# COMPARATIVE USE OF *PHRAGMITES AUSTRALIS* AND OTHER HABITATS BY BIRDS, AMPHIBIANS, AND SMALL MAMMALS AT LONG POINT, ONTARIO

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**ABSTRACT**

The recent expansion of an exotic genotype of *Phragmites australis* throughout many coastal wetlands of the lower Great Lakes has caused concern that it will reduce floral and faunal biodiversity. Few studies, however, have documented use of exotic *Phragmites* stands by wildlife. I surveyed birds, amphibians, and small mammals in various stand sizes of *Phragmites*, *Typha* spp., and marsh meadow at Long Point, Lake Erie, Ontario during 2001 and 2002. Avian point counts showed that stands of exotic *Phragmites* had fewer rails, waterfowl, and breeding Swamp Sparrows (*Melospiza georgiana*) than did stands of *Typha* or marsh meadow. Large stands of exotic *Phragmites*, however, had a high abundance of Red-winged Blackbirds (*Agelaius phoeniceus*) and Common Yellowthroats (*Geothlypis trichas*) and provided habitat for Least Bitterns (*Ixobrychus exilis*), swallows (Family Hirundinidae), juvenile Swamp Sparrows, and Marsh Wrens (*Cistothorus palustris*). Use of exotic *Phragmites* by Virginia (*Rallus limicola*) and Sora Rails (*Porzana carolina*) was limited to stand edges. Stand interiors of exotic *Phragmites* were used by Red-winged Blackbirds, Common Yellowthroats, and Tree Swallows (*Tachycineta bicolor*). Stands of exotic *Phragmites* did not affect migrating birds and may provide winter shelter for Black-capped Chickadees (*Poecile atricapillus*), American Tree Sparrows (*Spizella arborea*), and Dark-eyed Juncos (*Junco hyemalis*). Pitfall traps showed that Fowler's Toads (*Bufo woodhousii fowleri*) did not use large stands of exotic *Phragmites* and use by Northern Leopard Frogs (*Rana pipiens*) was limited. Small stands of exotic *Phragmites* had more amphibians [primarily juvenile toads (*Bufo* spp.)] than did small stands of *Typha* and marsh meadow in mid-summer. Interior traps in large stands of exotic *Phragmites* had fewer amphibians than did edge traps in *Phragmites* and traps in *Typha* and marsh meadow. Species richness of amphibians, however, was similar in all three habitats. Overall, all small stands, regardless of habitat type, had more individuals and higher species richness of amphibians than did large stands. Although only four species of small mammals were captured, large stands of exotic *Phragmites* had higher abundance and species richness of small mammals than did large stands of *Typha* and marsh meadow. Continued expansion of large stands of exotic *Phragmites* in coastal marshes at Long Point may negatively affect Swamp Sparrows, rails, waterfowl, Northern Leopard Frogs, and Fowler's Toads, but may benefit Least Bitterns, Red-winged Blackbirds, warblers (Family Parulidae), Meadow Voles, and shrews (Family Soricidae). However, given the current distribution of exotic *Phragmites* stands at Long Point and its current rate of expansion (50 % per year), management options may be warranted in order to preserve habitat heterogeneity. I recommend that studies designed to investigate use of *Phragmites* by vertebrates, particularly waterfowl, rails, bitterns, Fowler's Toads, Green Frogs, and Bullfrogs, be conducted during higher water levels. These studies, in conjunction with a management strategy focused on interspersion of habitats, will maintain wetland integrity at Long Point and increase understanding of the effects of *Phragmites* expansion on these animals.

Key words: avian, amphibian, bird, cattail, Common Reed, exotic, frog, Long Point, marsh meadow, marsh obligate, marsh user, *Phragmites australis*, pitfall trap, point count, Reed, small mammal, toad, *Typha*, waterfowl.

## CO-AUTHORSHIP

Dr. S.A. Petrie will be given second co-authorship on all published manuscripts from the major chapters of this thesis. Scott provided advice on all aspects of this project, reviewed and commented on earlier drafts of this thesis, and provided financial support for this research through the Long Point Waterfowl and Wetlands Research Fund. Dr. C.D. Ankney will be given third co-authorship on all published manuscripts from the major chapters of this thesis. Dave provided advice on study design, reviewed earlier drafts of this thesis, and provided financial assistance during the preparation of this thesis.

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# CHAPTER 1. GENERAL INTRODUCTION

## 1.1. OVERVIEW

### *1.1.1. Importance of wetlands to wildlife*

Wetlands are among the most important and productive ecosystems on Earth (Mitsch and Gosselink 1993). They are essential in hydrological and chemical cycles, and because of their unique position within the transitional zone between aquatic and terrestrial habitats support a rich diversity of flora and fauna (Mitsch and Gosselink 1993). This mosaic of plants and animals, in conjunction with a concentrated food supply (Lack 1968), creates a highly productive food web. Consequently, some of the most important breeding and staging habitats for wildlife exist within wetlands.

It is estimated that close to 80 % of breeding birds in North America rely on wetlands during at least one stage of their life cycle (Wharton et al. 1982). Many amphibians and reptiles depend on wetlands throughout their life cycle (Herdendorf 1992, Weller 1999) and are among vertebrate components of wetland ecosystems (Dodd and Cade 1998). Similarly, semi-aquatic mammals such as Muskrats (*Ondatra zibethicus*) and American Beavers (*Castor canadensis*) reside in wetlands and contribute to the productive and dynamic nature of this ecosystem (Clark 1994, Kurta 1995). Wetlands provide foraging habitat for many mammalian predators, such as Mink (*Mustela vison*), Common Raccoons (*Procyon lotor*), and Red Foxes (*Vulpes vulpes*) and provide protective cover and shelter for White-tailed Deer (*Odocoileus virginianus*) and many small mammals (Ward 1942, Kucera 1974, Glooschenko and Grondin 1988, Kurta 1995). Wetlands also provide important habitats for many endangered and threatened birds, amphibians, reptiles, and plants (Mitsch and Gosselink 1993).

There are more than 125 million ha of wetlands in Canada (Zoltai 1988) with the greatest concentration in the provinces of Manitoba (22.5 million ha) and Ontario (29.2 million ha) (National Wetland Working Group 1988). Along Lake Erie and Lake St. Clair, there are an estimated 19,306 ha of coastal wetlands (Smith et al. 1991). Because of their geographical position (between Arctic, prairie, and boreal forest breeding areas and Gulf and Atlantic coast wintering areas), these coastal wetlands provide some of the most important habitat for wetland dependent wildlife in southern Canada (Dennis et al. 1984).

Long Point, Lake Erie, is the most significant coastal wetland in southern Ontario based on size and bird use (Dennis et al. 1984, Glooschenko and Grondin 1988, Petrie 1998). The wetlands of Long Point provide vital spring and fall staging habitat for thousands of waterfowl as well as neotropical songbirds (Hummel 1981, Dennis et al. 1984, Petrie 1998). These coastal wetlands also provide important habitat for at least 12 bird species of conservation concern; four that are listed as endangered and three that are threatened (COSEWIC 2002). Presently, there are 10 species of herptiles and 7 plant species found on Long Point that are classified as endangered, threatened, or of "special concern", by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002).

*1.1.2. Loss and degradation of lower Great Lakes wetlands*

Despite their ecological importance, the loss of north-temperate wetlands has occurred at a rapid rate. Many coastal wetlands of the lower Great Lakes have been drained and developed with some areas, such as the western shore of Lake Erie, having lost more than 95 % of its wetlands (Herdendorf 1987). In southern Ontario, over 60 % of pre-European settlement wetlands have been lost, with some areas having lost more than 80 % (Snell 1987). Intensive pressure from competing land uses, such as agriculture, urbanization, and industry, have caused increased wetland fragmentation and loss (Herdendorf 1992). Many remaining wetlands also continue to be compromised. Anthropogenic stressors, such as sedimentation, and nutrient and contaminant loading (Miles et al. 1976, Murdoch 1981, Downey et al. 1994) have altered chemical and hydrological cycles. Increased dredging and recreational use (Herdendorf 1992, Knapton et al. 2000) have also degraded the quality of coastal wetland habitats by altering edaphic conditions as well as floral diversity (Marks et al. 1994). Therefore, the ecological functioning of remaining wetlands should be monitored and evaluated in order to preserve the biodiversity of wetland dependent wildlife.

*1.1.3. Exotic introductions into the Great Lakes*

After habitat loss, the introduction of exotic species is thought to be the leading cause of ecosystem degradation in North America. Invaders are often excellent colonizers and competitors due to their higher survivability in unfavorable conditions, adaptability to new environments, high reproductive capacity, and presence of few predators (Mills et al. 1993, Mackie 2001). Consequently, many invaders are difficult to remove once established (Harper 1965) and the native flora and fauna of an invaded ecosystem often experiences intense competition from these rapidly expanding populations.

Of the 139 non-indigenous aquatic species identified as established in the Great Lakes since the early 1800s, 59 are plants, 28 are invertebrates, 25 are fish, 24 are algae species, and 3 are disease pathogens (Mills et al. 1993). The invasion of exotic species, such as Purple Loosestrife (*Lythrum salicaria*) (Thompson 1987), Eurasian Milfoil (*Myriophyllum spicatum*) (Knapton and Petrie 1999), Zebra Mussels (*Dreissena polymorpha*) (MacIsaac et al. 1992, Dermott et al. 1993), and Common Carp (*Cyprinus carpio*) (Mills et al. 1993), have had an impact on habitat quality as native flora and fauna are displaced. Colonization by these exotic species may also disrupt the biological integrity of the invaded wetland as food webs are altered because of increased competition and changes in floral diversity (Meyerson et al. 2000, Pimentel et al. 2000). These changes may then alter the ecological function of wetland ecosystems as some wetland dependent species are displaced.

Recently, a new threat among plant species has been identified – cryptic invasions of a non-native genotype (Carlton 1996, Saltonstall 2002). Cryptic invasions involve a foreign genotype of a native plant species which is morphologically similar but biologically (i.e. reproductive potential) very different from the native genotype. Consequently, they are a concern as rapidly expanding populations are often unnoticed. Management or control programs may be controversial because of similarities between native and exotic genotypes. Different vegetative characteristics of the exotic genotype, however, such as growth, density, and litter accumulation can alter ecosystem functioning through increased competition (Rice et al. 2000) and changes in food web structure. Recently, genetic analyses of *Phragmites* haplotypes have confirmed a European genotype of *Phragmites australis* as exotic in North America (Saltonstall 2002).

## 1.2. STUDY ORGANISM

### *1.2.1. Ecology of Phragmites australis*

*Phragmites australis* (Cav.) Trin. ex. Steudel (hereafter referred to as *Phragmites*) has many common names including Common Reed, Reed-grass, Giant Reed, Reed, *Phragmites*, and Flag Reed (Haworth-Brockman 1987, Kiviat 1987). *Phragmites* is a colony-forming grass that thrives in brackish and freshwater environments (Marks et al. 1994). It has a cosmopolitan distribution and typically grows in wetland-upland interfaces of marshes, swamps, fens, and prairie potholes (Roman et al. 1984, Kiviat 1987), where it competes with other wetland plants including species in the genera: *Spartina*, *Carex*, *Nymphaea*, *Typha*, *Glyceria*, *Juncus*, *Myrica*, *Triglochin*, *Calamagrostis*, *Galium*, and *Phalaris* (Howard et al. 1978).

*Phragmites* may colonize newly opened sites by perennial horizontal stems (rhizomes) or by seeds dispersed by wind or birds (Kiviat 1987, Marks et al. 1994). Once established, *Phragmites* predominately spreads through vegetative reproduction at the expense of other marsh plants (Kiviat 1987, Buck 1995, Marks et al. 1994, Wilcox et al. submitted) often forming dense monotypic stands (Marks et al. 1994). The dense mats of rhizomes, extensive buildup of reed litter, high plant height, and high stem density within stands may discourage competitors by shading, crowding, and inhibiting seed germination of other plants (Jones and Lehman 1987, Rice et al. 2000). Therefore, *Phragmites* may cause ecological problems in areas where stands are rapidly expanding and reducing the availability of native plant communities.

### *1.2.2. History of Phragmites invasion*

Fossil records show that *Phragmites* has existed in southwestern North America for over 40,000 years (Hansen 1978) and along the Atlantic and Pacific coasts for several thousand years (Niering and Warren 1977). Over the last 150 years, however, *Phragmites* has expanded rapidly along the Atlantic coast of North America and the upper Midwest of the United States (Marks et al. 1993). For example, between 1973 and 1994, *Phragmites* spread in brackish *Typha*-dominated marshes at a rate of 3 % increase in area per year and in brackish short-grass meadows at a rate of 1% per year along the Connecticut River (Buck 1995). Within the last 10 years, *Phragmites* has also expanded rapidly throughout the lower Great Lakes. For instance, between 1995 and 1999, stands of *Phragmites* expanded at a rate of 50 % per year, primarily displacing *Typha* and marsh meadow vegetation at Long Point, Ontario (Wilcox et al. submitted).

Evidence suggests that an exotic genotype, introduced within the last 200 years, is responsible for the expansion of *Phragmites* (Rice et al. 2000, Saltonstall 2002, Wilcox et al. submitted). Genetic and morphological studies indicate that most *Phragmites* stands at Long Point, Ontario are of this exotic genotype of *Phragmites* (Saltonstall 2002, Wilcox et al. submitted). However, warmer, drier climatic conditions (Zemlin et al. 2000), changes in hydrologic regimes, and disturbances, such as increased runoff, dredging, pollution, eutrophication, and high soil salinity may also have contributed to the recent rapid expansion of *Phragmites* in North America (Kiviat 1987, Marks et al. 1994, Rice et al. 2000).

### *1.2.3. Ecological benefits of Phragmites*

*Phragmites* can be a natural component of a healthy wetland community (Ward 1942, Marks et al. 1994, Benoit and Askins 1999). Successionally, it is often the first colonizer of inhospitable or recently disturbed habitats and therefore provides valuable wildlife habitat (Rice et al. 2000). It also prevents degradation of exposed soils due to erosion and fluctuating water levels (Rice et al. 2000). Its characteristic monotypic stands retain abundant litter which provides habitat for some species of birds, invertebrates, small mammals, amphibians, and reptiles (Marks et al. 1994, Meyerson et al. 2000). For example, the aerial stems provide habitat for Marsh Wrens (*Cistothorus palustris*), Red-winged Blackbirds (*Agelaius phoeniceus*), and Swamp Sparrows (*Melospiza georgiana*) (Benoit and Askins 1999), and in Europe, *Phragmites* is the primary habitat of four rare birds; Marsh Harrier (*Cirus aeruginosus*), Bittern (*Botaurus stellaris*), Bearded Tit (*Panurus biarmicus*), and Savi's Warbler (*Locustella lusciniodes*) (Bibby and Lunn 1982). There is anecdotal evidence that Song Sparrows (*Melospiza melodia*) consume *Phragmites* seeds and at least one *Phragmites* insect (*Chaetococcus phragmitidis*) is sought by Black-capped Chickadees (*Parus atricapilla*) and other small birds (Kiviat 1987). In Europe, emerging *Phragmites* shoots are grazed by Greylag Geese (*Anser anser*) whereas the stems provide roosting and nesting cover for many bird species (Hudec and Stastny 1978, Bibby and Lunn 1982, Barbraud et al. 2002).

The extensive reed litter produced from the dead culms of *Phragmites* provides habitat and food (detritus) for some invertebrate species (Lopez et al. 1977, Rietsma et al. 1988, Angradi et al. 2001). Rice et al. (2000) found that dead culms provide protection for many invertebrate species in winter and enables them to withstand cold temperatures. Benoit and Askins (1999) also noted that *Phragmites* stands provide protection for invertebrates against some large, avian predators because the density of the vegetation impedes avian accessibility. *Phragmites* also provides escape cover, shelter, and food for Muskrats (Lynch et al. 1947) and White-tailed Deer (Ward 1968, Kucera 1974).

*1.2.4. Ecological detriments of Phragmites*

Although stands of *Phragmites* provide important habitats for several wildlife species in Europe (Hudec and Stastny 1978, Pelikan 1978, Bibby and Lunn 1982, Barbraud et al. 2002) and at least some in North America (Kucera 1974, Benoit and Askins 1999), many biologists in North America suggest that large, monotypic stands of *Phragmites* are impoverished environments with relatively low vertebrate biodiversity (Ward 1942, Jones and Lehman 1987, Kiviat 1987, Benoit and Askins 1999). Benoit and Askins (1999) concluded that some birds generally avoided the dense interior of large stands of *Phragmites*; open pools of water within stands also received limited use by some birds. This may be due to the height and density of *Phragmites* stands making potential food resources and cover inaccessible (Benoit and Askins 1999). *Phragmites* stands may also reduce important edge habitat when they occur between the interface of marsh embankments and open water (Benoit and Askins 1999).

*Phragmites*, through its growth habits and vegetative characteristics, outcompetes many native plants by shading, crowding, and inhibiting seed germination (Jones and Lehman, 1987, Rice et al. 2000). With the rapid colonization of the exotic genotype of *Phragmites* in North America, many wetland ecosystems are changing from a mosaic of habitats to monotypic environments with relatively low floral diversity (Ward 1968, Marks et al. 1994). If large stands of *Phragmites* are in fact impoverished with respect to wildlife use, then this low plant species richness and corresponding low habitat heterogeneity has the potential to impact wildlife biodiversity.

The effect of expanding stands of *Phragmites* on wildlife in freshwater ecosystems in North America has not been adequately investigated. This lack of information is a fundamental concern due to the rapid expansion of *Phragmites* stands throughout the lower Great Lakes region (Wilcox et al. submitted). A reduction in plant biodiversity is inevitable if endemic plant species are replaced by a more cosmopolitan species (Chambers et al. 1999). This is particularly true where stands of exotic *Phragmites* are colonizing areas that previously supported a diverse assemblage of emergent and submergent aquatic plant species. As other wetland plants, such as *Vallisneria*, *Potamogeton, Carex, Scirpus*, *Juncus*, *Spartina*, and *Typha* are replaced, food availability and habitat for waterfowl and other wetland dependent species may be reduced (Petrie 1998, Benoit and Askins 1999, Wilcox and Petrie 2000).

**1.3. STUDY AREA**

Long Point, Ontario, is a 35 km sand spit extending into the eastern basin of Lake Erie (80°30' E, 42°35' N to 80°03' E, 42°33' N) (Figure 1.1). The spit partially encompasses and protects a 72 $km^2$ shallow bay from the destructive wave action of Lake Erie. The spit, in conjunction with heavy sedimentation from water currents, has facilitated the formation of 24,000 ha of marsh habitat. For more detailed information regarding Long Point and its surrounding areas, refer to Petrie (1998) or Knapton and Petrie (1999). Because of its geographical location (between Gulf and Atlantic coast wintering areas and Arctic, prairie, and boreal forest breeding areas) as well as its rich diversity of aquatic habitats, it is one of the most important areas for wetland dependent birds in southern Canada (Dennis et al. 1984). Against this background of superlatives, Long Point and its associated wetlands were designated as a World Biosphere Reserve by UNESCO and a Globally Important Bird Area by Birdlife International and the North American Commission for Environmental Cooperation. It is also listed as a wetland of global importance under the Ramsar Convention on Wetlands of International Importance.

Aerial interpretation and digitizing of emergent vegetation at Long Point was completed by the Long Point Waterfowl and Wetlands Research Fund in 1999 (Wilcox et al. submitted). Results indicated that The Long Point Company had the most extensive stands of *Phragmites* but expansion of *Phragmites* was also occurring within the Long Point Wildlife Management Unit. Therefore, this study was conducted within the 2,661 ha wetland complex owned by The Long Point Company and within the 566 ha Long

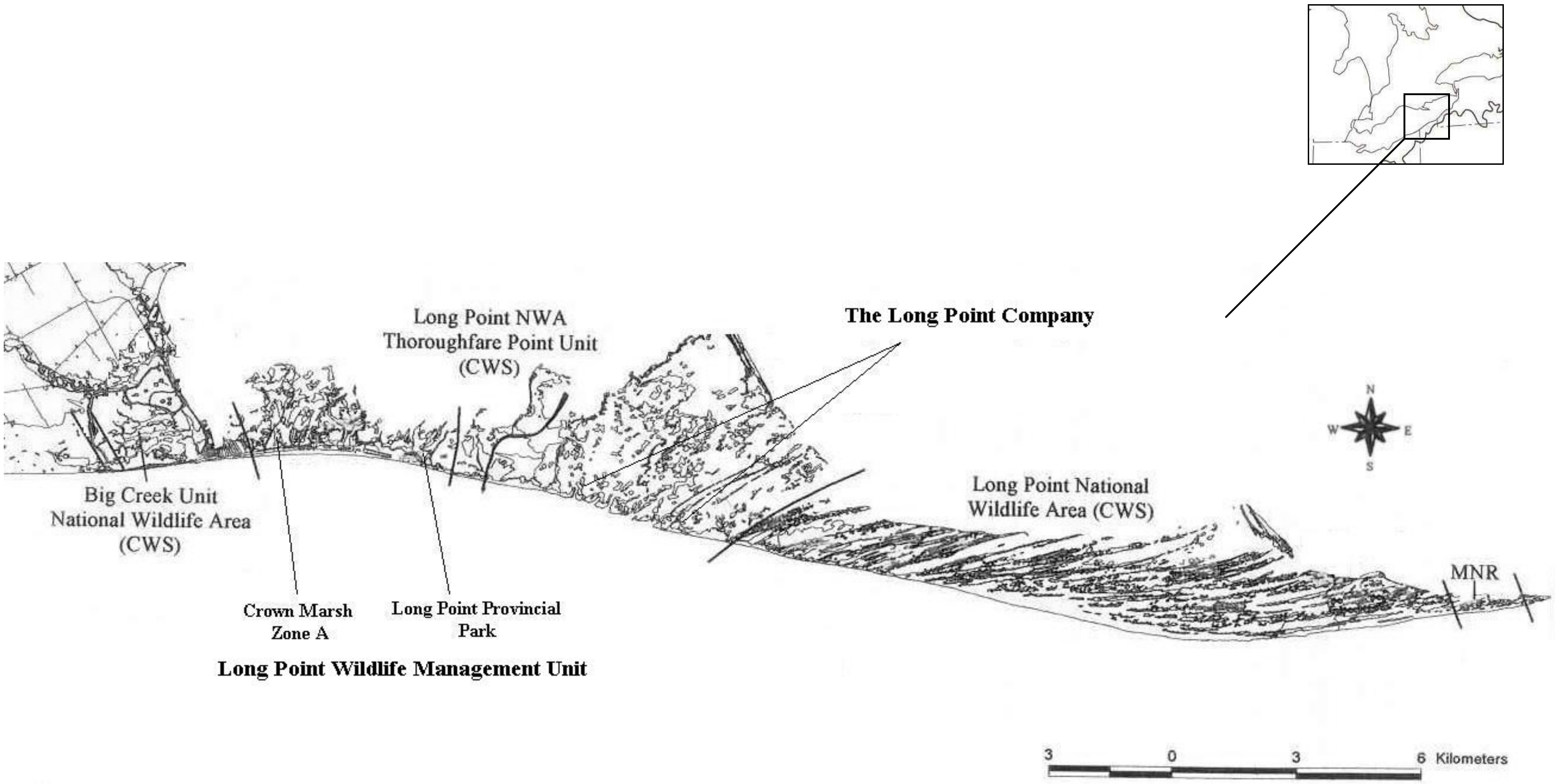


Figure 1.1. Long Point, Lake Erie, ON, showing locations of the Long Point Wildlife Management Unit and The Long Point Company.

Point Wildlife Management Unit (Zone A) which encompasses the Crown Marsh and portions of the Long Point Provincial Park (Figure 1.1).

## 1.4. HYPOTHESIS AND OBJECTIVES

My primary objective was to determine if *Phragmites* stands of various sizes compromise the integrity of Long Point's wetlands for vertebrates other than fish. My hypothesis was that *Phragmites* stands would have lower vertebrate biodiversity compared to similar sized stands of plant communities that are being replaced at Long Point. My specific objectives were: 1/ to investigate avian use of *Phragmites*, *Typha* spp., and marsh meadow habitats in relation to stand size (area) and 2/ to compare use of *Phragmites*, *Typha* spp., and marsh meadow habitats by amphibians and small mammals in relation to stand size (perimeter).

My secondary objective was to establish the distribution of the native versus exotic genotype of *Phragmites* at Long Point, Ontario. By comparing vertebrate diversity in these habitats relative to stand size and genotype, my data will help determine if expanding stands of the exotic genotype of *Phragmites* are compromising the integrity of these wetlands for wildlife. Therefore, this study will build a foundation for future management decisions pertaining to exotic *Phragmites* at Long Point, Ontario. Finally, this study has potential significance for all wetlands on the Lower Great Lakes where stands of the exotic genotype of *Phragmites* are expanding.

## 1.5. SCOPE OF THESIS

This thesis is organized into four chapters. Chapter One outlines the importance of coastal wetlands on the Great Lakes for wildlife and provides information on the loss and degradation of these habitats. The first chapter also introduces the study, discusses threats to wetlands on the lower Great Lakes, and provides background information on the study organism and study area. Lastly, it outlines my research hypothesis, objectives, and potential management implications of my research. Chapter Two compares the seasonal (spring, summer, fall, and winter) use of *Phragmites australis*, *Typha* spp., and marsh meadow habitats by birds at Long Point, ON. Chapter Three investigates the comparative use of *Phragmites australis*, *Typha* spp., and marsh meadow habitats by amphibians and small mammals at Long Point. Chapters Two and Three are written in manuscript format. Chapter Four outlines the major conclusions of the study, synthesizes my findings, and presents possible management implications. Eight appendices are included that list the Global Positioning System coordinates (GPS) and habitat types of all avian sample stations, maximum auditory distances recorded in each habitat type during 2001, all incidental observations of birds, herptiles, and mammals and the candidate set of AIC models used in the analysis of data in Chapters Two and Three.

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# CHAPTER 2. COMPARATIVE USE OF *PHRAGMITES AUSTRALIS, TYPHA* SPP., AND MARSH MEADOW HABITATS BY BIRDS AT LONG POINT, ONTARIO.

## 2.1. INTRODUCTION

During the past 200 years, over 60 % of wetlands in southern Ontario have been lost, with some areas of high human density having lost more than 80 % (Snell 1987). Although rates of wetland loss have decreased in the last few decades (Mitsch and Gosselink 1993), many remaining wetlands continue to be degraded by human activities, such as dredging, eutrophication, sedimentation, pollutants, altered hydrological regimes, and introduction of exotic species (Roman et al. 1984, Crowder and Bristow 1988, Herdendorf 1992). As of 1993, 139 exotic aquatic species were identified as established in the Great Lakes since the early 1800s (Mills et al. 1993). These exotic species may have surpassed habitat loss as the primary cause of wetland degradation. For instance, Zebra Mussels (*Dreissena polymorpha*) (MacIsaac et al. 1992, Dermott et al. 1993) and Purple Loosestrife (*Lythrum salicaria*) (Thompson 1987) have altered the ecological integrity of some coastal wetlands by disrupting food webs and displacing native flora. Therefore, evaluating the ecological impact of exotic species is an important step in maintaining the biodiversity of these ecosystems.

*Phragmites australis* (Cav.) Trin. ex Steudel (hereafter referred to as *Phragmites*) is a large, perennial rhizomatous reed that grows in aquatic, semi-aquatic, and terrestrial habitats (Kiviat 1987, Marks et al. 1994). Although *Phragmites* has been in North America for at least 3000 years (Niering and Warren 1977), an exotic genotype from Europe has been introduced into eastern North America sometime within the last century (Saltonstall 2002). This introduction, in conjunction with many large scale disturbances, such as increased dredging, sedimentation, pollution, salinity, temperatures, and altered hydrological regimes (Roman et al. 1984, Kiviat 1987, Marks et al. 1994, Meyerson et al. 2000, Zemlin et al. 2000) has favored the rapid expansion of *Phragmites*. For instance, between 1973 and 1994, *Phragmites* expanded at a rate of 3 % per year in *Typha*-dominated marshes and by 1 % per year in brackish short-grass meadows along the Connecticut River (Buck 1995). At Long Point, Ontario, *Phragmites* stands increased exponentially (50 % per year) between 1995 and 1999, primarily replacing *Typha* spp. and marsh meadow vegetation (Wilcox et al. submitted). Because of this rapid expansion and its aggressive growth and vegetative characteristics (Jones and Lehman 1987, Rice et al. 2000), the formation of large stands of *Phragmites* may be problematic for some birds. Structural changes, such as increased stand height, density, and litter accumulation (Kiviat 1987, Marks et al. 1994), in conjunction with associated changes in hydrological regimes and nutrient cycling (Ward 1942, Chambers et al. 1999, Meyerson et al. 2000), may lower floral diversity by shading, crowding, and inhibiting seed germination of other plants (Jones and Lehman 1987, Rice et al. 2000). Similarly, faunal diversity may decline due to effects of these structural changes on the penetrability of stand interiors (Ward 1942, Benoit and Askins 1999, also see Meyerson et al. 2000). This low diversity of plants and altered wetland environment may displace some populations of birds. For instance, as *Phragmites* replaces marsh meadow (Buck 1995, Wilcox et al. submitted), some birds, such as rails and waterfowl, as well as some endangered, threatened, or species of "special concern" may be displaced (Ward 1942, Benoit and Askins 1999).

Few studies have assessed use of *Phragmites* by breeding birds in North America (but see Benoit and Askins 1999) and use of *Phragmites* by migrating and overwintering birds has not been investigated. Therefore, the main objectives of this study were: 1/ to determine if *Phragmites* stands of various sizes have lower avian abundance and species richness than do similar sized stands of plant communities that are being replaced by *Phragmites* at Long Point, Ontario, and 2/ to determine if the *Phragmites* stands where I did my research were composed of the native or exotic genotype. By determining avian abundance and species richness in these habitats and in various stand sizes, this study will help determine if the expansion of *Phragmites* is compromising the integrity of coastal wetlands on the lower Great Lakes for marsh birds.

## 2.2. STUDY DESIGN AND METHODOLOGY

### *2.2.1. Sample Stations*

This study was conducted in the Crown Marsh, Long Point Provincial Park, and The Long Point Company at Long Point, Lake Erie, Ontario. Study areas were selected using aerial photographs and were based on the size of *Phragmites* stands and accessibility. Three marsh habitats were chosen, 1/ *Phragmites*, 2/ *Typha* spp., and

3/ marsh meadow. These habitats were chosen because they are the primary habitats being replaced by *Phragmites* at Long Point (Wilcox et al. submitted). Sample stations were placed within these habitats using the following criteria. Stations on the marsh perimeter were placed at least 50 m inside the habitat edge to ensure that surveys occurred within marsh vegetation. A compass bearing was then taken running parallel to the marsh edge and 250 m was paced off between stations. This distance ensured independence among stations and thereby limited recounting of birds (Bird Studies Canada 1997). To survey habitats in the marsh interior, a compass bearing was taken running perpendicular to the first line of sample stations and 250 m was paced off. Subsequent stations were then randomly placed along a line running parallel to the first row but separated by at least 250 m.

During late April / early May 2001, 55 sample stations were marked with flagging tape and 2.6 m wooden posts and their positions were recorded with a Global Positioning System (GPS) (Appendix 1). In 2001, sample stations consisted of 16 in *Phragmites*, 16 in *Typha* spp., and 18 in marsh meadow (total 50). (Five sample stations were classified as mixed vegetation in 2001 and therefore were not analyzed). In 2002, sample stations consisted of 18 in *Phragmites*, 13 in *Typha* spp., and 24 in marsh meadow (total 55). Unbalanced numbers of sample stations were due to random placement of stations in the marsh and to vegetation changes between years.

