SURVEY PROTOCOL AND THE INFLUENCE OF LAND USE ON BIRD COMMUNITIES IN SOUTHERN ONTARIO COASTAL MARSHES

BY

LYNDSAY ANN SMITH, B.Sc., M.Sc.

A Thesis

Submitted to the School of Graduate Studies

in Partial Fulfillment of the Requirements for the Degree

Doctor of Philosophy

McMaster University

Your file Votre référence
ISBN: 978-0-494-62533-0
Our file Notre référence
ISBN: 978-0-494-62533-0

DOCTOR OF PHILOSOPHY (2009) MCMASTER UNIVERSITY

(Biology) Hamilton, Ontario

TITLE: Survey protocol and the influence of land use on bird communities in southern Ontario coastal marshes

AUTHOR: Lyndsay Ann Smith, B.Sc. (Brock University), M.Sc. (Trent University)

SUPERVISOR: Dr. Patricia Chow-Fraser

NUMBER OF PAGES: xv, 221

GENERAL ABSTRACT

Concern over recent declines in many wetland-dependent bird species has led to a need to monitor marsh bird populations in response to anthropogenic activities. I conducted point counts and vegetation surveys at 26 coastal wetlands in the Laurentian Great Lakes Region of Canada from 2006-2008 to determine 1) effective methods to monitor marsh birds, and 2) the impacts of land use surrounding coastal wetlands on marsh bird communities. The first part of this dissertation showed that call-broadcasts are effective tools for monitoring marsh birds and that point counts for marsh birds should be conducted from both the shoreline and from the interior of large marshes. Because of the species-area relationship for wetland birds in southern Ontario, sampling effort should increase proportionally with wetland area to attempt the detection of all species present. In the second part of this thesis, I showed that marsh obligate-nesters preferred wetlands in rural areas as opposed to urban areas, while generalist marsh-nesting species showed no apparent difference in use. The Index of Marsh Bird Community Integrity (IMBCI), a biological index used to indicate wetland health, was significantly higher in rural than in urban marshes. Marsh isolation was also an important factor in predicting the marsh bird community, with more isolated wetlands containing fewer obligate species and associated with a lower IMBCI value. Wetlands of Georgian Bay were found to have quite different bird and plant communities than wetlands of Lake Ontario. Even though wetlands of Lake Ontario were considerably more degraded than those in Georgian Bay (according

to land use alteration and degree of water quality impairment), these two regions produced similar IMBCI scores, and this draws into question the applicability of some indicators on a basin-wide scale. The results of this thesis indicate how survey protocols in existing wetland bird monitoring programs should be modified and support current literature that urbanization negatively affects the marsh bird community.

PREFACE

The following Ph.D. thesis consists of manuscripts that are already submitted or will be submitted for publication in peer-reviewed journals. Chapters 1, 2 and 3 have already been submitted for publication and the remaining chapters are being prepared for submission to peer reviewed scientific journals. The following are proper citations for these papers, including co-authorship.

Smith, L.A, and P. Chow-Fraser. The influence of call-broadcasts and edge versus interior surveys in detecting secretive wetland birds.

Smith, L.A, and P. Chow-Fraser. Implications of the species-area relationship on sampling effort and conservation of marsh birds in southern Ontario.

Smith, L.A, and P. Chow-Fraser. Impacts of adjacent land use and isolation on marsh bird communities.

Smith, L.A, and P. Chow-Fraser. Application of the index of marsh bird community integrity to coastal wetlands of Georgian Bay, Ontario.

Smith, L.A, and P. Chow-Fraser. The influence of watershed land use and wetland water quality on marsh bird communities.

ACKNOWLEDGEMENTS

I would first and foremost like to thank my supervisor, Pat Chow-Fraser, for all of her guidance from start to finish. She has taught me many important lessons like how to design good experiments, how to fight for what is right and what you believe in, and the importance and usefulness of GIS in understanding ecological problems. I also thank her for taking a risk with me (and birds) and opening her lab to a more terrestrial view of wetlands.

Next, I need to thank all of the members of the Chow-Fraser lab past and present. Many of you had the heavily sought-after opportunity to join me in the wetland at 5am to sit and listen to birds for hours. Some of you even got the chance to get up at 3am to help me... On a serious note, I am grateful for the help of everyone who came with me to help with bird surveys at some point in time including Melanie Croft, Jon Midwood, Maja Cvetkovic, Stephanie Yantsis, Alexis Richardson, Rhiannon Leshyk, Kyna Intini, Sarah Thomasen, Dan Rokitnicki-Wojcik, Rachel De Catanzaro, Ashley Whitehead, Adam Scott, Jeffrey Gowan, Murray Smith, Suzanne Smith-Merkley (and Jacob Smith-Merkley), Jim Macpherson, and Betty Macpherson. Many other lab members helped me in one way or another, from help with GIS and statistics from Anhua Wei, Titus Seilheimer giving me the maps to almost all of the southern Ontario wetlands, and scores of undergrads for providing comments in lab meetings.

I need to thank my committee members, Jonathon Stone and Jim Quinn, for all of the meetings and presentations they sat through and all of their extremely valuable comments on the direction of my thesis. I also need to thank numerous individuals that contributed in some way to this project including Cathy Moulder, Jonathan Dushoff, Susan Dudley, Ben Evans, John Haselmayer, Barb Reuter, Pat Hayward, and Greg Cartwright.

I would also like to thank the Royal Botanical Gardens of Hamilton, Wye Marsh, and the Turkey Point Company for permission to access to wetlands. Additional thanks to the Georgian Bay Association and the GBA Foundation for their contribution to this project. Financial support was provided by McMaster University, a NSERC post-graduate scholarship to L.A.S., and research grants to PC-F from the GBA Foundation and the NSERC Discovery Grant program. Without this funding and support, this project would not have been possible.

Finally, I would like to thank my family and friends for all of their support over the past three years. Your encouragement, laughter, and patience got me to this point, and I sincerely thank you.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GENERAL INTRODUCTION

Wetlands

Wetlands are difficult to define due to their dynamic nature, but definitions usually include three main characteristics: the presence of water, unique soils that differ from adjacent habitats, and the ability to support hydrophytic vegetation (Mitsch and Gosselink 1993). The Canadian Wetland Classification System classifies wetlands into five main types including bogs, fens, marshes, swamps, and shallow open water, differing mainly in water quality, vegetation, and hydrology (National Wetlands Working Group 1988). Bogs are primarily nutrient-poor peatlands fed by precipitation with a low pH and support ericaceous shrubs and trees. Fens are also peatlands but instead are fed primarily by groundwater and are associated with predominately nutrient-rich water and sedges, grasses, and mosses (Mitsch and Gosselink 1993). Marshes are areas of wet or periodically wet land where the water is often nutrient-rich (but can be oligotrophic) and are often subject to lake water exchange or slow-moving waters. Vegetation includes reeds, cattails, sedges, rushes, and submergent species in deeper areas. Swamps are similar to marshes but contain predominantly woody vegetation (trees and shrubs) and most often standing water. Shallow water is the final wetland class and includes areas which have a water depth of less than 2m and less than 25% cover of vegetation in mid-summer.

Wetlands are unique habitats with many important functions, values, and benefits. Some physical/hydrological functions include controlling floods through reduced stream flow and temporary storage of run-off water, also providing erosion protection by absorbing wave energy (Williams 1990, Phillips 1996). Additional physical functions include helping to control atmospheric and climatic fluctuations, trapping sediments, and recharging aquifers. Wetlands also perform various chemical functions including trapping toxic residues such as heavy metals, herbicides, and pesticides, and filtering nitrogen and phosphorus from upland sources (Williams 1990, Mitsch and Gosselink 1993).

Over the past 30 years, studies on the biological functions of wetlands have propelled them to a previously unseen status, as they are now recognized as one of the most productive ecosystems in the world, just short of tropical rain forests (Mulamoottil et al. 1996). While wetlands cover only 6.4% of the Earth's surface, they perform 24% of the world's primary production (Williams 1990). The other very important biological function they provide is to contribute habitat for a variety of plants and animals. The awareness of this function was one of the main drivers for the conservation of wetlands in many parts of the world, including Canada (National Wetlands Working Group 1988, Williams 1990).

In 1971, Canada took part in the Ramsar Convention on Wetlands which resulted in an international agreement making wetlands the very first ecosystem to be protected by a global environmental treaty. This international treaty pledges to use wetlands wisely in Canada and in the rest of the world (Matthews 1993). The Canadian Federal Policy on Wetland Conservation was developed in 1991 and provides seven strategies to protect wetlands (Government of Canada 1991). These strategies are to increase public awareness, manage wetlands, promote conservation, enhance cooperation, conserve significant wetlands, use sound scientific basis for policy, and promote international actions for wetland conservation.

In Ontario, provincial policies have been developed in an attempt to limit development and site alteration in, or adjacent to, provincially significant wetlands (Provincial Policy Statement 2005). Significant wetlands refer to "Provincially Significant Wetlands", which receive this status only after having undergone a lengthy site evaluation process (OMNR 1993). Specifically, the policy states that development and site alteration shall not be permitted in, or adjacent to (within 120m), significant coastal wetlands, significant wetlands in ecoregions 5E, 6E, and 7E, and significant wetlands on the Canadian Shield north of ecoregions 5E, 6E, and 7E (OMNR 1999). On the surface, this policy appears to provide sufficient protection, but the policy goes on to state that development may be allowed if it can be shown that there will be no destruction or disruption of fish habitat, or degradation of water quantity and quality.

Coastal marshes of the Laurentian Great Lakes

Canada's Great Lakes are relatively new geological features, formed 10,000 years ago by the retreating Wisconsin glacier (Fig. i-1). Today, these lakes represent some of the largest lakes in the world by volume, and hold a disproportionate 20% of the world's fresh water. Lake Superior, alone, is large enough to swallow the other four lakes and Lake Erie a second, third, and fourth time (Annin 2006). The Great Lakes provide many socio-economic benefits and values including providing us with water for personal, municipal, and industrial uses, along with non-consumptive values such as navigation and transportation, and for recreational and spiritual reasons.

Coastal marshes represent a small fraction of all wetlands but are unique because they control the interactions between land and water (Burton 1985). While performing all of the similar functions as other wetlands, coastal marshes are forced to deal with intense wind and wave action, often from large water bodies, and fluctuating lake water levels. Coastal marshes are of higher importance in controlling water quality, as they are the last to filter out nutrients and pollutants before water finally enters lakes. They are also important habitats as spawning grounds for fish, and nesting and migratory stopover sites for birds (Jude and Pappas 1992, Smith et al. 2007).

Stressors

The Great Lakes lie at the end of the most heavily populated river drainage basin in Canada and are subject to additional pressures from the heavily populated United States coast (Williams 1990). Wetland loss statistics are staggering along the southern Ontario shoreline, with up to 90% of pre-settlement wetlands lost (Snell 1987). Agriculture is considered to be the cause of the majority of wetland losses in southern Ontario (Bardecki 1982), with coastal industrialization and urbanization also adding pressure (Pinder and Witherick

1990). Remaining wetlands within these urban and agricultural contexts are forced to deal with increased nutrient loading, turbidity, and human waste (Chow-Fraser 2006).

At the start of the twentieth century, the majority of the human population lived in rural areas, with few in cities (UNFPA 2002). With the growing human population, more and more people are living in urban areas, and 58% of the world's population is projected to be living in urban areas by 2025 (UNFPA 2002). Between 2015 and 2020, the urban population is expected to outnumber the rural population for the first time in history (UNFPA 2002). Since the human population is expected to reach 9 billion by 2050, the need for food, water, and urban infrastructure will continue to rise (Cohen 2003), and the pressures on the Great Lakes will follow suit.

In addition to land use threats, the Great Lakes face other challenges including exotic invasive species and water diversions. The creation of the St. Lawrence Seaway and Erie canal have facilitated the spread of many non-indigenous species, such as the infamous zebra mussel (*Dreissena polymorpha*), throughout the Great Lakes, and has caused economic losses estimated to be in the billions of dollars (Mills et al. 1994, Vitousek 1997). Exotic species disrupt natural systems and send repercussions throughout the food web, altering natural system functions. Water diversions will probably be one of the most severe threats to the Great Lakes in the future. Dropping water levels, as a result of water diversions and climate change, could potentially dry up wetlands and important wildlife habitat (Manny 1984). Integrated water resource management is the only way that our water resources can be managed in a sustainable and equitable manner (United Nations 2006).

A case for the birds

While there is a myriad of species suffering silently by the plight of humans, I have chosen to focus on birds for my research. Birds are very important participants in ecosystems providing many functions ranging from seed dispersal to ecosystem engineering (Sekercioglu 2006). Seed dispersal and pollen transfer are likely their most important functions, with plants relying heavily on birds as seed vectors. Both seed dispersal and pollen transfer make birds important as "genetic linkers", linking genes between individuals, or dispersing genes far from the parent plant (Sekercioglu 2006).

The role of birds in controlling herbivorous insects has been estimated to be USD $1820 per square kilometre per year (Takekawa and Garton 1984). Removal of insectivorous birds has been shown to cause an increase in foliage damage and even a decrease in crop yields, demonstrating the importance of birds as natural biological controls (Mols and Visser 2007). In addition to biological controls, birds provide humans with many other benefits such as providing down for garments, game for consumption, crop seed dispersal, scavenging carcasses, controlling vertebrate pest populations, fuelling the economy due to the billion dollar birding industry, and the spiritual and religious values they hold (Sekercioglu 2002, 2006).

Regardless of these important functions and values, an estimated one-quarter of bird species globally have been driven to extinction by human activities over the last two millennia, and of those species remaining, 11% are at risk of extinction (Steadman 1995, Barbault and Sastrapradja 1995). The statistics in North America echo that trajectory with 30% of all species showing significant declines between 1966 and 2007 according to the North American Breeding Bird Survey (Sauer et al. 2008). Reasons for these declines include predominantly habitat loss (Robbins et al. 1989, Bender et al. 1998, Owens and Bennett 2000) but also migration hazards such as the continued use of banned, poisonous pesticides on wintering grounds (Finch and Martin 1995), food shortages on stopover sites, and severe weather (Newton 2006). Some of the repercussions of habitat loss and fragmentation are increased predation rates by nest predators and increased parasitism rates by Brown-headed Cowbirds (*Molothrus ater*) on breeding grounds, and are dominant forces driving declines (Robinson et al. 1995).

Wetland breeding birds in southern Ontario coastal marshes

Coastal marshes of the Great Lakes have been primarily recognized for their importance as waterfowl nesting and breeding grounds and migratory habitat (National Wetlands Working Group 1988). These habitats are also important nesting and breeding grounds for several wetland-dependent rails, bitterns, and songbirds. Wetland-breeding birds have also shown continental declines, with 40% showing negative trend estimates between 1966 and 2007 (Sauer et al. 2008). Wetland-dependent species require marsh for nesting and feeding, often building floating nests and foraging primarily in the moist soil or aquatic areas for invertebrates and small fish. Solitary living in the dense marsh habitat has led to the evolution of primarily vocal communication methods (Kaufmann 1971). This solitary nature makes rails quite shy and uneasy to detect by conventional avian survey methods, such as passive point counts (Ralph 1981).

In the United States and Canada, there have been two main protocols established to monitor wetland bird populations. The Standardized North American Marsh Bird Monitoring Protocol, which is used primarily in the United States, and the Marsh Monitoring Program (MMP) protocol, which was established in Canada and is increasingly being established south of the border. The North American Protocol was only recently published in 2005, and was created to allow for detecting changes in population size over time and to alert managers quickly. The MMP was also developed to detect changes in population numbers; however, this program has been in use since 1995. These protocols are similar, but do differ based on several parameters (Table i-1). The MMP has already provided a 10-year report with a summary of population trends and shows significant declines over the past ten years for many wetland-dependent species in the Great Lakes region (Fig. i-2).

