# The Effects of Recreational Trail Design and Management Decisions on Northern Leopard Frog (*Rana pipiens*) Populations in an Urban Park

by

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## Author's Declaration for Electronic Submission of a Thesis

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

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# Abstract

In addition to their original purpose as recreational areas, urban parks provide important habitats for species living in urban settings. Reconciling recreational and environmental goals is problematic, especially for park planners. RIM Park, in Waterloo, Ontario, is an example of this attempted reconciliation, where planners and managers attempted to conserve herpetofauna in a provincially significant wetland. However, this area includes a paved nature trail used by hikers, in-line skaters and cyclists and is adjacent to a golf course (which lies within the boundaries of the park). Herpetofauna breeding ponds were constructed and a series of culverts and clearspans included in order to provide reptiles and amphibians with safe passage under the trails. My objective was to determine whether these measures have been effective, whether the park sustains a viable population of Northern Leopard Frogs, and what factors influence frog populations in the park. Two spring field seasons involving mark and recapture techniques were attempted to estimate population sizes of Northern Leopard Frogs at RIM Park, as well as control sites. In both seasons, a control site was a cedar swamp 14 km to the west of the park within an Environmentally Sensitive Policy Area in Waterloo city limits affected by housing development and shared trails. Also within Waterloo city limits, a storm water management pond 8 km to the west was added in field season two. In 2005 (field season 1), because there was a serious drought almost no Northern Leopard Frogs were captured at the two sites examined – RIM Park and the cedar swamp. In 2006, the more "normal" weather conditions revealed that RIM Park had significantly fewer Northern Leopard Frogs than either of the control sites. Given the lack of data in year 1, I compared the 2006 results to seven years of monitoring reports on RIM Park from consultants. The 2006 data were consistent with previous reports of small Northern Leopard Frog populations at RIM Park. Mark and recapture sessions revealed relatively low numbers, with a catch average of 4.33 (SD = 1.15). Calculations revealed an estimated population of 23 (SE = 13.42). The highest number of observed Northern Leopard Frogs ever recorded at the same location in consulting reports is 5. It is likely that the ponds at RIM Park do not support breeding in Northern Leopard Frogs as the only adults caught were late in the season, during the last week of May, and adults likely were transients from the nearby wetlands and uplands. It is possible, given the historical monitoring data, that the Northern Leopard Frogs were long absent from RIM Park because of intensive farming activities that had replaced the wetlands, and that construction of the golf course and trails further precluded colonization. The lack of adult frogs in the breeding ponds and the lack of dead or injured frogs on the trails or golf course support the hypothesis that the trails are not presently causing frog mortality. It is possible that the frogs are avoiding recolonizing the trail and golf course area. It is also likely that the breeding ponds need to be deepened and only then will it be apparent whether the frogs will colonize the ponds, lay eggs, and use the clearspans and culverts. Recommendations include a shift in priorities to put the emphasis on restoration, a discussion of restoration options (including a possible restoration plan), possible improvements in amphibian monitoring techniques (such as reducing the reliance on audio methods), and general suggestions for urban park planning and management.

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*Time's fun when you're having flies!*

*–(Kermit the Frog a.k.a. Jim Henson)*

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# Chapter 1
# Introduction

Two major and related themes in ecology are conservation, particularly of the biodiversity of species, and the impact of human activities on ecosystems. While ecologists tend to focus on areas that are viewed as less disturbed by human activities, or at least more likely salvageable, as in remote parks or protected areas (Chiesura, 2004), urban areas may offer a better opportunity to test how to conserve and restore ecosystem structures and functions under extreme human disturbances in a real-world context (Gross & Hoffmann-Riem, 2005). With growing populations and increasing urban sprawl, knowledge gained from this kind of research will be critical in the future. It may be that ecologists have unconsciously avoided working in urban areas as these might be considered lost causes or not a proper domain for ecological research.

This view is not universal, and a growing number of ecologists are breaking the trend (Grese, 1999; Pickett et al., 1997a; Pickett et al., 1997b; Zipperer et al., 2000). Urban ecology research tests survival under extreme and rapidly changing conditions. It may also serve to convince people that conservation and restoration are important and feasible particularly in areas where most North Americans actually live and where many citizens have relatively little knowledge or tactile contact with the "natural world." Place-based attachment can be an important starting point in environmental education and building community support for conservation and restoration (Ryan, 2005).

One location for this type of research is in urban parks. These areas traditionally reflected the Victorian garden style - one that is organized, sculpted, rational and civilized, without the messiness of untamed wilderness (Taylor, 1995). In recent years, however, urban planners and decision-makers are beginning to reconsider the role and value of urban parks and are now considering how parks might be used for purposes of ecological conservation and restoration. The incorporation of urban parks into city design has become a necessity in planning due to the influence of rapid urban development and diminishing green space. Urban parks, or parks within city limits, benefit people in numerous ways such as providing recreational opportunities and reducing stress. Moreover, parks can play an important role in maintaining the integrity of desired ecosystems and the overall long-term sustainability of a community (Srinivasan et al., 2003).

Urban parks come in a variety of forms. They can contain wetlands, or forested areas with walking trails, or they may be recreation based and include golf courses or sports fields. In many of their forms, urban parks can be home to a wide variety of flora and fauna. Even in designated park areas, however, urban pressure often poses a severe threat to resident populations of wild organisms and the integrity of the ecosystem. Many species are threatened or destroyed because of urban influences such as the application of pesticides (Bishop et al., 1999), the presence of invasive species (Niemela, 1999) and the fragmentation of natural habitats (Knutson et al., 1999).

Because of these problems and many more, planners and managers of urban parks are faced with a difficult challenge. They are given the task of integrating the desires of the community into a park plan, while attempting to maintain ecological integrity (Gobster, 2001). They must make difficult choices and compromises when it comes to restoration, conservation, development and maintenance.

One example of a multi-use park that has required a number of compromises is RIM Park in the City of Waterloo, Ontario, Canada. Chapter Three will include a detailed description of this park. RIM Park is representative of many urban situations. It was reclaimed in 1999 from agricultural lands along a major riparian corridor (the Grand River) and designed as a recreational complex, including sports fields, a golf course and paved trails that bisect and intersect woodlands, smaller riparian zones, and a provincially significant wetland (Natural Resource Solutions Inc., 2004c). In an attempt to facilitate multiple uses and goals of recreation and conservation, and address potential conflicts, certain design elements were included. A prominent element that the City of Waterloo incorporated and advertises is the way the trails and golf course were designed to provide habitats, movement corridors and refugia for Anurans. One particular species that was intended to benefit from these modifications is the Northern Leopard Frog (*Rana pipiens* Schreber [Ranidae]).

Frogs serve as excellent ecological indicators of ecosystem structure and function, particularly of wetlands and riparian corridors (Blaustein et al., 2001; Ficetola & DeBernardi, 2004). Frogs are sensitive to the integrity of their habitats, given their permeable skin, their dependence on different habitat components at different stages of life and at different times of the year, and their reliance on a very specific set of conditions for survival (Blaustein & Wake, 1995). The health and complement of frog populations in a wetland can indicate the quality of the habitat and the level of connectedness of the ecosystem, two factors which greatly determine their success (Ficetola & DeBernardi, 2004). Frogs can also serve as symbols of good stewardship as they are a charismatic species which the public can appreciate. Frogs are an integral part of a complete wetland ecosystem.

## 1.1 Purpose Statement

I constructed this study to be an evaluation of how human decisions and ecological factors can influence frog populations in an urban park, with a focus on trail design and management decisions. In this research, a Northern Leopard Frog population assessment was conducted with the use of standardized, quantitative, scientific techniques, as well as qualitative, observational ones. In particular, audio transect sampling and mark and recapture studies were used to determine population size (Heyer et al., 1994). Interviews and analyses of available reports provided additional information about park management. This evaluation was performed in order to assess the effectiveness of current techniques in park management and conservation as well as contribute to general knowledge about habitat modification and recreational trail design.

## 1.2 Main Research Questions

I selected three research questions in order to determine the success of current management strategies in RIM Park, as well as identify potential problems and suggest solutions.

- Do the affected areas in the park contain a sustainable population of Northern Leopard Frogs?
- How have park design and management influenced frog populations in RIM Park?
- What additional factors may influence frog population survival in RIM Park?

An investigation of these questions will help us to understand the complexities of effectively protecting desired wetland species in an urban habitat.

## 1.3 Outline

This introductory chapter sets the stage for the thesis and leads into Chapter 2 which explains the conceptual and theoretical background material that is key to understanding and evaluating the ecological condition of a wetland, the needs of amphibian populations and various park management strategies. In Chapter 3, the case study of RIM Park is introduced, and the park context and specific details about the condition of the park and the measures taken for the anuran populations are described. Chapter 4 outlines the specific methods used during the course of the study. They include the consulting report analysis and the methods used in two seasons of field work, as well as audio and mark and recapture methods. The results of these analyses and field seasons are provided in Chapter 5. Chapter 6 contains a discussion of these results and how they contribute to current knowledge. Finally, Chapter 7 provides recommendations for the future direction of RIM Park and urban parks in general, and concludes with a summary of the thesis which identifies the contributions of the thesis to both applied and theoretical fields.

# Chapter 2
# Literature Review

The field of Environmental Studies is transdisciplinary in nature. A thorough examination of the environment necessarily includes the cooperation of a number of people with an understanding of areas such as politics, planning, geography and biology. An integration of these fields is an important step in attaining the necessary information and the ability to effectively plan and manage ecosystems.

Naveh (2005) describes the importance of broadening scope, and achieving transdisciplinarity in research, with a particular focus on restoration. Although the writing in his paper was somewhat circuitous, the theoretical foundations were evocative and intriguing. He uses the term "Total Human Ecosystem (THE)" to describe the ideal integration of humans and all other organisms in the ecosystem. This, Naveh believes, may be achieved through the integration of natural and social sciences and the humanities, and will help ensure a sustainable future for both humankind and nature and prevent a global breakdown. In this research, I attempted to take a transdisciplinary approach, and integrated information from a broad array of fields and sources. In this way, the research is more socially applicable, as well as scientifically rigorous. In order to take this approach, I collected information from a vast array of primary and secondary sources. This literature provided me with the knowledge base necessary to address the issues at the park from a variety of angles, and ultimately create methodologies and devise integrative solutions.

This chapter outlines the conceptual and theoretical frameworks that are fundamental to the understanding of this topic. The conceptual framework includes the ethical, social science and natural science concepts that form the backbone of the study. This framework was designed in order to answer the following question: 'is the RIM Park habitat suitable for frog survival?' The theoretical framework discusses relevant theories including those concerning restoration and conservation, fragmentation, corridors, minimum viable populations, indicator species (with a focus on frogs), park management and park planning. These theories are drawn mainly from the disciplines of restoration and conservation biology, population and community ecology, urban planning and environmental management. All of these topics can reveal possible barriers to the survival of frog species in an urban park.

## 2.1 Conceptual Framework

Conceptually, this study is based on three main areas of inquiry: environmental ethics, the natural sciences and the social sciences. While the field of environmental ethics provides the motivation for the study, the other two provide the methodologies needed to answer the primary research questions.

### 2.1.1 Environmental Ethics

The motivation for this study emerges from an environmental ethic, and the assumption that preserving natural habitat is desirable. An environmental ethic involves “Stewardship of the living and non-living systems of the earth in order to maintain their sustainability for present and future, allowing development with forbearance and equity” and includes characteristics such as responsibility, freedom, justice, truthfulness, sensitivity, awareness, integrity and decisiveness (Berry, 1992).

Preserving natural habitats may be desirable from a human perspective, to maintain resources and natural areas for future enjoyment and use. In addition, another perspective is that natural space has intrinsic value, and we are responsible for protecting that space.

### 2.1.2 Natural and Social Sciences

The ultimate goal is for RIM Park to provide suitable habitat for frog survival. This study uses two fields, the natural and social sciences, and some of their related disciplines, to examine possible barriers to this goal. Both fields can reveal important information about the condition of a wetland. The framework in Figure 1 outlines the fields that will be examined in this study and the possible barriers to frog habitat suitability that are revealed by those fields.

Addressing both the natural and social sciences is imperative in order to determine attainable goals for the park. This conceptual framework identifies the major possible barriers to frog habitat suitability at RIM Park that this paper will focus on, as well as the disciplines that inform those barriers.

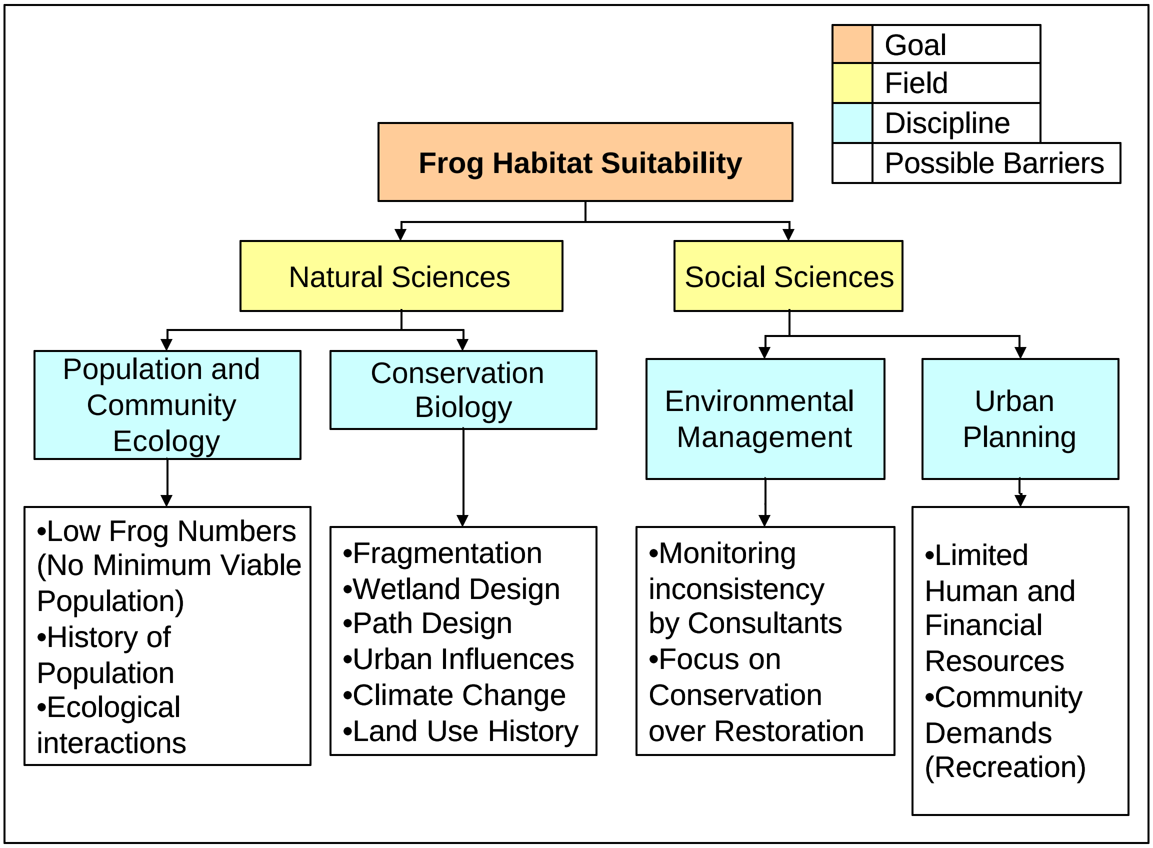


**Figure 1: Conceptual Framework**

### 2.1.2.1 Natural Science Framework

The natural science framework defines the scientific aspects of the methodology and was critical to the formation of the research questions. Gathering ecological data in a systematic and quantitative way allows us to extract information from species that are unable to speak for themselves.

Two relevant disciplines within the field of natural science are population and community ecology, and conservation biology. Population and community ecology examines the previous and existing populations of organisms in an ecosystem and their interactions with each other. The history of a population can determine its fate in a certain location. Ecological interactions in an area can strongly influence population integrity. Conservation biology lends useful insight into the areas of design and fragmentation and how to conserve bio diversity in a changing environment which must address issues such as climate change and changes in land use.

#### 2.1.2.2 Social Science Framework

The social science framework is based on an examination of the influences that people have on the design and management of the park. At least two social science disciplines may be used to address issues in the RIM Park habitat: environmental management and urban planning. Environmental management techniques can fail in their objective of sustaining habitat integrity in a number of ways. For example, monitoring can be inconsistent, or managers can erroneously focus on conservation rather than restoration in areas which will not sustain viable populations. Moreover, in terms of urban planning, barriers such as limited finances and community demands can limit habitat success.

## 2.2 Theoretical Framework

### 2.2.1 Conservation and Restoration Biology

It is increasingly important to restore and protect natural areas with the increasing pressure on natural spaces. Until recently, the focus has been on passive conservation, or preserving natural areas in their current state. Unfortunately, this may not be sufficient, particularly when natural areas are threatened by urban development.

#### 2.2.1.1 What is conservation?

Conservation is necessary to avoid the complete loss of ecosystems or particular species. When a pristine ecosystem exists, the best thing to do is conserve it in that state. Conservation is a broad term that has been used for many years. Restrictive definitions are not generally used (Harrington, 1999). However, the Society for Conservation Biology (2005) defines Conservation biology as “a mission-oriented science that focuses on how to protect and restore biodiversity, or the diversity of life on Earth.” Young (2000), who examines the differences between the fields of conservation and restoration ecology says conservation is responsible for “stemming the flow” of “habitat and biodiversity loss.”

Broadly used, conservation can help to conserve ecological integrity and function, to preserve endangered species and to protect ecologically sensitive areas. An ecosystem has integrity when it 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” (Department of Justice Canada, 2000). In addition, conservation helps to maintain green spaces for recreation, education and human enjoyment, by providing opportunities for interaction with nature.

Daniels and Lapping (2005) discuss the idea of 'smart growth' for communities, and how land conservation can fit well into creating sustainable, healthy communities, as well as helping the ecosystem. Smart growth helps to combat sprawl. They state that providing green spaces for a community should be as necessary as providing sewer and water lines.

Conservation, while necessary, may not take into account the fact that many areas have already deteriorated from a natural state, and have lost their natural functions. In these cases, when the resources and motivation are available, ecological restoration is an option.

#### 2.2.1.2 What is restoration?

Restoration can be defined as "…the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (Society for Ecological Restoration International Science & Policy Working Group, 2004). According to Young (2000), restoration is the "science of habitat and biodiversity recovery." There is a focus on preventing loss in conservation, and promoting improvement in restoration.

Restoration is the key to maintaining ecosystem function in many areas that are degraded past the point where conservation will provide any ecological benefits. Restoration can improve the integrity of the ecosystem as well as provide many of the same functions as the conservation of natural areas, in terms of providing usable green space for humans.

'Restoration' can be an ambiguous term. Based on the goals of a community and a variety of stakeholder visions, the restoration of a park can take many forms. This may mean attempting to restore the area to a previous state, or it may mean transforming it into a usable recreation space (Gobster, 2001). For this reason, restoration goals must be carefully considered and agreed upon. Goals can only be achieved when they are integrated into the local landscape, and take local factors into account. Otherwise, restoration can encounter unexpected limiting factors (Pfadenhauer, 2001).

In many cases, restoration is guided by the past conditions of the land. However, an adaptive environment is necessary in today's rapidly changing world. Factors such as urban development and climate change mean that older, historical ecosystem structures may not be viable in a particular location. Loeb (1992) demonstrated how human presence can change ecosystem structures, and how species in a restoration project should be selected for survival capability.

Restoration projects in urban settings have often been poorly evaluated. Because they are subject to continuing disturbances, they pose a difficult challenge to project managers. It has often been assumed that if structure is restored to an area, function is also. This is not necessarily the case (Grayson et al., 1999). We must move away from the "if you build it, they will come" attitude (Palmer et al., 1997). Function is not always restored with structure. Ecological function must be carefully evaluated during monitoring processes. Although many projects are evaluated as "successful," there is little in the way of scientific evaluation or proof that function is restored. After restoring the appropriate structure, it is important to consider two aspects of success: has the function been restored and have social expectations and values been fulfilled (Ehrenfeld, 2000)?

The success of a restoration project often depends on the relevance of the project to the local culture (Primack et al., 2000). Adding elements of interest (such as the preservation of amphibians) can increase public interest and participation, as well as offer educational opportunities. The importance of active restoration is being realized. The movement from passive conservation to active restoration projects is a critical step in establishing functioning ecosystems.

#### 2.2.1.3 Moving from conservation to restoration

Conservation should be a primary goal, particularly when working with pristine environments. Restoration can never re-create original natural spaces. The ability to restore or create mitigation areas is not an excuse for eliminating natural environments (Young, 2000). Conservation is extremely important, and not to be undervalued. However, conservation alone often constitutes a passive approach. Much of the emphasis in the past has been on conservation. Lately, however, there is a growing emphasis on restoration, an active approach to ecological management of degraded areas (Young, 2000). In many cases, it is possible to restore a site to a condition that is worth conserving.

Managers need to focus on the proper evaluation of a site so they may determine whether or not to pursue the option of simple conservation strategies, or a more extensive restoration initiative followed by conservation. Restoration is a more active approach, which takes more money and effort than basic passive conservation. However, it is a necessary step in many places.

Restoration and conservation are similar in many ways, but are different in some important ones. Conservation is based on a short time scale, while restoration has a long-term focus. Restoration can help to solve many of the conservation problems that we face in urban parks today (Young, 2000). Leaving restoration to nature alone takes a very long time, and there is the potential that an area could degrade further (Dobson et al., 1997).

The movement from passive conservation to active restoration also acknowledges the need to move to an interdisciplinary approach that considers the total human ecosystem. By acknowledging our role in the ecosystem, we can better understand how to find compromises between human development needs and wants, and environmental protection (Naveh, 2005).

