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# Some relationships between wetland characteristics and mammal species richness for wetlands in southern Ontario.

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SOME RELATIONSHIPS BETWEEN WETLAND CHARACTERISTICS AND MAMMAL SPECIES RICHNESS FOR WETLANDS IN SOUTHERN ONTARIO

by

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## ABSTRACT

In Southern Ontario, wetlands are becoming increasingly fragmented by human development, intensifying the potential for a decline in species richness. Data was collected from 27 wetlands in Southern Ontario, to assess the effects of wetland area, topographic diversity, diversity and land use of the surrounding matrix, disturbance within the wetland, and isolation of the wetland on mammal species richness.

Multiple regression analyses indicated that area is the most significant influence on species richness for the total species complement, wetland specific species only, and non-wetland specific species. Topographic diversity and matrix diversity were found to be significant for the total species complement and wetland specific species, and isolation was found to be significant for wetland specific species. It was also found that a large proportion of built areas in the surrounding matrix results in reduced species richness for the wetland, while a large proportion of agricultural development results in increased wetland specific species richness.

Analyses of the residuals showed that wetlands found in the Low Boreal wetland region have greater species richness than wetlands in the Eastern Temperate wetland region. It was concluded that the varying degree of development in these regions was responsible for the regional differences in species richness. Future wetland management must reflect the effects of wetland characteristics and the characteristics of the area in which the wetlands are found in order to preserve maximum species richness.

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# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER I

## Introduction

Wetlands are a commonly misunderstood resource. The most traditional approach to wetlands has been to drain, fill, dredge or otherwise alter the wetlands to make way for land uses with greater perceived values. Recently, however, a growing body of evidence shows that wetlands play an important role in the environment, ranging from aquifer recharge and wildlife habitat, to aesthetics and human recreation (Tiner, 1991). An environment without wetlands is lacking these important functions and clearly cannot be considered complete.

Wetlands occupy a position in the transitional zone between aquatic and terrestrial ecosystems. These highly productive landscapes provide habitat for a widely diverse range of plants and animals. In Canada there are over 200 species of birds, 50 types of mammals, and an extensive flora which depend upon wetlands for survival (National Wetlands Working Group, 1988). This diversity, however, can be adversely affected by the activities of humans within and near the wetlands. The continued fragmentation of wetlands reduces the habitat available for all wetland species, threatening the species diversity of Ontario's remaining wetlands.

The purpose of this study is to examine how mammal populations in wetlands vary with differences in wetland characteristics, such as area and human disturbance. The wetland characteristics used in this study include both measures of ecological factors of the wetlands themselves and measures of natural and human factors within and around the wetland. Analysis of the combined influence of wetland characteristics such as area, topographic diversity, diversity of the surrounding matrix, disturbance, and interaction with other wetlands allows for a more complete understanding of the relationship between wetland diversity and variations in the wetland environment. This study merges concepts of ecological studies of wetlands and studies of island biogeography. Through multiple regression analysis of wetland characteristics, and the application of island biogeographical concepts to the results, an understanding of wetland interaction, both with other wetlands and with the surrounding environment, may be achieved.

Chapter II describes the various types of wetlands in Ontario, their functions and values, and also includes an assessment of the status of wetlands in southern Ontario. Chapter III outlines the concept of species diversity and the effects of habitat fragmentation on diversity. Through an understanding of the general relationship between diversity and fragmentation, inferences may be made for Southern Ontario wetlands. Chapter IV deals with the methodology, outlining the characteristics of the study area, the reasons behind the choice of the variables, and the development of the equations on which further analysis will be based. Analysis of the variables is found in chapter V, and chapter VI provides conclusions and recommendations for further study.

# CHAPTER II

## Wetland Characteristics

### 2.1 Wetland Definition

Because of the great variety of wetland habitats, a definition of what constitutes a wetland is elusive. Commonly used terms such as swamp and marsh do not have common meanings. Depending upon one's scientific background, wetland definitions may focus on the vegetation related to flooded or saturated soil conditions, or on variations in the position of the water table over time (Tiner, 1984). It is agreed that wetlands are complex landscapes which occur on the soil moisture continuum between deep water and dry land (Tiner, 1991) (Figure 1). A generally accepted definition of wetlands is:

> land that has the water table at, near, or above the land surface, or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to the wet environment (Tarnocai, 1980, p.11).

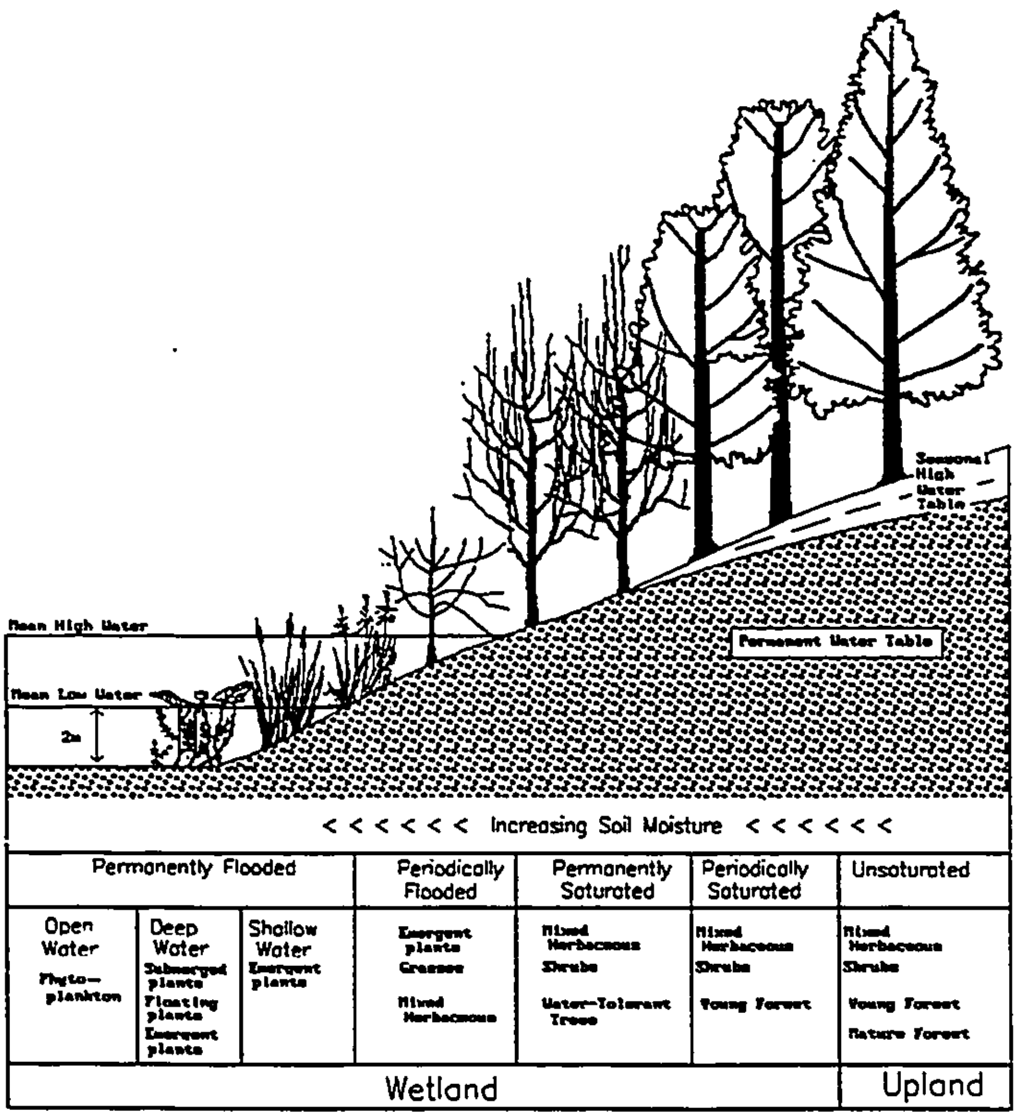



Figure 1. The General Location of Wetlands Along the Soil Moisture Gradient.
(Tiner, 1991; Smith, 1986.)

## 2.2 Wetland Classification

While all wetlands share the common characteristic of wetness, all wetlands are not the same. The system developed in Canada to classify wetlands distinguishes between wetlands according to class, form, and type. By combining the wetland type, form, and class descriptions, an accurate assessment of the vegetation and structure of the wetland is achieved (National Wetlands Working Group, 1987).

The descriptions for wetland types are based on the physiognomy of the vegetation rather than on identification of specific species. Sixteen wetland types have been identified in Canada (Wetlands Working Group, 1988). Wetland forms are descriptions based on surface morphology, surface patterns, water type and the structure of the underlying mineral soil (Tarnocai, 1980). In Canada, 70 wetland forms have been identified.

Finally, wetlands are distinguished by class. Wetland classes are terms used to describe the specific ecosystem types found in the wetland. There are five wetland classes in Canada: bog, fen, swamp, marsh and shallow open water (Patterson, 1986).

Bogs are peat-covered wetlands where the water table is at or near the surface. Bog water is highly acidic and nutrient poor. Bogs may be treed or treeless, but the dominant vegetation is peat.

Fens are peatlands with very slow internal drainage. Because of the movement in the water table, fens receive more nutrients than bogs. Fen vegetation often reflects the quality and quantity of water available; nutrient rich fens will feature trees and shrubs, while nutrient poor fens will be without trees.

Marshes are mineral wetlands that are periodically inundated by standing or slowly moving water. The surface pattern of marshes is a mosaic of pools or channels, interspersed with clumps of the characteristic vegetation of reeds, rushes, and sedges.

Swamps are treed wetlands on mineral soils where standing or gently moving water leaves the subsurface continually waterlogged. The water is usually nutrient rich, allowing luxuriant growth of trees and shrubs.

Shallow open water is semi-permanent or permanent, standing or flowing water with a maximum depth of 2 m. The surface water is free from emergent vegetation, but floating, rooted plants may be present.

## 2.3 Wetland Development

The location of wetlands is determined primarily by the amount of water which enters the region through precipitation, and by the surface morphology (National Wetlands Working Group, 1988). Combined with climate, these factors influence the vegetational and faunal communities which will develop in the potential wetland. Aside from catastrophic events such as fire or long-term floods, a wetland is a stable ecosystem. As such, it is able to resist change or recover rapidly after disturbance (Smith, 1986). Wetlands respond to alteration in the local environment, such as a lowered water table or climatic warming, by gradually changing to an ecosystem more suited to the new environment. Thus, effects of a shift in the abiotic or climatic factors may not become evident immediately. For this reason, great care should be taken to understand the complex relationship between wetlands and their surrounding environment, to prevent permanent and unforeseen damage to the wetlands through human activities in and around the wetland.

## 2.4 Wetland Regionalization in Southern Ontario

Wetlands in Canada differ over broad climatic zones, reflecting a north-south temperature and an east-west precipitation gradient (National Wetlands Working Group, 1988). A total of 20 wetland regions have been identified in Canada (Figure 2). Wetland regions are areas where climatic limits interacting with components such as topography or hydrology, affect the distribution and abundance of characteristic wetland ecosystems (Zoltai, 1979). The pattern of the wetland regions resembles that of broad vegetation regions (Rowe, 1972). Of the 20 wetland regions, two occur in southern Ontario: Eastern Temperate and Low Boreal (Figure 3).

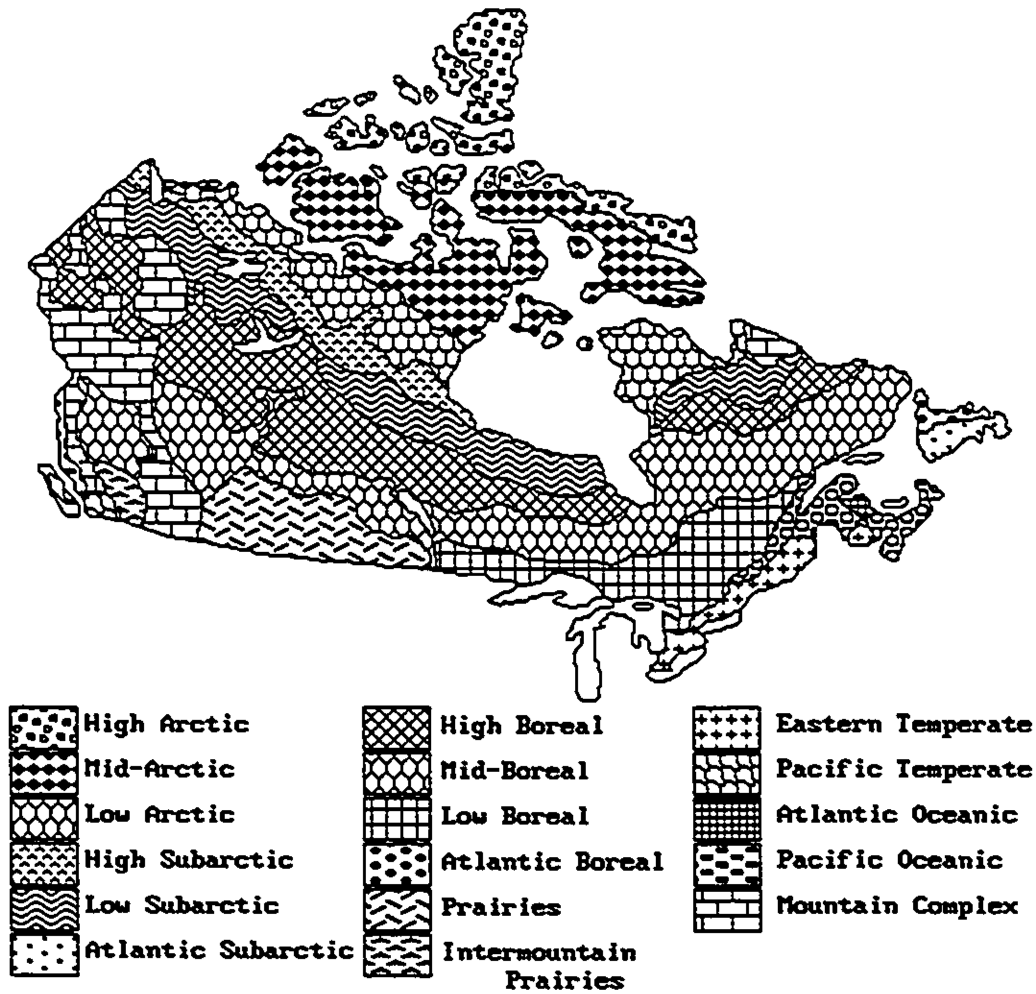



Figure 2. Wetland Regions of Canada (Rubec and Pollett, 1979).

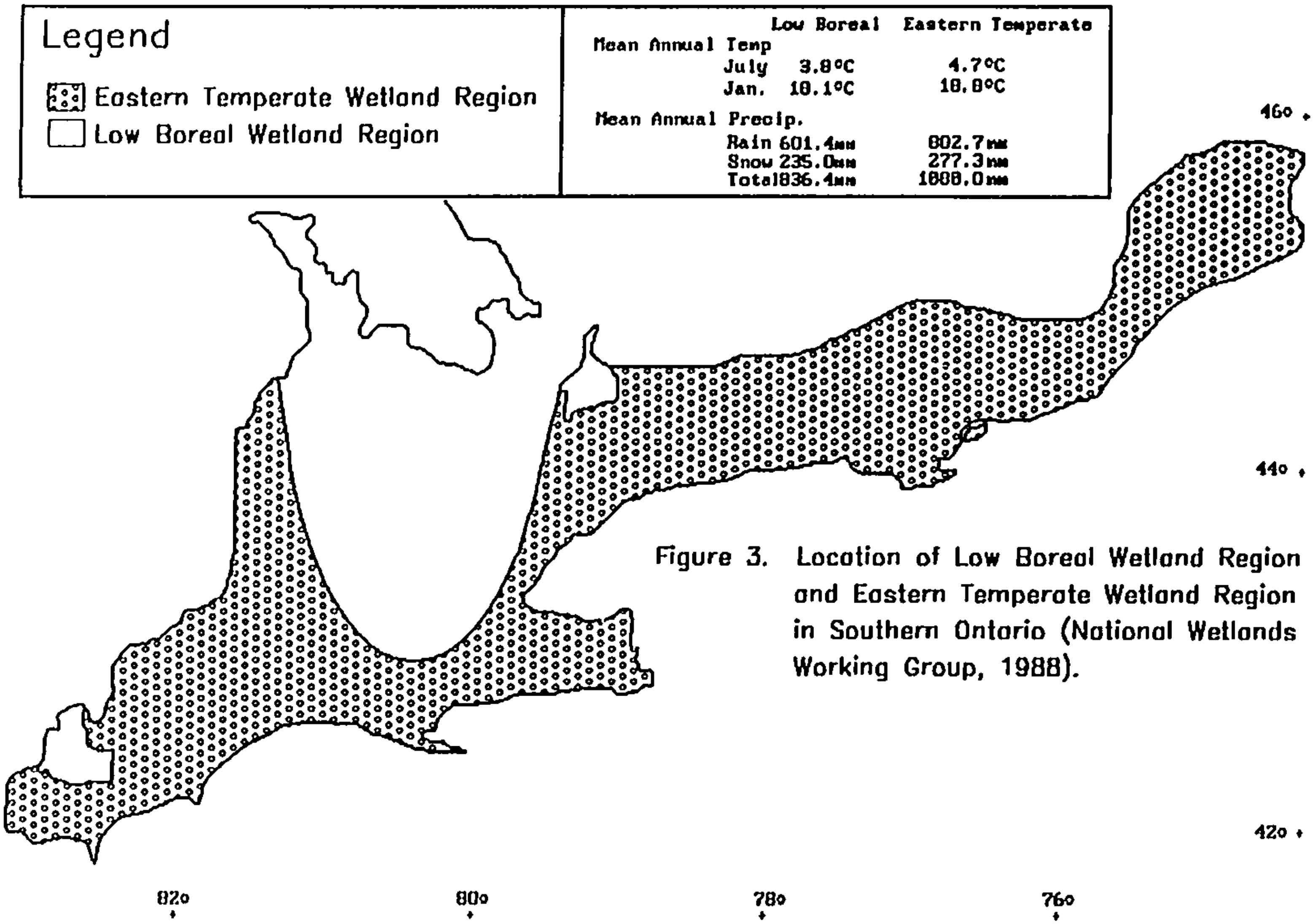



Figure 3. Location of Low Boreal Wetland Region and Eastern Temperate Wetland Region in Southern Ontario (National Wetlands Working Group, 1988).

## 2.5 Low Boreal Wetland Region

The Low Boreal Wetland Region extends from the north into southern Ontario. Its southern extent corresponds to the winter position of the arctic frontal zone (Bryson, 1966), resulting in a climate of cold winters and short warm summers, with relatively high precipitation. The physiography of the Low Boreal region includes both Precambrian rock of the Canadian Shield, and softer sedimentary rocks surrounding the shield (Chapman & Putnam, 1984). Thin deposits of glacial material, lakes, and poorly drained areas, are a common feature of the Boreal region, due to the poor drainage systems on the hard Precambrian rocks. The areas underlain by sedimentary rocks are found along the southern boundary of the Low Boreal region. Because of the soft rock in this area, drainage systems are well developed, although wetlands may develop in poorly drained flat areas. Topography of the Low Boreal region ranges from areas of rounded hills with 100 m or less of relief, to areas of gently rolling land.