Thesis objectives

The primary objective of my research is to contribute sound, scientific information to monitoring-program leaders and policy makers, which will help to monitor population trends effectively and preserve marsh habitat for wetland birds. This research is important because it examines aspects of marsh monitoring protocols that are very understudied and could have implications for monitoring programs. I also examine the impact of land use surrounding wetlands on marsh birds on a broad scale in southern Ontario, and this approach is unique for this region.

In Chapter 1, I examine several aspects of marsh bird monitoring protocols. The first is to determine the effectiveness of passive versus active surveys, and species response patterns to broadcasts. Second, I determine if survey location within the wetland affects which of the species are detectable; specifically if there is a difference between shoreline (edge) point counts and marsh interior point counts. I then examine the impact of point count location on the Index of Marsh Bird Community Integrity (IMBCI; DeLuca et al. 2004) which is used to determine the integrity, or health, of a wetland. The results of this chapter will be applicable to wetland bird monitoring programs, future scientific studies, and wetland conservation or restoration plans.

Chapter 2 examines various aspects and applications of the species-area relationship (SAR) for wetland birds. I first determine if a SAR exists for marsh birds in southern Ontario, and then determine if an integrity-area relationship is present as well, suggesting that larger marshes have a higher integrity. Area-sensitive requirements for many species are not well known, and in this chapter I determine which marsh bird species display area-sensitive distributions. The SAR was originally intended to be used to determine how many samples are needed to survey the plant community accurately (Arrhenius 1921), and in the chapter I apply this to marsh bird sampling requirements. These results allow for recommendations as to the size of marshes that should be preserved based on the avian community and also contribute methodological recommendations.

Chapter 3 investigates the impact of surrounding land use on marsh bird communities. I examine the impact of a forested buffer zone and the land use adjacent to that forested buffer on the abundance and richness of marsh birds. Specifically, I look at how land use affects obligate marsh-nesting birds (those that require marsh for nesting), generalist marsh-nesting birds (those that can nest in marshes and other habitats), synanthropic species (those living in a symbiotic relationship with humans), and the IMBCI. I also examine the impact of marsh isolation on the bird community, since research in other regions has shown the importance of surrounding marsh habitat on the richness of wetland birds (Brown and Dinsmore 1986).

Chapter 4 examines the applicability of the IMBCI to indicate land use disturbance between Lake Ontario and Georgian Bay. To do this, I compare bird communities between coastal marshes of Georgian Bay and coastal marshes of Lake Ontario. I use the Southern Ontario Land Resources Information System and IKONOS satellite imagery to detect differences in land use between Lake Ontario and Georgian Bay, respectively. Water quality and wetland vegetation are also compared between lakes to explain differences in the marsh bird community. The goal of this chapter is to shed light on lake-based differences in bird communities and to stimulate discussion and research into the basin-wide application of indicators in the Great Lakes Region.

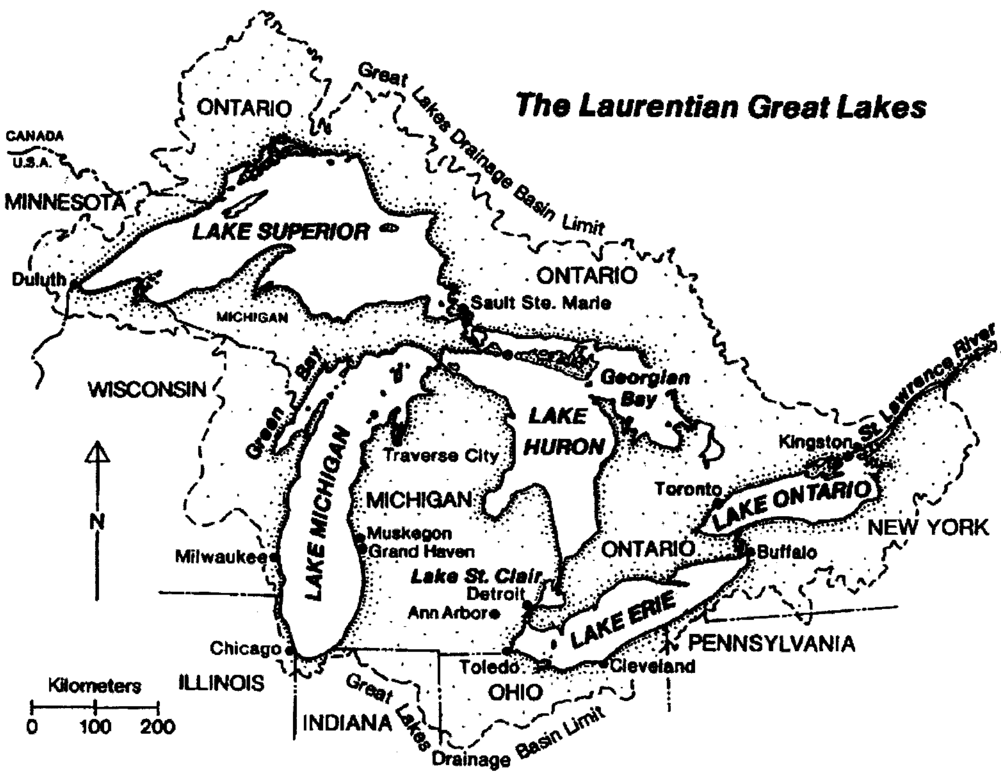
In Chapter 5, I determine if watershed land use indirectly influences the community of wetland birds through deterioration of water quality in wetland ecosystems. I use the Water Quality Index (WQI; Chow-Fraser 2006) to determine first if there is a relationship between the proportion of altered land use in the watershed and wetland water quality, and then a relationship between the WQI and the bird community. I also look at the impact of water quality on the abundance and richness of insectivorous bird species and obligate marsh-nesting species because of their important relationship with the aquatic environment. I attempt to make the link by examining relationships between the insect community and the bird community.

Table i-1. A comparison of protocol for two major marsh bird monitoring programs in North America extracted from Conway (2005) and the Marsh Monitoring Program Participant's Handbook (2008, 2009).

Parameter	North American Protocol	Marsh Monitoring Program
Marsh size	>0.5 ha	>1.5 ha
Point count size	Unlimited	100m radius semi-circle, focal species[1] unlimited
Point count location	Shoreline or interior	Shoreline or interior
Distance between survey points	400m	250m
Number of surveys at each point per year	3	2
Time of day	Morning or evening	Evening only (revised in 2009 to morning or evening)
Secretive species broadcast	Yes	Yes
Secretive species included in the broadcast	Varies based on geographic location and only birds heard in the first year	Focal species
Length of point count	5 min passive[2], 5 min active[3]	5 min passive, 5 min active, 5 min passive
Habitat analysis	Yes	Yes
Size of habitat analysis	50m radius circle	100m radius semi-circle
Personnel	Open to anyone	Volunteers
Training	Self-administered vocalization identification exam each year	Given training CD
Background noise measured	Optional	Yes
Water depth	Optional	No
Recording types of calls given	Optional	No
Water salinity levels	Optional	No

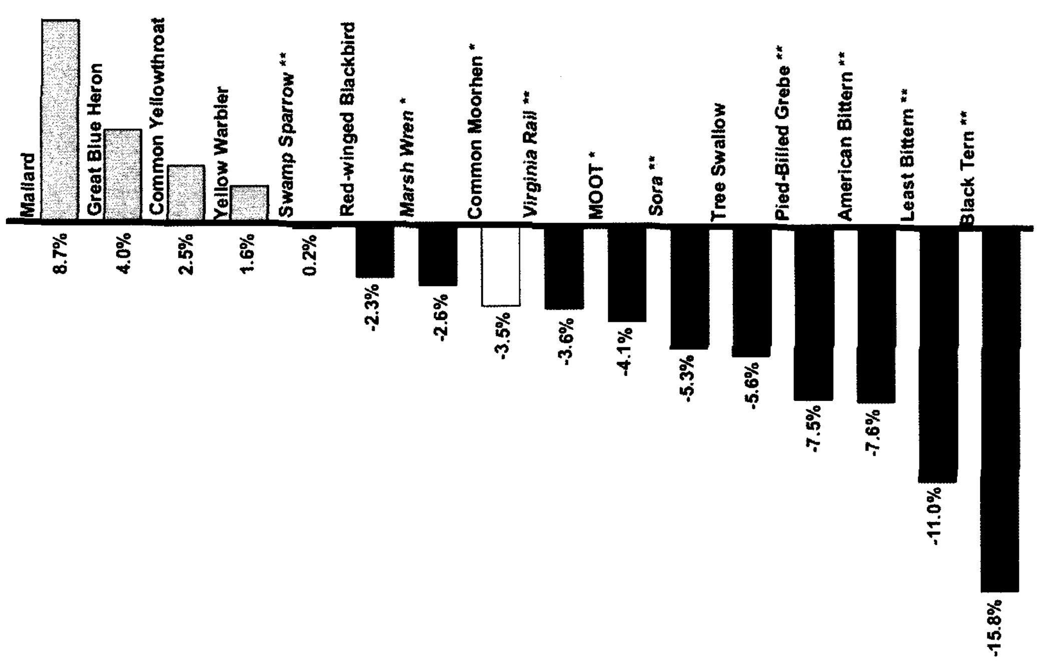
[1]- Focal species include American Bittern, American Coot, Black Rail, Common Moorhen, King Rail, Least Bittern, Pied-billed Grebe, and Virginia Rail.
[2]- Just listening, no broadcasting of calls.
[3]- Includes broadcasting secretive species calls.

Figure i-1. A map of the Laurentian Great Lakes drainage basin (from Herdendorf 2004).



The Laurentian Great Lakes
ONTARIO
CANADA
U.S.A.
MINNESOTA
LAKE SUPERIOR
Duluth
MICHIGAN
Great Lakes Drainage Basin Limit
ONTARIO
Sault Ste. Marie
Georgian Bay
WISCONSIN
Green Bay
LAKE MICHIGAN
Traverse City
LAKE HURON
MICHIGAN
Muskegon
Grand Haven
Milwaukee
Lake St. Clair
Detroit
Ann Arbor
Chicago
ILLINOIS
INDIANA
Toledo
OHIO
Cleveland
LAKE ERIE
ONTARIO
Buffalo
Toronto
LAKE ONTARIO
Kingston
St. Lawrence River
NEW YORK
PENNSYLVANIA
Great Lakes Drainage Basin Limit
N
Kilometers
0 100 200

Figure i-2. Percent annual change for marsh birds in the Great Lakes basin as surveyed by the MMP from 1995 to 2004. Significant increasing trends are shown in green, significant decreasing trends are shown in red and non-significant trends are shown in white. ** area-sensitive marsh nesters, * obligate marsh nesters (From Crewe et al. 2006).


Mallard
8.7%
Great Blue Heron
4.0%
Common Yellowthroat
2.5%
Yellow Warbler
1.6%
Swamp Sparrow **
0.2%
Red-winged Blackbird
-2.3%
Marsh Wren *
-2.6%
Common Moorhen *
-3.5%
Virginia Rail **
-3.6%
MOOT *
-4.1%
Sora **
-5.3%
Tree Swallow
-5.6%
Pied-Billed Grebe **
-7.5%
American Bittern **
-7.6%
Least Bittern **
-11.0%
Black Tern **
-15.8%

REFERENCES

Annin, P. 2006. The Great Lakes Water Wars. Island Press. Washington, USA.

Arrhenius, O. 1921. Species and area. The Journal of Ecology 9:95-99.

Barbault, R. and S. Sastrapradja. 1995. Generation, Maintenance and Loss of Biodiversity. *In* Global Biodiversity Assessment. V. H. Heywood Ed. Cambridge University Press, Cambridge.

Bardecki, M. J. 1982. The status of wetlands in southern Ontario. Wetlands 2: 262-270.

Bender, D. J., Contreras, T. A., and L. Fahrig. 1998. Habitat loss and population decline: a meta-analysis of the patch size effect. Ecology 79: 517-533.

Brown, M., and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. The Journal of Wildlife Management 50:392-397.

Burton, T. M. 1985. The effects of water level fluctuations on Great Lakes coastal marshes. *In* Coastal Wetlands. Prince, H. H. and D'Itri, F. M. Eds. Lewis Publishers, Inc., Chelsea, Michigan.

Chow-Fraser, P. 2006. Development of the Water Quality Index (WQI) to assess basin-wide land-use alteration on coastal marshes of the Laurentian Great Lakes. *In* T. P. Simon and P. M. Stewart, editors. Coastal Wetlands of the Laurentian Great Lakes: Health, Habitat and Indicators.

Cohen, J. E. 2003. Human population: the next half century. Science 302:1172-1175.

Conway, C. J. 2005. Standardized North American Marsh Bird Monitoring Protocols. Wildlife Research Report #2005-04. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, AZ.

Crewe, T. L., S. T. A. Timmermans, and K. E. Jones. 2006. The Marsh Monitoring Program 1995 to 2004: A Decade of Marsh Monitoring in the Great Lakes Region. Published by Bird Studies Canada in cooperation with Environment Canada. 28pp.

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24:837-847.

Finch, D. M. and T. E. Martin. 1995. Ecology and Management of Neotropical Migratory Birds: A Synthesis and Review of Critical Issues. Oxford University Press, New York.

Gosselink, J. G. and E. Maltby. Wetland losses and gains. *In* Wetlands: A Threatened Landscape. Basil Blackwell, Cambridge, Massachusetts.

Government of Canada. 1991. Federal Policy of Wetland Conservation. Published by Authority of the Minister of Environment.

Herdendorf, C. E. 2004. Morphometric factors in the formation of Great Lakes coastal wetlands. Aquatic Ecosystems Health and Management 7:179-197.

Jude, D. J., and Pappas, J. 1992. Fish utilization of Great Lakes coastal wetlands. Journal of Great Lakes Research 18: 651-672.

Kaufmann, G. W. 1971. Behavior and ecology of the Sora, *Porzana carolina*, and

Virginia Rail, *Rallus limicola*. Ph.D. University of Minnesota.

Manny, B. A. 1984. Potential impacts of water diversions on fishery resources in the Great Lakes. Fisheries 9: 19-23.

Marsh Monitoring Program Participant's Handbook for Surveying Marsh Birds. 2008 Edition. 17 pages. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. February 2008.

Marsh Monitoring Program Participant's Handbook: Getting Started. 2009 Edition. 13 pages. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. February 2009.

Matthews, G. V. T. 1993. The Ramsar Convention of Wetlands: It's History and Development. Ramsar Convention Bureau. Gland, Switzerland.

Mills, E. L., Leach, J. H., Carlton, J. T., and C. L. Secor. 1994. Exotic species and the integrity of the Great Lakes. BioScience 44:666-676.

Mitsch, W. J. and J. G. Gosselink 1993. Wetlands. 2nd Ed. Van Nostrand Reinhold, New York, USA.

Mols, C. M. M. and M. E. Visser. 2007. Great Tits (*Parus major*) reduce caterpillar damage in commercial apple orchards. PLoS ONE 2:e202. doi:10.1371/journal.pone.000202.

Mulamoottil, G., B. G. Warner, and E. A. McBean. 1996. Introduction. *In* Wetlands: environmental gradients, boundaries, and buffers. Mulamoottil, G., B. G. Warner, and E. A. McBean Eds. Lewis Publishers, Boca Raton, Florida.

National Wetlands Working Group. 1988. Wetlands of Canada. Ecological Land Classification Series, No. 24. Sustainable Development Branch, Environment Canada, Ottawa, Ontario, and Polyscience Publications Inc., Montreal, Quebec. 452 p.

Newton, I. 2006. Can conditions experienced during migration limit the population levels of birds? Journal of Ornithology 147:146-166.

OMNR (Ontario Ministry of Natural Resources). 1993. Ontario Wetland Evaluation System Southern Manual, 3rd Ed. NEST Technical Manual TM-002.