Conservation and restoration are not conflicting, but complementary, approaches that should be used together (Dobson et al., 1997). This joint approach needs to be taken in the case of RIM Park in Waterloo, Ontario, which will be discussed in detail in Chapter 3.

In the fields of conservation and restoration, some important theories and concepts form the basis for conservation and restoration design and implementation. These ideas are critical to the understanding of this project, as well as how ecosystems function and species interact.

#### 2.2.1.4 Fragmentation and Landscape Complementation

Restoration and conservation often focus on the concepts of habitat destruction and fragmentation. As urban development and agriculture continue to encroach on natural areas, animals are at risk of losing their homes, as well as their natural migration routes and food sources. In addition to losing these critical elements, they can also become genetically isolated and more prone to extinction due to weather or disease (Krebs, 2001). Even small pathways and roads through natural areas can effectively fragment habitats. Fragmentation theory makes the assumption that animals require intact habitats for survival. A large number of studies have demonstrated the impact of habitat fragmentation (Funk & Mills, 2003; Knutson et al., 1999; Krebs, 2001; Vos & Chardon, 1998).

It is dangerous to assume that a single type of landscape is sufficient for any particular species. The concept of landscape complementation acknowledges the variety of landscape needs of a particular species. For example, frogs need different types of areas for summer, winter and spring, depending on their adult, dormant and breeding stages. It is important to recognize the array of necessary habitats and their connections to promote conservation of these species (Pope et al., 2000). Landscapes are often connected by corridors that animals need to travel safely.

#### 2.2.1.5 Corridors

Another major issue in conservation and restoration ecology is landscape connectivity. Wildlife corridors provide routes for animals to travel between landscapes, or even to migrate long distances. Efforts are being made, such as the Algonquin to Adirondack Movement (The Algonquin to Adirondack Conservation Association, 2006), or the Yellowstone to Yukon Conservation Initiative

(Yellowstone to Yukon Conservation Initiative, 2006) to attempt to create giant corridors of natural connectivity. On a smaller scale, corridors can be broken simply through the addition of roads or paths through natural areas. Corridors may have many functions (Hess & Fischer, 2001), and are only part of a complex system. Many design features must be taken into account when creating corridors (Lindenmayer & Nix, 1993).

In general, connectivity in a landscape allows wildlife movement, and is a critical feature for animals that migrate, or depend on a variety of landscapes to survive. Populations of animals can be greatly affected by fragmentation, and the lack of ecological corridors. In this way, conservation and population biology are inseparably related.

### 2.2.2 Population and Community Ecology

The study of population and community ecology also offers a number of tools for understanding the way the ecosystem works. If we can understand a particular species' behaviours, demographics and interactions, we gain a better understanding of the condition of the ecosystem we are working to conserve or restore.

#### 2.2.2.1 Metapopulations

The concept of metapopulations refers to a collection of partly isolated breeding populations, with occasional dispersal between them (Smith & Green, 2005). The metapopulations theory has been important in amphibian conservation. Many types of amphibians (but not necessarily all (Smith & Green, 2005)) live in metapopulations, where individual populations live at partially isolated ponds, and occasional dispersal can help maintain genetic diversity, and overall metapopulation stability.

Metapopulations rely on their ability to navigate between individual populations. This means that the condition of the landscape is critical. Another related theory is landscape complementation. Animals such as amphibians require a variety of habitat types to satisfy their year-round survival needs. Considering all the landscape types and their connections can be critical in conserving overall amphibian populations (Pope et al., 2000). The connections and the habitat structure improve recolonization potential for areas that are in trouble. Because of these factors, classifying habitat and nonhabitat for animals that move around can be risky (Pope et al., 2000). Distances and barriers between habitats can determine occupancy. In one case, larger pond sizes, and the absence of roads were significantly positively correlated with the presence of Moor Frogs (Vos & Chardon, 1998).

To get a full picture of population survival, an expanded regional view is necessary. Individual habitats can experience very high turnover. Every year may see a new complement of species at one location. An overall picture may be more stable (Hecnar & M'Closkey, 1996).

#### 2.2.2.2 Minimum Viable Populations

When discussing population survival, another useful concept is the “Minimum Viable Population.” This concept refers to the population size that can be assumed to be relatively stable for some length of time, accounting for genetic factors, random demographic changes and environmental instability (Krebs, 2001). This concept also relies on a variety of assumptions, and assumes a level of statistically acceptable error. For example, researchers must make the assumption that there are no severe external pressures on the population that may eliminate it quickly. This analysis is often used on populations of threatened species (Krebs, 2001), or on indicator species. There are programs such as Vortex © (Lacy et al., 2005) that help determine survivorship of species, and help calculate minimum viable population sizes (Reed et al., 2003).

At the other end of the spectrum, another important factor to consider is intraspecific competition. Many species have ways of coping with low food availability, or high densities of conspecifics. In these situations, some animals will develop higher levels of corticoids (stress hormones) that increase intraspecific competition, and control the population (Glennemeier & Denver, 2002).

Population analyses can be used on indicator species to help determine the effects of habitat changes on ecosystem integrity. If populations of indicator species are stable in the environment, it may indicate that the rest of the ecosystem is in good shape.

#### 2.2.2.3 Indicators

The use of indicator species as representatives for ecological integrity is a common and widely spread practice. Indicators have been used in many fields (Cole, 2002; Hermy & Cornelis, 2000), and particularly by plant ecologists (Cole, 2002; Krebs, 2001). Indicator species should be chosen carefully based on a number of criteria. The species should be well known and easily recognized. The biology and history of the species should be well documented. The species should be easy to survey, and specialized to a particular habitat. Finally, it should be closely associated with the rest of the flora and fauna in the area so that it can indicate changes. Indicators chosen for ecological studies generally all meet these requirements (Krebs, 2001).

Still, the use of indicator species to establish ecosystem integrity relies on a number of assumptions. The species selected may be subject to unknown pressures that do not affect other species in the community. In addition, populations of indicator species may experience random changes and fluctuations that do not represent overall changes in the ecosystem. There is no way to be absolutely certain that the correct indicator has been chosen, and that it will accurately represent the integrity of the whole community.

Although there are risks and assumptions involved in the use of indicator species, they provide a useful shortcut in assessing ecosystem function. Due to limitations of time and money, indicator species can greatly simplify monitoring procedures (Krebs, 2001). There is no way to reasonably examine every component of the environment. At the same time, we must recognize that the health of one species won't necessarily represent the health of the entire ecosystem.

Research about the viability of one particular species can have larger implications. A healthy ecosystem requires that a whole host of wild populations remain intact. For example, an examination of frog populations in a wetland may lead to extrapolated conclusions about the sustainability of the wetland's wildlife in general. Changes in a wetland habitat, such as the introduction of a paved pathway which fragments the landscape could seriously affect frog lifecycles, migration patterns, and behaviour (frogs like to use pavement as a "sunning" platform) (Natural Resource Solutions Inc., 2004c). This type of change could even decrease frog abundance to below the minimum viable population. If a frog population was eliminated, the whole food chain of the area could be disrupted. Also, after determining the impact of small pathways and culverts on frog populations (as indicators), it may be possible to extrapolate from this information a broader understanding of the impact of roads or highways on animal populations.

Atypical behaviour or life cycles of indicator species may indicate a serious problem in wetland function. Knowledge in this field can help us to proactively minimize the impact of urban development on resident animals as well as help managers decide how large an area they need to design to sustain viable populations (Reed et al., 2003).

#### 2.2.2.4 Amphibians as Indicators

Many amphibians can be used as indicators of wetland integrity. They fit the criteria for good indicators, as they have been well studied and are easy to recognize. They are very specialized to their habitat, and have a wide range of habitat requirements. In addition, their permeable skin makes them particularly susceptible to changes in air and water (Blaustein & Wake, 1995). Because amphibians make such good indicators, reports of their declining status are alarming.

Amphibians are decreasing in many places all over the world (Hecnar & M'Closkey, 1996; Heyer et al., 1994; Stevens et al., 2002). This observation has received a great deal of attention from the scientific community, in the form of conferences and countless studies on amphibian physiology, habitat and behaviour (Cohen, 2001; Funk & Mills, 2003; Hecnar & M'Closkey, 1996; Heyer et al., 1994; Löfvenhaft et al., 2004). A variety of theories suggest a broad array of causes that can be either worldwide or local in nature.

The decline in amphibian (and more specifically frog) populations has been attributed to factors such as local habitat destruction, invasive species, ozone and climate change and pollution. Although each theory is well supported independently, it seems likely that a variety of causes combine to create an overall effect (Blaustein & Wake, 1995). That being said, the vast majority of studies appear to focus on local causes such as habitat destruction and water pollution. These are generally the issues that are the easiest to examine and change. Cause and effect assumptions are also simpler to make in these cases.

At a community level, amphibians are also subject to other influences, such as competition and predation. Competition and predation interact in complex ways to contribute to tadpole mortality (DeBenedictis, 1974). While there has been little consistency in outcomes of experiments or observations involving various amphibian species, studies have indicated that the populations of amphibian species can be altered by interspecific interactions with other amphibians (Relyea, 2000, 2002; Werner, 1992). One species of amphibian may inhibit growth and increase mortality of another species through chemical interference or aggressive behaviour (Faragher & Jaeger, 1998). These factors can be exacerbated by the introduction of invasive species, the addition of pesticides, or the alteration of habitat conditions which can change the ability of species to resist predation and compete effectively.

In terms of habitat scale variables' effect on frog populations, the complex relationships are a result of lifecycles that usually depend on both aquatic and terrestrial components of the landscape (Froom, 1982; Pope et al., 2000). Because of this, a wide range of factors can contribute to their decline. Wetland habitats are often subject to a number of human influences. As water pollution from industry and agriculture becomes a larger problem, many researchers are starting to examine the frogs in affected wetlands. Nutrient run-off from an agricultural area can contribute to lower diversity, density and reproductive success of anurans living downstream (Bishop et al., 1999). One species of

Leopard Frog was decimated by the encroachment of emergent vegetation, caused by the addition of fertilizer from agricultural lands (Bradford et al., 2004). Pollutants such as fungicides, herbicides and industrial chemicals may harm the development of frogs (Blaustein & Wake, 1995).

Changes in landscape features, such as the addition of roads, can contribute to the demise of frog populations. Fragmentation of habitats can be detrimental to populations of animals that live in metapopulations and rely on migration. Amphibian presence relies heavily on habitat quality and proximity to other wetlands. Wetlands that are near other wetlands are much more likely to support a viable frog population, because they allow migration and support a diverse metapopulation. When these wetlands become isolated, or fragmented by human alterations, they lose their ability to support a healthy frog population (Ficetola & DeBernardi, 2004). Pellett et al.'s study (2004) using concentric analysis, revealed that urban areas and roads strongly affect the presence of some frogs, even at great distances (up to 1 km). When ponds are created or altered, planners must take urbanization and traffic into account.

Consistent with the general and specific literature on fragmentation theory (Knutson et al., 1999; Pellet et al., 2004; Vos & Chardon, 1998), fragmentation of habitats is often blamed for reductions in frog population size and diversity. Distribution patterns and habitat selection can be greatly altered by fragmentation of the landscape (Vos & Chardon, 1998). In one instance, fragmentation was correlated with a 17% reduction in clutch size of an Amazonian frog. This was likely due to the smaller size of the female, which also correlated very well with the finding (Funk & Mills, 2003). Literature in this field appears to have influenced city and park planning, particularly in the placement of structures such as roads and bridges.

Local and immediate effects of these changes to amphibian quality of life are relatively clear. However, longer-term changes on a landscape scale are harder to detect, and therefore neglected in the academic literature. Loss of anuran diversity and abundance is likely due in part to historical and current land use patterns. Large-scale projects will be required to determine real environmental effects on metapopulations (Hecnar & M'Closkey, 1996).

Population studies of indicator species can help to assess ecosystem integrity. To determine frog population size and viability, there are a number of available tools used in the literature to help identify things such as the presence of a Minimum Viable Population. Mark and recapture studies are popular ways to estimate population sizes of mobile animals. They are used on a wide number of species, from frogs to birds to whales. The number of animals marked on one night and recaptured on another can, through a series of calculations, estimate the size of the population with decent accuracy (Brower et al., 1998).

Nelson and Graves (2004) found that calling indices are also good indicators of population size in frogs. They compared mark and recapture studies and call rates to calling indices to determine the effectiveness of the method. Calling indices will only detect breeding males, however, so this must be accounted for in calculations. Some studies have tested the use of call counts to estimate size of breeding populations in ponds, and found them to be effective (Stevens & Paszkowski, 2004). Despite the common use of auditory methods, the literature seemed to conflict on the methodology used to assess populations in this way. There was no one consistent method used in the literature, and estimates were very rough.

The best way to accurately assess a frog population size appears to be to combine methods (Ryan et al., 2001). Using mark and recapture studies as well as calling indices and general observations, it may be possible to get a relatively accurate picture of the population in question.

#### 2.2.2.5 Leopard Frogs as Indicators

One frog that is experiencing a rapid decline in Southern Ontario is the Northern Leopard Frog (Hecnar & M'Closkey, 1996). Leopard Frogs make excellent indicators of wetland ecosystem integrity. Leopard Frogs meet the indicator species requirements with ease. They are well studied, and have been labeled by Dickerson, in her book on frogs (1969), as the most common frog in North America. The Leopard Frog is very specialized, requiring a very specific set of conditions to survive, and it remains relatively confined for most of its life (Blaustein & Wake, 1995). It is closely integrated with the various components of the environment. These frogs require both aquatic and terrestrial components of the habitat for a successful lifecycle. Adult Leopard Frogs often live on land as carnivores, but inhabit the water as larvae, where they eat only vegetation. Frog skin is highly permeable, and subject to changes in the water quality (Blaustein & Wake, 1995), and Leopard Frogs are particularly susceptible to desiccation (Schmid, 1965). Adult frogs are better indicators of population size than are juveniles, because the population is less prone to fluctuation (Marsh, 2001). In addition, the Leopard Frog is an excellent indicator for particular changes in wetlands, such as the addition of roads, due to its high level of mobility compared to other species (Carr & Fahrig, 2001).

Because of this wide variety of landscape needs, or landscape complementation, wetland restoration and maintenance must consider both aquatic and terrestrial landscapes for frog preservation. It is important to preserve the terrestrial habitat surrounding wetlands to promote amphibian biodiversity (Porej et al., 2004). As development continues to encroach on wetlands and other natural habitats, it is becoming increasingly necessary to incorporate livable habitats for many types of species into urban designs and to minimize harmful interactions. In this way, we may be able to reduce the human impact on other species.

### 2.2.3 Urban Ecosystems

#### 2.2.3.1 Conservation and Restoration

In urban ecosystems, conservation and restoration are topics of much concern. Ecological theories, such as fragmentation and the need for ecological corridors, inform many of the decisions in terms of city planning and management.

Urban ecosystems present a difficult challenge. They face a number of barriers to ecological integrity, and yet, are often imperative for the long term survival of certain species. Urban ecosystems also present a number of advantages (Grese, 1999). For example, wetlands in urban areas face changes to hydrology, water chemistry, species composition and geomorphology, but still provide important functions such as habitat, corridors, storm water control and recreational and educational opportunities (Ehrenfeld, 2000). However, these areas must be properly maintained in order to provide these functions.

It is important to shift the ideology, particularly in urban environments from passive conservation to active restoration. Areas are frequently too degraded for simple passive conservation to be of any use in terms of maintaining intact ecosystems. Restoration biology has a much more long-term, sustainable focus (Young, 2000) that applies well to the changing conditions in urban settings. Restoration is an excellent tool for increasing the speed of recovery of degraded areas and for creating land for the purpose of conservation (Dobson et al., 1997). Urban environments are often the most degraded and, as such, offer significant opportunities for improvement. Restoration and conservation can reduce the effects of fragmentation caused by urban development.

Maintaining unfragmented, or at least connected habitats within human-occupied areas, is necessary in order to support animal needs. The effects of fragmentation can be reduced in many ways. These include options such as the creation of greenbelts and greenways (Taylor et al., 1995), a network of backyard gardens (Rudd et al., 2002), or a series of connected urban parks. Wildlife corridors are generally defined by their ability to allow safe passage for animals (Hess & Fischer, 2001). Animals that exist in metapopulations can particularly feel the effects of fragmentation caused by urban development. If areas are well connected, animals may be able to safely migrate through urban areas, and have the potential for population supplementation and recruitment (Pope et al., 2000).

In many places, researchers are working on finding compromises between multiple uses of natural spaces in urban ecosystems. Natural areas can be integrated creatively into human-used spaces. For example, naturalized golf courses are often used to provide wetland or woodland habitats to animals (and particularly birds) in urban settings, and can be connected to other naturalized city components (Terman, 1997).

At the same time, restoration projects that attempt to emulate historical conditions in urban environments can be doomed to failure. To be effective, restoration efforts have to be not only adapted to current local conditions, but also responsive to increasingly unpredictable and turbulent environmental changes. In an urban restoration project, hardy species should be selected based on observations of survival (Loeb, 1992). Partly because of the high potential for failure and the many possible barriers to success, restoration projects need to be carefully monitored and designed in an adaptive way. In urban environments, monitoring may be simpler than in remote areas, due to easier access, and the opportunity for volunteer involvement. Specific methods are being designed to enhance our ability to monitor projects in an urban context. In urban environments, a new set of criteria must be used (Hermy & Cornelis, 2000). Indicator species provide one way to measure the effectiveness of restoration and conservation projects within urban environments. Indicators can identify successes and point out potential problems in habitat structure and function. Function is not always restored with structure, and ecological function should be carefully evaluated during monitoring.

This kind of evaluation and restoration can not be achieved through traditional scientific approaches, such as controlled laboratory experimentation. It is time to move beyond this. Public, real world experiments in restoration in urban environments are the next step. This movement into real-world experiments will force people to listen to real-world concerns, and address unforeseen issues. Processes of recursive learning and positive feedback loops can now be used to increase the effectiveness and efficiency of restoration projects (Gross & Hoffmann-Riem, 2005). Restoration in urban environments provides important learning opportunities in an environment that people relate to, care about and understand. One of the best ways to preserve and restore green spaces in urban environments is through the inclusion of urban parks. These parks can serve any number of different functions and take any number of different forms.

### 2.2.4 Urban Parks

#### 2.2.4.1 Urban Park Use and Compromise

Urban parks, or parks within city limits, have many benefits for people as well as the ecosystem and the well-being and sustainability of a community (Fieldhouse, 2002; Srinivasan et al., 2003). Given the increasing importance of urban green spaces, there has been a great deal of attention in the literature paid to urban parks and the compromises that arise when dealing with people and parks (Brandon & Wells, 1992; Chiesura, 2004; Gobster, 2001). Issues that park managers are facing include restoration and conservation decisions (Young, 2000), negotiating between various visions of nature (Burgess et al., 1988; Gobster, 2001), and attempting to maintain ecological integrity and perform restoration in recreational areas (Zedler & Leach, 1998).

Visitor use of parks must be carefully managed and balanced with ecosystem management. Offering people a place to understand and appreciate the environment comes at a cost to the ecosystem (Eagles, 2002). Urban parks provide psychological and social benefits to people, as well as serving ecological functions. (Chiesura, 2004).

Many people have identified the benefits of the presence of urban parks in a community (Chiesura, 2004; Cornelis & Hermy, 2004; Gobster, 2001; Page, 1997; Spronken-Smith & Oke, 1998). Ecological benefits of urban parks include things such as improved ecological integrity, an increase in available habitats and migration corridors for local flora and fauna, and the preservation of biodiversity (Cornelis & Hermy, 2004). In addition, urban parks often serve important functions such as water control and temperature regulation (Spronken-Smith & Oke, 1998). As for humans, the benefits are also numerous. Urban parks are important in terms of recreation, physical activity and social and psychological health (Chiesura, 2004). Local naturalization projects also provide an important opportunity for children and adults to interact and learn about the natural environment, thereby fostering a love and respect for nature (Primack et al., 2000).

One major challenge facing park planners and managers is designing and maintaining parks that can be useful to a wide variety of people. In urban projects, there must be some element of compromise when it comes to discussions of park values. There appears to be little in the way of literature describing how to reach these compromises. Often, urban green spaces will be designed as multi-use parks, with the intention that they make as many people happy as possible. Parks may contain recreational areas, sports fields, playgrounds, recreational facilities, golf courses, protected areas, nature trails, wetlands etc. The possibilities are endless.

Zedler and Leach (1998) discuss how to manage urban wetlands for multiple uses, including recreation, research and restoration. Allowing recreation in natural areas is often necessary to garner public support for conservation and restoration. At the same time, recreational uses should be low-impact and passive such as bird watching or hiking. Restoration projects can improve the function and integrity of degraded sites. In addition, the research community can benefit and learn from this sort of easily accessible project. Zedler and Leach found that the three uses can be synergistic (1998). At the Tijuana Estuary, interpretational programs and the visitor centre are designed to complement an experimental restoration project. The design permits recreational activity, while limiting access and damage to sensitive areas, which are being restored and used in research. At the Wisconsin-Madison Arboretum, wet prairies were restored, providing opportunities for hikers and researchers as well as homes for native species. Conservation and restoration should be priorities in the process of reconciling different needs and desires in park design. Without these components, urban parks can not sustain any level of ecosystem integrity.

#### 2.2.4.2 Conservation and Restoration in Urban Parks

Generally in urban environments, green spaces are far from pristine and need encouragement to reach their full ecological potential. Leaving restoration to nature alone takes a very long time, and there is the potential that an area could degrade further (Dobson et al., 1997), especially in areas of high human density. Urban parks can be restored to a state worth conserving.

