Management of Urban Ecosystems and the Application of the Novel Ecosystem Evaluation Framework in the City of Kitchener

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is the true copy of the thesis, including any required revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Increasing urbanization and the impacts associated with human settlements are major factors in the degradation of ecological integrity and main contributors to the emergence of novel ecosystems. As landscapes across Southern Ontario change from near natural to human dominated systems, ecological changes are inevitable and changes to natural area and ecosystem integrity will occur. Understanding how to adapt to, and manage, ecosystem changes and new or novel ecosystems is a challenge for resource managers from local to global scales. The utility of the novel ecosystem framework as a tool for natural area and ecosystem management was investigated and applied in a case study to management challenges occurring within publically owned natural areas in the city of Kitchener. Using multiple evaluation techniques commonly available to municipal and resource agency managers, and applied in the form of a rapid assessment, this study considered how impacts associated with human recreation activities, housing encroachments, invasive species and informal trail networks contribute to the development of hybrid and novel ecosystems and to the selection of alternative management approaches. A series of individual natural area case examples further highlight the applicability of the framework. Results of the rapid assessment for human impacts, ecological indicators and comparative changes in species richness of several parks are analyzed in the context of their contribution to current state of ecological integrity and in their manifestation as barriers to management and restoration. Various scenarios, goals, targets and objectives for managing sites on hybrid and novel trajectories are discussed. The results of this study show that the synergistic effect and multiplicity of issues occurring within and external to natural areas often coalesce to act as barriers for management and restoration that is directed solely towards historic ecosystem conditions. By adopting a hybrid or novel ecosystem approach, managers have practical, forward-thinking and goal oriented options for managing urban ecosystems, especially when faced with limited resources and when working in ecosystems and natural areas that are disturbed and in various states of degradation.

Acknowledgements

My experience as a grad student over the past several years has been enhanced and influenced in so many ways by the presence and support of the amazing people in my life.

I am greatly indebted and forever thankful to Dr. Stephen Murphy who has helped me move through this process with ease and has given me the encouragement to become a better ecologist, stronger researcher and a more confident ecosystem manager. Secondly, to Dr. Andrew Trant, I can't express enough my sincere appreciation for all that he has done to help me bring this project to fruition. I greatly appreciate all the time and effort in helping me through these final and most important stages of my thesis.

Throughout this process, I have been fortunate to have the full support from my employer, the City of Kitchener and my Supervisor, Dan Ritz who encouraged me to take on this challenge and apply the work that I do to the pursuit of further knowledge. I also greatly appreciate the involvement and work of Les Misch, our Natural Area Technician for all of his dedication and commitment to the field work that went in to the assessment of our natural areas. I would also like to acknowledge and thank Theresa McKenzie from the Toronto and Region Conservation Authority for all of her assistance in developing the indicator monitoring program. With this, I am also very thankful for the volunteers who participated in the ecological indicator monitoring aspect of this project. The power of volunteerism and the value of citizen science were in full swing during this project.

I find myself in the position that I am in today in large part due to the support, encouragement and guidance of my family. Especially, to my Grandfather Myette who taught me how to discover nature and to my parents for ensuring that I could always be somewhere in the presence of plants and animals where I would be free to explore, discover and enjoy. Lastly, I could not have completed this project without the support and constant encouragement of Jill, my loving companion and partner in life. She has supported my every step and is here beside me now as I walk away from this journey with a greater understanding about ecology and a stronger passion for making a difference in our world.

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Chapter 1: Human Impacts, Urban Environments and Novel Ecosystems

Over the past 50 years, humans have caused the demise and disappearance of ecological communities resulting in social, political and economic implications with no foreseeable change in this trend (Millennium Ecosystem Assessment [MEA], 2005). Globally, this influence has increased with urban settlement which is troubling considering that by 2009, the number of people living in urban areas (3.42 billion) had surpassed the number living in rural areas (3.41 billion) creating an urban dominated world (United Nations, 2010). In Canada, 80% of the population lives in urban areas (Statistics Canada, 2011). Urbanization (conversion of land to industrialized and residential areas) significantly influences the functioning of ecosystems and the associated services they provide to humans (Alberti, 2005) which has a direct impact on human well-being (Millennium Ecosystem Assessment, 2005). The impacts of urbanization and the topic of urban-ecology has been the focus of many recent studies and has evolved into a sub-discipline of scientific study which incorporates humans as part of the environment (see Alberti et al., 2003 and Pickett et al., 2011 for a summary and review of urban ecology studies; see also Alessa & Chapin III, 2008).

1.1. Urban Ecosystems

Urban ecosystems are those eponymous where people live at high densities[1] with impervious surfaces (greater than 20%) covering the majority of the overall land surface (McKinney 2002). These types of ecosystems are often characterized as falling somewhere along a gradient between the built-up urban core and the urban fringe (McDonnell & Pickett, 1990; McDonnell et al.,1997) and comprise the forests, fields, wetlands and woodlots that were either purposively set aside for resource preservation (considered surplus open-space) or have re-established following urban development (Mertes & Hall, 1995). Urban natural areas are important for regional and global biodiversity, as they provide corridors for species movements, facilitate research and an applied understanding of ecosystem (and species) response to changes, contain high potential for resilience and provide numerous and direct ecosystem services (Dearborn & Kark, 2010; MEA, 2005). These areas also represent important locations where

[1] In Canada, an urban area is defined as having a population of at least 1000 and a density of 400 or more per km^2 (Statistics Canada, 2011).

people interact with natural surroundings (Miller & Hobbs, 2002; Swanwick et al., 2003) and participate in recreational activities such as hiking, biking and riding motorized vehicles (Ballantyne et al., 2014). The ability to educate urban people about human impacts can also greatly improve species and ecosystem conservation (McKinney, 2002; Ramalho & Hobbs, 2011).

The process of urbanization has resulted in the conversion of naturalized landscapes into housing developments, business districts and other human occupied lands and is having a significant impact on biodiversity (McDonnell et al., 1997, McKinney, 2002). All ecosystems are affected by the same general factors: climate, substrate, resident organisms and their residual effects, including relief, elevation, slope, aspect and history or the time over which these factors have been interacting (Pickett et al., 2011). In general, the conversion of natural landscapes into human landscapes affects the structure and function of the remnant ecosystems through alteration of biophysical processes, modification of habitats and interference with major biogeochemical cycles (Vitousek et al., 1997; Alberti, 2010). Negative impacts on urban natural areas can occur at both coarse and fine scales. At the coarse scale, urban development replaces productive agricultural lands and impacts connectivity between wildlife habitats reducing biodiversity while alterations of the abiotic-biotic interface typically occur at the immediate level or as a result of fine scale impacts (McWilliam et al., 2014). The fine-scale impacts appear as a result of the density and proximity of housing developments when located close to woodland cores and in direct interference of wildlife corridors which creates a negative abiotic and biotic flow (McWilliam et al., 2014). Some of these impacts have been shown to depend on size of protected area and housing density (Parks & Harcourt, 2002; Stenhouse, 2004), ability to implement proper planning and protection measures (McWilliam et al., 2012) and in the actual planning of public access and conservation objectives for individual parks (Ruliffson et al., 2003). Many studies have looked at the direct impacts of housing developments and have identified some of the key impacts occurring in nearby natural areas as vegetation trampling that causes reductions in soil organism diversity and soil fertility (Malmivaara-Lamsa & Fritze, 2003), reductions in local vegetation diversity (Stenhouse, 2004; Sukopp, 2004); reduction in wildlife biodiversity (Friesen et al., 1999); encroachment of private property (e.g., garden shed, plants, etc.) onto public property (McWilliam et al., 2010); recreation impacts (e.g., litter, campfires, structures etc.) and trail erosion (Lynn & Brown, 2003); dumping of garden refuse acting as an invasive species transport mechanism

(Hodkinson & Thompson, 1997) and as a general contributor to invasive species introductions (Robinson, 2008).

Humans have so drastically altered the global environment that human-dominated systems now cover more of the Earth's surface than 'wild' ecosystems (Vitousek et al., 1997) with more than one-third of ecosystems worldwide having been converted for human use and at least another one-third considered severely impacted or degraded (MEA, 2005). As Ellis & Ramankutty (2008) suggest, anthropogenic biomes, or anthromes cover more than 75% of the ice-free, terrestrial landscape. These 'anthromes' are best characterized as heterogeneous landscape mosaics that combine a variety of different land uses and land covers with natural ecosystems embedded within a matrix of lands that are altered by human populations.

Urban areas have become locations which are driving global environmental change (Grimm et al., 2008) causing detrimental ecosystem impairments and associated effects including: loss of specialized species (and gain in generalized species); proliferation of the urban heat island effect; colonization by invasive species; simplification of community structure, reduction of microclimate control, change in frequency and distribution of plant life; impacts on overall species richness, losses of beneficial soil properties, reduction in the capacity to retain nutrients, store carbon and regulate moisture (Clewell & Aronson, 2007, p169; Eigenbrod et al., 2011; Hooper et al., 2005; Kowarik, 2011).

The fragmentation of landscapes has serious environmental and ecosystem level implications as it contributes to an overall decrease in native vegetation in favour of exotic species and greater threats to native wildlife populations (Marzluff & Ewing, 2001). The change in landscape also decreases species richness and modifies interactions among species (Debinski & Holt, 2000). Rarely does urbanization manifest itself in the simplistic linear manner proposed by McDonnell (1997) but rather contemporary cities have developed in complex, non-linear forms. As Ramalho & Hobbs (2011) suggest, contemporary cities differ markedly from historic patterns of growth, and as consequence, the ecological implications and perceived impacts also appear in complex ways.

In addition to urban ecosystems serving critical purpose for biological conservation, there is also a pressing need to conserve intact and functioning ecosystems for the provision of ecosystem services. The protection of urban ecosystems for human well-being involves first recognizing that functioning ecosystems are critical for human survival and second, ensuring through preservation, active management and intentional ecological restoration, that these essential systems continue to persist intact and in perpetuity. Ecosystem services include provisioning services (fresh water, timber, fuel and industrial products) regulating plus supporting services (nutrient cycling, climate and air quality, regulation of natural hazards) and cultural services (MEA, 2005). Globally, there are ten identified ecosystems or ‘systems’ that are considered essential to human well-being and have been assessed. These include: marine fisheries systems, coastal systems, inland water systems, forest and woodland systems, dryland systems, island systems, mountain systems, polar systems, cultivated systems and urban systems (MEA, 2005). Human dominated landscapes are characterized by complex mosaics of ecosystems or patches in varying states of modification, each of which delivers various combinations of services and presents assorted management challenges and opportunities (Hobbs et al., 2014).

1.2. Ecological Integrity

According to the Canada National Parks Act (2015), and in reference to a park, ecological integrity is “…a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes” (p.1). An ecosystem has integrity or is viable when its dominant ecological characteristics occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions (Parrish et al., 2003). As discussed previously in section 1.1., urbanization causes changes to ecosystems and affects their integrity. By using integrity as a measure of ecosystem condition and as a management goal, assessing deviation from a system’s natural or historic range in composition, structure or function is a good way to evaluate management success or failure (Tierney et al., 2009). For the purposes of this research, ecological integrity is also referred to as integrity.

1.3. Ecosystem Restoration

As the proliferation and pervasiveness of human influence continues to degrade, damage and destroy ecosystems (and ecosystem services), ecological restoration becomes and is a suitable and desirable mitigation opportunity (Clewell & Aronson, 2007; Hobbs & Harris, 2001). This is especially true in the face of global climate change (Harris et al., 2006) and in urban settings where it can be used as an opportunity to restore ecosystem function and services (Bullock et al., 2011; Gobster & Hull, 2000; Suding, 2011) connect people with nature (Harris, 2010; Miller & Hobbs, 2002) and preserve and protect diversity (Gross & Hoffman-Riem, 2005; Tongway & Ludwig, 2011; van Andel & Grootjans 2006, p16).

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its function (processes), integrity (species composition and community structure) and sustainability (resistance to disturbance and resilience) (Society for Ecological Restoration and International Science and Policy Working Group [SER], 2004). Frequently, the ecosystem that requires restoration has been degraded, damaged, transformed or entirely destroyed as the direct or indirect result of human activities. Restoration therefore attempts to return an ecosystem to its historic trajectory or previous state prior to impact.

Hobbs & Norton (1996) suggest that restoration can be viewed as an attempt to force a transition towards a desired ecosystem state by removing the influences or barriers that caused the original disturbance. They identified ecosystem composition, structure, function, heterogeneity and resilience as attributes that should be considered for restoring an ecosystem. Hobbs & Harris (2001) suggest that function is the most critical attribute (or restoration goal) and where ecosystem function is not impaired, restoration should then focus on considering composition and structure. Function, refers to interactions between species or between species and its environment, the collective effects of multiple interactions (e.g., nutrient cycling) in relation to the sustained function of the whole system and the roles or purpose they serve (e.g., producers, consumers etc.) within the entire system (Jax, 2005).

Barriers to restoration can be considered to be either biotic or abiotic while the type of intervention needed to reverse damage depends on which thresholds have been crossed (Hobbs & Harris, 2001), extent of damage that has been experienced and whether the threshold is a permanent barrier that will prevent recovery of the system (Hobbs, 2007; Hobbs & Cramer, 2008). Ecological barriers can include reduced seed banks, altered disturbance regimes that favour non-native species spread or the presence of non-native species that prevent recruitment of desired native species (Hulvey et al., 2013). An ecological threshold is the point at which there is an abrupt change in an ecosystem condition, property or phenomenon or where small changes in an environmental driver produce large responses in the ecosystem (Groffman et al., 2006). When a driver or barrier changes an ecosystem, a tipping point is crossed which changes the ecosystem dynamic. Species extinctions or distribution shifts, habitat fragmentation, nutrient disposition, altered disturbance regimes, increased abundance of exotic species can be considered barriers (Hulvey et al., 2013). The ability to restore an ecosystem and amount of effort required will often depend on how much the system has moved from historic condition, the type of drivers and feedback dynamics that are interacting as well as whether the outcomes of actions are desirable or undesirable given the objectives of the restoration project (Holl & Aide, 2011; Suding & Hobbs, 2009).

As impacts threaten and compromise biological diversity and ecosystem services, policy makers and managers are pushed to evaluate investment in ecosystem restoration (Ramalho & Hobbs, 2011). A main challenge in the debate about investing in ecological restoration, even more so in urban areas where disturbed sites are often most visible and under social pressure, is when, where and how to intervene and restore so to best utilize available resources and have the greatest impact (Holl & Aide, 2011). Different strategies have been proposed and developed to aid with decision-making in the context of environmental restoration projects and in the management of urban ecosystems. Some strategies or frameworks (i.e., Hopfensperger et al., 2007) have focused more on decision-making relating to whether restoration of ecosystems should be attempted or will be effective and how to proceed to meet targeted goals. Others, including Clewell & Aronson (2007) and Dearborn & Kark (2010) have identified and focused on the motivating factors that influence restoration and conservation priorities.

Although there are some frameworks that have been developed to aid managers in prioritizing efforts such as the 'Interventionist Approaches' proposed by Hobbs & Cramer (2008) and the restoration options discussed by Hobbs & Harris (2001) or other frameworks which have focused on specific issues or ecosystems (i.e., habitat restoration; Miller & Hobbs (2007); river restoration; Beechie et al., (2008); forest restoration; Oris et al., (2011); landscape functionality; Tongway & Ludwig, (2011)) there is no universal framework that has been developed and applied to decision making in relation to the management and restoration of urban ecosystems.

Adding to the challenge of decision-making in relation to urban ecosystem management and restoration is a recently emerging debate in the field of restoration ecology. With the level and degree of human impacts and increasing number of ecosystem management barriers, many authors(i.e., Hobbs et al., 2009; Hobbs et al., 2013; Hulvey et al., 2013*;* Seastedt et al., 2008) suggest that restoring to and managing ecosystems towards a historic, pre-disturbance condition can be an unrealistic objective, especially in the realm of climate change (Harris et al., 2006) and instead, management should be directed towards seeking new strategies and techniques that promote ecosystem resiliency and support ecosystem service provision. Others (i.e., Murcia et al., 2014) argue that restoration is a valid option and can be successfully employed in disturbed landscapes. There are an increasing number of interacting factors that need to be considered, evaluated and understood in terms of the complexities of ecosystem dynamics and perceived barriers to restoration (social, ecological etc.) in order to determine where and how to effectively intervene to fix or improve damaged ecosystems (Hobbs & Cramer, 2008).

1.4. Novel Ecosystems

The novel ecosystem paradigm attempts to promote restoration and ecosystem management which is forward thinking, supportive of new techniques and accepting of change as a conduit of opportunity in the management of ecological systems. Many urban ecosystems have been transformed into new or 'novel ecosystems' which are so degraded that they differ in composition, and/or function from past or even present systems and are emerging mainly and largely due to rapid changes in climate and human influence (Hobbs et al., 2009). These novel systems, which are estimated to occupy between 28% and 36% of ice free land (Perring & Ellis, 2013), result from the biotic response (i.e., drastically different species compositions and abundances) of human-induced abiotic conditions such as land degradation, soil enrichment and introduction of exotic species and persist over time without the need for human management (Hobbs et al., 2006). Although Hobbs et al., (2006) consider these types of systems developing as result of ecosystem changes or abandonment (Figure 1), many of their described properties and characteristics resemble those of degraded urban ecosystems where native species have declined and many alien species have become pronounced (Kowarik, 2011; Lindenmayer et al., 2008).

Novel ecosystems are defined based on three main criteria: 1) ecosystem fluctuations and disturbance resulting in new combinations of species co-existing in an ecosystem where they previously did not exist; 2) existing biotic and abiotic characteristics of an ecosystem are tethered resulting in new combinations of species being able to survive; and 3) humans driving ecosystem dynamics, essentially perpetuating the existence of new ecosystems that become permanent features of the landscape (Mascaro et al., 2013). With increased levels of anthropogenic disturbance, the functioning and 'wildness' or naturalness of ecosystems will decrease and alternatively, where human footprint values are lower, more intact and functional ecosystems would be expected to persist (Sanderson et al., 2002).

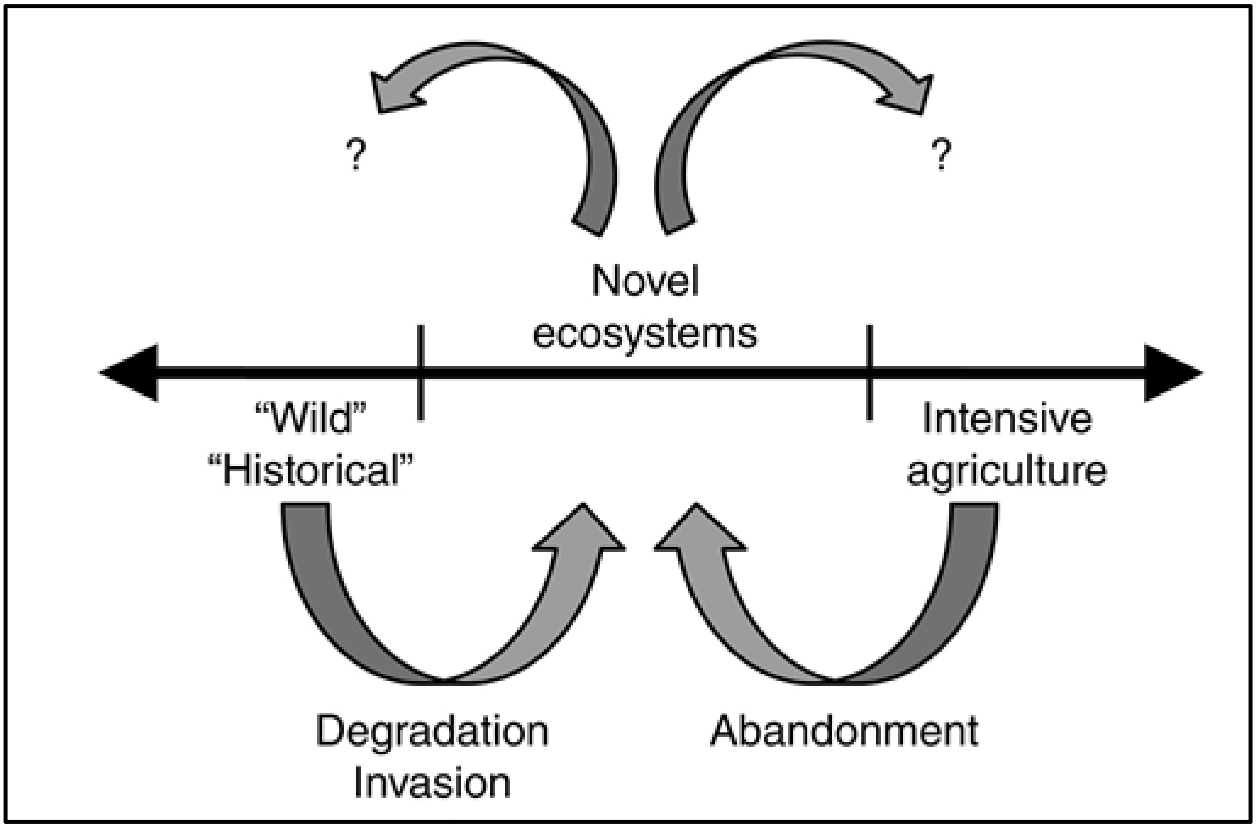

Figure 1: Novel ecosystem schematic. Novel ecosystems arise from direct degradation of wild or traditional ecosystems or when intensively managed systems (i.e. agricultural) are abandoned. Figure included with permission from Hobbs et al., (2006).

Humans are driving abiotic changes and in turn causing associated and reactionary biotic changes within ecosystems. These synergistic effects from onsite changes (i.e., urban development, trail creation etc.) plus offsite changes (i.e., climate change, increase in anthropogenic nutrients, invasive species etc.) are creating the conditions in which novel ecosystems will persist without further human intervention (Harris et al., 2013; Mascaro, et al., 2013). The major anthropogenic drivers of change which facilitate the development of novel systems include climate change (Starzomski, 2013); biological invasion or invasive species (Richardson & Gaertner, 2013), and landscape conversion from natural or wildlands into urban environs (Kowarik, 2011; Perring et al., 2013). In traditional ecosystem management, managers operate under the premise that ecosystems and nature will be healthier if protected from humans and that by maintaining native populations of plants and animals through aggressive removal of threats in order to return ecosystems to their traditional pre-disturbance trajectories or states, conservation and biodiversity goals will be better supported (Grumbine, 1997). This management approach strives to guide management decisions or restoration efforts that aim to maintain ecosystems within historic ecological and evolutionary regimes and in a state that existed prior to human disturbance or will continue to exist unaffected by people (Landres et al., 1999). In instances or locations where it is possible to predict the individual drivers of change on ecosystems, conceivably, traditional management could still be an effective management tool. Given the complexities of ecosystem drivers and volume of changes that are occurring, the impact of these synergistic effects creates high levels of uncertainty for ecosystem managers and a need for new management techniques and intervention strategies (Seastedt et al., 2008). The further an ecosystem changes from its historic range of variability and more that it becomes damaged, the level of effort and amount of resource (i.e., time and money) investment required to reverse changes and restore function increases substantially. Hobbs et al., (2009) classified this scenario by identifying three different types of ecosystems that would be expected to develop under varying degrees of biotic and abiotic changes (Figure 2). Within this model, there are historic, hybrid and novel ecosystems.

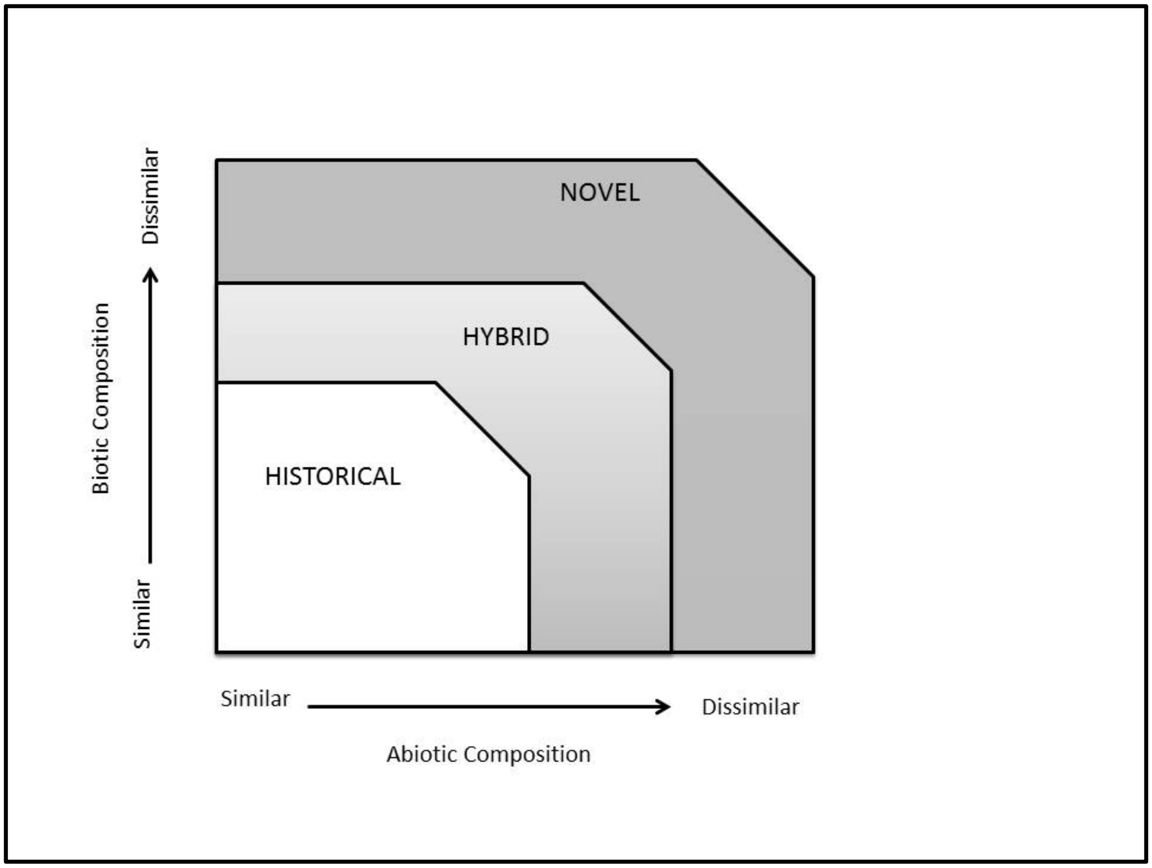

Figure 2: Historical, hybrid and novel ecosystems. New ecosystems develop as a result of modified abiotic conditions which create new biotic interactions and species combinations. Figure adapted from and included with permission from Hobbs et al., (2009).

As abiotic and biotic changes occur, the system transitions (crosses thresholds) from being characterized as a historic system which remains within expected range of variability to a hybrid system which has been modified and changed in some measurable manner and consists of both natural species and their interactions and new species and their interactions. The final stage is novel where the system has changed irreversibly by large modifications of abiotic and biotic elements and is considered to be a novel or new type of ecosystem.

A key differentiation between hybrid and novel systems, recognizing that both are comprised of non-historical species configurations, is that the changes occurring in a hybrid system could eventually be reversed through various efforts (e.g. active management, restoration or other techniques) while a novel system is believed to have crossed a barrier or changed so far from historic range that reversing and restoring would be near impossible or impractical (Hallett et al., 2013; Hobbs et al., 2009). This concept is represented in Figure 3.

