine system retains important *'ecological memory'* for the local region within which it is found, *i.e.,* species native to the region, natural ecological processes, genetic diversity, *etc.* (Schaefer, 2009).

Like other urban natural areas, ravines are prone to biodiversity loss and invasion of non-native species because of their small size, poor connectivity, and frequent anthropogenic disturbance (Matthies *et al.*, 2015). For example, human activities have led to structural and compositional deterioration in the ravine valleys of Highland Creek, Scarborough, Ontario, Canada (Carlton and Taylor, 1983), and urbanization has been shown to cause massive erosion and loss of plant diversity in the coastal ravines of Illinois, USA (Shabica *et al.*, 2010). Another study from Poland found that the number of non-native woody species in a river valley increased from 76 to 116 over the last three decades (Dyderski *et al.*, 2015). Unfortunately, little information is available on the impacts of urbanization within ravine or natural urban valley ecosystems.

Since ravines have narrow, irregular shape and are highly vulnerable to flooding, the building of houses in ravine systems has been prohibited since 1954 when Hurricane Hazel devastated the region (TRCA, 2004). Despite this constraint, human activity has continued to impact Toronto's natural heritage ravine system. As a result of growing concerns and interest in ravine conservation by the Ministry of Environment, Toronto Field Naturalists, and the Rosedale Ratepayers Association, a formal research study "The Rosedale Ravines Study" was initiated during the summer of 1977 (The Rosedale Ravine Study, 1977). In this study, students from the University of Toronto surveyed tree canopy, vegetation understory, ground cover, small mammals, breeding birds, reptiles and amphibians, invertebrates, debris, and soil in four ravines of the Rosedale area. The intent was to provide baseline data that would enable the condition of Toronto ravines to be assessed into the future. To date, however, this unique study has not been replicated. Thus, after 38 years of intense urban development in this area, it seems an opportune time to ask, who is *'winning'* and who is *'losing'* in terms of diversity? Has the ravine ecosystem changed? Has species richness changed? Have the proportions of native and non-native species changed? What will the ravines look like after 40 years? Will they still retain their original diverse ecological functions? These are important questions that can help elucidate potential ecological consequences of urbanization.

A resurvey of the same four ravines was initiated by E. Davies (PhD graduate student, Faculty of Forestry, University of Toronto) in the summer of 2015 following the Toronto Ravine Strategy Open House. The key purpose was to explore potential changes in the ravines over the intervening 38 years through the lens of ecological integrity. Specifically, a partial canopy resurvey was conducted in one of the ravines during August and September 2015 to provide forest inventory information and assess specific tree species '*winners*' and '*losers*'.

Objectives

The overall goal of this resurvey was to obtain estimates of the ecological integrity in the Park Drive Ravine. Specifically, the objectives were to:

1) Update the tree inventory for three plots in the Park Drive Ravine previously surveyed in 1977 with data collected in 2015;
2) Examine changes in the canopy composition in this Park Drive ravine since the 1977 historical baseline survey;
3) Provide quantitative evidence to the City of Toronto that will inform recommendations for developing a comprehensive management plan to restore, monitor and maintain these ravines into the future.

Methods

Study site

The Don River is the largest river in Toronto, Ontario, Canada, connecting the oak ridges moraine in the north with Lake Ontario in the south. Located on the west side of the Don River, the four ravines involved in The Rosedale Ravines Study, 1977 were formed by its tributaries; from north to south, Burke Brook Ravine, Moore Park Ravine, Park Drive Ravine, and Rosedale Valley. The total area of the ravines adds up to ~51 ha (= 126 acres). The following paragraphs in this section describe the history of these ravines during the past two centuries, and all the information are provided by the 1977 report (The Rosedale Ravines Study 1977).

In the 19th century, the wooded areas in Rosedale consisted of pines and mixedwood forests. White pine (*Pinus strobus* L.), oak (*Quercus spp.*), and tamarack (*Larix laricina* (Du Roi) K. Koch) used to be the dominant species in these areas. During the 1700s and 1800s these woodlands were heavily logged, mainly for fuel, furniture, ship masts, and building materials. Today, the majority of the large trees in these ravines represent regrowth that occurred during the 20th century.

The results of the 1977 study indicated that by 1977 white ash (*Fraxinus americana* L.), American beech, sugar maple, and Norway maple had become the dominant tree species in the ravine, with only a few conifers present and no regeneration. The proportion of non-native tree species at that time ranged from 2.5 to 25%. This 1977 study indicated that although the canopies of different ravines consisted of the same number of tree species, the identities and relative contribution of each species were distinct. For example, Norway maple was dominant in the Park Drive Ravine, but not common in the Burke Brook Ravine. In contrast, eastern hemlock (*Tsuga canadensis* (L.) Carrière) was abundant in the Burke Brook Ravine, but rare in the Park Drive Ravine.

The partial canopy resurvey was conducted in the Park Drive Ravine (43.679888N, 79.375845W; previously called North or Second Rosedale Ravine) (Fig. 1) in August and September 2015. This ravine was formed as a result of being carved by Mud Creek, one of the tributaries of the Don River. It has an area of 15 ha (= 35.9 acres) and represents a transition between tableland and bottomland (Fig. 2). The creek flows from northwest to southeast through the ravine resulting in north- and south-facing slopes.

In 1882, the Glen Road Viaduct (previously called the North Iron Bridge) was built to connect the north and south side of the Park Drive Ravine. The viaduct enabled travelers to cross the ravine more easily, and local residents became the main users of the ravine.

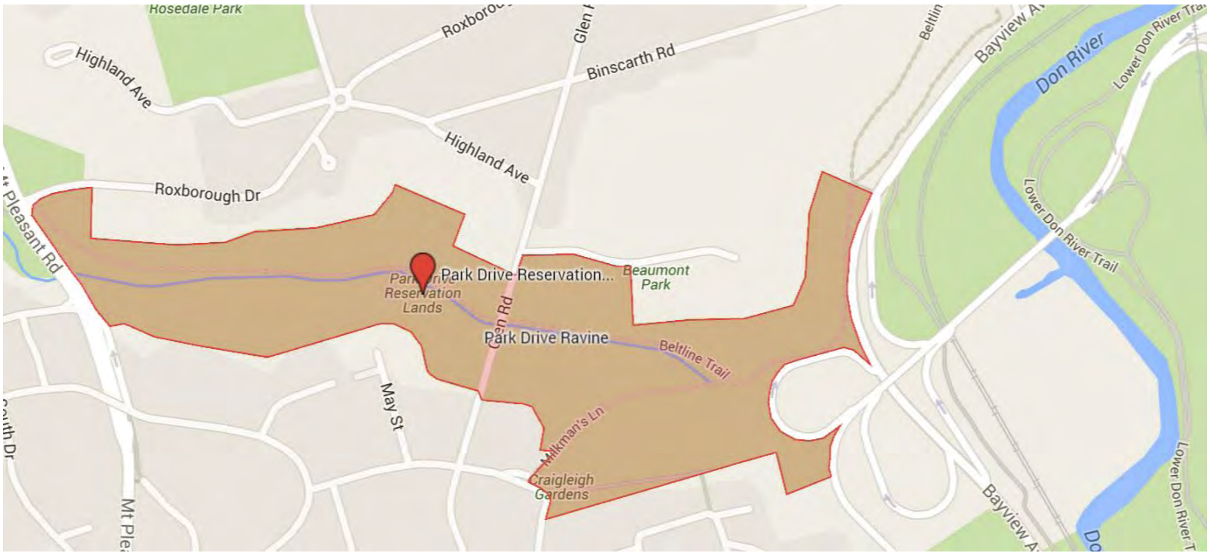

Figure 1. *Study area for the Park Drive Ravine, Toronto, ON where woody stems were surveyed in three subplots during the summers of 1977 and 2015 (highlighted in brown),*

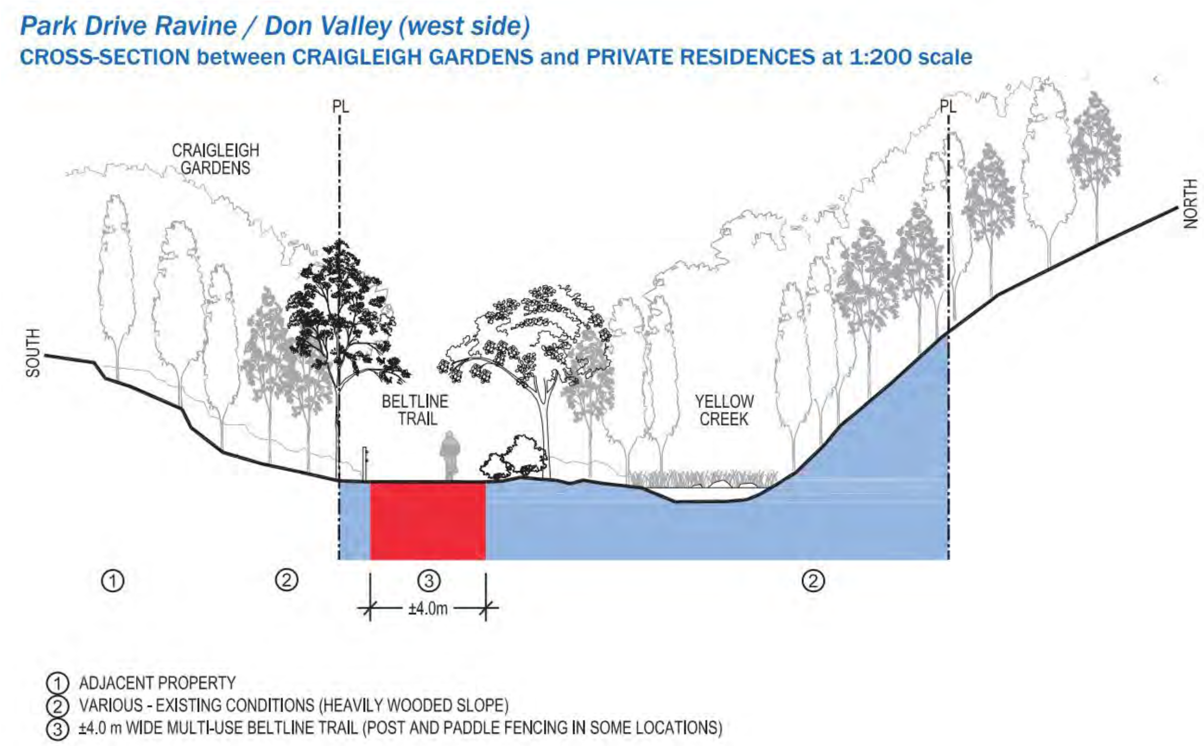

Figure 2. *A cross-sectional view of the Park Drive Ravine, Toronto, ON looking west in 2012 (City of Toronto Archives: http://www1.toronto.ca/city_of_toronto/policy_planning_finance__administration/public_consultation_unit/transportation_office/kaygardnerbeltline/files/pdf/2012-09-10_beltline_trail_conditions.pdf).*

In 1949, the Mt. Pleasant Road extension was built on the west side of the Park Drive Ravine, and Mud Creek was culverted to run below the ravine to avoid the construction site. Later in the 1950s, a large earth dike was built at the southeast end of the ravine to facilitate the construction of the Don Valley Parkway. In 1966, an open-channel storm sewer was built through the ravine using wire-enclosed stones resulting in a gabioned channel with gabioned banks. Part of the culverted Mud Creek was diverted back to the aboveground channel to maintain continuous flow.

Retrieving the 1977 report and preparing for field work

In July 2015, photocopies of the 1977 study report were obtained from Jane Weninger (Senior Planner from City of Toronto Planning, Strategic Initiatives, Policy and Analysis) via Eric Davies. The report consisted of background information, study methods, results, and discussion for four ravine systems in the Rosedale area, namely, Burke Brook Ravine, Moore Park Ravine, Park Drive Ravine, and Rosedale Valley (Fig. 3). Various taxonomic groups were surveyed in 1977: tree canopy, vegetation understory and ground cover, small mammals, breeding birds, reptiles and amphibians, and invertebrates. Measurements on debris and soil samples were also taken. Due to the constraint of time and budget in the current study, a resurvey was only conducted on the tree canopy and in one ravine system of the Park Drive Ravine. Other taxonomic groups and ravines are expected to be resurveyed in summer 2016.

Relocating plots

During the 1977 study, five plots were set up in the Park Drive Ravine. They were selected based on relatively uniform canopy structure and composition, as well as minimal human disturbance. Two of these plots were located on a south-facing slope, while the other three were located on a north-facing slope (Fig. 4). All had the same width (50m) although of slightly different length (depending on the distance from the creek to the margin of the ravine) and bearing. The total area of these plots represented ~10% of the wooded slope in the Park Drive Ravine. Data collection was conducted by University of Toronto students under the supervision of Professor Robert L. Jefferies (Department of Botany) and Professor Roger I. Hansell (Department of Zoology).

The study methods and the site map (Fig. 4) provided by the 1977 report were not sufficient for relocating the plots since no further details (e.g. latitudes and longitudes, landmarks, etc.) of the plot locations were available. Thus, the old site map was scanned, imported into Google Earth, and the latitudes and longitudes of the four corners for each plot determined by superimposing the old site map on the latest map of Park Drive Ravine (Fig. 5). This relocation was done without a GPS device. However these marked coordinates saved in Google Maps could be viewed on a smartphone through a Google account. Each corner of each plot was relocated in the ravine by moving the phone until the current location overlapped with a pair of saved coordinates. The accuracy of this approach was tested by measuring the width, length, and bearing (provided by the 1977 report) of each plot, and any fine adjustments were made as necessary.

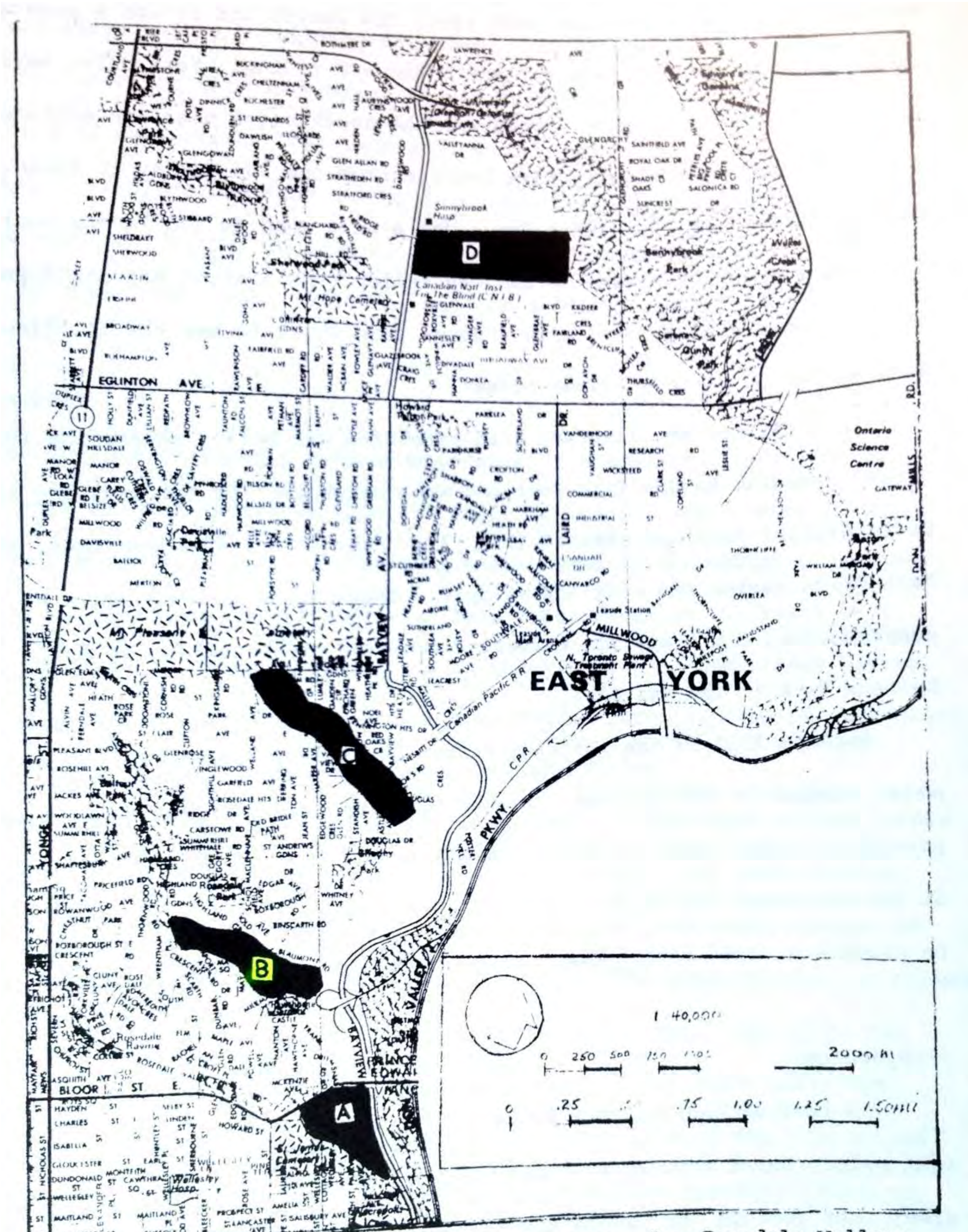

Figure 1. East-central Metropolitan Toronto. A = Rosedale Valley; B = Park Drive ravine; C = Moore Park ravine; D = Burke Brook ravine. (Creative Sales, 1976. Scale, ca. 1:40,000.)

Figure 3. *In 1977, four ravines in the Rosedale area, Toronto, Ontario were involved in a flora and fauna survey. From north to south, they are Burke Brook Ravine, Moore Park Ravine, Park Drive Ravine, and Rosedale Valley. This map was derived from the report written for this survey, The Rosedale Ravines Study 1977.*

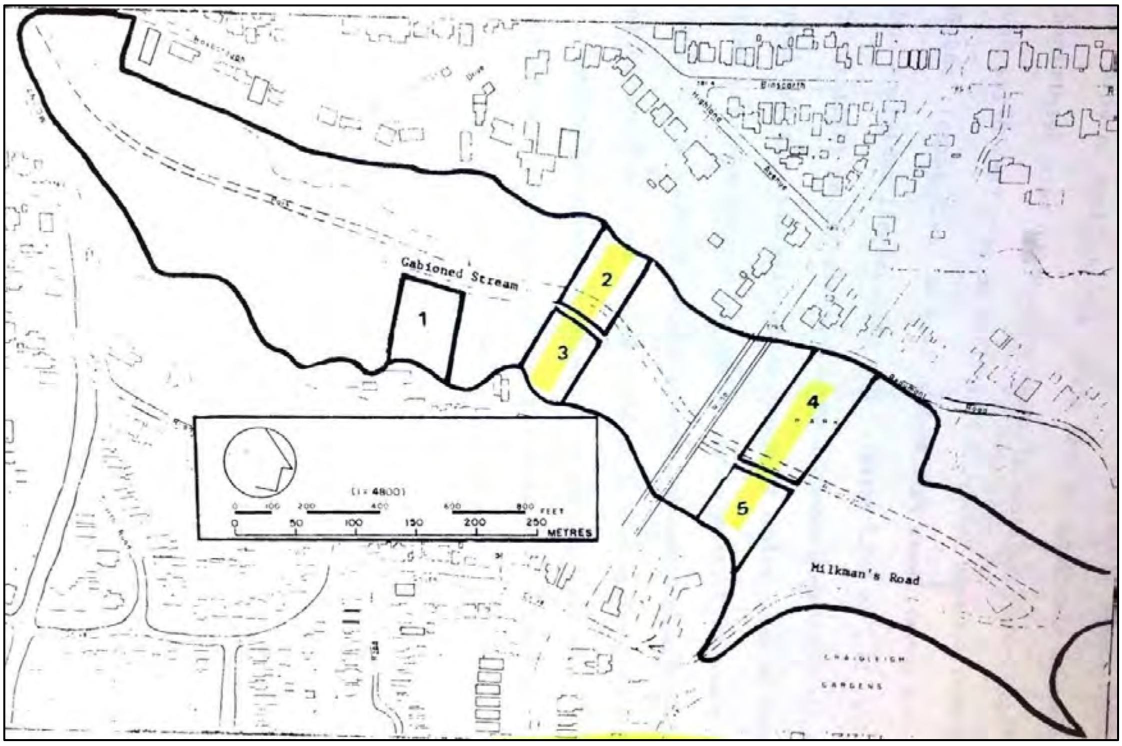

Figure 4. *Site map of the Park Drive Ravine, Toronto, Ontario provided by "The Rosedale Ravines Study, 1977". Heavy black lines delineate the boundary of the ravine and the locations of five plots used for data collection in 1977.*

Figure 5. *The original Park Drive Ravine (Toronto, ON) site map from1977 imported into Google Earth and superimposed with the most recent map of the Park Drive Ravine (2015). Latitudes and longitudes were determined by clicking on the corners of each plot.*

The relocation process revealed that some of the plots could not be accessed. For example, Plot 1 overlapped with a fenced area set up by the City and Plot 2 overlapped with a private property that was also fenced. Although a letter was left in the mailbox in the latter case, the owner could not be contacted. Therefore, only Plot 3, 4, and 5 were resurveyed in this study. Their sizes, aspects, and bearings will be presented in Table 1 in the Results section.

The four corners of each plot were marked with yellow tent pegs. To better organize data collection and identify habitat types, each plot was divided into 25m × 25m-quadrats (Fig. 6). For example, plot 3 was divided into four 25m × 25m-quadrats and two riparian quadrats of varying size (Table 1) due to the topography of the ravine. Plots 4 and 5 were set up in the same way in order to facilitate organized data collection.

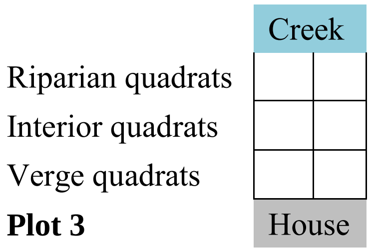

Figure 6. *An illustration of the plot set up for the 2015 tree canopy resurvey in the Park Drive Ravine, Toronto, Ontario. The Verge and Interior quadrats are 25m × 25m while the riparian quadrats have varying sizes depending on the length of each plot.*

Data collection

Data were collected in each quadrat of Plots 3, 4, and 5. Based on their locations, the quadrats can be categorized into three habitat types: Verge (top of the ravine, close to roads and houses); Interior (middle of the slopes, not adjacent to roads or the creek); and Riparian (bottom of the ravine, close to the creek).

In the 1977 study, woody stems with a diameter >= 3cm at breast height (DBH) were recorded by species. This was repeated in the 2015 resurvey using calipers (for smaller trees) and DBH tapes (for larger trees that exceeded the capacity of calipers). In addition, woody stems with a diameter between 2 and 3 cm were also recorded in order to make a better observation of regeneration. A minimal DBH was set at 2cm since this was the smallest diameter the calipers could measure.

While most of the data were collected from the 25m × 25m-quadrats, the plots were then divided into 50m × 10m-transects in order to collect some other data. In the 1977 study, plots were divided into transects rather than quadrats to facilitate data collection, and one of the parameters (Frequency, F) was calculated based on the presence and absence of species in each transect. However, in this resurvey, the necessity of setting up transects was not realized until the end of data collection. Therefore, transects were set up after collecting other data from the quadrats, and the presence and absence of different species in each transect were recorded. Similar to the number of quadrats, the number of transects in each plot varies depending on the plot length (Table 1).

Parameters

The 1977 study used seven parameters to quantify the absolute and relative contribution of each tree species: Absolute density (D); Relative density (%D); Absolute frequency (F); Relative frequency (%F); Absolute basal area (BA); Relative basal area (%BA); Importance value (IV); and Relative importance value (%IV). Formulae for the calculation of these parameters were provided in the method section of the 1977 report. A checklist of tree species found in each plot was also provided. Since the raw data from 1977 cannot be retrieved, the comparison between 1977 and 2015 data only involved some of the parameters. They will be listed and explained in the following section.

Comparing 1977 historical baseline data to 2015

All the tables and graphs provided in the 1977 report were digitized and entered into a Microsoft Excel datasheet in order to compare them with the data collected in 2015. In order to be consistent between years, the formulae and criteria used in 2015 followed those used in 1977. The parameters to be calculated/graphed/compared with the 1977 data were:

1) ***Absolute density (D) of each plot:***

$$\text{D } of\ a\ plot = \frac{\#\ of\ trees\ in\ the\ plot}{Area\ of\ plot\ (m^2)/10{,}000\ m^2}$$

2) ***Species richness of each plot:*** Calculated as number of species recorded in the plot.

3) ***Relative density (%D) of each species in each plot:***

$$\text{\%D of a species in a plot} = \frac{\#\ of\ individuals\ of\ this\ species\ in\ this\ plot}{\#\ of\ individuals\ of\ all\ species\ in\ this\ plot} \times\ o\%$$

After the calculation of %D, these species will be classified as native or non-native according to Table A8 of the 1977 report (The Rosedale Ravines Study, 1977, p. 96), and the proportions of each native or non-native species in 1977 and 2015 will be calculated.

4) Frequency (F) of each species in each plot:

$$\text{F of a species in a plot} = \frac{\#\ of\ transects\ with\ this\ species}{total\ \#\ of\ transects\ in\ this\ plot}$$

5) Relative frequency (%F) of each species in each plot:

$$\text{\%F of a species in a plot} = \frac{F\ of\ this\ species}{Sum\ of\ the\ F\ values\ of\ all\ species\ in\ this\ plot} \times 100\%$$

6) Basal area (BA) of each individual:

$$\text{BA} = \frac{1}{2}\pi \cdot DBH$$

7) Relative basal area (%BA) of each species in each plot:

$$\text{\%BA of a species in a plot} = \frac{BA\ of\ this\ species}{Sum\ of\ BA'\ s\ of\ all\ species\ in\ this\ plot} \times 100\%$$

8) Importance value (IV) of a species in a plot:

The sum of Relative density (%D), Relative frequency (%F), and Relative basal area (%BA) of this species.

9) Relative importance value (%IV) of each species in each plot:

$$\text{\%IV of a species in a plot} = \frac{IV\ of\ this\ species}{Sum\ of\ IV'\ s\ of\ all\ species\ in\ this\ plot} \times 100\%$$

10) Size class distribution:

Size class distribution of Ash species (*Fraxinus spp.*), American beech (*Fagus grandifolia*), and Norway maple (*Acer platanoides*) will be graphed.

All plots were set up in areas with relatively uniform canopy structure and composition, and all areas with heavy human disturbance and edge effect were avoided. These non-random plot selection criteria violate the assumption of running statistical tests, and the plots cannot be considered as replications of each other. As a result of this non-random, incomplete study design, the status of the ravine canopy in 1977 and 2015 could not be compared by pooling the three plots together and taking the mean for each parameter. Instead, because tree data were absolute measures, the temporal changes in each plot were studied independently between the two sample years.

Results

Absolute density (D) and species richness

In 2015, the number of trees per hectare found in the plots ranged from 377 to 883 per hectare, Compared to the corresponding data collected in 1977, the absolute densities of Plot 3 and 5 only increased by 1.3% and 0.2%, respectively, while the absolute density of Plot 4 almost doubled (increased by 85.1%).

The number of species recorded in the plots ranged from 14 to 30 (Table 1). The number of species recorded in Plot 3 and 5 had a net increase of one species (lost 6 but gained 7) and a net decrease of four species (lost 9 but gained 5), respectively, while the number of species recorded in Plot 4 doubled over the past 38 years (lost 2 but gained 17) (Table 1). Detailed information about which species were lost or gained will be provided when comparing native and non-native species.

Table 1. *Number of trees per hectare (absolute density (D)) and species richness (number of tree species recorded) in sample plots from the Park Drive Ravine, Toronto, Ontario (1977 and 2015); width, length, size, aspect, and bearing of each plot were obtained from Table D3, Appendix D, The Rosedale Ravine Study 1977.*

Plot	Width (m)	Length (m)	Size (ha)	Aspect	Bearing	Absolute density (trees/ha)		Species richness (# of species)	
						1977	2015	1977	2015
3	50	60	0.3	North-facing	26°	523	530	17	18
5	50	85	0.4	North-facing	29°	618	619	18	14
4	50	90	0.5	South-facing	195°	477	883	15	30

Relative importance value (%IV) and size class distribution

The species compositions as well as the %IV of the top eight species in each plot in 1977 and 2015 are presented in Fig. 7. The size class distributions of ash species, American beech, and Norway maple in each plot are presented in Fig. 8.

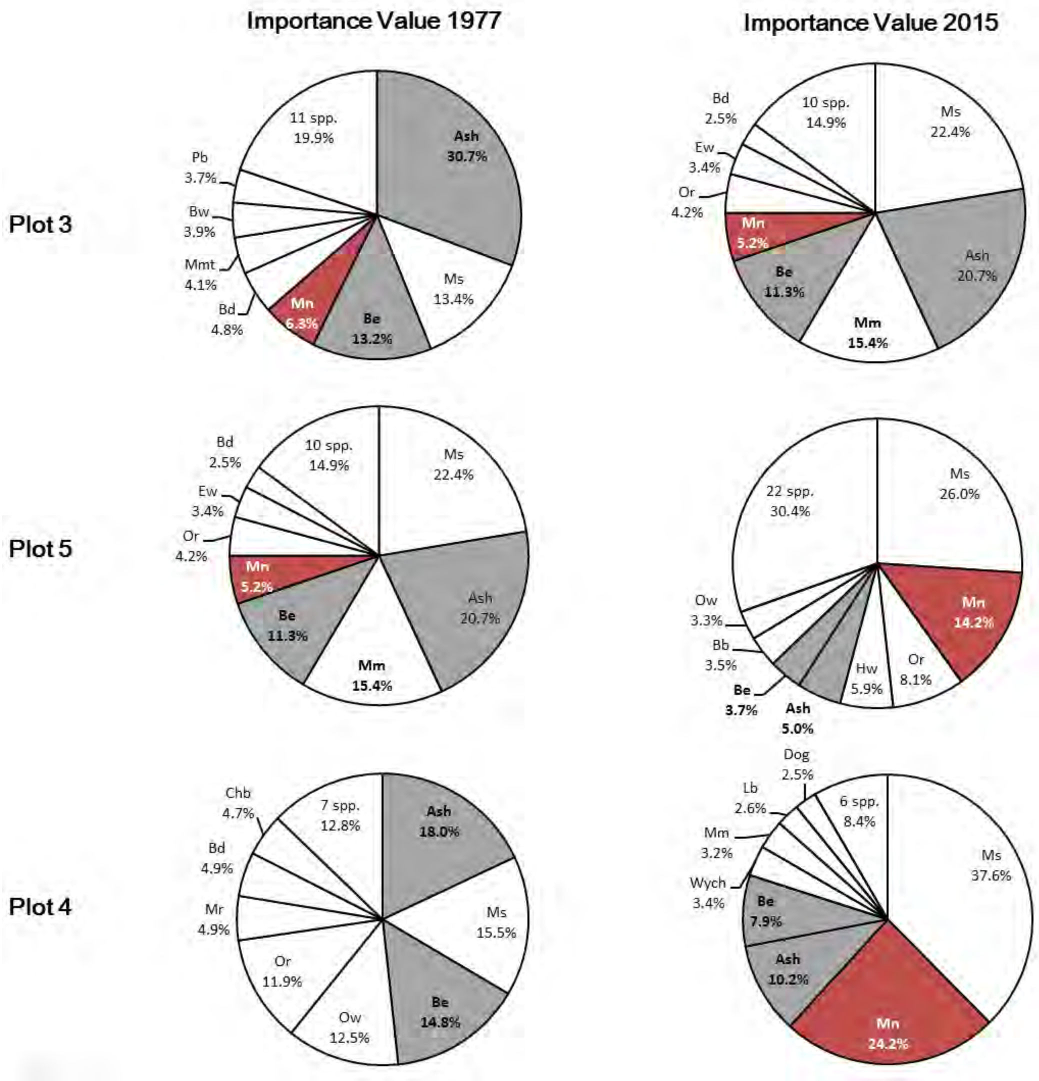

Figure 7. *The eight most common species and their relative importance values (%IV) in each plot in 1977 (left column) and 2015 (right column) in the Park Drive Ravine, Toronto, Ontario; relative importance value of each species in each plot in 1977 was obtained from Table A3, Appendix A, The Rosedale Ravine Study 1977. Plot 3 and 5 (top two rows) were located on the north-facing slope, and Plot 4 (bottom row) was located on the south-facing slope. Abbreviation used for each species in this figure (alphabetically): Ash = Ash species (Fraxinus spp.) that are native to Toronto; Bb = Blue beech (Carpinus caroliniana); Bd = American basswood (Tilia americana); Be = American beech (Fagus grandifolia); Bw = White birch (Betula papyrifera); Chb = Black cherry (Prunus serotinus); Dog = Dogwood species (Cornus spp.); Ew = White elm(Ulmus americana); He = Eastern hemlock (Tsuga canadensis); Ht = Hawthorn (Crataegus spp.); Hw = American witch-hazel (Hamamelis virginiana); Mm = Manitoba maple (Acer negundo); Mmt = Mountain maple (A. spicatum); Mn = Norway maple (A. platanoides); Mr = Red maple (A. rubrum); Ms = Sugar maple (A. saccharum); Or = Red oak (Quercus rubra); Ow = White oak (Q. alba); Pb= Balsam poplar (Populus balsamifera); Wych = Wych elm (U. glabra)*

The %IV of ash species ranged from 18.0 to 30.7% in 1977, but ranged from 4.9 to 12.6% in 2015 (Fig. 7). In 2015, its population size ranged from 11 to 49 with limited evidence of regeneration in Plot 3 and lots of absent cohorts in all three plots (Fig. 8).

