Butterfly Abundance and Diversity Along an Urban Gradient in the Region of Waterloo, Ontario, Canada

by

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AUTHORS DECLARATION

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.

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

ABSTRACT

Conservation biologists often use biological indicators to measure and monitor changes in biological diversity. This study examines butterflies as indicators using a gradient-based study approach. The urban gradient was characterized by Environmentally Sensitive Policy Areas (ESPAs), urban parks, golf courses, residential areas, and industrial areas. This thesis has been divided into two separate chapters.

Chapter 1 summarizes an extensive review of existing data on butterfly presence/absence in the Region of Waterloo to determine what species are relatively uncommon or rare in the Region and examine how butterfly presence/absence has changed over the last 80 year. Each butterfly species that occurs in the region was assigned a regional status which resulted in the identification of 46 uncommon and rare species.

Chapter 2 examines changes in butterfly abundance and diversity along a gradient of urbanization to determine how different land uses are potential affecting butterfly communities. Transects, 500 meters in length, were established at fifteen sites, each of which represented a land use within the urban gradient identified. Each transect was walked once a week for a total of 28 weeks over two years (2009 and 2010). Overall butterfly richness was observed to be highest within ESPAs, followed by urban parks and industrial areas and lowest within golf courses and residential areas. Shannon diversity scores were compared using a Kruskal Wallis test and indicated that species richness and evenness was significantly different between ESPAs and urban parks and compared to the remaining land uses, while species richness and evenness was not significantly different among residential areas, golf courses, and industrial areas in either 2009 or 2010. Significant differences in species richness and evenness was observed across the same land uses in 2009 and 2010 for all types except residential areas. Overall butterfly abundance was observed to be highest in industrial areas and lowest within golf courses and residential areas, a trend which was observed in both 2009 and 2010. Abundance was observed to be heavily influenced by counts of two non native species- the cabbage white (*Pieris rapae*) and European Skipper (*Thymelicus lineola*). ESPAs were identified as 1) supporting the most diverse butterfly community out of the 5 land uses examined and 2) providing habitat for the highest number of rare and uncommon species, indicating that current regional policies in place for protecting rare species are effective.

Through an extensive literature review it was concluded that butterflies are effective indicators in temperate regions within a small geographic area such as the Region of Waterloo. Therefore it is expected that the results of this study indicate how other terrestrial taxonomic groups, which are known to show a similar response to urbanized land uses, may be impacted by urbanization in the Region. It is anticipated that the results of this study may be used to guide urban land use planning as it identifies rare and uncommon butterfly species within the region as well as what land uses need habitat enhancement to support more diverse communities.

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INTRODUCTION

During urban land use planning, identifying and monitoring significant natural features and rare species can be expensive and time consuming. Consequently, conservation biologists often use biological indicators to measure and monitor changes in biological diversity. The use of select indicators to monitor or assess environmental conditions has become an established practice in a variety of scientific disciplines including ecology, environmental toxicology, pollution control, forestry, and wildlife management (Noss 1990). Within these disciplines indicators have been used to evaluate ecosystem health, toxicity levels, resource availability, the status of select taxa, and endemism (Hilty and Merenlender 2000). This approach is based on the premise that monitoring changes in the richness and abundance of selected taxa within a community has the potential to indicate changes occurring in the overall community. This information can then be used to guide conservation management decisions and land-use planning.

The type of indicator taxa examined is varied in the literature and includes birds (Morrison 1986; Temple and Wiens 1989; Gregory et al. 2003), mammals (Talmage and Walton 1991), herpetefauna (Lambert 1996; Hager 1998), insects (Pollard and Yates 1993; McGeoch 1997; Oostermeijer and Swaay 1998; Thomas 2005) and other invertebrates (Allred 1975; Rinderhagen et al. 2000) or a combination of multiple taxa (Pearman and Weber 2007; Lawler et al. 2003; Chase et al. 2001). The selection of which indicator taxa is appropriate for a given study depends on the research question being explored, the resources available, and the geographic location of study. Because they comprise more than half of all known species on the planet, insects are often a good choice, and unlike many groups of insects, butterflies (part of the order Lepidoptera) are well-known by amateurs and experts and highly visible in nature (Walpole and Sheldon 1999). Butterflies are recognized as useful indicators, both for their rapid and sensitive responses to subtle habitat or climatic changes (UKBMS 2006). In the United Kingdom (UK), researchers began monitoring butterfly abundance and diversity to detect changes in the environment in the mid 1970's (Pollard et al. 1975). The Butterfly Monitoring Scheme coordinated by the Centre for Ecology and Hydrology and Joint Nature Conservation Committee involved recorders (mostly volunteers) counting butterflies along fixed transect routes based on the methodology first outlined by Pollard et al. (1977) and subsequently refined by Pollard and Yates (1993).

This study examines butterflies as indicators using a gradient-based study approach. Ecologists have successfully studied a variety of natural gradients such as soil moisture, elevation, and salinity to understand the relationship between environmental variation and the structure and function of ecological systems (McDonnell et al. 1997). Some research suggests that this gradient paradigm also applies to urban environments (McDonnell and Pickett 1990; McDonnell et al. 1993; McDonnell et al. 1997). Human alteration of the landscape along urban to rural gradients provides an opportunity to address questions at different spatial scales. This view assumes that variation is ordered in space and that spatial ecological patterns correspond to the ecological structure and function of a given system (McDonnell and Pickett 1990). The gradient often appears as a dense, highly developed core surrounded by a succession of less dense, less developed areas moving outward toward rural areas. The study of selected taxa along urban to rural gradients has been undertaken in many ecological studies (Ruszczyk and De Araujo 1993; Blair and Launer 1997; McDonell et al. 1997; Blair 1999; Germaine and Wakeling 2000; Jokimäki and Huhta 2000; Alaruikka et al. 2002; Hogsden and Hutchinson 2004). This type of study provides researchers with an opportunity to explain or predict the ecological effects of different land uses on these taxa (McDonnell and Pickett 1990).

A suite of characteristics are required for a taxonomic group to be effective as a biological indicator (Noss 1990; Karr 1991; Stork et al. 1997; Lorenz et al. 1999; Dale and Beyler 2001). Butterflies effectively meet these criteria in the following ways:

1. *Butterflies are sufficiently sensitive to provide an early warning of environmental change.*

   Some research has found butterfly communities to be sensitive to even small, local habitat disturbances due to high habitat specificity (Spitzer et al. 1997). They are tied closely to the diversity and health of their habitats and can require different habitat types for mating, breeding, nectaring, and oviposition (Wiklund 1984). This is because for many species, larvae are extremely dependant on one specific host plant or a narrow range of plants within a specific genus and adults can be important pollinators for specific nectar plants (Ehrlich and Raven 1964; Sparrow et al. 1994). These sensitivities imply that butterflies offer the opportunity to provide an early warning of changes within a system.

2. *Butterflies are distributed over a wide geographical area.*

   Butterflies occur on every continent except Antarctica, so they can be studied just about anywhere (Layberry et al. 1998). There are 780 species of butterfly known to occur in North America not including Mexico (Opler and Warren 2003), 300 of these species occur within Canada (Hall 2009).

3. *Butterflies are capable of providing a continuous assessment of changes in the environment over a wide range of stresses.*

   Landscape features such as patch size, heterogeneity, and connectivity can be major controllers of species composition and abundance, and thus population viability, for sensitive species such as butterflies (Noss and Harris 1986). It has been observed that consistency in environmental conditions is important to the persistence of butterfly populations (Murphy and Weiss 1988). Southern Ontario is home to Canada's richest butterfly fauna, which includes species with habitat requirements ranging from generalist to quite specialist. This range in habitat requirements enables the examination of butterfly communities to occur over a wide range of anthropogenic stresses.

4. *Butterflies provide coverage of the key gradients across ecological systems (e.g. soils, vegetation types, temperature, etc.).*

   Butterflies are extremely sensitive to changes in temperature, humidity, and light levels, which are typically the results of habitat disturbance (Sparrow et al. 1994). They are also affected by rainfall patterns and local microclimates (Murphy and Weiss 1988). They require certain structural elements for orientation or basking and therefore are expected to show a strong response to changes in vegetation at a given site (Oostermeijer and van Sway 1998). Furthermore, changes in ground-level thermal conditions due to changes in vegetation structure affect the development rates of both butterflies and their host plants (Murphy and Weiss 1988).

5. *Butterflies are cost effective to measure.*
   Minimal equipment and man-power is required to monitor butterflies. In similar studies, researchers have found that butterflies are much easier to observe and take less time to survey than other indicators (Blair 1999).

6. *Studying butterflies provides the ability to distinguish between natural cycles or trends and those induced by anthropogenic stress.*
   Butterflies have been studied for hundreds of years and their life histories are generally well known (Scott 1986). There are two relatively recent publications that detail the life histories of Canadian butterflies as well as general population trends (Layberry et al. 1998; Hall 2009).

While the use of indicators has become widely employed in a variety of ecosystem studies, the appropriateness of this approach has been questioned (Hilty and Merenlender 2000). Criticisms of the indicator approach include the difficulties in differentiating between non-human and human induced impacts on indicator taxa, ambiguous assumptions about the ability of indicator taxa to accurately represent ecosystem trends, vague guidelines for data collection, and conflicts between the use of rare or common species as indicators (Landres et al. 1988; Pearman et al. 1995; Simberloff 1998; Pearman and Weber 2007). These criticisms are valid when researchers attempt to answer complicated questions about ecosystem functioning based on the response of one indicator. Using butterflies as indicators for this study is centered on the hypothesis that based on the criteria outlined above, collecting detailed baseline data on butterfly abundance and diversity at a given site will allow for general conclusions on terrestrial species diversity to be made on a regional scale. This is centered on the idea these general conclusions can then be used to guide decisions about additional study requirements and land use planning. It is hypothesized that butterflies will be valuable as indicators by which an area that is species-rich in butterflies will be species-rich in general, thus contributing to conservation of unknown or less represented species (Faith and Walker 1996).

This thesis is divided into two separate chapters written as manuscripts[1]. Each chapter begins with an introduction which presents a research question. The following sections in each chapter detail the methods used to examine each research question,

[1] As per the University regulations allowing this format

the results obtained, and a discussion of how effectively each research question was answered through the methods presented. Chapter 1 summarizes an extensive review of existing data on butterfly presence/absence in the Region of Waterloo to determine the proportional abundance of individual species and assign each species a regional status. Chapter 2 examines changes in butterfly abundance and diversity along a gradient of urbanization to determine how different land uses are affecting butterfly communities. These two chapters are followed by a conclusions section which summarizes the research presented, identifies gaps which could be filled by future work, and examines the use of butterflies as indicators of overall biodiversity. This examination of butterflies as indicators is presented in an attempt to draw conclusions about the overall effects of urbanization on species assemblages within the Region and provide valuable information to guide land use planning and management. The paper is organized this way in order to effectively answer the following research questions:

1. What species of butterfly are uncommon or rare within the Region? How has their presence/absence changed over the last 80 years?
2. How do different land uses affect butterfly abundance and diversity?
3. What does butterfly abundance and diversity indicate about overall biodiversity in different parts of the Region?
4. Are current regional environmental policies effective in protecting and preserving rare species and/or overall species diversity?

Chapter 1: The Butterflies of Waterloo Region

INTRODUCTION

The Region of Waterloo is located in southwestern Ontario, Canada and encompasses seven municipalities: Kitchener, Waterloo, Cambridge, and the Townships of Wilmot, Wellesley, Woolwich and North Dumfries (Figure 1). With a population of approximately 478, 000 people, the Region has consistently ranked as one of the fastest growing communities in Canada since its formation (Region of Waterloo 2006a). From 2001 to 2006, the Region's population has increased by approximately 9% and it is now the 10th largest urban area in Canada and the 4th largest in Ontario (Region of Waterloo 2006a). Residential development continues to grow faster than the population due to declines in family size, however the population is still expected to exceed half a million people by the year 2016 (Region of Waterloo 2006a). These trends in rapid urbanization make the Region of Waterloo an ideal location to examine the effects of urban development on biodiversity.

The Region of Waterloo was formed in 1973 from the County of Waterloo and a section of the former County of Wentworth (Region of Waterloo 2006a). Following European settlement in the early 1800's, the area that became the Region of Waterloo was cleared for agriculture. Currently, land use within the Region is still dominated by agriculture, which now surrounds urban centres. In 2006, agriculture represented 65% of land use activities in the Region with Woolwich Township accounting for almost one third of all farm land (Region of Waterloo 2006b). Urban centres include the Cities of Kitchener, Waterloo, and Cambridge, which collectively represent approximately 21.4% of land in the Region (C. Rumig pers. comm. 2010). Natural habitats have been preserved within 80 Environmentally Sensitive Policy Areas (ESPA), designated in the Region of Waterloo's Official Policies Plan, which stipulates that some types of development are prohibited within these areas (Region of Waterloo 2006c). ESPAs represent approximately 4.9% of land within the Region (C. Rumig pers. comm. 2010). The remaining 8.7% of land area within the region is represented by a variety of land uses including rural residential, natural habitats on private lands, city-owned natural areas, aggregate extraction, and recreational areas such as golf courses outside the urban boundary.

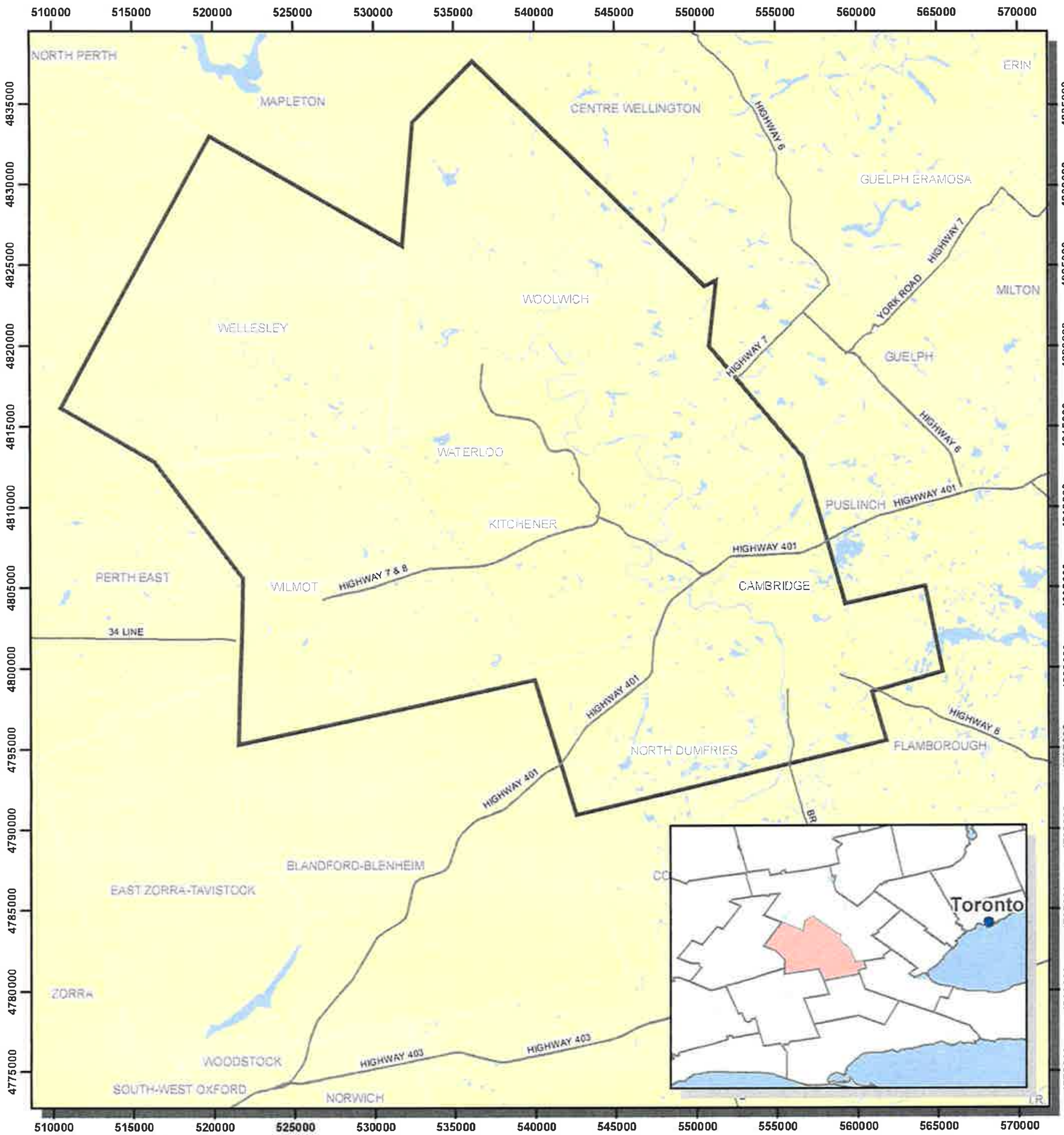
The rapid urbanization occurring in Waterloo Region is consistent with world trends. For example, by 2025 it is predicted that 60% of the world's population will be living in urban centres (University of Michigan 2002). This rapid increase in urbanization will increase detrimental impacts on the natural environment and existing biodiversity. Unlike many other types of habitat loss, urbanization is often more lasting and tends to expand continually (McKinney 2002).

Currently, species lists exist for regionally rare plants, breeding birds, and herpetofauna for the Region of Waterloo (Region of Waterloo 1985, Martin 1996 and Richardson and Martin 1999). These lists provide a reference for interested individuals or parties, including consultants, the Grand River Conservation Authority (GRCA), city staff, and the Regional Ecological and Environmental Advisory Committee (EEAC), to refer to when managing/restoring habitats or conducting environmental impact assessments.

Until now, information on regional butterfly communities has been inaccessible and thus it has not been able to be included during land use planning. In nearby regions, regional statuses have been assigned to a much greater diversity of taxonomic groups, including butterflies, dragonflies and damselflies (City of Guelph 2009; Wormington 2003; Wormington and Lammond 2006). This chapter provides an overview of butterfly presence/absence data collected for the Region of Waterloo in order to assign a regional status to individual species and answer the following research questions:

1. What species of butterfly are uncommon or rare within the Region?
2. How has their presence/absence changed over the last 80 or so years?

Answering these questions is essential to understanding how the regional butterfly community has changed over time and sets the context for the following chapters.



NRSI_Promo_WaterlooRegionMap_350K_2010_11_12_SWM

Figure 1

The Region of Waterloo

Legend

- Highway
- Region of Waterloo
- Township Boundary
- Major Urban Area
- Waterbody

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

Map Produced by Natural Resource Solutions Inc. This map is proprietary and confidential and must not be duplicated or distributed by any means without express written permission of NRSI. Source: Data provided by MNR © Copyright: Queen's Printer Ontario

Project: Waterloo Region
Date: November 12, 2010
NAD83 - UTM Zone 17
Scale 1:350,000 (11x17")

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METHODS

Record Compilation

The majority of records that were collected are in the form of presence/absence data from the last 80 years. This time period was chosen based on the earliest records for the Region, which date back to July 1929 according to available archives and interviews with local experts. These included the following sources[2]:

- Toronto Entomologist Association (Lepidoptera Summaries 1969-2002);
- Natural Heritage Information Centre (NHIC 2010);
- Canadian Biodiversity Information Facility (Government of Canada 2003);
- E.L. James Collection at the University of Waterloo;
- University of Guelph Insect Collection;
- Canadian National Insect Collection records (Government of Canada 2003);
- Royal Ontario Museum Collection records (Government of Canada 2003);
- Private collection of Lawrence Lamb;
- Waterloo County Butterfly Checklist (Lamb 1967);
- Private collection of Dr. John K. Morton;
- Private collection and field notes of Frank Stricker;
- Field notes, private collection, and various papers by Craig Campbell;
- Annual monitoring data from the rare Charitable Research Reserve (Grealey 2006; Moore 2009 and 2010);
- North American Butterfly Association (NABA) Cambridge Butterfly Count data (Grealey & Lamb 2006-2010);
- Field notes and personal observations of the author.

The most extensive set of data came from Frank Stricker's meticulously detailed collection and field notes from 1929 through to the 1990s. Collections and field notes, particularly those of Lawrence Lamb and Craig Campbell, were also an extremely valuable source of information. Public insect collections examined at the University of Guelph, the University of Waterloo, and the Canadian Insect Collection provided limited and sporadic data.

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[2] The Nature Conservancy of Canada and the North American Lepidopterist Society were unable to provide any records from the Region of Waterloo. A request for information was announced at a local Kitchener-Waterloo Field Naturalist's meeting (October 2008), which did not result in any additional records.

Interviews were conducted with local naturalists who provided local knowledge about regional butterflies. Frank Stricker is a local naturalist and amateur Lepidopterist who began collecting butterflies and moths in 1929 in the Region of Waterloo and kept meticulously detailed records of all specimens observed and collected from that time until about 1990. Craig Campbell is a well-respected local naturalist and amateur Lepidopterist who started keeping butterfly records in the 1950's. Lawrence Lamb is a local naturalist who retired as the Manager of the University of Waterloo's Ecology Lab in 2009. He started keeping butterfly records in the early 1960's and in 1967 he authored a checklist of Waterloo County's butterflies (Lamb 1967). Frank Stricker, Craig Campbell and Lawrence Lamb assisted in identifying general trends in butterfly communities observed in over the past 40 or so years. Dr. J.K. Morton is a retired professor from the University of Waterloo's biology department. Dr. Morton has an extensive collection of Lepidoptera which consists mostly of moths however it also contains a few drawers of butterflies. Dr. Morton was helpful in identifying several areas within the region where he has observed and/or collected rare or uncommon species.

In 2006, an annual North American Butterfly Association (NABA) count was established at the *rare* Charitable Research Reserve in Cambridge, organized by myself and Lawrence Lamb. These counts occur annually in July and involve local experts and volunteers conducting area searches of the reserve and recording all the butterflies observed. These counts have been particularly useful in identifying small colonies of inconspicuous species. Furthermore, two butterfly monitoring transects were established at the reserve in 2006 and they were monitored weekly to record species diversity and abundance (Grealey 2006). A third transect was added to the reserve in 2009 and a fourth in 2010 by Charlotte Moore at the University of Waterloo. Charlotte Moore conducted weekly surveys along all of the established transects in 2009 and 2010. All monitoring transects referred to were established using a modification of the methods outlined by Pollard & Yates (1993) which involves a combination of transect walks and point counts.

Status Definitions

Each species was assigned a regional status based on the number and distribution of known sites within the Region (Table 1). For consistency, these methods are based on similar undertakings in the nearby Regions of Hamilton (Wormington and Lamond

2003) and Halton (Wormington 2006)[3]. The thresholds identified for assigning regional statuses are subjective and were determined at the discretion of the author with input from local experts (A. Wormington pers. comm. 2010; L. Lamb pers. comm. 2010; C. Campbell pers. comm. 2010). Some modifications from the methods used in Hamilton and Halton were employed to account for differences in the data sets. This included using an additional status of ‘very common’ to account for species that were known from comparatively more sites and are frequently observed throughout the region. A ‘site’ is defined as a location that is separated from any other site by at least 1 kilometer (Wormington and Lamond 2003; Wormington 2006). In addition to this modification in terms of the number of known sites, I also modified the methodology by considering the following information when assigning a regional status:

- Published life history and distribution information (Layberry et al. 1998; Hall 2009);
- current status in Ontario (NHIC 2010);
- last known observation date; and
- status information available for nearby localities (Wormington and Lamond 2003; Wormington 2006).

Table 1. Regional Status Definitions.

Regional Status	**Definition**
Very Common	Known from 30 or more sites.
Common	Known from 20-29 sites.
Uncommon	Known from 11-19 sites.
Rare	Known from 10 or less sites.
Extirpated	Formally a resident, but is currently not known to occupy any sites within the Region.

I also determined whether each species was resident or not to make a distinction between which species live permanently in the Region and overwinter here, and those that migrate through the area and do not overwinter here (Table 2).

For the purposes of this study ‘generalists’ are species which occur in a variety of habitat types including disturbed areas. The larvae of generalist species will feed on several different plants, often represented by several genera or plants that are widespread and abundant in a variety of habitats. ‘Specialists’ are defined as species

[3] It is recognized that the City of Guelph has a regional butterfly list, however this list is self-described as preliminary and was therefore excluded from comparison (City of Guelph 2009).

that occur within a specific habitat type and are unlikely to occur in disturbed areas. Their larvae will usually have one or more specific foodplants represented by the same genus or family. Butterflies which are known specialists are indicated as such in Table 3 (Layberry et al. 1998; Hall 2009).

Table 2. Definitions for Butterfly Residency in the Region of Waterloo

Status	Definition
Permanent Resident	Long-term populations are present and species is known to overwinter in the region.
Temporary Resident	Long-term populations do not exist; however the species will overwinter and set up temporary colonies.
Former Resident (Extirpated)	A species was formally known to be a resident but is not longer found within the region.
Immigrant	A species that is not capable of overwintering in the region but migrates here from another area. Generally these species do not reproduce because larval food plants are scare or absent. Some immigrants arrive annually whereas others only appear sporadically.
Seasonal Colonist	A species that migrates to the region and successfully reproduces, however they cannot overwinter here.