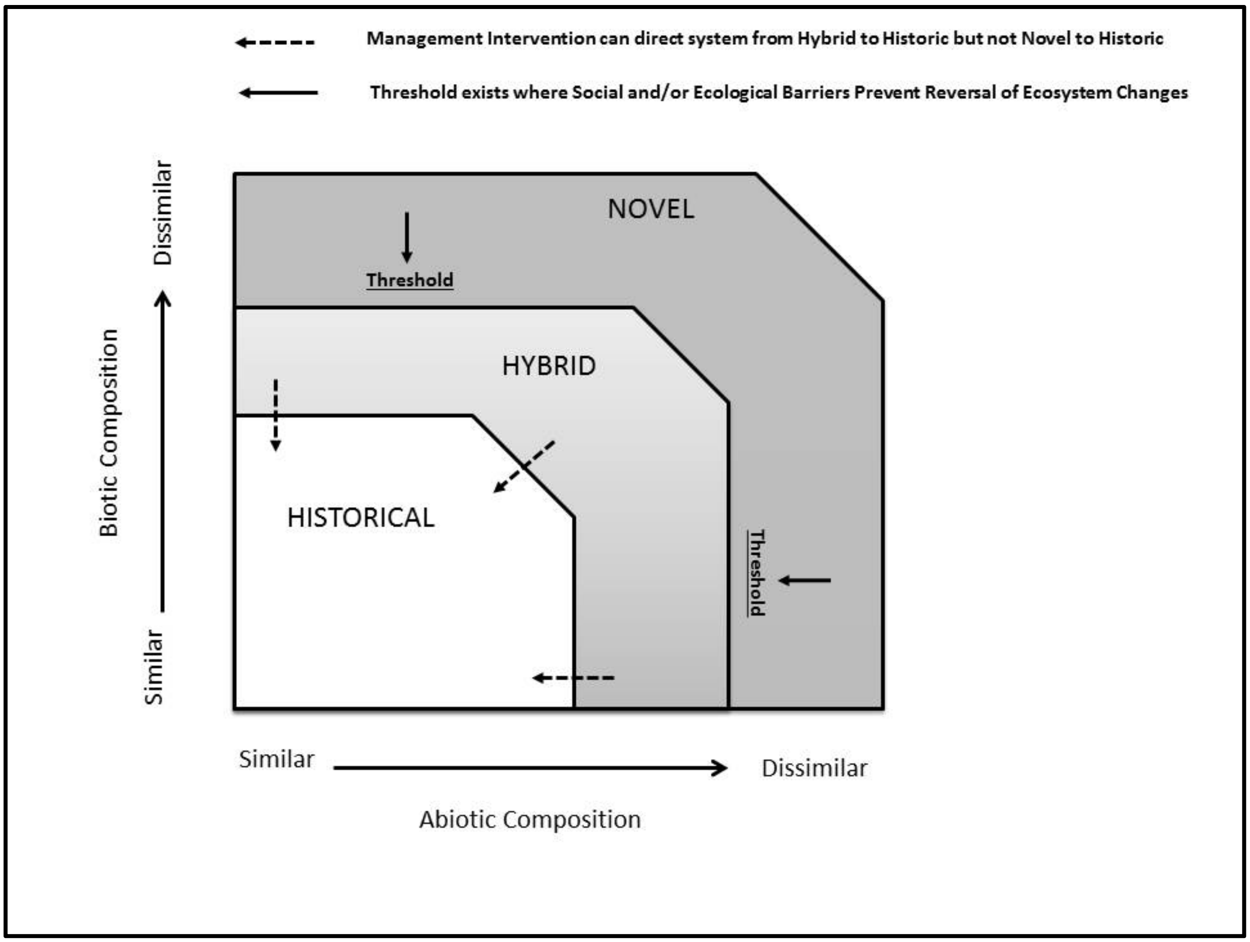

Figure 3: Ecosystem management under historical, hybrid and novel scenarios. Hybrid ecosystems are capable of being returned to historic conditions while novel ecosystems have crossed an ecological or social threshold. Figure adapted and included with permission from Hallett et al., (2013) as originally produced in Hobbs et al., (2009).

Change is a natural characteristic of ecosystems as they respond to disturbances and environmental perturbations. However, the rapid pace of current change combined with frequent and long distance movement of species, the magnitude of human influence and sheer complexity and volume of new interactions among drivers of change make novel ecosystems a mainstay in urban and non-urban environments (Hobbs et al., 2009; Jackson, 2013).

In urban areas, many ecosystems have experienced such high levels of degradation or are under the influence of multiple change agents such as habitat alterations, invasive species, the disappearance of pollinators and loss of seed source/dispersal mechanisms (Kueffer & Kaiser-Bunbury, 2014) that managing towards a state of historical or natural variability, especially without further human impact, is unlikely to be an achievable target. Instead, managers must strive to develop management strategies that accept humans as the major driver of ecological change and implement projects and management/intervention techniques that are adaptive to various scenarios of degradation. The increasing evidence of novel ecosystems is leading to calls for: 1) greater understanding of these systems so that future states can be accurately predicted; and 2) the investigation of adaptive ecosystem management as it applies to the management of new ecosystems (Lindenmayer et al., 2008). In addition, there is still very little information regarding the dynamics and management options of new anthropogenic habitats as the planet becomes more altered by human activities (Hobbs et al., 2009; Seastedt et al., 2008).

A focus on ecosystem functionality provides a means in which to evaluate management approaches and a platform where different intervention techniques can be implemented and measured. Hulvey et al., (2013) developed a decision-making framework intended to be a tool that can be used to guide major decisions as they relate to the assessment of management options for historic, hybrid and novel ecosystems. This framework will also act as the guiding theoretical framework for the subsequent research contained herein and is explained further in Chapter 2. This novel ecosystem framework highlights several critical decision points for determining management interventions and works through an assessment process that provides resource managers with clear direction on ways to assess ecosystem change. The assessment process leads to a confident ability to determine whether barriers dictate management towards or within historic conditions or as hybrid or novel systems.

1.5. Research Objectives

My role is both author of this thesis and the resource manager of publically owned (i.e., municipal) natural lands for the City of Kitchener. To be clear to readers, my framework and fundamental objective was solely focused on advancing the theory and practice of management and restoration options, as opposed to creating a simple report for a municipal agency. That statement is important given my dual roles here. As a matter of convergence, the case example I used enabled me to specifically evaluate natural areas within the City of Kitchener to determine how ecological barriers impact decision-making in relation to the selection and implementation of management and restoration options for urban ecosystems. My research was designed to test the applicability of the novel ecosystem decision-making framework and whether there can be a quantifiable evaluation of ecological barriers as they relate directly to the management of historic, hybrid and novel ecosystems. This thesis secondarily served as a rapid assessment of current ecological conditions within a natural heritage system and a means to determine whether levels of historical ecological integrity are being maintained or if these systems have transitioned into new states. A better understanding of current conditions will enable the selection and implementation of suitable management and intervention approaches. Once again, the utility of Kitchener as a case vehicle was possible because of my role but the objectives of the City or my role as an officer of the City did not circumscribe to the overall intent of the research.

Chapter 2: An Evaluation of Urban Ecosystems and Their Application in a Case Example - The City of Kitchener

2.1. Guiding Theoretical Foundation

The novel ecosystem conceptual framework (Figure 4) as developed by Hulvey et al., (2013) serves as an underlying theoretical foundation for this research and is applied as a tool for evaluating natural area conditions within urban areas like Kitchener.

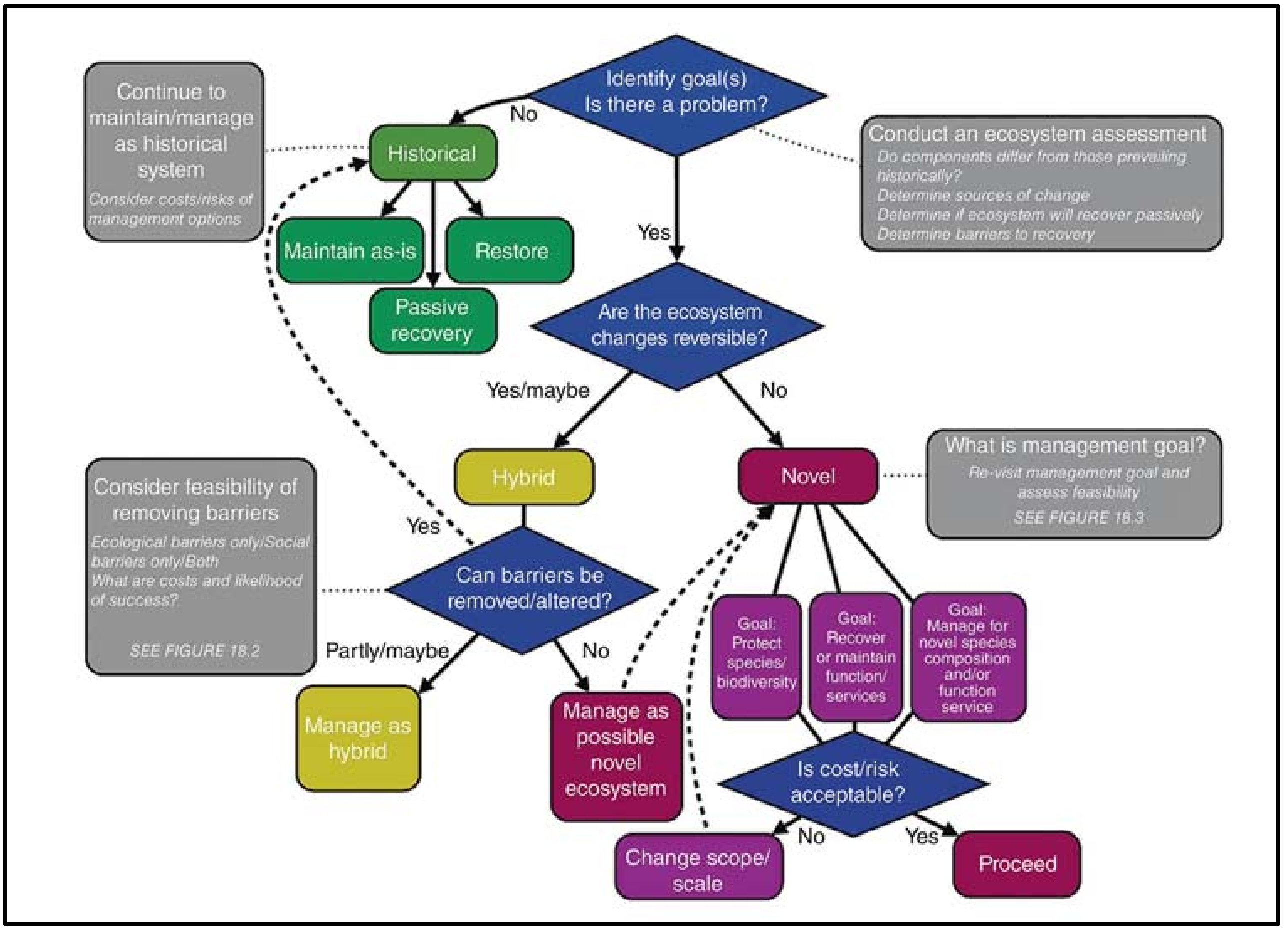

Figure 4: Novel ecosystem decision-making framework (Figure 18.1; Hulvey et al., 2013). A series of decision-making and assessment steps are proposed to aid managers with decision making. Figure included with permission from Wiley Publishers and Hulvey et al., (2013).

The flowchart and decision-making matrix (Figure 4) highlights the key variables or steps for assessment that are recommended to be undertaken to identify novel ecosystems with the underlying premise being that in order to determine appropriate management and intervention approaches, it is critical to assess whether historical ecosystem conditions are still being met or if the ecosystem(s) have transitioned into new states that require alternative strategies. Other researchers (Gardener, 2013; Hulvey 2013; Murphy, 2013a; Murphy, 2013b; Seastedt, 2013; Trueman et al., 2014) have also utilized and applied the novel ecosystem framework to varying degrees as a decision-making tool for restoration and ecosystem management projects.

The main steps from Hulvey et al., (2013) that have been incorporated in this research and are represented in Figure 5 include:

- Conduct an ecosystem assessment to determine whether current ecosystem components differ from those experienced historically;
- Quantify or evaluate barriers to determine feasibility of barrier removal; and
- Evaluate goals to seek alternate scenarios for restoration, management and intervention for historic, hybrid and novel systems.

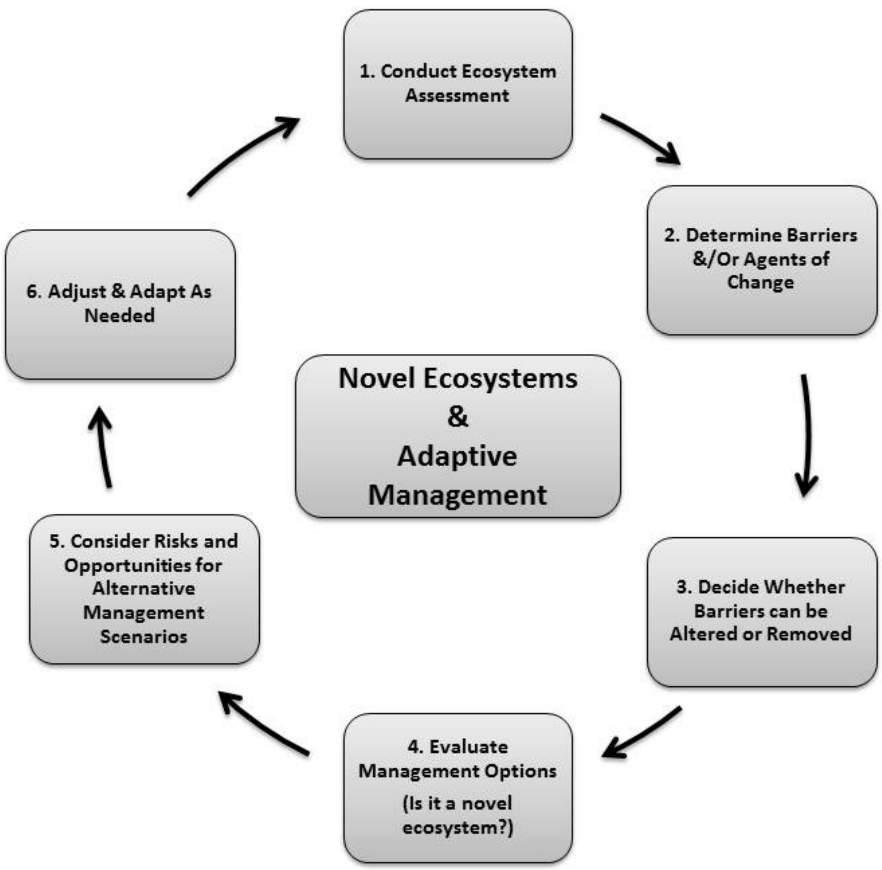

Figure 5: Novel ecosystems and adaptive management. The process of managing historical, hybrid and novel ecosystems follows an adaptive management approach. Figure adapted from steps identified in Hulvey et al., (2013), particularly Figures 18.2 and 18.3.

2.2. Case Study Area and Context

Publically-owned natural areas in the context of this research are those lands that are owned by the City of Kitchener and are being managed for their natural heritage and conservation value on behalf of public interest. This excludes natural lands that are also a facet of Kitchener's natural heritage system but are in private ownership. Privately owned lands, although consisting of significant natural heritage features and comprising the majority of the overall natural heritage system in Kitchener, were not considered in this research as this land base is not always managed with the same consistency and objectives as those being applied to public natural areas under municipal ownership.

The City of Kitchener is predominantly an urban municipality that is located in central Ontario (Figure 6). With a population of 233,700 people, Kitchener is the largest municipality within the Region of Waterloo (City of Kitchener, 2014) and is expected to grow 33 % over the next 28 years while the greater Central Ontario population is projected to increase by 24% (Ministry of Finance, 2014). Much of the Southern Ontario landscape is already heavily modified and can be characterized as more of a cultural than a natural landscape, as it is largely composed of fragmented woodlands interspersed in an agricultural and urban matrix (Schmitt & Suffling, 2006). This anticipated population increase will inevitably put greater pressure on the ecological landscapes of Ontario and of those in the City of Kitchener.

As a whole, these systems provide the elements necessary to maintain local biological diversity and ecosystem functionality and provide a wide range of public health, recreational, environmental and economic benefits to the city and its residents. Kitchener's publically owned natural heritage system can be further classified as falling within the parks and open space system and under the management responsibility of the City of Kitchener Operations (or 'Parks') Department. Within the parkland system, approximately 1200 ha are designated as natural areas. This includes 106 parks, encompassing over 60% of Kitchener's total parkland and representing all of the lands that are intended to be preserved in their natural state (see Figure 8) (Kitchener Parks Strategic Master Plan [KPSMP], 2010). Some of these areas also include culturally managed sites such as plantations and cultural meadows as well as stormwater management facilities. A range of size classes also exist with sites anywhere from <0.5 ha to 110 ha in size.

Kitchener's natural heritage system (Figure 7) is broadly defined as consisting of natural features or specifically, natural areas, which include: wetlands, valleylands, woodlands as well as the associated flora and fauna, significant landforms plus recharge and discharge areas (Kitchener's Natural Heritage System Background Report [KNHS], 2014). In total, Kitchener owns approximately 2500 ha of natural heritage lands or 37% of the approximately 7000 ha total. This breaks down into roughly 260 ha of wetland, 560 ha of woodland, 650 ha of valleyland plus restoration areas, stream features, and other landforms (KNHS, 2014). Not all of the publically owned natural heritage system falls within the parkland system and under management jurisdiction of the parks department. There are additional natural heritage lands in public ownership that are managed independently by the Region of Waterloo and Grand River Conservation Authority.

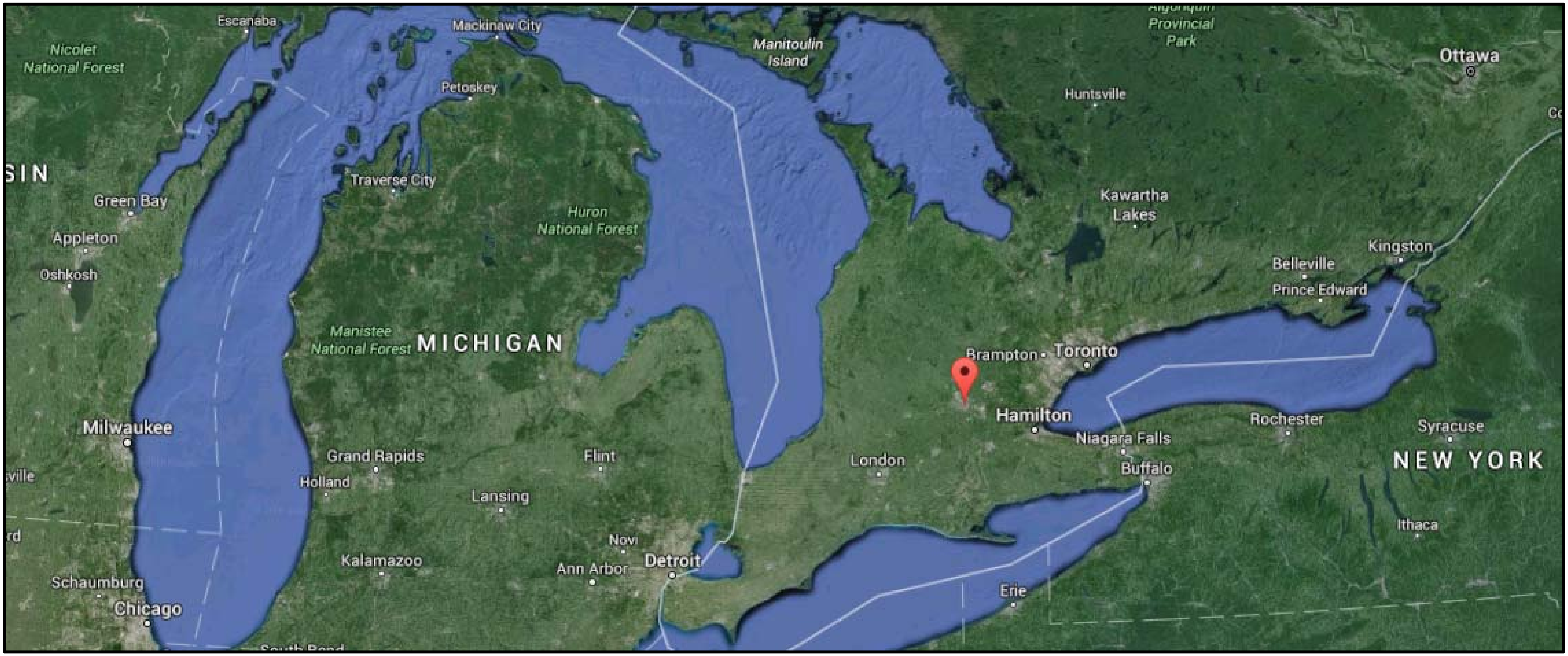

Figure 6: Geographic Location of Kitchener within Southern Ontario. (Google Maps, 2016).

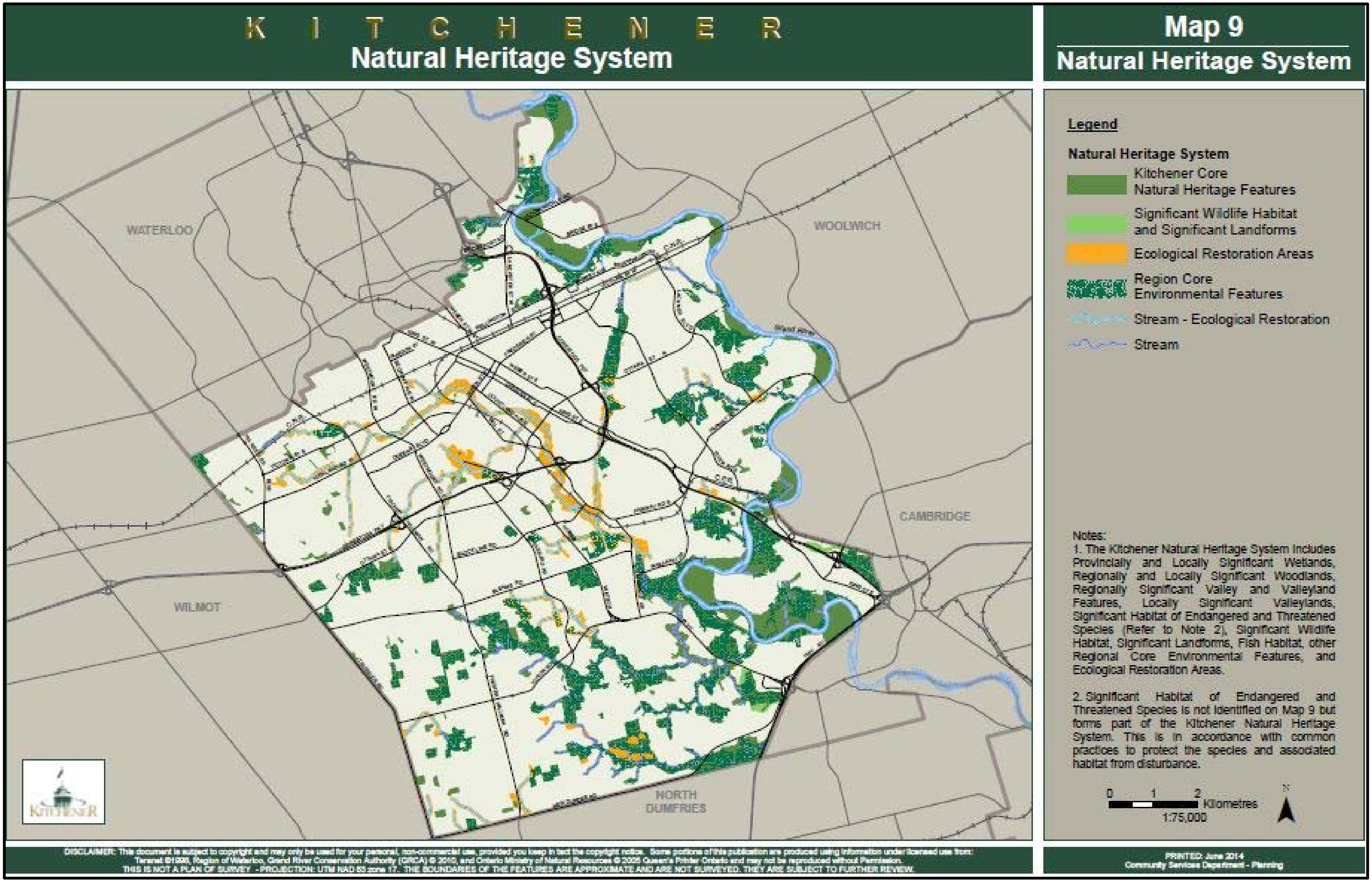

Figure 7: Map of Kitchener's natural heritage system (KNHS, 2014).

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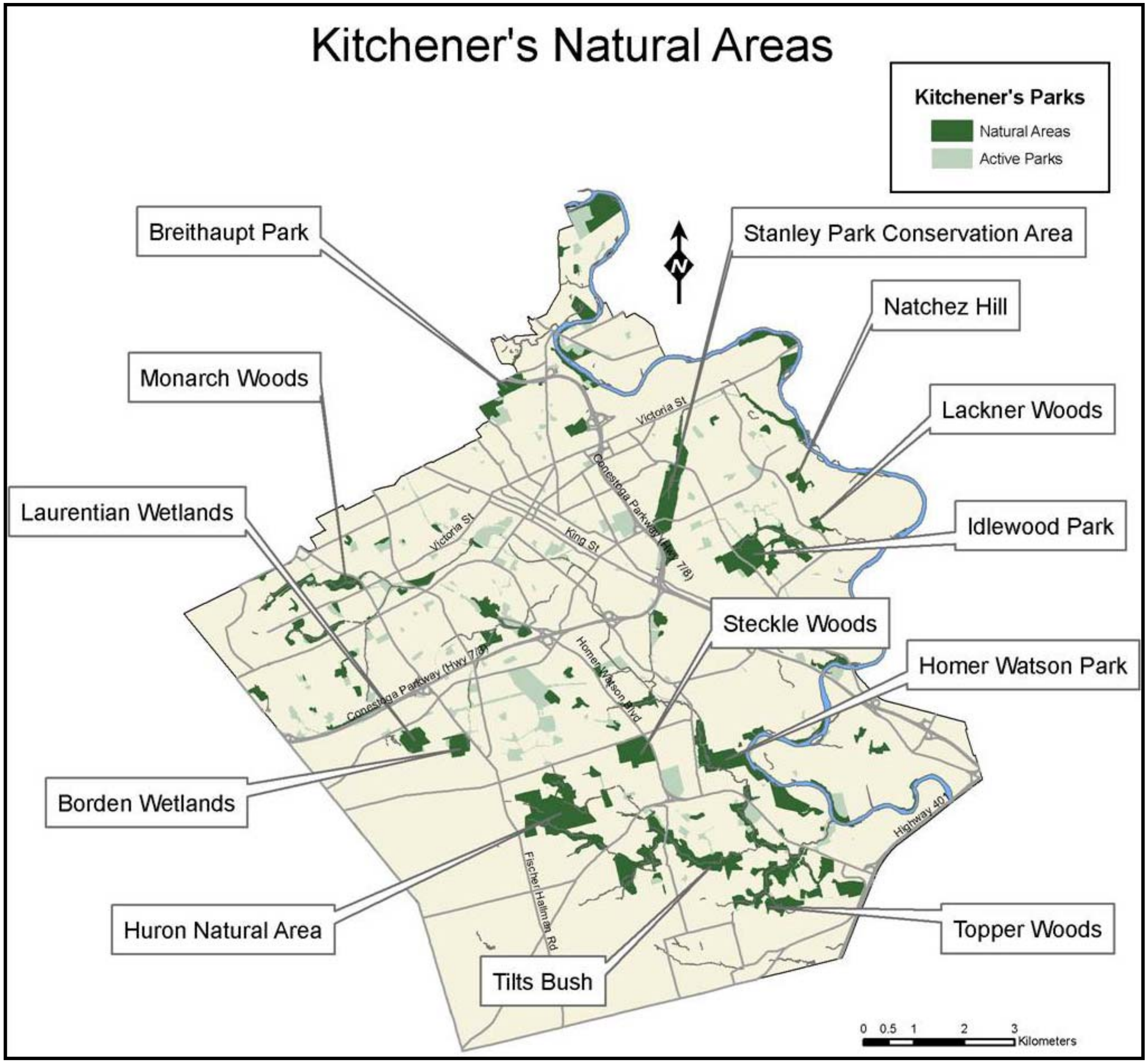

Figure 8: Map of Kitchener's natural area park system (KSPMP, 2010). Map originally produced by and included with permission from City of Kitchener GIS Department. Note: Not all natural areas are shown on this map.

2.3. Outline of Methodology

A multi-faceted approach was utilized to assess ecosystem conditions at micro and macro levels with some information being collected by professionals hired specifically for the project and other information by volunteers who were recruited, trained and involved in various aspects. This approach was implemented to seek efficiency, ensure data accuracy, be cost effective and help assess conditions and detect changes at various scales. An Ecological Land Classification (ELC) assessment was performed to inventory ecosystem types across the city as well as within individual natural areas. A citizen science monitoring program was also developed to assist with rapid assessment of current conditions and to act as an early detection system that can quickly and efficiently monitor current conditions and changes as they occur in the future.

2.3.1. Human Impact and Ecological Barrier Inventory and Assessment

The first step in the decision-making process seeks to understand whether new management challenges exist that will prevent historical ecosystem persistence (Hulvey et al., 2013; p 160). To understand this aspect, a comprehensive inventory at the site/ natural area level was conducted to assess human impacts and invasive species concentrations. In combination, human impacts and invasive species act as potential ecologic barriers to restoration and may influence management choices.

2.3.1.1. Human Impact Assessment

Impacts that occur at the natural area level can act as a stand-alone occurrence, or coalesce with other impacts to create an impasse towards managing for historic conditions and a significant barrier to restoration. The combined effect of each type of encroachment creates significant management challenges, puts strain on already strained budgets and forces managers to select some priorities at the expense of other objectives.

The actual assessment of human impacts involved an experienced field biologist visiting each site and visibly searching for occurrences of different human induced impacts (encroachments, trails, recreational impacts etc.). In addition to recording number of and presence/absence for the impact variable, additional abundance evidence was recorded and quantified. Surveys occurred between June and October within a single field season in 2014.

a) Human Impact/Recreation Management Issues:

Park visitor impacts (Table 1) were assessed while walking transacts through different habitats and while navigating the formal trail networks. A tally was completed during the survey to assign an abundance code to quantify extent of impacts. The code was an arbitrarily assigned abundance level with local (1-5 occurrences); widespread (6-10 occurrences) and extensive (>10 occurrences) categories being used.