Each sample station consisted of an observation, or focal point, where bird surveys were conducted within a circular survey area of 25 m radius (Figure 2.1). This fixed radius was chosen to standardize sampling effort among habitats and was determined by recording maximum auditory distances in each habitat (Appendix 2). At the beginning of every survey month, maximum auditory distances for each habitat were recorded by broadcasting selected marsh bird songs, [American Bittern (scientific names of birds are in Table 2.01, Table 2.07, Table 2.10, and Table 2.13), Virginia Rail, Sora Rail, Marsh Wren, Common Yellowthroat, Song Sparrow, Swamp Sparrow, and Red-winged Blackbird] with a tape recorder into the vegetation. My assistant was situated in the habitat on a stepladder. Tape broadcasting occurred perpendicular to him and songs were broadcast at the same volume in each habitat. I approached the assistant until a bird song was clearly audible (i.e. distinguishable) at which point the distance was measured.

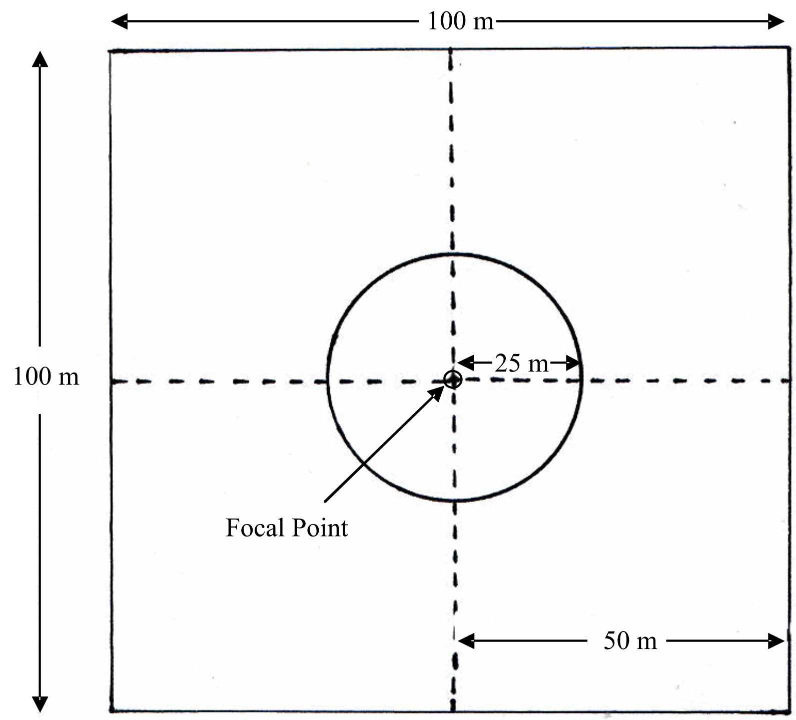



Figure 2.1. Sample station consisting of a focal point and a circular survey area with 25 m radius.

From these distances, it was determined that a sampling radius of 25 m would survey the calls of all birds in *Phragmites* vegetation.

*2.2.2. Point Counts*

Each point count (bird survey) was conducted on a 1.5 m step ladder because vertical dimensions of the habitats differed. Therefore, by elevating the observer above the vegetation among habitat differences in visual detectability were reduced. Each station was sampled six times between 1 May and 31 July in 2001 and 2002, two times between 30 September and 15 November in 2001, two times between 1 January and 15 February in 2002, and once between 1 April and 15 April in 2002, with a minimum of 10 days between surveys. This sampling schedule was designed to focus on breeding birds. Tozer (2002) concluded that four point counts per sampling station were required to detect 85% of wetland bird species during the breeding season. Therefore, I concluded that my sampling methodology was adequate to detect at least 85 % of breeding species.

Surveys began at sunrise (EST) and were finished by 1030 AM (Riffell et al. 2001). Each survey lasted for 10 minutes. Late spring and summer surveys consisted of 5 minutes of song broadcasting for secretive species [Virginia Rail, Sora, Least Bittern, Pied-billed Grebe, and a combination of Common Moorhen / American Coot (*Fulica americana*)] followed by 5 minutes of listening and observing. Song broadcasting consisted of 30 seconds of calls for each species followed by 30 seconds of silence (Bird Studies Canada 1997). The broadcast tape was played at full volume with two independent speakers directed into the study area in opposite directions. Fall, winter, and early spring surveys consisted of 10 minutes of listening and observing because call-response surveys are only useful for monitoring breeding birds (Swift et al. 1988, Gibbs and Melvin 1993).

All birds seen or heard within the sampling diameter during the 10 minute survey were recorded (Peterson 1980, National Geographic: Birds of North America 1999, Hughes 2001). To ensure that all recorded birds were within the survey area, landmarks were established by pacing off 25 m from the focal point; some birds observed on the periphery were measured with a range finder. Each bird observed or heard was assigned to one of the following categories:

1) Mapped Observations: birds that were observed in the vegetation of the sampling area during the 10 minute survey (Bird Studies Canada 1997).
2) Aerial Foragers: birds that were observed foraging in the sampling area and visually estimated at no higher than 100 m in the air during the 10 minute survey (Bird Studies Canada 1997).
3) Additional Observations: birds that were detected during the 10 minute survey but that were outside the sampling area.

Data from Mapped Observations and Aerial Foragers were used in subsequent analyses. Data from Additional Observations were presented but not used in analyses because sampling effort was not standardized (i.e. birds were observed outside the 25 m sampling area).

Abundance values were conservatively recorded based upon bird movement. For instance, if a second detection of a bird of a given species was within 10 m of the initial detection, this individual was considered to be the same bird unless two or more individuals were seen or heard in the same vicinity (Zimmerling and Ankney 2000). If my assistant had a problem identifying an individual bird to species, then it was identified to Family (i.e., unknown swallow - Hirundinidae). Bird nests, fledglings, and all flushed birds (i.e., while traveling between sample stations) were recorded as Incidental Observations (Appendix 3).

Bird surveys were only conducted under a specific range of weather conditions: the Beaufort Wind Scale did not exceed 3 (≤ 17 km/hr winds), precipitation, if present, was limited to a light drizzle, and there was good visibility (Bird Studies Canada 1997).

*2.2.3. Vegetation Surveys*

Habitat sampling was conducted in late July of each year after the completion of bird surveys and when vegetation reached its mature height (Haworth-Brockman 1987, Riffell et al. 2001). Vegetation at each sample station was mapped using line transects (Brower and Zar 1977). Each sample station was blocked off into a 100 m × 100 m square with the focal point of the survey area being the middle (Figure 2.1). A 50 m tape was extended into the vegetation four times forming an "X". The vegetation was categorized every metre for 50 m. If a portion of the block contained a habitat, such as shrubs, that was not intercepted by the transects then a visual estimation was made to within 5 % of the total vegetation. Composition of vegetation within each sample station was determined by calculating the sum of each vegetation type and dividing by the sum of the two transects (200 m) (Benoit and Askins 1999). Habitat blocks were considered monotypic if the percentage of vegetation that was one species was $100\ \% \geq x > 79\ \%$, or if $x \leq 79\ \%$, the proportion of the dominant species was at least 1.5 times that of the second ranking vegetation type.

The difference between the mean water depth for each survey month and the annual mean elevation of Lake Erie (in metres) was recorded using data collected at Port Stanley, ON by the Canadian Hydrographic Service, Department of Fisheries and Oceans in 2001 and 2002.

The area of the stand in which a sample station was placed was estimated using coloured aerial photographs taken of the study sites from an altitude of 500 m on 5 June, 2002. On each photograph, the vegetation of each stand was delineated with a marker, traced onto onion paper, overlayed with graph paper, and the squares counted. Distances between reference points, such as buildings, ponds, or trees, were measured in the field to obtain a scale for each photograph. Stand sizes were then estimated on each photograph by multiplying the number of squares in each stand by the area of each square. To ease interpretation, stand size was categorized as small, medium, or large, based upon three ranges; small stands were between 140 $m^2$ - 3000 $m^2$, medium stands were between 3001 $m^2$ - 8000 $m^2$, and large stands were > 8000 $m^2$.

Five stems from each sample station categorized as *Phragmites*, as well as from other monotypic stands of *Phragmites*, were collected during winter of 2003, following a protocol for *Phragmites* morphological identification (www.invasiveplants.net/diag/ diagnostic.asp 2003). Samples were shipped to Cornell University for determination of whether or not they were of the native or exotic genotype.

## 2.3. STATISTICAL ANALYSES

### *2.3.1. Data restrictions*

To ease interpretation and to isolate possible effects of survey date on response variables across seasons, each survey season was analyzed separately. Temporal replication occurred during summer 2001 and 2002, fall 2001, and winter 2002, but not in early spring 2002. Data from the two summer seasons were not pooled for two reasons. First, water levels in Lake Erie were about 0.25 m higher in 2002 than in 2001 (Canadian Hydrographic Service 2002). Therefore, some habitat characteristics changed that likely affected avian habitat selection (Riffell et al. 2001). For instance, some habitats were flooded in 2002 but not 2001. Second, nest site fidelity and success results in individuals of some bird species returning to the same area in subsequent years (Welty and Baptista 1988). Therefore, I could not assume that 2001 and 2002 samples were independent.

*2.3.2. Preliminary analyses - Species Accumulation Curves*

To evaluate species detectability in each habitat, the accumulated number of species per point count was plotted for each summer. Data were not plotted for fall, winter, and spring because I had too few surveys in these seasons.

*2.3.3. Bird Groups*

Birds surveyed during the summer were categorized into one of four groups. *Marsh obligates* included those species that exclusively rely on marshes for nesting. This group included all waterfowl (except Canada Geese), bitterns, rails, Marsh Wrens, Swamp Sparrows, and Common Snipe. *Marsh obligates* were subdivided into *marsh obligates - gleaners* and *marsh obligates - non-gleaners*. *Marsh obligates - gleaners* comprised birds that forage in the strata of vegetation and included Swamp Sparrows and Marsh Wrens. *Marsh obligates - non-gleaners* included birds that generally forage at stem bases and included all waterfowl (except Canada geese), bitterns, rails, and Common Snipe. *Marsh users* included birds that may nest or feed in marsh habitats, but are not exclusively dependent on them. These birds included Red-Winged Blackbirds, Common Grackles, Common Yellowthroats, Killdeer, American Woodcock, and Canada Geese. The group, *other birds*, included all birds generally not associated with wetlands such as American Robins, Northern Cardinals, warblers [other than Common Yellowthroats] (Family: Parulidae) plus aerial foragers such as swallows (Family Hirundinidae) (Bradstreet pers. comm.).

Data for birds observed during fall and spring surveys were categorized into these two groups: *marsh birds* included all waterfowl, bitterns, rails, Marsh Wrens, Swamp Sparrows, Common Snipe, Red-Winged Blackbirds, Common Grackles, Common

Yellowthroats, Killdeer, and American Woodcock; all other species were grouped as *other birds*. For the winter survey season, all species were categorized as *all birds*.

Survey data for each point count were summarized into 2 response variables: 1/ total abundance - total number of individuals of all species in each of the aforementioned groups detected during a survey season and 2/ species richness – total number of species in each group.

*2.3.4. Sample Station Correction*

To equalize survey effort in each habitat for each season, response variables were standardized by dividing each variable by the total number of sample stations in each habitat for each season. Response variables for each season were then plotted using MINITAB 11 (1996) to determine linearity and were $Log_{10}$ transformed if required.

*2.3.5. Avian Diversity Indexes*

To obtain an index of species equitability, Shannon-Wiener's diversity index was calculated. This index measures the likelihood that the next individual sampled will be of the same species as the previous individual and is appropriate for random samples drawn from a large community. The index was calculated for all birds (corrected for the number of sample stations in each habitat) surveyed in each habitat within each season using the equation:

$$H' = - \sum p_i \log p_i$$

where p is the proportion of individuals of a given species (Margalef 1958).

*2.3.6. Model Selection*

Akaike's Information Criterion, corrected for small sample size ($AIC_c$), was used to select the most parsimonious models that best described the response variables (see Burnham and Anderson 1998, Anderson et al. 2000). Statistical models were designed using PROC MIXED (SAS Institute 2001) and model selection was obtained using the IC (METHOD = ML [maximum likelihood]) option for this procedure. Models were ranked using $\Delta AIC_c$ (Burnham and Anderson 1998) and were calculated as: $\Delta AIC_c = AIC_{Ci} - AIC_{Cmin}$, where $AIC_{Ci}$ was the $i^{th}$ model from a candidate set. Akaike weights, $W_{AICC}$, were calculated to assess the relative likelihood of each model being the best model. The model with the lowest $AIC_c$ score was considered to be the one that best described those data.

Because I was interested in the effect of habitat on avian abundance and species richness, all candidate models included habitat (*Phragmites*, *Typha* spp., or marsh meadow) as an explanatory variable. Stand size (area) and survey date were included in some models in the candidate set because both may affect avian abundance and species richness. Model selection was done separately for each survey season and year and included a different set of candidate models.

A total of 24 candidate models involving combinations and interactions of habitat, survey date, water depth, and stand size were used to evaluate the response variables during the summer and fall survey seasons (1 May - 31 July 2001 and 2002, and 30 September - 15 November 2001) (Appendix 4). The largest candidate model included the following biologically interpretable effects: habitat, survey date, water depth, stand size, habitat × survey date, habitat × water depth, habitat × stand size, and habitat × survey date × water depth. The smallest model only included the main effect of habitat. Water depth, calculated as the difference between mean monthly water depth and annual mean elevation of Lake Erie, was included in the candidate set because water depth affects habitat use by Virginia and Sora Rails (Johnson and Dinsmore 1986).

Response variables for the winter (1 January - 15 February 2002) and early spring (1 April - 15 April 2002) survey seasons were analyzed using 10 candidate models (Appendix 5). The largest model included the following effects: habitat, survey date, stand size, habitat × survey date, and habitat × stand size. The smallest model included only the main effect of habitat. Water depth was excluded from winter analyses because of its unavailability (ice) to birds. The spring survey season encompassed two weeks at the beginning of April 2002 during which water levels did not change.

A null model (intercept only) was included in the set of candidate models for all analyses. Second best models and all candidate models with $\Delta AIC_C \leq 2.0$ are presented. As a general guideline, if $\Delta AIC$ values differ by > 2.0, the lowest $\Delta AIC$ value is superior whereas models with $\Delta AIC$ values differing by < 2.0 are similar in their ability to describe the data (Anderson et al. 2000). To aid in assessing the strength of evidence for each candidate model, all relevant model selection information (k [number of parameters], $\Delta AIC_C$, $W_{AICC}$, and $R^2$) is reported. Least-squares means (± 95 % confidence intervals) are reported for highest-ranking models.

To further investigate habitat use by birds, I examined the interaction of habitat type and sample station location (edge vs. interior) on avian abundance per station and species richness per station using a two-way analysis of variance (ANOVA) with $p \leq 0.10$ (PROC GLM, SAS Institute 2001) when habitat type was an important predictor for those variables.

## 2.4. RESULTS

### *2.4.1. Phragmites australis identification*

Morphological analyses of stems showed that plants at all *Phragmites* sample stations ($n$ = 18) were of the introduced genotype as were those in 7 of 8 other *Phragmites* stands that I sampled.

### *2.4.2. Summer Surveys (May - July 2001 and 2002)*

#### *2.4.2.1. Total Birds*

Species accumulation curves for data from each summer indicated that most bird species in each habitat were detected (Figure 2.2). I observed 1,519 birds of 32 species during 2001 and 1,530 birds of 38 species during 2002 (Table 2.1 and Table 2.2). There were more birds per station in *Phragmites* than in *Typha* or marsh meadow during both years. During 2001 and 2002, respectively, marsh meadow and *Phragmites* had more bird species per station than did the other habitats, but diversity per station was highest in marsh meadow during both years.

#### *2.4.2.2. Comparative use of Phragmites, Typha, and Marsh Meadows by Marsh Obligates - gleaners*

There were more *marsh obligates - gleaners* per station in marsh meadow than in *Phragmites* or *Typha* (Table 2.1 and Table 2.2). The models that best explained total abundance and species richness of *marsh obligates - gleaners* per station included habitat (Table 2.3). Overall, least-squares means and their 95 % confidence intervals showed that the habitat effect was not strong during 2001. There were more *marsh obligates - gleaners* per station and higher species richness per station in *Typha* than in marsh meadow and *Phragmites* during 2002. Per station, abundance and species richness of

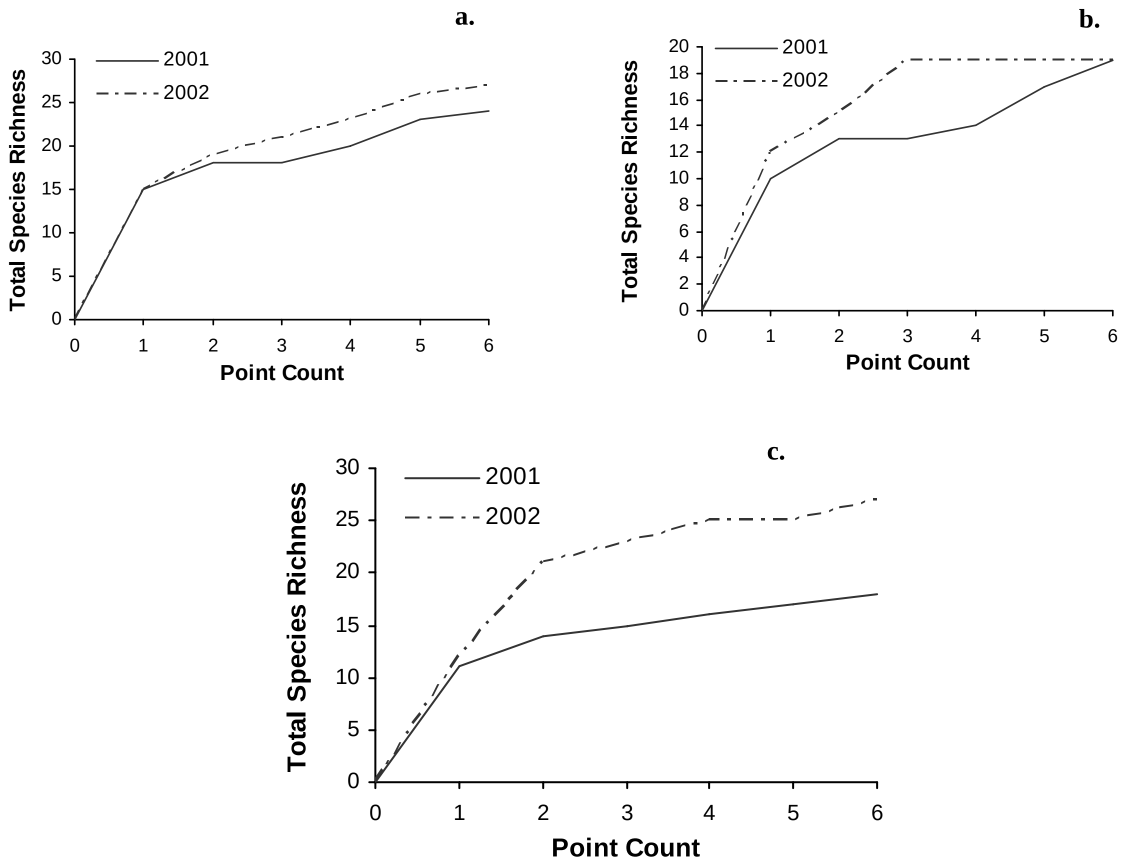



Figure 2.2. Species accumulation curves for birds observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat - marsh meadow (**a**), *Typha* spp. (**b**), and *Phragmites australis* (**c**).

Table 2.1. Birds observed during 10 minute point counts in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) at Long Point, ON, from 1 May until 31 July 2001 and 2002.

| Common Name | Scientific Name | *Phragmites australis* | | | | *Typha* spp. | | | | Marsh Meadow | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 |
| Pied-billed Grebe | *Podilymbus podiceps* | 0[1] | 0[1] | 0[2] | 0[2] | 0[1] | 0[1] | 3[2] | 6[2] | 0[1] | 0[1] | 0[2] | 2[2] |
| [3]Least Bittern | *Ixobrychus exilis* | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [3]American Bittern | *Botaurus lentiginosus* | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 4 | 0 | 1 | 1 | 3 |
| Green Heron | *Butorides virescens* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| [4]Canada Goose | *Branta canadensis* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 4 | 0 | 30 |
| [3]Wood Duck | *Aix sponsa* | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 9 | 4 | 0 | 7 |
| [3]Mallard | *Anas platyrhynchos* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 1 | 10 |
| [3]Green-winged Teal | *Anas crecca* | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 1 |
| Northern Shoveler | *Anas clypeata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 3 |
| [5]Northern Harrier | *Circus cyaneus* | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| American Kestrel | *Falco sparverius* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| [3]Virginia Rail | *Rallus limicola* | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 3 | 2 | 4 | 0 | 3 |
| [3]Sora Rail | *Porzana carolina* | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 1 |
| Common Moorhen | *Gallinula chloropus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Sandhill Crane | *Grus canadensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| [4]Killdeer | *Charadrius vociferus* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 2 |

**1** Data from Mapped Observations and Aerial Foragers.

**2** Data from Additional Observations.

**3** *Marsh Obligates - non-gleaner*.

**4** *Marsh user*.

**5** *Other bird*.

**6** *Marsh Obligates – gleaner*.

Table 2.1. Continued.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [5]Greater Yellowlegs | *Tringa melanoleuca* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Dowitcher spp. | *Limnodromus* spp. | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| [3]Common Snipe | *Gallinago gallinago* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| [4]American Woodcock | *Scolopax minor* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 |
| [5]Ruby-throated Hummingbird | *Archilochus colubris* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| [5]Northern Flicker | *Colaptes auratus* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Eastern Wood-Pewee | *Contopus virens* | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Willow Flycatcher | *Empidonax traillii* | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Eastern Kingbird | *Tyrannus tyrannus* | 5 | 3 | 0 | 2 | 0 | 1 | 0 | 2 | 7 | 4 | 0 | 0 |
| [5]Warbling Vireo | *Vireo gilvus* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Tree Swallow | *Tachycineta bicolor* | 95 | 103 | 0 | 0 | 108 | 69 | 0 | 0 | 104 | 132 | 0 | 0 |
| [5]Purple Martin | *Progne subis* | 3 | 12 | 0 | 0 | 20 | 9 | 0 | 0 | 14 | 31 | 0 | 0 |
| [5]Bank Swallow | *Riparia riparia* | 203 | 53 | 0 | 0 | 103 | 101 | 0 | 0 | 50 | 62 | 0 | 0 |
| [5]Cliff Swallow | *Petrochelidon pyrrhonota* | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Northern Rough-winged Swallow | *Stelgidopteryx serripennis* | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| [5]Barn Swallow | *Hirundo rustica* | 35 | 52 | 6 | 0 | 30 | 23 | 2 | 0 | 21 | 51 | 3 | 0 |
| [5]Unknown Swallow | Family Hirundinidae | 6 | 4 | 17 | 10 | 1 | 9 | 19 | 9 | 5 | 16 | 25 | 8 |
| [5]Red-breasted Nuthatch | *Sitta canadensis* | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| [6]Marsh Wren | *Cistothorus palustris* | 7 | 12 | 4 | 2 | 4 | 13 | 17 | 11 | 15 | 45 | 1 | 4 |
| [5]Ruby-crowned Kinglet | *Regulus calendula* | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]American Robin | *Turdus migratorius* | 2 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 0 | 3 |

Table 2.1. Continued.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [5]Gray Catbird | *Dumetella carolinensis* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| [5]European Starling | *Sturnus vulgaris* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 20 | 0 |
| [5]Chestnut-sided Warbler | *Dendroica pennsylvanica* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Palm Warbler | *Dendroica palmarum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| [5]Yellow Warbler | *Dendroica petechia* | 17 | 34 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 4 | 0 | 1 |
| [4]Common Yellowthroat | *Geothlypis trichas* | 36 | 50 | 7 | 5 | 9 | 10 | 0 | 1 | 3 | 12 | 0 | 0 |
| [5]American Redstart | *Setophaga ruticilla* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| [5]Unknown Warbler | Family Parulidae | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]Chipping Sparrow | *Spizella passerina* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| [5]Savannah Sparrow | *Passerculus sandwichensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| [5]Song Sparrow | *Melospiza melodia* | 6 | 6 | 1 | 0 | 2 | 4 | 0 | 0 | 6 | 6 | 0 | 0 |
| [6]Swamp Sparrow | *Melospiza georgiana* | 64 | 67 | 6 | 1 | 50 | 50 | 7 | 6 | 145 | 95 | 17 | 17 |
| [5]White-crowned Sparrow | *Zonotrichia leucophrys* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| [5]Unknown Sparrow | Family Emberizidae | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 |
| [5]Northern Cardinal | *Cardinalis cardinalis* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [4]Red-winged Blackbird | *Agelaius phoeniceus* | 137 | 125 | 9 | 7 | 57 | 63 | 1 | 11 | 88 | 114 | 3 | 7 |
| [4]Common Grackle | *Quiscalus quiscula* | 0 | 4 | 1 | 1 | 1 | 3 | 0 | 3 | 4 | 3 | 2 | 5 |
| [5]Brown-headed Cowbird | *Molothrus ater* | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| [5]American Goldfinch | *Carduelis tristis* | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 |

Table 2.2. Summarized data for total abundance and species richness of total birds, *marsh obligates - gleaners*, *marsh obligates - non-gleaners*, *marsh users*, and *other birds* observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) and number of sample stations in each habitat. Also shown for each habitat is Shannon - Wiener's diversity index, calculated for corrected bird totals (total number of birds per number of sample stations in that habitat). Based on data from Table 2.1, but only includes Mapped Observations and Aerial Foragers.

| Response Variable | *Phragmites australis* | | *Typha* spp. | | Marsh Meadow | | TOTAL | |
|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 |
| Number of Stations | 16 | 18 | 16 | 13 | 18 | 24 | 50 | 55 |
| Total Birds | 627 | 549 | 399 | 371 | 493 | 610 | 1519 | 1530 |
| Total Birds / Station | 39.19 | 30.50 | 24.94 | 28.54 | 27.39 | 25.42 | 30.38 | 27.82 |
| Species Richness | 18 | 27 | 19 | 18 | 24 | 28 | 32 | 38 |
| Species Richness / Station | 1.12 | 1.50 | 1.19 | 1.38 | 1.33 | 1.17 | 0.64 | 0.69 |
| Diversity Index / Station | 0.78 | 0.85 | 0.81 | 0.85 | 0.86 | 0.98 | 0.91 | 0.99 |
| *Marsh Obligates - gleaners* | 71 | 79 | 54 | 63 | 160 | 140 | 285 | 282 |
| *Marsh Obligates - gleaners* / Station | 4.44 | 4.39 | 3.38 | 4.85 | 8.89 | 5.83 | 5.70 | 5.13 |
| *Marsh Obligates - gleaner* Species Richness | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| *Marsh Obligates - gleaner* Species Richness / Station | 0.12 | 0.11 | 0.12 | 0.15 | 0.11 | 0.08 | 0.04 | 0.04 |

- *Marsh Obligates - gleaners* include Swamp Sparrows (*Melospiza georgiana*) and Marsh Wrens (*Cistothorus palustris*).
- *Marsh Obligates - non-gleaners* include Least Bitterns (*Ixobrychus exilis*), American Bitterns (*Botaurus lentiginosus*), Wood Ducks (*Aix sponsa*), Mallards (*Anas platyrhynchos*), Green-winged Teal (*Anas crecca*), Virginia Rails (*Rallus limicola*), Sora Rails (*Porzana carolina*), and Common Snipe (*Gallinago gallinago*).
- *Marsh users* include Canada Geese (*Branta canadensis*), Killdeer (*Charadrius vociferous*), American Woodcock (*Scolopax minor*), Common Yellowthroats (*Geothlypis trichas*), Red-winged Blackbirds (*Agelaius phoeniceus*), and Common Grackles (*Quiscalus quiscula*).
- Total Blackbirds include Red-winged Blackbirds and Common Grackles.
- *Other birds* include all other birds.
- Total Swallows include Tree Swallows (*Tachycineta bicolor*), Purple Martins (*Progne subis*), Bank Swallows (*Riparia riparia*), Cliff Swallows (*Petrochelidon pyrrhonota*), Northern Rough-winged Swallows (*Stelgidopteryx serripennis*), and Barn Swallows (*Hirundo rustica*).

Table 2.2. Continued

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Marsh Obligates - non-gleaners* | 1 | 2 | 2 | 11 | 13 | 12 | 16 | 25 |
| *Marsh Obligates - non-gleaners* / Station | 0.06 | 0.11 | 0.12 | 0.85 | 0.72 | 0.50 | 0.32 | 0.45 |
| *Marsh Obligates - non-gleaner* Species Richness | 1 | 1 | 2 | 4 | 3 | 5 | 4 | 7 |
| *Marsh Obligates - non-gleaner* Species Richness / Station | 0.06 | 0.06 | 0.12 | 0.31 | 0.17 | 0.21 | 0.08 | 0.13 |
| *Marsh users* | 174 | 179 | 68 | 78 | 100 | 135 | 342 | 392 |
| - Total Blackbirds | 137 | 129 | 58 | 66 | 92 | 117 | 287 | 312 |
| *Marsh users* / Station | 10.88 | 9.94 | 4.25 | 6.00 | 5.56 | 5.62 | 6.84 | 7.13 |
| *Marsh user* Species Richness | 3 | 3 | 4 | 4 | 6 | 6 | 6 | 6 |
| *Marsh user* Species Richness / Station | 0.19 | 0.17 | 0.25 | 0.31 | 0.33 | 0.25 | 0.11 | 0.11 |
| *Other birds* | 381 | 289 | 275 | 219 | 220 | 323 | 876 | 831 |
| - Total Swallows | 345 | 226 | 265 | 211 | 197 | 293 | 807 | 730 |
| *Other birds* / Station | 23.81 | 16.06 | 17.19 | 16.85 | 12.22 | 13.46 | 17.58 | 15.11 |
| *Other bird* Species Richness | 12 | 21 | 11 | 8 | 13 | 15 | 20 | 23 |
| *Other bird* Species Richness / Station | 0.75 | 1.17 | 0.69 | 0.62 | 0.72 | 0.62 | 0.40 | 0.42 |

Table 2.3. Model selection for variation in total abundance of *marsh obligates - gleaners* per sample station and species richness of *marsh obligates - gleaners* per sample station observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), difference between the mean monthly water depth and the annual mean elevation of Lake Erie (WD; m), and stand size (SIZE). Shown for each candidate model is the year, response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Year | Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|---|
| | **Total Abundance of *Marsh Obligates – gleaners* / Sample Station** | | | | | | | |
| 2001 | HAB, SIZE, WD, HAB × SIZE | 12 | 0.00 | 0.53 | 0.16 | 0.073 ± 0.014 | 0.042 ± 0.021 | 0.049 ± 0.014 |
| | HAB, SIZE, HAB × SIZE | 10 | 1.20 | 0.29 | 0.14 | | | |
| 2002 | HAB, SIZE, SD, WD, HAB × SIZE | 13 | 0.00 | 0.71 | 0.19 | 0.039 ± 0.010 | 0.108 ± 0.018 | 0.040 ± 0.011 |
| | HAB, SIZE, HAB × SIZE | 10 | 3.30 | 0.14 | 0.16 | | | |
| | **Species Richness of *Marsh Obligates – gleaners* / Sample Station** | | | | | | | |
| 2001 | HAB, WD, HAB × WD | 10 | 0.00 | 0.76 | 0.11 | 0.037 ± 0.006 | 0.025 ± 0.007 | 0.032 ± 0.007 |
| | HAB, SD, WD, SIZE, HAB × SD, HAB × WD, HAB × SIZE, HAB × SD × WD | 31 | 3.80 | 0.11 | 0.25 | | | |
| 2002 | HAB | 4 | 0.00 | 0.27 | 0.05 | 0.024 ± 0.006 | 0.043 ± 0.008 | 0.028 ± 0.006 |
| | HAB, SIZE, HAB × SIZE | 10 | 1.00 | 0.16 | 0.08 | | | |
| | HAB, SIZE | 6 | 1.10 | 0.16 | 0.06 | | | |
| | HAB, SD, WD | 7 | 2.00 | 0.10 | 0.06 | | | |

*marsh obligates - gleaners* also depended on survey date, water depth, and stand size. For instance, there were more *marsh obligates - gleaners* per station in large stands of marsh meadow and in small stands of *Typha* than in other habitats during 2001 and 2002, respectively (Figure 2.3). Marsh meadow had higher species richness of *marsh obligates - gleaners* per station than did *Phragmites* during the highest water depth recorded (i.e. June) in summer 2001 (Figure 2.4). Species richness per station, however, increased with declining water depths (i.e. June to July) in *Phragmites* during 2001.