Because of the recognized importance of restoration projects in urban parks, it is critical that we develop a good understanding of how to restore natural areas successfully, particularly under the stresses of an urban setting. Urban restoration projects should be treated as experiments (Gross & Hoffmann-Riem, 2005), and assessed thoroughly for future reference. Long-term assessments of restoration projects are probably necessary to accurately measure responses. Löfvenhaft, Runborg, & Sjögren-Gulve (2004), discuss a long term analysis of biotopes and distribution patterns of particular species to avoid damaging necessary habitats in Sweden. They also suggest that, even if no more biotope is lost, biodiversity will continue to decrease due to a lag effect from previous development. Although researchers have determined that monitoring is key to a successful restoration project, due to limited resources, many restoration projects are often lacking in this aspect. In addition, because this is a relatively new field, not enough time has passed to properly evaluate the long term results of many projects. Once projects are completed, and monitoring is underway, thorough, consistent reporting will improve the usefulness of these projects. Eventually, it would be extremely beneficial to have a widely accessible database of projects, their methods, results and monitoring to be used for cross comparisons.

#### 2.2.4.3 Park Challenges

Parks in urban settings face a large variety of challenges. These challenges are different than those faced by parks surrounded by wilderness. People have a variety of visions of what a park should look like, and the purpose it should serve (Gobster, 2001). The main challenge is reconciling the wants and needs of the community with protecting potentially sensitive areas. This can include things such as minimizing fragmentation, providing accessible trails, creating a safe environment, and preventing vandalism and pollution.

Parks which contain dense forested areas can be safety hazards. Unfortunately, in today's society, these areas can be dangerous, particularly at night for people walking alone. When a park gains a reputation as being dangerous, the public may lose interest (Page, 1997), and it can be difficult to gain support for its restoration and maintenance. Addressing community safety concerns is important (O'Brien, 2005). Parks that are appealing, safe and frequently used are more culturally sustainable (Gobster, 2001).

Nature trails provide important opportunities for people to interact with nature, and gain an appreciation for the park. Human experiences with nature have positive psychological and physical effects (Chiesura, 2004). At the same time, these trails fragment habitats, provide invasive species with access to vulnerable sites, interrupt natural behaviours, and increase potentially harmful contact between humans and other species. This increased access also elevates the potential for pollution, litter and vandalism.

Sometimes, parks may contain sensitive areas that need to be protected. Fragmentation should be avoided as well as the potential for encroachment. Growing human populations and the expansion of urban areas have caused an increase in the number and size of roads that travel through natural areas. Roads and trails can have a devastating effect on animal populations, not only through fragmentation, but also through an increase in wildlife road mortality. I will focus here on frog populations and roads as an example, given the relevance of the topic to this thesis.

Pellett et al. (2004) found that frog populations were significantly lower near roads. This effect was apparent to a distance of one kilometre away. If a road runs through important migratory routes or near breeding ponds, it may have a devastating effect on local frog populations. Animals that are more mobile are apparently at more risk from the presence of roads, because they are more likely to encounter and travel across or along them. Particular frogs, for example, are much more likely to suffer population changes due to traffic. Leopard Frogs are particularly mobile and were found to be much more vulnerable to traffic than other frogs (Carr & Fahrig, 2001). The amount of traffic mortality may not seem significant at first, but in some places, significant numbers of mortalities have been recorded. At one site in Denmark, an estimated 25% of a male frog population was killed by traffic (Hels & Buchwald, 2001).

Frogs are affected by traffic density as well as the simple presence of roads. In one study conducted by Fahrig et al. (1995), frog and toad population sizes, as identified by chorus intensity, decreased as traffic increased. This finding suggests that declines in frog populations may be in part due to increases in traffic volumes. Mazerolle (2004) also found that changes in traffic intensity can change amphibian mortality rates. All available literature on this topic strongly suggests that frogs are affected in many ways by the addition of roads through their natural habitats. This realization has led some park and road planners to devise ways to minimize this interference.

The addition of culverts is one strategy that has been used to attempt to reduce the population damage caused by roads in wetlands and urban parks. Culverts are passages that run underneath roads, and are often constructed to reduce animal use of roads to prevent wildlife mortality and promote natural migration. In one area in Florida, for example, the construction of a culvert dramatically decreased the number of animals killed on the road over a one-year period from 2411 to 158 (Dodd et al., 2004). A variety of factors in the design of culverts can influence their effectiveness for particular animals. These factors may include culvert dimensions, road width and vegetation (Yanes et al., 1995). Park challenges can be addressed in many ways but it takes time and careful planning to address all of them. That is why an adaptive strategy is so important.

### 2.2.5 Social Context

The adoption of an environmental ethic is inevitably accompanied by the acceptance of responsibility for the maintenance of the natural world (Berry, 1992). As such, society needs to assume the responsibility for preserving natural ecosystems. As the urban built environment proliferates, it is now necessary to find compromises within urban limits, allowing natural habitats to reside alongside, and be integrated with, urban development projects.

Nature can be valued in different ways, it may be viewed as *functional* (nature as a resource), *wilderness* (nature as apart from human influence) or *arcadian* (harmonious human and nature interactions). Understanding these various perspectives is key to making compromises that will increase support from the whole society (Swart et al., 2001).

Robertson and Hull (2003) describe the field of "public ecology" which would take advantage of scientific knowledge, but also values public participation and collaboration with a wide number of stakeholders in order to make policy recommendations and decisions. Public ecology focuses on the need to gather all relevant and valuable information and form a complete picture which ultimately helps to create an integrative system (Robertson & Hull, 2003). Many ecologists may prefer to ignore the social context, and create an ideal, pristine, natural habitat - this is not reasonable. Urban parks must necessarily include people to be sustainable, and to maximize benefits. Because of urban pressures, restoration must be conducted only under reasonable expectations. Restoration projects are subject to a number of limiting factors, and must be integrated appropriately into current land use patterns (Pfadenhauer, 2001).

Restoration ecology needs to become transdisciplinary in nature, and consider the Total Human Ecosystem by linking knowledge from the humanities and the natural and social sciences to ecological knowledge and ethics. This approach will make restoration ecology much more applicable to real life and usable in terms of policy (Naveh, 2005).

Not only do scientists agree that natural spaces are desirable, but citizens often feel strongly about the need for greenspaces in their communities. Community forests can serve as refuges for recharge (Hansen-Moller & Oustrup, 2004), as places for high quality sensory experiences, and non-commercialized areas for children to play in and learn (Burgess et al., 1988). Education that occurs in a multi-sensory environment can involve children in learning in a way that is impossible in a classroom (O'Brien, 2005). Many people experience feelings of well-being while interacting with nature and this kindles emotional attachment, and higher value placed on woodlands. Community values are key to the feeling of ownership and responsibility, and thus the sustainability of urban parks (O'Brien, 2005). Attachment appears to be related to experience. Various types of experiences lead to different perspectives on management, and how a park should be used and managed. For example, volunteers and staff in a park feel differently about the way a park should be managed than do the general public. Education and attachment lead to a better understanding of what is needed in a park (Ryan, 2005).

Some researchers have ventured outside the realm of traditional ecology and undertake integrated urban ecosystem research. This is a necessary step in the creation of harmony between the natural and built environment in urban ecosystems. Such analysts hope to link social, cultural and economic processes with the biological and physical realms while taking a long term perspective. Humans should be included in ecological models because they are clearly a very influential part of the ecosystem (Pickett et al., 1997a; Pickett et al., 1997b). Research about the role humans play in the ecosystem is an important step on the way to creating sustainable communities.

Many people have examined ways to create sustainable communities. Daniels and Lapping (2005) noted that livable communities require the incorporation of land preservation into the planning process. This would be an example of "smart growth," and would help curb urban sprawl. Niemela (1999) proposed examining urban ecosystems in stages. These stages would involve examining what kind of nature exists in the area, what ecological processes function there, and what appropriate management schemes will help preserve existing biodiversity.

Ecological planning is necessary for the long term sustainability of a community. Ecological knowledge is an important tool in this process (Zipperer et al., 2000). Theories and concepts such as patch dynamics and the classical ecosystem approach are necessary to properly manage urban ecosystems. Urban ecosystems are subject to many of the same rules of biodiversity as natural ecosystems (Savard et al., 2000)

The creation of sustainable communities with incorporated greenspaces preserves both the natural and the social environment. Mounting evidence indicates that built environments may be causing physical and mental health problems among city residents. Sustainable communities will benefit people through contact with the natural environment (Srinivasan et al., 2003).

Fortunately, environmental management and policy has become a critical component of city planning and management. Policies have emerged that stress the importance of conserving and restoring natural spaces as much as possible. The concept of sustainable cities has emerged, and this encourages the inclusion of greenspaces into city conceptual designs.

One good example of the emerging environmental focus in city planning is the City of Waterloo, which initiated an "Environment First" policy in 1989. This means that environmental concerns are a priority in all business activities in Waterloo, including development, corporate, and leisure services (City of Waterloo, 2002). The city also has an "Environmental Strategic Plan" to help with implementation and management strategies (City of Waterloo, 2002).

It seems that many agree that a holistic, interdisciplinary research approach when it comes to urban ecology and planning is preferable. This includes participatory democratic approaches, and involving a large variety of stakeholders (Robertson & Hull, 2003). In some places, these approaches are already being implemented, such as the community conference "Imagine! Waterloo" in 2000 (Pim & Ornoy, 2005).

#### 2.2.5.1 Environmental Management

The setting of appropriate goals is an important element in effective environmental management. Planners and managers may fail to consider all possible urban influences. Moreover it is important that goals not be vague, and that endpoints are clearly defined (Grayson et al., 1999).

In urban planning it is not uncommon to find goals that are often set that put either too much or not enough faith in scientific study. People planning restoration projects should proceed with caution, putting faith in tested theories and previous knowledge, but accepting the limitations of science, particularly in an urban setting. The concept of "no net loss," implemented in the United States is an example where policy makers put too much faith in science. In this case, policy makers appear to believe that restored wetlands can perfectly mimic the structure and function of natural wetlands, and that mitigation wetlands are an appropriate replacement for wetlands that are destroyed. This is usually not the case (Robertson, 2000) because such approaches do not recognize the complexities of ecological systems and functions. Another example of unrealistic expectations is the "if you build it, they will come" hypothesis. The re-establishment of structure does not necessarily imply the re-establishment of function. Long term, thorough monitoring is the only way to determine if function is restored (Palmer et al., 1997).

On the other hand, science is often ignored. In many cases, decision-makers have put a great deal of faith in the ability of nature to restore itself. This may be an unrealistic goal. In many cases, this is not possible, or is an extremely slow process. Simple passive conservation isn't always the answer in management, and there is scientific evidence to demonstrate this. Restoration should be considered (Dobson et al., 1997; Young, 2000). When the recommendation of restoration comes up in a political environment, science is often ignored in favour of cheaper, easier solutions, such as passive conservation.

While the focus has traditionally been on the impacts of urbanization on biodiversity, Savard et al. (2000) recommend that studies start to work on enhancing urban biodiversity. This is a much more integrative solution that may be more applicable in today's society.

One of the major elements that is missing in a surprising number of restoration projects is a long term monitoring plan. Success of restoration projects is rarely gauged. This is wasteful. Future restorationists can make the same mistakes, and can never learn from the successes and failures from a poorly documented project (Grayson et al., 1999). Long term studies are necessary to get the full picture in an urban setting, because these areas are subject to a great deal of fluctuation (Kentula et al., 2004). Scientists have often stressed the importance of thorough documentation, but choices are often made which neglect this factor.

A lack of effective environmental management can occur due to a lack of funding, or poor planning (Purcell et al., 2002). It can also occur simply because there is no legislation to enforce restoration or monitoring in ecological areas (Ruiz-Jaen & Aide, 2005).

#### 2.2.5.2 Urban Planning

Traditionally, the field of "planning" was used exclusively for planning development. More recently, this has changed to be a more integrative concept, planning whole communities and including parks and green spaces as well as development (Daniels & Lapping, 2005). Community members have noted the need for a diversity of natural settings in the urban environment, that serve a wide variety of needs (Burgess et al., 1988). Although there have been many positive changes in planning strategies, and the inclusion of green space in planning regimes, there are still many problems to solve in terms of urban planning methods.

When it comes to urban planning, ecological functions are placed secondary to human concerns, such as cost, safety, and convenience. In many cases, planning takes a municipality instead of watershed focus, but ecosystems do not follow municipality lines. In addition, natural disturbance regimes can not be established in urban settings (Ehrenfeld, 2000). Historically, managers of city parks often operated in isolation, ignoring the concept of parks as a network of greenspaces.

In addition, planning sometimes appears to take a short term perspective, and doesn't necessarily consider the long term implications or sustainability of urban restoration projects. There are ways to select species, and design urban ecosystems that will be able to withstand disturbances, and persist in the long run.

Ecological concerns in urban environments are definitely becoming more of a priority. Much of this concern is derived from concern about human health. People are spending more and more time indoors or at least within the built environment. This has been linked to human illnesses. Urban ecosystem planning is necessary to integrate green spaces with human living spaces. Land use, transportation, pesticide use, and industrial development are all health concerns in the urban environment. More research is necessary, but attention to these problems is growing, through increased government support, research programs, and conferences (Srinivasan et al., 2003).

As well as health concerns, it is critical to address safety worries when it comes to urban green spaces. Areas that are designed with heavy woodlands may become hazards in terms of providing cover for crime and anti-social behaviours (O'Brien, 2005).

All in all, human concerns appear to take precedence over environmental concerns in urban ecosystems. However, this perspective needs to change. Humans should be recognized as an important part of the ecosystem, not a separate entity (Pickett et al., 1997b). Differing attitudes towards environmental issues in urban environments can make decisions very difficult. Many people have a different vision of “nature,” and are unwilling to compromise.

Many ecologists want wild greenspaces that mimic natural ones, while many community members want manicured, organized greenspaces. By imposing a view of nature on others (Swart et al. (2001) called this ecological elitism), people risk losing the chance of negotiating and creating a mutually satisfactory solution. A greenspace that makes people in the community happy is more likely to persist. This is called cultural sustainability (Nassauer, 2004).

Because these issues are difficult to resolve, greenspaces are often designed towards one extreme or the other. This may lead to a loss of the sustainability of the space. For example, to some influential members of the policy community, native plantings may look like neglected weeds. The general public may not understand the value of the type of ecosystem, and this creates an unsustainable situation (Nassauer, 2004). A lack of education, and lack of natural experience, can lead to a limited view and understanding of natural processes in greenspaces. This is why natural experiences are so important. Those with a thorough environmental education and a high degree of interaction with the park have a better understanding of ecological goals (Ryan, 2005).

On the other hand, compromises can be found in many ways. For example, native plantings can be used in parks but maintained in a way so they look attractive and healthy. Compromises will be the only way to keep the greatest number of people happy. These compromises can only be discovered through integrative decision making, including a variety of stakeholders and the building of common ground (Robertson & Hull, 2003).

To achieve this, it will be necessary to better integrate science, social science, and policy. Decisions are often made based on human before ecological values, and this will not be sustainable in the long run. Ecology alone can not provide all information necessary about the influence of humans on the ecosystem, so an interdisciplinary approach is necessary (Niemela, 1999). In addition, decisions about funding that are based on quantitative decision making tools, such as those described by Guikema and Milke (1999) , may lack aspects of the social world that are necessary to consider.

Neither natural science nor social science alone possesses the necessary information to create a sustainable urban ecosystem. Only through improved cooperation between these fields, can we hope to create a lasting harmonious relationship between humans and the natural world.

## 2.3 Case Studies

Case studies that examine real world issues are becoming increasingly important in order to identify common problems and solutions that can be useful in the real world, and not only in a theoretical setting (Holling, 1995). Some researchers suggest treating every restoration project as an experiment. Through this technique, and with the use of consistent testing and reporting measures, we can improve future management, and reduce redundancy in restoration ecology (Grayson et al., 1999; Gross & Hoffmann-Riem, 2005). The following case study examines the ecological integrity of an urban park as it relates to conservation and restoration planning in an urban setting.

## 2.4 Summary

The literature discussed in this chapter provided the necessary ecological and social background material to construct a rigorous study, to understand how the ecosystem at RIM Park is currently functioning, and to identify the best possible long-term outcome for the Park. The conceptual framework for this thesis is based on a transdisciplinary approach, as identified by Naveh (2005). As such, the literature review was structured around four main disciplines: restoration and conservation ecology, population and community biology, urban planning and environmental management. The conceptual framework identified the rationale and methodologies that were used. The theoretical framework identified ecological and social theories that are important to the understanding of the urban ecosystem. These were considered important because they contribute basic tested knowledge about how urban and natural ecosystems work and are best designed and managed. Using these conceptual and theoretical frameworks, methods were devised to evaluate the condition of the wetland and the management techniques at RIM Park, the case study used in this thesis.

# Chapter 3
# Case Study: RIM Park, Waterloo, Ontario

Case studies are useful tools for establishing a foundation of practical knowledge in urban ecology. Case studies, by nature, are unique and are located within a unique historical, political and social context. This context can have a large influence on a particular case. This chapter begins with a discussion of the regional and municipal context in which RIM Park lies. A park's political setting, including community values and goals, is greatly responsible for the shape and direction that it ultimately takes. Moreover, a discussion of the park's history and current status provides important information about realistic ecological expectations for the park. A full understanding of the historical conditions of the park is necessary to determine the likelihood of success of various projects, and identify potential barriers to success. With this background in place, the chapter discussed the wetland's current status describing the park's built and natural features including measures taken to protect amphibian populations. This serves as a basic starting point for the identification of possible problems and solutions. The chapter concludes with a discussion of the particular goals and implications of this case study including academic and applied contributions.

## 3.1 The Regional Municipality of Waterloo

The Region of Waterloo is located in the heart of Southern Ontario, and contains the municipalities of Waterloo, Kitchener, and Cambridge. The region has a population of over 450 000, and is growing rapidly (Region of Waterloo, 2006a).

The Region, in publicity, policy, and practice, values environmental protection. This area was the first to introduce ESPAs (Environmentally Sensitive Policy Areas) through the Regional Official Policies Plan in 1976 (Pim & Ornoy, 2005). These areas are identified as of particular natural and scientific interest, and can be selected based on factors such as quality, uniqueness and habitat provision for rare species (Regional Municipality of Waterloo, 1998). The Regional Growth Management Strategy (Region of Waterloo, 2003b) includes “big picture environmental planning” as the first key element of the strategy. The Region of Waterloo has also recently won a Sustainable Community award from the Federation of Canadian Municipalities and CH2M HILL (Region of Waterloo, 2006b).

Because of the rapid growth of the region, protecting natural areas through policy is critical. In addition, the area is particularly prone to a growing population, since the establishment of the Greenbelt Act. Kitchener and Waterloo have been identified as "places to grow" in the Province's proposed growth plan (Ministry of Public Infrastructure Renewal, 2005).

## 3.2 The City of Waterloo

The City of Waterloo, Ontario, with a population of 110 800 (City of Waterloo, 2006a), is located at approximately 43'28 N, 80'33 W, and lies 334 metres above sea level (University of Waterloo, 2006). The City prides itself in being recognized as a leader in greenspace management and environmental planning (Pim & Ornoy, 2005). The City has adopted an Environment First strategy, which puts environmental concerns at the forefront of decision-making processes. The City has also made efforts to include the community in decision making through the use of conferences such as "Imagine! Waterloo" in 2000 (Pim & Ornoy, 2005).

Waterloo makes use of an Environmental Strategic Plan, which highlights the main environmental goals of the city (City of Waterloo, 2002). In addition, other efforts such as the Environmental Lands Acquisition Program helps to protect lands, and manage the rapidly growing population (Pim & Ornoy, 2005). Another city-run project is Partners in Parks. This is a volunteer program to get community members involved in environmental improvement activities (City of Waterloo, 2006b).

The Environmental Strategic Plan for the City of Waterloo lists the creation and restoration of green spaces as the first and second priorities concerning green spaces (City of Waterloo, 2002). Within urban limits, greenspaces often take the form of urban parks. The City of Waterloo is home to a number of such parks. One newly established urban park located in Northeast Waterloo is RIM Park.

## 3.3 RIM Park

### 3.3.1 Location

RIM Park, known previously as Millennium Recreation Park, was constructed in 2000-2001. It is an urban park containing both recreational and protected areas, located on approximately 2 $km^2$ of land in Northeast Waterloo, Ontario (Natural Resource Solutions Inc., 2003c). See Figure 2 for a map of Waterloo, with RIM Park indicated.