OMNR (Ontario Ministry of Natural Resources). 1999. Natural Heritage Reference Manual for Policy 2.3 of the Provincial Policy Statement.

Phillips, J. D. 1996. Wetland buffers and runoff hydrology. *In* Wetlands: environmental gradients, boundaries, and buffers. Mulamoottil, G., B. G. Warner, and E. A. McBean Eds. Lewis Publishers, Boca Raton, Florida.

Pinder, D. A. and M. E. Witherick. Port industrialization, urbanization and wetland loss. *In* Wetlands A Threatened Landscape. Williams, M. Ed. Basil Blackwell Ltd., Cambridge, Massachusetts.

Provincial Policy Statement. 2005. Section 3 of the Planning Act. Ministry of Municipal Affairs and Housing. Queen's Printer for Toronto, Ontario.

Ralph, J. C. 1981. Terminology used in estimating numbers of birds. Studies in Avian Biology 6: 577-578.

Robbins, C. S., Sauer, J. R., Greenberg, R. S. and S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. Proceedings of the National Academy of Science USA 86:7658-7662.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Sekercioglu, C. H. 2006. Increasing awareness of avian ecological function. Trends in Ecology and Evolution 21:464-471.

Smith, R. J., F. R. Moore, and C. A. May. 2007. Stopover habitat along the shoreline of northern Lake Huron, Michigan: emergent aquatic insects as a food resource for spring migrating landbirds. Auk 124:107-121.

Snell, E. A. 1987. Wetland distribution and conversion in southern Ontario, Working Paper No. 48. Inland Waters and Lands Directorate, Environment Canada.

Steadman, D. W. 1995. Prehistoric extinctions of Pacific island birds: biodiversity meets zooarchaeology. Science 267:1123-1131.

Takekawa, J. Y. and E. O. Garton 1984. How much is an Evening Grosbeak worth? Journal of Forestry 82:426-428.

UNFPA (United Nations Population Fund). 2002. The State of the World Population 2001. New York.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science 277:494-499.

Williams, M. 1990. Understanding Wetlands. *In* Wetlands A Threatened Landscape. Williams, M. Ed. Basil Blackwell Ltd., Cambridge, Massachusetts.

CHAPTER 1:

THE INFLUENCE OF CALL-BROADCASTS AND EDGE VERSUS INTERIOR SURVEYS IN DETECTING SECRETIVE WETLAND BIRDS

Lyndsay A. Smith and Patricia Chow-Fraser

ABSTRACT

There is a current push within the scientific community to accurately monitor bird populations in response to anthropogenic activities. We conducted point counts and vegetation surveys at 26 coastal wetlands in the Great Lakes Region from 2006-2008 to examine 1) the effectiveness of call-broadcasts in detecting secretive wetland birds, 2) general and species-specific response patterns to a multi-species broadcast sequence, 3) the importance of intervening silent periods, and 4) the effect of survey location (interior versus edge) in detecting marsh birds and on the results of the Index of Marsh Bird Community Integrity (IMBCI). Call-broadcasts detected significantly more species and individuals than did passive point counts. We detected significantly more secretive birds during silent periods between broadcasts as opposed to during broadcasts than would be expected by chance. We found more generalist marsh-nesting species and individuals at the edge of the wetland as opposed to point counts taken in the interior, where we found more obligate species and individuals. IMBCI values were significantly higher when calculated with both interior and edge points than with edge points alone. We suggest that wetland bird monitoring programs should incorporate 1) call-broadcasts in conjunction with passive periods, 2) silent periods between species calls during the broadcasts and at the end of all broadcasts, 3) multi-species broadcasts to facilitate detection, and 4) interior and edge point counts when surveying large wetlands. These results show that species distributions within wetlands may influence the results

of biological indices, which could potentially lead to misguided management decisions.

INTRODUCTION

Concern over the recent decline in many wetland-dependent bird species has led to an investigation into the potential role that humans are playing in this decline. To address these concerns, there is a major need for scientific studies on avian monitoring techniques and anthropogenic factors influencing bird communities (Ruth et al. 2003). It is important to recognize that these research needs are not mutually exclusive. If we are to effectively guide management and policy decisions, accurate survey techniques must be integrated into all scientific studies monitoring the impact of anthropogenic activities on marsh birds.

Many wetland-dependent bird species lead a secretive life because they vocalize infrequently and therefore are quite challenging to study (Gibbs and Melvin 1993). Secretive species such as the American Bittern (*Botaurus lentiginosus*), Least Bittern (*Ixobrychus exilis*), King Rail (*Rallus elegans*), Yellow Rail (*Coturnicops noveboracensis*), Virginia Rail (*R. limicola*), Sora (*Porzana carolina*), American Coot (*Fulica americana*), Common Moorhen (*Gallinula chloropus*), and Pied-billed Grebe (*Podilymbus podiceps*), are obligate marsh-nesters and are quite sensitive to changes in wetland habitat because they require the habitat for nesting and feeding (Peterson and Niemi 2007). The King Rail, Yellow Rail, and Least Bittern have been designated as species at risk and are listed federally in Canada as endangered, of special concern, and threatened, respectively (COSEWIC 2000, 2001a, 2001b). The North American Breeding Bird Survey shows continental-scale declines for the King Rail, American Bittern, American Coot, and Common Moorhen, while the Virginia Rail, Sora, and Pied-billed Grebe have had increasing or stable populations between 1966 and 2007 (Sauer et al. 2008). While the Breeding Bird Survey is currently the most extensive, long term record of avian population trends, it tends to under-represent secretive wetland birds (Ribic et al. 1999). The recent development of a Standardized North American Marsh Bird Monitoring Protocol (Conway 2005) and the current Marsh Monitoring Program in Canada (Crewe et al. 2006) focus on accurate sampling of wetland birds and will provide scientists and conservation biologists with a tool for long-term evaluation of marsh bird population trends.

To survey secretive wetland birds accurately, call-broadcasts are generally used in conjunction with point counts. Calls of secretive wetland birds are broadcast over the wetland (active sampling) and this entices the birds to respond by either flushing or calling. Increases in detection rates have been shown for many secretive marsh bird species (Swift et al. 1988, Legare et al. 1999, Bogner and Baldassarre 2002, Hinojosa-Huerta et al. 2002, Conway and Gibbs 2005). Broadcasts increased the detection of Pied-billed Grebes and American Bitterns by >90%, and by >500% for Soras, Virginia Rails, and Least Bitterns (Gibbs and Melvin 1993). Call-broadcasts were on average 2.9 times more effective than passive surveys in detecting Pied-billed Grebes, American Bitterns, Virginia Rails, and Soras (Allen et al. 2004). Additionally, Conway and Gibbs (2005) provided an extensive analysis of over 8,047 point counts from 11 cooperating scientists and determined that call-broadcasts are important for increasing detection probabilities for the King Rail, Virginia Rail, Sora, and Common Moorhen (Bart 2005). While there remains inconsistencies between some studies on species-specific responsiveness to call-broadcasts (Allen et al. 2004, Conway and Gibbs 2005), the overall utility of the call-broadcast technique is undisputed.

Some studies have examined in greater detail the responses of secretive species to broadcasts (Gibbs and Melvin 1993, Allen et al. 2004, Conway et al. 2004). The use of multi-species broadcasts as opposed to single species broadcasts has been debated, as broadcasting the calls of heterospecifics may inhibit calling of focal species. For example, only broadcasting California Black Rail (*Laterallus jamaicensis coturniculus*) calls after an initial passive period, decreased the probability of detecting other rails or bitterns that were already detected during the passive period (Conway et al. 2004). During multi-species broadcasts the Pied-billed Grebe, Least Bittern, and American Bittern replied most often to conspecific calls, while the Sora and Virginia Rail showed inconsistent results between studies in responsiveness (Gibbs and Melvin 1993, Allen et al. 2004). Conway et al. (2004) additionally examined the calling pattern of California Black Rails to the periods within a broadcast, and the importance of silent periods between broadcasts. Silent periods increased detection probabilities for Black Rails and should therefore be included in the broadcast sequence.

One aspect of marsh bird monitoring that has received little attention in the literature is the effect of survey location in detecting secretive wetland birds (but see Meyer et al. 2006, Tozer et al. 2006). Survey location refers to whether the survey is conducted from the edge of the wetland or the interior of the wetland. Shoreline point counts detected significantly more marsh-nesting generalists such as the Common Yellowthroat (*Geothlypis trichas*), Common Grackle (*Quiscalus quiscula*), and Red-winged Blackbird (*Agelaius phoeniceus*; Meyer et al. 2006). The addition of interior point counts significantly increased the abundance and richness of emergent marsh nesting obligates including the Sora, Least Bittern, American Bittern, Pied-billed Grebe, Virginia Rail, Swamp Sparrow (*Melospiza georgiana*), American Coot, Common Moorhen, and Marsh Wren (*Cistothorus palustris*; Meyer et al. 2006). Tozer et al. (2006) found that species richness was the same for point counts at the edge of large vegetation patches compared to the interior within large wetlands; however, their counts were conducted in wetlands with such low water levels that secretive species that depend on deep water, like bitterns and rails, were absent. Therefore, there still remains a need for studies into avian distribution patterns within wetlands and how these distributions affect survey results (Tozer et al. 2006).

The objectives of this paper are to 1) determine the effectiveness of call-broadcasts in detecting secretive wetland birds including the American Bittern, Least Bittern, King Rail, Yellow Rail, Virginia Rail, Sora, American Coot, Common Moorhen, and Pied-billed Grebe, 2) examine general and species-specific response patterns to a multi-species broadcast sequence, 3) determine the importance of intervening silent periods, and 4) determine the effect of survey location (interior versus edge) in detecting marsh birds and on the results of an Index of Biotic Integrity (the Index of Marsh Bird Community Integrity; IMBCI; DeLuca et al. 2004).

METHODS

Study sites

From 2006-2008, we conducted point counts in 26 wetlands of Lake Erie, Lake Ontario, and Georgian Bay (Fig. 1-1). These wetlands are primarily coastal marshes ranging in the degree of eutrophication and dominated by emergent vegetation. For the examination of survey location, we chose only wetlands with a large amount of interior habitat including Long Point, Turkey Point, Presqu'ile Provincial Park, Rondeau Provincial Park, Matchedash Bay, and Wye Marsh. The edge environment surrounding these large marshes was primarily forested consisting of provincial parks or undeveloped private land.

Influence of call-broadcasts

All point counts were sampled from a canoe between 5 May and 25 July each year from 2006 to 2008 and each count was recorded with a Marantz professional portable solid state digital recorder (Model PMD660) and an omni-directional microphone. Each count was conducted once during the season. All counts were conducted between sunrise and 4 h after sunrise, and no surveys were conducted in high winds > 20 km/h or during periods of rainfall. Point counts were 10 min in duration and a 25 m (2006 to 2007) or 50 m (2008) radius full circle was used.

The first sample point was located at least 25 m or 50 m from the shore at the emergent vegetation-water interface closest to where the canoe was launched. Once we reached the point count location we allowed one minute for the birds to settle before starting the point count. We recorded all birds seen and heard regardless of sex and counted all individuals which were landing, flushing, wading, perching, or calling within the point count area.

After the 10 min passive period, we broadcasted the songs of marsh birds including the American Coot, American Bittern, Least Bittern, Pied-billed Grebe, Sora, Virginia Rail, Common Moorhen, King Rail, and Yellow Rail in that order. Calls (70-85 dB 1 m from the source) were broadcast from speakers oriented directly into the patch of emergent vegetation at a height of 1 m above the water surface. In the broadcast sequence, each species' call varied in length (35 to 110 sec), but each species call was separated by a 30 sec pause. Call-broadcasts were played for a total of 14 min after the passive period and 2 min were left at the end of the call-broadcasts to listen for responses. Subsequent point counts were located by paddling further into the wetland, and all point counts were at least 200 m apart to ensure each individual was a new detection (Siegel et al. 2001). We conducted as many point counts at each site as was possible in the morning sampling period or until we surveyed the entire wetland.

Influence of broadcast composition

We analyzed the recordings and noted exactly when each bird called in response to the call-broadcasts. We compared if birds called more often during the silent period between species calls during the broadcast period, or actually during the species vocalizations of the broadcasts. We included only the initial detections of each individual and also noted whether birds were initially detected responding to conspecific or heterospecific playbacks.

Influence of survey location

The general survey protocol was identical to the examination of the influence of call-broadcasts except for the following modifications. We changed the shape of the point count to a 50 m radius semi-circle to exclude the edge environment when conducting edge counts. A 50 m radius semi-circular point count was also used at interior stations. Each point count was conducted twice throughout the breeding season between 8 May and 10 July, from 2007 to 2008, and the average of these two visits was used for the analysis. Each pair of interior and edge counts were surveyed on the same day and interior point counts were on average 501 ± 144 m (mean ± SD) directly into the centre of the marsh from the edge counts.

Vegetation surveys were conducted in conjunction with point counts and therefore each point was surveyed twice per year. We took the average between the two survey dates as our dependent variable for the vegetation analysis. We estimated the percent cover of emergent vegetation, floating vegetation, and open water within the 50 m radius semi-circle. Cattail species were not differentiated and therefore narrow-leaf (*Typha angustifolia*), broadleaf (*T. latifolia*), and hybrid species (*T.* X*glauca*) were grouped. Vegetation was called scrub if there was woody vegetation present in the marsh that was < 4 m in height. Floating vegetation included primarily fragrant water lily (*Nymphaea odorata*) and common yellow pond lily (*Nuphar variegate*), but if other floating species were found, they were included. Dominant emergent plants were identified and the height of the dominant vegetation species was estimated (Paracuellos and Telleria 2004).

Data analysis

All analyses were performed using Statistica 6.0 (StatSoft Inc. 2001). For the comparison of passive versus active surveys, we examined the effect on only secretive wetland birds and included all initial detections, visual and aural. American Coots and Common Moorhens were grouped together for this analysis because they were often difficult to distinguish aurally.

We used a repeated measures ANOVA with abundance or richness of secretive birds as the dependent variable, survey type (passive or active) as the repeated measure, and year as a categorical predictor. By looking at the effect of year we were essentially looking for a difference between 25 m and 50 m point counts because only 25 m point counts were used in 2006 and 2007, and 50 m point counts were used in 2008. We inspected the data for normality and used $\log_{10} + 1$ transformations to bring the data closer to normal.

For species-specific analyses, we conducted paired *t*-tests regardless of year effects to increase sample sizes (Bogner and Baldassarre 2002, Conway et al. 2004). Even though paired *t*-tests do not require normality and homogeneity of variances within groups, they do require that the difference between each paired datum be normally distributed. We were not successful in transforming the data for the Virginia Rail, and therefore used the Wilcoxon paired-sample test. The Sequential Bonferroni technique was not employed because it is considered to be overly conservative (Nakagawa 2004).

We used a χ^2 analysis to determine if secretive species were responding during the silent period between calls more often than would be expected by chance. Since silent periods occupied 32% of the time of the broadcast sequence, we would expect that 32% of the calls should occur during the silent periods. We also examined the number of responses to heterospecific and conspecific broadcasts for each secretive species. We calculated expected values based on the amount of time each species' call occupied in the broadcast sequence. We only performed species-specific analyses for the Common Moorhen and American Coot if they were confirmed visually after aural detection.

We looked for differences in the abundance and richness of generalist marsh-nesters and obligate marsh-nesters between interior and edge points (Table 1-1). Similar to the analysis of passive versus active surveys, we used a repeated measures ANOVA with abundance or richness of generalist or obligate marsh-nesters as the dependent variable, survey location (edge or interior) as the repeated measure, and year as a categorical predictor. For individual species analysis, we used paired *t*-tests and point count as the independent sample unit regardless of year effects to increase sample sizes.