Edge stations in marsh meadow had more individuals per station and higher species richness of *marsh obligates - gleaners* per station than did other stations during 2001 (Abundance: $p < 0.004$; Species Richness: $p < 0.03$) (Figure 2.5a and Figure 2.5b). There were also more *marsh obligates - gleaners* per station at interior stations in marsh meadow than at interior stations in *Typha* ($p < 0.02$) and edge stations in *Phragmites* (0.09).

Edge stations in *Typha* had more individuals and species of *marsh obligates - gleaners* per station than did edge (Abundance: $p < 0.0001$; Species Richness: $p < 0.0002$) and interior stations (0.0001; 0.04) in other habitats during 2002. Edge stations in marsh meadow had more *marsh obligates - gleaners* per station and higher species richness per station than did interior stations in marsh meadow ($p < 0.02$). Interior stations in marsh meadow had fewer species per station than did interior stations in *Typha* ($p < 0.0007$) and *Phragmites* (0.04) and edge stations in *Phragmites* (0.09).

#### *2.4.2.3. Comparative use of Phragmites, Typha, and Marsh Meadows by Marsh Obligates - non-gleaners*

Per station, there were fewer individuals and species of *marsh obligates - non-gleaners* in *Phragmites* than in other habitats (Table 2.1 and Table 2.2). During 2001 and 2002, respectively, marsh meadow and *Typha* had more *marsh obligates - non-gleaners* per station and higher species richness per station than did other habitats. I only observed Least Bitterns, however, in *Phragmites* (Table 2.1)

The models that best explained variation in total abundance of *marsh obligates - non-gleaners* per station included habitat (Table 2.4). Species richness per station was best described by the null model in 2001 and by the largest candidate model in 2002. Least-squares means and their 95 % confidence intervals for total abundance of *marsh*

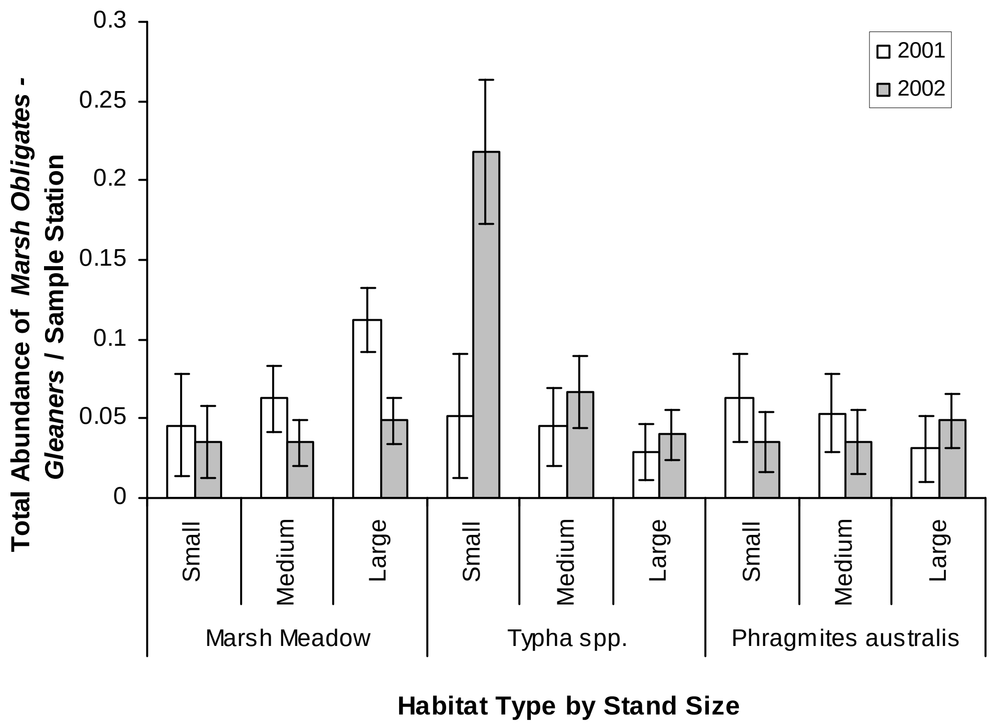



Figure 2.3. Least-squares means (± 95 % CI) for total abundance of *marsh obligates - gleaners* per sample station observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July in relation to year, habitat, and stand size (Small: 140 $m^2$ – 3000 $m^2$; Medium: 3001 $m^2$ – 8000 $m^2$; Large > 8000 $m^2$).

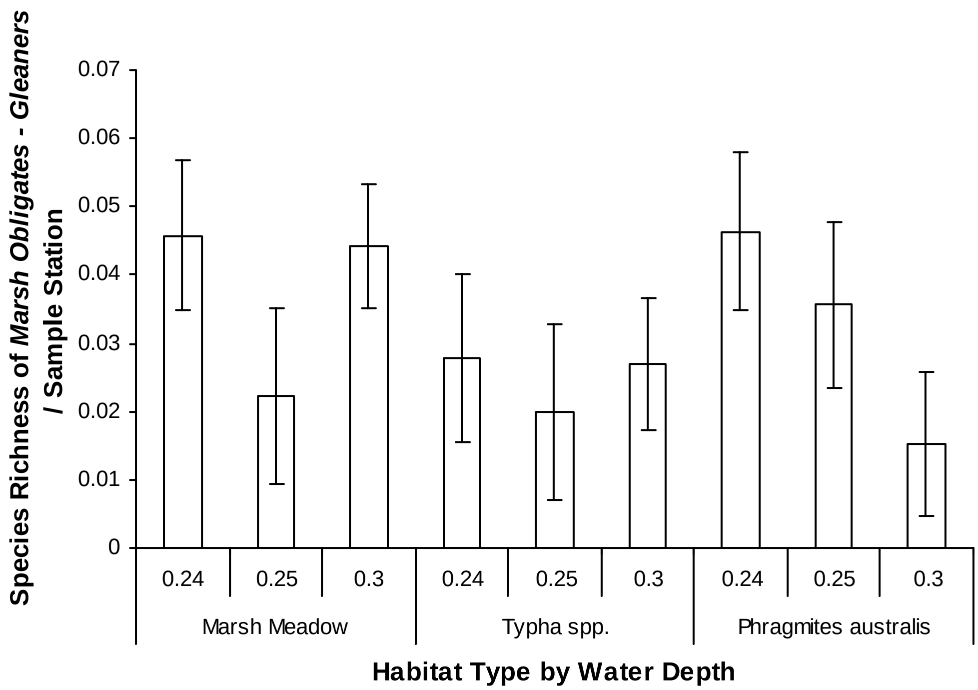



Figure 2.4. Least-squares (LS) means (± 95 % CI) for species richness of *marsh obligates - gleaners* per sample station observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 in relation to habitat and water depth (difference between the mean monthly water depth and annual mean elevation of Lake Erie in metres; 0.24 m = July; 0.3 m = June).

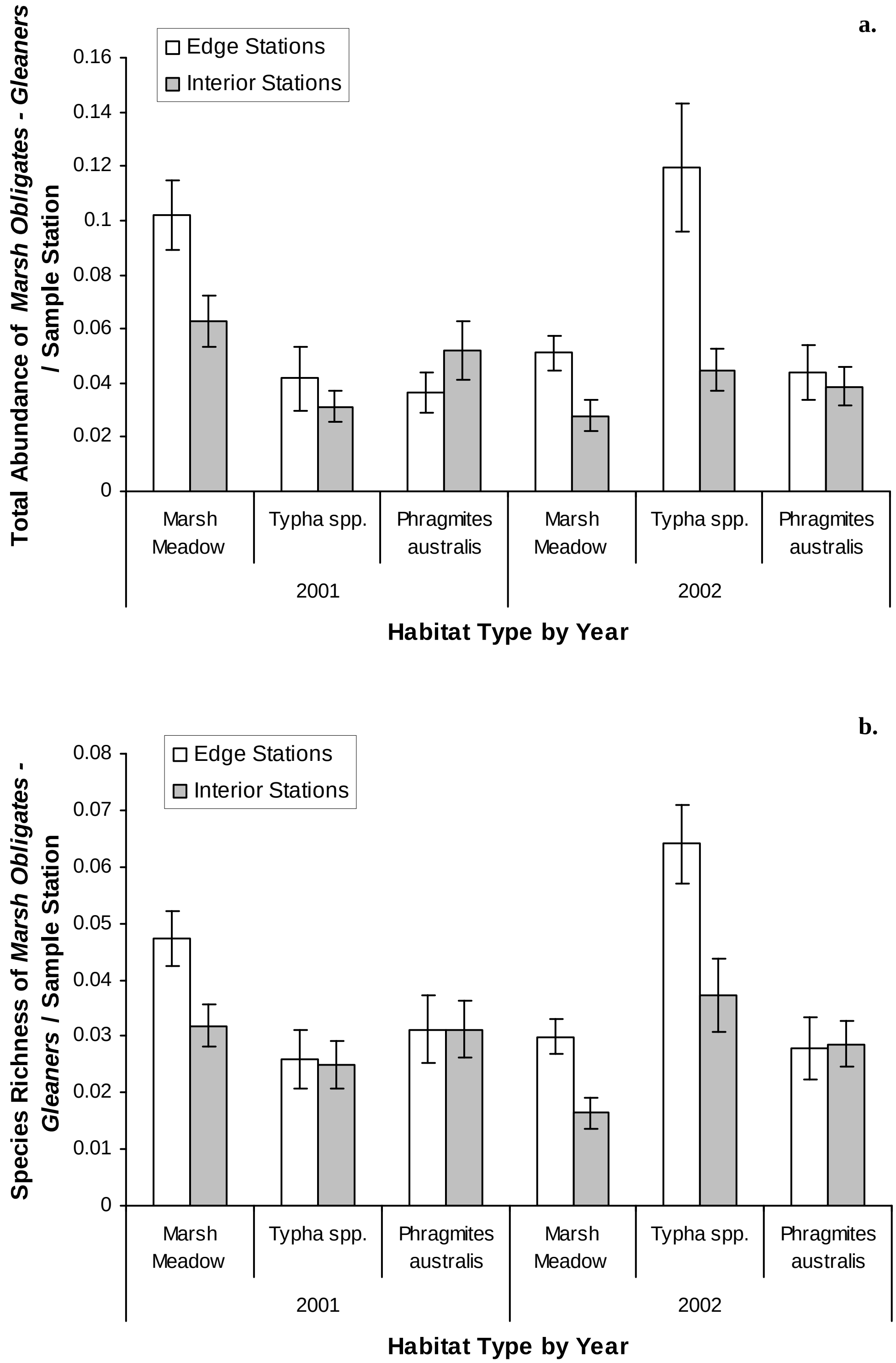



Figure 2.5. Least-squares means (± SE) for total abundance of *marsh obligates - gleaners* per sample station (**a.**) and species richness of *marsh obligates - gleaners* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July in relation to year, habitat, and sample station location.

Table 2.4. Model selection for variation in total abundance of *marsh obligates - non-gleaners* per sample station and species richness of *marsh obligates - non-gleaners* per sample station observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), difference between the mean monthly water depth and the annual mean elevation of Lake Erie (WD; m), and stand size (SIZE). Shown for each candidate model is the year, response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Year | Model | K | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|---|
| | **Total Abundance of *Marsh Obligates - non-gleaners* / Sample Station** | | | | | | | |
| 2001 | HAB | 4 | 0.00 | 0.43 | 0.02 | 0.007 ± 0.004 | 0.001 ± 0.004 | 0.0006 ± 0.004 |
| | NULL | 2 | 0.90 | 0.28 | 0.00 | | | |
| 2002 | HAB, SD, WD, SIZE, HAB × SD, HAB × WD, HAB × SIZE, HAB × SD × WD | 19 | 0.00 | 0.89 | 0.15 | 0.003 ± 0.005 | 0.010 ± 0.008 | 0.0009 ± 0.005 |
| | HAB, SD, WD, HAB × SD | 17 | 6.00 | 0.04 | 0.12 | | | |
| | **Species Richness of *Marsh Obligates - non-gleaners* / Sample Station** | | | | | | | |
| 2001 | NULL | 2 | 0.00 | 0.59 | 0.00 | | | |
| | HAB | 4 | 1.80 | 0.24 | 0.01 | 0.002 ± 0.002 | 0.001 ± 0.002 | 0.0006 ± 0.002 |
| 2002 | HAB, SD, WD, SIZE, HAB × SD, HAB × WD, HAB × SIZE, HAB × SD × WD | 19 | 0.00 | 0.32 | 0.15 | 0.002 ± 0.002 | 0.005 ± 0.004 | 0.0004 ± 0.002 |
| | HAB, SD, WD, HAB × SD | 17 | 0.30 | 0.28 | 0.14 | | | |
| | HAB, SD, WD, HAB × SD × WD | 17 | 0.30 | 0.28 | 0.14 | | | |

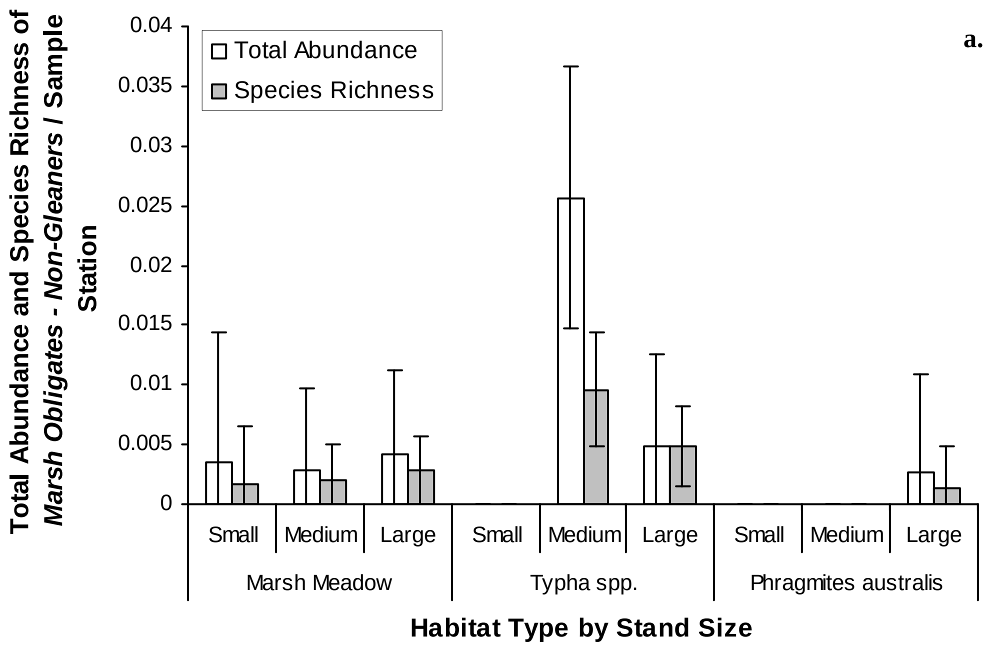
*obligates - non-gleaners* per station showed the habitat effect was not strong in either year. Per station, abundance and species richness also depended on survey date, water depth, and stand size. I did not detect any *marsh obligates - non-gleaners* in small and medium stands of *Phragmites* or in small stands of *Typha* (Figure 2.6a). Medium stands of *Typha* had more individuals per station than did other habitats. Proportionally, I detected *marsh obligates - non-gleaners* during more surveys in marsh meadow (4 of 6 surveys) and *Typha* (3/6) than in *Phragmites* (1/6) (Figure 2.6b).

There was no interaction between habitat and sample station location on either abundance, or species richness, of *marsh obligates - non-gleaners* per station during 2001 (Abundance: $p > 0.23$, Species richness: $p > 0.56$). Edge stations in *Typha* had more individuals per station and higher species richness of *marsh obligates - non-gleaners* per station than did other stations during 2002 (Abundance: $p < 0.002$; Species Richness: edge *Typha* and edge marsh meadow, $p < 0.08$; interior marsh meadow, 0.05; edge *Phragmites*, $p < 0.04$; interior *Phragmites*, 0.01) (Figure 2.7a and Figure 2.7). Interior stations in *Typha* and marsh meadow had more individuals and higher species richness per station than did *Phragmites* interiors. I detected Virginia Rails and Least Bitterns, however, only at edge and interior stations, respectively, in *Phragmites*.

*2.4.2.4. Comparative use of Phragmites, Typha, and Marsh Meadows by Marsh users*

*Phragmites* had more *marsh users* per station than did other habitats (Table 2.1 and Table 2.2). This difference was due to the high numbers of blackbirds (Family Icteridae) recorded in *Phragmites*. Canada Geese and Killdeer did not use *Phragmites* (Table 2.1 and Table 2.2).

The models that best explained variation in total abundance and species richness of *marsh users* per station included habitat in both years (Table 2.5). Overall, per station, there were more individuals and species of *marsh users* in *Phragmites* than in marsh meadow and *Typha* during 2001. *Phragmites* and *Typha* had more *marsh users* per station than did marsh meadow during 2002. Per station, abundance and species richness also depended on survey date, water depth, and stand size. For instance, small stands of marsh meadow and *Typha* had more *marsh users* per station than did larger stands during 2001 and 2002, respectively (Figure 2.8a). Small stands of *Typha* had more *marsh users*



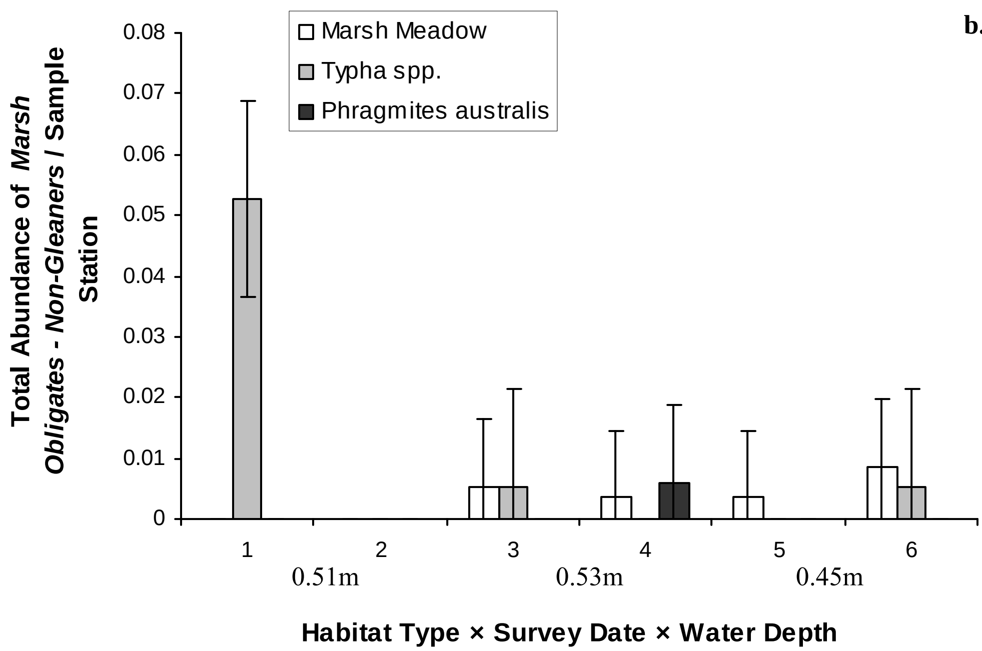




Figure 2.6. Least-squares (LS) means (± 95 % CI) for total abundance and species richness of *marsh obligates - non-gleaners* per sample station in relation to habitat and stand size (Small: 140 $m^2$ – 3000 $m^2$; Medium: 3001 $m^2$ – 8000 $m^2$; Large > 8000 $m^2$) (**a.**) and for total abundance of *marsh obligates - non-gleaners* per sample station in relation to habitat, survey date (1 = 1 May; 6 = 31 July), and water depth (difference between the mean monthly water depth and the annual mean elevation of Lake Erie) (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2002.

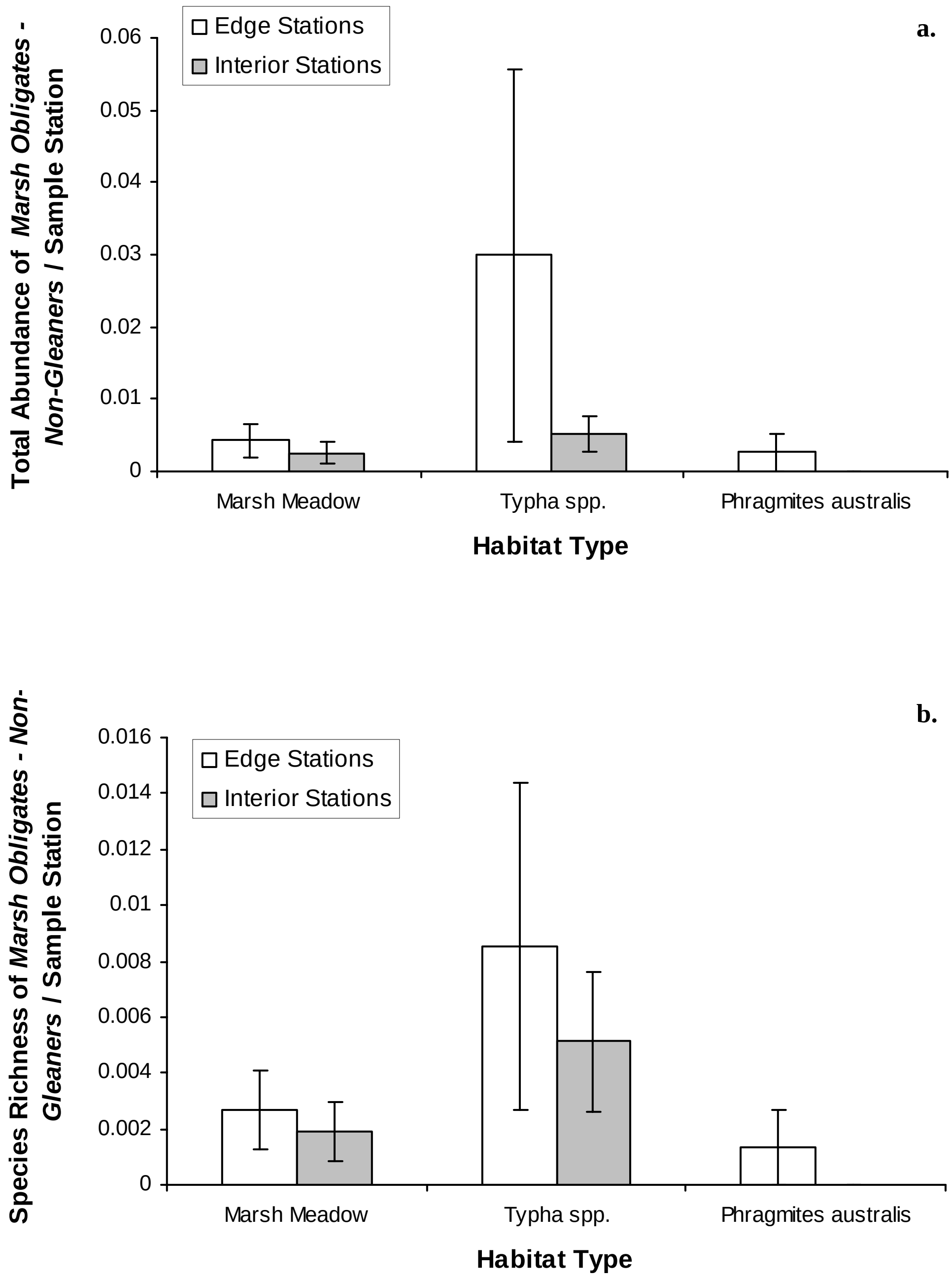



Figure 2.7. Least-squares means (± SE) for total abundance of *marsh obligates - non-gleaners* per sample station (**a.**) and species richness of *marsh obligates - non-gleaners* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat and sample station location.

Table 2.5. Model selection for variation in total abundance of *marsh users* per sample station and species richness of *marsh users* per sample station observed within 25 m fixed radius point counts, at Long Point, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), difference between the mean monthly water depth and the annual mean elevation of Lake Erie (WD; m), and stand size (SIZE). Shown for each candidate model is the year, response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Year | Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|---|
| | **Total Abundance of *Marsh users* / Sample Station** | | | | | | | |
| 2001 | HAB, SIZE, SD, HAB × SIZE | 15 | 0.00 | 0.44 | 0.20 | 0.058 ± 0.016 | 0.045 ± 0.024 | 0.109 ± 0.017 |
| | HAB, SIZE, WD, HAB × SIZE | 12 | 1.90 | 0.17 | 0.18 | | | |
| 2002 | HAB, SIZE, SD, WD, HAB × SIZE | 13 | 0.00 | 0.59 | 0.18 | 0.040 ± 0.013 | 0.107 ± 0.024 | 0.094 ± 0.014 |
| | HAB, SIZE, WD, HAB × SIZE | 12 | 3.30 | 0.11 | 0.17 | | | |
| | **Species Richness of *Marsh users* / Sample Station** | | | | | | | |
| 2001 | HAB, SIZE, SD, HAB × SIZE | 15 | 0.00 | 0.53 | 0.25 | 0.033 ± 0.008 | 0.030 ± 0.011 | 0.056 ± 0.008 |
| | HAB, SD | 9 | 1.60 | 0.24 | 0.22 | | | |
| 2002 | HAB, SD, WD, SIZE, HAB × SD, HAB × WD, HAB × SIZE, HAB × SD × WD | 19 | 0.00 | 0.76 | 0.28 | 0.022 ± 0.006 | 0.066 ± 0.011 | 0.055 ± 0.007 |
| | HAB, SIZE, SD, WD, HAB × SIZE | 13 | 2.70 | 0.20 | 0.24 | | | |

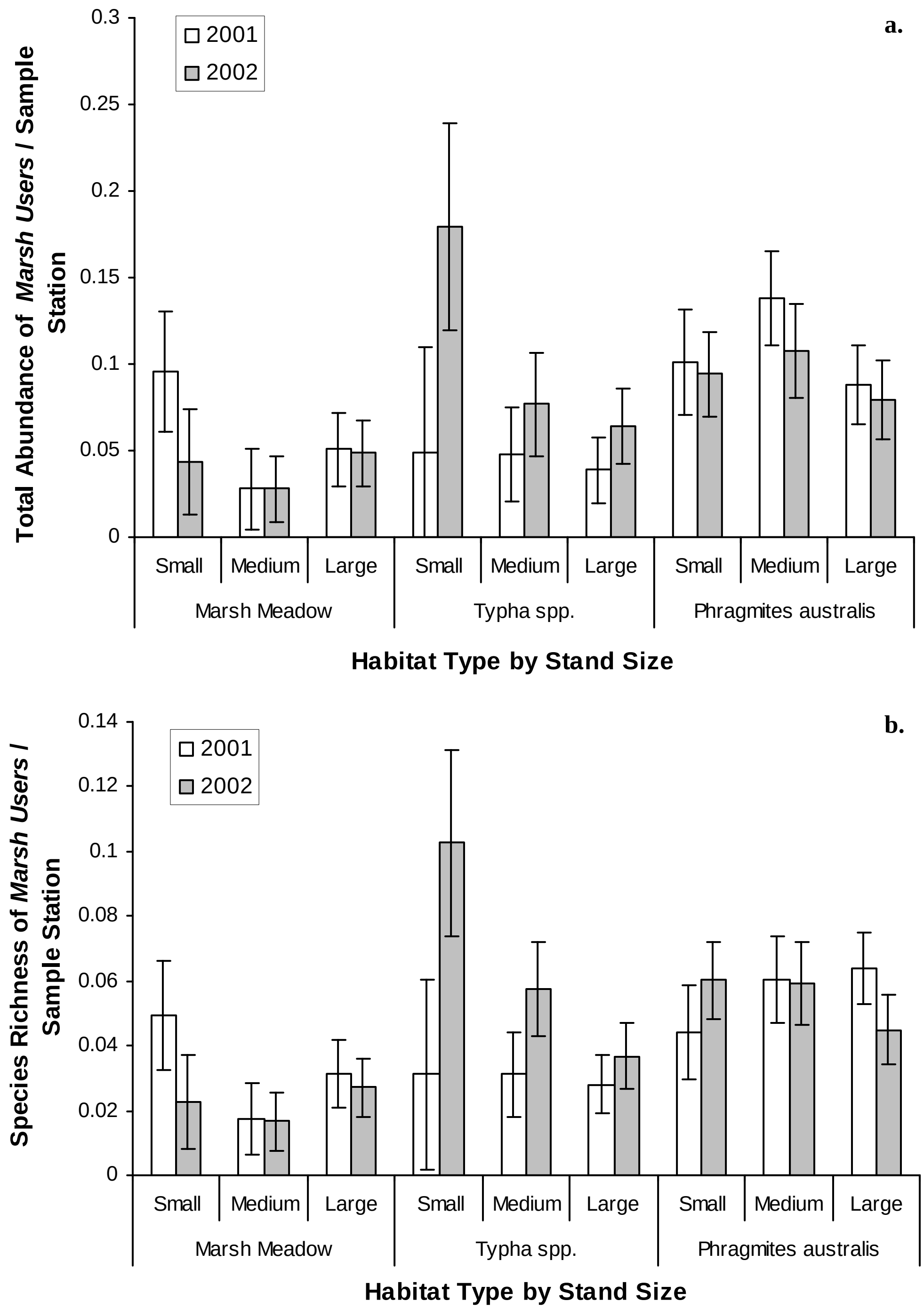



Figure 2.8. Least-squares (LS) means (± 95 % CI) for total abundance of *marsh users* per sample station (**a.**) and species richness of *marsh users* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July in relation to year, habitat, and stand size (Small: 140 $m^2$ – 3000 $m^2$; Medium: 3001 $m^2$ – 8000 $m^2$; Large > 8000 $m^2$).

per station than did other habitats except for medium stands of *Phragmites* during 2002. Stands of *Phragmites* had a high abundance of *marsh users* per station in both years. There was higher species richness per station in medium and large stands of *Phragmites* than in medium and large stands of other habitats during 2001 (Figure 2.8b). Small and medium stands of *Phragmites* and *Typha* had higher species richness per station than did stands of marsh meadow during 2002. There were more *marsh users* per station in *Typha* than in marsh meadow regardless of water depth during May and June of 2002 (Figure 2.9). *Phragmites* had higher species richness per station than did marsh meadow during early May and late July, 2002.

Total abundance and species richness of *marsh users* per station was higher in interior stations of *Phragmites* than in other stations during 2001 (Abundance: $p < 0.01$; Species Richness $p < 0.03$) (Figure 2.10a and Figure 2.10b). Edge stations in marsh meadow had more birds and species per station than did interior stations in marsh meadow (Abundance: $p < 0.004$; Species Richness: $p < 0.007$) and higher abundance per station than did interior (0.06) and edge stations in *Typha* (0.08). Edge stations in *Phragmites* had more birds and species per station than did interior stations in marsh meadow (Abundance: $p < 0.004$; Species Richness: $p < 0.001$) and interior (0.04; 0.05) and edge stations in *Typha* (0.06; 0.04).