The vegetation of the Low Boreal region is characterized by closed-canopied forests dominated by coniferous species. Hardwood swamps are rare in the Low Boreal region; the more common swamp forms are coniferous swamps. Domed bogs and basin bogs are the most common bog forms, while fens include basin fens and shore fens.

## 2.6 Eastern Temperate Wetland Region

The Eastern Temperate Wetland Region forms a band along the north shores of lakes Erie and Ontario (Figure 3). It passes through the most heavily settled portion of the province, and is characterized by mild winters and warm summers, with moderately high amounts of precipitation (Zoltai, 1979). The climate of much of this region is modified by warm moist air currents which develop over the Great Lakes. The northern boundary of the Eastern Temperate Region is difficult to define, and tends to blend into the southern boundary of the Low Boreal Region. The main difference between the Eastern Temperate Region and other wetland regions is the occurrence of hardwood swamps dominated by maple (National Wetlands Working Group, 1988). Although hardwood swamps do occur in the southern parts of the Low Boreal Region, these swamps are dominated by elm-ash communities.

In Ontario, the Eastern Temperate Region occurs in the St. Lawrence Lowlands physiographic region (Chapman and Putnam, 1984). This region is characterized by relatively flat topography, covered by thick glacial deposits. Because of the resistance to erosion of the underlying limestone plains, many areas within the region remain undrained, providing sites for wetland formation. Those areas covered with thick glacial deposits have somewhat better drainage systems, although in many areas adequate conditions exist for the formation of wetlands (Chapman and Putnam, 1984).

Floodplains and flat areas surrounding the Great Lakes have also provided ideal sites for the formation of swamps and marshes.

In Ontario, the Eastern Temperate Wetland Region is characterized by vegetational communities associated with the Carolinian Biotic Zone (Fox and Soper, 1954). Hardwood swamps are the most common wetland form in the Eastern Temperate Region. Extensive areas of marshes and shallow water wetlands are also common, characterized by tall standing vegetation, as well as a variety of standing, floating, and submerged vegetation. Bogs, both treed and treeless, and fens are also found throughout the region.

Because this region is heavily settled, and has been for over a century, much of the natural vegetation has been significantly altered. Agricultural development is extensive, and wetlands are under greater pressure than in any other region for conversion to urban, industrial, and recreational uses. As a result, the present distribution of wetlands does not reflect the original, natural pattern of wetland occurrences (National Wetlands Working Group, 1988).

In the 1980s, the Ontario Ministry of Natural Resources began a program to inventory significant natural areas. A number of these inventories were of significant provincial wetlands, the results of which were documented in a series of reports titled Life Science Inventories of Areas of Natural and Scientific Interest (Brunton, 1990). In these reports the areas are described in detail, including information on the various landscapes and habitats, vegetational communities and fauna, and descriptions of development or disturbance within the site. While these reports do not make any conclusions or recommendations, they do provide a consistent source of information which allows for comparison among various sites, and also provides a basis for further study.

## 2.7 Wetland Functions

The various goods and services provided by a wetland constitute wetland functions (Cox et al., 1992). Society may be directly or indirectly benefitted by these wetland functions, but their value is derived from society's perception of the function. Because the importance of the wetland functions is often misunderstood, wetlands are destroyed to make way for land uses with greater perceived value. However, alterations to a wetland impairs that wetland's ability to function and provide these benefits to society.

Wetland functions and values may be grouped in a number of ways (Tiner, 1984; OTA, 1984) but one of the most comprehensive includes four broad categories: 1. physical/ hydrological; 2. chemical; 3. biological; and 4. socio-economic (Williams, 1991). Physical factors include flood control through the storage of excess runoff, coastal protection through the dispersion of wave energy in coastal marshes, aquifer recharge, sediment trapping, and local climate regulation. Chemical functions include a wetland's ability to trap pollutants either through plant uptake or absorption in sediments. A wetland's biological functions include its productivity, which provides ample food for a wetland's fauna. Wetlands are also important habitats, acting as habitat for permanent wetland species and as staging areas for migratory birds. Wetlands provide habitat for some rare or endangered species; twelve of Ontario's 14 endangered species are dependent upon wetlands for survival (Soil Conservation Society, 1986). Two rare mammal species make use of wetland habitats: the eastern mole and grey fox.

Socio-economic functions may be divided into consumptive and non-consumptive. Consumptive values include the production of food, both on drained and undrained wetlands. Wetlands also are sources of energy through the production of peat and through the cutting of firewood. Trees with high economic value such as cedar are also cut from wetlands for use as lumber.

The non-consumptive benefits of a wetland include scenic, recreational, educational, aesthetic, archaeological, scientific, heritage and historical benefits (Williams, 1991). These benefits rarely garner the same degree of attention as benefits which are readily expressed in monetary terms. Functions which do not contribute to the production of a product, or have an immediate measurable benefit may not be valued. Most wetlands, however, contribute some profit to society and thus have some demonstrable value.

Assessing the value of a wetland presents a number of problems in making land use decisions (Mitsch and Gosselink, 1986). Most significant is the sheer number of functions or values found in a wetland. Prioritizing wetland values is difficult, as most wetlands have multiple and conflicting values. Economic values are currently the main assessment criteria. Unfortunately, many non-consumptive socio-economic benefits cannot be assessed using cost-benefit analysis due to the difficulty in assigning monetary costs to non-economic values. It is important to recognize the potential value of such functions, however, as future research may reveal important uses for currently undervalued functions. Thus, current land use decisions should not impair a wetland's ability to provide any function to ensure their availability in the future. Unfortunately, detailed information on the value of wetland functions and the impacts of human activity on these wetland functions is limited. Developing an understanding of the impacts of human activities in and around wetlands, combined with natural processes and characteristics of the wetlands themselves may help to guide land use decisions in the future.

## 2.8 Effects of Alterations to Wetlands

Wetlands are lost in many complex ways, the causes of which may be physical, chemical, or biological. Physical changes include alterations in topography or elevation. Chemical changes include changes to nutrient inputs, the addition of toxins, alterations to pH, and changes in water temperature. Biological changes include changes to biomass production, community composition, or changes to landscape patterns. Any development within or near the wetland may effect several of these changes to a wetland. These changes may be intentionally inflicted upon the wetland, or the effects may be the unintentional by-products of nearby activities (Gosselink and Maltby, 1990).

The effects of several common activities in wetlands have been ranked according to areal extent, intensity and permanence (Lee and Gosselink, 1988)(Figure 4). Activities such as mining cause permanent change to the substrate of the wetland, but generally only affect a small area. Agricultural land drainage causes an intensive and extensive change to the wetland, which often cannot be reversed due to significant alterations to local water and topography. Changes to wetlands which alter hydrology, or the wetland's substrate are considered more permanent than changes which affect only biota (Gosselink and Maltby, 1990). Thus, it is important to assess the impact of any potential development in terms of its effects on all components of the wetland system.

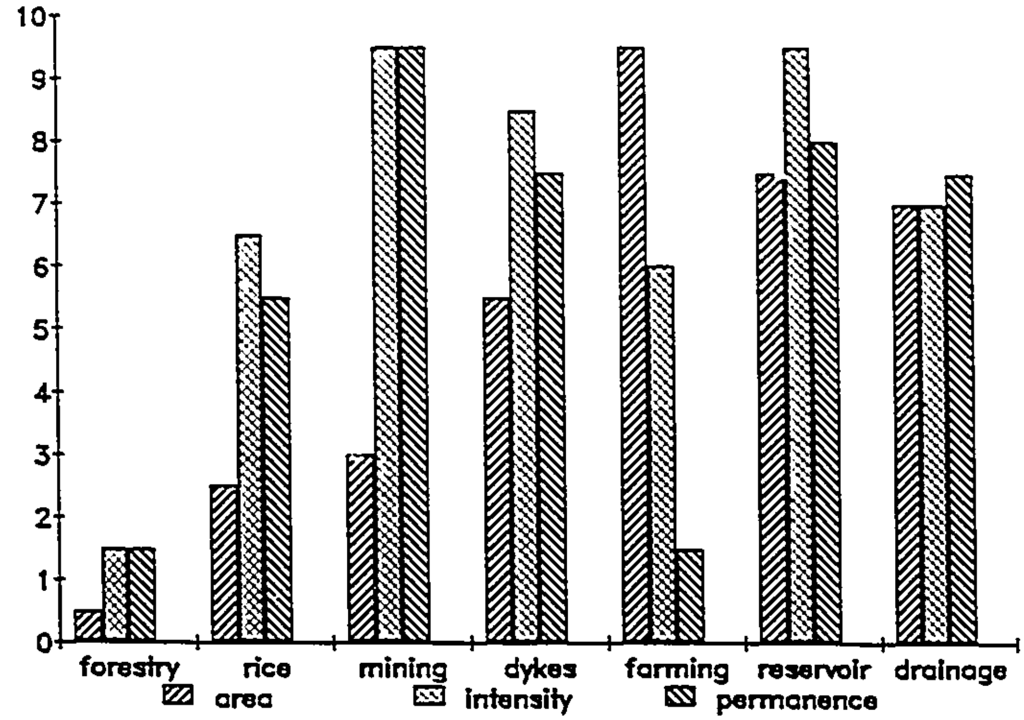



Figure 4. Ordination of Wetland Activities by the Importance of their Cumulative Effects Based on Area Affected, Intensity, and Permanence (from Lee and Gosselink, 1988).

2.9 Wetland Conversion and Fragmentation in Southern Ontario

Until recently, the degree to which wetlands in Southern Ontario have been altered was not well known. Most wetland research has dealt with inventory and evaluation. Few qualitative reports were compiled before the late 1960s, when awareness of the value of wetlands was beginning to be realized. The 1970s and 1980s saw an increase in quantitative reports dealing with specific cases of wetland conversion. One of the earliest studies was undertaken by Cox (1972), who estimated the total area of wetland soils and cleared wetlands up to 1950. Cox's findings, which were later confirmed by Snell (1987), Bardecki (1981, 1984) and Lynch-Stewart (1983), showed that originally 2,380,000 hectares, or 25.5 per cent of the total area of Southern Ontario was wetland. Wetland distribution varied, with the greatest concentrations of wetlands occurring in the southwestern and eastern counties of the province (Bardecki, 1981; Snell, 1987)(Figure 5). In these counties, 40 to 95 per cent of the total county areas were wetlands. Today, wetland distribution is the opposite of pre-settlement distribution (Figure 6). Less than five per cent of the area of the southwestern counties is now wetland. Southern Ontario wetland area has dropped by 1,447,000 hectares or 68 per cent of the original wetland total (Bardecki, 1981).

Three areas in particular display profound wetland conversion; the extreme southwest (Essex, Kent, Lambton counties), eastern Ontario, and the area south of Georgian

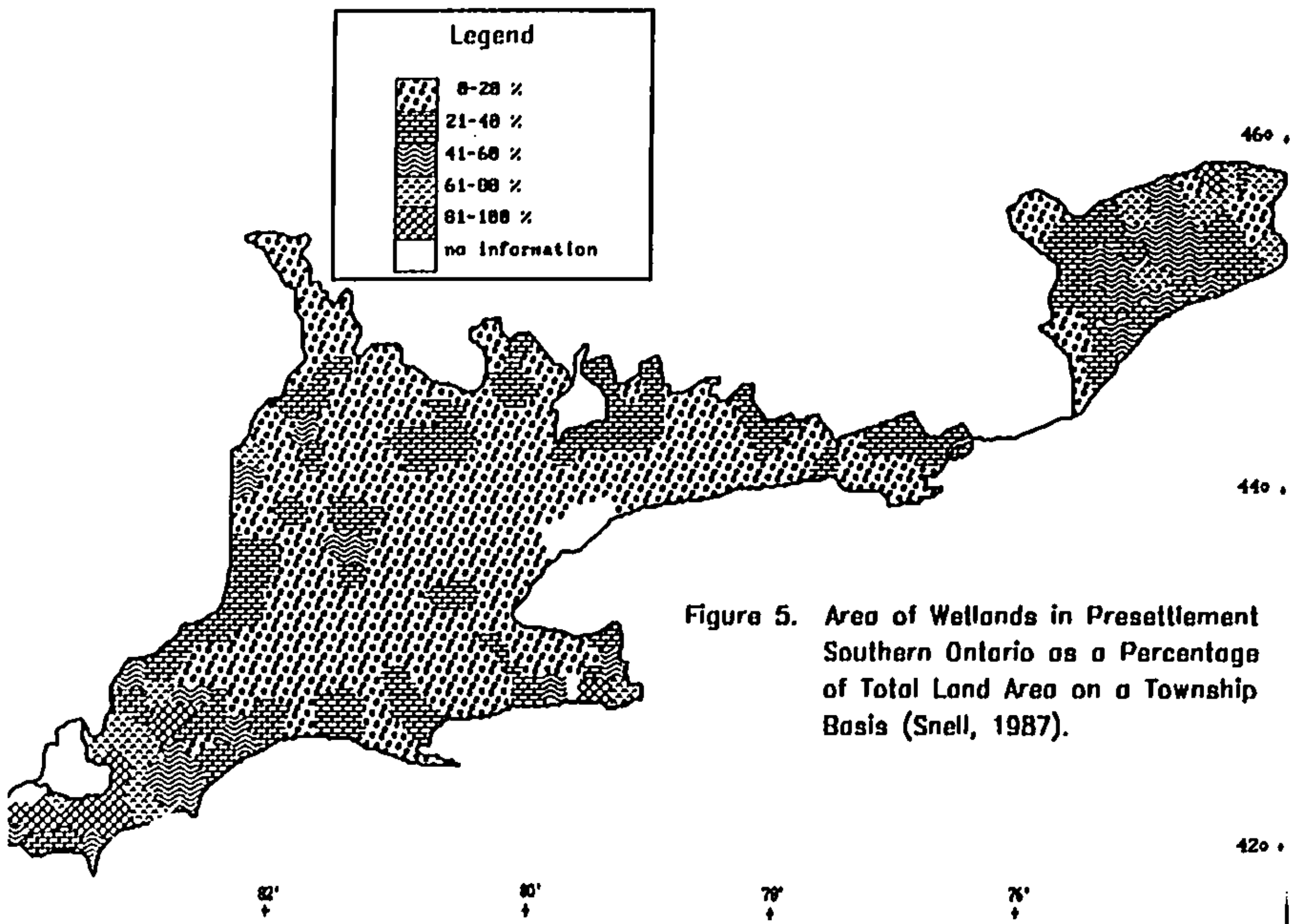



Figure 5. Area of Wetlands in Presettlement Southern Ontario as a Percentage of Total Land Area on a Township Basis (Snell, 1987).

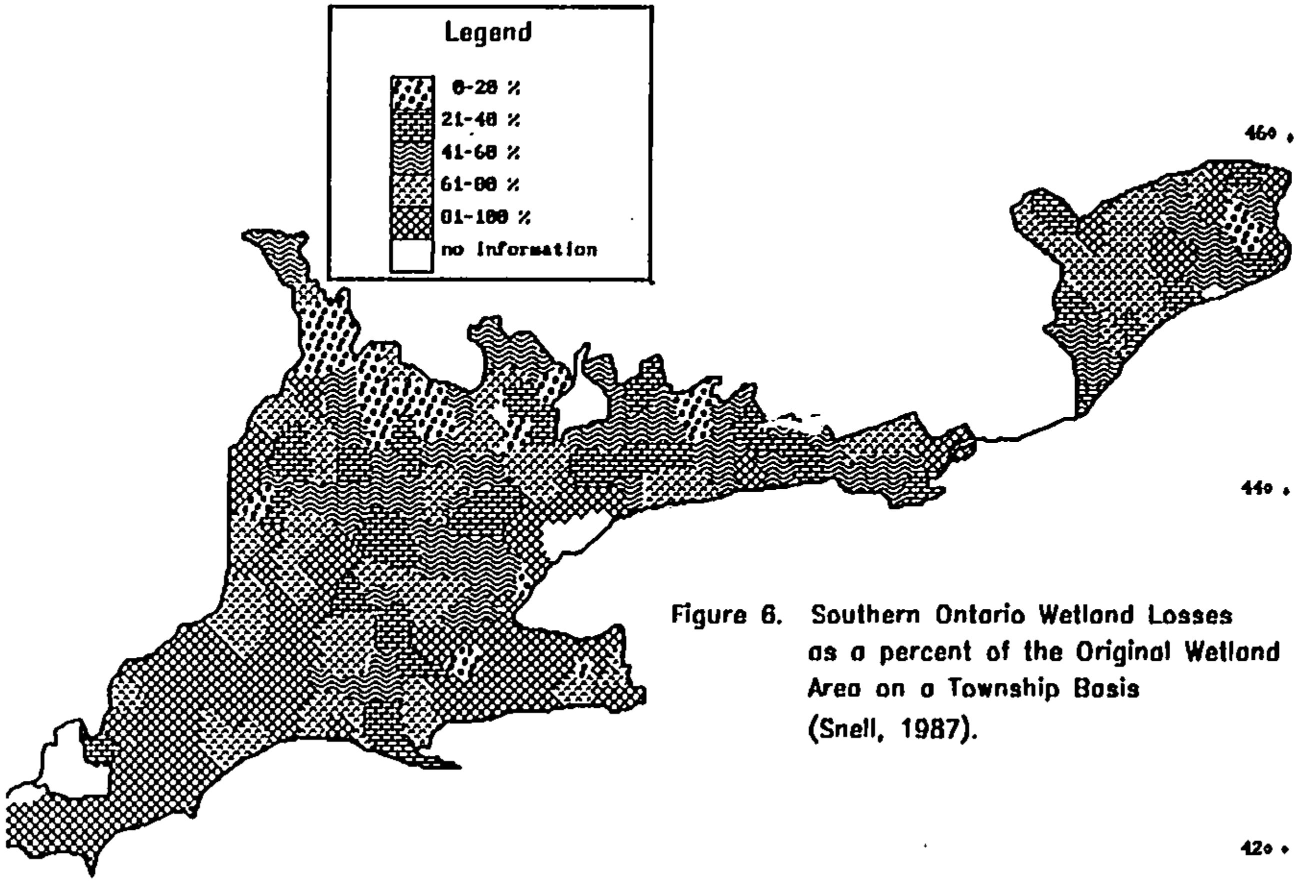



Figure 6. Southern Ontario Wetland Losses as a percent of the Original Wetland Area on a Township Basis (Snell, 1987).

Bay (Lynch-Stewart, 1983). The most significant loss of wetlands has occurred in the southwestern portion of the province. The southwest is an important field crop growing area, and its continued agricultural productivity is dependent on increasing field drainage. The area is of major concern, as to date Essex, Kent, and Lambton counties have lost 95 per cent, 93 per cent, and 81 per cent of their original wetlands, respectively (Snell, 1987).