The %IV of American beech slightly increased from 13.2 to 15.4% in Plot 3, decreased from 12.3 to 7.9% in Plot 5, and substantially decreased from 14.8 to 3.7% in Plot 4 (Fig. 7).

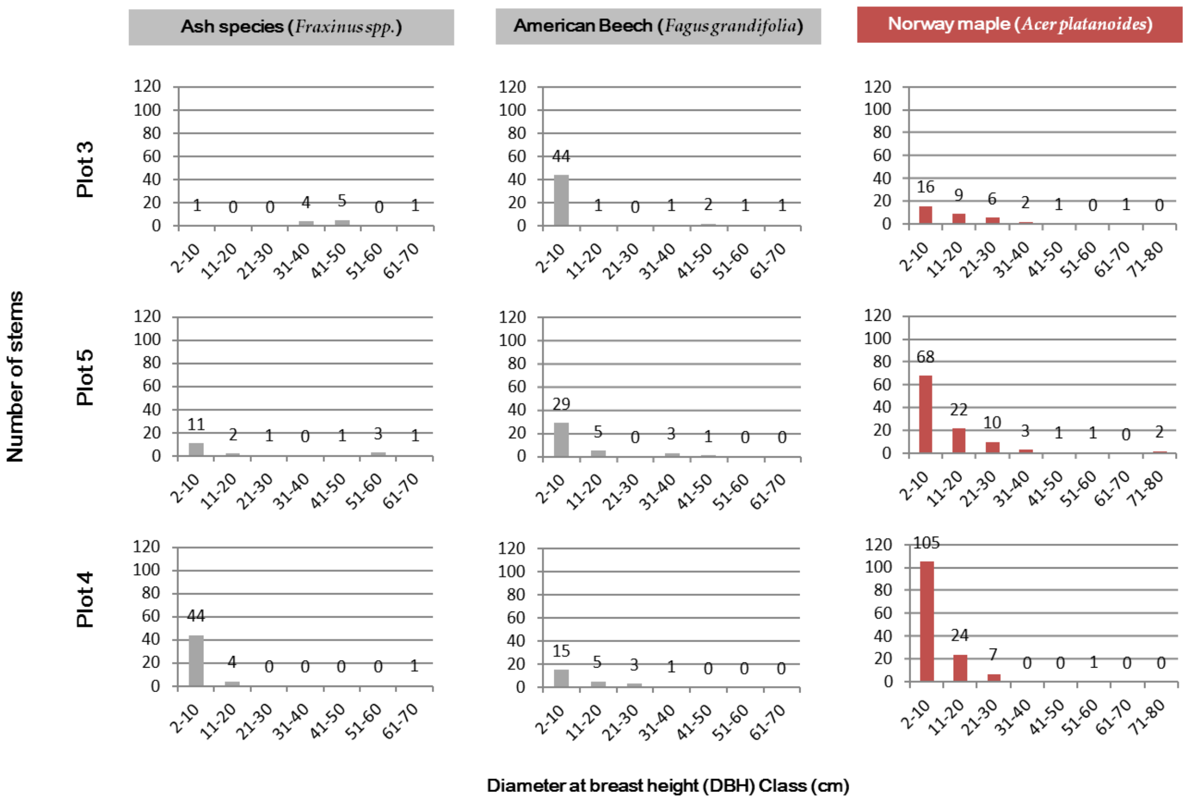

Figure 8. *The size class distribution of ash species (Fraxinus spp.) that are native to Toronto (left column), American beech (Fagus grandifolia, middle column), and Norway maple (Acer platanoides, right column) in each plot in the Park Drive Ravine, Toronto, Ontario, 2015. The horizontal axis represents different diameter at breast height (DBH) classes, and the vertical axis represents number of stems in each DBH class. Plot 3 and 5 (top two rows) were located on the north-facing slope, and Plot 4 (bottom row) was located on the south-facing slope.*

Eastern hemlock, white pine, and white oak (*Quercus alba* L.) were found to have no regeneration. For each of these species, no more than 5 stems were found from all three plots, and all of these stems had DBH>20cm.

Black cherry (*Serotina prunus* Ehrh.), black walnut (*Juglans nigra* L.), and red oak (*Quercus rubra* L.) were found to have limited regeneration. For each of these species, no more than 10 stems were found from all three plots, and the number of saplings (DBH<=10cm) was below 5.

The %IV of Norway maple ranged from 0 to 6.3% in 1977, but then substantially increased in all plots and ranged from 14.2 to 24.2% in 2015. More importantly, while no Norway maple was recorded in Plot 4 in 1977, it is now the second most dominant species in this plot.

Change in the proportions of native species with non-native species

Each species recorded by the 1977 study and/or the 2015 resurvey was classified as native or non-native to Toronto according to the native ranges of 679 woody species across North America defined by the United States Geological Survey (USGS) (data resource available at http://esp.cr.usgs.gov/data/little/). Table 2 summarizes the numbers of species that are native and non-native to Toronto in each plot in 1977 and 2015. In the last two rows, minus sign (-) represents the number of species that were lost, and plus sign (+) represents the number of species that were newly introduced since 1977. The bottom row shows the proportion of native and non-native species in terms of species richness (i.e. number of different species found).

From 1977 to 2015, the number of native species in Plot 3 did not change (14 in both years, lost 5 but gained 5), and the number of non-native species increased from 3 to 4 (lost 1 but gained 2).

The number of native species in Plot 5 decreased from 12 to 8 (lost 6 but gained 2), and the number of non-native species stayed the same (6 in both years, lost 3 but gained 3).

The number of native species in Plot 4 increased from 12 to 19 (lost 2 but gained 9), and the number of non-native species increased from 3 to 9 (did not lose any but gained 6). The origins of the remaining two species in Plot 4 could not be determined because they were only identified as *Salix spp*. and *Prunus spp*. and were therefore excluded from this analysis.

Overall, the species richness of native species increased from 18 to 22, but its proportion decreased from 69.2 to 62.9%. Meanwhile, the species richness of non-native species increased from 8 to 13, and its proportion increased from 30.8 to 37.1%. Two native species (*Juglans cinera* and *Populus balsamifera*) have disappeared from these plots, and six native species (*Acer saccharinum, Carya ovata , Cornus spp., Hamamelis virginiana, Juglans nigra,* and *Quercus velutina*) emerged. Three non-native species (*Acer pseudoplatanus, Morus alba,* and *Salix fragilis*) have disappeared, and eight non-native species (*Catalpa speciosa, Fraxinus excelsior, Malus spp., Picea abies, Rhamnus spp., Ulmus glabra,* and *U. pumila*) have been introduced.

In 1977, a total of 844 woody stems with DBH >= 3cm were recorded from the five plots. Among these stems, 769 were native to Toronto (91.1%) while 75 were non-native (8.9%) (Table 2).

In 2015, a total of 899 woody stems with DBH >= 3cm were recorded from the three resurveyed plots. 583 (65%) of them were native to Toronto while 316 (35%) were non-native (Table 2). 11 stems (10 individuals of *Prunus spp.* and 1 individual of *Salix spp.* in Plot 4) were excluded from this calculation because their origins could not be determined.

Since the breakdown between native and non-native woody stems by plot was not available, the proportion of native and non-native woody stems can only be compared between the total number of stems recorded in 1977 (five plots) and 2015 (three plots). Due to different sample sizes (five plots in 1977 and three plots in 2015) and the unknown status of the two plots that were not resurveyed, the validity of this comparison remains debatable.

Table 2. *Number of species that are native or non-native to Toronto in each plot in 1977 and 2015 in the Park Drive Ravine, Toronto, Ontario. In the last two rows, minus sign (-) represents the number of species that were lost, and plus sign (+) represents the number of species that were newly introduced since 1977. The bottom row shows the proportion of native and non-native species in terms of species richness (i.e. number of different species found). Checklist of species found in each plot in 1977 was obtained from Table A3, Appendix A, The Rosedale Ravine Study 1977; origin of each species was determined according to the native ranges of 679 woody species across North America defined by the United States Geological Survey (USGS) (data resource available at http://esp.cr.usgs.gov/data/little/).*

Plot	**Aspect**	**1977**		**2015**	
		Native	**Non-native**	**Native**	**Non-native**
3	North-facing	14	3	14 (-5+5)	4 (-1+2)
5	North-facing	12	6	8 (-6+2)	6 (-3+3)
4	South-facing	13	2	19 (-3+9)	9 (-0+7)
Total		**18**	**8**	**22 (-2+6)**	**13 (-3+8)**
		70%	**30%**	**63%**	**37%**

Discussion

Among the three plots that were resurveyed in 2015, Plot 4 was located on the south-facing slope, and Plot 3 and 5 were located on the north-facing slope (Fig.4 and Table 1). Because of its aspect, Plot 4 receives more insolation than Plot 3 and 5. This can be one of the factors that had led to the substantial increase of absolute density and species richness in Plot 4 (Table 1).

While conducting field work in 2015, it was noticed that Plot 4 was exposed to more human activities (i.e. construction and traffic) than Plot 3 and 5. Located in the city-owned Beaumont Park, Plot 4 is more accessible than the other two plots despite of its severely eroded slope. The top of Plot 4 is adjacent to Beaumont Road, a small road east to the Glen Road Viaduct. Ongoing construction (either by private property owners or the City) was seen on this road during every visit to Plot 4. Disturbance does not only come from the road and the trail, but also occurs within the ravine on the slope – some ash trees near Plot 4 were cut down probably as part of the City's ash management plan (Park, Forestry and Recreation, 2015).

On the other hand, the top of Plot 3 and 5 is adjacent to the backyards of properties on May Street, a small street within a residence area. Disturbance from these properties is expected to be weaker than those on Beaumont Road because heavy machines and large vehicles cannot access the backyards.

Over the past 38 years, there has been a net gain of both native and non-native species in terms of species richness. However, the relative contribution of most native species has decreased with little or no evidence of regeneration indicating a degraded ecological integrty. Ash species (*Fraxinus spp.* including *F. americana, F. pennsylvanica,* and *F. nigra*) and American beech (*Fagus grandifolia*) used to be two of the dominant native species in these three plots, but the sum of their %IV has decreased by 36, 73, and 45% by 2015. Their size class distributions showed lots of absent cohorts (Fig. 8). However, the relative contribution of non-native species, especially Norway maple (*Acer platanoides*), has increased with lots of natural regeneration (Fig. 8). Carleton and Taylor (1983) found similar results in the ravines in Toronto's Highland Creek valley system. This situation reflected one of the typical challenges in the conservation of urban natural areas – native species are disproportionately displaced by widespread non-native species resulting in reducing uniqueness of local ecosystems (McKinney, 2002). With native species being lost, the ecosystem loses its ecological integrity and resilience (Noss, 1990).

Since ash and beech are currently being infested by Emerald ash borer and beech bark disease, their populations will further decline. As the canopy loses these major contributors and other native tree species, Norway maple will fill in the gaps and severely degrade the ecological integrity both structurally and functionally.

Conclusion

The main objective of this study was to obtain estimates of ecological integrity in the Park Drive Ravine and to study its change over time. Ecological integrity has been an important concept in ecosystem management for decades. Although different systems define ecological integrity differently, the key component is always native species.

A comprehensive survey was conducted in this ravine in 1977. In 2015, the canopy of three of the plots was resurveyed. The results indicated a degraded ecological integrity. Native species are declining while non-native species (especially Norway maple) are becoming more dominant. The ecological integrity could be further degraded if the population of Norway maple is not controlled.

In order to restore the ecological integrity in this ravine, replicating and expanding the 1977 Rosedale Ravines Study with modern technique are highly recommended. Invasive species such as Norway maple need to be controlled, and the regeneration of native species needs to be assisted. Mature stems of native species need to be protected in order to preserve the local gene pool of Toronto. Agreement and collaboration among various stakeholders are critical.

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A Protocol for Seed Forecasting Oaks in the Toronto Ravines

A capstone project submitted in conformity with the requirements
for the degree of:

Masters in Forest Conservation

Faculty of Forestry
University of Toronto

Prepared under the supervision of: Eric Davies, Anne Koven and Barb Boysen

By: Jane Michener

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TABLE OF CONTENTS

Tables and Figures

ABSTRACT

The City of Toronto has been described as, “a city within a park” because of its extensive ravine system; they make up 17% of the urban landscape encompassing over 18,000 thousand hectares. Recent studies have shown that there is limited to no native regeneration occurring in the ravines while non-native species are thriving, this makes it important to identify native seed trees within the ravine ecosystem in order to begin implementing artificial regeneration. The aim of this study is to set up seed forecasting protocols for native *Quercus spp.* within six ravines by identifying and mapping *Quercus* trees species on public property with a DBH of >50cm and setting up specific seed forecasting protocols that examine the acorn yield of the whole tree in the crown and on the ground. One hundred and twenty eight *Quercus* species were identified of the subspecies *Erythrobalanu* and *Leptobalanus*: 107 *Quercus rubra*, 20 *Quercus alba* and 1 *Quercus marcrocarpa*. Seed forecasting was preformed the last two weeks of August and from Sept 10^{th}-21^{st} and all three species, *Quercus rubra*, *Quercus alba* and *Quercus marcrocarpa* experienced crop failures with no acorns detected in the crown and on the ground. First year acorn measurements on the terminal branches of *Erythrobalan* were conducted in October and November within five of the ravines in order to assess the potential acorn yield for 2017. We found an average of 1.04 acorns per branch indicating that next year’s acorn crop will also be a failure. These finding highlight the importance of having a set database and seed forecasting protocols for *Quercus spp*. within the ravines to monitor acorn production and assist in artificial regeneration.

INTRODUCTION

The ecological importance of the ravine system for the city of Toronto was first recognized after the devastation of Hurricane Hazel in 1954 where flooding caused millions of dollars worth of damage and 80 people lost their lives; before that they were seen as a barrier to economic development and concerted efforts were made to fill them in (Dong, 2015). Today piecemeal city plans, regulations and bylaws protect aspects of the ravines but there is still no comprehensive strategy plan that focuses solely on their management and protection (City of Toronto, 2016). In 1977 The Rosedale Ravine Study surveyed four ravines in the city of Toronto in an effort to provide " a detailed data base of the flora and fauna" within those ravines (Ravine Study, 1977). The study found that invasive species were escaping into the ravines and that, "because of their often unstable topography they are relatively delicate systems easily disrupted by poor conservation practice." (Ravine Study, 1977). In 2014 the Department of Forestry at the University of Toronto began to resurvey the 1977 plots and the initial study found that the non-native Norway Maple (*Acer Platanoides*) cover has increased from 6.3 in 1977 to 24.2 in 2015 and that there was little regeneration of the formerly dominate native *Fraxinus spp*. and *Fagus spp*. and no White Oak (*Quercus alba*) regeneration and limited Northern Red Oak (*Quercus rubra*) regeneration (Dong, 2015). These findings highlight the diminishing biodiversity and lack of natural regeneration in the ravines as well as the absence of conservation practices in the last forty years. With limited to no natural regeneration occurring in the ravines, finding and collecting native seeds is an important step in assisting artificial regeneration.

Quercus are a keystone species in North America forests, they are a nut-producing tree that drive community and ecosystems processes (Lusk et. al., 2007) and provide food for numerous wildlife species: white tailed deer (*Odocoileus virginianus*), wild turkeys (*Meleagris gallopavo*), *Sciuridae spp*., *Muridae spp*. and *Cricetidae spp*. (McShea, 2000). In urban environments they also support many species, mainly in the *Sciurida* family (Bowers & Breland, 1996) and as a long-lived native species they have an important cultural significance within cities as well as providing numerous ecological services (Nowak & Dwyer, 2000). The decline of oak regeneration is a disturbing worldwide phenomenon due to fire suppression, logging and the replacement of oaks by other species, especially shade tolerant *Acer spp.* (Dey, 2014) but there has been little research exploring *Quercus spp.* regeneration in urban environments. The variability of the oak species acorn production makes predicting acorn yields difficult and there are many complex factors that effect acorn production: masting behavior, resource allocation, environmental cues and genetics (Sork, 1993), (Koenig & Knops, 2005). Seed quality has a strong influence on phenotypes and genotypes of seedlings and certain individual oaks are inherently good producers within a population (Healy et. al., 1999). Therefore it is important to identify local seeds of know quality from good acorn producers in order improve regeneration potential. This makes it essential to identify and monitor the *Querus* populations in the ravines in order to gain specific information on acorn production of individual oaks. In this study the aim is to:

i) Identify and map all *Quercus spp*. on public property and <50cm DBH in six central Toronto ravines.

ii) Set up seed forecasting protocols to monitor current and future acorn production.

iii) Examine first year acorn production of *Quercus rubra* in the fall in order to gather data about the next year's acorn yields.

2. METHODS

The City of Toronto lies within the most southern Ecocregion of Ontario 7E (Lake Erie-Lake Ontario), the climate is one of the mildest in Canada with a mean annual temperature range of 6.3 to 9.4 C, and mean annual precipitation of 776 to 1,018mm with cool winters and long, hot and humid summers (Environment Canada, 2016). The region is underlain by Silurian and Devonian limestone bedrock, the topography is flat and overlain by deep undulating deposits of ground moraine. Most substrates are comprised of calcareous mineral material with a minor component composed of organic material (Environment Canada, 2016). It boosts some of the most diverse and threatened flora and fauna in Canada and is the most urbanized region in Ontario. The ravines sampled in this study, Burke Brook, Moore Park, Evergreen, Park Drive, Vale of Avoca and Rosedale Valley are part of the Don River valley watershed, which starts in the oak ridges moraine in the north and flows out through the Don River to lake Ontario in the south. They were formed by the Don River tributaries and the total area adds up to ~60ha.

In August we began surveying four of the ravines involved in the original 1977 Rosedale Ravine study (Figure 1): Burke Brooke, Moore Park, Park Drive, Rosedale and added two that were in the immediate vicinity, Evergreen and Vale of Avoca (Figure 2). The ravines are on both public and private property so in our study we identified all *Quercus spp* on public property with a DBH of >50cm. The reason we made sure that the species were on public property was for future Citizen Science initiatives, the goal is to get citizens out every year forecasting the oaks for which we will need public and accessible oak species.

Once the oaks were identified we recorded the DBH and conducted crown health assessments based on five semi-quantitative measures: live crown ratio, crown dieback, unbalanced crown, chlorisis and herbivory based on the urban forest Neighbourwoods guidelines. GSP coordinates of each tree were taken using a Garmin Montana 600, which

Figure 1: 1977 Rosedale Ravine Study

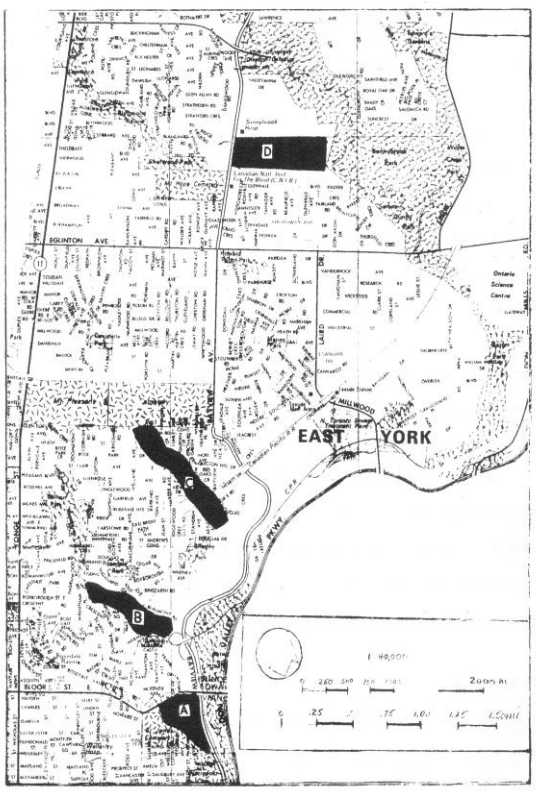


Figure 1. East-central Metropolitan Toronto. A = Rosedale Valley; B = Park Drive ravine; C = Moore Park ravine; D = Burke Brook ravine. (Creative Sales, 1976. Scale, ca. 1:40,000.)

Figure 2: 2016 Ravine Revitalization Study

were then uploading into ArcGIS and Open Tree Map.

We conducted two rounds of seed forecasting on the *Quercus spp.* from Aug 15-Aug 25 and Sept. 10-21st. Standard issued binoculars were used to view the crown of the trees which were accessed in four quadrants from the north, south, east and west. Ten branches from each quadrant were randomly picked and the acorns counted on the 60cm tips of the branches (Dey, 1995). Estimations of acorn crop yields were access using the "Seeds of Ontario Trees and Shrubs: Field Manuel for Crop Forecasting and Collecting" produced by the Forest Gene Conservation Association FGCA (Table 3 and Table 4). Acorn yields were then measured on the ground at the base of the tree, a 10 by 10 cm quadrant was placed one meter from the based of the tree at each north, south, east, west quadrant and the acorn yields calculated using the same FGCA guidelines. For the steep slopes in the ravines a two ground measurement were taken depending on the downward trajectory of the slope, one at one meter and another at three meters.

Table 3. Seeds of Ontario Acorn Yield Tables

Unit of Measure	Number of Units
1 lb coffee tin	1 litre
A hard hat	2 litres
5 gallon pail	20 litres
1 bushel basket	36 litres
1 full burlap	100 litres

Table 4. Seeds of Ontario *Quercus* Acorn Yields per tree

Acorn Crop Yields	Liters
Failure	<10L
Light	10-30L
Medium	30-50L
Heavy	50-80L
Bumper	80L+

To study the potential acorn crop in *Quercus rubra* for 2017 we examined branch falls within five ravine population in October and November. Branch falls were collected from each ravine site based on slope position and species within a 25 meter radius. If there were no conspecific species within 25 meters the branches collected within that area were classified as coming from a single tree, if there were two or more trees within a 25 meter radius branches collected within the area were classified as a small grove, 5-10 trees within a 25 meter were classified as a medium grove and >10 trees were classified as a large grove. Only green branches were collected to ensure that they came from this year's growth. The new terminal branch growth was measured on each individual branch and first year acorns and bud were counted (Appendix 2, Plate 1, 2 and 3). The buds were recorded as small (>1mm), medium (0.5mm) or large (<0.5mm) on the branch.

3. RESULTS

3.1 Mapping

Our survey of six ravines found small isolated populations within three of the ravines: Park Drive which had twenty-five *Quercus spp.* on the northern slope, Rosedale Ravine which had twenty-five on its northeastern slope and Burke Brooke which contained thirty-five *Quercus rubra* on the northeastern slope (Table 5). In Moore Park we found thirteen *Quercus spp.* on two separate slopes, eight *Quercus rubra* on an eastern slope and two *Quercus alba* and three *Quercus rubra* on the northern slope (Figure 6). In Evergreen Ravine on a northern slope we found eight *Quercus rubra* and three *Quercus alba* and on an exposed western edge there were three *Quercus rubra*. In Vale of Avoca there were four *Quercus alba* and ten *Quercus rubra* on level ground and the bottom of the eastern slope, six Quercus rubra further north on the eastern slope and one *Quercus rubra* on the top of the western slope (Figure 7).

Table 5. *Quercus spp.* distribution within the ravines.

RAVINE	*Quercus rubra*	*Quercus alba*	*Quercus marcrocarpa*	Average DBH
Park Drive	15	9	1	74.5
Rosedale	22	3		75.05
Burke Brook	34			69.68
Moore Park 1	8			75.6
Moore Park 2	3	2		72.86
Evergreen 1	3			69.66
Evergreen 2	9	3		68.82
Vale of Avoca 1	5	4		95.88
Vale of Avoca 2	6			73.53
Vale of Avoca 3	1			92.5

Figure 6. *Quercus spp.* in: Moore Park, Evergreen, Park Drive, Vale of Avoca and Rosedale Ravines.

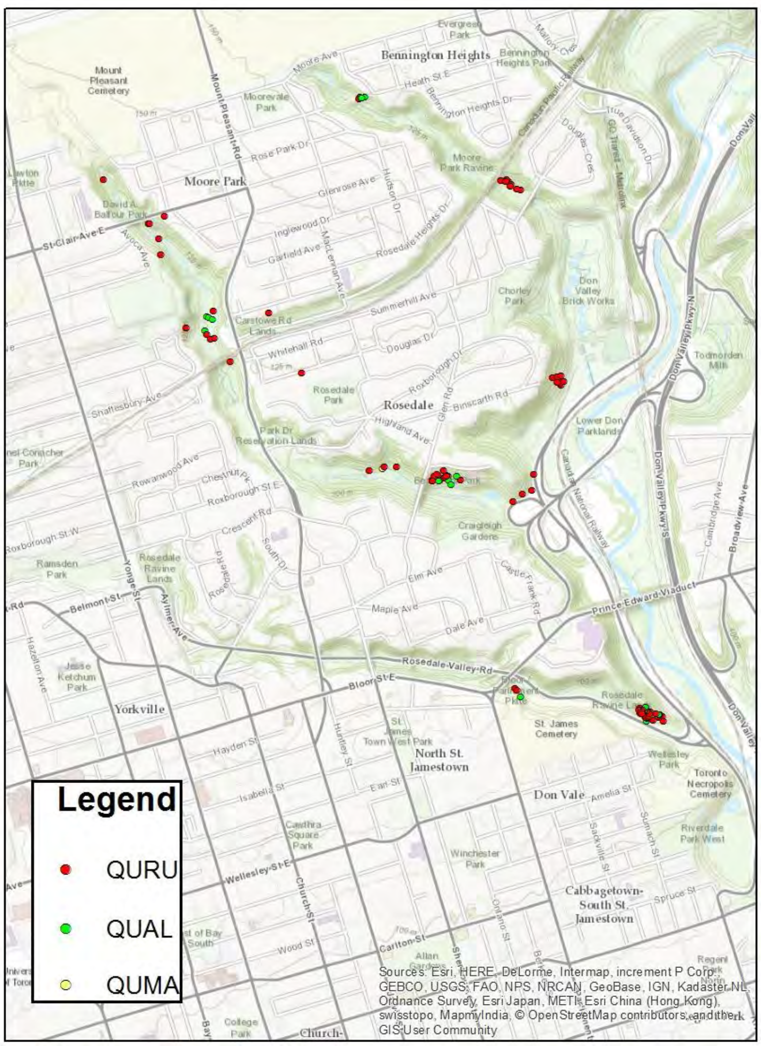
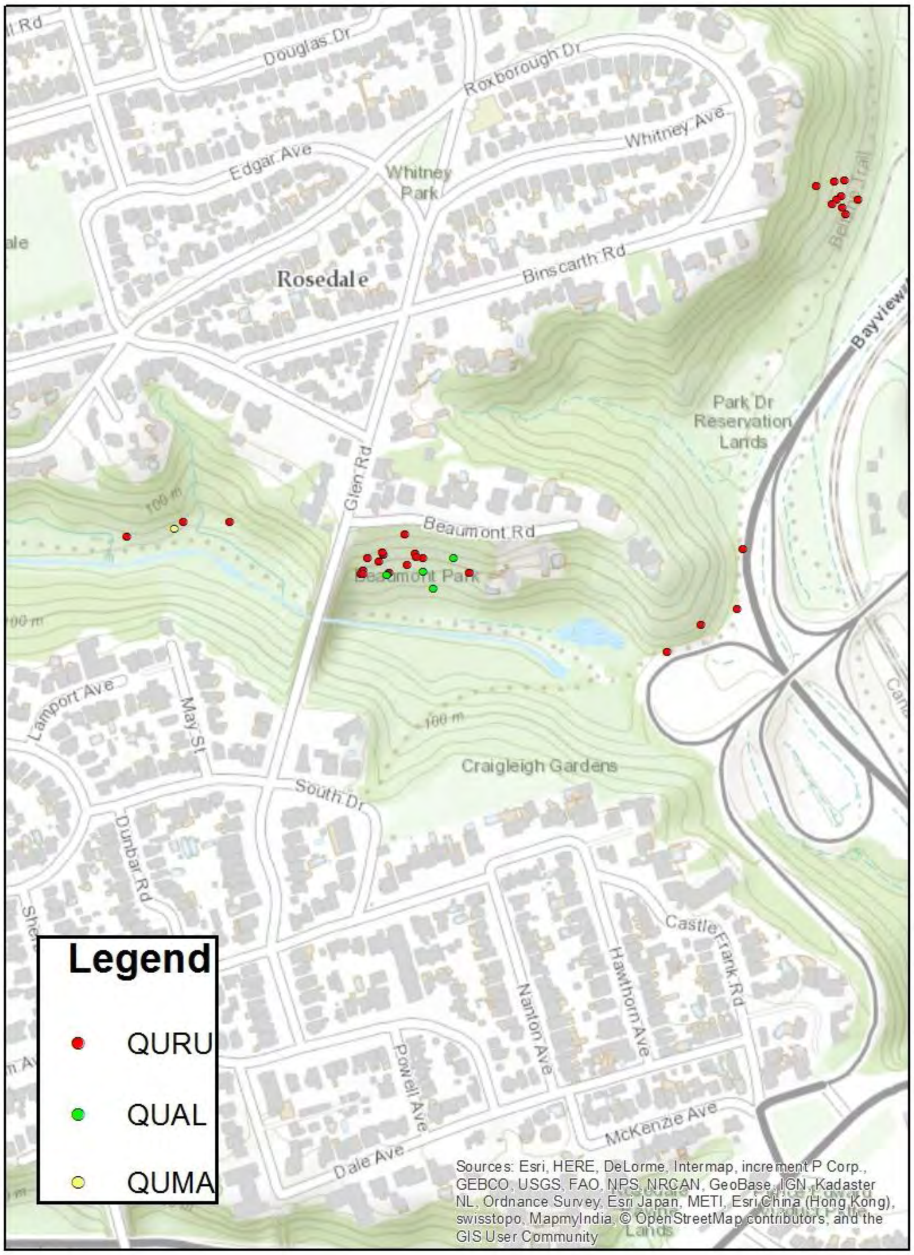


Figure 7: *Quercus spp.* in Evergreen and Park Drive Ravine.



3.2 Seed Forecasting: Crown and Ground

All *Quercus* species we surveyed were identified as having a failure in acorn production for 2016 in the six ravines (Appendix 1). Of 128 trees we surveyed with four (North, South, East, West) counts in the crown and four on the ground for a total of 1,024 observations we had a total acorn count of four.

3.3 Seed Forecasting: Branches

We collected 312 individual branches from five of the six ravines in this study and measured 599 terminal branches. The average number of acorns for each ravine was less than two with a total average of all ravines equaling 1.04 with a range of 0-17 and a standard deviation of 2.38 (Table 8).

Table 8. Average Acorn Count, Range and Standard Deviation.

	R1	**R2**	**R3**	**R4**	**R5**	**TOTAL**
Average	1.3636	0.6093	0.8867	1.0769	1.0576	1.0358
Range	0-17	0-6	0-16	0-7	0-6	0-17
STDEV	2.9844	1.2033	2.9914	1.7378	1.8086	2.3808

4. DISSCUSSION

In the ravines we surveyed 83% of the species were *Quercus rubra* and 16% *Quercus alba* species. Isolated populations were found on the northern slope in Park Drive and northeastern slopes of which is standard for *Quercus rubra* (Burns, 1990) as it is where they will receive the most sunlight. In Evergreen Ravine there were more *Quercus spp* on the northern and western edge but they were on private property and therefore excluded from the study. *Quercus spp.* were also present at the top on the southern or northern facing slope in Park Drive Ravine but again they were on private property and therefore excluded from our study.

4.1 Seed Forecasting: Crown & Ground

Every *Quercus spp.* that we surveyed had an acorn crop failure based on the Seeds of Ontario Acorn Yield Table, in fact we found virtually no acorns in the crown or on the ground. Correspondence with seed collectors in Toronto and seeds banks in Ontario found that they also experienced Northern Red Oak seed failures but that they were able to meet their quotas for *Quercus alba* and *Quercus marcrocarpa* (Derk Sluiter, Steve Smith and Dave Habec Correspondence, 2016). In the field we did observe an Eastern Grey Squirrel (*Sciurus carolinensis*) foraging in the crown of a *Quercus alba in* Park Drive Ravine. We observed it foraging for twenty minutes and casting green acorn husks to the ground so *Quercus alba* were producing acorn but they were being consumed in the crown (Field observation, 2016).