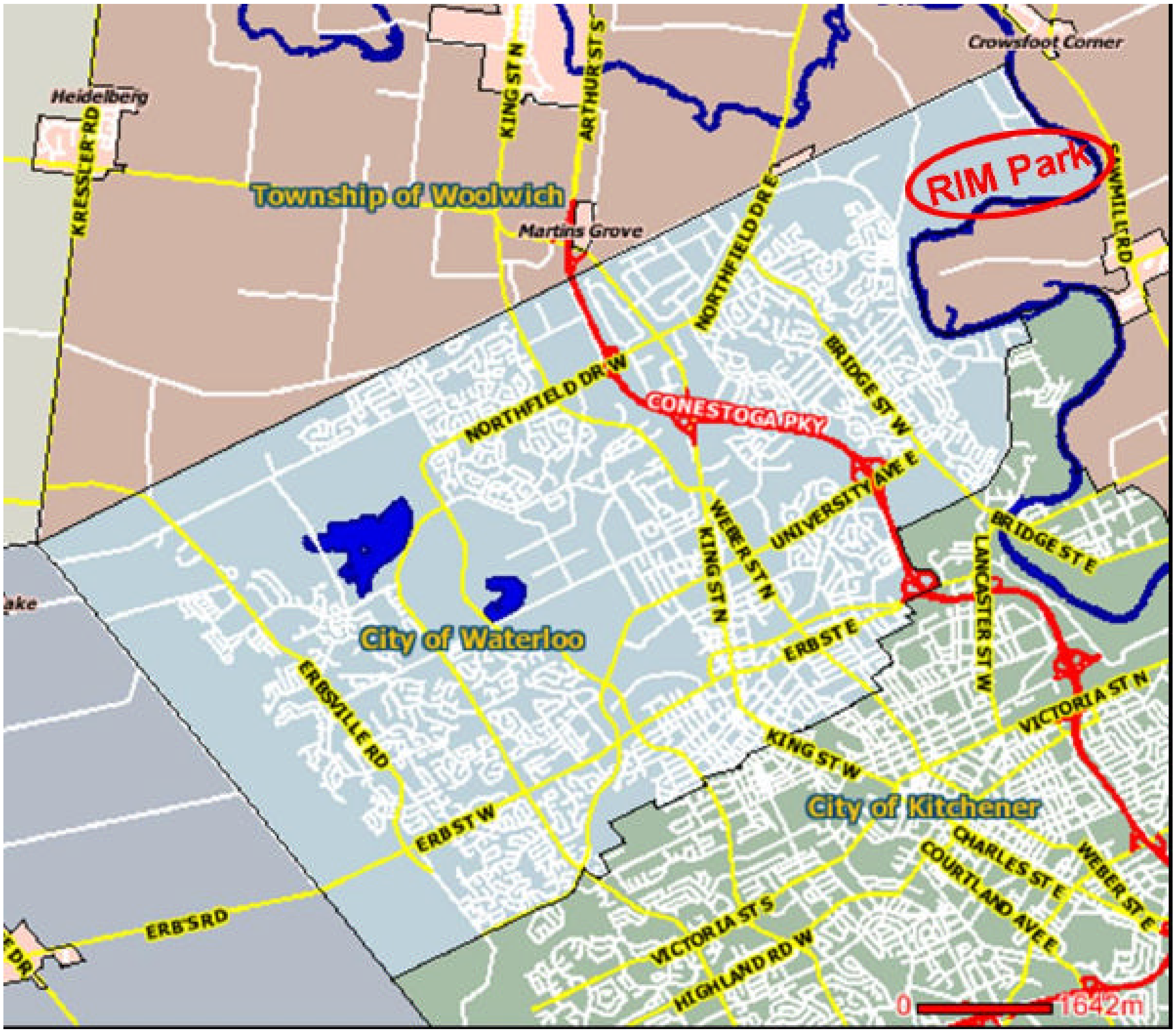


**Figure 2: Waterloo, Ontario with RIM Park's location circled in red. Adapted from the Region of Waterloo GIS Locator (Region of Waterloo, 2003a).**

### 3.3.2 History

Before the RIM Park land was purchased in 1999, it mostly consisted of agricultural land, modified greatly through human use, as well as some natural areas. The land has sustained crops, and been subject to cattle grazing, land clearing, drainage modification, and maple sugar production. A nearby homestead created a large amount of farm debris and ash from tire burning. A creek running through the park has been modified for agricultural purposes a number of times, which led to altered habitats and fragmentation. Barn waste and manure were also fed into the creek, causing a buildup of sediment and poor water quality (Natural Resource Solutions Inc., 2004c).

The history of the land in what is now known as RIM Park has caused changes in the landscape that pose a potential threat to its wildlife. This fact was recognized during the creation of the park, and is accounted for in current planning and monitoring schemes (Natural Resource Solutions Inc., 2004a).

Unfortunately, while the city was in the process of making financial arrangement to pay for the park, a large, very politically charged, financial scandal arose. The nature of an agreement between a financial group and the City of Waterloo was put into question, and the City became responsible for paying $33 000 000 more than was initially anticipated. The situation was analyzed through a full judicial inquiry, the "RIM Park Financing Inquiry," which took place in 2002 (RIM Park Financing - City of Waterloo Judicial Inquiry, 2003).

From a political point of view, it was now necessary to change the public image of RIM Park. At that point, RIM Park was a name that evoked images of millions of lost taxpayer money. Positive aspects of the park needed to be emphasized to improve community morale. Plans went forth, and the park has been designed to provide a wide variety of opportunities for the public.

### 3.3.3 RIM Park Planning and Current Conditions

When RIM Park was designed, City of Waterloo staff had a number of objectives, trying to meet the needs of the community as well as the environment so the park would be a "lasting legacy" for generations to come. In the building of the park, City of Waterloo staff tried to balance community land use and the sensitivity of the watershed (City of Waterloo, 2005b).

RIM Park includes elements that are beneficial or desirable to a wide variety of people. The land is now home to a large recreational facility, a golf course, sports fields, and significant environmental lands (Natural Resource Solutions Inc., 2004c). The park's walking trails and golf trails are paved for improved access for people using bicycles, roller blades, wheelchairs and golf carts. These trails wind around the provincially significant wetland (Natural Resource Solutions Inc., 2003c).

A survey was conducted in 2004 to evaluate community views about the park. Since its construction, RIM Park has been used by many people in the city. In their survey, the consulting group, P.M.G. Consulting, found that 80% of Waterloo residents surveyed have visited RIM Park at least once (P.M.G. Consulting / Weaver, 2004). They also found that of all the activities in the park, the trails were used by the highest number of people: 86%. Other facilities are not quite as popular, with 44% of people indicating someone in their household has used a skating rink in RIM Park at least once and only 34% of people surveyed had used the golf course. The number of community members surveyed was not included in the report. It seems clear that the community uses and values the nature trails.

When RIM Park was designed, there were two floodplains. One floodplain, the Horst floodplain, is now home to the majority of holes for the golf course, 2-17. The other floodplain, the Martin floodplain, is home to two of the holes, 1 and 18. See Figure 3 for an aerial photo of the two floodplains. These two holes lie between the provincially significant wetland and the Grand River.

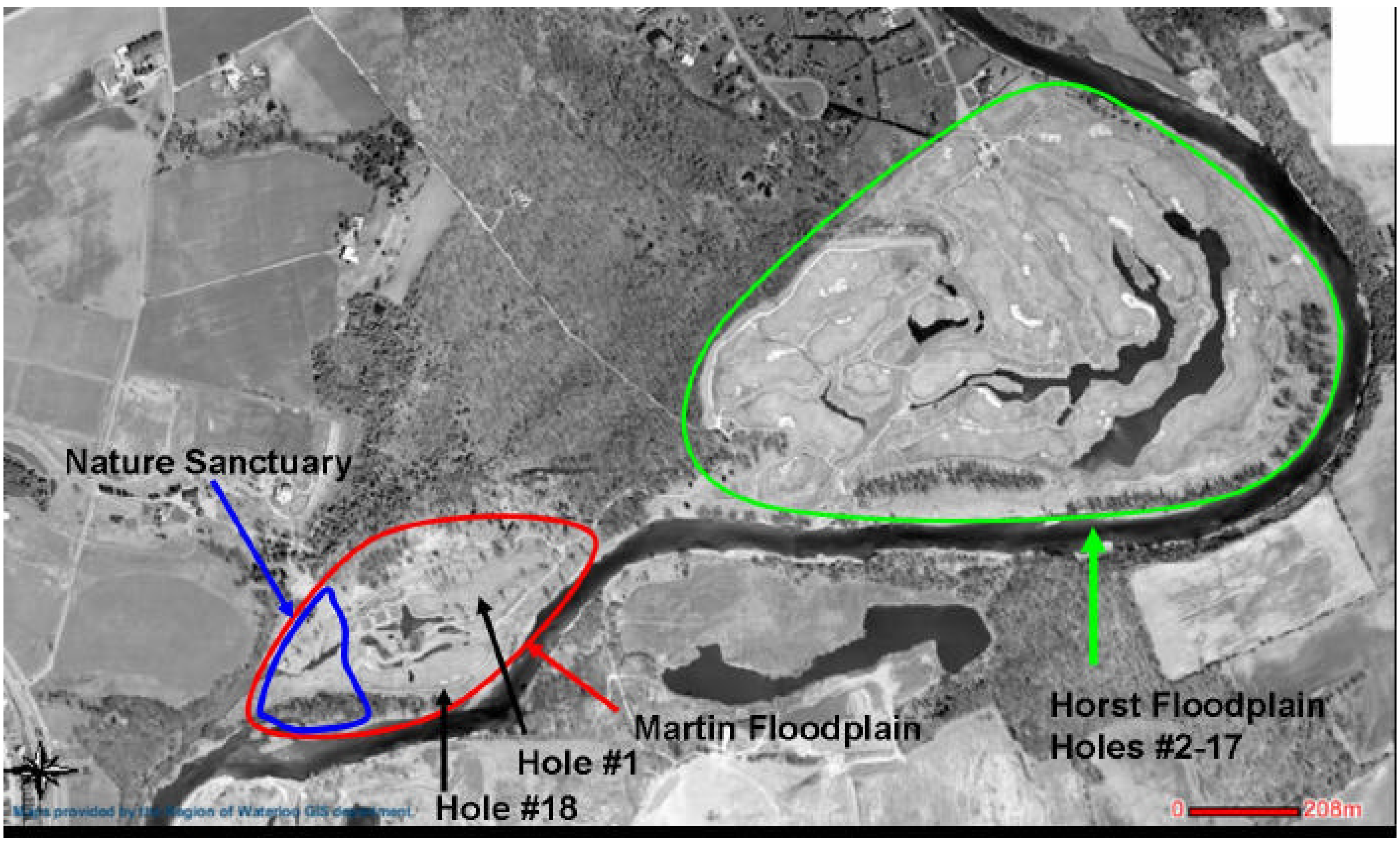


**Figure 3: Martin and Horst Floodplains, and associated components of the Grey Silo golf course. Adapted from the Region of Waterloo GIS Locator (Region of Waterloo, 2003a).**

Due to the fact that the Park contains significant environmental lands, an Environmental Implementation Team was appointed, an Environmental Impact study was conducted, and an

Environmental Management Plan (Natural Resource Solutions Inc., 2003c) was implemented. These were intended to help protect sensitive features during the planning, construction and maintenance of RIM Park (Natural Resource Solutions Inc., 2004c). Documents were provided by the consulting group: Natural Resource Solutions Inc.

The RIM Park Environmental Management Plan (Natural Resource Solutions Inc., 2003c) provides the history and detailed descriptions of each site within the park, as well as site-specific recommendations for each natural area. In addition, general park-wide activities are described. Site-specific recommendations include plant and wildlife inventories. Because this area contains a Provincially Significant Wetland, certain areas are identified as particularly important for herpetofauna (amphibians and reptiles).

Before the establishment of this park, inventories of herpetofauna populations and habitat were conducted (Dance Environmental Inc., 1999). Dance Environmental Inc. indicated that the Grand River and associated water areas are important for the life cycle of a number of amphibian species. Frogs and toads have been observed migrating from upland and wetland areas to lower pools in the Martin floodplain in spring to breed in RIM Park. The consultants recommended the maintenance of wildlife habitat linkages, and suggested that new trails or roads should be avoided (Dance Environmental Inc., 2001). Since then, further inventories have been conducted by Natural Resource Solutions Inc.

Because of the predicted conflict between migration patterns of amphibians in the park and the positioning of the paved pathways across the Martin floodplain, some changes were incorporated into the plan for the golf course and nature trails. Within the park, some areas were identified as of particular concern for frog populations. These areas lie at the interface between the provincially significant wetland and the nature sanctuary. An asphalt pathway runs directly through this interface, and is used heavily by pedestrians, cyclists, and service vehicles (Natural Resource Solutions Inc., 2004b). A system of culverts (See Figure 4) (the first set has four corrugated steel culverts, the second set has six), clearspan bridges (See Figure 5) and at-grade trail sections were incorporated into the trail system at strategic locations to reduce fragmentation effects and promote safer migration. In addition, pond areas were constructed to accept runoff from the golf course, as well as to provide breeding habitats for amphibians (See Figure 6).

**Figure 4: RIM Park: April 5, 2005. Culverts built for he rpetofauna and water movement (Photo taken by author).**

**Figure 5: RIM Park: April 5, 2005. Herpetofauna pond and clearspan (Photo taken by author).**

**Figure 6: RIM Park: June 8, 2005. Built herpetofauna breeding pond (Photo taken by author).**

In Figure 7, a closer view of the Martin Floodplain, green circles represent culverts that pass under the shared trail of the Western Throat. Brown rectangles represent clearspans that permit water and amphibians to pass below the trail. The dotted line indicates where the trail has been designed at-grade to permit easier crossing. The Eastern Throat was another area of concern, and contains two clearspans to allow water and animal movement under the path. Only one of the clearspans in the Eastern Throat is shown in Figure 7. The other lies just to the right of the picture, along the same path as the first.

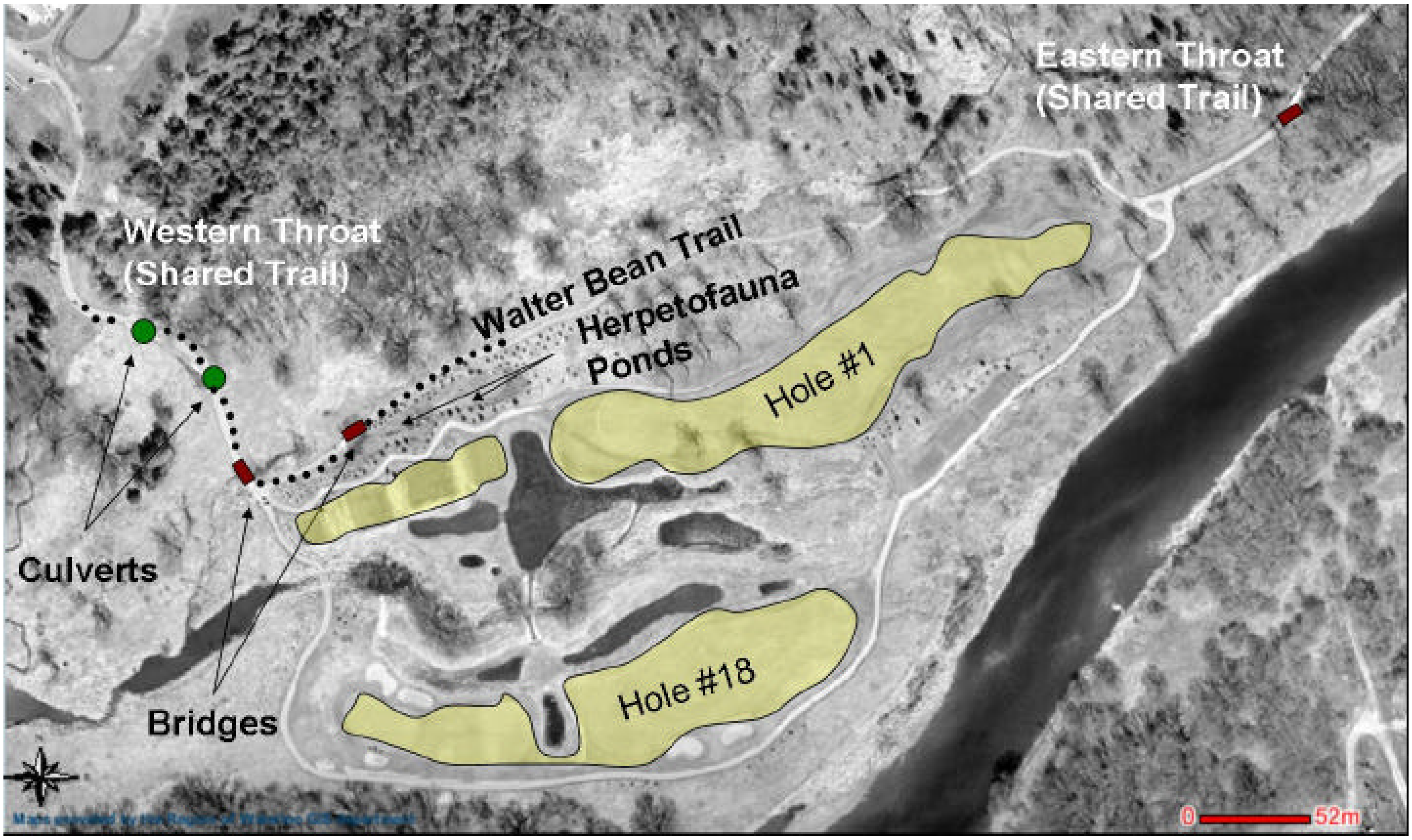


**Figure 7: Martin Floodplain. Adapted from Region of Waterloo GIS Locator (Region of Waterloo, 2003). Green circles represent sets of culverts. Brown rectangles represent clearspans. The dotted line indicates at-grade path segments.**

Because frogs and toads appear to still be using the roads to cross this interface, managers were – and are concerned about the effects of pedestrian and golfer traffic on the amphibian populations. Currently, Natural Resource Solutions Inc. is recommending the addition of barriers to enforce the use of the culverts (Natural Resource Solutions Inc., 2004b). Herpetofauna monitoring is ongoing, and includes evening call surveys, some herpetofauna searches in 2001 and 2002 and occasional observations during other studies (Natural Resource Solutions Inc., 2004a).

### 3.3.4 Research Approach to Case Study

RIM Park possesses many features that make it an ideal study site for the examination of trail design and amphibian migration management. RIM Park is within the City of Waterloo, it has a history of ecological disruption, and it possesses many unique features, such as the inclusion of culverts under newly asphalted pathways that run through wetlands. (Natural Resource Solutions Inc., 2004b). If Leopard Frogs are able to persist as a sustainable population at this location, it may be an indication that the culverts are effective in providing migration routes and healthy habitats for the frogs, even under strained conditions (such as the park's history of agriculture).

While the literature from RIM Park is broad in nature, and provides inventories of animal presence, it contains very few in-depth details about frog population dynamics. An audio survey can quickly determine the presence of frogs in an area, but it is not particularly useful when attempting to make a good estimate of population size. An audio survey can be used in combination with other methods to develop a clearer picture of the population. A detailed quantitative analysis of the frog populations in RIM Park has not been performed. Without knowledge of the state of its wildlife populations, it is difficult to determine whether the park is supporting a healthy ecosystem.

Amphibian monitoring surveys in RIM Park over the past few years will provide some baseline data for comparisons with current conditions. Although there have been limited surveys, there are some estimates of frog presence and density in the park. Geographical, structural and ecological changes over the course of the Park's development have been well documented, mostly by Natural Resource Solutions Inc. A series of management plans and amphibian monitoring reports include valuable maps and data on what has been seen in the park, and how the park has been designed to accommodate resident wildlife (Dance Environmental Inc., 1996, 1999, 2001; Natural Resource Solutions Inc., 2002a, b, 2003a, b, c, 2004a, b). These will be used to compare with current conditions. In addition, interviews with park managers and city officials will help develop a clear picture of the historical and current conditions in the park, as well as the future management direction.

Northern Leopard Frogs (See Figure 8) are the species of interest for this study. These frogs are particularly good indicators, and City documents have identified them as common in RIM Park. With the use of a variety of ecological methods, a thorough examination of the population of Northern Leopard Frogs at RIM Park will help to identify if this important indicator species has a minimum viable population that can sustain itself in the long run.

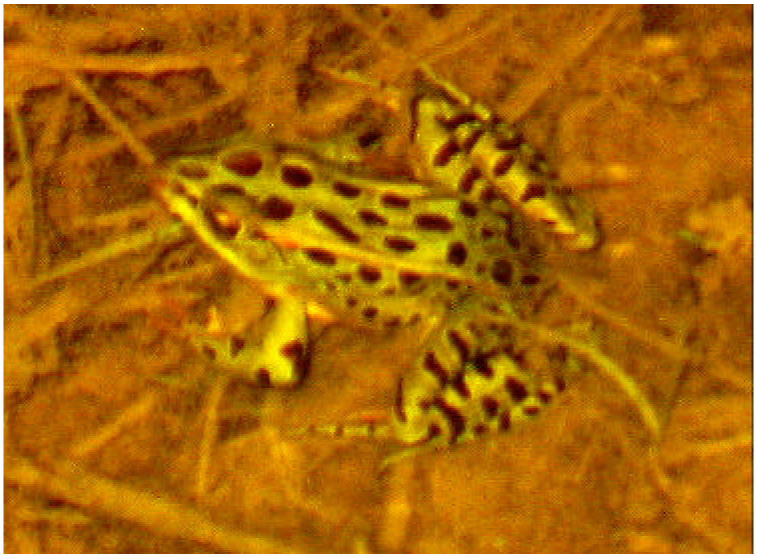

**Figure 8: Northern Leopard Frog in RIM Park (photo taken by author).**

This study will combine quantitative scientific methods, and qualitative, analytical methods. This combination of methods will help me determine whether or not the future direction of park management will be sufficient to maintain amphibian populations over the long term.

## 3.4 Implications of Research and Target Audiences

In-depth studies of this sort are required to make accurate assessments of ecological impacts. However, such research should be combined with other indicators and assessments to create a complete picture of the integrity and sustainability of the park's ecosystems. That being said, this project contributes both applied and theoretical aspects.

Park planners and managers should be able to use the information gathered in this project to determine the effectiveness of culverts in reducing amphibian population loss, as well as identify other factors that may be influencing amphibian success. Specifically, the project could reveal knowledge that promotes the overall understanding and maintenance of ecological integrity in RIM Park's ecosystem. In addition, this information could be valuable in promoting informed decision making in any urban parks which are home to amphibians.

In addition to the direct application, this information will be useful to the academic community because it offers a unique perspective by combining population viability, ecosystem integrity and park design and management. This study could contribute to literature in fields such as population ecology, urban planning and wildlife management. These fields are not often combined in literature. Specifically, this research will contribute to the understanding of how amphibian populations are influenced by park design and management. There is little literature that addresses this topic specifically.

### 3.5 Summary

As noted earlier, the Region and City of Waterloo are highly regarded for their environmental initiatives and leadership. One of these leadership projects was initiated at RIM Park through the inclusion of amphibian habitats and passageways. RIM Park's historical, political, ecological and social contexts provide an excellent opportunity for studying amphibian populations in an urban setting. This case study provides a thorough examination of these populations, and also offers a new perspective to the academic literature. An understanding of the details of this case study aided the development of methods for further analyses and field research.