Supplemental Site Checks

Specific field checks were conducted for mustard white (*Pieris oleracea*) and west Virginia white (*Pieris virginiensis*), which were formerly quite abundant in the Region but now appear to be absent (L. Lamb pers. comm. 2010; C. Campbell pers. comm. 2010). These species formerly occupied the following sites that still exist: Homer Watson Park, Roseville Swamp, Schaefer's Woods, and some remnant forest pockets in the Frederick Street, Kitchener area. These species are known to be on the wing in late April and throughout May in Southern Ontario (Layberry et al. 1998). Site checks were conducted during known flight times for these species in the Region (e.g. dated specimens collected by Frank Stricker, Larry Lamb, and Craig Campbell) on April 20, 2010 and May 4, 2010. This included area searches for these species and their larval foodplants (*Arabis* spp. and *Dentaria* spp.).

Authoritative Source for Scientific Names

The scientific butterfly names used throughout this paper are based on the *Scientific Names List for Butterfly Species, North of Mexico* (Opler and Warren 2003).

The first time a species is referred to, both the common name and scientific name are provided. Only scientific names are used thereafter.

RESULTS

The dataset collected included 4,433 records. Generally, the dataset indicates that butterfly collecting and record keeping in the Region of Waterloo has declined since the early 1980's. Prior to 1980 there were a number of individuals who regularly went out to observe and collect butterflies. As these individuals grew older and/or moved out of the Region it appears that no new individuals began observing or collecting. There is a noticeable data gap between 1998 and the early 2000s. The limited records collected between 1990 and 2005 were those that were reported to the Toronto Entomologist's Association annual Lepidoptera summaries and a few scattered collections by local naturalists (F. Stricker, J.K. Morton, and L. Lamb).

The annual NABA counts and transect monitoring at the *rare* Charitable Research Reserve, in combination with the transect monitoring completed for this study across the Region (detailed in Chapter 2), have provided a valuable source of more recent records that have allowed a comparison of species presence/absence in the Region between 1929 and 2010.

Although the records collected do not necessarily provide information about butterfly abundance for particular species in the Region, they provide an excellent source of presence/absence data and general regional distribution. These data were compared to determine how overall diversity has changed over time within the Region. These records in conjunction with consultation with local experts allowed for a qualitative analysis of butterfly community changes and trends. Generally, populations of permanent residents tend to occupy the same areas year after year although their relative abundance may fluctuate due to environmental stresses or changes in the landscape. Populations of immigrant species tend to fluctuate much more considerably from year to year. This trend was observed between 2009 and 2010 when extreme differences in average temperature and precipitation resulted in a large difference in the abundance of immigrants observed (J. Grealey pers. obs.).

Three hundred butterfly species are known to occur in Canada (Hall 2009). Over one third of these species have been documented in the Region of Waterloo (102 species), and 65 have been confirmed to be present within the last 5 years. Twenty-one butterfly species were assigned a regional status of ‘very common.’ These species, which included permanent residents and seasonal colonists, have been observed at 30 or more sites across the region and have been consistently observed over time up until 2010.

Thirteen species of butterfly were assigned a regional status of ‘common.’ These species, also permanent residents and seasonal colonists, have been observed at between 20 and 29 separate sites and all but one species, the white admiral (*Limenitis arthemis arthemis*), have been consistently observed over time until 2010. Based on the recent decline in observations apparent through the records review and discussions with local experts (L. Lamb and C. Campbell), the white admiral was assigned a regional status of ‘uncommon.’ Another eighteen permanent residents and one immigrant were assigned a regional status of ‘uncommon.’ The majority of these species were assigned this status based on the number of separate locations where they have been observed (11-19). Two species, the milbert’s tortoiseshell (*Nymphalis milberti*) and grey comma (*Polygonia pronge*), were also assigned a status of ‘uncommon’ despite the fact that they are known from more than 19 sites. This status reassignment was based on the consideration that the vast majority of records for these species were collected prior to the mid-1980’s. In the last 5 years the milbert’s tortoiseshell has only been observed 7 times at four sites and grey comma has only been observed once.

Lastly, 28 butterfly species were assigned a regional status of ‘rare’ permanent residents, seasonal colonists, or immigrants. For the majority of these species (23) this status assignment was based on the number of sites (10 or less). The remaining 5 species, the variegated fritillary (*Euptoieta claudia*), Aphrodite fritillary (*Speyeria Aphrodite*), pink-edged sulhpur (*Colias interior*), meadow fritillary (*Boloria selene*) and Baltimore checkerspot (*Euphydryas phaeton*), were also assigned a status of ‘rare’ due to the historical nature of records for these species. The results of the regional status assignment are included in Table 3. Table 3 also indicates provincial rankings assigned to each species by the Natural Heritage Information Centre (2010)[4], regional residency and which species have been identified as specialists.

[4] These ranks are used by the Natural Heritage Information Centre to set protection priorities for rare species and natural communities but are not legal designations (NHIC 2009).

Table 3. Regional Status Assignment

Family	Species name	Common Name	SRANK[1]	Regional Residency	Regional Status	Specialist[2]
HESPERIIDAE	*Euphyes vestris*	Dun Skipper	S5	PR	Very Common	
	*Thymelicus lineola***	European Skipper	SNA	PR	Very Common	
	Polites peckius	Peck's Skipper	S5	PR	Very Common	
	Poanes viator	Broad-Wing Skipper	S4	PR	Common	√
	Anatrytone logan	Delaware Skipper	S4	PR	Common	
	Poanes hobomok	Hobomok Skipper	S5	PR	Common	√
	Wallengrenia egeremet	Northern Brokendash	S5	PR	Common	
	Polites themistocles	Tawny-edged Skipper	S5	PR	Common	
	Euphyes conspicua	Black Dash	S3	PR	Uncommon	
	Ancyloxypha numitor	Least Skipper	S5	PR	Uncommon	
	Pompeius verna	Little Glassywing	S4	PR	Uncommon	√
	Polites mystic	Long Dash Skipper	S5	PR	Uncommon	
	Epargyreus clarus	Silver-spotted skipper	S4	PR	Uncommon	
	Carterocephalus palaemon	Arctic Skipper	S5	PR	Rare	
	Erynnis lucilus	Columbine Duskywing	S4	PR	Rare	√
	Pholisora catullus	Common Sootywing	S3	PR	Rare	
	Polites origenes	Crossline Skipper	S4	PR	Rare	
	Euphyes dion	Dion Skipper	S3	PR	Rare	√
	Erynnis icelus	Dreamy Duskywing	S5	PR	Rare	
	Hylephila phyleus	Fiery Skipper	SNA	SM	Rare	
	Erynnis juvenalis	Juvenal's Duskywing	S5	PR	Rare	
	Poanes massasoit	Mulberry Wing	S4	PR	Rare	√
	Thorybes pylades	Northern Cloudywing	S5	PR	Rare	√
	Euphyes bimacula	Two-Spotted Skipper	S4	PR	Rare	√
	Erynnis baptisiae	Wild Indigo Duskywing	S4	UN	Unknown	√

LYCAENIDAE	*Lycaena hyllus*	Bronze Copper	S5	PR	Very Common	√
	Celastrina neglecta	Summer Azure	S5	PR	Very Common	
	Celastrina ladon	Spring Azure	S5	PR	Common	
	Satyrium acadica	Acadian Hairstreak	S4	PR	Uncommon	
	Satyrium calanus	Banded Hairstreak	S4	PR	Uncommon	
	Satyrium titus	Coral Hairstreak	S5	PR	Uncommon	
	Cupido comyntas	Eastern Tailed Blue	S5	PR	Uncommon	
	Satyrium liparops strigosum	Striped Hairstreak	S5	PR	Uncommon	
	Lycaena dorcas	Dorcas Copper	S5	PR	Rare	√
	Callophrys niphon	Eastern Pine Elfin	S5	PR	Rare	√
	Satyrium edwardsii	Edward's Hairstreak	S4	PR	Rare	√
	Feniseca tarquinius	Harvester	S4	PR	Rare	√
	Satyrium caryaevorum	Hickory Hairstreak	S3	PR	Rare	
	Lycaena helloides	Purplish Copper	S3	PR	Rare	
NYMPHALIDAE	*Cercyonis pegala*	Common Wood Nymph	S5	PR	Very Common	
	Polygonia comma	Eastern Comma	S5	PR	Very Common	
	Satyrodes eurydice	Eyed Brown	S5	PR	Very Common	
	Speyeria cybele	Great Spangled Fritillary	S5	PR	Very Common	
	Megisto cymela	Little Wood Satyr	S5	PR	Very Common	
	Boloria bellona	Meadow Fritillary	S5	PR	Very Common	
	Danaus plexippus	Monarch	S2N,S4B	SM	Very Common	
	Nymphalis antiopa	Mourning Cloak	S5	PR	Very Common	
	Polygonia interrogationis	Question Mark	S5	SM	Very Common	
	Vanessa atalanta	Red Admiral	S5	SM	Very Common	
	Limenitis archippus	Viceroy	S5	PR	Very Common	
	Vanessa virginiensis	American Lady	S5	SM	Common	

	Coenonympha tullia	Common Ringlet	S5	PR	Common	
	Enodia anthedon	Northern Pearly eye	S5	PR	Common	√
	Vanessa cardui	Painted Lady	S5	SM	Common	
	Phyciodes tharos	Pearl Cresent	S4	PR	Common	
	Limenitis arthemis astyanax	Red-Spotted Purple	S5	PR	Common	
	Limenitis arthemis arthemis	White Admiral	S5	PR	Uncommon	
	Polygonia progne	Grey Comma	S5	PR	Uncommon*	
	Nymphalis milberti	Milbert's Tortoiseshell	S5	PR	Uncommon*	
	Satyrodes appalachia	Appalachian Brown	S4	PR	Uncommon	√
	Junonia coenia	Common Buckeye	SNA	IM	Uncommon	
	Nymphalis vaualbum	Compton Tortoiseshell	S5	PR	Uncommon	
	Phyciodes cocyta	Northern Cresent	S5	PR	Uncommon	
	Asterocampa clyton	Tawny Emperor	S2S3	PR	Uncommon	√
	Euphydryas phaeton	Baltimore Checkerspot	S4	PR	Rare*	√
	Boloria selene	Silver-bordered Fritillary	S5	PR	Rare*	
	Speyeria aphrodite	Aphrodite Fritillary	S5	PR	Rare*	
	Euptoieta claudia	Variegated Fritillary	SNA	IM	Rare*	
	Libytheana carinenta	American Snout	SNA	SM	Rare	√
	Speyeria atlantis	Atlantis Fritillary	S5	PR	Rare	
	Chlosyne nycteis	Silvery Checkerspot	S5	PR	Rare	
	Phyciodes batesii	Tawny Cresent	S4	PR	Rare	√
PAPILIONIDAE	*Papilio polyxenes*	Black Swallowtail	S5	PR	Very Common	
	Papilio glaucus	Eastern Tiger Swallowtail	S5	PR	Very Common	
	Papilio cresphontes	Giant Swallowtail	S3	PR	Uncommon	
PIERIDAE	*Pieris rapae***	Cabbage White	SNA	PR	Very Common	
	Colias philodice	Clouded Sulphur	S5	PR	Very Common	
	Colias eurytheme	Orange Sulphur	S5	PR	Very Common	

	Colias interior	Pink-edged Sulphur	S5	PR	Rare*	√
	Pontia protodice	Checkered White	SNA	SM	Rare	
	Pyrisitia lisa	Little Yellow	SNA	IM	Rare	
	Pieris oleracea	Mustard white	S4	PE	PE	

*Denotes that status was assigned not just in terms of number of sites, but through consideration of the apparent decline of records and discussions with local experts

**Denotes non-native species

[1]NHIC 2010; [2]Based on information in Layberry et al. (1998)

LEGEND

Provincial Rank (SRANK)	**Residency**
S2- Imperiled	PR- Permanent Resident
S3- Vulnerable	SM- Seasonal colonist
S4- Apparently Secure	IM- Immigrant
S5- Secure	PE- Possibly Extirpated
SNA- Not applicable	UN- Unknown

A total of 20 species of butterfly were excluded from the Regional status assignment. This was due to a number of considerations, most notably that all of these species had been observed 5 or fewer times in the Region and all existing records were more than 40 years old. It is possible that some of these records are misidentifications and most are rare strays from their known Canadian range. It most cases specimens were no longer available. These exclusions are presented in Table 4. If observed in the region today, their presence would be considered significant.

Table 4. Butterfly Species Excluded from the Regional Status Assignment.

Family	Species name	Common Name	SRANK[1]	# of Sites	Last year observed
HESPERIIDAE	*Erynnis martialis*	Mottled Duskywing	S2	1	1957
	Hesperia comma	Common Branded Skipper	S4S5	1	1967
	Pyrgus communis	Common Checkered Skipper	SNA	2	1967
	Amblyscirtes vialis	Common Roadside Skipper	S4	2	1967
	Hesperia sassacus	Indian Skipper	S4	1	1950
	Amblyscirtes hegon	Pepper and Salt Skipper	S4	1	1944
	Erynnis brizo	Sleepy Duskywing	S1	5	1967
LYCAENIDAE	*Lycaena phlaeas*	American Copper	S5	1	1957
	Lycaena epixanthe	Bog Copper	S4S5	1	1967
	Strymon melinus	Grey Hairstreak	S4	1	1957
	Callophrys polios	Hoary Elfin	S4	1	1942
NYMPHALIDAE	*Chlosyne harrisii*	Harris' Checkerspot	S4	3	1957
	Speyeria idalia	Regal Fritillary	SNA	4	1952
	Polygonia satyrus	Satyr Comma	S4	2	1970
PAPILIONIDAE	*Battus philenor*	Pipevine Swallowtail	SNA	4	1964
	Papilio trolius	Spicebush Swallowtail	S4	2	1944
	Eurytides marcellus	Zebra Swallowtail	SNA	1	1965
PIERIDAE	*Pieris virginiensis*	West Virginia White	S3	3	1967
	Eurema nicippe	Sleepy Orange	SNA	1	1934
LYCAENIDAE	*Plebejus saepiolus*	Greenish Blue	S4	1	1954

[1]NHIC 2010

LEGEND
Provincial Rank (SRANK)
S1- Critically Imperiled
S2- Imperiled
S3- Vulnerable
S4- Apparently Secure
S5- Secure
SNA- Not applicable

DISCUSSION

This qualitative analysis of butterfly presence/absence data in combination with discussions with local experts has allowed for a preliminary assessment of how butterfly communities have changed over the past 80 years in the Region of Waterloo. There are evident changes in the abundance of several species. Most of these changes have been recorded as overall declines in species presence but in a few cases increases in observations have been documented (Eberlie 1999; C. Campbell pers. comm. 2010; L. Lamb pers. comm. 2010). The methods used to assign a regional status to butterflies resulted in the identification of 47 uncommon or rare species. This is comparable to the identification of uncommon or rare species in the nearby region of Hamilton (43 species) and Halton (38 species) (Wormington and Lamond 2003; Wormington 2006). For the 23 species identified as rare permanent residents in Table 3, additional field work is required to check historic sites and potentially new sites containing suitable habitat.

The following sections provide a qualitative summary of the records collected on a species by species basis in order to identify general trends as well as changes observed in individual populations of species or specific groups. This section has been organized by Family and in some cases Subfamily and is followed by a summary of general trends.

Pieridae

The family Pieridae includes butterflies commonly referred to as the 'whites' and 'sulphurs'. Nine species in the family Pieridae have been recorded in the Region. The cabbage white (*Pieris rapae*) is the most commonly observed species of butterfly in the Region of Waterloo, as it is in most localities across Canada. An exotic species in North America, it was introduced in Quebec City in the 1860's and has spread throughout North America using a variety of plants in the mustard family (Brassicaceae) as a larval foodplant (Capinera 2000; Hall 2009; Walton 2010). Following the introduction of *P. rapae* in North America, the mustard white (*P. napi*) drastically decreased in abundance, a pattern that some researchers attribute to intense competition for habitat (Scudder 1989; Longstaff 1912; Klots 1951). *P. napi* was commonly observed in the Region until the early 1950's (F. Stricker pers. comm. 2009). By the early 1960's it was a rarity and has not been recorded in the Region since 1986. Some studies have suggested that despite the potential for intense interspecific competition among these two species, there is no evidence of ecological displacement, so the decline of *P. napi* is perhaps better attributed to land use changes and the prevalence of preferred larval foodplants such as rock cress (*Arabis* spp.) and toothwart (*Cardamine diphylla*) (Chew 1981; Keeler et al. 2006). Area searchers in localities where *P. napi* was historically present did not result in any new observations of this species although tootwart was observed within Schaeffer's Woods and Homer Watson Park. Because this species has not been observed in the Region of Waterloo in 24 years, it was assigned a status of 'possibly extirpated.' Additional field work is required in order to confirm its absence from the Region.

The checkered white (*Pontia protodice*) is widespread throughout the southern United States with colonies extending into Canada sporadically (Layberry et al. 1998). It is considered a rare seasonal colonist in the Region and has not been observed since 1967. If observed in the Region today it should be considered rare. The west Virginia white (*Pieris virginiensis*) is an uncommon woodland species in southern Ontario which was historically considered to be a Species at Risk in southern Ontario (Layberry et al. 1998). It was taken off the provincial Species at Risk list as new colonies were found farther north (Hall 2009). There are only 4 documented records of this species from 3 sites in the Region, the most recent being 1967 therefore it was not assigned a regional status (Lamb 1967). Permanent colonies of *P. virginiensis* have been documented in nearby regions and its larval foodplant (*Cardamine diphylla*) is common in Regional woodlands (TEA Occasional Publication 1975; Riotte 1967; Wormington and Lamond 2003; Wormington 2006). Field checks in 2010 in Springwood Park and Homer Watson Park did not result in any new records for this species although its larval foodplant was observed in small numbers. It is possible this species has been overlooked which has happened in nearby regions where it was thought not to persist then an abundance of colonies were discovered (A. Wormington pers. comm. 2010).

The clouded sulphur (*Colias philodice*) and orange sulphur (*Colias eurytheme*) have consistently been documented as common species since the 1930's. The caterpillar of both these sulphurs feed on members of the family Fabaceae, especially clover (*Trifolium repens*) and alfalfa (*Medicago sativa*), both of which are abundant throughout the agricultural landscape in the Region. The pink-edged sulphur (*Colias interior*) was historically reported as uncommon and local (F. Stricker pers. comm. 2009), which is consistent with its general trends in abundance throughout Canada (Layberry et al. 1998). Although it has historically been reported at 11 separate sites, it has not been observed in the Region since 1987 (F. Stricker collection), therefore it should be considered regionally rare until field work is completed to confirm its abundance in the region. The little yellow (*Pyrisitia lisa*) is a common migratory species that does not overwinter in Canada but has been observed infrequently in the Region (Hall 2009). Records for this species are sporadic although it has been reported as recently as 2006 in the southern end of the Region (Blair). There is no evidence to confirm if this species establishes breeding colonies in the Region, so it is currently considered a rare immigrant.

The sleepy orange (*Eurema nicippe*) is a rare stray in Canada and has been reported once in the Region of Waterloo in 1934 (Layberry et al. 1998; Wormington 1999). This species was excluded from the regional status assignment. A specimen was taken by E. Leonard James which is housed at the University of Waterloo. An attempt was made to view the specimen, however the collection was damaged by a flood a few years ago and the majority of specimens are completely ruined. Later it was discovered that this specimen was examined in 1991 prior to the flood, and its identification was confirmed as a *Eurema nicippe* (Wormington 1998).

Papilionidae

This family of butterflies includes those commonly referred to as the 'swallowtails.' There are 14 species of swallowtail in Canada (Layberry et al. 1998), 6 species of which have been reported in the Region of Waterloo. The eastern tiger swallowtail (*Papilio glaucus*) and the black swallowtail (*P. polyxenes*) are by far the most common species in this family in the region. *P. polyxenes* is common in southern Ontario and is commonly observed throughout the region. *P. glaucus* is also a common species in southern Ontario but confusion between this species and the more northern Canadian tiger swallowtail (*P. Canadensis*) presented difficulty in sorting through old records. Historically, *P. canadensis* was believed to be a subspecies of the *P. glaucus* but advances in physiological and genetic research have resulted in *P. canadensis* being classified as a distinct species (Hagen et al. 1991). *P. glaucus* is very common in the Region of Waterloo which means the majority of regional records for *P. canadensis* were likely misidentified or improperly labeled based on previous taxonomic classifications. For the purposes of this study, records for *P. canadensis* were considered *P. glaucus*.

The giant swallowtail (*P. cresphontes*) is Canada's largest butterfly. In Canada, this species was found in the Carolinian Zone of southwestern Ontario exclusively with periodic observations further north (Hall 2009). This species has expanded northward dramatically during the 21st century, often observed in gardens, using northern prickly ash (*Zanthoxylum americanum*), common hop tree (*Ptelea trifoliata*), common rue (*Ruta graveolens*), and gas plant (*Dictamnus albus*) as larval foodplants (Crolla 2009a). In the region, a well-known population occurs along the Grand River Floodplain at the *rare* Charitable Research Reserve in Cambridge where a colony of northern prickly ash is established. Prior to the discovery of this population, only a few sporadic records existed including 5 collections between 1935 and 1950 in Kitchener (F. Stricker collection) and two observations in 2001 (M. Burrell pers. comm. 2010) and 2003 (L. Lamb collection) in the City of Waterloo. In 2006 numerous *P. cresphontes* made up the population at the *rare* Charitable Research Reserve and larva could easily be found on larval foodplants. Since 2006 the population has appeared to decrease with only one individual observed in each 2009 and 2010.

The pipevine swallowtail (*Battus philenor*), spicebush swallowtail (*Papilio trolius*), and zebra swallowtail (*Eurytides Marcellus*) have been reported in the Region but were excluded from the regional status assignment. *Eurytides marcellus* is periodically reported in southwestern Ontario and has been known to breed using pawpaw (*Asimina triloba*) as a larval foodplant, however it is unknown if there is a resident breeding population in Ontario (Hall 2009). One specimen was collected in Kitchener by Frank Stricker in 1965 which is the only known occurrence of this species in the region. *Battus philenor* is considered a rare breeding immigrant in Canada (Layberry et al. 1998), and has only been reported in the Region on three occasions[5] in the City of Kitchener and in North Dumfries Township (F. Stricker field notes). *Papilio trolius* is a permanent resident of the Carolinian forests north of Lake Erie (Layberry et al. 1998). This species was collected in the City of Kitchener once in the 1930's and once in the 1940's by Frank Stricker who indicated in his field notes that it was once fairly common in the area however this cannot be confirmed due to the lack of historical records prior to the 1930s.

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[5] One additional record for this species was found (TEA 2005) however it is strongly suspected (based on anecdotal information) that the individual was raised in captivity and released in the garden where it was observed.

Lycaenidae

This family of butterflies includes the butterflies commonly known as the blues, coppers, hairstreaks, and harvesters. In Canada, there are 63 species that belong to this family (Layberry et al. 1998), 18 of which have been reported in the Region of Waterloo.

Hairstreaks and Elfins (Subfamily Theclinae)

Seven species belonging to the hairstreak subfamily have been recorded in the Region of Waterloo. The Acadian hairstreak (*Satyrium acadica*), banded hairstreak (*S. calanus*), striped hairstreak (*S. liparops strigosum*), and coral hairstreak (*S. titus*) are generally considered uncommon in the region although they can be locally abundant. The Edward's hairstreak (*S. edwardsii*) and hickory hairstreak (*S. caryaevorum*) have been documented much less commonly in the Region. Only three records exist for *S. edwardsii* (Ceasar 1957; Lamb 1967; J.K. Morton collection), although it may have been overlooked due to its similarity to *S. calanus* (Layberry et al. 1998). Historically, *S. caryaevorum* was only reported from one location where suitable habitat has been destroyed by development (C. Campbell pers. comm. 2010). In 2006 it was observed on two occasions at the *rare* Charitable Research Reserve in Cambridge. *S. caryaevorum* has been previously considered a sensitive species although it is now known populations tend to fluctuate from year to year (Hall 2009). Currently, *S. caryaevorum* is considered provincially 'imperiled' (S3) (NHIC 2010). In the region both *S. edwardsii* and *S. caryaevorum* are considered rare. The gray hairstreak (*Strymon melinus*) has only been documented in the Region once in 1957 in Waterloo (Ceasar 1957). This species appears sporadically throughout its Canadian range but can be common (Layberry et al. 1998).

Only two regional records exist for the eastern pine elfin (*Callophrys niphon*). It was first reported near Branchton in 1997 but more recently (2010) was observed at the Huron Natural Area (TEA 1997; J. Grealey pers. obs. 2010). It is possible that it has been overlooked due to its small size (22-27mm wingspan) and dark colouring which make it quite inconspicuous. Only one hoary elfin (*C. polios*) was collected in Kitchener in 1942 (F. Stricker collection) therefore it was excluded from the regional status assignment.