So why did we observe an overall acorn crop failure in the ravines for 2016? Oaks like many species in temperate and boreal forests oaks are a masting species. Characteristic masting behavior includes intermittent large corps, crop failures and semi regular masting cycles (Isagi et. al., 1997). There are numerous theories on the evolution of masting and some of the most supported are: predator satiation (Janzen, 1971), (Silvertown, 1980) resource balancing (Sork, 1993) and the increased efficiency of wind pollination (Kelly, 1994), (Koenig & Knops, 2014). Many studies have found intraspecific masting behavior in North American *Quercus* populations (Koenig et. al., 1994), (Lusk et. al., 2007), (Sork et. al., 1993), (Liebhold et. al., 2004), though there is no clear evidence of set masting cycles (Herrera et. al., 1998). In 1993 Sork et al. studied three species of oaks in Missouri Black (*Quercus velutina*), Red (*Quercus rubra*) and White (*Quercus alba*) and found that acorn crop size was auto correlated with prior acorn production and that each species seemed to have different inherent cycle of reproduction based on the evolution of resource allocation which are modified by weather conditions (Sork et. al., 1993). Within the city of Toronto there are no comprehensive databases of masting cycles for *Quercus rubra* and *alba* but one seed collection database of street and park trees indicates that there was a mast year in 1998 and 2001 for both species (Appendix 3). The variability and synchronization associated with masting behavior inherently makes predicting acorn yield difficult and when we examine the life history of acorn maturation cycles it becomes even more complex.

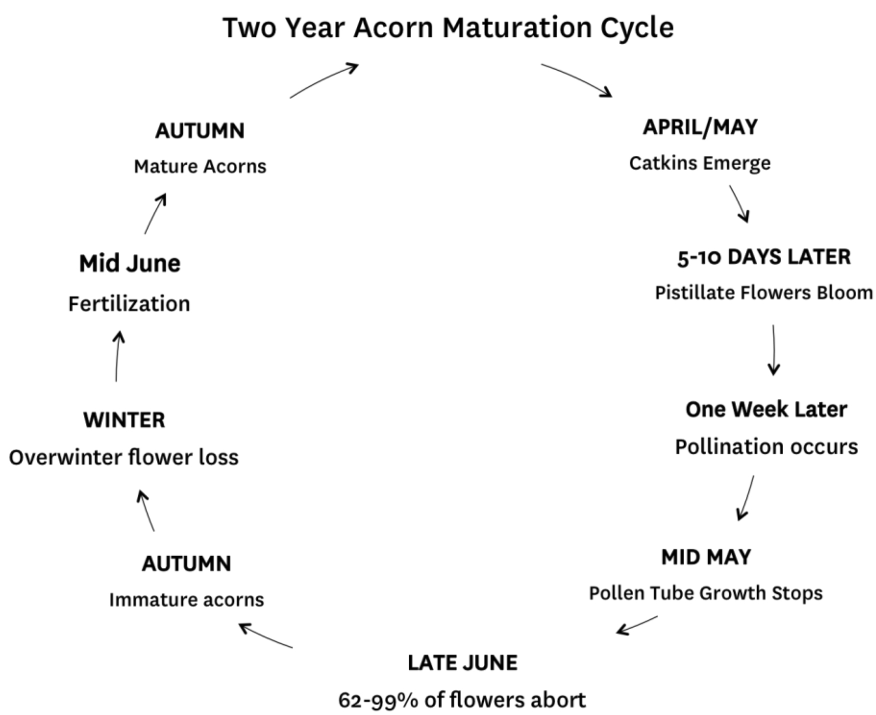
4.2 Seed Forecast: Branches

When we examined the branch throws for the *Quercus rubra* species we found a very low average of 1.04 acorns per branch across all five ravines and a range of 0-17 (Table 8). Finding numbers for the amount of first year acorns that should be present proved difficult for a number of reasons. First the number will vary based on the location of the species (Correspondence, 2016) and second since there are many factors within the species acorn production that can affect their yields, most studies do not look at first year acorn production in *Erythrobalanus* subspecies. One of the main studies on the reproductive cycle of Northern Red and Black Oaks by Cecich and Haenchen notes in their methods that while collecting branches to examine the pistillate flowers found that, " they average number of flowers per 2nd-year branch ranged from about 3-63, depending on the tree and the year." 3-63 is quite the range and as we discuss below there are numerous factors that affect the flowers at each stage of their life cycle. When seed forecasting *Quercus rubra* it is important to understand the stages of the acorn maturation life cycle and the factors that can affect acorn development at each for these stages.

4.3 *Quercus spp.* Life Cycle

Oaks begin to flower and produce acorns around 15-25 years old (Dey, 1995), (Johnson et. al., 2009) but they do not become prolific acorn producers until they reach the age of 50 and in general trees of large DBH produce more acorns than trees with smaller diameter (Dey, 1995), (Greenberg, 2000). Both Red and White Oak species are monoecious, in White Oak (*Quercus alba*) subgenus *Leptobalanus* acorn maturation takes one year and the reproductive cycle of this species has been closely studied (Johnson et. al., 2009). For Northern Red Oak (*Quercus rubra*) subgenus *Erythrobalanus* acorn maturation takes two seasons to mature and its reproductive cycle has not been as closely studied (Johnson et. al., 2009). In Northern Red Oaks acorn production begins when the staminate buds (male) are initiated in the spring of the year prior to flowering and the pisittlate buds (female) are initiated in the late summer (Sork et. al., 1993). The following year the staminate flowers emerge on catkins in April or May depending on the location and climate. They appear on the previous year's branch from male or mixed buds (Cecich, 1992), (Desmarais, 1998). Pollen is produced in the anthers and the pollen contains two cells, a generative cell that divides into two sperm cells and a tube cell, which produces the pollen tube (Desmarais, 1998), (Johnson et. al., 2009). The pistillate flowers emerge about a week after the staminate flowers; they appear in the axils of the present year terminal branch either individually or in small clusters of two, three or more ((Johnson et. al., 2009). The flowers seem to be receptive for no more than a week after they emerge when they are bight red and flexible (Cecich & Haenchen, 1995). The female flowers are pollinated when the pollen grains fall on the stigma surfaces and form pollen tubes (Cecich & Haenchen, 1995), (Johnson et. al., 2009). Numerous pollen tubes can form on the styles where they begin to penetrate downwards through the transmitting tissue until they reach the perinth where the pollen tube growth then ceases (Cecich & Haenchen, 1995). It is interesting to note that in the Cecich and Haenchen study both Northern Red and Black Oak pollen tube growth ceased on the same date even though the Northern Red Oak began growing one week before the Black Oak (Cecich & Haenchen, 1995). At this point the ovary tissues are not fully developed and in late June from 66-99% of the flowers abort (Cecich & Haenchen, 1995). In the fall in the immature acorns are present on the terminal braches, which we observed and measured in this study (Figure 9). Over winter there is further flower loss and in the spring both second year acorns and first year developing flowers can be observed on the branches. In mid June the pollen tube growth resumes, one of the five ovules are fertilized and the mature acorn begins to develop and is fully mature in the autumn (Cecich & Haenchen, 1995), (Desmarais, 1998), (Johnson et. al., 2009). Weather could be a possible cue for the resumption of the pollen tube growth, or it could be an endogenous hormonal cue once the ovule is fully developed (Cecich, 1992).

Figure 9. *Quercus rubra* Acorn Maturation Cycle



4.4 Factors affecting acorn survival

Within this two-year life cycle of acorn maturation there are numerous factors at each stage that can imped the survival of the fruit. Spring temperatures and humidity levels can affect pollination success. For the catkins to release pollen temperatures must be 10

Celsius or higher for ten consecutive days and humidity levels must not exceed 61% (Johnson et. al., 2009). A spring frost, temperatures below negative 4 Celsius can kill male and female flowers (Johnson et. al., 2009). Premature abscission affects the female flowers during many stages of their development into mature acorns (Cerich, 1992), (Johnson et. al., 2009) and can be caused by lack of fertilization, self-fertilization, weather and insects. In non-mast years there are high premature abscission rates in late June and July and flower losses can occur over the winter period of their first year of development (Cerich, 1992), (Johnson et. al., 2009). Treehoppers (*Membracidae*) a sucking insect with styles have been observed feeding on oak flowers in early May to mid-June killing the flowers (Cerich, 1992) and it is interesting to note that they are also found on Norway Maples (*Acer platanoides*) (Tim Mathers, Correspondence, 2016) though whether they are the same species that have been observed on oaks would need future study. Weevils (*Curculio*) lay their eggs in the developing acorns and the larvae consume will consume the cotyledons, epicotyl, hypocotyl and radicle of the acorn and then emerge leaving a small exit hole in the shell. (Desmarais, 1998). *Callirhytis* a genus of wasps depending on the species can form galls on the acorns and sap beetles (Stelidaota octomaculata) and moths (*Melissopus latiferreanus*) also prey on the developing acorns (Desmarais, 1998). Once the acorns are mature in the crown in cities birds and squirrels consume them as we observed in this study (these species also act as dispersers) and once they fall to the ground they become prey for numerous other species including *Sciuridae spp*., *Muridae spp*. and *Cricetidae spp*. (Johnson et. al., 2009), (McShea, 2000).

Our study examined the immature acorns of *Quercus rubra* in the fall, about half way through their development cycle. We did find acorns on the branches (Appendix 2), which indicates that they are getting pollinated but the average of 1.04 acorns per branch across five ravines indicates that there will not be a bumper crop next year considering the stages they still have complete and the factors that can affect their development before they become mature acorns. If we examine some of the weather factors at different stages of the acorn development in 2016 we see that in April and May temperatures fluctuated (Environment Canada, 2016) and Ontario experienced an unusually warm and dry summer (Environment Canada, 2016) both of which could have effected acorn pollination and abscission. Understanding and monitoring the different stages of acorn production for *Quercus spp.* within the ravines can help us to determine the factors that are affecting their growth and development and to predict potential acorn yields. This information is invaluable if we are going to start assisting regeneration of *Quercus* species in the ravines with native seed sources. Seed forecasting the whole tree, crown, ground and branches throughout the seed development stages are protocols that can be applied to all native seed trees in the ravines; these protocols can assist in the native regeneration of the Toronto ravine system.

CONCLUSION

Most studies on acorn development and production state that acorn yield are very difficult to predict in the early stages of their development because of all the factors that affect their growth (Dey, 1995), (Healy et al., 1999) but as this study highlights you can get valuable information from forecasting *Quercus rubra* acorn development through different stages in their acorn maturation cycle. This method does not help to determine when a bumper crop will occur since there are so many factors that affect acorn development in the two year *Erythrobalan* cycle but you can get information about what factors are influencing acorn development during each stage and it can help to predict poor crop years. This is important data for the *Quercus rubra* species in the ravines because the masting cycles are so intermittent and there is little to no natural *Quercus* growth occurring we need powerful tools that can help us predict crop yields and understand the factors affecting acorn development in order to gather native seeds to assist with future regeneration.

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Appendix 1

Acorn Seed forecasting 2016

Sept 11, 2016-Sept 21, 2016										
			Crown				Ground			
Tree	**Species**	**DBH**	N	**S**	**E**	**W**	**N**	**S**	**E**	**W**
1	Quru	73.3	0	0	0	0	0	0	0	0
2	Quma	64.8	0	0	0	0	0	0	0	0
3	Quru	56	0	0	0	0	0	0	0	0
4	Quru	92.2	0	0	0	0	0	0	0	0
42	Quru	78.5	0	0	0	0	0	0	0	0
43	Quru	66.7	0	0	0	0	0	0	0	0
44	Qual	69.7	0	0	0	0	0	0	0	0
45	Qual	77.5	0	0	0	0	0	0	0	0
46	Qual	80.6	0	0	0	0	0	0	0	0
47	Qual	73.2	0	0	0	0	0	0	0	0
48	Quru	74	0	0	0	0	0	0	0	0
49	Quru	93	0	0	0	0	0	0	0	0
50	Quru	84	0	0	0	0	0	0	0	0
51	Quru	65.9	0	0	0	0	0	0	0	0
52	Qual	84.8	0	0	0	0	0	0	0	0
53	Quru	103	0	0	0	0	0	0	0	0
54	Qual	69.3	0	0	0	0	0	0	0	0
55	Qual	73.6	0	0	0	0	0	0	0	0
56	Quru	66	0	0	0	0	0	0	0	0
57	Quru	68.2	0	0	0	0	0	0	0	0
58	Qual	68.2	0	0	0	2b		0	0	0
59	Quru	63.9	0	0	0	0	0	0	0	0
60	Quru	71.2	0	0	0	0	0	0	0	0
61	Quru	69.9	0	0	0	0	0	0	0	0
5	Quru	65.5	0	0	0	0	0	0	0	0
6	Quru	69	0	0	0	0	0	0	0	0
7	Quru	65	0	0	0	0	0	0	0	0
8	Quru	75	0	0	0	0	0	0	0	0
9	Quru	68	0	0	0	0	0	0	0	0
10	Quru	67.5	0	0	0	0	0	0	0	0
11	Quru	69	0	0	0	0	0	0	0	0
122	Quru	80	0	0	0	0	0	0	0	0
123	Quru	73.5	0	0	0	0	0	0	0	0
124	Quru	89	0	0	0	0	0	0	0	0
125	Quru	52.9	0	0	0	0	0	0	0	0
126	Quru	49	0	0	0	0	0	0	0	0

127	Qual	75	0	0	0	0	0	0	0	0
128	Qual	69	0	0	0	0	0	0	0	0
129	Qual	65	0	0	0	0	0	0	0	0
12	Quru	58	0	0	0	0	0	0	0	0
13	Quru	92	0	0	0	0	0	0	0	0
14	Quru	73	0	0	0	0	0	0	0	0
15	Quru	71	0	0	0	0	0	0	0	0
16	Quru	73	0	0	0	0	0	0	0	0
17	Quru	75.3	0	0	0	0	0	0	0	0
18	Quru	77.5	0	0	0	0	0	0	0	0
19	Quru	85	0	0	0	0	0	0	0	0
20	Qual	105	0	0	0	0	0	0	0	0
21	Qual	60	0	0	0	0	0	0	0	0
22	Quru	77	0	0	0	0	0	0	0	0
23	Quru	60.5	0	0	0	0	0	0	0	0
24	Quru	61.8	0	0	0	0	0	0	0	0
25	Quru	92.5	0	0	1	0	0	0	0	0
26	Quru	99	0	0	1	1	0	0	0	0
27	Quru	124	0	0	0	0	0	0	0	0
28	Qual	92	0	0	0	0	0	0	0	0
29	Quru	102.5	0	0	0	0	0	0	0	0
30	Qual	70	0	0	0	0	0	0	0	0
31	Qual	72	0	0	0	0	0	0	0	0
32	Qual	89.5	0	0	0	0	0	0	0	0
33	Quru	91	0	0	0	0	0	0	0	0
34	Quru	123	0	0	0	0	0	0	0	0
35	Quru	77	0	0	0	0	0	0	0	0
36	Quru	48.5	0	0	0	0	0	0	0	0
37	Quru	48.5	0	0	0	0	0	0	0	0
38	Quru	107	0	0	0	0	0	0	0	0
39	Quru	70.2	0	0	0	0	0	0	0	0
40	Quru	90	0	0	0	0	0	0	0	0
84	Quru	32.6	0	0	0	0	0	0	0	0
83	Quru	37	0	0	0	0	0	0	0	0
74	Quru	37.5	0	0	0	0	0	0	0	0
76	Quru	37.5	0	0	0	0	0	0	0	0
82	Quru	42.5	0	0	0	0	0	0	0	0
69	Quru	43.3	0	0	0	0	0	0	0	0
80	Quru	46.2	0	0	0	0	0	0	0	0
72	Quru	50.2	0	0	0	0	0	0	0	0
68	Quru	51.5	0	0	0	0	0	0	0	0
64	Quru	53	0	0	0	0	0	0	0	0
67	Quru	57	0	0	0	0	0	0	0	0
71	Quru	57.7	0	0	0	0	0	0	0	0

70	Quru	58.5	0	0	0	0	0	0	0	0
75	Quru	64	0	0	0	0	0	0	0	0
88	Quru	65	0	0	0	0	0	0	0	0
77	Quru	66.4	0	0	0	0	0	0	0	0
73	Quru	67.5	0	0	0	0	0	0	0	0
85	Quru	68.5	2	0	1	0	0	0	0	0
90	Quru	73	0	0	0	0	0	0	0	0
91	Quru	73.2	0	0	0	0	0	0	0	0
66	Quru	74.2	0	0	0	0	0	0	0	0
65	Quru	77.3	0	0	0	0	0	0	0	0
86	Quru	80.3	0	0	0	0	0	0	0	0
94	Quru	80.3	0	0	0	0	0	0	0	0
95	Quru	82	0	0	0	0	0	0	0	0
92	Quru	83.1	0	0	0	0	0	0	0	0
79	Quru	86	0	0	0	0	0	0	0	0
78	Quru	87.4	0	0	0	0	0	0	0	0
81	Quru	90.7	0	0	0	0	0	0	0	0
87	Quru	105	0	0	0	0	0	0	0	0
93	Quru	106	0	0	0	0	0	0	0	0
63	Quru	108	0	0	0	0	0	0	0	0
89	Quru	108	0	0	0	0	0	0	0	0
62	Quru	119	0	0	0	0	0	0	0	0
96	Qual	87	0	0	0	0	0	0	0	0
97	Quru	77.5	0	0	0	0	0	0	0	0
98	Quru	41.2	0	0	0	0	0	0	0	0
99	Quru	72	0	0	0	0	0	0	0	0
100	Quru	66.5	0	0	0	0	0	0	0	0
101	Qual	65.4	0	0	0	0	0	0	0	0
102	Quru	81	0	0	0	0	0	0	0	0
103	Quru	66.6	0	0	0	0	0	0	0	0
104	Quru	101.5	0	0	0	0	0	0	0	0
105	Quru	59.5	0	0	0	0	0	0	0	0
106	Quru	58	0	0	0	0	0	0	0	0
107	Quru	66.5	0	0	0	0	0	0	0	0
108	Quru	118.4	0	0	0	0	0	0	0	0
109	Quru	71.2	0	0	0	0	0	0	0	0
110	Quru	66.5	0	0	0	0	0	0	0	0
111	Quru	59	0	0	0	0	0	0	0	0
112	Quru	100.5	0	0	0	0	0	0	0	0
113	Quru	70.2	0	0	0	0	0	0	0	0
114	Quru	70	0	0	0	0	0	0	0	0
115	Quru	66.5	0	0	0	0	0	0	0	0
116	Quru	70	0	0	0	0	0	0	0	0
117	Quru	55	0	0	0	0	0	0	0	0

118	Quru	84.5	0	0	0	0	0	0	0	0
119	Qual	78.5	0	0	0	0	0	0	0	0
120	Qual	80.8	0	0	0	0	0	0	0	0
121	Quru	98.8	0	0	0	0	0	0	0	0

Appendix 2. Plate 1, 2 and 3 Immature acorn on *Quercus rubra* branches

Plate 1. Immature Acorns

Plate 2. Immature Acorns

Plate 3. Immature Acorns

Appendix 3. *Quercus rubra* and *Quercus alba* acorn yields from 1994-2016

Table 1. *Quercus rubra*

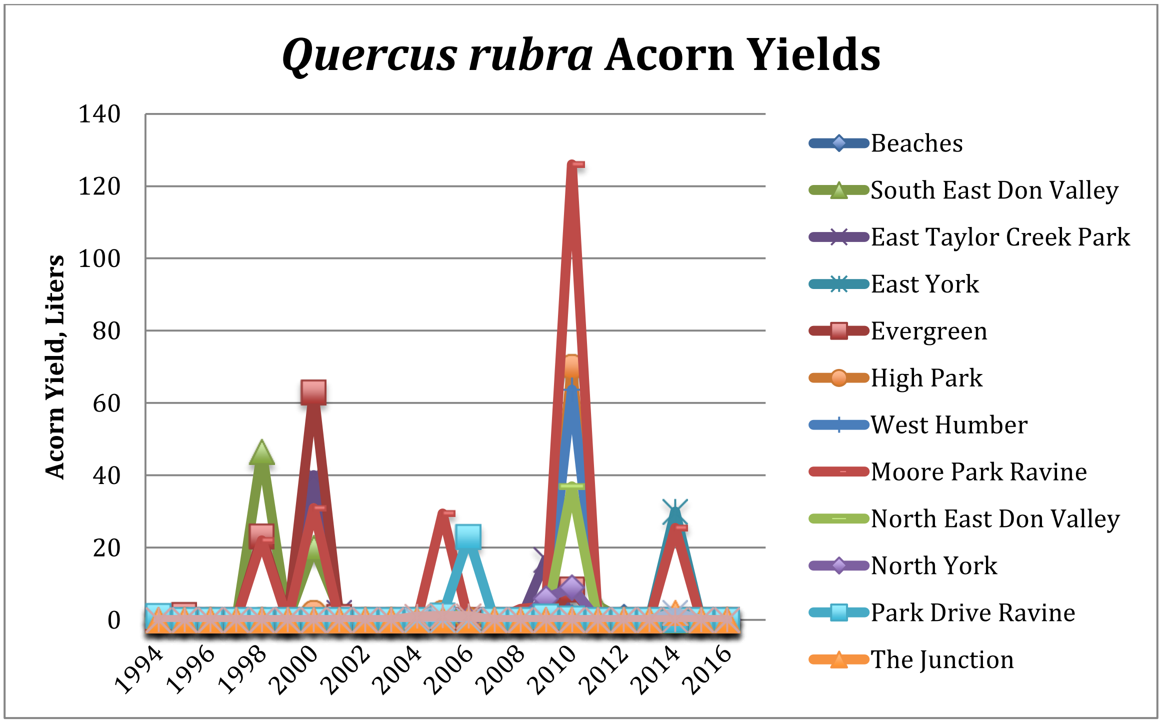
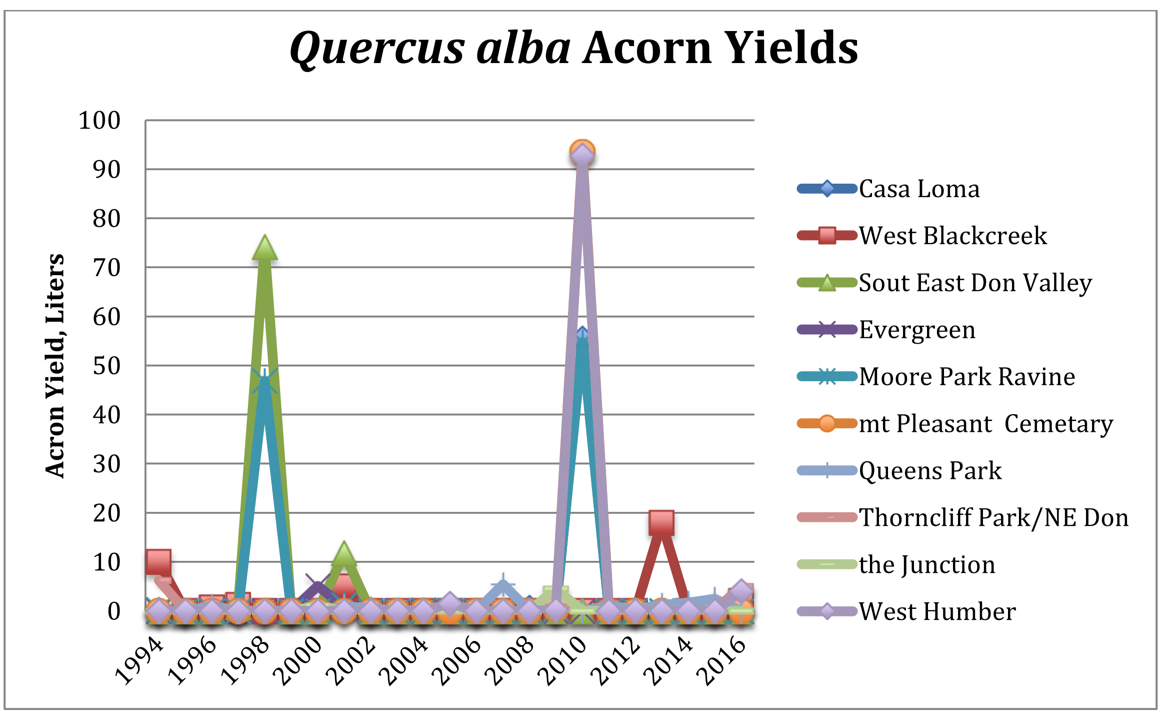


Table 2. *Quercus alba*



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Internship report : Old growth trees, seed collection in Toronto

LEPOIVRE Vincent
From 04/06/2017 to 22/09/2017

Internship report

Promotion 158

2016-2017

Internship supervisor: M. Eric Davies
Tutor: M. Olivier Scheurer

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Summary

Illustrations table

TABLEAUX

FIGURES

1. General introduction

As student in 3rd year in LaSalle engineer school, I have to do an internship as technician in order to put into practice the things we learned this year and in my technical school.

I had two criteria to do my internship: first go to Canada to improve my English and discover this fascinating country and then do it in a company in relation with the forestry. The forestry is required because I want to work in this domain after I get my diploma. I was in a first time thinking to do this in a company which harvest the wood but a friend of mine, working in Quebec says me that they don't look for an internship but someone who can work or with a lot of skills. So I decided to go in the Faculty of Forestry in the University of Toronto because this is a laboratory which welcomes a lot of students.

I have asked a mission in relation with my 4th year option which is "Agronomy and territory" then Eric proposed me to work on "the seed collection for old growth trees". I find this mission great because in France a lot of people speak about Canada as a wild place so I wanted to learn more about that. A study in the seed is a good thing for me, we can't work in forestry without thinking of the seed and the post harvest replanting.

My boss' mission is name "Toronto ravines revitalization study" the goal is to study the impact of non native trees on the native's one. In 1977, some researcher went to the ravine and determined the proportion of Norway maple (10%) then in 2015 a student done the same thing and he saw that the Norway maple take the advantage on the other trees with 30% of the cover.

My mission was to spot all the big native trees by GPS and then calculate if we have enough seed to replace the indigenous. And at the end of the research, collect seed from the native trees, sow them in a tree nursery and plant them in Toronto.

2. Laboratory presentation

Historic

The Faculty was founded in 1907 by Bernhard Fernow in Toronto and was Canada's first Forestry Faculty. The goal was to teach young student in forestry how to manage the forests without destroying them. This way of thinking began with the realization that our seemingly endless natural resources could in fact run out. It's first Dean, Bernhard Eduard Fernow, was North America's first practicing professional forester.

Graduates from the Faculty pioneered the integration of professional forestry into pulp and paper operations, set up Canada's first commercial reforestation program in Ontario, and pioneered wood preservation. Dr. Eric Jorgensen was the first to use the term "urban forestry" in its present meaning and the first to study it in depth, and in the 90s, the Faculty was the first to develop an interdisciplinary, professional Masters program in Forest Conservation

The actual president of the University of Toronto is Mr Meric Gertler. The address of the Faculty is:

33 Willcocks St

Toronto, ON M5S

Missions of the laboratory

The University has two main goals: produce engineer who know how to manage safely a forest and conduct research in pioneer domains.

The laboratory do a lot of research in many domains in relation with the wood, for example: the use of wood to made green chemistry, study the pest on the trees, the impact of the hive bee on the forest bee… The goal is to understand the ecological relations, use the forest and preserve it.

The Laboratory works thank to the subventions from the provincial government which give the more money, then contracts with invasive species center and from the Federal government. The way they function is when the government or a company faces to an ecological problem they ask the laboratory in return of money. The annual budget is about 200 000 Canadian dollars which allow to pay the material for the research, the charges links to the building and the staff.

Sandy's team is composed by 1 doctor, 9 PhD, 5 MFC and 10 summer students. There is no precise hierarchy all people work on his study but we can draw this organization chart.

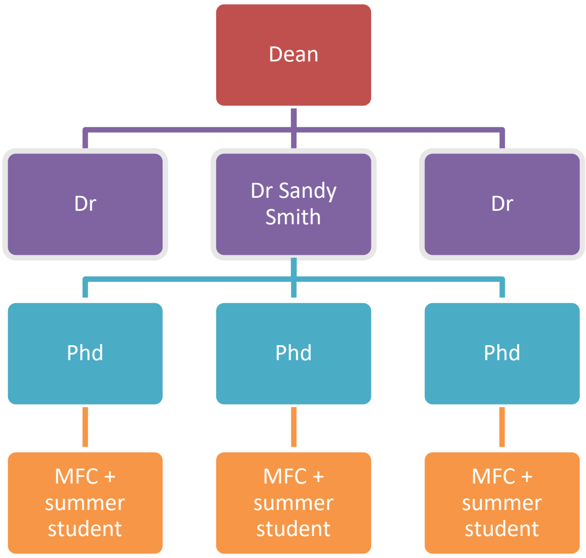

Figure 1- Laboratory's organisation chart

After a discussion with Mrs Sandy Smith, we can full fill the SWOT analysis table below. We learn that the laboratory answer a lot of problematic with 130 publications posted but there have to faces to a small budget.

Strenghs	weaknesses
- Laboratory is close to the problem because a lot of invasive species come from the cities. - Well filled address book. - Lot of experiences and knowledge. - Open the mind of the students thanks to the studies subjects - A lot of people with different backgrounds	- Can't spend too much time on a problematic because they need to answer a lot of question to earn money. - No connection between researchers and subjects.
Opportunities	**threats**
- Inhabitant living close to the ravine are interest in the invasive's plant study	- The government want to give less subvention to the laboratory

Table 1- SWOT analysis

3. State of the art

3.1. Increase tree cover in Toronto

In 2011, 81% of the Canadian population was living in a city with an urbanization rate of 1.1% per year (STATISTIC CANADA, 2011). This augmentation of the population in city cause an increase of the city area but when you first come Toronto you are very surprise to discover that the population density is low (4 149.5 inhabitants/km² compare to Paris 21 000 inhabitants/km²; WIKIPEDIA). Another think surprising is that there are a lot of trees, about 1 to 2 trees per house, people are proud of that. By this way the Toronto's tree cover is estimate at about 19.5% (CBC NEWS, 4 January 2017) but the goal is to reach 40 % in 2022 (City of Toronto, Parks, Forestry and Recreation, Urban Forestry, 2013).

3.2. Native and Invasive trees

The native trees are the species which were growing in North America prior to colonial times. For example the red maple, *Acer rubrum,* is native to eastern North America with an extreme range from Newfoundland to North Dakota and south to Texas. If someone plant a red maple in another region it will not grow well because it isn't adapt to the day length (HENRY KOCK, 2008)

The invasive plants are able to grow in many locations because they come from a similar climate in Europe or Asia so they grow well. In the colonial times horticulturists and foresters have planted some trees from where they come from and they become to grow. Some species have well growth in North America and replaced in some place the native trees. It can be explain by a simple reason because they are bring from Europe to Canada the trees don't have to face they pest so they grow well and in another hand the native trees have to resist they pest so they reproduce less and have more difficulty to produce seeds.

3.3. Toronto's ravines

The ravine was few century ago a big river which created a cavity, the slope is too high for people to built there. By this way and after few floods in some place in Canada due to over cutting wood, people have let this place wild so this place is cover by a lot of trees. Now the place is control by the government because of the ecological interest. The ravines are some forest in the city which are a place where a lot of runner who come every day practicing sport and walk with their dogs. There are about 300 km of trails but the rest stay wild. This is a good place for the research because there aren't people who cut wood or plants so we can study the impact of invasive trees. This is a wild place near to the University and makes the research easier.

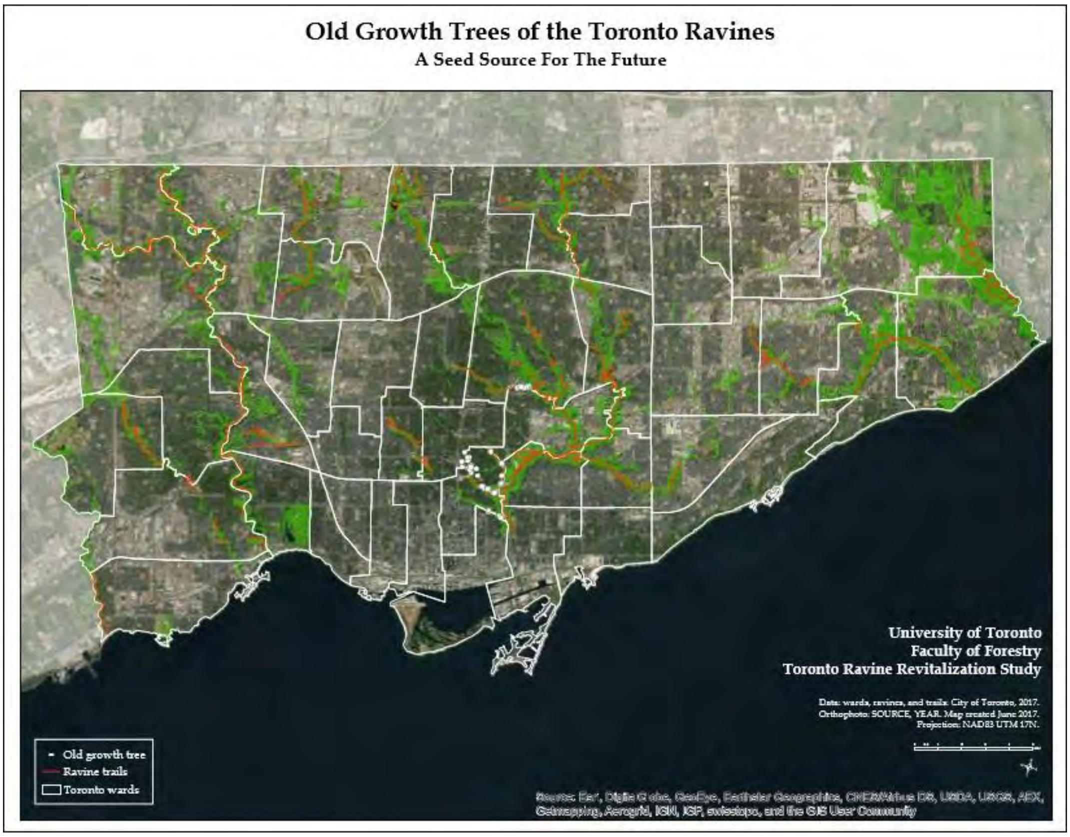

Figure 2-Ravines Map

3.4. Research mission

In 1977, two researchers went in the ravines, look at the trees and spots on a map where the Norway maple which is an invasive tree was, this was the beginning of the research. Then in 2015, a student went to the same place and looks the expansion of this species. He discovers that in 40 year to tree cover increase by 30% in the area.