Rutherford (1979) examined losses of wetlands in Southern Ontario, specifically the Point Pelee and Lake St. Clair marshes, from the late 1800s to the late 1970s. Rutherford concluded that the area of the Point Pelee marsh declined by 71 per cent by the late 1970s, and the Lake St. Clair marshes decreased in area by 39 per cent. The main cause of wetland decline in this area was due to agricultural drainage, while cottage development, oil and gas drilling, and industrial development contributed in a minor way.

The second major area of wetland drainage is in Eastern Ontario (Bardecki, 1981). It is estimated that up to 80 per cent of wetlands in Renfrew and Frontenac counties have been converted to other land uses (Lynch-Stewart, 1983). The pressure on these wetlands is expected to remain high.

An increasing degree of wetland drainage is occurring in the area south of Georgian Bay (Lynch-Stewart, 1983). Grey, Wellington, Dufferin, and Simcoe counties are noted for their concentrations of wetlands, but pressure for their conversion is growing (Snell, 1987).

Lewies and Dyke (1973) and McCullough & Collins (1976) assessed the status of the Kawartha Lakes wetlands. Their objective was to prioritize the Kawartha Lakes on the basis of marsh per unit, as well as the rate of marsh loss. It was found that the marshes on the Kawartha Lakes decreased by approximately 20 per cent between 1960 and 1964. The conclusion made is that despite their importance for wildlife, the marshes of the Kawartha Lakes are endangered and in need of protection. The study area represents an area of extensive cottage development, which, for this area was found to be the main cause of wetland decline.

## 2.10 Land Use of Converted Wetlands in Southern Ontario

In Southern Ontario, wetlands have been converted to a number of new land uses, the most common of which is agriculture (Figure 7). Between 1967 and 1982, 31,830 hectares or 81 per cent of wetlands converted to alternate uses were converted to agriculture (Snell, 1987).

Historically, wetlands have been converted to agriculture in order to bring every available acre into production, as well as to facilitate the movement of large machinery. Often, the expansion of urban and industrial land uses onto prime agricultural land forces remaining farms onto marginal or less productive land. Most wetland conversions are small in scale; however, the cumulative

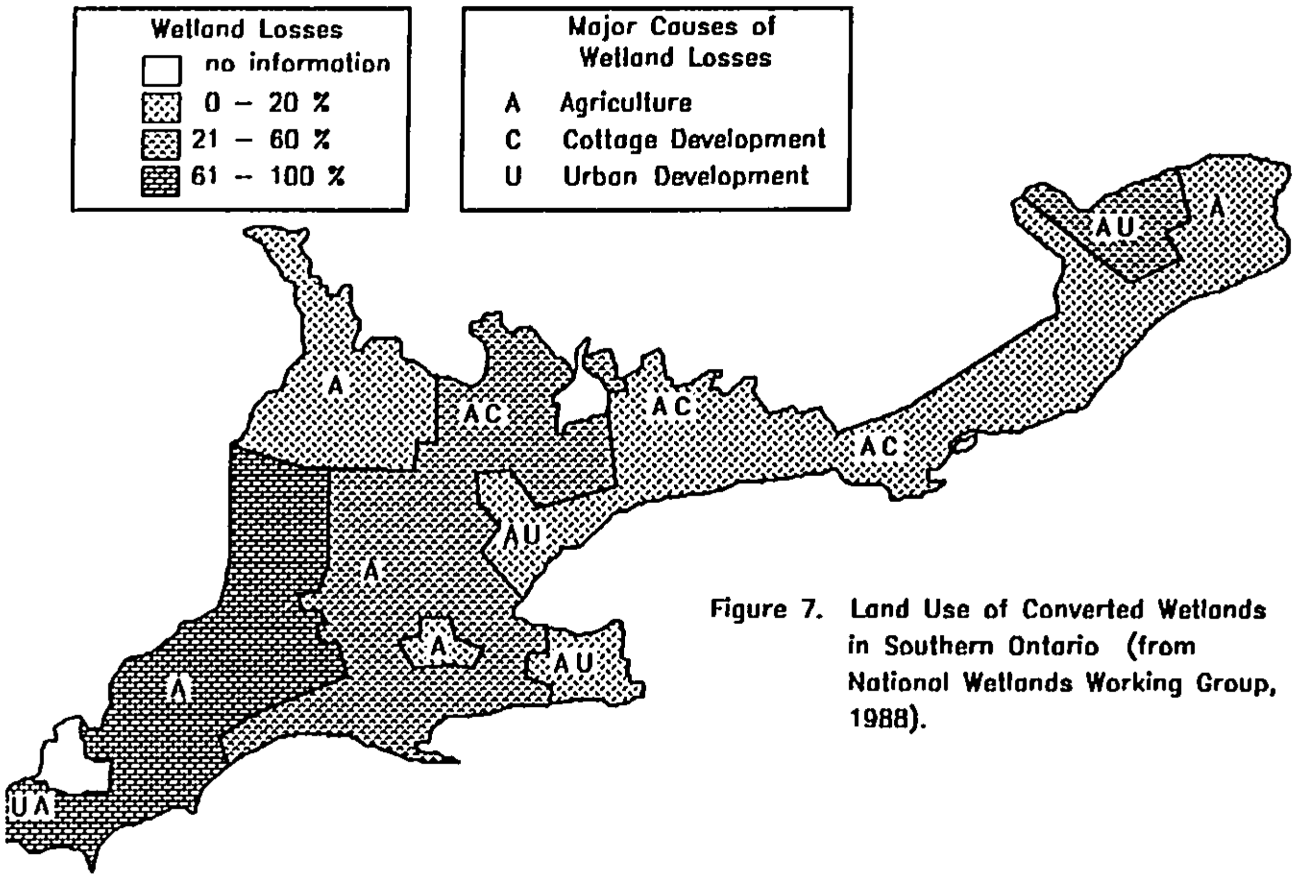



Figure 7. Land Use of Converted Wetlands in Southern Ontario (from National Wetlands Working Group, 1988).

effects of many drainage operations may be devastating to water supplies, soil quality and wildlife habitat. Indirect drainage also affects wetlands. Agricultural drains lower the local water table and result in partial drainage of neighbouring wetlands. The subsequent ecological impairment affects a greater wetland area than is actually converted to agriculture (Bardecki, 1981).

While not reaching the magnitude of agricultural land drainage, urban and industrial development play a significant role in wetland conversion. Wetlands near cities have great value for recreation and conservation, but these same wetlands are under the greatest direct pressure from conflicting uses (Rubec, 1980). Ontario's wetlands are converted to such uses as harbours, sites of manufacturing plants, warehouses, roads, airports, housing developments, utility rights-of-way, and shopping centres (Lynch-Stewart, 1983; McCullough, 1981; Lemay, 1980). Ontario's wetlands have also been converted to recreational uses. Wetlands converted to recreational uses other than cottages or marinas between 1967 and 1982 had an area of 960 hectares (Snell, 1987) Because many rural economies benefit from tourism, wetlands are removed to make way for tourism oriented recreational development.

Ontario wetlands are also used for energy production and transmission. Impoundment and construction of transmission line corridors affect wetland areas, and the potential use of peat as a source of energy threatens additional wetlands areas (Moneco, 1981).

The ultimate result of the conversion of wetlands to other land uses is that the remaining wetland fragments become increasingly isolated from other similar habitats. Since the early 1960s, ecologists and biogeographers have recognized the importance of studying ecological isolates for the purpose of conservation (MacArthur & Wilson, 1967; Preston, 1962). An isolate is a discrete ecological unit which is separated from other similar units by some other environment which limits the movement of organisms between units (Soule & Wilcox, 1980). In the field of biological conservation, ecologists have recognized that almost all natural habitats will eventually resemble islands in that they will be only fragments of previously larger habitats (Smith, 1986). Fragmentation of natural habitats has a negative effect on the ecosystem, due to habitat reduction, an increase in distance between similar habitat fragments, and subsequent alterations to the taxonomic composition of the fragment (Wilcox, 1980).

# CHAPTER III

## Habitat Fragments and Species Diversity

### 3.1 Species Diversity

Loss of species diversity is one alteration which commonly occurs with habitat fragmentation. Species diversity is a measure which relates the abundance of each species to the total number of species present in a habitat. A community with a few individuals of many species has a greater species diversity than a community in which most of the individuals are of the same species. A similar measure of diversity is species richness, which is simply the number of species found in a habitat, without accounting for the abundance of each species (Smith, 1986).

A reduction in species diversity or species richness can have extreme effects on the rest of the ecosystem. Because each species places limitations on all other species sharing the same habitat in terms of space, food, and other resources, each species is important in order to keep the ecosystem healthy and functioning normally. The removal of even one species can have devastating effects, either due to a loss of food for carnivores which feed on that species, or by reducing competition which allows other species to multiply rapidly (Ricklefs, 1984). Loss of diversity usually begins with species at higher trophic levels; the implications of this are unknown because of the lack of understanding of the effects of predators on the lower trophic levels of an ecosystem (Terborgh, 1976). It is known, however, that the removal of certain important predators can lead to significantly altered and less diverse communities.

Preservation of biodiversity is important for a number of reasons. Diverse biological resources provide numerous forest, fishery and wildlife, and food crops for current and future use. In addition to economic benefits, a highly diverse ecosystem supports a wide variety of species, which in turn provide a number of ecological functions. These functions include regulating hydrological cycles, local climate, soil formation and nutrient transport, as well as a number of social uses such as recreation, tourism, and research (McNeely, 1992). Despite the importance of biodiversity, threats to the diversity of remaining species and habitats continue to grow. The main threats to biodiversity arise from habitat destruction and degradation, rather than direct exploitation of individual species. Long-term maintenance of species diversity is dependent upon conservation of a number of ecotypes throughout a geographical area (Harris, 1984).

### 3.2 The Species-Area Relationship

One of the main foci of insular ecology is the species-area relationship, which states that if isolates or islands are censused, a greater number of species will be found on the larger isolates (Smith, 1986), The concept of increasing species richness with increasing area has existed since the observations of Darwin (1863) in the Galapagos Islands. Others have since observed the relationship between area and species numbers (Cain, 1938; Williams, 1943; Evans et al., 1955) but attempts to explain or quantify the phenomenon were uncommon until the 1960s. MacArthur and Wilson (1967) and MacArthur (1973) undertook studies of tropical island birds to assess the relationship between island size and species diversity. Island size was related to the number of species and each species' abundance. It was found that larger islands, and shorter distances between islands resulted in greater species diversity.

Johnston (1968) undertook a study of insular effects on vegetation. The species diversity on a number of islands and mainland areas was related to area, elevation, latitude, and distance from mainland or nearest intervening island. The results of regression analyses showed that area is a better predictor of species diversity than elevation, and the addition of variables in multivariate regression analyses improves the precision of prediction. His results indicate that a number of factors affect species diversity, but area is the most significant.

Two models of the mathematical relationship between species and area were proposed in the 1960s. Preston (1960, 1962) proposed a power function model which refers to log species/log area transformations based on an assumption of dynamic equilibrium of species exchange between islands. This model reduces the importance of habitat diversity by explaining species number as a function of immigration and extinction rates. Williams (1964) proposed the exponential model, which refers to a species/log area transformation that emphasizes habitat heterogeneity. This model proposes that as the amount of area sampled increases, new habitats and their associated species are included, and thus species number increases with area. Connor and McCoy (1979) sought to clarify the relationship between these models to determine the best fit for biological data. By analyzing previous studies which had used these approaches, Connor and McCoy found that both hypotheses are possibly correct. One virtually always finds a positive correlation between species number and area regardless of whether the mechanism is based on habitat diversity or area alone. Connor and McCoy conclude that the parameters of the power function and exponential models may provide some biological significance through the comparison of species-area curves.

The use of the species-area relationship in conservation has been a cause for debate. The controversy is centred on those who feel the species-area relationship promotes a single large reserve as the most effective conservation strategy (Higgs, 1981; Diamond et al., 1976; Diamond and May, 1976; Cole, 1980) and those who believe several smaller reserves preserve more species (Simberloff and Abele, 1976; Simberloff, 1974, 1982; Gilpin, 1980; Higgs and Usher, 1980). Two studies which advocated several smaller reserves were based on empirical studies of islands. Gilpin (1980) studied 13 New Hebrides islands, while Higgs and Usher (1980) studied chalk quarries in the United Kingdom. The number of distinct species on each island was determined for each possible island pairing, and this was related to the total area for each pairing. Regression lines for the relationship show that two small islands hold five to ten per cent more species than expected for a single large island of the same area.

The other side of the debate favours a single large reserve. These authors (Higgs, 1981; Diamond, 1976; Diamond and May, 1976; Cole, 1980) argue that the several small reserves strategy fails to account for the differing colonization abilities of different species. They argue that if all species had the same probability of survival, large numbers of small reserves would be satisfactory. With enough reserves, any given species would be likely to be found on at least one reserve. This strategy's flaw is that different species have different areal requirements (Diamond and May, 1976). The species most in need of preservation have little chance for survival in a system of small refuges (Diamond, 1976).

Cole emphasizes the argument for a single large reserve. Taking the data from Simberloff and Abele's (1975) work, Cole adjusted it to account for the differing colonizing abilities of the various species. After this adjustment, Cole found that several small reserves actually have lower species diversity than a single large reserve. The claim that small reserves have more species is valid only for islands which contain a very small portion of the total available species pool. These areas are inappropriate as wildlife preserves (Cole, 1980).

A further argument against several small reserves is based upon the concept of nesting. Bolger et al. (1991) stated that if a pronounced gradient in survival ability exists among the species occupying a series of fragments, then fragments of similar area or species number should all have the same species composition. This pattern is known as nesting, and asserts that all species which occur in fragments with (**n**) species will also occur in fragments containing (**n+1**) species. Bolger et al. found that for a group of islands, the species which are found in smaller and older fragments are a subset of species found in larger and younger fragments. The species found in the smaller fragments were species with the least vulnerability to extinction. Strong nesting among groups of fragments results in a collection of reserves containing the same subsets of species, and hence less species richness than in a single large reserve. Where nesting is less prominent, large reserves may not be necessary. However, in areas where nesting is prominent, the potential exists for a system-wide extinction of species, emphasizing the need for large reserves to preserve the more vulnerable species.

### 3.3 Habitat Islands

In the field of island ecology, a distinction is made between oceanic islands and islands which are a fragment of a formerly continuous landscape or habitat. The distinction is made due to the reduced species richness found on true oceanic islands. On these islands, growth of species number depends upon the ability of a species to travel across water. A continental fragment "island" usually has higher species diversity due to the greater proximity of the colonizing source pool. The equilibrium diversity of such islands is reached when the number of species immigrating equals the number of species becoming extinct, due to inadequacy in size or habitat of the island.

### 3.4 Island Effects on Species Diversity

Loss of species diversity is an inevitable result of habitat fragmentation. Habitat loss contributes to a lessening of species diversity first by excluding a portion of the region's fauna, in particular species whose distribution areas are rare or patchy (Wilcox, 1980). It also contributes to loss of diversity by reducing the population of the remaining species, which subsequently increases the extinction rate.

The creation of fragments of habitat results in a loss of diversity within the fragment in two ways. The first is by extirpating species which are protected within the "island", but which also require outside resources. Many species are unable to travel across hostile environments, and thus cannot survive in a fragment if other necessary resources are not accessible. The second result of the creation of habitat fragments occurs through a reduction in accessibility to potential colonists, which intensifies extinction rates.

Three classes of island effects exist, depending on the time scale of the fragment. Unless one sets aside a reserve of an extremely large size, there will inevitably be species lost in the fragment which would be normally found in the region. This is known as the sample effect, or a 30 per cent reduction in regional fauna for a 10 per cent reduction in area (Wilcox, 1980). The potential impacts of the sample effect should be assessed before any decisions for nature reserve management are considered.

Species diversity is also affected by habitat fragmentation through short-term island effects. An area designed as an ecosystem preserve, but which does not include the entire area of that ecosystem will not be able to support all of the ecosystem's species. However, as long as adequate habitat exists around or near the boundaries of the fragment, species which would not have sufficient habitat within the fragment to survive remain. As the adjacent habitat disappears, the species which depend upon that habitat disappear from the fragment; this phenomenon is known as short-term island effects. Unless managed intensively, species able to survive in the fragment only because of additional nearby habitat will disappear with the removal of adjacent habitat.

As the amount of similar habitat adjacent to a habitat fragment decreases there is a corresponding decrease in the colonization from distant species sources. Because long-term extinctions will occur in any isolate regardless of its size, the decreased colonization results in a net loss of species (Wilcox, 1980). Such long-term insularization effects will continue until colonization and extinction rates reach equilibrium based on the new conditions around and within the fragment.

Management decisions can only be made by keeping in mind the results of sample effect, short-term and long-term island effects. The question of an effective size for an island to support an optimal number of species can only be addressed in the context of the conditions of the area surrounding the fragment (Harris, 1984). The main factors determining the effective size of an fragment are: actual size; distance from similar habitat "islands"; and the degree of habitat difference of the surrounding matrix. Each of these factors, and their cumulative and potential effects on the species diversity of a fragment or potential reserve should be assessed prior to any land management decisions. Thus, it is necessary to determine for each ecosystem type how each of these factors affects species diversity, as conceivably each community type will be affected in slightly different ways.

3.5 Species Diversity of Southern Ontario Wetland Fragments

Wetland literature has primarily been concerned with inventory of, or hydrology of wetlands, ignoring the issue of wetland species diversity. Wetlands, however, continue to be disturbed and fragmented without basic knowledge of the effects such alterations are having on the diversity of wetland species. Knowledge of how wetland species are affected by such basic factors as area and disturbance is necessary for appropriate wetland management. This study proposes to address the relationship between a wetland's characteristics and species richness. Through the use of statistical measures, the main factors responsible for influencing species richness may be identified for southern Ontario wetlands. The results may provide a basis for further study, and provide a framework upon which future wetland management decisions may be made.

# CHAPTER IV

## Methodology

### 4.1 Study Area

The study area consists of southern Ontario, or the area south of North Bay (figure 8). The reasons for selecting this study area are as follows:

First, the study area is a region of extensive economic development. Pressures from agriculture, urban, and recreational development subject the wetlands to pressures for disturbance unique to this part of the country. Second, all wetland classes which once were widespread throughout the region continue to deteriorate in quantity and quality. Third, all wetlands in the study area are within the jurisdiction of the same management agencies, and therefore have equal potential for protection.