Coppers (Subfamily Lycaeninae)

Twelve species belonging to this subfamily are known to occur in Canada (Layberry et al. 1998), 5 of which have been reported in the Region. The bronze copper (*Lycaena hyllus*) is the only species in this subfamily that is commonly encountered in the Region. It is not abundant but can be locally common, especially along the floodplain of the Grand River (J. Grealey pers. obs.). The American copper (*L. phlaeas*) has only been reported on one occasion in 1957 in Ayr therefore it was excluded from the regional status assignment (Lamb 1967). In nearby regions it is reported as an uncommon permanent resident (Wormington and Lammond 2003; Wormington 2006). The bog copper (*L. epixanthe*) was excluded from the regional status assessment as it has also only been documented once from the Glen Morris Area (North Dumfries Township) in 1967 (Government of Canada 2003- ROM Collection). The dorcas copper (*L. dorcas*) was discovered in the Region in 1980 in a wet meadow in North Dumfries Township (Sharp and Campbell 1980). It has been more recently observed at Taylor Lake in 1990 and collected at Oliver Bog in 1996 (TEA 1990; L. Lamb collection). Habitat for this species is limited in the region to wet areas where shrubby cinquefoil (*Potentilla fruticosa*) occurs but small, isolated populations may still persist. The purplish copper (*L. helloides*) has been reported from more sites than *L. dorcas* throughout the Region. The most recent records have been in North Dumfries Township in 1977 (TEA 1977) and Cambridge in 1996 (L. Lamb collection). Both *L. helloides* and *L. dorcas* were assigned a regional status of rare however field work is required to confirm their persistence in the region. In Ontario, *L. helloides* is considered ‘imperiled’ (S3) meaning it is vulnerable to extirpation (NHIC 2010).

Blues (Subfamily Polyommatinae)

This relatively large subfamily of Lycaenidae consists of 19 species in Canada, 4 of which have been documented in the Region of Waterloo. The spring azure (*Celastrina ladon*) and the summer azure (*C. neglecta*) are the two most commonly encountered species. Previously *C. neglecta* was treated as a summer ‘form’ or subspecies of *C. ladon*, but it was later determined that it was in fact a distinct species (Layberry et al. 1998; Pavulaan and Wright 2000). Based on this distinction, historical records collected in the Region were sorted by reported flight times (Layberry et al. 1998). Observations made between April and May were classified as *C. ladon* and observations made from June on were considered *C. neglecta*. The eastern-tailed blue

(*Cupido comyntas*) has been consistently observed over the years in the region although it has never been observed as abundant (C. Campbell pers. comm. 2009; J. Grealey pers. obs.). Lastly, the greenish blue (*Plebejus saepiolus*) has been documented once in the Region in 1944 (F. Stricker field notes). This species is common throughout its Canadian range, which includes northern Ontario, but is very rare in the southern portion of the province (Layberry et al. 1998). It was excluded from the regional status assignment.

Harvesters (Subfamily Miletinae)

Only one member of this subfamily, which has carnivorous larvae, occurs in North America- the harverster (*Feniseca tarquinius*). It has been recorded 8 times in the region within 5 sites, most recently in 1990 at Riverside Park (TEA 1990). Because this species often occurs singly, is a fast, erratic flyer, and tends to be extremely local it may easily be overlooked (Layberry et al. 1998). It is considered regionally rare.

Nymphalidae

This family was previously treated as several separate families which were reclassified into the single largest family of butterflies in the world. These butterflies are commonly referred to as the 'brush-footed' butterflies due to their reduced forelegs which are covered in long hairs, resembling a brush (Layberry et al. 1998). In Canada there are 101 species in the family Nymphalidae, 36 of which have been documented in the Region of Waterloo.

Snouts (Subfamily Libytheinae)

This subfamily is only represented by one species in Canada – the American snout (*Libytheana carinenta*). This species is a rare migrant throughout most of its Canadian range, although some years it arrives in large numbers (Layberry et al. 1998). It is a confirmed breeder in the province of Ontario, however because this species' numbers fluctuate considerably from year to year it is difficult to assign the species a national conservation status (Hall 2009). *Libytheana carinenta* has been documented in the Region on 7 occasions since the 1960's, most recently in 2008 and 2010 at the *rare* Charitable Research Reserve (J. Grealey and L. Lamb 2008; 2010) and in a residential garden in northwest Waterloo (J. Grealey pers.obs.). It was considered a rare immigrant in the Region until 2010 when it was observed to lay eggs on a hackberry tree (*Celtis occidentalis*) behind *rare*'*s* main office building (G. Richardson per. comm. 2010). Its regional status is now considered a rare seasonal colonist.

Fritillaries (Subfamily Argynninae)

This Subfamily is further divided into two groups - the greater fritillaries which includes species in the genus *Speyeria* and *Euptoieta,* and the lesser fritillaries in the genus *Boloria.* Twenty-five species of fritillary have been recorded in Canada, however the majority of them are associated with the more northern habitats and climates (Layberry et al. 1998). Only 7 species belonging to this subfamily have been documented in the Region of Waterloo.

Of the greater fritillaries, the great spangled fritillary (*Speyeria Cybele*) is by far the most common. The other greater fritillaries have declined dramatically in abundance over the last few decades (L. Lamb pers. comm. 2009; F. Strick pers. comm. 2009; C. Campbell pers. comm. 2010). The variegated fritillary (*Euptoieta claudia*) has been documented at 13 separate sites however it has not been observed since 1967. The Atlantis fritillary (*S. atlantis*) has been documented at 10 sites but has not been observed since 1983. If these species persist in the Region, they should be considered rare. The regal fritillary (*S. idalia*) has been observed at 4 separate sites but not since 1952. It is a very conspicuous species and would be difficult to overlook. *S. idalia* has experienced widespread declines over its range and appears to be an accidental vagrant in Canada, with no known permanent colonies (Mason 2001; Hall 2009). Six specimens were collected in the Kitchener area between 1937 and 1952 by Frank Stricker who indicated that small colonies were present historically (F. Stricker pers. comm. 2009). *S. atlantis* and the Aphrodite fritillary (*S. Aphrodite*) were historically common in the Region of Waterloo until the 1960's (F. Stricker pers. comm. 2009; L. Lamb pers. comm. 2009). *S. aphrodite* was last documented in the region in 1970. Its original status of 'uncommon' (based on the number of sites (23) it was observed at) was changed to 'rare' due to the time elapsed since the last observation of this species in the region. *S. atlantis* was last documented in 1983 (F. Stricker field notes). *S. atlantis* and *S. aphrodite* are fairly common throughout their Canadian range and may still be present in small numbers throughout the region (Layberry et al. 1998). *Euptoieta claudia* is a rare migratory stray in Ontario (Layberry et al. 1998). It has been historically documented in Cambridge, Kitchener and North Dumfries Township, but never reported as common (F. Stricker field notes; L. Lamb collection; C. Campbell pers. comm. 2009). It was last observed in the late 1960's and should be considered a rare immigrant.

The lesser fritillaries are represented by two species in the region; the meadow fritillary (*Boloria bellona*) and silver-bordered fritillary (*B. selene*). *B. bellona* is the most widespread of the lesser fritillaries in Canada and *B. selene* is reported as common in eastern Canada (Layberry et al. 1998). Previously, both of these species were documented frequently within the region. Records sharply decrease for *B. selene* in the late 1960's, with the last documented record in 1990 (TEA 1990), therefore its status of 'common' was reassigned to be 'rare'. Records for *B. bellona* occur up until 2010, but have declined dramatically in abundance since the early 1970's.

Checkerspots and Crescents (Subfamily Melitaeinae)

This subfamily of butterflies is represented by 17 species in Canada, 6 of which have been documented in the Region of Waterloo. The harris's checkerspot (*Chlosyne harrisii*) is reported as a very local species which can be common in northwestern Ontario (Layberry et al. 1998). It has only been documented in the Region of Waterloo on 3 occasions (F. Stricker field notes; Caesar 1957), most recently in 1957, and was therefore excluded from the regional status assignment. The silvery checkerspot (*C. nycteis*) has been documented in the Region on numerous occasions but not after 1965. Both of these species are believed to be declining within their known ranges in the eastern United States (O'Donnell et al. 2007; Webster and deMaynadier 2005).

The Baltimore checkerspot (*Euphydryas phaeton*) was previously much more common in the Region of Waterloo (L. Lamb pers. comm. 2009; F. Stricker pers. comm. 2009). It has been observed at 33 separate sites however all of these observations except 1 (in 2001), occurred prior to 1990. It was therefore assigned a regional status of rare. This species is known to be fairly localized to where its larval food plant, turtlehead (*Chelone glabra*) occurs (Layberry et al. 1998). In the Region, turtlehead grows in small numbers in marshes and swamps but is not considered rare (B. Woodman pers. comm. 2010; Richardson and Martin 1999).

The crescents are represented by 3 species in the Region. The pearl crescent (*Phyciodes tharos*) and northern crescent (*P. cocyta*) are both common throughout the Region. The tawny crescent (*P. batesii*) has only been documented in the Region on 4 occasions at 3 sites, most recently in 1978 (TEA 1978). This species is considered uncommon and local throughout its Canadian range and rare within the region (Layberry et al. 1998).

Anglewings, Tortoiseshells, Thistle Butterflies, and Peacocks (Subfamily Nymphalinae)

This morphologically diverse group of butterflies is represented by 16 species in Canada, 11 of which have been documented in the Region of Waterloo. Several members of this subfamily are common and relatively abundant in the region. The mourning cloak (*Nymphalis antiopa*) and eastern comma (*Polygonia comma*) are often two of the first species observed in early spring and are commonly observed through to autumn (J. Grealey pers. obs.). The red admiral (*Vanessa atalanta*), painted lady (*V.cardui*), and question mark (*Polygonia interrogationis*) are all common, seasonal colonists in southern Ontario and are common in the Region of Waterloo (Layberry et al. 1998). The American lady (*V. virginiensis*) is also considered a common seasonal colonist although it has been reported less frequently. The common buckeye (*Junonia coenia*) is also a migrant in Canada and has been observed less commonly in the region then other migrants. It is known to sometimes establish temporary breeding colonies during good migration years such as the one experienced in 2010 (Layberry et al. 1998). In 2010 it was observed in Branchton, the Huron Natural Area in Kitchener, and Laurel Creek Conservation Area (Shea pers. comm. 2010; TEA 2010).

Historically, the grey comma (*Polygonia progne*) was also reported as common in the region (F. Stricker field notes). This species is still present in the region (Grealey and Lamb 2009), however it has not been frequently observed since the late 1980s and is therefore considered uncommon. The satyr comma (*P. satyrus*) has been documented in the region on two occasions, most recently in 1970 (F. Stricker field notes). These observations are likely rare strays as this species in known from a more western range in Canada (Layberry et al. 1998). It was therefore excluded from the regional status assignment.

The milbert's tortoiseshell (*Nymphalis milberti*) and Compton's tortoiseshell (*N. vaualbum*) were previously much more abundant in the region (L. Lamb pers. comm. 2009; F. Stricker pers. comm. 2009). Although these species appear to be less common, both are still present in small numbers in the region and both should be considered uncommon. *N. vaualbum* was most recently observed in 2009 (J. Grealey pers. obs.), while *N. milberti* was observed at 3 separate sites in 2010 (Moore 2010; B. Woodman pers. comm; J. Grealey pers. obs.).

Admirals (Subfamily Limenitidinae)

This subfamily of butterflies is only represented by 4 species in Canada, 2 of which have been documented in the region. The white admiral (*Limenitis arthemis arthemis*) is common throughout Canada while the red-spotted purple (*Limenitis arthemis astyanax*), a subspecies of *arthemis*, is only found in southern Ontario (Layberry et al. 1998). Historically both were observed throughout the region, however in recent years *Limenitis arthemis astyanax* has become more abundant. There are only 4 documented records of *Limenitis arthemis arthemis* since 2001 (Burrell pers. comm. 2010; 2001; Grealey and Lamb 2006; Moore 2009). The viceroy (*Limenitis archippus*) is the other member of this subfamily which occurs in the Region. This species has consistently been observed to be very common and is often observed in a variety of habitats throughout the region.

Emperors (Subfamily Apaturinae)

This subfamily is represented by 2 species in Ontario: the hackberry emperor (*Asterocampa celtis*) and the tawny emperor (*A. clyton*). *A. clyton* is reported as less common and more restricted in range than *A. celtis* (Layberry et al. 1998) however several small, known colonies are present within the Region (J.K. Morton, pers. comm. 2009; J. Grealey pers. obs.). *A. clyton* is considered provincially 'imperiled' (S3) and indicating it is at risk of extirpation (NHIC 2010). There are no documented records of *A. celtis* in the region although it is known to often occupy the same habitats and fly with *A. clyton*.

Satyrs and Wood Nymphs (Subfamily Satyrinae)

This relatively large subfamily of butterflies is represented by 34 species in Canada, but only 6 within the Region of Waterloo. The northern pearly eye (*Enodia anthedon*), eyed brown (*Satyrodes Eurydice*), Appalachian brown (*S. Appalachia*), common wood nymph (*Cercyonis pegala*) and little wood satyr (*Megisto cymela*) are all commonly encountered species in the region. *Enodia anthedon* and *Satyrodes appalachia* are almost always observed in wooded habitats, while *S. eurydice* and *Megisto cymela* are observed in more diverse habitats including woodland edges, thickets, and meadows (J. Grealey pers. obs.). Historically, the common ringlet (*Coenonympha tullia*) was much less common in southern Ontario however it is now one of the most commonly observed species during its flight time in the region (Eberlie 1999; J. Grealey pers. obs.). Subspecies *inornata* is most commonly encountered, however for the purposes of this study individuals have not been broken down into subspecies.

Milkweed Butterflies (Subfamily Danainae)

The monarch (*Danaus plexippus*) is the only representative of this subfamily in Canada. *D. plexippus* is a well-known and studied species due to its spectacular annual migration. Individuals who breed in southern Ontario migrate from Canada to Mexico every year. It is not uncommon for *D. plexippus's* abundance to fluctuate from year to year however it should be considered a widespread and common seasonal colonist in the region. *D. plexippus* is the only species that occurs in the Region which is considered to be a Species at Risk both provincially and nationally (OMNR 2009; COSEWIC 2009). This status affords this species protection under the *Species at Risk Act* 2002 and *Endangered Species Act* 2007.

<u>Hesperidae</u>

This family of butterflies, commonly referred to as the 'skippers' is represented by 70 species in Canada belonging to 3 Subfamilies (Layberry et al. 1998). Thirty-two of these species have been documented in the Region of Waterloo. Skipper butterflies are often overlooked by observers due to their drab appearance and have been excluded by some local record compilers (Lamb 1967). The current abundance of many of the species within this subfamily is not accurately known. Skipper observations were frequently documented in the region prior to the 1970's by Frank Stricker. Records for several localized species discontinue in the 1980's and 1990's which have been reported during the relatively recent Cambridge NABA butterfly count. It is likely that the large data gap that exists for skippers is due to lack of interested observers and that many of these species are present in local colonies that have been overlooked.

Pyrigine Skippers (Subfamily Pyrginae)

This subfamily is represented by 2 species in the region. The silver-spotted skipper (*Epargyreus clarus*) is the largest skipper species found in Canada. It is never observed in large numbers but can be locally common in the Region of Waterloo, often observed visiting gardens in more developed areas (F. Stricker pers. comm. 2009; J.

Grealey pers. obs.). The northern cloudywing (*Thorybes pylades*) has been documented in the region on 4 occasions, most recently in 2009 at the Sudden Tract (J. Grealey pers. obs.). This species is common and widespread throughout its Canadian range but is reported as rarely abundant (Layberry et al. 1998). It is possible that this small, dark skipper that is partial to wooded areas may have been overlooked by local observers and it is actually more common than the records suggest.

The duskywings (*Erynnis*) are a larger group of medium-sized skippers that are often difficult to identify (Layberry et al. 1998). Five species of duskywings have been documented in the Region of Waterloo. The dreamy duskywing (*E. icelus*), juvenals duskywing (*E. juvenalis*), and columbine duskywing (*E. lucilus*) are common within their southern Ontario ranges and their larval foodplants are found throughout the region (Layberry et al. 1998). *E. icelus* has not been observed in the Region since 1978. *E. juvenalis* and *E. lucilus* had not been observed in the region since the late 1960's until 2010. It is possible that these early spring flyers have simply been overlooked by observers who typically do not go out looking for butterflies until later in the season. The wild indigo duskywing (*E. baptisiae*) was documented in the region for the first time in 2010 (J. Grealey pers. obs.). Historically this species was uncommon and restricted to habitats in southwestern Ontario where its larval foodplant wild indigo (*Baptisia tinctora*) occurred (Hall 2009). Recently, this species has been observed to be rapidly expanding its range using crown vetch (*Coronilla varia*), a non-native plant commonly used in local hydroseed mixtures, as a larval foodplant (Crolla 2009b). In 2010, *E. baptisiae* was observed at 8 separate sites to be quite abundant (J. Grealey pers. obs.). It is too early to tell if this species has established permanent colonies in the region therefore it was the only species assigned a residency and regional status of 'unknown.'

The sleepy duskywing (*E. brizo*) is uncommon throughout its Canadian range and is closely associated with oak woodlands (Layberry et al. 1998). It has been observed in the region on 9 occasions at 5 sites, most recently in 1967, in areas that have been since severely altered by development (F. Stricker field notes). *E. martialis* was documented in the region on one occasion in 1957 (Ceasar 1957). This species is rare, very local, and only found in dry habitats where its larval food plant, New Jersey tea (*Ceanothus americanus*), occurs (J. Grealey 2009). This isolated record of *E. martialis* in Kitchener is considered a rare stray or possible misidentification[6]. The common checkered skipper (*Pyrgus communis*) has been documented in the region on two

[6] No specimen taken to confirm.

occasions in 1937 and 1967 (F. Stricker field notes). It is common resident in the southern portion of the Prairie Provinces but is also known to stray into southwestern Ontario (Layberry et al. 1998). Due to the limited records and the time elapsed since they were last observed all three of these species were excluded from the regional status assignment

The common sootywing (*Pholisora catullus*) can be locally common in southern Ontario but is considered provincially 'imperiled' (S3) and rare in the region (Layberry et al. 1998; NHIC 2010). It was historically documented in Waterloo and Kitchener infrequently and in recent years has been observed at the *rare* Charitable Research Reserve (F. Stricker field notes; Grealey and Lamb 2006 and 2010; Grealey 2007; Moore 2009).

Intermediate Skippers (Subfamily Heteropterinae)

The arctic skipper (*Carterocephalus palaemon*) is the only representative of this subfamily in Canada. It is reported as common throughout its Canadian range although it has only been documented in the Region at 7 sites (Layberry et al. 1998). The most recent observations subsequent to 1990 were at the Huron Natural Area and the *rare* Charitable Research Reserve (TEA 1990; J. Grealey per. obs. 2010; Moore 2010).

Branded Skippers (Subfamily Hesperiinae)

Twenty-one species belonging to this large subfamily have been observed in the Region of Waterloo, many of which are common. The European skipper (*Thymelicus lineola*) is by far the most commonly observed skipper species in the Region (J. Grealey pers. obs.). *Pieris rapae* is the only species that rivals it as the most common species in southern Ontario (Hall 2009). After its introduction from Europe to London, Ontario in 1910, it spread throughout Canada and can now be observed by the thousands at single locations (Hall 2009). There are several other species of branded skippers that are commonly observed throughout the region such as the least skipper (*Ancyloxypha*), tawny-edged skipper (*Polites Themistocles*), dun skipper (*Euphyes vestries*), long dash (*Polites mystic*), and peck's skipper (*Polites peckius*). The broad-wing skipper (*Poanes viator*), northern broken-dash (*Wallengrenia egeremet*), and dion skipper (*Euphyes dion*) have been observed less frequently within the Region but colonies have been observed to persist at the *rare* Charitable Research Reserve in Cambridge and may persist elsewhere in the region. *Euphyes dion* is considered provincially 'imperiled' (S3) (NHIC

2010). The black dash (*Euphyes conspicua*) is reported as an uncommon and very local species in southern Ontario and is also considered provincially 'imperiled' (S3) (Layberry et al. 1998; NHIC 2010). This species has been observed in numerous locations throughout the southern portion of the region, most recently at the *rare* Charitable Research Reserve in Cambridge during the 2006, 2008, 2009, and 2010 annual butterfly counts (identified by G. Richardson) and the Branchton Prairie in 2005 (TEA 2005). The mulberry wing (*Poanes Massasoit*) also tends to be a very local species but can be common within colonies (Layberry et al. 1998). This species has also been observed mainly in the southern portion of the region, most recently in 2005 at the Branchton Prairie and in 2010 at the Sudden Tract (TEA 2005; Moore 2010). The little glassywing (*Pompeius verna*) has been documented in a number of localities throughout the Region although it is considered local and uncommon in southern Ontario (F. Stricker field notes; TEA 1990; Layberry et al. 1998). It was reported by the TEA as being known from upwards of 20 localities in the region in 1990 but since then has only been observed once in 2010 at the rare Charitable Research Reserve (TEA 1990). The Crossline skipper (*Polites origenes*) is also local and uncommon in Ontario (Layberry et al. 1998). It has been documented in the region at 5 sites, most recently in 2006 during the Cambridge NABA butterfly count (J. Grealey and L. Lamb 2006).

The two-spotted skipper (*Euphyes bimacula*) is uncommon and very local in Ontario (Layberry et al. 1998). It has been documented in the region on 8 occasions, all prior to 1968 (F. Stricker field notes; Government of Canada 2003- ROM Collection). The salt and pepper skipper (*Amblyscirtes hegon*) and common roadside skipper (*A. vialis*) have been documented once and twice respectively in the region which are the only known records of these species in this area therefore they were excluded from the regional status assignment (F. Stricker field notes). It is likely these observations were of rare strays outside their usual range, however *A. vialis* has been observed recently to be expanding in numbers (Hall 2009). The fiery skipper (*Hylephila phyleus*), the common branded skipper (*Hesperia comma*), and Indian skipper (*Hesperia sassacus*) are uncommon species in southern Ontario (Layberry et al. 1998). *Hylephila phyleus* has been observed 2 times, once in 1955 and once in 1967 while *Hesperia comma* and *H. sassacus* have been documented once in 1967 and 1950 respectively (F. Stricker field notes; Government of Canada 2003- ROM Collection; Lamb 1967). Based on these isolated observations, it is unlikely that permanent colonies persist in the region therefore they were excluded from the regional status assignment.

General Trends

Several general conclusions can be drawn from interviews with local collectors, personal observations, and the database of records that was compiled. In general, the abundance and richness of native butterflies in the region has declined. Some of the historically common species, such as *Vanessa atalanta*, *V. cardui, Nymphalis antiopa, Cercyonis pegala, Polygonia interrogationis*, and *P. comma,* are still common in the region. However certain groups of butterflies, such as the fritillaries, swallowtails, checkerspots, and tortoiseshells have dramatically declined in abundance. This general decline is consistent with a trend across Canada that has been attributed to the cumulative effects of habitat loss due to the rapid urbanization of the landscape, pesticide use, collecting, and the lack of protection afforded to butterflies and their habitats (Hall 2009).

In 2008 the regional government launched a campaign to eliminate the use of non-essential lawn pesticides. A temporary pesticide by-law was later replaced by the *Pesticide Act of Ontario* which prohibits the use of pesticides for cosmetic use on lawns and in public areas (MOE 2009). This ban is relatively recent and it is therefore very difficult to assess the impact of local pesticide use on butterfly communities. Pesticides are still permitted on agricultural fields, golf courses, and in public areas with pest infestations.

Collecting, particularly of rare or uncommon species, may have impacted the butterfly population. Based on the record collection and research done for the regional status assignment it can be said with certainty that butterfly collecting was much more popular in the region prior to 1980. Some collectors' notes indicate that they were taking hundreds and even thousands of specimens in the region every year. Even rare species were caught and mounted rather then left to reproduce.

Only two non-native species, *Pieris rapae* and *Thymelicus lineola,* are found in the region which are the most commonly encountered species. According to the Natural Heritage Information Centre these are the only two non-native butterfly species occurring in Ontario (NHIC 2010). At this time there is no evidence to suggest that the increase in non-native species abundance is related to the decline of native species. It is likely that the generalist tendencies and abundance of larval foodplants has made it easier for non-native populations to persist. The diversity of species that has been observed to persist at the *rare* Charitable Research Reserve implies that if a similar search effort was applied elsewhere in the Region (within similar habitats) that local colonies of less common species may be found however more field work is required to confirm this.

A large data gap exists between 1980 and 2005, particularly for butterflies in the skipper family (Hesperiidae). Based on recent efforts to document butterfly species in the region through annual NABA counts, the establishment of permanent butterfly monitoring transects, and field work completed as part of this research, several species not documented since the 1970's have been confirmed to be present within the Region e.g. *Poanes viator*, *Erynnis lucilus*, *Poanes Massasoit*, *Thorybes pylades*. Habitat exists for several other species historically known from the region indicating that colonies may still persist if they have been overlooked due to lack of observers.

Some species historically reported as uncommon or rare have been confirmed in recent years to persist within the region e.g. *Euphyes conspicua*, *Nymphalis vaualbum*, *Pompeius verna* however field checks are required to confirm the presence/absence of other rare species in habitats that still exist. There is currently no regional policy that requires butterfly surveys to be completed as part of Environmental Impact Studies for future development projects; therefore small, isolated colonies of butterflies could be destroyed without consequence. If butterfly surveys were required as part of development impact assessments like breeding birds, plants, and herpetofauna, the regional status assignment presented in this chapter could be used by local agencies to determine the importance of habitat for butterflies within proposed development areas. This regional status assignment could also be used in identifying conservation targets, restoration projects, and mitigation plans.