The Problematic of this mission is:

How can we reach the 40% tree cover in 2022 and faces the invasive species?

My supervisor's idea is to use the ravines as the seed bank because there are big native trees in a public area.

The action mode is to go in the ravines spot all big native trees by GPS, write the diameter and the species on the map. By this way we will have an inventory of the bigger native trees then we will be able to calculate the approximate amount of seed that we would sow and estimate how many trees we will produce. The goal is to find enough trees and seed to reach the goal of 40% tree cover in the area of Toronto and plant native tree instead of invasive tree like they do actually.

In spotting the big trees we are almost sure that this is a native and that he was here before colonial period. Indeed when an oak measure 50 cm of diameter under bark we can say that he is 100 years old. So in spotting only over 60 cm diameter trees, most of them have about 150 years before the European come. (NATUROSCOUT, official website)

4. Material and methods

4.1. Matérial

During my work I have used:

- A GPS system Garmin MONTANA 600 to spot the trees
- DBH tape to measure the diameter
- A map
- A computer to report all the results
- Microsoft excel
- Admin access to https://www.opentreemap.org/torontoravines/map/

Figure 3- Garmin Montana 600 use on the field

4.2. Methods

Theory

The first step of my mission was to meet Mrs Marry who is a cartographer. She made the different maps you can find in the report. On these map we can see all official trails and subway stations. Each day I draw on the map how to go there and which trail I would walk next day. After each day I have write on the board which work is done, download the data on excel convert the file in a file which can be download on opentreemap.

Practice

To realize my work I had to walk around the forest trail with my two colleagues and look at about 20-30 meter around us if we see a big native tree. Then we have to examine it to be sure that it is healthy because some trees look very big and healthy but in the other side of the tree you can found dead bark or bark disease like on the American beech.

Figure 4- American beech bark disease (white fungus)

Then we measure the tree and report this information in the GPS. In this, we enter the name of the species, the diameter and the name of the ravine.

We have walked the 70 km of trail and then I have entered all the references in my laptop to export them in opentreemap.

5. Old growth tree seed collection

5.1. Big trees spotting

During my walk I have spot the trees with the GPS, the point was edit as: Date-species-DBH

So after downloaded it on my laptop I obtain this file:

ID	lat	lon	ele	time	name
1	43.69051999412477	-79.370066039264202	96.949150000000003	2017-06-26T16:57:56Z	June26beech66.4
2	43.678970988839865	-79.370058998465538	84.843711999999996	2017-06-26T14:34:56Z	June26blackmaple69
3	43.683612970635295	-79.384518032893538	97.583931000000007	2017-06-26T15:28:57Z	June26blackwalnut68.5
4	43.680182006210089	-79.376351963728666	66.111205999999996	2016-08-22T14:33:26Z	June26buroak62
5	43.684946028515697	-79.385203002020717	101.74520099999999	2017-06-26T15:33:10Z	June26hemlock45
6	43.679869025945663	-79.374892003834248	86.447104999999993	2017-06-26T14:51:52Z	June26norwaymaple95
7	43.678948022425175	-79.369927989318967	85.114806999999999	2017-06-26T14:30:15Z	June26redoak64.5
8	43.68912398815155	-79.368735998868942	105.867783	2017-06-26T17:08:56Z	June26redoak73
9	43.685935009270906	-79.38512203283608	106.900871	2017-06-26T15:39:07Z	June26redoak85
10	43.689162964001298	-79.368829037994146	107.573616	2017-06-26T17:06:57Z	June26redoak87
11	43.689418025314808	-79.368704985827208	100.85786400000001	2017-06-26T17:04:38Z	June26redoak91
12	43.689214009791613	-79.368685036897659	101.466843	2017-06-26T17:09:45Z	June26silvermaple79
13	43.68678099475801	-79.385313978418708	108.721542	2017-06-26T15:43:08Z	June26silvermaple82
14	43.687058016657829	-79.385501984506845	110.771141	2017-06-26T15:45:46Z	June26silvermaple82,1
15	43.687121970579028	-79.385797027498484	113.305466	2017-06-26T15:47:19Z	June26silvermaple99
16	43.679429981857538	-79.373739995062351	80.931061	2017-06-26T14:44:16Z	June26sugarmaple66
17	43.680175971239805	-79.376310976222157	88.854293999999996	2017-06-26T15:00:58Z	June26SUGARMAPLE74
18	43.692255970090628	-79.373248983174562	104.916229	2017-06-26T16:48:25Z	June26sugarmaple77
19	43.679454959928989	-79.368929034098983	79.742462000000003	2017-06-26T14:24:05Z	June26sugarmapple76.5
20	43.679703986272216	-79.374821009114385	83.592094000000003	2017-06-26T14:49:52Z	June26whitepine55.6

Figure 5-excel file after exportation

Then I have to change the form in template downloaded on opentreemap.org as following. I have to inverse the coordinate (longitude become point x) and enter the name in Latin.

	A	B	C	K	L	M	Q
1	Point X	Point Y	Street Address	Tree Present	Genus	Species	Diameter
2	-79.370066039264202	43.69051999412477	Park Drive Reservation Lands	TRUE	Fagus	Grandifolia	66,4
3	-79.370058998465538	43.678970988839865	Park Drive Reservation Lands	TRUE	Acer	Nigrum	69
4	-79.384518032893538	43.683612970635295	Park Drive Reservation Lands	TRUE	Juglans	Nigra L	68,5
5	-79.376351963728666	43.680182006210089	Park Drive Reservation Lands	TRUE	Quercus	Macrocarpa	62
6	-79.385203002020717	43.684946028515697	Park Drive Reservation Lands	TRUE	Tsuga	Canadensis	45
7	-79.369927989318967	43.678948022425175	Park Drive Reservation Lands	TRUE	Quercus	Rubra L	64,5
8	-79.368735998868942	43.68912398815155	Park Drive Reservation Lands	TRUE	Quercus	Rubra L	73
9	-79.38512203283608	43.685935009270906	Park Drive Reservation Lands	TRUE	Quercus	Rubra L	85
10	-79.368829037994146	43.689162964001298	Park Drive Reservation Lands	TRUE	Quercus	Rubra L	87
11	-79.368704985827208	43.689418025314808	Park Drive Reservation Lands	TRUE	Quercus	Rubra L	91
12	-79.368685036897659	43.689214009791613	Park Drive Reservation Lands	TRUE	Acer	Saccharinum	79
13	-79.385313978418708	43.68678099475801	Park Drive Reservation Lands	TRUE	Acer	Saccharinum	82
14	-79.385501984506845	43.687058016657829	Park Drive Reservation Lands	TRUE	Acer	Saccharinum	82,1
15	-79.385797027498484	43.687121970579028	Park Drive Reservation Lands	TRUE	Acer	Saccharinum	99
16	-79.373739995062351	43.679429981857538	Park Drive Reservation Lands	TRUE	Acer	Saccharum	66
17	-79.376310976222157	43.680175971239805	Park Drive Reservation Lands	TRUE	Acer	Saccharum	74
18	-79.373248983174562	43.692255970090628	Park Drive Reservation Lands	TRUE	Acer	Saccharum	77
19	-79.368929034098983	43.679454959928989	Park Drive Reservation Lands	TRUE	Acer	Saccharum	76,5
20	-79.374821009114385	43.679703986272216	Park Drive Reservation Lands	TRUE	Pinus	Strobus L	55,6

Figure 6-file with opentreemap.org template

We can see the GPS position, the name of the ravine or river, then the Latin name and the DBH. The file is added as manager user on the website to obtain this map, with the tree as green points.

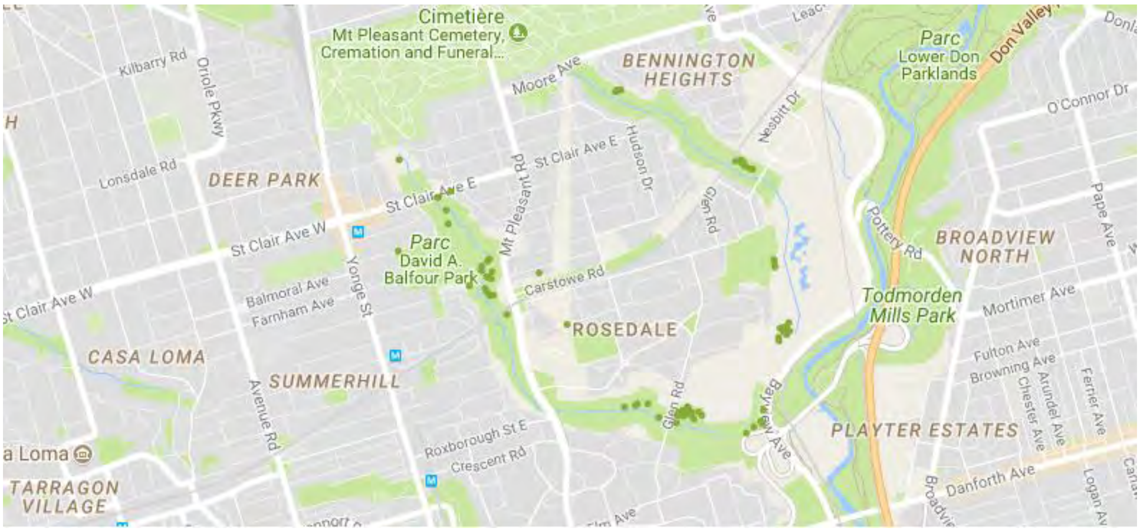

Figure 7-Map obtain on the web site

The website allow clicking and seeing only one species, this think is very useful because the seed harvesting season are not the same for all species.

The tree summary is below:

Genus-Species	number of trees	DBH Mini	DBH Max	Average DBH
Acer	**72**	**45**	**133**	**80,82**
Nigrum	1	69	69	69,00
platanoide	1	95	95	95,00
Saccharinum	19	68	111	84,84
Saccharum	51	45	133	79,27
Betula	**5**	**28**	**67**	**48,40**
alleghaniensis	3	37	55	49,00
Papyrifera	2	28	67	47,50
Carya	**7**	**34**	**58**	**42,43**
Cordiformis	6	34	58	42,00
ovata	1	45	45	45,00
Fagus	**21**	**40**	**81**	**57,67**
Grandifolia	21	40	81	57,67
Juglans	**21**	**24**	**82**	**54,52**
Cinerea	11	24	70	44,45
Nigra	10	45	82	65,60
Juniperus	**15**	**36**	**63**	**44,53**
Verginiana	15	36	63	44,53
Larix	**1**	**32**	**32**	**32,00**
Laricina	1	32	32	32,00
Morus	**1**	**63**	**63**	**63,00**
Rubra	1	63	63	63,00
Ostrya	**4**	**23**	**40**	**29,00**
Virgianiana	4	23	40	29,00
Pinus	**26**	**44**	**96**	**70,23**
Strobus	26	44	96	70,23
Populus	**10**	**45**	**106**	**80,70**
deltoides	10	45	106	80,70
Prunus	**19**	**31**	**68**	**50,53**
Serotina	19	31	68	50,53
Quercus	**190**	**37**	**136**	**81,67**
Alba	28	45	102	75,07
Macrocarpa	10	37	91	68,30
Rubra	132	56	136	83,64
Velutina	20	64	113	84,60
Salix	**7**	**86**	**144**	**107,71**
Salix	7	86	144	107,71
Tilia	**3**	**39**	**78**	**57,00**
Americana	3	39	78	57,00
Tsuga	**34**	**31**	**89**	**52,26**
Canadensis	34	31	89	52,26
Ulmus	**1**	**57**	**57**	**57,00**
Americana	1	57	57	57,00
Total général	**437**	**23**	**144**	**72,00**

We have spot 26 species and 16 genus, it is a good summary because of the presence of a lot of species. We have spot the bigger trees of each species. We can see that the major species are the oak *(Quercus)* and maple *(Acer).*

5.2. Seed Forecasting

The seed forecasting is a practice which consist in observing the branch of the trees and determinate the potential of seeds production. There is a scale for the seeds production you have to know before going to the field (ONTARIO TREE SEED PLANT, 2014).

Unit of Measure	Number of Liter
1lb coffee tin	1 liter
A hard hat	2 liter
5 gallon pail	20 liter
1 bushel basket	36 liter
1 full burlap bag	100 liter

Table 2- seed forecasting volume unit

After having spot 437 big trees we have decided to do the seed forecasting, the first step was to check when the seed forecasting period of each tree is. I discover that most of the tree we have spotted can be survey by beginning of august (ONTARIO TREE SEED PLANT, 2014): all species of Oak, Ironwood, Maples, Walnut, Ash, and Hickory. But the seed collecting season will be different for example October for all the Oaks.

So we came back to all trees previously spot on the GPS and look on the branch to look for the seed and write down in which category the seed production is. The scale below:

Main Species	failure	Light	Medium	Heavy	Bumper
White Pine	< 20 L	20-30 L	30-50 L	50-70 L	70 L+
Oaks	< 10 L	10-30 L	30-50L	50-80 L	80 L+
Maples	< 10 L	10-30 L	30-50 L	50-80 L	80 L+

Table 3- Estimating Crop size (Liter per Tree)

The results are not actually collected for all species but we already have done it for the Oaks and send 5 000 acorn to a nursery to be sow.

During the seed forecasting I was surprise to see that the big reproducers are not always the biggest Oak in the ravines so I had create an Excel file to be sure of this point. The x-axis is the diameter in cm and Y-axis is the seed forecasting.

The encoding of the seed forecasting in digital is below:

seedforecasting	code
Failure	O
Low	1
Medium	2
High	3

Table 4-encoding seed forecasting

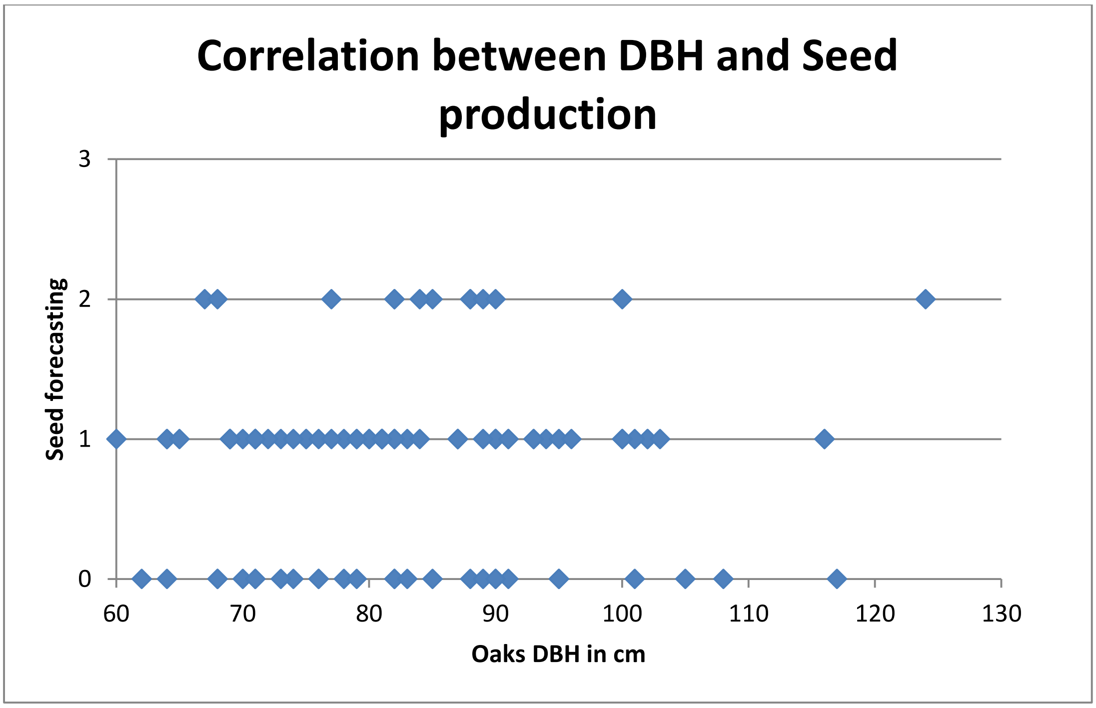

Figure 8- Correlation between DBH and Seed production

With this figure we can quickly notice that there is no eventual correlation between the DBH and the seed producing so that confirms what I was seeing on the field. This is stange because normally it has to follow a gauss curve. In fact, when the tree is too small he doesn't produce seeds and when he is too old he stop producing acorns.

This figure can be explain by the fact that in some places there is just one or somes Oaks maybe there isn't enough pollen in the atmosphere and there is no fecundation so no acorns production.

5.3. Goal of 40% canopy cover

We know that the Toronto city want to increase the tree cover by two and there is actually 10 million trees. That means that the city needs 10 millions more trees from 2013 to 2022: 9 years. The city will needs 1.11 million trees a year without taking care of the 40% invasive trees. If we want to reach the goal of 40% of cover in 2022 and replace all the invasive one we will need 1.5 million trees per year.

Example based on Oak plantation:

We know that the average rate of germination for the oak is from 80% to about 58% (Semis et plantations dans la forêt de chêne-liège de la Maâmora, 2011)

To have 1.5 trees a year we will maybe need between 1.9 and 2.59 million seeds per year. This number is just based on Oak so we had to search for each species the germination rate and the number of seeds collected. On it we need to subtract the number of trees which dead or cut by the inhabitant and the young tree which dead after planting. In another hand we have to take care of the natural regeneration.

After this discussion, we can say that the city will need about 3 million seeds a year to produce about 1.5 millions which is quiet impossible by the quantity of seeds needed and the place needed in the nursery.

6. Ameliorations

6.1. Local seeds

We can think that the easy way to have native seed is to go in the bottom of the country where no invasive were planted and take the seeds on the ground. This will be easier to collect the seed but we will not have the same enthusiasm from the Ravines inhabitants. Actually, Eric's team earns enough money to works thanks to the donation indeed the inhabitants are very proud of the place they live. Collect the seed in Toronto is more expensive than the other solution but people in Toronto are very proud to know that the tree they plant come from their city so the price is not a problem.

6.2. Seed forecasting

We can have save time in doing the seed forecasting at the same time that spotting the trees. It would have allowed us to save about 70 km of walking. The spotting will have taken more time because we need to spot the tree and do the seed forecasting but the longer was to walk from one tree to another one. However we would have to wait 3 week to begin the trees spotting because it wasn't the season to do the seed forecasting in July.

6.3. Native's species?

Another point can be purpose to discussion, in fact we supposed that all trees bigger than 60 cm of DBH are older than 100 year but how can we be sure? In this case we should have drill some trees to count the number of ring and determine the medium age of the trees.

Then we are not sure that we collect seeds from the tree spotted because we take them on the ground, how can we be sure that they come from the tree up our head? In a second time how can we know the genetic quality because we don't know with which tree these one have reproduce himself? So we have to ask ourselves: do we want native seed or native seed with a good genotype? If we want a perfect tree we would have to work on the tree reproduction. For example we could protect the flower and practice a manual reproduction as it's done for some species of tree.

6.4. Information given

I think that a big step of work can be made on link with marketing and data processing work. During my work I have discover that some big trees are identify with official tag but we have no information on it. A lot of people work on the trees, trails and ravines but there is no discussion between the different institutions. I think it would be interesting for all of us to link the wards, the city and the laboratory to work together. Another interesting point is that the city write on is policy that she want to fight the invasive species but in fact when you walk in the ravines you can see a lot of cut trees but not a lot of invasive one's. There is a big work to do on it in fact if they let some of them they will produce a lot a seed and colonize all those places.

Another point which can be improved is the tourism in the ravines, you can meet a lot of people in this wild place. People go there to walk with their pet but they just go in the ravine they know near to their house. There are some maps in some place but not a lot. It would be interesting to create a website of "the Toronto's city trail" where you can plan a big trip for sport. This website can be link to different websites for tourism in Toronto and do advertising of this place.

7. Personnal review

This internship is a great experience because before this moment I didn't know the urban forestry. This is a good job which seems like landscape architects because we have to think the forest to be welcoming for the biodiversity for the pleasure of the people walking here. In the case of Toronto ravine the goal was to control different invasive species of trees.

For the future I want to stay in my first position and work in wood production in big forest in France like in the east in the Meuse, Alsace and Moselle country. I would prefer to work in the management of wood production than study the impact of the human activity on this resource because I want to work on the plant's production. In wood production there are more pressure and challenge, it is close to my character. But I know that I have to keep in mind that the exploitation of the wood has to be thinking with the background of biodiversity chain. If we cut wood in bad condition, the soil and the biodiversity is broke so this is bad for the environment and by this way for the future trees too.

Out of my job I can say that this internship was an amazing experience. I was alone in a foreign country during 4 month and have to speak English all the time. Speaking English was very enjoyable for me. I love to discover a country, his way of life and try to have a better level of English. I have met a lot of very friendly people, Toronto is a very active city where shops, bar and museum are open almost all the time. I have discovered some amazing landscape, people live in the middle of nowhere with big house, car and road. But the Canadians live in a perfect respect with the environment for example there is no paper on the side walk.

After coming back to France I have discover that there is a huge difference of size between the thinks in Europe and America. By this way I think that in Europe we act to decrease the pollution but when you see the way of life in America you discover that we act at a small level. In fact America uses a lot of fossil resources so we can't imagine the pollution in Asia. In France We are look for the small pollution but I think we have to think at a global scale and not just in France.

8. Professional review

This internship allowed me to discover the domain of academic research. The goal was to recreate a wild place in the middle of the city. I have discovered Dialog Company which has the strong that the headmaster was a teacher in the faculty. He has a real impact on the society because his company designs the building of the future.

I have discovered how to use a walking GPS and how to manage the data to create a map on an open data. During this internship I have developed an interests on the seed preparation in the goal of sow them so maybe I could look for a job in this branch of the agronomy at the end of my studies.

During this internship I was in a total autonomy in the field I just saw my boss every night and morning. He gave me the goal of the week and then I have to organize my work for the week. I have to plan where to walk, how to go there (subway or bike) and then contact my colleagues.

This experience makes me proud because I am a part of the creation of a big project. In fact, this is the biggest project actually in the environment in Toronto. All the seeds use to plant trees in the park will come from the trees I have spotted with the help of my colleagues.

During this internship, I have learned how to do an inventory of fauna and flora in a forest and know now all the common name of plant in a forest.

- During these 3 month I have improved English level and I am now fluent.
- This experience allows me to discover that the Canada is a country where the environment is a big discussion and act a lot in this way.

9. Conclusion

The city can't reach his goal of 40% canopy cover because the city will need too much trees and by walking in the ravines I didn't found empty place where we can add as much tree.

The goal of protecting the forest is a great job, I think Toronto is a very great city in the hand of ecology. My opinion is that this mission has to continue but forget about the city goal. This mission will have to be done for some place in the ravine. Indeed some places have a lot of invasive species so for me the right goal is to collect seed and produce trees to replace all the invasive.

The big interesting point is that most of the people in Toronto are very interest by the ecology and their environment. Indeed people in Toronto live in a big city but with a lot of green place to walk and have great time.

To end this thesis I don't think the city can reach the goal of 40% of canopy and replace all the invasive species. I think the city have to focus on the protection of the native species and help the inhabitant to plant trees in their front garden. Toronto is a green city so for me the best choose will be to keep this canopy cover and work on the health of the ravines and replace all the dead tree and in the future the old one because a lot of trees in the garden will dead soon because of their ages.

In the point of learning I can say that I have learn a lot of things for my studies and in the hand on my English I can say that I am now fluent, speak and understand English is not anymore a problem for me.

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Glossary

DBH= Diameter at Breast height, diameter taken at 1.3m

GPS= Global Position Satellite

Abstract

During this internship carried out in Toronto, in the Toronto ravines revitalization team, a work on the native species has been done. The first goal was to spot all the big natives trees in the city, for this year 437 trees of 26 species have been referenced. Then a big work has been done in the seed forecasting to know the potential number of seeds that we could collect. In a same time we have determine the health of different big seeder, collect the seed and send them to a nursery.

Thanks to these experiments, we could grow in the future trees with native genotype to replace the invasive species in some part of the Toronto's Ravines.

Résumé

Cette mission a été conduite dans la ville de Toronto, au sein de l'équipe de recherche « Toronto ravines revitalization ». L'objectif principal été de fournir à «un cabinet d'architecte des jeunes arbres qu'il puisse planter dans un projet de parc dans le quartier financier. Pour cela, tous les arbres d'intérêt de situant à moins de 30 m autour des sentiers de balades ont été inventorié dans les ravines (anciennes rivières maintenant sèches mais avec pente trop importante pour la construction). L'aspect général de l'arbre, son état sanitaire, ses dimensions et déterminer son potentiel semencier ont été analysés. Les relevés ainsi que la localisation GPS ont été consigné dans un fichier Excel.

Ainsi 437 arbres ont été sélectionnés et cartographiés. Ce qui représente 16 familles d'arbres avec 26 espèces différentes. Seuls les plus gros arbres ont été repérés. Ces variétés augmenteront la biodiversité du nouveau parc.

Les principaux arbres rencontrés sont l'érable *Acer* avec 72 arbres sur 437 et le chêne *Quercus* : 190/437.

Key words:

Big trees

GPS

Native genotype

Ravines

Seed collection

UNIVERSITY OF TORONTO – FACULTY OF FORESTRY

Ecological Integrity of Mammals and Birds in Toronto's Ravines

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Master of Forest Conservation Capstone

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Abstract

With the increasing trend of urbanization throughout the world, the conservation of natural environments and their floral and faunal inhabitants becomes increasingly more important as well as challenging. Ecosystem services are provided by biodiversity and these services provide benefits that are highly desirable by humans. To secure the existence of healthy ecosystems and to facilitate restoration efforts, a monitoring system is necessary to determine the conservational or restoration needs of a given ecosystem. Monitoring systems such as the concept of „ecological integrity" has been successfully used by the US National Park Service and Parks Canada to assess and communicate the health of ecosystem to managers and the public. With global loss of bird and mammal species in cities, I found it important to determine the ecological integrity of these populations within the urban context in the City of Toronto"s mature forests. I found that compared to historic populations, there has been a decline in a number of small mammal species since the late 1800"s, but little species change since 1977. My study on birds had found that Toronto is missing many „area-sensitive" forest bird species and is also missing bird species that are typically found just north of Toronto in York region. I recommend that the City of Toronto must preserve its natural features and designate areas for naturalization to promote biodiversity in the city. Furthermore, increasing connectivity between naturalized areas and making citizens aware of potential human impacts on wildlife are other important factors that must be considered in urban planning.

Introduction

The current global trend of rapid urbanization is drawing more people to city living than ever before, and this trend is predicted to increase by 2050 (United Nations, 2014). Currently in North America, 82% of the population is in located in urban centers (United Nations, 2014). With this increase, the consequences of urban development on natural ecosystems, and animal and plant populations must be evaluated in order for effective conservation of nature to be possible in urban areas (Kowarik, 2014). In urban environments, forested ecosystems and their features have been linked to a large range of positive health benefits in humans, from lowering blood pressure to improved mental health (Lee et al., 2011). Economically, the ecosystem services that nature provides to humans in urban areas can be quantified in the hundreds of millions to billions of dollars (TD Economics, 2014). The urban forest is a recognized public good and protecting it is recognized as directly beneficial to citizens. However, urban forests around the globe are under threat due to loss of biodiversity, and although this loss in urban landscapes is well documented, the causal factors contributing to decline of biodiversity are not well researched (Marzluff et al., 2005; Kowarik 2011; Villarreal et al., 2013; Shochat et al., 2010). Marzluff et al. note that urbanization is increasing throughout the world and thus to conserve them it must be determined if flora can survive and thrive in urban conditions and what human-based impacts can be mitigated or eliminated to increase biodiversity (2005). Furthermore, conservation of biodiversity in urban areas will require "cooperation among a diverse group of planners, ecologists, policy makers, home owners, educators, and activists." (Marzluff et al., 2005)

It is known that having a diverse range of animals and plants is a critical to maintaining ecological health and perpetuity of these ecosystems (Pasaria et al., 2013). Species richness is highly important for ecosystems, and higher species richness has been found to have a positive causal relationship with ecosystem services (Balvanera et al., 2006). As shown in a recent study by Oliver et al. (2015), one of the primary concerns of the loss of biodiversity within ecosystems is the subsequent loss of ecosystem resilience. With a continued loss of species, "functional redundancy" of ecosystem services is reduced, and can lead to cascading losses of ecosystem function (Oliver et al., 2015). For example, if one plant pollinator species is extirpated, plants might still achieve pollination via other pollinator species; however, if enough pollinators are removed from a system, systematic ecological decline is expected.

Urban environments are continually being developed, and thus for city planners to effectively account for biodiversity and ecosystem health during urban planning, ecological research of these environments is necessary (Villarreal et al., 2013). One metric used to quantify the health of an ecosystem is ecological integrity (EI), which is the standard by which Parks Canada assesses the health of its parks (Parks Canada, 2007). Within the EI framework, quantitative data on animal and plant populations are used as indicators relative to an expected baseline and translated into easily understood descriptors of ecosystem health (for example, „Good", „Fair" and „Significant Concern"). This framework is useful for communicating the results of scientific research to the public and lawmakers, as it is intuitive and can be utilized easily and efficiently by planners and managers (Tierney et al., 2009; Mitchell et al., 2014).

With urban spread, the decline of native small mammal species and native forest bird species is well documented. For example, small mammal species richness declines as urbanization increases (Reim et al., 2013); similarly bird species richness and abundance are also lower in metropolitan areas as compared to natural areas (Banville et al., 2017). Small mammals and birds provide key functions necessary for a healthy ecosystem, from plant seed dispersal, spore dispersal of mycorrhizal fungi, control of herbivorous insect populations, to pollination of flowers (Sieg 1987, Şekercioğlu et al., 2004). These ecosystem functions make the two groups important to study. Aside from ecological function, they also give residents enjoyment and the true experience of being with wildlife, which can be an uncommon opportunity in dense urban centers.

Unfortunately, there has been little research on small mammal species composition within the urban context in North America (Reim et al., 2013; Buchanan et al., 2013). However, such studies can be particular useful in indicating the health of urban ecosystems. For example, in a small mammal study conducted in central Pennsylvania, Mahan et al. (2005) found evidence of a gradient of small mammal community change in response to urbanization, with the most intact communities being found in mature riparian forests, while simplified communities with generalist species were found in highly disturbed areas. A study on the effects of urbanization on small mammals in Poland concluded that mammal species richness declines across the urban gradient, but also saw that urban biodiversity was maximized when habitat connectivity was established between suitable habitat patches in the city core and the natural environment surrounding the city (Lopucki et al., 2013). Similar patterns for decline of mammal species richness along an urban gradient can be seen throughout the world in urban environments (Kowarik et al., 2011; van der Ree and McCarthy, 2005). Van der Ree and McCarthy had found that in Melbourne, Australia, many native mammal species have undergone significant declines in abundance and range, with a loss of over 50% (from 54 to 26) of historically native mammal species within the city limits (2005).

Nilon et al. (1995) found that interior forest bird species of Missouri historic wildlands had declined as urbanization in wildlands increased, and concluded that the increase of forest edge due to development is a significant factor in forest bird species decline. In a study in Phoenix, Arizona, the researchers found that with increased urbanization, bird species commonly found in riparian zones become replaced by urban resident species, indicating a decline in specialists (Banville et al., 2017). An indirect impact that humans have on urban birds is the predation pressure by pet cats: A study in the UK found that with increased cat densities, bird fecundity declines which can translate to a large loss in bird abundance (Beckerman et al., 2007). A bird study in York region to the north of Toronto, Ontario, found significant species differences in bird communities between fragments of large and small sizes in a peri-urban environment (McMartin, unpubl. PhD, University of Toronto, 2007). Environment Canada‟s Canadian Wildlife Survey has determined that out of 43 potential area-sensitive forest breeding bird species within the Greater Toronto Area, only 14 species have been regularly observed, with the remaining 29 being lost or having never expanded into Toronto‟s urban forest (Environment Canada:CWSO, 2007).

