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A Comparison of Created and Natural Wetlands and the Effect of Landscape Characteristics on Vegetation, Amphibian and Bird Variables in Freshwater Marshes of Upstate New York

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and
the Effect of Landscape Characteristics on Vegetation, Amphibian and Bird Variables in Freshwater Marshes of Upstate New York

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David Porter

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ABSTRACT

Wetlands provide a number of ecological and social functions, including flood abatement, improvement of water quality, recharge ground water and support for a great diversity of flora and fauna. Despite their many functions and values, wetlands have not always been appreciated. Since the 1780s, it is estimated that 53% of wetland acreage in the United States has been lost due to draining, filling and the subsequent development of land for roads or farms.

In 1972, the Clean Water Act (CWA) was established to try to reverse declining wetland acreage in the U.S. According to Section 404 of the CWA, any loss of wetland acreage due to development or other means must be compensated in the form of mitigation wetlands. Mitigation wetlands are created wetlands built to replace both wetland acreage and function. The success of mitigation wetlands is varied, and there are questions as to our ability to replace lost wetland functions.

In 2000 and 2001, I surveyed plants, amphibians and birds at nine created and nine natural wetlands and calculated a series of twelve response variables. I used the Wilcoxon paired sample test to look for differences among created and natural wetlands.

I found no significant differences between created and natural wetlands for any of the response variables.

Wetlands are important components of the landscape and their functions are influenced by their position within the landscape and the watershed. Many wetland animals require and depend on surrounding terrestrial land for foraging, migration, breeding, cover and hibernation. If we are to create wetlands that are ecologically similar

to natural wetlands, then we must view and understand them from a larger, landscape perspective.

Since I found no significant differences among created and natural wetlands, I combined the wetlands into a larger set of 18. GIS software was used to map each wetland and its surrounding land, and calculate a set of landscape-level predictor variables. I used simple linear regression and best subset multiple regression analyses to look for predictor variables that might account for the variation found in amphibian, bird and plant response variables.

I found positive significant relationships between open water classification and plant, amphibian and bird species richness in both years. In addition, open water class was positively associated with bird and amphibian species diversity, and also the number of birds per census in both 2000 and 2001. The only negative significant association with open water class was with the proportion of *T. latifolia*.

Watershed area was a significant positive predictor of amphibian in 2001, and of bird species richness, plant species richness, the number of birds per census and plant species diversity in both years. Wetland area was significant and positively related, in both years, to the number of birds per census and plant species richness.

Invasive plant species richness was significant and positively associated with the length of the road in the watershed in both years, while invasive plant species cover was significant and positively associated with the percentage of urban, commercial and industrial land within 1 km of wetlands.

Plant species richness and diversity were significant and positively associated with bird species richness and bird species diversity in both years, and with the number of birds per census in 2001.

Open water class was part of four of the best subset models in 2000 and five models in 2001. Watershed area was part of seven best subset models in 2000 and five in 2001.

The functions of wetlands are influenced by their position within a landscape. Therefore, the selection of an appropriate site for a mitigated wetland project should consider the surrounding landscape properties. The results of my study suggest that mitigated wetlands should be located 1) in large watersheds, 2) far from roads and urban areas, and near other wetlands. Also, mitigated wetlands should be constructed and maintained in a "hemimarsh" state so that the cover to water ratio is between 1:1 and 1:2, and the establishment and spreading of aggressive plant species such as *T. latifolia* should be controlled to help maintain a high level of structural diversity.

DEDICATION

I dedicate this thesis to the memory of my Mother

Annie L. Porter

(1931 - 1994)

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I am grateful to Dr. Chris Norment of the Department of Environmental Science and Biology at SUNY Brockport for his support, advice and guidance throughout this project. His patience, understanding and assistance in editing my thesis have been paramount in my ability to complete this work. I could not have completed this work without Dr. Norment's help. I am exceedingly thankful.

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A number of the wetlands used in this study were created by the New York State Department of Transportation. Robin Salsbury of the NYS DOT spent a good deal of time and resources helping me to select some of these wetlands for study.

Early in this study, I made a number of phone calls to Fred Dieffenbach of the United States Army Corps of Engineers in Buffalo in trying to select appropriate study sites. I had a chance to meet with Fred in Buffalo to review section 404 permits. I appreciate the time he spent with me as I reviewed possible wetland sites.

My wife Danette and my son Patrick - my family - have been incredibly supportive, untiring and encouraging throughout this project. I am infinitely grateful for their patience and understanding throughout this long journey. Thank you.

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INTRODUCTION

Wetlands are important and complex components of a landscape. They are unique habitats with unique properties, and therefore support vegetation and animals that are not often found in other habitats (Gibbs 1993, Mitsch and Gosselink 2000). Their uniqueness is partly attributable to their location within a landscape. Wetlands are ecotones, found transitionally between terrestrial systems and deep-water aquatic systems, or as isolated patches within an upland matrix (Gibbs 1995, Mitsch and Gosselink 2000).

Wetlands are difficult to define for a number of reasons. There are a great number of wetland types that exist under a variety of hydrologic conditions. Swamps, marshes, prairie potholes, tidal marshes, estuaries and bogs are just a few common names for wetlands that have diverse hydrologic characteristics (Mitsch and Gosselink 2000).

Another difficulty in developing a single definition for wetlands is the objective under which the definition is to be used. There are several scientific and several legal definitions for "wetland," depending upon which political, regulatory or ecological implications are being addressed (Shaw and Fredine 1956, Cowardin et al. 1979, Niering 1991, NRC 1995, Mitsch and Gosselink 2000).

The definition most commonly used, and the one adopted by the U.S. Fish and Wildlife Service, is the one established by Cowardin et al (1979). This definition is the standard used for most wetland inventory and mapping studies in the United States (Dahl 2000, Mitsch and Gosselink 2000).

According to Cowardin;

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water."*

In addition, Cowardin (1979) stated that a wetland must have at least one of the following attributes: 1) at least periodically, the land must support wetland vegetation (hydrophytes), 2) the substrate is composed primarily of hydric soil, and 3) the land is either saturated with water or covered with water for part of the growing season. This definition encompasses the idea that hydrology is the dominant factor in the formation and persistence of wetlands. The presence of water for all or part of the growing season affects the type of soil present (hydric soil), and in turn the soil condition determines the type of vegetation that will be supported (Niering 1991). Cowardin's definition was significant in part because it was one of the first to use the terms hydrophyte and hydric soil (Mitsch and Gosselink 2000).

Wetlands provide a number of both ecological and social functions (McMillan 2000). They help to lessen flood damage by holding and slowly releasing large quantities of water. Wetlands improve water quality by removing sediments and pollutants, recharge groundwater supplies, and help to protect shorelines from erosion. And though they comprise less than 6% of the Earth's surface (Niering 1991), wetlands have a significant effect on the stability of the global climate because they function as carbon sinks, sequestering large quantities of carbon dioxide (Mitsch and Gosselink 2000, NRC 2001). Carbon sequestration by wetlands has become a more recent concern as scientists have gained a better understanding of the effects of certain gasses on global climate change (Bridgham et al. 1995).

Wetlands are also crucial habitats for many species of plants and animals (Dahl 2000) and are some of the most bioproductive ecosystems on earth, maintaining a rich biodiversity that rivals some tropical rain forests (Tiner 1989, Niering 1991, Mitsch and Gosselink 2000). They provide a unique environment, in part due to their transitional placement in the landscape that supports such a diverse array of flora and fauna (Mitsch and Gosselink 2000). In addition, wetlands support a majority of the rare and endangered species of the U.S. (NRC 2001).

Many wetland functions provide direct benefits to humans (i.e. flood control, pollution treatment, recreation), and therefore wetlands possess important societal and economic values. Public awareness and appreciation of wetland economic, social and ecological values have increased recently (Dahl 2000, Conservation Foundation 1988). A survey of 1012 Michigan residents found that most were familiar with wetlands and 60% felt that it was important that these ecosystems be protected (Kaplowitz and Kerr 2003). While residents' community type seemed to have little effect on their perception of wetlands, younger, wealthier, and better-educated residents seemed to have higher regard for wetland preservation.

Wetland functions and values have not always been appreciated by people of the United States. These ecosystems were once considered wastelands, harboring disagreeable creatures, foul smells and disease. They were obstacles to agriculture and travel, and so had little use or economic value (Niering 1991). In the 1700s, Colonel William Byrd is credited with naming the Great Dismal Swamp that straddles the eastern border of Virginia and North Carolina. He described this wetland ecosystem as "a horrible desert" having "foul damps" that "corrupt the air" (Mitsch and Gosselink 2000). Since wetlands were not considered useful or valuable, they were drained, filled or plowed to be "reclaimed," and to make way for farming and roads (Niering 1991).

From the time of the first European settlers up through the 1970s, destruction of wetland acreage was not only accepted, but also encouraged. In 1849, Congress passed the Swamp Land Act which gave away large acreage of wetlands in Louisiana to be reclaimed. This act was later extended to other states in the years following (Niering 1991, Mitsch and Gosselink 2000).

Wetland loss in the United States has occurred at an alarming rate. Dahl (1990) has estimated that when European settlers began arriving in the 1600s, there were 221 million acres (89.5 million ha) of wetlands in the conterminous U.S. Between the 1780s and the mid 1980s, Dahl estimated that 53% of wetland acreage in the U.S. had been lost (1990).

However, the rate of wetland loss in the United States has slowed (Figure 1) due to the implementation of wetland protection measures, increased awareness and education, and wetland restoration and creation programs (Dahl 2000). Between the 1950s and the 1970s, it is estimated that the annual rate of wetland loss was 458, 000 acres (185,400 ha) (Dahl 2000). From the mid 1970s to the mid 1980s, the annual rate of loss was 290, 000 acres (117,400 ha) (Dahl and Johnson 1991), and between 1986 to 1997, the annual rate of loss was 58,500 acres (23,700 ha). Ninety-eight percent of the wetlands lost between 1986 and 1997 were freshwater wetlands (Dahl 2000). As of 1997, Dahl (2000) estimated that there were 105.5 million acres of wetland remaining in the conterminous U.S.

The New York State Department of Environmental Conservation (DEC) estimated that there were 2.4 million acres (0.97 million ha) of wetlands in New York as of the mid 1990s, with most of these acres are in the Lake Plains and Adirondak ecozones. Between the mid 1980s and the mid 1990s there was a net gain of approximately 15,000 acres (6,100 ha) of wetlands, primarily due to the restoration of agricultural lands and changes in hydrology. Most of these gained acres occurred in the Lake Plains ecozone (NYS DEC 2004).

As scientists in the 1970s began to better understand the important functions and values of wetlands, protection and conservation mechanisms were developed through

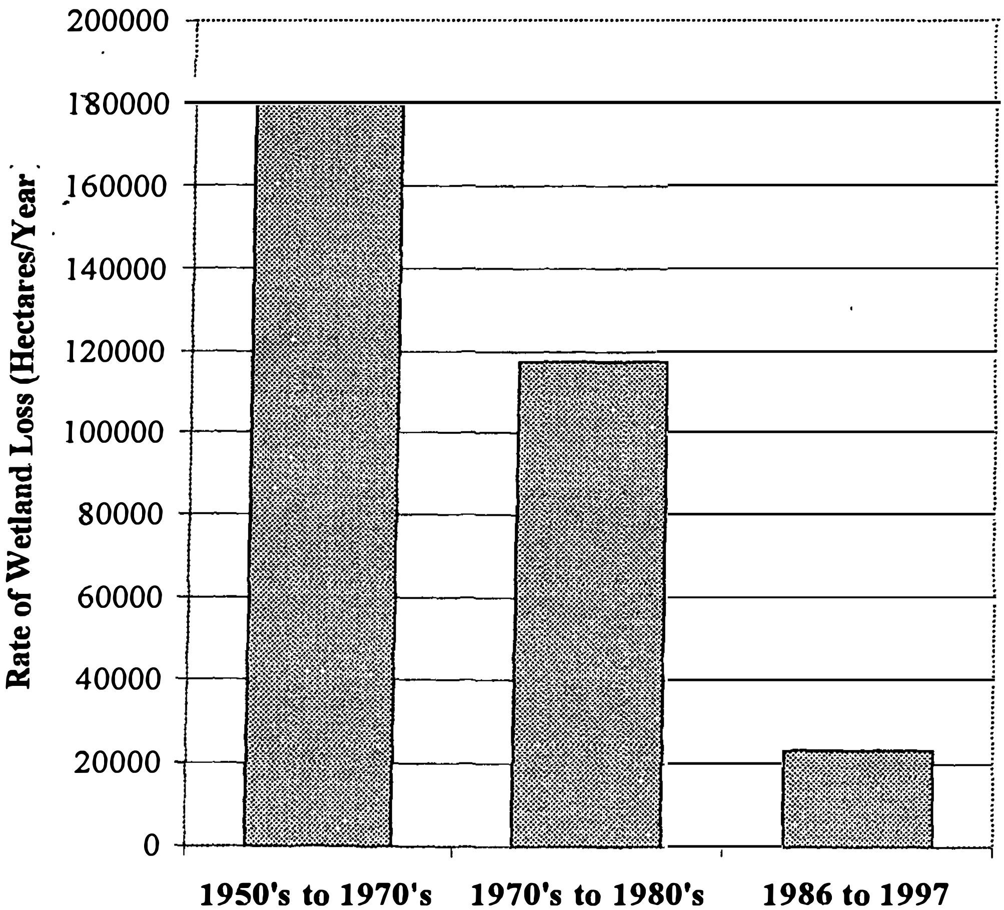

Figure 1: Estimated annual loss rate of wetlands in U.S. for three time periods (Dahl 2000).

Presidential orders, acts of Congress and federal and state policies. Two executive orders issued by President Jimmy Carter in 1977 were important because they began to establish a federal policy regarding wetland protection. While there are a number of policies in place designed to help preserve wetlands, there still does not exist a law aimed specifically at wetland protection (Mitsch and Gosselink 2000).

The Clean Water Act of 1972 (CWA) is the fundamental mechanism for wetland protection and regulation. It's objective is "...to restore and maintain the chemical, physical and biological integrity..." of the navigable waters of the U.S. While wetlands may not always be considered "navigable waters," the objective of the CWA could not be met if wetlands were not protected because they help to improve the water quality of these waters (CWA 1972, NRC 2001). Under Section 404 of the CWA, a permit from the Environmental Protection Agency (EPA) or the United States Army Corps of Engineers (USACE) is required for any dredging or filling of the nation's wetlands. Prior to the issuance of a Section 404 permit, alternatives to wetland impact are investigated. First, attempts are made to avoid any impact to the wetland. If avoidance is not possible, attempts are then made to minimize the impact to the wetland. When significant impact is unavoidable, compensation for the lost wetland is required in the form of mitigation. Mitigation for wetland loss is conducted through restoration or creation of wetland area (CWA 1972, NRC 2001). Mitigation wetlands are those that are built to replace both the loss of wetland acreage and the loss of wetland function. It is generally agreed that to replace the lost function, the mitigated wetland should be the same kind and in the same watershed as the impacted wetland (NRC 2001).

In 1988, the EPA established the National Wetland Policy Forum to investigate wetland management in the U.S. The forum's recommendation was that there should be "no net loss" of the remaining wetlands of the United States, and that efforts should be made to increase the "quality and quantity of the nations' remaining wetland resource base." (NWPF 1988).

The National Resource Council (NRC) established the Committee on Mitigating Wetland Losses to evaluate the mitigation process under Section 404 of the CWA. The committee investigated the success and failure of compensatory mitigation with regard to the "no net loss" policy, and issued their report in 2001 (NRC 2001).

The NRC committee concluded that while the annual rate of wetland loss has decreased over the past 20 years (Dahl 2000), the goal of "no net loss" had not been met. They suggested a number of reasons for failure to meet this goal. Some of these reasons were: 1) insufficient data on the status of compensatory wetlands and the functions lost, 2) mitigation projects that were permitted but not undertaken, and 3) mitigation projects that did not meet the Section 404 requirements (NRC 2001).

In a review of mitigation projects, the NRC committee found that only 70 to 76% of permitted projects in the U.S. were actually implemented, and that 47 to 50% of the implemented mitigation projects failed to meet the requirements stated in the Section 404 permit. In addition, the NRC concluded that comparing ecological functions of mitigated wetlands to similar natural wetlands is not often part of the permit process (NRC 2001).

Erwin (1991), evaluating mitigation projects in Florida, found that approximately 50% of the wetlands had actually been created and that 60% of those that were created had hydrological problems. Wilson and Mitsch (1996) assessed the ecological functions of five mitigated wetlands in Ohio and found that four wetlands (80%) demonstrated "medium to high ecosystem success".

Kentula et al. (1992) investigated Section 404 permits in Oregon and Washington state. They found that in Oregon, 74 ha of wetlands were impacted, but only 42 ha were created (43% net loss). In Washington, 61 ha of wetlands were impacted, but only 45 ha were created (26 % net loss). In a study of 331 mitigation projects in Massachusetts, Brown and Veneman (2001) found that nearly 55% of projects did not meet the requirements of the stringent Massachusetts wetland regulations, and nearly 65% of the created wetlands were smaller than was required. Although 71% of the impacted wetlands were forested wetlands; the wetlands created for mitigation were some other wetland type.

Studies of compensatory mitigation projects suggest that there is a good deal of variation in terms of success (Kusler and Kentula 1990, NRC 2001). However, there are many questions about the success of wetland mitigation. Many mitigation projects have been considered failures because they do not function in the same manner as the natural wetlands they are supposed to replace, and this leads to a number of questions (Erwin 1991, Kentula et al. 1992, Wilson and Mitsch 1996). Can we build a wetland that provides the same value and the same function as a natural one? How do we know if a mitigation wetland is "successful"? What should be measured, and what methodology should be used to evaluate and monitor mitigated wetlands? These are important questions and present a number of challenges, one of which is establishing suitable techniques, procedures and standards that allow for adequate assessment of the complex functions that take place in wetlands (Hunt et al. 1999).

Defining the success of a mitigation project is difficult. The presumption that if wetland vegetation is established and the wetland is "green," or that if the created wetland is physically and hydrologically similar to the impacted wetland, other ecological processes will follow, is not always valid (D'Avanzo 1986, Turner 2000, Campbell et al. 2002). Most scientists agree that mitigation projects should be deemed successful based on detailed studies of wetland functions that include not just hydrology, soils and vegetation, but also wildlife utilization, species diversity and abundance. In addition, these studies should be based on the mitigated wetland's ability to provide the hydrological, biogeochemical and biological functions of the impacted wetland (Brooks and Hughes 1990, Erwin 1990, Kusler and Kentula 1990, Weller 1990, Brooks and Croonquist 1991, Galatowitsch and van der Valk 1994, Kentula 1999, Mitsch and Gosselink 2000). Danielson (1998) suggested that the most direct way to determine the health of a wetland ecosystem is to measure the characteristics of its biological communities first, and then measure its physical and chemical properties.