Interior stations in marsh meadow had fewer individuals and species of *marsh users* per station than did other stations during 2002 (Abundance: $p < 0.001$; Species Richness: $p < 0.0001$) (Figure 2.10a and Figure 2.10b). Edge stations in marsh meadow also had lower abundance and species richness per station than did other stations except those in *Typha* and marsh meadow interiors (Abundance: $p < 0.03$; Species Richness: $p < 0.002$). Interior stations in *Typha* had fewer individuals and species of *marsh users* per station than did edge stations in *Typha* (Abundance: $p < 0.04$; Species Richness: $p < 0.01$) and interior stations in *Phragmites* (0.04; 0.06).

##### *2.4.2.5. Comparative use of Phragmites, Typha, and Marsh Meadows by Other birds during summer*

During 2001 and 2002, respectively, more *other birds* per station were observed in *Phragmites* and *Typha* than in other habitats (Table 2.1 and Table 2.2). *Phragmites* had higher species richness of *other birds* per station than did other habitats during both

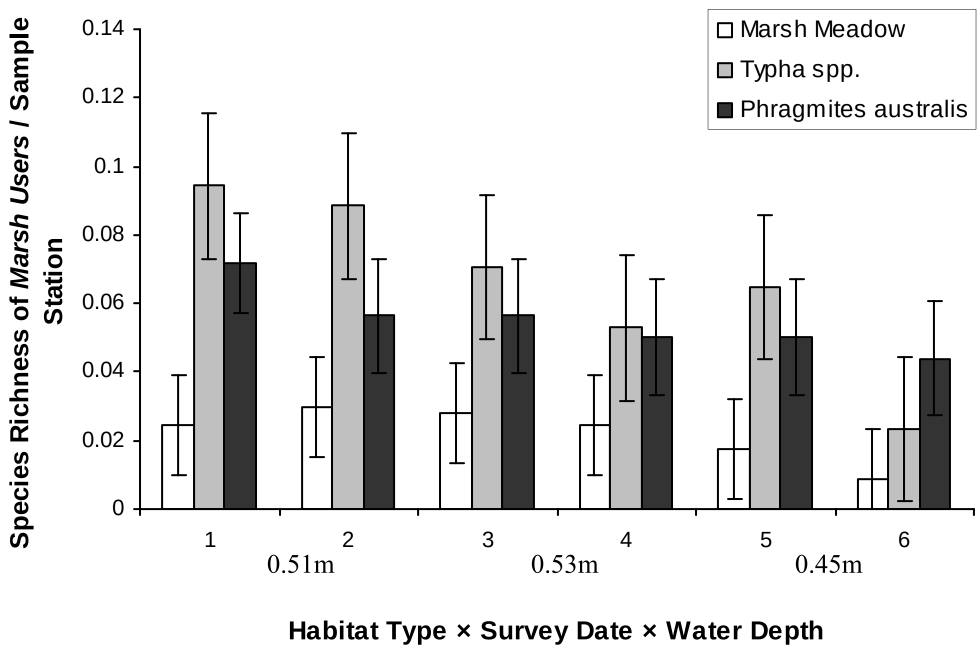
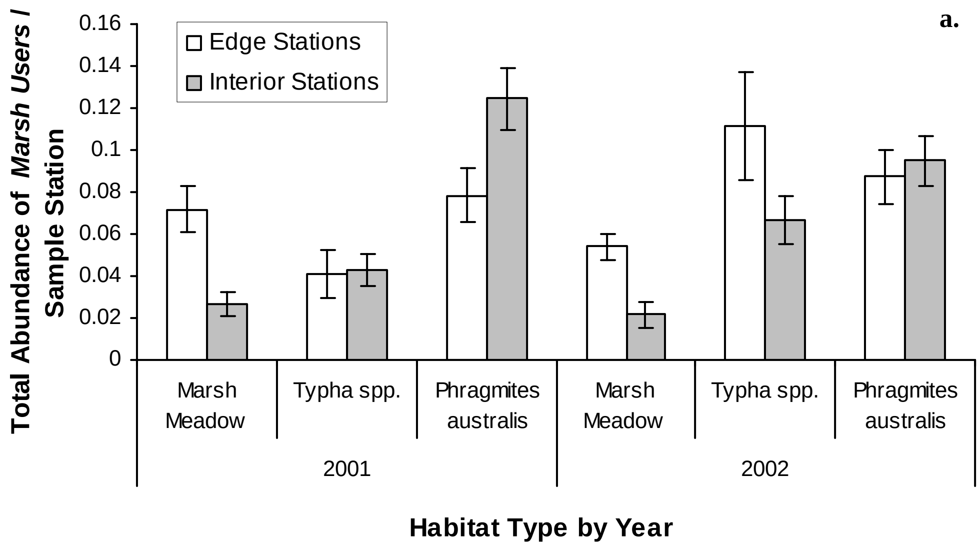



Figure 2.9. Least-squares (LS) means (± 95 % CI) for species richness of *marsh users* per sample station observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat, survey date (1 = 1 May; 6 = 31 July), and water depth (difference between the mean monthly water depth and annual mean elevation of Lake Erie).



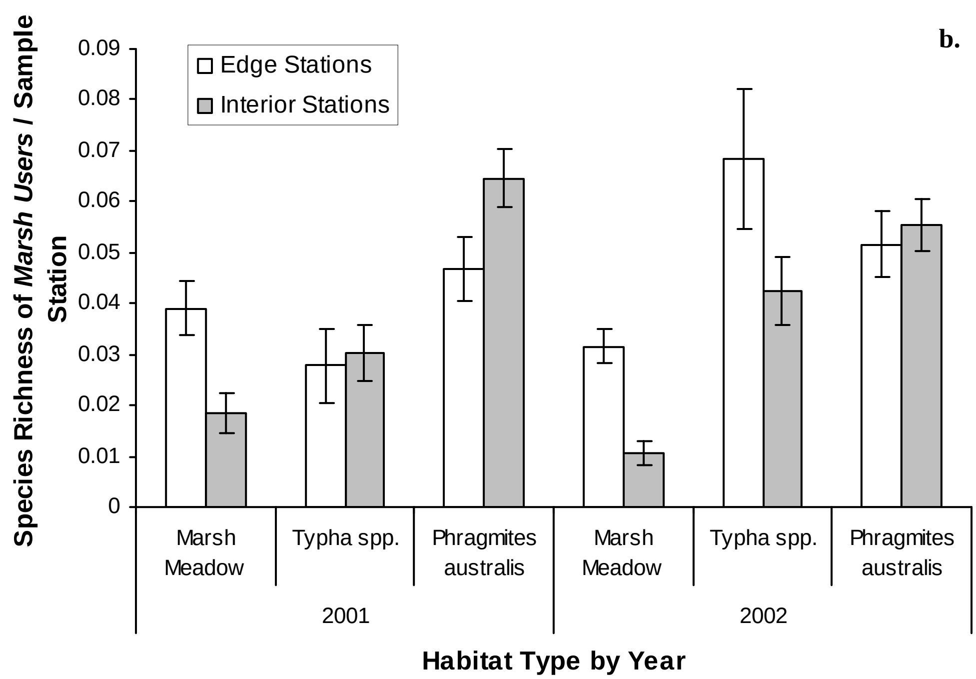




Figure 2.10. Least-squares means (± SE) for total abundance of *marsh users* per sample station (**a.**) and species richness of *marsh users* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July in relation to year, habitat, and sample station location.

years.

Per station, the models best explaining total abundance and species richness of *other birds* included habitat (Table 2.6). Overall, least-squares means and their 95 % confidence intervals for total abundance per station showed that the habitat effect was not strong in either year. Marsh meadow had lower species richness per station than did *Typha* and *Phragmites* during 2002. Per station, abundance and species richness also depended on survey date, water depth, and stand size. For example, there were more *other birds* per station in *Typha* and *Phragmites* than in marsh meadow during the lowest water depth recorded (i.e. July) in 2001 (Figure 2.11). *Typha* had more *other birds* per station than did marsh meadow and *Phragmites* during the last survey (i.e. late July) in 2002 (Figure 2.12a). There was higher species richness per station in *Phragmites* than in marsh meadow during late May, 2002, (survey 2) and in *Typha* than in other habitats during late July (survey 6) (Figure 2.12b). Medium stands of *Typha* had more *other birds* per station than did medium stands of marsh meadow during 2002 (Figure 2.13a). Medium stands of *Phragmites* had higher species richness per station than did medium stands of marsh meadow during 2001 (Figure 2.13b). Medium and large stands of *Typha* and medium stands of *Phragmites* had more species per station than did equivalent sized stands of marsh meadow during 2002.

There was no interaction between habitat and sample station location on either abundance, or species richness, of *other birds* per station during 2001 (Abundance: $p > 0.49$; Species richness: $p > 0.53$). Edge stations in marsh meadow had fewer individuals and species of *other birds* per station than did edge stations in *Typha* (Abundance: $p < 0.06$; Species Richness: $p < 0.08$) and *Phragmites* (0.08; 0.0005) and interior stations in *Typha* (0.002; 0.0005) during 2002 (Figure 2.14a and Figure 2.14b). There were fewer *other birds* per station and species per station in interior stations of marsh meadow than in edge stations of *Typha* (Abundance: $p < 0.04$; Species Richness: $p < 0.04$) and *Phragmites* (0.05; 0.0001) and interior stations in *Typha* (0.001; 0.0001). Interior stations in *Typha* had more individuals and species per station than did interior stations in *Phragmites* (Abundance: $p < 0.03$; Species Richness: $p < 0.03$). There were also more species per station in edge stations of *Phragmites* than in interior stations of *Phragmites* ($p < 0.02$), but interior stations of *Phragmites* had more species per station than did

Table 2.6. Model selection for variation in total abundance of *other birds* per sample station and species richness of *other birds* per sample station observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), difference between the mean monthly water depth and the annual mean elevation of Lake Erie (WD; m), and stand size (SIZE). Shown for each candidate model is the year, response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Year | Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|---|
| | **Total Abundance of *Other birds* / Sample Station** | | | | | | | |
| 2001 | HAB, WD, HAB × WD | 10 | 0.00 | 0.26 | 0.26 | 0.109 ± 0.045 | 0.160 ± 0.050 | 0.175 ± 0.050 |
| | HAB, SIZE, SD, HAB × SIZE | 15 | 0.50 | 0.20 | 0.28 | | | |
| | HAB, WD, SD, HAB × WD | 15 | 0.90 | 0.16 | 0.28 | | | |
| | HAB, SIZE, WD, HAB × SIZE | 12 | 1.30 | 0.13 | 0.27 | | | |
| 2002 | HAB, SD, WD, SIZE, HAB × SD, HAB × WD, HAB × SIZE, HAB × SD × WD | 19 | 0.00 | 0.79 | 0.24 | 0.102 ± 0.036 | 0.183 ± 0.063 | 0.150 ± 0.038 |
| | HAB, SD, WD, HAB × SD ×WD | 17 | 4.40 | 0.09 | 0.22 | | | |
| | **Species Richness of *Other birds* / Sample Station** | | | | | | | |
| 2001 | HAB, SIZE, SD, HAB × SIZE | 15 | 0.00 | 0.46 | 0.28 | 0.056 ± 0.012 | 0.070 ± 0.018 | 0.070 ± 0.012 |
| | HAB, SD, SIZE | 11 | 1.70 | 0.20 | 0.26 | | | |
| 2002 | HAB, SD, WD, SIZE, HAB × SD, HAB × WD, HAB × SIZE, HAB × SD × WD | 19 | 0.00 | 0.91 | 0.27 | 0.051 ± 0.010 | 0.083 ± 0.018 | 0.078 ± 0.011 |
| | HAB, SD, WD, HAB × SD × WD | 17 | 6.30 | 0.04 | 0.24 | | | |

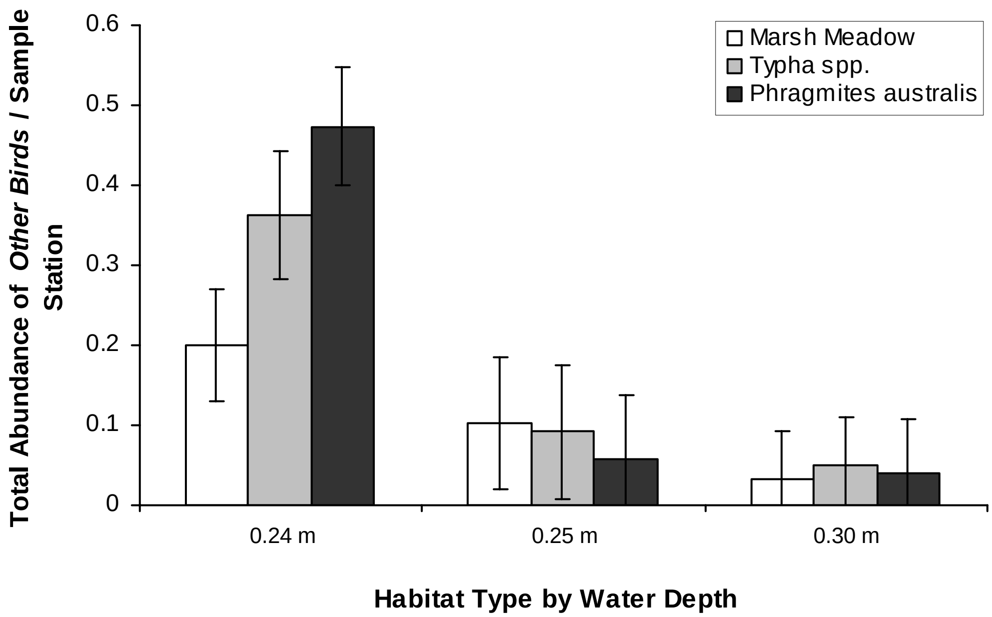



Figure 2.11. Least-squares means (± 95 % CI) for total abundance of *other birds* per sample station observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 in relation to habitat and water depth (difference between the mean monthly water depth and annual mean elevation of Lake Erie in metres).

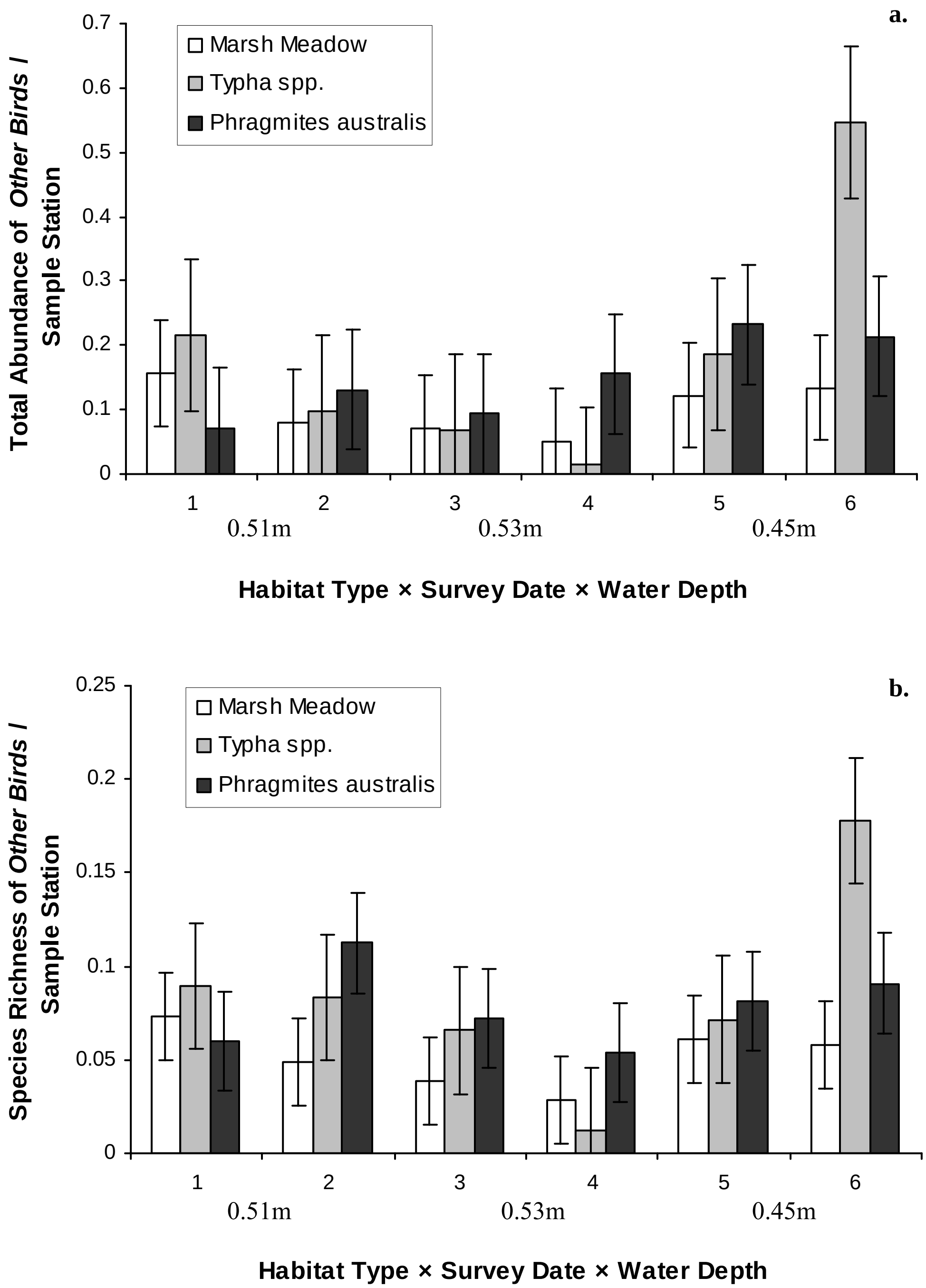



Figure 2.12. Least-squares means (± 95 % CI) for total abundance of *other birds* per sample station (**a.**) and species richness of *other birds* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat, survey date (1 = 1 May; 6 = 31 July), and water depth (difference between the mean monthly water depth and annual mean elevation of Lake Erie).

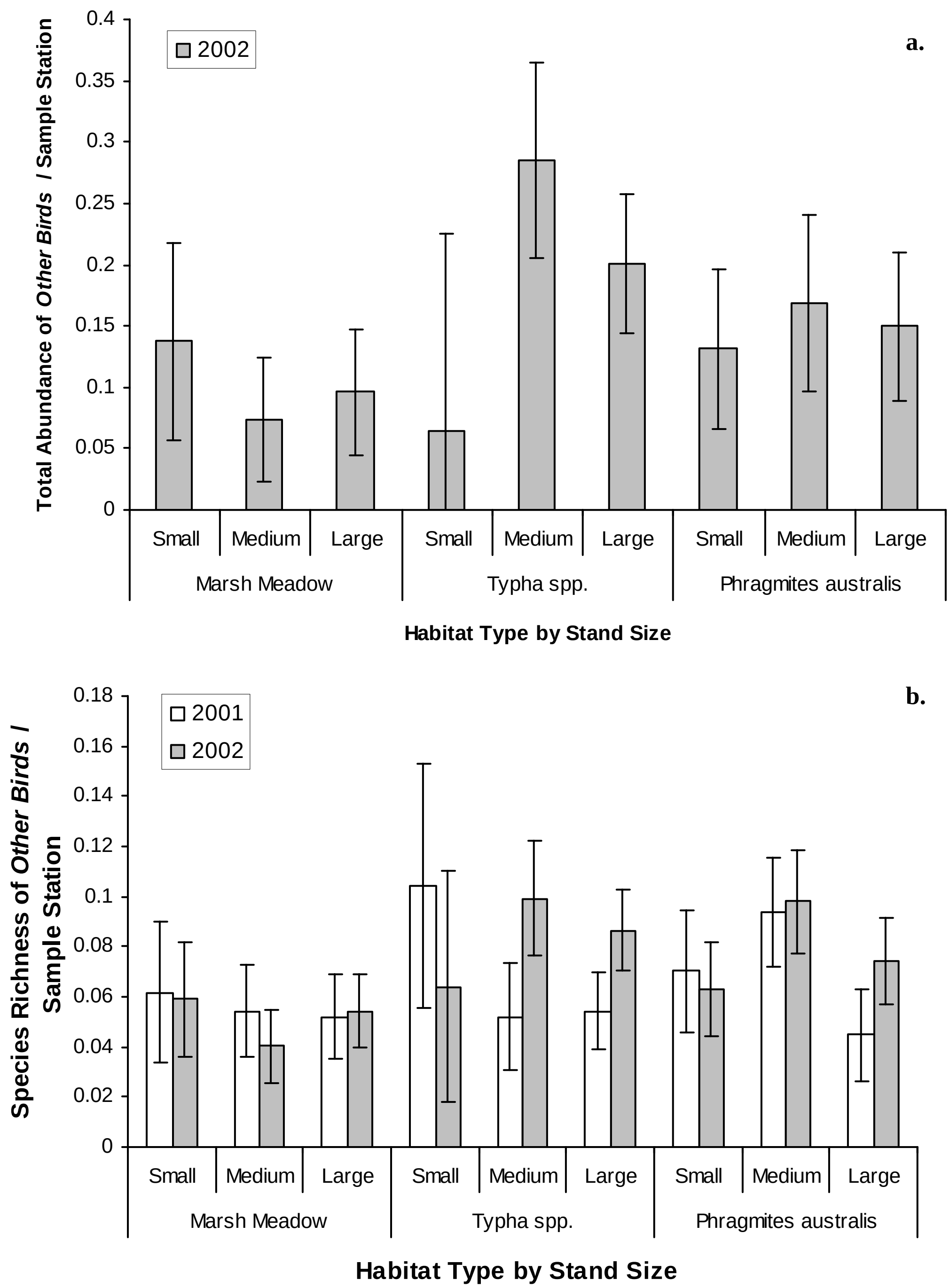
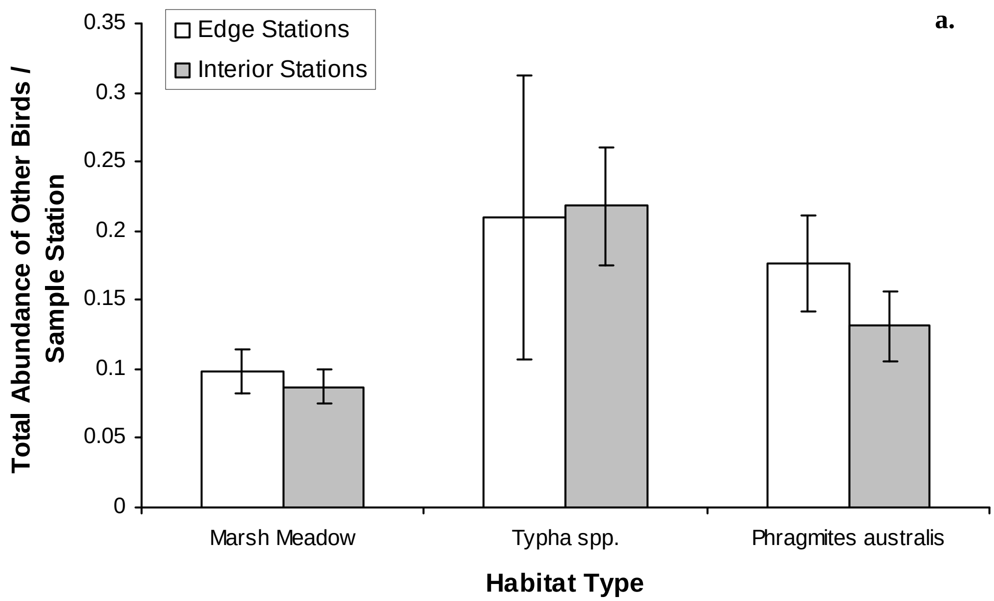



Figure 2.13. Least-squares means (± 95 % CI) for total abundance of *other birds* per sample station (**a.**) and species richness of *other birds* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July in relation to year, habitat, and stand size (Small: 140 $m^2$ – 3000 $m^2$; Medium: 3001 $m^2$ – 8000 $m^2$; Large > 8000 $m^2$).



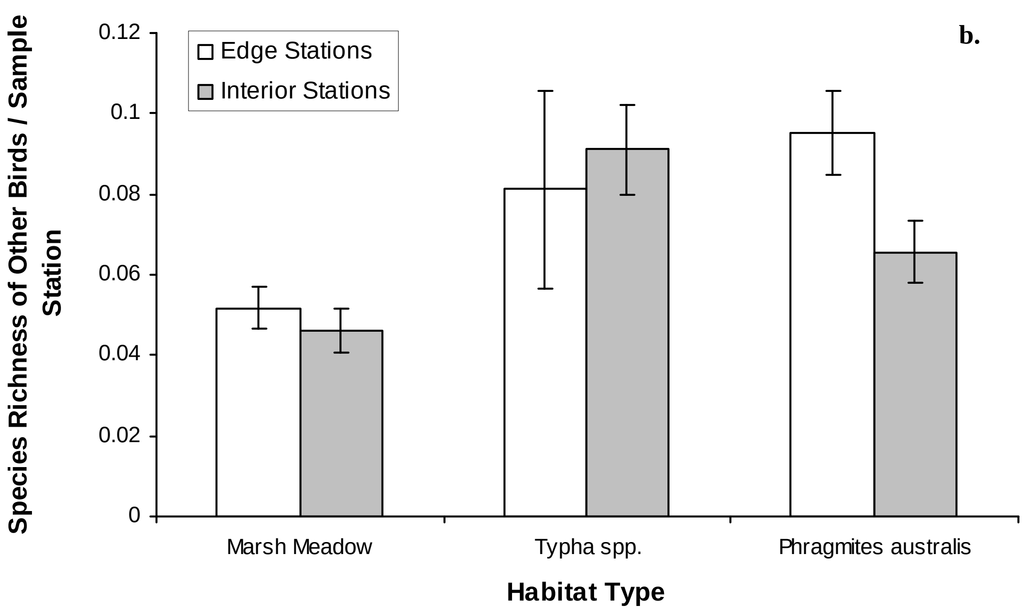




Figure 2.14. Least-squares means (± SE) for total abundance of *other birds* per sample station (**a.**) and species richness of *other birds* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat and sample station location.

interior stations in marsh meadow ($p < 0.08$).

*2.4.3. Fall Surveys (September - November 2001)*

*2.4.3.1. Total Birds*

During fall, I observed 194 birds of 16 species (Table 2.7 and Table 2.8). Per station, there were more birds and species in *Phragmites* than in other habitats. However, *Phragmites* had a lower diversity index per station than did *Typha* and marsh meadow.

*2.4.3.2. Comparative use of Phragmites, Typha, and Marsh Meadows by Marsh birds during fall*

Per station, *Phragmites* had more individuals and higher species richness of *marsh birds* than did other habitats during fall (Table 2.8). More blackbirds (Red-winged Blackbirds and Common Grackles) were observed in *Phragmites* than in marsh meadow or *Typha*.

Total abundance of *marsh birds* per station surveyed during fall was not related to habitat because the null model had the lowest $AIC_C$ score of any model ($W_{AICC}$: 0.38) (Table 2.9). The model that best explained species richness of *marsh birds* per station during fall included habitat. Overall, least-squares means and their 95 % confidence intervals showed that this effect was not strong. Species richness per station, however, also depended on survey date. Species richness of *marsh birds* per station was lowest in *Phragmites* in early fall, but highest in *Phragmites* in late fall (Figure 2.15). There was no interaction between habitat and sample station location on species richness of *marsh birds* per station during fall ($p > 0.94$).

*2.4.3.3. Comparative use of Phragmites, Typha, and Marsh Meadows by Other birds during fall*

Per station, there were more individuals and higher species richness of *other birds* in *Phragmites* than in other habitats during fall (Table 2.7 and Table 2.8). This difference was partly due to high numbers of Dark-eyed Juncos observed in *Phragmites*.

Per station, the models best explaining total abundance and species richness of *other birds* during fall included habitat (Table 2.9). However, least-squares means and their 95 % confidence intervals showed this effect was not strong. Edge stations in *Phragmites* had more *other birds* per station and higher species richness per station than

Table 2.7. Birds observed during 10 minute point counts in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) at Long Point, ON, from 30 September until 15 November 2001.

| Common Name | Scientific Name | *Phragmites australis* | | *Typha* spp. | | Marsh Meadow | |
|---|---|---|---|---|---|---|---|
| Mallard | *Anas platyrhynchos* | 0[1] | 0[2] | 0[1] | 0[2] | 0[1] | 3[2] |
| [3]Northern Harrier | *Circus cyaneus* | 1 | 0 | 1 | 1 | 1 | 0 |
| [3]American Kestrel | *Falco sparverius* | 0 | 0 | 0 | 0 | 1 | 0 |
| [4]Common Snipe | *Gallinago gallinago* | 0 | 0 | 0 | 0 | 2 | 1 |
| [3]Morning Dove | *Zenaida macroura* | 0 | 0 | 0 | 0 | 1 | 0 |
| [3]Eastern Kingbird | *Tyrannus tyrannus* | 0 | 0 | 0 | 0 | 1 | 0 |
| [3]Black-capped Chickadee | *Poecile atricapillus* | 3 | 5 | 0 | 0 | 2 | 0 |
| [4]Marsh Wren | *Cistothorus palustris* | 3 | 0 | 8 | 1 | 3 | 0 |
| Golden-crowned Kinglet | *Regulus satrapa* | 0 | 0 | 0 | 0 | 0 | 1 |
| [3]Ruby-crowned Kinglet | *Regulus calendula* | 1 | 0 | 0 | 0 | 3 | 0 |
| [3]Unknown Kinglet | Family Regulidae | 1 | 0 | 0 | 0 | 0 | 0 |
| [4]Common Yellowthroat | *Geothlypis trichas* | 0 | 1 | 0 | 0 | 0 | 0 |
| [3]American Tree Sparrow | *Spizella arborea* | 4 | 0 | 2 | 0 | 0 | 0 |
| [3]Song Sparrow | *Melospiza melodia* | 1 | 0 | 0 | 0 | 0 | 0 |
| [4]Swamp Sparrow | *Melospiza georgiana* | 6 | 0 | 8 | 1 | 10 | 2 |
| [3]White-throated Sparrow | *Zonotrichia albicollis* | 7 | 1 | 5 | 0 | 5 | 0 |

**1** Data from Mapped Observations and Aerial Foragers.

**2** Data from Additional Observations.

**3** *Other birds*.

**4** *Marsh birds*.

Table 2.7. Continued.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| [3]Unknown Sparrow | Family Emberizidae | 3 | 0 | 0 | 0 | 2 | 0 |
| [3]Dark-eyed Junco | *Junco hyemalis* | 27 | 1 | 3 | 0 | 9 | 0 |
| [4]Red-winged Blackbird | *Agelaius phoeniceus* | 42 | 194 | 5 | 0 | 0 | 1 |
| [4]Common Grackle | *Quiscalus quiscula* | 22 | 6 | 0 | 0 | 0 | 0 |
| [3]American Goldfinch | *Carduelis tristis* | 1 | 0 | 0 | 0 | 0 | 0 |

Table 2.8. Summarized data for total abundance and species richness of total birds, *marsh birds*, and *other birds* observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 30 September until 15 November 2001 in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) and number of sample stations in each habitat. Also shown for each habitat is Shannon - Wiener's diversity index, calculated for corrected bird totals (total number of birds per number of sample stations in that habitat). Based on data from Table 2.7, but only includes Mapped Observations and Aerial Foragers.

| Year | Response Variable | *Phragmites australis* | *Typha* spp. | Marsh Meadow | **TOTAL** |
|---|---|---|---|---|---|
| **Fall 2001** | Number of Stations | 16 | 16 | 18 | 50 |
| | Total Birds | 122 | 32 | 40 | 194 |
| | Total Birds / Station | 7.62 | 2.00 | 2.22 | 3.88 |
| | Species Richness | 12 | 7 | 11 | 16 |
| | Species Richness / Station | 0.75 | 0.44 | 0.61 | 0.32 |
| | Diversity Index / Station | 0.77 | 0.81 | 0.87 | 0.93 |
| | *Marsh birds* | 73 | 21 | 15 | 109 |
| | - Total Blackbirds | 64 | 5 | 0 | 69 |
| | *Marsh birds* / Station | 4.56 | 1.31 | 0.83 | 2.18 |
| | *Marsh bird* Species Richness | 4 | 3 | 3 | 5 |
| | *Marsh bird* Species Richness / Station | 0.25 | 0.19 | 0.17 | 0.10 |
| | *Other birds* | 49 | 11 | 25 | 85 |
| | - Total Juncos | 27 | 3 | 9 | 39 |
| | *Other birds* / Station | 3.06 | 0.69 | 1.39 | 1.70 |
| | *Other bird* Species Richness | 8 | 4 | 8 | 11 |
| | *Other bird* Species Richness / Station | 0.50 | 0.25 | 0.44 | 0.22 |

- *Marsh birds* include waterfowl, rails, bitterns, Killdeer (*Charadrius vociferous*), Common Snipe (*Gallinago gallinago*), American Woodcock (*Scolopax minor*), Marsh Wrens (*Cistothorus palustris*), Swamp Sparrows (*Melospiza georgiana*), Common Yellowthroats (*Geothlypis trichas*), Red-winged Blackbirds (*Agelaius phoeniceus*), and Common Grackles (*Quiscalus quiscula*).
- Total Blackbirds include Red-winged Blackbirds and Common Grackles.
- *Other birds* include all other birds.
- Total Juncos include Dark-eyed Juncos (*Junco hyemalis*).