CHAPTER 2: Butterfly Distribution Along an Urban Gradient

INTRODUCTION

The rapid modification of the landscape that is currently occurring on a global scale is one of the greatest threats to biodiversity. As human populations are projected to further increase to 9-10 billion by the end of the century more modifications are expected to occur (World Bank 2004). One rather obvious form of modification is urbanization. Urbanization can be unsustainable because of the massive need for resources and energy it requires. Resources and energy are used internally in urban areas thereby creating a system that does not require local natural resources to persist (McDonnell and Pickett 1990). Such urban areas and their surrounding landscapes consist of a variety of land uses ranging from completely built-up areas to natural or semi-natural areas (Stearns and Montag 1974). Urban sprawl has resulted in the conversion of naturalized landscapes into housing developments, business districts, and recreational areas and the overexploitation of natural resources to accommodate this sprawl. It is common practice for large scale residential or commercial developments to completely clear the land before construction, removing vegetation and displacing the topsoil. Such practices often result in the rapid colonization of exotic or invasive species and the local extinction of native species (McKinney 2002). Urban sprawl to surrounding rural areas fragments native habitat patches by introducing new types of habitat associated with more urban environments such as recreational areas, parks, gardens, and golf courses (Randa and Yunger 2006). The resulting loss in overall biological diversity has been experienced world-wide (Forester and Machlis 1995). Although these new urban habitats may attract some wildlife species, overall biodiversity may be negatively affected by the creation of abrupt habitat edges, introduction of exotic species, and anthropogenic pollution (McKinney 2002; Pickett et al. 2001).

Researchers have examined species assemblages along a gradient of urbanization to evaluate changes in the distribution and abundance of a variety of taxa. These have included reptiles (Germaine and Wakeling 2000), birds (Clergeau et al. 1998; Jokimäki and Huhta 2000; Blair 1996), mammals (Randa and Yunger 2006), beetles, butterflies and Arachnids (Ruszczyk and De Araujo 1993; Blair and Launer 1997Alaruikka et al. 2002; Harley 2003; Hogsden and Huntchinson 2004). These studies have shown that when communities are monitored in the context of known environmental change due to human disturbance, monitoring results can provide a basis for improved management decision making (Kreman 1992).

Germaine and Wakeling (2000) observed a significant relationship between lizard species distributions and habitat variables describing physiognomy, floristics, and spatial relationships along the urban gradient. They attributed this to the fact that areas of natural, undisturbed vegetation became increasingly diminished and fragmented as urban features such as building density and paved area increased. Their study was also successful in identifying species of lizard which were the most adapted to urban landscapes and those that were the most sensitive. It remains unclear as to whether the species most adapted to the urban landscapes were actually superior at exploiting urbanized environments or if they were simply displaced from the remaining natural habitat in urban areas. However they did find distinct habitat variables characteristic of different land uses influenced lizard communities which they believe can be used to guide land use planning and mitigation activities.

Clergeau et al. (1998) examined bird abundance and diversity along urban gradients in two cities, Quebec (Canada) and Rennes (France) to determine general responses of wildlife to urbanization. The cities were similar in structure but located in entirely different climates. Results indicated that bird diversity decreased, while abundance increased, as sites became more urbanized within both cities. In that study, vegetation structure along the urban gradient was the factor identified as most influential to bird communities. Similar results in response to vegetation structure and cover were derived from a comparative study that examined avian communities within residential and natural areas by Beissinger and Osborne (1982). Randa and Yunger (2006) examined the distribution of mammalian carnivores along an urban gradient. Compared to other taxa examined in urban gradient studies, they found that the abundance of mammalian carnivores along an urban gradient in Chicago, Illinois was influenced by a more diverse array of factors, including patch size, habitat type, prey abundance, and anthropogenic food sources.

Using similar approaches to this study, Blair and Launer (1997), Ruszczyk (1986), and Hogsden and Huchinson (2006) examined the distribution and abundance of butterflies along an urban gradient. Blair and Launer (1997) and Ruszczyk (1986) found that butterfly communities were sensitive to urbanization, and thus there was a general decrease in abundance and diversity closer to the urban centre. Hogsden and Huchinson (2006) found that butterfly assemblages along the gradient did not follow such a clear pattern, but did find strong correlations between mowing events and plant species diversity and butterfly species richness and diversity. Both Blair and Launer (1997) and Hogsden and Huchinson (2006) concluded that their findings were consistent with the intermediate disturbance hypothesis, which predicts that species diversity will be highest in areas characterized by intermediate levels of disturbance (Connell 1978). These areas were identified in the middle of the urban gradient between areas representing the 'most natural' and the 'most urban.'

Overall, a review of urban gradient studies indicates that they are an effective way to collect data on species abundance and diversity for select taxa. These studies imply that highly mobile species such as birds and large mammals may be influenced more by habitat structure and size while smaller, less mobile species such as reptiles and butterflies appear to show a strong response to conditions along a gradient of urbanization. There may be limitations, however, to interpreting results of urban gradient studies due to the sheer number of variables that can influence a community at a given site. The two general patterns that have emerged from urban-rural gradient studies are: there are distinct physical changes along the gradient and habitat-loss caused by these physical changes increases towards the urban centre (McKinney 2002). This suggests that the ecological consequences of urbanization on particular taxa can indicate the degree of disturbance and may be useful in developing strategies for conservation (Ruszczyk and De Araujo 1993). This chapter examines the following research question using a gradient-study approach: How do different land-use activities in the Region of Waterloo affect butterfly abundance and diversity?

It was hypothesized that butterfly community composition would differ between different land uses along an urban gradient due to the combination of environmental variables that characterize each land use type. This included the type of habitats present, herbaceous vegetation cover, abundance of non-native plant species, canopy cover and availability of nectar plants. Typically, designated natural areas in the Region of Waterloo are characterized by forested upland or wetland habitats. Because butterflies are sun lovers that tend to prefer more open habitats, it was thought that designated natural areas may not support the highest diversity of species. It was also hypothesized that land uses that had little habitat diversity or low overall vegetation cover would support less diverse butterfly communities.

METHODS

The Urban Gradient

Ordering the Gradient

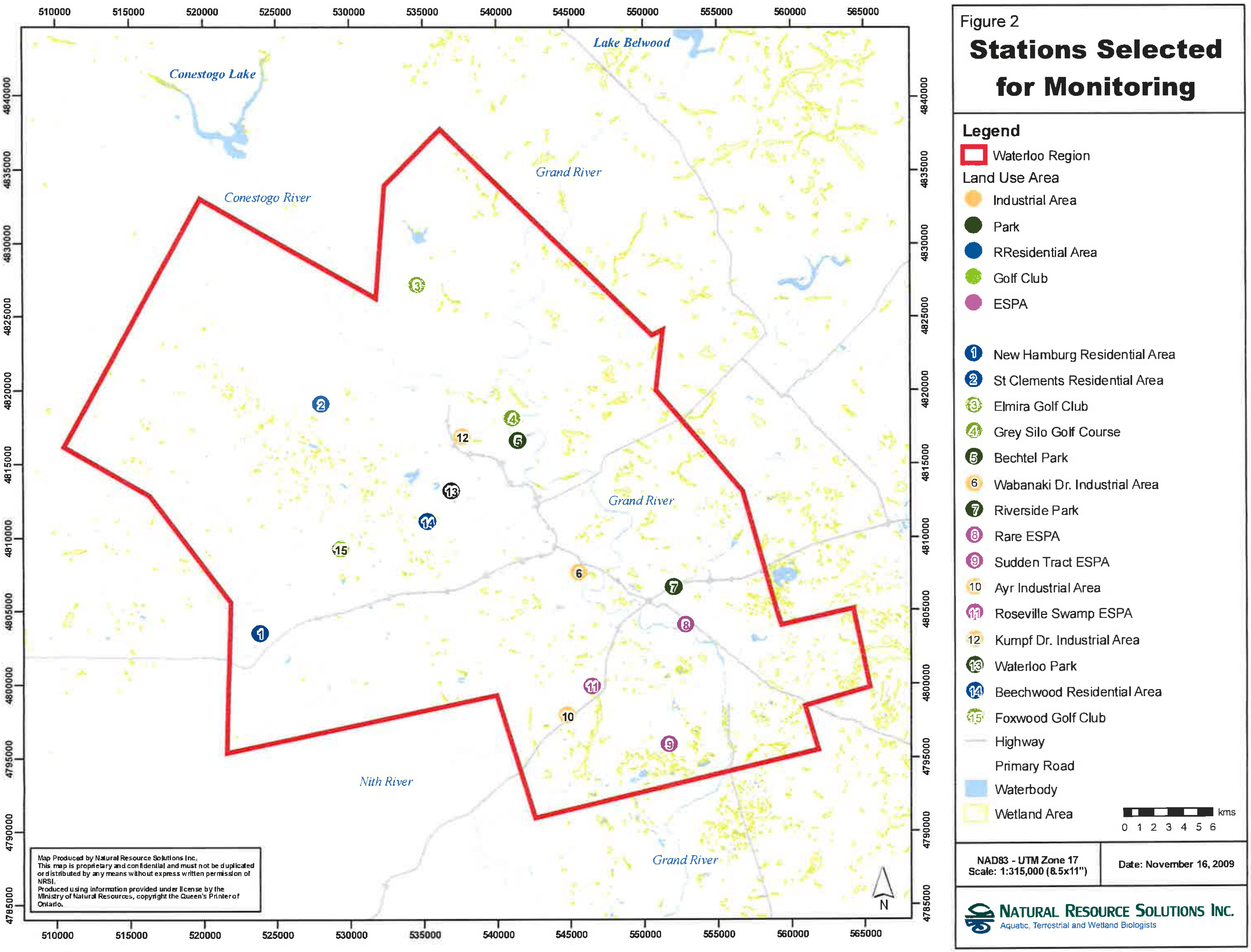
To determine the order of the gradient, or rank the land-use types from the 'most natural' to the 'most urban' a simple questionnaire was prepared asking 20 participants to order the land-use types from what they consider the most natural area to the most urban. The selected participants are all employed in a related field to the study (i.e. terrestrial and wetland biologists) and were therefore considered 'experts.' The results of the questionnaire were compiled and the most common ordering was applied. This technique is a modification in that action of repeating the questionnaires and ordering was not conducted.

Site Selection

A total of 15 sites were selected using aerial photographs to represent a variety of land-uses across the Region (Figure 2). These included ESPA's, urban parks, recreational areas, golf courses, residential neighborhoods, and industrialized areas. Sites were selected based on a number of factors including 1) geographical location within the Region 2) site accessibility 3) how well they represented a particular land use. These sites were visited one week prior to the commencement of the 2009 monitoring season to further refine and map the transect routes. Maps of each transect route are provided in Appendix I. To ensure the sites selected for monitoring provided a representative data set for their particular land use, three sites of each land use type were selected. The following is a brief description of the sites selected for monitoring.

Environmentally Sensitive Policy Areas (ESPA)

Natural areas designated as ESPAs were selected for this study given the regional context of the research questions being examined. Natural areas owned and managed on a city scale are also present in the region and it seems reasonable to assume that the butterfly abundance and richness within regional ESPAs would be similar in city-owned natural areas which are managed in a similar way and represent similar habitats.



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Roseville Swamp

This site, located in the Township of North Dumfries, is designated as an ESPA and a regional Life Science Area of Natural and Scientific Interest (ANSI). It is the headwater area for Blair and Cedar Creeks and supports a variety of vegetation communities as well as rare flora and fauna (NHIC 2008). Although some disturbance is evident such as logging, the area has remained relatively untouched for many years (Frank Stricker, pers. comm. 2008). A transect was established on a private parcel of land which included marsh, deciduous and coniferous swamp vegetation communities.

Sudden Tract

The Sudden Tract is located near the southern boundary of the region in the Township of North Dumfries. This area is also designated as an ESPA and a regional Life Science ANSI. This area is dominated by maple-beech forest moraine hills interspersed with extensive wetland swamp and open water. Portions of this site have been actively logged in the past and plantations are present. The transect route monitored included portions of deciduous forest, marsh, and forested swamp.

rare Charitable Research Reserve

The *rare* Charitable Research Reserve (formally the Cruickston Charitable Research Reserve) is within the Cruickston Park ESPA and the Blair Environmentally Sensitive Landscape, located at the confluence of the Speed and Grand Rivers. The reserve covers an area of approximately 370ha and exists within both the City of Cambridge and the Township of North Dumfries. This site is known as a hotspot for biodiversity within the region as one third of all known plants within the Region are found at *rare* (CCRR 2003).

Residential Neighborhoods

Beechwood West Subdivision

This area is characterized by high-density housing with vegetation consisting of residential lawns and gardens, street trees and school and park areas. The subdivision is approximately 250ha and was constructed approximately 20 years ago. Located in Waterloo, it is bounded by Fischer-Hallman Road to the east, Erb Street West to the south, Erbsville Road to the west and Columbia Street West to the north. A transect was established along a hydro corridor within this neighbourhood which is relatively naturalized.

New Hamburg

This residential neighbourhood is located in the Town of New Hamburg in Wilmot Township. The transect started at the corner of King St. and Webster St. and followed the residential block northeast Webster St, northwest on Victoria St., southwest on George St. and southeast on King St. This area appears to have been developed a number of years ago as the street trees are quite large and numerous and the properties are larger than is common in newer developments. The area is approximately 56ha and contains portions of small and larger woodlots as well as a small wetland area. A transect was established along a residential block which limited vegetation to lawns and gardens.

St. Clements

This residential neighbourhood is located in the Town of St. Clements, in the Township of Wellesley. This transect also followed a residential block which started at the corner of Voison Crescent and Expo Dr. From the starting point the transect went north on Expo Dr., west on Ottawa St., south on sunset Dr., and east on Voison Dr. back to the start location. The site is approximately 18ha in area and naturalized vegetation is limited to gardens, street and yard trees of varying age. A wooded area with wetland pockets is present along the northern edge of the site. A transect was established along a residential block which limited vegetation to lawns and gardens.

Golf Courses

Grey Silo Golf Course

This public golf course is owned and operated by the City of Waterloo. It was constructed in northeast Waterloo's RIM Park approximately 10 years ago and although the city has commissioned ongoing annual monitoring of breeding birds, breeding amphibians, and vegetation, no specific surveys of the butterfly community have been undertaken there. Naturalized vegetation is relatively abundant compared with many other golf course and includes large areas of woodland, wetland, and cultural meadow that golfers are encouraged not to disturb. A transect route was established along a cart path adjacent to the Grand River.

Elmira Golf Club

This golf course was constructed approximately 40 years ago in Woolwich Township, just outside the Town of Elmira. The naturalized vegetation within this site is characterized by a number of mature trees, a naturalized riparian area, and there are landscaped gardens present throughout the course. At the request of the club manager, a transect was established based on minimal presence of the recorder on the actual course. The transect included a portion of a cart path, an area of the green that was more naturalized and the edge of the course which abutted an agricultural field planted with corn.

Foxwood Golf Club

This golf course is located on Erbs Road, west of St. Agatha in the Township of Wilmot. This course is characterized by extensive naturalized areas, a riparian area, several ponds, and landscaped plantings. A transect was established along a cart path which included golf greens, naturalized areas, and ponds.

Urban Parks

Bechtel Park

This recreational area is approximately 70ha in area and is located near the east side of Waterloo, south of University Ave. East. Recreational uses at the park include soccer fields, baseball diamonds, an indoor sports centre, a network of walking trails and a leash-free dog park. Naturalized areas include large areas of woodland, and wetland with a creek system transecting the park. A transect was established which included recreational and natural areas.

Waterloo Park

This 45ha park area is centrally located in the City of Waterloo. The park is home to a number of historical features and is used for a variety of community events. It also contains a large picnic area, a small petting zoo, and recreational sports facilities. Natural features in the park include woodland, wetland, and portions of Laurel Creek.

There are a variety of native and non-native landscaped trees and gardens. A transect was established which included recreational and natural areas.

Riverside Park

This park is the City of Cambridge's largest urban park, approximately 102ha. It is located immediately south of Highway 401 on the west side of Cambridge. Recreational uses at the park include soccer fields, baseball diamonds, tennis courts, picnic areas, walking trails and playgrounds. The park has large areas of woodland and wetland and the Speed River flows through the park. A transect was established which included recreational and natural areas.

Industrialized Area

Kumpf Drive

This industrial area is located in north Waterloo and is bounded by Kumpf Drive to the east, Northfield Drive to the south, Weber Street North to the west and the St. Jacob's Farmers Market, cultural meadow and a stormwater management pond to the north. Naturalized vegetation consists of small pockets of woodland and wetland as well as cultural meadow. Manicured lawns and gardens exist around many of the factories present in this area. A transect was established along a rail line and a riparian area which included old field habitat and manicured areas.

Wabanaki Drive

This industrialized area in Kitchener is located south of the intersection of Wilson Ave. and Fairway Road. The industrialized area is bordered on three sides by ESPAs including Homer Watson Park, Hidden Valley, and Petrifying Springs, it therefore contains more naturalized vegetation then other industrialized areas in the Region, including large areas of old field habitat surround what was formally the Goodrich Tire Plant. A transect was established along Wabanaki Drive which included old field habitat and manicured lawns and gardens characteristic of the area.

Ayr Industrial Area

This site is located in an industrial area located northeast of Ayr, just south of Highway 401, in the Township of North Dumfries. Naturalized vegetation is limited to old fields on the site and the area is surrounded by agricultural lands and some woodland. Landscaped trees and ornamental gardens are present around buildings. A transect was established along Darrel Drive and a heavily disturbed site that has become old field habitat.

Monitoring Butterfly Abundance and Diversity

Transect Counts

I adopted the method of transect counts, which form the basis of the UK's Butterfly Monitoring Scheme, the largest-scale butterfly monitoring effort in the world (UKBMS 2006). Transect counts provide an index of population size and therefore can be used to measure changes in abundance (Pollard and Yates 1993). The reliability of transect counts has been fully tested in Europe and to date it is the most cited method used to monitor butterflies. Transect counts were chosen over other methods outlined in the literature to estimate butterfly abundance and richness such as point counts or area searches because they are described repeatedly as a reliable method but also due to time and resource constraints. This method has proven to be a successful way of monitoring butterfly population trends, the status of individual butterflies, and phenology (UKBMS 2006). The methods outlined below follow Pollard and Yates (1993), with a few modifications based mainly on geographical and climate considerations.

Preliminary site selection began as a simple desktop exercise. A regional transect was drawn on a map which transected the three main urban areas in the Region (the cities of Waterloo, Kitchener, and Cambridge) as well as some smaller satellite towns (New Hamburg, Elmira, St. Clements). Fifteen sites were selected along this transect to represent 5 different land uses. These land use types were selected because they are found in or near every urbanized area in the Region: ESPA's, golf courses, residential areas, industrial areas, and urban parks. A smaller transect (approximately 500m long) was drawn on an aerial photo within each of the 15 sites selected (Appendix I). These transects were further refined through field checks. This methodology allowed for data on abundance and diversity to be collected at a number of locations across a variety of land-uses types. The data collection protocol outlined by Pollard and Yates (1993) was employed: the recorder imagined themselves inside a 5m box and walked at a uniform pace along the transect route recording all the butterflies seen within the 5m prescribed limits. The precise width of the observation area used by researchers in other studies has varied. The width of the "box" may be decided by the recorder but once it has been adopted it may not change (Pollard and Yates 1993). In open habitat types butterflies can be identified at greater distances. The 5m 'box' was selected so that the observation area would be consistent across sites. A larger observation area would not be possible at some sites due to dense vegetation. Stops were made to resolve identification problems and recording was resumed from the point where the walk was interrupted. A digital camera was used to photograph species which could not be identified in the field.

Pollard and Yates (1993) recommended recording for 26 weeks in the United Kingdom, and this is standard practice in the UK Butterfly Monitoring Scheme. This timeframe was modified to more accurately reflect the flight times of local butterflies (Layberry et al. 1998). Originally, it was planned that the recording season for the current study would be shortened to 23 weeks, beginning the second last week of May and ending the last week of October. Based on flight times of Ontario butterfly species this recording season would capture all species within the region including the flight times of early migrants and overwintering adults that appear in early May and the late-flying butterflies seen until the end of October (Holmes et al. 1991; Layberry et al. 1998). Butterfly observations usually peak in July, but July 2009 was the coldest year since 1915 (Seglenieks 2009). This led to a shorter recording season in 2009 that was only 17 weeks long, beginning the last week of May and ending the last week of September. To obtain a data set that would more likely account for yearly weather conditions, a second recording season occurred in 2010, beginning the second week of May and ending the last week of July (a total of 11 weeks). This time period was chosen to effectively capture the flight times of all butterflies known from the region. Poor weather (rain and/or temperatures <19°C) cancelled four weekly counts in 2009 and one weekly count in 2010. These missed counts were estimated as the mean of the preceding and succeeding counts (Pollard and Yates 1993). This method is undesirable but must be considered due to the length of the sampling period.

I walked each transect once per week. This level of effort was required because of the differing flight times of different species and because mobile species such as butterflies have imperfect probabilities of detection and are not always detected at the sites they sometimes occupy (Thomson et al. 2005). Transect walks occurred between the hours of 0900hrs and 1700hrs when temperatures exceeded 19ºC and wind speed did not exceed a force of 5 (38 km/hour) on the Beaufort Scale (Environment Canada

2007). This made recording at the beginning and end of the observation season difficult due to spring rains and cooler temperatures. Sunny or partly sunny days were preferred although it was not always possible to conduct every survey in ideal weather conditions. Weather conditions such as percent cloud cover, wind speed, and air temperature were recorded during all site visits.

Habitat Types

The transect routes were broken down by sections based on general habitat type which were drawn on an air photo base (Appendix I). These general habitat type classifications were based on generalized habitat units defined by the Ecological Land Classification for Southern Ontario (Lee et al. 1998) i.e. meadow, thicket, forest, etc. Butterfly abundance and diversity data collected along each transect was broken down by these general habitat types to allow for general comparisons between data collected on butterflies between not only sites, but different habitats. The relative abundance of habitat types within land uses was described to provide a general overview of what habitats characterized each land use. This involved a simple count, for example, how many meadow habitats were present along transects located industrial areas. These relative abundances of habitat were further categorized as naturalized or created habitats along the urban gradient. Any habitat resulting directly from anthropogenic activities i.e. mowed lawn, pavement, etc. was considered 'created' and any habitat that was natural occurring, including those which were the result of succession following some anthropogenic disturbance, were considered 'natural.'

Plant Richness

A multi-season (spring, summer, and fall) plant inventory for each site's transect route was compiled in 2009 to determine overall plant diversity and percent non-native plant species. A multi-season approach was taken to ensure a high detection rate of all plants within a site regardless of bloom time. This involved seasonal area searches along each transect route which included lands extending approximately 10 m from the walked route. Depending on the plant community present, 1 to 3 hours was spent conducting each area search. Species were recorded on field note paper or using an audio recorder and were later transcribed. Specimen which could not be identified in the field were collected and pressed for more detailed examination. Vascular plants observed at each site are included in Appendix II, which is presented using a modification of the Ontario Plant List (Newmaster et al. 1998). Furthermore, during each transect walk, the number of vascular plants in bloom was recorded to assess the richness of plants available for nectaring.

Estimating Percent Vegetation Cover

To estimate percent herbaceous vegetation cover, four randomly selected vegetation monitoring plots, each 1 x 1 m, along each transect route were sampled. Plot sampling took place in the spring (late May/early April) and summer (July/August) of 2009. These monitoring plots were visited in two seasons to assess seasonal variation in flowering plants and other herbaceous species that may influence butterflies. Plots were selected based on compass bearings and distances provided by an Excel random number generator (Table 5). These compass bearings were followed outward at the distance indicated from the centre of each transect route at 100m intervals and the plot was established using that location as the northwest corner of the plot (ex. Figure 3). For example, at the 100 m mark along a transect, the northwest corner of the vegetation plot was established 4.9 m, 175° from the transect. During each sampling event, the herbaceous species within the plot were recorded along with the number of individual stems, and approximate area they covered within the plot as a percentage. In order to estimate herbaceous cover within the transect site the total percent herbaceous cover for each of the four plots over two seasons was averaged and calculated as the average percent cover over the entire site (5000 m^2).