# Chapter 4
# Methods

In order to follow a transdisciplinary approach as suggested by Naveh (2005), two basic types of research, which cover both social and natural science approaches, were conducted during the course of this study. A detailed study of the consulting reports, historical records and management plans of RIM Park was conducted, as well as an interview with the Environmental Coordinator for the City of Waterloo. This process allowed me to understand the political and social aspects of the park management. To examine the natural science aspects of RIM Park, two seasons of field work, which mainly involved mark and recapture studies, and included comparisons with control sites, were undertaken in 2005 and 2006. During this time, I developed a better understanding of the ecological conditions and the status of frog populations in the park. Methods used in the field deviated from intended methods due to unforeseen circumstances.

## 4.1 Report Analysis and Interview

Background information and data collected by consulting companies was gathered. Amphibian and Reptile monitoring reports, as well as initial surveys and the Environmental Management Plan were all examined and analyzed before any field work started in 2005. This was accompanied by an extensive literature review. Results from the monitoring reports were summarized into tables to compare results and observations from all available years. Particular attention was paid to weather conditions and amphibian abundance. An interview was conducted with Karen Moyer, Environmental Coordinator for the City of Waterloo on February 23, 2006.

## 4.2 Field Season 1: (Spring 2005)

### 4.2.1 Site Selection

Three sites were examined in the 2005 field season (see Figure 7 in Chapter 3). The three sites were the Western Throat shared trail, the Eastern Throat shared trail, and an unshared segment of the Walter Bean Trail at the built herpetofauna breeding ponds. All three areas were identified as heavily used by migrating frogs (Dance Environmental Inc., 2001). A shared trail is used both by pedestrians using it as a nature trail, and by service vehicles and carts for the golf course. An unshared trail is used only by pedestrians. Shared trail areas are a potential problem because maintenance vehicles are large and move swiftly and therefore pose a potential threat to amphibians. The unshared trail near the herpetofauna ponds is in an area not identified as problematic for frog populations as the trail is only used by pedestrians. All three sites contain frog passages in the form of culverts, bridges or at-grade segments (Natural Resource Solutions Inc., 2004b).

### 4.2.2 Species Description

Northern Leopard Frogs are found in all provinces in Canada, but are particularly abundant in Southern and Central Ontario (Hebert, 2002). These frogs can be found in many habitats, including lakes, rivers, ponds and marshes, where they feed mainly on insects and worms. They are considered particularly good indicator species (Blaustein & Wake, 1995; Carr & Fahrig, 2001).

In some areas of Canada, the Northern Leopard Frog is listed under *special concern*. It is protected under the Species at Risk Act and some populations are even listed as endangered (Environment Canada, 2004). Northern Leopard Frogs have a very specific set of conditions they require to survive. Area, water depth, the proportion of emergent vegetation, altitude, date of drying, spatial position, water flux, and shore and bottom characteristics are all predictive of wetland suitability for frog success (Bosch & Martinez-Solano, 2003).

Northern Leopard Frogs need different areas for overwintering, breeding and summer (Pope et al., 2000; Porej et al., 2004). During the winter, Leopard Frogs hibernate beneath the mud and water (Froom, 1982). In the spring, they are among the first frogs to emerge from hibernation and travel to their breeding sites (Dickerson, 1969). This occurs when the water temperature reaches 7 to 10 degrees Celsius (Environment Canada, 2004). Spawning begins in April or May, depending on the weather. An early spring thaw will encourage early spawning. Females lay egg masses in the water, and tadpoles appear approximately two weeks after this. After nine to twelve weeks, tadpoles transform into frogs (Froom, 1982). If a pond dries up too early, tadpoles die. Breeding ponds are typically from 30 to 60 m in diameter, and 1.5 to 2 m deep (Environment Canada, 2004). Leopard Frogs prefer areas away from forests (Guerry & Hunter, 2002) and also prefer approximately equal ratios of emergent vegetation to open water (Balcombe et al., 2005). Wetlands should also be sunny, lacking in fish, and near occupied wetlands (Ficetola & DeBernardi, 2004). In general, the home range of the Leopard frog is approximately $500m^2$ (Hebert, 2002).

Leopard frog tadpoles regulate their population density through the use of corticoids. When the density of the population is too high, or the food supply is low, Leopard Frog tadpoles release these stress hormones which increase intraspecific competition, and thus result in a lower population, which is easier to support (Glennemeier & Denver, 2002). Leopard Frogs maximize prey diversity by using a variety of feeding strategies (for example, feeding on both nocturnal and diurnal insects) (Collier et al., 1998).

Studies on Leopard Frogs and competition with other species vary in their results. Some studies indicate that Leopard Frogs will generally fare poorly when competing directly with wood frogs, but will do better once predators are introduced (Relyea, 2000, 2002). Another study (Werner, 1992) demonstrated the competitive superiority of the Leopard Frog.

Adult Leopard Frogs are generally between eight and ten centimetres in length. They reach sexual maturity after two to three years, and have a lifespan of six to nine years (Hebert, 2002). These frogs are often used as bait for fishing as well as in research laboratories (Froom, 1982).

### 4.2.3 Sampling

Initially, Leopard Frog population sizes were going to be assessed using two separate methods, audio strip transect sampling and mark and recapture. These two methods used in two consecutive field seasons, along with data collected in previous assessments were intended to provide a good estimate of Leopard Frog population size in RIM Park at the affected locations. These two methods are very commonly used population measurements and have been standardized for research. For an example, see Nelson and Graves (2004). The text that details the standardized methods was written by Heyer et al. (1994). As noted in the sections below, these methods were altered to accommodate unexpected conditions.

Other information, such as climate (as taken from the nearby University of Waterloo weather station: (University of Waterloo, 2006)) and habitat conditions were recorded in order to determine whether other factors may be interfering with population measurements. During the course of the study, additional observations, such as habitat condition, and the presence of related species, were also informally recorded.

### 4.2.4 Audio Sampling

Audio transect sampling is a commonly used tool in the assessment of frog populations. It is simple to perform, and does not involve any direct observer interference with the populations. It must be assumed that all males are calling in the area of interest, and females and juveniles will not be counted. In addition, the call of these males should be simple to identify and distinguish with limited training, and are only counted once (Heyer et al., 1994). It must also be assumed that standard male: female ratios exist in the site. Environmental hormones found in pesticides and other synthetic chemicals, however, have been known to alter sex ratios in certain species (Cheek & McLachlan, 1998). These assumptions should not affect relative findings between sites.

Prior to entering the field, I learned to identify Leopard Frogs by sound. I conducted the research in the field with the assistance of one other person late in the evening when frogs begin to call; at approximately 8:00 p.m. Care was taken to minimize the impact of the research team on the species. This means that when the site was reached, lights were turned off, and researchers remained silent for at least one minute before making any observations. This allowed frogs to be acclimated to human presence (Stevens et al., 2002). The number of individuals calling, their approximate position and time of call were to be recorded manually.

The three chosen sites are small and independent enough that only one transect per site needed to be assessed. Heyer et al. (1994) state that 6 to 9 surveys per breeding season should be sufficient. If a sufficient number of frogs had been found or heard, a formal call survey would have been conducted at each of these transects every three nights for three weeks. Depending on the number of frogs detected during the pre-testing, either the number of individual frogs, or a category of frog numbers would have been recorded. Hazell et al. used a logarithmic scale to estimate frog population sizes (Hazell et al., 2004).

The maximum count of individuals is typically divided by the audio strip area to attain mean density (Heyer et al., 1994). Using this method, population density may be estimated, and compared to previous data recorded by Natural Resource Solutions Inc. (2004a), as well as to data collected by mark and recapture methods. This audio method is often used in the field (Nelson & Graves, 2004). However, a sample field day allowed me to compare my estimates with those provided by Natural Resource Solutions Inc. (2004a). If sufficient frogs had been heard, data could have been collected and spreadsheets, tables and graphs compiled for analysis and comparisons to other data. ANOVAs or t-tests would have been used to compare the population density estimates for the three areas.

Unfortunately, as will be noted in the results, in 2005, no Leopard Frogs were heard distinctly at RIM Park. This halted this portion of the methodology at the time of the initial survey work.

### 4.2.5 Mark and Recapture Sampling

Mark and recapture sampling techniques are known to provide good estimates of population size, particularly for mobile vertebrates (Brower et al., 1998). A method known as the Lincoln-

Peterson estimate illustrates how a sample that is marked one day, will be re-sampled on a subsequent day and reveal marked individuals at some level of dilution. Using this and related formulas, it is possible to calculate the level of dilution, and thus estimate the population size (Brower et al., 1998).

Although mark and recapture studies are well known to be good estimators of population size, they are also accompanied by a number of assumptions. One main assumption is that the sample is representative of the whole population. It is also assumed that the frogs remain within one pond during the breeding season. If they are moving around a great deal, it will be impossible to get an accurate picture of the population size. Another main assumption is that the marking technique, toe clipping, will not affect the breeding success or lifespan of the frog, or the potential for that frog to be re-captured. Finally, it is assumed that the frogs will be redistributed randomly before the next sampling session (Heyer et al., 1994). These assumptions should not affect the end result, but must be addressed.

The mark and recapture studies were to be conducted at the same three sites of interest. On either side of the path at each site, frogs were to be netted, uniquely marked using a toe-clipping technique, and released. In one night, repeated attempts at each site would be made to capture as many frogs as possible. Following initial surveys to identify frog presence, these capture events were planned to occur every three nights for three weeks. If frogs were re-captured on subsequent nights, their numbers would have been recorded, and they would have been released without further marking.

Toe clipping protocols followed the methods of Heyer et al. (1994) and the toe-clipping scheme of Martof (Heyer et al., 1994). Frogs were to be netted, and the tips of specific toes, in a unique combination, would be clipped with sharp sterilized clippers. Finally, an antiseptic would be applied to the wound. The frogs would have been measured from head to tail and then released, with data recorded.

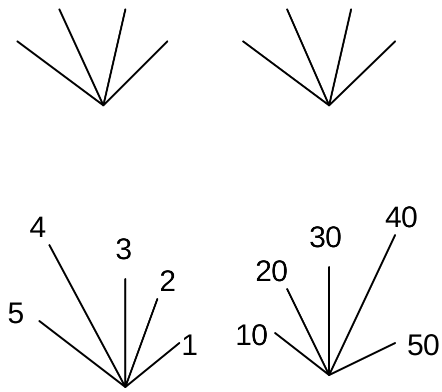


**Figure 9: Martof Scheme (Heyer et al., 1994). Each of the lines represents a frog toe. Using only the back feet, a sufficient number of frogs could be uniquely identified. For example, to identify frog "73" toes #50, #20 and #3 would be clipped.**

These mark and recapture techniques are well documented and frequently used to sample frog populations around the world. Standard methods for monitoring amphibian populations were established by Heyer et al. (1994).

Data were to be collected manually in the field and transferred to a spreadsheet. Calculations of population estimates using adaptations of the Lincoln-Peterson method would have been performed. T-tests and ANOVAs may have then been used to compare population densities in the three different sites.

This field study was intended to cover two field seasons. Each field season would consist of approximately three weeks during April or May (depending on the weather and breeding behaviour observed). During this time, field trips were to be taken at around 8:00 in the evening every three days.

Material requirements were minimal consisting only of flashlights, nets, latex gloves, clippers, ethanol, antibacterial cream and notebooks. After data was collected by both the audio transect and mark and recapture methods, it would have been examined for consistency and compared with data collected by Natural Resource Solutions Inc. It was expected that the three sources (audio, mark and recapture, and written material) would reveal converging evidence.

Unfortunately, over the course of April and May, 2005, and numerous visits to RIM Park, only an occasional Northern Leopard Frog was found (Over the course of 10 visits to RIM Park, only 5 Northern Leopard Frogs were found total, and none clearly heard). No formal call surveys or mark and recapture studies were performed in 2005. An Environmentally Sensitive Policy Area (ESPA), Forested Hills, in Northwest Waterloo was also examined on a routine basis by the supervisor of this thesis, Stephen Murphy. Similar results were observed.

The findings resulted in a reassessment of the City of Waterloo's assumption that Northern Leopard Frogs are resident at RIM Park in vast quantities and led to the following changes for the methods in Field Season #2.

## 4.3 Field Season 2: (Spring 2006)

After discovering only a handful of Northern Leopard Frogs at RIM Park in the first year of field study, a change to methods was implemented. Two of the same sites at RIM Park were examined, and the ESPA was also surveyed in detail. In addition, a storm water management pond in Northwest Waterloo was added to the observations. This storm water pond was identified through casual observations as home to a large number of Leopard Frogs late in the 2005 field season.
The Eastern Throat site at Rim Park was eliminated after initial observations, and the assessment that the area is unsuitable for Leopard Frogs, as it is quite heavily forested. Therefore, four sites (two at RIM, plus the two additional sites, the storm water management pond, and the ESPA) were examined regularly starting at the beginning of April. See Figure 10 for the locations of these sites in Waterloo. Any significant evidence of frogs and toads at these sites was recorded. This included visual and audio observations. Leopard Frogs remained silent for nearly all sessions, so audio observations were not analyzed.

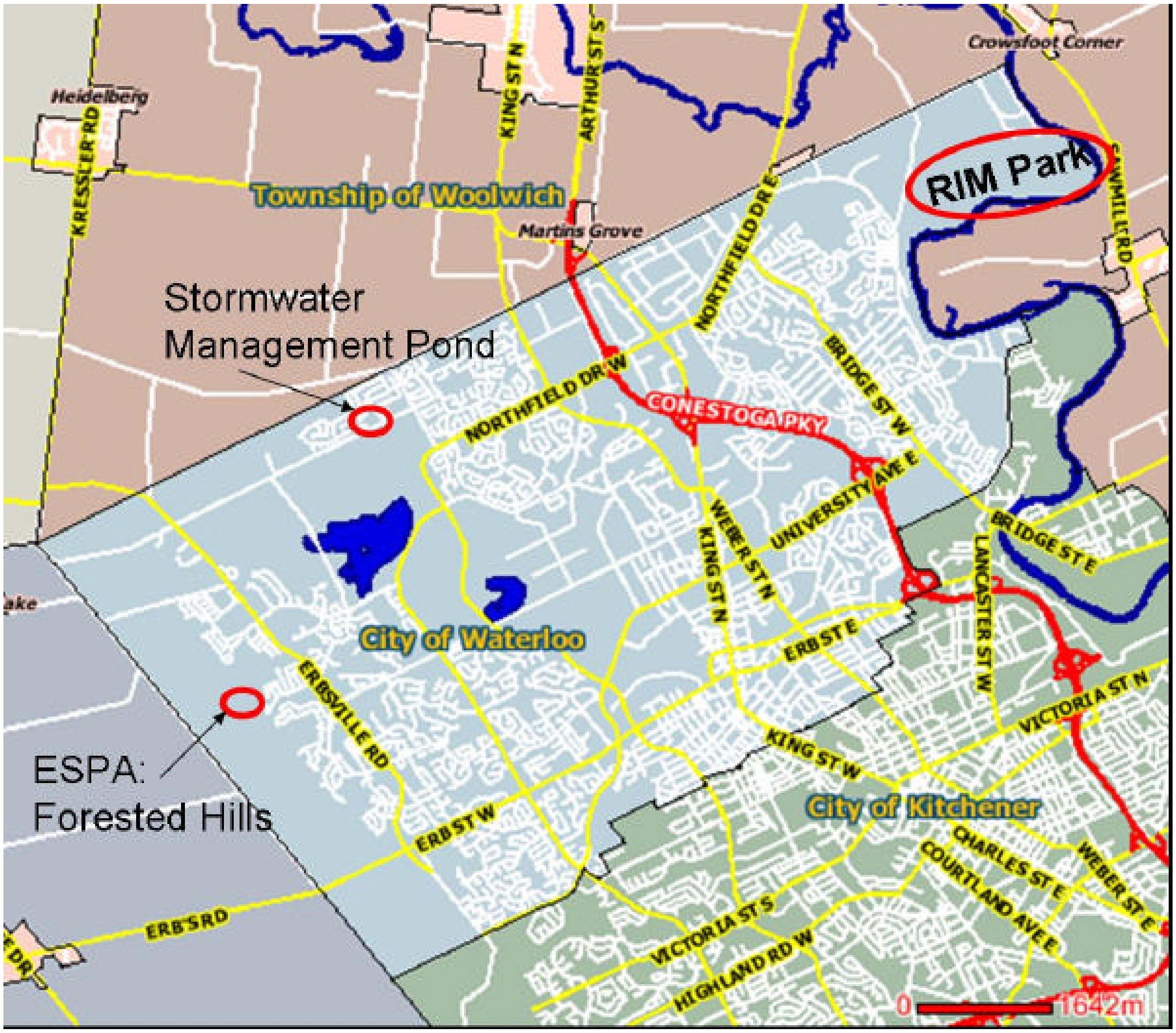


**Figure 10: The City of Waterloo with RIM Park, the Stormwater Management Pond and the Environmentally Sensitive Policy Area: Forested Hills indicated. Adapted from the Region of Waterloo GIS Locator (Region of Waterloo, 2003a).**

Once a visible and apparently countable number of Leopard Frogs were identified at any site for a sustained period of time, mark and recapture studies commenced, following the methods planned for field season #1 with a few changes. Mark and recapture sessions at each site were performed a minimum of three times in close succession. Each site experienced an abundance of Leopard Frogs at different times, and therefore, the mark and recapture sessions were conducted on separate days. Mark and Recapture data were recorded for three of the sites. No frogs were found at the Western Throat at RIM Park.

Petersen Estimates with Chapman's Modification (for small sample sizes) were conducted on the results of the first two nights of each site to estimate population size. ANOVARs (repeated measures analyses of variance) were employed to determine significant differences between the numbers of frogs at these sites.

## 4.4 Boundaries of the study

Geographically, this study focuses on the Walter Bean Trail in RIM Park, in Northeast Waterloo, Southern Ontario. The project is limited to specific segments of interest along the path, particularly those with culverts and bridges. The study is also limited to two field seasons. Frogs are easiest to assess during the mating season, so these two field seasons are each limited to a span of 3-4 weeks in April and May. In addition to these limitations, the study will only focus on one species, the Northern Leopard Frog.

These three factors, geography, time and unit of study limits the generalizability of the study. Other species at other times of the year and under different conditions may behave quite differently. A span of two years may not be enough to account for random population fluctuations.

The methodology also contains limitations. Audio and visual sampling rely on a certain amount of estimation and subjectivity, and are thus susceptible to human error. Other variable factors, such as amounts of emergent vegetation, may affect frog catchability. Observers going into the field were aware of the hypotheses, and may have been, as a result, biased. Because of these factors, it was important for the researcher to remain as unbiased in measurements as possible. Observations were made relative to control sites, so while absolute numbers may lack accuracy, comparisons between sites may reveal interesting information. Despite the limitations, the field work revealed interesting trends, especially when linked with observations about weather and historical data.

## 4.5 Summary

This chapter delineated natural and social science methods that were originally planned and those that were actually used. During the field work process, changes in methodology to adapt to the conditions are often necessary. Particularly because of this problem, it is important to carefully document particular methods used, and changes to methods, in order to establish the study as a valuable tool for future use. Results revealed by these methods are outlined in the next chapter.

# Chapter 5
# Results

Chapter 5 lists the results from the data analysis and the two field seasons. Consulting reports and weather conditions were summarized into tables to enable comparisons. Observations from the field on weather conditions, habitat quality and incidental frog sightings were compiled for each site. Results from the audio surveys and mark and recapture studies were recorded. As the two field seasons varied in methodologies, they are listed separately. Calculations revealed a number of significant differences in frog populations.

## 5.1 Historical Data

### 5.1.1 Report Summary

Consultants have conducted yearly amphibian and reptile monitoring since the early stages of planning RIM Park. Dance Environmental Inc. did the consulting work until 2000, and Natural Resource Solutions Inc. has continued this work since 2001. Amphibian monitoring was performed without an established method for the first few recorded years, and then more consistently after 2002. Results of this monitoring were recorded in annual Amphibian and Reptile monitoring reports. For the most part, observations were made through audio monitoring, but some incidental visual observations were recorded. In Table 1, a summary of the maximum number of Northern Leopard Frogs heard or seen at the park on any given night during the survey is recorded. In addition, the table provides each report's explanation of the conditions that may have led to low amphibian numbers.

**Table 1: RIM Park Amphibian Monitoring Report Results for Northern Leopard Frogs at three sites, and explanations provided for frog numbers**

| Year | Report | Max. # Leopard Frogs Seen or Heard | | | Site Condition |
|---|---|---|---|---|---|
| | | Western Throat & Breeding Pond | Sedge Meadow[1] | Eastern Throat | |
| 1996 | (Dance Environmental Inc., 1996) | * | * | * | Spring was late and cool, thus little breeding occurred before the end of April. Water levels were higher than usual. |
| 1999 | (Dance Environmental Inc., 1999) | + | * | * | Spring was dry and had above average temperatures. Habitats contained little water. Breeding was hastened and sparse. |
| 2000 | (Dance Environmental Inc., 2001) | 3 | 10 | 3 | Spring was wetter and cooler than usual. There were frequent floods. |
| 2001 | (Natural Resource Solutions Inc., 2002a) | 5 | >50 | 0 | Water levels started high, but dried up early, including the herptile pool. High water temperatures could have caused tadpole mortality. |
| 2002 | (Natural Resource Solutions Inc., 2002b) | + | + | + | One week of abnormally high temperatures in April may have confused amphibians into mating earlier. A cold spell in May could have confused frogs into reduced breeding activity. Stations (including the herptile pool) dried up and provided little habitat. High water temperatures could have caused tadpole mortality. |
| 2003 | (Natural Resource Solutions Inc., 2003a) | 1 | 1 | 0 | Stations dried up early and provided little habitat. Water levels fluctuated and may have had an impact on abundance. |
| 2004 | (Natural Resource Solutions Inc., 2004a) | 0 | 3 | 0 | Dry conditions reduced available breeding habitat.<br>Alkaline pH readings were observed and may have affected frogs. |
| 2005 | (Natural Resource Solutions Inc., 2005) | 0 | 0 | 0 | The spring was very dry with little rain. Breeding ponds dried up completely. |

1 = The sedge meadow lies along the Walter Bean Trail between the breeding ponds and the Eastern Throat.
* = missing data
+ = listed as "present" or "routinely observed"

The 1996 report provided by Dance Environmental states that: "Pools on the Grand River flood plain south of the proposed extraction site provide habitat for Northern Leopard Frogs" (Dance Environmental Inc., 1996). Reports from both 1996 and 1999 consisted of inconsistent and superficial reporting of incidental observations of amphibians. Later reports use these early ones as a baseline for making evaluations of current conditions. Reports consistently cite weather and in particular, dry conditions, as the main cause for low amphibian numbers as compared to the reference conditions recorded in the first two reports.