We also calculated the Index of Marsh Bird Community Integrity (IMBCI) developed by DeLuca et al. (2004). Indices of biotic integrity are often used to determine the quality of a wetland or other area of interest (Niemi and McDonald 2004), and we compared these values between the edge and the interior of the wetland. The IMBCI uses species-specific attributes including migration distance, where it nests and feeds, and its North American breeding range to calculate a unique value for each species. A species producing a high score would be a Neotropical migrant, nest and feed only in wetlands, and have a limited breeding range in North America. A species producing a low score would be a resident species, nest outside the wetland, occasionally feed in wetlands, and would be widely distributed throughout most of North America. Scores for individual species are shown in Table 1-1 and are produced by simply adding each life history trait. Next, a total W_{IMBCI} value can be calculated for the wetland as:

$$W_{IMBCI} = \left[\left(\frac{\sum S_{IMBCI}}{S_N} \right) + MO_N \right] - 4$$ DeLuca et al. (2004)

Where S_{IMBCI} is each species' individual score, S_N is the total number of species, MO_N is the number of marsh obligate nesters detected. Four is subtracted to keep a scoring scale that starts at zero and is constant (DeLuca et al. 2004). We used a repeated-measures analysis of variance with the W_{IMBCI} score as the dependent variable, edge and interior as the repeated measure, and year as a categorical predictor. A Tukey's HSD test was used post hoc to identify differences in the W_{IMBCI} between survey locations used for the calculations (edge only, interior only, or edge and interior).

Repeated measures ANOVA was also used to determine if there was a difference in the percent cover of cattails, common reed (*Phragmites australis*), scrub, floating vegetation, open water, and dominant vegetation height between interior and edge sites. We used interior and edge as the repeated measure as each edge count was paired with an interior count, and year as a categorical predictor.

RESULTS

Influence of call-broadcasts

Between 2006 and 2008, we counted a total of 299 secretive wetland birds which were detected at 89 of 306 point counts (29%) using 25 m and 50 m full-circle radius point counts. We found no difference in the abundance ($F_{2,86}$ = 0.474, P = 0.624; Fig. 1-2a) or richness ($F_{2,86}$ = 0.256, P = 0.775; Fig. 1-2b) of marsh birds calling between passive and active point counts between years and there was no interactive effect (abundance: $F_{2,86} = 1.218$, $P = 0.301$; richness: $F_{2,86} = 0.919$, $P = 0.403$). Essentially, the same change in calling frequency between passive and active point counts was seen regardless of year.

Not only did we detect more secretive birds during the active broadcasting period than in the passive listening period ($F_{1,86} = 32.91$, $P < 0.0001$; Fig. 1-2a), a greater number of species in general responded during the active period than in the passive period ($F_{1,86} = 30.60$, $P < 0.0001$; Fig. 1-2b). Species-specific analysis showed that the Sora, Virginia Rail, and American Coot/Common Moorhen group were detected significantly more often during the active period than in the passive period, as was the Least Bittern although these differences were not statistically significant (Table 1-2). We did not detect the King Rail or Yellow Rail at any point counts and detected an insufficient number of American Bitterns for species-specific analysis.

Influence of broadcast composition

We detected significantly more initial calls during silent periods between broadcast vocalizations than expected by chance (42/78 calls), and the number of initial calls detected during broadcast vocalizations was lower than expected (36/78 calls; $\chi^2 = 17.01$, $P < 0.0001$). Species-specific response patterns to broadcasted calls showed that species occupying similar feeding guilds called territorially to each other during broadcasts (Table 1-3). For example, the Sora and Virginia Rail primarily vocalized to their own calls, the calls of each other, or those of other solitary rails. The American Coot and Common Moorhen called primarily to either their own call or the calls of each other. Sample sizes were small for the American Bittern and Least Bittern, but they tended to respond at the start of the broadcasts, to their own call, or shortly after their own call was played. The Sora, Virginia Rail, and Common Moorhen were more likely to vocalize to the calls of conspecifics than would be expected by chance (Table 1-4).

Influence of survey location

We found no inter-annual variation in the abundance and richness of generalist marsh-nesters at interior or edge point counts (abundance: $F_{1,4} = 0.166$, $P = 0.705$; richness: $F_{1,4} = 0.471$, $P = 0.530$; Fig. 1-3a) and there was no significant interaction between year and survey location (abundance: $F_{1,4} = 0.991$, $P = 0.376$; richness: $F_{1,4} = 1.60$, $P = 0.275$). However, we found significantly more generalist species at the edge of the wetland compared to the interior ($F_{1,4} = 25.6$, $P < 0.01$), and this trend was similar for the abundance of generalists ($F_{1,4} = 2.80$, $P = 0.17$).

We also found no inter-annual variation in the abundance and richness of obligate marsh-nesting birds at interior or edge point counts (abundance: $F_{1,4} = 1.232$, $P = 0.329$; richness: $F_{1,4} = 0.118$, $P = 0.749$; Fig. 1-3b), and no significant interaction between year and survey location (abundance: $F_{1,4} = 0.255$, $P = 0.640$; richness: $F_{1,4} = 0.400$, $P = 0.561$). There was a trend towards a greater number and species richness of obligate marsh-nesting birds at interior survey points compared to edge survey points, although neither of these were statistically significant ($F_{1,4}$ = 6.36, P = 0.065; $F_{1,4}$ = 6.40, P = 0.065, respectively).

The Least Bittern, Pied-billed Grebe, and Marsh Wren showed individual preferences for wetland interior as compared to wetland edge environments (Table 1-5). By contrast, the Yellow Warbler, Common Yellowthroat, and Swamp Sparrow showed preferences for wetland edge environments. Sample sizes for all other species were too small to include in the species-level analysis.

Since IMBCI scores for wetlands were based on individual species surveyed, we determined how these index scores would be affected by inclusion of data only from interior points, only from edge points, and from both interior and edge points. We found significant variation in IMBCI scores based on survey location ($F_{2,8}$ = 5.35, P = 0.034; Fig. 1-4), and there was no significant variation in IMBCI values between 2007 and 2008 ($F_{1,4}$ = 0.02, P = 0.902). We found that scores based on interior points were higher than those based on edge points alone (post hoc P = 0.093), and significantly higher when both interior and edge point counts were used (post hoc P = 0.035).

These differences associated with interior and edge points could not be attributed to significant differences in aquatic vegetation between survey locations (Table 1-6). We also found no inter-annual variation or interactive effects between survey location and year except for the mean percent cover of scrub habitat, which was significantly higher at wetlands surveyed in 2008 (10.62 ± 1.49%) than in 2007 (1.25 ± 1.49%; $F_{1,4}$ = 19.86, P = 0.011).

DISCUSSION

Marsh bird survey results are affected by many factors including 1) the use of call-broadcasts, 2) silent periods during broadcasts, 3) multi-species broadcast sequences, and 4) survey location. Results may be influenced by changing the likelihood of detecting secretive species, many of which are species of conservation concern and represent marshes of high integrity (DeLuca et al. 2004, COSEWIC 2000, 2001a, 2001b). Missing these species in field surveys could have grave consequences, especially for surveys used to assess the quality of a wetland prior to alteration or development. This study has identified several aspects of survey protocol that are important for accurate surveys and areas where marsh bird surveys could be improved.

Communication methods in the rail family appear to have evolved to meet the demands of the dense marsh habitat. These environments have favoured vocal signals as opposed to visual communication methods such as sexual dimorphism (Kaufmann 1971). Call-broadcasts should therefore increase the responsiveness of these secretive species, and this expectation is consistent with our findings. Similar to other call-broadcast studies (Allen et al. 2004, Conway and Gibbs 2005), we found that the Sora, Virginia Rail, Least Bittern, and Common Moorhen/American Coot group were more likely to be detected using broadcasts. Even though the rail family appear to be the most responsive to broadcasts, this technique may increase responsiveness of Least Bitterns as well, demonstrating the importance of the continued use of broadcasts in monitoring rail and bittern populations.

Our species-specific analysis of responses during the silent periods show the importance of incorporating silence during call-broadcast sequences. This is similar to Conway et al.'s (2004) study in which Black Rails were detected more often than expected during silent periods. Therefore, incorporating a silent listening period between each species call in the broadcast sequence, as well as at the end of the broadcasts, is important in facilitating detection.

Our broadcast composition analysis showed that many marsh bird species will respond territorially to conspecific calls but also to other species sharing the same niche within the marsh. For example, we found Soras and Virginia Rails to be most responsive to the calls of conspecifics (63% and 50% respectively), but they were also highly responsive to the calls of heterospecifics (37% and 50% respectively) such as the King Rail and Yellow Rail. These four species are solitary, and forage for seeds or probe the mud and vegetation for invertebrates and are likely to compete for resources (Meanley 1956, Kaufmann 1971, Stalheim 1974). Similarly, Common Moorhens tended to respond preferentially to the calls of conspecifics or those of the American Coot. Although these two species are also members of the rail family, they have evolved more duck-like habits, spending more time wading and foraging in the water (Fitzner et al. 1980, Steen et al. 2006), and are therefore not likely in competition for resources with solitary rails. We therefore stress the importance of including multi-species broadcasts to maximize detection rates.

While current monitoring programs strive to perform accurate marsh bird surveys, it is often difficult to balance volunteer availability and marsh accessibility with survey results. We have shown that some marsh birds show preferences for interior or edge environments, and therefore, survey results may vary within the same wetland depending on point count location. Edge avoidance in marshes may have evolved in some species for reasons similar to the well-documented forested systems where edge environments show increased nest predation rates (Robinson et al. 1995, Keyser 2002, Manolis et al. 2002, Albrecht 2004). These differences could be due to changes in predator communities at edges, such as those bordering urban areas (Haskell et al. 2001), or changes in water depth, which can affect the ability of mammalian predators to infiltrate the marsh (Jobin and Picman 1997). Water depth may also influence the tendency of the Least Bittern, Pied-billed Grebe, and Black Tern (*Chlidonias niger*) to occupy interior habitats as these species rely on areas with more open water or deeper water for breeding and foraging (Weller 1961, Steen et al. 2006).

Species-specific preferences for edge or interior environments can significantly influence the results of a wetland integrity index, with interior sites scoring better than edge sites. Indices of biotic integrity were developed to be used by other scientists and managers to determine the health of a wetland or other environment and to aid in management decisions. If survey methods do not accurately reflect the true marsh bird community, then decisions could be made that may jeopardize the future management of a marsh or other natural area. There remains a great need for further research on why wetland bird communities differ in their distribution and how these factors influence nest success and population productivity.

Based on the results of this research, we suggest that wetland bird monitoring programs should incorporate 1) call-broadcasts in conjunction with passive listening periods, 2) silent periods between species calls during the broadcasts and at the end of all broadcasts, 3) multi-species broadcasts, and 4) both interior and edge point counts when surveying large wetlands and calculating indices of biotic integrity. The results of this research have important applications for wetland bird monitoring programs, future scientific studies, and wetland conservation or restoration action plans using birds as indicators of wetland quality. While our study region included primarily Great Lakes coastal wetlands, we see this research having the potential to be applied to other wetland systems and should be tested and applied to other species of conservation concern to ensure our use of ecological indices is as intended.

MANAGEMENT IMPLICATIONS

The MMP has been used extensively throughout the Great Lakes Region and therefore I would recommend its use for tracking long-term population trends in southern Ontario wetlands with the following modifications. The MMP should be modified to include both shoreline and interior point counts instead of the option of performing one *or* the other. Interior point counts, especially in very large marshes, were more effective than edge point counts at detecting focal species, but edge point counts detected more generalist species. I suggest including both types of counts in order to get a good representation of the entire marsh bird community. The inclusion of both shoreline and interior point counts has obvious implications for scientific studies and site assessments prior to development. If the information from these programs is being used to describe wetland health, then using only shoreline counts is not an accurate representation of the bird community.

REFERENCES

Albrecht, T. 2004. Edge effect in wetland-arable land boundary determines nesting success of Scarlet Rosefinches (*Carpodacus erythrinus*) in the Czech Republic. Auk 121:361-371.

Allen, T., S. L. Finkbeiner, and D. H. Johnson. 2004. Comparison of detection rates of breeding marsh birds in passive and playback surveys at Lacreek National Wildlife Refuge, South Dakota. Waterbirds 27:277-281.

Bart, J. 2005. Monitoring the abundance of bird populations. Auk 122:15-25.

Bogner, H. E., and G. A. Baldassarre. 2002. The effectiveness of call-response surveys for detecting least bitterns. Journal of Wildlife Management 66:976-984.

Conway, C. J., C. Sulzman, and B. E. Raulston. 2004. Factors affecting detection probability of California black rails. Journal of Wildlife Management 68:360-370.

Conway, C. J., and J. P. Gibbs. 2005. Effectiveness of call-broadcast surveys for monitoring marsh birds. Auk 122:26-35.

Conway, C. J. 2005. Standardized North American Marsh Bird Monitoring Protocols. Wildlife Research Report #2005-04. U.S. Geological Survey, Arizona Cooperative Fish and Wildlife Research Unit, Tucson, Arizona, USA.

COSEWIC, 2000. COSEWIC assessment and update status report on the King Rail (*Rallus elegans*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +10pp.

COSEWIC, 2001a. COSEWIC assessment and status report on the Yellow Rail (*Coturnicops noveboracensis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 62 pp.

COSEWIC, 2001b. COSEWIC assessment and update status report on the Least Bittern (*Ixobrychus exilis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 10pp.

Crewe T. L., S. T. A. Timmermans, and K. E. Jones. 2006. The marsh monitoring program 1995 to 2004: a decade of marsh monitoring in the Great Lakes region. Published by Bird Studies Canada in cooperation with Environment Canada. 28pp.

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24:837-847.

Fitzner, R. E., E. T. Sipco, and R. G. Schreckhise. 1980. American Coot nesting and feeding habits in southeastern Washington. Northwest Science 54:

Gibbs, J. P., and S. M. Melvin. 1993. Call-response surveys for monitoring breeding waterbirds. Journal of Wildlife Management 57:27-34.

Haskell, D. G., A. M. Knupp, and M. C. Schneider. 2001. Nest predator abundance and urbanization. Pages 243-255 *in* Avian ecology and conservation in an urbanizing world (J. M. Marzluff, R. Bowman, and R. Donnelly, Eds.). Kluwar Academic Publishers, Norwell, Massachucetts, USA.

Hinojosa-Huerta, O., S. DeStefano, and W. W. Shaw. 2002. Evaluation of call-response surveys for monitoring breeding Yuma Clapper Rails (*Rallus longirostris yumanensis*). Journal of Field Ornithology 73:151-155.

Jobin, B., and J. Picman. 1997. Factors affecting predation on artificial nests in marshes. Journal of Wildlife Management 61:792-800.

Kaufmann, G. W. 1971. Behaviour and ecology of the Sora, *Porzana carolina*, and Virginia Rail, *Rallus limicola*. Ph.D. Dissertation, University of Minnesota, Minneapolis.

Keyser, A. J. 2002. Nest predation in fragmented forests: landscape matrix by distance from edge interactions. Wilson Journal of Ornithology 114:186-191.

Legare, M. L., W. R. Eddleman, P. A. Buckley, and C. Kelly. 1999. The effectiveness of tape playback in estimating black rail density. Journal of Wildlife Management 63:116-125.

Manolis, J. C., D. E. Andersen, and F. J. Cuthbert. 2002. Edge effect on nesting success of ground nesting birds near regenerating clearcuts in a forest-dominated landscape. Auk 119:955-970.

Meanley, B. 1956. Food habits of the King Rail in the Arkansas rice fields. Auk 73:252-258.

Meyer, S. W., J. W. Ingram, and G. P. Grabas. 2006. The marsh monitoring program: evaluating marsh bird survey protocol modifications to assess lake Ontario coastal wetlands at a site-level. Technical Report Series 465. Canadian Wildlife Service, Ontario Region, Ontario.

Nakagawa, S. 2004. A farewell to Bonferroni: the problems of low statistical power and publication bias. Behavioural Ecology 15:1044-1045.