Table 2.9. Model selection for variation in total abundance of *marsh birds* per sample station, species richness of *marsh birds* per sample station, total abundance of *other birds* per sample station, and species richness of *other birds* per sample station observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 30 September until 15 November 2001 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), difference between the mean monthly water depth and the annual mean elevation of Lake Erie (WD; m), and stand size (SIZE). Shown for each candidate model is the response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|
| **Total Abundance of *Marsh birds* / Sample Station** | | | | | | | |
| NULL | 2 | 0.00 | 0.38 | 0.00 | | | |
| HAB | 4 | 1.30 | 0.20 | 0.03 | 0.022 ± 0.096 | 0.044 ± 0.109 | 0.143 ± 0.105 |
| HAB, SD | 5 | 2.00 | 0.14 | 0.04 | | | |
| **Species Richness of *Marsh birds* / Sample Station** | | | | | | | |
| HAB, SD, HAB × SD | 7 | 0.00 | 0.36 | 0.11 | 0.016 ± 0.011 | 0.020 ± 0.012 | 0.020 ± 0.012 |
| NULL | 2 | 1.00 | 0.22 | 0.00 | | | |
| **Total Abundance of *Other birds* / Sample Station** | | | | | | | |
| HAB | 4 | 0.00 | 0.36 | 0.06 | 0.036 ± 0.038 | 0.023 ± 0.042 | 0.096 ± 0.041 |
| HAB, SD | 5 | 1.00 | 0.22 | 0.08 | | | |
| **Species Richness of *Other birds* / Sample Station** | | | | | | | |
| HAB, SD | 5 | 0.00 | 0.27 | 0.11 | 0.021 ± 0.012 | 0.018 ± 0.014 | 0.041 ± 0.014 |
| HAB, WD | 6 | 0.30 | 0.24 | 0.13 | | | |
| HAB | 4 | 1.90 | 0.11 | 0.07 | | | |
| HAB, SD, WD | 7 | 1.90 | 0.11 | 0.07 | | | |

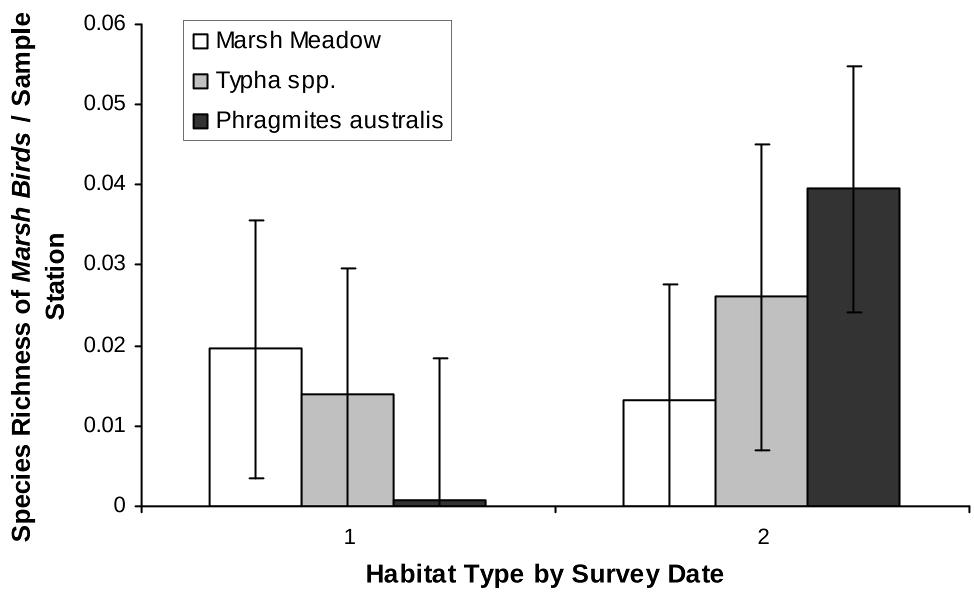



Figure 2.15. Least-squares (LS) means (± 95 % CI) for species richness of *marsh birds* per sample station observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 30 September until 15 November 2001 in relation to habitat and survey date (1 =30 September – 28 October; 2 = 30 October – 15 November).

did edge stations in marsh meadow (Abundance: $p < 0.002$; Species Richness: $p < 0.006$) and *Typha* (0.004; 0.004) and interior stations in marsh meadow (0.004; 0.0005), *Typha* (0.001; 0.0004), and *Phragmites* (0.009; 0.007) (Figure 2.16a and Figure 2.16b).

*2.4.4. Winter Surveys (January - February 2002)*

*2.4.4.1. Total Birds*

During winter, I observed 37 birds of 5 species (Table 2.10 and Table 2.11). *Phragmites* and marsh meadow had similar abundance per station which was higher than that of *Typha*. Per station, there was higher species richness and diversity in *Phragmites* than in other habitats.

*2.4.4.2. Comparative use of Phragmites, Typha, and Marsh Meadows by All birds*

Total abundance of *all birds* per station surveyed during winter was not related to habitat because the null model had the lowest $AIC_C$ score of any model ($W_{AICC}$: 0.75) (Table 2.12). The model that best explained species richness of *all birds* per station included habitat. However, least-squares means and their 95 % confidence intervals showed that this effect was not strong. There was no interaction between habitat and sample station location on species richness of *all birds* per station during winter ($p > 0.15$).

*2.4.5. Spring Surveys (April 2002)*

*2.4.5.1. Total Birds*

During spring, I observed 111 birds of 15 species (Table 2.13 and Table 2.14). Per station, there was higher abundance, species richness, and diversity in marsh meadow than in other habitats.

*2.4.5.2. Comparative use of Phragmites, Typha, and Marsh Meadows by Marsh birds during spring*

Per station, marsh meadow had more individuals and species of *marsh birds* than did other habitats (Table 2.14). There were more *marsh birds* per station in *Phragmites* than in *Typha* but species richness per station was similar.

Per station, the models that best explained total abundance and species richness of *marsh birds* during spring included habitat (Table 2.15). However, least-squares means and their 95 % confidence intervals showed that this effect was not strong. There was no

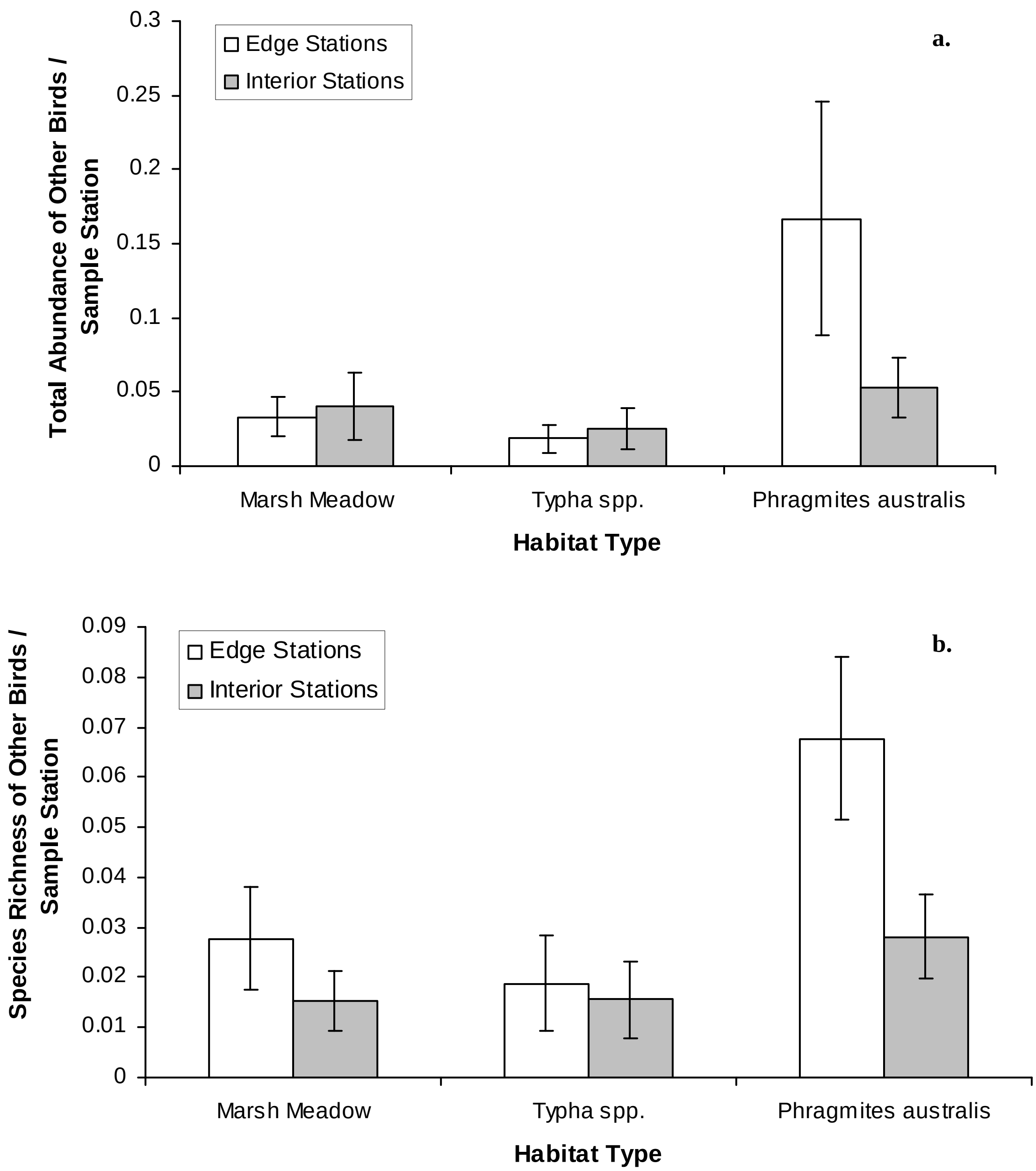



Figure 2.16. Least-squares means (± SE) for total abundance of *other birds* per sample station (**a.**) and species richness of *other birds* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 30 September until 15 November 2001 in relation to habitat and sample station location.

Table 2.10. Birds observed during 10 minute point counts in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) at Long Point, ON, from 1 January until 15 February 2002.

| Common Name | Scientific Name | *Phragmites australis* | | *Typha* spp. | | Marsh Meadow | |
|---|---|---|---|---|---|---|---|
| [3]Northern Harrier | *Circus cyaneus* | 0[1] | 0[2] | 1[1] | 0[2] | 0[1] | 0[2] |
| Horned Lark | *Eremophila alpestris* | 0 | 0 | 0 | 0 | 0 | 6 |
| [3]Black-capped Chickadee | *Poecile atricapillus* | 4 | 10 | 0 | 0 | 0 | 0 |
| [3]American Tree Sparrow | *Spizella arborea* | 4 | 3 | 1 | 0 | 0 | 0 |
| [3]Dark-eyed Junco | *Junco hyemalis* | 2 | 2 | 0 | 0 | 0 | 0 |
| [3]Red-winged Blackbird | *Agelaius phoeniceus* | 5 | 15 | 3 | 0 | 17 | 0 |

**1** Data from Mapped Observations and Aerial Foragers.

**2** Data from Additional Observations.

**3** *All birds*.

Table 2.11. Summarized data for total abundance and species richness of *all birds* observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 January until 15 February 2002 in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) and number of sample stations in each habitat. Also shown for each habitat is Shannon - Wiener's diversity index, calculated for corrected bird totals (total number of birds per number of sample stations in that habitat). Based on data from Table 2.10, but only includes Mapped Observations and Aerial Foragers.

| Year | Response Variable | *Phragmites australis* | *Typha* spp. | Marsh Meadow | **TOTAL** |
|---|---|---|---|---|---|
| **Winter 2002** | Number of Stations | 16 | 16 | 18 | 50 |
| | *All birds* | 15 | 5 | 17 | 37 |
| | - Total Blackbirds | 5 | 3 | 17 | 25 |
| | - Total Chickadees | 4 | 0 | 0 | 4 |
| | *All birds* / Station | 0.94 | 0.31 | 0.94 | 0.74 |
| | *All bird* Species Richness | 4 | 3 | 1 | 5 |
| | *All bird* Species Richness/ Station | 0.25 | 0.19 | 0.06 | 0.10 |
| | Diversity Index / Station | 0.58 | 0.41 | 0.00 | 0.45 |

- *All birds* include all birds.
- Total Blackbirds include Red-winged Blackbirds (*Agelaius phoeniceus*) and Common Grackles (*Quiscalus quiscula*).
- Total Chickadees include Black-capped Chickadees (*Poecile atricapillus*).

Table 2.12. Model selection for variation in total abundance of *all birds* per sample station and species richness of *all birds* per sample station observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 January until 15 February 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), and stand size (SIZE). Shown for each candidate model is the response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|
| **Total Abundance of *All birds* / Sample Station** | | | | | | | |
| NULL | 2 | 0.00 | 0.75 | 0.00 | | | |
| HAB | 4 | 3.00 | 0.17 | 0.01 | 0.026 ± 0.029 | 0.010 ± 0.031 | 0.029 ± 0.031 |
| **Species Richness of *All birds* / Sample Station** | | | | | | | |
| HAB | 4 | 0.00 | 0.34 | 0.06 | 0.003 ± 0.007 | 0.006 ± 0.008 | 0.016 ± 0.008 |
| HAB, SD | 5 | 0.20 | 0.31 | 0.08 | | | |
| NULL | 2 | 1.60 | 0.15 | 0.00 | | | |

Table 2.13. Birds observed during 10 minute point counts in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) at Long Point, ON, from 1 April until 15 April 2002.

| Common Name | Scientific Name | *Phragmites australis* | | *Typha* spp. | | Marsh Meadow | |
|---|---|---|---|---|---|---|---|
| [3]Mallard | *Anas platyrhynchos* | 0[1] | 0[2] | 0[1] | 0[2] | 4[1] | 8[2] |
| [3]American Black Duck | *Anas rubripes* | 0 | 0 | 0 | 0 | 2 | 3 |
| Green-winged Teal | *Anas crecca* | 0 | 0 | 0 | 0 | 0 | 1 |
| American Wigeon | *Anas americana* | 0 | 0 | 0 | 0 | 0 | 4 |
| Northern Shoveler | *Anas clypeata* | 0 | 0 | 0 | 0 | 0 | 6 |
| [4]Northern Harrier | *Circus cyaneus* | 0 | 0 | 0 | 1 | 1 | 0 |
| [3]Common Snipe | *Gallinago gallinago* | 0 | 0 | 0 | 0 | 1 | 0 |
| [4]Tree Swallow | *Tachycineta bicolor* | 3 | 5 | 1 | 0 | 11 | 0 |
| [4]Purple Martin | *Progne subis* | 1 | 0 | 0 | 0 | 0 | 1 |
| [4]Black-capped Chickadee | *Poecile atricapillus* | 1 | 0 | 0 | 0 | 0 | 0 |
| [4]Brown Creeper | *Certhia americana* | 0 | 0 | 0 | 0 | 1 | 0 |
| [4]Golden-crowned Kinglet | *Regulus satrapa* | 3 | 0 | 0 | 0 | 0 | 0 |
| [4]Ruby-crowned Kinglet | *Regulus calendula* | 2 | 0 | 0 | 0 | 0 | 0 |
| Savannah Sparrow | *Passerculus sandwichensis* | 0 | 0 | 0 | 0 | 0 | 1 |
| [4]Song Sparrow | *Melospiza melodia* | 1 | 0 | 0 | 0 | 4 | 0 |
| [3]Swamp Sparrow | *Melospiza georgiana* | 14 | 3 | 6 | 1 | 12 | 1 |

**1** Data from Mapped Observations and Aerial Foragers.

**2** Data from Additional Observations.

**3** *Marsh birds*.

**4** *Other birds*.

Table 2.13. Continued.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| [4]Unknown Sparrow | Family Emberizidae | 1 | 0 | 0 | 0 | 0 | 0 |
| [4]Dark-eyed Junco | *Junco hyemalis* | 0 | 0 | 0 | 0 | 2 | 0 |
| [3]Red-winged Blackbird | *Agelaius phoeniceus* | 14 | 9 | 6 | 14 | 18 | 10 |
| [3]Common Grackle | *Quiscalus quiscula* | 0 | 1 | 0 | 0 | 2 | 0 |

Table 2.14. Summarized data for total abundance and species richness of total birds, *marsh birds*, and *other birds* observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 April until 15 April 2002 in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) and number of sample stations in each habitat. Also shown for each habitat is Shannon - Wiener's diversity index, calculated for corrected bird totals (total number of birds per number of sample stations in that habitat). Based on data from Table 2.13, but only includes Mapped Observations and Aerial Foragers.

| Year | Response Variable | *Phragmites australis* | *Typha* spp. | Marsh Meadow | **TOTAL** |
|---|---|---|---|---|---|
| **Spring 2002** | Number of Stations | 16 | 16 | 18 | 50 |
| | Total Birds | 40 | 13 | 58 | 111 |
| | Total Birds / Station | 2.50 | 0.81 | 3.22 | 2.22 |
| | Species Richness | 8 | 3 | 11 | 15 |
| | Species Richness / Station | 0.50 | 0.19 | 0.61 | 0.30 |
| | Diversity Index / Station | 0.67 | 0.49 | 0.89 | 0.81 |
| | *Marsh birds* | 28 | 12 | 39 | 79 |
| | - Total Waterfowl | 0 | 0 | 6 | 6 |
| | - Total Blackbirds | 14 | 6 | 20 | 40 |
| | *Marsh birds* / Station | 1.75 | 0.75 | 2.17 | 1.58 |
| | *Marsh bird* Species Richness | 2 | 2 | 6 | 6 |
| | *Marsh bird* Species Richness / Station | 0.12 | 0.12 | 0.33 | 0.12 |
| | *Other birds* | 12 | 1 | 19 | 32 |
| | - Total Swallows | 4 | 1 | 11 | 16 |
| | *Other birds* / Station | 0.75 | 0.06 | 1.06 | 0.64 |
| | *Other bird* Species Richness | 6 | 1 | 5 | 9 |
| | *Other bird* Species Richness / Station | 0.38 | 0.06 | 0.28 | 0.18 |

- *Marsh birds* include waterfowl, rails, bitterns, Marsh Wrens (*Cistothorus palustris*), Swamp Sparrows (*Melospiza georgiana*), Common Snipe (*Gallinago gallinago*), American Woodcock (*Scolopax minor*), Killdeer (*Charadrius vociferous*), Common Yellowthroats (*Geothlypis trichas*), Red-winged Blackbirds (*Agelaius phoeniceus*) and Common Grackles (*Quiscalus quiscula*).
- Total Waterfowl include Mallards (*Anas platyrhynchos*) and American Black Ducks (*Anas rubripes*).
- Total Blackbirds include Red-winged Blackbirds and Common Grackles.
- *Other birds* include all other birds.
- Total Swallows include Tree Swallows (*Tachycineta bicolor*) and Purple Martins (*Progne subis*).

Table 2.15. Model selection for variation in total abundance of *marsh birds* per sample station, species richness of *marsh birds* per sample station, total abundance of *other birds* per sample station, and species richness of *other birds* per sample station observed within 25 m fixed radius point counts, at Long Point, Lake Erie, ON, from 1 April until 15 April 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), and stand size (SIZE). Shown for each candidate model is the response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | Marsh Meadow | *Typha* spp. | *Phragmites australis* |
|---|---|---|---|---|---|---|---|
| **Total Abundance of *Marsh birds* / Sample Station** | | | | | | | |
| HAB, SD | 5 | 0.00 | 0.41 | 0.16 | 0.110 ± 0.043 | 0.063 ± 0.050 | 0.102 ± 0.047 |
| NULL | 2 | 1.30 | 0.21 | 0.00 | | | |
| HAB | 4 | 1.70 | 0.17 | 0.08 | | | |
| **Species Richness of *Marsh birds* / Sample Station** | | | | | | | |
| HAB, SD | 5 | 0.00 | 0.68 | 0.24 | 0.062 ± 0.018 | 0.037 ± 0.021 | 0.046 ± 0.020 |
| HAB, SD, SIZE | 7 | 3.40 | 0.12 | 0.27 | | | |
| **Total Abundance of *Other birds* / Sample Station** | | | | | | | |
| HAB, SD | 5 | 0.00 | 0.37 | 0.22 | 0.053 ± 0.024 | 0.017 ± 0.028 | 0.042 ± 0.026 |
| HAB, SD, SIZE | 7 | 1.40 | 0.18 | 0.27 | | | |
| HAB, SIZE | 6 | 1.50 | 0.17 | 0.23 | | | |
| **Species Richness of *Other birds* / Sample Station** | | | | | | | |
| HAB, SD | 5 | 0.00 | 0.51 | 0.25 | 0.036 ± 0.017 | 0.016 ± 0.020 | 0.034 ± 0.019 |
| HAB, SD, HAB × SD | 7 | 1.70 | 0.22 | 0.36 | | | |

interaction between habitat and sample station location on total abundance of *marsh birds* per station during spring ($p > 0.20$). Edge stations in marsh meadow, however, had more species per station than did edge stations in *Typha* ($p < 0.001$) and *Phragmites* (0.06) and interior stations in *Typha* (0.04) (Figure 2.17a). There was also higher species richness at interior stations in all habitats than at edge stations in *Typha*.

*2.4.5.3. Comparative use of Phragmites, Typha, and Marsh Meadows by Other birds during spring*

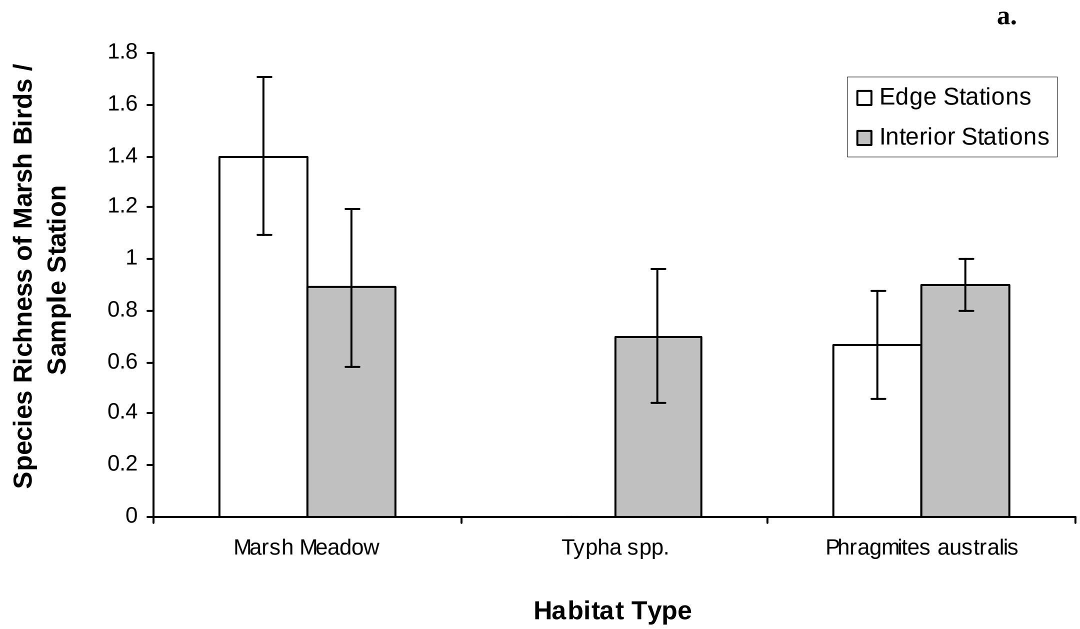
There were more *other birds* per station in marsh meadow than in other habitats during spring (Table 2.14). *Phragmites* had higher species richness of *other birds* per station than did other habitats.

Per station, the models that best explained total abundance and species richness of *other birds* during spring included habitat (Table 2.15). Overall, least-squares means and their 95 % confidence intervals showed that this effect was not strong. There was no interaction between habitat and sample station location on total abundance of *other birds* per station during spring ($p > 0.17$). Edge stations in marsh meadow, however, had higher species richness per station than did edge stations in *Typha* (0.02) and interior stations in marsh meadow ($p < 0.05$) and *Typha* (0.02) (Figure 2.17b). There was also fewer species per station at *Typha* edges than at other stations.

## 2.5. DISCUSSION

Stands of an exotic genotype of *Phragmites* have recently replaced many stands of *Typha* spp. and marsh meadow at Long Point, Ontario (Wilcox et al. submitted) and this genotype is likely responsible for the rapid expansion of *Phragmites* elsewhere on the lower Great Lakes (Saltonstall 2002, Haggeman, pers. comm.). Because of this rapid expansion and its aggressive growth and vegetative characteristics (Jones and Lehman 1987, Rice et al. 2000), this exotic form of *Phragmites* may compromise the suitability of wetlands for some birds (Ward 1942, Benoit and Askins 1999). Therefore, I examined avian abundance and species richness in stands of *Phragmites* and other habitats at Long Point, Ontario. As far as I am aware, this was the first investigation of avian use of exotic *Phragmites* and other habitats in a freshwater coastal wetland.

*Marsh obligates* - *gleaners* did not nest in *Phragmites* but did use this habitat after fledging. For example, breeding Marsh Wrens tended to use *Typha* and breeding Swamp



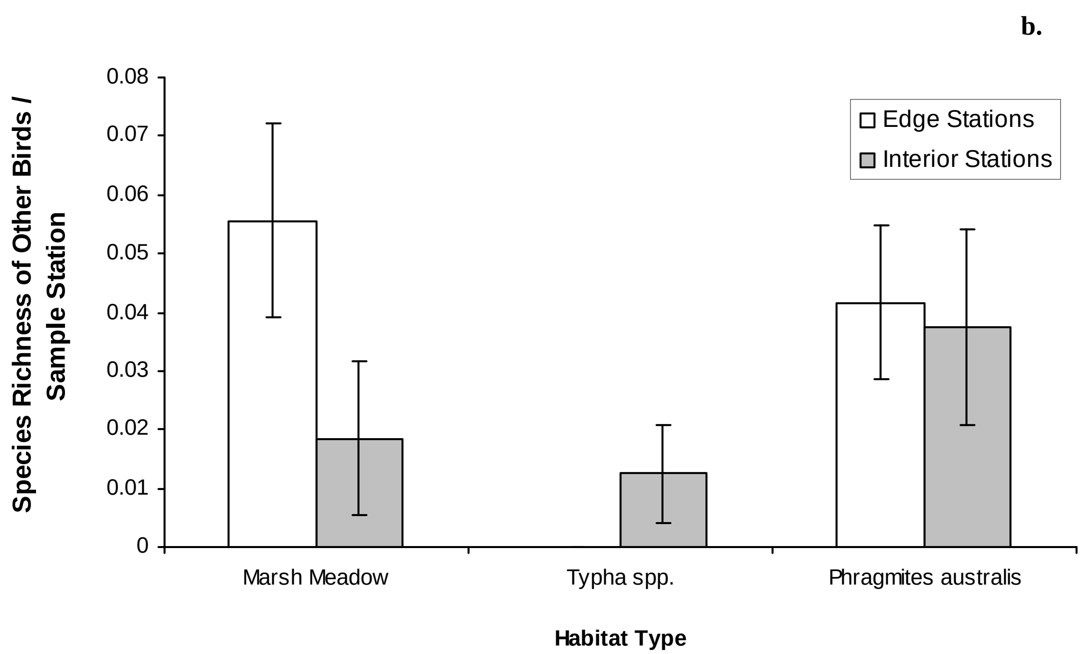




Figure 2.17. Least-squares means (± SE) for species richness of *marsh birds* per sample station (**a.**) and species richness of *other birds* per sample station (**b.**) observed within 25 m fixed radius point counts at Long Point, Lake Erie, ON, from 1 April until 15 April 2002 in relation to habitat and sample station location.

Sparrows used marsh meadow (Figure 2.3, Figure 2.4, and Appendix 3). Other studies have also shown that Marsh Wrens prefer *Typha* (Kirk et al. 2001, Naugle et al. 2001) and Swamp Sparrows nest in graminoid vegetation (Whitt et al. 1999, Kirk et al. 2001, Riffell et al. 2001). Generally, large, monotypic stands of tall, emergent vegetation are considered low quality breeding habitat for birds (Marks et al. 1993). This may explain the low use of large stands of *Phragmites* and *Typha* by breeding Swamp Sparrows and Marsh Wrens (Figure 2.3). Large stands of marsh meadow, however, are important for breeding Swamp Sparrows (Riffell et al. 2001). Although anecdotal evidence suggests that *Phragmites* provides nesting habitat for Swamp Sparrows and Marsh Wrens (see Kane 2001), I did not detect any Swamp Sparrow or Marsh Wren nests in *Phragmites* (Appendix 3). *Phragmites* stands, however, were used after young fledged (Figure 2.4; 0.24 m occurred in July after young fledged). High stem density, plant height, and litter accumulation within *Phragmites* stands (Kiviat 1987, Marks et al. 1994) may benefit Swamp Sparrow and Marsh Wren fledglings by providing cover and access to invertebrate food. Benoit and Askins (1999) also documented a high abundance of Swamp Sparrows and Marsh Wrens in *Phragmites* stands in Connecticut during summer. In their study, however, they only surveyed birds once in June and July and therefore could not adequately differentiate between nesting and fledging habitat. This may explain why Swamp Sparrows were not recorded in short-grass meadows in their study. However, other graminoid dependent birds such as Saltmarsh Sharp-tailed Sparrows (*Ammodramus caudacutus*) and Seaside Sparrows (*Ammodramus maritime*) were more abundant in marsh meadows than in *Phragmites*. Therefore, continued expansion of *Phragmites* stands may negatively affect Swamp Sparrows as nesting habitat disappears.