Table 1: Human impact variables recorded for each natural area site

Human Impact Variable
1. Campfire pit 2. Graffiti/vandalism 3. Tree forts or structures 4. Litter 5. Bike jumps 6. Earth displacement (e.g., soil dug out to build bike jumps). 7. Trees being illegally cut or damaged 8. Destruction or intentional removal of plants (e.g., digging up of wildflowers). 9. Intentional feeding of wildlife

b) Encroachments:

Any vegetation, structure, building, man-made object or object of personal property that exists wholly upon or extends from the private property onto City-owned lands is considered an encroachment (City of Kitchener, 2012, p.4). The periphery of each site that had residential, commercial or industrial development directly abutting natural area land was walked and each occurrence of an encroachment was recorded. A tally was completed during the survey to assign an abundance code to the total number of infractions per natural area (not per issue) in order to quantify the extent of impacts occurring at an individual site. The code was an arbitrarily assigned abundance level with local (1-5 occurrences); widespread (6-10 occurrences) and extensive (>10 occurrences) categories being used. Additional notes were made in instances where severity of encroachment was significant and would raise the overall level of impact for an individual property.

The following encroachments were inventoried at 54 natural area sites:

Table 2: Encroachment variables recorded at each natural area site

Encroachment Variable	Definition/Example
1. Yard/garden debris	Plant materials, grass clippings, tree branches, piles of sod or soil.
2. Garbage/dumping	Can include piles of rubble, rocks, construction materials, compost, carpets, cardboard or other common refuse items.
3. Firewood	Storing of wood piles for stove or campfire pit; generally piled and organized.
4. Fencing	Construction or installation of a permanent fence structure into the adjacent natural area.
5. Garden extension	Plantings of perennials, annuals or garden vegetables into the adjacent natural area. Can also include the spread of a perennial ground cover (e.g., periwinkle, ivy).
6. Clearing	The obvious and intentional removal of plant material in the adjacent natural area. Can also include the extension of mowing practices into the natural area boundary.
7. Structure	The construction or placement of a structure (permanent and non-permanent) into the adjacent natural area. Can include buildings such as sheds or animal cages, play structures such as playgrounds, trampolines or sitting furniture, picnic tables.
8. Private trail into natural area	The obvious and intentional creation of a pathway or trail from a private residence into the adjacent natural area. Trails can be created by means of continual and repeated use.
9. Other	Uncommon impacts or incidences not covered in other categories (e.g., emptying of pools onto parkland).

c) Unauthorized/Informal Trails:

The City of Kitchener has a range of formal trail networks that run throughout the city. These include hard surfaced asphalt trails, wide gravel based trails in neighbourhood parks and narrow earthen (sometimes gravel) trails that run through natural areas (Kitchener Multi-Use Pathways and Trails Master Plan, 2012). The formal trail networks located in natural areas have been planned and designed to be of least impact and are not built near or within significant or sensitive features.

It is the proliferation of unauthorized or informal trails that are often responsible for trail-related habitat fragmentation and other ecological impacts (Ballantyne et al., 2014). The movement of people along unauthorized trails can also act as dispersal mechanisms for invasive plants (Pickering et al., 2011). Informal trails are visually discernable pathways created and used by park visitors (Leung et al., 2011). It can be very costly and often not feasible to minimize the cumulative effects of multiple informal trail networks through restoration or management (Cole, 2008).

Unauthorized trail networks were identified by walking the authorized trail network and visibly searching for trails that existed in the field but were not part of the existing inventory of authorized trails as identified on field maps. These trails included extensions or visible footpaths that led from the main pathway to another destination (i.e., a shortcut or trail to unauthorized destination). An informal trail was recorded based on it being considered worn or used well enough to be defined as having 'some bare ground' or 'barren' based on the criteria developed by Leung et al., (2011) (Table 3). The exact condition was not recorded but these classes were used to discern whether a trail was being used enough to be considered informal. The total number of informal trails was recorded for each park and the sum was used to assign an abundance code. The code was an arbitrarily assigned abundance level with local (1-3 occurrences); widespread (4-6 occurrences) and extensive (7+ occurrences) categories being used.

Table 3: Trail class conditions and their identification criteria (adapted from Leung et al., 2011).

Trail Condition Class	**General Characteristics or Definition**
Some bare ground	- Clearly discernable trail feature - Well-defined trail boundary present in some areas - Heavy repeated human use is evident - Trampled and matted vegetation - Noticeably impeded vegetation growth - Some bare ground present in trail head
Barren	- Clearly discernable trail feature - Extensive repeated human use - No vegetation present - Bare ground present in trail head and throughout

2.3.1.2 Invasive Species Inventory:

A major barrier to the restoration and management of urban ecosystems and key contributor to the development of hybrid and novel ecosystems are invasive species (Kowarik, 2011; Lindenmayer et al., 2008; Richardson & Gaertner, 2013). Invasive species were defined for this project as alien species whose introduction or spread negatively impact native biodiversity. Alien in this context refers to the fact that these plants have been accidentally or deliberately introduced into areas beyond their native range (Ontario Invasive Plant Council, 2009). The term ‘non-native’ is also used in this research to refer to invasive species or those of alien origin. Invasive species affect the composition and functioning of an ecosystem by altering or changing pollination and seed dispersal interactions (Traveset & Richardson, 2006), causing declines in species richness of native species (Gaertner et al., 2009), and altering community structure, nutrient cycling and hydrology (Levine et al., 2003). Urban natural areas are subject to a constant flow of introduced exotic plant species (Golivets, 2014) with studies demonstrating that forest patches within urban landscapes have a significantly higher proportion of alien species than fragments located in agricultural or expansive forested landscapes (Duguay et al., 2007). Notwithstanding the evidence of impacts caused by invasive species, some authors (Bauer, 2012; Didham et al., 2005; MacDougall & Turkington, 2005), suggest that invasive species are better considered as passengers among the other effects that are acting simultaneously to create new conditions. The ecological impact of invasive species on ecosystems can be very complex and will often depend on the ecosystem that is being invaded, the alien species involved and their characteristics as to whether they are actually transforming the system and facilitating its transition into new states (Richardson & Gaertner, 2013).

In order to accurately assess changes and current ecosystem conditions as well as to assist with determining threats or barriers, a targeted inventory of invasive species was completed. The selection of the target species was based on an evaluation criterion and matrix developed by Magee et al., (2010) and adapted from the monitoring program developed previously by Toronto and Region Conservation Authority [TRCA], (2008) which assessed severity of invasion on conservation properties using invasive indicator species. Magee et al., (2010) created an invasiveness impact score (Index of Alien Impact) to predict invasiveness of individual species. The index considers life history of the species (based on nine criteria), ecological amplitude (eight criteria), and ecosystem alteration (six criteria). Table 4 outlines the ecological traits that were used to assess invasiveness of individual invasive species and were applied in this study. As with the TRCA (2008) program, the ecosystem alteration traits were modified from those developed by Magee et al., (2010) with the ‘altering fire regime’ being removed from the ecosystem alteration criteria because fire is no longer considered a primary driver of ecosystem alteration in Waterloo Region.

Candidate species for inventory (Table 5) were selected subjectively based first on those species proposed for the TRCA (2008) program that would be expected to have similar range and impact as those found in Kitchener and secondly, were those species previously vetted against the criteria established by Magee et al., (2010). From the TRCA list, a modified list was developed based on knowledge of local ecology and familiarity of the floral species for Waterloo Region, especially those species currently considered to be the main invasive threats in Kitchener. This list was further assessed against the ranking of invasive species developed by Smith (2012), which assigned invasive species to a category based on threat to the ecosystem.

Table 4: Ecological traits used to assess invasiveness. Adapted from Magee et al., (2010) and from TRCA (2008).

Life history (n=9)	**Ecological amplitude (n=8)**	**Ecosystem alteration (n=6)**
Strongly clonal – perennials able to spread aggressively via features such as rhizomes, tillers or stolons	**Drought tolerant** - described as drought or xeric adapted, growing in dry soil or in rangeland habitat, or where annual precipitation is less	**Alters hydrology** – changes flooding patterns; raises or lowers water table or surface water levels; changes seasonal
Large propagule crop - 1,000 seeds/plant or 1,000 seeds/m^2 classified as prolific or high seed producers	**Wide moisture regime** – described as growing in conditions that range from xeric to saturated, xeric to mesic, or mesic to saturated	**Alters nutrient cycling** – depletes or adds nutrients, alters nutrient cycling patterns
Small seeds/fruits - <5mm in longest dimension	**Flooding/saturation tolerant** – described as growing in wet conditions, or adapted to intermittent flooding	**Alters soil stability** – either facilitates erosion or enhances stability
Wind dispersal – presence of specialized structures or traits that facilitate movement in wind, and observation of movement in wind	**Wide nutrient or soil texture ranges** – described as growing on a wide range of soil types, or across low to high nutrient ranges	**Excretes salts or toxins** – produces salts or toxins that are known or suspected to alter soil chemistry or act as allelopathic compounds
Animal dispersal – presence of specialized structures or traits that facilitate attachment, survives consumption and excretion by animals	**Wide light regime** – described as shade tolerant or able to grow under multiple light conditions, e.g. from bright sun to partial or deep shade	**Forms monocultures or near-monocultures** – forms dense patches, excludes other species
Water dispersal – observation of floating or long distance water dispersal or seed or plant fragments	**Alkaline or saline tolerant** – documented as salt tolerant, or growing in alkaline soils, saline soils, or coastal habitats	**Invades in absence of human disturbance** – able to establish and spread into relatively intact natural vegetation
Specialized dispersal – unique dispersal traits such as explosive dehiscence, tumbling of seed laden plants	**Grazing tolerant or increaser** – documented as resilient to direct grazing impacts; increases with grazing due to low palatability, to toxicity, or release from competition	
Dispersal over time – persistent seed bank, long seed life, staggered germination, staggered dispersal from inflorescence	**Increases post-fire or other vegetation-clearing disturbance** – able to expand aerial coverage and biomass following disturbance	
Plasticity – high morphological, phonological or genetic variability		

Table 5: Invasive indicator species and their associated rankings plus category of invasiveness

Invasive Indicator Species	**Invasiveness Impact Score**[2] **(TRCA)**	**Level of Invasiveness**[3] **(TRCA)**	**Category of Invasiveness and Threat to Natural Area (Smith)**
Dog-strangling vine (*Cynanchum rossicum C.Nigrum* Linneaus.)	38	Aggressive	*Category 1:* Aggressive Invasive. *(Can dominate a site to exclude all other species and remain dominant on the site indefinitely).*
Garlic mustard (*Alliaria petoilata* L.)	36	Strong	*Category 1:* Aggressive Invasive.
Periwinkle (*Vinca minor* L.)	15	Weak/poorly understood	*Category 2:* Highly Invasive. *(Spread vegetatively and may have been deliberately planted. Tend to dominate certain niches or do not spread rapidly from major concentrations)*.
Common buckthorn (*Rhamnus cathartica* L.)	89	Extreme	*Category 1:* Aggressive Invasive.
Glossy buckthorn (*Rhamnus frangula* L.)	21	Moderate	*Category 1:* Aggressive Invasive.
Himalayan balsam (*Impatience glandulifera* Royle)	19	Moderate	*Category 1:* Aggressive Invasive.
Goutweed (*Aegopodium podagraria* L.)	N/A	N/A	*Category 1:* Aggressive Invasive.
English ivy (*Hedera helix* L.)	N/A	N/A	Category 3: Moderately Invasive. *Become locally dominant when proper conditions exist.*

The inventory of invasive species involved an experienced field biologist systematically walking transects through each habitat polygon in each of the 54 natural areas and recording the

[2] Invasiveness Impact Score: Ranked on a scale from 0 to 100 and shown as percentage of possible total of attributes present from Table 4; (Magee et al., 2010);
[3] Level of invasiveness: Based on levels of estimated population invasiveness; an arbitrarily assigned class based on where the distribution scores were broken into categories.

number of occurrences or patches[4] for each of the eight species. The total quantity for each species was assigned into one of four categories: few or scattered individual plants, < 5 patches, 5 to10 patches and > 10 patches. A running tally was kept to quantify the exact number of patches. In addition, the estimated size of largest patch was recorded for each natural area using one of three size categories: 1) <10 m^2 but >10m^2; 2) <50 m^2 and 3) >50 m^2. The habitat type where each species was found was recorded by selecting all habitat types (forest, riparian, wetland and/or meadow) that were applicable.

2.3.2. Ecosystem Assessment

Selecting management options for disturbed ecosystems requires knowledge about changes that have occurred within a system and some form of understanding as to whether the changes can be reversed. Once a system has moved from its historical range of variation due to abiotic changes, subsequent changes in species composition and biogeochemical cycling are likely to occur (Seastedt et al., 2008).The ecosystem assessment is a consideration of how similar current ecosystems are to those experienced at a previous time prior to disturbance. To assess condition, a comparison of contemporary ecosystems with a historical reference is conducted. In some instances, the absence of historical reference point makes evaluation difficult (Murphy, 2013a) however where historic information exists, comparisons of species compositions by survey of unmodified vegetation at the same time but in a different place or in the same place at an earlier time (Harris et al., 2013; Trueman et al., 2014) can provide valuable information.

2.3.2.1. Comparative Analysis of Contemporary to Historic Ecosystem Conditions

In Kitchener, characterizing historic conditions by using a reference site without human modification would not be possible. Instead, detailed ecosystem or biological surveys were conducted at three natural area sites – Homer Watson Park, Steckle Woods and Lakeside Park with current results of these natural area inventory studies being evaluated against similar surveys conducted in these locations approximately 28 (Homer Watson and Steckle) and 40 years prior (Lakeside). It is important to note that even surveys conducted 40 years ago cannot be certain to be representative of conditions prior to disturbance as significant landscape

[4] A patch was defined as species growing tightly together with few or no other species interspersed between them. At the point when a noticeable or defined gap occurred, a new patch was recorded. Some variation of the definition for 'patch' exists for each species.

modifications had and were occurring in these areas at the time of assessment. Historic conditions for Homer Watson Park and Steckle Woods were obtained by reviewing Environmental Management Plans that were prepared by the Region of Waterloo to evaluate these sites for designation as Environmentally Sensitive Policy Areas (Region of Waterloo, 1986a; Region of Waterloo 1986b). Comprehensive park inventories were completed for Lakeside Park as part of a proposed road development (Ecologistics, 1973). A comparative analysis was performed by reviewing contemporary vegetation and comparing it against historic vegetation types as one measure of change. Other fauna records (i.e., bird, amphibian and reptile) were also analyzed and used to assess novelty of these systems.

2.3.2.2. Evaluation of Significant Wildlife Habitat Features

As a measure of current ecosystem condition, an inventory of the presence of Significant Wildlife Habitat (SWH) features was conducted during the human impact and invasive species surveys. Significant wildlife habitat was identified based on provincial criteria (Ontario Ministry of Natural Resources [OMNR], 2000). Wildlife habitat is defined according to the Ontario Provincial Policy Statement as areas where plants and animals, and other organisms live, and find adequate amounts of food, water, shelter and space needed to sustain their populations (KHNS, 2012, p. 41). The term significant in the context of wildlife habitat is meant to imply ecologically important in terms of features, functions, representation or amount, and contributing to the quality and diversity of an identifiable geographic area or natural heritage system. Determining what constitutes SWH will vary across Ontario due to variation in landscapes as well as the amount, distribution and quality of remaining habitat (OMNR, 2012a). There are four categories of SWH that are identified: 1) habitats of seasonal concentrations of animals; 2) rare vegetation communities or specialized habitat for wildlife; 3) habitat of species of conservation concern; and 4) animal movement corridors. Most SWH features are identified or evaluated as part of development applications with the intent that they be protected during subsequent activities. Once a feature has been identified as ‘candidate’ more field study is usually undertaken to confirm whether wildlife are using the habitat as well as to identify protection measures (OMNR, 2012a). More detailed investigation usually involves additional evaluation, with in-depth assessments, methodologies and longer duration monitoring to study the populations of the candidate wildlife in question.

For the purposes of this inventory, only a cursory assessment was done in that a visual assessment of habitat features or the presence of an indicator (i.e., wildlife species, habitat feature, seepage) was used to identify the habitat as a candidate site. No additional or detailed investigations were undertaken to confirm the status as per OMNR (2012a) criteria. The use of the term ‘confirmed’ in this evaluation was understood to denote ‘presence’ in that the habitat feature based on use of identification criteria was confirmed to be present in the area. This did not imply that the wildlife species in question was confirmed using the feature during an expected life stage or other positive criterion. The SWH criteria defined by OMNR (2012a) were used when visiting each natural area in order to identify whether the habitat would support the species in question or serve the identified habitat function. The Significant Wildlife Habitat Technical Guide was also used to identify criteria to determine SWH (OMNR, 2000).

The following significant wildlife habitat features (29 in total) were assessed as to whether they were present or had potential to be confirmed. For each feature, the main assessment criterion is also identified. As with the other surveys, 54 natural areas were inventoried.

a) Seasonal Concentration Areas of Animals: areas where wildlife species occur annually in aggregations at certain times of the year, on an annual basis. Such areas are sometimes highly concentrated with members of a given species, or several species, within relatively small areas. In spring and autumn, migratory wildlife species will concentrate where they can rest and feed. Other wildlife species require habitats where they can survive winter.

Table 6: Seasonal concentration areas and their assessment criteria

Wildlife Habitat Feature	Assessment/Identification Criteria
1. Deer (*Odocoileus virginianus*, Zimmerman) yarding/congregation area	Areas deer move to in response to the onset of winter snow and cold; habitat composed primarily of coniferous trees (pine, hemlock, cedar, spruce) with a canopy >60%; presence of high levels of deer sign including tracks, pellets and evidence of browse; an open water source (e.g., seepage areas) must be present.
2. Wild turkey (*Meleagris gallopavo*, L.) winter area	Dense coniferous forests; presence of seeps in forest; available food (e.g., acorns) including adjacent or nearby agricultural fields.
3. Raptor wintering area	Open fields, agricultural areas; fields with herbaceous vegetation that supports small mammals; roosting sites include mature mixed or coniferous woodlands that abut fields;
4. Turtle wintering area	Often same general area as core habitat in summer; water deep enough not to freeze and has a soft mud substrate; permanent bodies of water, large wetlands;
5. Bat hibernaculum	Hibernacula may be found in caves, mine shafts, underground foundations and Karsts.

	The locations of bat hibernacula are relatively poorly known.
6. Snake hibernaculum	For snakes, hibernation takes place in sites located below frost lines in burrows, rock crevices and other natural locations. Areas of broken and fissured rock are particularly valuable since they provide access to subterranean sites below the frost line.
7. Bat maternity roost	Can be found in forested sites with high snag density; mature deciduous or mixed forest stands with >10 ha or large >25 cm dbh wildlife trees.
8. Colonial nesting bird habitat	Can be bank/cliff (exposed soil banks, undisturbed or naturally eroding), tree/shrubs (nests in dead standing trees in wetlands or large ponds), or ground based (gull colonies associated with open water or wetland) habitat.
9. Shorebird migratory stopover	Shorelines of rivers and wetlands, muddy and un-vegetated shoreline habitats.

b) **Specialized Habitat**: some wildlife species require large areas of suitable habitat for their long-term survival. Many wildlife species require substantial areas of suitable habitat for successful breeding. Their populations decline when habitat becomes fragmented and reduced in size. Specialized habitat for wildlife is a community or diversity-based category, therefore, the more wildlife species a habitat contains, the more significant the habitat becomes to the area in question.

Table 7: Specialized wildlife habitat features and their assessment criteria

Specialized Wildlife Habitat	Assessment/Identification Criteria
1. Area-sensitive species habitat	Supports bird species identified as area-sensitive; large forest habitats >30 ha with at least 10ha interior habitat; large mature trees >60yrs old.
2. Woodland raptor nesting habitat	All natural or conifer plantation; interior habitat with 200 m buffer; presence of stick nests in a variety of intermediate-aged to mature conifer, deciduous or mixed forests. Presence of one or more active nests.
3. High habitat diversity	Associated with a NA where any of the following four criteria was met: various ELC types, forest stratification, denning sites, cavity trees/snags, micro-macro topography, downed-woody debris, deer/wildlife browse, supercanopy trees.

4. Waterfowl nesting habitat	An area near a wetland, extending 120 m from the edge of a wetland, or a wetland (>0.5 ha) and any small wetlands (0.5 ha) within 120 m or a cluster of three or more small wetlands within 120 m of each individual wetlands where waterfowl nesting is known to occur. Nesting studies to confirm breeding status of certain species is required.
5. Bald eagle (*Haliaeetus leucocephalus*, L.)/ osprey (*Pandion haliaetus*, L.)/ habitat	Nests associated with aquatic habitats; confirmed nesting structure on man-made objects (osprey); shoreline habitat; presence of large mature trees adjacent to aquatic habitats.
6. Amphibian breeding habitat	Mainly woodland ponds, forests or forests with associated wetlands; Also used to include other locally significant amphibian breeding and could include wetlands, ponds, and storm water ponds.
7. Turtle nesting habitat	Close to water and away from roads; must provide sand and gravel that turtles are able to dig in and are located in open, sunny areas.
8. Fish habitat	Permanent water capable of supporting fish populations; can include natural or man-made ponds, streams and river.
9. Mink (*Mustela vison* L.) denning sites	Shorelines dominated by coniferous or mixed forests for feeding, and denning. Dens usually located underground, especially where shrubs and deadfall provide cover; abandoned muskrat lodges are suitable.
10. Seeps and springs	Seepage areas, springs, and small intermittent streams provide habitat for numerous uncommon species such. In winter, wild turkey and white-tailed deer also forage in these areas because of the lack of snow on the ground. Often these areas support a high diversity of plant species.

c) Habitats of Species of Conservation Concern: habitat that supports species identified as nationally endangered or threatened and not protected by Endangered Species Act (ESA), provincially vulnerable, rare or historical in Ontario and species whose populations are known to be experiencing substantial declines.

Table 8: Habitat for species of conservation concern and their assessment criteria

Habitat of Conservation Concern	Assessment/Identification Criteria
1. Marsh breeding bird habitat	Meets habitat criteria of select species (e.g., green heron (*Butorides virescens* L.); wetlands are present, cattails or other vegetative cover; must have shallow water with emergent aquatic vegetation.
2. Woodland area-sensitive bird species breeding habitat	Habitats where interior forest breeding birds are breeding, typically large mature (>60 yrs. old) forest stands or woodlots >30 ha; Meets habitat requirements of select species of birds identified as area sensitive.
3. Open country bird breeding habitat	Large grassland areas (includes natural and cultural fields and meadows) >30 ha; Meets habitat requirements of select indicator species.
4. Shrub/early successional bird breeding habitat	Large field areas succeeding to shrub and thicket habitats>10 ha in size. Meets habitat requirements of select suite of indicator species.
5. Special concern and rare species habitat	Habitat for rare or endangered species as listed federally or provincially (S1-S3 rankings).
6. Terrestrial crayfish habitat	Meadow and edges of shallow marshes (no minimum size) identified should be surveyed for terrestrial crayfish; burrows in marshes, meadows and flats, well-formed tunnels or chimneys.

d) Linkages and Movement Corridors*:* Animal movement corridors are elongated areas used by wildlife to move from one habitat to another. They are important to ensure genetic diversity in populations, to allow seasonal migration of animals (e.g. deer moving from summer to winter range) and to allow animals to move throughout their home range from feeding areas to cover areas. Animal movement corridors function at different scales often related to the size and home range of the animal.

Table 9: Linkage and movement corridor features and their assessment criteria

Linkage or Corridor Feature	Assessment/Identification Criteria
1. Close proximity to other nearby natural features	A natural area or vegetated area is close to an adjacent and complimentary habitat.
2. Herpetofauna movement corridor	Movement corridors between breeding habitat and summer habitat.
3. Mammal corridor	Areas between summer and wintering habitat; large vegetated corridors for movement of deer and other mammals.
4. Natural linkage/ecological stepping stone	Good connections between individual natural areas that would allow the movement of species and connect them to the remainder of the heritage system; series of smaller natural areas that connect to a large natural area.

2.3.2.3. Ecological Land Classification Assessment

A professional biological consulting firm was hired to complete an assessment using the Ecological Land Classification System (ELC) for Ontario protocol. This system provides a standard approach to evaluating and classifying natural features according to site features at various scales (Lee et al., 1998). This classification system breaks the entire natural area into vegetation units (Figure 9) that are classified based on bedrock, climate (temperature/precipitation), physiography (soils, slope, aspect), and corresponding dominant vegetation types. These units roughly translate into the different ecological units or ecosystem types that are found within a site. ELC assessment is a valuable management tool that can be used for individual site analysis and for broad scale comparison of vegetation and ecosystem types across Kitchener. Of the 106 natural areas, 48 were assessed using this technique. An inventory of ecosystem types provides a valuable baseline of current ecological conditions in Kitchener and can be used as a management decision-making tool to compare sites across the city, assess ecosystem rarity and determine restoration and management priorities. ELC community analysis is also used to assess significant wildlife habitat.

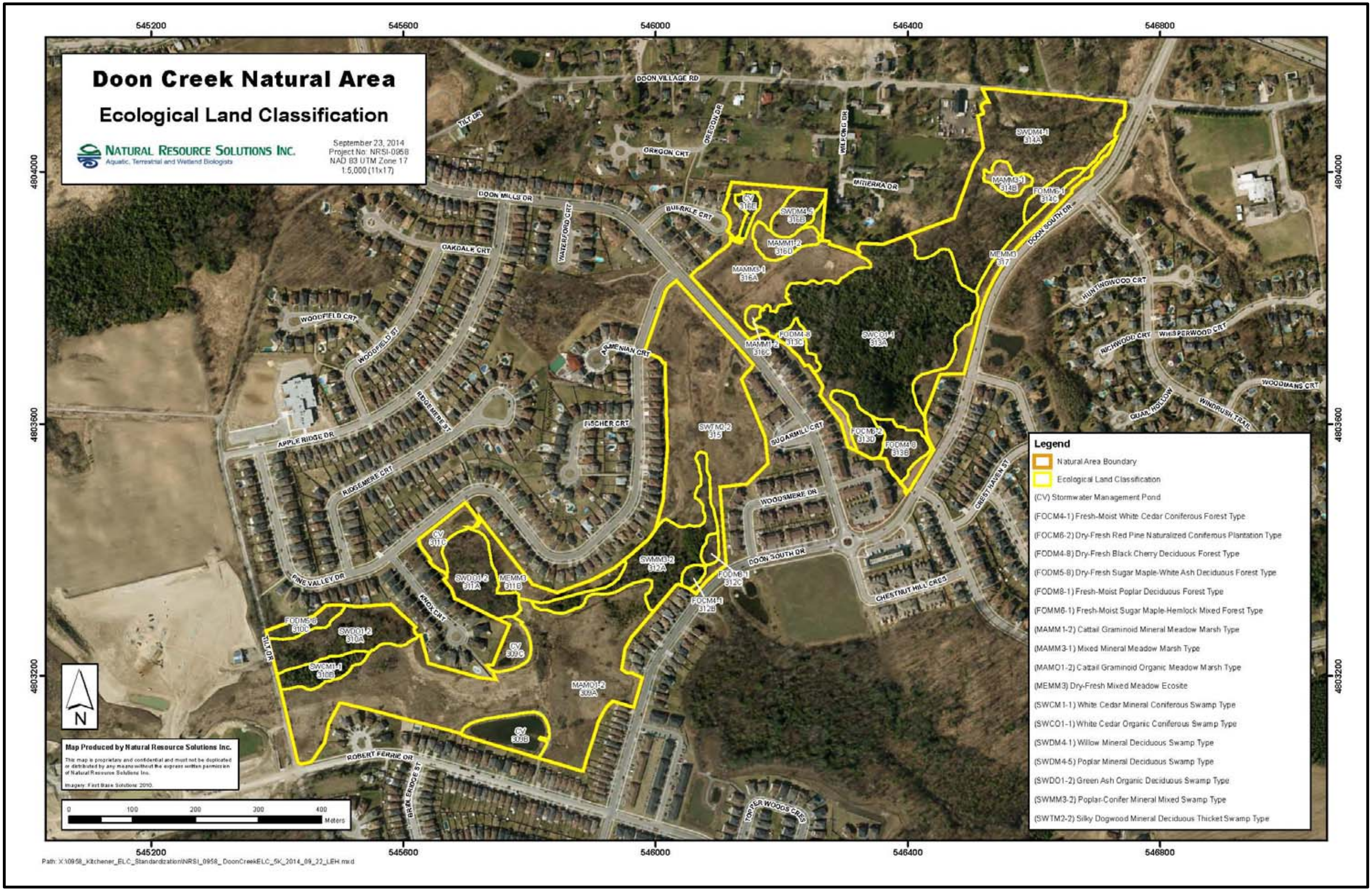

Figure 9: Example of ecological land classification map. Individual ecotypes are mapped with polygons (in yellow). This map shows 26 vegetation communities of 18 distinct ecosystem types. Map included with permission from Natural Resource Solutions Inc.

2.3.2.4. Citizen Science Volunteer Monitoring Program

An ecological indicator monitoring program was implemented to rapidly evaluate indicators of ecological integrity of natural areas in Kitchener. In the context of this project, the indicator monitoring program was not a stand-alone evaluation of ecosystem integrity and was incorporated as a macro-level assessment tool used in combination with other complimentary methods to assess ecosystem conditions. In addition, this tool or program can be enacted in subsequent years to detect changes and provide assessment of trends. It can also be used as a novel ecosystem monitoring tool for managers in which indicators of novelty are selected as opposed to integrity indicators as was selected here. This ecological indicator monitoring program was adapted with permission after TRCA (2008) which had implemented a similar program and amassed five years of volunteer monitoring data.