Niemi, G. J., and M. E. McDonald. 2004. Application of ecological indicators. Annual Review of Ecology, Evolution and Systematics 35:89-111.

Paracuellos, M., and J. L. Telleria. 2004. Factors affecting the distribution of a waterbird community: the role of habitat configuration and bird abundance. Waterbirds 27:446-453.

Peterson, A. C., and G. J. Niemi. 2007. Evaluation of the Ohio Rapid Assessment Method for wetlands in the western Great Lakes: an analysis using bird communities. Journal of Great Lakes Research 33:280-291.

Ribic, C. A., S. Lewis, S. Melvin, J. Bart, and B. Peterjohn. 1999. Proceedings of the marsh bird monitoring workshop. Region 3 Administrative Report, U.S. Fish and Wildlife Service, Fort Snelling, Minnesota, USA.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Ruth, J. M., D. R. Petit, J. R. Sauer, M. D. Samuel, F. A. Johnson, M. D. Fornwall, C. E. Korschgen, and J. P. Bennett. 2003. Science for avian conservation: priorities for the new millennium 120:204-211.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Siegel, R. B., D. F. Desante, and M. P. Nott. 2001. Using point counts to establish conservation priorities: how many visits are optimal? Journal of Field Ornithology 72:228-235.

Stalheim, P. S. 1974. Behavior and ecology of the Yellow Rail (*Coturnicops noveboracensis*). Master's thesis, University of Minnesota, Minneapolis.

StatSoft, Inc. (2001). STATISTICA (data analysis software system), version 6. www.statsoft.com.

Steen, D. A., J. P. Gibbs, and S. T. A. Timmermans. 2006. Assessing the sensitivity of wetland bird communities to hydrologic change in the eastern Great Lakes region. Wetlands 26:605-611.

Swift, B. L., S. R. Orman, and J. W. Ozard. 1988. Response of Least Bitterns to tape-recorded calls. Wilson Bulletin 100:496-499.

Tozer, D. C., K. F. Abraham, and E. Nol. 2006. Improving the accuracy of counts of wetland breeding birds at the point scale. Wetlands 26:518-527.

Weller, M. W. 1961. Breeding biology of the Least Bittern. Wilson Bulletin 73:11-35.

Table 1-1. Individual species scores for calculation of the Index of Marsh Bird Community Integrity (IMBCI). S_{IMBCI} represents the score for each species. Each category ranges from one to four with one representing marsh-feeding generalists, non-marsh nesters, resident species, and those distributed throughout North America. Species with a category score of four are marsh obligates, Neotropical migrants, and have a distribution limited within North America.

Common name	Scientific name	Foraging habitat	Nesting substrate	Migratory status	Breeding range	S_{IMBCI}
American Goldfinch	*Carduelis tristis*	1	1	1	1	4
Mourning Dove	*Zenaida macroura*	1	1	1	1	4
European Starling	*Sturnus vulgaris*	1	1	1	1	4
American Robin	*Turdus migratorius*	1	1	1	1	4
Northern Cardinal	*Cardinalis cardinalis*	1	1	1	1	4
American Crow	*Corvus brachyrhynchos*	1	1	1	1	4
Herring Gull	*Larus argentatus*	1	1	1	1	4
Ring-billed Gull	*Larus delawarensis*	1	1	1	1	4
Gull spp.	*Larus* spp.	1	1	1	1	4
Black-capped Chickadee	*Poecile atricapillus*	1	1	1	1	4
Cedar Waxwing	*Bombycilla cedrorum*	1	1	1	1	4
Red-tailed Hawk	*Buteo jamaicensis*	1	1	1	1	4
Mute Swan	*Cygnus olor*	1	2.5	1	1	5.5
Canada Goose[a]	*Branta Canadensis*	1	2.5	1	1	5.5
Mallard	*Anas platyrhynchos*	2.5	1	1	1	5.5
Wood Duck[a]	*Aix sponsa*	2.5	1	1	1	5.5
Duck spp.	Family: Anatidae	2.5	1	1	1	5.5
Song Sparrow[a]	*Melospiza melodia*	1	2.5	1	1	5.5

Yellow-rumped Warbler	*Dendroica coronata*
Common Grackle[a]	*Quiscalus quiscula*
Red-winged Blackbird[a]	*Agelaius phoeniceus*
Tree Swallow	*Tachycineta bicolour*
Barn Swallow	*Hirundo rustica*
Purple Martin	*Progne subis*
Bank Swallow	*Riparia riparia*
Swallow spp.	Family: Hirundinidae
Caspian Tern	*Sterna caspia*
Sedge Wren[a]	*Cistothorus platensis*
Eastern Kingbird	*Tyrannus tyrannus*
Common Loon	*Gavia immer*
Willow Flycatcher	*Empidonax traillii*
Brown-headed Cowbird	*Molothrus ater*
Yellow Warbler[a]	*Dendroica petechia*
Veery	*Catharus fuscescens*
Alder Flycatcher	*Empidonax alnorum*
Trumpeter Swan[a]	*Cygnus buccinator*
Common Moorhen[b,c]	*Gallinula chloropus*
Common Yellowthroat[a]	*Geothlypis trichas*
Gray Catbird	*Dumetella carolinensis*
Osprey	*Pandion haliaetus*
Wilson's Snipe[b]	*Gallinago delicate*
Sandhill Crane[a]	*Grus Canadensis*
CommonMoorhen/ American Coot[b,c]	*Gallinula chloropus/ Fulica Americana*
Common Tern	*Sterna hirundo*
Swamp Sparrow[b]	*Melospiza Georgiana*

1	1	2.5	1	5.5
1	2.5	1	2	6.5
1	2.5	2.5	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	2.5	2.5	1	7
1	1	4	1	7
1	2.5	2.5	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	2	8
1	1	4	2	8
2.5	4	2	1	8
2.5	2.5	2.5	1	8.5
1	2.5	4	1	8.5
1	2.5	4	1	8.5
1	2.5	4	1	8.5
2.5	4	1	1	8.5
2.5	2.5	2.5	1	8.5
2.5	3.25	2.5	1	9.25
1	2.5	4	2	9.5
2.5	4	1	2	9.5

Great-blue Heron[a]	*Ardea herodias*	2.5	2.5	4	1	10
American Coot [b,c]	*Fulica Americana*	2.5	4	2.5	1	10
American Bittern [b,c]	*Botaurus lentiginosus*	2.5	4	4	1	11.5
Marsh Wren[b]	*Cistothorus palustris*	4	4	4	1	13
Black Tern[b]	*Chlidonias niger*	4	4	4	1	13
Sora[b,c]	*Porzana Carolina*	4	4	4	1	13
Virginia Rail[b,c]	*Rallus limicola*	4	4	4	1	13
Least Bittern[b,c]	*Ixobrychus exilis*	4	4	4	1	13
Pied-billed Grebe[b,c]	*Podilymbus podiceps*	4	4	4	1	13

[a]Marsh-nesting generalists, [b]marsh-nesting obligates, [c]secretive species.

Table 1-2. The effect of call-broadcasts in detecting specific secretive marsh bird species during point counts. Shown are the mean, standard error, paired *t*-test or Wilcoxon paired-sample test results (*Z*), *P*-values, and sample sizes for paired comparisons of each species.

Species	Passive	Active	Test statistic	*P*	*N*
Sora	0.471 ± 0.15	1.06 ± 0.16	$t = 2.42$	0.028	17
Virginia Rail	0.240 ± 0.07	1.40 ± 0.09	$Z = 5.84$	<0.0001	50
Least Bittern	0.455 ± 0.16	0.909 ± 0.21	$t = 1.46$	0.176	11
Pied-billed Grebe	1.38 ± 0.53	0.625 ± 0.18	$t = 1.16$	0.285	8
American Coot/ Common Moorhen	1.12 ± 0.22	1.62 ± 0.24	$t = 2.12$	0.042	34

Table 1-3. Number of initial responses by secretive wetland birds to call-broadcasts of different species. All surveys conducted in 2008 at coastal marshes of southern Ontario.

Species of playback call (in order of broadcast)	Number of responses by species									
	American Coot	American Bittern	Least Bittern	Pied-billed Grebe	Sora	Virginia Rail	Common Moorhen	King Rail	Yellow Rail	Total
American Coot	0	2	1	1	1	2	3	0	0	10
American Bittern	0	1	0	0	0	0	1	0	0	2
Least Bittern	0	0	0	0	0	1	1	0	0	2
Pied-billed Grebe	0	0	3	0	0	1	0	0	0	4
Sora	0	0	0	0	10	10	0	0	0	20
Virginia Rail	0	0	0	0	3	19	1	0	0	23
Common Moorhen	0	0	0	1	1	0	4	0	0	6
King Rail	0	0	0	0	1	2	0	0	0	3
Yellow Rail	0	0	0	0	0	3	0	0	0	3
Silence after all calls	0	0	0	0	0	3	1	0	0	4
Total	0	3	4	2	16	41	11	0	0	77

Table 1-4. Number of initial responses by each species to conspecific calls or heterospecific calls during the call-broadcast sequence.

Species	Number of responses (row %)				χ^2	*P*
	During conspecific calls		During heterospecific calls			
	Observed	Expected	Observed	Expected		
American Bittern	1 (33)	0.3 (10)	2 (66)	2.7 (90)	1.81	0.178
Least Bittern	0 (0)	0.3 (7)	4 (100)	3.7 (93)	0.324	0.569
Pied-billed Grebe	0 (0)	0.2 (8)	2 (100)	1.8 (92)	0.222	0.637
Sora	10 (63)	3.0 (19)	6 (37)	13.0 (81)	20.10	<0.0001
Virginia Rail	19 (50)	6.5 (17)	19 (50)	31.5 (83)	29.00	<0.0001
Common Moorhen	4 (40)	1.4 (14)	6 (60)	8.6 (86)	5.62	0.018

Table 1-5. Species-specific preferences between edge and interior habitats within coastal wetlands of southern Ontario. Shown are the mean number of birds detected at each point count ± standard errors, *t*-values from paired *t*-tests, *P*-value, and sample size represented as the number of paired interior/edge points.

Marsh-nesting guild	Species	Edge	Interior	*t*	*P*	*n*
Generalist	Common Yellowthroat	1.29 ± 0.21	0.750 ± 0.20	1.95	0.077	12
	Red-winged Blackbird	7.29 ± 1.1	6.83 ± 1.2	0.301	0.770	12
	Song Sparrow	0.955 ± 0.16	0.546 ± 0.14	1.53	0.158	11
	Yellow Warbler	1.36 ± 0.20	0.136 ± 0.07	6.29	< 0.0001	11
Obligate	Least Bittern	0.00 ± 0.00	0.583 ± 0.08	7.00	< 0.001	6
	American Bittern	0.333 ± 0.11	0.500 ± 0.13	1.00	0.363	6
	Pied-billed Grebe	0.00 ± 0.00	1.38 ± 0.43	3.22	0.049	4
	Black Tern	0.25 ± 0.13	1.25 ± 0.66	1.51	0.229	4
	Swamp Sparrow	2.38 ± 0.18	1.5 ± 0.28	2.68	0.021	12
	Virginia Rail	0.357 ± 0.21	0.571 ± 0.20	0.570	0.589	7
	Common Moorhen/ American Coot	0.200 ± 0.12	1.30 ± 0.82	1.26	0.276	5
	Marsh Wren	1.29 ± 0.40	3.21 ± 0.58	3.12	< 0.01	12

Table 1-6. A comparison of wetland vegetation composition at edge and interior point counts for six marshes in Ontario surveyed in 2007 and 2008. F-values represent the effect of the repeated measure (interior/edge).

	Edge	Interior			
Vegetation variable	Mean ± SE	Mean ± SE	$F_{1,4}$	P	N
% Cattails	62.5 ± 7.2	69.2 ± 4.9	0.531	0.507	6
% *Phragmites*	7.71 ± 4.5	3.75 ± 2.6	2.777	0.171	6
% Scrub	9.58 ± 2.8	2.29 ± 2.0	2.772	0.171	6
% Floating	4.88 ± 4.3	9.38 ± 4.9	0.503	0.518	6
% Open water	10.6 ± 7.1	12.5 ± 1.6	0.052	0.831	6
Average vegetation height (m)	1.81 ± 0.17	1.82 ± 0.17	0.006	0.941	6

Figure 1-1. Wetland study sites used to survey marsh birds in southern Ontario, Canada between 2006 and 2008. Sites are marked for whether they were used for the analysis of survey location (interior versus edge), broadcast analysis, or both.

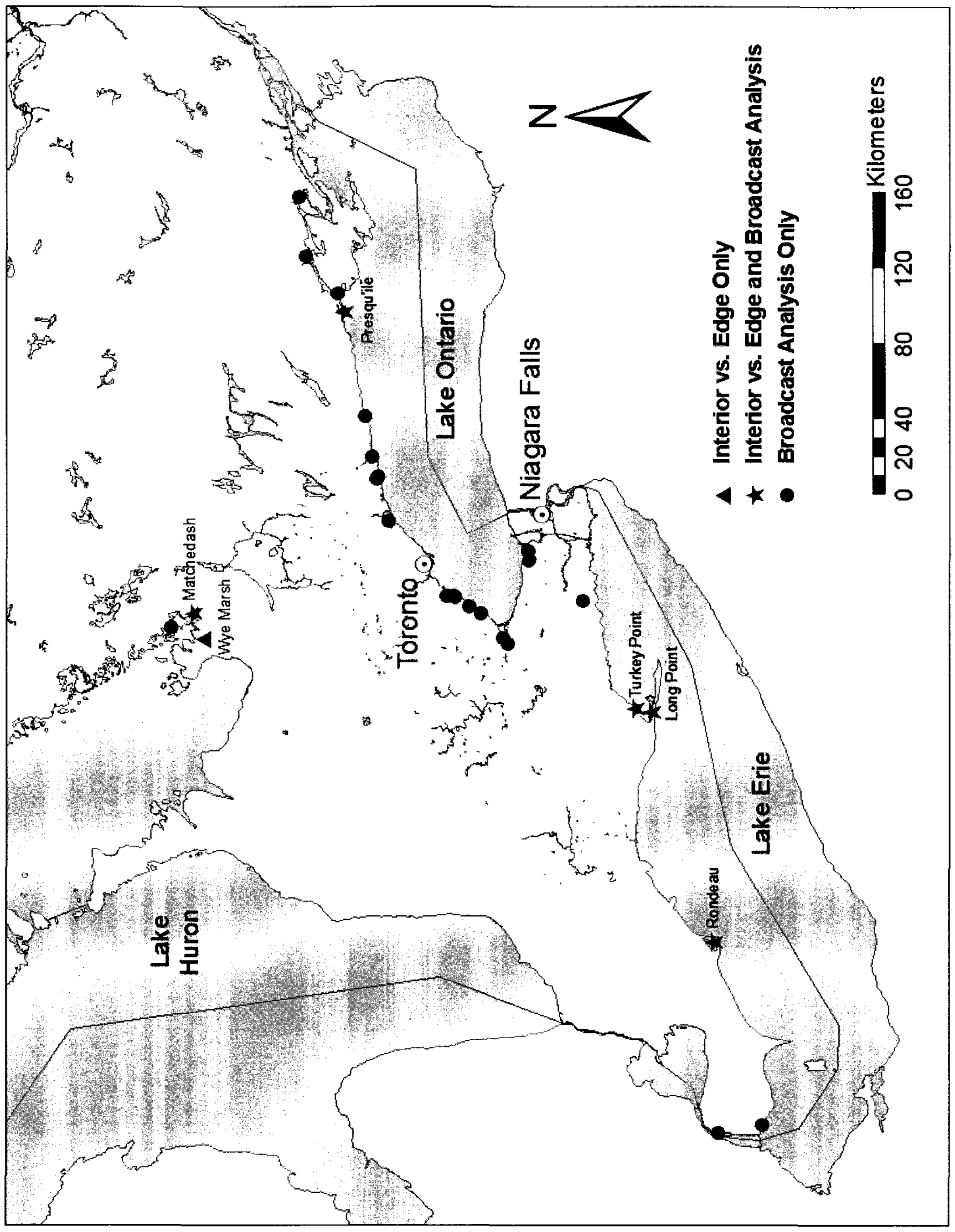
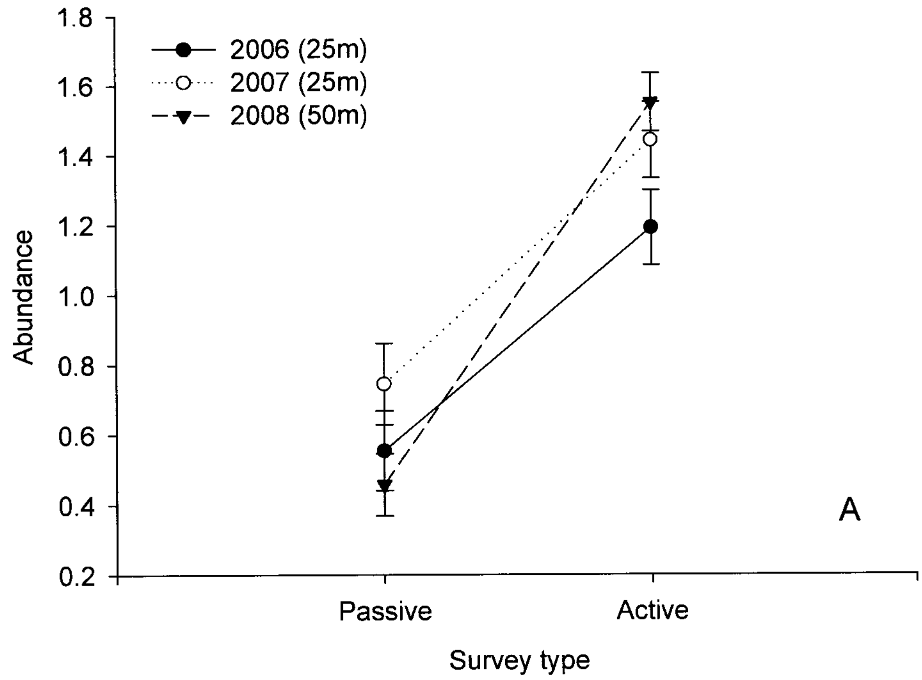