Table 5. Random Numbers Generated for Plot-based Vegetation Sampling

Interval (m)	Random Compass Bearing (°)	Distance (m)
100	175	4.9
200	86	0.1
300	72	3.2
400	228	2.6

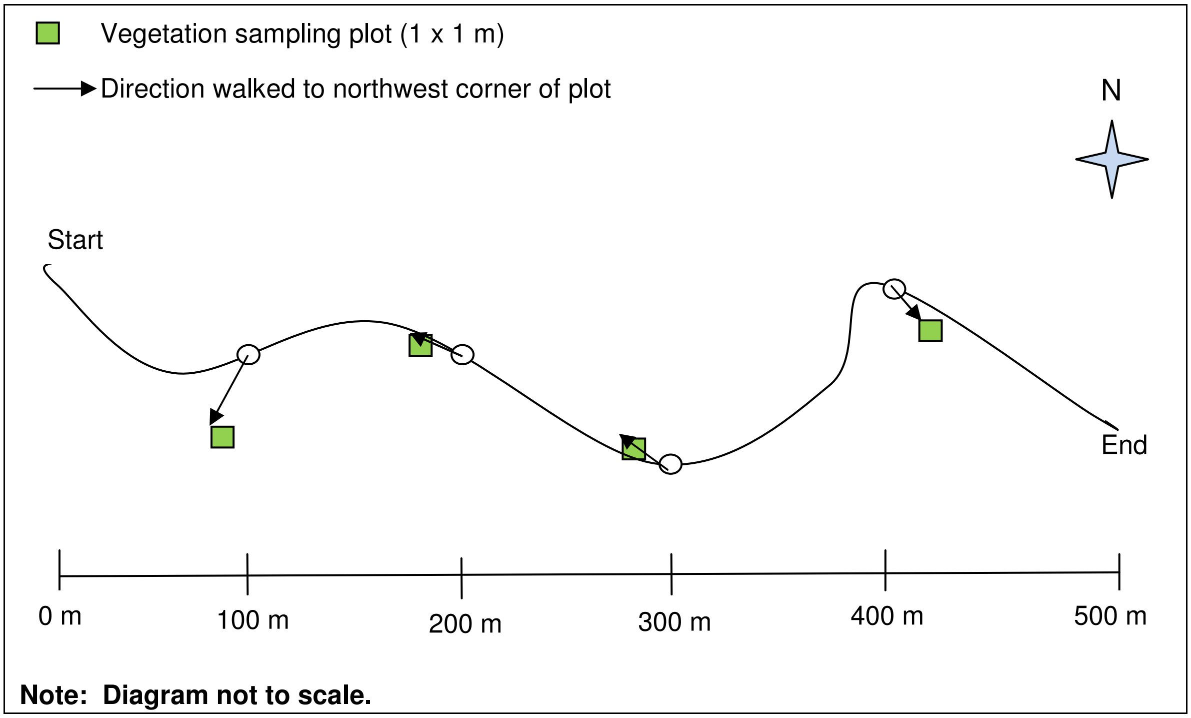

Figure 3. Diagram of Vegetation Sampling Plots at Each Site

This method was selected in order to provide an efficient sample of the herbaceous vegetation cover at each site using a random sample. The level of effort to sample 20 plots over two seasons was substantial and additional sample plots were not possible due to time and resource constraints.

Canopy Cover

Canopy cover was estimated using a densiometer. Four point readings (north, east, south, and west) were taken from the centroid of each vegetation monitoring plot in the spring and summer (for a total of 8 readings) which were then averaged for each site. This involved holding the densitometer out in front of the recorder and counting the quarter squares not occupied by canopy (i.e. open sky) (Figure 4). The total number of quarter squares was then multiplied by 1.04 which calculated total canopy cover at that point. This method was chosen because it provides a rapid and inexpensive measure of canopy cover compared to some more involved methods such as hemispherical photography (Fiala et al. 2006).

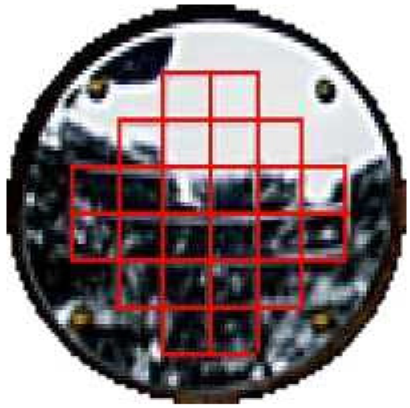

Figure 4. Visual Example of a Densiometer Reading to Estimate Canopy Cover

Weather

During each transect survey, temperature (ºC), percent cloud cover, and wind speed were recorded. Temperature was recorded using a small alcohol thermometer. Cloud cover was estimated by the recorder using a densiometer and wind speed was estimated using the Beaufort wind scale (Environment Canada 2007).

Data Analysis

Each week, butterfly abundance was recorded as the total number of individuals observed at each site. Overall butterfly abundance for each land use was calculated as the total of the weekly counts for each site represented by a particular land use. The abundance of each butterfly species was recorded separately to allow comparisons between sites for the same species. Butterfly richness across land uses was calculated simply as total richness across sites representing the same land uses. In order to determine if butterfly richness and evenness was significantly different between land uses, Shannon-Weaver Diversity indices were calculated for each land use for comparison using non-parametric Kruskal-Wallis test and Tukey's test.

Mean butterfly abundance and richness was compared to mean plant richness, relative abundance of non-native plant species, and the mean diversity of blooming flowers across land uses using linear regression. This technique was employed to simply assess the relationship between each variable and the butterfly community present. When this analysis indicated a significant relationship, a Spearman's rank correlation coefficient was used to further measure the statistical dependence between two variables.

RESULTS

The Urban Gradient

The five land-use types were ranked to represent a gradient of urbanization (Figure 5). ESPA areas were consistently ranked the 'most natural' followed by urban parks, golf courses, residential areas and lastly, industrial areas were considered the 'most urban' land use.

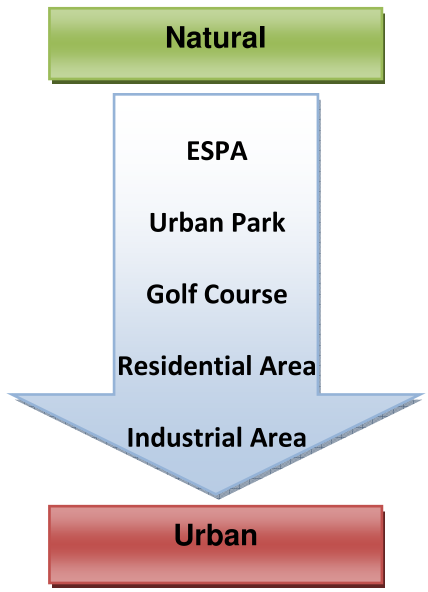

Figure 5. The Urban Gradient

Butterfly Abundance and Richness

During the 2009 and 2010 transect counts, a total of 38 species were observed. Twenty species were observed during transect counts in both years while an additional 9 different species were observed in passing each year. Overall butterfly richness was calculated by land use for 2009 and 2010 (Figure 6). These results were consistent with some hypotheses about the urban gradient: the highest average diversity was observed within ESPA areas and decreased moving down the gradient to more urbanized landuses. In both 2009 and 2010 species richness was observed to be highest in ESPAs and urban parks. In 2009 overall species richness was equal within golf courses, residential areas, and industrial areas while in 2010 industrial areas were observed to have a higher species richness then golf courses and residential areas. Shannon diversity scores for each land use were compared using a Kruskal Wallis test. This analysis revealed that species richness and evenness was not significantly different between golf courses, residential areas, and industrial areas in either 2009 or 2010. There were significant differences in Shannon diversity scores however between urban parks and ESPAs as well as significant differences between these two land uses and golf courses, residential areas and industrial areas in both 2009 and 2010 (Figure 4). When Shannon diversity scores were compared between years among each of the land uses, significant differences were observed between all land uses (P= <0.05) except residential areas (P=0.529) where species richness and evenness was significantly greater in 2009 than 2010. Overall species richness recorded within each land use type was similar in 2009 and 2010. The most variation (4 species) between years was observed within golf courses, residential areas, and industrial areas.

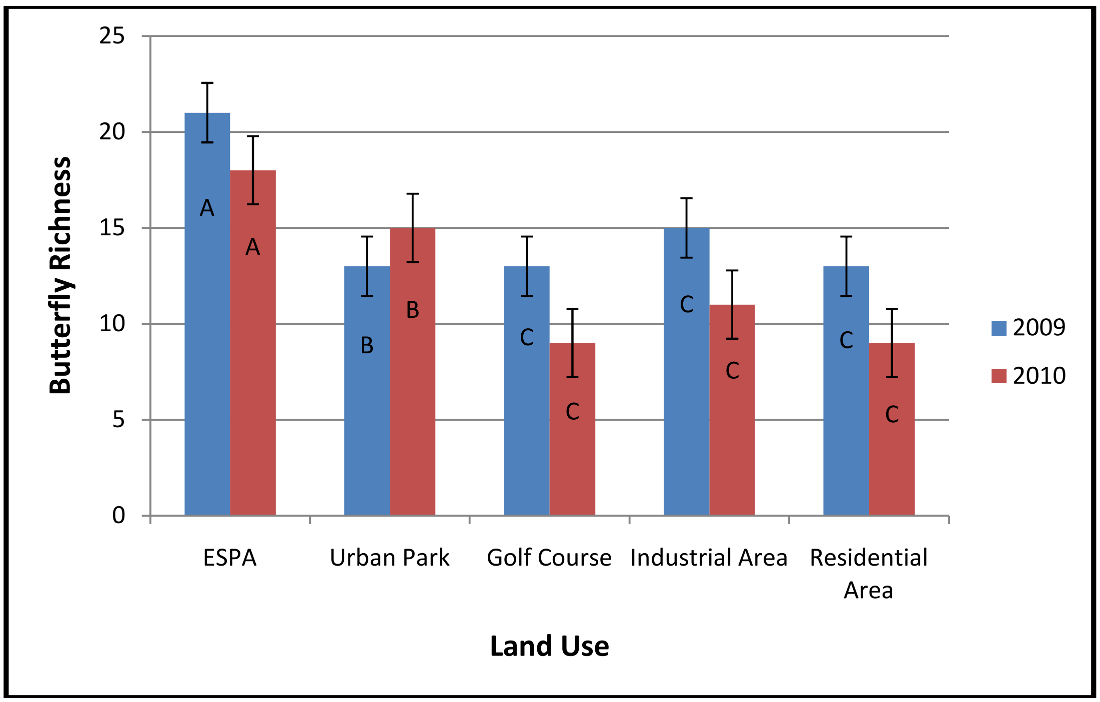

Figure 6. Overall Butterfly Richness by Land Use in 2009 and 2010.
Note: Different letters represent significant differences in Shannon scores ordered highest to lowest using a Kruskal Wallis Test.

A total of 1,334 individual butterflies were counted during transect walks in 2009 and 2010. Table 5 displays individual species by family and the number of individuals observed within each land use type. Over half of these individuals (n=767) were two non-native species: *Pieris rapae* and *Thymelicus lineola*. Five individuals observed during transect counts could not be identified to species (3 skippers, 1 anglewing in the genus *Polygonia*, and 1 greater fritillary in the genus *Speyeria)* because they escaped capture. Based on relative abundances of species in the region, the unidentified

Polygonia is thought to be either a question mark (*Polygonia interrogationis*) or eastern comma (*Polygonia comma*), while the fritillary was thought to be a great spangled fritillary (*Speyeria cybel*). Skipper butterflies are too difficult to identify on the wing and could therefore not be classified further than family.

Based on the regional status assignment detailed in chapter 1, half of all butterfly species observed during transects counts are considered 'very common.' Species designated as very common were observed within each of the 5 land use types and represented the most abundant and diverse group of species observed. Species designated as 'common' were also observed within all 5 land use types. The highest species richness of common species was observed within ESPA areas (n=5) while only 2 or 3 common species were observed within each of the other land uses. This trend was also observed for 'uncommon' species, with 4 species observed within ESPA areas but only 1 or 2 within the four other land uses. Species designated as 'rare' were only observed within ESPA areas.

Table 6. Butterfly Species Observed Across Land Uses and Their Relative Abundance.

Family	Scientific Name	Common Name	Regional Status	ESPA	Urban Park	Golf Course	Residential Area	Industrial Area
HESPERIIDAE	*Ancyloxypha numitor*	Least Skipper*	Uncommon	1				
	Epargyreus clarus	Silver-spotted skipper*	Uncommon		1			
	Erynnis baptisiae	Wild Indigo Duskywing**	Unknown		1			6
	Erynnis juvenalis	Juvenal's Duskywing**	Rare	1				
	Euphyes vestris	Dun Skipper*	Very common	3				
	Poanes hobomok	Hobomok Skipper	Common	4			2	
	Polites themistocles	Tawny-edged skipper*	Common		1			
	Thorybes pylades	Northern Cloudywing*	Rare	1				
	Thymelicus lineola	European Skipper	Very common	39	78	53	10	94
		Skipper sp.	N/A	3				
LYCAENIDAE	*Celastrina ladon*	Spring Azure**	Common	1				
	Celastrina neglecta	Summer Azure	Very common		1	1		1
	Lycaena hyllus	Bronze Copper*	Very common			4		
NYMPHALIDAE	*Cercyonis pegala*	Common Wood Nymph	Very common	10	4	4	1	1
	Coenonympha tullia	Common Ringlet	Common	22	8	15	10	15
	Danaus plexippus	Monarch	Very common	7	12	7	6	22
	Enodia anthedon	Northern Pearly Eye	Common	8				
	Limenitis archippus	Viceroy*	Very common		1	1	2	1
	Limenitis arthemis astyanax	Red-Spotted Purple	Common	2				
	Megisto cymela	Little Wood Satyr	Very common	34	17		26	3
	Nymphalis antiopa	Mourning Cloak	Very common	1		3	1	1
	Nymphalis vaualbum	Compton's Tortoiseshell*	Uncommon	2				
	Phyciodes cocyta	Northern Crescent	Uncommon	11		1	2	
	Phyciodes tharos	Pearl Crescent**	Common			1		
	Polygonia comma	Eastern Comma	Very common	1	4		1	
	Polygonia sp.	Polygonia Sp.	N/A		1			

	Polygonia interrogationis	Question Mark**	Very common	1	1	1		
	Satyrodes appalachia	Appalachian Brown	Uncommon	12				1
	Satyrodes eurydice	Eyed Brown	Very common	6		1		
	Speyeria cybele	Great Spangled Fritillary*	Very common		1	3		
	Speyeria sp.	Fritillary Sp.**	N/A			1		
	Vanessa atalanta	Red Admiral**	Very Common	23	46	15	20	44
	Vanessa virginiensis	American Lady**	Common		2		1	1
PAPILIONIDAE	*Papilio glaucus*	Eastern Tiger Swallowtail	Very common	4			2	
	Papilio polyxenes	Black Swallowtail	Very common		1			3
PIERIDAE	*Colias eurytheme*	Orange Sulphur**	Very common		1			
	Colias philodice	Clouded Sulphur	Very common	8	23	20	11	13
	Pieris rapae	Cabbage White	Very common	67	109	90	100	127

*Species only observed during 2009 transect counts

**Species only observed during 2010 transect counts

Although the actual number of butterflies counted during transect walks in 2009 (n=800) was higher than in 2010 (n=537), so was the percentage of non-native species observed. In 2009, 63.9% of butterflies observed were non-native while in 2010 only 42.5% were non-native, indicating that the difference in overall abundance observed between years may have been due to population fluctuations of two very common species. Figure 7 displays overall butterfly abundance by land use in 2009 and 2010 as well as the mean abundance of non-native species for both years.

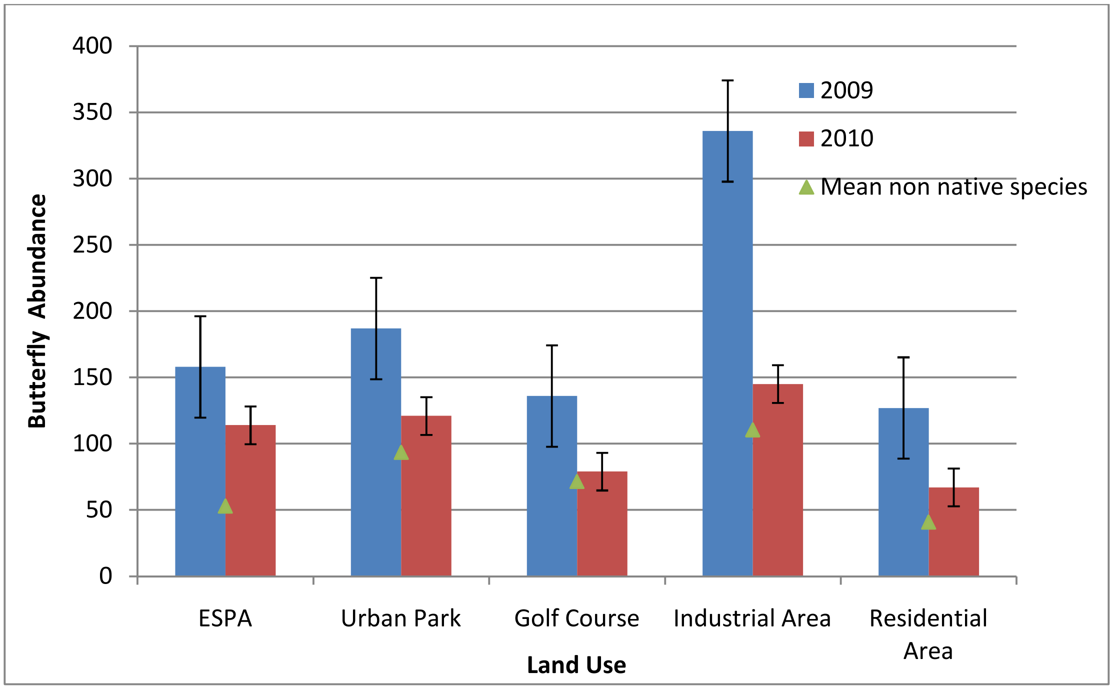

Figure 7. Overall Butterfly Abundance by Land Use in 2009 and 2010.

Habitat Types

General habitat types present within the 15 transect sites were divided into 16 general categories which were further classified as natural or created habitats. Table 6 summarizes these general habitat categories and indicates which land uses had areas representing these habitat types. Figure 8 displays the relative abundance of natural and created habitats between land uses. Transects within ESPAs had the least amount of created habitats which were limited to dirt or woodchip trail systems. Residential areas and industrial areas surveyed had the highest amount of created habitat, the majority of which was manicured lawn and pavement (roads). Golf courses surveyed had a surprising amount of natural habitat mainly due to the presence of woodland edges and natural regeneration area (i.e. areas that were previously cleared but which have been left to naturally regenerate), but also a high proportion of manicured lawn. Urban parks surveyed had a relatively high diversity of natural habitats but also abundant areas of manicured lawn.

There was a weak correlation between natural habitat diversity within land uses and mean butterfly richness (r=0.86; p=0.06). However generally speaking, the highest diversity of butterflies was observed within ESPA areas which also had the highest diversity of naturalized habitats. This trend continued along the urban gradient. The land uses with the least amount of naturalized habitats (Industrialized areas and residential areas) were also observed to also have the lowest mean butterfly richness. Mean abundance of butterflies within each land use was not observed to be strongly correlated to the diversity of naturalized habitats present within a given land use (r=0.08; p=0.89).

Table 7. Habitat Types Present within each Land Use Type.

Habitat Type	ESPA	Urban Park	Golf Course	Residential Area	Industrial Area
Natural Habitat					
Meadow	X		X		
Woodland edge	X	X	X		
Open water			X		
Marsh	X	X		X	
Deciduous Swamp	X				
Deciduous Forest	X				
Natural regeneration	X		X	X	X
Thicket	X	X		X	
Riparian	X	X			X
Mixed Swamp	X				
Hedgerow		X			
Created Habitat					
Manicured Lawn (open)		X	X	X	X
Manicured Lawn (with trees)		X	X	X	
Garden				X	X
Pavement		X		X	X
Gravel (road shoulders, pathways)	X	X		X	X

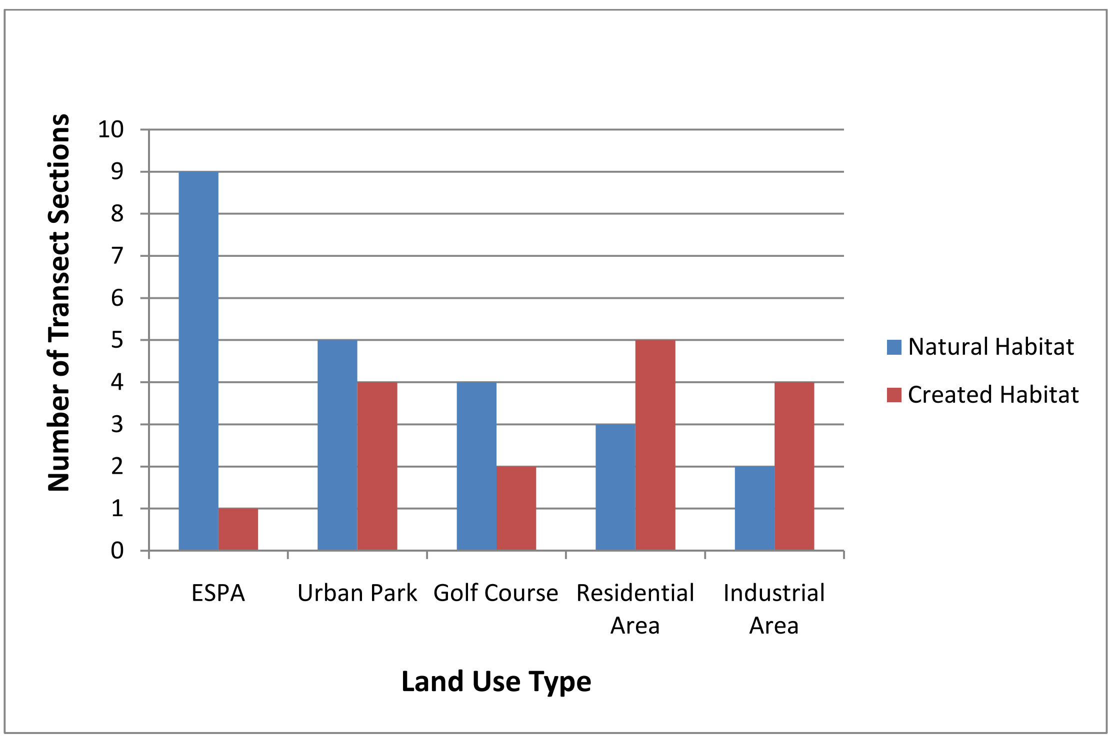

Figure 8. Relative Abundance of Natural and Created Habitat by Land Use

Plant Richness

During plant inventories, a total of 300 plants were identified within the 15 transect sites (Appendix II). An additional 23 species were noted but could not be identified to species level. This included ornamental garden plants at New Hamburg Residential area and St. Clements Residential area as well as a hawthorn (*Crataegus* sp.), two sedges (*Carex* sp.), a grass (*Poa* sp.) and an ornamental maple tree (*Acer* sp.). The highest average plant richness of 107 species was observed within ESPAs, which was substantially higher than the remaining four land uses which all averaged between 63 and 73 species. Using linear regression a relationship was found between mean butterfly richness and plant richness (r=0.88, p=0.04) however this correlation was weaker than suggested when analyzed using a Spearman's correlation (0.27). A weak correlation was observed between mean plant richness and mean butterfly richness across land uses. Mean plant richness however was not strongly correlated to mean butterfly abundance (r=0.03, p= 0.95).

Mean richness of non-native plant species at ESPA sites was also substantially different from the other four land uses and represented only 29.1% of plants observed (Figure 9). Non-native plants represented more than half of the overall plant richness within urban parks, golf courses, residential areas, and industrial areas. This observation is consistent with the hypothesis about the urban gradient where the fewest non-native plant species are observed in the most natural (or least disturbed) area and the highest number of exotic plant species are observed in the most urban (or most disturbed) areas. A weak correlation was observed between mean butterfly diversity and mean non-native plant richness across land uses (r= 0.58, p= 0.30). When mean butterfly abundance was also compared to mean non-native plant richness across land uses, no correlation was observed (r= 0.05, p= 0.93).

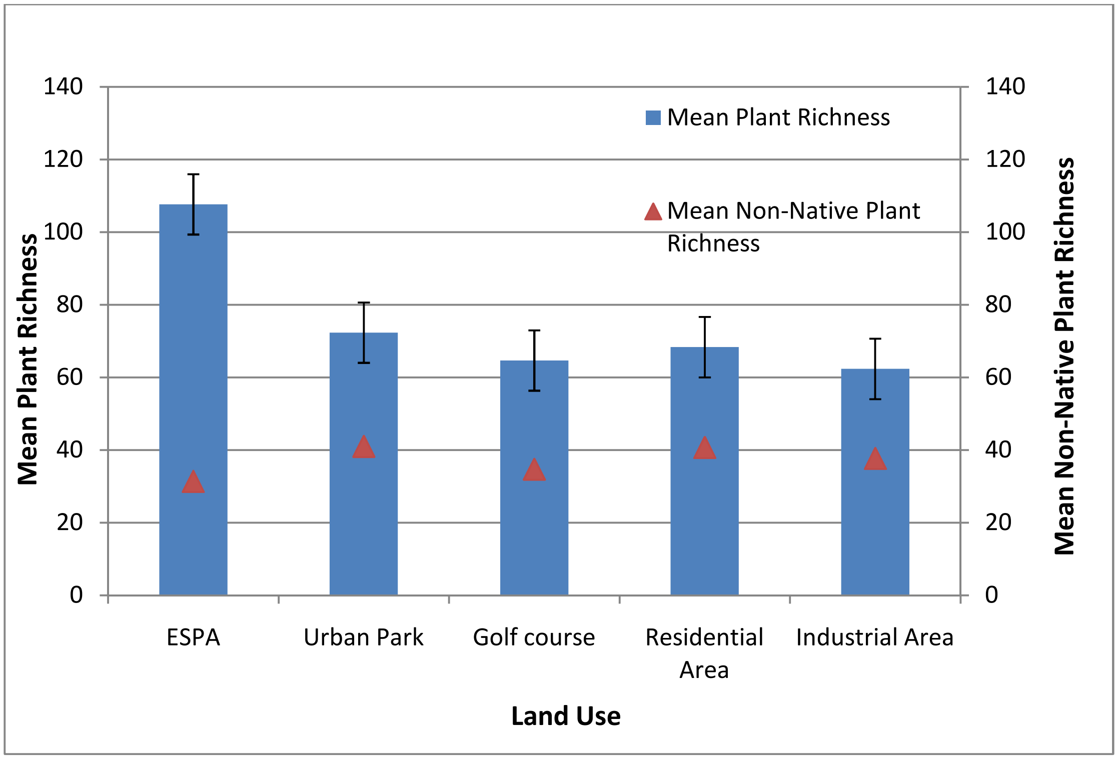

Figure 9. Mean Plant Richness vs. Mean Non Native Plant Richness by Land Use.