Using indicators to assess integrity (ecosystem structure and function) requires the selection of indicators at the species, stand, landscape and ecosystem levels and the selection of indicators that are representative of the structure, function and composition of the ecological system (Carignan & Villard, 2002; Dale & Beyeler, 2001). Indicators selected for this study met the criteria proposed originally by Lambeck (1997) and Noss (1999) and summarized in Carignan & Villard (2002).

The 17 monitoring sites (Table 10) were arbitrarily selected for inclusion in the study and were assigned to volunteers randomly. In some cases, a site was assigned to a volunteer based on proximity to where the volunteer lived or worked however no consideration was given as to the knowledge level or identification skills of that particular volunteer. In addition the sites were not selected based on their perceived integrity or condition. This approach was employed in order to reduce any potential bias associated with the pairing of volunteers and sites.

The indicators identified in Table 11 were selected for this program and were consistent with criteria recommended by Carignan & Villard (2002) and modified from those proposed by TRCA (2008) to include regionally appropriate species for Kitchener and eliminate species (porcupine *(Erethizon dorsatum* L. and ruffed grouse *Bonasa umbellus* L.) that do not commonly occur in Waterloo Region. In total, 17 natural area sites were monitored using this method. Indicators are commonly chosen in biological monitoring and evaluation programs when the ability to evaluate the entire biodiversity of a site or region is not feasible (Heink & Kowarik, 2010). Indicators provide a cost effective and time-efficient mean to assess impacts of environmental disturbances on an ecosystem (Carignan & Villard, 2002), respond to chemical, physical and other biological phenomena and can be used to identify potential actions for remediation (Niemi & MacDonald, 2004).

Table 10: Natural area sites evaluated for indicators by volunteer monitors

Natural Area Sites Monitored by Volunteers	
1. Breithaupt Park	10. Laurentian Wetlands
2. Brigadoon Woods	11. Monarch Woods
3. Carisbrook NA	12. Stanley Park
4. Fallowfield NA	13. Steckle Woods
5. Grand River/Sims Estate	14. Strasburg Creek
6. Huron NA	15. Tilts Bush
7. Idlewood Park NA	16. Topper Woods
8. Lackner Woods	17. Waldau Woods
9. Lakeside Park	

Table 11: Monitoring indicators and seasonal requirements

		Indicator	
Season	**Month**	**Fauna**	**Flora**
Winter	January or February (one 1½ hr. early morning visit)	mink	eastern hemlock (*Tsuga Canadensis* L.) white pine (*Pinus strobus* L) eastern white cedar (*Thuja occidentalis* L.)
	March (one ½ hr. visit at dusk)	eastern screech-owl (*Megascops asio* L.)	
Spring	April (two 1 hr. evening visits) 1 – early April 1 mid-late April	American woodcock (*Scolopax minor* L.) spring peeper (*Pseudacris crucifer* Wied.) wood frog (*Lithobates sylvaticus* Le Conte.) western chorus frog (*Pseudacris triseriata* W.) northern leopard frog (*Lithobates pipiens* Le.) American toad (*Anaxyrus americanus* Holbrook)	

	May (one 2 hr. early morning visit)	pileated woodpecker (*Hylatomus pileatus* L.) wood duck (*Aix sponsa* L.)	marsh marigold (*Caltha palustris* L.) white trillium (*Trillium grandiflorum (*Michx.) Jack-in-the-pulpit (*Arisaema triphyllum* L.) narrow-leaved spring beauty (*Claytonia virginica* L.) foam flower (T*iarella cordifolia* L.*)* bloodroot (*Sanguinaria Canadensis* L.)
Summer	June (two 2 hr. evening fauna visits) July and August (one 2 hr. daytime flora visit each month)	eastern wood-pewee (*Contopus virens* L.) wood thrush (*Hylocichla mustelina* Gmelin) swamp sparrow (*Melospiza georgiana* Latham) Virginia rail (*Rallus limicola* Vieillot) green heron eastern kingbird (*Tyrannus tyrannus* L.) savannah sparrow (*Passerculus sandwichensis* G.) eastern meadowlark (*Sturnella magna* L.) green frog (*Rana clamitans* Latreille) grey treefrog (*Hyla versicolor* Le.)	Michigan lily (*Lilium michiganense* Farw) mayapple (*Podophyllum peltatum* L.) swamp milkweed (*Asclepias incarnate* L.) spotted Joe-pye weed (*Eutrochium maculatum* L.)
Fall	October (one 3 hr. daytime visit)		Christmas fern (*Polystichum acrostichoides* Michx) zigzag goldenrod (*Solidago flexicaulis* L.)

Beginning in 2011, the monitoring program was advertised strategically through networks of community environmental groups (Kitchener-Waterloo Field Naturalists) and through the University of Waterloo Ecology Lab with the intent that specialized volunteers could be recruited. In addition, the program was advertised through the City of Kitchener via the Volunteer Resources Division and within Kitchener's Natural Areas Program [KNAP] (2010) existing volunteer network. Anyone interested in participating in the program was expected to commit for two years to ensure consistent data collection and were asked to fill out an application form that identified related experience, education and professional background so that applicants could be screened appropriately.

All volunteers were expected to attend mandatory training sessions each season (spring, summer, fall and winter) during the initial year of the program. Failure to do so resulted in removal from the program. The training sessions provided detailed information, tips and techniques on identifying the target indicators for each season including both audio and visual guides as well as information about the data collection protocol. Audio playback recordings were provided for several bird species to aid in locating the species and to help eliminate data collection errors. Using this method helped ensure that the territorial male of the species in question would reply to the audio recording of its song, thereby confirming its presence as a bird on territory. Following each training session, a field visit was arranged to facilitate better understanding of protocols and help with identification of indicators during each season. For example, the spring training session was held in early evening which allowed participants to participate in an indoor session plus an outdoor walk. The outdoor walk provided spring amphibian audio identification plus spring ephemeral plant identification training. A similar approach was taken during each seasonal training session. In addition to the in-person training, a detailed training manual was provided to each participant with identification guides, additional resources and written notes on the protocol and data submission requirements. An ELC field map was provided for each site with direction on how to use habitat maps to find the preferred habitat type for each indicator.

Volunteers worked in pairs for safety reasons though only the lead volunteer (and one who attended the training) was to collect the data. Each site was visited ten times over four seasons with volunteers searching the site to locate the target indicator species for the season. Each visit was conducted within a specific date range and time of day to aid with data collection accuracy and standardization. The survey protocol was designed to determine whether an indicator was present at the site with surveys taking place during the time of year (e.g., spring) or stage of lifecycle (e.g., courtship/breeding) when the likelihood of detection is highest. Table 11 also provides general timing and seasonal monitoring requirements for each target species. Observations were recorded on data sheets (see Appendix 1 for sample data sheet) by checking boxes for primary, secondary and tertiary (where applicable) characteristics for the target species. Data was submitted electronically via email or on paper and sent via mail following each monthly visit or seasonally if only one visit was required. Each submission was reviewed for errors and additional follow-up or a field check to confirm accuracy was performed if needed.

Chapter 3: Summary of Results

All data that were collected for management/human impact issues, encroachments, informal trail networks, ELC community information as well as invasive species indicator and wildlife habitat features were stored and maintained in a custom built Microsoft Access database. Occurrence data was collated into data tables and extrapolated and analyzed by individual management issue. Analysis was performed using Microsoft Excel pivot tables which allowed data to be manipulated and sorted by natural area and according to variable of interest. Information for each variable was first analyzed independently and then assessed collectively to present a quantitative overview of conditions within individual natural areas and across the City of Kitchener. In combination, this information is then used to evaluate novelty and ecosystem management options as discussed in Chapter 4.

Analysis of contemporary versus historic conditions for three natural areas (Homer Watson Park, Steckle Woods, and Lakeside Park) was performed by reviewing current ecosystem assessment data for different taxa including plants, birds, and amphibians and where available, also for mammals, reptiles, fish and butterflies. The current condition was compared quantitatively to historic condition by assessing the changes in species composition over time and qualitatively by assessing management implications of these changes.

Human impact/recreation based impacts, encroachments, invasive species concentrations, and significant wildlife features were assessed in 54 natural areas. Ecological land classification was completed for 48 natural areas while native species integrity indicator monitoring was conducted at 15 sites.

3.1. Ecological Land Classification Assessment

Ecological Land Classification provides an overview and characterization of the landscape across Kitchener based on results of a standardized ecosystem assessment protocol. ELC analysis was performed at 48 parks which included approximately 830 ha of land. Based on size characteristics, the 48 parks were split evenly with 24 parks being >10 ha in size and 24 parks <10 ha in size which for management purposes can have significant implications. Larger parks support larger ecosystems based on species richness theory, while smaller more isolated fragments are expected to retain fewer species than larger less isolated ones (Debinski & Holt, 2000). The 24 parks that were >10 ha are listed in Table 12.

Table 12: List of all parks that are greater than ten hectares in size or larger

Park Name	Size (ha)
Huron Natural Area	103.19
Stanley Park	74.29
Homer Watson Park	62.04
Idlewood Park	49.47
Tilt's Bush	37.00
Doon Creek Natural Area	34.65
Brigadoon Woods	33.82
Kiwanis Park	31.46
Lackner Woods	30.34
Steckle Woods	29.87
Pinnacle Hill	24.56
Topper Woods	20.49
Pioneer Tower	19.71
Breithaupt Park	19.38
Laurentian Wetland	19.26
Paige Park	17.32
Borden Wetland	15.53
Monarch Woods	13.86
Springmount	12.99
Grand River Natural Area - Sims Estate	12.37
Carisbrook Park	11.53
Biehn Park	11.19
Idlewood Creek	10.73
Lakeside Park	10.19

The ten most frequently encountered ecosystem types based on total area are provided in Table 13. The dominance of sugar maple (*Acer saccharum* Marshall*)* forest types is also highlighted in this table.

Table 13: Largest ecosystem types as per ELC evaluation results as listed by size (ha)

Ecosystem Type	Size (ha)	Number of Parks
Sugar Maple-Beech	82	13
Sugar Maple Deciduous (Dry-Fresh)	35	5
Sugar Maple-Oak	31	6
Willow lowland Deciduous Forest	30	9
Forb Meadow	28	6
Coniferous Plantation	27	8
Swamp Maple Deciduous Swamp	20	2
Mixed Meadow	19	7
Sugar Maple Ecosite	17.2	3
White Cedar Organic Swamp	16.9	2

A review of ecosystem types also provides opportunity to consider dominance of native vs. non-native or invasive species as a whole. There were 18 ecosystems classified as being dominated by a non-native species. These ecosystems represent 64.7 ha of total land and are highlighted in Table 14.

Table 14: Non-native ecosystem types from ELC evaluation results as listed by size (ha)

Ecosystem Type	Size (ha)	Number of Parks
Moist Exotic Lowland Deciduous Type	10.87	2
Manitoba Maple Lowland Forest	10.69	3
Annual Row Crop	10.30	1
Moist Manitoba Maple Woodland	5.19	4
Reed Canary Mineral Marsh	4.44	8
Manitoba Maple Mineral Swamp	4.02	2
Buckthorn Deciduous Shrub Thicket	3.40	6
Reed Canary Grass Meadow	2.78	2
Non-native Mineral Swamp	2.64	2
Scotch Pine Coniferous Plantation	2.30	1
Smooth Brome Meadow	1.80	2
Reed Canary Organic Meadow	1.38	3
Open Recreation (turf grass)	1.37	1
Parkland (turf grass)	1.35	3
Common Reed Shallow Marsh	1.18	4
Manitoba Maple Deciduous Woodland	0.66	1
Common Reed Mineral Marsh	0.30	3
Reed Canary Grass Shallow Marsh	0.03	1

3.2. Assessment of Recreation-Based Impacts

Recreation based impacts were found to be present in varying magnitudes across the 54 parks surveyed. There were nine different issues (Figure 10) that were assessed with 148 instances being recorded overall and a mean of three issues found per natural area. Seven parks had no management issues and one park had all nine issues occurring. Litter was the most frequently recorded issue and found at 83% or 45 of 54 parks. This was followed by wildlife feeding (39%) and campfire pits plus destruction/removal of plants (26%).

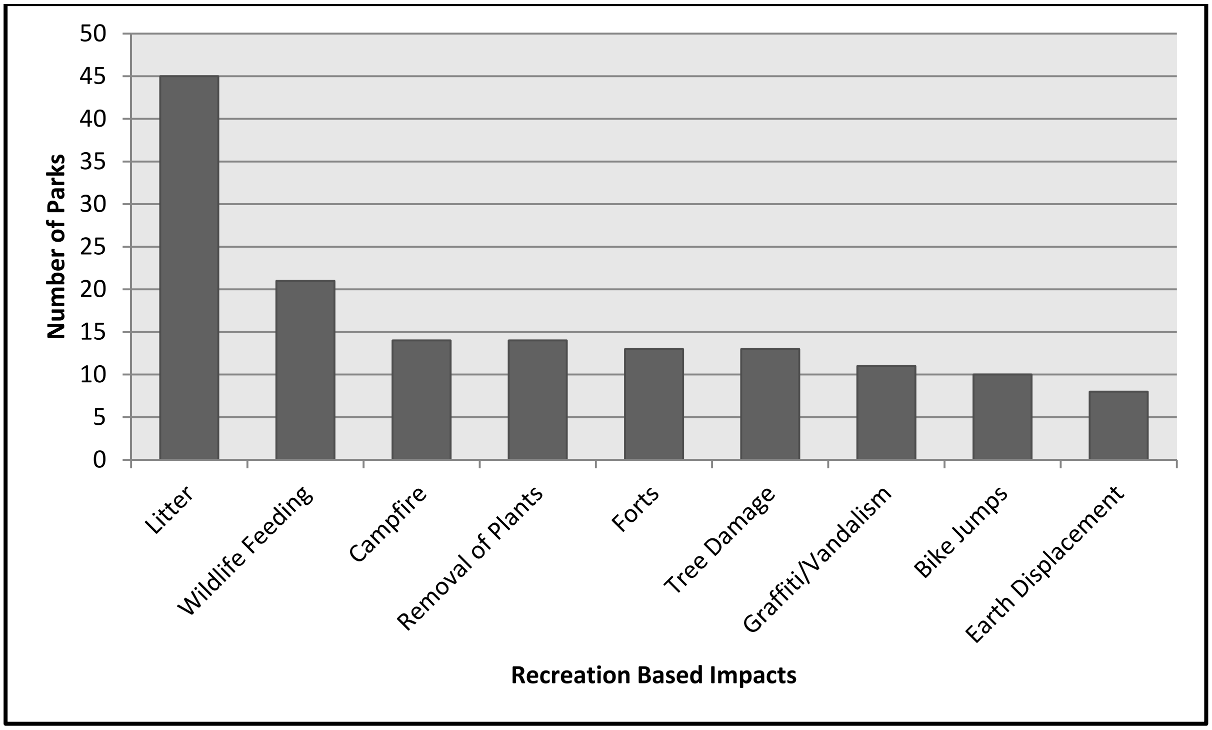

Figure 10: Count of natural areas according to recreation impacts.

For each of the nine issues (see Table 15) that were assessed, all of the impacts were noted to be occurring at the local abundance level in the 48 parks sampled. This essentially means that there were more than one instance (from 1-5) of each occurrence. Four of the issues: litter, bike jumps, earth displacement and wildlife feeding were noted to be occurring at a widespread (6-10 occurrences) level while the litter issue was also recorded at an extensive level with >10 occurrences happening in five different parks.

Table 15: Results of the recreation issue assessment reported by number of parks

Issue	Total Parks	% Total	**Local** (1-5 occurrences)	**Widespread** (6-10 occurrences)	**Extensive** (>10 occurrences)
Litter	45	83%	31	9	5
Wildlife feeding	21	39%	19	2	0
Campfire pits	14	26%	14	0	0
Destruction/removal of plants	14	26%	14	0	0
Forts	13	24%	13	0	0
Tree damage	13	24%	13	0	0
Graffiti/vandalism	11	20%	11	0	0
Bike jumps	10	18%	9	1	0
Earth displacement	8	15%	6	2	0

In order to assess cumulative impacts of management issues, the total number of issues being reported was first organized by park and assigned a magnitude of impact score based on the number of impacts occurring at a single site. The categories were identified as not applicable (no issues present), low (1-3 issues), medium (4-6 issues) and high (7+ issues). Table 16 presents these results and the associated parks. The magnitude or level of impact is intended to imply that parks with no issues would not be impacted and those with more issues would be expected to be under greater threat of change and require higher levels of management intervention.

Table 16: Magnitude of impact scores for the assessment of recreation based impacts

Magnitude Impact Score	# of Issues	Park/Natural Area Name	
		(n =7)	
N/A	**0**	Carisbrook Park Brittania Cres - SWP Idle Creek Drive Paige Park Pioneer Tower Strasburg SWP Unnamed 63	
		(n = 30)	
Low impact	**1-3**	Battler Road – SWP Brigadoon Park Kiwanis Park Kolb Park Lancaster Business Park/ Trail Parkvale Park Schneider Creek Manitou Strasburg Creek North Branch Steckle Woods Waldau Woods Park Biehn Park Briarfield Park Breithaupt Park Grand River Natural Area/ Sims Estate Lynnvalley Park	Millwood Park Petrifying Springs Springwood Park Stauffer Park Windrush Park Concordia Park Idlewood Creek Meinzinger Park Stanley Park Stanley Park Optimist Trailview Park Upper Canada Park Westheights Park Woodfield Court Woolner Woods
		(n = 14)	
Medium impact	**4-6**	Borden Wetlands Brigadoon Woods Doon Creek Hearthwood – SWP Lakeside Park Monarch Woods Strasburg Creek Summerside Woods Topper Woods Laurentian Wetland Idlewood Park Natchez Woods Springmount Tilt's Bush	
		(n = 3)	
High impact	**7+**	Homer Watson Park Pinnacle Hill Lackner Woods* (all 9 issues present)	

Some recreation impacts create management challenges and a further strain on management budgets but do not necessarily change the ecological structure or function of the system. To assess the impact of recreation issues on ecological functioning, the nine different issues were categorized according to level of impact and whether their presence would have a low, medium or high level of impact on the ecological structure and function (considered together) of the natural area being assessed. For example, the presence of litter as a recreation impact, although prevalent throughout Kitchener (found at 45 of 54 parks) would be considered to have a low amount of influence on the functioning of the ecological community however could have a potential contribution to the site being classified and managed as a hybrid or novel ecosystem if it creates a significant strain on management budget and is considered a barrier for management.

The ranking of ecological impact for each recreation issue considered the following criteria: contributes to the existence, potential introduction, spreading or persistence of detrimental non-native exotic plant or animal species; creates a reduction in or impact on the presence of native species and therefore detracts from the traditional or historic ecosystem conditions, creates conditions that inhibit ecosystem functioning (i.e., soil compaction, loss of reproductive capability in native plants or animals, reduction or inhibition of species interactions) and creates or fosters conditions supportive of hybrid and novel ecosystem development.

Table 17 provides results for park issues at low, medium and high levels of ecological impact. An individual park could be considered to be affected at low, medium and high levels depending on the number of issues present at the site however number of occurrences alone does not provide suitable justification for impact levels. From a management perspective, identifying parks being affected by issues causing highest levels of ecological impact is of high priority and representative of overall impact. These sites could be considered strong candidates for greater management intervention or potentially sites where management barriers could elicit an alternative management approach (i.e., manage as hybrid or novel system). The alternative could also be true in that sites with low impact scores (both magnitude and ecological scores) could have greatest potential to be managed towards historic conditions. Of course, additional assessment of other factors is required in order to assess overall park condition and determine appropriate management approaches.

Table 17: Ecological impact scores based on cumulative totals for recreation impacts

a) Ecological Impact Score	b) Issue	c) Park/Natural Area Name
Low impact	**Litter** **Graffiti/vandalism**	**(both issues)** Concordia Park Stanley Park Optimist Westheights Park Natchez Woods Homer Watson Park Lackner Woods Laurentian Wetlands Strasburg Creek Stanley Park Borden Wetlands Idlewood Park
Medium impact	**Wildlife feeding** **Campfire pits** **Forts**	**(all three issues)** Springmount Pinnacle Hill Tilt's Bush Lackner Woods
		(two of three issues) Meinzinger Park Upper Canada Park Summerside Woods Woolner Woods Biehn Park Doon Creek Lakeside Park
High impact	**Removal of plants** **Bike jumps** **Earth displacement** **Tree damage**	**(all four issues)** Homer Watson Park Lackner Woods
		(three of four issues) Hearthwood SWP Pinnacle Hill Idlewood Park
		(two of four issues) Brigadoon Woods Natchez Woods Topper Woods Springmount Laurentian Wetlands Monarch Woods Strasburg Creek Tilt's Bush

3.3. Assessment of Encroachments

Impacts were also assessed at each park according to whether they were occurring directly behind or adjacent to a private business or residential building. These impacts were classified as encroachments and assessed separately than recreation impacts.

There were 128 encroachments recorded for the 54 sites with a mean of 2.3 issues being found per natural area. 85% or 46 of 54 sites had encroachment issues. The total number of individual encroachments was tallied for each natural area (Figure 12) and then used to assign the site an abundance code (Figure 11). Most sites were scored as occurring at a local level (between 1-5 encroachments). The full results and abundance codes listed by park are provided in Table 18.

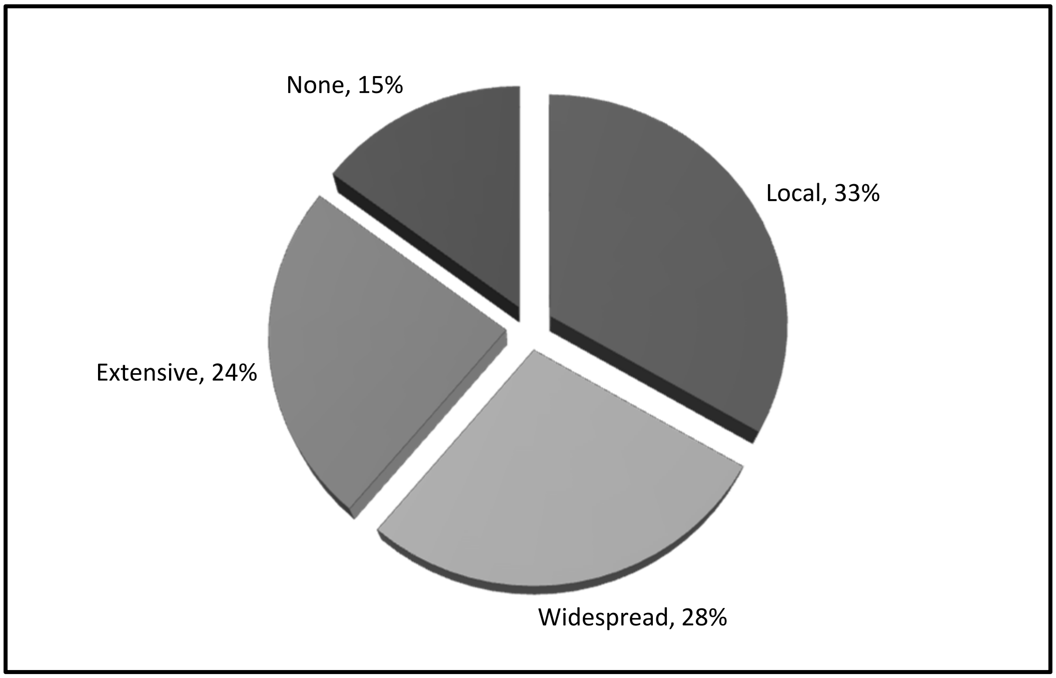

Figure 11: Abundance totals for encroachments.

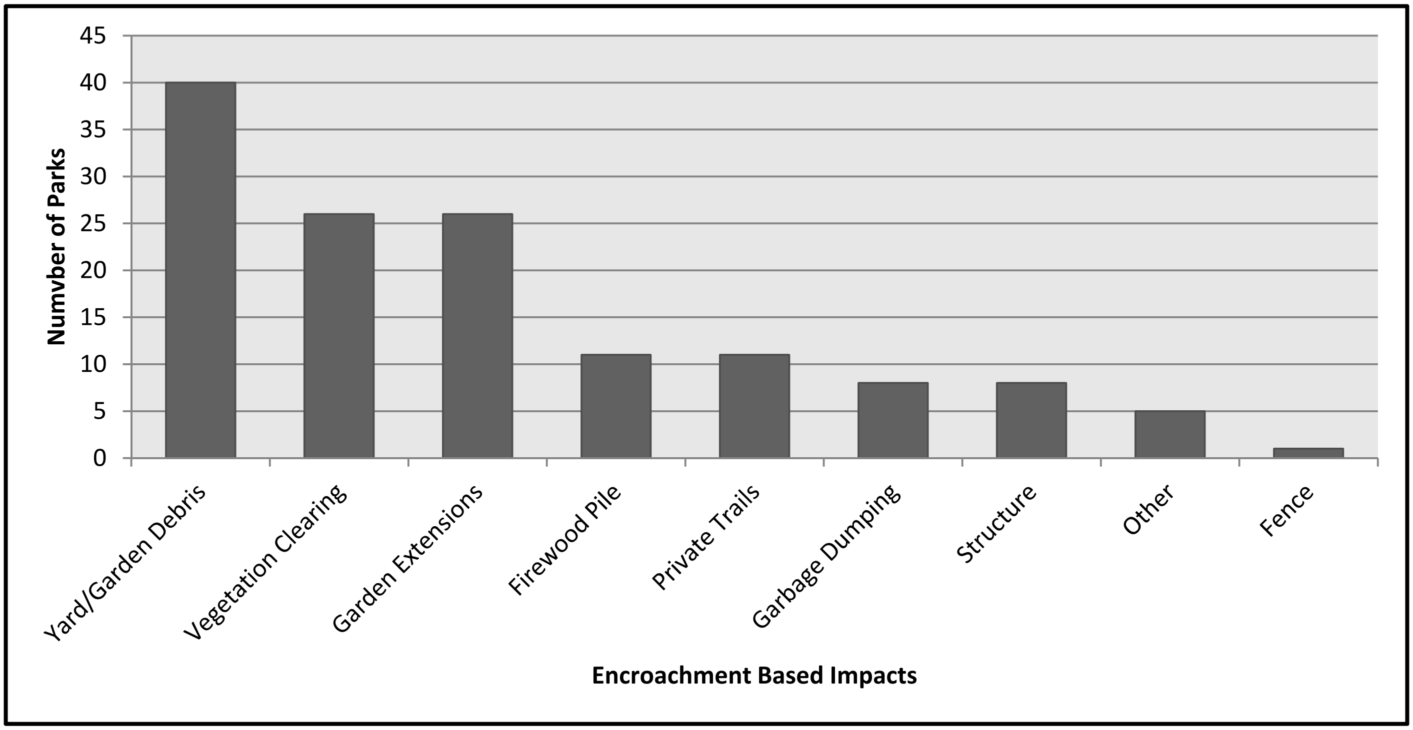

Table 18: Categorization of parks according to their respective cumulative totals for encroachment based impacts

Figure 12: Count of natural area with each encroachment type

Local (1-5)	**Widespread (6-10)**	**Extensive (>10)**	**No Encroachments**
(n = 18)	**(n = 15)**	**(n = 13)**	**(n = 8)**
Battler Road - SWP	Biehn Park	Borden Wetlands	Brittania Cres SWP
Brigadoon Woods	Briarfield Park	Breithaupt Park	Carisbrook Park
Homer Watson Park	Brigadoon Park	Doon Creek	Kiwanis Park
Idle Creek Drive	Concordia Park	Grand River Natural Area - Sims Estate	Kolb Park
Lakeside Park	Hearthwood - SWP	Idlewood Creek	Paige Park
Lancaster Business Park Trail	Laurentian Wetland	Idlewood Park	Pioneer Tower
Lynnvalley Park	Millwood Park	Lackner Woods	Springwood Park
Meinzinger Park	Monarch Woods	Springmount	Steckle Woods
Parkvale Park	Natchez Woods	Stanley Park	
Petrifying Springs	Pinnacle Hill	Strasburg Creek	
Schneider Creek Manitou	Summerside Woods	Tilt's Bush	
Stanley Park Optimist	Waldau Woods Park	Topper Woods	
Stauffer Park	Westheights Park	Upper Canada Park	
Strasburg Creek North Branch	Windrush Park		
Strasburg SWP	Woodfield Court		
Trailview Park			
Unnamed 63			
Woolner Woods			

The type of issue occurring most frequently was yard/garden debris dumping which was found at 74% of the sites (40 parks). This issue was followed by garden extensions and vegetation clearing both of which were recorded at 48% of sites. Of the 26 parks where these two issues were observed, 16 were the same park.