Lake Huron
Lake Ontario
Lake Erie
Toronto
Niagara Falls
Matchedash
Wye Marsh
Presqu'ile
Turkey Point
Long Point
Rondeau
N
Interior vs. Edge Only
Interior vs. Edge and Broadcast Analysis
Broadcast Analysis Only
0 20 40 80 120 160
Kilometers

Figure 1-2. The effect of call-broadcasts on detecting secretive marsh birds during point counts represented as a) abundance and b) species richness. Shown are means ± SE.


1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Abundance
2006 (25m)
2007 (25m)
2008 (50m)
A
Passive
Active
Survey type

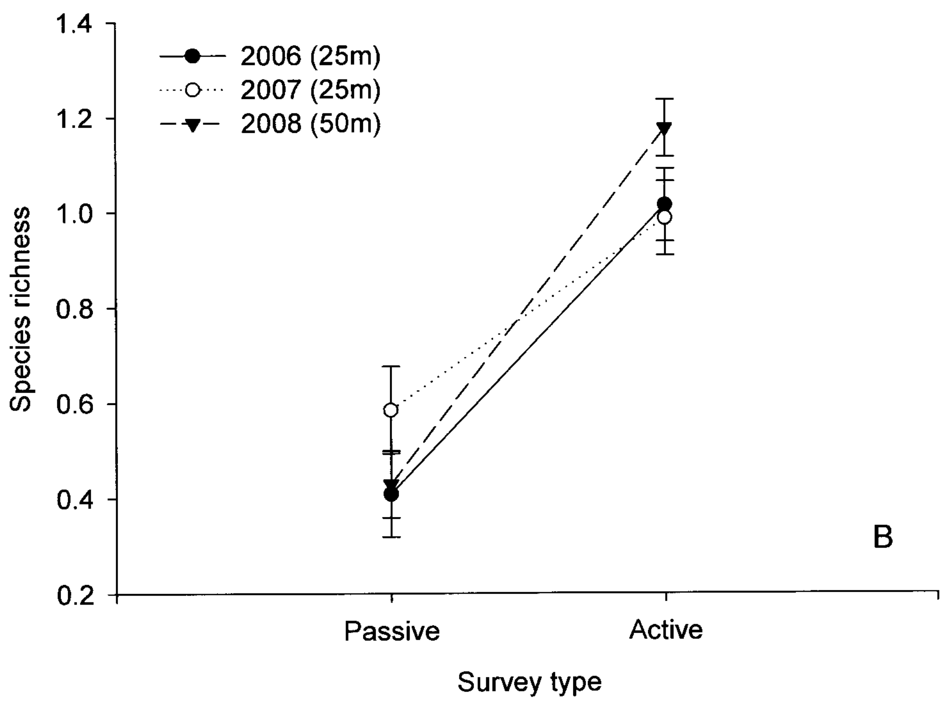
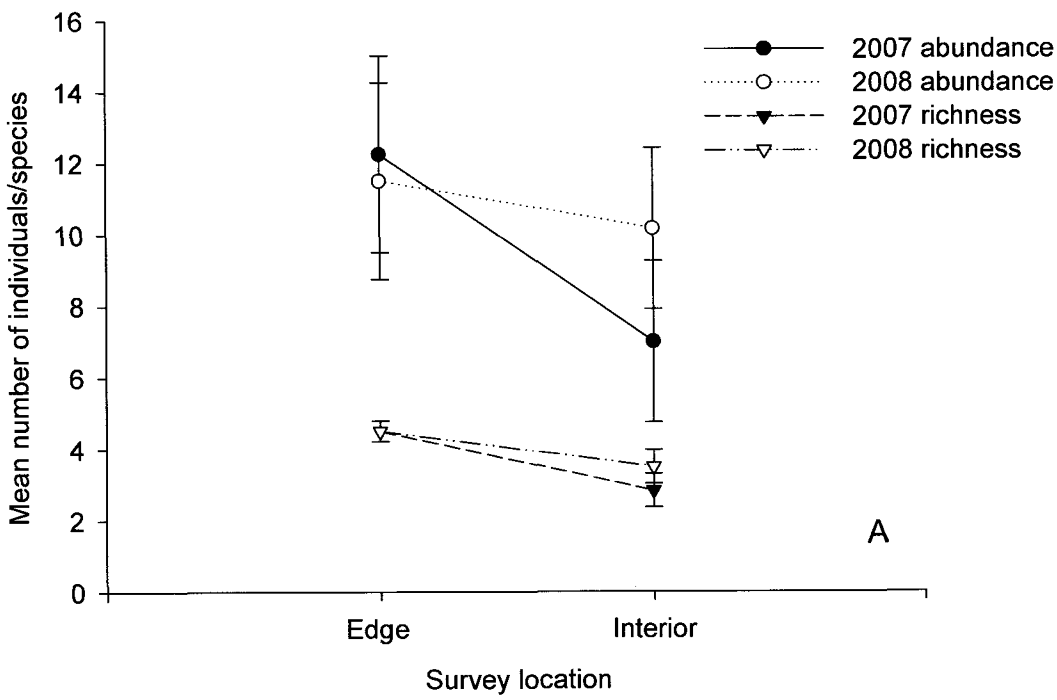

1.4
1.2
1.0
0.8
0.6
0.4
0.2
Species richness
2006 (25m)
2007 (25m)
2008 (50m)
B
Passive
Active
Survey type

Figure 1-3. The effect of survey location on detecting marsh-nesting a) generalists, or b) obligates. Edge point counts were conducted from the shoreline while interior point counts were taken on average 501 ± 144 m (mean ± SD) directly into the centre of the marsh. Shown are means ± standard errors.


16
14
12
10
8
6
4
2
0
Mean number of individuals/species
2007 abundance
2008 abundance
2007 richness
2008 richness
A
Edge
Interior
Survey location

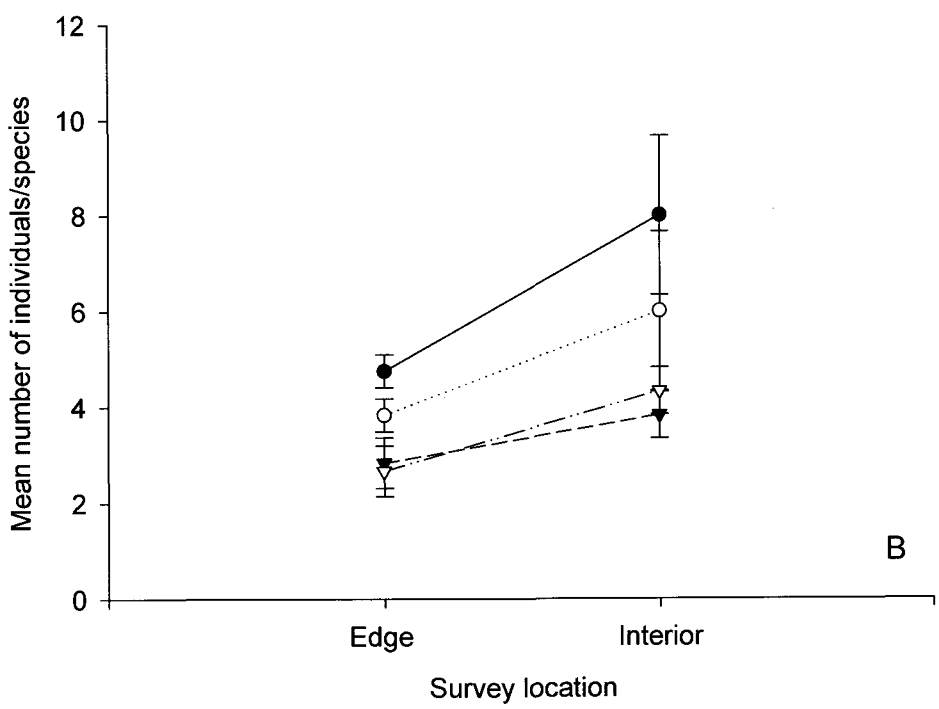
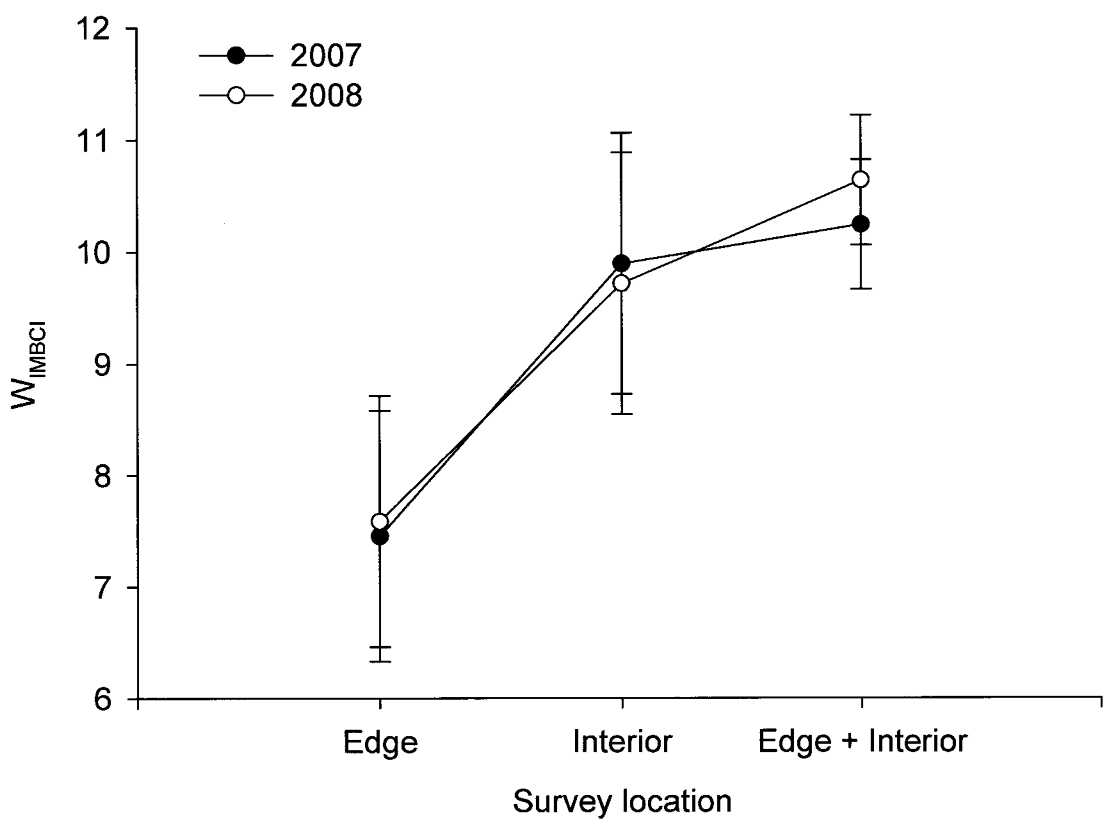

12
10
8
6
4
2
0
Mean number of individuals/species
B
Edge
Interior
Survey location

Figure 1-4. Comparison of Index of Marsh Bird Community Integrity (W_{IMBCI}) values calculated with only edge points, only interior points, or both interior and edge points sampled in 2007 and 2008. Shown are means ± SE.


12
11
10
9
8
7
6
2007
2008
W_{IMBCI}
Edge
Interior
Edge + Interior
Survey location

CHAPTER 2:

IMPLICATIONS OF THE SPECIES-AREA RELATIONSHIP ON SAMPLING EFFORT AND CONSERVATION OF MARSH BIRDS IN SOUTHERN ONTARIO

Lyndsay A. Smith and Patricia Chow-Fraser

ABSTRACT

Coastal wetlands of southern Ontario are highly fragmented and exist as islands within a primarily urbanized and agriculturally disturbed matrix. They are the last refuges for migratory birds as well as wetland-dependent breeding birds. Given the large variation in size of remaining fragments, it is important to determine if species-area relationships exist for wetland birds, so that sampling effort can be adjusted for different sizes of wetlands and to develop appropriate size criteria for conservation. We surveyed marsh birds in 21 coastal wetlands of southern Ontario and found a positive species-area relationship, and a positive relationship between an index of biotic integrity and wetland area. Only the Marsh Wren, Swamp Sparrow, and all obligate species combined showed area-sensitive distribution patterns, and no other species individually demonstrated this relationship. The number of point counts required to reveal 80% or 90% of the cumulative species richness for a given wetland varied directly with its size, indicating that sampling effort must be increased to avoid underestimating species richness in large wetlands. We also recommend conservation of all coastal wetlands, regardless of size, because both small and large marshes provide habitat for wetland-dependent bird species.

INTRODUCTION

Species-area relationships (SARs) are considered one of the few fundamental laws of ecology (Rosenzweig 1999). First identified empirically in plant communities (Jaccard 1912, Arrhenius 1921), this relationship has been extended to many organisms ranging from terrestrial mammals (Newmark 1986) to bacteria (Green et al. 2004, Horner-Devine et al. 2004). While many mathematical functions have been proposed to explain this relationship (Tjørve 2003, Martin and Goldenfeld 2006), the most widely accepted equation is the power curve $S = cA^z$ where S is the number of species, A is the area, and c and z are constants. It has been suggested that these constants have biological significance for both the organism and the environment they occupy (Martin 1981).