### 5.1.2 Weather

Weather conditions can have a significant impact on amphibian survival and behaviour. Historical weather conditions listed in Table 2 are summarized from data recorded at the weather station at Waterloo-Wellington Airport (The Weather Network, 2006), as well as the weather station at the University of Waterloo (University of Waterloo, 2006).

**Table 2: April and May Total Accumulated Precipitation, and average daily low and high temperatures in Waterloo (The Weather Network, 2006; University of Waterloo, 2006)**

| **Year** | **April & May Total Accumulated Precipitation (mm)** | **Average Daily Low Temp for April & May (°C)** | **Average Daily High Temp for April & May (°C)** |
|---|---|---|---|
| 2006 | 163 | Not Yet Available | Not Yet Available |
| 2005 | 85.5 | 2.51 | 14.57 |
| 2004 | 167 | 4.22 | 14.43 |
| 2003 | 163 | 2.68 | 13.50 |
| 2002 | 185.6 | 2.87 | 12.91 |
| 2001 | 130.3 | 4.80 | 15.74 |
| Average (last 30 years) | 149 | 3.00 | 15.00 |

It is clear that, in 2005, there was substantially less rain than in other years and relative to the 30-year average. Other than that year, the accumulated spring precipitation between 2001 and 2006 appears to be relatively stable or even high compared to the average over the last 30 years. Average daily low and high temperatures for April and May over these years appear to be relatively consistent with the 30-year average. April and May, 2005, had a slightly colder average daily low temperature than other years.

## 5.2 Observations 2005

### 5.2.1 Weather

The spring of 2005 was generally a bad breeding season for frogs all over Waterloo Region. Frogs require a particular set of conditions to breed successfully. April and May of 2005 had about one-half the precipitation of other years. It was an exceptionally dry spring, and even cold late into the season. This could have inhibited frog breeding patterns. There must be a combination of appropriate weather and habitat for "normal" breeding to occur. Frogs started to emerge early in the spring at RIM Park when the water levels were high from melted snow. However, as soon as the numbers of frogs and toads in the park started to increase, the weather and all the available amphibian habitats dried completely. Once this happened, there were no frogs found in any of the three areas at RIM Park.

### 5.2.2 Habitat

Three sites of interest at RIM Park were identified as important breeding areas for a number of amphibian species, including American Toads, Green Frogs and Northern Leopard Frogs. These sites were examined in this study in terms of their suitability as frog breeding habitats. Please see Figure 7 for a picture of these sites. (Please note: these are slightly different than those summarized in the reports above in Table 1. The three used in this study were identified by their proximity to water.)

At site 1, at the Western Throat, there are two sets of culverts and some at-grade sections of trail. The first set of culverts is located high and did not ever contain water in 2005. The second set was deeper and while at the beginning of the spring it contained water, it quickly dried out. The path was at first surrounded on either side by marsh, but the water evaporated.

At site 2, there is a clearspan bridge, and some built herpetofauna ponds. Toads were often observed at this site early on, crossing the path. Some green frogs were also observed. However, the ponds quickly dried up, and ultimately did not provide adequate habitat for any amphibians.

At site 3, at the Eastern Throat, there are two clearspan bridges separated by a length of path. These bridges allow water to flow from the wetland to the Grand River. The area contained some water the whole time, but towards the end became very shallow and muddy. I never observed any amphibians at this site. It was subsequently dropped from the study in 2006.

Although reports indicate that the public is clearly informed of frog habitat, a sign indicating a “frog crossing” has been torn down, presumably by vandals. There is an undamaged herptile interpretational sign further along the path.

### 5.2.3 Observations

Observations started on April 10th, 2005. At this time, Spring Peepers (*Pseudacris crucifer* Wied-Neuwied. [Hylidae]) were calling loudly at Site 1. One Northern Leopard Frog (*Rana pipiens* Schreb. [Ranidae]) was identified on April 17th, and some Wood Frogs (*Rana sylvatica* LeConte. [Ranidae]) and American Toads were heard along with the Spring Peepers at this time.

Following these observations, the temperature dropped and no herpetofauna were seen, and few heard. On May 7th, four American Toads were identified on the road. American Toad and Spring Peeper calls were abundant. May 10th brought about many Green Frogs and American Toads on the road. Toads were calling loudly. On May 17th, one Northern Leopard Frog was heard, and very few Spring Peepers. On May 22nd, three Northern Leopard Frogs were found. Lots of green frogs (*Rana Clamitans* Latreille. [Ranidae]) appeared. The Spring Peepers were quiet by this time.

By May 26th, the water had dried up entirely. No Spring Peepers or other frogs or toads were seen or heard. Later June visits, even after heavy rains, did not reveal any frogs or toads. While the paths clearly cross through the intended amphibian habitats, only three amphibians were found injured or dead on paths during the surveys.

### 5.2.4 Audio Survey

Spring peepers provided a deafening full chorus early in the spring at Sites 1 and 3. They appeared to be abundant in the area. Once the weather dried out, they stopped. Some American Toads were heard in April and May, but after the weather dried out, none were heard. There was no reason to perform a complete audio survey on the Northern Leopard Frog population in this year.

### 5.2.5 Mark and Recapture

Since there were never enough Northern Leopard Frogs to warrant a mark and recapture study, this was not conducted in 2005. The maximum number of Northern Leopard Frogs identified on any one visit was three (May 22, 2005).

### 5.2.6 Comparison sites

Upon visiting a number of storm water management ponds around the City of Waterloo later in the summer, on July 28th, 2005, I noticed that some of them had a population of Northern Leopard Frogs. One pond in particular, on the Northwest side of Waterloo had an extremely large population of Leopard Frogs. Every step through the grass would result in three to four frogs jumping out of the way. The observed Leopard Frogs appeared to be relatively small. They were only observed casually since the beginning of July, and not before. It should be noted that this site maintained water throughout the dry season.

Observations at another site, an Environmentally Sensitive Policy Area (ESPA) called Forested Hills, also in Northwest Waterloo also revealed a dearth of Northern Leopard Frogs in 2005. Conditions at this site were extremely dry, similar to those at RIM Park (Murphy, 2006).

## 5.3 Observations 2006

Sites for observations were slightly different in 2006. Conditions and frog populations at a storm water management pond on Conservation Drive and Sites 1 and 2 (the Western Throat and Breeding Ponds) at RIM Park were examined, as well as the ESPA swamp at Forested Hills, as collected by Murphy (2006).

### 5.3.1 Weather

The spring of 2006 was much more suitable for frog breeding at all locations in Waterloo. Wetter, warmer conditions led to filled breeding ponds, and an abundance of tadpoles in many locations.

### 5.3.2 RIM Park

Observations started on March 29th, 2006. At this time, Spring Peepers were calling from a distance at RIM Park. There was little other activity until around April 20th. After this time, Spring Peepers were heard consistently, and American Toads, Green Frogs, Wood Frogs, and Northern Leopard Frogs were heard occasionally. American Toads were particularly abundant in the breeding pond at the end of April. Daily observations around this time revealed some occasional sightings of Northern Leopard Frogs. The highest number of Northern Leopard Frogs seen in April was on the 22nd, when 4 were sighted. Frogs and toads were almost exclusively seen near the breeding pond area, and not in the Eastern Throat, or in the Western Throat culvert area.

#### 5.3.2.1 Habitat

At RIM Park in 2006, the weather permitted the herpetofauna ponds at Site 2 to remain wet for the entire spring season. These ponds were not deep, and were full of dense emergent vegetation. At Site 1, the Western Throat, the culverts remained mostly dry throughout the season, though they were surrounded by shallow water and marsh vegetation.

#### 5.3.2.2 Audio

At RIM Park, again in 2006, no consistent audio observations were taken, as the only consistently calling amphibians were the Spring Peepers. Only on two occasions were Leopard Frogs clearly heard, with only 2-3 frogs calling.

#### 5.3.2.3 Mark and Recapture

Continued visits to RIM Park revealed no significant numbers of Northern Leopard Frogs until the end of May. At this time, enough were observed that a Mark and Recapture study was initiated. This was restricted to the herpetofauna ponds, the only location where Leopard Frogs appeared to be residing. This took place on May 26th, 28th and 30th. On May 26th, 3 frogs were captured and marked. On May 28th, 5 were captured (none were recaptures), and on May 30th, 5 were captured (none were recaptures).

### 5.3.3 Storm Water Management Pond – Conservation Drive

#### 5.3.3.1 Habitat

At the storm water pond on Conservation Drive, the pond was full of water and deep, and contained little emergent vegetation, except around the edges. This pond is adjacent to a major street, and is within a residential area.

#### 5.3.3.2 Audio

At the storm water pond on Conservation Drive, Spring Peepers were occasionally heard. Leopard Frogs were never heard at that location, so audio surveys were never conducted there.

#### 5.3.3.3 Mark and Recapture

Northern Leopard Frog tadpoles were seen in abundance near the middle of April. By April 20th, there were many Northern Leopard Frogs at this pond. By the beginning of May, there were enough Northern Leopard Frogs at the storm water management pond to start counting. The Mark and Recapture survey took place on May 8th, 10th and 13th. On May 8th, 10 frogs were captured and marked. On May 10th, 11 were captured (1 was a recapture). On the 13th, 13 were captured (2 were recaptures).

### 5.3.4 Forested Hills - Environmentally Sensitive Policy Area

An additional Mark and Recapture survey at the Environmentally Sensitive Policy Area, Forested Hills, in Northwest Waterloo, was performed around the same time as the survey at the storm water management pond, and had consistently high numbers of Northern Leopard Frogs. On May 5th, 22 were captured and marked. On May 8th, 26 were captured (4 were recaptures). On May 11th, 28 were captured (5 were recaptures).

## 5.4 Calculations

### 5.4.1 Population Estimates

Using the Mark and Recapture data from these three locations (RIM Park, the storm water management pond, and Forested Hills ESPA), it is possible to calculate a rough estimate of the population size using Petersen's Estimate with Chapman's Modification and calculations for standard error. The modification is included to account for low sample sizes. Table 3 contains the formulas used to perform these calculations. Figure 11 shows a comparison of the population estimates and standard error for each location. Table 4 contains the values used in Figure 11.

**Table 3: Formulas used to calculate population estimates. r = # frogs caught on day 1; n = # frogs caught on day 2; m = frogs caught on day 2 that were also caught day 1 (recaptures); Nc = population size estimate; SEc = standard error. Formulas are from Heyer et al. (1994).**

| | **Formula** |
|---|---|
| Chapman's Modification of the Petersen Estimate | $Nc = [(r+1)(n+1)/(m+1)] - 1$ |
| Standard Error for Chapman's Modification | $SEc = [(r+1)(n+1)(r-m)(n-m)/(m+1)2(m+2)]^{1/2}$ |

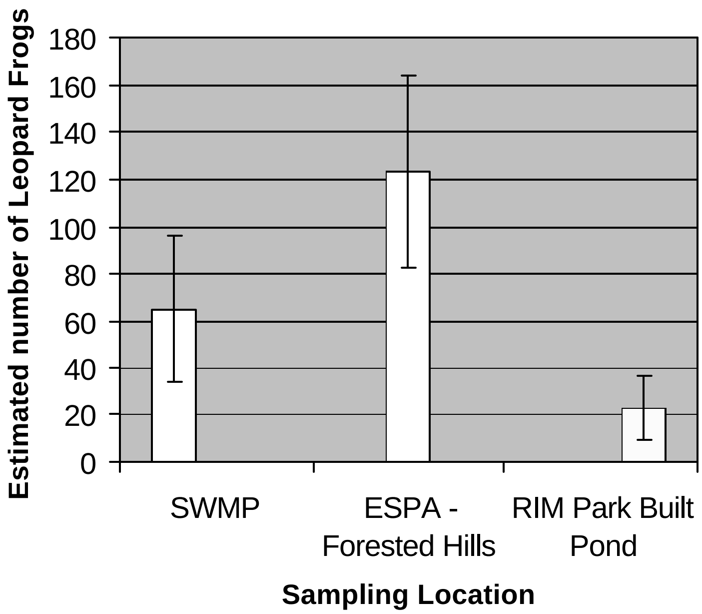


**Figure 11: Population estimates with standard error bars for each location surveyed with mark and recapture methods .**

**Table 4: Northern Leopard Frog population estimates and standard error for each site using the Petersen Estimate and Chapman's Modification**

| | **ESPA – Forested Hills** | **SWMP – Conservation Drive** | **RIM Park – Built Herpetofauna Pond** |
|---|---|---|---|
| Population Estimate | 123.2 | 65 | 23 |
| Standard Error | 40.49 | 31.46 | 13.42 |

### 5.4.2 Capture Statistics

Figure 12 depicts the average number of Leopard Frogs caught in a sampling session, and the standard deviation across sessions. This is subject to a great deal of error, given variable effort, and frog accessibility. Table 5 contains the data used in Figure 12.

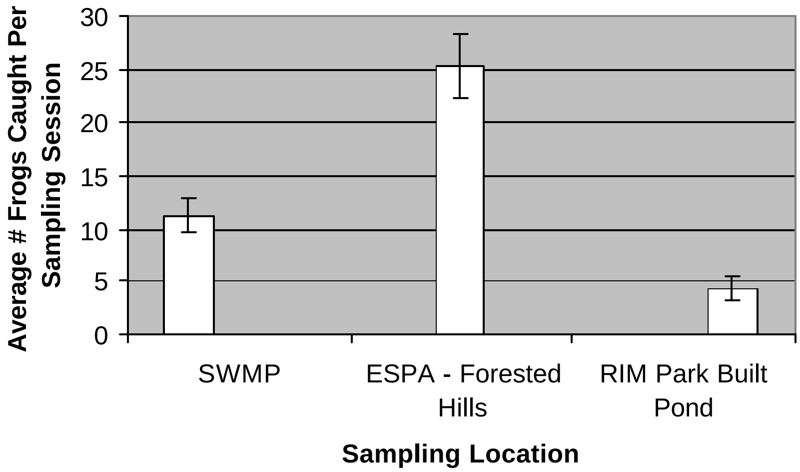


**Figure 12: Average Number and Standard Deviation of Leopard Frogs caught across three survey days.**

**Table 5: Average number and standard deviation of Leopard Frogs caught across three survey days**

| | **Storm Water Management Pond** | **ESPA – Forested Hills** | **RIM Park – Built Herpetofauna Pond** |
|---|---|---|---|
| Average catch | 11.33 | 25.33 | 4.33 |
| Standard Deviation of catch | 1.53 | 3.06 | 1.15 |

### 5.4.3 Significance Testing

A number of factors were tested using ANOVAR, Type III sums of squares. In Table 6, 'Year' refers to the comparison between 2005 and 2006. 'Site' includes the Storm Water Management Pond, RIM Park, and the ESPA – Forested Hills. Each of these surveys was conducted on three separate days, so 'Day' can also be a significant factor. The results are revealed in Table 6. Data are not available for the storm water management pond in 2005, so it is excluded in many cases.

Year, site, and day (nested in year) all have a significant impact on frog catch size. The interaction of site and year, and site and day were also significant.

**Table 6: ANOVAR - Type III Sums of Squares**

| Factor | F | P | Notes |
|---|---|---|---|
| Year | 91.45 | < 0.001 | SWMP omitted |
| Site | 15.61 | < 0.001 | |
| Day (Nested in Year) | 8.41 | < 0.01 | |
| Site * Year | 56.71 | < 0.001 | SWMP omitted |
| Site * Day (Nested in Year) | 43.18 | < 0.001 | |

Tukey's Honestly Significant Difference (at level p = 0.05) was also tested, to identify particular differences between factors. These results are listed in Table 7. 2005 had significantly lower numbers overall than 2006. 'Day' was only significant for the ESPA, given its larger catch sizes. 'Site' was significant, in that RIM Park contained the lowest number, followed by the storm water management pond, and the ESPA contained the highest number. The interaction of 'Site' and 'Year' revealed that the ESPA had higher numbers than RIM Park.

**Table 7: Tukey's HSD (p = 0.05)**

| Factor | Result | Notes |
|---|---|---|
| Year | 2005 << 2006 | SWMP excluded |
| Day (Nested in Year) | Significant at ESPA only | |
| Site | ESPA >SWMP> RIM | |
| Site* Year | ESPA > RIM | SWMP excluded |

## 5.5 Summary

The compilation of the consulting reports and weather data allowed comparisons of factors across a number of years, something that has not been thoroughly conducted in previous reports. These comparisons reveal interesting trends in amphibian populations in the park, and particularly about their relationship to weather conditions. The field work, while only crossing two seasons, revealed a number of significant results. These will be discussed in detail in the next chapter.

# Chapter 6
# Discussion

The key findings for this study reveal some interesting and significant trends. Weather conditions appear to play a major role in habitat suitability. Other factors that influence frog populations in RIM Park likely include habitat quality (particularly as it relates to the hydrological layout of the wetland), historical conditions and park design and management choices. These factors are likely inhibiting the full ecological potential of the RIM Park wetland. The following discusses these factors, as well as the role of public relations, a critical aspect in both environmental management and urban planning.

## 6.1 Key Findings

The field study and subsequent calculations revealed key results for a number of factors. Most importantly, 2005 saw significantly fewer frogs than 2006 in the two locations where they were observed, the RIM Park breeding ponds, and Forested Hills, the Environmentally Sensitive Policy Area (ESPA). Extremely dry weather in 2005 caused usual breeding ponds to dry up entirely early in the season.

The site where frogs were caught was also significant. The ESPA had the highest estimated number of Northern Leopard Frogs and highest number of successful catches, followed by the storm water management pond, followed by RIM Park's Herpetofauna ponds. These differences are all significant. The factor "day" was also significant for Forested Hills. Conditions on a particular day can influence catch success. Interactions were also significant. The interaction of site and year reveals that site conditions, and therefore, frog populations across years can vary significantly.

The results of this study can be used for some general observations, but are subject to a number of limitations. However, as the results are consistent with general observations, they are worth further examination.

## 6.2 RIM Park Status

### 6.2.1 Amphibian Populations

In relatively normal or wet years, Northern Leopard Frogs are probably using the RIM park herpetofauna ponds as a summer, non-breeding, habitat. When weather is dry, as it was in 2005, this location is of no use. They still are not (likely) breeding significantly at this location. In 2006, Leopard Frogs were identified at this habitat at least two weeks later than when large numbers were identified in the two other locations and none of the consulting reports indicate any contrary evidence.

It is unclear whether there is a minimum viable population at the Park. The population estimate in 2006 for Northern Leopard Frogs at the RIM Park herpetofauna breeding ponds, using Petersen's estimate, with Chapman's modification was 23 (SE = 13.42). This is likely an underestimate given the difficulty of catching frogs in densely vegetated ponds. One suggested minimum viable population for a frog species was 451 (Reed et al., 2003). It seems unlikely that the ponds sustain close to that number. While 2006 showed a low number of Northern Leopard Frogs early in the breeding season, other amphibians were observed. Spring Peepers were heard in abundance both years very early in the spring, though they are small and difficult to observe visually. In 2006, there was a large number of American Toads in the ponds for a short period early in the breeding season. Green frogs appear to follow the same trends as Leopard Frogs at RIM Park.

Given the different phenologies of the various species of amphibians appearing at the park, and the low numbers of all amphibians observed, it is less likely that interspecific competition within the ponds are affecting Northern Leopard Frog populations at RIM. Predators may be important but no known predators of Northern Leopard Frogs were observed at RIM Park during the study. A systematic assessment of competition and predation is still warranted but the current importance of these factors is questionable. As discussed below, habitat quality, weather, site history and park management are more likely to be influencing the Northern Leopard Frog populations at this time. The literature generally supports the hypothesis that factors such as these are either directly or indirectly responsible for declines in amphibian populations (Alexander & Eischeid, 2001; Blaustein & Wake, 1995; Carey & Alexander, 2003; Funk & Mills, 2003; Pope et al., 2000). Predation and competition were not addressed as possible reasons for decline. The results that identify a much higher number in two other areas, including the storm water management pond in a suburban neighbourhood, indicate that RIM Park's constructed ponds are not a habitat to sustain breeding or even much early summer habitat for Northern Leopard Frogs.

### 6.2.2 Habitat

Amphibian presence depends strongly on appropriate habitat and habitat quality (Ficetola & DeBernardi, 2004). Some of the habitats identified as important, or that were "designed" for amphibians did not meet the criteria they require.

The Eastern Throat is one area in RIM Park that was identified as important for amphibians (Figure 7). This is a forested area, and frogs were not found here, though Spring Peepers were occasionally heard. Leopard Frogs do not like forested areas (Guerry & Hunter, 2002). The Eastern Throat was subsequently dropped from the investigation.

Another area of main concern was the Western Throat. There are two groups of culverts at this location intended to allow passage of frogs. No frogs were found at this location, however, throughout 2005 and 2006. These culverts were almost always entirely dry, except at times of flooding and snowmelt. The surrounding area is also usually dry, so the frogs are not likely using the area much. The culverts are likely mostly helpful for water movement in flood situations.