If the goal of mitigation is to produce a wetland that replaces the functions of the lost wetland, it is important to use reference wetlands. Reference wetlands are sites located within a particular geographical area that are used to assess the functioning (success) of created wetlands. The advantages of using reference wetlands to determine the success of compensatory mitigation projects are: 1) they help to set mitigation goals by establishing reference standards for a particular geographic region, 2) they provide templates for the design of created and restored wetlands, and 3) they supply a benchmark from which declines in functioning can be determined (Brinson and Rheinhardt 1996). The Committee for Mitigating Wetland Loss (NRC 2001) concluded that "Biological dynamics [of mitigated wetlnds] should be evaluated in terms of populations present in reference models for the region and the ecological requirements of those species."

There are a number of methods used to assess wetland function. There is no single functional assessment method consistently used to evaluate mitigated wetlands, and because of the variation in wetland types and their functions, this may not be possible (NRC 2001). Bartoldus (1999), in a review of assessment techniques, recognized 40; however, most of these are designed to assess only a few wetland functions. The Wetland Evaluation Technique (WET) is designed specifically for wetlands and rates a number of wetland functions with a somewhat subjective quality rating (Adamus et al. 1989, Wilcox et al. 1992). Using the Hydrogeomorphic Approach (HGM), wetlands are classed by type and sampling from reference wetlands are used to assess hydrologic, biogeochemical, flora and fauna habitat characteristics. HGM is a significant technique because it can be used at both the landscape and watershed level (Brinson 1993, Brinson and Rheinhardt 1996, Wilcox 2002).

The Index of Biological Integrity (IBI) technique was developed to assess stream conditions using fish populations (Karr et al. 1986). Biological integrity is defined as "...the ability to support and maintain a balanced, integrated adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." (Karr et al. 1986). The success of IBI in stream environments has prompted scientists to try to adapt it for use in wetland assessment (Wilcox et al. 2002).

Ecological equivalency refers to comparisons of ecological function between mitigation sites and reference wetlands. Some of these functions include wildlife habitat, water quality and vegetation support. However, there have been few studies that adequately evaluate and compare ecological functioning between mitigated and natural wetlands (NRC 2001). Brown and Veneman (2001) analyzed 391 mitigation project files from 1983 to 1994 in Massachusetts. The files compared plant communities in replacement wetlands and impacted wetlands. They found that plant communities in the mitigated wetlands were significantly different from the plant communities of the impacted wetlands. The mitigated wetlands had lower plant species richness, less total plant cover and fewer wetland plant species.

Wilson and Mitsch (1996) investigated the success of five mitigated wetlands in Ohio in terms of ecological success. They collected data on hydrology, soils, vegetation, wildlife and water quality. Using the WET method they concluded that 80% of the wetlands demonstrated medium to high ecological success. However, wildlife utilization was determined with observational data gathered during one visit.

Confer and Niering (1992) compared hydrologic, soil, vegetation and wildlife characteristics of five created wetlands to five similar natural wetlands. They used WET to compare functional values at paired sites. They found that there was no significant difference in plant species richness between created and natural wetlands, and that plant diversity was higher at natural sites. Invasive plants species *Phragmites australis* and *Lythrum salicaria* were more abundant at created sites than at natural sites. More species of wildlife were observed at natural sites than at created sites.

Campbell et al. (2002) compared soil characteristics, plant species richness and total plant cover between natural and created wetlands in Pennsylvania. They found that vegetation species richness and total cover were greater in natural wetlands than in created wetlands, and that there was a greater proportion of upland plant species in created wetlands.

Wetlands are important components of a larger landscape, and both abiotic and biotic factors within a wetland interact to affect biodiversity at the landscape level (Gibbons 2003). If we are to successfully create wetlands that are ecologically equivalent to natural wetlands, then they must be viewed from a landscape perspective (Mitsch and Gosselink 2000). A recommendation from the Committee on Mitigating Wetland Losses states: "Site selection for wetland conservation and mitigation should be conducted on a watershed scale in order to maintain wetland diversity, connectivity, and appropriate proportions of upland and wetland systems needed to enhance the long-term stability of the wetland and riparian systems" (NRC 2001). The terrestrial habitat that surrounds a wetland must be part of the mitigation design if the biological and ecological functions of the lost wetland are to be replaced. Unfortunately, created wetland position within the landscape is not usually part of the mitigation standards or design (Bedford and Preston 1988, NRC 2001).

Many species of wetland-dependent organisms also require terrestrial habitat . There are many wetland-dependent species that are characterized by metapopulations, a series of small local populations that are linked by migration and complex source-sink dynamics (Semlitsch 1998, Gibbs 2000, Guerry and Hunder 2002). Amphibians are one example of a group of wetland-dependent animals that often exist as metapopulations, and therefore depend on terrestrial connectivity between aquatic habitats (Gibbs 1993, Semlitsch 2000). In addition to movement, amphibian species require appropriate surrounding terrestrial habitat for foraging and hibernating. Moreover, because most species of amphibians have limited dispersal ranges, the proximity of terrestrial and aquatic habitat is vital (Guerry and Hunter 2002). The significance of the terrestrial area surrounding a wetland has been well documented for a variety reptile and amphibian species (Semlitsch 1986, Burke and Gibbons 1995, Semlitsch 1998, Knutson et al. 1999, Guerry and Hunter 2002).

Knutson et al. (1999) investigated relationships between anuran abundance and species richness, and landscape variables in Iowa and Wisconsin. They found that both anuran abundance and richness were higher when there was high habitat diversity, especially when there were other wetlands and forest habitat nearby. They also found that the effects of agricultural land on amphibian response variables differed among states. In Wisconsin the relationship with agricultural was positive, while in Iowa it was negative. Other studies tended to find negative associations between amphibians and agriculture (Hecnar 1997, Bonin et al. 1997). Knutson et al. also found a negative association between amphibians and urban land use.

Guerry and Hunter (2002) investigated relationships between nine amphibian species with forested area within 1 km of breeding ponds in Maine. They found that for some species there was a positive association with the amount of forest area (*Rana sylvatica*, *Rana clamitans*, *Notophthalmus viridescens*, *Ambystoma maculatum* and *Ambystoma jeffersonianum*), while other species showed a negative association (*Rana pipiens*, *Bufo americanus*). Their findings suggest the importance of species-specific landscape effects.

Richter and Azous (1995), in a study of 19 palustrine wetlands in the Puget Sound Basin, found no significant relationship between amphibian richness and wetland size (size range 0.4 to 12.4 ha). However, wetlands in watersheds in which more than 40% of the land area was urban had significantly lower amphibian richness than those wetlands in watersheds with less urban land use.

Findlay and Houlan (1997) investigated relationships between landscape variables and four different taxa (birds, mammals, plants and herptiles) in 30 wetlands of southeast Ontario. They found significant negative associations between road density within a 2 km radius of the focal wetland and herptile species richness. They found positive relationships between the amount of forested land within 2 km and herptile richness, and a positive relationship between wetland area and richness. The authors concluded that the removal or destruction of forested area and the presence of roads had negative impacts on herptile species richness in wetlands.

There have been few studies that comprehensively compare wildlife utilization of created and natural wetlands. In this study I compared created and natural wetlands in western New York for differences in amphibian, bird and vegetation characteristics. I used paired sample hypothesis testing, meaning that for every created wetland, a similar natural wetland was selected. I selected nine created and nine natural wetlands as study sites in western New York. The created wetlands ranged in age from 2 to 12 years, and so another objective of this study was to investigate differences in amphibian, bird and vegetation variables based on wetland age.

In addition, I used GIS software to investigate the effects of site and landscape-level predictor variables on vegetation, amphibian and bird response variables at each wetland. Some of these predictor variables included wetland and watershed size, proportion of open water at each wetland, and land use properties (residential, agricultural, etc.) of the area surrounding each wetland.

METHODS

Study Sites

In 2000, I selected 18 study sites, all within the Great Lakes Plain ecozone (Andrle and Carroll 1988) of western New York. All 18 wetlands were located in Monroe County, New York. I worked with environmental and landscape engineering firms, the Army Corps of Engineers, the New York Department of Environmental Conservation, and other state and local government agencies to select nine created wetlands. Three criteria were used to select these wetlands. The created wetland had to be; 1) an inland marsh not directly affected by Lake Ontario, 2) created for the mitigation of loss or impact to a natural wetland, and 3) built where no wetland had existed before. The nine created wetlands ranged in age from 3 to 12 years in 2000.

Since this was a paired study, I selected a similar natural, "reference" wetland for each of the created wetlands. I used three criteria in selecting appropriate natural wetlands. Each natural wetland had to: 1) be similar in size to its paired, created wetland; 2) have a similar proportion of open water to emergent vegetation as its paired, created wetland; and 3) be within 10 km of its created, paired wetland, although most were within 5 km of the created wetland. The size of each wetland was initially estimated by visual inspection, and later confirmed using GPS and ArcView GIS software. I estimated the proportion of open water at each wetland visually and classed each wetland based on that estimation (Table 1). Proximity of wetlands in a pair was measured using 7.5' USGS topographical maps and the GIS.

Wetland size was an important factor because of its potential influence on abundance and diversity of wetland-dependent taxa, particularly birds (Brown and Dinsmore 1986, Brown and Smith 1998). The proportion of open water to vegetation at each wetland was important because of its effect on the presence or absence of waterfowl, as well as the influence it may have on amphibian species richness (Strijbosch 1979, Ildos and Ancona 1994, Richter 1997). For example, managers often attempt to maintain shallow wetlands in a "hemimarsh" state, with an approximate 1:1 ratio of open water to emergent vegetation (Payne 1992, Weller 1999). It was also important that paired created and natural wetlands be as close to each other as possible so that the effects of surrounding landscape features were similar. I used USGS topographical maps and the National Wetlands Inventory (USFWS) to select natural wetlands meeting the above criteria, thereby establishing nine created-natural wetland pairs. Table 2 shows the created-natural wetland pairs along with the variables used in their selection.

Wetlands were mapped using a GPS and put into ArcView GIS. ArcView software and 7.5' USGS topographical maps were used to calculate the following landscape level predictor variables: 1) wetland area, 2) watershed area, 3) distance from the center of

Table 1: Percentage of open water categories.

Percentage of Open Water	Class
10%>	1
10% - 25%	2
25% - 50%	3
50% - 75%	4
75% - 90%	5
>90%	6

Table 2: Variables used to select wetland pairs (created and natural). Created wetlands are listed in italics. Open water classifications are described in Table 1. Wetlands marked with an * were not mapped.

Wetland Pairs		Distance between Wetlands (km)	Open Water Classification	Size (ha)
1	*DOT A*	1.01	1	6.69
	Smiths		1	*
2	*DOT B*	6.99	5	17.47
	Golden Road		5	8.48
3	*DOT C*	6.02	4	12.62
	King Road		4	8.95
4	*DOT D*	0.25	2	3.38
	Blodgett		2	1.69
5	*DOT E*	3.35	6	6.80
	Morgenberger		5	3.33
6	*Tinker Created*	2.48	5	0.91
	Thruway		5	1.92
7	*Roxbury Road*	4.41	1	1.00
	Tinker Natural		1	1.74
8	*Spall Homes*	5.27	6	2.17
	Round Pond		5	19.82
9	*Mason Road*	2.82	4	13.05
	Packard Farm		4	*

wetland to nearest road, 4) length of road within a 100 m buffer of the wetland, 5) length of road in the watershed, 6) percentage of agricultural land within 1 km of the wetland, 7) percentage of residential land within 1km of the wetland, 8) percentage of forested land within 1 km of the wetland and 9) percentage of urban, commercial, industrial land within 1 km of the wetland (Table 3). Wetlands Smith and Packard were not mapped and therefore not part of the analysis involving landscape variables.

I also used five plant variables as predictors to explain variation in amphibian and bird variables. The plant predictor variables were 1) plant species richness, 2) species diversity, 3) proportion of *Typha latifolia* to total vegetation cover, 4) invasive plant species diversity, 5) invasive plant species richness and 6) invasive plant species cover.

Vegetation Surveys

In 2000, I established 15 permanent $1m^2$ plots at each wetland. Ten of these plots were along two transects (five plots per transect, 4 m apart) and five plots were located randomly within each wetland. I identified all plant species within each plot and used a $1m^2$ PVC sampling frame to estimate the percent cover of each species. For each wetland, I averaged these values over the 15 plots to obtain cover estimates for each species. I conducted plant surveys at the same plot locations in both 2000 and 2001 and calculated both plant species richness and species diversity (Shannon-Weiner index, $H = - \Sigma p_i (\log p_i)$) for each wetland in each year.

I calculated the proportion of common cattail (*Typha latifolia*) by dividing the cover estimates for *T. latifolia* by the total vegetation cover at each wetland.

Table 3: Summary of response variables used in paired sample tests among created and natural wetlands, and for linear regression and best-subset regression analyses for combined created and natural wetlands. Predictor variables are those used in linear and best-subset analyses. OBL, FACW and FAC are defined in Table 4.

Response Variables

Amphibians	Vegetation	Avifaunal
Amphibian Species Richness	Plant Species Richness	Bird Species Richness
	Plant Species Diversity	Bird Species Diversity
	Invasive Plant Species Diversity	Number of Birds per Census
	Invasive Plant Species Cover	Proportion of OBL+FACW+FAC Birds
	Proportion of *Typha latifolia*	Proportion of OBL+FACW Birds
		Proportion of OBL Birds

Predictor Variables

Landscape		Vegetation
Created Wetland Age (yr 2000)	Length of Road in Watershed (m)	Plant Species Richness
Area of Wetland (m^2)	Length of Road within 100 m Buffer (m)	Plant Species Diversity
Area of Watershed (m^2)	Percent Agricultural Land within 1 km radius	Invasive Plant Species Diversity
Area of Other Wetlands within 500 m (m^2)	Percent of Urban Land within 1 km radius	Invasive Plant Species Cover
Distance to Nearest Road (m)	Percent of Forest Land within 1 km radius	Proportion of *Typha latifolia*
	Percent of Residential Land within 1 km radius	Proportion of *Typha latifolia*
		Proportion of Open Water Class

Many invasive plant species, including *Lythrum salicaria*, *Typha X glauca*, *Myriophyllum spicatum*, *Phalaris arundinacea*, and *Phragmites australis*, have been found in temperate North America wetlands. These taxa are often difficult to remove and may adversely affect the quality of a wetland (Galatowitsch et al. 1999). I calculated invasive plant species cover, richness and diversity at each wetland. I calculated the proportion of invasive plant species cover by dividing the sum of the cover estimates of the invasive species by the total vegetation cover of the wetland. I calculated a species diversity value for invasive plants using the Shannon-Weiner index ($- \sum p_i (\log p_i)$).

Amphibian Surveys

I surveyed calling amphibians using a protocol established by the Long Point Observatory's Marsh Monitoring Program (MMP), a program established for monitoring calling amphibians in wetlands of the Great Lakes Basin (Chabot and Helferty, 1995). The MMP uses a point count survey method, and so at each wetland I established a "station", or a point from which surveys were conducted. During a survey, all calling amphibians identified within an unlimited semicircle radius of this station were recorded. According to the MMP, amphibian survey stations should be at least 500 m apart. Most of the wetlands in this study were small enough so that only one station needed to be established at each site.

I surveyed each wetland two times in 2000 and four times in 2001. The dates of the surveys coincided with the breeding periods of the amphibians found in this area (Figure 2). The MMP protocol calls for only three surveys during the breeding season. In regions between the 43^{rd} and 47^{th} parallels, the first is done between 15 and 30 April, the second between 15 and 30 May and the last between 15 and 30 June. I added an

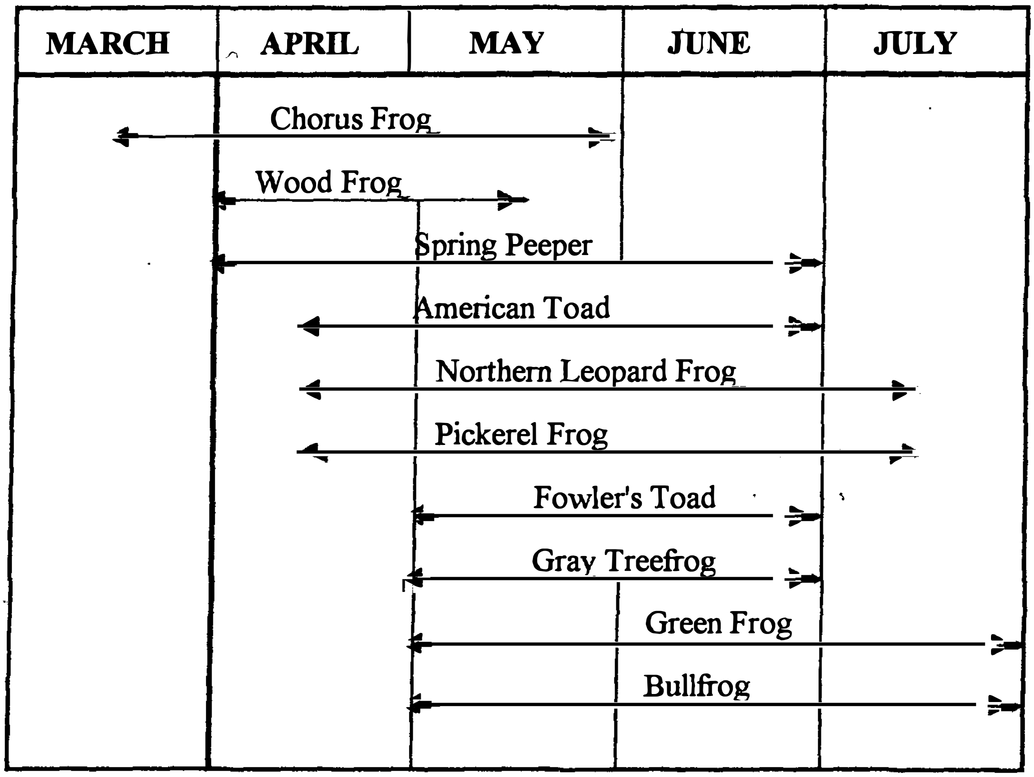

Figure 2: Breeding periods for calling amphibians of the Central Great Lakes Basin (Chabot and Helferty 1995)

additional survey period in early April of 2001 to try to detect the wood frog (*Rana sylvatica*). This study was to begin with a full field season of data in 2000. However, because of delays in finding suitable wetland pairs, just two surveys were conducted in 2000, one in late May and the other in late June.