Within this region, 27 wetlands were selected for the study. The sample is limited to those wetlands for which data has been collected, rather than a random sample of all of Southern Ontario's wetlands. The data were compiled by conservation authorities, the Ministry of Natural Resources, and other government and non-government agencies between 1985 and 1990, by biologists and trained volunteers who had undertaken mammal censuses for specific wetlands within their jurisdictions. Wetland fragments range in size from 0.4 hectares to 7500 hectares, and are separated from other

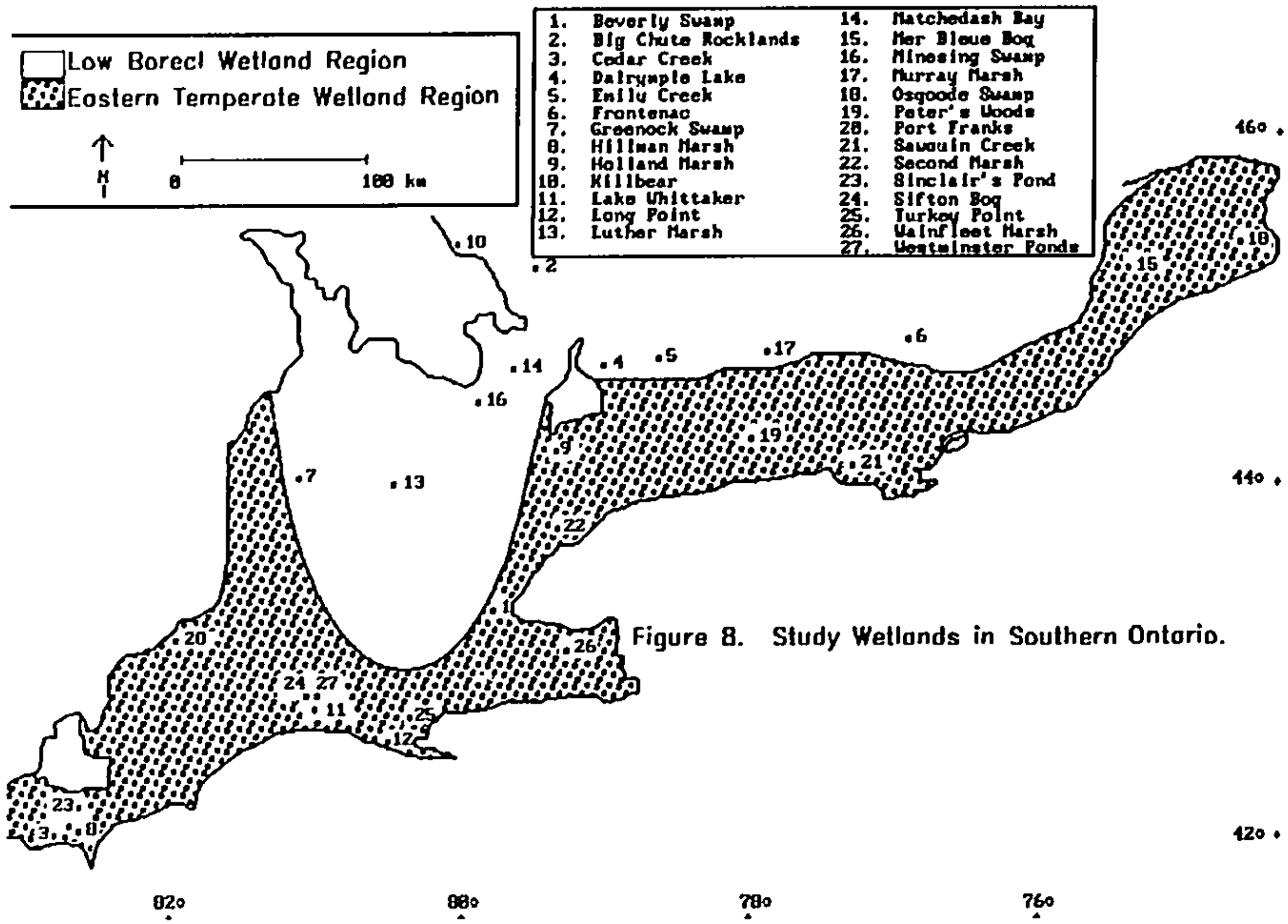



Figure 8. Study Wetlands in Southern Ontario.

wetlands by agricultural land, urban development or other natural ecosystems.

4.2 Variables

For the study, a series of structural equations, in the form of a systems model, were developed to produce values which would serve as variables. The choice of wetland attributes influencing species diversity was made from a review of previous island biogeography studies. Area has been shown to be the most significant influence on species richness, but several other environmental factors have been demonstrated as having an effect on species diversity also.

Harris *et al*. (1982) indicated the effects of environment on species diversity. Harris shows that presence or absence of surface water, elevation, and structural complexity of the community are the principal environmental characteristics which influence forest fragment species diversity. Characteristics such as area, latitude, topography, isolation, canopy height, and climate also exert an influence on the numbers of species found in a forest island (Harris, 1984).

Mathiae and Stearns (1981) performed a study of mammals of forest fragments in Wisconsin, to define the relationship between mammal species richness and area of a given fragment, and also to determine whether the character of the surrounding landscape affected the species richness of the fragment. Data collected from mammal trapping provided species richness measures. Comparing richness to measures of isolation, area, and land use of the surrounding area indicated that greater area usually resulted in greater species richness, while high isolation and low diversity of adjacent land resulted in reduced species richness.

In a study of vegetation diversity in Wisconsin woodlots, Rudis and Ek (1981) developed measures for area, topographic diversity, successional age and degree of disturbance on the fragment, and forest fragment interactions. Their objectives in developing the systems model were to identify the effects of the variables on vegetation species diversity, and to use the model to maximize the preservation of species, while minimizing the number of fragments needed to achieve the goal.

The structural equations used in the study were based to a large extent on those developed by Rudis and Ek (1981), for vegetation in Wisconsin woodlots, with alterations made to suit the equations for use on southern Ontario wetland fragments. The variables which were selected to be tested as predictors of species richness of southern Ontario wetland fragments were area, topographic diversity, diversity of the surrounding matrix, disturbance within the wetland, and isolation. Previous biogeographic studies have shown these variables to be significant in predicting species richness. It is assumed that the five variables chosen represent the major factors which impact a wetland's species diversity.

## 4.3 Measurements and Equations

### Area

Area has been widely recognized as a variable which directly affects species richness, regardless of the ecosystem or taxa studied (MacArthur *et al.*, 1966; MacArthur & Wilson, 1967; Harris *et al.*, 1982). Greater area usually results in greater species diversity.

Each fragment of wetland considered in the study was measured from National Topographic Survey (NTS) maps and aerial photos using a transparent grid overlay method (Appendix A). The area of each wetland fragment was expressed in hectares.

The area variable used was the measure of the wetland area in hectares. The species-area relationship as expressed by Rudis and Ek (1981) is:

$$S_i=f(A_i)$$

where $S_i$= species richness of island i; and $A_i$= the area of island i.

### Topographic Diversity

Area alone does not account for variations in species richness (Johnston *et al.*, 1968; Levenson, 1976). Levenson (1981) found that as the diversity of the landscape increases, the number of species found also increases, due to the additional number of habitats available. The measure of topographic diversity acts as an indirect gauge of habitat complexity.

Topographic diversity in wetlands was measured as follows: the boundaries of the wetlands, as well as each 10 m contour interval were outlined on topographic maps. Using the transparent grid overlay method (Appendix A), the wetland area within each contour interval was calculated and expressed in hectares. It was assumed that for a wetland community where the landscape generally exhibits little variation in elevation, the 10 m interval in topography would result in a significant habitat change.

The measure of topographic diversity used by Rudis and Ek (1981), as well as the present study was based upon the Shannon-Weiner index of diversity (after Pielou, 1969):

$$T_i = - \sum_{k}^{Q_i} p_k \log_2 p_k$$

where $T_i$= index of topographic diversity for fragment i; $p_k$= proportion of area within a contour interval k, with Q contour intervals on fragment i.

<u>Disturbance Within the Wetland</u>

Rudis and Ek also used a measure of the degree of disturbance, derived from successional age as measured by the density and height of the woodlot. The assumption used to obtain the value was that younger, more disturbed woodlots have lower density and canopy height. On average, older, undisturbed stands have a higher species richness than younger, more disturbed stands (Harris, 1984). Species richness is highly variable relative to disturbance and ecosystem age (Harris, 1984). For the wetland study, however, a measure of stand height is inappropriate. Therefore, an alternative measure of disturbance was derived.

From the information contained in topographic maps and aerial photos, the area within the wetland which had been converted to some other land use was measured, using the transparent grid overlay (Appendix A) and expressed in hectares. For the study wetlands, disturbance included lands drained for agriculture and structures constructed within the wetland, roads, power corridors, railways, drainage ditches, peat mines, and gravel pits or quarries. The total area within the wetland which was altered by human activity was the value used in the disturbance equation.

Because any activity within the wetland alters vegetation, hydrology, water and air quality, it is assumed that a measure of disturbance is necessary due to the potential effects on habitat and species diversity. For the wetland study, the equation used was:

$$W_i = \frac{a_d}{a_n}$$

where $W_i$= degree of disturbance; $a_d$= area within wetland affected by human activity; $a_n$=total area of wetland.

Isolation of the Wetland

Rudis and Ek used a modified gravity interaction model to consider the degree of isolation of a woodlot. In the study of woodlot fragments, several variables must be added to the basic gravity model. Because the dispersal of tree seeds is subject to transportation by wind, birds and animals, interaction between forest islands differs from interactions observed in more mobile species. Thus, because the pattern of propagule distribution is negatively exponential, an exponent was added to the model to account for this distribution.

For the wetland mammal study, however, the use of the exponential distribution was not necessary, due to the greater ability of mammals to travel and interact among fragments. However, because the land use of the area separating wetlands is not uniform, the ability for mammals to interact among wetlands may vary, due to the presence or lack of corridors joining the islands. This variability can be expressed through the exponent used on the distance value.

Stewart (1954) studied travel patterns of people of varying ethnic and socio-economic backgrounds for several

American cities. His findings indicated that the ability to travel is influenced by such socio-economic barriers as race and income. Stewart's standpoint maintains that the exponent of the distance component of the gravity model should be either 1 or 2.

For the wetland mammals, varying travel conditions are expected to influence the ability of mammals to travel between wetlands, and hence influence wetland interaction. Wetlands joined by a direct link such as a creek or river, which would allow the movement of wetland mammals were given an exponent of one in the gravity model, while those wetlands with no direct connection to their neighbours were given an exponent of two. Neighbouring wetlands were considered to be wetlands 10 km or less from the boundaries of the wetlands (Powell, 1981). In this way, the differing linkage possibilities between wetland fragments was addressed. The equation used in the wetland study uses area as an alternative for the mass or population variable:

$$I_{ij} = \sum_{j}^{n} \frac{A_i A_j}{d_{ij}^{r}}$$

where $I_{ij}$=interaction between islands i and j; $A_i$ $A_j$= area of islands i and j; $d_{ij}$= distance between nearest edges of islands; r= connectivity exponent.

Diversity of Surrounding Matrix

The final variable in the study was a measure of the diversity of the matrix surrounding the fragment. The type of land use surrounding the wetlands determines the degree of interaction between the fragment, and other fragments and ecosystems, and also the number of species which may enter the fragment from other surrounding ecosystems. A fragment surrounded by a distinctly different land use experiences maximum habitat differences for wildlife, and the negative effects of an edge ecosystem (Harris, 1984). In cases where there is only a subtle difference between the fragment and the surrounding area, the fragment may not appear as a small island at all, effectively increasing the area of the fragment.

For the study, the surrounding matrix was expressed as those lands within 120 metres of the boundary of the wetland (Ontario Ministry of Natural Resources, 1990). The area of each land use was measured from topographic maps and aerial photographs using the transparent grid overlay, and expressed in hectares. Land uses include buildings and other structures, roads, railways, power corridors, gravel pits and quarries, agriculture, forest, streams or rivers, scrub, and meadows.

The diversity of the matrix is measured using a diversity index. For the wetlands study, the diversity index used was Simpson's index of diversity (Smith, 1981):

$$L = \frac{N(N-1)}{\sum n(n-1)}$$

where L=diversity of land uses; N=total area of all land use types; n=area of each land use type.

The final systems model incorporates the values of the five structural equations for each of the study fragments. This model includes the major elements which influence the richness of species within a given fragment (Rudis and Ek, 1981): area, topographic variation, disturbance within the fragment, interaction among fragments, and the diversity of the surrounding matrix. The effects of these variables on species diversity and their significance was evaluated through the use of multiple regression analyses.

# CHAPTER V

## Analysis

### 5.1 Introduction

Multiple regression analysis is used to measure the extent to which selected factors explain the variation in mammal species richness among southern Ontario wetland fragments. The analyses also identify the relative importance of each of the independent variables. Three analyses were performed: one to evaluate the effects of the independent variables on the total number of mammal species found in a wetland, one to evaluate the influence of the independent variables on non-wetland specific species, and one to evaluate the effects of the independent variables on mammals whose habitat is restricted to wetland habitats. These three analyses were chosen to determine whether habitat specific mammal species respond differently to environmental characteristics than less habitat specific species. Because wetland species are restricted in their habitat it was hypothesized that alterations to their habitat would have a greater impact than on more mobile and less habitat specific species.

Prior to selecting the factors for use in the regression analyses, the degree of normality of the independent variables was checked. The Kolmogorov-Smirnoff test, at the 95 per cent probability level, was used to confirm that all five independent variables were normally distributed (Table 1).

5.2 Multiple Regression

One independent variable may explain a considerable amount of variance but still leave some variation unexplained. The addition of several other variables to the equation helps find the best-fitting plane in n-dimensional space which most accurately describes the relationship between the variables. The simultaneous effects of several independent variables on the dependent variable can be assessed through the construction of a multiple regression equation:

$$Y= a + b_1X_1 + b_2X_2 + \ldots + b_nX_n$$

where Y= the dependent variable ; $X_1$, $X_2$, $X_n$= independent variables; a= intercept of the linear surface; $b_n$= regression coefficient of the nth variable, "$X_n$".

In the calculations, the **b** values are partial regression coefficients. Each **b** value represents the rate of change in the dependent variable (species richness) for a unit change in each independent variable (wetland characteristics), while the remaining independent variables are held constant. In the present form, the **b** values are unstandardized, due to the use of different measurement scales for the variables. In order to compare these values, they must be standardized. The resulting coefficients are called beta weights, symbolized by **B**. The relative impacts

Table 1

Kolmogorov-Smirnoff Test For Normality of Independent Variables

| Variable | K-S value (95%) |
|---|---|
| Area | 0.20 |
| Matrix Diversity | 0.19 |
| Topographic Diversity | 0.20 |
| Interaction | 0.22 |
| Disturbance | 0.10 |

K-S crit= 0.27

of the variables can be identified from the magnitude of the beta weights.

While the beta weights indicate the degree to which the dependent variable is affected by the independent variables, they do not express a precise value of explained variance. A partial correlation coefficient measures the strength of the relationship between **y** and a single independent variable by considering the relative amount that the unexplained variance is reduced by including this variable in the regression equation (Harnett, 1975). While a partial correlation coefficient measures reduction in the unexplained variation in **y**, a multiple correlation coefficient measures reductions in the total variation of **y**. The strength and significance of the standardized regression coefficients provide a degree of validity to the proportion of explained variance of the independent variable.

Three multiple regression analyses were run to assess the strength and validity of the relationships between the independent variables (wetland characteristics) and the dependent variable (species richness). The first used the total number of mammal species found in the wetlands as the dependent variable. The second used only the wetland specific mammals as the dependent variable, and the third used non-wetland habitat specific mammals as the dependent variable. The analyses identify the factors which exert a significant impact on the species richness of a wetland.

5.3 Total Mammal Species Complement

The total number of mammal species found in a wetland is directly, and most strongly affected by the area of the wetland (Table 2). This single factor accounts for 91.16 per cent of the variation in mammal species richness. Thus, it is evident that for the total mammal complement of a wetland, maintaining maximum species richness entails maintaining the maximum area possible. Land management programs should be created to ensure that wetlands be maintained at the greatest possible area.

The diversity of the surrounding matrix is also responsible for influencing the species richness of a wetland. An additional 1.46 per cent of the variance left unexplained by area, is explained by the addition of matrix diversity to the analysis. Matrices with a greater diversity of habitat types tend to result in wetlands with greater overall species diversity. Wetland management plans and local planning should include the area surrounding the wetland in order to help preserve maximum species diversity.

Topographic diversity is also a significant variable. The addition of this variable increases the explained variation by 1.3 per cent. The relationship, however, is negative, suggesting that a wetland with a high degree of topographic diversity has lower species richness than wetlands with less topographic diversity.

Table 2

Total Species Complement
Multiple Regression Analysis

| Independent Variable | Standardized Regression Coefficient | t | Significant | Proportion Explained Variation (per cent) |
|---|---|---|---|---|
| Area | 0.95 | 16.06 | yes | 91.16 |
| Topographic Diversity | - 0.11 | 2.09 | yes | 1.30 |
| Matrix Diversity | 0.12 | 2.63 | yes | 1.46 |
| Disturbance | - 0.22 | 0.36 | no | 0.03 |
| Interaction | 0.06 | 0.81 | no | 0.04 |
| Total Regression | R= 0.97<br>$R^2$= 0.94<br>F= 66.32 | | yes | 93.99 |

The least significant value of $t^{(0.05)}$ is 2.08.
The least significant value of $F^{(0.05)}$ is 2.68.
R= Correlation Coefficient
$R^2$= Coefficient of Determination (total explained variation)

While many studies indicate that disturbance and isolation often influence species richness, for the total mammal complement in Southern Ontario, these factors were found to be insignificant. These variables together account for only 0.07 per cent of the variance.

To enhance the analysis, the total mammal species complement was divided into those species which are wetland habitat specific, and those which do not rely solely on wetlands for survival. Multiple regression analyses were performed on both groups.

## 5.4 Non-Wetland Specific Species

Of the selected independent variables, area was the only significant variable for non-wetland specific species. Wetland area accounts for 92.45 per cent of the variation in species richness for non-wetland specific species (Table 3). Apparently, the greater the size of the wetland fragment, the greater the number of non-wetland specific mammals which may be found there. In order to maintain a high level of richness in non-wetland specific mammals, wetland preserves should be maintained at as great an area as possible.

The four remaining variables, matrix diversity, topographic diversity, interaction, and disturbance are not significant variables, accounting for 0.84 per cent of the variation. Evidently, the variety of habitats provided by a high degree of topographic diversity or matrix diversity

Table 3

Non-Wetland Specific Species
Multiple Regression Analysis

| Independent Variable | Standardized Regression Coefficient | t | Significant | Proportion Explained Variation (per cent) |
|---|---|---|---|---|
| Area | 0.96 | 13.44 | yes | 92.45 |
| Topographic Diversity | - 0.02 | 0.37 | no | 0.04 |
| Matrix Diversity | 0.07 | 1.45 | no | 0.54 |
| Disturbance | - 0.00 | 0.06 | no | 0.00 |
| Interaction | - 0.06 | 0.84 | no | 0.26 |
| Total Regression | R= 0.97<br>$R^2$= 0.93<br>F= 58.34 | | yes | 93.28 |

The least significant value of $t_{(0.05)}$ is 2.08.
The least significant value of $F_{(0.05)}$ is 2.68.
R= Correlation Coefficient
$R^2$= Coefficient of Determination(total explained variation)

does not influence non-wetland mammal species richness. Also, interaction among wetlands and the degree of disturbance within the wetland exert little influence over the species richness of non-wetland specific mammals.