In urban areas, habitat loss is restricting animal populations to the remaining naturalized areas and consequently makes parklands and riparian corridors key centres of biodiversity in the urban landscape (Ferguson et al., 2001; Oliver et al., 2015). In Toronto, the ravine systems represent 17% of the City‟s total area, and may be some of the last naturalized habitats available for wildlife (City of Toronto, 2016). Recently efforts by the City of Toronto have been focusing on ravine restoration with the City‟s newly launched Toronto Ravine Strategy, which recognizes the need for efforts in conservation and ecological research.

The purpose of the present study is to assess the ecological integrity of the Rosedale Valley ravines of south-central Toronto, with a focus on small mammal and bird communities. The ravines are of particular interest in this context. For one, they are home to mature forests, and hence potentially provide an area of concentrated biodiversity in the city. Perhaps most significantly, however, they were the subject of a detailed biodiversity inventory in 1977 (Kaiser et al., 1977), and the intervening 40 years provides an opportunity to examine the ravine communities for possible change. Taken together, information on the ecological integrity of small mammal and bird communities will help guide future policy development and land use planning in the City of Toronto. With the recently established Toronto Ravine Strategy, the City has committed to preserving the "ecological diversity, resilience, stability and natural environment" of the ravines, so with my study we will assist in these goals by focusing on a significant part of ravine ecology: small mammal and bird communities. Furthermore, I present information on the downed coarse woody debris of the ravines, which is an important habitat for many forest species, and plays a key role in forest nutrient cycling. I also examined temporal changes in small mammal communities using the Royal Ontario Museum database of mammal records, which provided records from 1866 to 2015. Finally, using potential bird presence lists, the bird species observed in 1977 and 2017 were also compared to the historic native area-sensitive forest breeding bird community of the region (Environment Canada: CWSO, 2007).

Methods

Four ravine sites within the Rosedale, Toronto area were chosen to perform the study, which was conducted from May 2017 to the end of August 2017. The four ravines were Rosedale Valley Ravine (1), Park Drive Ravine (2), Moore Park (3) and Burke Brook Ravine (4) (see **Figure 1**). These were the same sites used in the 1977 Rosedale Ravines Study (Kaiser et al., 1977), providing for a direct comparison. These ravines are located in the mixed-wood plains ecoregion of Ontario, where waterways and lakes are abundant and has cool winters (avg. -5 C) and warm summers (avg. 17 C) (McGill, Retrieved 2017). As Kaiser et al. noted, the Toronto ravines were formed by the running water from melting glaciers that of the last ice age, but in modern times only small streams remain, yet are important spillways for the city when heavy rainfall occurs. The ravines were cleared in the beginning of the 19th century, so the forest is largely comprised of regrowth that occurred after the mid to late 1800s (Kaiser et al., 1977).

Small Mammals

Across the four ravine sites, I established 7 small mammal trapping grids (**Figure 2**). In Burke Brook Ravine, only one grid was used, but in Park Drive Ravine and Rosedale Valley Ravine, three and two grids were placed within one ravine, respectively. The grids sampled different slopes within a ravine, and hence are treated as replicates here. Each 50 m x 90 m ravine site was gridded into 10 x 10 m squares. Eighteen Sherman traps (23 cm x 9 cm x 8 cm) were baited with sunflower seeds, apple and an oatmeal and peanut butter mixture and were placed 20 m apart along the grid and set for 3 consecutive trap-nights per grid, during the period July 6th to August 3rd, 2017. The Moore Park ravine site did not use grids, but traps were placed haphazardly 20 m apart. Traps were set in the morning of the first day, checked in the afternoon of the first day, checked twice a day during the second and third days, and removed on the morning of the fourth day. During early trials of the study, I found that raccoons had been depredating the traps. To prevent raccoon tampering, a 1 m long, 15 cm diameter corrugated and perforated plastic drainage pipe was cut in half longitudinally, placed over each Sherman trap, then staked down using metal spikes (Machtinger, personal communication, 2017). This cover prevented raccoons from accessing the traps, while allowing smaller mammals to enter them. Upon capture, each mammal was identified, weighed, sexed, and ear-marked with a uniquely numbered ear tag.

A second data set used to assess the ecological integrity of Toronto small mammal communities was the historic database of the Royal Ontario Museum mammal collection (years 1866 to 2015). I accessed the database online through the Global Biodiversity Information Facility and downloaded records for the GTA region and restricted my search to native species of Insectivores and Rodents (GBIF Occurrence Download doi:10.15468/dl.ugqekg accessed via GBIF.org on 13 Sep 2017). I divided the data into 5 temporal periods (1866-1930, 1931-1935, 1936-1944, 1945-1967 and 1968-2015) that had approximately the same number of individuals in each, and hence could be used to assess community change over time.

Birds

For each of the four ravine sites, a Songmeter SM2 (Wildlife Acoustics, Inc., Massachusetts, USA) was fixed approximately 3 meters up a tree in the center of a ravine study plot, in the same grids that were used for CWD and small mammal trapping. In Park Drive, and Rosedale Valley ravines, two Songmeters were set up on opposite sides of the ravine (**Figure 2**). The Songmeters were programmed to record for 30 minutes for 45 days, starting at 10 minutes before sunrise each day. The time of recording was the May 28th 2017 to July 8th 2017. Birds were identified from their songs by an expert, Kevan Cowcill. Only bird songs captured at sunrise were analyzed, and only 6 days were chosen for analysis as a representation of the entire recording period, due to time constraints. The record dates of analyzed recordings were: May 28th, June 5th, June 11th, June 19th, June 25th and July 3rd, 2017. One recorder, placed in Rosedale Valley Ravine site #4, was missing its June 25th and July 3rd recordings due to technical difficulties. To analyze these data, for each ravine I took the maximum number of birds of a given species singing on any given day during the sample as the abundance measure for that species.

Downed Coarse Woody Debris & Live Tree Volume

The downed woody debris for each site was measured using measuring tape and calipers via the line intercept method (Van Wagner, 1968). Starting at the top of the ravine bank, line intercept transects followed the entire width of the plot, down one grid square, then back across the ravine width, etc., until the entire plot was sampled (**Figure 9**). In Park Drive Ravine, 350 m of line was sampled in plot 3, 480 m in plot53, and 590 m in plot 4. In Rosedale Valley, 410 m of line was sampled in Plot 4. In Burke Brook Ravine, 520 m of line was sampled. No line sampling was done in Moore Park ravine as there was no established grid. Each piece of downed woody debris that intercepted the line had its diameter measured and was assigned a decay class (I through V), based on the degree of bark decay as well as the percentage of tree diameter that could be penetrated with a 0.5 cm metal rod (Goodburn et al., 1998; Maser et al., 1976; Van Wagner, 1968).

The downed woody debris data were used as potential correlates of small mammal communities; however, I was also interested in it as an indicator of ecological integrity in its own right. Tierney et al. (2009) argued that the volume of downed woody debris relative to tree volume could serve as an indicator of integrity, with the proportion of downed woody debris (DWD) to live tree volume (LTV) indicating „Good" ecological integrity if above 0.15. Accordingly, I also estimated tree volumes in the sites. At one site, tree heights and diameters at breast height (DBH) of the various trees were recorded. Using these data, allometric equations relating tree height to diameter was estimated (Peper et al., 2009) and the equations were then used to estimate heights of all trees sampled in the ravines from the field-measured diameters (Dong et al. 2015, unpubl.). In a final step, total volumes of trees (≥ 10 cm DBH) at each site were determined using the equation of a cone. Separate height-DBH equations were fitted for the three most common species: maple (*Acer saccharum*), beech (*Fagus grandifolia*) and red oak (*Quercus rubra*). For all other species, an equation fitted to height observations for all observed species was used.

Statistical methods

All statistical analyses were performed in SAS (v. 9.4). All PCA biplots were created in Canoco (v. 4).

Results

Small Mammals

Across all sampled grids, three mammal species were captured*:* *Peromyscus leucopus* (white-footed mouse), *Tamias striatus* (eastern chipmunk) and *Blarnia brevicauda* (short-tailed shrew). Similarly, in the 1977 Rosedale Ravines Study, three species of mammals were found: *Peromyscus leucopus*, *Tamias striatus* and *Microtus pennsylvanicus*. **Table 1** highlights the differences in capture rates between 1977 and 2017.

In the 1977 and 2017 small mammal studies, *P. leucopus* and *T. striatus* were the most abundant species found in the ravines. *T. striatus* was about equally abundant in the two studies, whereas in 2017 *P. leucopus* was more than twice as abundant in 2017 as in 1977. Looking at individual ravines, Moore Park had the lowest percent success of mammals in 1977, but had the highest in 2017. Rosedale Valley, the most urbanized ravine study site due to a road passing through it and its close proximity to dense, urban buildings and infrastructure, had relatively low abundances of chipmunks in both studies.

Using Mahan et al.‟s Pennsylvanian forest mammal study (2005) as a baseline for comparison, two species of forest-dwelling small mammals that might be expected to be found *Peromyscus maniculatus* (deer mouse) and *Neozapus insignis* (woodland jumping mouse) were not found in Toronto either in 1977 or 2017. These two species have range distributions across Pennsylvania and Ontario (Reid, 2006). Another common forest mammal in small mammal trapping in Ontario, *Myodes gapperi* (red-backed vole) was also absent from the ravines.

From the 1866-2015 Royal Ontario Museum mammal collection, 16 small mammal species were historically observed in the Greater Toronto Area since 1866, and 4 of those have not been seen since 1945 or earlier: *Glaucomys sabrinus* (northern flying squirrel)*, G. volans* (southern flying squirrel)*, Sorex fumeus* (smokey shrew) and *S. hoyi* (pygmy shrew). Among the remaining species, a strong decline in abundances overtime was observed for *P. maniculatus* and a strong increase for *S. cinereus* (common shrew). These trends are illustrated in **Figure 3**, where it is seen that species such as *P.maniculatus*, *S. fumeus* and *G. volans* are associated with the earliest time period. **Table 2** shows a summary of all ROM small mammal records that were analyzed and their corresponding year that they were added to the collections.

<u>Birds</u>

Using an Environment Canada Canadian Wildlife Service list of Area Sensitive Forest Birds of Toronto as a baseline comparison, we found that in 2017, only 7 out of 43 of these species were found, indicating 84% were missing. Similarly, in the 1977 study only 5 area-sensitive forest bird species were observed. These results are visualized in **Figure 4** and a summary of these species can be found in **Table 3**. A similar species absence was found in Toronto when examining a larger subset of forest-dwelling birds, instead of just area-sensitive birds, see **Figure 5**. It was particularly apparent that two guilds of birds from the area-sensitive forest bird species list, warblers and raptors were absent in our findings (see **Table 3**).

In the comparison with the York region study (McMartin, unpubl. Univ. of Toronto PhD, 2000), where landscapes and forests are much less developed, we found that there were significantly different abundances of bird species between the two regions. This data is summarized in **Table 4** and visualized in **Figure 6**, where we see that there are species of birds that were observed in York region, but not seen in Toronto"s forests. It is clear from this visual representation that the York region bird community has a significantly higher species richness than the present study in Toronto"s ravines (see **Figures 6 and 7**).

<u>Coarse Woody Debris</u>

Using current ecological indicators (Tierney et al, 2009; Mitchell et al. 2014) an assessment of coarse woody debris volume and live tree volume in each ravine site was made and given a status. See **Table 5** for a summary of course woody debris results at each study site.

Furthermore, a comparison was made with the calculated DWD volumes and the observed small mammal abundances. A significant correlation ($P < 0.05$) was found between higher levels of DWD in a ravine site and chipmunk abundances, where chipmunk abundances were higher in ravine sites with higher DWD volumes.

Discussion

I found a trend of biodiversity loss in these urban areas for bird and mammal communities; this trend is seen worldwide (Marzluff et al., 2005; Kowarik 2011; Villarreal et al., 2013; Shochat et al. 2010). Evidently, much of this loss is caused by the activity of humans particularly habitat disturbances, so attention must be paid to urban environments with their large populations of humans if ecological conservation is to take place (Kowarik, 2011).

A general decline in small mammal diversity has been seen in cities across the globe from Poland, Australia and the United States (Lopucki et al., 2013; van der Ree & McCarthy 2005; Mahan et al., 2005; Kowarik, 2011). Our observations on small mammals as well as the 1977 findings indicate that Toronto‟s small mammal community is "poor" in its ecological integrity. Directly comparing to the Mahan (et al., 2005) experiment in Pennsylvania, it is evident that *P. maniculatus* (deer mouse) and *N. insignis* (woodland jumping mouse) are forest dwelling mammals that should be in Toronto yet were not found in 1977 nor 2017 (Mahan et al., 2004; Reid, 2006). Our ROM findings further illustrate that *Peromyscus maniculatus* (deer mouse) was most correlated with the earliest temporal period (1866-1930), and was subsequently lost from the Toronto landscape. Herman‟s (1983) study in Nova Scotia found a prolonged decline between 1977 and 1983 in *P. maniculatus* in forested hardwood and mixed woodlands near human development. Although he did not study areas where *P. leucopus* was sympatric with *P. maniculatus,* he did note that no such decline in *P. leucopus* was seen elsewhere in Nova Scotia. Herman (1983) dismissed climate factors as the cause of *P. maniculatus*‟ decline, although he had no direct evidence. A study by Wolff in the Appalachian Mountains, USA found that in areas of sympatry, cold winters had a higher negative impact on *P. leucopus* fitness when little food was available than the effects winters had on *P. maniculatus* (1996). Furthermore, he found that *P. leucopus* populations increase more than *P. maniculatus* when high number of tree mast is available (Wolff, 1996). In Toronto where the urban heat island effect and global warming, as well as lake mediation is a factor in temperature regulation, the warmer temperatures may have a negative effect on *P. maniculatus* compared to *P. leucopus*. Similarly, research on small mammal communities in the Great Lakes region has shown that more southernly species (e.g. *P. leaucopus*) are moving northwards in range due to climate warming (Myers et al, 2009). Wolf and Batzli (2002) in their research on *P. leucopus* had hypothesized that the species would prefer forest edge habitat, but had concluded that forest interior habitat saw higher white-footed mouse abundances than forest edges (2002). In my results, I found that there was no difference in species richness between 1977 and 2017, except for *B. brevicauda* being a novel mammal found in 2017, and the absence of the grass specialist *M. pennsylvanicus* in 2017.

From our observations, there is evidence to support a decline in bird species richness in Toronto ravines, especially area-sensitive forest breeding birds. Our observations were similar to the findings of Environment Canada"s Canadian Wildlife Service – Ontario, which found that a large portion of area-sensitive forest breeding birds have been extirpated from Toronto"s forests or were never established in the first place (Environment Canada: CWSO, 2007). From examining the 1977 bird observations and our study"s bird song recordings, it is evident that from all of the area-sensitive forest bird species that could potentially be in Toronto, only a minority of them were actually found. Although a specific threshold analysis was beyond the scope of this study, we conclude that the ecological integrity of forest bird species in Toronto is "poor". Our findings fit into the greater North American trend that bird species are declining, including many species needing „urgent conservational action" (NABSCI, 2016).

Direct human disturbance was found to be a factor in reducing bird species richness in Madrid Spain, where humans approaching birds in forested areas would “flush” them out, and these persistent interactions would disturb bird feeding and parental care (Fernández-Juricic, 2000).

This phenomenon may also be at play in Toronto‟s ravines, which are heavily utilized as recreational trails by the city‟s residents and their pets. To further aggravate this factor, many dog owners have been observed to let their dogs off leash and run throughout the ravines, which would further increase disturbances.

Chemical contaminants are another factor that negatively affects bird populations, especially in urban populations. Chandler et al. (2004) concluded that house sparrows have higher lead blood concentration in urban areas than agricultural areas, and this saw that raptors that feed on house sparrows also had higher lead accumulation. With the myriad chemicals used in industrial, commercial and residential settings in urban environments, chemical contaminants may be a factor in declining bird communities.

In our analysis of Downed Woody Debris, we found that most ravine sites had a dead wood:live tree volume of over 0.15, indicating "good" ecological integrity according to Tierney et al. (2009). In Toronto, the urban forest is not logged, so any natural tree felling would stay in the ecosystem as DWD. Due to it being an urban environment, any fires in the urban forests are suppressed which further allows DWD to stay in the ecosystem. Diseased trees such as ash (*Fraxinus americana*) trees afflicted with EAB, elm trees with Dutch elm disease and butternuts with butternut canker are regularly cut by the city if they are deemed “hazard” trees that could fall on trails. This creates additional downed woody debris, especially in the case of ash trees which are currently devastated by EAB in southern Ontario. Further increases in downed woody debris can be seen on private properties, where owners may fell trees for aesthetic purposes and put the remains further into the ravine lands. Interestingly, the abundance of chipmunks was correlated with DWD volumes, indicating the value of deadwood resources in an urban context.

Such DWD resources may be especially important for small mammals in an urban context given the potentially high predation pressure from pets.

Management Implications

The economic and social benefits of forests in urban areas are well documented and furthering conservation efforts now will help minimize resources needed to conserve urban forests in the future. With ecological integrity, mangers and policymakers will have an easily understood metric of forest health, which can be used to plan urban development.

For ecological restoration, greater forest fragment area, greater forest canopy and increased fragment connectivity are well known strategies that can improve biodiversity and ecological integrity (Threllfall et al., 2017; Lopucki et al., 2013). Although conceptually simple, these strategies can be very difficult to put into practice in urban environments such as Toronto, where real-estate is limited, developments are constantly expanding, and where municipal bureaucracy can severely impede conservation efforts.

Ecological restoration can be promoted by enacting legislation to prevent certain natural areas from being developed. In instances where development of natural land is in the best interest for the City, a mandate to include patches of connectivity could be a good requirement to have as if established, would preserve wildlife corridors within the city. Linkages between ravines are especially important as the ravines contain most of Toronto‟s biodiversity (City of Toronto, 2016). One novel way of creating these linkages is with human made wildlife crossings that can be in the form of tunnels or bridges with naturalized features that facilitates animals moving through them. These infrastructure features could plausibly link habitats such as the north and south side of the Rosedale Valley ravine, which is intersected by a heavily used road. There is considerable potential for reforestation of other ravine and natural areas of the city, some of which (such as large areas of the Don Valley) have little forest cover.

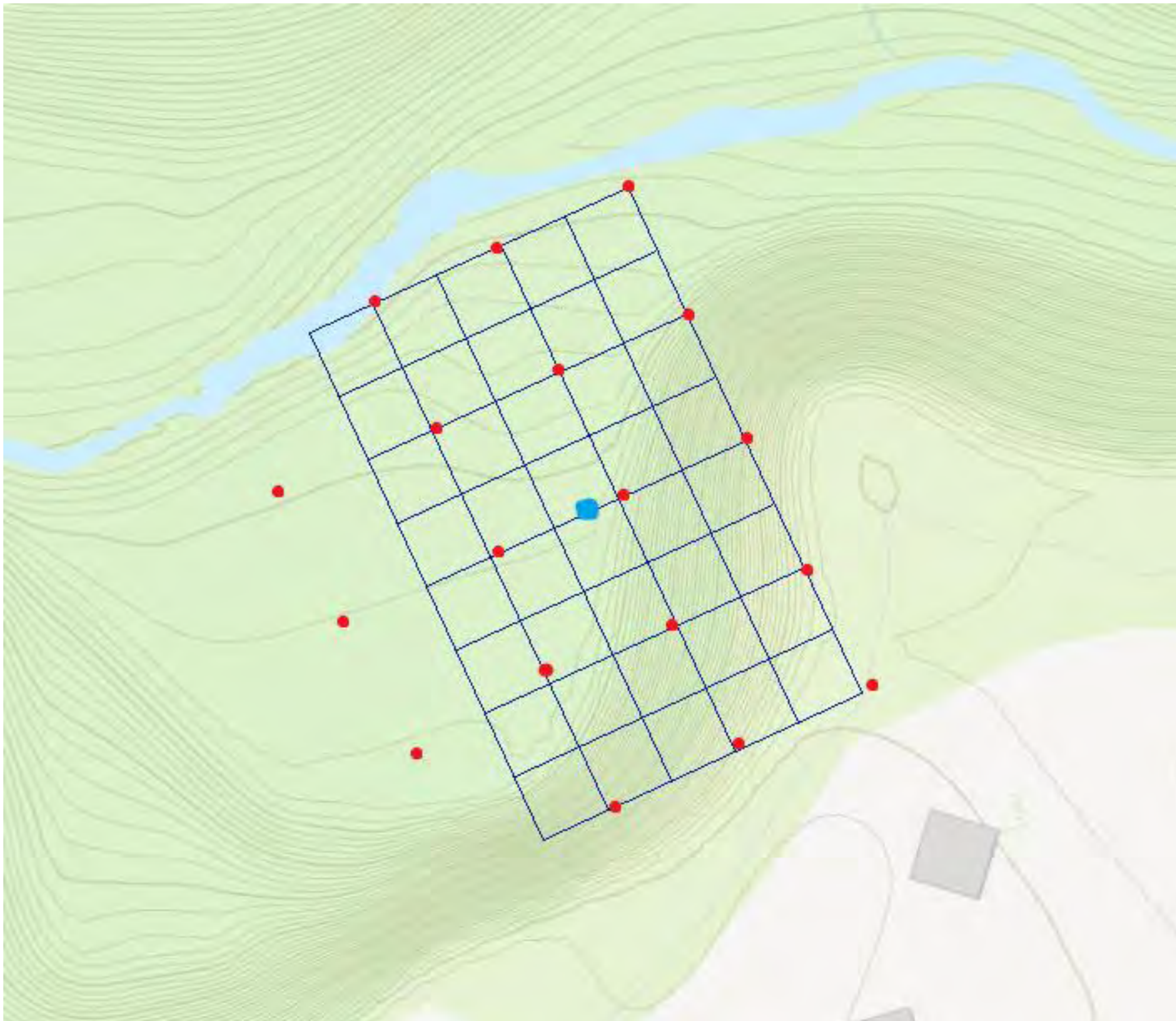
Projects such as F.L.A.P or the Fatal Light Awareness Project should continue to be promoted and utilized by property managers. This program brings awareness to reflective windows and offices that are brightly illuminated during dusk and dawn, which has caused many bird mortalities (FLAP Canada, 2018). Although not directly adjacent to high-rise buildings, the Toronto ravines are close enough to the urban core that birds can move to them freely from densely developed areas. It would be beneficial to the ravine bird communities if lethal window collisions were reduced.

Figures and Tables

Figure 1: A map of the Toronto ravine sites used in the study, with Bloor St. and Mt Pleasant Rd. highlighted. Ravine site #1 is Burke Brook Ravine, #2 is Moore Park, #3 is Park Drive ravine and #4 is Rosedale valley. Red dots indicate locations where Sherman traps were placed and blue dots represent where song recorders were placed:

Figure 2 - A-E: A map of the sampling grids within each ravine study site. The red dots represent locations of Sherman traps, while the blue dot represents the location of a Bird Song Monitor. All 18 traps were spaced 20 m apart. Each blue square on the grid is 10 m x 10 m in size:

A) Burke Brook Ravine:



B) Park Drive Ravine:

C) Rosedale Valley Ravine (Left is West end, Right is East end):

D) Moore Park (No grid system - haphazardly placed around pond):


Moore
Moore Park
Ravine
Beltline Trl
205
215
209
199
201
195
193
191
Hudson Dr
200
198
194
163
161
24
22
20
18
Beltline Trl

Figure 3: A principal components biplot (axes 1 and 2) of all small mammal records in the ROM database for five time periods in which they were found (correlation matrix). The red dots indicate specific time periods: 1= 1866-1930, 2= 1931-1935, 3= 1936-1944, 4= 1945-1967, 5= 1968-2015. From the plot it is clear that *P. maniculatus, S. fumeus* and *G. volans* are strongly correlated with only the 1st time period. The first axis represented 72% of the total variance; the second represented 20%:

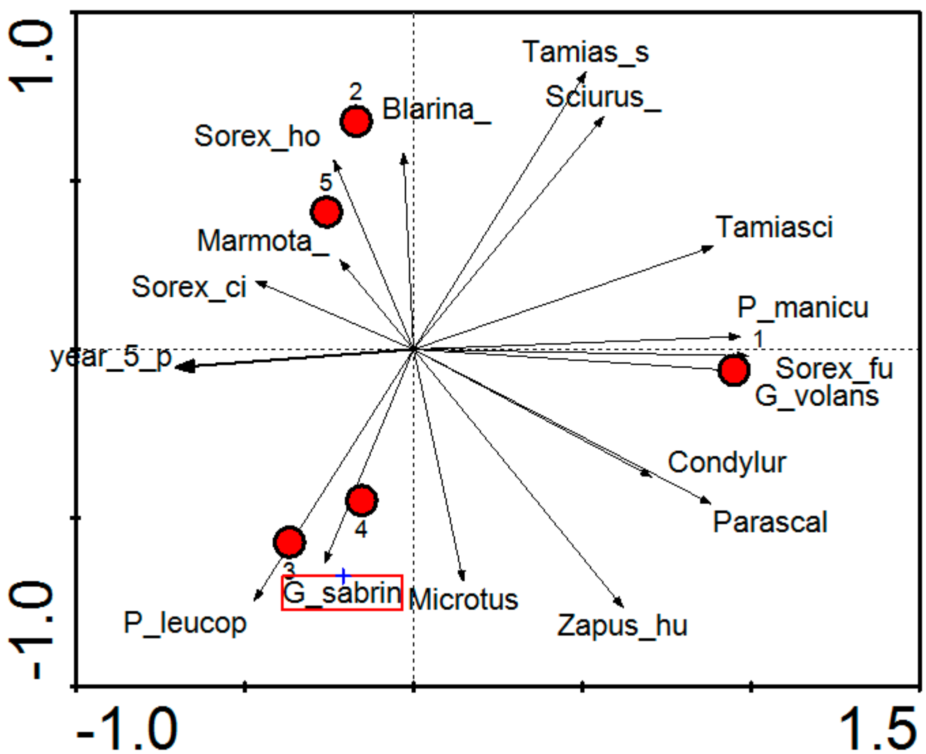


Figure 4: A comparison of area-sensitive forest breeding birds (from Environment Canada"s Canadian Wildlife Service) between 1977 and 2017 as well as how these years compare to the potential number of native species that inhabit Toronto"s forests:

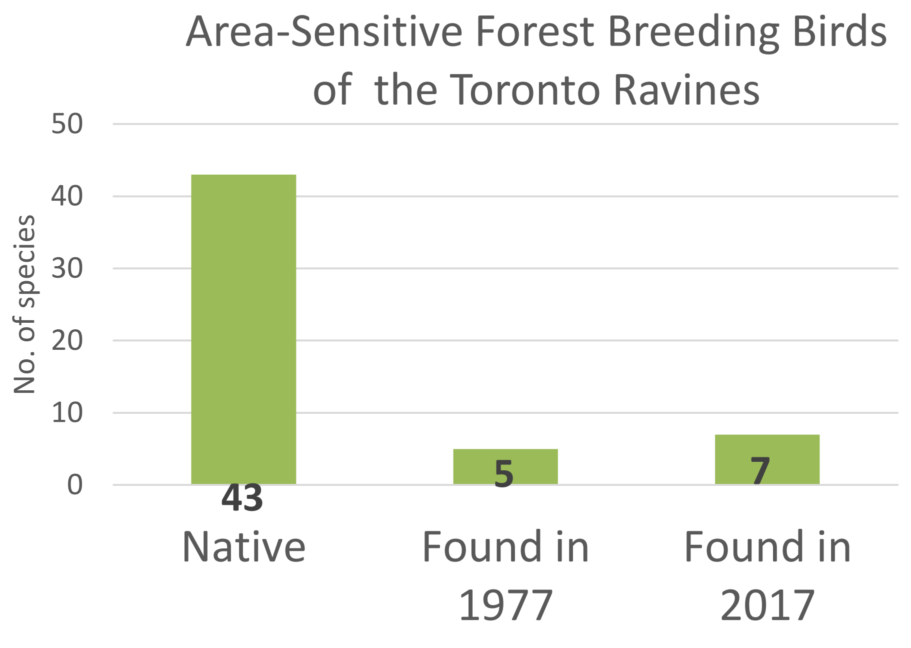


Figure 5: A comparison of all forest breeding birds that are native to Toronto and likely to be present, and the observed bird species in 1977 and 2017. The historic native list was compiled by Kevan Cowcill who used a modified list by Bill Coady, then further filtered down to include only plausible species:

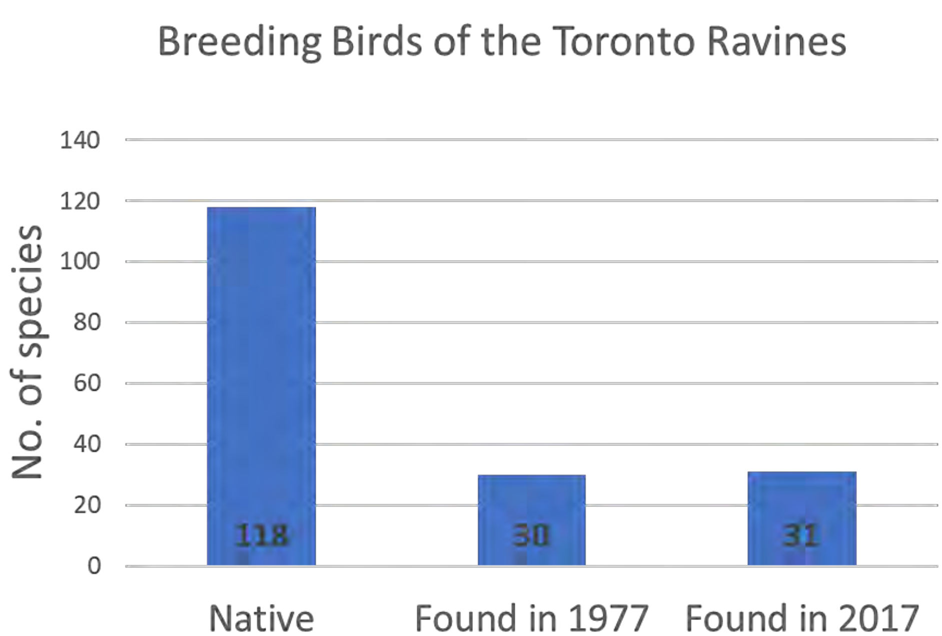


Figure 6: A principal components biplot (axes 1 and 2) of our studies bird observations as well as bird data from McMartin‟s study in York region (McMartin, unpubl. Univ. of Toronto PhD, 2000). The red dots indicate the Toronto ravine study sites, while green dots represent York region sites, light green being small fragments and dark green representing large fragments (see map, **Figure 8**). From the plot it is evident that Toronto has a unique bird community compared to York region. The first axis represented 18.2% of the total variance; the second represented 10.6%:

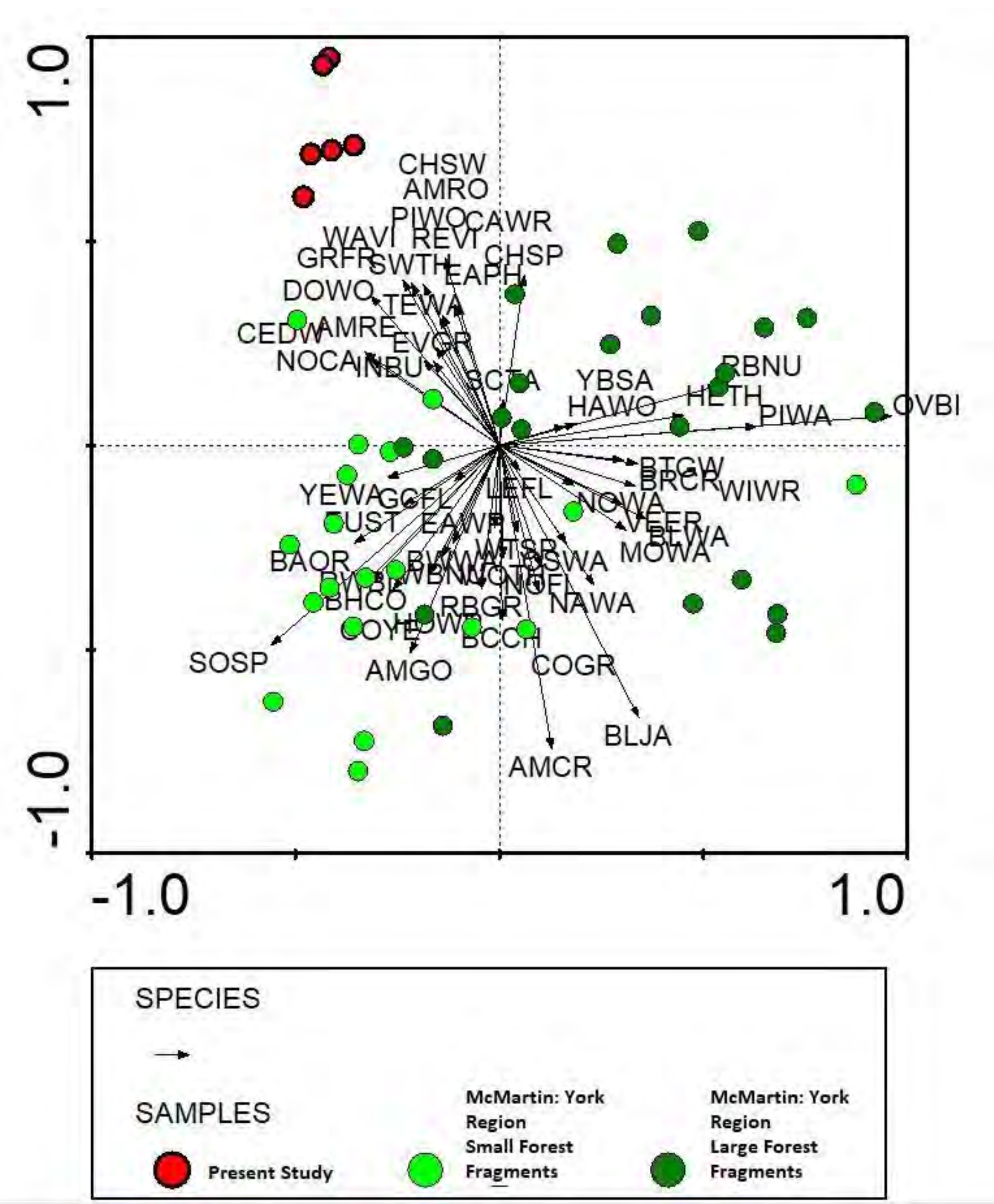


Figure 7: A boxplot of the species richness comparison between the present bird study and McMartin‟s unpublished 2000 York region study. The York region bird community has a significantly higher species richness than the Toronto ravines:

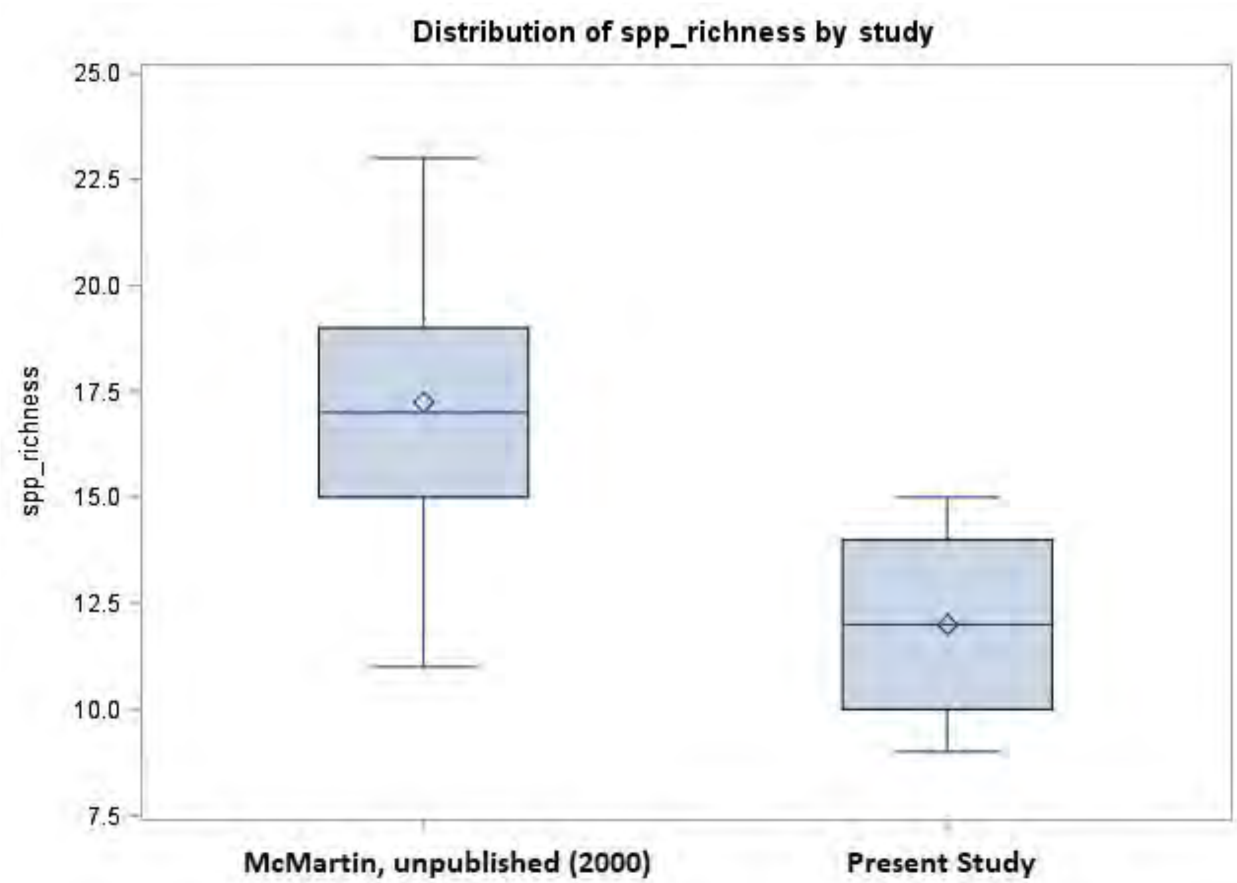


Figure 8: Map of bird sampling sites (red dots) in McMartin‟s York region study, near the southern tip of Lake Simcoe, Ontario. The small and large fragments are easily seen in green on this map:

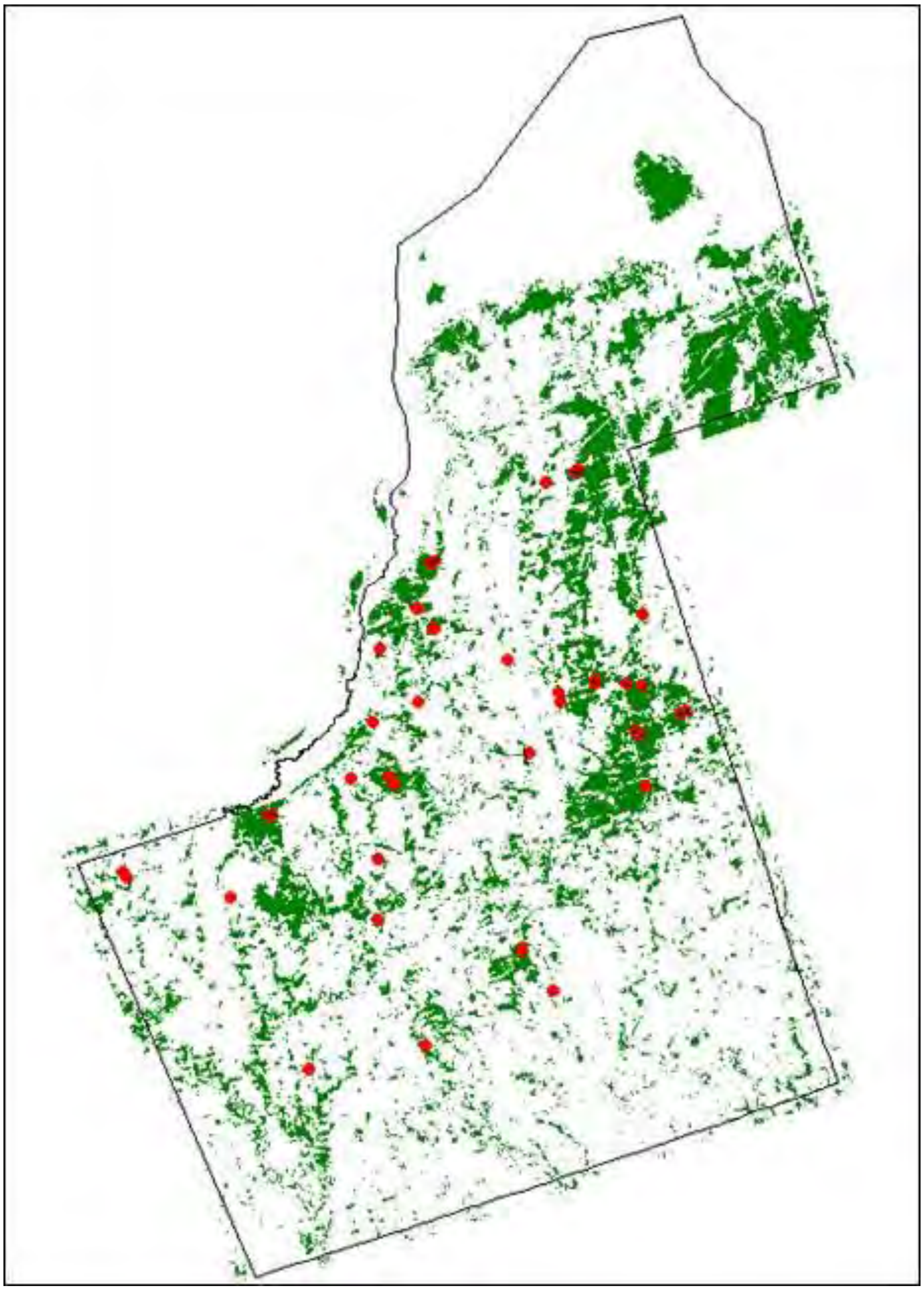


Figure 9: Sketch map of a typical line transect pattern followed for measuring coarse woody debris. All measurements were started from the top of bank and transects followed down the slopes in an "S" shaped pattern:

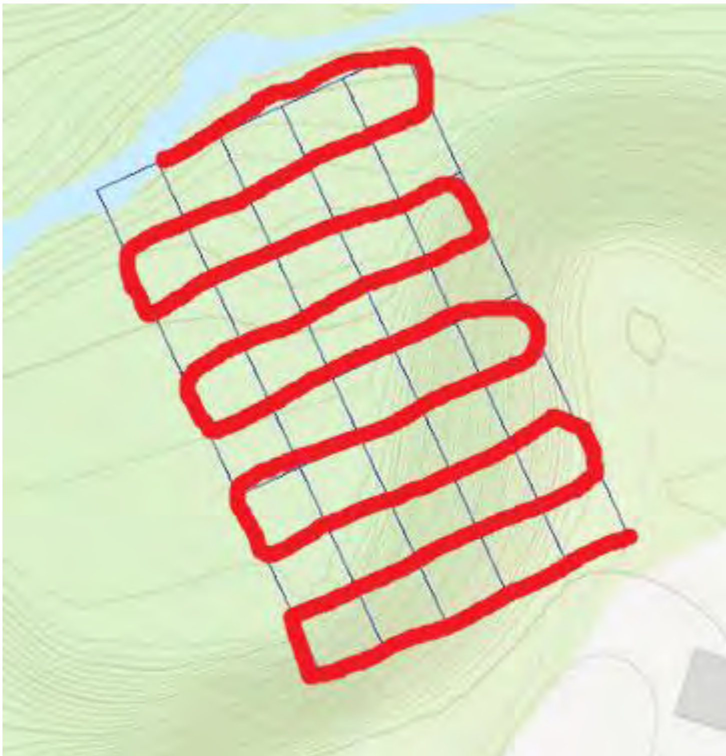


Table 1: A comparison of individual captures of two species of small mammals caught as a percentage of trap success (individuals per 100 trap nights) between different ravines, as well as between study years for the Rosedale ravines of south central Toronto (1977 and 2017):

	Peromyscus leucopus	*Tamias striatus*
Kaiser et al 1977		
Rosedale Valley	7	2.6
Park Drive	4.7	5.2
Moore Park	1.3	2.1
Present study 2017		
Rosedale Valley	9.3	1.9
Park Drive	7.4	3.7
Moore Park	14.8	7.4
Burke Brook	13.0	0.0

Table 2: The small mammals of the ROM collection from years 1866 to 2015. The number of specimens for each species is listed as well as the period in which it was added:

	Years				
Species	1866-1930	1931-1935	1936-1944	1945-1967	1968-2015
Blarina brevicauda	21	37	19	20	16
Condylura cristata	8	1	3	6	5
Microtus pennsylvanicus	44	40	51	45	23
Sciurus carolinensis	20	16	8	12	20
Sorex cinereus	9	13	30	28	86
Tamias striatus	9	10	4	5	7
Tamiasciurus hudsonicus	22	13	4	3	4
Zapus hudsonius	9	4	7	8	5
Glaucomys volans	2	0	0	0	0
Marmota monax	2	1	2	2	7
Parascalops breweri	7	1	3	3	1
Peromyscus leucopus	49	50	80	59	50
Peromyscus maniculatus	22	3	1	5	7
Sorex fumeus	5	1	0	1	0
Sorex hoyi	0	3	0	1	0
Glaucomys sabrinus	0	0	1	4	0

Table 3: The list of area-sensitive forest breeding birds from Environment Canada – Canadian Wildlife Service – Ontario. Whether or not each species was found in the 1977 or 2017 ravine study was noted:

Area-Sensitive Forest Breeding Bird Species of Toronto	**Observed in 1977**	**Observed in 2017**
Sharp-shinned Hawk	No	No
Cooper‟s Hawk	No	No
Northern Goshawk	No	No
Red-shouldered Hawk	No	No
Broad-winged Hawk	No	No
Ruffed Grouse	No	No
Barred Owl* (nocturnal)	No	n/a
Yellow-bellied Sapsucker	No	No
Red-bellied Woodpecker	No	No
Hairy Woodpecker	No	Yes
Pileated Woodpecker	No	Yes
Acadian Flycatcher	No	No
Least Flycatcher	No	Yes
Red-breasted Nuthatch	No	Yes
White-breasted Nuthatch	No	No
Tufted Titmouse	No	No
Brown Creeper	No	No
Winter Wren	No	Yes
Golden-crowned Kinglet	No	No
Blue-gray Gnatcatcher	No	No
Veery	No	No
Hermit Thrush	No	Yes
Wood Thrush	Yes	No
Yellow-throated Vireo	No	No
Blue-headed Vireo	No	No
Prothonotary Warbler	No	No
Chestnut-sided Warbler	No	No
Black-throated Blue Warbler	No	No
Black-throated Green Warbler	No	No
Blackburnian Warbler	No	No
Pine Warbler	No	No
Cerulean Warbler	No	No
Black-and-white Warbler	No	No
American Redstart	No	Yes
Ovenbird	No	No
Northern Waterthrush	No	No
Louisiana Waterthrush	No	No
Mourning Warbler	No	No

Canada Warbler	No	No
Hooded Warbler	No	No
Scarlet Tanager	No	No
White-throated Sparrow	No	Yes
Purple Finch	No	No

Table 4: The list of bird species that were found to be significantly different between observations in McMartin"s York region study and our study in the Toronto ravines. A median test was performed to determine significance ($P < 0.05$):

Bird Species (common name)	Abundance in Toronto's ravines relative to forest fragments in York region ($P < 0.05$)
American crow	lower
American goldfinch	lower
American redstart	lower
American robin	lower
Baltimore Oriole	lower
Blue jay	lower
Carolina wren	higher
Cedar waxwing	higher
Chipping sparrow	higher
Common grackle	lower
Downy woodpecker	higher
Eastern phoebe	higher
Eastern wood-pewee	lower
Evening grosbeak	higher
Hairy woodpecker	lower
Indigo bunting	higher
Ovenbird	lower
Pileated woodpecker	higher
Rose-breasted grosbeak	lower
Tennessee warbler	higher
Veery	lower
Warbling vireo	higher
Wood thrush	lower

Table 5: A comparison between live tree volume (LTV) and downed coarse woody debris (DWD) in the Rosedale ravines of south-central Toronto sampled in 1977. The ratio of DWD/LTV corresponds with a known ecological indicator of health. According to Tierney et al. (2009), a CWD to LTV ratio ≥ 0.15 indicates "good" ecological integrity, 0.15 – 0.10 indicates „fair‟, and < 0.10 indicates „poor‟:

Ravine	DWD volume(m^3/ha)	Live tree volume (m^3/ha)	Ratio	Ecological Indicator (Tierney et al. 2009)
Burke Brook	59.9	356.0	0.17	Good
Park Drive 4	143.2	269.2	0.53	Good
Park Drive 5	89.7	226.8	0.40	Good
Park Drive 3	62.1	154.4	0.40	Good
Rosedale Valley	37.6	270.8	0.14	Fair

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Assessing Understory Vegetation Communities as Indicators of Ecological Integrity in the Toronto Ravine System

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Dr. Sean Thomas

A thesis submitted in conformity with the requirements for the degree of Masters of Forest Conservation

Graduate Department of Forestry

University of Toronto

Abstract

Urbanization has resulted in the disturbance and loss of ecosystems around the globe. As this trend is unlikely to stop, it is essential for urban planning to adopt ecological concepts in order to increase the sustainability of urban centres. One of the first steps required for this to happen is the implementation of ecological monitoring within urban areas – this would allow a better understanding of the current ecological state of urban environments, from which future studies and management recommendations can be based on. The concept of ecological integrity, which aims to quantify the wholeness of an ecosystem's structure, composition, and function, can be used as a guiding principle for such monitoring schemes. In this study, the ecological integrity of the urban ravine system in Toronto, Ontario is quantified using understory vegetation communities as an indicator group. Vegetation sampling sites were established in three ravines located in downtown Toronto, with plot selection based on a 1977 study of the same ravines. Each plot was then ranked as having low, medium, or high ecological integrity based on the proportion of native versus non-native ground cover in each plot. Additionally, two possible drivers of these patterns in ecological integrity were tested – the role of plot position along a slope, and the effect of non-native ground cover abundance. It was found that while invasive species dominated most plots, pockets of native vegetation were persisting within the ravines. Additionally, the majority of invasive ground cover appeared to be "leaking" down from residential areas at the tops of ravines, indicating the role of "garden escapes" as propagules for invasive establishment. Management recommendations include the implementation of citizen science programs to monitor the state of these vegetation communities, as well as using the information gathered to target their efforts.

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Table of Contents

Background

Ecological Integrity

In ecology, it is widely known that urban ecosystems face high levels of disturbance and loss. Attempts to curb these trends are beginning to incorporate ecological concepts and strategies more frequently (Niemelä et al. 2011). The continued growth of applied ecological theory onto urban landscapes is of great importance to human well-being – the majority of projected global population growth over the next 20 years is expected to be centred around urban areas (Alberti 2010). Although urbanization is often interpreted as a long-term disturbance event that destroys and fragments natural habitat, it is unlikely that any policy or management will slow it down in the near future. As such, urbanization must be planned with long-term sustainability and ecological concepts in mind, in order to maintain the structural and functional characteristics of the natural ecosystems being replaced (Bryant 2006). One ecological metric that is currently being used to measure the "wholeness" of ecosystems across the globe is that of ecological integrity.

Ecological integrity is a metric that quantifies an ecosystem's structure and function relative to the landscape's known historical variation, while taking anthropogenic disturbance into account (Angermeier and Karr 1994). The term "ecological integrity" was initially popularized by Aldo Leopold in *A Sand County Almanac* (1949) where he states, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Many scholars today have interpreted the "integrity" Leopold speaks of to refer to the maintenance of key ecosystem components that allow the persistence of the entire system, with the preservation of native species pools being a frequent example in his later works and essays (Simberloff 2012). However, today's understanding and usage of ecological integrity stems from an ecology-based policy framework, rather than the ethical framework Leopold conceived.

This study uses the definition of ecological integrity presented by Karr and Dudley (1981) when first operationalizing ecological integrity as a policy directive: ecological integrity henceforth refers to the capability of supporting and maintaining a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region. As such, an ecosystem is considered to have integrity when its species pool and natural ecological processes are observed to be within these known natural ranges of variation and demonstrate high degrees of resilience – the ability to recover from disturbances both natural and human-induced (Parrish et al. 2003). The usage of ecological integrity as an indicator of an ecosystem's condition is distinct from simply measuring overall biodiversity or species richness – ecological integrity emphasizes the preservation of natural processes that sustain an ecosystem as well as its biotic components.

In recent years, the concept of ecological integrity has become formally adapted by organizations and municipalities as a central guiding principle in land and natural resource management. Ecological integrity has been used for some time now as a key principle by Parks Canada in its management practices (Woodley 2010), by the US National Parks Service in their Vital Signs program (Fancy et al. 2009), and has even found a place in international conservation guidelines through the United Nations (United Nations Millennium Ecosystem Summit 2000). In fact, ecological integrity has even been proposed as a *grundnorm* (fundamental principle) for international law, giving it similar status to concepts such as human rights or rule of law (Kim and Bosselman 2015). This is likely due to an increased understanding on the part of managers and policy-makers of how crucial ecological monitoring is to infrastructure and human well-being (Lovett et al. 2007).

Due to the large spatial scale involved when managing entire landscapes and ecosystems, it is impractical and often impossible to take measures of every possible ecological metric that relates to an ecosystem's structure and function. As such, ecological integrity is often taken as a summary of ecological indicators that have been chosen specifically for the ecosystem being monitored (Tierney et al. 2009). Ideally, metrics should be selected on the basis of their sensitivity to significant stressors within the ecosystem in question, their ability to be measured and quantified, their ability to be modified by management actions, and the accuracy and predictability of their responses to being altered (Dale and Beyeler 2001). The chosen indicators should then be measured across several sites across the ecosystem that represent a gradient of stressor effects (DeKeyser et al. 2003).

Monitoring Ecological Integrity in Urban Ecosystems

Within an urban forest ecosystem context, the notion of ecological integrity is faced with unique challenges. To establish a context for this study, the urban forest is broadly defined as not just the trees planted within urban centres, but rather to all the processes that influence both natural processes and the human residents within cities, such as species pools, carbon capture, soil quality, and so forth (de Groot et al 2002). Indicator selection can be difficult in urban centres due to the differentiated nature of the urban forest's structure – the underlying processes in urban ecosystems exhibit a high degree of specificity towards the scales that they operate on, creating large amounts of heterogeneity within the urban environment (Dorney et al. 1984). One of the predominant lines of thought in the urban ecology literature regarding ecological integrity views the maintenance of ecological structure and function at natural levels as paramount to maintaining healthy ecosystems, with native species proportion commonly used as its primary indicator metric (Ordóñez and Duinker 2012). This tends to involve management strategies that aim to fundamentally "rewild" urban ecosystems, with the goal of recreating pre-urbanization conditions of the managed landscape.

The use of native species as an indicator of ecological integrity has been justified for several reasons. Some of these points include how native species are the most efficient at utilizing the resources available in an area, how natives tend to control invasive species at high-enough abundances, and how natives would theoretically have the most diverse gene pool available (McKinney 2002). Native species loss also tends to be directly correlated with anthropogenic disturbance, making its use as an indicator metric ideal along an urbanization gradient (Zeeman et al. 2017). Parks Canada, in their operational definition for ecological integrity, lists the composition and abundance of native species as a key metric for measuring ecosystem health (Parks Canada Agency 2000). As such, this can be seen as a precedent for the use of native species as an indicator metric for urban ecological integrity.

The city of Toronto represents one urban centre where such a monitoring method can be applied. It has an extensive system of green areas, with over 12% of its urban area covered by greenspace – 71% of which are classified as natural heritage lands (De Sousa 2003). A large portion of these sites are part of Toronto's ravine system, an ecologically significant array of wetland and riparian zones that function as habitats and corridors for many native species who would otherwise not persist in an urban environment (Foster 2005). Monitoring the ecological integrity of these ravines would assist in the restoration of their structure and function, as well as the maintenance of ecosystem services these greenspaces provide to nearby residents.

Citizen Science and its Role in Ecological Monitoring

One of the key challenges faced by ecological monitoring programs today is a lack of professional ecologists to carry out necessary fieldwork. This has led to a large increase in the use of data collected by non-professionals, which has led to increased efficiency of data collection in ecology and conservation projects (Dickinson et al. 2015). However, it is important to keep in mind the increased chance for human error when incorporating laypeople into monitoring programs. While often highly-passionate, it would be unrealistic to expect citizen scientists to voluntarily sample harsh terrain and remote locations, leading to the potential for geographic sampling bias (Botts et al. 2010). Similarly, the voluntary nature of citizen science may lead to high participant turnover rate, leading to uneven data collection rates throughout the year (Dunn and Weston 2008). Additionally, certain species may be a challenge to identify in the field, even for trained biologists – these would likely be misidentified by volunteer citizens.

When supplemented with coordination, communication, and data quality control from professional ecologists, citizen science initiatives related to data collection have proven to be accurate and effective means of bolstering conservation efforts worldwide (Spooner et al. 2015). These programs have been found to have consistent rates of bias and error when compared with data collected by professional scientists (Bird et al. 204). Even with limited training, citizen science monitoring data has been shown to be reliable so long as unambiguous standardized protocols are prepared by trained scientists (Fuccillo et al. 2015).

Project Objectives

The primary goal of this project is to quantify the ecological integrity of the Toronto ravine system, using the proportion of native understory vegetation species versus non-native species as an indicator of integrity. Understory vegetation was selected as the indicator target due to successful prior use in forestry as an accurate proxy measure of overall forest health in the face of anthropogenic disturbance (Gachet et al. 2007). The potential for citizen science as a tool for ecological monitoring in the ravines was also taken into account.

Additionally, potential drivers of trends in ecological integrity were also analyzed – the two that this study looked at were plot position along the ravine slopes and proportion of non-native cover per plot. With regards to plot position on the ravines, it was hypothesized that vegetation communities on the tops and bottoms of ravine slopes would have more invasive ground cover, due to proximity to increased propagule pressure from residential areas and waterways. With regards to proportion of non-native cover per plot, it was hypothesized that a negative correlation exists between proportion of non-native ground cover to native ground cover, due to competitive exclusion and lack of predators for non-native species.

Methods

Study Site Selection

The entire project was initially based on an unpublished 1977 study on the Rosedale ravine system done by P. H. Scrivener and R. D. Taylor, which aimed to create a database of ravine flora and fauna that was to be updated periodically. Due to updates in methodology concerning sampling protocol, only their site selection was kept for this study. Six sites were selected in Park Drive ravine, four in Rosedale ravine, and one in Burke Brook ravine (**fig. 1**). An additional ravine in Moore Park was selected for bird monitoring and mammal sampling, but no vegetation sampling was done there. Each site was then divided into varied amounts of 10m x 10m square plots, arranged into five columns. The number of rows per site was based on practicality – where possible, the sample sites traversed the entire ravine slope, stopping where private property boundaries began.

Understory Vegetation Sampling

Field sampling of understory vegetation was done in teams of two to control for observer bias and error. Sampling was done one 10m x 10m plot at a time, starting with one observer on each upper corner of the plot and looking down the slope. Observers then walked through the plot in a systemic manner, recording the species and percent ground cover of all vascular non-woody plants encountered. Plant identification in the field was done with the aid of the field guide "Plants of Southern Ontario" by Richard Dickinson and France Royer. Any plants that could not be identified in the field were photographed and later identified using online sources and the National Audubon Society Field Guide to North American Wildflowers.

Rather than taking exact measurements of percent ground cover for each species encountered, binned estimates of cover were used. This was done to reflect a simpler, more feasible approach for future citizen science initiatives aiming to monitor these vegetation communities. The categories corresponded to less than 1% for trace cover, 1-10% for low cover, 11-50% for medium cover, and 51-100% for high cover. More weight was assigned to medium and high percent ground cover to reflect the importance of managing for highly-abundant invasive species, which are quite prominent in the ravine systems.

Each 10m x 10m plot was then assigned a score of low, medium, or high ecological integrity based on the ratio of native to non-native ground cover, where low corresponded to less than 60% native cover, medium to 60-99% native cover, and high to 100% native cover. As ecological integrity measures an ecosystem's deviation from its "natural" condition, an ecosystem with high integrity should have no non-native species. Since ground cover data was collected as categories rather than exact measures, proportion was calculated by assigning number values to each category, then summing the score for native and non-native cover per plot.

Drivers of Ecological Integrity

To analyze the effects of slope position on a plot's ecological integrity, each plot was assigned to a position category of bottom, low slope, high slope, and top. The bottom category represents plots which were located at the base of each ravine on flat ground. Similarly, the top category represents plots located at the top of each ravine on flat ground. The low slope and high slope categories represent the bottom half and top half of the slopes themselves. The mean proportion of non-native ground cover per position category was calculated, and a one-way ANOVA was run for statistical analysis.

To analyze the effects of non-native ground cover on native ground cover, a correlation analysis was run to generate Pearson's correlation coefficient. The proportion of non-native ground cover was measured against the native ground cover score rather than the proportion of native cover, as this would have yielded a straight line (e.g. all plots with 60% non-native cover would by definition have 40% native cover).

Results

Ecological Integrity of Understory Vegetation

Based on this study, it appears that the understory vegetation communities of the Toronto ravine systems are currently at low levels of ecological integrity. **Figs. 2-5** display each individual ravine site divided into their 10m x 10m sampling plots, all ranked based on ecological integrity. 24 10m x 10m plots (7% of all plots) were ranked as having high ecological integrity, 102 plots (30%) were ranked at medium, and 214 plots (63%) were ranked at low. These findings are summarized in **fig. 6**. A full list of species found, along with data on how many plots they appeared at each abundance category, can be found at **table 1**.

Effects of Plot Position on Ecological Integrity

The one-way ANOVA found that understory vegetation communities at the tops of ravine slopes had significantly higher proportions of non-native ground cover, returning a p-value of 0.0162 ($p < 0.05$) with a sample size of $n = 327$. The three other categories each had similar proportions of native to non-native ground cover. These results are displayed in **fig. 7**.

Effects of Non-Native Cover on Native Vegetation

The correlation analysis returned a Pearson's correlation coefficient of -0.375 ($p < 0.05$) with a sample size of $n = 327$. This can be interpreted to mean a strong negative correlation between non-native and native ground cover. Results are displayed in **fig. 8**.

Discussion

The Ecological Integrity of Understory Vegetation

Under Karr and Dudley's 1981 definition of ecological integrity, restoring the ravines' ecological integrity with regards to herbaceous vegetation would require both the reintroduction of native plants and the removal of non-natives. Additionally, invasive re-establishment would have to be accounted for in the long-term. While one may be quick to jump to the conclusion that the ravine vegetation communities have been disturbed beyond recovery, the presence of a few 10m x 10m plots with 100% native cover, some with species of regional conservation concern, indicate potential value for at least a partial restoration of native plant communities. Currently, ecological literature appears to be lacking quantitative studies on urban ravine dynamics with regards to native restoration. However, a substantial amount of restoration ecology literature exists which focuses separately on urban vegetation communities and on ravine ecology.

Looking at restoration of native urban vegetation, one finds that the benefits to this are well-documented. Urban forests with higher rates of native biodiversity tend to be more resilient to disturbance – that is, they have a higher capacity to resist damage and recover from disturbance events (Folke et al. 2004). A healthy urban forest also tends to provide more ecosystem services – tangible goods and services beneficial to humans – than an unhealthy one (Almas and Conway 2016). Unfortunately, urban forests tend to be small, fragmented, and subject to strong edge effects, resulting in increased propagule pressure from invasive species (Overdyck and Clarkson 2012). Additionally, international hubs such as Toronto have increased propagule pressure from invasives that spans longer distances – this is due to human transport carrying species from one location to another on a daily basis (Hulme 2009).

Regarding ravines, they and similar waterways have considerable effect on erosion control (Naiman and Décamps 1990), nutrient cycling (Naiman et al. 1993), and act as refugia and corridors for various taxonomic groups (Tickner et al. 2001). Unfortunately, the riparian nature of ravines leads to a suite of challenges for native restoration and invasive species control; these challenges include high habitat heterogeneity (Nilsson et al. 1989), propagule dispersion along waterways (Jansson et al. 2005), and edge effects arising from the linear shape of ravines (Cummings 2002). When taking these ravine-based issues into consideration alongside the issues brought about by the urban environment, combatting that future re-establishment of invasives post-removal will likely be a much greater challenge than the actual removal of the plants. While the manual removal of invasive plants continues, further research should focus on ways to minimize the re-establishment potential of invasive species once removed. This will likely involve identifying and quickly removing propagules where possible.

In order to restore ecological integrity across the entire landscape, herbaceous vegetation cannot be considered in isolation from the other taxonomic groups within the ravines. In fact, taking a holistic ecosystem-based approach may be the most efficient way of achieving this goal – studies have shown that both cover and species richness of invasive understory plants is negatively correlated with increased canopy cover (Holl and Crone 2004). Working towards improving understory vegetation ecological integrity will feed back towards the well-being of the tree community as well – having an understory layer composed largely of native species will likely facilitate the establishment of native tree saplings (Kueffer et al. 2010). Additionally, the overall long-term success of native community restoration in forests is often evaluated based on the success of long-lived shade-tolerant trees – these indicate that natural forest dynamics are occurring continuously with no need for further management actions (Bertacchi et al. 2016). As such, the monitoring of other taxonomic groups, particularly trees and woody shrubs, should be considered alongside understory vegetation.

Having quantified data on the ravine system's ecological integrity will allow for better policies and management actions to be implemented throughout the landscape. This initial monitoring effort has highlighted the poor state that these vegetation communities are currently in, based on the establishment and propagation of invasive species that have overtaken native ground cover in the majority of this study's sampling plots. This data can be brought forward to city council to justify investment towards ravine health, which is of particular importance today given the current development of Toronto's ravine strategy plan. In particular, this study's findings can be used as a call to adopting an ecological integrity focus towards maintaining the ravines rather than simple estimates of canopy cover – this will ensure that green space is developed with long-term sustainability in mind.