As per the MMP protocol, I conducted surveys between one half-hour after sunset and midnight on nights when there was little or no wind. Ambient air temperature has an important effect on calling amphibians, and surveys were conducted when temperatures were above 5°C for the first and second survey periods, 10°C for third, and 17°C for the fourth survey period. Each survey was done for 3 min.; during this time the number and species of calling amphibians were recorded. The MMP uses call level codes to determine the number of individuals calling for each species. A call level code of 1 indicates that individuals are easily counted, with little simultaneous calling. Call level code 2 is used when a few individuals of the same species are calling at the same time and a completely accurate count is not possible. Call level code 3 is used when individuals of a species are calling in such numbers, and at once, that an accurate count of individuals is not possible. I was not able to gather accurate abundance data for amphibians because many species call in choruses at levels 2 or 3. Therefore, I compared only species richness among wetlands, and not abundance and diversity values.

Bird Surveys

Birds were surveyed using a protocol adapted from that used by the Marsh Monitoring Program (Chabot and Helferty 1995). I established stations at each wetland and surveyed all birds within the wetland or within a 100 m fixed radius semicircle from this point, depending upon the size of the wetland.

I conducted two surveys in 2000 and four in 2001 between May and July, with surveys separated by at least 10 days. The MMP protocol calls for bird surveys to be done in the evening between 1800 hours and sunset. However, because several of the wetlands selected for this study are along noisy roadways, I conducted surveys between 0.5h and 2h after sunrise, when traffic noise that would make it difficult to conduct surveys was less.

Surveys were done for 10 min and all birds identified by sight or by call within the wetland were recorded. Because many marsh birds are seldom seen or heard, I used a broadcast tape containing the calls of some of these secretive birds to try to invoke a response. Taped calls of the Pied-Billed Grebe (*Podilymbus podiceps*), Least Bittern (*Ixobrychus exilis*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), Common Moorhen (*Gallinula chloropus*), and the American Coot (*Fulica americana*) were played at the end of the 10 min survey for 5 min, and any responses were recorded.

For each wetland, I calculated bird species richness and species diversity. Species diversity was determined using the Shannon-Weiner diversity index. I also classified bird species into five habitat preference groups based on their wetland dependency (Brooks and Croonquist 1990). These classifications are Obligate (OBL), Facultative Wet (FACW), Facultative (FAC), Facultative Dry (FACD) and Upland (UPL) (Table 4). Using this classification scheme, I calculated the proportion of wetland birds (OBL + FACW) and the proportion of obligate wetland birds (OBL) at each wetland by dividing the number of birds in each group (OBL+ FACW and OBL) by the total number of birds. I classified birds into habitat preference groups and calculated data separately for each year.

Table 4: Bird species classifications based on dependence on wetland habitats. (Brooks and Croonquist 1990).

Species Classification	Wetland Dependency	Score
Obligate (OBL)	>99%	5
Facultative Wet (FACW)	67-99%	3
Facultative (FAC)	34-66%	1
Facultative Dry (FACD)	1-33%	0
Upland (UPL)	<1%	0

Analysis of Predictor and Response Variables

Biotic surveys and GIS analyses resulted in a set of predictor and response variables used in subsequent univariate and multivariate statistical analyses (Table 3).

I used the Wilcoxon paired-sample test in all of the paired analyses to detect differences among created and natural wetlands in vegetation, amphibian and avifaunal variables at $\alpha = 0.05$ (Table 3). The Wilcoxon test is a powerful nonparametric test similar to the paired-sample t test, but more appropriate when the data may not be normally distributed (Zar 1999). I conducted analyses on data from each year separately.

In this study, I found no significant differences in response variables between created and natural wetlands (see Results). The absence of a treatment effect meant that I could combine the created and natural wetlands into a larger set of 18 wetlands and search for predictor variables that may account for the variation in amphibian, plant and bird response variables.

Predictor variables were evaluated for normality by generating a probability plot of each using Minitab 14 statistics software and the Anderson-Darling normality test. Those variables that were not from a normal distribution were transformed. Proportional data were transformed with the arcsine transformation and nonproportional data with the logarithmic transformation (Zar 1999).

Univariate Analyses

I used simple linear regression to identify significant relationships between predictor and response variables (Table 3). Analyses were done separately for each year of the study.

Multivariate Analyses

Best subsets regression is a way to determine which set of predictor variables creates the simplest, best-fitting model for a particular response variable. It is a method that can be used to describe models that reach a particular goal with the fewest predictor variables. For example, best-subsets regression analysis might be used to determine which subset of landscape-level predictor variables would explain the highest proportion of variance in the response variable, bird species diversity, in a freshwater wetland (Minitab Inc. 2004). I used Minitab 14 statistics software to run best-subset regressions on predictor and response variables from the set of created plus natural wetlands. Minitab 14 inspects all possible subsets of predictors and creates a set of models starting with the first and second best models (based on R^2 values) containing one predictor, then the first and second best models containing two predictors, and so on. The final model is created using all of the predictor variables.

The Minitab14 output of a best-subset regression displays each model on a different line, and the R^2, adjusted R^2, Mallows C-p value, standard deviation, and the predictor variables used for that particular model. The Mallows C-p value indicates the difference between a fitted regression and a true model. The "p" in the C-p value represents the number of predictor variables used for a particular model. Ideally, the best model would be one in which the C-p value is equal to or less than p + 1 (MTSU 2004).

I chose the best fitting model for each response variable by identifying the model having the highest adjusted R^2 value, the lowest Mallow C-p value and the lowest standard deviation. In cases where two models were very similar in the above values, I chose the model having the fewest predictor variables.

RESULTS

Paired Sample Analysis

Vegetation

Species Richness and Diversity

In both 2000 and 2001, the Wilcoxon paired-sample test showed no significant differences in plant species diversity ($P > 0.500$ in both years) or plant species richness ($P > 0.50$ in 2000, $P = 0.400$ in 2001) between created and natural wetlands (Tables 5 and 6). Average plant species diversity and plant species richness were slightly higher, although not significantly, at natural wetlands than at created wetlands in both years. In 2000, average plant species diversity was 0.4572 for natural wetlands and 0.4428 for created wetlands. In 2001, average plant species diversity was 0.4658 in natural wetlands and 0.4514 in created wetlands. Average plant species richness in 2000 was 10.4 for natural wetlands and 9.9 for created wetlands. In 2001, average species richness in natural wetlands was 10.3 and 9.8 in created wetlands (Tables 5 and 6). The plant species observed in created and natural wetlands in 2000 and 2001 are summarized in Appendix B.

Invasive Plant Species

There were no significant differences in invasive plant species richness or diversity between wetland types in either 2000 or 2001 (Tables 5 and 6). The invasive species *Typha x glauca* was not found in any wetland in either year (Figure 3). Purple loosestrife was present at three natural wetlands (King Road, Golden Road, Thruway) and in only

Table 5: Summary for year 2000 comparing created and natural wetlands using Wilcoxon paired-sample test (n = 9, $\alpha = 0.05$).

	Created Wetlands		Natural Wetlands		
	Mean	SE	Mean	SE	P value
Amphibian					
Species Richness	2.4	0.242	2.2	0.465	0.400
Birds					
Species Richness	7.89	1.220	9.444	1.230	0.350
Species Diversity	0.694	0.074	0.799	0.055	0.150
Number of Birds/Census	15.1	3.000	10.5	2.173	0.225
Proportion of OBL+FACW+FAC Birds	0.83	0.035	0.683	0.090	0.400
Proportion of OBL+FACW Birds	0.665	0.046	0.5621	0.080	> 0.500
Proportion of OBL Birds	0.327	0.066	0.2143	0.048	0.204
Plants					
Species Richness	9.9	1.896	10.4	0.9876	>0.500
Species Diversity	0.443	0.088	0.457	0.0572	>0.500
Invasive Species Diversity	0.095	0.033	0.054	0.0410	0.150
Invasive Species Richness	1.4	0.242	1.0	0.3333	0.300
Relative Proportion of *T. latifolia*	0.5801	0.1115	0.4432	0.0909	0.250

Table 6: Summary for year 2001 comparing created and natural wetlands using Wilcoxon paired-sample test ($n = 9$, $\alpha = 0.05$). Values in parentheses were calculated excluding Canada goose data. Significant differences are shown in bold.

	Created Wetlands		Natural Wetlands		
	Mean	SE	Mean	SE	P value
Amphibian					
Species Richness	4.3	0.471	4.1	0.611	> 0.500
Birds					
Species Richness	10.1	1.6111	10.6	1.1318	> 0.500
Species Diversity	0.7470	0.0843	0.8510	0.0412	0.150
Number of Birds/Census	21.1 (17.2)	4.513 (3.173)	12.4 (12.0)	1.521 (1.370)	0.100 (0.100)
Proportion of OBL+FACW+FAC Birds	0.876	0.0427	0.767	0.0315	0.068 (0.450)
Proportion of OBL+FACW Birds	0.6823	0.0568	0.5283	0.0599	0.200 (0.375)
Proportion of OBL Birds	0.3175	0.0657	0.1711	0.0367	**0.050** (0.250)
Plants					
Species Richness	9.8	1.706	10.3	1.000	0.400
Species Diversity	0.4514	0.0861	0.4658	0.0548	> 0.500
Invasive Species Diversity	0.1043	0.0370	0.0516	0.0410	0.150
Invasive Species Richness	1.4	0.242	1.0	0.3333	0.300
Relative Proportion of *T. latifolia*	0.5810	0.1086	0.4413	0.0900	0.250

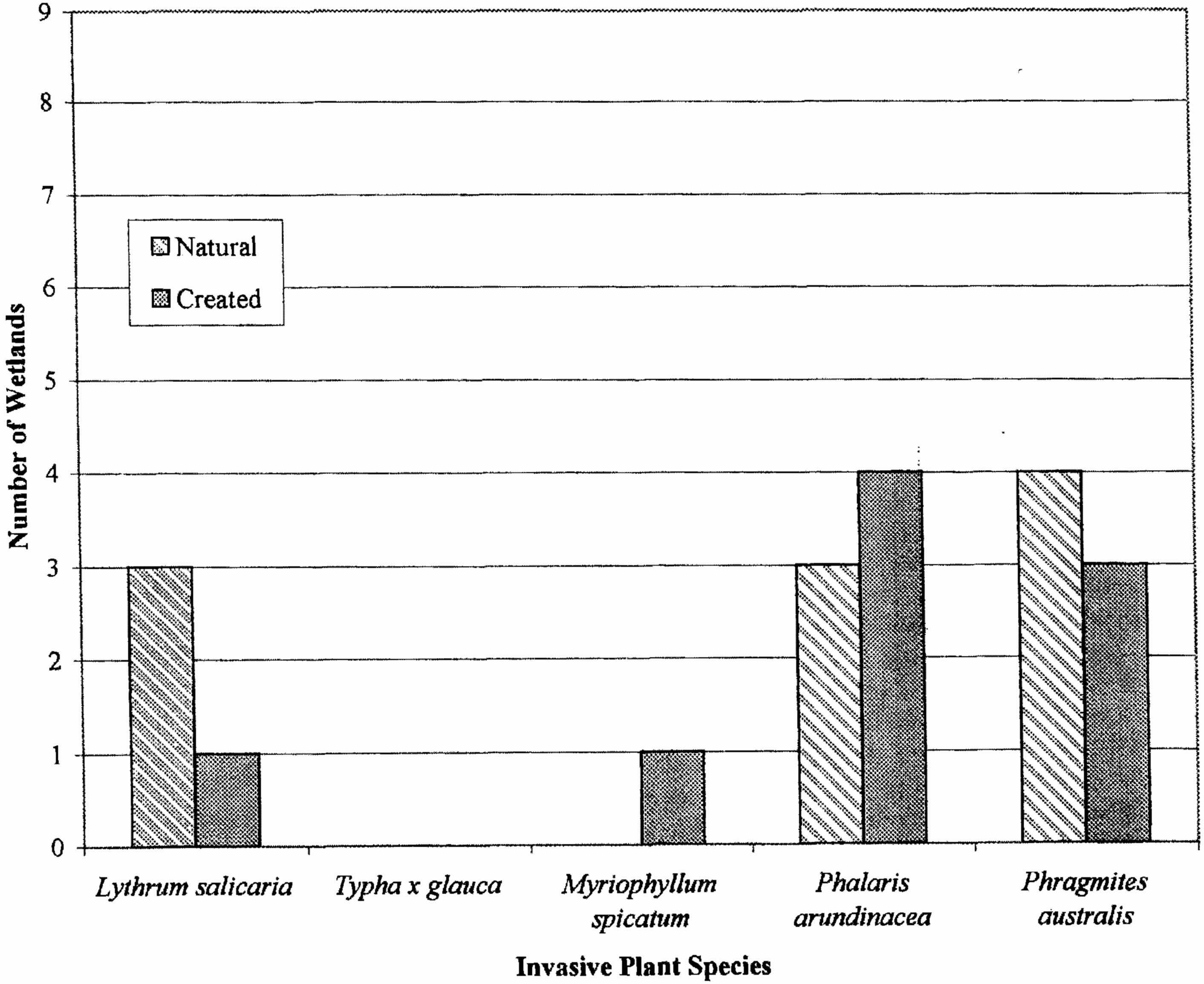

Fig 3. Number of wetlands at which each invasive plant species was found in both 2000 and 2001.

one created wetland (Mason). *Myriophyllum spicatum* was found only in created wetland Tinker Created. *Phalaris arundinacea* was found in four created wetlands (DOT B, DOT C, DOT E and Mason) and in three natural wetlands (Morgenberger, Thruway andPackard). *Phragmites australis* was the dominant plant species at Blodgett and was found in three other natural wetlands (Thruway, Packard and Tinker Natural). *P. australis* was found at three created wetlands (DOT C, DOT D and DOT E).

Proportion of Typha latifolia

There were no significant differences in the proportion of *Typha latifolia* between created and natural wetlands for either year of the study (P = 0.250 for both years) (Tables 5 and 6). *T. latifolia* was found in all wetlands of the study and the mean proportion of *T. latifolia* was higher, though not significantly, in created wetlands (0.5801 in 2000, 0.5810 in 2001) than in natural wetlands (0.4432 in 2000, 0.4413 in 2001).

Amphibians

Species Richness

There were no significant differences in amphibian species richness between natural and created wetlands for either year (P = 0.400 in 2000, P > 0.500 in 2001) (Tables 5 and 6). I found seven species of calling amphibians at both natural and created wetlands (Figure 4). Spring peepers and chorus frogs were found at twice as many natural wetlands as created wetlands, while northern leopard frogs were found at twice as many created wetlands as natural wetlands. Green frogs were found at all nine created wetlands and at seven natural wetlands. Amphibian species observed at created and natural wetlands in

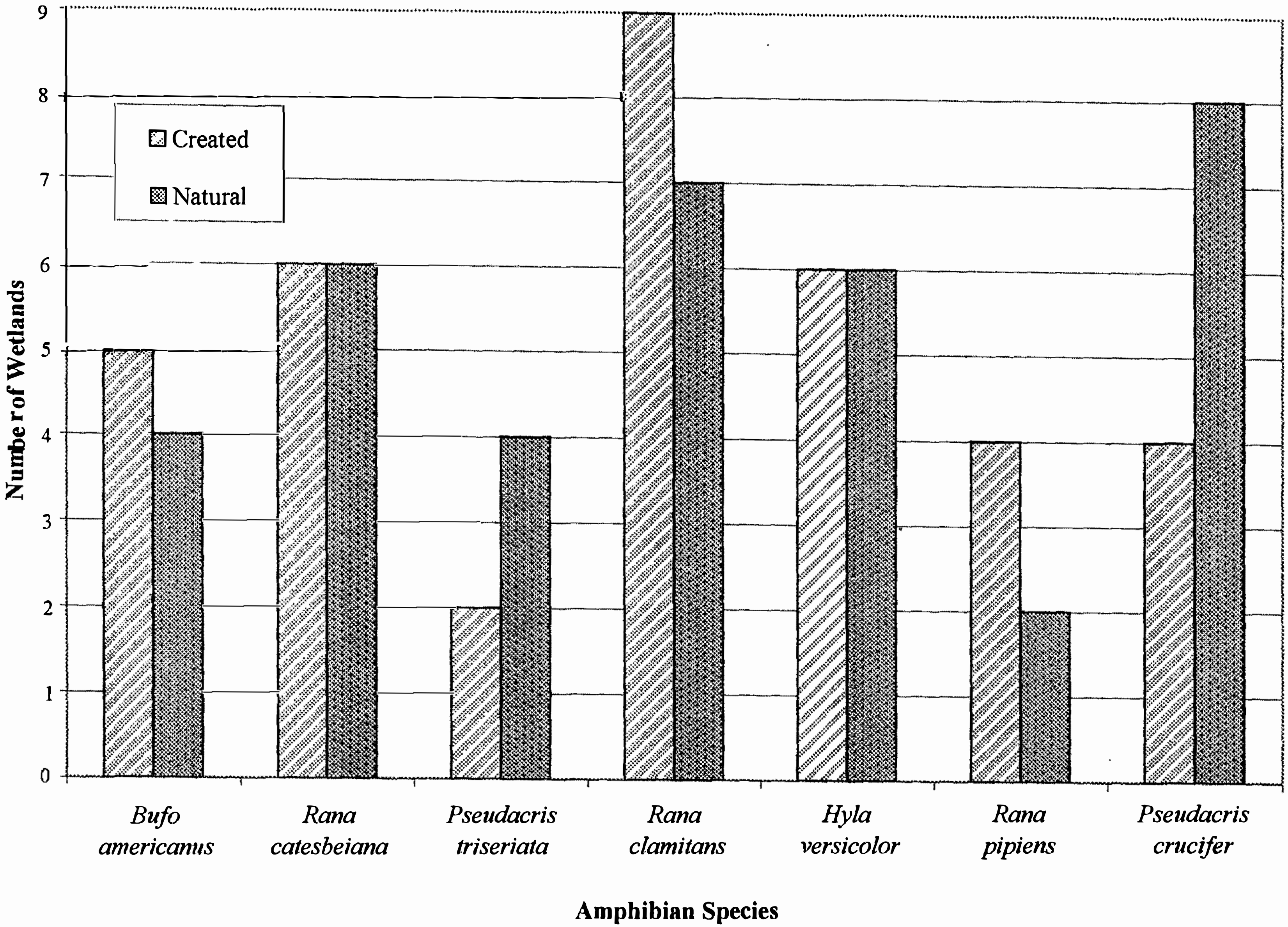

Fig. 4. Number of wetlands at which each amphibian species was found in both 2000 and 2001.

2000 and 2001 are summarized in Appendix D.