5.5 Wetland Specific Species

For wetland mammalian species diversity, wetland area accounts for 50.13 per cent of the total explained variation (Table 4). Apparently, the importance of area as an influence on wetland species diversity is less than that for non-wetland specific species richness. This suggests that other characteristics of the wetlands in addition to area are more significant in influencing wetland species richness.

The amount of additional variance explained by the diversity of the surrounding matrix increases in importance compared to non-wetland specific species richness. For wetland species, the matrix accounts for 4.82 per cent of the variance. Thus, for wetland species, a highly diverse surrounding matrix is important for maintaining a high degree of species richness.

The species richness of wetland mammals is influenced by the topographic diversity of the wetland. Topographic diversity accounts for 11.36 per cent of the explained variance; thus, species specific to wetlands are influenced to a greater degree by habitat variation than species which have less specific habitat needs. The correlation is

Table 4

Wetland Specific Species
Multiple Regression Analysis

| Independent Variable | Standardized Regression Coefficient | t | Significant | Proportion Explained Variation (per cent) |
|---|---|---|---|---|
| Area | 0.71 | 5.01 | yes | 50.13 |
| Topographic Diversity | - 0.33 | 2.81 | yes | 11.36 |
| Matrix Diversity | 0.22 | 2.57 | yes | 4.82 |
| Disturbance | 0.03 | 0.20 | no | 0.37 |
| Interaction | 0.40 | 2.80 | yes | 9.31 |
| Total Regression | R= 0.87<br>$R^2$= 0.76<br>F= 13.29 | | yes | 75.99 |

The least significant value of $t^{(0.05)}$ is 2.08.
The least significant value of $F^{(0.05)}$ is 2.68.
R= Correlation Coefficient
$R^2$= Coefficient of Determination(total explained variation)

negative, however. Thus, unlike forest ecosystems where a highly diverse topography results in greater species diversity, wetland mammal species show greater diversity when the topography is less diverse. Since topographic diversity in fact means the interjection of higher terrain, or non-wetlands into a wetland area, a wetland with little topographic diversity has more wetland and less upland, providing more habitat for the wetland specific species.

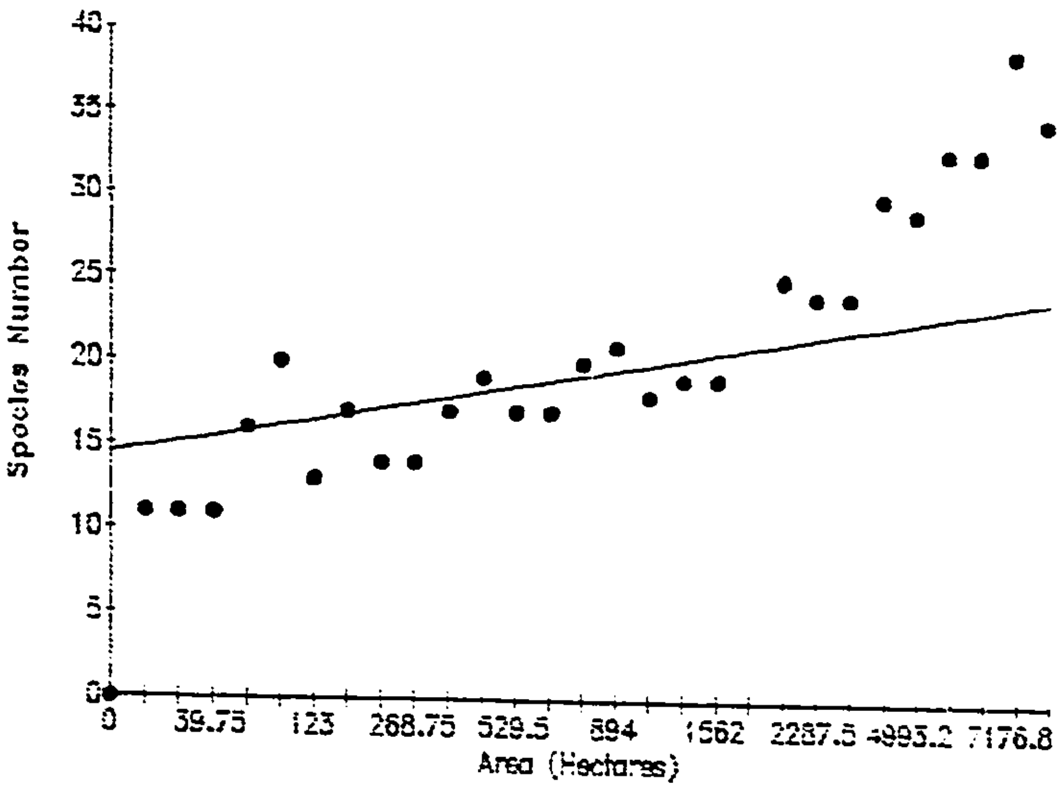
The degree of interaction among wetlands also influences the wetland species richness. This factor is of greater importance for wetland mammal species than for the total species complement, accounting for an additional 9.31 per cent of the explained variation. This may be due to wetland species' need for wetland corridors through which to travel from wetland to wetland. Wetlands with a high degree of interaction, and joined by similar habitat corridors, have a greater ability to maintain a higher species diversity through migration than wetlands with less interaction. For land management decisions, care should be taken to maintain similar habitat corridors between wetlands to maximize population movement among the fragments.

The total explained variance for wetland species alone is 75.98 per cent, while for all species the total explained variation is 93.99 per cent. While much of the wetland species variation is explained, 18 per cent of the variance remains unexplained. Thus, wetland species diversity is influenced by one or more additional factors beyond those identified in the study. Future study should attempt to identify these additional factors.

### 5.6 Species / Area Relationship in Wetland Fragments

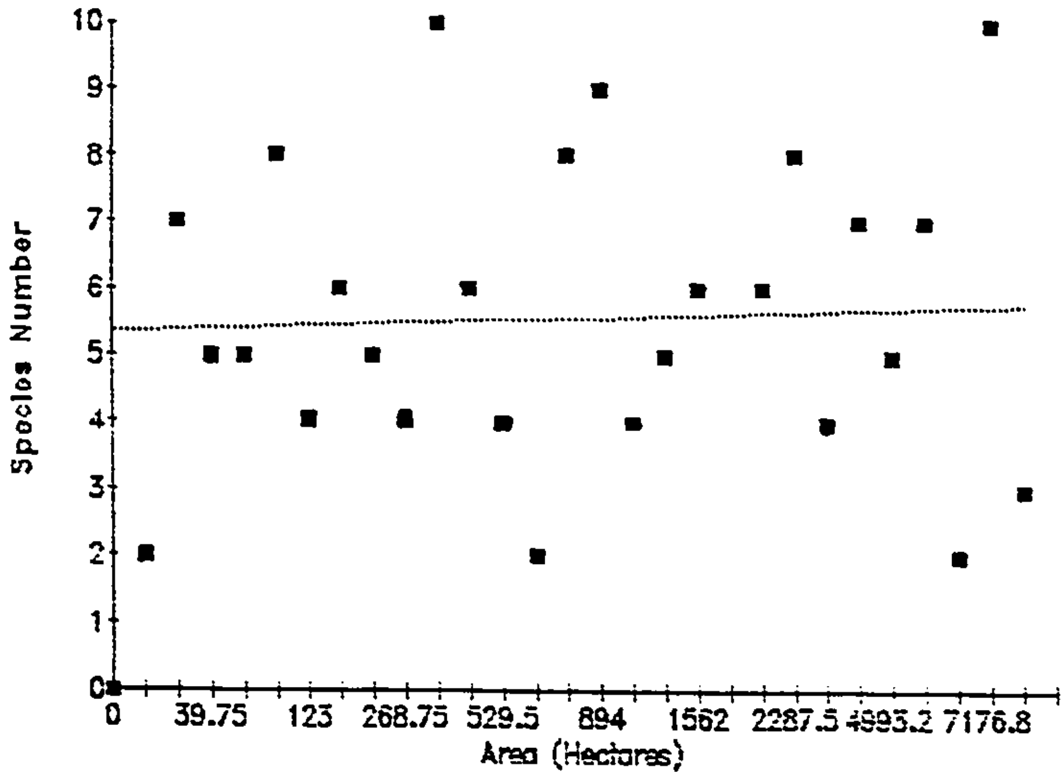
Surprisingly, the regression analyses show that area is much less important for determining species richness among wetland specific mammals, than for non-wetland specific mammals. It was expected that the richness of wetland specific mammals would be affected by area to a greater degree than for less habitat specific mammals. Apparently, factors in addition to area are responsible for determining wetland species richness.

Scatterplots of area and each of the three independent variables were produced. The data were then tested through the use of an expanded ANOVA table to determine if the relationship between area and species richness is linear. The ANOVA table includes a value for variation through non-linear residuals. If the non-linear residual value is found to be insignificant through an F-test, the relationship between X and Y is assumed to be approximately linear (Clark & Hosking, 1986). It was postulated that the decrease in importance of area on wetland species richness could be explained by the lack of fit of linear regression on a non-linear relationship between area and wetland species richness. Figures 9, 10, and 11 show the scatterplots for area and the richness of the total species complement; area and wetland specific species richness; and area and non-




F= -3.86
$F_{crit}$= 3.05

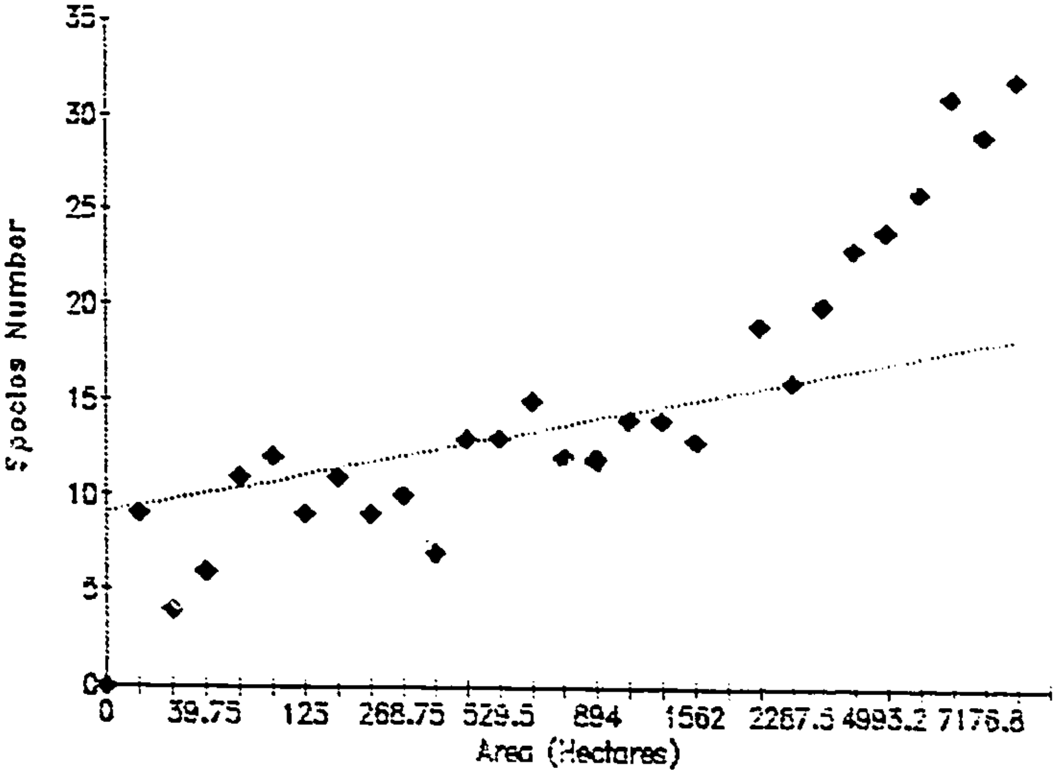
Figure 9. Species / Area Relationship for the Total Wetland Mammal Species Complement.




F= -3.55

$F_{crit}$= 3.05

Figure 10. Species / Area Relationship for Wetland Specific Mammal Species.




F= -0.81
$F_{crit}$= 3.05

Figure 11. Species / Area Relationship for Non-Wetland Specific Mammal Species.

wetland specific species richness, respectively. In each case, the F-test indicates that a linear relationship exists between area and the dependent variables. Thus, one must conclude that lack of fit of the linear regression is not the cause of the decreased importance of area for determining wetland species richness. The richness of these species rests to a greater degree on other characteristics of the wetland, characteristics which are not included in the analyses. Future study of the effects of such factors as water quality, water quantity, or pollution on wetland species may indicate the nature of these additional characteristics (Gosselink and Maltby, 1990).

### 5.7 Analysis of Regression Residuals

The residuals for each of the three regression analyses were examined to determine if regional or locational factors influence wetland species diversity. Prior to the residual examination, however, the residuals were subjected to a T-test to determine if regional differences do indeed occur between Low Boreal and Eastern Temperate wetlands. Table 5 shows the results of the T-tests and indicates that for the total species complement and wetland specific species regional differences in the residuals do occur. No regional difference exists for non-wetland specific species.

Table 6 shows the casewise plot of residuals for the total species complement. The majority of the residuals above the trend line correspond to wetlands located in the

Table 5

T-test of Residuals

| | Low Boreal | Eastern Temperate |
|---|---|---|
| **Total Species Complement** | | |
| Mean Residual $\bar{X}$ | 0.99 | -0.58 |
| Standard Deviation | 1.48 | 2.43 |
| Sample Size | 10 | 17 |
| $t_{(0.05)} = -2.09$ | | |
| Wetland Specific Species | | |
| Mean Residual $\bar{X}$ | 1.18 | -0.69 |
| Standard Deviation | 0.87 | 1.30 |
| Sample Size | 10 | 17 |
| $t_{(0.05)} = -4.04$ | | |
| **Non-Wetland Specific Species** | | |
| Mean Residual $\bar{X}$ | - 0.09 | 0.05 |
| Standard Deviation | 1.34 | 1.81 |
| Sample Size | 10 | 17 |
| $t_{(0.05)} = 0.21$ | | |

The least significant value of $t_{(0.05)}$ is 2.06.

Table 6

Casewise Plot of Standardized Residuals
for the Total Wetland Species Complement

```
*: Eastern Temperate   @: Low Boreal

          -3.0      0.0      3.0
 Case #   O:........:........:O   ALLSP    *PRED    *RESID
      1   .         *         .      19    19.16     -0.16
      2   .         .@        .      16    15.20      0.80
      3   .       * .         .      14    15.86     -1.86
      4   .         . @       .      24    22.31      1.67
      5   .        @.         .      19    20.00     -1.00
      6   .         .  @      .      19    16.65      2.35
      7   .         .@        .      39    37.94      1.06
      8   .         .*        .      17    16.08      0.92
      9   .         . *       .      24    22.52      1.48
     10   .         . @       .      17    15.40      1.60
     11   .      *  .         .      13    15.40     -2.40
     12   .     *   .         .      35    38.17     -3.17
     13   .      @  .         .      29    30.96     -2.00
     14   .         .  @      .      20    17.58      2.42
     15   .         .   *     .      25    22.25      2.75
     16   .         .@        .      33    32.56      0.44
     17   .         .@        .      30    29.01      1.00
     18   .         .   *     .      21    17.86      3.14
     19   .    *    .         .      11    15.02     -4.02
     20   .         *         .      17    17.16     -0.16
     21   .         *         .      33    32.82      0.18
     22   .         .     *   .      20    15.36      4.64
     23   .    *    .         .      11    15.00     -4.00
     24   .*        .         .      11    15.13     -4.13
     25   .         *         .      17    16.70      0.30
     26   .         *         .      18    18.22     -0.22
     27   .       * .         .      14    15.67     -1.67
 Case #   O:........:........:O   ALLSP    *PRED     RESID
          -3.0      0.0      3.0
```

Low Boreal wetland region. Only two Low Boreal wetlands (5 and 13), had residuals below the trend line, while the residuals for the Eastern Temperate wetlands were more evenly distributed on the plot. The residuals suggest that latitude may play a role in determining the species diversity of a wetland. The relationship, however, does not seem to be related to changing climate with changing latitude. Were this the case, Eastern Temperate wetlands would be found primarily above the trend line, and Low Boreal wetlands would be found primarily below the trend line, as in general, species diversity increases with lower latitude (Smith, 1984). For southern Ontario wetlands, however, the opposite seems to occur. This may be due to the greater degree of development found in the southern part of the study area. Greater human populations, larger and more numerous developed areas result in a variety of environmental changes for wetlands. Pollution, drainage, widespread hydrological alterations and microclimate changes associated with urban areas result in major ecosystem modifications all around the wetlands of the Eastern Temperate region.

The Eastern Temperate region roughly corresponds to the three parts of Ontario which have experienced the greatest losses of wetland area: the extreme southwest, the area south of Georgian Bay, and the extreme east (Bardecki, 1981; Lynch-Stewart, 1982; Snell, 1982). Perhaps the factors which resulted in the extreme losses of wetlands in these areas in the past, continue to influence the remaining wetlands with the result of decreased species diversity.

The plot of residuals for the regression of area on wetland specific species shows a similar and even more consistent pattern (Table 7). In this case, the majority of residuals above the trend line correspond to Low Boreal wetlands. Residuals corresponding to Eastern Temperate wetlands occur mainly below the trend line. Variations associated with changing latitude and major ecosystem modification influence the diversity of wetland mammals in the same way as the total mammal complement. Wetlands in the more developed southern areas of the study area show less species diversity than those in the less developed northern regions.