SARs are important tools for setting conservation priorities, as these curves may be used to predict the amount of area needed to protect a certain level of biodiversity or predict extinction rates (Desmet and Cowling 2004, Thomas et al. 2004). Coastal wetlands have been altered at a high rate globally (Vitousek et al. 1997), and specifically those in southern Ontario have been lost at an alarming rate over the past century with only 10% remaining in some areas (Snell 1987). The remaining coastal wetlands are highly fragmented creating islands within a primarily anthropogenic matrix. These wetlands perform important ecosystem functions such as controlling sediment and water quality, providing erosion protection, and flood attenuation. In addition to these ecosystem services, coastal wetlands provide important stopover sites for migratory birds, as well as breeding grounds for many wetland-dependent species. Identifying SARs in this region is extremely important to determine conservation priorities as the human population in this region continues to grow (Cohen 2003).

The North American Breeding Bird Survey shows continental-scale declines for wetland obligates including the King Rail (*Rallus elegans*), American Bittern (*Botarus lentiginosis*), Black Tern (*Chlidonias niger*), American Coot (*Fulica americana*), and Common Moorhen (*Gallinula chloropus*) between 1966 and 2007 (Sauer et al. 2008). The King Rail, Yellow Rail (*Coturnicops noveboracensis*), and Least Bittern (*Ixobrychus exilis*) have been designated as species at risk and are listed federally in Canada as endangered, of special concern, and threatened, respectively (COSEWIC 2000, 2001a, 2001b). The Swamp Sparrow (*Melospiza georgiana*), Marsh Wren (*Cistothorus palustris*), Virginia Rail (*R. limicola*), and Pied-billed Grebe (*Podilymbus podiceps*) show significant increases, while the Least Bittern and Sora (*Porzana carolina*) populations are stable (Sauer et al. 2008).

SARs for birds have been established on continental and global scales (Preston 1960), and for specific environments such as forest fragments (Blake and Karr 1987) and islands (Ricklefs and Lovette 1999). The significant positive relationship between species richness and wetland area has also been demonstrated for wetland birds in wet meadow environments (Riffell et al. 2001), and in marshes (Tyser 1983, Hoyer and Canfield 1994, Findlay and Houlahan

1997, Paracuellos and Telleria 2004, Benassi et al. 2007). SAR's have also been extended to Indices of Biotic Integrity, which are often used to indicate the quality of a wetland or other area of interest (DeLuca et al. 2004, Niemi and McDonald 2004). DeLuca et al. (2004) developed the Index of Marsh Bird Community Integrity (IMBCI) based on several life-history traits, including the migratory strategy of the species as well as its dependence on wetland habitat. They were one of the first to demonstrate the integrity-area relationship (IAR), showing a significant positive correlation between the IMBCI and wetland area for birds in Chesapeake Bay, USA.

Wetland area is not only useful as a predictor of species richness but may also be used to determine species-specific area-sensitivity (Brown and Dinsmore 1986, Naugle et al. 1999, Riffell et al. 2001). Several species of wetland-dependent birds, including the Swamp Sparrow, Pied-billed Grebe, and Black Tern, have been identified as area-dependent because they show a significant positive relationship between marsh size and frequency of occurrence (Brown and Dinsmore 1986, Naugle et al. 1999). By comparison, both the Virginia Rail and Sora exhibited area-independent trends (Brown and Dinsmore 1986). The American Coot, Marsh Wren, Least Bittern and American Bittern were identified as possibly area-dependent because they were associated with a positive though not statistically significant trend (Brown and Dinsmore 1986). However, this contrasts the finding of Tyser (1983) who found these to be the two most area-sensitive species. Such discrepancies point to the need for further studies on species-specific area-sensitivities (Riffell et al. 2001).

We found no evidence in the literature of SARs being used within wetlands to determine sampling effort requirements even though this was one of the original reasons for their development (Cain 1938, Connor and McCoy 1979). Hanowski et al. (2007) studied wetlands of varying sizes to determine optimal sampling effort for wetland bird monitoring programs. They suggested that three samples per wetland were sufficient to obtain precise estimates of species richness for wetlands of any size. The objectives of this study are three-fold. First, we determine if a SAR exists for wetland birds of southern Ontario. Secondly, we investigate species-specific area-sensitivities for wetland birds, and thirdly, we provide guidance on how SARs can be used to determine optimal sampling effort to accurately survey marsh birds in wetlands of different sizes.

METHODS

Study sites

We surveyed 21 coastal wetlands throughout southern Ontario between 2006 and 2008 ranging in wetland size (Table 2-1, Figure 2-1). In 2006 and 2007 we surveyed wetlands to identify a SAR for fragmented wetlands in the anthropogenic matrix of southern Ontario. In 2008, we selected a subset of wetlands to examine within wetland species-area relationships or “census patches” (Tjørve 2003), to use these relationships to predict effective sample sizes for surveying marsh birds. These wetlands are coastal marshes dominated by emergent vegetation and ranging in the degree of eutrophication. The landscape of southern Ontario is dominated by agricultural and urban areas with a highly fragmented forest cover of only 11% (OMNR 2000).

We measured wetland size as the amount of aquatic vegetation (excluding open water) using the Southern Ontario Land Resources Information System (SOLRIS; OMNR 2008) and ArcMap 9.2 (ESRI Inc. 2006). SOLRIS is a geographic information system that has delineated southern Ontario into digital polygons of varying land uses and types of natural areas using a combination of topographic maps, aerial photos, and satellite imagery from 2000-2002. We updated wetland polygons to reflect the most current size using Google Earth images captured between 2004 and 2007 (Google Earth 2007).

Bird surveys

To meet our first and second objectives, we conducted point counts from a canoe between 1 May and 12 July, 2006 and 2007. Each count was conducted between sunrise and four hours after sunrise, no surveys were conducted in high winds >20 km/h or during periods of rainfall, and each point was surveyed twice throughout the season. Point counts were 10 min in length and a 25 m radius full circle was used.

The first sample point was located at least 25 m from the shore at the emergent vegetation-water interface closest to where the canoe was launched.

Once we reached the point count location we allowed one minute for the birds to settle before starting the point count. We recorded all birds seen and heard regardless of sex and counted all individuals which were landing, flushing, wading, perching, or calling within the point count area.

After the 10 min passive period, we broadcasted the songs of secretive marsh birds including the American Coot, American Bittern, Least Bittern, Pied-billed Grebe, Sora, Virginia Rail, Common Moorhen, King Rail, and Yellow Rail in that order. Calls (70-85 dB 1 m from the source) were broadcast from speakers oriented directly into the patch of emergent vegetation at a height of 1 m above the water surface. In the broadcast sequence, each species' call varied in length (35 to 110 sec), but each species call was separated by a 30 sec pause. Call-broadcasts were played for a total of 14 min after the passive period and 2 min were left at the end of the call-broadcasts for us to listen for responses. Subsequent point counts were located by paddling further into the wetland and were at least 200 m apart to ensure each individual was a new detection. We conducted more point counts in larger wetlands to maintain proportionally accurate effort with increasing size.

To meet our third objective, the general survey protocol remained the same except for the following modifications. We chose a subset of 11 marshes and changed the point count radius to 50 m to survey each marsh in less time. We conducted only one survey at each point count between 12 May and 9 July in only 2008. To thoroughly sample large marshes, up to 15 point counts were needed, so we often needed multiple days to cover the full area (up to 3 days). We wanted to ensure that the species composition was not changing between days, so prior to initiating this objective, we chose one wetland (Cootes Paradise) to examine temporal changes in composition. Between 5 May and 8 May 2008, we surveyed three point counts per day, and looked for changes in species richness, abundance, and the IMBCI.

Statistical analysis

All analyses were performed using Statistica 6.0 (StatSoft Inc. 2001). For the analysis of SARs for southern Ontario marshes at the landscape scale, we used simple linear regression after $\log_{10}$ transformation of all variables. This produced an alternative, yet commonly used, form of the SAR: $\log S = z \log A + \log c$ also known as the Arrhenius equation (Preston 1960). In this form, z represents the slope of the relationship and log c describes the intercept. For all regression analyses, we report adjusted R^2 values and corresponding P-values.

We looked for a relationship between wetland area and species richness, abundance, and the IMBCI. For species richness we used overall site presence/absence, and for abundance, we first took the average of the seasonally repeated point counts then added these values for all the point counts at each marsh. The IMBCI uses species-specific attributes including migration distance, where it nests and feeds, and its North American breeding range to assign a unique value for each species. A species associated with a high score would be a

Neotropical migrant that nests and feeds only in wetlands, and has a limited breeding range in North America. A species associated with a low score would be a resident species that nests outside the wetland, occasionally feeds in wetlands, and is widely distributed throughout most of North America. Scores for individual species are shown in Table 2-2 and are produced by simply adding each life history trait. Next, a total W_{IMBCI} value can be calculated for the wetland as:

$$W_{IMBCI} = \left[\left(\frac{\sum S_{IMBCI}}{S_N} \right) + MO_N \right] - 4$$ DeLuca et al. (2004)

Where S_{IMBCI} is each species' individual score, S_N is the total number of species, MO_N is the number of marsh obligate nesters detected. Four is subtracted to keep a scoring scale that starts at zero and is constant (DeLuca et al. 2004).

We used logistic regression to examine species-specific area-sensitivity. Species were marked as either present (1) or absent (0) at a wetland, and our continuous predictor was wetland size which we $\log_{10}$-transformed. Logistic regression yields a χ^2 statistic where significance indicates that the probability of finding a certain species is dependent on the size of the wetland (Hosmer and Lemeshow 1989).

For the analysis of sampling effort, we first used a repeated measures analysis of variance to determine if surveys could be conducted over four consecutive days without any change in richness, abundance, or the IMBCI. We tested the data a priori to ensure they met the assumption of sphericity using the Mauchley sphericity test. Each of the 11 wetlands was surveyed individually with more point counts conducted at larger marshes. Within each wetland we determined the logarithmic relationship between the number of point counts and cumulative species richness. Using this function, we calculated the number of point counts needed to obtain 80% and 90% of the cumulative species richness at each of the 11 marshes. We then took these values and regressed them against the wetland size of each marsh to create two species-area functions. By surveying the entire marsh, we assumed that the cumulative species richness after the last point count represented all the species.

RESULTS

Species-area relationships

Species richness increased significantly with wetland area ($R^2 = 0.427$, $P < 0.01$) (Figure 2-2a) and this trend was also seen for abundance ($R^2 = 0.710$, $P < 0.0001$) (Figure 2-2b). We also found a significant relationship between the W_{IMBCI} and wetland size, indicating larger wetlands hold high integrity values ($R^2 = 0.204$, $P < 0.05$) (Figure 2-2c). Based on the log-log relationships we obtained, we found z-values of 0.076 for species richness and 0.240 for abundance.

Area-sensitivity

Both the Swamp Sparrow and Marsh Wren were significantly more likely to be found in large wetlands than in small wetlands (Table 2-3). This area-sensitivity could not be demonstrated for any other species. However, this should be interpreted cautiously because of low detection rates for several species. The Black Tern and American Bittern were only found in a single wetland each, corresponding to the third (483 ha) and fourth (393 ha) largest wetland, respectively. All obligates combined also produced a positive relationship as marsh obligate nesters were absent in smaller wetlands (Oakville; 3.49 ha, Bronte Creek; 7.18 ha, and Van Wagner's Pond; 12.60 ha).

Sampling effort

We found no significant day-to-day variation in the richness ($F_{3, 6} = 1.277$, $P = 0.364$) (Figure 2-3a), abundance ($F_{3, 6} = 1.278$, $P = 0.364$) (Figure 2-3b), or W_{IMBCI} ($F_{3, 6} = 1.141$, $P = 0.406$) (Figure 2-3c) values for wetland birds at Cootes Paradise. Therefore, surveying a wetland over four consecutive days (to survey the entire wetland) did not significantly affect the richness, abundance, or integrity values.

We used the logarithmic function to fit data for each completely sampled wetland (those sampled in 2008) (Table 2-4). We have included a sample graph of Second Marsh to explain the calculation of the number of point counts needed to sample 80% or 90% of the species (Figure 2-4). Based on these results, we have created two functions that can be used as an aid to determine the optimal number of point counts to accurately survey wetlands of different sizes (Figure 2-5). For example, one would need to conduct 9 point counts using 50-m radius circular plots to survey 90% of the wetland birds in a marsh of 50 ha.

DISCUSSION

We found a significant species-area relationship for wetland birds in southern Ontario, and this is consistent with many published studies for birds in other habitats. We obtained a z-value of 0.076 for the logarea/logrichness relationship that is lower than published values in other studies of wetland birds: 0.23 (Brown and Dinsmore 1986), 0.24 (Findlay and Houlahan 1997), and 0.26 (Benassi et al. 2007). It has been suggested that these values are meaningless and merely a coincidence, but the literature shows more log/log z-values falling between 0.20 and 0.40 for all species than would be expected by chance (Connor and McCoy 1979). Even though many studies have shown similar results, there remain inconsistencies among studies (including this one) and caution is needed for the interpretation of z-values (Martin 1981). Studies only including a very small range of habitat sizes may yield z-values that do not accurately represent the rate of increase of species accumulation. When the larger wetlands were removed from the SAR in this study, the z-value increased, indicating potential inflation of z-values when only a small range of sizes are included (Martin 1981).

Consistent with DeLuca et al. (2004), we found a significant positive relationship between the integrity index (IMBCI) and wetland size. Our sample size was considerably smaller than theirs (by 73 sites), but regardless, the scatter in our data (before transformation) is quite similar to their study. It is important to note that even though we found a significant positive relationship, some small wetlands still had high integrity scores. Southern Ontario wetlands truly are insular habitats, and it is quite likely that these remnants are habitats into which wetland-dependent species are "funnelled" due to the lack of choice. Also, if most bird species are to some degree philopatric, and these wetlands were historically larger, they may continue to attract wetland-dependent species such as the Least Bittern.

Consistent with the literature (Table 2-3), we found that the Swamp Sparrow and Marsh Wren were significantly more likely to be found in larger than in smaller marshes (Tyser 1983, Brown and Dinsmore 1986, Riffell et al. 2001). Although we did not find significant area-sensitivity for other wetland-dependent species, results for the Black Tern and American Bittern should be interpreted with caution. While we detected these species only once each in a single wetland, these were two of the largest wetlands in our dataset (third and fourth largest, respectively), and it is possible that there are too few marshes of a size large enough to show area sensitivity for these species in southern Ontario.

When all obligate species were combined, a significant positive relationship was produced, indicating that marsh obligate species were more likely to be detected in larger marshes. The inflection point of the logistic curve suggests that when a marsh in larger than 5.52 ha, there is a better probability of detecting a marsh-nesting obligate than not detecting one. These species-specific and guild-based area-sensitivities may aid in restoration efforts by setting goals for which species to expect in marshes of varying size.

Other species showing area-independence appear to reflect true patterns such as the Least Bittern, Virginia Rail and Sora which were all detected at more than three wetlands. These findings are consistent with other studies where the Sora and Virginia Rail were found in both small and large wetlands (Tyser 1983, Brown and Dinsmore 1986); however, Riffell et al. (2001) found these species to be area-sensitive. Inconsistencies remain for the Least Bittern as well, with one paper finding area-sensitivity (Tyser 1983) and another showing only possible area-dependence (Brown and Dinsmore 1986).

One of the most significant findings of this study is that the number of point counts required to reveal 80% or 90% of the cumulative species richness for a given wetland varies directly with its size. This indicates that sampling effort must be increased when sampling large marshes to fully represent its species assemblage. We acknowledge that there is a trade-off between sampling effort within the wetland and the number of wetlands surveyed, and of course this should be taken into account when designing any monitoring program (Hanowski et al. 2007). Based on our results, we have created two functions that can be used to determine the appropriate number of point counts that should be used to accurately survey marsh birds in a wetland of a given size. These relationships are easy to use once the size of the wetland (in hectares) is substituted into the appropriate equation. In theory, the wetland SARs used to create this function (such as Figure 2-4) should reach an asymptote. We encourage further studies to determine the applicability of these relationships outside the size range of wetlands sampled here (3.49-63.50 ha).