Birds

Species Richness and Diversity

In both 2000 and 2001 the Wilcoxon paired-sample test showed no significant differences between wetland types in bird species richness ($P > 0.500$ in 2000, $P = 0.400$ in 2001) or in bird species diversity ($P > 0.500$ in both years). The average species richness was higher, though not statistically significant, in natural wetlands (9.4 in 2000, 10.6 in 2001) than in created wetlands (7.9 in 2000, 10.1 in 2001). Similarly, the average Shannon-Weiner diversity index in natural wetlands (0.7988 in 2000, 0.8510 in 2001) was higher, though not significantly, than in created wetlands (0.6937 in 2000, 0.7470 in 2001) (Tables 5 and 6). The bird species observed at both wetland types in 2000 and 2001 are listed in Appendix C.

Number of Birds per Census

The number of birds per census did not differ significantly between wetland types in 2000 ($P = 0.225$). The number of birds per census was higher in created wetlands in 2001 though it approached statistical significance ($P = 0.100$) (Tables 5 and 6).

In created wetlands, the red-winged blackbird (*Agelaius phoeniceus*) was the most abundant bird species at six of the nine (67%) wetlands in 2000 and at five of nine (56%) wetlands in 2001. In 2000, Canada goose (*Branta canadensis*) was the most abundant species at three of nine (33%) created wetlands, and at two of the nine (22%) created wetlands in 2001. Marsh wrens (*Cistothorus palustris*) were found at just two created wetlands during 2001 (Spall and Mason). Virginia rails were found in both DOT A and Mason for both years of the study, and in Roxbury in 2000.

In natural wetlands, the red-winged blackbird was the most abundant bird species in seven of the nine (78%) wetlands in 2000 and in eight of nine (89%) wetlands in 2001. Marsh wrens were found at three natural wetlands in both 2000 (Smith, Packard, and Golden Road) and 2001 (Smith, Morgenberger, and Mendon), and Virginia rails were found at three natural wetlands in 2000 (Packard, Morgenberger and Tinker Natural) and one in 2001 (Morgenberger).

Canada goose was found in more created wetlands that natural wetlands in both years. In 2000, Canada goose was found in six of nine (67%) created wetlands and just two of nine (22%) natural wetlands. Similarly, in 2001, Canada goose was found in five of nine (56%) created wetlands and three of nine (33%) natural wetlands.

Proportion of Birds based on Wetland Dependency

The only significant difference relating to wetland dependency among created and natural wetlands was the proportion of OBL birds in 2001 ($P = 0.050$). Created wetlands had a significantly higher proportion of OBL birds in 2001 than natural wetlands. Created wetlands also had a higher proportion of OBL + FACW + FAC birds than natural wetlands in 2001, though not significantly ($P = 0.068$) (Table 6).

There were a number of bird surveys in 2001 in which large flocks of Canada goose were present at a few of the study sites. For example, during a survey in July 2001, I recorded 19 Canada goose at both DOT B and Mason. Similarly, during surveys in June 2000, 24 were recorded at DOT C and 40 individuals were found at Spall. I believed that high numbers for this particular species may have skewed the results of the proportion of birds in the various wetland dependency categories. Therefore, I recalculated the 2001 results excluding Canada goose values for all 18 wetlands. With Canada goose excluded, I found no significant differences in the proportion of birds in any of the three classification groupings (OBL+FACW+FAC, OBL+FACW, OBL).

Univariate and Multivariate Analyses, Response versus Predictor Variables

Since there were no significant differences between created and natural wetlands, I combined the two types of wetlands into a larger set of 18 and as an exploratory tool, used simple linear regression to look for significant relationships between predictor and response variables within each year of the study. Tables 7 and 8 summarize the linear regression analyses for the entire set of wetlands.

I then conducted best subset regressions on all of the response variables listed in Table 3 separately for each year. Tables 9 and 10 are summaries of best subset regression analyses for 2000, and Tables 11 and 12 are summaries for 2001

Vegetation

Species Richness and Diversity

Sixty-five plant species were identified in the 18 wetlands over the 2 years of the study, and species richness values ranged from 3 at DOT D (in both 2000 and 2001) to 18 species at DOT C (in 2000). Average species richness was 10.2 in 2000 and 10.1 in 2001. Using linear regression I found significant, positive relationships between plant species richness and wetland area (m^2), watershed area (m^2) and open water class (see Table 1) in both 2000 and 2001 (Table 8, Figure 5). The strongest relationship was between richness and watershed area ($P = 0.0001$ in 2000, and 0.001 in 2001).

Table 7: Summary of regression analyses comparing amphibian and bird response variables to vegetation predictor variables for combined set of created and natural wetlands (n=18). P values are listed for relationships that are significant ($P < 0.050$), in boldface, or are approaching significance ($0.050 \leq P \leq 0.100$). Negative relationships are in parentheses. Abbreviations for bird wetland dependency (OBL, FACW, FAC) are defined in Table 4.

	Predictor Variables							
	Plant Species Richness		**Plant Species Diverstiy**		**Proportion of *T. latifolia***		**Invasive Plant Species Cover**	
Response Variables	2000	2001	2000	2001	2000	2001	2000	2001
Amphibians								
Species Richness	-	0.085	-	**0.042**	**(0.039)**	**(0.042)**	-	-
Birds								
Species Richness	**0.007**	**0.009**	**0.037**	**0.024**	-	(0.087)	-	-
Species Diversity	**0.015**	**0.018**	**0.007**	**0.023**	(0.084)	**(0.036)**	-	-
Number of Birds per Census	0.081	**0.025**	-	**0.044**	-	-	-	-
Proportion of OBL+FACW+FAC Birds	-	-	-	-	0.100	**0.010**	**(0.047)**	**(0.035)**
Proportion of OBL+FACW Birds	-	-	-	-	-	0.055	-	0.075
Proportion of OBL Birds	0.083	-	**0.001**	**0.025**				

Table 8: Summary of regression analyses comparing amphibian, bird and vegetation response variables to landscape predictor variables for combined set of created and natural wetlands (n=18). P values are listed only for relationships that are significant ($P < 0.050$), in boldface, or are approaching significance ($0.050 \leq P \leq 0.100$). Negative relationships are in parentheses.

	Predictor Variables																					
	Created Wetland Age (yrs)		**Open Water Class**		**Wetland Area (m^2)**		**Area of Wetlands w/in 500m (m^2)**		**Watershed Area (m^2)**		**Length of Road in Watershed (m)**		**Length of Road w/in 100m Buffer (m)**		**% Agriculture**		**% Industrial, Commercial, Urban**		**% Forest**		**% Residential**	
Response Variables	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Amphibians																						
Amphibian Species Richness	-	-	**0.002**	**0.001**	-	-	-	-	-	**0.022**	-	-	-	-	-	(0.058)	0.073	-	-	0.075	-	-
Birds							-	-			-	-										
Species Richness	-	-	**0.023**	**0.001**	-	-	-	-	**0.002**	**0.002**	-	**0.017**	-	-	-	-	-	-	-	-	**0.003**	**0.024**
Species Diversity	-	-	**0.022**	**0.001**	-	-	-	-	**0.022**	-	-	-	-	-	-	-	-	-	-	-	0.059	-
Number of Birds per Census			**0.030**	**0.005**	**0.028**	**0.022**	**(0.026)**	-	**0.008**	**0.001**	**0.034**	**0.037**	-	-	-	-	-	-	-	-	**0.018**	0.087
Proportion of OBL+FACW+FAC Birds	-	0.099	-	(0.054)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proportion of OBL+FACW Birds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proportion of OBL Birds	-		**0.016**	**0.004**	-	0.084	-	-	-	0.086	-	-	-	-	-	-	-	-	-	-	-	-
Plants																						
Species Richness	-	-	**0.027**	**0.034**	**0.002**	**0.034**	-	-	**0.0001**	**0.001**	-	-	-	-	(0.096)	-	-	-	0.091	0.058	0.077	0.080
Species Diversity	-	-	**0.002**	**0.001**	-	-	-	-	**0.031**	**0.034**	-	-	-	-	-	-	-	-	-	-	-	-
Proportion of Typha latifolia	-	-	**(0.050)**	**(0.030)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Invasive Species Richness	-	-	-	-	-	-	-	-	-	-	**0.038**	**0.038**	0.093	0.093	-	-	-	-	-	-	-	-
Invasive Species Diversity	-	-	-	-	-	-	-	-	-	-	-	-	0.074	0.064	-	-	-	-	-	-	-	-
Invasive Species [illegible]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0.029**	**0.024**	-	-	-	-

Table 9: Summary of best subset regression analyses for vegetation response variables for the year 2000.

	Vegetation Response Variables				
Predictor Variables	**Species Richness**	**Species Diversity**	**Proportion of *T. latifolia***	**Invasive Species Richness**	**Invasive Species Cover**
Open Water Class			X		
Wetland Area (m^2)				X	
Watershed Area (m^2)	X	X	X		X
Area of Other Wetlands w/in 500m (m^2)	X	X			
Length of Road in Watershed (m)					
Length of Road w/in 100m Buffer (m)					
Distance to Road (m)			X	X	X
% Agriculture within 1km				X	
% Industrial, Commercial, Urban within 1km				X	X
% Forest within 1km				X	
% Residential within 1km			X		X
Adj r^2	75.0	60.9	62.0	48.5	49.4
C-p	4.8	6.7	2.3	3.5	1.1
s	0.10135	0.04668	0.23694	0.12200	0.27896

Table 10: Summary of best subset regression analyses for amphibian and bird response variables for the year 2000.

	Response Variables						
Predictor Variables	**Amphibian Species Richness**	**Bird Species Richness**	**Bird Species Diversity**	**No. of Birds/Census**	**Proportion of OBL+FACW+FAC Birds**	**Proportion of OBL+FACW Birds**	**Proportion of OBL Birds**
Plant Species Richness	X			X	X	X	X
Plant Species Diversity				X	X	X	X
Proportion of *Typha latifolia*					X		X
Invasive Plant Species Cover							
Invasive Plant Species Diversity							
Open Water Class	X			X	X		
Wetland Area (m^2)			X			X	
Watershed Area (m^2)		X	X	X			
Area of Other Wetlands w/in 500m (m^2)	X	X	X	X			
Length of Road w/in 100m Buffer (m)							
% Forest within 1km							X
% Industrial, Commercial, Urban within 1km	X				X		
% Residential within 1km		X	X				
Adj r^2	56.5	67.8	63.1	89.2	67.2	38.1	73.4
C-p	33.9	-2.2	-2.3	3.4	4.4	-2.3	1.4
s	0.109400	0.096494	0.032564	0.081974	0.156690	0.182300	0.121040

Table 11: Summary of best subset regression analyses for vegetation response variables for the year 2001.

	Vegetation Response Variables				
Predictor Variables	**Species Richness**	**Species Diversity**	**Proportion of *T. latifolia***	**Invasive Species Richness**	**Invasive Species Cover**
Open Water Class			X		
Wetland Area (m^2)				X	
Watershed Area (m^2)	X	X	X		X
Area of Other Wetlands w/in 500m (m^2)	X	X			
Length of Road in Watershed (m)					
Length of Road w/in 100m Buffer (m)					
Distance to Road (m)			X	X	X
% Agriculture				X	
% Industrial, Commercial, Urban within 1km				X	X
% Forest within 1km				X	
% Residential within 1km			X		
Adj r^2	68.6	63.3	61.5	48.5	49.4
C-p	9.4	7.3	2.8	3.5	1.1
s	0.13495	0.04178	0.22957	0.12200	0.27471

Table 12: Summary of best subset regression analyses for amphibian and bird response variables for the year 2001.

	Response Variables						
Predictor Variables	**Amphibian Species Richness**	**Bird Species Richness**	**Bird Species Diversity**	**No. of Birds/Census**	**Proportion of OBL+FACW+FAC Birds**	**Proportion of OBL+FACW Birds**	**Proportion of OBL Birds**
Plant Species Richness			X		X		X
Plant Species Diversity							X
Proportion of *T. latifolia*	X					X	
Invasive Plant Species Cover							
Invasive Plant Species Diversity							
Open Water Class	X	X	X	X			
Wetland Area (m^2)				X			X
Watershed Area (m^2)		X					
Area of Other Wetlands w/in 500m (m^2)				X			
Length of Road w/in 100m Buffer (m)							
% Forest within 1km	X		X		X	X	
% Industrial, Commercial, Urban within 1km					X		
% Agriculture within 1km			X	X	X		
% Residential within 1km		X			X		
Adj r^2	80.1	70.6	69.3	66.9	57.7	23.2	45.7
C-p	-1.8	-1.4	0.5	1.8	2.4	-0.7	11.3

In both 2000 and 2001, the best multiple regression models for plant species richness contained the same two predictor variables, 1) watershed area and 2) the area of wetlands within 500 m (Tables 9 and 11). When selecting the best subset of predictor variables for a particular response variable, the Mallows C-p value should ideally be less than the number of variables plus 1 (MTSU 2004). The ideal C-p values for models for plant species richness would be less than three for both years. However, none of the models for plant species richness in 2000 (C-p = 4.8) or 2001 (C-p = 9.4) had C-p values that met this ideal. Therefore, I chose the simplest model that had the highest R^2 value, ignoring the Mallows C-p.

Using linear regression I found significant, positive relationships between plant species diversity (Shannon Weiner index) and open water class and wetland area in both years (Figure 6, Table 8). The strongest relationship was with open water class (P = 0.002 in 2000 and 0.001 in 2001). The created wetland Spall had the highest species diversity in both 2000 (0.7508) and 2001 (0.7603). DOT D, also a created wetland, had the lowest

The best subset models for plant species diversity (Shannon-Weiner) in both 2000 and 2001 contained the same two predictor variables; watershed area and the area of other wetlands within 500m (Tables 9 and 11). As with the models for plant richness, none of the models for plant diversity in either 2000 (C-p = 6.7) or 2001 (C-p = 7.3) had ideal C-p values, therefore I again selected models based on simplicity and R^2 values.

The relationship between plant species diversity and the area of other wetlands within 500 m was positive, though not significant, in both years (P = 0.137 in 2000, P = 0.122 in 2001). While open water class was significantly associated with both plant richness and plant diversity in 2000 and 2001 (Table 8), it was not part of the best subsets for either of these response variables in either year.

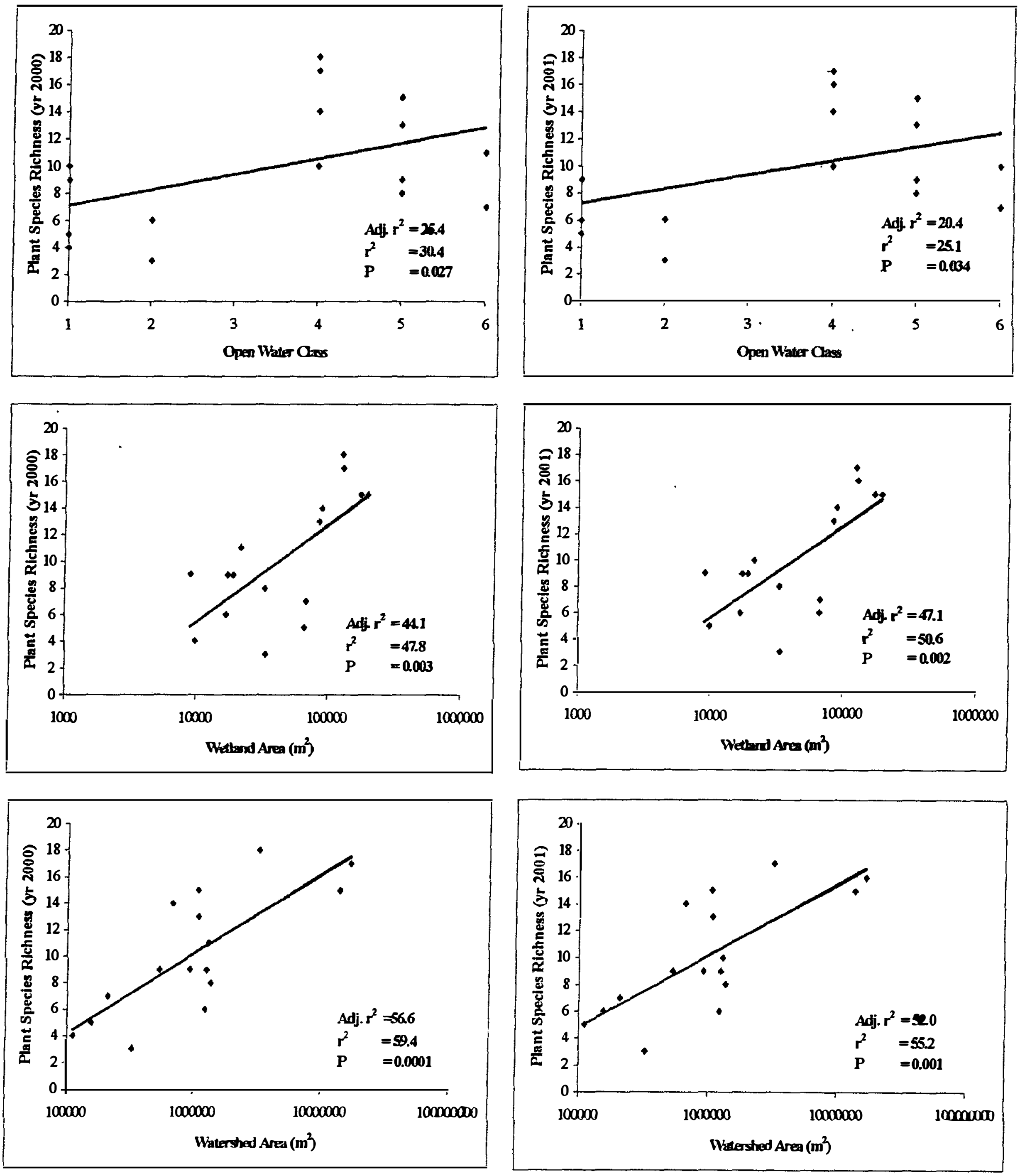

Fig. 5: Relationship between plant species richness and open water class, wetland area (m^2), and watershed area (m^2) for 2000 and 2001.