An ecological impact assessment was also performed for encroachment issues by categorizing the issue according to level of impact its presence would have on the structure and function of the natural area being sampled (Table 19). The same criterion for recreation impacts (Section 3.2) was used to evaluate whether encroachment impacts were negatively affecting the integrity or historic conditions of the site. Most encroachment issues were noted to be occurring at a low overall level (1-3 issues). Two parks (Idlewood Park and Lackner Woods) had six of eight issues present and six parks (Borden Wetlands, Biehn Park, Doon Creek, Lakeside Park, Stanley Park & Tilt's Bush) had five issues which together represents the highest number of encroachments detected. The two issues noted to be occurring most frequently across Kitchener (yard waste dumping and vegetation clearing) also have a high impact on the ecosystem structure and can contribute to ecosystem level changes at these sites. Specifically, the dumping of garden refuse acts as a transport mechanism for invasive species (Hodkinson & Thompson, 1997) which directly impact ecosystem integrity by causing declines in species native species richness and by altering community structure (Gaertner et al., 2009; Levine et al., 2003).

Table 19: Ecological impact scores based on cumulative totals for encroachment impacts

a) Ecological Impact Score	b) Issue	c) Park/Natural Area Name
Low impact	**Garbage dumping** **Fence** **Firewood storage**	**(two of three issues)** Millwood Park Borden Wetlands Lackner Woods
Medium impact	**Permanent structure** **Private footpath**	**(both issues)** Borden Wetlands Doon Creek Tilt's Bush Idlewood Creek
High impact	**Garden extensions** **Vegetation clearing** **Yard waste dumping**	**(all three issues)** Unnamed 63 Brigadoon Park Upper Canada Park Breithaupt Park Hearthwood SWP Idlewood Creek Trailview Park Woolner Woods Biehn Park Laurentian Wetlands Monarch Woods Strasburg Creek Stanley Park Doon Creek Lakeside Park Pinnacle Hill Idlewood Park Lackner Woods
		(two of three issues) Summerside Woods Topper Woods Woodfield Court Westheights Park Briarfield Park Stauffer Park Lynnvalley Park SpringwoodPark Schneider Creek-Manitou Idle Creek Drive

3.4. Combined Assessment of Recreation plus Encroachment Impacts

When considering overall impact, it is important to consider whether the same parks are being affected by recreation issues as those being impacted by encroachments. Immediately, some differences will occur simply because not all parks have residential or commercial land use adjacent to them. These same parks may still be subject to human or recreation based impacts.

An assessment of all 17 issues combined (recreation based plus encroachments) for each park was also performed. There were no parks that had all 17 issues present. Lackner Woods had 15 issues followed by Idlewood Park with 12, Tilt's Bush with 11 and Pinnacle Hill with ten.

Results for the combined assessment of high level ecological impacts are presented in Table 20. Only Lackner Woods was found to be under threat from all four high level recreation impacts (removal of plants, bike jumps, earth displacement, tree damage) plus all three high level encroachment impacts (garden extension, vegetation clearing, yard waste dumping). There were two parks, Pinnacle Hill and Idlewood Park being impacted by six of seven high level impact issues. Just over half (55%) of all parks surveyed were found to have 50% or more of their detected issues classified as high-level type impacts. Of the 13 parks with more than eight issues recorded, six had >50% of their total considered to be high ecological impact type issues.

Table 20: Assessment of total ecological impact as a factor of the combined totals for recreation based and encroachment issues

Criteria (a) Recreation: High Impact Level (all issues)	**Criteria (b) Encroachment: High Impact Level (all issues)**	**Parks Meeting Criteria (a) + (b)**
(n = 2)	**(n = 18)**	**(n =1)**
	Unnamed 63	Lackner Woods
Homer Watson Park	Brigadoon Park	
	Upper Canada Park	
Lackner Woods	Breithaupt Park	
	Hearthwood SWP	
	Idlewood Creek	
	Trailview Park	
	Woolner Woods	
	Biehn Park	
	Laurentian Wetlands	
	Monarch Woods	
	Strasburg Creek	
	Stanley Park	
	Doon Creek	
	Lakeside Park	
	Pinnacle Hill	
	Idlewood Park	
	Lackner Woods	

3.5. Informal Trail Networks

Informal trails were identified as being present in 28 parks or just over half (52%) of the sites surveyed. Full results of the informal trail network assessment are provided in Table 21. A similar magnitude of impact scale was adopted as was used for recreation impacts in that the more trails present at a site, the higher perceived level of combined impact. The majority of the parks where trail networks were present only had one occurrence (11 parks) while two sites had the highest abundance level with eight occurrences recorded. No efforts were made to identify the length, size or significance of the unauthorized trails. Of the 28 parks with informal networks, the majority of sites (22) had low a level (1-3) of occurrences.

Table 21: Assessment and organization of parks by the total number of informal trail networks detected

Impact Level	# of Occurrences	Park/Natural Area Name
		(n =26)
No informal trails	**0**	Battler Road - SWP Biehn Park Briarfield Park Brittania Cres - SWP Carisbrook Park Doon Creek Grand River Natural Area - Sims Estate Homer Watson Park Idle Creek Drive Kiwanis Park Kolb Park Lakeside Park Lancaster Business Park Trail Meinzinger Park Paige Park Parkvale Park Petrifying Springs Schneider Creek Manitou Springmount Stanley Park Strasburg Creek North Branch Strasburg SWP Unnamed 63 Waldau Woods Park Windrush Park Woolner Woods
		(n = 22)
Low	**1-3**	Borden Wetlands Brigadoon Park Brigadoon Woods Concordia Park Hearthwood - SWP Idlewood Creek Lackner Woods Laurentian Wetland Lynnvalley Park Millwood Park Monarch Woods Natchez Woods Pioneer Tower Springwood Park Stanley Park Optimist Stauffer Park Summerside Woods Tilt's Bush Topper Woods Trailview Park Upper Canada Park Woodfield Court
		(n = 3)
Medium	**4-6**	Pinnacle Hill Steckle Woods Westheights Park
		(n=3)
High	**7+**	Breithaupt Park Idlewood Park Strasburg Creek

3.6. Invasive Species

Eight invasive plant species were assessed with at least one species being found in all 54 parks. Common buckthorn was the most prevalent and found in 52 of 54 parks or 96% of sites. Garlic mustard and periwinkle were the next abundant and found at 85% and 54% respectively. Dog-strangling vine was found at only one park and in a small amount (<10 m^2 and <5 patches). Figure 13 provides full results for all species that were assessed.

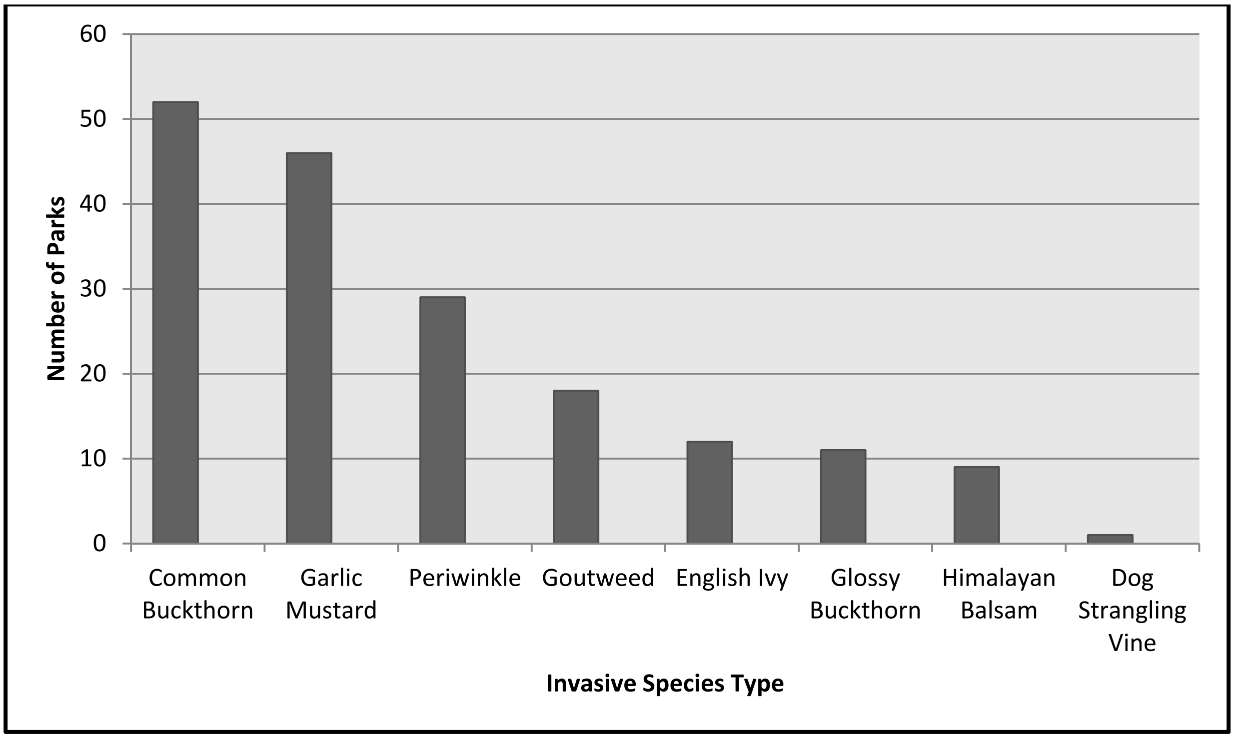

Figure 13: Count of natural area according to invasive species type.

Springmount Park had seven of eight species while the mode for all 54 parks was four species present. There were four parks (Idlewood Park, Lakeside Park, Stanley Park and Tilt's Bush) that had six species recorded and three parks (Borden Woods, Monarch Woods and Waldau Woods) that had five species which together represent the highest recorded values for number of invasive species found per park.

Additional effort was made to determine impact level of invasive species as a representation of the impact on the park as a whole. This assessment provides a better indication of overall impact on integrity of the park. The maximum score and what can be considered as having greatest impact was >10 as the high value for number of patches and >50 m^2 as the highest size value for patch of any species. Common buckthorn scored highest in terms of patch size with 41 parks having a patch size >50 m^2 and also scored highest in terms of number of parks with 28 parks having > 10 patches. There were 25 parks that had both >10 patches and at least one patch >50 m^2. This does not imply that all patches were >50 m^2 but instead is used to reflect the max score possible for the category. There were some parks in the study that had >10 patches of an individual species but none of the patches were >50 m^2 in size. Periwinkle and garlic mustard were the next most abundant and scored much lower in terms of number of parks with five and four parks respectively. The total number of parks for each impact category in relation to the eight species is presented in Table 22.

Table 22: Results for invasive species assessments as organized by number of parks and by patch size

Species	Number of parks with largest patch size >50 m^2	Number of parks with >10 patches	Number of parks with >10 patches and largest patch >50 m^2
Common buckthorn	41	28	25
Garlic mustard	19	5	4
Periwinkle	11	5	5
Goutweed	6	0	0
Himalayan balsam	4	0	0
English ivy	3	0	0
Glossy buckthorn	1	0	0
Dog-strangling vine	0	0	0

Based on the criteria for invasive species, Breithaupt Park and Stanley Park represent the parks scoring highest (or worst in terms of potential impact) with each park having with >10 patches of garlic mustard, periwinkle and common buckthorn as well as at least one patch of each of those species >50 m^2 in size. Monarch Woods and Tilt's Bush met these criteria for two of the three species. As mentioned previously, Stanley Park also had six of the eight species present overall.

Although Springmount Park had seven species present, a review of the distribution and quantity of these species suggests that the amounts are relatively low with four of the six species with <5 patches, two with 5-10 patches and only one, common buckthorn with >10 patches. In terms of magnitude of impact, only two species, common buckthorn and periwinkle had patches >50 m^2. Idlewood Park in comparison, had all six species present with patch sizes >50 m^2 and two of those (common buckthorn and periwinkle) with >10 patches plus patch size scores of >50 m^2. Also considered to be under greatest impact from invasive species was Stanley Park where four species were found in patches >50 m^2 and three of those species had >10 patches.

Waldau Woods had concentrations at the lower end of the spectrum with zero patches that were >50 m^2 and all but one species (garlic mustard) with >5 patches. Borden Wetland was also a site where only one species (common buckthorn) was found in a patch >50 m^2 in size. All of the other five species at Borden Wetland were <10 m^2 and <5 patches total per species.

Table 23 provides a characterization of invasive species abundance levels for the eight parks that had the highest number of species present. These results help provide some context for assessing impact of species by considering impact on a park by park basis using volume (based on number of patches) and magnitude based on size of largest patch. This data provides support for making educated decisions about management approaches as parks with high numbers and large volume of invasive species would be expected to require more intervention and resource allocations than parks with less. Alternatively, this assessment can also aid in prioritizing restoration and management projects as parks with low levels of invasive species could be managed for historic conditions while it might be more appropriate to manage parks with high levels of invasive species as hybrid or novel systems.

Recognizing that any level of invasion could impact a system's integrity and move it further from historic conditions, these results should be interpreted in the context of amount and effort required to control and remove each species from the site as well as whether the species is having or could cause ecosystem level impacts.

Table 23: Characterization of the abundance levels for invasive species impacts as presented for parks with the greatest overall number of species detected for those being assessed

Park Name	Species	Number of Patches Found			Size of Largest Patch		
		<5	5-10	>10	<10m^2	<50m^2	>50m^2
Springmount Park	**(n=7)**						
	Common buckthorn			x			x
	English ivy	x			x		
	Garlic mustard		x		x		
	Glossy buckthorn	x				x	
	Goutweed	x			x		
	Himalayan balsam	x			x		
	Periwinkle		x				x
Idlewood Park	**(n=6)**						
	Common buckthorn			x			x
	English ivy	x					x
	Garlic mustard		x				x
	Glossy buckthorn	x					x
	Goutweed		x				x
	Periwinkle			x			x
Lakeside Park	**(n=6)**						
	Common buckthorn			x			x
	Garlic mustard		x				x
	Glossy buckthorn		x			x	
	Goutweed	x			x		
	Himalayan balsam	x				x	
	Periwinkle	x					x
Stanley Park	**(n=6)**						
	Common buckthorn			x			x
	English ivy	x			x		
	Garlic mustard			x			x
	Goutweed		x				x
	Himalayan balsam	x			x		
	Periwinkle			x			x
Tilt's Bush	**(n=6)**						
	Common buckthorn			x			x
	English ivy	x			x		
	Garlic mustard		x				x
	Glossy buckthorn	x			x		
	Goutweed		x		x		
	Periwinkle			x			x
	(n=5)						
Waldau Woods	Common buckthorn	x			x		
	English ivy	x				x	
	Garlic mustard		x		x		
	Goutweed	x			x		
	Periwinkle	x				x	

Borden Wetland	**(n=5)**						
	Common buckthorn		x				x
	English ivy	x			x		
	Garlic mustard	x			x		
	Goutweed	x			x		
	Periwinkle	x			x		
Monarch Woods	**(n=5)**						
	Common buckthorn			x	x		
	English ivy		x				x
	Garlic mustard			x			x
	Goutweed	x					x
	Periwinkle			x			x

3.7. Comparative Analysis of Historic versus Contemporary Conditions

In order to characterize an ecosystem or natural area site as novel, some attempt to determine change or a comparison of the altered or degraded site against a reference system must be sought (Harris et al., 2013). For three natural areas, a comprehensive inventory was completed by professional biological consultants in an attempt to characterize current ecosystem conditions using species richness as the main measurement value. The current conditions for different taxa were compared to historic survey records for the same sites. It is important to note that the historic conditions do not represent a pre-human disturbance point as development was occurring in these areas of Kitchener at the time of the historic inventories and human impacts would have been present. The information gathered through this assessment can be used to set management directions and potential restoration targets.

3.7.1. Lakeside Park

Lakeside Park is a 15 hectare natural area located in close proximity (approx. 2.5 km) to the urban core of Kitchener. Although this park is largely fragmented and surrounded by residential and other urban development, there are several features that are attractive to urban adapted wildlife. The current ecosystem conditions are considered disturbed and typical of those found in urban environments.

Prior to 1955, Lakeside Park was mainly farmland with an active sand quarry from 1920 -1960. Around 1989, grass cutting was reduced in the park and natural succession of the adjacent forest and meadow communities took place.

A vegetation inventory was completed in Lakeside Park during 2013 as part of background collection for the development of an environmental management plan (Dance et al., 2014). To characterize the historic conditions for Lakeside Park, published data from a 1973 road extension environmental assessment project was compared to the results of the 2013 study.

The 1973 study inventoried plants in July 1973 and identified 187 plant species, plus 18 species, which at the time, were only identified to the genus level (Ecologistics Limited, 1973). These 18 species were not included in the analysis of comparative condition as their identification was not confirmed and therefore cannot be accurately compared to the species found in 2013. In 2013, 272 plant species were identified. Table 24 provides a comparison of species richness for both time periods as well as comparison of richness for both native and non-native species. There has been an increase in total plant species with the non-native species accounting for an increase of 44 species and the native species increasing by 41 species. The increase in total species from 1973 has also meant an increase in weediness value for the species present with an additional eight species being considered as having a high level of invasiveness potential (Dance et al., 2014; Oldham, 1995). The 2013 survey results could have detected more species as there were additional hours dedicated to spring and summer flora surveys whereas the 1973 surveys were only noted as occurring in July.

Table 24: Changes in plant species richness for both native and non-native species in Lakeside Park between 1973 and 2013

	1973		**2013**	
	Number of Species	**% of Identified Species**	**Number of Species**	**% of Identified Species**
Native species	105	56.15	146	53.7
Non-native species	82	43.85	126	46.3

Other taxa were also compared to historic records from Lakeside Park to give a more comprehensive overview of ecosystem changes based on species richness values. Suitable historic records were available for birds, amphibians, reptiles and fish. Surveys for birds were conducted in June, July and September 1973. The comparison of results to the surveys conducted in 2013 indicates a slight increase in the number of breeding bird species with the loss of some habitat specialists. For amphibians, the same two species – American toad and green frog were present in 2013 as were found in the 1980's (K. Dance, personal communications, 2013). For turtles, the same three species found in 2013 were also noted in the 1980's with the non-native red-eared slider (*Trachemys scripta elegans* W.) also recorded in the park historically (K. Dance, personal communications, Sept, 2013).

The results for fish species can provide insight into the presence or absence of some of the other taxa (particularly birds) mentioned previously. Fisheries records were available for Shoemaker Pond dating back to 1971 with detailed electrofishing survey results as well as incidental observations. Electrofishing results from 1992 identified pumpkinseed (*Lepomis gibbosus* L.), *r*ock bass (*Ambloplites rupestris* Rafinesque*)*, and goldfish (*Carrassius auratus* L.*)* as the main three species found in the pond. Further sampling in 2004 revealed that fathead minnow (*Pimephales promelas* R.*)* and creek chub (*Semotilus atromaculatus* R.*)* were also present. The sampling done in 2010 (Natural Resource Solutions Inc. 2010) was the most recent survey data and confirmed that the composition of the fish population has generally progressed towards a dominance of non-native and pollution tolerant species with the common carp (*Cyprinus carpio* L.*)* and goldfish now being the most abundant component of the overall present day fish community.

Interestingly and based on several anecdotal observations including Figure 14, the goldfish seemingly also represent a significant food source for other commonly observed species that use the park. Species including herons, kingfishers, osprey and the pied-billed grebe (*Podilymbus podiceps* L.), which is a Regionally Significant breeding bird species for Waterloo Region (Dance et al., 2014), frequent Lakeside and also feed on goldfish.

Figure 14: Adult pied-billed grebe (left) with young of year (right) feeding on goldfish at Lakeside Park (Photo Credit with permission: Luanne Hickey).

3.7.2. Steckle Woods

Steckle Woods is a 30 hectare tract of upland deciduous forest located in southcentral Kitchener surrounded by industrial development and major road networks. This natural area features many large diameter tree species including sugar maple, red oak (*Quercus rubra* L.), American beech (*Fagus grandifolia* Ehrh) and black cherry (*Prunus serotine E.)* (NRSI, 2014a). There are no wetlands onsite although the rolling topography within the forest does create moist pockets and microclimates throughout the entire forest. A small naturalized coniferous plantation and meadow habitat exists along the southern edge of the mature forest. The park is designated as an Environmentally Sensitive Policy Area (ESPA) by the Region of Waterloo (ROW) and a Core Environmental Feature in the Regional Official Plan (ROW 2010). This area receives a high volume of use by trail walkers, bikers, outdoor enthusiasts and dog walkers. The park is surrounded entirely by intense industrial development, major road networks and commercial establishments.

An initial ecological management study was carried out by the University of Waterloo in 1967-1968 (Barker, 1968) and Waterloo Region Nature (formerly the Kitchener-Waterloo Field Naturalists) has conducted a number of outings to the park over the years, documenting bird and plant life. The Regional Municipality of Waterloo (RMOW) carried out a formal study of the park and its natural features in 1986 complete with an analysis of factors related to the effective management of this area. Using recommendations from this management plan, the City of Kitchener's Parks and Recreation Department completed a Master Plan for the use of Steckle Woods, addressing issues related to acceptable uses, trails, roads and parking, visitor facilities and signage (City of Kitchener, 1989).

The ROW 1986 (ROW, 1986a) study and subsequent City of Kitchener 1989 study are the main sources of information for the historical conditions and species records for the park. The historic records were compiled over time by various local biologists with plant records being confirmed in the field during seasonal surveys prior to the ROW ESPA designation in 1986. A four season's natural heritage inventory was completed by Natural Resource Solutions (NRSI, 2014a) for the park and provides information of current ecological condition as well as detailed flora and fauna records.

The 1986 study identified 195 plants species for the park. The park inventory completed in 2014 identified fewer plants overall with 123 species. Table 25 below provides the breakdown comparison for plants from 1986 to 2014 including the comparison of exotic non-native species and native species. An overall decrease in number of plant species has occurred in the 28 years between surveys which could be attributed to many factors including habitat succession, trail development, poaching of native wildflowers or hydrological changes associated with adjacent road widening.

Table 25: Changes in plant species richness for both native and non-native species in Steckle Woods between 1986 and 2014

	1986		**2014**	
	Number of Species	**% of Identified Species**	**Number of Species**	**% of Identified Species**
Native species	145	74.4	91	72.8
Non-native species	50	25.6	34	27.2

Plant species richness decreased overall with 54 less native species being detected and 16 less non-native species detected in the 2014 surveys.

For other taxa, a similar decrease in diversity was noted for birds and mammals while no comparative data was available for herpetofauna, lepidoptera and odonate species. There was a decrease of eight species for birds and decrease of one species for mammals.

3.7.3. Homer Watson Park

Homer Watson Park is a 62 hectare contiguous natural area containing a variety of ecosystem types and diversity of habitats including forests, plantation, wetland, riparian zones and areas of steep bluffs. The park itself is designated as a Region of Waterloo Environmentally Sensitive Policy Area (ESPA) and is under ownership of three different parties: City of Kitchener, Region of Waterloo and Grand River Conservation Authority. The area is regularly used by the public for passive (walking) and active (biking) recreational pursuits. Human disturbances have been present in the area since 1827 when a road was constructed though a portion of the park (NRSI 2014b). The park is adjacent to the Grand River with a small amount of residential development as well as some institutional development abutting the area.

Historic conditions were identified via a 1986 study performed as part of the ESPA designation study (ROW 1986b) while current conditions were determined via a four-season natural heritage inventory completed in 2014 (NRSI 2014b). As with records for Steckle Woods, the Homer Watson Park historic records were compiled over time by various local biologists and confirmed in the field during seasonal surveys prior to the ROW ESPA designation in 1986. The 1986 study identified 121 plant species within the park while the 2014 inventory identified 355 species for an overall increase in plant richness of 234 species. Table 26 highlights the relative increases in native and non-native species including the 12 % increase in non-native species.

Table 26: Changes in plant species richness for both native and non-native species in Homer Watson Park between 1986 and 2014

	1986		**2014**	
	Number of Species	**% of Identified Species**	**Number of Species**	**% of Identified Species**
Native species	108	89.2	274	77.1
Non-native species	13	10.7	81	22.9

In the 28 years between studies, native plant richness increased by 166 species while non-native species richness increased by 68 species. Again this difference could be attributed to natural habitat changes such as succession; however, some differences could also be due to differences in sampling intensity as exact methodology for the original inventory was not available. Regardless, the increase in overall diversity is associated with increases in both native and non-native species. The increase in non-native species includes more weedy species with 33 species at medium levels, 27 at low level and 20 at a high weedinesss level.

Comparative data was also available for breeding birds with species lists compiled for the park in 1986 and in 2014. There was also an increase in overall breeding bird diversity with 29 more species being detected in 2014 for a total of 54 species versus 24 identified in 1986. Notable changes include the addition of 12 Regionally Significant species now found breeding in the park.

No comprehensive data was available from the 1986 surveys for other taxa so therefore no analysis of change for mammals or herpetofauna was attempted.

3.8. Significant Wildlife Habitat Assessment

Significant Wildlife Habitat (SWH) was assessed and used as a measure of habitat quality and ecological integrity as the presence of different features would be expected to provide the necessary conditions for target species of wildlife.

There were four SWH categories assessed featuring evaluation criteria for 29 different possible features. SWH was evaluated as either present where the feature or attribute was found and would support the wildlife in question or not present. The totals were calculated by park and assessed for the same 54 natural areas as those surveyed for human impacts, informal trails and invasive species. The presence of significant wildlife habitat features can provide insight into the functioning of specific ecosystems and/or is an indicator of overall natural area condition. The absence of these features can also indicate potential variance from traditional or historical conditions. Further, the use of wildlife habitat features as an indicator of ecosystem condition was chosen based on the notion that if the habitat feature is present or has potential to support the species in question, then further conservation, restoration or ecosystem management efforts could either restore function to the system or help ensure minimum population viability for the species or taxa in question (OMNR, 2000).

3.8.1. Seasonal Concentration Areas

There were 29 parks that had at least one seasonal concentration feature present. Potential bat maternity roost sites and turtle wintering areas were the most frequently encountered wildlife habitat features with each being found in 14 parks. The criteria for bat maternity roost habitat are presence of tree snags which could be used by bats. No further effort was made to determine whether bats were actually using these features during the maternal period. Turtle wintering areas were considered present if suitable permanent water features were found. No additional effort was made to confirm the presence of turtles in these habitats which would confirm the actual utilization of the habitat feature. Table 27 provides full results for the proportion of parks where the respective eight wildlife features were found.

Table 27: Results of seasonal wildlife concentration assessment organized by number of parks where these features were detected

Wildlife Feature	Number of Parks	% Total of Parks
Bat maternity roost/colony	14	26
Turtle wintering area	14	26
Snake hibernaculum	8	15
Deer yarding/congregation area	6	11
Shorebird migration stopover area	6	11
Wild turkey winter habitat	6	11
Waterfowl stopover/staging area	2	4
Raptor wintering area	1	2

Homer Watson Park was the park with the greatest number of wildlife features present with five possible features identified. There were 11 parks with one and two features present, five parks had three features present, one park had four and one park had five features representing the high values for this category. Results for the top five parks with highest proportion of wildlife features are provided below in Table 28.

Table 28: Results for top five parks where seasonal wildlife concentration areas were detected.

	Seasonal Wildlife Concentration Areas								
	BMR	**DYA**	**RWA**	**SMS**	**SH**	**TWA**	**WSA**	**WTWH**	
Homer Watson Park	X	X		X	X			X	5
Natchez Woods	X	X			X			X	4
Strasburg Creek	X	X				X			3
Doon Creek		X			X	X			3
Idlewood Park	X				X	X			3

Legend: BMR – bat maternity roost; DYA – deer yarding area; SMSA – shorebird migratory stopover area; SH – snake hibernaculum; TWA – turtle wintering area; WSA – waterfowl staging area; WTWA – wild turkey wintering area.

3.8.2. Specialized Habitat

There were ten specialized habitat categories evaluated with 51 of 54 (94%) parks that were surveyed having at least one specialized habitat feature present. Amphibian breeding habitat ranked the highest and was found at 33 locations or 61% of parks. This was followed by area-sensitive species (31 parks) and high habitat diversity (25 parks). The least common features were bald eagle/osprey habitat (five parks), mink denning sites and turtle nesting habitat found at 11 parks and woodland raptor nesting found at 12 parks. Full results for all ten categories are listed in Table 29.

Table 29: Results of specialized wildlife habitat assessment organized by number of parks where these features were detected

Wildlife Feature	Number of Parks	% Total of Parks
Amphibian breeding habitat	33	61
Area-sensitive species	31	57
High habitat diversity	25	46
Fish habitat	24	44
Waterfowl nesting habitat	22	41
Seeps and springs	14	26
Woodland raptor nesting	12	22
Turtle nesting habitat	11	20
Mink denning sites	11	20
Bald eagle/osprey habitat	5	9

Overall, the mode for wildlife features per park was one with 12 parks scoring in this range. Homer Watson Park was again the park with most features with nine of ten followed by Tilt's Bush, Brigadoon Woods and Strasburg Creek each with seven features and eight parks that had six features which represents the highest overall scores. The results for top five parks with specialized wildlife features are provided below (Table 30).