Drivers of Ecological Integrity

Results surrounding the effect of both drivers tested falls somewhat in line with the established literature. With regards to the effect of plot position along a ravine slope on herbaceous plant integrity, the results were unsurprising. It has already been found that garden waste acts as a significant propagule source for plant establishment (Rusterholz et al. 2012). As residences in the ravine system are located uphill, it made sense that there were higher proportions of non-native ground cover at the crests of the ravines. This is further supported by the specific plant species being found near the tops of the ravines – English ivy (*hedera helix*), common periwinkle (*Vinca minor*), and lily of the valley (*Convallaria majalis*), all of which are common garden plants, were quite prominent in these areas.

What was surprising, however, was that plots at the bottom of the ravines along streams and waterways had significantly lower proportions of non-native ground cover than the tops, especially when considering the increased propagule pressure that riparian zones tend to have (Jansson et al. 2005). This may be due to the fact that while there were indeed high amounts of invasive ground cover in these areas, particularly Japanese knotweed (*Fallopia japonica*), these areas were also highly species rich with regards to native plants, albeit while having low levels of ground cover. An understanding of these relationships will allow management efforts to be done in a targeted manner, rather than through a broad approach. As it has been observed that plots at the tops of ravines have more non-native ground cover, invasive species removal can be focused onto these areas, as well as near any residential areas adjacent to the ravines.

With regards to the effects of non-native ground cover on native ground cover, results were not surprising in the direction they went, but rather in the strength of the observed correlation. The competitive advantage experienced by invasive species is already well-documented in the literature. According to the enemy release hypothesis, invasive species fare well due to the lack of natural predators in novel environments that co-evolved with them (Keane and Crawley 2002). Invasive species also tend to have functional traits that resulted in generalist propagation strategies such as fast growth, rapid reproduction, high rates of dispersion, phenotypic plasticity, and ecological competence (Kolar and Lodge 2001). As such, it was expected that a negative correlation existed between proportion of non-native ground cover and native ground cover. This negative correlation was found to be quite strong – although the observed value was -0.375, this can be argued to be relatively high due to the coarse estimates of cover and coarse spatial resolution of the data collected. Further sampling efforts should avoid such broad categories and use numerical estimates of cover instead.

The Application of Citizen Science

This project also aimed to serve as a proof-of-concept study highlighting how citizen science initiatives towards ecological monitoring are feasible strategies for long-term data collection. This study's methods were designed for simplicity of use by laypeople, and appear to have been sufficient enough to yield accurate data on the state of the ravines. A citizen science monitoring program could possibly be developed for the ravines, with training focused on recognizing the most abundant invasive species and ecologically-significant native species. With such a program in place, enough long-term data can be collected for further restoration initiatives to be undertaken.

Citizen-based initiatives can also be used for the planting and re-establishment of native plant communities where appropriate. These efforts will likely have to wait until after invasive species have been removed, in order to avoid wasting investment if the invasive species manage to outcompete the native plantings. Additionally, further studies should be done on understanding the limiting factors towards native restoration specific to the Toronto ravine system. Steinfeld et al. (2007) identified nine categories of limiting factors that tend to hinder plant establishment – of these, surface stability, slope stability, weeds, pests, and human interference all likely play a role in the ravines. An understanding of the dynamics that prevent plant establishment will enable planting efforts to be targeted towards areas with the most chance of success and plant persistence, rather than taking a broad approach and wasting resources.

Even if these citizen-based efforts end up initially yielding fairly low-quality results, the promotion of stewardship within communities is still a goal in of itself. It has been shown that participating in environmental workshops, lectures, and seminars aimed towards laypeople can boost scientific literacy, as well as increase the chances of engaging in further conservation work (Crall et al. 2012). Areas with stronger senses of stewardship and community involvement in conservation efforts have also been found to be more receptive towards governments and conservation authorities implementing new environmental policies and protections (Hall and Pretty 2008). As such, any citizen-based conservation efforts in the ravines should also take into consideration increased awareness and resident participation when evaluating the success of their work.

Areas for Improvement

This study represents a first attempt at quantifying the ecological integrity of vegetation communities within this ravine system. With that in mind, further refinement of the methods and protocol should be considered before attempting to replicate this study. One of the main challenges faced during the sampling period for this study was time, particularly when considering how ephemeral some understory vegetation species are. Further monitoring of ravine vegetation should be performed by a dedicated team the entire sampling season, rather than one team attempting to quantify the ecological integrity of several taxonomic groups all at once.

Additionally, non-native species and invasive species should be differentiated when calculating ecological integrity – not all non-native species spread to outcompete native biodiversity when left to persist (Davis 2009). In fact, many non-native non-invasive plants have been found to generate ecosystem services where native species can no longer thrive (Ewel et al. 1999), and have even been found to facilitate conservation goals at the ecosystem level (Gozlan 2008). The use of non-native non-invasive plants may be necessary to preserve any level of forest cover at all in light of anthropogenic climate change – if a business as usual approach continues, many ecosystems will no longer be able to support most species currently considered native to them (Kiesel 2014).

One final issue was that the exact thresholds for ranking plots as having low, medium, or high ecological integrity were somewhat arbitrary, based more on the ease of use for potential citizen volunteers rather than solid ecological concepts. This is particularly true when looking at the threshold of 60% native ground cover proportion that separates medium and low ecological integrity. Additionally, while high ecological integrity can be agreed upon to require a complete native species pool, points from the previous paragraph can be used to argue that high integrity can still be achieved with the presence of non-invasive non-native species.

Conclusion

While this study found that the herbaceous plant communities in Toronto's ravine systems are indeed quite disturbed, there are still opportunities to restore their ecological integrity for the benefit of the city's residents. However, achieving these goals will require significant amounts of planning and field work. The management recommendations from the discussion are summarized below:

- The establishment of citizen-based monitoring initiatives for both woody and herbaceous plants in Toronto's ravine system;
- The adoption of ecological integrity as a guiding principle for urban forest management within the ravines;
- The use of a targeted approach for invasive removal and native plantings based on highest potentials of success, rather than spreading resources thin across the entire landscape;
- The differentiating between invasive and non-invasive non-native plants, in order to derive benefits from them instead of excluding them based solely on native status.

Unfortunately, the above recommendations will likely be treating the symptoms rather than the causes of native species loss and invasive establishment. Further studies that would benefit the restoration of ravine ecological integrity include:

- Exploring the drivers of invasive species re-establishment following their removal;
- Looking at the rate of spread of known invasives already established in the ravines, in order to be able to prioritize which ones require immediate removal;

- Further examining the ecological dynamics specific to Toronto's urban ravine system, in order to create scientifically-sound thresholds for defining the state of its ecological integrity.

This study has been done at an opportune time for the ravines – the City of Toronto's own Ravine Strategy is nearing completion, and should be guided by informed policy-makers and ecological concepts. Additionally, residents living in various neighbourhoods around the ravines have already expressed significant interest in assisting in ravine revitalization – this entire study was largely funded by residents. As such, it can be concluded that while the ravines are currently in a relatively poor ecological state, the opportunities to restore their integrity are now visible. When combined with a passionate and large amount of citizens willing to put in work, guided by professional ecologists and biologists, the ability to improve their current condition is quite high.

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Tables and Figures

***Table 1*:** Complete list of all 61 species found in the study plots. Each species is listed by both its common and scientific names. The TRCA rank column refers to each species conservation concern status as described by the Toronto and Region Conservation Authority – rank 4 species are "of conservation concern in urban areas", rank 5 species are "of no conservation concern at this time", and species with a + sign are considered to be non-native. The final 5 columns indicate how many times each species was found to be at each level of ground cover, as well as the total number of plots each species occurred in.

Species - Common Name	Species - Scientific Name	TRCA Rank	Trace	Low	Medium	High	Total
Wild Leek	*Allium tricoccum*	4	42	6	0	0	48
Hispid Buttercup	*Ranunculus hispidus*	4	5	11	0	0	16
Wild Geranium	*Geranium maculatum*	4	3	1	0	0	4
False Nettle	*Boehmeria cylindrica*	4	0	1	1	0	2
Marsh Marigold	*Caltha palustris*	4	0	2	0	0	2
White Trillium	*Trillium grandiflorum*	4	2	0	0	0	2
Common Arrowhead	*Sagittaria latifolia*	4	1	0	0	0	1
Marsh Blue Violet	*Viola cucullata*	4	1	0	0	0	1
Zigzag Goldenrod	*Solidago flexicaulis*	5	30	137	14	2	183
Canada Goldenrod	*Solidago canadensis*	5	56	73	2	0	131
Spotted Touch-Me-Not	*Impatiens capensis*	5	20	54	6	6	86
Yellow Avens	*Geum aleppicum*	5	20	61	0	0	81
Enchanter's Nightshade	*Circaea lutetiana*	5	22	39	3	0	64
White Avens	*Geum canadense*	5	49	12	2	0	63
Jack in the Pulpit	*Arisaema triphyllum*	5	17	33	3	0	53
Virginia Creeper	*Parthenocissus quinquefolia*	5	16	33	1	1	51
Wild Red Raspberry	*Rubus idaeus*	5	7	16	0	0	23
Poison Ivy	*Toxicodendron radicans*	5	6	14	1	1	22
Purple Flowering Raspberry	*Rubus odoratus*	5	11	9	0	0	20
Yellow Sorrel	*Oxalis acetosella*	5	9	11	0	0	20
False Solomon's Seal	*Maianthemum racemosum*	5	9	9	1	0	19
Virginia Waterleaf	*Hydrophyllum virginianum*	5	2	15	1	0	18

Canada Anemone	*Anemone canadensis*	5	5	2	0	0	7
Mayapple	*Podophyllum peltatum*	5	1	2	0	0	3
Heart-Leaved Aster	*Symphyotrichum cordifolium*	5	2	0	0	0	2
Virgin's Bower	*Clematis virginiana*	5	1	1	0	0	2
Yellow Trout Lily	*Erythronium americanum*	5	0	2	0	0	2
Canada Elderberry	*Sambucus nigra*	5	0	1	0	0	1
Canada Nettle	*Laportea canadensis*	5	0	1	0	0	1
Red Elderberry	*Sambucus racemosa*	5	0	1	0	0	1
Wild Strawberry	*Fragaria virginiana*	5	1	0	0	0	1
Garlic Mustard	*Alliaria petiolata*	+	54	137	23	39	253
Common Dandelion	*Taraxacum officinale*	+	53	35	0	0	88
Nipplewort	*Lapsana communis*	+	20	28	0	0	48
Stinging Nettle	*Urtica dioica*	+	8	35	0	0	43
English Ivy	*Hedera helix*	+	0	11	4	23	38
Goutweed	*Aegopodium podagraria*	+	1	19	8	6	34
Japanese Knotweed	*Fallopia japonica*	+	1	15	6	7	29
Siberian Scilla	*Scilla siberica*	+	6	17	2	1	26
Crown Vetch	*Securigera varia*	+	12	12	0	0	24
Ground Ivy	*Glechoma hederacea*	+	8	16	0	0	24
Common Burdock	*Arctium minus*	+	16	7	0	0	23
Wild Carrot	*Daucus carota*	+	11	11	0	0	22
Common Plantain	*Plantago major*	+	0	15	0	0	15
Dog Strangling Vine	*Cynanchum rossicum*	+	5	8	1	0	14
Greater Celandine	*Chelidonium majus*	+	4	8	2	0	14
Common Periwinkle	*Vinca minor*	+	1	7	4	1	13
European Gooseberry	*Ribes uva-crispa*	+	2	5	3	0	10
Wood Avens	*Geum urbanum*	+	2	8	0	0	10
Wild Chervil	*Anthriscus sylvestris*	+	2	4	0	2	8
Lily of the Valley	*Convallaria majalis*	+	3	2	2	0	7

Chicory	*Cichorium intybus*	+	3	1	0	0	4
Coltsfoot	*Tussilago farfara*	+	1	3	0	0	4
Halberd-Leaved Tearthumb	*Atriplex patula*	+	1	2	0	0	3
Redcurrant	*Ribes rubrum*	+	2	1	0	0	3
Bittersweet Nightshade	*Solanum dulcamara*	+	1	1	0	0	2
Bull Thistle	*Cirsium vulgare*	+	0	2	0	0	2
Black Medick	*Medicago lupulina*	+	0	1	0	0	1
Canada Thistle	*Cirsium arvense*	+	0	1	0	0	1
Sweet Woodruff	*Galium odoratum*	+	0	1	0	0	1
Virginia Bluebells	*Mertensia virginica*	+	1	0	0	0	1

***Figure 2*:** Map with all study ravines highlighted. Note that no understory vegetation monitoring was done in site 2 (Moore Park) as it was not done there in the initial 1977 study.

Figure 3: Map of Park Drive ravine with all six study sites displayed. Each site is divided into 10m x 10m sampling plots, which have been colour-coded based on ecological integrity – red is low integrity, yellow is medium, and green is high. Low integrity corresponds to sites with less than 60% native ground cover. Medium corresponds to sites with native ground cover between 60-99%. High integrity corresponds to plots with 100% native species cover. Empty plots were classified as medium integrity due to the potential to be colonized by either native or invasive species. Note that two sites are not completely colour-coded – the unfilled plots were located on private property, which was not the case in the 1977 study.

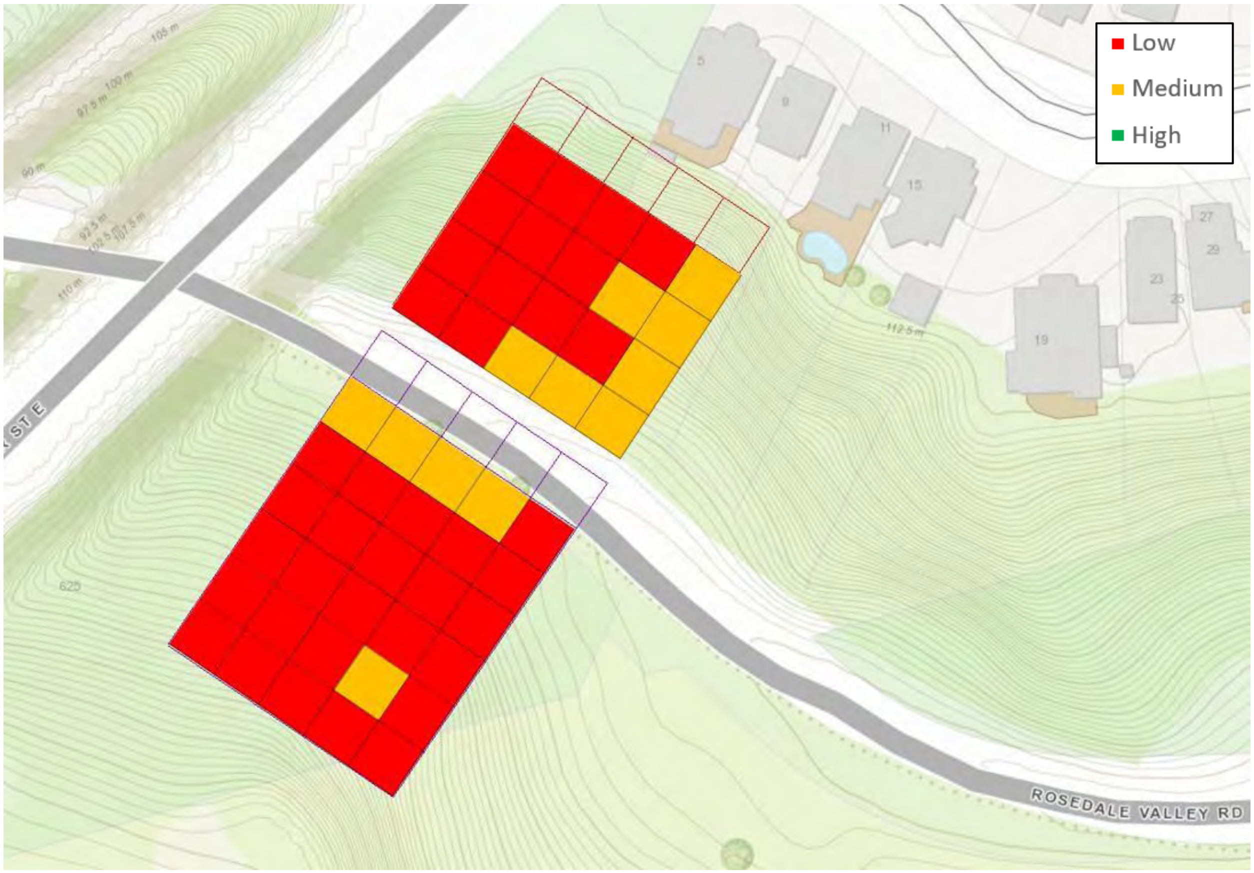

Figure 4: Map of the west side of Rosedale ravine with its two study sites displayed. Each site is divided into 10m x 10m sampling plots, which have been colour-coded based on ecological integrity – red is low integrity, yellow is medium, and green is high. Low integrity corresponds to sites with less than 60% native ground cover. Medium corresponds to sites with native ground cover between 60-99%. High integrity corresponds to plots with 100% native species cover. Empty plots were classified as medium integrity due to the potential to be colonized by either native or invasive species. Note that both sites are not completely colour-coded – the unfilled plots were located either on private property or on a busy paved road, which was not the case in the 1977 study.

Figure 5: Map of the east side of Rosedale ravine with its two study sites displayed. Each site is divided into 10m x 10m sampling plots, which have been colour-coded based on ecological integrity – red is low integrity, yellow is medium, and green is high. Low integrity corresponds to sites with less than 60% native ground cover. Medium corresponds to sites with native ground cover between 60-99%. High integrity corresponds to plots with 100% native species cover. Empty plots were classified as medium integrity due to the potential to be colonized by either native or invasive species.

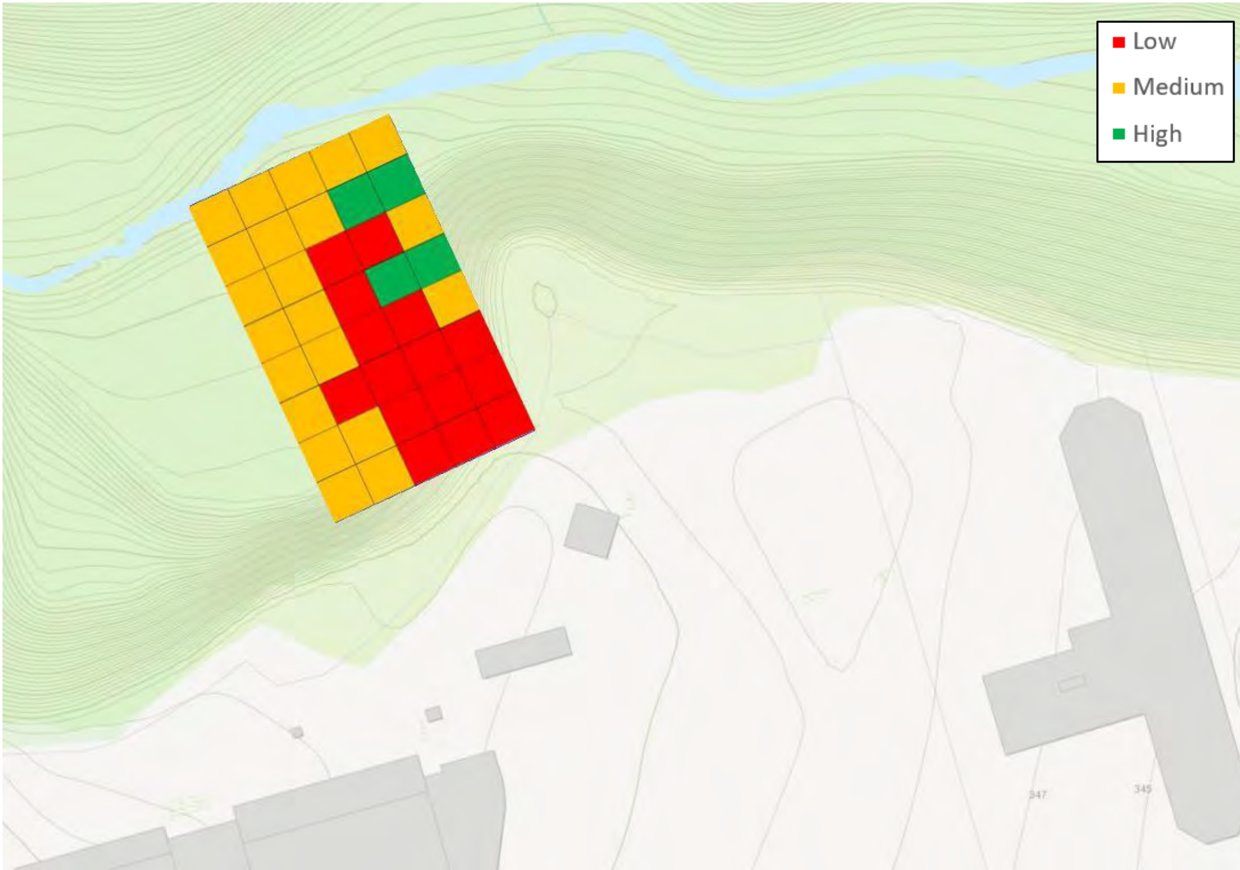

Figure 6: Map of Burke Brook ravine with its study site displayed. Each site is divided into 10m x 10m sampling plots, which have been colour-coded based on ecological integrity – red is low integrity, yellow is medium, and green is high. Low integrity corresponds to sites with less than 60% native ground cover. Medium corresponds to sites with native ground cover between 60-99%. High integrity corresponds to plots with 100% native species cover. Empty plots were classified as medium integrity due to the potential to be colonized by either native or invasive species.

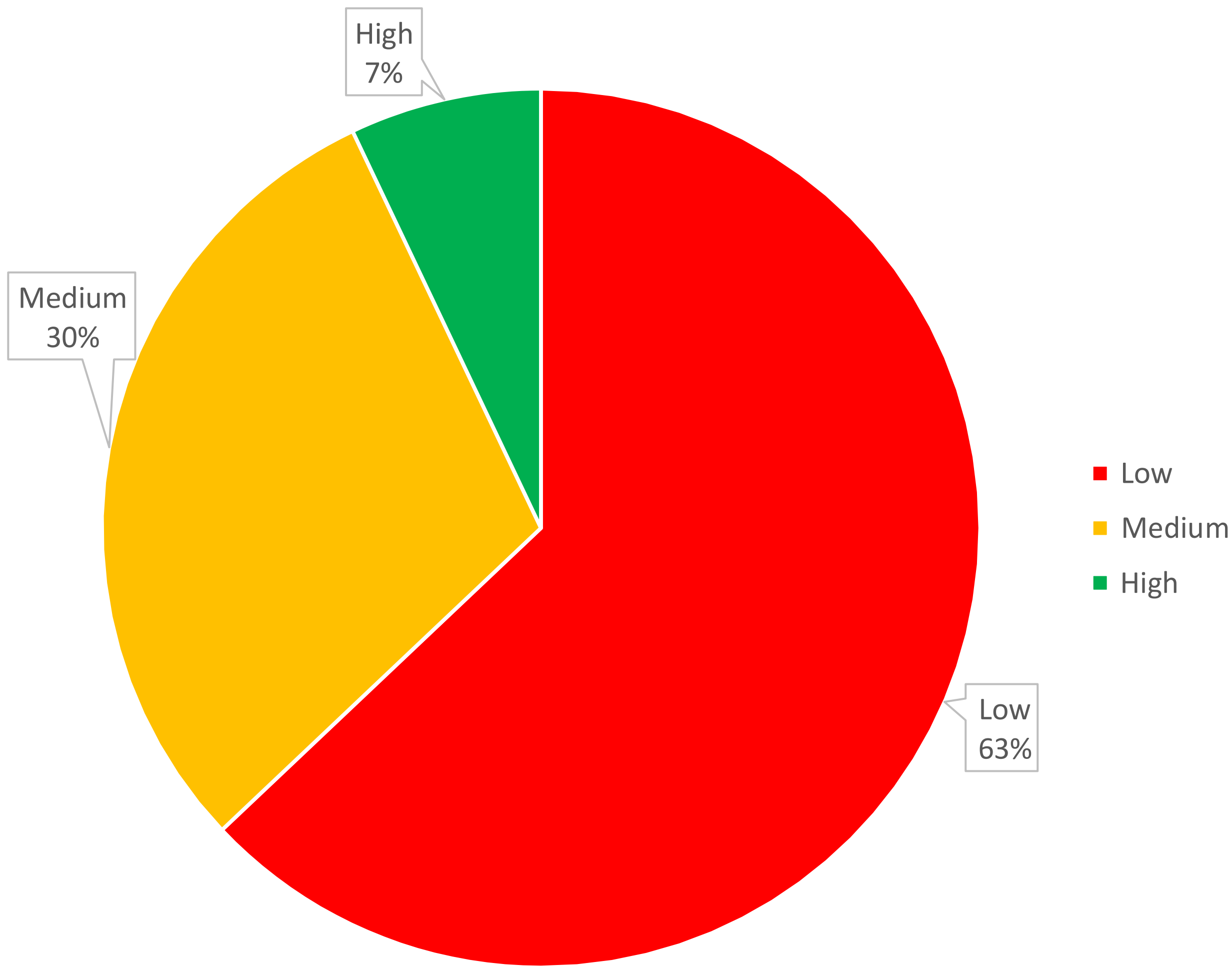

Figure 6: Pie chart outlining the distribution of plots across the ecological integrity rankings of low, medium, and high. Sample size was equal to n = 340. Low corresponds to less than 60% native ground cover, medium to between 60-99% native ground cover, and high to 100% native ground cover.

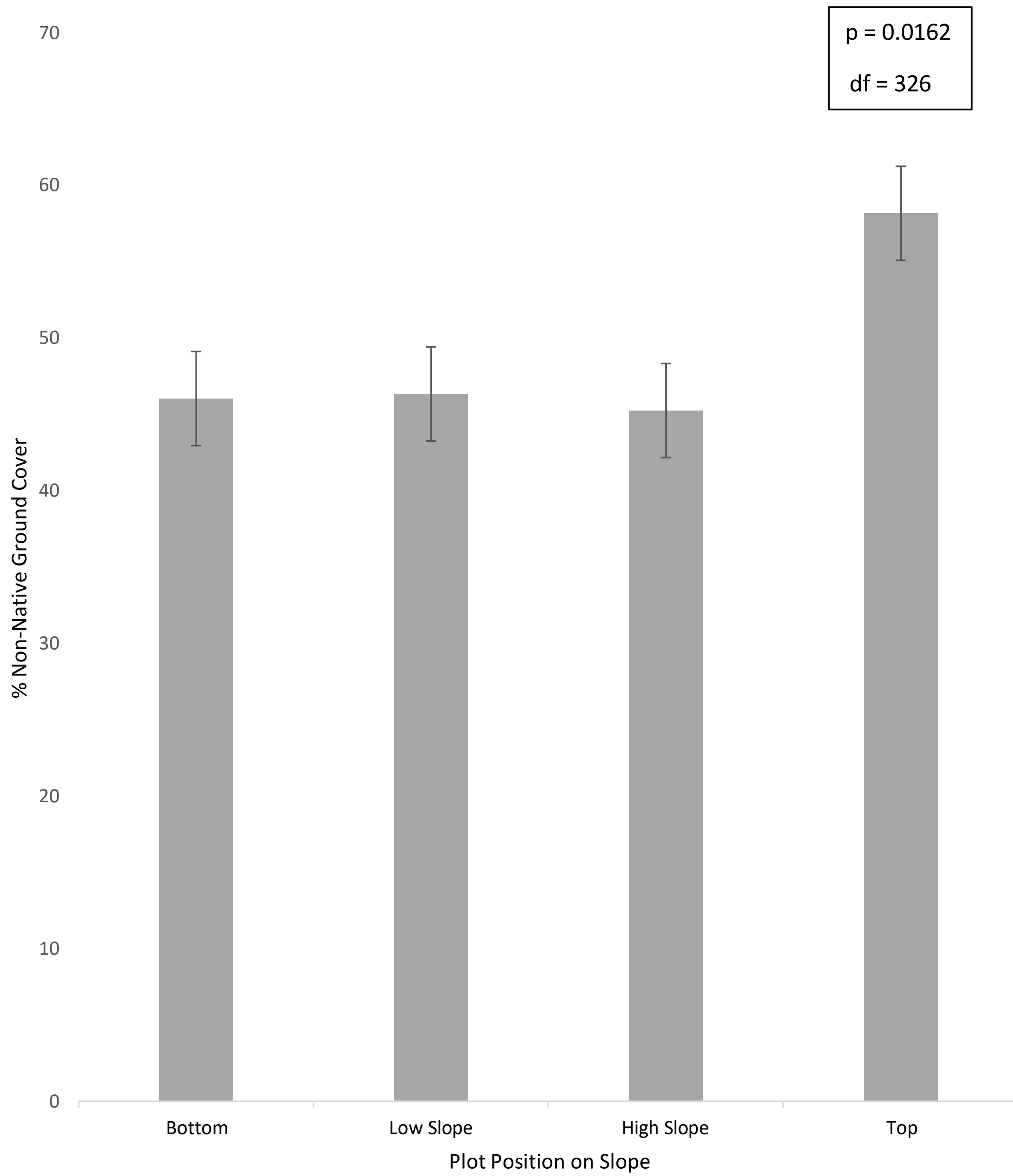

Figure 7: Bar graph displaying mean % non-native ground cover for each plot position along the ravine slopes. The bottom category corresponds to plots located at the bottom of slopes, where the ground is relatively flat. Similarly, the top category corresponds to plots at the tops of ravines where the slope flattens out. The low and high slope categories represent the bottom and top halves of the actual sloped ground. A one-way ANOVA found that plots at the top of the ravines had significantly higher proportions of non-native ground cover – this is likely due to increased propagule pressure from garden escapes coming from residential areas. Surprisingly, the bottoms of slopes had non-native cover proportions comparable to low and high slope plots – while there were indeed high levels of non-native cover around waterways, these bottom slopes also housed plenty of native species, albeit at low ground cover.

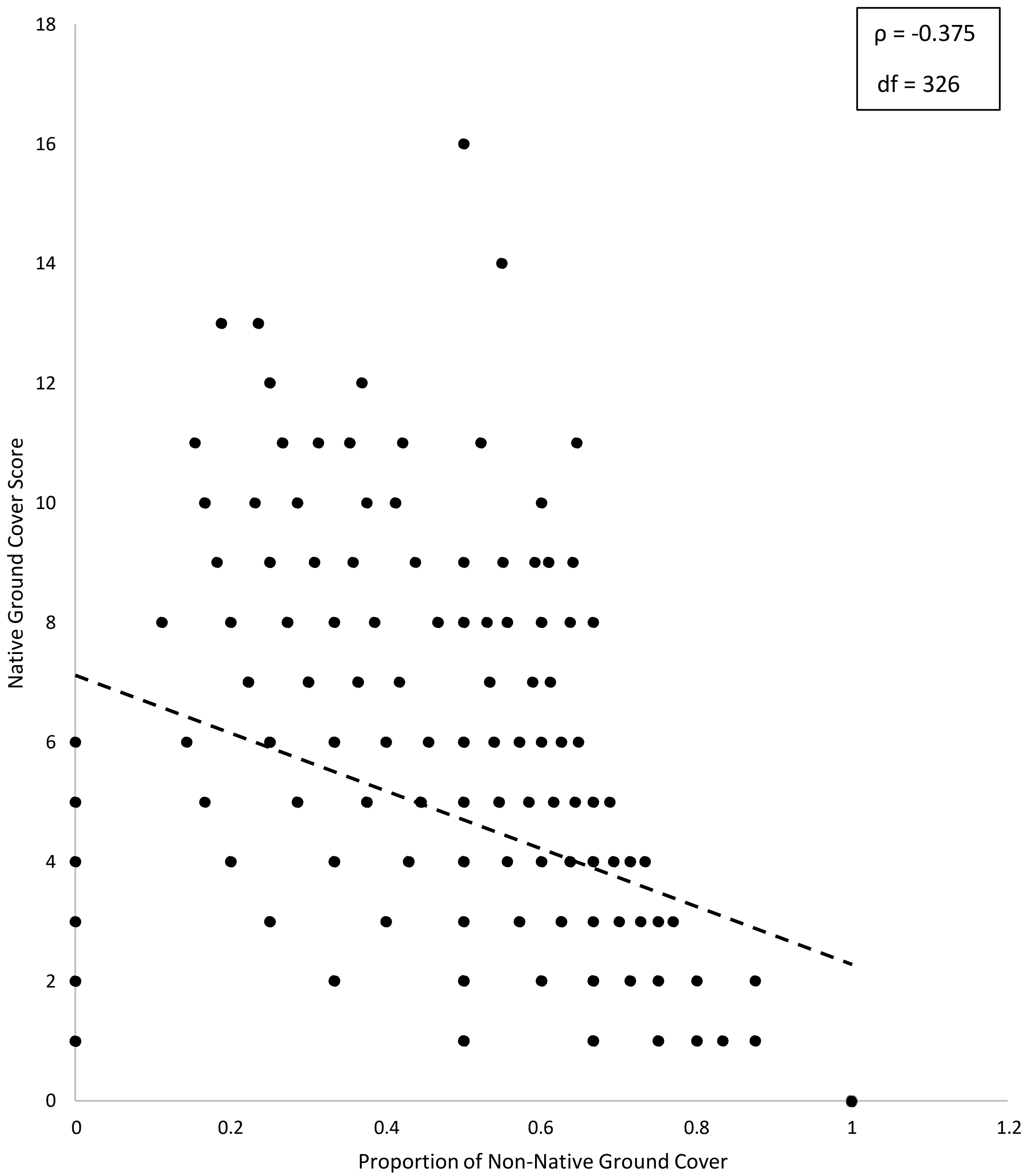

Figure 8: Scatterplot displaying proportion of non-native ground cover plotted against native ground cover. As ground cover was collected as categories (trace, low, medium, high) rather than as numerical estimates, proportion was calculated by assigning each category a score from 1 to 4 (trace to high) and looking at the ratio of native to non-native ground cover this way. For this graph, native cover is represented as the total score per plot rather than as proportion – if both native and non-native cover was taken as proportion, this would have yielded a straight line (e.g. all plots with 60% non-native cover would by nature have 40% native cover). A correlation analysis yielded a Spearman's correlation coefficient of -0.375, which is a fairly high correlation strength given the coarse categories and spatial resolution of the data collected.