Vegetation Cover

Data collected through the established vegetation monitoring plots indicated that golf courses had the highest average percent herbaceous vegetation cover followed by urban parks, ESPAs, industrial areas, and residential areas (Figure 10). These results are influenced heavily by the abundance of manicured lawn at some of these sites which was considered for this study to be vegetation cover. Although likely not the most desirable habitat for butterflies, manicured lawns do consist of vascular plants and butterflies were observed on dandelions (*Taraxacum officinale*) and clovers (*Trifolium* spp.) growing on lawns during surveys. ESPA areas, which had the highest relative abundance of naturalized habitats also had high proportions of bare ground or leaf litter which were not considered vegetation cover for this study. Residential and industrial areas had a high proportion of pavement compared to the other land uses which resulted in low average percent vegetation cover. Mean butterfly richness was not observed to be significantly correlated to mean herbaceous vegetation cover (r= 0.17, p= 0.77) or the average number nectar sources (r= 0.82, p= 0.08) across land uses.

Similarly, no correlation (r= 0.54, p= 0.30) was observed between butterfly abundance and average number of nectar sources (blooming flowers) across land uses.

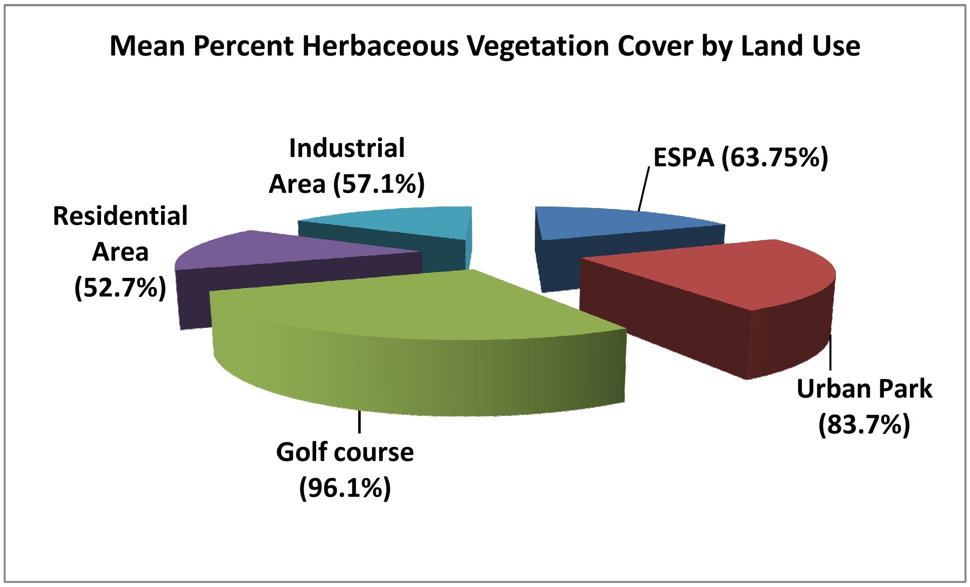

Figure 10. Average Percent Herbaceous Vegetation Cover by Land Use

Canopy Cover

As indicated previously, the majority of ESPA areas in the Region of Waterloo are forested therefore not surprisingly ESPA areas had the highest average canopy cover of over 77% (Figure 11). Urban parks had the second highest canopy cover which was substantially lower than ESPA's while residential areas, industrial areas, and golf courses all had relatively low average canopy cover. Surprisingly, the highest mean butterfly richness was observed within land uses with the highest canopy cover: ESPAs. However when tested using a Spearman's correlation a weak relationship was observed (0.36). This is likely due to the fact that the canopy cover measured within ESPAs was an obvious outlier. Mean butterfly abundance was not observed to be strongly correlated with canopy cover (r= 0.13, p= 0.83).

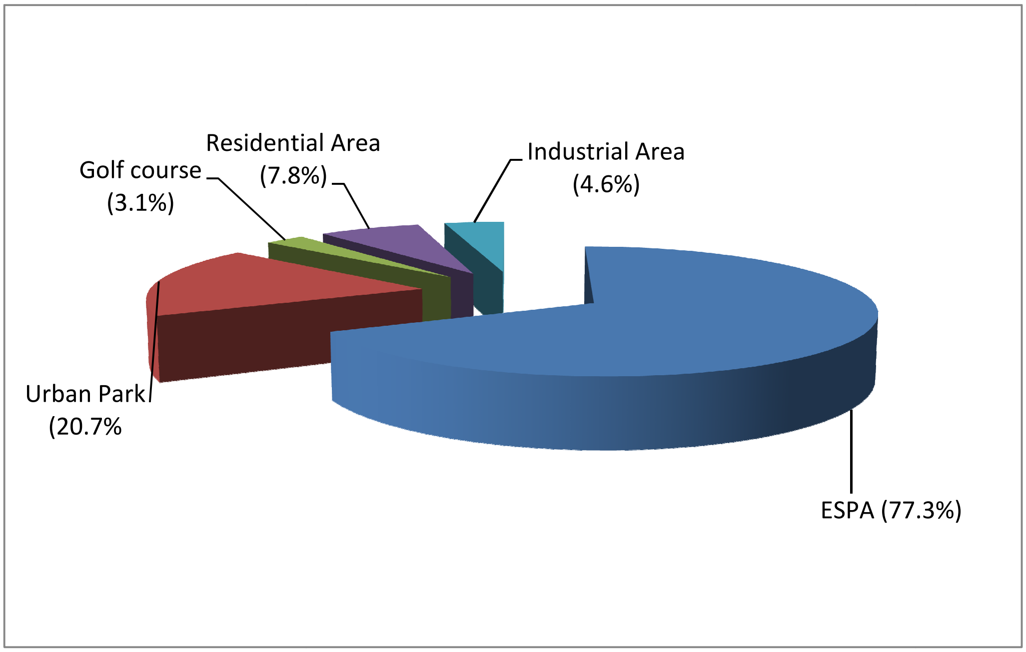

Figure 11. Average Canopy Cover by Land Use

DISCUSSION

Assumptions about the ordering of the urban gradient were very similar to another study by Blair (1999) which employed similar techniques for ranking similar land uses. Protected ESPAs are characterized as the 'most natural' and industrial areas or business districts are characterized as the 'most urban.' Urban parks, open spaces, residential areas and golf courses are characterized as intermediate. The diversity and types of habitat within these different land use types were consistent with assumptions about the urban gradient: the higher a land use was on the urban-rural gradient the higher diversity of created habitats and non-native plant species it was observed to have.

Shannon diversity scores between years across the same sites were significantly different however general trends in overall butterfly richness and abundance were similar between monitoring years across the urban gradient. Overall butterfly richness observed was very similar between land uses in 2009 and 2010, however overall butterfly abundance was observed to be substantially higher in 2009 than 2010. This difference in abundance is attributed to the abundance of two non-native species observed in 2009: *Pieris rapae* and *Thymelicus lineola.* There are a number of factors that may have contributed to why these species were less abundant in 2010 but the difference in the sampling effort (17 weeks in 2009 vs. 11 weeks in 2010) and weather are likely important factors. The highest species richness was observed within ESPAs followed by urban parks, industrial areas, golf courses and residential areas. Abundance was observed to be highest within industrial areas followed by urban parks, ESPAs, golf courses, and residential areas. The land uses that represented the highest butterfly abundance also had the highest counts of *Pieris rapae* and *Thymelicus lineola* which indicate that these non-native species are able to exploit resources in urban environments and adapt to urban land uses easily.

As with other similar studies (Blair and Launer 1997), the causes of these observed patterns in distribution and abundance are difficult to isolate and are almost certainly a combination of multiple factors. Significant correlations between mean butterfly richness and factors that differ across land uses such as plant richness and canopy cover were not observed. However a higher overall richness of butterflies *was* observed in areas with a more naturalized habitats and a richer plant community with minimal invasive plant species. A higher overall richness of butterflies was also observed along transects which had more canopy cover although this is heavily influences by canopy cover within ESPAs which are an obvious outlier. Observing the highest overall species richness within areas with the highest canopy cover was surprising given that butterflies are typically sun lovers and few species prefer shaded areas. This observation could be because a higher average canopy cover does not necessarily translate to more overall shade in an area, particularly along edges or within areas with scattered trees. Trees and shrubs that provide canopy cover can also provide nectar and larval food sources for butterflies. Comparisons between mean butterfly richness, non-native plant richness and herbaceous vegetation cover did not indicate a strong relationship. During transect counts, several butterfly species were observed to be nectaring on non-native flowering plants which provided an abundant nectar source. It has also been documented that several native butterflies have adapted to use non-native plant species as larval foodplants such as the *Papilio polyxenes* and the *Erynnis baptisiae* (Layberry et al. 1998). Overall, none of the parameters examined were observed to strongly influence mean butterfly abundance.

ESPA areas supported the highest diversity of butterfly species with a relatively low abundance of non-native species. Industrial areas were hypothesized to support the lowest diversity of butterfly species however they supported more diversity than residential areas and golf courses. The highest proportion of non-native butterfly species was observed within industrial areas which resulted sites represented by industrial landuses having the highest overall abundance of butterflies in both 2009 and 2010. Based on the results of this study, it appears that residential areas, golf courses, and industrial areas provide habitat for a significantly less diverse butterfly community than ESPAs and urban parks. This was surprising given the abundance of flowering plants in gardens, the recent pesticide ban, and the relatively recent increase in public interest in butterfly gardening due to promotion at several local garden nurseries and the development of two, local indoor butterfly attractions. It was hypothesized that due to tendency for ESPA areas to be characterized by forested habitats, that they would not necessarily support the highest diversity of butterflies. This was proven not to be the case. Average species diversity among land uses was observed to be the highest within ESPA areas in both 2009 and 2010. Transects within ESPA areas were also observed to have the highest overall diversity of plants and the lowest proportion of non-native plants indicating that these areas are effective at preserving native butterfly and plant diversity. A total of 9 species observed were restricted to ESPA areas during transect counts compared to 3 restricted to urban parks and 2 restricted to golf courses. Based on the regional status assignment, only two rare species were observed during transect counts, both only within ESPA areas. The highest proportion of regionally uncommon species was also observed within ESPA areas (four species) compared to one uncommon species observed in golf courses, industrial areas, and residential areas. The results of this study indicate that although ESPA areas tend to be characterized by forested habitat they still support the highest diversity of butterfly species. This could be due to a number of factors but is likely a combination of their relatively intact native plant communities and the open edge communities that are often formed as a result of trails and adjacent roads.

Urban parks surveyed supported a relatively high species richness and abundance which was not anticipated given the tendency for these land uses to be heavily manicured. Although these land uses had the highest proportion of manicured lawn and general landscaping, they also had patches of naturalized edges associated with wetland, woodland and riparian habitat which may be attracting butterflies. Golf courses on the other hand, which are also heavily manicured, were observed to support a low species richness. Pesticide use was observed at all three golf courses in 2009 and 2010 on two separate occasions for the control of weeds (early spring and mid-summer). These pesticides were assumingly only applied to the golf greens and not the naturalized edges however it is not known what sort of impact the application of these chemicals may have on the butterfly community.

Overall these findings are consistent with a study by Clergeau (1998) who observed that in large cities, local habitat features seem more important than the landscape setting of the city. If these results are applied to urban land use planning then goals should include maintaining a diversity of naturalized habitat types, increasing plant diversity, providing a variety of nectar sources, and maintaining some canopy cover.

CONCLUSIONS

The purpose of Chapter 1 was to present detailed baseline data on butterfly presence/absence within the Region to determine which species of butterfly are uncommon or rare and draw conclusions about how butterfly communities have changed over the last 80 years. Through the collection and review of over 4,400 records, interviews with local experts, field checks, and review of field notes and local unpublished literature, general conclusions were drawn about changes in butterfly communities and a regional status was assigned to each known to occur within the region. It was determined that 46 species should be considered rare or uncommon while 34 should be considered common or very common. It is suggested that this regional status assignment could be a valuable resource for local agencies and government bodies during land use planning to identify important butterfly habitats for protection. The collection of this baseline data presents an opportunity for additional and continued research on butterfly presence/absence within the Region. It would be extremely useful to add a spatial component to the database by creating a Regional butterfly atlas. Data collection could also continue on a regular basis by building a web-based interface where butterfly observations could be consistently directed. Both of these undertakings are considerable and require time and resources that are currently not readily available. The Region of Waterloo's Ecological and Environmental Advisory Committee however, has expressed interest in creating an annotated reference list of butterflies and their habitat preferences for their Greenlands Network. This is one small but progressive step for including butterflies in Regional landscape planning. Additional gaps that could be filled by future work include species-specific studies to estimate population sizes of rare or uncommon species, as well as an inventory the amount of suitable habitat for these species in the region.

The purpose of Chapter 2 was to determine how different land uses within the Region of Waterloo affect butterfly abundance and diversity. This question was examined through an urban gradient study which identified Environmentally Sensitive Policy Areas, designated by the Region of Waterloo, as the 'most natural' areas, followed by urban parks, golf courses, residential areas. Lastly, industrial areas were identified as the 'most urban' environments along the gradient. Butterfly richness and evenness between ESPAs and urban parks and compared to other land uses differed significantly. Residential areas, industrial areas, and golf courses were observed to not to differ significantly in terms of their species richness and evenness. Generally, overall species richness was consistent with assumptions about the urban gradient although a slightly more diverse community was observed within industrial areas than residential areas and golf courses. Butterfly abundance was observed to be heavily influenced by the abundance of two non native species considered to be the most common species in the region. Trends were observed between factors that characterized the different urban land uses such as plant diversity, canopy cover, and habitat types and overall butterfly species richness, however significant relationships between these variables was not observed. Based on the results of this study it appears that local habitat features play a more important role in characterizing the butterfly community then the overall urban landscape. Opportunities for additional research into landscape influences are apparent and encouraged to build on the results of this study which is focused on site-level analysis. Due to the fragmented nature of the urban landscape in the Region, the urban gradient examined in this study includes natural and urban sites that are disconnected. For example, the residential areas of New Hamburg and St. Clements are relatively isolated from the urban centers of Waterloo, Kitchener, and Cambridge. Therefore an examination of landscape drivers between these disconnected residential areas and residential areas in the main urban hubs is of interest to determine if colonization of isolated areas by less mobile butterfly species is even possible. This type of examination would increase knowledge on how landscape connectivity is influencing local butterfly communities in the Region.

Furthermore, the data collected for this study provides the opportunity for many more research questions to be examined which expand beyond the scope of a single thesis. Data on butterfly richness and abundance within each site was collected by habitat which would allow for a detailed examination of how butterfly communities within similar habitats, nested in sites characterized by different urban land uses, differed. The data also presents the opportunity to examine how the abundance of individual species across sites and habitat types differed. Given that climate change is an issue that little is known about in terms of its impacts to individual taxa, the detailed site-level data collected in 2009 and 2010 also presents an interesting opportunity to examine how climate change may impact local butterfly populations. The data collected in 2009 represents butterfly abundance and richness in an uncharacteristically cool and wet year, while the data in 2010 represents a long, warm season where a noticeable influx of seasonal colonists and immigrants was observed. Lastly, baseline data on the availability of nectar resources was also collected which could help frame research questions focuses on the quality, abundance and diversity of nectar sources available within different land uses types perhaps not only for butterflies, but other pollinators.

It has been suggested by some researchers that examining butterflies as a select taxa could provide valuable insight into how different land uses are affecting overall biodiversity in an area (Gilbert 1984; Brown 1991; Eberhardt & Thomas 1991; Sutton & Collins 1991; Kreman 1992; Pollard and Yates 1993; Oostermeijer & van Sway 1998; Blair 1999). In some sense, the presence, absence or abundance level of any organism must always indicate something about the biotic or abiotic environment (Kremen 1992). Comparison of studies that examine the effectiveness of indicators is complicated by differences in sampling effort, geographical location, site size, target species, and the way in which data has been analyzed. Literature was found that supports the use of indicators for developing conservation strategies, as well as literature that did not (Noss 1990; Kremen 1992; Prendergast et al. 1993; Debinski and Brussard 1994; Flather et al. 1997; Blair 1999; Kremen 1994; Germaine and Wakeling 2002).

In a similar local, urban gradient study, Blair (1999) examined if birds and butterflies could be surrogate taxa for assessing biodiversity. He argued that both birds and butterflies meet the criteria for effective indicators put forward by Noss (1990). Noss (1990) suggests that an effective indicator should be 1) sensitive enough to provide an early warning of change; 2) widely distributed geographically; 3) capable of providing a continuous assessment over a wide range of stresses; 4) relatively independent of sample size; 5) simple to collect and measure; 6) well known so that natural cycles can be distinguished from changes based on human disturbance; and 7) relevant to ecologically significant phenomenon. Many of the criteria were employed to assess the suitability of butterflies as indicators in this study. Blair (1999) found that patterns in the distribution of both taxa were significantly similar along the gradient. Species richness for both groups was very similar across the gradient and both bird and butterfly species richness was highest at sites that were characterized by intermediate levels of development (birds at golf courses and butterflies in open space recreational areas). No correlation was observed between bird and butterfly abundance, where butterfly abundance tended to decrease toward the urban centre while the number of birds increased. Certain species of bird and butterfly were only recorded within one site type providing insights about rarity within those sites. This observation is similar to the findings of this study where species considered regionally rare were only observed in ESPAs. The results of this study imply that taxonomic surrogates in assessing species diversity do not necessarily have to use the environment in the same way but overall their response to urbanization may be similar (Blair 1999). Blair (1999) also points out that the effort required to survey the butterfly community was significantly lower than the effort required to survey the bird community, but achieved the same results. He brings attention to the fact that the results of this study may not apply over a larger landscape scale. Germaine and Wakeling (2002) found the response of lizards along an urban gradient mimicked that of breeding birds in two different studies (Germain et al. 1998; Blair 1996). In these studies, three distinct responses to urbanization became apparent: species readily exploit the urbanized environment, species adapt to moderate levels of urbanization, or species are sensitive to even low levels of urban development (Germaine and Wakeling 2002).

Research was also found that refuted the idea that community composition of one taxonomic group could be indicative of the composition of other groups occupying the same habitats. Prendergast et al. (1993) examined the distribution of a suite of well-known taxa (birds, butterflies, dragonflies) and less-known taxa (liverworts and aquatic angiosperms) across a large geographic scale (the entire United Kingdom) to assess if one group could be a surrogate for the other in estimating species richness. The authors concluded that the well-known taxa are not good surrogates for lesser-known taxa, however one might argue that they do not adequately take into account the data gap that defines these groups as ‘well’ or ‘less’ known. Faith and Walker (1996) also argued that there are limitations in their approach given that the goal of the study was to identify a limited number of individual areas with high biodiversity instead of examining a set of areas may allow for more general comparisons. Van Jaarsveld et al. (1998) also examined the correlation between eight different taxa (mammals, birds, plants, butterflies, termites, antlions, and two types of beetles) over a wide geographic area in Africa. They argued that assumptions about species surrogacy are not supported and there was little correlation between any of the eight groups. Similarly, Lawton et al. (1998) inventoried eight taxa (represented by birds, butterflies, beetles, ants, nematodes, and termites) along a gradient of disturbance in a tropical environment (Cameroon), and observed general decreases in species richness with increased disturbance. They concluded however, that species richness for not one of the eight groups serves as a good indicator of the other as there was no significant correlation between species richness between groups. Debinski and Brussard (1994) examined species diversity patterns for birds and butterflies to determine if these taxa could be inventoried to serve as indicators for overall biological diversity in Glacier National Park which is 4,000 square kilometers in area. They did not find a positive correlation between butterfly species richness and bird species richness but did find that in general, birds were more habitat specific than butterflies.

Pearson and Cassola (1992) suggested that in many geographical areas tiger beetles (Cicindelidae) are even more effective indicators than butterflies and birds. Regardless of the indicator of choice, Pearson and Cassola (1992) did suggest a positive correlation in species richness between these three taxonomic groups across several continents suggesting that they could in fact act as surrogates for one another when assessing species richness. Flather et al. (1997) argued that Pearson and Cassola (1992) results are weaker than they indicate by reanalyzing their data controlling for changes in latitude across a continental geographical scales. Flather et al. (1997) also argue that a more effective approach than the indicator assumption is simply to use the best information available rather than implying that inventoried taxa have the potential to reflect the diversity pattern of the regional species pool.

Although some researchers have suggested that there may be a strong positive correlation butterfly diversity and plant diversity (Murphy and Wilcox 1986; Van Jaarsveld et al. 1998), in a study which examined the indicator properties of butterflies in Madagascar, Kremen (1992) found that butterflies were poor indicators of plant diversity. Other strong relationships were observed however between the diversity of plants in flower and climatic conditions and overall butterfly diversity. New (1997) however argues that butterflies act as an effective "umbrella group" for guiding conservation management because of their dependence on plants. Umbrella species are those that occupy expansive tracts of habitat or specific types of habitat so that conserving such a species automatically saves many other species occupying the same area (Simberloff 1998). He argues that conservation activities undertaken to protect butterflies may also help to protect flowering plants as well as highly complex habitats, rare habitats, and/or other insect taxa (Launer and Murphy 1994; New 1997). New (1997) puts forth that the following trends may indicate the need for conservation management:

- disappearance of species is likely to reflect changes in other biota;
- changes in the proportions of species may constitute an 'early warning' system for undesirable or unplanned changes;
- patterns of species richness may be used to rank the conservation importance of different areas; and

- the presence of rare or ecologically specialized species may indicate the presence of specialized resource suites also used by other taxa.

In many instances, areas have been compared using indicators are very widely distributed and therefore differ enormously in their overall species richness (Balmford et al. 1996). The key to the effective use of indicators may be the scale at which such a technique is applied. If sites are in close proximity to one another then variation in species richness may be more predictable. Murphy and Wilcox (1986) found that correlations between bird and butterfly species richness varied with scale. Studies that occurred over wide geographical areas (Debinski and Brussard 1994; Flather et al. 1997; Van Jaarsveld et al. 1998), have tended to conclude that select indicators are not good at predicting overall biodiversity, while smaller, local studies have found the opposite to be true (Blair 1999; Kremen 1994; Balmford et al. 1996). It seems that in areas that have a high variation in latitude indicators may not be as effective because the driving force in biodiversity is elevation (Kremen 1992; Flather et al. 1997). Ideally, surveying a suite of indicator taxa to assess biodiversity would produce the most accurate results however this leads back to the challenge of dealing with time, effort and monetary constraints (Kremen 1992; Kremen 1994; Lawton et al. 1998). Generally, conservation management goals occur on a local or regional scale therefore the use of indicators to guide these goals would appear to be a reasonable approach at this scale.

Geographic location may be an important driving factor influencing the effectiveness of indicators as well. It is obvious why results from indicator studies in tropical areas may not be applicable to temperate regions due to extreme differences in abiotic and biotic factors. Most evidence supporting the use of indicator species to make predictions about overall biodiversity comes from temperate regions (Balmford et al. 1996). There is an enormous difference in butterfly diversity between the temperate and tropical regions and variation in species richness within tropical regions is still poorly understood (Robbins and Opler 1996). One of the reasons butterflies are preferred as indicators in temperate regions is because their life histories are very well known and generally there is little difficultly in identification. To put this into context, there is an estimated 1250 species of butterfly in Costa Rica alone compared to only 321 in all of Europe and an estimated 7,500 hundred species in South America versus only 750 in all of North America including Mexico (Robbins and Opler 1996). In a tropic based study, Balmford et al. (1996) found that species richness within individual genera or families is potentially as powerful an indicator of the overall species diversity of a site as the number of individual species it contained. It may be more appropriate to only use species richness as an indicator in local, temperate regions where there is more knowledge about presence/absence of a particular region and the species that live there. Habitat modifications induced by urbanization appear generally similar across large geographical areas however general conceptualizations may be misleading as the area considered increases (Clergeau et al. 1998).

Although there is conflicting research on the subject of indicators, examining butterfly abundance and diversity on a regional scale may provide a cost effective way to gain insights into overall biodiversity. There is research to suggest that butterfly diversity is closely correlated to plant diversity and there is some evidence to suggest that the proportion of butterfly diversity may indicate a higher diversity of birds (New 1997; Murphy and Wilcox 1986; Van Jaarsveld et al. 1998; Blair 1999). Some researchers have also found similarities in community composition among birds, lizards, and beetles (Pearson and Cassola 1992; Germaine and Wakling 2002). Where there is evidence to support these relationships, there is also evidence to refute them although these studies tend to examine indicators in highly diverse tropical regions and/or at large geographic scales. Based on the evidence in the literature that supports the use of indicators at small scales in temperate regions, it is considered reasonable to assume here that in areas representing a particular land use, butterfly diversity could be an effective indicator of overall plant and bird diversity which in turn is an indicator of habitat quality for supporting overall biodiversity. This study has provided baseline data on butterfly community composition within a variety of land uses. Therefore as New (1997) contends- changes in the community composition may provide an early warning of undesirable ecosystem changes or reflect changes in other biota.