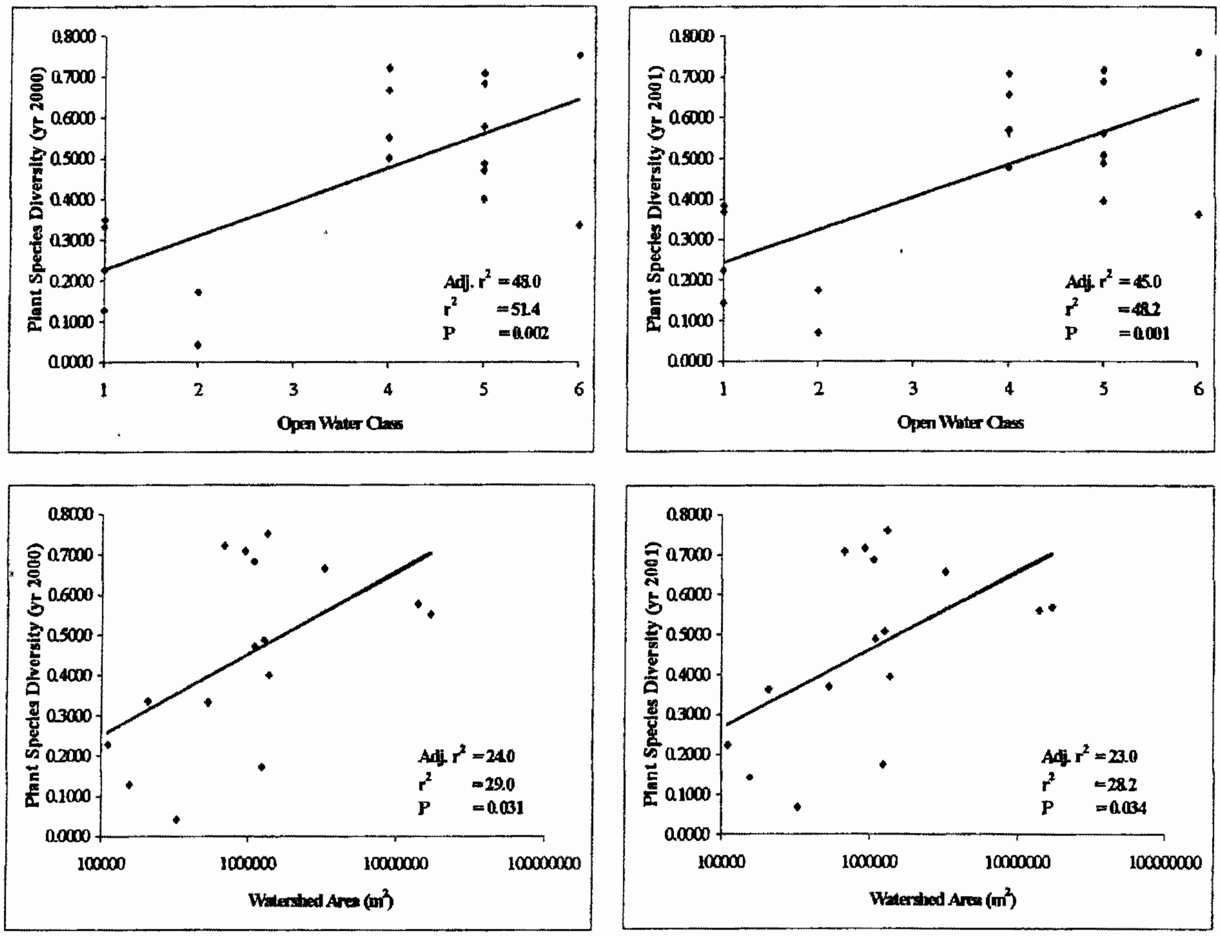

Fig. 6: Relationships for both years, between plant species diversity and open water class and watershed area.

Invasive Plant Species

The best subset models for invasive plant species richness contained five predictor variables and were identical in both years (Tables 9 and 11). None of these five predictors were statistically significant under simple linear regression.

The univariate relationship between invasive plant species richness and the length of the road within the watershed was positive in both years (Figure 7, Table 8); however, this predictor was not part of the best subset models for either year. Similarly, the association between invasive plant species richness and the length of the road within a 100 m buffer approached positive statistical significance (P = 0.093) in both years, but this predictor was not part of the best subsets model. Roxbury had the smallest amount of road within its watershed at 10 m, while Mason had the most at 19,739 m. I found no invasive plant species at Roxbury in either year. Roxbury is located at the end of a recently developed (13 years) cul de sac and is bordered on its west and north sides forested wetlands. The nearest road is the low traffic cul de sac, which is 141 m away. Mason is a large wetland composed of a series of pools, and is adjacent to a stream on the east, a housing development on its west side and agriculture fields on its north side. I found two invasive plant species at Mason. The wetland called Thruway had the highest invasive species richness (3) for both years. Thruway is 31 m north of the highly traveled New York State thruway and has 984 m of road within its watershed.

The best subset models for invasive plant species cover for both 2000 and 2001 shared watershed area, distance to road and the percentage of industrial, commercial and urban land surrounding the wetland. The 2000 model added the percentage of residential land surrounding the wetland variable (Tables 9 and 11). The only predictor variable that

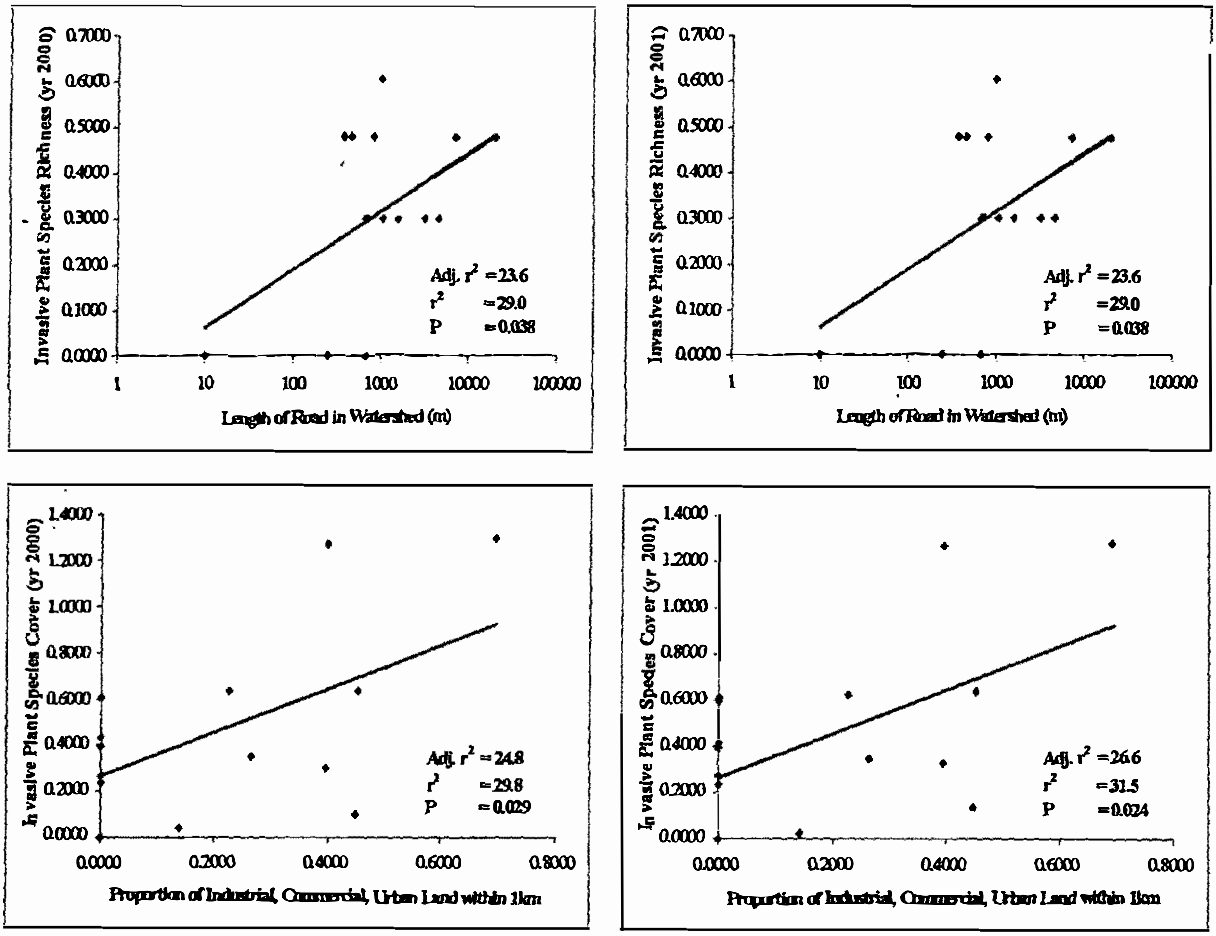

Figure. 7: Relationships between invasive species richness and the length of road within in the watershed, and between invasive species cover and the percentage of industrial, commercial and urban land within 1 km of wetland for both 2000 and 2001.

produced a statistically significant univariate relationship (P = 0.029 in 2000, P = 0.024 in 2001) with invasive plant species cover was the percentage of industrial, commercial and urban land within 1 km (Figure 7). In both years the relationships were positive.

Thruway wetland had the greatest percentage of industrial, commercial and urban surrounding land (41%) and also the largest percentage of invasive species cover (92% in 2000, 91% in 2001). The most abundant plant species at Thruway was *Phalaris arundinacea,* and the second most abundant was *Lythrum salicaria* in both years, both of these are invasive.

Proportion of Typha latifolia

The best subset models for the proportion of *T. latifolia* contained the same four predictors in both years (Tables 9 and 11). Open water class, watershed area and the distance to road were all negative associations in both years under simple linear regression, however the only statistically significant relationship was with open water class in 2001 (P = 0.030). The association between the proportion of *T. latifolia* and open water class approached statistical significance (P = 0.050) in 2000 (Table 8). The relationship between the proportion of *T. latifolia* and the percentage of residential land within 1 km was positive in both years, though not statistically significant (P = 0.610 in 2000 and 0.619 in 2001).

DOT D had the highest proportion of *T. latifolia* in both years (0.98 in 2000, and 0.97 in 2001), and an open water class of 2 (see Table 1). This wetland also had the lowest plant species richness (3) of all wetlands. *T. latifolia* and *Phragmites australis* were the only emergent plant species found at DOT D. Wetlands DOT A, Roxbury and Smith all had less than 10% open water and 0.92, 0.85, and 0.77 proportions of *T. latifolia*, respectively.

Amphibians

Species Richness

The models for amphibian species richness were quite different between 2000 and 2001, and this difference may have been because of the number of surveys I conducted in each year. In 2000 I conducted just two surveys, while in 2001 I conducted four.

I selected a model for the year 2000 that included open water class, watershed area, area of other wetlands within 500 m and the percentage of industrial, commercial and urban land surrounding the wetlands (Table 10). Open water class was a significant (positive) factor affecting amphibian richness in 2000 ($P = 0.002$) under simple regression analysis (Figure 8). Watershed area and the percentage of industrial, commercial and urban land surrounding the wetland both had positive though not significant univariate associations with amphibian richness. The relationship between amphibian richness in 2000 and the area of other wetlands within 500 m of the wetland was negative though not significant ($P = 0.534$). The association between amphibian richness and the proportion of *T. latifolia* was negative and statistically significant in 2000 ($P = 0.039$), however this predictor was not part of the best subset model (Figure 8).

The model for amphibian richness in 2000, while it has a relatively high adjusted R^2 value (72.4), has a Mallows C-p value (44) that is much higher than ideal. None of the models for amphibian species richness in 2000 had ideal C-p values, therefore I selected the best model based on adjusted R^2 values.

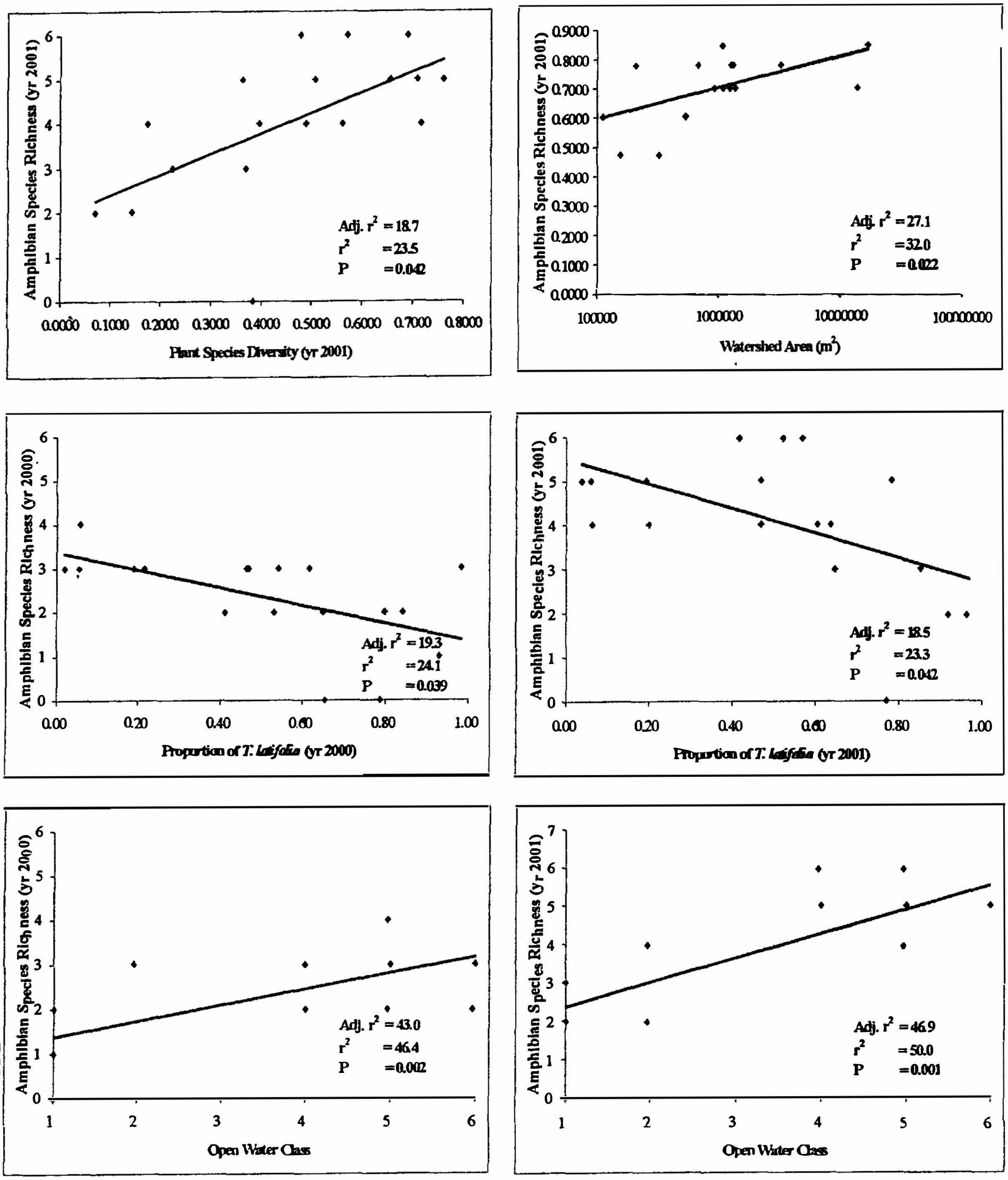

Figure 8: Relationship between amphibian species richness and plant species diversity for 2000, proportion of *T. latifolia*, and open water class for both 2000 and 2001. Open water classifications did not change among years.

The best multiple regression model for amphibian richness in 2001 contained three variables; 1) proportion of *T. latifolia*, 2) open water class and 3) the percentage of forest within 1 km of the wetland (Table 12). The univariate relationship between amphibian richness and open water was positive and significant (P = 0.001) in 2001, and the relationship with the percentage of forest within 1 km was also positive, and approached statistical significance (P = 0.075). The proportion of *T. latifolia* had a significant negative association with amphibian richness (P = 0.042).

Plant species diversity and watershed area were significant positive factors affecting amphibian richness in 2001 (Tables 7 and 8), however neither was part of this model. Similarly, the percentage of agricultural land within 1 km of wetlands was not part of the best subset model, however it approached negative, statistical significance (P = 0.058) in 2001 (Figure 8).

Mason, Round Pond and Packard wetlands shared the highest amphibian species richness at six in 2001, and I found no calling amphibians in either year at Smith. Smith is a relatively isolated wetland with no open water and is surrounded primarily by agricultural fields and residential land. I found no water in Smith during either year of the study, and there did not appear to be any above ground source of water flowing into this wetland. Roxbury is similar to Smith in that it has less than 10% open water; however, Roxbury is adjacent to forested wetlands on both the north and west. I found three species of calling amphibians at Roxbury in 2001.

Birds

Species Richness and Diversity

I found a total of 33 bird species over the two years of the study. The most common was the red-winged blackbird, which was found at all wetlands in both years. In both years, wetland DOT A had the lowest bird species richness (3 in both years) and Golden Road had the highest (17 in 2000, 19 in 2001). The three bird species found at DOT A were the same in both years (red-winged blackbird, song sparrow and Virginia rail).

In both 2000 and 2001, there were significant, positive univariate relationships between bird species richness and plant species richness, plant species diversity, open water class, watershed area and the percentage of residential land within 1 km. In 2001, the length of the road in the watershed was significant and positively associated with bird species richness (Tables 7 and 8, Figures 9 and 10).

The best subset model for bird richness in 2000 contained three predictor variables; 1) watershed area, 2) area of other wetlands within 500m, and 3) percentage of residential land surrounding the wetland (Table 10). While all three of these predictors were positively associated with bird richness in univariate analyses, only watershed area ($P = 0.002$) and the percentage of residential land within 1 km ($P = 0.003$) were statistically significant (Table 8, Figure 10).

The best multiple regression model for bird richness in 2001 also contained three predictors; 1) open water class, 2) watershed area and 3) percentage of residential land surrounding the wetland (Table 11). All three of the predictors in this model produced significant positive associations with univariate analyses (Table 8, Figure 10).