Although 2005 showed very few amphibians overall, in 2006, the herpetofauna ponds were one location where frogs and toads were regularly observed. Here, there is more open water when the weather permits. The clearspans are probably important areas for movement of certain species across the path during wet years. In 2006, American Toads were observed moving beneath the clearspans. Many species, including Spring Peepers, American Toads, Green Frogs and Northern Leopard Frogs were found here. These ponds are extremely dense with emergent vegetation. Near this area, at-grade segments of the trail are likely used for crossing. Frogs were occasionally found on the path. However, very few were ever seen injured or killed on the trail at this location. This part of the path is not shared with the golf carts. Studies regarding traffic and amphibian mortality are usually concerned with full sized roads and traffic larger than bicycles or golf carts (Carr & Fahrig, 2001; Fahrig et al., 1995; Hels & Buchwald, 2001; Mazerolle, 2004). Results from these studies would not necessarily apply in this case.

Additional ponds can be found across the golf course towards the Grand River, but they would be relatively inaccessible to frogs, as they are not connected to the rest of the wetland. In addition, nearby sedge meadows seem to be populated with amphibians in some years, such as 2001, not for breeding, but for summer habitat. No counts were conducted in this area for this study.

## 6.3 Weather

Weather had a noticeable impact on which ponds were used for breeding between the two years studied. Significant differences in numbers of amphibians ($P < 0.001$) were found at each site per year in Waterloo. In dry years, some ponds dry up completely, while others provide persistent water through the spring and summer. This is consistent with Greenberg and Tanner's study (2004) which demonstrates that weather can play a significant role in pond selection and breeding. Although there was no census conducted in 2005 on the storm water management pond, casual observations revealed a large number of very young Northern Leopard Frogs appearing later in the season. This suggests that this may have been a location for breeding in 2005. The storm water management pond retained water throughout the spring and summer, while the other two areas, at RIM Park and Forested Hills – ESPA, were completely dry in 2005.

Clearly, dry years lead to microclimate changes, and changes in frog behaviour patterns. Dry ponds observed in one year still have the potential to be breeding grounds in a wetter year (Kentula et al., 2004). Global changes in weather may have devastating effects on frog populations (Carey & Alexander, 2003).

### 6.3.1 Climate change

Global climate change may be a contributing factor in frog population decline. Some studies focus on long term changes in frog breeding patterns. In one study, the first spawning periods of frogs has changed by 9 days over 25 years (Tryjanowski et al., 2003). When direct effects are not obvious, other researchers have suggested a more indirect effect. (Alexander & Eischeid, 2001) For example, climate change may increase the spread of infectious disease (Carey & Alexander, 2003). The evidence for the effects of climate change on frog populations is very inconclusive. According to one study by Blaustein et al. (2001), climate change has not influenced the timing of breeding in amphibians in North America. Nevertheless, a reasonable argument can be made that local microclimate conditions drastically alter frog survival. Given local weather fluctuations caused by global climate change, we may be able to make management decisions that help habitats to be more sustainable under such unpredictable circumstances.

### 6.3.2 Habitat Selection

Local habitat changes can directly alter frog breeding patterns and survival. For example, changes in the configuration of a wetland, caused by human activities, can change the potential breeding suitability of the area, through changes in the hydroperiod, and the composition of other species in the ponds (Babbitt & Tanner, 2000). RIM Park is one location that has been hydrologically modified, and is, as a result susceptible to changes in breeding habitat suitability. The only ponds with water in 2005, the dry year, were located in the middle of the golf course, unconnected to other wetland areas. These were not suitable for frog breeding.

Both biotic and abiotic factors are involved in the selection of frog breeding sites. Factors can include area, water depth, proportion of the water surface covered by vegetation, altitude, date of drying, spatial position, water flux and characteristics of the shore and bottom of the ponds (Bosch & Martinez-Solano, 2003). In addition, the ponds should be connected to other wetlands, and upland areas. These very specific details mean that slight changes in a habitat can make it unsuitable in some years and suitable in others. Wet-dry cycles can influence where breeding occurs in a landscape (Greenberg & Tanner, 2004).

Paton and Crouch (2002) stated that "ponds with suitable hydroperiods in even a minority of years should be considered important habitat." They also said that hydroperiod length and timing of a pond is critical for anuran breeding, and wetland size and pond isolation should also be considered in assessing the suitability of ponds. As Kentula, Gwin and Pierson noted, after a drought, sites can return to normal after normal rainfall occurs (2004). Even in a wet year, however, the constructed herpetofauna pond could never be 30-60 m in diameter, or reach a 1.5 to 2.0 m depth, which are typical of Northern Leopard Frog breeding ponds (Environment Canada, 2004). It is simply not that large. Leopard Frogs may decide not to use this area for breeding due to a lack of open water. Frogs have specific needs, and they will select breeding areas based on these.

### 6.3.3 Extreme weather events

During shorter studies, it is sometimes difficult to tell if conditions are "typical" for the area. Extreme weather conditions may cause rapid fluctuations of frog populations. This may have been the case in 2005, when the Northern Leopard Frogs did not appear in what are usually breeding ponds. If we are experiencing extreme weather conditions, it is important to understand the effects of these conditions on frogs. Extreme weather events can cause changes in behaviour and habitat selection (Doan, 2004) as well as body condition. These changes may lead to altered reproductive effort and success. Generally, higher temperatures can cause tadpole mortality and a year of drought may cause frogs not to breed that year. Variation in rainfall can result in changed species composition. Dynamic habitats, those that may change as a result of flooding, can result in varied species assemblages

(Babbitt & Tanner, 2000). Extreme weather can clearly change frog patterns. It is important to account for this possibility in any frog research.

### 6.3.4 Detection Probability

In addition to noting the effects of the weather on the frogs, it is important to remember the limitations of scientific study, and accept that detection capabilities are probability altered by weather (Pellet & Schmidt, 2005). In times of cold, or wind, we may not be able to detect the same number of frogs with the same audio methods. For example, frogs will only start to call when the weather is warm enough. A lack of frog calls does not necessarily mean a lack of frogs. A surveyor who relies on one weather-dependent method of enumeration (such as call surveys) runs the risk of reporting a false negative.

## 6.4 Site Histories

The history of RIM Park and the Martin floodplain has likely influenced the integrity of frog populations in the area. Because the floodplain was historically used as farmland, it is possible that there has not been a substantial number of frogs living there for a very long time. In addition, residual herbicides and pesticides possibly used on the farm may have accumulated, and could potentially be affecting amphibians living in the floodplain pools. Pesticides are also known to affect gender ratios by reducing the number of males in an area (Hayes et al., 2006). This would render estimations that use audio methods inaccurate as male frogs are the ones that call.

If frogs are desired in the area, it may not be a question of conserving them, but restoring the site to a condition where they will be able to use this area as a new site. There does appear to be amphibian populations residing in the area at the moment, and populations may grow as time goes on. A lack of detailed data from before the RIM Park development precludes the possibility of making before and after comparisons. It is also important to remember that RIM Park is located in an urban location, and is subject to urban influences.

## 6.5 Park Management and Design

### 6.5.1 Environmental Management Plan

In September 2003, Natural Resource Solutions Inc. prepared a management plan for RIM Park. This report is a good example of how to manage a large area and at the same time narrow down important areas which require more attention. As well as providing park-wide management goals, the plan divides the park into components that need to be managed individually. The management plan cites the EPS (environmental planning study) conducted by Stantec in March 2000. This document, identifies many significant and sensitive features of the park (Natural Resource Solutions Inc., 2003c). These features include plants and wildlife, wetlands and habitat linkages. The plan also provides recommendations for how to manage these features.

In addition to identifying the important components of the park, the Management Plan also provides site-specific strategies for maintaining and improving the condition of RIM Park's ecosystems. These strategies include the addition of buffers, stabilizing and landscaping the nature sanctuary, collecting and treating runoff to improve water quality, as well as the addition of things like signage, interpretive opportunities and water monitoring.

Monitoring has been listed as a necessary park-wide management activity. Bird and herptile surveys have been conducted on a yearly basis since 2000, and are continuing. Consulting was initially performed by Dance Environmental Inc, and was continued by Natural Resource Solutions Inc. These reports are available individually.

### 6.5.2 An Evaluation of the Consulting Studies

#### 6.5.2.1 Summary

Amphibian and reptile monitoring reports contain information on a number of species, for a number of locations. For the purpose of this study, I focus on information from these reports collected in the Martin Floodplain on Northern Leopard Frogs. The first survey occurred in 1996, and simply consisted of some casual recordings of amphibian sightings (Dance Environmental Inc., 1996). The next survey provided was in 1999, and was also conducted by Dance Environmental (Dance Environmental Inc., 1999). In this one, simple amphibian presence or absence is recorded, which may have been performed through egg searches, call surveys or visual observations. This is unclear. Dance Environmental continued to survey in 2000, and followed similar observation techniques (Dance Environmental Inc., 2001).

In 2001, Natural Resource Solutions took over the herptile monitoring. This was also the year when construction of the park began. Reports from this point on were much more comprehensive, running from 2001 to the present. Once the initial reports identified amphibian presence, more thorough and consistent investigation may have been thought necessary. Natural Resource Solutions consultants used the Marsh Monitoring Program protocol as well as field surveys focusing on eggs and larvae and incidental observations. The Marsh Monitoring Protocol is mostly concerned with audio surveys. In addition, these reports examined the habitat and weather in detail. The reports contain details of every survey event in every location. (Natural Resource Solutions Inc., 2002a).

Because of concern about interference with herptile movement patterns caused by the construction in the park, and the effectiveness of the culverts and clearspans, some movement monitoring also took place. Some casual observations occurred in earlier studies, followed by more detailed analyses and suggestions. In the 2001 study, consultants stated that culverts do not provide adequate provision for movement, but that this should improve in post construction years. They also noted that ponds had dried up completely that year (Natural Resource Solutions Inc., 2002a). If the ponds were dry during observations, it would have been difficult to extrapolate whether amphibians would use the tunnels in wet years.

#### 6.5.2.2 Problems

Many later reports appear to use previous reports as a baseline for data collected. Later reports by Natural Resource Solutions claim that “background sources noted that a number of permanent ponds and lakes in the study area are important to amphibians” (Natural Resource Solutions Inc., 2002a). They do not make this claim themselves. They only refer to the “anecdotal descriptions” given by the previous reports (Natural Resource Solutions Inc., 2002a). Anecdotal descriptions do not appear to give much solid scientific evidence of frog abundance in the park.

There is a lack of consistent data on frog numbers in RIM Park. Some reports contradict each other. The report from the year that the largest number of Leopard Frogs was recorded also stated that they believe numbers of Leopard Frogs to be lower than in previous years (Natural Resource Solutions Inc., 2002a). Other years, such as in 2002, numbers were not recorded again, and were only “routinely” observed (Natural Resource Solutions Inc., 2002b). Please see Table 1. In addition, call surveys for Leopard Frogs would not reveal accurate numbers, as very few were ever heard calling, even at times and places where abundant numbers were visually observed. This may render previous reports, which rely on this method, meaningless.

In 2002, a survey was conducted by Natural Resource Solutions to examine amphibian movement. The consultants in this paper refer to the previous mention of the high productivity of the pools in RIM Park (Natural Resource Solutions Inc., 2003b). The Western Throat, and the start of the sedge meadows were the areas of interest in this study. Stations were searched with flashlights, and the movement of amphibians recorded on camera. During 2002, Spring Peepers, American Toads, Green Frogs and Leopard Frogs were all observed crossing the trails. Movement monitoring, however, did not reveal large numbers of amphibians, and this was blamed on unusual weather conditions. Frogs and toads were observed crossing the second set of culverts, the cart path, and the second bridge. They were never observed crossing the first set of culverts or the first bridge. At some times, over 20 dead amphibians have been recorded on the trail. Overall, the at-grade portions of trail are the most frequently used by amphibians (Natural Resource Solutions Inc., 2003b).

The monitoring report in 2003 (Natural Resource Solutions Inc., 2003a) included a section on movement and mortality. Few amphibian species were ever seen in the culverts, though some were seen on either side. A significant number were found killed on the path, at least 50 during the monitoring season. This was generally in shared path areas, which are used by golf carts.

Another study was conducted on preventing amphibian mortality in 2004. This study provides recommendations for improvements to the existing structures to increase their usage. They suggest installation of a wildlife fence system at the western throat and landscaping be modified near the herpetofauna ponds to direct amphibians (Natural Resource Solutions Inc., 2004b). While this suggestion would likely be helpful if there is an abundant number of amphibians, there were not enough amphibians crossing the roads in either 2005 or 2006 to warrant this added expense.

It is difficult to see how any conclusions can be drawn from this information. At the least, however, it is clear that amphibians are sometimes using these areas. There is some evidence of Northern Leopard Frogs living at some of the locations of interest at certain times of the year. There is no way of knowing if there is a sustainable population based on these inconsistent estimates.

Reports consistently contain explanations for the lack of frogs which are related to “unusual” weather (Dance Environmental Inc., 1996, 1999, 2001; Natural Resource Solutions Inc., 2002a, b, 2003a, b, 2004a). Please see Table 1 for the summary of excuses. The fact that unusual weather is implicated in poor amphibian breeding for this many years indicates that there may be other influential factors. If, in fact, the weather has been unusual every year, it is likely that the habitat needs to now be adapted to account for unusual weather.

### 6.5.3 Design Elements

In the design of RIM Park, many environmental concerns were addressed. Because of the presence of a provincially significant wetland, certain changes to the design were included. The three main areas of interest are the Martin Floodplain, the Nature Sanctuary and the Golf Course.

#### 6.5.3.1 Martin Floodplain

Historically, the Martin Floodplain was pasture. Now there are floodplain pools connected by channels. When these channels dry up, the pools become completely isolated. The Martin Floodplain also contains a large sedge dominated wetland which has been designated as a provincially significant wetland. It is part of the herptile monitoring program.

Many of the pools in the floodpla in were constructed partly to receive runoff from the golf course, and partly as habitat for local herpetofauna. During an interview with the Environmental Coordinator for the City of Waterloo, it was clear that the park was designed and constructed with the understanding that the area was important habitat for specific amphibians. This information was derived from consulting reports. Migration routes of certain animals, such as amphibians, and white tailed deer intersected proposed pathways. The people designing and constructing these pools recognized the need for specific criteria to be adequate habitat for herpetofauna (Moyer, 2006).

One area that is of great concern is the interface between the nature sanctuary and golf course. This takes the shape of the cart path. Amphibians were noted to move from wetland and upland habitats into the nature sanctuary and floodplain pools. A previous study suggested the temporary closure of trails during these dispersal periods, but this idea was rejected. A system of underpasses was designed, as well as alternative breeding habitats. The Environmental Implementation Team was also pushing for something unique and special so the trail would serve as a leadership movement or demonstration project (Moyer, 2006). This was part of the motivation for the amphibian pond construction and culvert addition.

For the design of the breeding ponds, the implementation team needed to maximize south facing shoreline, minimize shading, ensure that water is in the pond throughout spring for breeding to occur, and enough water so it doesn't freeze solid in the winter, provide a muddy, non-uniform bottom, and fulfill specific vegetation requirements. These pools also serve as a "stepping stone" to other wetland complexes (Natural Resource Solutions Inc., 2003c).

Because of this belief and these suggestions, alterations were made in the plans to accommodate this habitat, and reduce the potential impact the project could have (through the inclusion of culverts, clearspans, breeding ponds and at-grade trail segments). In addition, these changes were intended to have benefits for other animals and for water movement. They had also hoped that the alterations would encourage amphibian immigration into the area (Moyer, 2006). Based on information provided by consultants, the inclusion of these features was warranted. However, given the reports, the effect may have been exaggerated.

Unfortunately, certain objectives, such as providing a pond with sufficient water, were not fulfilled. Breeding ponds dry out entirely in dry years, and have very shallow water in wet years. Culverts and some of the clearspans are placed in areas that are not helping amphibians.

#### 6.5.3.2 Nature Sanctuary and Protected Areas

RIM Park has protected areas, such as the Nature Sanctuary (See Figure 3) and the Provincially Significant Wetland. This protection is critical for preserving sensitive features. It prevents future development and provides enhancement opportunities. While these sorts of steps help conserve natural habitats and features in the landscape, the compromises in the park appear to favour recreation over conservation or restoration. Paths run right through the sensitive wetland, though signs have been erected asking visitors to keep to the path. The nature sanctuary is home to wetlands which experience considerable fluctuations, but also historically experienced trampling and grazing.

#### 6.5.3.3 Golf Course

The golf course has been constructed over both the Martin and Horst floodplains, cutting off potential breeding pools from the network of wetlands and uplands. The golf course is also maintained with pesticides. This is potentially very dangerous to the health of amphibians in the area. Pesticides such as carbaryls become even more lethal in situations where amphibians are threatened by predators (a common situation for most frogs) (Relyea, 2003). Pesticides can also play havoc with gender ratios, and reduce the number of male amphibians (Hayes et al., 2006). Pools are intended to serve both as breeding pools, and storm water management for the golf course. Paved paths for the golf course, as well as the trail system were introduced right through this wetland, cutting off migration routes, despite recommendations against this action (Dance Environmental Inc., 1999). A few clearspans and bridges could not make up for the disruption to natural habitat. Golf carts careen around the pathways, with little regard for wildlife.

Golf courses may play an important role in providing or connecting wildlife habitats, where there are no other alternatives (Terman, 1997). However, they are far from ideal when it comes to providing natural habitats.

## 6.6 Public Relations

The scandal (see section 3.3.2 of this thesis) surrounding RIM Park's financing has made public relations concerning the success of the park into a very delicate issue. Even in 2004, many members of the community still have "residual anger" about this issue (P.M.G. Consulting / Weaver, 2004). The park needs to be positively regarded by the public in order to restore faith in municipal government. To this end, innovative approaches and environmental issues have been stressed in park advertising and interpretational materials.

Publicly available information describes the importance of RIM Park's floodplain areas for amphibian habitat (City of Waterloo, 2005a). While the goal of protecting wetlands and informing the public about these efforts is commendable, it remains unclear which data pointed to that conclusion. Data were inconsistent and lacking detail at best. In certain years, some amphibians seem to be using the ponds sporadically. The goal of providing excellent amphibian habitat is perhaps being confused with real data. Most projects, most project leaders, and even most scientists tend to put the best interpretation on goals and results to build consensus. In the case of community urban planning, there can be a tendency to focus more on vision than empirical data because the latter takes a long time to gather and is of less interest to the public.

There is a gap between the public relations effort (the idea that RIM Park will provide homes for amphibians), and the actual utility of amphibians (they are an appropriate indicator to identify whether or not the project is a success). People likely associate the presence of amphibians with a healthy wetland habitat. If they are told (through interpretational materials) that frogs are using the area, they are unlikely to question that statement, and simply approve of the conservation efforts.

### 6.7 Summary

In the future, if RIM Park supports wetlands of appropriate sizes, chemical and physical conditions, community and ecosystem dynamics, and relationships to the matrix, more amphibians of different species may select the area as an appropriate breeding habitat. This is unlikely to happen, however, given the passive approach to restoration, and the current state of the wetland. In addition, agricultural and river management activities in the last hundred years are probably important reasons why many species are absent. The historical data don't exist to test this possibility. Many types of frogs need a more permanent pond for breeding and overwintering. The designated areas tend to dry up completely, particularly in dry years, and are cut apart from other larger ponds by trails and the golf course.

The results communicated to the public about the ecological value of the area are optimistic and exaggerated. However, the public is more likely to support a project that is successful than failing. Perhaps an optimistic outlook is necessary to gain support. Recommendations for the future of

RIM Park, as well as amphibian monitoring and urban parks in general are included in the next chapter.

# Chapter 7
# Recommendations and Conclusions

Over the course of this study, I have compiled a list of suggestions which could enhance the management strategy of the park, and improve on current techniques, as well as provide direction for future projects. A change in priorities and a focus on restoration over conservation will be necessary to establish a fully functioning yearly wetland. Current amphibian monitoring methods do not reveal any significant information about amphibian populations, other than simple species presence. I have also included a number of suggestions for urban park management in general which address park values, design, monitoring and communication with the public. These recommendations are based on my two years of observations at RIM Park, as well as an extensive literature review.

## 7.1 Priorities

The priorities at RIM Park seem to be primarily focused on recreational use and not on natural conservation or restoration. This is at odds with a city that claims to be an "Environment First" community and a "leader in greenspace management." Park priorities should be reconsidered. Presently, RIM Park is primarily recreational, with some natural features included.

Two holes of the golf course were positioned right in the centre of a floodplain that could have been restored to a properly functioning wetland. In addition, pesticides are still used on the golf course at RIM Park (Moyer, 2006). This could have potentially harmful effects on the populations of frogs using the ponds (Relyea, 2003). There are alternatives to pesticides that should be considered. In addition, the difference between conservation and restoration should be made clear. If the priority is conservation, this contradicts the Environmental Strategic Plan designed by the city in 2002 (City of Waterloo, 2002), which gives priority to restoration and improvement of green spaces. Restoration is tertiary to recreation and conservation in the RIM Park plan. The herpetofauna breeding ponds are not consistently providing an appropriate breeding ground for many advertised species. If Northern Leopard Frog breeding habitats are desired, active restoration should be initiated.

A change in the focus of the RIM Park project from conservation to restoration would also mean a change from passive to active management. This type of a move would take considerable financial support and a great deal of detailed planning. Funding should only be allocated to this type of project if the benefits appear to be worthwhile. There are decision analysis tools available to help identify the value of a variety of projects (Guikema & Milke, 1999). Unless restoration is being planned, further allocation of funding for conserving the frog populations, such as the installation of wildlife fencing, may be wasted.

The park is heavily used for a diverse array of activities. If ecological function is of primary concern, restoration should be a priority in RIM Park. If the park is going to advertise certain features, such as the presence of Northern Leopard Frogs, and the important breeding grounds, it is imperative that these features exist and continue to do so. On the other hand, species such as Spring Peepers appear to be abundant in the park. A change in focus to emphasize to the public the presence of abundant species that appear yearly would be much more accurate.