There is currently no provincial standard that require butterfly surveys to be completed as part of land use planning studies. Typically subwatershed studies, natural heritage studies, Environmental Assessments, and Environmental Impact Studies (EIS) require field work to characterize natural heritage features including inventories of flora and fauna. Butterflies or other insects may be incidentally documented during these studies but very rarely targeted for inventories. Even if butterflies are considered in the land development process, there is no local status listing to use to measure significance of individual species. Therefore, butterflies, as a group, are usually unidentified and not considered in this process and it is very likely that colonies of butterfly species are destroyed without consequence. Development proposed within open habitats greater than 120m from a wetland, watercourse, or woodland such as an agricultural field or a meadow are generally not required to go through the EIS process (GRCA 2005; Region of Waterloo 2010). Open habitats are frequently overlooked as protection of natural features is usually focused on protecting woodlands and wetlands. These ecosystems however, can be incredibly important for butterflies, odonates, and open country birds. Some butterflies can live out their entire life history within a very small geographic area. If colonies are widely dispersed they may perish if their habitat is heavily disturbed or wiped out all together.

A general decline in the abundance and diversity of butterflies has occurred in the Region of Waterloo. This trend will continue unless policy makers force land use planners to give them consideration. This should involve butterfly inventories of proposed development sites including open areas which provide suitable habitat for uncommon or rare butterfly species identified in this study. Butterflies are not only beautiful, they can be important pollinators and food sources for other insects as well as an important early warning of changes in an ecosystem. Land-use planning should include the creation, protection, and maintenance of open naturalized habitats, edge habitats, and butterfly gardens all which can provide habitat for other wildlife species or act as linkage habitat between lager natural areas.

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COLLECTIONS EXAMINED

1. James, E.L. Collection housed at the University of Waterloo, Department of Biology. November 3, 2008.

2. Lamb, L. Collection housed at a private residence in Waterloo, Ontario. Examined January 30, 2010.

3. Morton, J. K. Collection housed at a private residence in Waterloo, Ontario. Examined December 8, 2008.

4. University of Guelph Insect Collection, Department of Environmental Biology. Examined December 15, 2008.

5. Stricker, F. Collection housed at a private residence in Kitchener, Ontario. Examined December 5, 2008.

RECORD OF INTERVIEWS AND PERSONAL CORRESPONCE

Burell, M. Email correspondence May 28, 2009.

Campbell, C. Formal interview conducted on November 27, 2008. Ongoing Correspondence from September 2008 to November 2010.

Lamb, L. Formal interview conducted on November 10, 2008. Ongoing Correspondence from November 2008 to November 2010.

Morton, J. Formal interview conducted on December 8, 2008 at J. Morton's private residence.

Richardson, G. Email correspondence August 24, 2010.

Rumig, C. Email correspondence October 28 and 29, 2010.

Shea, J. Email correspondence September 23 and October 8, 2010.

Stricker, F. Formal interview conducted December 5, 2008 at F. Stricker's private residence.

Woodman, B. Email correspondence March 2, 2010 and April 1, 2010.

Worminton, A. Phone correspondence October 24, 2010.

Appendix I

Transect Maps

Grand River Conservation Authority

Map created: July 27, 2009

Waterloo Park

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- DRAINAGE-NETWORK (GRCA)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)
- WOODED AREA (MNR)
  - HEDGEROW
  - PLANTATION
  - TREED

GRCA Disclaimer

The source for each data layer is shown in parentheses in the map legend. For a complete listing of sources and citations go to:

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0 30 60 90 120 m.

NAD 1983, UTM Zone 17 Scale 1:2,597 N

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Grand River Conservation Authority
Map created: July 27, 2009

Ayr Industrial

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)

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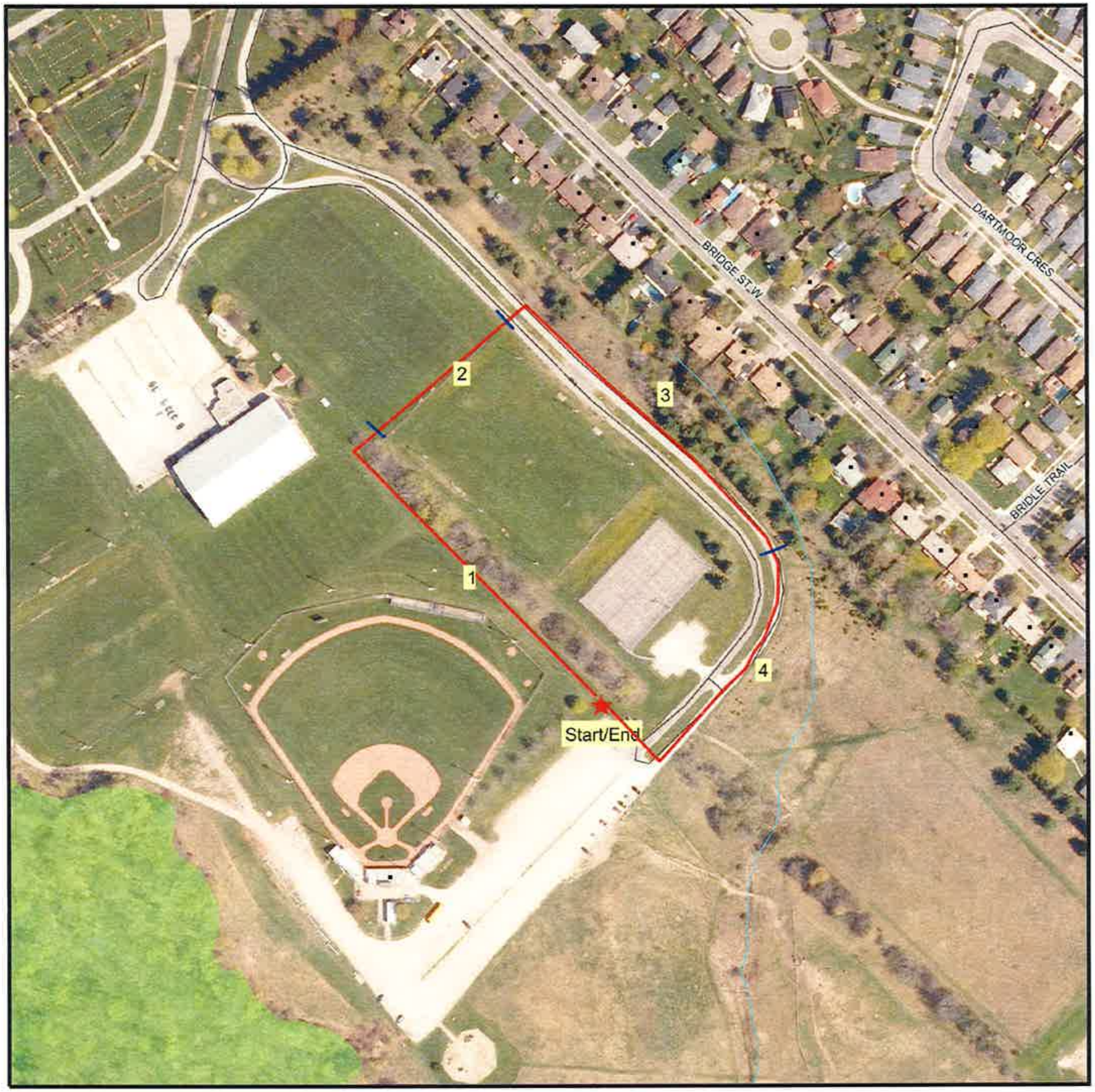
0 60 120 180 240 m

NAD 1983, UTM Zone 17 Scale 1:5,369 N

THIS MAP IS NOT TO BE USED FOR NAVIGATION



Grand River Conservation Authority

Map created: July 27, 2009

Bechtel Park

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- DRAINAGE-NETWORK (GRCA)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)
- WOODED AREA (MNR)
  - HEDGEROW
  - PLANTATION
  - TREED

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0 34 68 102 136 m

NAD 1983, UTM Zone 17 Scale 1:2,929 N

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Grand River Conservation Authority

Map created: July 27, 2009

Beechwood Residential

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- DRAINAGE-NETWORK (GRCA)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)
- WOODED AREA (MNR)
  - HEDGEROW
  - PLANTATION
  - TREED

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0 70 140 210 280 m

NAD 1983, UTM Zone 17 Scale 1:6,250

N

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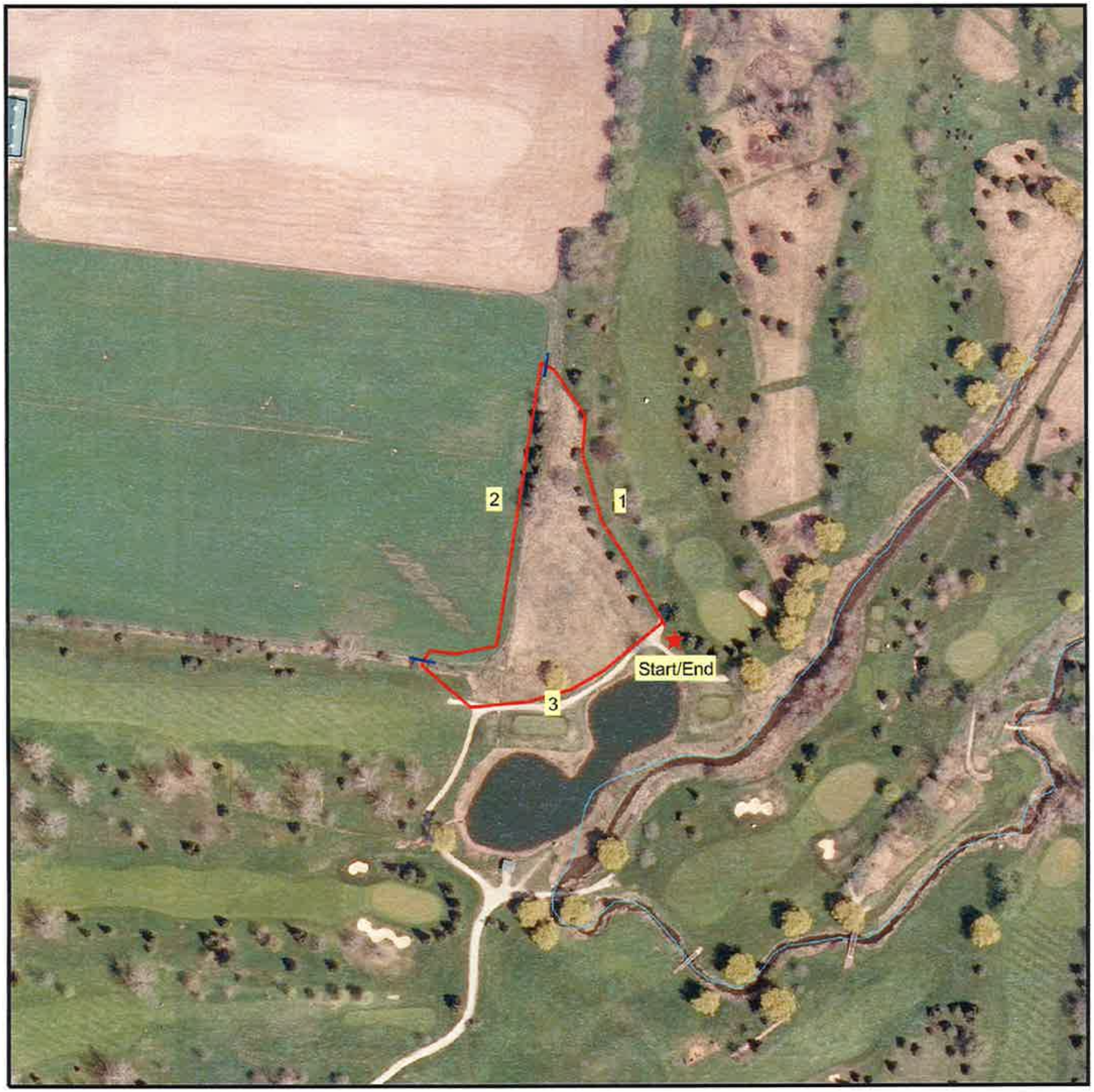
Grand River Conservation Authority

Map created: July 29, 2009

Elmira Golf Club



LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- DRAINAGE-NETWORK (GRCA)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)
- WOODED AREA (MNR)
  - HEDGEROW
  - PLANTATION
  - TREED

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0 34 68 102 136 m

NAD 1983, UTM Zone 17 Scale 1:2,929 N

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Grand River Conservation Authority

Map created: July 29, 2009

Foxwood Golf Club

LEGEND

WATERSHED MASK
BUILDING - SYMBOLIZED (NRVIS)
BUILDING - TO SCALE (NRVIS)
WATERSHED BOUNDARY (GRCA)
UTILITY LINE (NRVIS)
ROADS-ADDRESSED (MNR)
RAILWAY (NRVIS)
DRAINAGE-NETWORK (GRCA)
PARKS (GRCA)
DRAINAGE-POLY (NRVIS)
WOODED AREA (MNR)
HEDGEROW
PLANTATION
TREED

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0 65 130 195 260 m

NAD 1983, UTM Zone 17 Scale 1:5,541 N

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Grand River Conservation Authority

Map created: July 27, 2009

Grey Silo Golf Course

LEGEND

WATERSHED MASK
BUILDING - SYMBOLIZED (NRVIS)
BUILDING - TO SCALE (NRVIS)
WATERSHED BOUNDARY (GRCA)
UTILITY LINE (NRVIS)
ROADS-ADDRESSED (MNR)
RAILWAY (NRVIS)
DRAINAGE-NETWORK (GRCA)
PARKS (GRCA)
DRAINAGE-POLY (NRVIS)
WOODED AREA (MNR)
HEDGEROW
PLANTATION
TREED

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0 35 70 105 140 m

NAD 1983, UTM Zone 17 Scale 1:3,135 N

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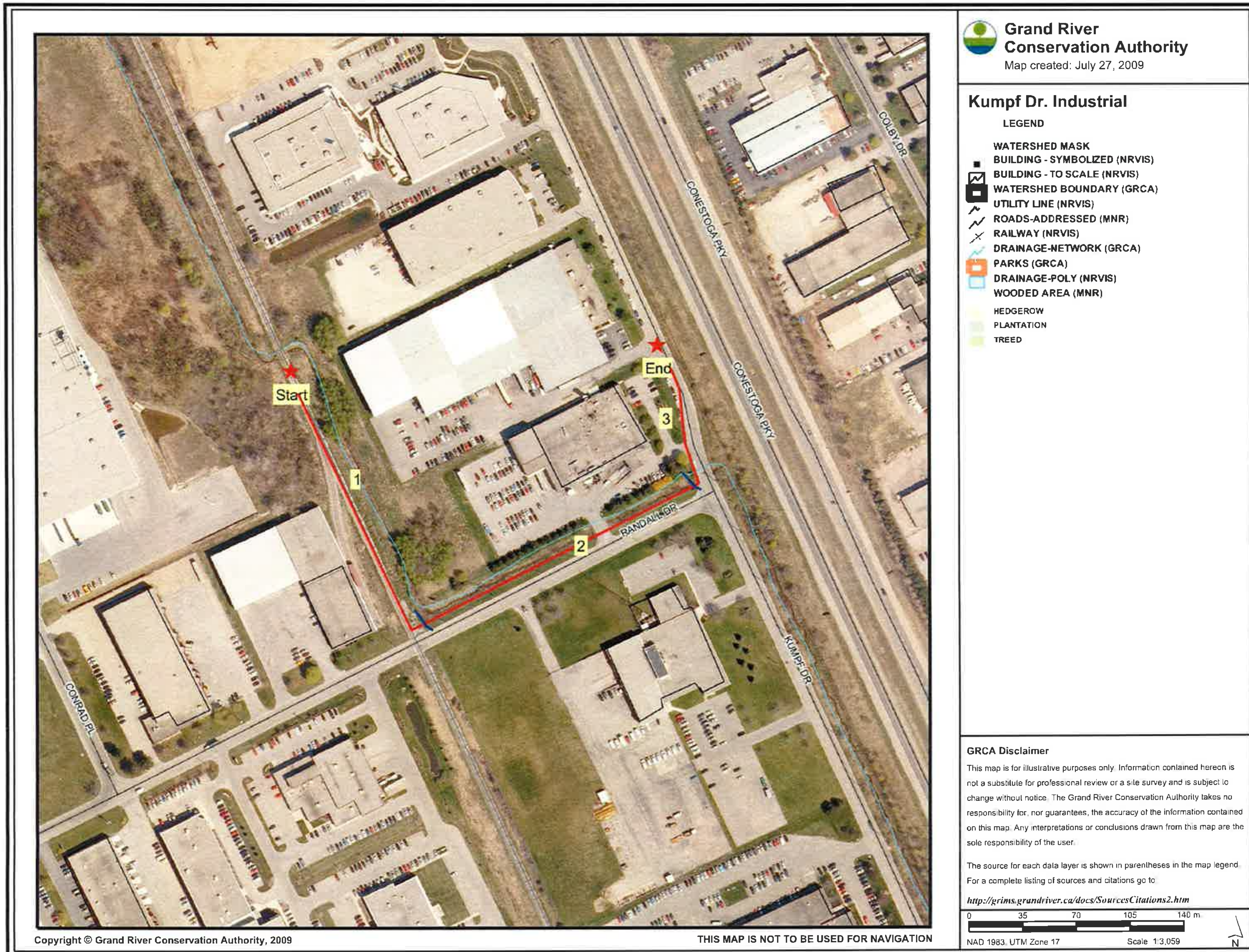

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Grand River Conservation Authority

Map created: July 29, 2009

New Hamburg Residential

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- DRAINAGE-NETWORK (GRCA)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)
- WOODED AREA (MNR)
  - HEDGEROW
  - PLANTATION
  - TREED

0 29 58 87 116 m

NAD 1983, UTM Zone 17 Scale 1:2,487

N

Grand River Conservation Authority

Map created: July 27, 2009

Rare ESPA

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)

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0 65 130 195 260 m

NAD 1983, UTM Zone 17 Scale 1:5,484 N

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Grand River Conservation Authority

Map created: July 27, 2009

Riverside Park

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)

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0 37 74 111 148 m

NAD 1983, UTM Zone 17 Scale 1:3,189 N

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Grand River Conservation Authority

Map created: July 27, 2009

Roseville Swamp ESPA

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)

0 45 90 135 180 m.

NAD 1983, UTM Zone 17 Scale 1:3,820 N

Grand River Conservation Authority

Map created: July 29, 2009

St. Clements Residential

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- DRAINAGE-NETWORK (GRCA)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)
- WOODED AREA (MNR)
- HEDGEROW
- PLANTATION
- TREED

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0 37 74 111 148 m.

NAD 1983, UTM Zone 17 Scale 1:3,214

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Grand River Conservation Authority
Map created: July 27, 2009

Sudden Tract ESPA

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
- RAILWAY (NRVIS)
- PARKS (GRCA)
- DRAINAGE-POLY (NRVIS)

GRCA Disclaimer

This map is for illustrative purposes only. Information contained hereon is not a substitute for professional review or a site survey and is subject to change without notice. The Grand River Conservation Authority takes no responsibility for, nor guarantees, the accuracy of the information contained on this map. Any interpretations or conclusions drawn from this map are the sole responsibility of the user.

The source for each data layer is shown in parentheses in the map legend. For a complete listing of sources and citations go to:

http://grims.grandriver.ca/docs/SourcesCitations2.htm

0 80 160 240 320 m

NAD 1983, UTM Zone 17 Scale 1:7,126

N

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THIS MAP IS NOT TO BE USED FOR NAVIGATION

Grand River Conservation Authority

Map created: July 27, 2009

Wabanaki Dr. Industrial

LEGEND

- WATERSHED MASK
- BUILDING - SYMBOLIZED (NRVIS)
- BUILDING - TO SCALE (NRVIS)
- WATERSHED BOUNDARY (GRCA)
- UTILITY LINE (NRVIS)
- ROADS-ADDRESSED (MNR)
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0 65 130 195 260 m

NAD 1983, UTM Zone 17 Scale 1:5,626 N

Appendix II

Vascular Plants Listed by Transect Site

BOTANICAL NAME		COMMON NAME	Co-efficient of Conservatism	Wetness Index	Weediness Index	New Hamburg Residential Area	Beechwood Residential Area	St. Clements Residential Area	Wabanaki Drive Industrial	Ayr Industrial Area	Kumpf Drive Industrial	Riverside Park	Waterloo Park	Bechtel Park	Rare ESPA	Roseville Swamp ESPA	Sudden Tract ESPA	Grey Silo Golf Course	Foxwood Golf Course	Elmira Golf Club
Dennstaedtiaceae		**Bracken Fern Family**																		
Pteridium	*aquilinum var. latiusculum*	Eastern Bracken-fern	2	3													X			
Dryopteridaceae		**Wood Fern Family**																		
Athyrium	*filix-femina var. angustum*	Northern Lady Fern	4	0												X	X			
Cystopteris	*bulbifera*	Bulbet Bladder Fern	5	-2													X			
Dryopteris	*carthusiana*	Spinulose Wood Fern	5	-2			X									X	X			
Matteuccia	*struthiopteris var. pensylvanic*	Ostrich Fern	5	-3			X									X	X	X		
Onoclea	*sensibilis*	Sensitive Fern	4	-3			X									X	X		X	
Polystichum	*acrostichoides*	Christmas Fern	5	5													X			
Equisetaceae		**Horsetail Family**																		
Equisetum	*arvense*	Field Horsetail	0	0			X				X					X	X			
Equisetum	*palustre*	Marsh Horsetail	10	-3													X			
Equisetum	*sylvaticum*	Wood Horsetail	7	-3												X				
Cupressaceae		**Cedar Family**																		
Juniperus	*communis*	Common Juniper	4	3				X												
Juniperus	*virginiana*	Eastern Red Cedar	4	3		X							X							
Thuja	*occidentalis*	Eastern White Cedar	4	-3		X		X				X	X	X		X		X		X
Pinaceae		**Pine Family**																		
Picea	*abies*	Norway Spruce		5	-1	X		X				X	X	X				X	X	X
Picea	*glauca*	White Spruce	6	3		X			X											
Picea	*pungens*	Colorado Spruce			NA			X	X			X	X						X	
Pinus	*banksiana*	Jack Pine	9	3		X							X							
Pinus	*nigra*	Austrian Pine		-5	-1				X											
Pinus	*strobus*	Eastern White Pine	4	3				X			X		X	X			X	X	X	X

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Pinus	*sylvestris*	Scotch Pine		5	-3															X
Tsuga	*canadensis*	Eastern Hemlock	7	3												X	X		X	
Taxaceae		**Yew Family**																		
Taxus	*canadensis*	American Yew	7	3		X							X							
Aceraceae		**Maple Family**																		
Acer	*negundo*	Manitoba Maple	0	-2		X	X		X				X	X				X		
Acer	*platanoides*	Norway Maple		5	-3	X		X		X	X		X							
Acer	*saccharinum*	Silver Maple	5	-3		X							X							
Acer	*saccharum ssp. saccharum*	Sugar Maple	4	3		X	X	X	X				X	X		X	X		X	
Acer	*species*	Ornamental Maple				X														
Anacardiaceae		**Sumac or Cashew Family**																		
Rhus	*aromatica*	Fragrant Sumac	8	5			X							X						
Rhus	*hirta*	Staghorn Sumac	1	5			X			X		X		X						
Toxicodendron	*radicans ssp. negundo*	Poison-ivy	5	-1												X	X			
Apiaceae		**Carrot or Parsley Family**																		
Cicuta	*maculata*	Spotted Water-hemlock	6	-5												X	X			
Daucus	*carota*	Wild Carrot		5	-2	X	X		X	X	X			X	X	X	X	X	X	X
Heracleum	*lanatum*	Cow-parsnip	3	-3								X			X					
Apocynaceae		**Dogbane Family**																		
Apocynum	*androsaemifolium ssp. andro*	Spreading Dogbane	3	5			X									X	X	X		
Asclepiadaceae		**Milkweed Family**																		
Asclepias	*incarnata ssp. incarnata*	Swamp Milkweed	6	-5							X								X	

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Asclepias	*syriaca*	Common Milkweed	0	5			X			X	X	X		X	X			X	X	X
Asclepias	*tuberosa*	Butterfly-weed	8	5		X														
Asclepias	*variegata*	Variegated Milkweed	5				X													
Asclepias	*verticillata*	Whorled Milkweed	6	5																
Asteraceae		**Composite or Aster Family**																		
Achillea	*millefolium ssp. borealis*	Yarrow				X	X		X	X		X			X				X	
Ambrosia	*artemisiifolia*	Common Ragweed	0	3		X	X	X	X	X				X			X		X	
Ambrosia	*trifida*	Giant Ragweed	0	-1											X					
Anaphalis	*margaritacea*	Pearly Everlasting	3	5					X											
Antennaria	*howellii ssp. petaloidea*	Field Pussytoes							X					X						
Arctium	*lappa*	Great Burdock															X			
Arctium	*minus ssp. minus*	Common Burdock		5	-2	X	X				X	X	X		X	X			X	X
Bidens	*coronata*	Swamp Beggar-ticks	9	-5							X							X		
Bidens	*frondosa*	Devil's Beggar-ticks	3	-3											X					
Centaurea	*jacea*	Brown Knapweed		5	-1		X		X	X		X								
Centaurea	*maculosa*	Spotted Knapweed		5	-3				X	X		X								
Cichorium	*intybus*	Chicory		5	-1				X	X				X		X				
Cirsium	*arvense*	Canada Thistle		3	-1	X	X	X	X	X	X	X	X	X		X			X	X
Cirsium	*discolor*	Field Thistle	9	5			X				X	X	X						X	
Cirsium	*vulgare*	Bull Thistle		4	-1					X	X	X	X	X						X
Coreopsis	*species*	Coreopsis sp.																		
Erigeron	*annus*	Daisy Fleabane	0	1			X		X	X			X		X	X			X	
Erigeron	*philadelphicus ssp. philadelpl*	Philadelphia Fleabane	1	-3			X		X				X	X	X	X		X		
Eupatorium	*perfoliatum*	Boneset	2	-4												X	X			
Eupatorium	*maculatum ssp. maculatum*	Spotted Joe-pye-weed	3	-5											X	X	X	X		
Eurybia	*macrophylla*	Large-leaved Aster	5	5												X	X			
Euthamia	*graminifolia*	Grass-leaved Goldenrod	2	-2			X		X		X	X			X	X		X	X	X