Use of *Phragmites* stands by *marsh obligates - non-gleaners* was limited to Least Bitterns and Virginia Rails (Table 2.1). Although water levels in Lake Erie were low during the study, some *Phragmites* stands were flooded. However, I did not detect any ducks using *Phragmites* and Virginia Rails only used stand edges (Figure 2.7). My results are consistent with other studies which have documented limited use of *Phragmites* by ducks and rails (Ward 1942, Hochbaum 1944, Benoit and Askins 1999). Benoit and Askins (1999) suggested that limited interior use of *Phragmites* stands by some large wading birds such as Snowy Egrets (*Egretta thula*) may be related to inaccessibility. My results differ from Benoit and Askins (1999) in that Least Bitterns, a wading bird, were only observed within the interior of a large stand of *Phragmites*. Although I did not find any bittern nests, other studies have recorded bitterns nesting in *Phragmites* (Weller 1961, Gibbs et al. 1992). Strong structural support of *Phragmites* stems (Kiviat 1987) may benefit breeding bitterns by providing nest and roost sites. This may explain use of *Phragmites* by these birds and other species of the Family Ardeidae in Europe (Bibby and Lunn 1982, Barbraud et al. 2002), elsewhere in North America (Weller 1961, Gibbs et al. 1992), and possibly at Long Point. High silica content in *Phragmites* stems, however, reduces rates of decomposition (Kiviat 1987) thereby leading to an accumulation of litter. Therefore, rails are less likely to gain access into the interior of *Phragmites* stands (Figure 2.7). Consequently, use of *Phragmites* by rails was limited to stand edges.

Ducks did not use *Phragmites* stands possibly because of a lack of open water. Other studies have documented the importance of open pools of water for attracting waterfowl (Bibby and Lunn 1982, Benoit and Askins 1999). My results are similar to these studies in that stands of *Typha* and marsh meadow had more open pools of water than did stands of *Phragmites* and, thus, these habitats were used by ducks (Table 2.1 and Figure 2.6). Open pools of water within *Typha* stands were likely created by foraging muskrats (Clark 1994). Ward (1942) concluded that *Phragmites* is not a preferred muskrat food. This, in conjunction with low water levels, may explain why I did not observe open pools of water in any *Phragmites* stand. Weller (1961) concluded that open pools of water were also significant indicators for breeding Least Bitterns. However, I did not detect any Least Bitterns in *Typha* and marsh meadow (Table 2.1). Least Bitterns possibly did not use *Typha* and marsh meadow because of nesting preferences for *Phragmites*. The presence of open water in *Phragmites* stands, however, may increase the use of this habitat by ducks, rails, and possibly bitterns and should be investigated further.

The dominant *marsh users* in *Phragmites* were Red-winged Blackbirds, Common Grackles, and Common Yellowthroats (Table 2.1). Blackbirds (Red-winged Blackbirds and Common Grackles) primarily used *Phragmites* as roosting habitat, but some nests were also recorded (Appendix 3). Benoit and Askins (1999) also showed that Red-winged Blackbirds were a dominant species using *Phragmites* in Connecticut during summer and Zimmerling (pers. comm.) documented Red-winged Blackbirds commonly nesting and roosting in *Phragmites* in eastern Ontario. Use of stand interiors in *Phragmites* by *marsh users* was affected by water levels (Figure 2.10a and Figure 2.10b). Possibly, low water levels during 2001 increased the accessibility of roosting birds to some terrestrial mammalian predators. Because stem density and litter accumulation within *Phragmites* are likely related to age, stand interiors possibly provided roosting sites that were inaccessible to many predatory mammals. This effect, however, was not evident during 2002 due to flooding of *Phragmites* stands. However, use of stand interiors of *Phragmites* by *marsh users* was still high (Figure 2.10a). Other studies have documented use of *Phragmites* by marsh birds as roosting habitat (Ward 1942, Hudec and Stastny 1978). The use of *Phragmites* by Common Yellowthroats is likely due to their preference for dense habitats (Riffell et al. 2001) (Table 2.1). Benoit and Askins (1999), however, recorded more Common Yellowthroats in *Typha* than in *Phragmites* in Connecticut. This difference is likely due to the low number of Common Yellowthroats recorded in their study (3 observations versus 86 in this study) which was insufficient to detect this habitat effect. Regardless, my data showed that *Phragmites* provided roosting and nesting habitat for blackbirds and Common Yellowthroats.

Canada Geese and Killdeer did not use *Phragmites* and use by American Woodcock was limited (Table 2.1). Low use of *Phragmites* by these species was likely due to the denseness of *Phragmites* stands. Benoit and Askins (1999) also did not record any Canada Geese using *Phragmites* in Connecticut. It is possible, however, that numbers of these species, particularly Killdeer and American Woodcock, were underestimated in *Phragmites*. Higher visual detectability in marsh meadows may account for more observations and nests in this habitat than in *Typha* and *Phragmites* (Table 2.1 and Appendix 3). Further research investigating the use of *Phragmites* by waterfowl and other marsh non-gleaners should be conducted to better assess the effects of *Phragmites* expansion on these birds.

*Phragmites* stands had a more diverse community of *other birds* than did *Typha* and marsh meadow during the breeding season. I detected more warblers (Family Parulidae) and Ruby-crowned Kinglets in *Phragmites* than in *Typha* and marsh meadow

(Table 2.1). Migrating shorebirds, such as Greater Yellowlegs and Dowitchers, however, did not use *Phragmites*. Use of *Phragmites* by *other bird* species during late spring of 2002 (Figure 2.12b) may be related to late migration and possibly due to limited vertical structure in the marsh at this time of year. Ward (1942) suggested that a high abundance of insects in *Phragmites* attracted some warblers and that may explain the use of *Phragmites* by warblers in this study. The association of Yellow Warblers to dense habitats (Riffell et al. 2001) may also explain why I found a high abundance and nests of this species in *Phragmites* in this study (Table 2.1 and Appendix 3). Clearly, *Phragmites* stands were not used by shorebirds due to a lack of openings within stands. Similarly, Benoit and Askins (1999) did not record any shorebirds using *Phragmites* in Connecticut. Although expansion of *Phragmites* stands will negatively affect shorebirds because of replacement of marsh meadows, this effect will be minimal because these birds primarily used mudflats along the shores of Lake Erie. Therefore, waves will limit the expansion of *Phragmites* stands and tidal seiches will likely maintain foraging habitat for shorebirds.

*Phragmites* stands provided roosting habitat for swallows (Family Hirundinidae) and flycatchers (Family Tyrannidae), but these species used *Typha* and marsh meadow more heavily for foraging habitat. Use of *Phragmites* by swallows may be important because I did not observe swallows roosting in any other habitat. This use was highest during late summer after young fledged (Figure 2.11). A colder spring delayed reproduction and reduced swallow abundance during 2002 (Table 2.2). Therefore, higher energy demands and possible later fledging of young may explain higher use of *Typha* and marsh meadows during 2002 than during 2001 (Figure 2.11 and Figure 2.12a). This, in conjunction with fewer swallows during 2002, also likely explained the lack of differences in habitat use. Fewer insects such as midges (Family Chironomidae) in *Phragmites* (Angradi et al. 2001) may explain the use of this habitat by aerial insectivores primarily for roosting. Conversely, *Spartina* meadows and *Typha* have a high abundance of some aerial insects (Angradi et al. 2001, Turner and McCarthy 1998) and were used by many birds for foraging. Similarly, Hudec and Stastny (1978) concluded that *Phragmites* provided roosting habitat for Barn Swallows, Bank Swallows, and Black-headed Gulls (*Larus ridibundus*), but that they depended on the surrounding area for food. Benoit and

Askins (1999) also showed that *Phragmites* had more Tree Swallows and Willow Flycatchers than did *Typha* and marsh meadow. However, it is unclear whether these birds used *Phragmites* for roosting or foraging habitat. My results also differ from Benoit and Askins in that use of *Typha* by swallows was higher than that of marsh meadow. This difference is possibly due to the low water levels in Lake Erie during the study which likely negatively affected aquatic insects in marsh meadows. Thus, *Phragmites* stands provided important roosting habitat for many birds, but most used *Typha* and marsh meadow for foraging habitat.

There was no difference in numbers of birds using *Phragmites* versus the numbers using *Typha* and marsh meadow during fall. However, I only conducted 2 surveys per sample station, which may have been too few to detect differences especially during peak migration. Although I did not detect a habitat effect on avian abundance during fall, blackbirds and Dark-eyed Juncos used *Phragmites* as roosting habitat (Table 2.7 and Appendix 3). In Europe, Hudec and Stastny (1978) documented use of *Phragmites* by migrating European Starlings and in North America, anecdotal evidence suggests that *Phragmites* provides roosting habitat for migrating blackbirds (see Jones and Lehman 1987). Species richness of *marsh birds*, however, was higher in *Phragmites* in late than in early fall (Figure 2.15). This difference was due to the use of *Phragmites* by migrating Red-winged Blackbirds and Common Grackles in late, but not early fall. Common Snipe used only marsh meadows during fall possibly for foraging habitat (Table 2.07). More intensive fall sampling will be required to assess whether *Phragmites* stands are used more or less than are other habitats by migrating birds.

Some bird species used *Phragmites* during winter. Although the data for total abundance of birds during winter did not support a habitat effect, *Phragmites* stands had more Black-capped Chickadees, American Tree Sparrows, and Dark-eyed Juncos than did *Typha* and marsh meadow. Similarly, Hudec and Statsny (1978) documented use of *Phragmites* by Blue Tits (*Parus caeruleus*) for overwintering shelter in Europe and anecdotal evidence suggests that American Tree Sparrows use *Phragmites* during winter in New Jersey (see Kane 2001). Use of *Phragmites* by birds during winter is likely due to the protective shelter provided from the litter and stems and possibly because of an abundant food source [the insect (*Chaetococcus phragmitidis*)] under leaf sheaths (Kiviat

1987). Marsh meadows were only used by foraging Red-winged Blackbirds during winter. Low use of marsh meadows by birds during winter may be due to a lack of vertical structure in this habitat. My results suggest that *Phragmites* stands provided important winter shelter for some birds.

Although there was only a weak habitat effect for *marsh birds* and *other birds* during spring, I did not observe any waterfowl using *Phragmites* or *Typha* (Table 2.13). Red-winged Blackbirds, however, used *Phragmites* for roosting and perch sites. Use of *Phragmites* by Red-winged Blackbirds during spring is likely related to reduced vertical structure in windswept (i.e. flattened) *Typha* stands (Table 2.13) (Meyer pers. obs.). Although vertical structure in marsh meadow was also low during spring, meadows provided foraging habitat for Red-winged Blackbirds and waterfowl. These birds used marsh meadow more than *Phragmites* possibly because of higher aquatic invertebrate density and activity. Angradi et al. (2001) documented a higher invertebrate density in *Spartina* meadows than in *Phragmites*. High stand height, density, and litter accumulation within *Phragmites* may negatively affect aquatic invertebrates by reducing thermal heating during spring. This may explain why stand edges in *Phragmites* and *Typha* were used by fewer species of *marsh birds*, such as waterfowl, than stand edges in marsh meadow (Table 2.13 and Figure 2.17). However, more intensive studies investigating the use of these habitats during early spring are required to better assess the effects of *Phragmites* expansion on birds.

Overall, my results showed that *Phragmites* stands within the wetland ecosystem at Long Point, Ontario were used by many birds. Large stands of *Phragmites* did not have fewer birds or fewer bird species than did stands of *Typha* or marsh meadow. In fact, large stands of *Phragmites* had more Red-winged Blackbirds, Common Yellowthroats, and Tree Swallows than did stands of *Typha* and marsh meadow. *Phragmites* was also used for overwintering shelter and, in spring, as perch sites by some species. The continued expansion of the exotic genotype of *Phragmites*, however, may negatively affect Swamp Sparrows and Marsh Wrens as *Typha* and marsh meadow are replaced. Currently, however, breeding populations of both species within the coastal wetlands of Lake Erie are stable (Timmermans, unpublished report). Therefore, as *Phragmites* stands continue to expand, populations of Swamp Sparrows and Marsh

Wrens should be monitored. Virginia and Sora Rails, however, are currently declining (Timmermans, unpublished report). Thus, studies investigating use of *Phragmites* by *marsh obligates - non-gleaners*, particularly during higher water levels, are required to determine if their decline is related to *Phragmites* expansion. Such research, in conjunction with an investigation of the importance of open pools of water within *Phragmites* stands, will increase understanding of the effects of continued *Phragmites* expansion on marsh birds.

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# CHAPTER 3. COMPARATIVE USE OF *PHRAGMITES AUSTRALIS*, *TYPHA* SPP., AND MARSH MEADOW HABITATS BY AMPHIBIANS AND SMALL MAMMALS AT LONG POINT, ONTARIO.

## 3.1. INTRODUCTION

Many amphibians and some small mammals depend on wetlands for both foraging and breeding habitat (Herdendorf 1992, Weller 1999, Semlitsch 2000) and are important vertebrate components of wetland ecosystems (Dodd and Cade 1998). Hypothetically, recent declines in some amphibian populations in North America are related to changes in integrity of wetland ecosystems (Barinaga 1990, Blaustein and Wake 1990, Phillips 1990). Landscape-scale factors such as roads (Ashley and Robinson 1996), deforestation around wetlands (Findlay and Houlahan 1997, Dodd and Cade 1998, Knutson et al. 1999), and the introduction of predatory vertebrates (Fisher and Schaffer 1996) are compromising wetland habitats for some amphibians. Few studies, however, have investigated impacts of exotic vegetation on these animals even though local habitat degradation is causing declines in some amphibian populations (Blaustein and Wake 1990, Semlitsch 2000).

*Phragmites australis* (Cav.) Trin. ex Steudel (hereafter referred to as *Phragmites*) is a large, perennial, rhizomatous reed that thrives in brackish and freshwater environments (Marks et al. 1994). It has a cosmopolitan distribution and typically grows in wetland-upland interfaces of marshes, swamps, fens, and prairie potholes (Roman et al. 1984). Although fossil records show that *Phragmites* has been in North America for at least 3000 years (Niering and Warren 1977), it has expanded rapidly over the past few decades. For instance, between 1973 and 1994, *Phragmites* expanded at a rate of 3 % per year in *Typha*-dominated marshes and by 1 % per year in brackish short-grass meadows along the Connecticut River (Buck 1995). At Long Point, Ontario, Wilcox et al. (submitted) determined that *Phragmites* increased exponentially (50 % per year) between 1995 and 1999, primarily replacing *Typha* spp. and marsh meadow vegetation. Such rapid expansion has been attributed to the introduction of an exotic genotype of *Phragmites* (Saltonstall 2002, Wilcox et al. submitted) as well as to increased temperatures, (Zemlin et al. 2000), runoff, dredging, pollution, soil salinity, eutrophication, and altered hydrological regimes (Roman et al. 1984, Kiviat 1987, Marks et al. 1994).

Formation of large stands of *Phragmites* may be problematic for some marsh animals due to structural changes such as increased stand height, density, and litter accumulation (Kiviat 1987, Marks et al. 1994). These growth characteristics, in conjunction with associated changes in hydrological regimes and nutrient cycling (Ward 1942, Chambers et al. 1999, Meyerson et al. 2000), may lower floral diversity by shading, crowding, and inhibiting seed germination of other plants (Jones and Lehman 1987, Rice et al. 2000). Similarly, faunal diversity may decline due to effects of these structural changes on the penetrability of stand interiors (Ward 1942, Benoit and Askins 1999, also see Meyerson et al. 2000). This low diversity of plants and altered wetland environment may displace some populations of amphibians and small mammals, including some endangered, threatened, or species of “special concern”.

My main objective in this study was to determine if small (perimeter: 377 – 533 $m^2$) and large (perimeter: 761 – 1350 $m^2$) stands of *Phragmites* have lower abundance and species richness of amphibians and small mammals than do small and large stands of plant communities that are being replaced by *Phragmites* at Long Point, Ontario. My secondary objective was to determine if the *Phragmites* stands where I did my research were composed of the native or exotic genotype. By determining the abundance and species richness of amphibians and small mammals in these habitats and stand sizes, this study will help determine if the expansion of the exotic genotype of *Phragmites* is compromising the integrity of coastal wetlands on the lower Great Lakes for amphibians and small mammals.

## 3.2. STUDY DESIGN AND METHODOLOGY

The study was conducted in the Crown Marsh and Long Point Provincial Park at Long Point, Lake Erie, Ontario. Study areas were selected using aerial photographs and were based on stand size of *Phragmites* and accessibility. Three marsh habitats, 1/ *Phragmites*, 2/ *Typha* spp., and 3/ marsh meadow were chosen for trapping. *Typha* and marsh meadow were chosen because these are the primary habitats that *Phragmites* is replacing at Long Point (Wilcox et al. submitted). Pitfall traps were used for sampling because such traps enable simultaneous and multiple captures especially of small mammals (Williams and Braun 1983, Meeks and Higgins 1998). Pitfall traps were constructed of 11 litre plastic buckets without lids or handles. Buckets were buried flush to the ground (Meeks and Higgins 1998) and anchored by two tent stakes and 3/8" wooden dowel placed across the midline of the pail. Drift fences are normally used with pitfall traps to increase capture rates (Kurta 1995), but I did not use them to avoid excessive habitat alteration. Other studies have captured adequate samples of small mammals without the use of drift fences (Whitaker et al. 1994, Meeks and Higgins 1998).

Trapping was conducted between 1 May and 31 July in 2001 and 2002. One trap line with a maximum of 5 pitfall traps was set up in each habitat at each study site. A trap line consisted of a line transect through the habitat in which the first trap was placed 3.5 m from the edge and subsequent traps were placed 20 m apart (Figure 3.1). The number of traps set depended on stand size and year. Fifteen traps (five traps per habitat) were set in one study site (Crown Marsh) in 2001 to assess trapping efficiency in these habitats. Forty-two traps (14 traps per habitat) were set in three locations in two study sites (Crown Marsh and Long Point Provincial Park) in 2002.

Traps were checked daily during mid-morning. Live captured amphibians and small mammals were identified to species except juvenile toads, which were identified to genus (Burt and Grossenheider 1976, Kurta 1995, Conant and Collins 1998), and then released at least 5 m away from traps. Captured individuals were identified by trap number, trap location, survey date, and habitat. Opportunistic observations of amphibians and mammals were also recorded during avian surveys (Chapter 2) and while checking pitfall traps (Appendix 6).

Stand size, for each habitat, was estimated in July, 2002, with an 18 inch measuring wheel. To simplify interpretation, each stand was categorized as either small (perimeter: 377 – 533 $m^2$) or large (perimeter: 761 – 1350 $m^2$). All stands were categorized as large in 2001.

Five *Phragmites* stems from each of the three stands where trapping occurred in *Phragmites*, as well as from 23 other monotypic stands of *Phragmites*, were collected during winter, 2003, following a protocol for *Phragmites* morphological identification (www.invasiveplants.net/diag/diagnostic.asp 2003). Samples were shipped to Cornell University to determine if they were of the native or exotic genotype.

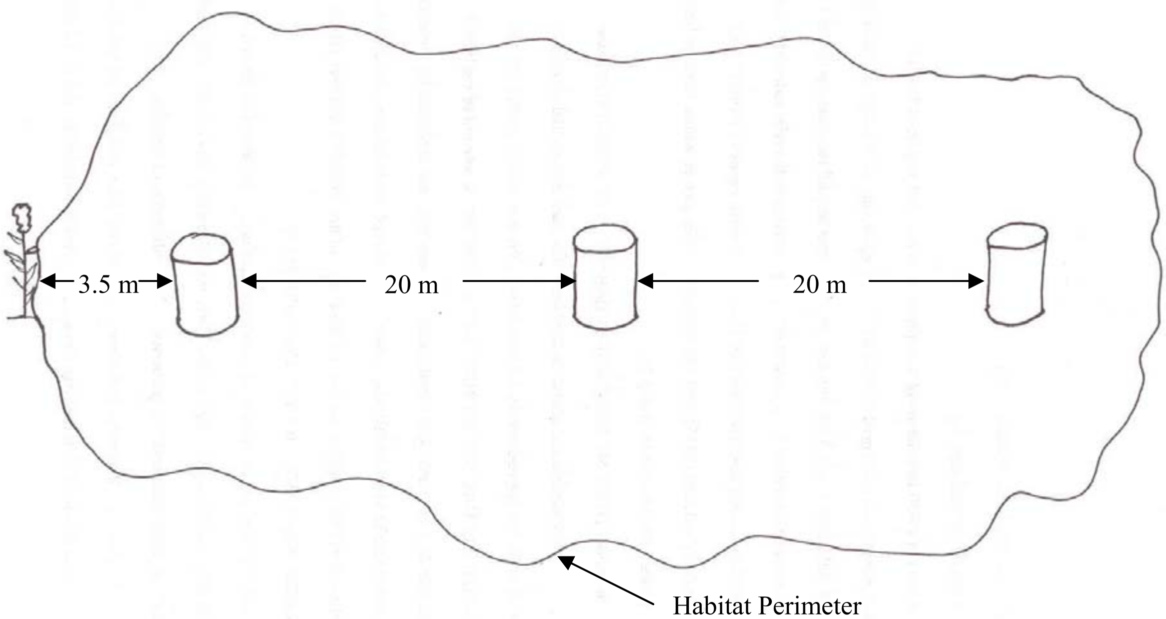


Figure 3.1. Illustration of pitfall trap placement used for sampling amphibians and small mammals at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002.

## 3.3. STATISTICAL ANALYSES

### *3.3.1. Data restrictions*

Flooding of some traps occurred after heavy rainfall. Because flooded traps were either submerged or expelled from the ground, vertebrates were not captured. Consequently, data from those survey days from all traps were excluded from analyses.

Data from the two years were not pooled for two reasons. First, water levels in Lake Erie were about 0.25 m higher in 2002 than in 2001 (Canadian Hydrographic Service 2002). Therefore, some habitat characteristics changed that likely affected habitat use by some amphibians and small mammals. Second, some amphibians are philopatric, which results in individuals of some species returning to the same area in subsequent years (Oldham 1966, Berven and Grudzien 1990, Schlupp and Podloucky 1994). Therefore, I could not assume 2001 and 2002 samples were independent.

### *3.3.2. Preliminary analyses - Vertebrate Groups*

Data for amphibians and for small mammals were summarized into two response variables: 1/ total abundance (total number of individuals of all species in each of the aforementioned groups captured on a survey date during a survey season) and 2/ species richness (total number of species, in each group, captured on a survey date during a survey season). To equalize effort in each stand, response variables for each stand were standardized by dividing each variable by the total number of pitfall traps set in each stand. Response variables were also categorized into 13 weekly intervals.

### *3.3.3. Diversity Indexes of Amphibians and Small Mammals*

To obtain an index of species equitability, Shannon-Wiener's diversity index was calculated. This index measures the likelihood that the next individual captured will be of the same species as the previous one captured and is appropriate for random samples drawn from a large community. The index was calculated for the two groups for each habitat (corrected for the number of traps set in each stand) for each year using the equation:

$$H' = - \sum p_i \log p_i$$

where p is the proportion of individuals of a given species (Margalef 1958).

*3.3.4. Model Selection*

Akaike's Information Criterion, corrected for small sample size ($AIC_c$), was used to select the most parsimonious models that best described the response variables. Statistical models were designed using PROC MIXED (SAS Institute 2001) and model selection was obtained using the IC (METHOD = ML [maximum likelihood]) option for this procedure. Models were ranked using $\Delta AIC_c$ and were calculated as: $\Delta AIC_c = AIC_{Ci} - AIC_{Cmin}$, where $AIC_{Ci}$ was the $i^{th}$ model from a candidate set. Akaike weights, $W_{AICC}$, were calculated to assess the relative likelihood of each model being the best model. The model with the lowest $AIC_c$ score was considered to be the one that best described those data (see Burnham and Anderson 1998, Anderson et al. 2000).

Because I was interested in the effect of habitat on abundance and species richness of amphibians and small mammals, all candidate models included habitat (*Phragmites*, *Typha* spp., or marsh meadow) as an explanatory variable. Stand size and survey week were included in some models in the candidate set because both may affect abundance and species richness of amphibians and small mammals. Model selection was done separately for each year.

A total of 4 candidate models involving combinations and interactions of habitat type and survey week were used to evaluate the response variables during 2001 (Appendix 7). The largest model in the candidate set included the following biologically interpretable effects: habitat, survey week, and habitat × survey week. The smallest model included only the main effect of habitat type. Stand size was excluded from the analyses in 2001 because only large stands were sampled.

A total of 11 candidate models involving combinations and interactions of habitat type, survey week, and stand size were used to evaluate the response variables during 2002 (Appendix 8). The largest model in the candidate set included the following effects: habitat, survey week, stand size, habitat × survey week, habitat × stand size, and habitat × survey week × stand size. The smallest model included only the main effect of habitat type.

A null model (intercept only) was included in the set of candidate models for all analyses. Second best models and all candidate models with $\Delta AIC_C \leq 2.0$ are presented. As a general guideline, if $\Delta AIC$ values differ by > 2.0, the lowest $\Delta AIC$ value is superior whereas models with ΔAIC values differing by < 2.0 are similar in their ability to describe the data (Burnham and Anderson 1998). To aid in assessing the strength of evidence for each candidate model, all relevant model selection information (k [number of parameters], $\Delta AIC_C$, $W_{AICC}$, and $R^2$) is reported. Least-squares means (± 95 % confidence intervals) are reported for highest-ranking models.

To further investigate use of habitat type by amphibians and small mammals, I examined the interaction of habitat type and pitfall trap location (interior vs. edge) on total abundance and species richness of amphibians and small mammals using a two-way analysis of variance (ANOVA) with $p \leq 0.10$ (PROC GLM, SAS Institute 2001). Traps situated within 3.5 m of the habitat edge were classified as edge locations and all other traps represented interior locations. Response variables were corrected for sampling effort by dividing the total daily captures in each location by the number of traps set in each location. Response variables for each year were graphed using MINITAB 11 (1996) to determine linearity and were $Log_{10}$ transformed if required.

## 3.4. RESULTS

### *3.4.1. Phragmites australis identification*

Morphological analyses of stems showed that the plants at all *Phragmites* trap locations (*n* = 3) were of the introduced genotype as were those in 22 of 23 other *Phragmites* stands that I sampled.

### *3.4.2. Comparative use of Phragmites, Typha, and Marsh Meadows by Amphibians*

Overall, I captured five species of amphibians: American Toad (scientific names are in Table 3.1), Fowler's Toad, Northern Leopard Frog, Green Frog, and Pickerel Frog. In 2001, I captured an average of 15.7 individual amphibians per trap and a total of 4 species; in 2002, those numbers were 41.6 individuals per trap and 5 species (Table 3.1). There were approximately 2.0 and 1.4 times more amphibians captured per trap in marsh meadow and *Typha* than in *Phragmites* during 2001. I captured approximately 2.1 and 1.5 times more amphibians per trap in large and small stands of marsh meadow than in large and small stands of *Phragmites* during 2002. Per trap, large stands of *Typha* had approximately 2.5 times more amphibians than did large stands of *Phragmites*, but small stands of *Typha* had approximately 70 % fewer amphibians than did small stands of

Table 3.1. Summarized data for total abundance of amphibians per pitfall trap and small mammals per pitfall trap captured in large (761 – 1350 $m^2$) and small (377 – 533 $m^2$) stands of *Phragmites australis*, *Typha* spp., and marsh meadow at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002.

| Common Name | Scientific Name | 2001 (Large Stands) | | | 2002 (Large Stands) | | | 2002 (Small Stands) | | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Phragmites australis* | *Typha* spp. | Marsh Meadow | *Phragmites australis* | *Typha* spp. | Marsh Meadow | *Phragmites australis* | *Typha* spp. | Marsh Meadow | 2001 | 2002 |
| **AMPHIBIANS** | | | | | | | | | | | | |
| American Toad | *Bufo americanus* | 0.8 | 1.2 | 0.8 | 2.3 | 1.4 | 1.4 | 13.5 | 6.2 | 9.5 | 0.9 | 4.0 |
| Fowler's Toad | *Bufo woodhousii fowleri* | 0 | 0.2 | 0.2 | 0 | 0.1 | 0.3 | 0.8 | 1.0 | 2.0 | 0.1 | 0.4 |
| Juvenile Toad | *Bufo* spp. | 8.2 | 13.6 | 19.4 | 7.4 | 30.6 | 5.4 | 46.0 | 32.0 | 83.5 | 13.7 | 25.7 |
| Northern Leopard Frog | *Rana pipiens* | 0.2 | 0 | 0.6 | 5.9 | 6.8 | 25.8 | 7.5 | 8.5 | 7.0 | 0.3 | 11.4 |
| Green Frog | *Rana clamitans melanota* | 1.6 | 0.4 | 0.2 | 0.2 | 0 | 0.1 | 0 | 0 | 0.2 | 0.7 | 0.1 |
| Pickerel Frog | *Rana palustris* | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0.02 |
| **SMALL MAMMALS** | | | | | | | | | | | | |
| Meadow Jumping Mouse | *Zapus hudsonius* | 0.4 | 0.2 | 0.8 | 0.4 | 0.4 | 0 | 0 | 0.2 | 0 | 0.5 | 0.2 |
| Meadow Vole | *Microtus pennsylvanicus* | 0.2 | 1.8 | 0 | 1.4 | 0.4 | 0.7 | 0.5 | 1.5 | 0 | 0.7 | 0.8 |
| Short-tailed Shrew | *Blarina brevicauda* | 0 | 0.2 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0.02 |
| Masked Shrew | *Sorex cinereus* | 0 | 0 | 0 | 0.2 | 0 | 0 | 0.2 | 0.2 | 0 | 0 | 0.1 |
| Total Amphibians / Trap | | 10.8 | 15.4 | 21.2 | 15.8 | 38.9 | 33.1 | 67.8 | 47.7 | 102.2 | 15.7 | 41.6 |
| Amphibian Species Richness / Trap | | 0.8 | 0.6 | 0.8 | 0.3 | 0.3 | 0.5 | 0.8 | 0.8 | 1.0 | 0.3 | 0.1 |
| Total Mammals / Trap | | 0.6 | 2.2 | 0.8 | 2.1 | 0.8 | 0.7 | 0.7 | 2.0 | 0 | 1.2 | 1.1 |
| Mammal Species Richness / Trap | | 0.4 | 0.6 | 0.2 | 0.4 | 0.2 | 0.1 | 0.5 | 0.8 | 0 | 0.2 | 0.1 |
| Number of Trap Nights | | 78 | 78 | 78 | 87 | 87 | 87 | 87 | 87 | 87 | 78 | 87 |

*Phragmites*. Diversity indices for amphibians per trap were higher in *Phragmites* (2001: 0.33; 2002: 0.44) than in *Typha* (0.20; 0.32) or marsh meadow (0.17; 0.42). Low diversity indices for amphibians per trap in *Typha* and marsh meadow during 2001 were due to a high proportion of juvenile toads captured in these habitats.

Total abundance of amphibians per trap during 2001 was not related to habitat as the null model had the lowest $AIC_C$ score of any model ($W_{AICC}$: 0.65) (Table 3.2). The model containing the variables habitat, survey week, stand size, habitat × survey week, habitat × stand size, and habitat × survey week × stand size best explained 45.4 % of variation in total abundance of amphibians per trap during 2002. Overall, least-squares means and their 95 % confidence intervals showed that marsh meadows had more amphibians per trap than did *Typha*, but not *Phragmites*. Abundance per trap, however, also depended on survey week and stand size. For instance, there was no difference in abundance of amphibians per trap among habitats during late spring, but small stands generally had more amphibians per trap than did large stands (Figure 3.2a and Figure 3.2b). Stands of marsh meadow had more amphibians per trap (mostly juvenile anurans) than did other habitats of equivalent size during early summer. Small stands of *Phragmites* had more amphibians per trap than did small stands of marsh meadow in mid-summer. There were more amphibians per trap in large stands of *Typha* during survey week 7 than in other stands. Per trap, amphibian abundance generally increased in small stands of *Phragmites* during summer, whereas abundance decreased in stands of marsh meadow and large stands of *Typha*. Abundance per trap, however, generally remained stable in large stands of *Phragmites* during summer.