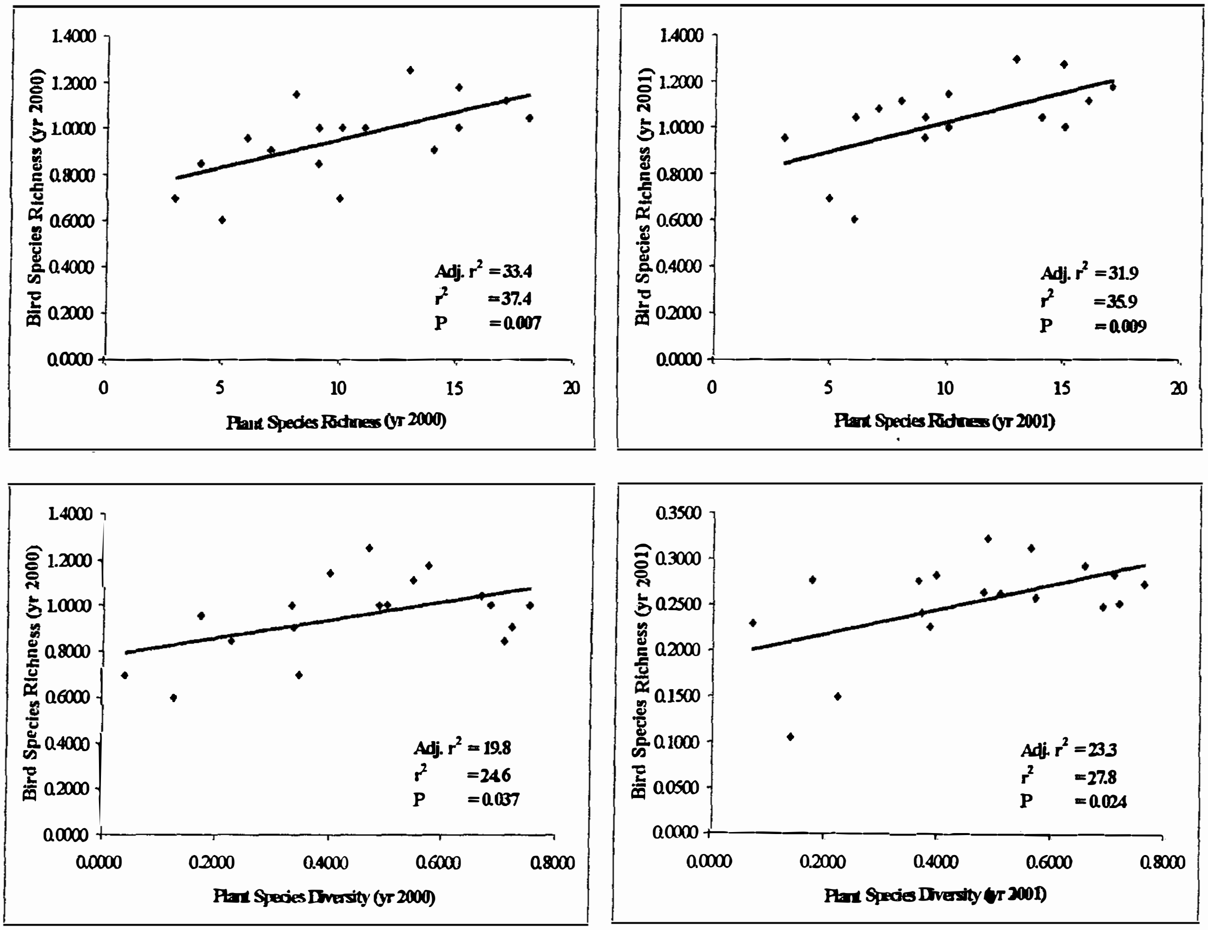

Figure 9: Relationship between bird species richness and plant richness, plant diversity in 2000 and 2001.

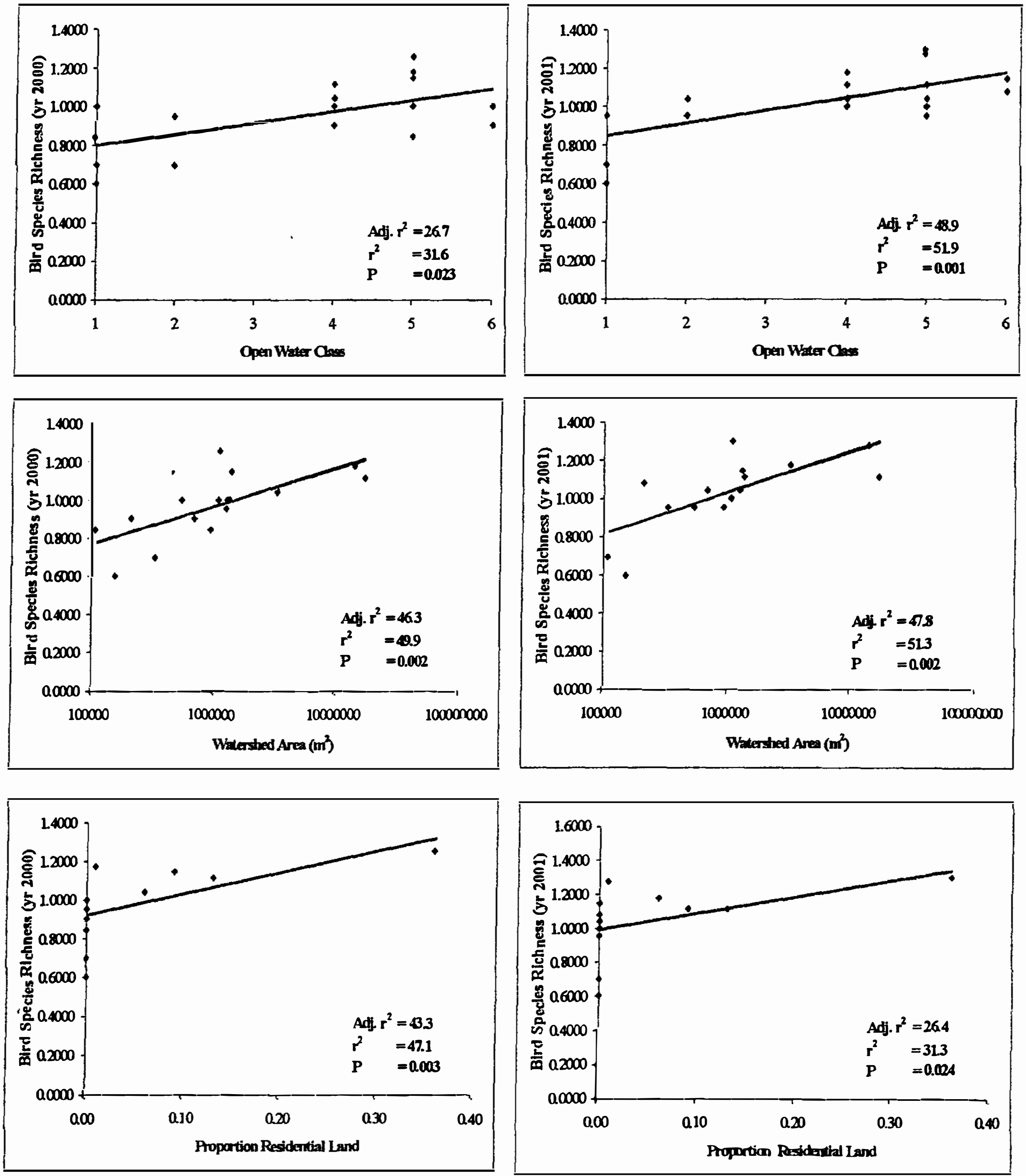

Figure 10: Relationship between bird species richness and open water class, watershed area and percentage of residential land within 1 km of wetland for 2000 and 2001.

Bird species diversity (Shannon-Weiner) ranged from 0.2726 to 1.0279 in 2000, and from 0.2743 to 1.1015 in 2001. As with bird species richness, the low and high values in both years were at DOT A and Golden Road, respectively. The best subset models in both 2000 and 2001 included four predictor variables, however; they had no predictor variables in common.

The best subset model for bird species diversity in 2000 included 1) wetland area, 2) watershed area, 3) area of other wetlands within 500m and 4) percentage of residential land surrounding the wetland (Table 9). All four of the predictors in the year 2000 model had significant positive relationships with bird diversity using simple linear regression. In addition, open water class, plant species richness and plant species diversity produced significant, positive associations with bird diversity using simple linear regression (Tables 7 and 8, Figure 11).

The best multiple regression model for bird diversity in 2001 also contained four variables; 1) plant species richness, 2) open water class, 3) percentage of forest surrounding wetland and 4) percentage of agricultural land surrounding the wetland (Table 12). This model had the highest adjusted R^2 (69.3) value of any of the models for this response variable. Plant species richness and open water class both produced positive significant associations with bird diversity using linear regression (Tables 7 and 8, Figure 11). The only significant negative association with bird species diversity in 2001 was with the proportion of *T. latifolia* (P = 0.036).

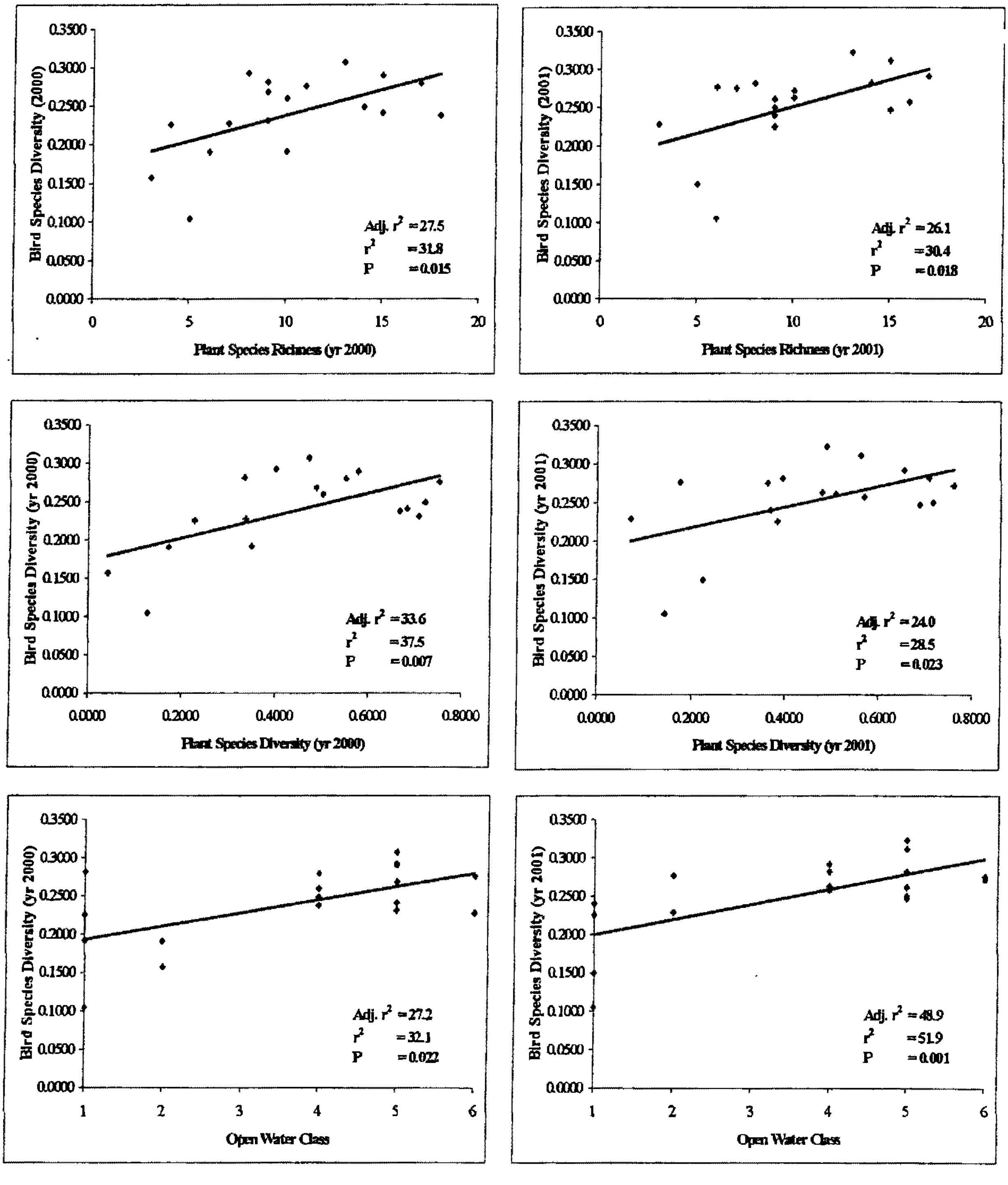

Figure 11: Relationship between bird species diversity and plant richness, plant diversity and open water class for 2000 and 2001.

Number of Birds per Census

I counted 467 individual birds over 2 surveys in 2000, producing an average of 26 birds per wetland, and an average of 13 birds per census. In 2001, I counted 1207 birds over 4 surveys, resulting in an average of 67 birds per wetland, and an average of 16.7 birds per census. The fewest total number of birds was found at Smith in both 2000 (7) and 2001 (25), and the greatest total number of birds was found at DOT C in 2000 (54) and at DOT B in 2001 (168). Twenty-six of the 54 birds (48 %) found at DOT C in 2000 were Canada goose. Twenty-seven of the 168 (16%) birds at DOT B in 2001 were also Canada goose, and 34 were mallards (20%).

The best subset regression model for the number of birds per census in 2000 contained five predictor variables; 1) plant species richness, 2) plant species diversity, 3) open water class, 4) watershed area and 5) the area of other wetlands within 500 m of the wetland (Table 10). Open water class and watershed area formed positive significant associations with the number of birds per census, while the area of other wetlands within 500 m was significant and negatively associated. Wetland area, the length of the road within the watershed and the percentage of residential land surrounding the wetlands also produced significant positive univariate relationships with the number of birds per census (Tables 7 and 8, Figure 12)

The best multiple regression model for the number of birds per census in 2001 included four variables; 1) open water class, 2) wetland area, 3) area of other wetlands and 4) the percentage of agricultural land within 1 km of the wetlands (Table 12). Open water class and wetland area were both significant and positively associated with the number of birds per census using simple linear regression, while the percentage of agricultural land

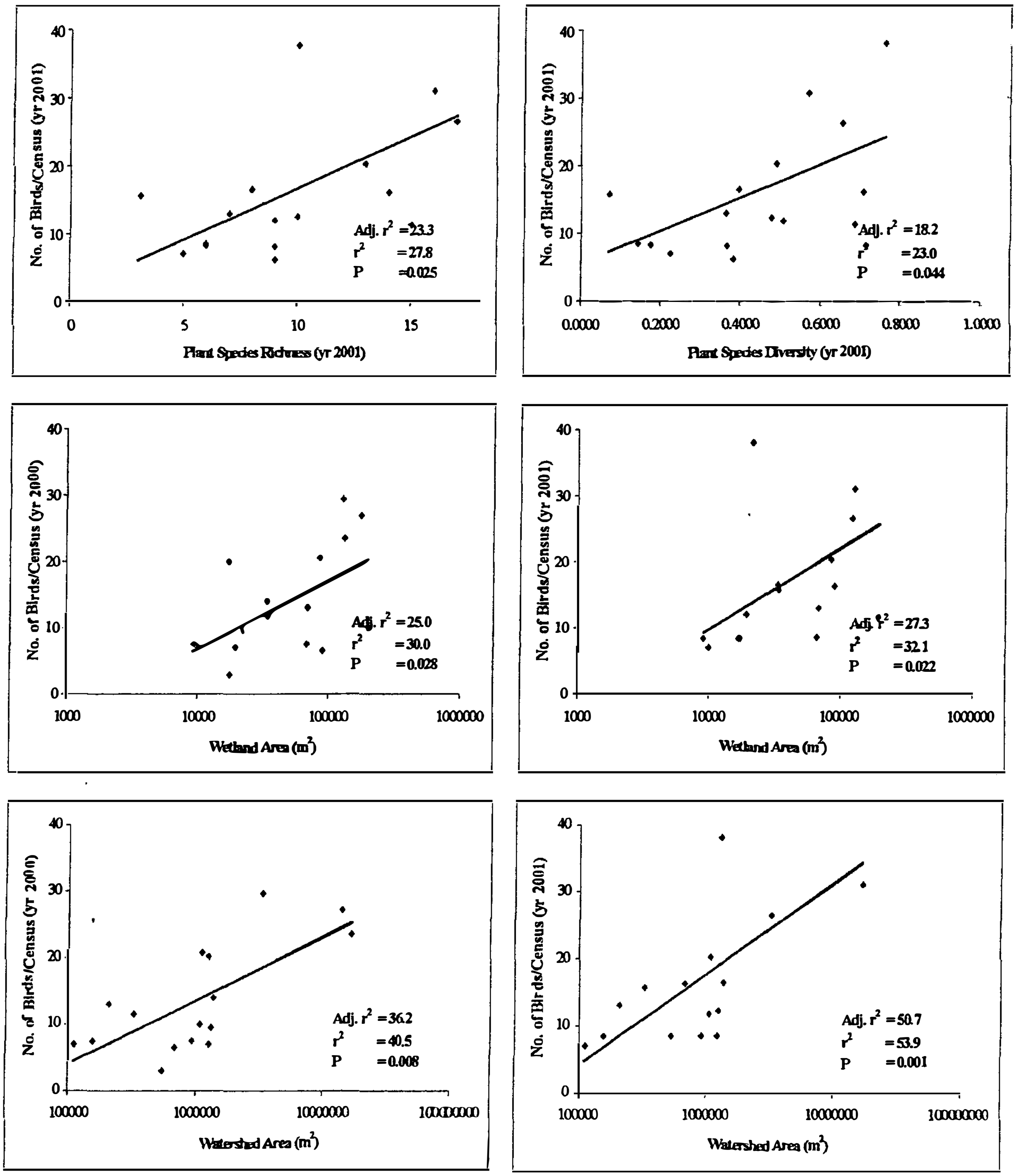

Figure 12: Relationship between the number of birds per census and wetland area and watershed area in both 2000 and 2001, and between the number of birds per census and plant species richness and plant diversity in 2001.

surrounding wetlands approached positive statistical significance (P = 0.087) (Tables 7 and 8, Figure 12).

Proportion of Birds based on Wetland Dependency

The best subset model for the proportion of OBL+FACW+FAC birds in 2000 contained five predictor variables; 1) plant species richness, 2) plant species diversity, 3) proportion of *T. latifolia,* 4) open water class and 5) percentage of industrial, commercial and urban land surrounding the wetland (Table 10). None of the predictors in this model were statistically significant under univariate analysis, though the proportion of *T. latifolia* approached positive statistical significance (P = 0.100). The only statistically significant univariate association was with invasive plant species cover and was negative (P = 0.047) (Table 7). The proportion of OBL+FACW+FAC birds found at DOT A, DOT D and King Road in 2000 was 1.00, indicating that no FACD or UPL birds were surveyed at these wetlands.

The multiple regression model for the proportion of OBL+FACW+FAC birds in 2001 also consisted of five predictor variables; 1) plant species richness, 2) percentage of forested land within 1 km, 3) percentage of industrial, commercial and urban land within 1 km, 4) percentage of agricultural land within 1 km and 5) percentage of residential land within 1 km (Table 12). However, none of these five predictors produced statistically significant relationships under simple linear regression. The only predictors having statistical significance were the proportion of *T. latifolia* (positive, P = 0.010) and invasive plant species cover (negative, P = 0.035) (Table 7).

The best subset model for the proportion of OBL+FACW birds in 2000 contained three predictor variables, and the model for 2001 contained two (Tables 10 and 12). Both of these models had relatively low adjusted R^2 values (38.1 in 2000, 23.2 in 2001). There were no significant relationships between OBL+FACW birds with any predictor variables in either 2000 or 2001, however the associations between this category of birds to the proportion of *T. latifolia* (P=0.055) and to invasive plant species cover approached positive statistical significance in 2001 (P=0.075).