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Helianthus	*divaricatus*	Rough Woodland Sunflower	7	5													X			
Hieracium	*caespitosum ssp. caespitosum*	Field Hawkweed		5	-2	X								X						
Hieracium	*canadense*	Canada Hawkweed																		X
Inula	*helenium*	Elecampane		5	-2		X													
Lactuca	*canadensis*	Tall Lettuce	3	2												X				
Lactuca	*serriola*	Prickly Lettuce		0	-1		X				X	X		X	X			X		
Leucanthemum	*vulgare*	Ox-eye Daisy		5	-1	X	X	X	X	X	X	X		X	X	X		X		
Matricaria	*discoidea*	Pineapple-weed						X				X								
Prenanthes	*altissima*	Tall White Rattlesnake-root	5	3													X			
Rudbeckia	*hirta*	Black-eyed Susan	0	3		X	X													X
Solidago	*altissima var. altissima*	Tall Goldenrod	1	3											X					
Solidago	*caesia*	Blue-stem Goldenrod	5	3													X			
Solidago	*canadensis*	Canada Goldenrod	1	3			X		X	X	X	X	X	X	X	X	X	X	X	X
Solidago	*flexicaulis*	Zig-zag Goldenrod	6	3								X				X	X		X	
Solidago	*gigantea*	Late Goldenrod	4	-3											X					
Solidago	*nemoralis ssp. nemoralis*	Gray Goldenrod	2	5						X							X			
Solidago	*patula*	Rough-leaved Goldenrod	8	-5											X	X	X	X		
Sonchus	*arvensis ssp. arvensis*	Field Sow-thistle					X	X		X			X			X		X	X	X
Symphyotrichum	*ericoides var. ericoides*	White Heath Aster								X					X		X			
Symphyotrichum	*lanceolatum var. hesperium*	Panicled Aster										X			X	X				
Symphyotrichum	*lanceolatum var. lanceolatum*	Tall White Aster	3	-3											X			X		
Symphyotrichum	*lateriflorum var. lateriflorum*	Calico Aster	3	-2												X	X		X	
Symphyotrichum	*species*	Aster species													X	X	X			
Symphyotrichum	*novae-angliae*	New England Aster	2	-3			X		X	X	X	X	X	X	X	X	X	X		
Symphyotrichum	*puniceum var. puniceum*	Purple-stemmed Aster								X	X	X	X		X	X		X	X	
Tanacetum	*vulgare*	Common Tansy		5	-1	X		X	X			X		X	X	X		X		X
Taraxacum	*officinale*	Common Dandelion		3	-2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tragopogon	*dubius*	Doubtful Goat's-beard		5	-1		X			X	X	X			X	X			X	

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Tussilago	*farfara*	Coltsfoot		3	-2		X					X		X		X	X	X	X	X
Balsaminaceae		**Touch-me-not Family**																		
Impatiens	*capensis*	Spotted Touch-me-not	4	-3			X				X	X	X		X	X	X	X	X	X
Berberidaceae		**Barberry Family**																		
Berberis	*vulgaris*	Common Barberry		3	-2										X					
Caulophyllum	*giganteum*	Blue Cohosh													X		X			
Betulaceae		**Birch Family**																		
Betula	*alleghaniensis*	Yellow Birch	6	0												X	X		X	
Betula	*papyrifera*	White Birch		2		X		X								X				
Carpinus	*caroliniana ssp. virginiana*	Blue Beech	6	0													X			
Ostrya	*virginiana*	Hop Hornbeam	4	4													X			
Bignoniaceae		**Bignonia Family**																		
Catalpa	*speciosa*	Northern Catalpa		3	-1	X		X												
Boraginaceae		**Borage Family**																		
Echium	*plantagineum*	Purple Viper's Bugloss							X	X	X	X		X	X					X
Myosotis	*scorpioides*	Field Forget-me-not		0	-1	X							X							X
Brassicaceae		**Mustard Family**																		
Alliaria	*petiolata*	Garlic Mustard		0	-3		X		X			X	X				X			X
Barbarea	*vulgaris*	Yellow Rocket		0	-1	X	X		X	X	X				X			X	X	X
Brassica	*juncea*	Indian Mustard		5	-1						X									
Brassica	*rapa*	Field Mustard		5	-1	X			X	X		X								
Cardamine	*diphylla*	Toothwort	7	5												X	X			

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Cardamine	*pratensis var. angustifolia*	Cuckoo-flower	7	-5											X					
Erysimum	*cheiranthoides ssp. cheiranth*	Wormseed Mustard		3	-1										X					
Hesperis	*matronalis*	Dame's Rocket		5	-3		X		X		X	X	X		X			X	X	
Rorippa	*sylvestris*	Creeping Yellow-cress		-5	-1					X										
Sisymbrium	*altissimum*	Tall Tumble-mustard		3	-1					X		X								
Thlaspi	*arvense*	Field Penny-cress		5	-1					X										
Campanulaceae		**Bellflower Family**																		
Campanula	*rotundifolia*	Harebells	7	1		X									X					
Lobelia	*siphilitica*	Great Lobelia	6	-4												X				
Caprifoliaceae		**Honeysuckle Family**																		
Diervilla	*lonicera*	Bush Honeysuckle	5	5		X	X	X					X							
Lonicera	*tatarica*	Tartarian Honeysuckle		3	-3	X	X					X	X	X	X					X
Sambucus	*canadensis*	Common Elderberry	5	-2			X				X					X		X	X	
Caryophyllaceae		**Pink Family**																		
Cerastium	*fontanum*	Larger Mouse-ear Chickweed		3	-1			X				X	X	X					X	X
Dianthus	*armeria*	Deptford Pink		5	-1										X					
Saponaria	*officinalis*	Bouncing-bet		3	-3	X	X		X						X			X		
Silene	*latifolia*	Bladder Campion					X			X	X				X					
Silene	*noctiflora*	Night-flowering Catchfly		5	-1					X	X	X								
Convolvulaceae		**Morning-glory Family**																		
Calystegia	*sepium*	Hedge Bindweed							X									X		X
Convolvulus	*arvensis*	Field Bindweed		5	-1	X		X		X	X				X				X	X

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Cornaceae		**Dogwood Family**																		
Cornus	*alternifolia*	Alternate-leaved Dogwood	6	5															X	
Cornus	*foemina ssp. racemosa*	Red Panicled Dogwood	2	-2								X			X		X			
Cornus	*stolonifera*	Red-osier Dogwood	2	-3			X		X		X	X	X		X	X	X	X		X
Cucurbitaceae		**Gourd Family**																		
Echinocystis	*lobata*	Prickly Cucumber	3	-2							X	X						X		X
Dipsacaceae		**Teasel Family**																		
Dipsacus	*fullonum ssp. sylvestris*	Wild Teasel		5	-1		X	X			X	X	X	X	X					X
Elaeagnaceae		**Oleaster Family**																		
Elaeagnus	*angustifolia*	Russian Olive		4	-1		X													
Ericaceae		**Heath Family**																		
Vaccinium	*angustifolium*	Low Sweet Blueberry	6	3													X			
Euphorbiaceae		**Spurge Family**																		
Euphorbia	*esula*	Leafy Spurge		5	-2						X	X			X			X		
Fabaceae		**Pea Family**																		
Amphicarpaea	*bracteata*	Hog Peanut	4	0					X								X			
Coronilla	*varia*	Variable Crown-vetch		5	-2		X		X			X				X				
Desmodium	*canescens*	Hoary Tick-trefoil	10	5													X			
Lotus	*corniculatus*	Bird's-foot Trefoil		1	-2	X	X			X	X	X		X	X		X	X	X	X
Medicago	*lupulina*	Black Medick		1	-1	X	X	X	X	X	X	X		X	X		X	X	X	X
Medicago	*sativa ssp. sativa*	Alfalfa		5	-1				X	X						X				
Melilotus	*alba*	White Sweet-clover		3	-3		X		X	X		X		X	X					X

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Melilotus	*officinalis*	Yellow Sweet-clover		3	-1				X							X			X	X
Robinia	*pseudo-acacia*	Black Locust		4	-3							X								
Trifolium	*hybridum ssp. elegans*	Alsike Clover		1	-1	X	X	X			X	X	X	X				X	X	X
Trifolium	*pratense*	Red Clover		2	-2		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Trifolium	*repens*	White Clover		2	-1	X	X	X	X	X		X	X					X	X	X
Vicia	*cracca*	Tufted Vetch		5	-1		X		X	X	X							X		X
Fagaceae		**Beech Family**																		
Fagus	*grandifolia*	American Beech	6	3			X										X			
Quercus	*alba*	White Oak	6	3					X				X	X			X			
Quercus	*macrocarpa*	Bur Oak	5	1											X					
Quercus	*rubra*	Red Oak	6	3					X								X		X	
Geraniaceae		**Geranium Family**																		
Erodium	*cicutarium ssp. cicutarium*	Stork's-bill		5	-1							X								
Geranium	*robertianum*	Herb-robert		5	-2		X						X			X	X			
Grossulariaceae		**Currant Family**																		
Ribes	*americanum*	Wild Black Currant	4	-3			X										X			
Ribes	*rubrum*	Red Currant		5	-2											X				
Ribes	*vulgare*	Red Garden Currant														X				
Guttiferae		**St. John's-wort Family**																		
Hypericum	*perforatum*	Common St. John's-wort		5	-3		X		X	X	X	X			X	X	X	X	X	X
Hamamelidaceae		**Witch-hazel Family**																		
Hamamelis	*virginiana*	Witch-hazel	6	3													X			

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Juglandaceae		**Walnut Family**																		
Juglans	*nigra*	Black Walnut	5	3		X		X						X						
Lamiaceae		**Mint Family**																		
Clinopodium	*vulgare*	Wild Basil	4	5									X		X	X	X		X	
Lamium	*maculatum*	Spotted Dead-nettle				X														
Leonurus	*cardiaca ssp. cardiaca*	Common Motherwort		5	-2				X					X		X				X
Lycopus	*americanus*	Cut-leaved Water-horehound	4	-5												X	X			
Lycopus	*uniflorus*	Northern Bugleweed	5	-5												X				
Mentha	*arvensis ssp. borealis*	American Wild Mint	3	-3			X						X		X					
Monarda	*fistulosa*	Wild Bergamot	6	3											X		X			
Nepeta	*cataria*	Catnip		1	-2		X			X			X							X
Prunella	*vulgaris ssp. vulgaris*	Common Heal-all		0	-1	X	X					X	X		X	X				
Thymus	*pulegioides*	Thyme		5	-1										X					
Lythraceae		**Loosestrife Family**																		
Lythrum	*salicaria*	Purple Loosestrife		-5	-3						X				X		X	X	X	
Malvaceae		**Mallow Family**																		
Malva	*sylvestris*	High Mallow		5	-1	X		X				X		X		X			X	
Oleaceae		**Olive Family**																		
Fraxinus	*americana*	White Ash	4	3		X	X		X	X	X	X		X	X	X	X		X	X
Fraxinus	*nigra*	Black Ash	7	-4													X			
Fraxinus	*pennsylvanica*	Green Ash	3	-3											X	X	X			
Syringa	*vulgaris*	Common Lilac		5	-2		X	X					X	X						

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Onagraceae		**Evening-primrose Family**																		
Circaea	*lutetiana ssp. canadensis*	Enchanter's Nightshade	3	3			X					X			X	X	X		X	X
Epilobium	*hirsutum*	Great Hairy Willow-herb		-4	-2							X	X		X					X
Oenothera	*biennis*	Common Evening-primrose	0	3			X		X	X	X			X					X	
Oenothera	*fruticosa ssp. glauca*	Common Sundrops		2	-1		X													
Oxalidaceae		**Wood Sorrel Family**																		
Oxalis	*stricta*	Upright Yellow Wood-sorrel	0	3		X	X	X	X			X	X	X	X	X	X		X	
Papaveraceae		**Poppy Family**																		
Chelidonium	*majus*	Celandine		5	-3								X							
Plantaginaceae		**Plantain Family**																		
Plantago	*lanceolata*	Ribgrass (narrow-leaved plan		0	-1		X		X		X	X		X	X	X				
Plantago	*major*	Common Plantain		-1	-1	X	X	X		X		X	X	X		X	X		X	X
Polygonaceae		**Smartweed Family**																		
Persicaria	*pensylvanica*	Pennsylvania Smartweed	3	-4							X							X		
Polygonum	*cuspidatum*	Japanese Knotweed		3	-1								X							
Polygonum	*neglectum*	Narrow-leaved Knotweed	7	5																X
Polygonum	*persicaria*	Lady's-thumb		-3	-1	X				X	X				X					
Rumex	*crispus*	Curly-leaf Dock		-1	-2		X		X	X	X	X	X	X	X					X
Rumex	*obtusifolius ssp. obtusifolius*	Bitter Dock		-3	-1		X						X							X
Primulaceae		**Primrose Family**																		
Lysimachia	*ciliata*	Fringed Loosestrife	4	-3												X				
Lysimachia	*quadrifolia*	Fringed Loosestrife	8	5													X			

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Ranunculaceae		**Buttercup Family**																		
Actaea	*pachypoda*	White Baneberry	6	5			X								X					
Actaea	*rubra*	Red Baneberry	5	5													X			
Anemone	*canadensis*	Canada Anemone	3	-3					X		X	X			X	X	X	X		
Anemone	*acutiloba*	Sharp-lobed Hepatica	6	5													X			
Anemone	*americana*	Round-lobed Hepatica	6	5											X					
Anemone	*cylindrica*	Thimbleweed	7	5												X				
Aquilegia	*canadensis*	Wild Columbine	5	1													X			
Caltha	*palustris*	Marsh-marigold	5	-5													X			
Ranunculus	*acris*	Tall Buttercup			-2		X					X			X	X	X		X	
Ranunculus	*hispidus var. nitidus*	Swamp Buttercup														X				
Ranunculus	*recurvatus var. recurvatus*	Hooked Buttercup	4	-3			X					X	X		X	X			X	
Thalictrum	*pubescens*	Tall Meadow-rue	5	-2											X		X			
Rhamnaceae		**Buckthorn Family**																		
Rhamnus	*cathartica*	Common Buckthorn		3	-3		X		X	X	X	X	X	X	X	X		X		
Rhamnus	*frangula*	Glossy Buckthorn		-1	-3										X	X	X			
Rosaceae		**Rose Family**																		
Amelanchier	*sanguinea*	Roundleaf Juneberry	7	5					X											
Crataegus	*species*	Hawthorn species											X	X					X	
Fragaria	*vesca ssp. americana*	Woodland Strawberry	4	4											X	X	X		X	
Fragaria	*virginiana ssp. virginiana*	Scarlet Strawberry	2	1												X				
Geum	*aleppicum*	Yellow Avens	2	-1			X					X	X		X		X			
Geum	*canadense*	White Avens	3	0												X	X			
Geum	*laciniatum*	Rough Avens		-3			X				X		X	X						
Malus	*pumila*	Common Crabapple		5	-1									X						
Physocarpus	*opulifolius*	Ninebark	5	-2								X	X		X					

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Potentilla	*recta*	Rough-fruited Cinquefoil		5	-2		X			X		X			X					
Potentilla	*simplex*	Old-field (Common) Cinquefo	3	4					X	X		X			X			X		
Prunus	*serotina*	Black Cherry	3	3		X	X					X	X	X		X			X	
Prunus	*virginiana ssp. virginiana*	Choke Cherry	2	1															X	
Rubus	*allegheniensis*	Alleghany Blackberry	2	2			X													
Rubus	*idaeus ssp. idaeus*	Red Raspberry					X				X	X		X	X	X	X		X	X
Rubus	*odoratus*	Purple Flowering Raspberry	3	5			X													
Rubus	*pubescens*	Dwarf Raspberry	4	-4												X				
Sorbus	*aucuparia*	European Mountain-ash		5	-2			X		X			X							
Spiraea	*chamaedryfolia*	Meadow-sweet															X			
Rubiaceae		**Madder Family**																		
Galium	*mollugo*	White Bedstraw		5	-2	X	X	X	X		X		X	X	X	X		X		X
Galium	*palustre*	Marsh Bedstraw	5	-5												X				
Galium	*triflorum*	Sweet-scented Bedstraw	4	2					X		X		X			X	X			
Rutaceae		**Rue Family**																		
Zanthoxylum	*americanum*	American Prickly-ash	3	5											X					
Salicaceae		**Willow Family**																		
Populus	*balsamifera ssp. balsamifera*	Balsam Poplar	4	-3		X	X			X										X
Populus	*tremuloides*	Trembling Aspen	2	0			X		X	X	X	X	X	X		X				
Salix	*bebbiana*	Long-beaked Willow	4	-4			X													
Salix	*eriocephala*	Wolly-headed willow	4	-3			X				X				X				X	
Salix	*exigua*	Sandbar Willow	3	-5			X				X					X			X	
Salix	*fragilis*	Crack Willow		-1	-3		X				X	X								X
Salix	*nigra*	Black Willow	6	-5												X				
Salix	*purpurea*	Basket Willow		-3	-1													X		

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Scrophulariaceae		**Figwort Family**																		
Linaria	*vulgaris*	Butter-and-eggs		5	-1				X	X	X	X			X	X		X		
Verbascum	*thapsus*	Common Mullein		5	-2		X		X	X								X	X	
Veronica	*arvensis*	Corn Speedwell		5	-1															X
Veronica	*longifolia*	Long-leaved Speedwell		5	-1	X														
Veronica	*officinalis*	Common Speedwell		5	-2	X	X					X	X	X	X					
Veronica	*persica*	Bird's-eye Speedwell		5	-1					X		X	X							
Veronica	*serpyllifolia ssp. serpyllifolia*	Thyme-leaved Speedwell	0	-3									X							
Solanaceae		**Nightshade Family**																		
Lycopersicon	*esculentum*	Tomato		5	-1	X														
Physalis	*heterophylla*	Clammy Ground-cherry	3	5														X	X	
Solanum	*dulcamara*	Bitter Nightshade		0	-2		X				X		X	X		X	X		X	X
Tiliaceae		**Linden Family**																		
Tilia	*americana*	American Basswood	4	3		X							X	X		X	X	X		
Tilia	*cordata*	Small Leaf Linden				X														
Ulmaceae		**Elm Family**																		
Ulmus	*americana*	White Elm	3	-2									X		X	X	X			
Urticaceae		**Nettle Family**																		
Laportea	*canadensis*	Wood Nettle	6	-3												X	X			
Urtica	*dioica ssp. dioica*	European Stinging Nettle		-1	-1													X		X
Verbenaceae		**Vervain Family**																		
Verbena	*hastata*	Blue Vervain	4	-4																X

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Verbena	*urticifolia*	White Vervain	4	-1									X	X	X	X		X		
Violaceae		**Violet Family**																		
Viola	*bicolor*	Field Pansy	8	3															X	
Viola	*blanda*	Sweet White Violet	6	-2			X													
Viola	*pubescens*	Downy Yellow Violet	5	4													X			
Viola	*rostrata*	Long-spurred Violet	6	3			X										X			
Viola	*septentrionalis*	Northern Blue Violet	7	3			X													
Viola	*species*	Violet species														X	X			
Vitaceae		**Grape Family**																		
Parthenocissus	*inserta*	Inserted Virginia-creeper	3	3			X		X		X	X	X	X		X	X		X	
Vitis	*riparia*	Riverbank Grape	0	-2						X	X	X		X	X		X	X	X	X
Alismataceae		**Water-plantain Family**																		
Alisma	*plantago-aquatica*	Common Water-plantain	3	-5							X						X			
Sagittaria	*latifolia*	Broad-leaved Arrowhead	4	-5												X	X			
Araceae		**Arum Family**																		
Arisaema	*triphyllum ssp. triphyllum*	Small Jack-in-the-pulpit	5	-2			X										X			
Symplocarpus	*foetidus*	Skunk-cabbage	7	-5													X			
Cyperaceae		**Sedge Family**																		
Carex	*species*	Sedge species													X					
Carex	*gracillima*	Graceful Sedge	4	3												X	X			
Carex	*hystericina*	Porcupine Sedge	5	-5												X				
Carex	*intumescens*	Bladder Sedge	6	-4													X			
Carex	*laxiflora*	Loose-flowered Sedge	5	0													X			

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Carex	*lupulina*	Hop Sedge	6	-5												X				
Carex	*plantaginea*	Plantain-leaved Sedge	7	5											X					
Carex	*pseudo-cyperus*	Cypress-like Sedge	6	-5													X			
Carex	*species*	Sedge species													X		X			
Carex	*spicata*	Spiked Sedge		5	-1											X				
Carex	*stipata*	Awl-fruited Sedge	3	-5											X					
Carex	*vulpinoidea*	Fox Sedge	3	-5									X			X	X		X	
Scirpus	*atrovirens*	Dark-green Bulrush	3	-5								X				X				
Scirpus	*cyperinus*	Wool-grass	4	-5			X						X				X			X
Scirpus	*microcarpus*	Small-fruited Bulrush	4	-5															X	
Iridaceae		**Iris Family**																		
Iris	*pseudacorus*	Yellow Iris		-5	-2				X									X		
Iris	*versicolor*	Multi-coloured Blue-flag	5	-5													X			
Juncus	*tenuis*	Path Rush	0	0									X		X	X	X			
Lemnaceae		**Duckweed Family**																		
Lemna	*minor*	Lesser Duckweed	2	-5												X				
Liliaceae		**Lily Family**																		
Allium	*oleraceum*	Wild Garlic												X						
Asparagus	*officinalis*	Garden Asparagus		3	-1										X					
Erythronium	*americanum ssp. americanun*	Yellow Dog's-tooth Violet	5	5													X			
Lilium	*lancifolium*	Tiger Lily		5	-1	X						X								
Lilium	*michiganense*	Michigan Lily	7	-1		X											X			
Maianthemum	*canadense*	Wild Lily-of-the-valley	5	0												X	X			
Maianthemum	*racemosum ssp. racemosum*	False Solomon's Seal	4	3			X										X		X	
Polygonatum	*biflorum*	Hairy Solomon's Seal	8	3													X			

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Trillium	*erectum*	Purple Trillium	6	1													X			
Trillium	*grandiflorum*	White Trillium	5	5			X									X				
Orchidaceae		**Orchid Family**																		
Epipactis	*helleborine*	Common Helleborine		5	-2											X	X		X	
Platanthera	*grandiflora*	Early Purple-fringed Orchis	10	-3													X			
Poaceae		**Grass Family**																		
Bromus	*inermis ssp. inermis*	Awnless Brome		5	-3		X		X	X	X	X		X	X			X	X	X
Calamagrostis	*canadensis*	Blue-joint Grass	4	-5													X			
Dactylis	*glomerata*	Orchard Grass		3	-1		X		X	X	X	X		X	X	X	X			
Echinochloa	*crusgalli*	Common Barnyard Grass		-3	-1		X								X			X		
Elymus	*hystrix*	Bottle-brush Grass	5	5													X			
Elymus	*repens*	Quack Grass		3	-3				X			X						X		
Glyceria	*striata*	Fowl Meadow Grass	3	-5												X				
Phalaris	*arundinacea*	Reed Canary Grass	0	-4			X				X	X	X		X	X	X	X	X	
Phleum	*pratense*	Timothy		3	-1		X			X	X		X	X	X			X	X	X
Phragmites	*australis*	Common Reed	0	-4			X													
Poa	*palustris*	Fowl Meadow Grass	5	-4															X	
Poa	*pratensis ssp. pratensis*	Kentucky Bluegrass	0	1			X			X	X	X		X		X		X	X	X
Poa	*species*	Grass Species					X			X					X		X			
Zea	*mays*	Indian Corn		5	-1															X
Typhaceae		**Cattail Family**																		
Typha	*latifolia*	Broad-leaved Cattail	3	-5							X						X		X	

X- Indicates Presence

EXPLANATION OF TERMINOLOGY

Botanical and Common Name: From Newmaster et. al, 1998. Species requiring confirmation noted (cf).

Co-efficient of Conservatism: This value, ranging from 0 (low) to 10 (high), is based on a species tolerance of disturbance and fidelity to a specific habitat integrity.

Wetness Index: This value, ranging from -5 (obligate wetland) to 5 (upland) provides the probability of a species occurring in wetland or upland habitats.

Weediness Index: This value, ranging from -1 (low) to -3 (high) quantifies the potential invasiveness of non-native plants. In combination with the percentage of non-native plants, it can be used as an indicator of disturbance.

Provincial Status: Provincial ranks are used by the NHIC to set protection priorities for rare species and natural communities. These ranks are not legal designations. S4 and S5 species are generally uncommon to common in the province. Species ranked S1-S3 are considered to be rare in Ontario.