There was no interaction between habitat and pitfall trap location on total abundance of amphibians per trap during 2001 ($p > 0.17$). There were fewer amphibians per trap in interior traps of large stands of *Phragmites* than in interior ($p < 0.005$) and edge traps (0.0001) in large stands of marsh meadow and *Typha* (0.0009; 0.005) and edge traps in large stands of *Phragmites* (0.04) during 2002 (Figure 3.3). Edge traps in large stands of marsh meadow also had more amphibians per trap than did edge traps ($p < 0.057$) in large stands of *Phragmites*. In small stands, edge traps in marsh meadow had more amphibians per trap than did interior ($p < 0.09$) and edge traps in *Typha* (0.0003) and edge traps in *Phragmites* (0.06). There were more amphibians per trap in interior

Table 3.2. Model selection for variation in total abundance of amphibians per pitfall trap, species richness of amphibians per pitfall trap, total abundance of small mammals per pitfall trap, and species richness of small mammals per pitfall trap captured at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002 in relation to habitat (HAB = *Phragmites australis*, *Typha* spp., and marsh meadow), stand size (SIZE; Small: 377 – 533 $m^2$; Large: 761 – 1350 $m^2$), and survey week (SW; Week 1 = 1 May; Week 13 = 31 July). Shown for each candidate model is the year, response variable, number of parameters (k), ($\Delta AIC_c$), model weight ($W_{AICC}$), the proportion of variance explained ($R^2$), and the least-squares means (± 95 % confidence intervals) for the main effect of habitat from the best models.

| Year | Model | k | $\Delta AIC_C$ | $W_{AICC}$ | $R^2$ | *Phragmites australis* | *Typha* spp. | Marsh Meadow |
|---|---|---|---|---|---|---|---|---|
| | **Total Abundance of Amphibians / Trap** | | | | | | | |
| 2001 | NULL | 2 | 0.00 | 0.65 | 0.00 | | | |
| | HAB | 4 | 1.80 | 0.26 | 0.02 | | | |
| 2002 | HAB, SW, SIZE, HAB × SW, HAB × SIZE, HAB × SW × SIZE | 79 | 0.00 | 1.00 | 0.45 | 0.23 ± 0.04 | 0.21 ± 0.04 | 0.30 ± 0.04 |
| | HAB, SW, SIZE, HAB × SW | 41 | 90.9 | 0.00 | 0.32 | | | |
| | **Species Richness of Amphibians / Trap** | | | | | | | |
| 2001 | HAB, SW | 14 | 0.00 | 0.66 | 0.25 | 0.20 ± 0.03 | 0.17 ± 0.03 | 0.18 ± 0.02 |
| | NULL | 2 | 2.10 | 0.23 | 0.00 | | | |
| 2002 | HAB, SW, SIZE | 17 | 0.00 | 0.63 | 0.39 | 0.10 ± 0.01 | 0.09 ± 0.01 | 0.10 ± 0.01 |
| | HAB, SIZE, SW, HAB × SIZE | 19 | 1.10 | 0.37 | 0.39 | | | |
| | **Total Abundance of Small Mammals / Trap** | | | | | | | |
| 2001 | HAB, SW | 14 | 0.00 | 0.99 | 0.35 | 0.05 ± 0.03 | 0.08 ± 0.03 | 0.04 ± 0.02 |
| | NULL | 2 | 17.5 | 0.01 | 0 | | | |
| 2002 | HAB, SIZE, SW, HAB × SIZE | 19 | 0.00 | 0.52 | 0.05 | 0.01 ± 0.004 | 0.01 ± 0.004 | 0.002 ± 0.004 |
| | HAB, SIZE, HAB × SIZE | 7 | 1.70 | 0.22 | 0.02 | | | |
| | **Species Richness of Small Mammals / Trap** | | | | | | | |
| 2001 | HAB, SW | 14 | 0.00 | 0.99 | 0.30 | 0.04 ± 0.03 | 0.061 ± 0.02 | 0.025 ± 0.021 |
| | NULL | 2 | 8.90 | 0.01 | 0.00 | | | |
| 2002 | HAB, SIZE, SW, HAB × SIZE | 19 | 0.00 | 0.90 | 0.06 | 0.008 ± 0.004 | 0.01 ± 0.004 | 0.003 ± 0.004 |
| | HAB, SW | 16 | 6.10 | 0.04 | 0.01 | | | |

- The variable stand size was not included in the candidate set of models in 2001.

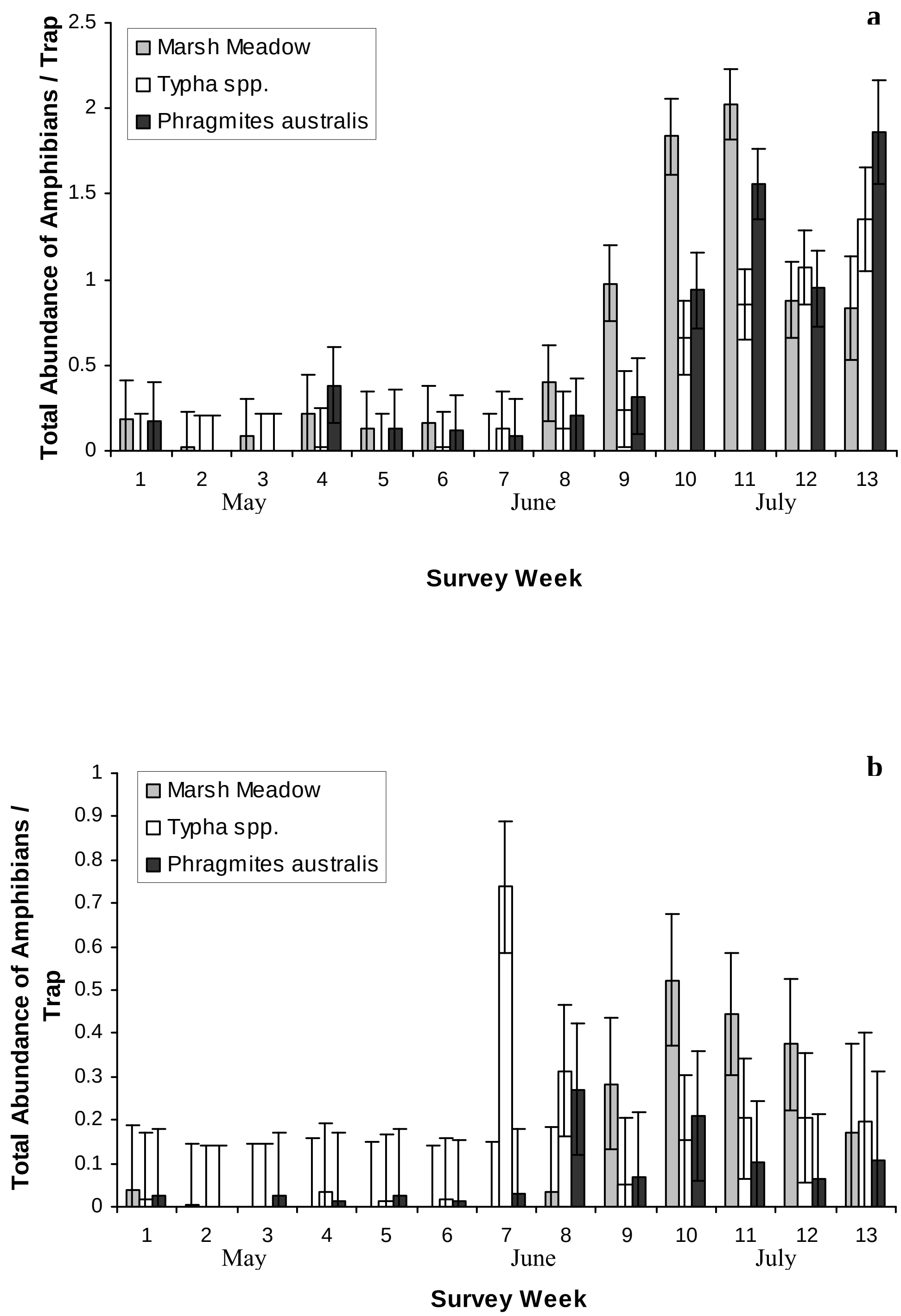


Figure 3.2. Least-squares means (± 95 % CI) for total abundance of amphibians per pitfall trap captured at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat, stand size (a = small stands: 377 – 533 $m^2$; b = large stands: 761 – 1350 $m^2$), and survey week.

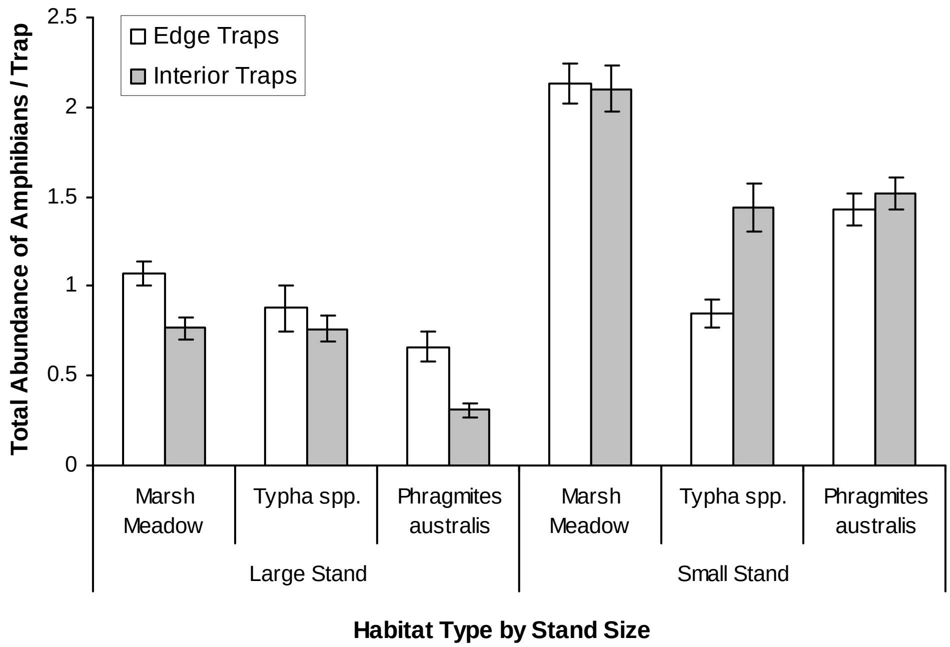


Figure 3.3. Least-squares means (± SE) for total abundance of amphibians per pitfall trap captured at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat, stand size (small stands: 377 – 533 $m^2$; large stands: 761 – 1350 $m^2$), and pitfall trap location.

traps in small stands of marsh meadow than in edge traps in small stands of *Typha* ($p < 0.0004$) and *Phragmites* (0.08). Edge traps in small stands of *Typha* had fewer amphibians per trap than did interior traps in small stands of *Typha* ($p < 0.06$) and edge and interior traps in small stands of *Phragmites* (0.03, 0.05).

Species richness per trap was best explained by the model containing the variables habitat and survey week during 2001 ($R^2 = 25.1$ %) (Table 3.2). The model best explaining species richness of amphibians per trap during 2002 included habitat, survey week, and stand size and explained 38.6 % of the variation. However, least-squares means and their 95 % confidence intervals showed that this effect was not strong in either year. Small stands had higher species richness of amphibians per trap than did large stands regardless of habitat type during 2002 (Table 3.1 and Figure 3.4b).

Edge traps in large stands, regardless of habitat type, had higher species richness per trap than did interior traps during 2001 (Figure 3.4a). However, there were no differences among edge traps within habitat types. Interior traps in large stands of *Typha* had fewer species per trap than did interior traps in large stands of *Phragmites* ($p < 0.05$).

Edge traps in large stands of marsh meadow had higher species richness per trap than did other traps in large stands during 2002 (Figure 3.4b). Interior traps in large stands of marsh meadow had more species per trap than did interior traps in large stands of *Phragmites* ($p < 0.02$). In large stands, edge traps in *Typha* had fewer species per trap than did edge traps in *Phragmites* ($p < 0.06$), but had more species per trap than did interior traps in *Phragmites* (0.07). Edge traps in large stands of *Phragmites* had higher species richness per trap than did interior traps in large stands of *Typha* ($p < 0.003$) and *Phragmites* (0.0004). There was no interaction between habitat and pitfall trap location on species richness of amphibians per trap in small stands.

*3.4.3. Comparative use of Phragmites, Typha, and Marsh Meadows by Small Mammals*

Overall, I captured four species of small mammals: Meadow Jumping Mouse, Meadow Vole, Short-tailed Shrew, and Masked Shrew (Table 3.1). In 2001, I captured an average of 1.2 individual small mammals per trap and a total of 3 species; in 2002, those numbers were 1.1 individuals per trap and 4 species. There were approximately 1.3 and 3.7 times more mammals per trap in marsh meadow and *Typha* than in *Phragmites* during 2001. Large stands of *Phragmites* had approximately 3.0 and 2.6 times more

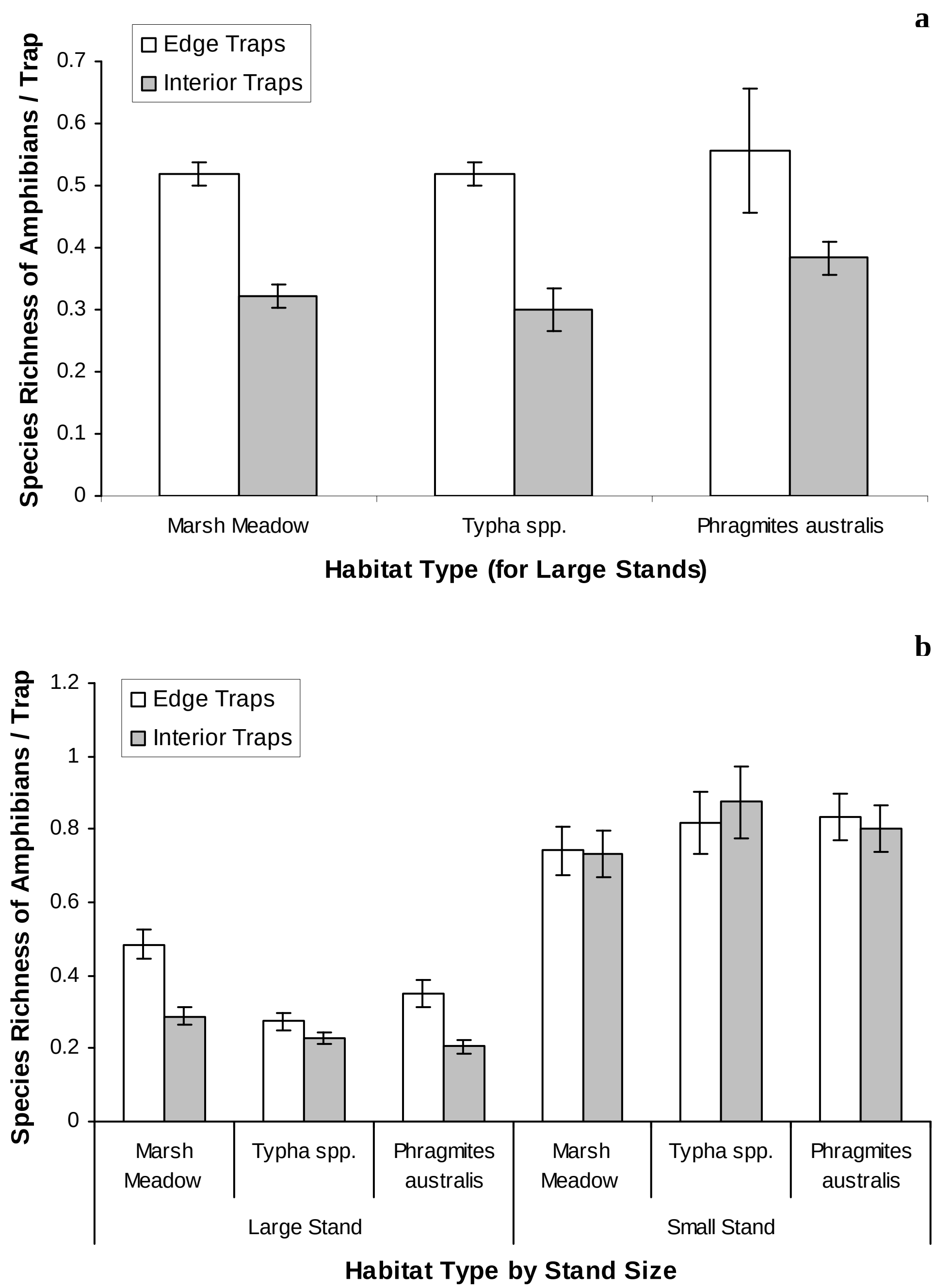


Figure 3.4. Least-squares means (± SE) for species richness of amphibians per pitfall trap captured at Long Point, Lake Erie, ON, from 1 May until 31 July in relation to year (a. = 2001; b. = 2002), habitat, stand size (small stands: 377 – 533 $m^2$; large stands: 761 – 1350 $m^2$), and pitfall trap location.

mammals per trap than did large stands of marsh meadow and *Typha* during 2002. Small stands of *Typha*, however, had approximately 2.8 times more small mammals per trap than did small stands of *Phragmites*. I did not capture any mammals in small stands of marsh meadow. There was higher diversity of small mammals per trap in *Phragmites* (2001: 0.28, 2002: 0.42) than in *Typha* (0.26, 0.36). Only one small mammal species was captured in marsh meadow during each year (2001: Meadow Jumping Mouse; 2002: Meadow Vole).

The model containing the variables, habitat and survey week, was superior to other models in explaining total abundance and species richness of small mammals per trap during 2001 ($W_{AICC}$: 0.99; 0.99) (Table 3.2). The model that best explained total abundance and species richness of small mammals per trap during 2002 included habitat, stand size, survey week, and habitat × stand size. However, least-squares means and their 95 % confidence intervals showed that the habitat effect was not strong in either year. Per trap, abundance and species richness of small mammals also depended on stand size during 2002. For instance, I did not capture any small mammals in small stands of marsh meadow (Figure 3.5). Small stands of *Typha* had more individuals per trap and higher species richness per trap than did other stands. Large stands of *Phragmites* had the second highest abundance and species richness of small mammals per trap during 2002.

There was no interaction between habitat and pitfall trap location on total abundance of small mammals per trap during 2001 ($p > 0.42$). Meadow Jumping Mice, however, were only captured in edge traps in large stands of *Typha* and *Phragmites* whereas 67 % of Meadow Voles were captured in interior traps in *Typha*. One Short-tailed Shrew was captured at the edge of *Typha*. Within *Typha* and marsh meadow, I captured 54 % and 50 % of all small mammals in interior traps.

Edge traps in large stands of *Phragmites* had more small mammals per trap than did any other habitat location (Figure 3.6). In small stands of *Typha*, I captured all Meadow Jumping Mice and 83 % of Meadow Voles in edge traps whereas one Masked Shrew and 50 % of Meadow Voles were captured in edge traps in small stands of *Phragmites*. At edge traps, 43 % of Meadow Voles were captured in large stands of marsh meadow and 100 % of Meadow Voles and 25 % of Meadow Jumping Mice in large stands of *Typha*. I captured all Masked Shrews, Short-tailed Shrews, 75 % of

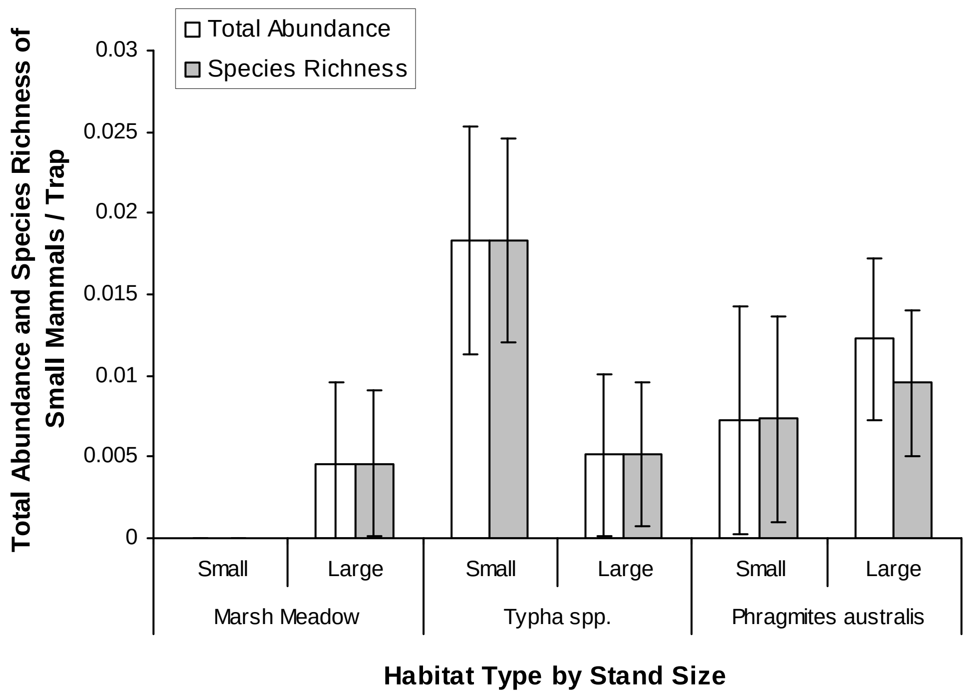


Figure 3.5. Least-squares means (± 95 % CI) for total abundance and species richness of small mammals per pitfall trap captured at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat and stand size (small stands: 377 – 533 $m^2$; large stands: 761 – 1350 $m^2$).

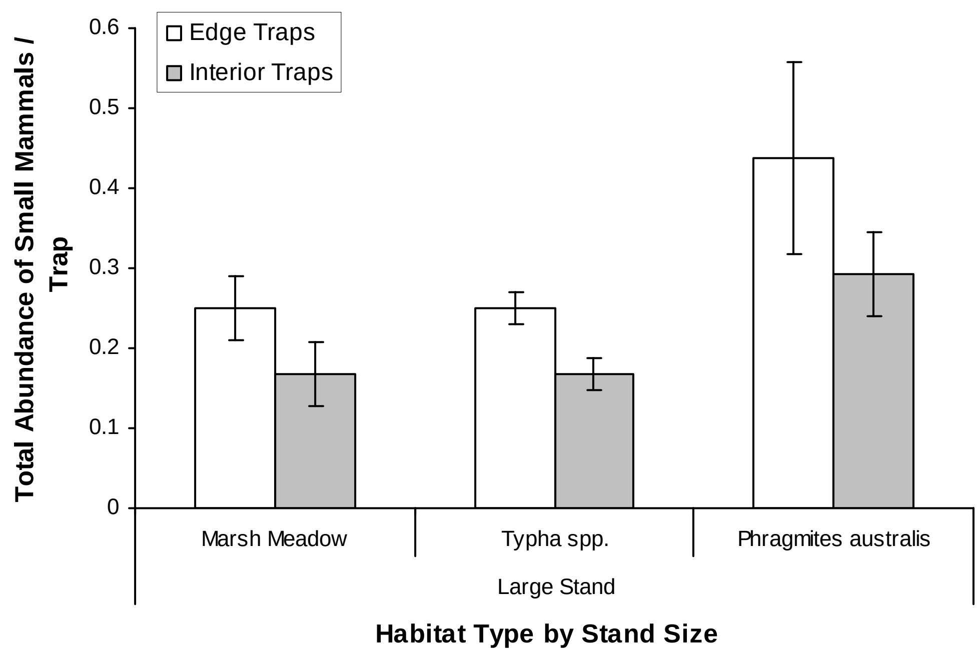


Figure 3.6. Least-squares means (± SE) for total abundance of small mammals captured per pitfall trap at Long Point, Lake Erie, ON, from 1 May until 31 July 2002 in relation to habitat and pitfall trap location (Large stands, perimeter = 761 – 1350 $m^2$).

Meadow Jumping Mice, and 57 % of Meadow Voles in interior traps in large stands of *Phragmites*.

### 3.5. DISCUSSION

Stands of an exotic genotype of *Phragmites* have recently replaced many stands of *Typha* spp. and marsh meadow at Long Point, Ontario (Wilcox et al. submitted) and this genotype is likely responsible for the rapid expansion of *Phragmites* elsewhere on the lower Great Lakes (Saltonstall 2002, Haggeman, pers. comm.). These stands of exotic *Phragmites* may be less suitable as habitat for some amphibians and small mammals than the stands which they replaced. Therefore, I examined abundance and species richness of amphibians and small mammals in stands of exotic *Phragmites*, *Typha* spp., and marsh meadow at Long Point, Ontario. As far as I am aware, this was the first study to investigate use of exotic *Phragmites* by amphibians and small mammals in a freshwater coastal wetland.

Few amphibians used ephemeral ponds within *Phragmites* stands for breeding. Clarke (1974) showed that newly transformed anurans live in the wet litter of nursery ponds for about a week after transformation. Metamorphic synchrony of tadpoles also occurs in many amphibian species (Clarke 1974, Green 1989, Smelitsch 2000). Thus, an influx of amphibians into *Typha* and marsh meadow shortly after transformation (Figure 3.2a and Figure 3.2b) likely reflected their closeness to ephemeral breeding ponds. Ephemeral ponds within *Phragmites*, however, may dry up faster than do those in *Typha* and marsh meadow because rates of transpiration and sedimentation are likely higher in *Phragmites* (Marks et al. 1993, Chambers et al. 1999). That may explain why I only observed tadpoles in ponds within stands of *Typha* and marsh meadow and not in ponds within stands of *Phragmites*. Water levels, however, may affect use of ephemeral ponds within *Phragmites* by amphibians. For instance, Green (1982) documented American and Fowler's Toads calling (breeding) in *Phragmites* stands in the Crown Marsh at Long Point. Although my study was also conducted in the Crown Marsh, low water levels likely affected amphibian use of *Phragmites* (water levels were approximately 0.75 m higher in Green's study than in mine) (Canadian Hydrographic Service 2002). Therefore, future studies should investigate use of *Phragmites* by breeding amphibians, specifically anurans, during higher water levels.

After dispersal, juvenile toads used small stands of *Phragmites* more than large stands. Although Clarke (1974) concluded that toads (*Bufo* spp.) tend to use habitats with open patches and low amounts of vegetation, small stands of *Phragmites*, which had no open patches, had a high abundance of adult American and Fowler's Toads as well as juvenile toads (Table 3.1). Use of *Phragmites* by toads may be related to protective cover. Other studies have documented use of *Phragmites* for cover by mammals (Lynch et al. 1947, Ward 1968, Kucera 1974, Pelikan 1978) and birds (Benoit and Askins 1999, Meyer unpublished data). Although some predatory birds such as bitterns and herons (Family Ardeidae) use *Phragmites* (Weller 1961, Gibbs et al. 1992, Meyer unpublished data), high litter accumulation within stands may protect amphibians from predation by providing cover for them. Similarly, *Phragmites* may provide safety for toads due to the apparent absence of some predators, such as Eastern Garter Snakes, within stands (Appendix 6) (Green 1989, Harding 1997). A high abundance of some invertebrates such as springtails (Family Collembola) and beetles (Family Coleoptera) in *Phragmites* (Angradi et al. 2001) may also explain why some amphibians use *Phragmites*. Both of these invertebrates are important prey for toads, particularly juveniles (Clarke 1974, Green 1989, Harding 1997). Because survival in many amphibians is related to growth rate (Duellman and Trueb 1986, Pough et al. 2001), *Phragmites* stands may benefit some amphibians by providing cover and access to invertebrate food.

Fowler's Toads did not use large stands of *Phragmites*. Large stands of *Phragmites* also had fewer juvenile toads and Northern Leopard Frogs than did large stands of *Typha* and marsh meadow. Dickerson (1908) concluded that anurans require tall vegetation for protection from desiccation. High litter accumulation within *Phragmites* stands, however, may negatively affect toads and frogs because ambush predators, such as anurans, require low litter cover to maximize foraging (Clarke 1974, Green 1989). Licht (1991) also concluded that Northern Leopard Frogs tend to use habitats on the margins of permanent water. Although all large stands in the study area were situated next to permanent water, fewer Northern Leopard Frogs used large stands of *Phragmites* than small stands (which were not next to permanent water). Similarly, Fowler's Toads used small stands of *Phragmites*, but not large stands. Because stand height, density, and litter accumulation within *Phragmites* stands are likely related to stand age, large stands may negatively affect foraging amphibians more than do small stands. This effect was also evident for amphibian use of stand interiors. During 2001, there was no effect of trap location on abundance in *Phragmites*, but during 2002, when I captured more Northern Leopard Frogs and Fowler's Toads (Table 3.1), edge traps in *Phragmites* had more amphibians than did interior traps (Figure 3.3). This effect, however, was not evident in small stands of *Phragmites*. Therefore, expansion of *Phragmites* may negatively affect Fowler's Toads, juvenile toads, and Northern Leopard Frogs as stands continue to grow and stand interiors become even larger.

*Phragmites* had more Green Frogs than did *Typha* and marsh meadow. Although McAlpine and Dilworth (1989) concluded that Green Frogs tend to use more open habitats with short plants, I captured more Green Frogs in *Phragmites* than in other habitats (Table 3.1). Green Frogs may use *Phragmites* for protective cover. Habitat differences may also reflect interspecific competition between Northern Leopard Frogs and Green Frogs because of dietary overlap. McAlpine and Dilworth (1989) showed that Northern Leopard Frogs exclude Green Frogs in areas of overlap. Future studies should investigate habitat use in relation to anuran communities. *Phragmites* may also negatively affect Bullfrogs (*Rana catesbeiana*). Although I did not capture any Bullfrogs, I only detected these frogs in *Typha* and marsh meadows (Appendix 6). Bullfrogs possibly did not use *Phragmites* because of low water levels during the study. McAlpine and Dilworth (1989) also showed that Bullfrogs tend to use aquatic habitats situated away from shorelines. Use of *Phragmites* by Bullfrogs should be investigated further to determine whether current population declines at Long Point (Timmermans, unpublished report) are related to *Phragmites* expansion.

I caught more small mammals in stand edges and interiors of *Phragmites* than in stand edges and interiors in *Typha* and marsh meadow. Use of *Phragmites* by mammals may be related to protective cover. Although dense vegetation in *Phragmites* stands (Kiviat 1987, Marks et al. 1994) negatively affected some amphibians, it may benefit some small mammals. The use of *Phragmites* for protective cover has been documented for Muskrats (Lynch et al. 1947) and White-tailed Deer (Ward 1968, Kucera 1974), but no published data exists for small mammals. High stand density and plant height in *Phragmites* may also impede large predatory vertebrates (Ward 1942, Benoit and Askins

1999; also see Meyerson et al. 2000), thereby providing escape and protective cover for some small mammals. An accumulation of litter in *Phragmites* stands, which are not inundated, may also benefit some small mammals by providing material for nests and burrows as well as shelter from inclement weather (Lynch et al. 1947, Pelikan 1978, Ward 1968, Kucera 1974). Protective cover, in conjunction with a high density of some invertebrates such as beetles (Family Coleoptera) in the interior of *Phragmites* stands (Angradi et al. 2001), may explain the use of large stands of *Phragmites* by insectivorous mammals such as Short-tailed and Masked Shrews (Table 3.1 and Figure 3.5) (Kurta 1995). Similarly, seeds and shoots of *Phragmites* may provide food for Meadow Voles (Kurta 1995). However, use of *Phragmites* by small mammals was also related to water levels (i.e. year). Although Meadow Voles tend to use moist habitats (Kurta 1995), high water levels may negatively affect habitat use if burrows are flooded and food becomes inaccessible. Therefore, higher water levels, during 2002 than during 2001, possibly resulted in the redistribution of Meadow Voles from interiors to edges in large stands of *Typha* as well as to small stands of *Typha* and adjacent large stands of *Phragmites* (Table 3.1, Figure 3.5 and Figure 3.6). Future studies should investigate use of *Phragmites* by small mammals during fall and winter to better assess the possible effects of continued *Phragmites* expansion on these animals.