Table 30: Results for top five parks where specialized wildlife habitat features were detected

	Specialized Wildlife Habitat Features										
	ABH	**ASSH**	**FH**	**HHD**	**MDS**	**BEOH**	**SAS**	**TNH**	**WNH**	**WRN**	
Homer Watson Park	X	X	X	X	X	X	X		X	X	9
Tilt's Bush	X	X	X	X	X		X		X		7
Brigadoon Woods	X	X	X	X	X		X			X	7
Strasburg Creek	X	X	X	X	X	X			X		7
Lackner Woods	X	X		X	X		X			X	6

<u>Legend:</u> ABH – amphibian breeding habitat; ASSH – area-sensitive species habitat; FH – fish habitat; HHD – high habitat diversity; MDS – mink denning sites; BEOH – Bald eagle/osprey habitat; SAS – seepage and springs; TNH – turtle nesting habitat; WNH – waterfowl nesting habitat; WRN – woodland raptor nesting.

3.8.3. Habitats of Species of Conservation Concern

Species considered to be of Conservation Concern have been identified by the Province of Ontario and are species considered to be in decline and ranked as either Special Concern or Rare. This assessment considered whether a habitat for species of conservation concern was present and included five different habitat types as well as a general category. Results for species of special concern were low overall with only 20 parks or 37% of sites sampled having at least one feature present. Special Concern and rare species habitat was highest with eight (only 15% of sites) while only two parks had shrub/early successional habitats. The majority of sites (12) had one habitat type present while Natchez Woods scored highest with four habitats of species of special concern present. Table 31 identifies the number of parks with each habitat type present.

Table 31: Results of assessment for habitats of species of conservation concern organized by number of parks

Habitat Type	Number of Parks	% Total of Parks
Special concern and rare species habitat	8	15
Marsh breeding bird habitat	7	13
Open country bird habitat	7	13
Woodland area-sensitive bird habitat	5	9
Shrub/early successional habitat	2	4

3.8.4. Linkage and Movement Corridors

The ability of species to successfully move from one natural area to another or from habitat to habitat can have significant implications on species survival and overall ecosystem function (Hess & Fischer, 2001). Fifty-two of 54 parks had at least one of four features present. Table 32 provides full results for the features as well as the breakdown for number of parks.

Table 32: Results for linkage and movement corridor features assessment as presented by number of parks where these features were detected

Wildlife Feature	Number of Parks	% Total of Parks
Close proximity to natural feature	49	91
Mammal movement corridor	24	44
Natural linkage/ecological stepping stone	17	31
Herpetofauna movement corridor	15	28

The mode for features per park was one feature while eight parks had the maximum features present. In general, most parks (91%) are located in proximity to adjacent open space, parkland or similar natural habitat. No efforts were made to identify road density, adjacent habitat quality or other potential barriers to species movements.

3.9. Indicator Monitoring

Results for the indicator monitoring assessment were included for 15 parks. This number was adjusted from the original 17 sites that were identified for inventory as two sites were removed from the data analysis due to incomplete data sets and inconsistent data collection by the volunteer monitors assigned to the site.

Two full years of data collection were performed by the same volunteer and the indicator was considered present or positive if identified by the site monitor using the accepted monitoring protocol or as identified by 'other' which included the author of this study during a site reconnaissance visit or by a professional biological consultant working at the site.

For each season of monitoring, the presence or absence of the indicators provides information about current ecosystem condition and helps allude to whether the parks have their characteristic or historic species composition intact or have undergone changes due to various disturbance factors.

The monitoring results for indicators were broken down by site and are reported below (Table 33) by season, taxa and combined total. There were 35 indicators selected for monitoring. The Huron Natural Area had the highest number of indicators present with 29 of 35. Overall, only five of the 15 parks sampled had >50% of the indicators present.

Table 33: Results for the volunteer assessment of ecological indicators for each monitoring season for all 15 parks that were assessed

	Spring (n =14)	**Summer (n=14)**	**Fall (n=2)**	**Winter (n=5)**	**Total (n=35)**	**% of Total**
Huron Natural Area	13	10	1	5	29	83%
Brigadoon Woods	8	7	2	3	20	57%
Strasburg Creek	8	7	2	3	20	57%
Tilt's Bush	8	7	1	4	20	57%
Lackner Woods	7	5	2	4	18	51%
Topper Woods	8	4	1	4	17	49%
Waldau Woods	8	7	1	1	17	49%
Fallowfield NA	4	6	1	4	15	43%
Steckle Woods	3	3	2	3	11	31%
Carisbrook NA	3	4	1	2	10	30%
Monarch Woods	5	1	1	3	10	29%
Stanley Park	4	4	0	2	10	29%
Lakeside Park	3	3	0	3	9	26%
Breithaupt Park	3	2	1	3	9	26%
Laurentian Wetlands	2	2	0	2	6	25%

Spring indicators included spring ephemerals, amphibians and birds. The summer indicators included late season spring ephemerals plus summer plants, birds that are indicative of forest and grassland habitats, as well as amphibian species which would be expected to be found in late spring/early summer. The fall season monitoring only had two indicators of which, both were plant species. Winter indictors included trees, birds and the only mammal species in the study.

The full results were broken down and analyzed by taxa and by habitat and are provided below in Tables 34 and 35.

Table 34: Results for the volunteer assessment of ecological indicators arranged by each taxa that was assessed for all 15 parks

	Birds (n = 12)	**Amphibians (n=7)**	**Plants (n=12)**	**Trees (n=3)**	**Mammal (n=1)**
Breithaupt Park	2	0	4	2	0
Brigadoon Woods	4	5	9	3	0
Carisbrook NA	4	3	2	1	1
Fallowfield NA	4	5	4	3	0
Huron NA	10	7	9	3	1
Lackner Woods	3	4	7	3	1
Lakeside Park	1	2	3	2	1
Laurentian Wetlands	1	3	0	2	0
Monarch Woods	3	1	4	2	0
Stanley Park	2	3	3	2	0
Steckle Woods	3	0	5	3	0
Strasburg Creek	3	6	8	3	0
Tilt's Bush	3	4	9	3	1
Topper Woods	5	4	5	3	0
Waldau Woods	4	5	8	1	0

Native spring ephemeral flora are good indicators of ecosystem condition and are integral to the functioning of the forest ecosystem as they serve a critical nitrogen cycling role (Zak et al., 1990). Of the 15 parks that were surveyed, four parks had six of the seven ephemeral species present while two parks that had suitable woodland habitat did not have any. Overall, just under half of the parks surveyed (7 of 15) had three or less of the spring plant species present.

For amphibians, American toad and green frog were the most consistently detected species being found at 12 of 15 parks. This was followed by spring peeper at ten sites and northern leopard frog at six locations. The Huron Natural Area had all seven species present and was the only site with this result. Overall 10 of the 15 parks (66%) had three or more species present.

There were two sites that did not have water features and therefore were unlikely to have amphibian species present during the breeding season.

Four bird species were assessed for each habitat type (forest, grassland/meadow and wetland) and included 12 possible species. The Huron Natural Area had 10 of 12 bird species present while the overall results were actually quite low with no other parks having >50% of bird indicators present and the mode for detection overall, only at four species.

Of the birds that were detected during surveys, forest bird species were detected most frequently which is likely associated with the fact that forest habitat was the most common habitat type being surveyed. At least one of the four forest species was detected at all 15 sites with the eastern wood pewee being detected at 10 of 15 (66%) sites. The other species were detected at low overall rates with pileated woodpecker and eastern screech owl found at five (33%) of the sites surveyed and wood thrush at four (27%).

Grassland bird species were the lowest guild detected with no reports of eastern meadowlark, two detections of American woodcock (13%), four detections of savannah sparrow (27%) and five detections for eastern kingbird (33%).

Wetland birds were also detected at low rates with Virginia rail not being found at all, wood duck found at three sites (20%), green heron at four (27%) and swamp sparrow at six or 40% of sites surveyed.

The results by habitat type (Table 35) revealed information which was indicative of the habitat composition in Kitchener with more forest species being detected overall than grassland and wetland species.

Table 35: Results for the volunteer assessment of ecological indicators arranged by habitat type for all 15 parks

	Forest (n = 15)	**Grassland (n=4)**	**Wetland (n=16)**
Breithaupt Park	6	0	0
Brigadoon Woods	11	2	7
Carisbrook NA	3	1	6
Fallowfield NA	6	1	8
Lackner Woods	10	0	8
Lakeside Park	4	0	5
Laurentian Wetlands	2	0	4
Monarch Woods	9	0	1
Stanley Park	4	1	5
Steckle Woods	11	0	0
Strasburg Creek	9	1	10
Tilt’s Bush	11	0	9
Topper Woods	10	0	7
Waldau Woods	9	1	7

There were several sites that had a high proportion of the forest indicators present, with nine parks having >60% of the indicators present, three with 73% (11 of 15) and one (Huron Natural Area) with 80% or 12 of 15 indicators detected. Other ecosystem types, namely, grasslands and wetlands scored much lower which was expected given the ecosystem compositions across Kitchener. Five sites had at least 50% of wetland indicators present. Two parks, Huron Natural Area and Strasburg Creek had scores on the high range with 88% (14 of 16) and 63% (10 of 16) respectively. For grasslands, only the Huron Natural Area and Brigadoon Woods had more than one indicator present with three and two detections respectively.

Chapter 4: Analysis of Results and Application of Novel Ecosystem Decision Framework

A combination of traditional as well as emerging ecosystem assessment techniques were selected and applied to evaluate ecological conditions and where possible, the current state of novelty. This approach utilized and applied the novel ecosystem framework (Hulvey et al., 2013) while also straying slightly to include assessments of impacts associated with human residential encroachments and recreation based impacts (Figure15).

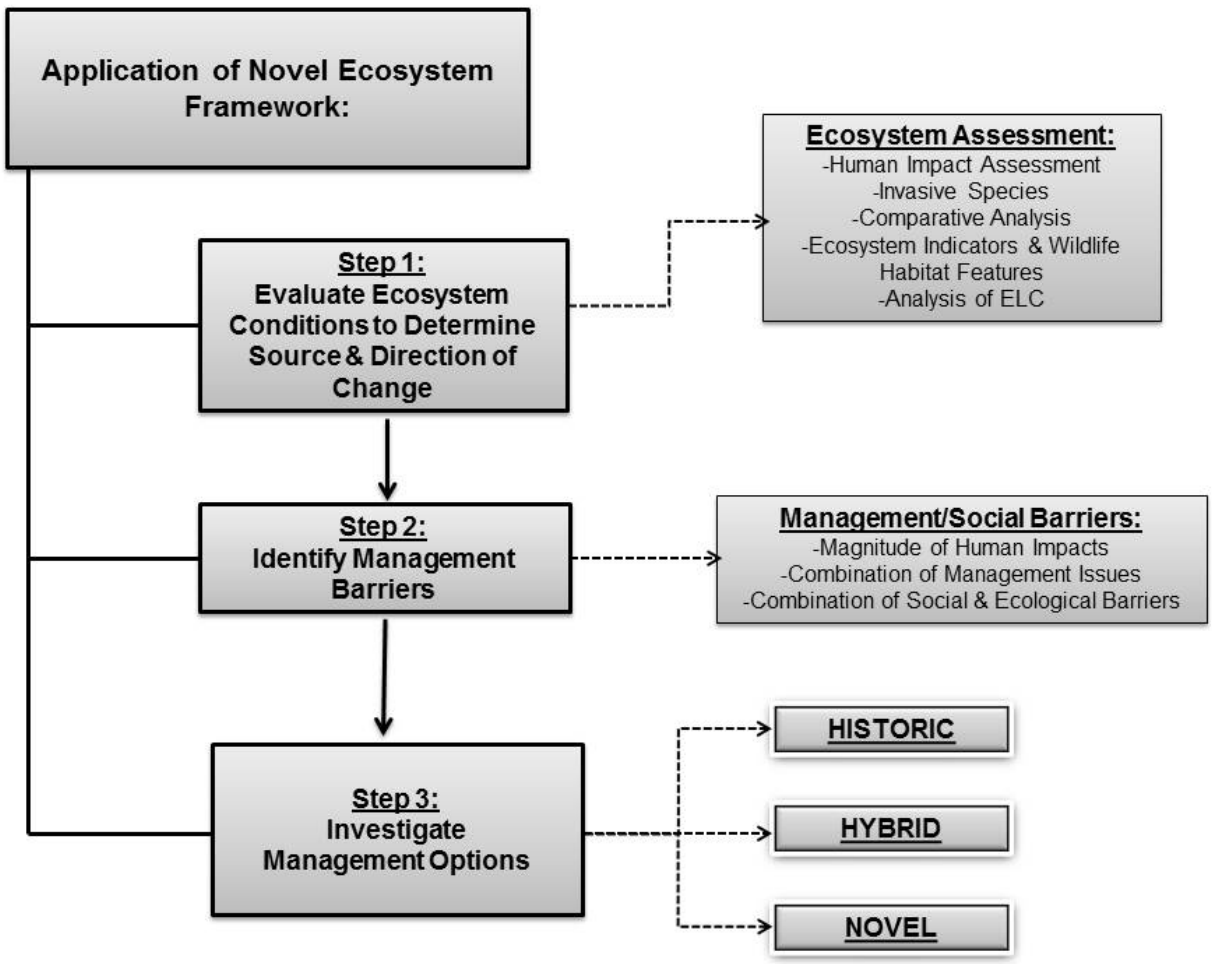

Figure 15: Application of the novel ecosystem decision-making framework. Three steps are identified in the management of urban ecosystems: 1. Assess ecosystem conditions; 2. Identify barriers, and 3. Investigate management options. Steps originally identified in Hulvey et al., (2013).

The emphasis on a combination of evaluative techniques and those directly associated with human impacts on urban natural areas was selected to provide a rapid assessment of ecosystem change agents occurring at macro and micro levels and to aid in the development of better understanding of how these contribute to urban novel ecosystems and the eventual selection of modified or alternative management frameworks.

The evaluation process used in this research was a novel investigation in that no other published studies used this exact methodology nor has the novel ecosystem framework been applied previously in this fashion. The specific results are not directly related to the detection and determination of novel ecosystems rather they are treated circumstantially and used as a tool to infer possible management direction based on multiple evidence-based indicators of current ecosystem conditions. Not all possible assessments or evaluations were completed to identify presence/absence of all species or to comprehensively study ecosystem conditions and full ecological integrity. Instead, this study and the subsequent results are reflective of a rapid, short-term assessment that provides immediate information that can be used to select and implement management actions. The elements that were selected were identified to highlight and understand the main issues, agents of change and management challenges currently being observed in Kitchener. These issues are not unique to Kitchener and are occurring in many urban municipalities. The evaluation process and specific methodology used in this study can be easily replicated by managers as the issues and ability to gather information is relatively simple and standardized across locations. Most resource management agencies, including municipalities have access to Geographic Information System (GIS) datasets that can be used in combination with the study of macro conditions to layer various sources of information in order to make ecosystem management decisions.

The results of the rapid assessment are interpreted to determine whether barriers impede management or dictate a transition towards alternative approaches (i.e., hybrid or novel management). The pathway of analysis that was utilized and the associated results can be applied to decision-making at broad scales (i.e., across Kitchener) or to specific natural area management challenges occurring within an individual park or natural area (e.g., Lakeside Park).

Step 1 from Figure 15 is the initial process used to understand current ecosystem conditions across Kitchener. This step also represents the ecosystem assessment phase which was identified by Hulvey et al., (2013) which suggests that managers begin by understanding current ecosystem/park conditions to determine whether problems exist.

The investigation into novelty in Kitchener's natural areas were targeted where possible, at population, community and landscape levels and were focused on assessing macro as well as meso-ecological conditions of ecosystem composition, structure and function (Harris et al., 2013, p.196). The rapid assessment involved some field based evaluation of specific change agents (invasive species, human impacts and wildlife habitat features) as well as a synthesis of existing and recently collected information (comparative analysis of park inventories and analysis of ecological land classification data).

<u>Step 2</u> identifies the analysis stage where the results for each variable or the cumulative total for the assessment are used to determine whether alternative management approaches are better situated for the conditions occurring in a specific park or according to management objectives that have been identified. The inference of results from the rapid assessment and analysis helps determine whether thresholds (management or ecological) have been crossed and if a return to previous conditions is possible. This decision is also largely based on the availability of budget and/or staff resources and the predicted achievability of desired goals. The results from the different assessments (human impacts, invasive species, wildlife features) are also used to identify whether individual sites are exhibiting hybrid or novel conditions and would be more appropriately managed as such. The novel ecosystem decision framework as applied in this case, not only aids in helping to identify whether specific park and ecosystems are experiencing conditions considered hybrid or novel but also aids managers in applying alternative strategies for managing these hybrid and novel ecosystems. The cumulative results (i.e., city wide assessment) can be used to make resource allocation and prioritization decisions, especially when applied to the whole landscape (Hobbs et al., 2014). This can be especially true where certain natural areas are no longer found to be exhibiting conditions within their historic ranges of variability and have transgressed into new states by way of significantly altered abiotic and biotic conditions.

<u>Step 3</u> identifies the critical point in the decision-making process where results of the ecosystem assessment lead managers to the identification of new or alternative management approaches. These alternative management scenarios focus on managing as a hybrid site with prevention of further change as a key goal or managing as a novel site with alternative management goals and objectives based on the site conditions and characteristics. Various combinations of the

above can also be chosen based on the needs of the system, desired management goals and influence of social and economic barriers. In instances where conditions have changed significantly, interventions or directed management and restoration efforts would be better received in parks that have more ecosystem components intact and less management or human impact issues.

The ability to unequivocally determine whether thresholds have been crossed and are preventing sites from being returned to historic conditions would take comprehensive study, many years of time and leave many municipal and other land managers without the ability to make immediate and proactive decisions. Resource managers, especially those with annual fixed budgets and priorities that compete with other municipal needs (e.g., engineering projects, municipal infrastructure, social programs etc.) are under pressure to make decisions, set direction and implement projects in real time without opportunity to comprehensively and proactively study all resource conditions. This scenario often fosters uncertainty and decisions that are made using rapid assessment studies, sometimes with incomplete data and frequently without the benefit of long-term scientific datasets based on targeted research. Further, the uncertainty in ecological management is associated with the inherent variability in abiotic, social and ecological processes. This uncertainty makes management difficult and can be a result of the challenges associated with detecting and alleviating changes that are occurring at both social and ecological levels (Hulvey et al., 2013). Harris et al., (2013) suggest regime shifts and persistence of novel ecosystems are often largely driven by new species benefiting from the altered abiotic conditions. The need to consider alternative management approaches is therefore also based on management thresholds or social barriers where the level and magnitude of issues or impacts have created new abiotic conditions which favour altered biotic conditions and require different directions for management. For example, the presence of human impacts occurring at high levels, plus the presence of multiple or a high volume of informal trails (>7) combined with invasive species populations scoring at the highest rank (species >50 m^2 patch plus >10 patches) coalesce to create significant management challenges and potential barriers against management that is being directed towards historic ecosystem integrity. At this decision point, an alternative management approach could be taken with an emphasis of resource allocation being placed in locations of greatest need and on projects with highest potential for success.

The management of urban ecosystems, especially those developing hybrid and novel conditions is largely an adaptive decision-making challenge that often requires a heuristic approach

(Seastedt et al., 2008; Suding & Hobbs, 2009). Concluding or identifying that a site is a hybrid or novel system based solely on ecological conditions without long term statistical data and a comprehensive study of ecosystem dynamics is difficult (Harris et al., 2013). As many of the researches currently involved in the study of novel ecosystems and those specifically applying aspects of the decision-making framework contend, there is no single indicator or definition for managers to use to determine if or when alternative management solutions should be implemented (Gardener, 2013; Hulvey 2013; Murphy, 2013a; Murphy, 2013b; Seastedt, 2013; Trueman et al., 2014). The combination of assessment techniques at macro and micro levels as well as the ability to detect changes in abiotic elements (i.e., human impact variables) reduces uncertainty and can assist in identifying changes in ecosystem function before permanent regime shifts occur. This approach also encourages and supports informed intervention instead of reactive management that is based on less available options.

4.1. Lackner Woods Case Example

Using Lackner Woods as a case example (Figure 16), this site was found to be affected by the greatest number of human impact issues (15 of 17: encroachments plus recreation impacts) including many that have a high degree of overall impact and potential to cause ecosystem level changes.

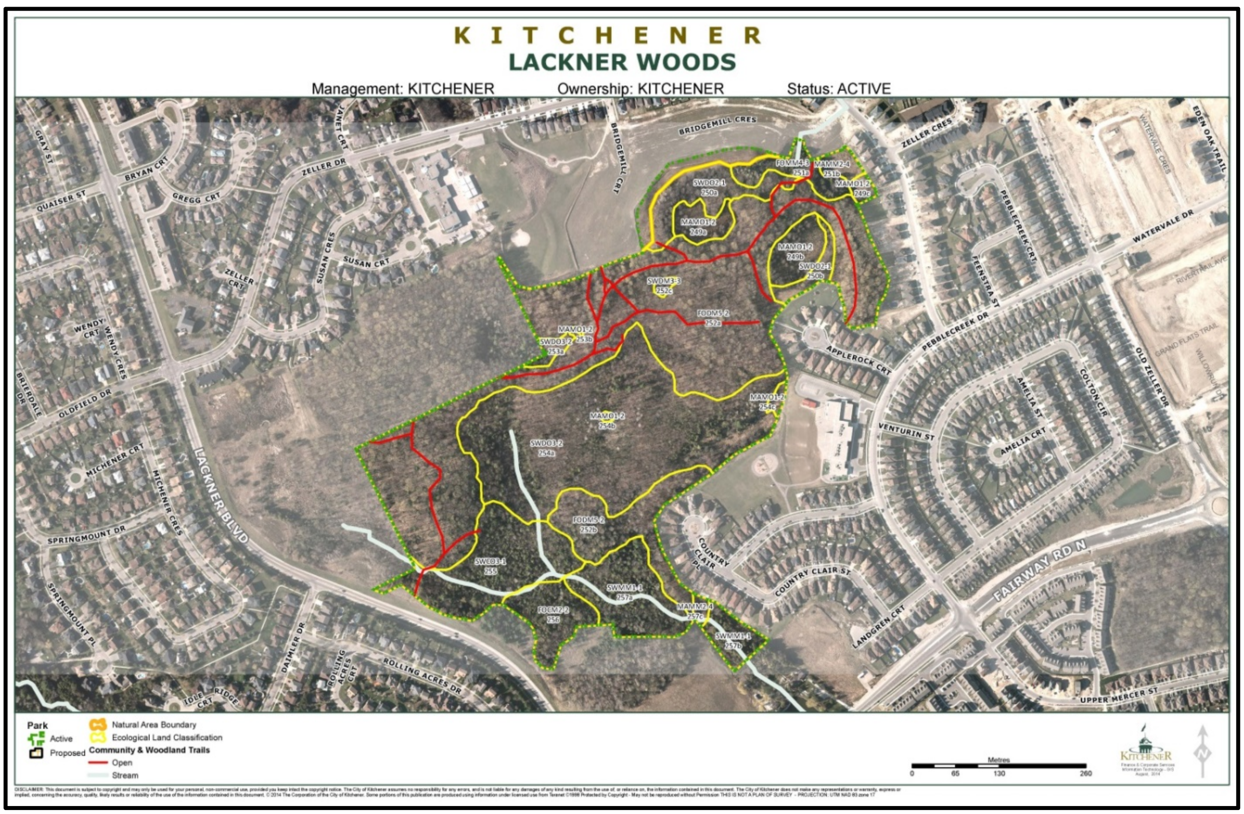

Figure 16: Map of Lackner Woods Natural Area. Map produced by City of Kitchener GIS Department (June 2014).

These types of issues would immediately place great strain upon management budgets and require significant attention to address. Analysis of other conditions including presence and volume of invasive species, significant, specialized and seasonal wildlife habitat features and native species indicators is done to determine whether elements of historic or intact integrity exist. Depending on the outcome, management strategies focused on retaining existing conditions and/or prevention of further degradation would be sought. Lackner Woods, is one of the larger sites (30 ha) in Kitchener and has ten different ecosystem types including the largest Sugar Maple-Beech Deciduous forest habitat type of all sites surveyed. Given its size, the proportion of invasive species was also found to be low with only four of the seven species found including at least one patch of goutweed and common buckthorn that were >50 m^2 in size. The other two species (garlic mustard and periwinkle) had greatest patch sizes at <10 m^2. In terms of wildlife features, this site was the highest ranking of five parks with 60% of the specialized wildlife features present. In regards to native species indicators, Lackner Woods also scored high with 51% of the total indicators present (third highest score of parks surveyed) including a high proportion of native spring ephemerals present, four of seven breeding amphibians and overall ten of the total 15 forest indicators present which would suggest that much of the native community composition remains intact in varying degrees on the site.

This site however, also appears to be further along a spectrum of disturbance by humans, creating a significantly altered abiotic regime which is creating a cascading affect towards further undesirable changes in biological conditions. By utilizing the approach suggested by Hobbs et al., (2014) which differentiates landscape patches, in this case parks, by degree of change from historic state and likely extent to which these changes are reversible, this site would be identified and managed as a hybrid site. The characterization as ‘hybrid’ identifies some element of change and gives management a state of conviction and purpose and implies that the degree of change is such that concentrated intervention efforts have potential to reverse some of the changes though not all. In this case, passive restoration and low-level intervention is also out of consideration. This classification also aids in the setting of management goals during future phases of public engagement and consultation. From a public park management perspective, having a clearly defined management objective helps in the selection of realistic and practical management goals suitable to the dynamics of the site. Clear goals and a well-defined approach also help in the setting of limitations and of public expectations.

With many of the ecological elements currently intact and the spectrum of disturbance mostly concentrated in specific areas at Lackner Woods, management tactics could focus on targeted education and landowner outreach, active removal of the large patches of non-natives and other active management strategies focused on preventing the site from declining further. Using results of the wildlife habitat features assessment to set management goals, management could also focus specifically on direct habitat management or species protection efforts to encourage and support the proliferation of specific species or preservation of habitat features. This management strategy would also align with the priorities of novel ecosystem management where efforts are focused on preventing the shift from hybrid to novel as the former is more likely to be returned to or managed towards previous conditions than the latter (Hallett et al., 2013).

Some of the factors occurring at Lackner Woods such as the intensity and immediate adjacency of residential development renders a full reversal of all abiotic change agents impractical and in the case of eliminating the houses, purely impossible. Other abiotic factors associated with resident behaviours including physical encroachments onto city property, dumping and private trail construction can conceivably be addressed via municipal by-law enforcement and planning policy in combination with landowner outreach and education. The success of this management approach and ability to reverse changes and prevent further decline is dependent upon several factors. The effectiveness of municipalities (in Southern Ontario) in preventing residential encroachments has been shown to have many significant barriers including insufficient municipal direction or leadership, lack of financial resources to prevent and address the issues and in general, the ineffectual dynamic of enforcement (McWilliam et al., 2014). McWilliam et al., (2014) also identified a glaring inability by the study municipalities to remove existing encroachments once they had occurred which in the case of Lackner Woods could be a significant barrier in reversing existing conditions. In this case, prevention of future impacts is likely to be a more successful strategy than working towards a full reversal of existing encroachments. Another aspect is the difficulty and potential barriers that arise when working with adjacent private land owners and members of the public who have differing views and perceptions of the project. Hulvey et al., (2013) identified this as a social norm and a property system barrier. This can be especially true with invasive species eradications where the populations of goutweed and periwinkle occurring in Lackner Woods originate on private property and extend into the public natural area property. This dynamic renders full eradication of these exotics a significant challenge as coordinated effort between private landowners and government is required and their individual restoration efforts and buy-in is also independently required (Gardener et al., 2010). Further, the perception of nature, perspectives on invasive species and what is considered healthy, and the type of management approach deemed most acceptable are all social factors to be considered in the management of the site (Gobster, 2012). The pattern of residential development surrounding this type of remnant urban forest immediately favours invasion of exotic species, especially those preferred as ornamental ground covers (Duguay et al., 2007; Sullivan et al., 2005). All of these factors will also inevitably impact management outcomes. The selection of a hybrid management approach accepts these factors as barriers to management and looks forward to alternative and additional strategies. This approach seeks management options that are feasible based on all site variables (abiotic and biotic), and are achievable plus economical. This case example represents extreme conditions where the contrast between the number and significance of human induced site level impacts and the relative ecological integrity of the site represent a conundrum for resource management as not all issues can be solved immediately or simultaneously with a single solution. The Lackner Woods analysis also highlights the utility of the novel ecosystem framework (Hulvey et al., 2013) as an effective tool used to guide difficult and often competing resource management and restoration decisions. The outcome of management decisions and ultimately, the response of the ecology in Lackner Woods will be determined following the implementation of recommendations and an action plan devised as part of a subsequent management plan. To date, no management plan has been developed for this park so outcomes are still yet to be determined.

For the Lackner Woods case, historic data is not available for comparison and therefore a snap-shot understanding of current conditions is gathered and then applied to the individual site. In cases or locations where historic data is available and a comparative analysis of previous versus current conditions can be completed, a more concrete and detailed analysis of options for restoration and management can be accomplished. A comparative approach also provides more confidence in determining ecological thresholds and potential regime shifts in the system where long-term data or rigorous studies are not available or feasible (Suding & Hobbs, 2009). In the scenario at Lackner Woods and without historic baselines for comparisons, an evidence based inference approach is adopted which utilizes a variety of tools and information sources to determine management strategies.

4.2. Novel Ecosystems and Applied Decision Making: Homer Watson Park, Steckle Woods and Lakeside Park

For three Kitchener parks (Steckle Woods, Homer Watson Park and Lakeside Park), substantial historic records were available which provided a baseline understanding of how far from the historic range the sites have changed and the levels of alteration to ecological integrity.