From the consulting survey conducted (P.M.G. Consulting / Weaver, 2004), it seems clear that the community values the nature trails. If the community values the trails, and the city has an Environment First policy which embraces restoration projects and the improvement of green space, they may support a restoration project of this type. Northern Leopard Frogs are in trouble, and projects such as this one have the potential to mitigate human impacts on their habitats. RIM Park managers have the potential to make small changes which will have large impacts on animal populations.

RIM Park is not unusual in its structure. Parks all over the world attempt to reconcile the wants and needs of a variety of users. This is never an easy task. The advertised values for the park are unclear. The values that have been demonstrated during the building of the park are based on what certain members of the public would like to see. The construction and maintenance of the golf course and the recreational facilities have clearly taken priority over environmental objectives. There are other parks which claim to have reconciled recreation, restoration and research (Zedler & Leach, 1998). Perhaps some of these would be good examples to follow.

### 7.1.1 Can conservation work at RIM?

The environmental management plan for RIM Park states that "preservation is the key component of our forest management program" (Natural Resource Solutions Inc., 2003c). If the floodplain was historically used as farmland (Natural Resource Solutions Inc., 2004c), what is there to conserve in a natural state? Is conservation even possible? The park's advertising and interpretational signage stress the importance of the herpetofauna breeding habitats in the park. However, there does not appear to be an abundant amount of breeding among many advertised species in the park. Particularly in dry years, the hydrology of the area is such that the ponds become unusable by most species.

This is not to minimize the importance of conservation. Paton and Crouch (2002) say that "ponds with suitable hydroperiods in even a minority of years should be considered important habitat." On the other hand, they also say that hydroperiod length and timing of a pond is critical for anuran breeding, and wetland size and pond isolation should also be considered in assessing the suitability of ponds. If conservation of amphibians is truly a goal in the area, these factors need to be considered.

Conservation is important, particularly in areas that are used for breeding. It is unclear, however, whether or not this area ever was truly a popular breeding location. While some more tolerant species, such as American Toads and Spring Peepers, may be using the site for breeding in wet years, when weather dries out, it becomes useless. Therefore, conservation needs to be a secondary goal to restoration. Once a proper breeding site is established, it may be worth conserving. As it stands, conservation efforts are wasted in the park.

### 7.1.2 Can restoration work at RIM?

If the floodplain was historically used as farmland and pasture, it is likely that substantial restoration would need to be done to create a desirable green space, particularly if it is decided that a herpetofauna breeding pond would be appropriate in the area. Only some species, in some years can reside there currently. A number of projects have been successful in restoring a habitat to an appropriate amphibian breeding area (Babbitt & Tanner, 2000; Hazell et al., 2004; Pechmann et al., 2001). The success of these projects relies on a number of factors.

Factors that influence the choice of ponds by amphibians can include pond area, water depth, proportion of the water surface covered by vegetation, altitude, date of drying, spatial position, water flux and characteristics of the shore and bottom of the ponds (Bosch & Martinez-Solano, 2003). The herpetofauna ponds currently installed at RIM Park do not appear to be appropriate for breeding. Breeding ponds should be generally about 30-60m in diameter, 1.5 to 2.0m deep, with emergent vegetation (Environment Canada, 2004). Winter sites are generally streams or ponds that do not freeze solid. In addition, frogs like wetlands that are close in proximity to other wetlands, and that do not support fish (Ficetola & DeBernardi, 2004). Many of these details were addressed in the management plan (Natural Resource Solutions Inc., 2003c), but apparently were not followed. The ponds at RIM Park are much smaller and shallower than the ideal breeding ponds. To reach other, wetter ponds at RIM Park, frogs would be forced to cross the golf course.

Simple conservation in this area is clearly not an option if it is desired as a yearly amphibian breeding ground. Other factors would need to be considered. It is possible that this land is not appropriate for this use, and resources and attention should be directed elsewhere. If the presence of frog habitat is a priority for park management, more extensive restoration should be considered. For RIM Park's amphibian habitats to serve as a true ecological leadership project, it would be necessary to reconfigure the golf course, expand the pools and create better connections to upland habitats.

## 7.2 Restoration at RIM Park

If it were decided that frog breeding habitat was a priority over the long term in RIM Park, a number of changes should be made. The drying out of the ponds precludes the possibility of frogs using this area in dry years. Particularly considering our changing climate and unpredictable weather, an adaptable landscape could be designed that would allow frogs to breed, even in dry years. At the very least, some simple changes could connect wetlands better to permit migration, and access to more appropriate areas.

The goal of a restoration project in this area of RIM Park would be to restore a resilient wetland habitat, with the ability to endure natural disturbances and to sustain a variety of wildlife. The wetland would ultimately require minimum maintenance. If a wetland can endure natural disturbances, it is less likely to require extensive intervention (Middleton, 1999). Parts of the project could involve rehabilitation (or improving existing wetland areas), and other parts would require restoration (building new wetlands).

Issues that would need to be addressed would be the golf course layout, pond size and depth and the layout of the paths. Clearly, there are many forms and degrees of intensity that a restoration project could take. A complete reformatting of the golf course would likely not be feasible. An optimal ecological solution would involve the movement of Holes #1 and #18 to an alternate location, to make room for a large wetland in the Martin floodplain, connected to the Grand River. As this would not likely be feasible, other alternatives, such as moving one hole, or even just modifying the design of the holes would provide a great deal of space to create a connected wetland at this location.

Please see Figure 13 for a picture of one potential wetland layout. In reality, a feasibility analysis that includes hydrological analyses would need to be conducted, and the changes to the golf course approved. This is just one possible solution. This particular design would reduce the length of the first hole. Currently, Hole #1 poses a problem for wetland function, as it disconnects floodplain pools from the rest of the wetland.


**Figure 13: Martin Floodplain with recommended wetland restoration area shaded blue. The orange line represents the reconfigured path which connects to an existing path on the right. Arrows represent the movement of water. Brown rectangles represent existing clearspans. Adapted from Region of Waterloo GIS Locator (Region of Waterloo, 2003a).**

In this layout, once the raised tee-off areas were eliminated, ponds could be constructed, or enlarged within the proposed area indicated in Figure 13. Within this area, the ponds could be large enough to support Northern Leopard Frogs, as well as provide sunny habitats. Some of the ponds would be permanent, and some seasonal, so as to accommodate a variety of frog species at various life stages. There should be at least one very large pond area that would be resistant to drought. This pond should be connected to smaller, possibly ephemeral pond areas, as well as to upland habitats, thereby creating a viable habitat for frogs that require connected landscapes. Pond bottoms would need to be sculpted at varying depths to ensure a diverse habitat. Different depths support different hosts of vegetation and animals. With this design, no new bridges would need to be constructed. Instead, there would be a better use of current clearspans and culverts by water and also frogs migrating between upland terrestrial and breeding habitats.

As soon as possible after the sculpting of the new wetlands, plantings should commence to prevent erosion and to speed recovery of the site. A variety of native wetland vegetation could be used to both support the soil and re-vegetate the wetland. Local native plant sources are simple to find. However, one possible source could involve local elementary schools, where children can be involved in the *Classroom Propagation Program*. In this program, children assist in growing native wetland plants from seeds. Classrooms are sent kits that provide instructions and materials for growing aquatic plants from seed (CWS Ontario Region, 2005). This program provides children with a learning opportunity, as well as an opportunity to be involved in the restoration of the environment. Students can also become volunteers for the planting stage of the restoration project.

In planting, it is critical to remember the inclusion of buffer zones around the wetland areas. This is particularly important in a wetland near a golf course that is using pesticides (Libby et al., 2004), such as this one (Moyer, 2006). This would be aided by taller emergent vegetation such as sedges and bulrushes. Dense plantings along path edges would encourage the use of the culverts and clearspans.

Once landscape changes were complete, and the area was replanted with native wetland species, it would be hoped that species such as Northern Leopard Frogs would naturally recolonize. Another option would be to use the area for an experimental reintroduction of the frogs. In Alberta, they have undertaken a massive project to recover the Northern Leopard Frog, given that they have "Threatened" Status under the Alberta Wildlife Act (Alberta Northern Leopard Frog Recovery Team., 2005). One project in Alberta that reintroduced Leopard Frogs with apparent success used a technique of egg mass transfers (Kendell, 2002).

If a larger population of amphibians decided to use this location, or were introduced, at this time it would likely be important to take measures to enforce the use of the culverts and clearspans. In the past, frogs and toads have been noted on top of the clearspans instead of traveling under them (personal observation). As mentioned earlier, to enforce the use of culverts and clearspans, wildlife fences could be installed, along with preventative plantings to inhibit movement over the top (Dodd et al., 2004; Natural Resource Solutions Inc., 2004b) and direct amphibians towards safer passages.

A restoration project of this sort would be deemed successful if and when the wetland is inhabited by a sustainable population of frogs as well as other wetland animal species, when native wetland plants are dominant, when the hydrology is stable over time, and when the system is capable of resisting the effects of natural disturbances. Even if these goals were not attained, if monitoring and adaptive management is employed diligently, the project would have been successful as an experiment to demonstrate the effectiveness of this particular restoration scheme. Information gathered would be useful for future restoration efforts, by providing examples of strategies that succeed, and the methodologies necessary to follow those. In addition, information gathered would also record failed strategies, and help future projects avoid repetition of mistakes. Extensive monitoring is key to providing valuable information on the success of projects.

## 7.3 Monitoring at RIM Park

Whether or not a restoration project is attempted at RIM Park, monitoring should continue in order to determine the success or failure of the measures taken, and the changing conditions of the wetland (Grayson et al., 1999). This soon after the park development, it is very difficult to determine, with any certainty, the condition of the ecosystem. However, the choice of indicators should be re-examined by a panel of experts, and previous monitoring reports should be included in this analysis. The consistent lack of frogs should be noted.

A more thorough investigation of resident wildlife prior to park development would have been of great assistance. Through this, the sizes and health of populations naturally living in the area would have been revealed for future comparisons. Future projects should ensure this step is given more attention.

Continued monitoring of the park may reveal increasing numbers of amphibians. Long term monitoring is required to get an accurate picture of the situation (Marsh, 2001). The limited timeframe of this study does not reveal the necessary information to make an accurate assessment of the frog populations. Results indicated that “year” was a significant factor in frog population sizes. Populations can change drastically year to year. Monitoring changes in populations may reveal necessary management actions. For example, if the amphibian populations increase, and the amount of road kill subsequently increases, installing wildlife barriers may become more important.

Monitoring techniques should be revisited. The habitat suitability and the community composition should be routinely examined, instead of just audio estimates of animal numbers. A more detailed assessment of the amphibian populations, using a variety of techniques could also reveal much more information (Marsh, 2001). Current audio techniques are probably not providing much useful information about many of the species, other than whether or not they are present. Frogs may be much more abundant than is observed in the monitoring reports, as call counts seem to underestimate the frogs present.

Future monitoring reports should not rely on anecdotal observations from previous reports. Previous anecdotal indications that the area is important for amphibians should not be the basis for an analysis of the current situation. This has led to assumptions, such as that poor weather has inhibited frog breeding in every year. These types of assumptions can lead to flawed conclusions about the cause of problems, and a lack of adaptive management.

## 7.4 Amphibian Monitoring

Frog monitoring has been performed by a number of different people using a variety of techniques. In my experience, techniques vary in their usefulness. Audio methods, which are cheap, quick, and simple to perform, appear to be dominant in research.

After spending a great deal of time observing the Northern Leopard Frogs, in areas where they were abundant, I noticed they were calling very infrequently. At the storm water management pond, where a large number of Northern Leopard Frogs were captured, Leopard Frogs calls were never heard. It would be difficult to determine any sort of accurate information about Leopard Frogs (other than presence) from listening to calls. Other species, such as Spring Peepers and American Toads seem to call more consistently, and audio surveys may be an appropriate method if studying those species.

In addition, amphibian monitoring should be long-term in nature. There are natural fluctuations in frog populations (Marsh, 2001), as well as cycles of weather and appropriate conditions. These fluctuations mean that short term studies do not provide an adequate picture of the integrity of the frog population. In one study, Skelly et al. (2003) found that resurvey methods for identifying a decline in a population are very sensitive to duration of the study. A longer study revealed significantly less of a decline than a shorter study. If I had only examined RIM Park for one year, 2005, I would have concluded there were no Northern Leopard Frogs inhabiting the area of interest at RIM Park. In a study such as mine, the short term has revealed some interesting observations, but little in the way of firm conclusions.

Finally, amphibian monitoring should be used in conjunction with other factors. An examination of the entire habitat and community can reveal much more about ecological integrity than the examination of a single indicator species. Indicator species are useful, but much more so when used in conjunction with other indicators and a broad array of analyses. Individually, they are subject to a large host of variables. A larger view of the landscape will address the needs of a number of species, and give a longer-term view of ecological integrity.

## 7.5 Urban Parks

Urban parks clearly hold a great deal of potential for increasing the amount of available habitat for animals in urban settings. These parks, however, must be managed with great care. Managers have an important responsibility and a significant challenge when it comes to attempting to manage parks for multiple uses. They are responsible for finding a compromise between recreation and ecological integrity that is not easy to establish.

To begin with, values to be attached to the park must be established early in the process and involve the public and a wide variety of stakeholders. The values clearly guide the way it will be designed, used and managed, and determine park priorities. When the public becomes involved, local individuals will take more interest in using, caring for and supporting conservation and restoration projects. When people begin to understand the importance of conservation and restoration, they are more likely to follow rules, donate money and support local projects. It has been shown that expert views of a park and user views differ in many ways. Although the public may be attached to a space, they may not understand ecological processes, and the necessity of certain actions. Attachment and understanding can be built through experience and education (Ryan, 2005).

Compromises may be made, but certain priorities (such as the maintenance and restoration of ecological integrity), which may be overshadowed by public desires (such as recreational facilities), should not be compromised. Ecological integrity should be a priority over recreation, as these areas are often the last available refuge for species trying to survive in an urban setting. These priorities should be clear and easy to defend, particularly in areas that are identified as Provincially Significant.

Connectedness is also important to consider. Often, parks or park components are managed independently of each other, when really they should be well connected to provide corridors for migration between sites. This migration allows movement between seasonal habitats, allows the exchange of genetic material between populations, and gives animals the opportunity to escape from unfavourable or dangerous situations. RIM Park's design included analyses of and attempts to facilitate animal movement.

Another important factor in urban parks is to promote active restoration over passive conservation in urban environments whenever possible. Urban areas are often simply too degraded for conservation to serve any ecological purpose. An active approach to restoration can give an ecosystem the boost it needs to re-establish both structure and function. A focus on restoration takes dedication and resources, but will be extremely beneficial in the long run.

Consistent and thorough monitoring of restoration projects, before, during and after development is critical. This is the only way to increase the bank of practical restoration knowledge acquired in the world. Monitoring is the key to understanding success, and adapting to possible problems that may arise during the process. Monitoring can also lead to more accurate reporting, and fewer wasted resources. There are methods being developed for monitoring for the success of restoration done within urban parks (Cornelis & Hermy, 2004; Hermy & Cornelis, 2000).

Fundamentally, a flexible design and adaptive management approach are critical in the creation of a park so that it can withstand both disasters and gradual changes in the world. Without an adaptive strategy, even carefully restored areas can easily degrade due to unexpected circumstances. Every restoration project should be treated as an experiment, and the design process should be recursive (Gross & Hoffmann-Riem, 2005).

Finally, it is critical that park planners and managers be realistic with expectations and honest with the public. Restoration does not happen in an instant. It takes time and dedication for a project to pay off. It can be difficult for the public to understand this concept, so interpretational materials and other educational opportunities should be provided. In addition, while recreational features such as golf courses provide some opportunity for ecological features, they are not necessarily good habitats, and can be harmful to resident wildlife. The public needs to understand that ecological compromises are being made for their recreational desires. Once they understand these compromises, they may be more willing to make sacrifices for the greater ecological good.

## 7.6 Conclusions

Urban parks are a growing necessity in today's world of increasing urban development. They provide animals living in urban environments with some form of usable habitat. Humans also need these spaces as refuges from the urban commotion, as well as for recreation and overall public health. Park design can be a difficult task, as planners must incorporate the desires and needs of many different groups in a community, as well as preserving natural spaces and habitats for animals in urban environments.

This study focused on one park in particular: RIM Park, in Waterloo, Ontario. This park has many positive features. It is a place that many people of different ages, interests and backgrounds use frequently for a variety of recreational activities. Positive steps have been taken in the areas of conservation and in the monitoring of indicator species. They include the provision of breeding ponds for amphibians and the inclusion of pathways to encourage safe amphibian migration. In addition, park managers have implemented regular yearly ecological monitoring of a number of species that use the park. On the other hand, the compromises involved in the building of the park, including the addition of the golf course and the nature trails are interfering with the full ecological potential of the area. For example, as noted earlier, the golf course and nature trails cut off significantly sized breeding areas from migration routes.

When wetland ecosystems occur in urban settings, it is important that all components of the ecosystem are protected. Amphibians are particularly vulnerable in urban settings, where they are susceptible to problems such as fragmentation and pollution. Amphibians make good indicators of wetland integrity, and can identify the success or failure of a wetland to meet habitat standards for an array of species. In RIM Park, Northern Leopard Frogs must deal with cut-off migration routes, pesticides, low habitat quality, and extremely variable conditions, despite efforts to reduce some of these effects.

In years that have a sufficient amount of rainfall, such as 2006, the built herpetofauna ponds at the park are home to a number of amphibian species. In these years, Northern Leopard Frogs seem to be using these ponds as a summer habitat, but probably not for breeding. In dry years, the ponds provide no benefits to any amphibians. Very few amphibians have ever been seen near the culverts in the Western Throat area, even in wet years. In addition, the Eastern Throat appears to be home to few amphibians. Measures taken at these areas to help conserve amphibians are going to waste. Consulting reports have provided little helpful information regarding the condition of the amphibians in these areas, and consistently blame the weather, rather than the habitat suitability, for low numbers of amphibians.

Habitat suitability combined with weather condition appears to determine the usefulness of the ponds at RIM Park as a breeding habitat in any particular year. If weather conditions consistently dry out the ponds, the pond construction needs to be altered to provide permanent habitats. Yearly consulting reports, as well as my two years of field work have indicated the presence of certain amphibians in some years, but do not provide any evidence of sustainable populations. It is difficult at this point to determine whether there is a minimum viable population of any amphibian species at RIM Park. Thorough, long-term monitoring would be necessary to find this information.

This study has provided some interesting observations, but few firm conclusions. It raises a number of related significant questions that would be worthy of further examination. For example, the park appears to be much more useful to a number of other, more tolerant amphibian species, such as Spring Peepers and American Toads than it is to Northern Leopard Frogs. Are these sustainable populations? Long term monitoring of indicator species, as well as of community composition and habitat integrity would assist in determining the success of the project, and whether changes need to be made. The golf course continues to use pesticides. Are these having a detrimental effect on frog populations? Are these pesticides combining with the predation factor to increase mortality, as suggested by Relyea (2003)? Water analyses and the effects of the pesticide treatments on local frogs should be examined. A more thorough study of Northern Leopard Frogs, which would involve tagging and tracking them, would help determine where and when they visit particular areas of the park. Which areas of the park are most important to the frogs, and are they capable of migrating to proper breeding grounds and upland terrestrial habitats? How are levels of competition and predation affecting the frogs in the park? These are only a few of the questions about RIM Park's amphibian populations that this study raises. The answers to these questions would help us to better understand the condition of the amphibians in the park, and the ecological condition that they represent.

RIM Park was designed as a compromise between recreational use and environmental protection. While emphasizing the positive features of the development, the harmful effects of the inclusion of recreational activities and their maintenance have been given little attention, or at least attention in the wrong direction. For the managers at RIM Park to truly take an environmental leadership role, serious restoration efforts within this area of the park should be considered. Ponds need to be larger and better connected. This would likely require a reconfiguration of the golf course and restructuring of the trail system. A large functioning wetland system in this area would provide a good opportunity for restoration research and for community education as well as serve as a good example of responsible environmental stewardship. The building of a suitable amphibian habitat is not a simple process. On top of factors such as landscape configuration, hydrology and plant assemblages which are relatively simple to manipulate, other complex and unpredictable factors such as climate change, competition and predation can play a role. As many factors as possible should be incorporated into the design.

Whether or not a restoration project is initiated, monitoring programs are critical in order to identify possible problems, and further understand the success or failure of the project (Grayson et al., 1999). Monitoring programs should involve a diversity of indicators and habitat observations. While frogs are important indicators of wetland function and integrity, they can not provide all of the necessary information.

This sort of development is a learning process, and the city has provided opportunities for study and recursive learning. This park reveals important information to assist in the design and management of future urban parks. As we learn more about our natural environment, it becomes clear that instead of building wetlands and animal habitats around urban development, we should be building urban environments to accommodate existing wetlands and other natural features. Natural features can never be reconstructed perfectly and restoration projects take a very long time to establish. If this perspective becomes dominant, it may be possible to maintain these valuable ecosystems and their resident species as a lasting legacy. As our cities continue to grow, and our green spaces become more and more limited, it is our responsibility to learn how to make educated decisions about how to protect and rehabilitate natural features.

Urban environmental studies such as this one provide a new perspective on ecological research. While a great deal is known about pristine environments, the field of urban ecology is in dire need of a greater knowledge base. Historically, urban planning has tended to focus on the human aspects of city life to the detriment of the ecological functions of the natural environment. This is now changing. This study, which uses a transdisciplinary approach, is one example of an emerging field that recognizes the necessary interrelationship between the biophysical and social systems, by examining the importance of wetland ecosystems within the urban environment. To some, amphibians living in urban settings may appear to play a minor role, but they really represent the integrity of the network of wetlands throughout our communities.

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