The best multiple regression model for the proportion of OBL birds in 2000 contained four variables; 1) plant richness, 2) plant diversity, 3) proportion of T. latifolia and 4) percentage of forest within 1 km of the wetland, and the adjusted R^2 was 73.4 (Table 9). Plant species diversity was the only predictor variable in of this model that produced a statistically significant (positive) association with OBL birds in 2000 (P = 0.001). Though not part of the best subset model, open water class (P = 0.016) was statistically significant and positively associated with the proportion of OBL birds in 2000 (Table 8, Figure 13).

I selected a three variable model as best for the proportion of OBL birds in 2001; 1) plant species richness, 2) plant species diversity and 3) wetland area, (Table 12). Plant species diversity (P = 0.025) was the only predictor in this model that was statistically significant (positive) with the proportion of OBL birds. Though not part of the best subset model, I found a positive statistically significant association between the proportion of OBL birds and open water class (Figure 13).

I found no OBL bird species at Blodgett in 2000 or 2001, and none at Tinker Marsh in 2001. Both Blodgett and Tinker Marsh have low open water classifications (2 and 1 respectively), and the most common bird species found at both were the red-winged blackbird (FACW), the common yellowthroat (*Dendroica dominica*) (FACW) and the song sparrow (*Melospiza melodia*) (FAC). Spall had the greatest proportion of OBL bird

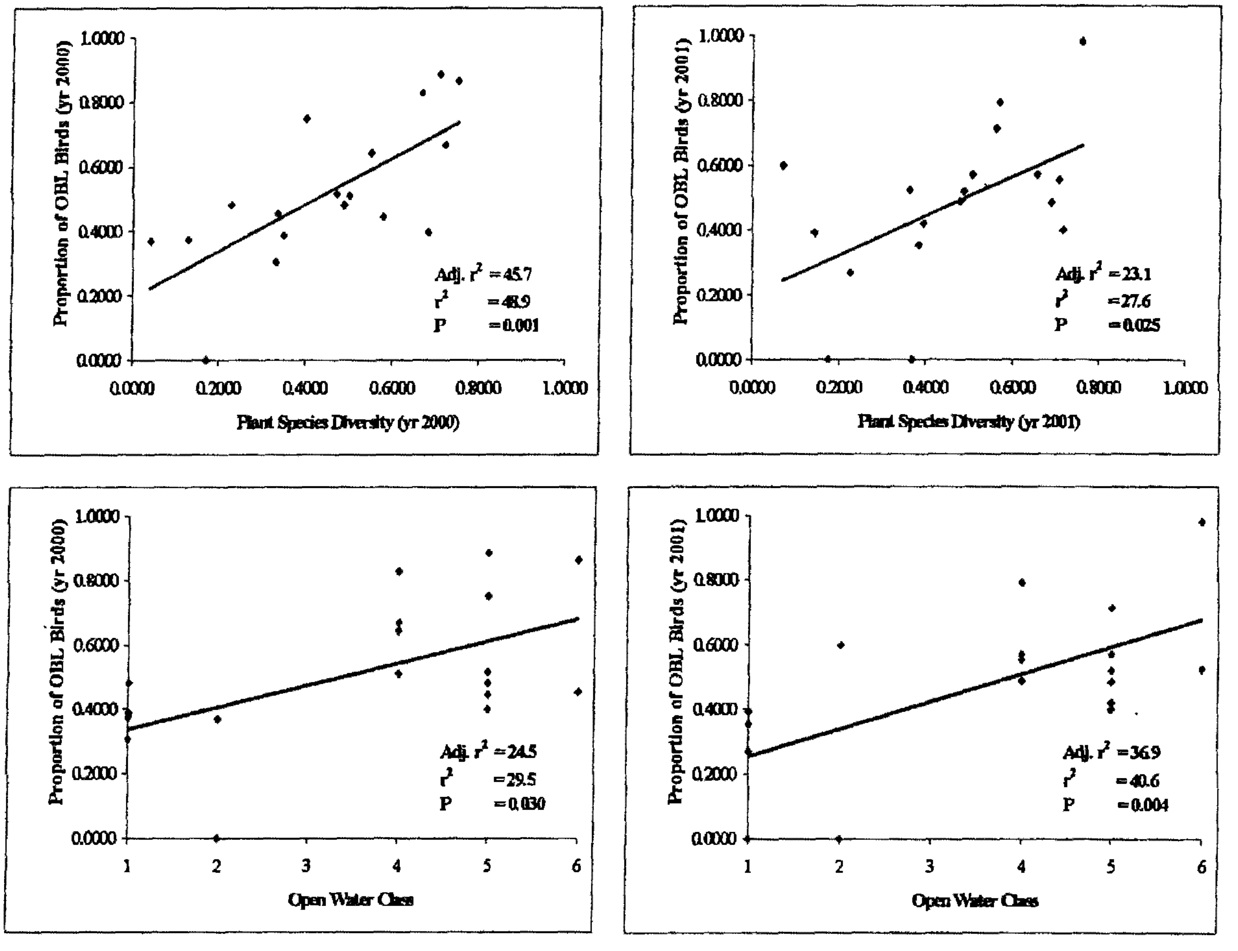

Figure 13: Relationship between the proportion of OBL birds and plant species diversity and open water class for 2000 and 2001.

species in 2000 (0.5789) and 2001 (0.6908). This created wetland was 3 years old in 2000 and had more than 90% open water.

Summary of Results

Paired Sample Analysis

Over the two years of the study, I found no statistically significant differences between created and natural wetlands for any of the response variables tested (Table 3). Since I found no significant differences among the wetland types, I combined them into a larger set (n = 18) and used simple linear regression and best subset multiple regression analyses to look for significant relationships between response and predictor variables.

Plants

The predictor variables that had the most effect on plant response variables were open water class and watershed area. In both years, these two predictors had positive, significant associations with plant species diversity and plant species richness. Watershed area was part of the best subset models for plant species richness and for plant species diversity in both 2000 and 2001; however, open water class was not for either of these plant response variables. Open water class also had a significant, negative effect on the proportion of *T. latifolia* in both years, and also was part of the best subset model for this response variable (Table 8).

Invasive plant species variables were not significantly associated with open water class or watershed area using simple regression analyses. The only predictor variable in both years, that was significantly associated (positive) with invasive plant species richness was the length of the road in the watershed, while the percentage of industrial, commercial and urban land within 1 km of wetlands was positively related to invasive plant species cover

(Table 8). The best subset models for both invasive plant species richness and cover, in 2000 and in 2001, included the distance to the road and the percentage of industrial, commercial and urban land surrounding the wetlands (Tables 9 and 11).

Amphibians

Open water class and watershed area were important variables significantly affecting amphibian species richness with simple linear regression. Amphibian richness was positively associated with watershed area in 2001 and with open water class in both years (Table 8). Amphibian richness was negatively associated with the proportion of *T. latifolia* in both 2000 and 2001 (Table 7).

I surveyed amphibians twice in 2000 and four times in 2001, therefore the 2001 data on amphibian richness is likely more reliable than 2000 data. This may account for differences in the best subset models for amphibian richness in 2000 and 2001. However, open water class was a part of the best subset models in both years (Tables 10 and 12).

Birds

There were a number of predictor variables that significantly affected bird response variables, and these predictors included open water class and watershed area. Bird species richness, species diversity and the number of birds per census were all positively related to open water class and watershed area in both 2000 and 2001. I also found a significant positive relationship between the proportion of OBL birds and open water class (Tables 7 and 8).

In addition, bird richness and diversity were positively associated with plant species richness and plant species diversity in both years. The number of birds per census was positively affected by plant species richness and plant diversity in 2001 (Tables 6 and 7).

The only best subset models for bird response variables that contained both open water class and watershed area were those for the number of birds per census in 2000 and bird species richness in 2001 (Tables 10 and 12).

Overall and in general, the predictor variables that had the most effect on plant, amphibian and bird response variables using simple linear regression were open water class and watershed area. Watershed area was positively associated with six of the response variables. Open water class was positively associated with seven response variables, and negatively associated with just the proportion of *T. latifolia* (both years). Moreover, watershed area was part of four of the five best subset models for vegetation response variables in both 2000 and 2001.

DISCUSSION

The objective of section 404 of the Clean Water Act of 1972 was to slow the loss of wetlands in the U.S. by establishing guidelines for their protection and regulation. The Committee on Mitigating Wetland Losses concluded that the goal of "no net loss" under the CWA had not been met (NRC 2001). The NRC suggested a number of reasons for the failure to meet this goal, one being insufficient data on lost wetland functions and the status of mitigation projects. In addition, they found that comparisons of ecological functioning of mitigated wetlands to natural wetlands were uncommon (NRC 2001)

The success of a mitigated wetland should be determined by how completely it replaces not just wetland area, but also the functions of the natural wetland that were lost. Zedler (1996) suggests that mitigated wetlands should replace both the structural and functional characteristics of the lost wetlands, and that created wetlands that do not adequately replace functions, merely add to wetland loss. Although wetlands support many ecological functions, mitigation success historically has been determined only by the development or creation of proper hydrology and vegetation (Kusler and Brooks 1988, Galatowitsch and van der Valk 1994, Richter 1997). This approach to mitigation assumes that proper vegetation is an indicator of other wetland functions; therefore, if vegetation at a created wetland is similar in structure and diversity to vegetation in natural wetlands, then other ecological functions should be similar. However, many authors suggest that this assumption may not always be true (D'Avanzo 1986, Turner 2000, NRC 2001, Campbell et al. 2002).

Many scientists suggest that the basis for success in a mitigated wetland project should incorporate all wetland functions, including wildlife utilization (Brooks and Huges 1990, Erwin 1990, Kusler and Kentula 1990, Mitsch and Gosselink 2000). However, few project designs incorporate methods or criteria to establish and monitor animals (NRC 2001).

Comparison of Created and Natural Wetlands

The initial purpose of my study was to use paired sample analysis to compare wildlife utilization at created and natural wetlands. I found no statistically significant differences among created and natural wetlands for any of the response variables evaluated. My results suggest that the created wetlands of this study were ecologically equivalent or at least structurally comparable to similar natural wetlands. My results also suggest that the created wetlands of this study have replaced not just lost wetland area, but also vegetation structure and composition, and the important function of providing amphibian and bird habitat.

There have been a number of studies comparing the vegetation characteristics of created or restored wetlands, to natural wetlands, and the results have been varied. My vegetation results differed from a study conducted by Brown and Veneman (2001) in Massachusetts. In a study of 391 mitigation projects, they found statistically significant differences in plant communities between created and natural wetlands. Natural wetlands had significantly higher plant richness, total percent cover and plant species composition values than created wetlands. They suggest that these differences were likely caused by differences in hydrology and soils between the wetland types, and that restoration of wetlands, in which hydrology and soils are already established, may be more effective than the creation of wetlands where none had previously existed (Brown and Veneman 2001).

Campbell et al. (2002), in a study of wetlands in Pennsylvania, also found significant differences in vegetation characteristics between created and natural wetlands. Similar to Brown and Veneman (2001) they found that plant species richness and plant cover were significantly higher in natural wetlands than created wetlands. They also found significant differences within the set of created wetlands, and suggested that these differences may be due to the position of the created wetlands within the landscape. Many of the created wetlands in their study were in uplands not near other wetlands, and they suggested that the lack of adequate seed sources may have contributed to low species richness values in created wetlands. I also found that there was variation in vegetation variables within the set of created wetlands. For example, in 2001, plant species richness varied from 3 to 17 and plant species diversity ranged from 0.0702 to 0.7603 among created wetlands.

Campbell et al. (2002) also found that created wetlands were typically dominated by common cattail, a clonal species that often out competes other plant species, resulting in lower species richness (Mitsch and Gosselink 2000, Campbell et al. 2002). Most of the created wetlands in my study (78%) were also dominated by common cattail. However, the majority of natural wetlands in my study (67%) were also dominated by this aggressive species. While I found that the average proportion of common cattail in both 2000 and 2001 tended to be higher in created wetlands than in natural wetlands, the difference was not statistically significant.

Confer and Neiring (1992) in a paired study of created and natural wetlands in Connecticut, had results similar to mine. They found no significant difference in plant species richness between created and natural wetlands, though the mean species richness was slightly higher in created wetlands.

I found no significant relationships between created wetland age and vegetation variables. Interestingly, the five DOT wetlands, which were all built during the same year, had notable differences in plant variables. For example, the plant species diversity index for these five, same age wetlands ranged from 0.0702 (DOT D) to 0.6555 (DOT C) in 2001.

However, the two youngest created wetlands, Spall (3 years) and Tinker Created (2 years) had the highest and second highest plant species diversity, respectively, in both 2000 and 2001. A possible explanation for this may have to do with early successional processes that occur soon after a wetland is built. The creation of a wetland is a disturbance, after which secondary succession proceeds and many early pioneer species invade the area and establish themselves (Barbour et. al 1999, Mitsch and Gosselink, 2000). These pioneer species may contribute to an increase in plant diversity early in the life of a created wetland. Other plant species that follow are slower to establish but are more successful than the colonists and may out compete them, thereby reducing plant diversity.

There are 14 species of calling amphibians commonly found in the Great Lakes Basin (Chabot and Helferty 1995), however, I detected only seven in this study. Still, the seven amphibian species I found are the most widely distributed species in the Great Lakes Basin (Weeber and Vallianatos 2000). These species were all found at both created and natural wetlands in both years. There was no significant difference in amphibian richness between created and natural wetlands in both 2000 and 2001, in fact this variable was nearly identical between wetland types in both years. Robinson (2000) had similar results in her comparison of natural wetlands to restored wetlands in Jefferson County, New York, and

Petranka et al. (2003), in a long term study comparing created and natural wetlands in North Carolina, found that amphibian richness was higher in created wetlands.

While some studies have shown that amphibians tend to establish populations in created and restored wetlands rather quickly (Lehtinen and Galatowitsch 2001, Pechmann et al. 2001, Petranka et al. 2003), I found that created wetland age was not a significant factor affecting amphibian richness in either year. Similarly, Lehtinen and Galatowitsch (2001) comparing amphibian variables in restored and reference wetlands in Minnesota, found no significant relationship between amphibian richness and restored wetland age. It is likely that amphibian richness is more affected by the proximity and interconnectivity to other wetlands. Both of these factors affect the source-sink dynamics of metapopulations common in many amphibian species (Gibbs 1993, Semlitsch et al. 1996, Semlitsch 1998, Guerry and Hunter 2002, Gibbons 2003).

For nearly all avifaunal variables, the created wetlands of this study were comparable to natural wetlands. The only exceptions were in bird species diversity and in the proportion of obligate wetland birds. In both years, species diversity was slightly higher in natural wetlands while the proportion of obligate birds was higher in created wetlands (Tables 5 and 6). In 2001, the difference in diversity among the wetland types was not significant at an alpha of 0.05, but would be significant at 0.10. The presence of large flocks of Canada goose during a few survey periods contributed to the significant difference I found in obligate wetland bird species among the two wetland types. Reanalysis of these data without Canada goose changed the P value from 0.02 to 0.40.

There have been very few studies that have compared wildlife utilization of created and natural wetlands, and fewer still that have included avifaunal use. However, there have been a number of studies that looked at bird use in restored wetlands. Brown (1998) compared bird abundance and density in recently restored (3 years) and natural wetlands in upstate New York. He found no significant differences in either of these variables, but did find significant differences in percent similarity (Bray-Curtis) of bird communities between the wetland types. He suggested that over time successional development may minimize the differences found between restored and natural wetlands.

Hemesath and Dinsmore (1993) investigated bird usage of restored wetlands in Iowa and found that the age of the wetland had no effect on bird species richness, but that bird species richness increased with wetland area. VanRees-Siewert and Dinsmore (1996) found that the number of breeding bird species in four-year-old restored wetlands in Iowa were significantly higher than breeding species in one-year-old restored wetlands. However, they did not find a significant relationship between restored wetland age and total bird species richness. They suggested that breeding bird species were more affected by wetland area than plant characteristics in restored wetlands, and that total bird species richness was affected by vegetation structure and characteristics. According to VanRees-Siewert and Dinsmore (1996), long term wetland restorations will likely result in bird communities that are similar to natural wetlands due to the establishment over time, of similar vegetation characteristics.

Based on my data, I conclude there were no significant differences in plant, amphibian and bird variables between the created and natural wetlands included in my study. The question then becomes, - what factors might account for variation in response variables among wetlands? For example, plant species diversity values ranged from 0.0560 to 0.7557 for created wetlands and from 0.1734 to 0.7143 for natural wetlands. Because the created and natural wetlands in my study did not differ from one another in plant, amphibian and vegetation response variables, I combined the two categories of wetlands into a single group of 18 wetlands. I then examined the entire set of wetlands to determine which, if any predictor variables may have accounted for the variance in response variables among the wetlands.

Univariate and Multivariate Analyses of Biotic Response Variables

I found that open water class and watershed area were positive significant predictor variables for amphibian species richness, plant species richness and diversity, and bird species richness, diversity and the number of birds per census. Tables 7 and 8 summarize the regression analyses for this study.

Open water classification was positively associated with both plant species richness and plant species diversity using univariate analysis, the only negative significant relationship I found with open water class was with *T. latifolia* in both years (Table 8). Although open water class was not part of the best subset models for either plant species richness or plant species diversity in both years, it was part of the best subset models for the proportion of *T. latifolia*, amphibian species richness and the number of birds per census. Additionally, in 2000, this predictor was also part of the models for the proportion of OBL+FACW+FAC birds, and in 2001 it was a component of the models for bird species richness and bird species diversity (Tables 9 through 12).

The proportion of open water is related to the concentric zones of vegetation that form in marshes. The zonation of vegetation and the proportion of open water are affected by the depth and the topography of the wetland, and certainly by its hydrologic characteristics (Weller 1978). According to Mitsch and Gosselink (2000), plant species richness increases as the rate of water flow increases due to the transport and renewal of minerals and the deposition of sediments.

Watersheds are areas of land that drain into a particular body of water, and the functioning of a wetland is affected by its position within the watershed. Wetlands and other sources of water within a watershed are connected through hydrology, and so the functions of the wetlands within a watershed are also connected (Mitsch and Gosselink 2000). While a number of studies have investigated the effects of surrounding landscape properties on plant variables (Findlay and Houlahan 1997, Gibbs 2000, De Steven and Toner 2004, Houlahan et al. 2006), I found none that tested watershed area. I found significant positive relationships between plant species richness and plant diversity and watershed area. Watershed area may contribute to increased plant species richness and diversity because of hydrological connectivity to other wetlands and thus a source of propagules.

I found that plant species richness and plant species diversity increased with both increasing wetland area and with the area of other wetlands within 500 m of the focal wetland. The relationship between plant species richness and wetland size has been well documented (Findlay and Houlahan 1997, Weiher 1999, NRC 2001, Houlahan et al. 2006). and is not surprising. It also supports the thought that large wetlands overall have greater ecological value (Findlay and Houlahan 1997).