The inclusion of stand size was an important explanatory variable for amphibians but not for small mammals (Table 3.2). Generally, large stands of all 3 habitats had fewer individuals and species of amphibians than did small stands (Figure 3.3 and Figure 3.4b). Currently, however, stands of exotic *Phragmites* are rapidly expanding (50 % per year) and, consequently, replacing stands of *Typha* and marsh meadow at Long Point (Wilcox et al. submitted). Although there was no difference in amphibian use of stand interiors in *Phragmites*, *Typha*, and marsh meadow during 2001, higher water levels during 2002 than during 2001, resulted in less use of interiors in large stands of *Phragmites* (Figure 3.3 and Figure 3.4b). Therefore, large stands of *Phragmites* may be a management concern if they continue to expand.

Overall, my results showed that stands of exotic *Phragmites* within the wetland ecosystem at Long Point, Ontario were used by some amphibians and small mammals. Stands of exotic *Phragmites* did not have fewer individuals and species of amphibians and small mammals than did similar sized stands of *Typha* and marsh meadow. In fact, stands of exotic *Phragmites* had more American Toads, Green Frogs, Short-tailed Shrews, and Masked Shrews than did similar sized stands of *Typha* and marsh meadow. Large stands of exotic *Phragmites*, however, may negatively affect Northern Leopard Frogs, juvenile toads, and Fowler's Toads, but may benefit Meadow Voles and shrews. Currently, populations of Northern Leopard Frogs and Fowler's Toads within the coastal wetlands of Long Point are stable (Timmermans, unpublished report). Green Frogs and Bullfrogs are declining at Long Point. However, given the current exponential rate of growth (50 % per year) of exotic *Phragmites* at Long Point (Wilcox et al. submitted) and the low use of interiors in large stands of *Phragmites* by some amphibians, managing stands of *Phragmites* at Long Point may be warranted. Further experimental studies, such as creating open pools of water in stand interiors and reducing stem density around edges, could be conducted to determine how such habitat alterations affect amphibian and small mammal communities.

### 3.6. ACKNOWLEDGEMENTS

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# CHAPTER 4. GENERAL DISCUSSION

## 4.1. CONCLUSIONS

After habitat loss, the introduction of exotic species is thought to be the leading cause of wetland degradation in North America. Recently, a European genotype of *Phragmites australis* has been identified in North America (Saltonstall 2002). Exotics are often excellent colonizers and competitors due to their higher survivability in unfavorable conditions, adaptability to new environments, high reproductive capacity, and presence of few predators (Mills et al. 1993, Mackie 2001). Consequently, many invaders are difficult to remove once established (Harper 1965) and the native flora and fauna of an invaded ecosystem often experiences intense competition from these rapidly expanding populations. Colonization by exotic plant species may also disrupt the biological integrity of invaded wetlands as food webs are altered because of increased competition and changes in floral diversity (Meyerson et al. 2000, Pimentel et al. 2000). These changes may then alter the ecological function of the entire wetland ecosystem as some wetland dependent species are displaced.

This study was conducted to determine if expanding stands of *Phragmites australis* at Long Point, Ontario, were affecting the presence and abundance of birds, amphibians, or small mammals. Expansion of *Phragmites* stands could affect wetland dependent wildlife by altering plant diversity (Marks et al. 1994, Buck 1995, Wilcox et al. submitted) and by forming large stands with inaccessible interiors (Ward 1942, Hudec and Statsny 1978, Benoit and Askins 1999, also see Meyerson 2000). As far as I am aware, this was the first study to investigate wildlife use of exotic *Phragmites* in a freshwater coastal wetland on the lower Great Lakes.

My results showed that *Phragmites* stands had more *marsh users*, such as Red-winged Blackbirds (*Agelaius phoeniceus*) and Common Yellowthroats (*Geothlypis trichas*), than did stands of *Typha* and marsh meadow. Tree Swallows (*Tachycineta bicolor*) and Red-winged Blackbirds used stand interiors of *Phragmites* for roosting habitat. I suggested that Least Bitterns (*Ixobrychus exilis*) used large stands of *Phragmites* for nesting and perch sites and that Short-tailed Shrews (*Blarina brevicauda*) and Masked Shrews (*Sorex cinereus*) used stand interiors for cover and foraging habitat.

Use of *Phragmites* by other small mammals, such as Meadow Voles (*Microtus pennsylvanicus*) and Meadow Jumping Mice (*Zapus hudsonius*), birds, such as Marsh Wrens (*Cistothorus palustris*) and Yellow Warblers (*Dendroica petechia*), and amphibians, such as American Toads (*Bufo americana*) and juvenile toads (*Bufo* spp.), was also evident and may be related to protective cover provided by *Phragmites*. *Phragmites* stands also had a high diversity of *other birds*, such as warblers (Family Dendroica) and kinglets (Family Regulidae). Therefore, my results showed that *Phragmites* stands were used by some birds, amphibians, and small mammals.

My results, however, also showed that stands of exotic *Phragmites* had fewer individuals and species of *marsh obligates*, such as Virginia Rails (*Rallus limicola*) and breeding Swamp Sparrows (*Melospiza georgiana*), than did stands of *Typha* and marsh meadow. Some *marsh obligates - non-gleaners*, such as Mallards (*Anas platyrhynchos*), *marsh users*, such as Canada Geese (*Branta canadensis*) and American Woodcock (*Scolopax minor*), *other birds*, such as Greater Yellowlegs (*Tringa melanoleuca*) and dowitchers spp. (*Limnodromus* spp.), and amphibians, such as Fowler's Toads (*Bufo woodhousii fowleri*), did not use *Phragmites* stands. Interiors of large stands of *Phragmites* were used less by *marsh obligates - non-gleaners*, such as Virginia Rails, and amphibians, such as Northern Leopard Frogs (*Rana pipiens*), than those of *Typha* and marsh meadow. Stands of *Typha* and marsh meadows were also more heavily used by breeding *marsh obligates - gleaners*, such as Marsh Wrens and Swamp Sparrows, as well as by breeding amphibians, such as American Toads and Northern Leopard Frogs, than were stands of *Phragmites*.

Although I found that stands of exotic *Phragmites* had as many species and numbers of some birds as did stands of *Typha* and marsh meadow during fall, winter, and spring, some birds, such as waterfowl, did not use *Phragmites* stands. *Other birds*, such as Black-capped Chickadees (*Poecile atricapillus*) and American Tree Sparrows (*Spizella arborea*), used *Phragmites* more than *Typha* or marsh meadow during fall and winter. *Marsh birds*, such as Red-winged Blackbirds, used *Phragmites* extensively for roosting and perch sites during fall, winter, and spring, but this use was no different from that of *Typha* and marsh meadow.

Overall, my results suggest that the replacement of stands of *Typha* and marsh meadow by stands of *Phragmites* negatively affected most *marsh obligates* and amphibians, but possibly benefited most *other birds* and small mammals. Therefore, continued expansion of *Phragmites* stands are a cause for concern because *marsh obligates* and amphibians depend on marsh environments for breeding. However, further studies investigating use of *Phragmites* by these *marsh obligates* and amphibians are required to better assess the effect of *Phragmites* expansion on these animals.

### 4.2. SUGGESTIONS FOR FUTURE RESEARCH

My research showed that the replacement of stands of *Typha* and marsh meadow by stands of exotic *Phragmites* affected some wetland dependent wildlife. However, it has also elucidated several other questions that should be answered to better understand the effect of expanding stands of exotic *Phragmites* on some birds, amphibians, and small mammals. Because expansion of exotic *Phragmites* is negatively affecting some *marsh obligates*, such as rails and waterfowl, while possibly benefiting others such as bitterns and herons, it is important that a more intensive study of habitat use by these species be undertaken to better assess the effect of *Phragmites* expansion on these species. Because water levels also affect many waterfowl and rails (Johnson and Dinsmore 1986), I suggest that such research be conducted during periods of normal and high water levels so that use of *Phragmites* by these birds can be assessed under those conditions.

Studies investigating avian use of *Phragmites* in an area with a medium to high density of muskrats (*Ondatra zibethicus*) should be conducted. The importance of herbivory in creating open pools of water within stands and reducing stand density around edges in relation to use of *Phragmites* by birds, amphibians, and small mammals could then be adequately assessed. Such a study would also determine if *Phragmites* stands are used by muskrats. In the absence of a high population of muskrats, however, stand manipulation experiments, such as opening up interiors and reducing stem density around stand edges, could be conducted to assess the importance of these structural changes on *Phragmites* use by birds, amphibians, and small mammals.

### 4.3. MANAGEMENT IMPLICATIONS

Stands of exotic *Phragmites* are rapidly replacing stands of *Typha* spp. and marsh meadow at Long Point, Ontario (Wilcox et al. submitted) and elsewhere on the lower

Great Lakes (Saltonstall 2002, Haggeman per comm.). Consequently, this habitat replacement, in conjunction with the low use of interiors in large stands of *Phragmites* by some birds and amphibians, may result in the displacement of some populations, including species that are endangered, threatened, or of "special concern". Currently, Virginia and Sora Rails (*Porzana carolina*), Pied-billed Grebes (*Podilymbus podiceps*), Bullfrogs (*Rana catesbeiana*), and Green Frogs (*Rana clamitans melanota*) are declining within the coastal wetlands of Lake Erie (Timmermans, unpublished report). Although these declines have not been related to the expansion of exotic *Phragmites*, the current distribution and continued rate of expansion of exotic *Phragmites* (50 % per year) at Long Point (Wilcox et al. submitted) may negatively affect these animals and others as habitat heterogeneity is lost.

Studies have documented the positive relationship between habitat heterogeneity and diversity of marsh birds (Kantrud and Stewart 1984, Craig and Beal 1992) and amphibians (Knutson et al. 1999). Although *Phragmites* stands had a high diversity of *other birds*, such as Yellow Warblers, notably absent from these stands were *marsh obligates*, such as Mallards, *marsh users*, such as Canada Geese, and amphibians, such as Fowler's Toads, yet these species were present in *Typha* and marsh meadow. Therefore, rapidly expanding stands of exotic *Phragmites* could become a serious problem if marsh habitat for some wetland dependent birds and amphibians is replaced (Buck 1995, Wilcox et al. submitted). If so, then management of expanding stands of *Phragmites* may be warranted (also see Jones and Lehman 1987).

I suggest that the first step in any plan to manage *Phragmites* should be to distinguish exotic from native stands. Then, large stands of exotic *Phragmites* should be managed where they are primarily expanding into habitats with standing water because this habitat is vital for marsh birds and amphibians. Management strategies should encourage a well interspersed plant community with open water and/or mudflats. Strategies that encourage a diversity of emergent vegetation, including *Carex* (sedges), *Scirpus* (bulrush), *Typha* (cattail), and seed-producing annuals, while retaining 30 - 60 % of the wetland in open shallow water or mudflats, have been suggested to optimize habitat for many marsh birds, including Virginia and Sora Rails (Johnson and Dinsmore 1986, Conway and Eddleman 1994, Melvin and Gibbs 1994), Common Moorhens

(*Gallinula chloropus*) (Post and Seals 2000), shorebirds (Rundle and Fredrickson 1981), waterfowl (Kantrud 1986) as well as for amphibians (Anderson et al. 1999). Least Bitterns (*Ixobrychus exilis*) also require interspersed patches of open water for breeding (Weller 1961, Gibbs et al. 1992). Therefore, I suggest that similar strategies be employed for *Phragmites* management at Long Point. Managers should also try to maintain large marsh meadows because many breeding birds, such as Swamp Sparrows and Mallards, utilize these habitats extensively (Riffell et al. 2001). These measures will benefit many marsh birds, amphibians, and small mammals by maintaining better interspersion and habitat heterogeneity, which provides a diversity of cover and food.

### 4.4. SUMMARY

In summary, my results did not support my overall hypothesis that expanding stands of *Phragmites australis* have lower vertebrate biodiversity in comparison to similar sized stands of plant communities that are being replaced at Long Point, Ontario. In fact, some stands of *Phragmites* had more birds, amphibians, and small mammals than did stands of *Typha* and marsh meadow. Results, however, also showed that some birds, such as Mallards, and amphibians, such as Fowler's Toads, did not use large stands of *Phragmites*. Similarly, rails did not use stand interiors of *Phragmites* and use by frogs was limited. However, stand interiors and edges of *Phragmites* were used by some passerines (e.g., Red-winged Blackbirds) and small mammals (e.g., Meadow Voles). Therefore, I conclude that large stands of the exotic genotype of *Phragmites* at Long Point, Ontario, negatively affected amphibians, waterfowl, rails, and breeding Swamp Sparrows, but may have benefited some small mammals and passerines. Studies investigating habitat use and nesting preferences of *marsh obligates* and amphibians, particularly during higher water levels, would further understanding of the effects of continued expansion of exotic *Phragmites* stands on wetland dependent wildlife. However, the importance of habitat heterogeneity and interspersion of open pools of water for most wildlife will necessitate the management of exotic *Phragmites* given its current rate of expansion, distribution, and negative effect on some marsh wildlife.

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APPENDIX 1. Global Positioning System coordinates (latitude / longitude) and habitat type (2001 and 2002) for sample stations where avian surveys were conducted using 25 m fixed radius point counts at Long Point, Lake Erie, ON.

| Location | Sample Station | Habitat Type | GPS coordinates |
|---|---|---|---|
| Crown Marsh | 1 | *Phragmites australis* (01 & 02); EXOTIC | 423452 / 802528 |
| | 2 | *Phragmites australis* (01 & 02); EXOTIC | 423452 / 802520 |
| | 3 | *Phragmites australis* (01 & 02); EXOTIC | 423453 / 802513 |
| | 4 | Mixed Vegetation (01 & 02) | 423454 / 802504 |
| | 5 | Mudflat (01) / Marsh Meadow (02) | 423501 / 802500 |
| | 6 | Marsh Meadow (01 & 02) | 423459 / 802509 |
| | 7 | *Phragmites australis* (01 & 02); EXOTIC | 423458 / 802517 |
| | 8 | Mixed Vegetation (01 & 02) | 423457 / 802525 |
| | 9 | Mixed Vegetation (01) / Marsh Meadow (02) | 423457 / 802532 |
| | 10 | Mixed Vegetation (01) / Marsh Meadow (02) | 423458 / 802540 |
| | 11 | *Typha* spp. (01 & 02) | 423502 / 802535 |
| | 12 | *Typha* spp. (01) / Marsh Meadow (02) | 423504 / 802528 |
| | 13 | Marsh Meadow (01 & 02) | 423503 / 802520 |
| | 14 | Mixed Vegetation (01 & 02) | 423503 / 802512 |
| | 15 | Mudflat (01) / Marsh Meadow (02) | 423505 / 802504 |
| | 16 | *Typha* spp. (01 & 02) | 423509 / 802459 |
| | 17 | Mixed Vegetation (01 & 02) | 423509 / 802507 |
| | 18 | Mixed Vegetation (01 & 02) | 423516 / 802504 |
| | 19 | *Typha* spp. (01) / *Phragmites australis* (02); EXOTIC | 423522 / 802506 |
| | 20 | *Typha* spp. (01 & 02) | 423525 / 802511 |
| Long Point Provincial Park | 1 | Marsh Meadow (01 & 02) | 423456 / 802311 |
| | 2 | Marsh Meadow (01 & 02) | 423500 / 802304 |
| | 3 | *Typha* spp. (01 & 02) | 423504 / 802258 |
| | 4 | *Typha* spp. (01 & 02) | 423458 / 802257 |
| | 5 | Marsh Meadow (01 & 02) | 423453 / 802300 |
| | 6 | Marsh Meadow (01 & 02) | 423451 / 802240 |
| | 7 | Marsh Meadow (01 & 02) | 423448 / 802234 |
| | 8 | Marsh Meadow (01 & 02) | 423443 / 802233 |
| | 9 | Mixed Vegetation (01 & 02) | 423447 / 802228 |
| | 10 | *Typha* spp. (01 & 02) | 423440 / 802225 |
| | 11 | *Typha* spp. (01 & 02) | 423445 / 802219 |
| | 12 | Marsh Meadow (01 & 02) | 423453 / 802228 |
| | 13 | Marsh Meadow (01 & 02) | 423458 / 802223 |
| | 14 | *Typha* spp. (01 & 02) | 423501 / 802229 |
| | 15 | *Typha* spp. (01 & 02) | 423504 / 802235 |
| | 16 | Marsh Meadow (01 & 02) | 423500 / 802239 |
| | 17 | Marsh Meadow (01 & 02) | 423456 / 802235 |
| | 18 | Marsh Meadow (01 & 02) | 423456 / 802244 |
| | 19 | *Phragmites australis* (01 & 02); EXOTIC | 423500 / 802249 |
| | 20 | *Typha* spp. (01 & 02) | 423505 / 802249 |
| | 21 | Marsh Meadow (01 & 02) | 423454 / 802254 |
| Long Point Company – Courtright Ridge | 1 | *Phragmites australis* (01 & 02); EXOTIC | 423347 / 801733 |
| | 2 | *Phragmites australis* (01 &02); EXOTIC | 423346 / 801726 |
| | 3 | Mixed Vegetation (01 & 02) | 423344 / 801711 |
| | 4 | *Phragmites australis* (01 & 02); EXOTIC | 423344 / 801702 |

Appendix 1. Continued.

| | | | |
|---|---|---|---|
| | 5 | Marsh Meadow (01 & 02) | 423346 / 801656 |
| | 6 | Marsh Meadow (01& 02) | 423349 / 801651 |
| | 7 | *Phragmites australis* (01 & 02); EXOTIC | 423351 / 801657 |
| | 8 | *Typha* spp. (01 & 02) | 423352 / 801704 |
| | 9 | *Phragmites australis* (01 &02); EXOTIC | 423350 / 801708 |
| | 10 | *Phragmites australis* (01 & 02); EXOTIC | 423352 / 801711 |
| | 11 | *Phragmites australis* (01 & 02); EXOTIC | 423350 / 801717 |
| | 12 | *Phragmites australis* (01 & 02); EXOTIC | 423346 / 801718 |
| Long Point Company – Jeremy's Cabin | 1 | *Phragmites australis* (01 & 02); EXOTIC | 423425 / 802029 |
| | 2 | Mixed Vegetation (01 & 02); NATIVE *Phragmites* | 423430 / 802023 |
| | 3 | *Phragmites australis* (01 &02); EXOTIC | 423428 / 802037 |
| | 4 | *Phragmites australis* (01 & 02); EXOTIC | 423427 / 802035 |
| | 5 | Mixed Vegetation (01) / *Phragmites* (02); EXOTIC | 423430 / 802049 |
| | 6 | Marsh Meadow (01 & 02) | 423428 / 802103 |
| | 7 | Marsh Meadow (01 & 02) | 423437 / 802058 |
| | 8 | Mixed Vegetation (01) | 423439 / 802049 |
| | 9 | Marsh Meadow (01 & 02) | 423437 / 802043 |
| | 10 | *Typha* spp. (01 & 02) | 423436 / 802035 |

APPENDIX 2. Maximum auditory distances (in metres) recorded for selected marsh bird songs broadcasted with a tape recorder in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) from 7 May until 3 July 2001.

| Bird Species | | 7 May | |
|---|---|---|---|
| | *Phragmites australis* | *Typha* spp. | Marsh Meadow |
| American Bittern (*Botaurus lentiginosus*) | 55.0 | 68.1 | 90.0 |
| Virginia Rail (*Rallus limicola*) | 50.3 | 50.0 | 63.0 |
| Sora Rail (*Porzana carolina*) | 66.3 | 74.2 | 89.2 |
| Marsh Wren (*Cistothorus palustris*) | 44.6 | 45.5 | 58.5 |
| Common Yellowthroat (*Geothlypis trichas*) | 46.2 | 54.0 | 70.3 |
| Song Sparrow (*Melospiza melodia*) | 53.4 | 52.1 | 67.8 |
| Swamp Sparrow (*Melospiza georgina*) | 43.6 | 49.2 | 68.9 |
| Red-winged Blackbird (*Agelaius phoeniceus*) | 46.6 | 57.0 | 65.0 |
| | | 3 July | |
| | *Phragmites australis* | *Typha* spp. | Marsh Meadow |
| American Bittern | 70.7 | 70.0 | 85.0 |
| Virginia Rail | 37.2 | 51.7 | 79.7 |
| Sora Rail | 53.9 | 83.0 | 84.2 |
| Marsh Wren | 26.4 | 29.7 | 75.1 |
| Common Yellowthroat | 28.7 | 32.0 | 84.9 |
| Song Sparrow | 39.3 | 52.0 | 68.9 |
| Swamp Sparrow | 26.2 | 31.5 | 80.5 |
| Red-winged Blackbird | 47.5 | 52.4 | 68.0 |

APPENDIX 3. Incidental observations of avian species and nests observed in relation to habitat (*Phragmites australis*, *Typha* spp., and marsh meadow) at Long Point, Lake Erie, ON, (2001 and 2002).

| Common Name (Scientific Name) | *Phragmites australis* | *Typha* spp. | Marsh Meadow |
|---|---|---|---|
| Least Bittern (*Ixobrychus exilis*) | 1 | 0 | 0 |
| American Bittern (*Botaurus lentiginosus*) | 1 | 2 | 6 |
| Green Heron (*Butorides virescens*) | 0 | 3 | 9 |
| Great Blue Heron (*Ardea herodias*) | 0 | 9 | 21 |
| Canada Goose (*Branta canadensis*) | 0 | 0 | 59 |
| Wood Duck (*Aix sponsa*) | 0 | 0 | 11 |
| Mallard (*Anas platyrhynchos*) | 4 | 9 | 57 |
| - nests | 0 | 0 | 3 |
| American Black Duck (*Anas rubripes*) | 2 | 0 | 3 |
| Gadwall (*Anas strepera*) | 2 | 0 | 4 |
| Green-winged Teal (*Anas crecca*) | 0 | 0 | 8 |
| Northern Shoveler (*Anas clypeata*) | 0 | 2 | 16 |
| Blue-winged Teal (*Anas discors*) | 0 | 1 | 7 |
| Virginia Rail (*Rallus limicola*) | 0 | 2 | 8 |
| Sora (*Porzana carolina*) | 0 | 2 | 1 |
| Sandhill Crane (*Grus canadensis*) | 0 | 2 | 9 |
| Common Snipe (*Gallinago gallinago*) | 0 | 1 | 21 |
| American Woodcock (*Scolopax minor*) | 1 | 2 | 13 |
| - nest | 0 | 0 | 1 |
| Short-eared Owl (*Asio flammeus*) | 0 | 0 | 3 |
| Marsh Wren (*Cistothorus palustris*) | 0 | 8 | 0 |
| - nests | 0 | 6 | 1 |
| Yellow Warbler (*Dendroica petechia*) | 2 | 0 | 0 |
| - nests | 3 | 0 | 0 |
| Common Yellowthroat (*Geothlypis trichas*) | 5 | 0 | 0 |
| - nests | 2 | 0 | 0 |

Appendix 3. Continued.

| | | | |
|---|---|---|---|
| Swamp Sparrow (*Melospiza georgina*) | 4 | 1 | 27 |
| - nests | 0 | 1 | 13 |
| Bobolink (*Dolichonyx oryzivorus*) | 0 | 0 | 4 |
| Eastern Meadowlark (*Sturnella magna*) | 0 | 0 | 2 |
| Red-winged Blackbird (*Agelaius phoeniceus*) | 354 | 56 | 14 |
| - nests | 18 | 11 | 8 |
| Common Grackle (*Quiscalus quiscula*) | 39 | 2 | 0 |

APPENDIX 4. Set of candidate models for the response variables total abundance and species richness of *marsh obligates - gleaners* per sample station, *marsh obligates - non-gleaners* per sample station, *marsh users* per sample station, *other birds* per sample station, and *marsh birds* per sample station in relation to the predictor variables of habitat (HAB, *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), water depth (WD = difference between the mean monthly water depth and annual elevation of Lake Erie in metres), and stand size (SIZE; 1 = small, 2 = medium, 3 = large), two-way interactions involving habitat, and the three-way interaction between (HAB*SD*WD). A null model (intercept only) was also included in the candidate set of models.

| Candidate set of models |
|---|
| {HAB, SD, WD, SIZE, HAB*SD, HAB*WD, HAB*SIZE, HAB*SD*WD} |
| {HAB, SD, WD, SIZE, HAB*SD*WD} |
| {HAB, SD, WD, SIZE, HAB*SD*WD} |
| {HAB, SIZE, WD, HAB*SIZE} |
| {HAB, SIZE, SD, HAB*SIZE} |
| {HAB, SIZE, SD, WD, HAB*SIZE} |
| {HAB, SIZE, HAB*SIZE} |
| {HAB, WD, SD, SIZE, HAB*WD} |
| {HAB, WD, SIZE, HAB*WD} |
| {HAB, WD, SD, HAB*WD} |
| {HAB, WD, HAB*WD} |
| {HAB, SD, WD, SIZE, HAB*SD} |
| {HAB, SD, SIZE, HAB*SD} |
| {HAB, SD, WD, HAB*SD} |
| {HAB, SD, HAB*SD} |
| {HAB, SD, WD, SIZE} |
| {HAB, WD, SIZE} |
| {HAB, SD, WD} |
| {HAB, SD, SIZE} |
| {HAB, SIZE} |
| {HAB, WD} |
| {HAB, SD} |
| {HAB} |
| {NULL} |

APPENDIX 5. Set of candidate models for the response variables total abundance and species richness of *marsh birds* per sample station, *other birds* per sample station, and *all birds* per sample station in relation to the predictor variables of habitat (HAB, *Phragmites australis*, *Typha* spp., and marsh meadow), survey date (SD), and stand size (SIZE; 1 = small, 2 = medium, 3 = large), and two-way interactions involving habitat. A null model (intercept only) was also included in the candidate set of models.

| Candidate set of models |
| --- |
| {HAB, SD, SIZE, HAB*SD, HAB*SIZE} |
| {HAB, SIZE, SD, HAB*SIZE} |
| {HAB, SIZE, HAB*SIZE} |
| {HAB, SD, SIZE, HAB*SD} |
| {HAB, SD, HAB*SD} |
| {HAB, SD, SIZE} |
| {HAB, SIZE} |
| {HAB, SD} |
| {HAB} |
| {NULL} |

APPENDIX 6. Incidental observations of amphibians, reptiles, and mammals observed in relation to habitat at Long Point, Lake Erie, ON, from 1 May until 31 July 2001 and 2002.

| Common Name (Scientific Name) | *Phragmites australis* | | *Typha* spp. | | Marsh Meadow | |
|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2001 | 2002 | 2001 | 2002 |
| **AMPHIBIANS**: | | | | | | |
| American Toad (*Bufo americanus*) | 0 | 1 | 1 | 2 | 1 | 5 |
| Fowler's Toad (*Bufo woodhousii fowleri*) | 0 | 0 | 0 | 1 | 1 | 0 |
| Bullfrog (*Rana catesbeiana*) | 0 | 0 | 4 | 11 | 3 | 0 |
| Northern Leopard Frog (*Rana pipiens*) | 1 | 0 | 0 | 0 | 30 | 2 |
| Green Frog (*Rana clamitans melanota*) | 0 | 0 | 0 | 0 | 1 | 0 |
| Pickerel Frog (*Rana palustris*) | 0 | 0 | 0 | 0 | 0 | 1 |
| **REPTILES:** | | | | | | |
| Common Snapping Turtle (*Chelydra serpentina serpentina*) | 1 | 0 | 3 | 0 | 2 | 2 |
| Spotted Turtle (*Clemmys guttata*) | 2 | 1 | 0 | 0 | 3 | 3 |
| Blandings Turtle (*Emydoidea blandingii*) | 1 | 0 | 2 | 2 | 2 | 7 |
| Common Map Turtle (*Graptemys geographica*) | 0 | 0 | 0 | 0 | 1 | 0 |
| Eastern Garter Snake (*Thamnophis sirtalis*) | 0 | 1 | 0 | 2 | 8 | 15 |
| Black Rat Snake (*Elaphe obsolete obsoleta*) | 0 | 0 | 0 | 0 | 3 | 4 |
| **MAMMALS:** | | | | | | |
| Virginia Opossum (*Didelphis virginiana*) | 0 | 0 | 0 | 0 | 1 | 0 |
| Meadow Jumping Mouse (*Zapus hudsonius*) | 0 | 0 | 0 | 0 | 0 | 1 |
| Meadow Vole (*Microtus pennsylvanicus*) | 0 | 1 | 0 | 1 | 0 | 0 |
| Red Fox (*Vulpes vulpes*) | 0 | 0 | 0 | 3 | 0 | 4 |
| - *tracks* | *0* | *0* | *0* | *0* | *0* | *1* |
| Northern Raccoon (*Procyon lotor*) | 1 | 0 | 0 | 0 | 2 | 2 |
| - *tracks* | *0* | *0* | *5* | *2* | *10* | *3* |
| Mink (*Mustela vison*) | 2 | 4 | 1 | 0 | 0 | 2 |
| Striped Skunk (*Mephitis mephitis*) | 0 | 0 | 0 | 0 | 0 | 1 |
| White-tailed Deer (*Odocoileus virginianus*) | 0 | 1 | 5 | 1 | 6 | 1 |
| - *tracks* | *0* | *0* | *3* | *6* | *14* | *22* |

APPENDIX 7. Set of candidate models for the response variables total abundance and species richness of amphibians per pitfall trap and total abundance and species richness of small mammals per pitfall trap in relation to the predictor variables of habitat (HAB, *Phragmites australis*, *Typha* spp., and marsh meadow) and survey week [SW; 1 = 1 May, 13 = 31 July)], and two-way interactions involving habitat in 2001. A null model (intercept only) was also included in the candidate set of models.

| Candidate set of models |
|---|
| {HAB, SW, HAB*SW} |
| {HAB, SW} |
| {HAB} |
| {NULL} |

APPENDIX 8. Set of candidate models for the response variables total abundance and species richness of amphibians per pitfall trap and total abundance and species richness of small mammals per pitfall trap in relation to the predictor variables of habitat (HAB, *Phragmites australis*, *Typha* spp., and marsh meadow), survey week [SW; 1 = 1 May, 13 = 31 July)], and stand size [SIZE; 1 = small (perimeter: 377 – 533 $m^2$), 2 = large (perimeter: 761 – 1350 $m^2$)], and three-way interactions involving habitat in 2002. A null model (intercept only) was also included in the candidate set of models.

| Candidate set of models |
|---|
| {HAB, SW, SIZE, HAB*SW, HAB*SIZE, HAB*SW*SIZE} |
| {HAB, SIZE, SW, HAB*SW*SIZE} |
| {HAB, SIZE, SW, HAB*SIZE} |
| {HAB, SIZE, HAB*SIZE} |
| {HAB, SW, SIZE, HAB*SW} |
| {HAB, SW, HAB*SW} |
| {HAB, SW, SIZE} |
| {HAB, SIZE} |
| {HAB, SW} |
| {HAB} |
| {NULL} |

## CURRICULUM VITAE

| | |
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| **Name**: | Shawn William Meyer |
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| **Post-secondary Education and Degrees:** | University of Western Ontario<br>London, Ontario, Canada<br>2001 – 2003 M.Sc., Zoology – Ecology & Evolution |
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**Presented Papers:**

Meyer, S.W., S.A. Petrie, and C.D. Ankney. 2003. Use of *Phragmites australis* by Waterbirds at Long Point, Lake Erie, Ontario. Fourth Conference Aquatic Birds Working Group of Societas Internationalis Limnologiae (SIL) Limnology and Waterbirds Conference, Sackville, New Brunswick.

**Publications:**

Wilcox, K.L., S.A. Petrie, L.A. Maynard, and S.W. Meyer. Submitted. Historical distribution and abundance of *Phragmites australis* at Long Point, Lake Erie, Ontario. Journal of Great Lakes Research.