Table 8 shows the residual plot for non-wetland specific species. Most of the residuals above the trend line correspond to wetlands in the Low Boreal region. Four Low Boreal wetlands have residuals below the trend line (4,5,13,17), while Eastern Temperate wetlands are evenly distributed across the residual plot. The residuals suggest that there is no regional difference in species richness for non-wetland specific species. It appears that less habitat specific species are not affected by the regional differences in ecosystem modifications in the same way as wetland habitat specific mammals. This phenomenon may be due to the less specific habitat needs of non-wetland specific mammals. Such mammals may be more adaptable to the

Table 7

Casewise Plot of Standardized Residuals
for Wetland Specific Species

```
*: Eastern Temperate   @: Low Boreal

         -3.0       0.0       3.0
 Case #   O:........:........:O   WETSP    *PRED    *RESID
      1   .         *         .       5     5.04     -0.04
      2   .         .@        .       5     4.24      0.76
      3   .        *.         .       4     4.37     -0.37
      4   .         .    @    .       8     5.68      2.32
      5   .         . @       .       6     5.21      0.79
      6   .         .  @      .       6     4.53      1.47
      7   .         . @       .      10     8.85      1.15
      8   .        *.         .       4     4.42     -0.42
      9   .         .*        .       6     5.72      0.28
     10   .        @.         .       4     4.28     -0.28
     11   .      *  .         .       3     4.28     -1.29
     12   .*        .         .       5     8.89     -3.89
     13   .         .@        .       8     7.43      0.57
     14   .         .  @      .       6     4.72      1.28
     15   .         .  *      .       7     5.67      1.33
     16   .        @.         .       7     7.76     -0.76
     17   .         .   @     .       9     7.04      1.96
     18   .         .   *     .       7     4.78      2.22
     19   .     *   .         .       2     4.20     -2.20
     20   .    *    .         .       2     4.64     -2.64
     21   .         *         .       8     7.81      0.19
     22   .         .*        .       5     4.27      0.73
     23   .     *   .         .       2     4.20     -2.20
     24   .         *         .       4     4.23     -0.23
     25   .        *.         .       4     4.54     -0.54
     26   .         *         .       5     4.85      0.15
     27   .        *.         .       4     4.33     -0.33
 Case #   O:........:........:O   WETSP      *PRED  *RESID
         -3.0       0.0       3.0
```

Table 8

Casewise Plot of Standardized Residuals
for Non-Wetland Specific Species

*: Eastern Temperate   @: Low Boreal

```
         -3.0      0.0       3.0
 Case #   O:........:.........:O   DRYSP     *PRED     *RESID
      1   .         *          .   14.00     14.12      -0.12
      2   .         @          .   11.00     10.96       0.04
      3   .      *  .          .   10.00     11.49      -1.49
      4   .        @.          .   16.00     16.63      -0.63
      5   .      @  .          .   13.00     14.78      -1.78
      6   .         . @        .   13.00     12.12       0.88
      7   .         @          .   29.00     29.09      -0.09
      8   .         . *        .   13.00     11.66       1.34
      9   .         . *        .   18.00     16.79       1.21
     10   .         .  @       .   13.00     11.12       1.88
     11   .       * .          .   10.00     11.12      -1.12
     12   .         .*         .   30.00     29.28       0.72
     13   .     @   .          .   21.00     23.53      -2.53
     14   .         . @        .   14.00     12.86       1.14
     15   .         . *        .   18.00     16.58       1.42
     16   .         . @        .   26.00     24.80       1.20
     17   .       @ .          .   21.00     21.97      -0.97
     18   .         . *        .   14.00     13.08       0.92
     19   .      *  .          .    9.00     10.82      -1.82
     20   .         .   *      .   15.00     12.52       2.48
     21   .         *          .   25.00     25.01      -0.01
     22   .         .      *   .   15.00     11.09       3.91
     23   .      *  .          .    9.00     10.80      -1.80
     24   .  *      .          .    7.00     10.91      -3.91
     25   .         .*         .   13.00     12.15       0.85
     26   .        *.          .   13.00     13.37      -0.37
     27   .       * .          .   10.00     11.33      -1.33
 Case #   O:........:.........:O   DRYSP     *PRED     *RESID
         -3.0      0.0       3.0
```

variety of human land uses, and the habitats provided therein. Thus, these mammals are able to survive in areas of heavy development, as well as in areas less altered by human activity.

5.8 Spatial Analysis of Residuals

The residuals were mapped in order to determine if there is a spatial pattern in the distribution of residuals. While the T-tests indicated that there is a regional difference in species richness between Low Boreal and Eastern Temperate wetlands for the total mammal species complement, and wetland specific species, the residual maps were prepared to show precisely how the residuals are distributed within each wetland region. Figure 9 shows the residual map for the total species complement, and indicates that the southwestern portion of the study area consists mainly of negative residuals. Positive residuals are found in a cluster in the area south of Georgian Bay, and a small cluster in the extreme eastern portion of the region. This map suggests that the degree of development in the study area determines the distribution of residuals. The extreme southwest has the greatest degree of both agricultural and urban development, and also the wetlands with the lowest species richness. Much less development is found in the Low Boreal region, with the result of greater species richness. While the residuals in the extreme eastern part of the study area are Eastern Temperate wetlands, they exhibit positive

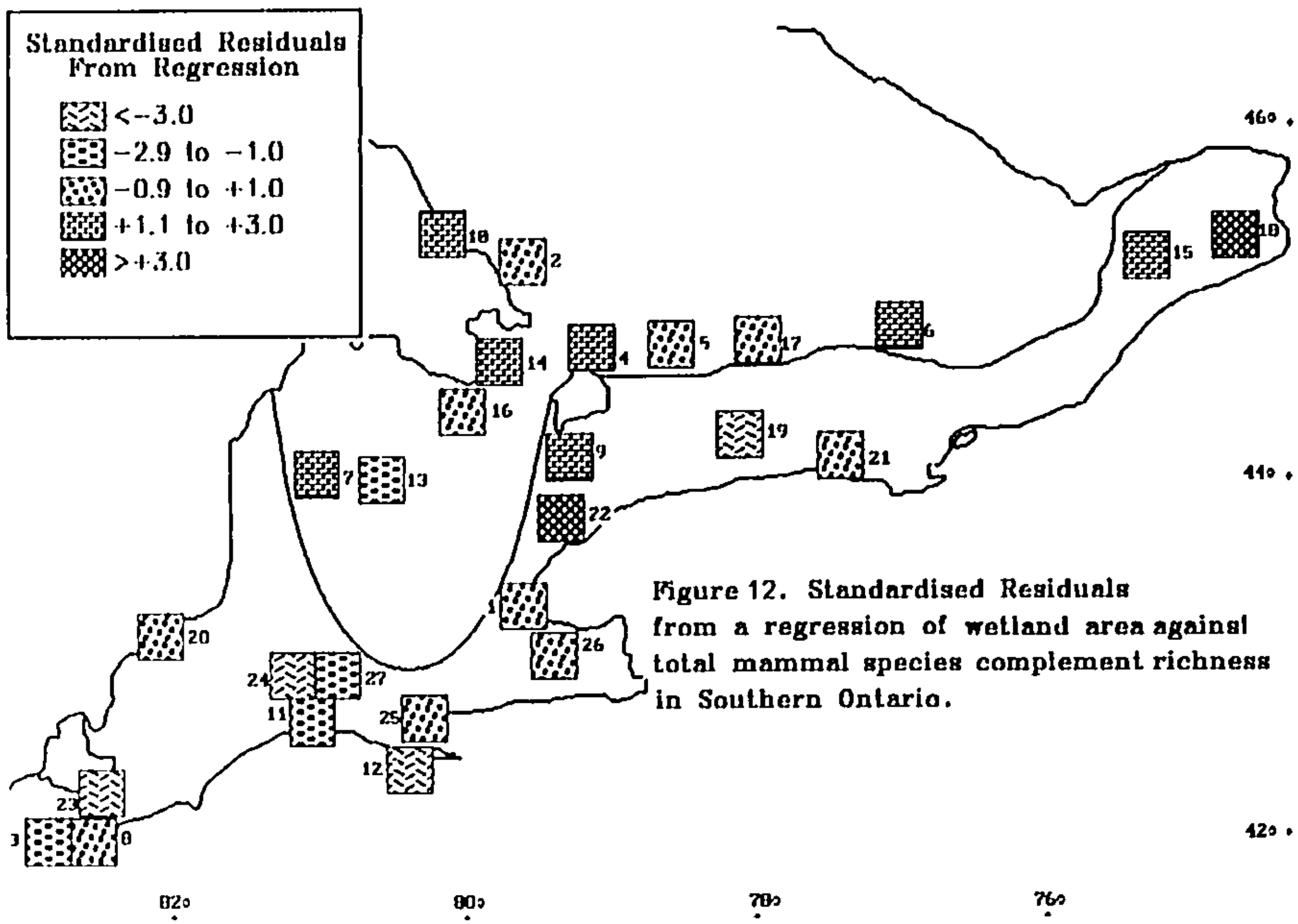



Figure 12. Standardised Residuals from a regression of wetland area against total mammal species complement richness in Southern Ontario.

residuals. This may be due to the fact that development in this area is much less than that in the more southwestern part of the study area. As a result of less development, wetlands in this part of the Eastern Temperate region may be able to support a greater number of mammals than wetlands in the extreme southwestern part of the Eastern Temperate region.

A similar distribution of residuals is evident when the wetland specific residuals are mapped (Figure 10). Negative residuals tend to cluster in the extreme southwest, and a cluster of positive residuals are found in the extreme east. Again, the degree of development suggests itself as the cause of this distribution. High agricultural and urban development in the southwestern and central parts of the Eastern Temperate area may result in lowered species richness in this region. Development in the extreme east may be less intensive, allowing greater richness of wetland specific mammals than in the southwest. The wetlands of the Low Boreal region are less clustered. Development in the Low Boreal region is not as uniform as in the Eastern Temperate region. The residuals suggest that wetlands in this area respond to local development conditions, but do not indicate a uniform set of condition which influences species richness throughout the Low Boreal Region.
Non-wetland specific species were not found to have regional differences between Low Boreal and Eastern Temperate regions. However, the pattern of mapped residuals

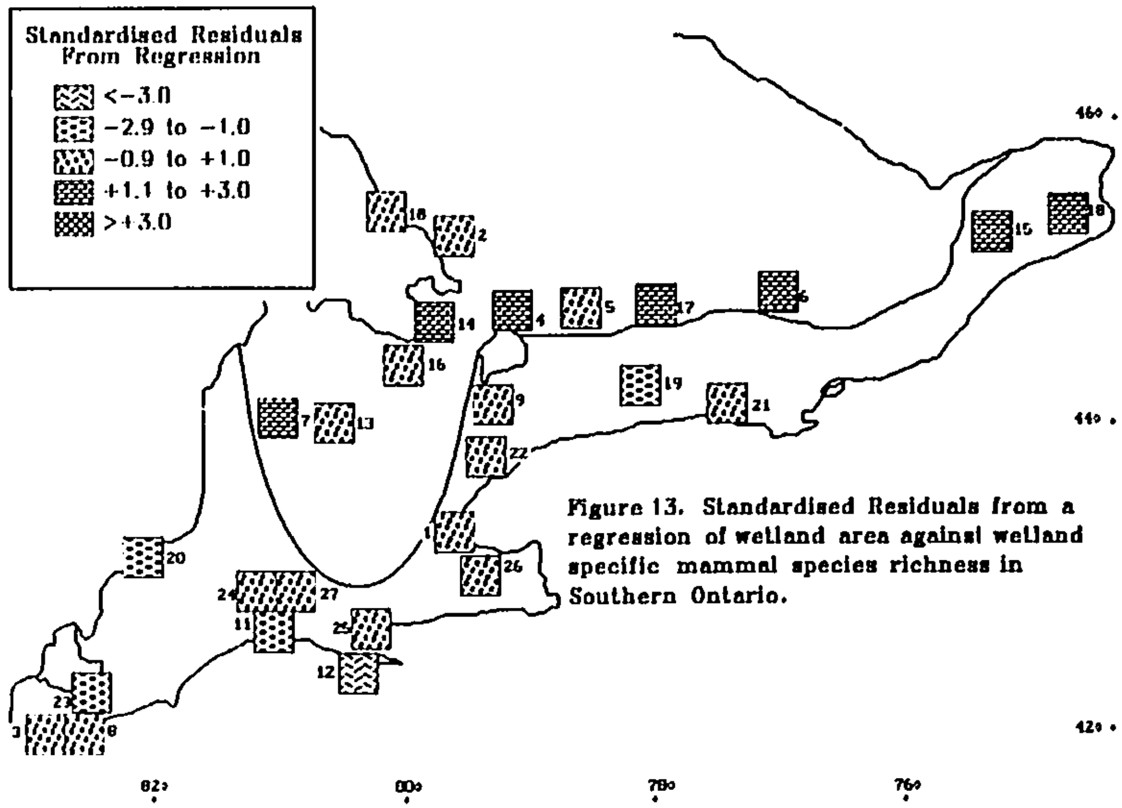



Figure 13. Standardised Residuals from a regression of wetland area against wetland specific mammal species richness in Southern Ontario.

suggest differences in the responses of wetland specific and non-wetland specific mammals to adjacent development (Figure 11). Non-wetland specific species have positive and negative residuals fairly evenly distributed across the entire area. In neither the Low Boreal nor the Eastern Temperate region does there seem to be a pattern in the distribution of the residuals. Regardless of whether a wetland is located near urban or agricultural areas, species richness may be either positive or negative. This suggests that non-wetland specific species are not influenced by development in the same way as wetland specific species. Non-wetland specific species may be more adaptable to a variety of environmental characteristics, a trait which allows them to survive in both disturbed and undisturbed areas. For this reason, the distribution of non-wetland specific mammal species richness does not reflect the varying degrees of development found in the study area.

## 5.9 Influences of Matrix Composition

The residual analyses indicate that there is a regional difference in species richness, in that Low Boreal wetlands have, in general, greater species richness than Eastern Temperate wetlands. The residuals also suggest that this difference may be a result of differing degrees of development in the Low Boreal and Eastern Temperate regions. In order to determine if the type of development surrounding the wetland is indeed the main cause of this regional

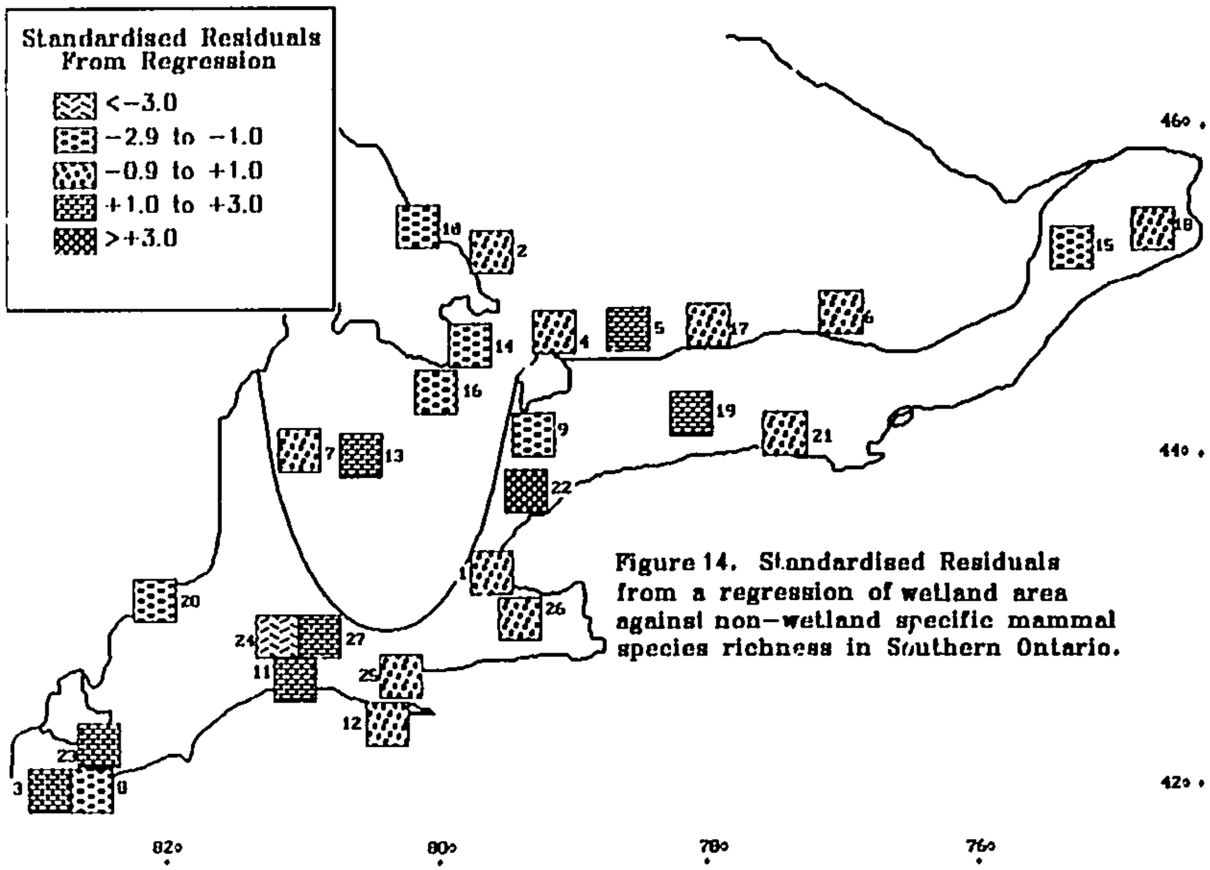



Figure 14. Standardised Residuals from a regression of wetland area against non-wetland specific mammal species richness in Southern Ontario.

difference, the matrix variable was broken down into its three components of agriculture, forest and meadow, and built areas, to see how the composition of the matrix affects species diversity. In this way, the veracity of the residual analysis could be determined.

From the raw data, the percentage of the surrounding matrix in forest and meadow, agricultural use, and built areas was determined for each wetland. These three variables were regressed against total species richness, non-wetland specific species richness, and wetland specific species richness, to determine the relative importance of matrix composition on species richness. Table 9 shows the results for the total species complement. The results show that only one variable, proportion of built areas, significantly influences total species diversity. The relationship is negative, however. Thus, for the entire wetland mammal species complement, matrices which have a high degree of human activity result in wetland fragments with reduced species richness. While the percentage of the matrix in agricultural use and forest were not found to be significant variables, the results do show their relative importance. In this case, the proportion of the matrix in agriculture is more important in influencing species richness than the proportion of the matrix in forest.

For wetland specific mammals, both the proportion of the matrix in built areas, and in agricultural development were found to be significant (Table 10). The proportion of

Table 9

Total Species Complement Multiple
Regression Analysis: Matrix Variables

| Independent Variable | Standardized Regression Coefficient | t | Significant | Proportion Explained Variation (per cent) |
|---|---|---|---|---|
| Forest | -0.20 | 0.99 | no | 0.10 |
| Built | -0.43 | 2.48 | yes | 1.10 |
| Agriculture | 0.30 | 1.58 | no | 0.87 |
| Total Regression | R= 0.14<br>$R^2$= 0.02<br>F= 2.17 | | no | 2.02 |

The least significant value of $t_{(0.05)}$ is 2.07.
The least significant value of $F_{(0.05)}$ is 3.03.
R= Correlation Coefficient
$R^2$= Coefficient of Determination(total explained variation)

Table 10

Wetland Specific Species Multiple
Regression Analysis: Matrix Variables

| Independent Variable | Standardized Regression Coefficient | t | Significant | Proportion Explained Variation (per cent) |
|---|---|---|---|---|
| Forest | -0.20 | 0.94 | no | 0.40 |
| Built | -0.21 | 2.87 | yes | 2.01 |
| Agriculture | 0.25 | 2.89 | yes | 2.41 |
| Total Regression | R= 0.69<br>$R^2$= 0.48<br>F= 1.02 | | no | 4.82 |

The least significant value of $t_{(0.01)}$ is 2.07.
The least significant value of $F_{(0.01)}$ is 3.03.
R= Correlation Coefficient
$R^2$= Coefficient of Determination (total explained variation)

matrix in forest was not found to exert any significant influence on species richness. For wetland specific species, matrices which have a high proportion of built areas usually result in lowered species richness. However, a high degree of agricultural development usually results in a greater species richness. It seems that great expanses of built areas limit wetland species, in terms of habitat and movement among wetlands, with the result of lower species richness than wetlands with less surrounding human development. Hydrological, climatic, and vegetational alterations to the local environment associated with development may create an environment hostile to wetland specific mammals. Agriculture, however, seems to provide wetland mammals with the means to increase species richness. Perhaps the variety of land uses which constitute agricultural development provides wetland mammals with additional habitat or food, or acts as a buffer between the wetland and the detrimental effects associated with other forms of human development.