The relationship between plant species richness and diversity and the area of surrounding wetlands might be explained by the processes by which wetland ecosystems are developed and sustained. Proper hydrology is foundational to proper wetland function and to the establishment and continuance of wetland vegetation structure and composition (Mitsch and Gosselink 2000, NRC 2001). Keddy and Reznicek (1986) stated that fluctuations and variability in hydrology lead to increased plant diversity because most seeds will not germinate in standing water, rather they require moist soil. Moreover, the continuous introduction of seeds and propagules contribute to the successional processes and functional development of the wetland ecosystem. According to Mitsch et al. (1998), if a wetland is open to a continuous supply of seeds and propagules, it will naturally select the assemblage of organisms best adapted for the conditions at the wetland. This concept, described by Mitsch et al. (1998) is known as ecosystem self-design. The presence of other wetlands near a particular wetland may act as a source of seeds and propagules, assuming connectivity between wetlands, and thereby influence the plant species richness and diversity.

The amount of paved road surrounding wetlands was important in predicting invasive plant species variables. I found in both years, that invasive plant species richness was positively associated with the length of the road within the watershed, and that invasive plant species cover was positively associated with the percentage of industrial, commercial and urban land within 1 km of the wetlands. These positive associations suggest a relationship between invasive plant species and paved areas surrounding wetlands. The best subset models for invasive plant species variables also suggested an important relationship with paved area surrounding wetlands. The best subset models for both invasive plant species richness and invasive plant species cover, in both years, included distance to road and the percentage of industrial, commercial and urban land area within 1 km of the wetland.

Invasive plant species are good colonizers and tend to spread aggressively (Harper 1965, Rejmanek and Richardson 1996). Some invasive plant species, such as *Lythrum salicaria* and *Phragmites australis*, are salt tolerant and therefore are likely found in wetlands near roads where road salt runoff enters the wetland (Galatowitsch et al. 1999). Schultz (2006) examined the water quality in the wetlands of my study and found that as the length of roads within a 100 m buffer of the wetlands increased, sodium levels increased. The wetland Thruway is located adjacent to the highly traveled New York State Thruway, and was dominated in both years of the study by *Phalaris arundincea*. The second most common plant species at this wetland in both years was *Lythrum salicaria*. This suggests that the establishment of these two invasive plant species are more likely in wetlands located near roads that are salted during winter months.

Amphibians require both wetlands and uplands to complete their life cycle. Wetlands are required for reproduction and uplands are needed for migration, foraging and hibernation (Guerry and Hunter 2002). The requirement of amphibians for suitable terrestrial habitat surrounding wetlands and interconnectivity among wetlands has been well documented (Gibbs 1993, Semlitsch et al. 1996, Semlitsch 1998, Guerry and Hunter 2002, Gibbons 2003). In my study, the best subset model for amphibian species richness in 2001 included three variables; open water class, the proportion of *T. latifolia* and the percentage of forest within 1 km of the wetland. In addition, significant positive univariate relationships were found with plant species richness and diversity, watershed area. The significant relationship between amphibian species richness and the proportion of *T. latifolia* was negative.

Knutson et al. (1999) in a study of anuran abundance and richness in Iowa and Wisconsin, found positive relationships with habitat diversity and complexity. A number of studies have found that amphibian species richness increased with increased forest adjacent to the wetlands (Findlay and Houlahan 1997, Knutson et al. 1999, Lehtinen et al. 1999, Guerry and Hunter 2002). I found that the percentage of forest within 1 km of wetlands approached positive statistical significance ($P = 0.075$) in 2001 using linear regression, and was part of the best subset model in 2001. I also found that the relationship between amphibian richness and the percentage of agricultural land within 1 km of wetland in 2001 was negative and approached statistical significance (P = 0.058). Knutson et al. (1999) found a positive association between anuran abundance and surrounding agricultural land in Wisconsin, but not in Iowa. They suggest that the positive association found in Wisconsin may be due to greater proportion of forested land surrounding these wetlands than those studied in Iowa.

I did not find any significant associations between amphibian species richness and road length within the watershed or within a buffer surrounding the wetlands. However, Findlay and Houlahan (1997) did find a significant negative relationship between road density and amphibian richness. Carr and Fahrig (2001) found a negative relationship between amphibian richness and traffic density surrounding wetlands. Both of these studies suggest that the construction or presence of roads near wetlands may have significant negative effects on amphibian richness and diversity in wetlands.

The positive relationship between wetland area and bird species richness and composition has been well documented (Weller 1978, Brown and Dinsmore 1986, Hemesath and Dinsmore 1993, Hartman 1994, Brown 1995). I found no significant relationships between wetland area and either bird richness or bird species diversity using simple linear regression. However, in 2001, the best subset model for bird species diversity did include wetland area. The number of birds per census was positively associated with wetland area in both years using simple linear regression, but only the 2001 best subset model for number of birds per census contained wetland area. Larger wetlands likely support more bird species for a number of reasons. Large wetlands tend to have more zones of vegetation and, therefore, greater structural diversity. Also, there are more resources in the terms of space, food sources and water supply (Weller 1978, Hemesath and Dinsmore 1993, Naugle et al. 2000, Muir-Hotaling et al. 2002)

Plant species richness and plant species diversity were important positive predictors of bird species richness and bird species diversity in both years, and of the number of birds per census in 2001 (Tables 7 and 9). However, in 2001, these two predictors were not part of the best subset models for either bird richness or bird diversity, but were part of the three models for bird wetland dependency and the model for the number of birds per census (Tables 9 and 11). In addition, I found significant positive relationships between open water class and bird species richness, bird species diversity, the number of birds per census and the proportion of obligate birds in both years.

Weller (1978) described the vegetation of a marsh as series of concentric zones of plant communities surrounding an area of open water that creates horizontal structural diversity. The vegetative heterogenicity attracts a diversity of wildlife.
Layers of vegetation in the form of vegetation zones can increase the number of available niches, and therefore, positively influence the species diversity in a wetland (MacArthur 1958, Weller 1978). The open water in a wetland can be considered another layer and is attractive to waterfowl, especially near the vegetation-water edge. Moreover, many bird species prefer a 1:1 ratio of cover to water, called a "hemimarsh" (Weller and Spatcher 1965). Weller and Fredrickson (1974) found the proportion of open water in a wetland was positively associated with bird species richness, and that richness was greatest in wetlands that had a cover-water ratio of 1:1 or 1:2. Other studies have also found significant positive relationships between bird species richness and cover-water ratios (Kaminski and Prince 1981, Murkin et al. 1982, Nelson and Kadlec 1984, VanRees-

Siewart and Dinsmore 1996). However, in a study of bird use of restored wetlands in Maryland, Muir Hotaling et al. (2002) found no significant relationship between bird species richness and cover-water ratio. Hemesath and Dinsmore (1993) found that bird species richness was significantly higher in restored wetlands having more than 30% emergent vegetation, and that bird species richness was greatest in wetlands having 30 to 70% open water. The structural diversity created by plant community zonation in the wetlands likely affected bird richness and diversity because it offers a greater variety of habitats for nesting, protection and foraging.

Watershed area was positively associated with bird species richness and the number of birds per census in both years, and positively associated with bird species diversity in just 2000. In 2000, this predictor and the area of other wetlands within 500m were part of the best subset models for all three of these bird response variables. In 2001, watershed area and the area of other wetlands were part of the model for only the number of birds per census.

Populations of many wetland animals are dependent upon metapopulation source-sink dynamics, and those that move over land require connectivity between wetland habitats via open terrestrial corridors (Gibbs 1993, Semlitsch 2000). Obviously, birds are not limited by obstructed terrestrial corridors. However, some wetland birds require a variety of wetland types to complete their life cycles. Some serve as feeding habitat, while others are better suited for breeding, and still others are better suited for rearing young (Batt et al. 1989, Gibbs, 1993, Naugle et al. 2000, Leibowitz 2003). Gibbs (1993) simulated the loss of small wetlands in an area of Maine to investigate the effect on metapopulations of turtles, mammals, amphibians and birds. In his model, he found that turtles and birds were most likely to become extinct following the loss of small wetlands. He suggests that mosaics of small wetlands in the landscape play an important role in the metapopulation dynamics of certain wetland animals. In my study, the inclusion of the area of other wetland within 500 m of the focal wetland in the best subset models for bird response variables suggests the importance of a mosaic of wetland habitats within the landscape.

Management Recommendations and Future Research

There were two questions I attempted to answer in this study. The first was - are created wetlands similar to natural wetlands in terms of vegetation, amphibian and bird variables? In essence, this question asks can we create wetland habitats that mimic the wildlife utilization and plant characteristics found in similar natural wetlands? Based on the results of my study, the answer is yes. I found no significant differences among the two types of wetlands.

Many studies comparing created and natural wetlands have focused only on vegetation structure and composition. However, scientists warn that basing success on this single wetland function does not necessarily assure other wetland functions have been restored (D'Avanzo 1986, Turner 2000, NRC 2001, Campbell et al. 2002). Wetlands provide a number of functions and it is recommended that a more comprehensive set of these functions, including wildlife utilization, be part of the assessment procedures and requirements for mitigated wetlands.

Since the created and natural wetlands studied were not significantly different for any of the response variables, I grouped them into a larger set and addressed my second question - what accounts for the variation in vegetation, amphibian and bird variables detected among wetlands? Based on my results, the variation can be attributed primarily to the position of the wetlands within the landscape.

Wetland functions are affected by the surrounding landscape, therefore, the creation and subsequent management of wetlands must consider their placement within the watershed. Understanding the relationship between wetland function and landscape position is important in determining where in the landscape a mitigation project should be built.

Watershed area was an important positive predictor of many response variables. For example, species richness increased with increasing watershed area for all three groups of response variables (plants, amphibians and birds). However, I found no studies that compared wetland functions to watershed area. This is an important area for future research. Mitigation projects should be built in large watersheds.

Open water class and plant species diversity and richness were important positive predictors of bird and amphibian response variables. These predictors suggest the importance of a wetland's structural diversity in attracting a diversity of wildlife. Managers should create and maintain wetlands in a "hemimarsh" state, such that the cover to water ratio is between 1:1 and 1:2. In addition, efforts should be made to reduce the establishment and spread of *T. latifolia* within wetlands since this aggressive species can have a negative impact on plant species diversity, and hence structural heterogenicity.

Invasive plant species were positively correlated with the amount of paved road surrounding wetlands. I recommend that mitigation projects be located as far from roads and urban land use areas as possible to reduce the presence of invasive plant species.

Metapopulation dynamics are important for a number of wetland animals, including birds (Batt et al. 1989, Gibbs 1993, Naugle et al. 2000, Leibowitz 2003). Mitigation projects should be built within a mosaic of other wetlands to maintain the metapopulation dynamics, and importantly, there should be terrestrial connectivity to other wetlands for those animals that move over land.

In summary, wetland functions are affected by their position within the landscape and within the watershed. Therefore, it is important for project managers to carefully consider the placement of mitigation projects within the landscape. The results of my study suggest that mitigation projects should be located: 1) in large watersheds, 2) far from roads and urban areas and 3) near other wetlands. In addition, mitigation projects should have a cover to open water ratio of between 1:1 to 1:2 and be managed to reduce the spread of aggressive plant species such as *Typha latifolia*.

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Appendix A: Location of created - natural wetlands pairs.

Created Wetland (Age in yr 2000)	Longitude Latitude (approx. center)	Natural Wetland	Longitude Latitude (approx. center)
DOT A (6)	43.18182 77.82573	Smith	43.17909 77.83390
DOT B (6)	43.17701 77.79732	King Road	43.11404 77.77618
DOT C (6)	43.17569 77.76913	Golden Road	43.12209 77.75394
DOT D (6)	43.15979 77.72462	Blodgett	43.16151 77.74642
DOT E (6)	43.17727 77.78359	Morgenbergyer	43.17541 77.74390
Tinker Created (2)	43.06771 77.57345	Thruway	43.04705 77.56733
Roxbury (10)	43.06811 77.55619	Tinker Natural	43.05863 77.57000
Spall (3)	43.06447 77.56852	Round Pond	43.01929 77.56288
Mason (12)	43.07326 77.39960	Packard	*

Appendix B: Summary of plant species observed in created and natural wetlands. Species are listed alphabetically by scientific name.

Common Name	Scientific Name	Created Wetland	Natural Wetland
Algae		X	
Water plantain	*Alisma triviale*	X	X
Smooth aster	*Aster laevis*	X	X
New England aster	*Aster novae-angliae*	X	X
Bur marigold	*Bidens cernua*	X	
Fox sedge	*Carex vulpinoidea*	X	X
Water hemlock	*Cicuta bulbifera*	X	X
Swamp thistle	*Cirsium muticum*		X
Knob-styled dogwood	*Cornus amomum*		X
Red osier dogwood	*Cornus sericea*		X
Flatsedge	*Cyperus strigosus*	X	
Swamp loosestrife	*Decodon verticillatus*		X
Teasel	*Dipsacus sylvestris*		X
Blunt spikerush	*Eleocharis ovata*	X	
Creeping spikerush	*Eleocharis palustris*	X	
Waterweed	*Elodea canadensis*	X	
Purple-leaved willow-herb	*Epilobium coloratum*	X	
Norther willow-herb	*Epilobium glandulosum*	X	
Hairy willow-herb	*Epilobium hirsutum*		X
Common horsetail	*Equisetum arvense*	X	
Water horsetail	*Equisetum fluviatile*	X	
Scouring rush	*Equisetum hyemale*	X	X

Common Name	Scientific Name	Created Wetland	Natural Wetland
Harbinger-of-spring	*Erigenia bulbosa*		X
Hollow Joe Pye Weed	*Eupatorium fistulosum*		X
Purple boneset	*Eupatorium perfoliatum*		X
Sweet Joe Pye Weed	*Eupatorium purpureum*	X	
Marsh pennywort	*Hydrocotyle americana*	X	
Spotted touch-me-not	*Impatiens capensis*	X	X
Soft rush	*Juncus effusus*	X	
Duckweed	*Lemna minor*	X	X
Butter-and-eggs	*Linaria vulgaris*		X
Water horehound	*Lycopus americanus*	X	X
Bugleweed	*Lycopus virginicus*	X	X
Purple loosestrife	*Lythrum salicaria*	X	X
Wild mint	*Mentha arvensis*		X
Water milfoil	*Myriophyllum spicatum*	X	
Water nymph	*Najas spp*	X	
Sensitive fern	*Onoclea sensiblis*		X
Virginia creeper	*Parthenocissus quinquefolia*		X
Reed canary grass	*Phalaris arundinacea*	X	X
Common reed	*Phragmites australis*	X	X
Clearweed	*Pilea pumila*		X
Water smartweed	*Polygonum amphibium*	X	X
Cottonwood	*Populus deltoides*	X	
Floating pondweed	*Potamogeton natans*	X	
Sago pondweed	*Potamogeton pectinatus*	X	

Common Name	Scientific Name	Created Wetland	Natural Wetland
Sweet crab apple	*Pyrus coronaria*		X
Swamp rose	*Rosa palustris*		X
Curled dock	*Rumex crispus*		X
Broad-leaved arrowhead	*Sagittaria latifolia*		X
Weeping willow	*Salix babylonica*	X	
Peachtree willow	*Salix amygdaloides*	X	X
Chairmaker's rush	*Scirpus americanus*		X
Hardstem bullrush	*Scirpus acutus*	X	
Softstem bulrush	*Scirpus validus*	X	X
Common skullcap	*Scutellaria galericulata*		X
Meadow spikemoss	*Selaginella apoda*		X
Water parsnip	*Sium suave*		X
Bittersweet nightshade	*Solanum dulcamara*		X
Canada goldenrod	*Solidago canadensis*	X	X
Giant bur reed	*Sparganium eurycarpum*		X
Poison ivy	*Toxicodendron radicans*		X
Common Cattail	*Typha latifolia*	X	X
Stinging nettle	*Urtica dioica*		X
New England grape	*Vitis novae-angliae*		X

Appendix C: Summary of bird species observed in created and natural wetlands. Species are listed alphabetically by scientific name.

Common Name	**Scientific Name**	**Created Wetland**	**Natural Wetland**
Spotted sandpiper	*Actitis macularia*	X	
Red-winged blackbird	*Agelaius phoeniceus*	X	X
Wood duck	*Aix sponsa*		X
Mallard	*Anas platyrhynchos*	X	X
Great blue heron	*Ardea herodias*	X	X
Cedar waxwing	*Bombycilla cedrorum*		X
Canada goose	*Branta canadensis*	X	X
Green heron	*Butorides striatus*	X	X
Northern cardinal	*Cardinalis cardinalis*	X	X
American goldfinch	*Carduelis tristis*	X	X
Purple finch	*Carpodacus purpureus*		X
Killdeer	*Charadrius vociferus*	X	
Marsh wren	*Cistothorus palustris*	X	X
Common flicker	*Colaptes auratus*	X	X
American crow	*Corvus brachyrhynchos*	X	X
Blue jay	*Cyanocitta cristata*		X
Yellow-throated warbler	*Dendroica dominica*	X	X
Yellow warbler	*Dendroica petechia*	X	X
Gray catbird	*Dumetella carolinensis*	X	X
Willow flycatcher	*Empidonax traillii*	X	X
Wood thrush	*Hylocichla mustelina*	X	
Northern oriole	*Icterus galbula*		X

Common Name	**Scientific Name**	**Created Wetland**	**Natural Wetland**
Tree swallow	*Iridoprocne bicolor*	X	X
Belted kingfisher	*Mega ceryle alcyon*	X	X
Swamp sparrow	*Melospiza georgiana*	X	X
Song sparrow	*Melospiza melodia*	X	X
Black capped chickadee	*Parus atricapillus*	X	X
Pied-billed grebe	*Podilymbus podiceps*		X
Virginia rail	*Rallus limicola*	X	X
European starling	*Sturnus vulgaris*	X	X
American robin	*Turdus migratorius*	X	X
Eastern kingbird	*Tyrannus tyrannus*	X	X
Red-eyed vireo	*Vireo olivaceus*		X

Appendix D: Summary of amphibian species observed in created and natural wetlands. Species are listed alphabetically by scientific name.

Common Name	Scientific Name	Created Wetland	Natural Wetland
Green frog	*Rana clamitans*	X	X
Bullfrog	*Rana catesbeiana*	X	X
Spring peeper	*Pseudacris crucifer*	X	X
American toad	*Bufo americanus*	X	X
Gray tree frog	*Hyla versicolor*	X	X
Wood frog	*Rana sylvatica*	X	X
Chorus frog	*Pseudacris triseriata*	X	X
Northern leopard frog	*Rana pipiens*	X	X