4.2.1. Homer Watson Park

In the case of Homer Watson Park (Figures 17 and 18), this site is Kitchener's third largest park (62 ha) and has a high biodiversity and low overall levels of human encroachment. Homer Watson Park did have levels of recreation impacts however these types of impacts are more manageable or reversible when compared to encroachment impacts. Plant diversity has increased in 28 years between analyses with both native and non-native plants contributing to the overall increase in species diversity. Native plant species accounted for the highest percentage of plants detected in 2014 and represented the greatest amount of change with an increase of 166 plant species compared to 68 for non-native. In addition to plants, the number of pairs of breeding birds has also increased (29 additional records) with a notable addition of 12 Regionally Significant species. Homer Watson Park is not without its management challenges with several areas of the park having small and isolated populations of aggressive invasive species including common buckthorn, glossy buckthorn, tartarian honeysuckle (*Lonicera tatarica* L.) and phragmites (*Phragmites australis ssp australis* Cav.). In addition to threats associated with non-native species, there are some human recreation impacts including a substantial and unauthorized BMX Bike course which has caused soil and ground vegetation disturbances.

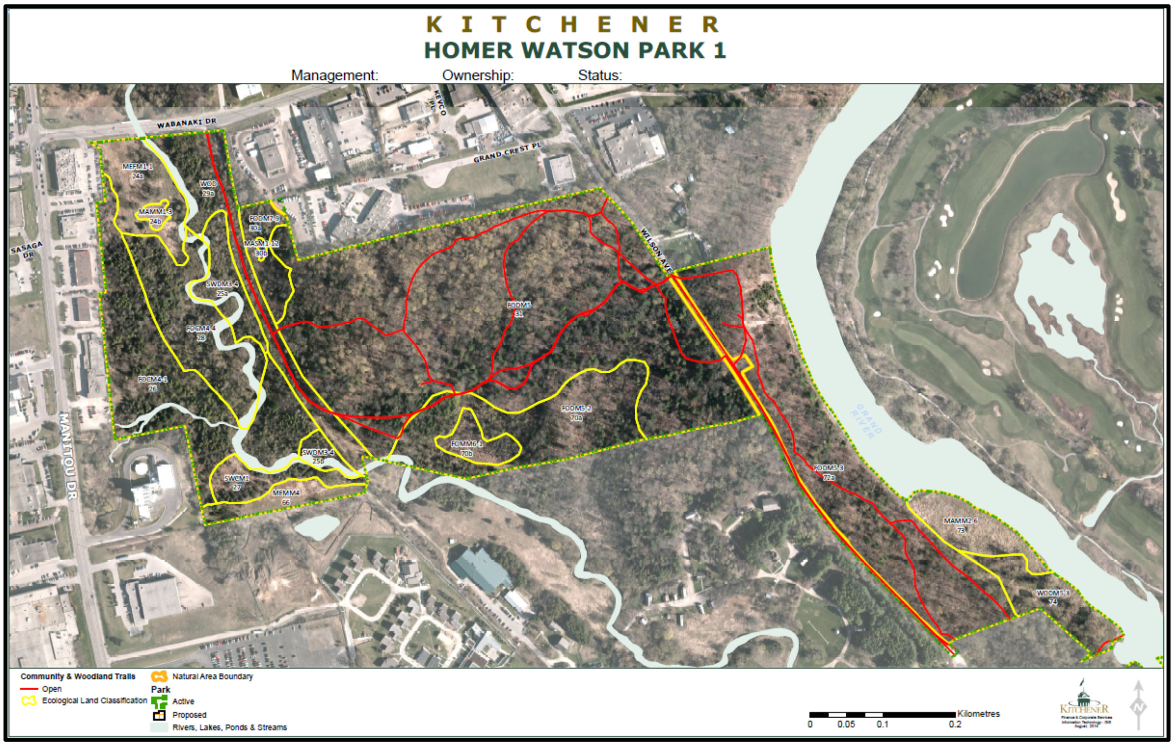

Figure 17: Map showing north portion of Homer Watson Park. Map produced by City of Kitchener GIS Department. (June, 2014).

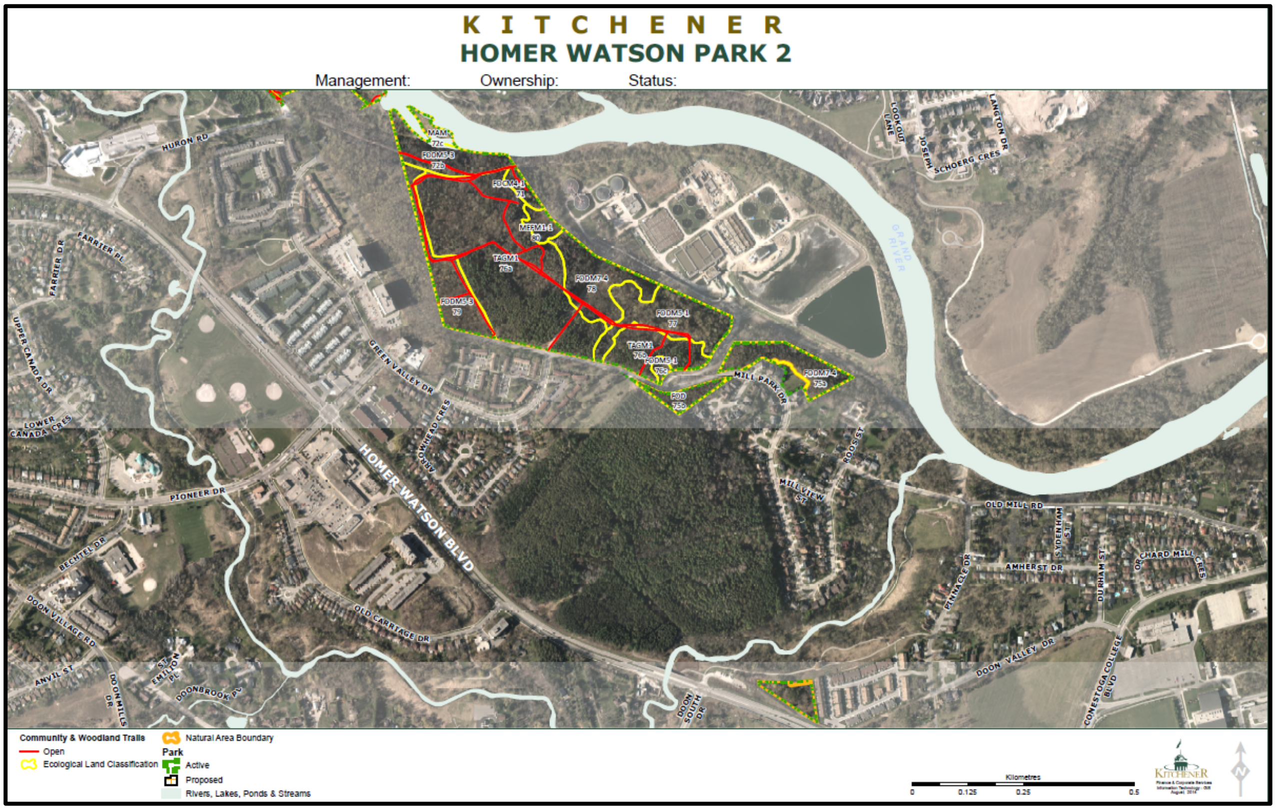

Figure 18: Map showing south portion of Homer Watson Park. Map Produced by City of Kitchener GIS Department. (June, 2014).

A site like this with intact biological elements which, as a whole, is acting as a hotspot for regional biodiversity and large overall size with good connectivity would conceivably be receptive to intervention approaches (e.g., removal of invasive species) focused on maintaining the historic fidelity of the site.

4.2.2. Steckle Woods

At Steckle Woods (Figure 19), site conditions have changed more drastically. Although there has been virtually no change in native versus non-native plant composition in the 28 years between sampling, there has been an overall decrease in plant richness from 195 to 125 plants. Although the decrease was detected in both native and non-native species, non-native species now include more species that are considered to be weedy species according to the weediness index (Oldham et al., 1995). Interestingly, garlic mustard was not found in 1986 however is now located throughout the park in all communities that were sampled. Of the 13 non-native species that were found in 2014 but not detected previously, five are considered to be a low weediness score, four were high and two medium. There were also two species found that are not ranked on the weediness scale. For the entire current compliment of exotic plants (34 species), most were at a medium to low levels of weediness with 13 species at medium, and ten at low. There were nine species which scored high and two additional with unknown ranking.

In addition to the decrease in plant diversity, a similar trend was noted for breeding bird communities where total recorded breeding bird species has declined by eight species. The decrease in birds could be indicative of changing habitat conditions with less open meadow and grassland habitat and therefore the vesper sparrow (*Pooecetec gramineus,* G.*)* and savannah sparrow are no longer found breeding in the park. The maturing forest canopy could also be indicative of the disappearance of least flycatcher (*Epidonax minimus,* Baird), veery (*Catharus fuscescens,* Stephens*)*, yellow-billed cuckoo (*Coccyzus americanus,* L.*)* and chestnut-sided warbler (*Setophaga pensylvanica,* L.*)* all of which occupy successional and shrubby breeding habitats which have likely declined in occurrence as forest canopy and maturity have increased. Other species such as ovenbird (*Seirus aurocapilla,* L.*)*, yellow-throated vireo (*Vireo flavifrons,* Vieillot*)* and great-horned owl (*Bubo virginanus,* G.*)* are no longer found breeding in this forest which could be due to a loss of surrounding forest cover and overall decrease in contiguous woodlot as these species prefer large forest tracts for breeding (Cadman et al., 2007).

This site has undergone significant physical alterations with intense industrial development and major road networks now surrounding all edges of the property and no immediate connectivity or proximity to any adjacent natural sites. Although the tree canopy remains dominated by native species, the shrub and ground layers are slowly being overtaken by non-native species, especially common buckthorn and Russian knapweed (*Acroptilon repens* L.). The red coloured lines in Figure 19 represent a prolific trail network that currently pervades throughout the entire site, essentially creating an internal fragmentation effect (Ballantyne, 2014).

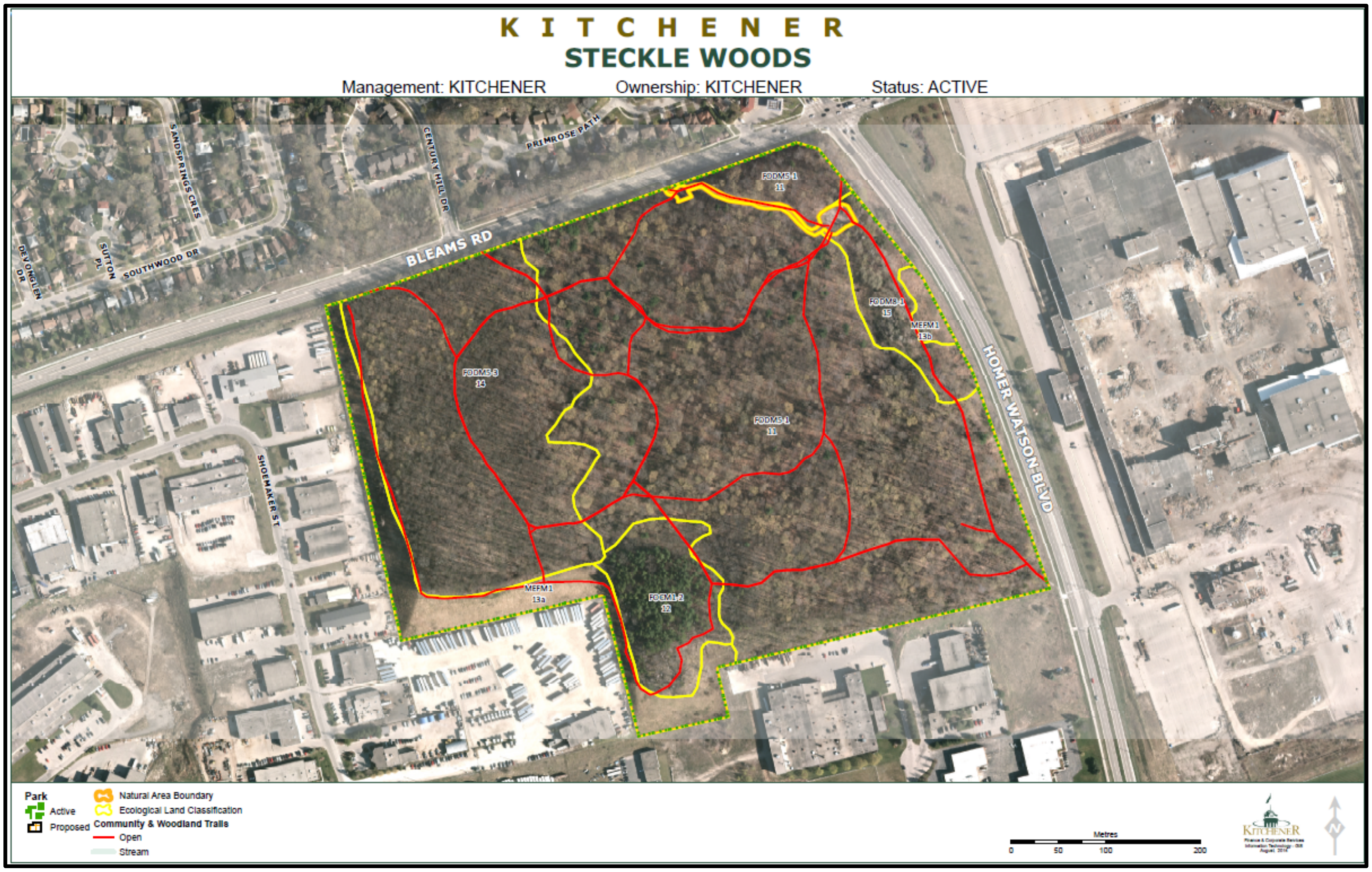

Figure 19: Map of Steckle Woods Natural Area. Map produced by City of Kitchener GIS Department (June, 2014).

The dynamics at play here are not attributed to one single forcing or causative event; rather the changes at Steckle Woods experienced over the past 28 years have been a gradual process reflective of the cumulative influence of habitat fragmentation, urbanization, human recreation impacts and long-term transcontinental invasive species introductions. Together these influences have coalesced to create an overall biodiversity deficit or debt (Jackson & Sax, 2009) as well as, although difficult to measure, a likely regime shift (Harris et al., 2013). The current mix and complement of species plus the above mentioned factors suggest that passive system recovery without human intervention is unlikely to occur.

In consideration of the factors within this park and the barriers currently impacting integrity, the management goals or targets need to consider whether this park should be managed solely for ecological value or if it is better suited as a site that functions more appropriately as an area providing quality outdoor nature experiences and recreation for urban park users. The proximity of Steckle Woods to adjacent business and residential neighbourhoods makes it a popular recreation destination for many people, especially dog walkers and hikers. This trend is expected to continue with a predicted increase in local population and with the completion of the planned redevelopment of an adjacent industrial area into a mixed-use area. Obviously some efforts to control and reduce informal trail networks would benefit ecological integrity however intensive efforts to remove all exotics is likely to be futile in the long-term. Management efforts focused solely on maintaining ecological integrity would require substantial effort and resources as well as a direct focus on eliminating human access as the main agent of change. There would also be a requirement that on-going attention be paid to keeping new invasions out should a level of control be established. In consideration of these barriers and the current state of the park, this site is likely a novel ecosystem with altered abiotic and biotic conditions. In this situation, goals for management are better focused on alternatives which may include providing sustainable access to nature for urban residents. By encouraging a higher volume of public use at Steckle Woods where ecological integrity is already inhibited, other nearby parks such as Homer Watson Park and the Huron Natural Area, both sites with high ecological integrity can be managed for historical ecological conditions. The novel ecosystem approach in this application accepts that changes have and will continue to occur. The decision-making approach uses site conditions plus identified barriers against certain restoration and management interventions and instead, looks for alternative goals that are relevant to the situation at hand and conducive to broader (i.e., across Kitchener) resource management objectives.

4.2.3. Lakeside Park

The development of management objectives or a management plan for specific urban natural areas requires consideration of many of the above factors: site novelty, public and stakeholder involvement, potential management and restoration opportunities/barriers as well as the interplay and dynamics of various change agents. In 2014, the City of Kitchener developed a comprehensive process for developing a natural area management plan that is based on the foundations of the novel ecosystem decision-making framework. This process was applied to the development of a management plan for Lakeside Park and incorporated significant public engagement to help select and set objectives and targets complementary to site conditions and to desired goals.

Relative to other Kitchener parks, Lakeside is a small site (15 ha) that is a mix of park classifications with active parkland and natural area parkland plus a small portion of privately owned property making up the overall park matrix (Figure 20). This neighbourhood level park draws a high volume of nearby residents who enjoy a variety of outdoor pursuits including walking, biking, skiing, nature exploration, bird watching, photography, picnics and sports (in the open space areas).

Figure 20: Map of Lakeside Park Natural Area. Map produced by City of Kitchener GIS Department (June, 2014).

In developing the Lakeside Park Environmental Management Plan (see Dance et al., 2014 for full report), significant efforts were made by the City of Kitchener to seek input, ideas and involvement from the public and engage them in the process of understanding the ecological dynamics of this urban natural area and the complexities and challenges associated with its management. A 'Friends of Lakeside Park' group formed organically in the process as community members gathered to share ideas and over time developed a strong common interest in Lakeside and in the development of a plan. Several informal (park picnic, guided walk, neighbourhood gatherings, and annual park clean-ups) and formal (surveys, public meetings, open houses) mechanisms of idea sharing and input gathering were held. This group worked through all aspects of the plan including the selection of goals, targets and objectives related to the management of this site. The close working relationship between city staff and the Friends of Lakeside supported an essential aspect of managing novel ecosystems: developing dialogue with the public about novel ecosystems. This critical stage as outlined by Yung et al., (2013) helps in the understanding of the novel ecosystem concept as a whole and in the selection of complimentary targets and goals. Most importantly, by engaging people in the process of management plan development, it builds a capacity for them to be engaged and informed with respect to the decision-making process. This stage of the process also provided the values upon which the goals for management were set as public input identified many of the social, recreational and cultural aspects that were valued within the park. By identifying the human or social values, it was possible to develop complimentary goals which bridge human interests with ecological interests. There was also a transparent understanding of the limitations and an on-going dialogue about opportunities.

Some of the goals that were identified for Lakeside Park included: conserving and enhancing the ecological integrity, improving water quality, increasing environmental education and awareness, supporting recreation opportunities conducive to ecological attributes, minimizing negative human behaviours (i.e., feeding ducks, dumping, off-leash dogs), and fostering community engagement, municipal leadership and park stewardship (Dance et al., 2014). None of these goals are contradictory to managing novel ecosystems. Even a goal of conserving ecological integrity can be implemented in the management of a novel system as managing for specific species such as turtles or fish-eating birds allows for some level of integrity (especially functional integrity) to be achieved within the ecosystem. The integration of these management goals into specific management strategies is explained further below.

Lakeside Park as a whole is on a novel ecosystem trajectory with an altered abiotic regime that is influenced by humans via internal and external drivers, non-historical species configurations with functioning interactions and a strong combination of barriers that draw it further from its historic range and away from realistic restoration potential. Although the entire park could be classified as a novel system, not all of the individual ecosystems within the larger site appear to be on novel trajectories. A thorough review of historic ecosystem conditions and a comparative analysis of current ecosystem state provide a baseline for which decisions on future management can be made. The mixture of parkland designations also plays into this decision-making in that by the very nature of active and open park space combined with adjacent natural area designation, there is an element of novelty to the site and to the management objectives. The boundary between types is merely a formality and a planning zone defined according to management practices where grass is cut and maintained in active parklands and conditions are managed in their natural state (whatever condition that might be) on natural area lands. Some objectives for managing natural habitats may not be conducive within open space parkland designations. For example, many park users expressed interest in having open space areas for active recreation while others suggested that efforts be focused on reducing areas where grass is cut and supports more biodiversity. The ecological features of the park include wetlands, early successional forest and a large open water pond known historically to function as a kettle lake ecosystem. There are also some smaller meadow communities developing in some open areas of the park. Several features are designated as locally significant (wetland and woodland) according to the KNHS (2012). This remnant natural area has been subject to many change agents since being designated as Kitchener parkland around the 1960's when residential lots, streetscapes and the subdivision construction began. The previously farmed and aggregate lands (sand quarry) were left fallow around 1969 when the full park area was turned over to the Kitchener Parks and Recreation Commission from the Kitchener Water Commission (McCauley, 2012).

The comparative analysis utilized historic survey records from a 1973 study and treated these records as a baseline of conditions for which comparisons could be drawn. Obviously the 1973 records are not the true historic condition of the system however this period of time does represent a significant stage in the timeline of disturbance as it is shortly after many of the surrounding neighbourhoods were constructed (1960-70's) and not too long after (1920-1960's), the area surrounding the pond (what is now an early successional forest) was actively mined as a sand quarry and most of the broader landscape was farmed. For a time the grass was mowed annually in the filled pit area, but around 1989 mowing ceased and natural succession took over, resulting in the current vegetation community structure of trees, shrubs and herbs (Dance et al., 2014). Figure 21 below shows the landscape level changes that occurred around Lakeside Park between 1955 and 2013.

Figure 21: Landscape changes at Lakeside Park from 1955-2013.

The species richness for the floral community increased with non-native species accounting for a higher overall increase in the 40 years between sampling. Although the native species still account for just over half (53%) of the total plants on record and are more abundant than non-native species, the change in percentage between natives and non-natives over time has been minimal at a 3% difference. Of the 126 non-native species detected in 2013, 67 were 'new' invaders and 59 individuals or 46 % were the same species found in the 1973 survey. There were 23 non-native species found in 1973 that were no longer found in 2013. For the native species, the increase was represented by 75 new species or 51% of the total found in 2013 were new additions to the ecosystem and not detected in 1973. This is an interesting trend in that during 40 years of change, much of the plant community identified in 1973 as invasive continues to persist while the native plant community has increased overall but by a slightly smaller margin than the non-natives.

A cursory review of the non-native plants currently growing at Lakeside Park reveals many species well adapted to disturbed conditions and considered to be passengers of ecosystem change or merely present as a by-product of the disturbance regime, not the driver facilitating the actual changes (MacDougall & Turkington, 2005). Of the 126 non-natives, only 17 were identified as Category 1 invasive species which exclude all other species and dominate sites indefinitely according to the rankings developed by Smith (2012). Ten species were considered Category 2 species, 15 Category 3 and 16 Category 4. Fifty-four percent of the total or 68 plants did not warrant inclusion or mention in the ranking system and therefore are considered of low-level concern.

The breeding bird records also suggest that Lakeside Park is transitioning further from historic and less disturbed conditions to one more heavily influenced by urbanization, especially fragmentation and urban development. The bird records are also indicative of forest succession where open shrubby habitats have been overtaken by more closed forest canopies. Although there has been a slight numerical increase in the number of breeding birds, this increase has been at the expense of species which favour specialized habitat features. The increase in breeding pairs from 26 pairs (1986 survey record) to 29 pairs includes more species considered to be habitat generalist and tolerant to using smaller habitats and more than one habitat of differing suitability (Andren, 1994; Environment Canada, 2014). Species such as the wetland breeding bird sora rail (*Porzana Carolina,* L.*),* grassland species brown thrasher *(Toxostoma rufum,* L.*)* and open habitat species yellow warbler (Dendrioca petechial, *L.*) have disappeared while species such as house finch (*Carpodacus mexicanus* Müller*),* Canada goose (*Branta* *canadensis,* L.*)* and chipping sparrow (*Spizella passerine,* Bechstein) have moved in. The pied-billed grebe and blue-gray gnatcatcher (*Polioptila caerulea,* L.) are newly arrived and the only Regionally Significant bird species found breeding at Lakeside Park (Dance et al., 2014). The breeding bird results - specifically, their functional guilds - can also be interpreted to determine functionality of the ecosystem (DeGraaff & Wentworth, 1986). The hybrid plant ecosystem is supportive of a variety of breeding bird species including those belonging to several different functional feeding (seed eaters, frugivores, insectivores, omnivores and carnivores) and nesting (upper and lower canopy, shoreline, tree cavity) guilds. Management of this hybrid forest ecosystem, which has retained parts of its historic composition, is focused on preventing further system changes by aggressively controlling the Category 1 non-native invaders in order to support the establishment of native plant (and animal) populations (Smith, 2012). Species such as common buckthorn, himalayan balsam, phragmites, and autumn olive (*Elaeagnus umbellate*, Thunb.) will be the focus of control and restoration programs in order to prevent further system changes.

Results for amphibians and reptiles show little change with the same richness for amphibians and reptiles including the historic records of the non-native red-eared slider turtle. For mammals, there has been an increase in the number of species and in the presence of urban-adapted mammals, namely the eastern coyote (*Canis latrans var.* Say.), white-tailed deer and beaver (*Castor canadensis,* L.)*.*

The dynamics occurring within Shoemaker Pond (the 'lake' of Lakeside Park) provide some of the strongest evidence for the consideration of an alternative management regime, one that is focused not on restoration or management towards historic conditions but rather on seeking realistic forward thinking goals and achieving practical ecological targets. Historically, and prior to development, the area around Shoemaker pond would have received very little run-off and water entering the pond would have come from infiltration of surface water with little inputs from the farm fields. Around the 1950s, when the houses were built adjacent to the park, the hydrology changed due to all the hard surfaces associated with development (roofs, driveways, roads etc.), causing increased runoff drained to the pond. The storm drains in the Lakeside Park neighbourhood outlet directly to the pond, with no pre-treatment occurring (Dance et al., 2014). In 2013, a series of water quality tests were conducted to determine the current state of the aquatic system in order to better understand degree of change from previous conditions. Water quality parameters, namely temperature, dissolved oxygen (DO), total phosphorus (P), nitrates (N), chloride (Cl), total dissolved solids (TDS), and total coliforms were measured and compared to historic results and evaluated against water quality standards to understand current ecosystem conditions. Recent electrofishing results were also reviewed and compared to those collected for the site historically.

The limnological, chemical and bacterial results for 2013 when compared to those recorded previously (1973) suggest that the pond ecosystem has changed drastically and moved significantly far from its historic origins as a kettle lake (pond) system. The historical average for chloride was already high in 1973 at 130 mg/L and is even higher in 2013 at 322 mg/L. Both of these values exceed and greatly exceed the long-term Canadian exposure guideline for chloride of 120 mg/L. This is a troubling result considering that the *Canadian Council of Ministers of the Environment (CCME) Guidelines for the Protection of Aquatic Life* (2011) suggest that at approximately 300 mg/L chloride levels, 20% of aquatic species are affected. Small increments of increase in chloride levels are predicted to cause detrimental effects to the aquatic ecosystem. For example, it is predicted that a chloride increase from 210 mg/L to 240 mg/L would double the number of species being impacted (Dance et al., 2014). The 2013 dissolved oxygen levels in the pond range from being completely absent to very low. The historical water quality results also confirm that, even since the early 1970's, Shoemaker Pond has had low DO levels, especially in the central basin of the pond (Dance et al., 2014). Coliform bacteria levels were high in 1973 and continue to be on the high ranges in 2013 due to the presence and volume of waterfowl (namely Canada geese) that frequent the pond. In summer months there continues to be low oxygen and high conductivity or turbid conditions while total phosphorus and chloride levels are found to be in excess of both the long-term and short-term exposure concentrations for the protection of aquatic life (Dance et al., 2014). Lakeside Park, more specifically, Shoemaker Pond, has also been described as one of the most eutrophic bodies of water in Ontario (McCauley & Goodchild, 1983) with conditions of very high plant growth due to nutrient loading.

The water quality results, some which have changed from conditions sampled in 1973 and others that have not, suggest that the ecosystem dynamics in this aquatic system are being heavily influenced by human drivers, especially drivers that are external to the site. Chloride deposition into the pond is a major driver of change and stems from a larger societal issue of salting roads, sidewalks and walkways for human safety. This is an ultimate agent of change that is acting at a scale and level beyond the immediate scope of management (Seastedt, 2013). Although there are known thresholds for chloride in aquatic systems, many of which have been crossed at Shoemaker Pond, the ability and potential opportunity to prevent Shoemaker from crossing these thresholds has likely already passed. Preventative management or an alternative design at or around the time of residential and major road construction would have been critical to prevent the run-off and accumulation of toxins directly into this urban water body. Reversibility of water chemistry changes associated with chloride would be near impossible due to the overwhelming probability of it being a continued source of change and additive to the system and also largely due to the nature of the chloride chemical which does not actively breakdown in water over time (CCME, 2011; Dance et al., 2014).

It is apparent from the water quality results that the abiotic parameters of Shoemaker Pond are significantly altered. Further review of the biological properties of the system helps to determine and select a suitable management approach without the benefit of a long-term dataset which could have been used to improve the predictive capacity for determining the threshold limit and shift of the system.

Historical records for fish were present for Shoemaker Pond from sampling performed on several occasions from 1973 to 2010. Additional records were available from personal observations made by local biologists living in the area. Table 36 presents the composition of the fish community in the pond in 1992 based on electrofishing survey results.