For non-wetland specific species, none of the matrix components exerts a significant influence on the species richness (Table 11). The presence of built areas, agriculture, or forest in the matrix do not significantly affect the richness of non-wetland specific species.

The results of the matrix analyses are consistent with those of the previous residual analyses, which suggested that species richness is greater in areas with less

Table 11

Non-Wetland Specific Species Multiple Regression Analysis: Matrix Variables

| Independent Variable | Standardized Regression Coefficient | t | Significant | Proportion Explained Variation (per cent) |
|---|---|---|---|---|
| Forest | 0.05 | 0.68 | no | 0.15 |
| Built | -0.06 | 1.01 | no | 0.31 |
| Agriculture | -0.05 | -0.74 | no | 0.08 |
| Total Regression | R= 0.0735<br>$R^2$= 0.0054<br>F= 1.0246 | | no | 0.54 |

The least significant value of $t_{(0.01)}$ is 2.07.
The least significant value of $F_{(0.01)}$ is 3.03.
R= Correlation Coefficient
$R^2$= Coefficient of Determination(total explained variation)

development, and lower in areas of greater development. Analysis of the matrix composition suggests that species richness is impaired by the presence of built areas in the matrix, but enhanced for wetland specific species by the presence of agricultural areas. Forested areas exert almost no influence on species richness.

The negative effect of a matrix with a high proportion of built areas on species richness would seem to be due to the major environmental changes which invariably follow human development. Alterations to hydrology, vegetation, water quantity and quality, and even microclimate variations associated with human development reduce available habitat and food, and also reduce the ability for wetland mammals to interact with other wetlands or natural ecosystems. The greater the degree of matrix development, the more hostile the matrix becomes, both to the mammals within the wetland, and to those from other wetlands.

The enhancement of wetland specific species richness resulting from the presence of agricultural areas in the surrounding matrix may be due to additional habitat created in these areas for a number of mammal species. For species which easily adapt to a number of habitat types, agricultural areas within a matrix may provide a variety of additional habitats and sources of food. Matthiae and Stearns (1981) found that mammal species diversity was often higher in forest fragments in the transition area between urban land use and agriculture, due to the habitat and foraging opportunities located there.

Surprisingly, the percentage of forest in the surrounding matrix was not found to be a significant variable for any of the three analyses, and in fact, exerts a negative influence on species richness. Rather than causing a greater degree of species richness in the wetland, a matrix with a high proportion of forest reduces the species richness of the wetland. This phenomenon may be due to differences in the topography of the matrix associated with the presence of forested areas. In general, forests locate on drier uplands, so a matrix with a high proportion of forested areas may limit the suitable additional habitat available to wetland specific species. While more adaptable species may thrive in agricultural or forested matrices, wetland specific mammals may be limited by the presence of dry forested uplands.

For both the total mammals species complement and wetland specific mammals, latitudinal variations in species richness appear to be due to the greater degree of development in the Eastern Temperate region. Matrices with high proportions of built environments tend to reduce species richness; hence, Eastern Temperate wetlands, located in their region of heavy development, generally have lower species richness than Low Boreal wetlands. Non-wetland specific mammals, however, appear to be more adaptable to human land uses, as there is no significant difference in species richness between wetlands in the highly developed Eastern Temperate region, and wetlands in the less developed Low Boreal Region.

It is evident that management must reflect the needs of the specific mammal complement of a wetland. Whether the conservation goal be to preserve maximum total species diversity, or to preserve a certain segment of wetland or non-wetland specific species, wetlands should be assessed individually, to determine the management strategy most suited to that wetland's particular species composition.

### 5.10 Summary

The analyses identify several factors important to determining mammal richness in southern Ontario wetlands. The most profound influences are area and the diversity of the surrounding matrix. Wetland mammals are additionally affected by topographic diversity and interaction. Analysis of residuals indicates that wetlands in the more densely populated and ecologically modified Eastern Temperate wetland region generally have lower species diversity than wetlands in the Low Boreal wetland region, due to the greater degree of human development in the southern part of Ontario.

# CHAPTER VI

## Conclusions and Recommendations

### 6.1 Introduction

Analysis of the effects of wetland characteristics on mammal species diversity indicates that species richness is highly dependent on the character of the wetland, and the surrounding environment. Consideration of the rate of decline of Ontario wetlands, coupled with the intensive development of southern Ontario suggests that in some areas of Southern Ontario, mammal species richness may be at risk. The relationship between wetlands and their surrounding environments must be considered in the development of a wetland management plan, in order to check the deterioration of remaining wetlands and preserve biotic diversity, while allowing development to continue.

The analyses indicate some difference among the insular effects on the total mammal complement of a wetland, the non-wetland specific mammals, and the wetland specific mammals. These differences should be addressed in wetland management to ensure preservation of maximum species richness.

### 6.2 Area

The area of the wetland is the single most important factor contributing to the species richness of a wetland for the total species complement, for non-wetland specific species, and for wetland species only. Conflicting legislation and negative perceptions towards wetlands contribute to the continuing destruction of wetlands. For instance, the Drainage Act encourages the installation of drains on and around farm wetlands, while Ontario Wetland Policies strive to protect wetlands by limiting development and disturbance on wetlands (Ontario Wetland Policies, 1985). Legislation which limits development in and around wetlands equally addresses the importance of maximum wetland area to species diversity, and human development needs.

## 6.3 Diversity of Surrounding Matrix

The more diverse the area surrounding the wetland, the greater the variety of mammal species which will be found in the wetland, due to the matrix's role as additional habitat for species within the wetland (Mathiae and Stearns, 1981).

A fragment which is surrounded by a diversity of habitats which are suitable for the species found in the wetland experiences an increase in its effective area, buffering the wetland from nearby development, and reducing the minimum size of the fragment necessary to maintain the ecosystem processes. Because many wetland mammal species require a variety of habitats throughout their lifecycle, wetland management should address the importance of maintaining a diversity of habitats in the matrix surrounding a wetland.

Matrix diversity should not be considered without considering the composition of the matrix. Analysis of the composition of the matrix indicates that a matrix with a high proportion of built environments experiences reduced species richness, while matrices which are high in agricultural land uses result in greater wetland specific mammal richness. Matrices should be provided with a diversity of appropriate habitat types, while avoiding land uses which impair species richness. The varying responses of wetland mammals to their matrix should be addressed in any management plan, in order to provide the greatest amount of protection for the greatest number of species, while considering the special needs of rare or extremely habitat specific species.

## 6.4 Interaction with Neighbouring Wetlands

The degree of interaction between wetlands depends upon the distance between wetland islands and the composition of the area between wetlands. This study indicates that wetland mammals are more diverse in wetlands which are joined by a corridor of similar habitat, such as a creek or river, where interaction is greater. Because, in southern Ontario, there is not a large, stable source of species from which to maintain immigration, each habitat island must act as both recipient and source of species for other fragments (Harris, 1982). A travel corridor facilitates this dual role, allowing continual movement of species between islands. Diversity of a region can be maximized by increasing the interaction among islands through maintenance of corridors (Rudis and Ek, 1981).

## 6.5 Topographic Diversity

Topographic diversity affects the species diversity of wetland specific mammals. Wetlands which show little variation in topography generally have greater richness of mammal species. Even small topographic variations in a wetland may sufficiently alter the habitat to limit the survival of wetland mammal species. Human activities such as dredging, draining or filling which cause significant changes to a wetland's topography should be limited, to prevent loss of habitat for wetland species.

## 6.6 Recommendations

The purpose of this study was to answer three questions: does species diversity vary with wetland characteristics; does the response of species richness differ among the total wetland mammal complement, non-wetland specific species, and wetland specific species; and does species diversity differ between the Eastern Temperate Wetland Region and the Low Boreal Wetland Region. It was felt that by answering these questions, useful information for the future management of southern Ontario wetlands may be produced. While the study did answer these questions, it also brought to the fore a number of additional questions. In future studies, these questions may also be answered, providing further insight into the relationship between wetlands and mammal species diversity.

The study indicated that species diversity does vary with certain wetland characteristics. Area is the main influence, while matrix diversity, topographic diversity and interaction are also important characteristics. While these characteristics accounted for much of the variance, unknown characteristics exert their influence on species diversity. Future studies should attempt to identify these factors so that their effects may be accounted for in wetland management.

While the study identifies area, matrix diversity and interaction as important influences on species diversity, it does not identify critical values for these variables. Knowledge of the minimum area a wetland should be to maintain maximum species diversity would prove useful in the creation and maintenance of wetland preserves. Because area alone does not determine species diversity, critical distances for interaction, and critical areas of surrounding matrices should also be determined. Future study of mammal species diversity should be designed to determine these critical values.

This study's goal was also to determine if a difference exists between the species diversity for the total mammal complement, non-wetland specific species and wetland specific mammals. The findings indicate that area and matrix diversity influence the richness of the total mammal complement, while richness of wetland specific mammals is influenced by area, matrix diversity, topographic diversity and interaction. Non-wetland specific species richness is influenced by area only. These differences in response indicate that the factors which determine species richness differ, depending upon the habitat needs of the mammals. Such variation may be an important consideration in the management of wetland reserves. Wetlands may be managed to maintain maximum species diversity, or to protect endangered species, of which many are wetland specific species. In order to properly achieve such management goals, knowledge of the differing responses of the total mammal complement, of non-wetland specific species, and of wetland specific species to wetland and environmental characteristics is necessary. This study suggests that the response is different; future studies should determine the precise factors which influence the species diversity of both the total mammal complement and wetland specific mammals so that the resulting information may assist in the management of wetland areas.

The third question to be answered by this study was whether species diversity of wetlands varies between the Eastern Temperate Wetland Region and the Low Boreal Wetland Region. The results of the residual analyses indicate that contrary to what is expected, the wetlands of the Low Boreal region generally have greater mammal species diversity than wetlands of the Eastern Temperate Region. For all species, this phenomenon may be due to the greater degree of development, and major ecosystem alterations found in the Eastern Temperate Region. Further study should be implemented to determine exactly how the two regions differ to result in this unusual pattern of species richness. Analysis may include measures of air and water quality, differences in water table levels, and population levels and distribution. By understanding the differences between these two regions, management may differ in the Eastern Temperate Region to prevent additional species diversity impairment, and may also use the information to prevent future species diversity losses in the Low Boreal Region, in areas slated for future development.

Chapter III outlined three effects of habitat insularization: sample effect, short-term island effects, and long-term island effects. At different time scales, each of these island effects results in a reduction of species in response to a reduction in fragment area and habitat. The results of the study indicate that island effects may be occurring in southern Ontario wetlands, in that reduction in wetland area, matrix diversity and interaction result in extinctions and reduced species diversity over time. While this study does not specifically test for these phenomena, the results may be interpreted as an indication of their presence. Future study may be designed to identify and measure these effects, through the use of a longitudinal study. The information obtained from such study may be useful in further understanding the effects of habitat loss on wetland mammals.

### 6.7 Wetland Management Strategy

The need to develop a wetland management strategy for southern Ontario is obvious. While protection is given to significant wetlands through existing legislation, a comprehensive land management plan which recognizes the relationship between wetlands, urban development, agriculture, and other ecosystems does not exist. A province wide system should be developed which assesses the value of wetlands to the system, and which recognizes the need to manage land uses outside of wetlands, as these land uses contribute to the wetlands system as well (Powell, 1981).

Most natural reserves, unless very large, cannot survive without active management, to preserve the factors for which the reserve was created. The effects of human activity on large reserves can be absorbed to a greater degree than for small reserves. A fully functioning ecosystem is often not completely contained within a fragment and is vulnerable to the effects of external factors such that intensive management is required to maintain the system.

This study indicates that species richness is greatest in a landscape of large reserves, with diverse matrices, connected to neighbouring reserves of the same habitat type.

In Ontario, wetland fragments should be managed to maintain biotic diversity within each fragment while ensuring that the fragments function within the region in an integrated landscape system (Harris, 1984). The ideal management plan may include conservation of large, significant wetland preserves, provision of adjacent diverse habitat and travel corridors, and to provide for re-invasion by species which have locally disappeared, but exist elsewhere in the region.

The main management objective of the wetland system is to preserve maximum species diversity. The logical outcome of this strategy is to preserve sites with the highest diversity. However, this does not address the needs of endemic, rare, or threatened species in the region, which may only occur in specific sites. A strategy which only addresses species diversity may not address the needs of species with unique features and special needs. For this reason, site selection should include both areas of high diversity, and areas with special features (Harris, 1984). In this way, not only is biodiversity addressed, but the needs of endangered species, a large genetic pool is provided, and both known and unknown processes of the wetland are included and preserved in the system. Because this system recognizes the need to consider both the needs of the individual wetlands with the needs of unique species, the potential contribution to the entire wetland system are addressed.

This study has outlined the principal features of southern Ontario wetlands, the challenges to their continued existence and the factors which contribute to the mammal species diversity. While limited only to mammals it is hoped that the findings indicate a direction to follow for all wetland taxa. Little work exists relating to wetlands and their biodiversity with respect to the area around them. Future studies may build upon the findings presented here to determine specific protection strategies which recognize the relationship between wetlands and their surrounding environment, with the goal of halting the current wetland losses and providing habitat for all species now and in the future.

# Appendix A

## Transparent Grid Overlay Method for Measuring Wetland Area

A transparent grid is placed over the region whose area is to be determined. The number of squares which the wetland completely or partially fills is counted. Using the known scale of the map, and the known size of the squares, the area of the wetland is calculated.

scale of map 1:50 000
length of square 0.5 cm

if 1 cm on the map equals 50 000 cm on the ground,
0.5 cm on the map equals $\frac{(0.5 \times 50\,000)}{1} = 25\,000$ cm $= 0.25$ km on the ground.

Therefore, the area within one square is:

$$0.25 \text{ km} \times 0.25 \text{ km} = 0.0625 \text{ km}^2.$$

If the wetland on the map encompasses 7 squares, the area of the wetland is:

$$7 \times 0.625 \text{ km}^2 = 0.4375 \text{ km}^2 = 43.75 \text{ hectares}.$$

Appendix B

## Wetland Data

NB. Species names in lowercase type are non-wetland specific species; species names in UPPERCASE type are wetland specific species.

........................................................

### Beverly Swamp

| | |
|---|---|
| location | 43° 22′ 80° 22′ |
| area (ha) | 1301.00 |
| topographic diversity | 0.17 |
| matrix diversity | 2.04 |
| forest & meadow (%) | 22.25 |
| agriculture (%) | 67.54 |
| built areas (%) | 10.21 |
| interaction | 180.60 |
| disturbance | 0.09 |
| all mammal species | 19.00 |
| wetland mammal species | 5.00 |
| non-wetland mammal species | 14.00 |

#### Species List

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
MINK
mole, hairy-tailed
mouse, deer
mouse, woodland jumping
MUSKRAT
opossum, virginia
raccoon
SHREW, MASKED
SHREW, SMOKY
skunk, striped
squirrel, northern flying
squirrel, red

**Big Chute**

| | |
|---|---|
| location | 44° 53′ 79° 40′ |
| area (ha) | 62.30 |
| topographic diversity | 0.00 |
| matrix diversity | 2.12 |
| forest & meadow (%) | 84.03 |
| agriculture (%) | 0.00 |
| built areas (%) | 15.97 |
| interaction | 17.85 |
| disturbance | 0.18 |
| all mammal species | 16.00 |
| wetland mammal species | 6.00 |
| non-wetland mammal species | 10.00 |

**Species List**

BEAVER
chipmunk, eastern
deer, white-tailed
hare, snowshoe
mole, hairy-tailed
MOLE, STAR-NOSED
mouse, meadow jumping
mouse, white-footed
porcupine
shrew, common
SHREW, MASKED
SHREW, SMOKY
SHREW, WATER
squirrel, northern flying
squirrel, red
WEASEL, SHORT-TAILED

**Cedar Creek**

| | |
|---|---|
| location | 42° 01′ 82° 49′ |
| area (ha) | 268.75 |
| topographic diversity | 0.45 |
| matrix diversity | 2.94 |
| forest & meadow (%) | 26.53 |
| agriculture (%) | 54.08 |
| built areas (%) | 19.39 |
| interaction | 0.00 |
| disturbance | 0.25 |
| all mammal species | 14.00 |
| wetland mammal species | 1.00 |
| non-wetland mammal species | 13.00 |

**Species List**

chipmunk, eastern
cottontail, eastern
deer, white-tailed
fox, red
groundhog
mouse, meadow jumping
mouse, white-footed
mole, eastern
MUSKRAT
raccoon
shrew, short-tailed
skunk, striped
squirrel, grey
vole, meadow

**Dalrymple Lake**

| | |
|---|---|
| location | $44^{o}$ 38′ $79^{o}$ 07′ |
| area (ha) | 2287.50 |
| topographic diversity | 0.54 |
| matrix diversity | 1.91 |
| forest & meadow (%) | 79.25 |
| agriculture (%) | 18.72 |
| built areas (%) | 2.03 |
| interaction | 215.51 |
| disturbance | 0.03 |
| all mammal species | 24.00 |
| wetland mammal species | 8.00 |
| non-wetland mammal species | 16.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
marten
MINK
MOLE, STAR-NOSED
mouse, deer
mouse, white-footed
mouse, woodland jumping
MUSKRAT
OTTER, RIVER
porcupine
raccoon
shrew, pygmy
shrew, short-tailed
SHREW, SMOKY
skunk, striped
VOLE, RED-BACKED
weasel, long-tailed
WEASEL, SHORT-TAILED

**Emily Creek**

| | |
|---|---|
| location | 44° 30′ 78° 37′ |
| area (ha) | 1562.00 |
| topographic diversity | 0.19 |
| matrix diversity | 1.36 |
| forest & meadow (%) | 10.05 |
| agriculture (%) | 85.08 |
| built areas (%) | 4.87 |
| interaction | 601.27 |
| disturbance | 0.03 |
| all mammal species | 19.00 |
| wetland mammal species | 6.00 |
| non-wetland mammal species | 13.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
fox, red
groundhog
MINK
MOLE, STAR-NOSED
mouse, deer
mouse, white-footed
MUSKRAT
porcupine
raccoon
SHREW, MASKED
SHREW, SMOKY
squirrel, northern flying
squirrel, grey
squirrel, red
skunk, striped

**Frontenac**

| | |
|---|---|
| location | 44° 32′ 76° 30′ |
| area (ha) | 515.00 |
| topographic diversity | 0.53 |
| matrix diversity | 1.11 |
| forest & meadow (%) | 98.25 |
| agriculture (%) | 0.00 |
| built areas (%) | 1.75 |
| interaction | 151.41 |
| disturbance | 0.01 |
| all mammal species | 19.00 |
| wetland mammal species | 6.00 |
| non-wetland mammal species | 13.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
MINK
MOLE, STAR-NOSED
mouse, white-footed
mouse, woodland jumping
MUSKRAT
porcupine
raccoon
SHREW, MASKED
skunk, striped
squirrel, grey
squirrel, red
WEASEL, SHORT-TAILED