An Analysis of Toronto's Urban Ravine Policies and the Achievement of Ecological Integrity

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Masters of Forest Conservation

FOR-3008

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Executive Summary

The city of Toronto contains a valuable urban forest that is composed of street trees, parks and ravines with a combined total of over 10.2 million trees. In order to protect the previous ravines and its native species, the City of Toronto requires strong, meaningful policies that will direct the ecological management of this ecosystem. While policymakers and the managers of urban forests have often relied upon canopy cover objectives as a measure by which to direct management, the use of ecological integrity measures as a standard for guiding management has gained popularity and usage in recent years, particularly following the declaration of Parks Canada, who announced that this principle would become the primary priority with federal parks management system (Parks Canada, 2016). Ecological integrity represents a sound principle for ecological management within urban forest areas, such as Toronto's ravines. This project reviewed the critical policies of the current policy framework that guides the management of the Toronto's ravines to evaluate how well compositional, structural, and functional measures of ecological integrity were protected within this framework. These policies included the City of Toronto Official Plan, the Ravine and Natural Feature Protection By-law of the Municipal Code, and the Conservation Authorities Act. These policies were found to contain provisions which promoted the achievement of certain components of ecological integrity but were inhibited by the scope of their policy framework, lacking clear guidelines and specific management restrictions. Further, it was found that the body of policy governing Toronto's ravines contained no outright restriction on the planting of invasive species, directly compromising the compositional integrity of the ecosystem. To increase the degree to which Toronto's policy framework protects for components of ecological integrity within the ravines, both short and long-term policy recommendation were made. These recommendations included both minor provisions within the existing policy framework, as well as larger changes to the policies which guide ravine management itself.

Table of Contents

Introduction

The City of Toronto contains an urban forest that consists of more than 10.2 million trees (City of Toronto, 2013). These can be found along Toronto's various streets and in parks or private backyards, but also within Toronto's vast network of precious ravines. Toronto's ravines are natural corridors that contain a variety of wildlife and plant species, and also support critical natural processes within the city's densely urban environment (City of Toronto, 2016). While Toronto's ravines account for 17% of the city's total area, they a contain 87% of Toronto's Environmentally Significant Areas (City of Toronto, 2016). Environmentally Significant Areas (ESA's) are natural areas of critical importance to wildlife, plant species and natural processes, and are identified by a criteria outlined within Toronto's Official Plan, which legally protects these areas (City of Toronto, 2015). Not only are the ravines highly valuable to the city of Toronto because they make up the majority of the city's ESA's, but the ravines also provide value to the city and its inhabitants due to the number of ecological, social and economic benefits that are created by this unique urban ecosystem. The ravines provide greenspace for citizens of Toronto to recreate, improving their quality of life, as well as improving the city's aesthetic (City of Toronto, 2013). Additionally, the ravines and urban forested areas like them provide climate and environmental benefits in the form of high temperature mitigation, storm water retention, and improvements to air quality through their ability to filter air pollution (Conway & Urbani, 2007).

However, given that the ravines are a component of Toronto's urban forest, they face the same series of pressures that are symptomatic of this type of ecosystem. Specifically, the ravines are vulnerable a variety of pressures due to their proximity to the rest of the city and, like other urban forests, face a significant amount of anthropogenic disturbances as a result of this (Steenberg et al., 2016). Furthermore, urban forests such as the ravines often face stresses such as invasive species and fragmentation, which may be further exacerbated by divisions in ownership classification within the forest. This is the case within

Toronto's ravines, as 40% of the ravines are privately owned, while the remaining 60% is on public land (City of Toronto, 2013). In order to adequately protect urban forests from the stresses they face, as well as the variety of values they provide cities, strong policy is required in order to effectively guide ecological management of urban forest ecosystems (Steenberg et al., 2016). Toronto's ravines are no different in this regard, as the ravines have been found to be highly susceptible to invasive species, insect pests, diseases amongst its trees and human disturbances. Invasive species have been found to be particularly problematic, as a large proportion of Toronto's urban forest and ravines is heavily dominated by Norway Maple trees (*Acer platanoides)* a non-native, invasive species that impedes the growth and succession of native tree species and other plants within these areas (Millward & Sabir, 2011). Norway Maple trees were heavily favoured for city planting during the mid-1900's due to their ability to thrive while in city conditions, but the invasiveness of this species has had significant impacts on Toronto's ravines and other forested areas resulting in the extirpation of native plant species (Martin, 1999). While the degree to which Norway Maple trees have impacted and impeded native species within the ravines and city has been clearly observed, the City of Toronto does not currently prohibit or restrict the planting of this invasive species within any body of policy, and remains available for citizens to plant this species on their property (Millward & Sabir, 2011). However, given the highly invasive nature of this species and the impact Norway Maple has been observed to have on impeding native plant succession within the ravines, this lack of policy threatens native plant species within the city of Toronto and its ravines. Furthermore, this is exacerbated by the fact that 40% of the ravines are privately owned, resulting in just less than half of the total area of the ravines being open to the planting of this invasive species by private citizens. As the ravines and native species within them already face significant pressure for invasive species such as Norway Maple trees, this lack of policy is highly problematic (Martin, 1999). To ensure that the ravines are able persist within the urban environment, policy that will guide effective ecological management that protects against invasive species and other threats to the ravines is required for this ecosystem.

Policy Background

Unlike other countries, such as the United States, urban forests within Canada are managed by the municipality in which they exist and guided by municipal law (City of Toronto, 2013). As a result of this, the management of the urban forests of Toronto, including Toronto's network of ravines, falls under the jurisdiction of the City of Toronto who develop the body of policy to govern how the ravines are managed (City of Toronto, 2013). However, management of the ravines is impacted by policies from the municipal, provincial and federal levels of government, resulting in a variety of different policies that have varying amounts of influence within this policy framework. Despite this, the management of the ravines are most significantly guided by provincial and municipal policies, and therefore are managed by the City of Toronto and Toronto and Region Conservation Authority, who act on the authority of the provincial government. In addition to the City of Toronto, the majority of the ravines fall within the jurisdiction of the Toronto and Region Conservation Authority, as established by Conservation Authorities Act, which was first introduced in 1946 (Conservation Authorities Act, 1990). This is a provincial piece of legislation which assigns watersheds throughout Ontario to fall under the protection of different conservation authorities. As such, the Toronto and Region Conservation Authority (TRCA) is responsible for the management and protection of the ravines, stream corridors and valleys that fall within the eleven different watersheds under its jurisdiction, as mandated by the government of Ontario (Conservation Authorities Act, 1990). While the TRCA is responsible for a large proportion of the management activity that is undertaken within the ravines and may create management plans, the City of Toronto remains responsible for the development of legislation and policy that has the ability to further guide management specifically related to the ravines and broader urban forest. This is because the body of policy that provides the TRCA its authority in managing, conducting research and various other activities related to their work in the ravines is a broader piece of policy that encompasses and applies to all conservation authorities within Ontario. With this understanding, the City of Toronto is the primary policymaking institution within the context of Toronto's ravines, while the TRCA and City mutually share the management of this ecosystem. Within the City of Toronto's Official Plan, the TRCA is described as partner in managing the ravine ecosystem and natural areas of Toronto, which reflects this relationship (City of Toronto, 2013).

Methodology

This project conducted a policy analysis that critically reviewed policy framework specific to the ravines of Toronto, that the City of Toronto has in place to manage this ecosystem. Toronto's ravines are defined legally, within the Ravine and Natural Feature By-Law, as a "discernable land form with a minimum two-metre change in grade between the highest and lowest points of elevation that may have vegetation cover and that has or once had water flowing through, adjacent to, or standing on, for some period of the year" (City of Toronto, 2008). Policies guiding management on this specific type of ravines land classification were reviewed and analyzed. Policies such as the Federal Species at Risk Act, the Canadian Environmental Protection Act, Invasive Species Act, the Environmental Assessment Act and the Planning Act, while having some influence on ravines management, were not assessed within this project as these policies are not the key drivers of ravine's management in Toronto. It is further necessary to note that Toronto has a Strategic Forest Management Plan (2012-2022) as well as a Parks Plan (2013-2017), both of which actively guide management activities within the ravines. However, these plans are in place for a limited period of time, and must be created in accordance with both provincial and municipal laws and by-laws (City of Toronto, 2008). With this understanding, the framework of policies pertaining to the ravines largely have the power to influence the development of management plans, and management plans must comply with the existing policy framework. For this reason, these legal policies alone were the focus of this study.

The group of policies evaluated specifically included the City of Toronto's Official Plan, the Ravine and Natural Feature Protection By-law (Chapter 658 of the Toronto Municipal Code), and the Conservation Authorities Act, as these are the central policies that most significantly guide the management of Toronto's ravines. To conduct this policy analysis, this project employed the use of ecological integrity as a qualitative metric against which the pertinent City of Toronto policies were each reviewed. Each policy was individually analyzed to determine which of its provisions related to the protection and promotion of the achievement of components of ecological integrity within Toronto's ravine ecosystem.

Methodology – Ecological Integrity

While various frameworks of ecological integrity have been utilized to assess and measure ecosystems, the assessment of policies against this concept is less familiar. As such, it was necessary to develop a framework that would effectively serve to identify policies that contributed to the achievement of ecological integrity within Toronto's ravines. In 2007, Parks Canada released a report titled "Monitoring and Reporting Ecological Integrity within Canada's Parks" which outlined a program by which the ecological integrity of an ecosystem may be monitored and assessed. This has been since readdressed in 2016, at which point Parks Canada released a report on the State of Canada's Natural and Cultural Heritage Places, which proclaimed that from that point forward, maintaining and restoring ecological integrity within Canada's national parks would be the primary priority of the organization (Parks Canada Agency, 2016). Not only does this development mark a clear change in how the federal government will manage parks and natural ecosystems, it characterizes a broader popularization of the use of ecological integrity as a standard to which ecosystems should be managed. The federal government describes an ecosystem as having ecological integrity when it is "characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes" within the

Canada Parks Act, s. 2(1). (Canada National Parks Act, 2000). Within this definition, the ecological integrity of an ecosystem requires that that ecosystem maintain its native components, including both plants and animals, physical structure, as well as its natural processes that allow it to persist (Parks Canada, 2007). Critical components identified within this definition include native species, landscape structure, and natural processes.

While the concept of ecological integrity as a method by which to guide ecological management has become widely used within the context of larger wilderness areas and national parks, its use within urban forest management plans remains less developed (Ordonez & Duinker, 2012). This represents an important next step in urban forest management, which has previously revolved around canopy cover goals for the direction of management rather than comprehensive management criteria based on the urban ecosystem itself (Kenney et al., 2011). However, the diversity of ecosystems in which ecological integrity is used as a measurement of an ecosystem requires that ecological integrity be transferrable as a method of ecological monitoring throughout different regions (Ordonez & Duinker, 2012). This requirement of applying the concept of ecological integrity broadly is also relevant in using ecological integrity as a method by which to analyze policy. In order to effectively analyze different policies in the context of ecological integrity, it is necessary to identify key criteria of ecological integrity. Many indicators of ecological integrity have been developed for various different ecosystems, but a consensus throughout the literature on ecological integrity is that compositional, structural, and functional measures are the critical components of ecological integrity (Tierney et al., 2009) (Reza & Abdullah, 2011). For this reason, this project utilized these three components of ecological integrity as criteria by which to examine policy.

The compositional component of ecological integrity is concerned with the various species within the ecosystem of focus, measuring the composition of the species that are present, as well as to what extent those species are native or invasive (Reza & Abdullah, 2011). Achieving a high level of compositional ecological integrity would prioritize the insurance that native species pools occupy the ecosystem, while invasive species do not (Tierney et al., 2009). With this understanding, policy that protects for the compositional measures of ecological integrity within an ecosystem would aim to maintain and promote native wildlife and plant species and control for invasive species. Next, the structural component of ecological integrity is largely concerned with the physical environment and landscape of the ecosystem itself and ensuring that the ecosystem has the necessary physical requirements to support the compositional and functional aspects of the ecosystem (Taylor et al., 1993). While this is largely related to ecosystem resilience, policies that would protect or promote the structural component of ecological integrity would be those that maintain an ecosystems ability to be resilient and intact (Tierney et al, 2009). For example, this would include policies that mandate the retention of a certain volume of coarse woody debris (CWD), standing deadwood or protect the ecosystem from destruction to the landscape (Tierney et al., 2009). Maintaining the physical structure of the ecosystem is key to this component. Finally, the functional component of ecological integrity concerns the critical processes of an ecosystem. This may include ecological, hydrological, or even evolutionary processes, but is concerned with an ecosystems ability to be self-organizing, resilient and sustainable (Reza & Abdullah, 2011). Within this regard, policies that benefit tree growth rates or nutrient cycle of an area by protecting the ecosystem from contaminants or other threats to that ecosystem may contribute its functional ecological integrity (Tierney et al., 2009). While a variety of different ecological integrity frameworks exist, the majority of work on the topic concludes that measures of composition, structure and function are the three critical components of ecological integrity criteria for an ecosystem (Tierney et al., 2009) (Reza & Abdullah, 2011). This project relied upon a qualitative analytical framework that was structured around these three components of ecological integrity and analyzed how effectively the City of Toronto's different policies, that direct management within the ravines, achieve protection for these ecological integrity measures.

Results

The City of Toronto's Official Plan

The City of Toronto's Official Plan contains policies that lend themselves to the achievement of compositional, structural and functional measures of ecological integrity within Toronto Ravines. However, the language utilized within the Official Plan limits how effective these policies are in enforcing certain ecological standards due to their lack of specificity and explicit requirements regarding the ravines. Policy 3.4.1. (a) i) and ii) of the Official Plan both concern minimizing and containing soil, and groundwater contaminants (City of Toronto, 2015). Ensuring contaminants are removed from soil and groundwater benefits the nutrient cycle of the ecosystem and serves as a benefit to the functional component of the ravines ecological integrity (Tierney et al., 2009). However, due to the language of this policy, there is no specific requirement on ensuring or minimizing contamination; the requirement is only that efforts occur. As there is no measureable requirement set for the extent to which soil and groundwater contamination must be minimized, the policy is flexible and does not mandate the strict avoidance of all contaminants from the ecosystem (City of Toronto, 2015). This is seen again within section (a) iv) of the same policy, which requires the release of invasive species only to be minimized, not restricted. While the aim of this policy is to contribute to the compositional integrity of the Toronto's urban forest and ravines, assisting the regeneration of native species, it limits its success in this objective by failing to employ decisive language within the policy framework that will effectively restrict the proliferation of invasive species (City of Toronto, 2015).

Ravine and Natural Feature Protection By-law

Chapter 658 of the Toronto Municipal Code, known as the Ravine and Natural Feature Protection By-law, evolved from a series of former by-laws that governed the ravines within Toronto, and is now a singular by-law applying to all ravine areas that fall within the description outlined within this policy. Alternative to the Toronto Official Plan, provisions within the By-law are specific in their requirements and objectives, creating clear restrictions and constraints on certain activities within the ravines. The provisions within this policy protect the ravine ecosystem by prohibiting the "injury or destruction of trees", alternation of the slope or grade of land, and the filling, grading, dumping of soils and other materials within the ravines (City of Toronto, 2008). The by-law mandates that for these activities to occur, a permit must first be attained by the applicant, submitted to the General Manager of Parks, Forestry and Recreation, and approved. In cases where the permit is requesting the removal of a tree, the permit must include a detailed tree inventory, protection plan, tree removal plan and also a tree replacement plan. Alternatively, in cases of a permit requesting to alter the grade of land within the ravines, the applicants permit must include a plan showing existing site conditions, a future drainage plan and a geotechnical report of the area (City of Toronto, 2008). The By-law lists the 14 contexts under which permits for the removal of trees or alternation of land grade may be approved by the General Manager and four additional criteria under which a permit may be issued with conditions. These contexts for permit approval include conditions such as those in which tree removal is required for the remediation of contaminated soils, tree removal required as it is threatening structural damage of a building, or if in cases where the tree or landscape change is required based on an approved ravine restoration or forest stewardship plan (City of Toronto, 2008). Conditions under which a trees removal does not require a permit require that the tree be certified by the General Manager as dead or highly diseased. Additionally, changes in land grade or slope may occur without a permit if the area of concern and change is minor (grade change $<10\%$ and 5 cubic metres), or if the change is being managed by the TRCA (City of

Toronto 2008). While there are some changes under which the Ravine and Natural Feature Protection By-law allow for the removal trees and alternation the physical landscape within the ravines, this policy effectively mitigates these alternations to the natural landscape. In this way, the Ravine and Natural Feature Protection By-law protects the both the structural and functional elements of the ravine ecosystem by prohibiting interference and destruction of the trees, forest structure, and physical landscape conditions within the ravines. The Ravine and Natural Feature Protection By-law does not contain policy provisions that contribute to compositional measures of the ravine's ecological health.

Conservation Authorities Act

The Conservation Authorities Act, R.S.O. 1990, C.27, is a provincial statute that first came into force in 1946, now a Revised Statute of Ontario (R.S.O.), that governs and assigns 36 conservation authorities throughout Ontario to the management of their respective jurisdiction based on watersheds (Conservation Authorities Act, 1990). Section 5 of this statute designates the Toronto and Region Conservation Authority (TRCA) as responsible for 11 watersheds within the Greater Toronto Area. The Conservation Authorities Act establishes the TRCA as having power to conduct research within their jurisdiction, create structures and reservoirs through dam construction in areas susceptible to flooding, and also regulate the dumping of fill in areas significant to the control of flooding and pollution (Conservation Authorities Act, 1990). An important amendment to the Conservation Authorities Act was included in 2006, which expanded the area regulated by conservation authorities as well as the regulatory authority of the TRCA. This mandated that any development, site alteration, construction, or placement of fill by property owners within these regulated areas would first require a permit from the respective conservation authority (Lyons, 2015). This regulation is known was Ontario Regulation 166/06, and it focuses largely on protecting waterways and stream corridors within the TRCA's jurisdiction, which serves to benefit both structural and functional elements of the ravine ecosystem. Specifically, this regulation within the

Act assists in primarily protecting and regulating critically important hydrological processes within Toronto's ravines. Furthermore, the regulation of dumping and site alterations within the TRCA's jurisdiction protects the physical structure of the ravines, in addition to limiting pollution within the ravines and thereby contributing to the nutrient cycle's protection and the ravines functional processes (Lyons, 2015) (Tierney et al., 2009). Similar to the Ravine and Natural Feature Protection By-law, the Conservation Authorities Act does not contain policy provisions that protect for the compositional integrity of the ravines ecosystem, or other protected areas under TRCA authority.

Discussion

Both the Toronto Official Plan and the Conservation Authorities Act are policies that are broad in scope. The Toronto Official Plan contains a variety of policy issues ranging from regulating public transportation within the city to concerns regarding economic growth, while the Conservation Authorities Act is a provincial policy that concerns the assignment of over 30 conservation authorities throughout the Ontario (City of Toronto, 2013) (Conservation Authorities Act, 1990). Within the context of the Toronto Official Plan, the lack of detailed objectives within these policies is likely a symptom of the nature of this piece of legislation, as the Official Plan has a broad spectrum of objectives and covers a variety of policy issues. As a result of this, the Official Plan provides numerous provisions on a variety of topics and develops broad goals and directions for these policies, but lacks the specific objectives that contain measurable standards and strict directives to guide management within policy areas such as the ravines. However, the provisions within policy 3.4.1 of the Toronto Official Plan remain beneficial to the achievement of ecological integrity measures within Toronto's ravines as they identify the need to preserve growing environments for trees, improve habitat for native species, regulate the removal and destruction of trees, and support physical processes of Toronto's natural areas (City of Toronto, 2015). Each of the policy sections identified within Toronto's Official Plan by this project have been found to contribute to the compositional, structural and functional components of the ravine's ecological integrity, but remain limited in their ability to mandate stronger ecological requirements for this ecosystem due to a lack of measureable requirements within provision and the broad scope of this particular policy. Despite this, the Toronto Official Plan still contains policy provisions that contribute towards the compositional, structural, and functional measures of the Toronto ravine's ecological integrity. The Official Plan repeatedly states its prioritization of native species, as well as the need to regulate the destruction of trees, contributing to the ravine's compositional integrity (City of Toronto, 2013) (Tierney et al., 2009). Further, the Official Plan includes provisions discussing the need to minimize and remediate soil and water contamination within the city's natural areas, control invasive species and maintain a growing environment for trees within the ravines (City of Toronto, 2013). These provisions serve to benefit compositional, structural and functional aspects of the ravine ecosystem by guiding the management plans and management activities to pursue these objectives, despite their lack of specify (Reza & Abdullah, 2011).

The Ravine and Natural Feature Protection By-law of Toronto's, Chapter 658 of the Municipal Code, includes clear restrictions and guidelines within its policy framework, prohibiting certain land activities within the ravines or requiring the acquisition of approved permits prior in order to authorize physical changes within the ravines. Specifically, the Ravine and Natural Feature Protection By-law prohibits the removal and destruction of trees within the ravines, as well as the dumping within the ravines, and alterations of the slope and grade of land. While the by-law provides that these activities may occur when a permit to do so is attained and approved, the series of conditions under which a permit may be approved do not appear to allow for the compromise of the ravine's ecological integrity and are most often approved when justified by a greater ecological objective. One exception to this can be found under sections 658-6(2) and 658-6(3) of the By-law. Section 658-6(2) states permits may be obtained,

> "Where site plan approval, subdivision approval, consent or Committee of Adjustment approval under the *Planning Act* has been obtained, and:
>
> (a) Tree injury or destruction is required based on plans approved by the Ontario Municipal Board, City Council, or a final and binding decision of the Committee of Adjustment.
>
> (b) The placing or dumping of fill or the alteration of the grade of land is required based on plans approved by the Ontario Municipal Board, City Council, or a final and binding decision of the Committee of Adjustment.
>
> (3) Where a building permit, front yard or boulevard parking permit or permission for driveway widening has been obtained, and:
>
> (a) Tree injury or destruction is required to facilitate construction in accordance with an approved permit or permission.
>
> (b) The placing or dumping of fill or the alteration of the grade of land is required in order to facilitate construction in accordance with an approved permit or permission."

(Ravine and Natural Feature Protection By-Law: Toronto Municipal Code, 658-6(2-3). 2008.)

Both of these provisions allow for the destruction and removal of trees, as well as the dumping of fill and alteration of grade of land based on building requirements for parking lots, subdivisions, or other structures, so long as the building has attained the necessary permits (City of Toronto, 2008). Unlike the other conditions within the by-law that allow for the approval of a tree removal or grade change permit, these provisions are not based on ecological considerations or the betterment of the ravine ecosystem. While the majority of this by-law protects for structural and functional elements of the ravines by limiting damage to the forest and landscape structure within the ravines, as well as disturbances to the grade of land that are critical to natural processes within the ravines, these particular provisions represent a gap within the policy, leaving the areas of the ravines vulnerable to development. An additional policy gap within the by-law is the lack of focus on compositional measures of ecological integrity within the ravines. Specifically, the by-law lacks planting guidelines, restrictions, or any other measure to control invasive species within the ravines and also fails to include measures to prioritize and promote native species against invasive species pressure. Due to extent to which the ravines and its native species have been observed to be vulnerable to invasive species pressure, particularly Norway maple trees, this appears to be an obvious gap which requires attention (Martin, 1999).

The Conservation Authorities Act contains provisions within it that provide more specific measures of regulation than the Toronto Official Plan, including clear limitations on dumping and filling, restrictions on development within the TRCA's protected stream corridors and waterways in order to maintain hydrological processes. While this serves to protect structural and functional aspects of the ravines ecological integrity, the Conservation Authorities Act does not contain regulations that contribute to compositional aspects of the ecosystem's ecological integrity. This reflects a gap in the achievement of policies pertaining to the achievement of ecological integrity within the ravines, as structural and functional components of the ravines are protected with the body of provisions, while compositional aspects of the ecosystem are not. The Conservation Authorities Act also regulates development within its protected areas, ensuring that no development can be undertaken without the approval of a TRCA permit (Conservation Authorities Act, 1990). This serves to assist in 'filling' the policy gap within the Ravine and Natural Feature Protection By-law's lack of regulatory power limiting development, as it contains greater conditions pertaining to protecting hydrological processes, such as ensuring any proposed development has a detailed drainage plan (Conservation Authorities Act, 1990).

Policy Recommendations

Strong policy that is well constructed is necessary in order to effectively guide ecological management within the ravines. Unlike a management plan which may be relevant for a specific park or time frame, a policy has binding legal authority over the issues that it outlines, until that policy is replaced, amended or removed (Béland, 2009). A policy that pertains to Toronto's ravines, has binding authority over all areas that fall under the outlined definition of ravines within the Toronto. This provides policies a widespread, authoritative impact on policy subjects, allowing them the potential to serve as highly effective tools to guide management in an impactful way. However, when policy gaps are identified and policy change is required to in order to improve management outcomes, the process of policy change has been observed to face institutional constraints that impede how this change can occur and resulting in the process of policy changing becoming one that is incremental (Béland, 2009). For this reason, seeking to make policy changes and recommendations to a body of policy that is less broad and therefore less constrained by varying objectives, is more easily amended and changed than one with a broad scope of policy objectives (Béland, 2009). Due to these considerations, the process of policy change for the Toronto Official Plan, or the Conservation Authorities Act would face a greater series of institutional impediments compared to the process of policy change for the Ravine and Natural Feature Protection By-law, which is a municipal body of policy with a more concentrated focus of objectives. Further, previously conducted amendments to the Ravine and Natural Feature By-law are encouraging that this by-law could be further adapted for the betterment of the ravines, towards the achievement of greater ecological integrity within a shorter period of time (City of Toronto, 2008). For this reason, both short and long-term policy recommendations have been made. Short-term policy recommendations have been created within the context of the Ravine and Natural Feature Protection By-law's policy framework, while longer-term recommendations have been made towards the Toronto Official Plan, as well as towards new policy for the City of Toronto.

Short-term Recommendation

To begin with a short-term recommendation, within section 658-5 B. 3(d), 658-6 A. 12(c), 13(c), 14 (b) 658-6 B. 1-3, the by-law contains guidelines which mandate the replanting of new trees to replace damaged or injured trees that have been removed, as well as trees that have been removed for the purposes of development and soil remediation. A simple yet highly beneficial amendment to these provisions would be to require that all tree replanting guidelines and provisions require the planting of native species of trees native species within the ravines, benefiting the native composition of the ecosystem. This would serve as an ongoing benefit to the ravine's native species composition, while working within pre-exiting policy provisions, as these replanting guidelines currently exist within the by-law. Next, to further benefit native species and control for invasive species within the ravines, it is recommended that an outright prohibition be introduced on the planting of invasive, non-native species within the ravines, such as Norway maple. This policy provision would effectively forbid the planting of invasive species within the areas outlined by the Ravine and Natural Feature By-law.

An additional policy that is recommended to be made in the near to immediate future is the adoption of the Toronto Ravine Strategy. The Toronto Ravine Strategy is an ongoing project that seeks to guide the policy and management of Toronto's ravines, and prioritizes the restoration of ecological integrity within the ravines (City of Toronto, 2016). While the Ravine Strategy is currently going through the City of Toronto's policy process and ultimately awaiting budgetary approval and the adoption of the final strategy, it would serve to be highly beneficial and improve the policy framework surrounding the Toronto ravines, allowing for the greater protection ecological integrity within this ecosystem. One such component contained in the Toronto Ravine Strategy that would bolster ecological integrity is proposed requirement of management plans for all Environmentally Significant Areas within the City of Toronto. It is recommended that the Toronto Official Plan, the body of policy which designates ESA's, require that management plans be created for all ESA's in order to better ensure their preservation. As Toronto's ESA fall under the varying ownership of the Toronto and Region Conservation Authority, the City of Toronto, and private citizens respectively, it is necessary to mandate the requirement of management plans for ESA's by way of policy to ensure that ESA's within each of these different ownership categories are forced to have management plans created. Mandating this action by way of policy will assist in ensuring this action occurs, despite the challenge created by varying public and private ownership categorizations. However, given that this policy recommendation can be expected to create more significant impacts on the structure of ravines management, it requires a greater amount of time to attain institutional approval, as demonstrated by the current Toronto Ravine Strategy timeline, which has been underway for well over three years (City of Toronto, 2016). For this reason, this policy recommendation of adopting the final Toronto Ravines Strategy and mandating the creation of management plans for all Toronto ESA's has been established as a long-term recommendation.

A final, long-term policy recommendation relates to Toronto's Official Plan. While Toronto's natural areas are prioritized within this plan, the ravines themselves are not specifically designated under individual policy provisions. As the ravines represent a unique and valuable natural ecosystem to the City of Toronto, it is recommended that an amendment be made to the Official Plan to prioritize and protect the ravines specifically. Further, within the wording of this policy provision, it is recommended that ecological integrity be used as the standard to which the ravines are directed to be managed, "protecting and promoting compositional, structural and functional measures of ecological integrity within the ravines". While the adoption of the Toronto Ravine Strategy will greatly benefit the management of the ravines, the Toronto Official Plan represents a superior body of policy. For this reason, it will serve as beneficial to the ravines to acknowledged and protected within this policy.

Conclusion

Toronto's urban forest, and the highly valuable ravine ecosystem within it, is a precious resource to the city of Toronto that requires protection in order to ensure its longevity. In order to protect the ravines, strong policy is required to guide ecological management and sufficiently protect the ravines from the various pressures that it faces, such as invasive species and urban development. This requires policies that go beyond canopy cover objectives and instead represent a nuanced policy framework that is reflective of the different requirements of the ecosystem over which they govern. By reviewing the body of policy that guide the Toronto ravine's ecological management for provisions that protect compositional, structural and functional components of the ecosystem, this project analyzed these policies to determine how effectively they protected and promoted the ecological integrity of the ravines. While the Toronto Official Plan contained a variety of provisions that related to the benefit of compositional, structural and functional measures of ecological integrity, these provisions were non-specific and lacked clear guidelines that could be enforced within the ravines and natural areas. Next, the Conservation Authorities Act contained clear measures and restrictions with its framework, particularly protections for structural components of the physical landscape, as well as protections for stream corridors and waterways within the TRCA's regulated area, maintaining functional, specifically, hydrological, processes. Finally, the Ravine and Natural Feature Protection By-law was found to maintain both structural and functional processes through restrictions within the by-law, limiting the destruction and removal of trees, as well as the alteration land grade or filling within the ravines. However, both the Conservation Authorities Act and the Ravine and Natural Feature Protection By-law failed to include provisions that protected the ravines against invasive species, and lacked considerations towards the composition of the ecosystem. It is imperative to note that this analysis strictly assessed the policy framework that guides management within the ravines, identifying gaps within that framework. Both the TRCA and City of Toronto conduct management activities that go beyond the mandated requirements of the bodies of policy which direct them, however what is important to understand about this is that stronger policy requirements for the ravines have the ability to increase the standard of management that must be achieved within this ecosystem. This represents the opportunity for ecological integrity to be placed within the policy framework of the ravines as a management guiding priority.

While policy gaps were identified within each of the policies, short and long-term policy recommendations were made for the Ravine and Natural Feature Protection By-law and Toronto Official Plan, as well as the forthcoming Toronto Ravine Strategy. Policy recommendations were made within the current policy framework to allow for the achievement of greater measures of ecological integrity protection within a short period of time, but recommendations were made to the policy structure surround the ravines as a whole. While these recommendations will require a greater amount of time to achieve due to the institutional constraints the inhibit the process of policy change, they will create more meaningful protection of ecological integrity within Toronto's ravines and mandate management based on the requirements of this ecosystem. This has been repeatedly acknowledged as an effective basis for the sustainable management an ecosystem, as the compositional, structural and functional components of an ecosystem may act as indicators for the integrity of that ecosystem, assisting managers in the formation of management objectives and direction (Reza & Abdullah, 2011).

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