Table 36: Fish species composition in Shoemaker Pond in 1992

Common *Name*	**Scientific Name**	**Number of Individuals**	**Water Temperature Preference (Ontario Freshwater Fish Database, OFFD 2015)**	**Tolerance Level (OFFD, 2015)**
Fathead minnow	*Pimphales promelas*	9	Warm water	Tolerant
Pumpkinseed	*Lepomis gibbosus*	8	Warm water	Intermediate
Creek chub	*Semotilus atromaculatus*	1	Warm water	Intermediate
Rock bass	*Ambloplites rupestris*	1	Cool water	Intermediate
Goldfish	*Carassius auratus*	1	Warm water	Tolerant

The goldfish have been known to be present in Shoemaker Pond since at least 1981. Also, although not detected in surveys, the largemouth bass (*Micropterus salmonids,* Lacépéde*)* would have been the main native predator species and was reported from the pond historically. The smallmouth bass (*Micropterus dolomieu*, La.) was also believed to have been stocked into the pond around 1969 as per the 1971 Ontario Department of Lands and Forests Report (Dance et al., 2014). Table 37 provides an overview of the present day fish community based on survey results from 2010.

Table 37: Fish species composition in Shoemaker Pond in 2010

Common *Name*	**Scientific Name**	**Number of Individuals**	**Water Temperature Preference (Ontario Freshwater Fish Database, 2015)**	**Tolerance Level (Ontario Freshwater Fish Database, 2015)**
Common carp	*Cyprinus carpio*	19	Warm water	Tolerant
Goldfish	*Carassius auratus*	19	Warm water	Tolerant
Brown bullhead	*Ameiurus nebulosus*	11	Warm water	Intermediate
Pumpkinseed	*Lepomis gibbosus*	7	Warm water	Intermediate
Fathead minnow	*Pimphales promelas*	4	Warm water	Tolerant
White sucker	*Catostomus commersonii*	3	Cool water	Tolerant
Black crappie	*Promoxis nigromaculatus*	1	Cool water	Tolerant

The current fish community is dominated by the introduced and non-native common carp and goldfish and can be classified as a warm water fish community. The mere presence of fish species in the pond indicates some level of ecosystem functionality and tolerance by these organisms to the current ecosystem conditions. The common carp, goldfish and brown bullhead are all species that are tolerant of high water temperatures, low dissolved oxygen and variable levels of turbidity. The fathead minnow is considered to be the most chloride tolerant of the fish species but is less tolerant of turbidity than the other species, especially the common carp and goldfish (CCME, 2011). The decline in abundance of fathead minnow from the early 1990's to 2010 could be attributed to the increases in chloride levels however more information and further study would be needed to confirm this association. As per the CCME (2011) guidelines, it is the aquatic invertebrates that are most susceptible to increasing chloride concentrations and the first to disappear from a system due to chronic chloride exposures. Managing for a native fish community in Shoemaker pond would require that the current non-native fish species be removed and those species that have been lost from the system be re-introduced to mirror that of a traditional kettle lake ecosystem. This approach would also assume or require that either the re-established native fish population survive in the current water quality conditions or the water quality conditions be reversed to those experienced historically in order to support the historic, native species assemblage. Not only would the financial costs of removing common carp and goldfish be prohibitive to current budget allocation, the probability of success with potential new fish being constantly added by unaware members of the public would be very low. It would only take one person to dump additional fish to support the re-establishment of a new population. As mentioned, even if removal was advocated for, the current water quality conditions are unlikely to support a more diverse native fishery than the current hybrid one that exists.

A review of the interactions between birds breeding in and frequenting the park and the current fish community reveals a strong functional relationship and supports a novel ecosystem management approach. The presence of various piscivorous (fish-eating) bird species that either breed in Lakeside Park, frequent the park during the breeding season or utilize the site as a stopover location during spring/fall migration suggests that there is a strong attraction to the pond for its availability of fish as a primary source of food. A variety of bird species have been observed by the author of this thesis, reported anecdotally and via photographic evidence to the City of Kitchener by members of the public and recorded on the online E-bird database (E-Bird, 2015). Species including belted kingfisher (*Megaceryle alcyon* L.), osprey, great blue heron (*Ardea Herodias,* L.) and green heron (*Butorides virescens,* L*.) a*re species that breed elsewhere in the City of Kitchener and frequent Lakeside Park to forage. The double crested cormorant (*Phalacrocorax auritus,* Lesson), black-crowned night-heron (*Nycticorax nycticorax*, L.), and great egret (*Ardea alba,* L.) are migratory species that are frequently observed in the park during the spring and fall seasons and utilize the park as a feeding or stop-over location. The pied-billed grebe is a level one (one being highest) bird species of conservation of concern for the Grand River Basin (Couturier, 2000), a Regionally Significant Species for Waterloo Region (Region of Waterloo, 1996) and a newly detected species that breeds in Lakeside Park. This record is suspected to be the only breeding record occurring within the City of Kitchener. Further, on many occasions, the above noted species were also observed catching and consuming the goldfish from Shoemaker Pond (Figure 22).

The presence of fish eating birds is a large attractor for park visitors, especially those who visit the park frequently to pursue photography. This component of the park ecology also compliments the goal for Lakeside Park which is to provide opportunities for people to discover nature in the city and to increase environmental awareness and appreciation.

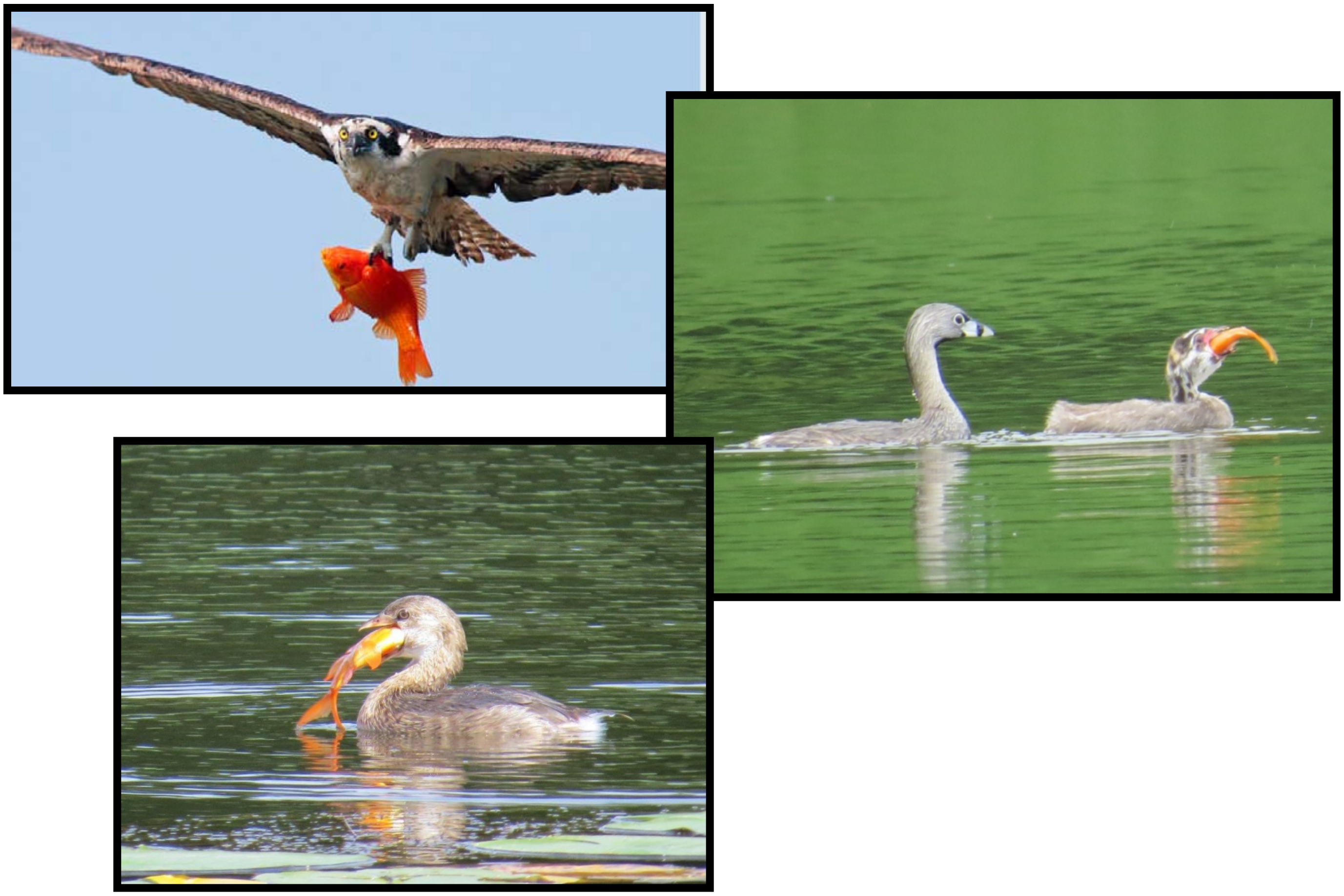

Figure 22: Goldfish-eating birds observed at Lakeside Park. Photo Credits (with permission): osprey (top left) Bob Goertz; pied-billed grebe (bottom) and pied-billed grebe with young (right) Luanne Hickey.

Not only is the biological and chemical structure of Shoemaker pond altered, there are a number of novel interactions occurring within the system and several significant and interacting drivers of change that make managing for historic properties a serious challenge and an impractical goal. Adopting the novel ecosystem management approach and managing the pond ecosystem as a novel ecosystem suggests that management be focused on setting pragmatic and forward thinking management goals that are achievable and realistic given the current limitations to restoration. This approach also advocates for consideration of ecosystem function over species origin and historic conditions. There are several barriers that exist and reversing or overcoming all of them in the current political and ecological climate is unrealistic. The presence of salt is expected to be a continuing element in the ecosystem as no practical alternatives have been developed within the current City of Kitchener winter maintenance program. Although the City of Kitchener does have a progressive salt management program in comparison to other Southern Ontario municipalities, no other suitable melting agents exist to replace salt application outright

(S. Berry, personal communications, 2014). This introduced element to the abiotic system of the pond limits which organisms can survive in the current water chemistry. The practical management option would be to allow the system to progress on its current trajectory given the infeasibility of altering or reversing the salinity levels and the fact that the current fish population includes species that are adapted or able to withstand the existing and predicted to be future conditions. It is understood that there is a limit of salt tolerance for all aquatic organisms (CCME, 2011) and this limit will likely be reached at an undetermined time in the future whereby alternative management solutions will be required or the system will transition into a new and potentially undesirable state. An adaptive management and monitoring program has been implemented for Lakeside Park which can be used as a mechanism to detect changing conditions and impending shifts (Suding & Hobbs, 2009). The *Lakeside Park Management Plan* (Dance et al., 2014) also provides direction for the implementation of an education and outreach program focused on lot level/neighbourhood level water quality improvements including salt and lawn fertilizer reduction. These initiatives are intended to alleviate although unfortunately not eliminate some of the current pollutant loading occurring in the pond. The challenge of chloride deposition and direct neighbourhood and road run-off is a management challenge and driver of change that is out of the immediate scope for individual natural area management and that of the manager responsible. This facet of municipal governance is a barrier to historic management and a mismatch of issue to management ability (Hulvey et al., 2013).

A more aggressive and onsite management approach targeting the proximate drivers (i.e., geese and ducks which influence phosphorus loading) would be a more appropriate focus and more likely to have measurable effects (Seastedt, 2013). A focused effort to reduce open grass areas which are favoured by the Canada goose and mallard duck (*Anas platyrhynchos,* L.) commenced in late 2014 with aggressive shoreline planting to create undesirable feeding and loafing areas and ultimately reduce the number of breeding pairs that utilize the park. These efforts will be complimented by educational initiatives to discourage the feeding of waterfowl by park visitors. Together, these targeted interventions are focused on reducing nutrient loading to the system to slow or ultimately prevent further transitions.

When non-native species naturalize in an ecosystem they can form facilitative relationships with existing species and provide valued (though not necessarily historical) ecosystem functions (Hallett et al., 2013). This is especially true in the case of the common carp and goldfish that are foreign in origin but are providing an essential ecological function as food to the fish-eating birds. These same two species are also known to modify the aquatic ecosystem by disturbing aquatic vegetation and creating turbid water conditions of which they are known to tolerate and prefer (OFFD, 2015; OMNR, 2012b). This in effect is a positive feedback loop that shapes the novel ecosystem (and helps move it from hybrid to novel) where the non-native species not only survive the low quality water conditions but they have created favourable conditions for their own survival and that of the overall ecosystem (Hobbs et al., 2006; Hobbs et al., 2009; Richardson & Gaertner, 2013). Another aspect of this potential positive feedback and novel ecosystem development is the presence of the non-native aquatic plant Eurasian water-milfoil (*Myriophyllum spicatum,* L.). This species is an aggressive exotic that will outcompete native species (OMNR, 2012c) and is known to be more tolerant to chloride exposure than the native aquatic plants (Evans & Frick, 2001). This relationship would be expected to facilitate its continued presence and potential dominance in the ecosystem. The synergistic effect of multiple drivers of change on the aquatic ecosystem of Shoemaker Pond coalesces to create a significant management barrier (Hulvey et al., 2013). In this scenario, the system can be managed as a novel ecosystem until new technologies are developed to remove salt from the environment or suitable alternatives are selected for using chloride salt as an ice melting agent.

The interface between terrestrial ecosystem and aquatic ecosystem and the impact of humans has also been evident in the issues relating to turtle nesting and turtle population survival in Lakeside Park. Snapping turtle (*Chelydra serpentine,* L.), painted turtle (*Chrysemys picta marginata,* Schneider) and the non-native red-eared slider are the species of turtle that currently inhabit the park. The snapping turtle and painted turtle are confirmed to be breeding in the park while it is not believed that the exotic red-eared sliders are successfully reproducing. The issue of nesting habitat has created a significant challenge to the population survival for both native species and causes conflicts with park use and some park management and maintenance activities. Traditionally, both species of turtle nested along the northeast portion of the pond and in what is now the active area of the park where the playground is located. Both of these areas provide open and sandy soil habitat for egg laying purposes. As succession of the park has taken place, the northeastern habitat has closed in with forest habitat while the playground maintenance schedule consequently and negatively conflicted with the egg laying time period where maintenance staff would till the playground sand for safety purposes. This activity has had a negative impact on egg and offspring survival. Figure 23 provides an overview of this issue and the prescribed novel ecosystem management choices that are being implemented.

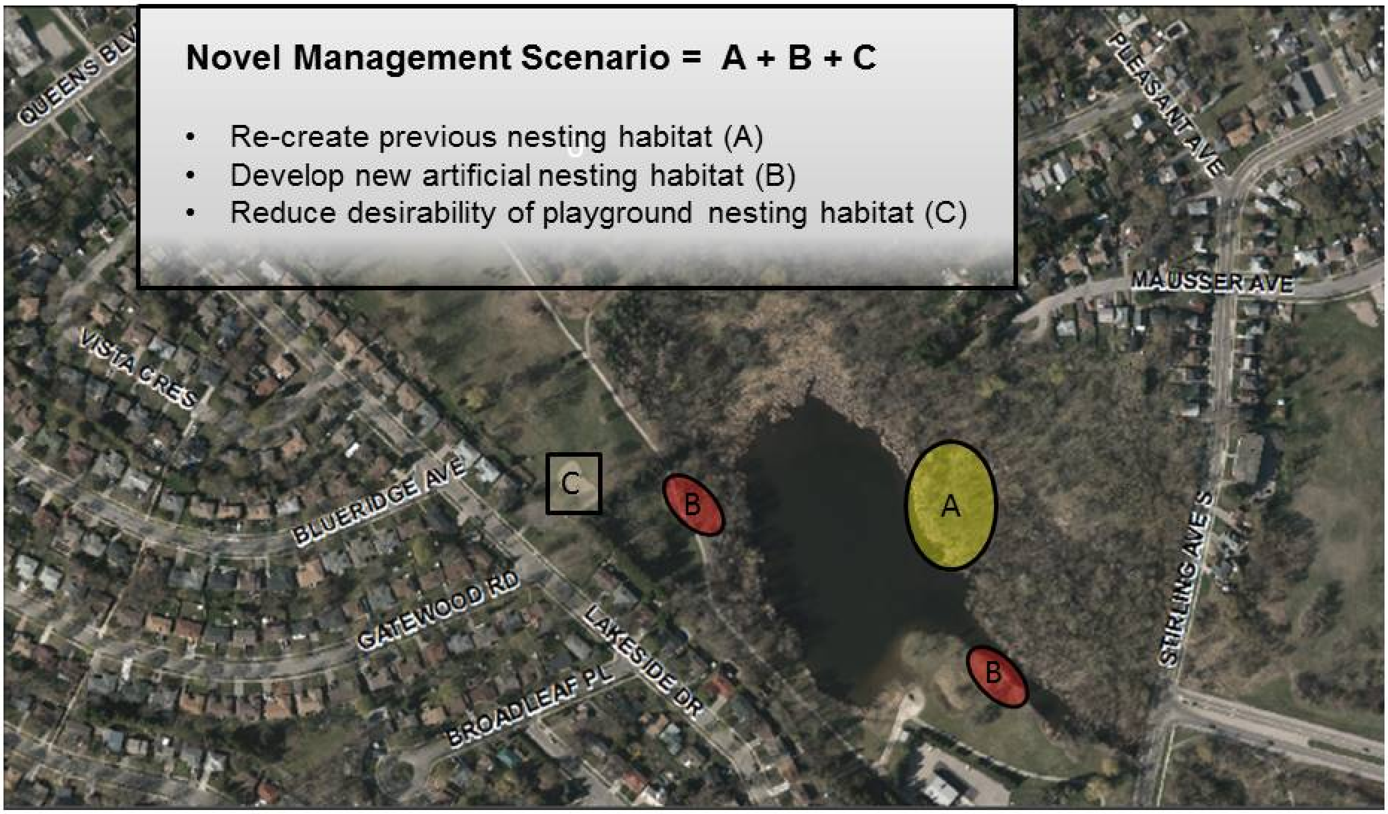

Figure 23: Novel management scenarios for species specific management goals.

The novel management in this situation involves management for the maintenance of a target species or in this case, multiple species. The creation of artificial turtle nesting habitat and active management of existing habitat is consistent with the novel ecosystems framework in that management is focused on re-creating habitat that provides the species with the functionally similar habitat to the historic ecosystem without actively restoring the system. By alleviating the threat or the limiting factor which in this case is the availability of nesting habitat, the targeted intervention ensures attempts to ensure long-term survival of the species. Additional efforts will be made in the future to change the surface of the playground from sand to an alternate surface (i.e., rubber) to reduce desirability for nesting species. In the case of the forest environment, cutting trees and creating an open gap will not only facilitate turtle nesting but may also create desirable habitat for other non-target native species like butterflies or birds that prefer open sunny areas or gaps in the forest. This technique will inevitably require some active and on-going maintenance as well as public education about the benefits of forest management and tree cutting. Although the artificial nesting sites are made using natural materials, the act of intervention and management specifically for ecosystem function still implies a novel ecosystem management approach regardless of the inclusion or interaction of a non-native species. The nesting of turtles in human created areas like playgrounds has been noted in other Kitchener parks and is a factor of habitats being altered and species adapting to conditions, some with success and some without. Novel ecosystems imply novel interactions and it could be argued that species using artificial environments for their survival is exactly that and is a direct manifestation of human impacts and ecosystem changes. This scenario is similar in nature to that experienced in mine reclamation projects where permanent landscape changes have created novel habitats that are being utilized by a variety of species (Doley & Audet, 2013; Harvie & Hobbs, 2013). The active intervention and strategic management for target species is consistent with the management regime for novel ecosystems.

There are both internal (e.g., people dumping goldfish into the pond and feeding ducks) and external drivers (e.g., salt loading, budget limitations and road runoff) that are facilitating further ecosystem changes within Lakeside Park. With the myriad of interacting factors, managing to reverse or simultaneously address all of these drivers to mitigate further change is a significant and daunting management challenge. As Hobbs et al., (2014) point out, “regardless of terminology used, novel, emerging, recombinant, no-analog – ecosystems that challenge conventional conservation and restoration are a present reality” (p. 562). Lakeside Park as a whole is one of these ecosystems. It defies traditional restoration and management frameworks and functions in a new state of organization with a variety of interacting components, some with historical properties and some without. As a park environment, it provides a great deal of enjoyment and benefit to park users and urban residents where it functions as a site of refuge from city life, a location to observe and witness interactions among species and a peaceful place to enjoy and discover nature, native or not. It is a place that conserves local biodiversity and supports a variety of habitats, ecosystems and biological communities. The pure utility and sheer applicability of the novel ecosystem decision-making framework is that it allows and encourages managers to creatively support goals focused on any or all of these aspects without compromising an ecology first mandate. Within Lakeside, there are individual novel ecosystems (i.e., Shoemaker Pond) and individual hybrid ecosystems (i.e., forest ecosystem). The long-term management of Lakeside Park will involve different approaches for different challenges.

For Shoemaker Pond, a novel ecosystem management approach is implemented where a level of acceptance for novel species, properties and interactions is encouraged. This system is likely to continue on its current novel trajectory without human intervention or management and is providing benefit to individual species, members of the public and community at large. The risk to manage outweighs the potential benefits or rewards of re-establishing the historic conditions. In the case of the current fish population, these species are the emergent assemblage that has been able to respond to the on-going environmental changes associated with the water quality parameters (Hallett et al., 2013) are those species likely to be able to persist. From a practical and budgetary perspective, resources will be better spent in Lakeside Park (or elsewhere in Kitchener) on pursuits that will have impacts of greater magnitude such as managing the non-native plant species that are driving the forest ecosystem further towards novel conditions or in the investment of sustainable and proper public access measures such as trails, lookouts or boardwalks that will invite people to experience Lakeside Park but in ways that minimize harm to the ecological community. In no sense is this giving up but rather the practical limitations of reversing current conditions within the pond ecosystem renders management for historic conditions a moot endeavour. The novel ecosystem approach promotes a forward thinking management strategy where opportunities are sought to target management efforts in areas deemed to be feasible, practical and most likely to have success. Managing for individual species such as the pied-billed grebe and snapping turtle for example allows managers to assign resources to areas and efforts deemed important, which in this case, was determined via public engagement and to those ecosystem assessments and those areas most in need of intervention efforts.

For the hybrid forest ecosystem, management acknowledges that changes have occurred and the system is on a hybrid trajectory. The invasive species are a significant component of the forest ecosystem with many providing critical functions and their overall contribution to the system more pronounced now than 40 years prior. In this case, management efforts should attempt to prevent further ecosystem changes by way of active intervention which will reduce the threat of invasive species. Targeting the aggressive populations of ecosystem drivers and re-establishing the native community, educating neighbouring landowners/park users will reduce negative behaviours and engage them in active solutions. Collateral efforts such as creating park stewardship programs, landowner outreach and education which encourages the planting of native species on private property and providing hands-on park visitor education programs are valuable pursuits focused on dual retention of historic properties and hybrid functions. Again, focused interventions are based on an informed manager being able to quickly allocate resources to an ecosystem that will be responsive to restoration and management efforts.

4.3. Conclusion

This research examined the utility of the novel ecosystem framework and how it could be applied to the assessment of various types of urban natural areas and their respective ecological conditions. Not only, does this research occur at the interface between the science and the practice of ecosystem management but it helps to directly address some of the research gaps identified for novel ecosystems. Specifically, this research tested the novel ecosystem framework by identifying functional and management threshold for ecosystems embedded within urban parks across various landscape types (Hobbs et al., 2014). This research was also an investigation into adaptive ecosystem management as applied to the management of new ecosystems (Lindenmayer et al., 2008).

From the perspective of an ecosystem manager, this study generates the foundation for which a prioritization and implementation strategy can be developed. The results of the rapid assessment for encroachments, recreation impacts, unauthorized trails, and invasive species as well as the comparative analyses and indicator monitoring support informed decision-making and form the basis for ecosystem management that is prescribed with confidence and effectiveness. By systematically working through the decision-making framework, a triage approach to intervention is taken where the results support management occurring under different scenarios and based on need and priority. The outcomes of each assessment can not only be used independently to address a specific management issue, for example to target encroachment issues or close and restore informal trail networks but they can also be interpreted in combination with other results to implement management, restoration and intervention that is focused on directing ecosystem conditions towards the historic state or within hybrid or novel ecosystem conditions. The decision as to how best to proceed under this triage scenario does not imply that an ecosystem would be allowed to 'die' or would be intentionally overlooked, but rather, resources would be assigned proactively based on management objectives or goals and on the respective ecosystem conditions or trajectory.

The inventories for encroachments, recreation impacts and informal trails provide an overview of the abiotic change agents and how they are distributed across Kitchener and within individual parks. In many instances, the same parks are under siege simultaneously from several of these impacts and are moving these sites further from their historic ranges in terms of their abiotic structure. The assessment of invasive species populations provide understanding as to how biological communities have responded to these abiotic changes and whether invasive species have become or have potential to become established components of the ecosystem. In addition to invasive species assessments, the inventory of wildlife habitat features and monitoring of ecosystem indicators contributes to knowledge about the biotic structure of these parks and provides a cursory overview as to their ecological integrity.

The interpretation of results for abiotic (i.e., human) impacts plus results for biological properties and indicators guides the resource manager in the decision-making process. In parks where there are low levels of human impacts and high biological potential, resources can be spent on restoration, stewardship and habitat enhancements instead of on managing human impacts which can end up costing lots of money and often become irreversible or unavoidable. In addition to developing management plans and intervention strategies for individual or specific sites, a holistic or landscape approach can also be taken. The landscape level approach to managing changing ecosystems was identified by Hobbs et al., (2014) and is based on the adaptable decision-making framework prescribed by Hulvey et al., (2013) which accepts change as an opportunity for ecosystem management and sets directions for the wise allocation of management resources.

The City of Kitchener is comprised of a patchwork of ecosystems characterized by varying degrees of non-native species invasions, urban-adapted native flora and fauna and individual ecosystems operating at various levels of function as influenced by direct and indirect human impacts. The adoption of a landscape approach for Kitchener and the application of results from both the abiotic and biotic assessments will involve classifying natural areas according to degree of change, levels of human impacts and their biological conditions/potential and then managing accordingly. Applying the results from both spectrums (abiotic change agents and the biotic components) supports proactive management that is strategically directed on maintaining historic conditions or on managing hybrid and novel systems. This inevitably means making difficult decisions about the allocation of resources including staff time, restoration efforts, education programs, volunteer resources and other management techniques and deploying these resources in the most effective fashion. This proactive approach is based on the premise that informed allocation of management resources and informed intervention will have the greatest impact on preventing irreversible changes and maximize conservation potential. This same management strategy should be encouraged at a regional level for natural area properties that are being managed by the Region of Waterloo or are subject to policy direction of the upper tier government. Adopting a cohesive management approach would have an even greater impact across the broader landscapes not only in management approach but in planning for and preventing impacts associated with development and changes over time. It is recognized that in a two-tier government system as is the case in the Region of Waterloo, it may not always be feasible for the same approach to be applied across the entire region however this study does certainly demonstrates what can be possible at the local level and gives encouragement to those doing similar work elsewhere.

The novel ecosystem management approach does have various implications including those mentioned above which are considered positive and focused on maximizing benefit of investment. There are other potential social implications such as what has been discussed for sites like Steckle Woods or Lakeside Park where management takes on a hybrid or novel approach and acknowledges that going back is not the most suitable approach at the present time under the present circumstances. In these cases, the adoption of new approaches can be subject to public scrutiny and sometimes opposition. Employing a landscape level, novel ecosystem management approach will require on-going engagement, education and community involvement to garner appropriate understanding about novel ecosystems as well to develop an acceptance for new management approaches.

As resource and land managers adopt the novel ecosystem approach, knowledge will be gained and shared amongst practitioners and new approaches will be developed as challenges and opportunities continue to arise. This is especially true in jurisdictions and within individual natural areas where the multiplicity of issues and management barriers are dictating a new direction for ecosystem management, one that is forward thinking and embracing of novelty.

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Appendix 1

Spring Visit # 1 & # 2 Data Sheet

Observer Name: ______________________ Date: Visit #1 ______________

Site Number: ______ Date: Visit #2 ______________

Survey Start Time (24 hr clock): #1 __________ #2 __________
Survey End Time (24 hr clock): #1 __________ #2 __________
Temperature (0C): #1 __________ #2 __________
% cloud cover: #1 __________ #2 __________
Precipitation: #1 __________ #2 __________

	#1	#2
American woodcock (*Scolopax minor)*		
Primary: Call note is a nasal 'peent' from the ground …………………………………..…………..	☐	☐
Secondary: Chipping trill during courtship flights ……………………………………….……….….…	☐	☐
Tertiary: size of a small, plump, downtown pigeon ………………………………..…...…………..	☐	☐
Wood frog (*Rana sylvatica*)		
Primary: Call is a hoarse clacking sound (group may sound like quiet ducks quacking) ……….	☐	☐
Secondary: Black raccoon-like mask on side of the face ……………………………..………..	☐	☐
Spring peeper (*Pseudacris crucifer crucifer*)		
Primary: Call is a single note 'peep' with an upward slur ………………………….……….…..…	☐	☐
Secondary: Territorial call - similar to chorus frog call, but less dry sounding; intermittent ……..	☐	☐