**Greenock Swamp**

| | |
|---|---|
| location | 44° 09′ 81° 22′ |
| area (ha) | 7176.86 |
| topographic diversity | 0.03 |
| matrix diversity | 1.72 |
| forest & meadow (%) | 21.00 |
| agriculture (%) | 73.98 |
| built areas (%) | 5.02 |
| interaction | 938.37 |
| disturbance | 0.05 |
| all mammal species | 39.00 |
| wetland mammal species | 10.00 |
| non-wetland mammal species | 29.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, grey
fox, red
groundhog
hare, european
hare, snowshoe
LEMMING, SOUTHERN BOG
MINK
MOLE, STAR-NOSED
mouse, deer
mouse, house
mouse, meadow jumping
mouse, white-footed
mouse, woodland jumping
MUSKRAT
opossum, virginia
OTTER, RIVER
porcupine
raccoon
rat, norway
shrew, common
shrew, hairy-tailed
SHREW, MASKED
shrew, pygmy
shrew, short-tailed
SHREW, SMOKY
SHREW, WATER
skunk, striped
squirrel, grey
squirrel, northern flying
squirrel, red
squirrel, southern flying
vole, meadow
weasel, long-tailed
WEASEL, SHORT-TAILED

**Hillman Marsh**

| | |
|---|---|
| location | $42^{o}$ 05′ $82^{o}$ 45′ |
| area (ha) | 337.50 |
| topographic diversity | 0.00 |
| matrix diversity | 1.40 |
| forest & meadow (%) | 5.20 |
| agriculture (%) | 83.84 |
| built areas (%) | 10.96 |
| interaction | 0.00 |
| disturbance | 0.13 |
| all mammal species | 17.00 |
| wetland mammal species | 4.00 |
| non-wetland mammal species | 13.00 |

**Species List**

cottontail, eastern
deer, white-tailed
fox, red
groundhog
MINK
mole, eastern
mouse, deer
mouse, meadow jumping
mouse, white-footed
MUSKRAT
raccoon
SHREW, MASKED
SHREW, SMOKY
skunk, striped
squirrel, grey
squirrel, red
vole, woodland

**Holland Marsh**

| | |
|---|---|
| location | 44° 08′ 79° 33′ |
| area (ha) | 2350.50 |
| topographic diversity | 0.00 |
| matrix diversity | 2.61 |
| forest & meadow (%) | 9.36 |
| agriculture (%) | 83.94 |
| built areas (%) | 6.70 |
| interaction | 6.43 |
| disturbance | 0.10 |
| all mammal species | 24.00 |
| wetland mammal species | 6.00 |
| non-wetland mammal species | 18.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
deer, white-tailed
fox, red
groundhog
MINK
MOLE, STAR-NOSED
mouse, deer
mouse, meadow jumping
mouse, white-footed
mouse, woodland jumping
MUSKRAT
raccoon
shrew, common
shrew, hairy-tailed
shrew, pygmy
SHREW, SMOKY
skunk, striped
squirrel, northern flying
squirrel, southern flying
vole, meadow
weasel, long-tailed
WEASEL, SHORT-TAILED

**Killbear**

| | |
|---|---|
| location | 45° 21′ 80° 11′ |
| area (ha) | 125.00 |
| topographic diversity | 0.39 |
| matrix diversity | 1.14 |
| forest & meadow (%) | 93.48 |
| agriculture (%) | 0.00 |
| built areas (%) | 6.52 |
| interaction | 25.89 |
| disturbance | 0.06 |
| all mammal species | 17.00 |
| wetland mammal species | 4.00 |
| non-wetland mammal species | 13.00 |

**Species List**

BEAVER
chipmunk, eastern
deer, white-tailed
ERMINE
fisher
fox, red
groundhog
marten
mole, hairy-tailed
MOLE, STAR-NOSED
moose
mouse, deer
mouse, meadow jumping
porcupine
raccoon
SHREW, WATER
squirrel, southern flying

**Lake Whittaker**

| | |
|---|---|
| location | 42° 48′ 81° 03′ |
| area (ha) | 123.00 |
| topographic diversity | 0.59 |
| matrix diversity | 1.48 |
| forest & meadow (%) | 9.99 |
| agriculture (%) | 81.34 |
| built areas (%) | 8.67 |
| interaction | 14.96 |
| disturbance | 0.12 |
| all mammal species | 13.00 |
| wetland mammal species | 3.00 |
| non-wetland mammal specie | 10.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
deer, white-tailed
fox, red
groundhog
MOLE, STAR-NOSED
mouse, deer
mouse, white-footed
MUSKRAT
opossum, virginia
raccoon
squirrel, grey

**Long Point**

| | |
|---|---|
| location | $42^{o}$ 45′ $80^{o}$ 05′ |
| area (ha) | 7250.00 |
| topographic diversity | 0.39 |
| matrix diversity | 1.54 |
| forest & meadow (%) | 81.61 |
| agriculture (%) | 18.00 |
| built areas (%) | 0.39 |
| interaction | 0.00 |
| disturbance | 0.02 |
| all mammal species | 35.00 |
| wetland mammal species | 5.00 |
| non-wetland mammal species | 30.00 |

**Species List**

chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, grey
fox, red
groundhog
hare, european
marten
mole, hairy tailed
mole, hairy-tailed
MOLE, STAR-NOSED
mouse, deer
mouse, house
mouse, meadow jumping
mouse, white-footed
mouse, woodland jumping
MUSKRAT
opossum, virginia
raccoon
rat, norway
shrew, common
shrew, least
SHREW, MASKED
shrew, pygmy
shrew, short-tailed
SHREW, SMOKY
skunk, striped
squirrel, grey
squirrel, northern flying
squirrel, red
squirrel, southern flying
vole, meadow
VOLE, SOUTHERN RED-BACKED
weasel, long-tailed

**Luther Marsh**

| | |
|---|---|
| location | 43° 57′ 80° 26′ |
| area (ha) | 4993.25 |
| topographic diversity | 0.08 |
| matrix diversity | 1.76 |
| forest & meadow (%) | 16.30 |
| agriculture (%) | 74.38 |
| built areas (%) | 9.32 |
| interaction | 295.32 |
| disturbance | 0.09 |
| all mammal species | 28.00 |
| wetland mammal species | 8.00 |
| non-wetland mammal species | 20.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
hare, snowshoe
LEMMING, SOUTHERN BOG
MINK
MOLE, STAR-NOSED
mouse, deer
mouse, house
mouse, meadow jumping
mouse, white-footed
MUSKRAT
raccoon
shrew, common
SHREW, MASKED
shrew, pygmy
shrew, short-tailed
SHREW, SMOKY
skunk, striped
squirrel, southern flying
vole, meadow
VOLE, SOUTHERN RED-BACKED
vole, woodland
weasel,long-tailed

**Matchedash Bay**

| | |
|---|---|
| location | $44^{o}$ 44′ $79^{o}$ 40′ |
| area (ha) | 807.40 |
| topographic diversity | 0.00 |
| matrix diversity | 3.39 |
| forest & meadow (%) | 55.91 |
| agriculture (%) | 27.67 |
| built areas (%) | 16.42 |
| interaction | 304.42 |
| disturbance | 0.04 |
| all mammal species | 20.00 |
| wetland mammal species | 6.00 |
| non-wetland mammal species | 14.00 |

**Species List**

BEAVER
chipmunk, eastern
coyote
deer, white-tailed
fox, red
groundhog
hare, snowshoe
MINK
mouse, woodland jumping
MUSKRAT
porcupine
raccoon
SHREW, SMOKY
SHREW, MASKED
skunk, striped
squirrel, grey
squirrel, red
vole, meadow
WEASEL, SHORT-TAILED

**Mer Bleue Bog**

| | |
|---|---|
| location | 45° 24′ 75° 30′ |
| area (ha) | 2268.00 |
| topographic diversity | 0.01 |
| matrix diversity | 2.98 |
| forest & meadow (%) | 29.55 |
| agriculture (%) | 54.42 |
| built areas (%) | 16.03 |
| interaction | 6.61 |
| disturbance | 0.01 |
| all mammal species | 25.00 |
| wetland mammal species | 7.00 |
| non-wetland mammal species | 18.00 |

**Species List**

BEAVER
bobcat
chipmunk, eastern
coyote
deer, white-tailed
ERMINE
fox, red
groundhog
hare, snowshoe
mole, hairy-tailed
MOLE, STAR-NOSED
mouse, deer
mouse, meadow jumping
mouse, white-footed
MUSKRAT
NUTRIA
porcupine
raccoon
SHREW, MASKED
shrew, short tailed
SHREW,WATER
skunk, striped
squirrel, grey
squirrel, red
vole, meadow

**Minesing Swamp**

| | |
|---|---|
| location | 44° 23′ 79° 51′ |
| area (ha) | 5493.75 |
| topographic diversity | 0.16 |
| matrix diversity | 1.50 |
| forest & meadow (%) | 2.69 |
| agriculture (%) | 78.75 |
| built areas (%) | 18.56 |
| interaction | 292.94 |
| disturbance | 0.04 |
| all mammal species | 33.00 |
| wetland mammal species | 7.00 |
| non-wetland mammal species | 26.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
hare, european
hare, snowshoe
marten
MINK
mole, hairy-tailed
MOLE, STAR-NOSED
mouse, deer
mouse, house
mouse, meadow jumping
mouse, white-footed
MUSKRAT
porcupine
raccoon
rat, norway
shrew, common
shrew, pygmy
shrew, short-tailed
SHREW, SMOKY
skunk, striped
squirrel, grey
squirrel, northern flying
squirrel, red
vole, meadow
VOLE, SOUTHERN RED-BACKED
weasel, long-tailed
WEASEL, SHORT-TAILED

**Murray Marsh**

| | |
|---|---|
| location | 44° 13′ 77° 45′ |
| area (ha) | 4383.50 |
| topographic diversity | 0.43 |
| matrix diversity | 3.80 |
| forest & meadow (%) | 52.68 |
| agriculture (%) | 38.55 |
| built areas (%) | 8.77 |
| interaction | 309.48 |
| disturbance | 0.01 |
| all mammal species | 30.00 |
| wetland mammal species | 9.00 |
| non-wetland mammal species | 21.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
hare, european
LEMMING, SOUTHERN BOG
MINK
MOLE, STAR-NOSED
mouse, deer
mouse, meadow jumping
mouse, white-footed
mouse, woodland jumping
MUSKRAT
OTTER, RIVER
porcupine
raccoon
shrew, common
shrew, pygmy
SHREW, MASKED
SHREW, SMOKY
skunk, striped
squirrel, grey
squirrel, red
squirrel, southern flying
vole, meadow
weasel, long-tailed
WEASEL, SHORT-TAILED

**Osgoode Swamp**

| | |
|---|---|
| location | $45^{o}$ 28′ $75^{o}$ 10′ |
| area (ha) | 894.00 |
| topographic diversity | 0.00 |
| matrix diversity | 3.11 |
| forest & meadow (%) | 51.93 |
| agriculture (%) | 41.90 |
| built areas (%) | 6.17 |
| interaction | 95.53 |
| disturbance | 0.12 |
| all mammal species | 21.00 |
| wetland mammal species | 7.00 |
| non-wetland mammal species | 14.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
fox, red
groundhog
hare, snowshoe
MINK
MOLE, STAR-NOSED
mouse, meadow jumping
mouse, white-footed
mouse, woodland jumping
MUSKRAT
porcupine
raccoon
SHREW, MASKED
SHREW, SMOKY
skunk, striped
squirrel, red
VOLE, SOUTHERN RED-BACKED

**Peter's Woods**

| | |
|---|---|
| location | 44° 08′ 78° 02′ |
| area (ha) | 4.50 |
| topographic diversity | 0.35 |
| matrix diversity | 1.64 |
| forest & meadow (%) | 73.75 |
| agriculture (%) | 26.25 |
| built areas (%) | 0.00 |
| interaction | 0.34 |
| disturbance | 0.00 |
| all mammal species | 11.00 |
| wetland mammal species | 2.00 |
| non-wetland mammal species | 9.00 |

**Species List**

chipmunk, eastern
deer, white-tailed
groundhog
hare, snowshoe
mouse, meadow jumping
MOLE, STAR-NOSED
raccoon
squirrel, red
shrew, common
vole, meadow
WEASEL, SHORT-TAILED

**Port Franks**

| | |
|---|---|
| location | 43° 13′ 81° 54′ |
| area (ha) | 675.00 |
| topographic diversity | 1.06 |
| matrix diversity | 2.99 |
| forest & meadow (%) | 30.37 |
| agriculture (%) | 51.05 |
| built areas (%) | 18.58 |
| interaction | 0.00 |
| disturbance | 0.24 |
| all mammal species | 17.00 |
| wetland mammal species | 2.00 |
| non-wetland mammal species | 15.00 |

**Species List**

chipmunk, eastern
cottontail, eastern
deer, white-tailed
fox, red
groundhog
MOLE, STAR-NOSED
mouse, deer
mouse, meadow jumping
mouse, white-footed
MUSKRAT
raccoon
shrew, common
shrew, short-tailed
skunk, striped
squirrel, grey
squirrel, northern flying
vole, meadow

**Sawguin Creek**

| | |
|---|---|
| location | 44° 07′ 77° 20′ |
| area (ha) | 5575.00 |
| topographic diversity | 0.45 |
| matrix diversity | 3.58 |
| forest & meadow (%) | 47.58 |
| agriculture (%) | 38.84 |
| built areas (%) | 13.58 |
| interaction | 0.00 |
| disturbance | 0.01 |
| | |
| all mammal species | 33.00 |
| wetland mammal species | 8.00 |
| non-wetland mammal species | 25.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
marten
MINK
mole, hairy-tailed
mole, hairy-tailed
MOLE, STAR-NOSED
mouse, house
mouse, meadow jumping
mouse, white-footed
mouse, woodland jumping
mouse,deer
MUSKRAT
OTTER, RIVER
porcupine
raccoon
shrew, common
SHREW, MASKED
shrew, pygmy
shrew, short-tailed
SHREW, SMOKY
skunk, striped
squirrel, grey
squirrel, northern flying
squirrel, red
vole, meadow
weasel, long tailed
WEASEL, SHORT-TAILED

**Second Marsh**

| | |
|---|---|
| location | 43° 52′ 78° 49′ |
| area (ha) | 112.50 |
| topographic diversity | 0.00 |
| matrix diversity | 3.37 |
| forest & meadow (%) | 72.17 |
| agriculture (%) | 0.00 |
| built areas (%) | 27.83 |
| interaction | 0.00 |
| disturbance | 0.07 |
| all mammal species | 20.00 |
| wetland mammal species | 5.00 |
| non-wetland mammal species | 15.00 |

**Species List**

BEAVER
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
mole, hairy-tailed
MOLE, STAR-NOSED
mouse, deer
mouse, meadow jumping
mouse, white-footed
MUSKRAT
NUTRIA
porcupine
raccoon
SHREW, MASKED
skunk, striped
squirrel, grey
squirrel, red
vole, meadow

**Sifton Bog**

| | |
|---|---|
| location | 42° 55′ 81° 15′ |
| area (ha) | 39.75 |
| topographic diversity | 0.49 |
| matrix diversity | 2.39 |
| forest & meadow (%) | 26.10 |
| agriculture (%) | 0.00 |
| built areas (%) | 73.90 |
| interaction | 0.00 |
| disturbance | 0.06 |
| all mammal species | 11.00 |
| wetland mammal species | 4.00 |
| non-wetland mammal species | 7.00 |

**Species List**

chipmunk, eastern
cottontail, eastern
groundhog
LEMMING, SOUTHERN BOG
MUSKRAT
raccoon
SHREW, MASKED
shrew, short-tailed
SHREW, SMOKY
skunk, striped
squirrel, grey

**Sinclair's Pond**

| | |
|---|---|
| location | $42^{o}$ 19' $82^{o}$ 25' |
| area (ha) | 0.40 |
| topographic diversity | 0.00 |
| matrix diversity | 0.00 |
| forest & meadow (%) | 90.38 |
| agriculture (%) | 5.77 |
| built areas (%) | 3.85 |
| interaction | 0.00 |
| disturbance | 0.00 |
| all mammal species | 11.00 |
| wetland mammal species | 2.00 |
| non-wetland mammal species | 9.00 |

**Species List**

cottontail, eastern
deer, white-tailed
fox, red
groundhog
MOLE, STAR-NOSED
mouse, white-footed
raccoon
SHREW, MASKED
shrew, short-tailed
squirrel, grey
vole, meadow

**Turkey Point**

| | |
|---|---|
| location | 42° 40′ 80° 22′ |
| area (ha) | 529.50 |
| topographic diversity | 0.00 |
| matrix diversity | 4.17 |
| forest & meadow (%) | 22.93 |
| agriculture (%) | 39.26 |
| built areas (%) | 37.81 |
| interaction | 0.00 |
| disturbance | 0.14 |
| all mammal species | 17.00 |
| wetland mammal species | 4.00 |
| non-wetland mammal species | 13.00 |

**Species List**

chipmunk, eastern
cottontail, eastern
deer, white-tailed
fox, red
groundhog
MINK
mouse, meadow jumping
mouse, white-footed
MUSKRAT
raccoon
shrew, least
SHREW, MASKED
shrew, pygmy
SHREW, SMOKY
skunk, striped
squirrel, southern flying
weasel, long-tailed

**Wainfleet Marsh**

| | |
|---|---|
| location | $42^{\circ}$ 55′ $79^{\circ}$ 18′ |
| area (ha) | 1006.00 |
| topographic diversity | 0.00 |
| matrix diversity | 2.31 |
| forest & meadow (%) | 24.36 |
| agriculture (%) | 62.83 |
| built areas (%) | 12.81 |
| interaction | 0.00 |
| disturbance | 0.36 |
| all mammal species | 18.00 |
| wetland mammal species | 5.00 |
| non-wetland mammal species | 13.00 |

**Species List**

BEAVER
chipmunk, eastern
cottontail, eastern
coyote
deer, white-tailed
fox, red
groundhog
hare, snowshoe
LEMMING, SOUTHERN BOG
MINK
MOLE, STAR-NOSED
MUSKRAT
opossum, virginia
porcupine
raccoon
shrew, pygmy
skunk, striped
vole, meadow

**Westminster Ponds**

| | |
|---|---|
| location | 42° 54′ 81° 12′ |
| area (ha) | 207.00 |
| topographic diversity | 0.15 |
| matrix diversity | 2.52 |
| forest & meadow (%) | 13.62 |
| agriculture (%) | 0.00 |
| built areas (%) | 86.38 |
| interaction | 4.14 |
| disturbance | 0.11 |
| all mammal species | 14.00 |
| wetland mammal species | 4.00 |
| non-wetland mammal species | 10.00 |

**Species List**

chipmunk, eastern
cottontail, eastern
fox, red
groundhog
MOLE, STAR-NOSED
mouse, deer
mouse, white-footed
MUSKRAT
raccoon
SHREW, MASKED
shrew, short-tailed
SHREW, SMOKY
skunk, striped
squirrel, grey

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