In conclusion, we have demonstrated the importance of both large and small wetlands as habitat for wetland birds because both contain wetland-dependent species. Small wetlands are often viewed as less important because they contain fewer species than larger wetlands, and therefore more small marshes remain unprotected (Connor and McCoy 1979, Naugle et al. 2000). The loss of small, isolated wetlands increases the distance between wetland patches and could lead to changes in metapopulation dynamics for many organisms. This could be through a reduction in gene flow, decreasing the probability of "rescue effects", and potentially leading to extirpation or extinction (Semlitsch and Bodie 1998).

Understanding SARs will be imperative in the future as humans continue to fragment natural areas into insular environments. Indices of biotic integrity are important to incorporate into SARs because they include species-specific life history traits, which are lost in the measurement of species richness. Although it is tempting to set fixed targets for habitat conservation based on SARs, this may only lead to "clearing down to target" by developers, a philosophy where once the target has been set, all other suitable habitat may be plundered (Desmet and

Cowling 2004). Policy-makers must therefore recognize the growing body of scientific literature demonstrating the importance of small and large wetlands, and act accordingly in policy development.

MANAGEMENT IMPLICATIONS

The first and most prominent finding of this study was the importance of large marshes. IMBCI scores were higher in larger wetlands, but several small wetlands still produced high scores. Therefore, wetland management plans should strive to preserve wetlands of all sizes because they contain wetland-dependent species that rely solely on wetland habitat for survival.

REFERENCES

Arrhenius, O. 1921. Species and area. The Journal of Ecology 9:95-99.

Benassi, G., C. Battisti, and L. Luiselli. 2007. Area effect on bird species richness of an archipelago of wetland fragments in Central Italy. Community Ecology 8:229-237.

Blake, J. G. and J. R. Karr. 1987. Breeding birds of isolated woodlots: area and habitat relationships. Ecology 68:1724-1734.

Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. The Journal of Wildlife Management 50:392-397.

Cain, S. A. 1938. The species-area curve. The American Midland Naturalist 19:573-581.

Cohen, J. E. 2003. Human population: the next half century. Science 302:1172-1175.

Connor, E. F. and E. D. McCoy. 1979. The statistics and biology of the species-area relationship. The American Naturalist 113:791-833.

COSEWIC, 2000. COSEWIC assessment and update status report on the King Rail (*Rallus elegans*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +10pp.

COSEWIC, 2001a. COSEWIC assessment and status report on the Yellow Rail (*Coturnicops noveboracensis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 62 pp.

COSEWIC, 2001b. COSEWIC assessment and update status report on the Least Bittern (*Ixobrychus exilis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 10pp.

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24:837-847.

Desmet, P. and R. Cowling. 2004. Using the species-area relationship to set baseline targets for conservation. Ecology and Society 9:11-33.

ESRI Inc. 2006. ArcMap 9.2.

Findlay, C. S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000-1009.

Google Earth, Version 4.2. 2007. Google Inc. Mountain View, California.

Green, J. L., A. J. Holmes, M. Westoby, I. Oliver, D. Briscoe, M. Dangerfield, M. Gillings, and A. J. Beattie. 2004. Spatial scaling of microbial eukaryote diversity. Nature 432:747-749.

Hanowski, J. M., N. P. Danz, R. W. Howe, R. R. Regal, and G. J. Niemi. 2007. Considerations for monitoring breeding birds in Great Lakes coastal wetlands. Journal of Great Lakes Research 33:245-252.

Horner-Devine, M. C., M. Lage, J. B. Hughes, and B. J. M. Bohannan. 2004. A taxa-area relationship for bacteria. Nature 432:750-753.

Hosmer, D. W. and S. Lemeshow. 1989. Applied logistic regression. John Wiley

& Sons, Inc., New York, NY, USA.

Hoyer, M. V. and D. E. Canfield Jr. 1994. Bird abundance and species richness on Florida lakes: influence of trophic status, lake morphology, and aquatic macrophytes. Hydrobiologia 297/280:107-119.

Jaccard, P. 1912. The distribution of the flora in the alpine zone. The New Phytologist 11:37-50.

Martin, T. E. 1981. Species-area slopes and coefficients: a caution on their interpretation. The American Naturalist 118:823-837.

Martin, H. G. and N. Goldenfeld. 2006. On the origin and robustness of power-law species-area relationships in ecology. Proceedings of the National Academy of Sciences 103:10310-10315.

Naugle, D. E., R. R. Johnson, M. E. Estey, and K. F. Higgins. 2000. A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. Wetlands 20:588-604.

Newmark, W. D. 1986. Species-area relationship and its determinants for mammals in western North American national parks. Biological Journal of the Linnean Society 28:83-98.

Niemi, G. J. and M. E. McDonald. 2004. Application of ecological indicators. Annual Review of Ecology, Evolution and Systematics 35:89-111.

OMNR. 2000. A silvicultural guide to managing southern Ontario forests, version 1.1. Ontario Ministry of Natural Resources, Queen's Printer for Ontario, Toronto.

OMNR. 2008. Southern Ontario Land Resource Information System. Ver.1.2. Land Information Ontario, Ministry of Natural Resources, Queen's Printer for Ontario, Toronto.

Paracuellos, M. and J. L. Telleria. 2004. Factors affecting the distribution of a waterbird community: the role of habitat configuration and bird abundance. Waterbirds 27:446-453.

Preston, F. W. 1960. Time and space and the variation of species. Ecology 41:611-627.

Ricklefs, R. E. and I. J. Lovette. 1999. The roles of island area per se and habitat diversity in the species-area relationships of four Lesser Antillean faunal groups. Journal of Animal Ecology 68:1142-1160.

Riffell, S. K., B. E. Keas, and T. M. Burton. 2001. Area and habitat relationships of birds in Great Lakes coastal wet meadows. Wetlands 21:492-507.

Rosenzweig, M. L. 1999. Heeding the warning in biodiversity's basic law. Science 284:276-277.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Semlitsch, R. D. and J. R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Snell, E. 1987. Wetland distribution and conversion in southern Ontario. Working paper No. 48. Canada Land Use Monitoring Program, Inland Waters and Lands Directorate. Environment Canada, Burlington, ON, Canada.

StatSoft, Inc. (2001). STATISTICA (data analysis software system), version 6. www.statsoft.com.

Thomas, D. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, C. Collingham, B. F. N. Erasmus, M. F. de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A. S. van Jaarsveld, G. F. Midgley, L. Miles, M. A. Ortega-Huerta, A. T. Peterson, O. L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature 427:145-148.

Tjørve, E. 2003. Shapes and functions of species-area curves: a review of possible models. Journal of Biogeography 30:827-835.

Tyser, R. W. 1983. Species-area relations of cattail marsh avifauna. The Passenger Pigeon 45:125-128.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science 277:494-499.

Table 2-1. Twenty-one coastal marshes of southern Ontario surveyed between 2006 and 2008. Sites surveyed in 2006 or 2007 were used for the landscape scale SARs while those surveyed in 2008 were used for the within-wetland, sampling effort analysis.

Wetland	Site Code	Size (ha)	Years sampled
Oakville Marsh	OK	3.49	2008
Crysler Point	CY	4.12	2007
Bronte Creek	BR	7.18	2006, 2008
Rattray Marsh	RT	7.36	2007, 2008
Darlington	DA	8.46	2008
Port Britain	PB	10.29	2007
Van Wagner's Pond	VW	12.60	2007
Credit River	CR	14.63	2006, 2008
Turkey Creek	TC	16.18	2007
Grindstone Creek	GC	18.14	2006, 2008
Port Darlington	PD	21.58	2007, 2008
Fifteen Mile Creek	FI	22.34	2008
Jordan Harbour	JH	32.70	2007, 2008
Westside Creek	WC	33.32	2007
Cootes Paradise	CP	62.96	2006, 2008
Second Marsh	SM	63.50	2007, 2008
Blessington Bay	BB	98.06	2007
Hay Bay	HB	392.56	2007
Rondeau	RN	483.37	2007
Grand River	GR	810.97	2006
Long Point	LP	5963.58	2006

Table 2-2. Individual species scores for calculation of the Index of Marsh Bird Community Integrity (IMBCI). S_{IMBCI} represents the score for each species. Each category ranges from one to four with one representing marsh-feeding generalists, non-marsh nesters, resident species, and those distributed throughout North America. Species with a category score of four are marsh obligates, Neotropical migrants, and have a limited distribution within North America.

Common name	Scientific name	Foraging habitat	Nesting substrate	Migratory status	Breeding range	S_{IMBCI}
American Goldfinch	*Carduelis tristis*	1	1	1	1	4
Mourning Dove	*Zenaida macroura*	1	1	1	1	4
European Starling	*Sturnus vulgaris*	1	1	1	1	4
American Robin	*Turdus migratorius*	1	1	1	1	4
Northern Cardinal	*Cardinalis cardinalis*	1	1	1	1	4
American Crow	*Corvus brachyrhynchos*	1	1	1	1	4
Herring Gull	*Larus argentatus*	1	1	1	1	4
Ring-billed Gull	*Larus delawarensis*	1	1	1	1	4
Gull spp.	*Larus* spp.	1	1	1	1	4
Black-capped Chickadee	*Poecile atricapillus*	1	1	1	1	4
Cedar Waxwing	*Bombycilla cedrorum*	1	1	1	1	4
Northern Flicker	*Colaptes auratus*	1	1	1	1	4
Blue Jay	*Cyanocitta cristata*	1	1	1	2	5
Turkey Vulture	*Cathartes aura*	1	1	2.5	1	5.5
Double-crested Cormorant	*Phalacrocorax auritus*	1	1	2.5	1	5.5
Mute Swan	*Cygnus olor*	1	2.5	1	1	5.5
Canada Goose	*Branta Canadensis*	1	2.5	1	1	5.5
Song Sparrow	*Melospiza melodia*	1	2.5	1	1	5.5

Mallard	*Anas platyrhynchos*
Wood Duck	*Aix sponsa*
Duck spp.	Family: Anatidae
Common Grackle	*Quiscalus quiscula*
Eastern Phoebe	*Sayornis phoebe*
Chimney Swift	*Chaetura pelagica*
Killdeer	*Charadrius vociferus*
Spotted Sandpiper	*Actitis macularia*
Lesser Yellowlegs	*Tringa flavipes*
Semipalmated Plover	*Charadrius semipalmatus*
Tree Swallow	*Tachycineta bicolor*
Barn Swallow	*Hirundo rustica*
Purple Martin	*Progne subis*
Bank Swallow	*Riparia riparia*
Cliff Swallow	*Petrochelidon pyrrhonota*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
Swallow spp.	Family: Hirundinidae
Caspian Tern	*Sterna caspia*
Baltimore Oriole	*Icterus galbula*
Belted Kingfisher	*Ceryle alcyon*
Yellow Warbler	*Dendroica petechia*
Willow Flycatcher	*Empidonax traillii*
Eastern Kingbird	*Tyrannus tyrannus*
Sedge Wren	*Cistothorus platensis*
Red-winged Blackbird	*Agelaius phoeniceus*

2.5	1	1	1	5.5
2.5	1	1	1	5.5
2.5	1	1	1	5.5
1	2.5	1	2	6.5
1	1	2.5	2	6.5
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	2.5	2.5	1	7
1	2.5	2.5	1	7

Common Loon	*Gavia immer*
Great Egret	*Ardea alba*
Common Moorhen	*Gallinula chloropus*
Common Yellowthroat	*Geothlypis trichas*
Gray Catbird	*Dumetella carolinensis*
Osprey	*Pandion haliaetus*
Common Moorhen/American Coot	*Gallinula chloropus/ Fulica Americana*
Common Tern	*Sterna hirundo*
Swamp Sparrow	*Melospiza georgiana*
Black-crowned Night Heron	*Nycticorax nycticorax*
Great-blue Heron	*Ardea herodias*
American Coot	*Fulica Americana*
American Bittern	*Botaurus lentiginosus*
Marsh Wren	*Cistothorus palustris*
Black Tern	*Chlidonias niger*
Sora	*Porzana Carolina*
Virginia Rail	*Rallus limicola*
Least Bittern	*Ixobrychus exilis*

1	2.5	2.5	1	7
2.5	1	4	1	8.5
2.5	2.5	2.5	1	8.5
1	2.5	4	1	8.5
1	2.5	4	1	8.5
1	2.5	4	1	8.5
2.5	3.25	2.5	1	9.25
1	2.5	4	2	9.5
2.5	4	1	2	9.5
2.5	2.5	4	1	10
2.5	2.5	4	1	10
2.5	4	2.5	1	10
2.5	4	4	1	11.5
4	4	4	1	13
4	4	4	1	13
4	4	4	1	13
4	4	4	1	13
4	4	4	1	13

Table 2-3. Relationships between the presence/absence of obligate marsh-nesting bird species and wetland size. Significant logistic regression results indicate that the probability of finding each species increases with increasing wetland area. The threshold represents the inflection point of the logistic curve and therefore the wetland size at which one would be equally likely to find or not find a certain species. Sample size (*n*) represents the number of sites (out of 18) at which each species was detected. Consistency with other literature is included where a "✓" indicates our results are consistent, and a "✗" indicates our results are inconsistent with each respective paper.

Species	Relationship	χ^2	P	Threshold (ha)	n	Consistency with previously published literature			
						Tyser (1983)	Brown and Dinsmore (1986)	Riffell et al. (2001)	Naugle et al. (1999)
Black Tern	-	1.498	0.221	-	1	✗*	✗*	-	✗*
Swamp Sparrow	Positive	8.335	0.004	11.06	13	✓	✓	✓	-
Marsh Wren	Positive	7.697	0.006	17.27	11	✓	✓	-	-
Sora	-	0.032	0.859	-	3	✓	✓	✗	-
Virginia Rail	-	0.867	0.352	-	7	✓	✓	✗	-
American Bittern	-	1.268	0.260	-	1	✗*	✗*	✗*	-
Least Bittern	-	0.139	0.709	-	4	✗	✗	-	-
Common Moorhen/ American Coot	-	1.602	0.206	-	5	-	-	-	-
All obligates combined	Positive	6.093	0.014	5.52	16	-	-	-	-

* Inconsistencies with other studies may be due to low detection rates in this study.

Table 2-4. The relationship between sampling effort (number of point counts) and cumulative marsh bird richness at each of 11 wetlands in southern Ontario. Data were fit using logarithmic functions where s = cumulative species richness and pc = number of point counts. Shown are R^2 values, *p*-values, and *n* represents the number of point counts per wetland.

Wetland	Logarithmic function	R^2	*P*	*n*
Bronte Creek	s = 5.08+18.98*log10(pc)	0.998	0.026	3
Oakville Marsh	s = 5.99+16.75*log10(pc)	0.999	0.004	3
Rattray Marsh	s = 6.10+25.30*log10(pc)	0.998	0.026	3
Darlington	s = 8.75+16.39*log10(pc)	0.978	0.096	3
Grindstone Creek	s = 5.08+26.07*log10(pc)	0.993	<0.0001	6
Fifteen Mile Creek	s = 5.78+13.65*log10(pc)	0.934	<0.001	7
Credit River	s = 8.71+14.63*log10(pc)	0.965	<0.0001	8
Port Darlington	s = 8.89+16.34*log10(pc)	0.975	<0.001	6
Cootes Paradise	s = 9.57+21.67*log10(pc)	0.981	<0.0001	14
Jordan Harbour	s = 8.28+12.35*log10(pc)	0.976	<0.0001	11
Second Marsh	s = 9.01+22.60*log10(pc)	0.983	<0.0001	15

Figure 2-1. A map of wetland study sites in southern Ontario surveyed between 2006 and 2008. Site codes correspond to site names in Table 2-1.

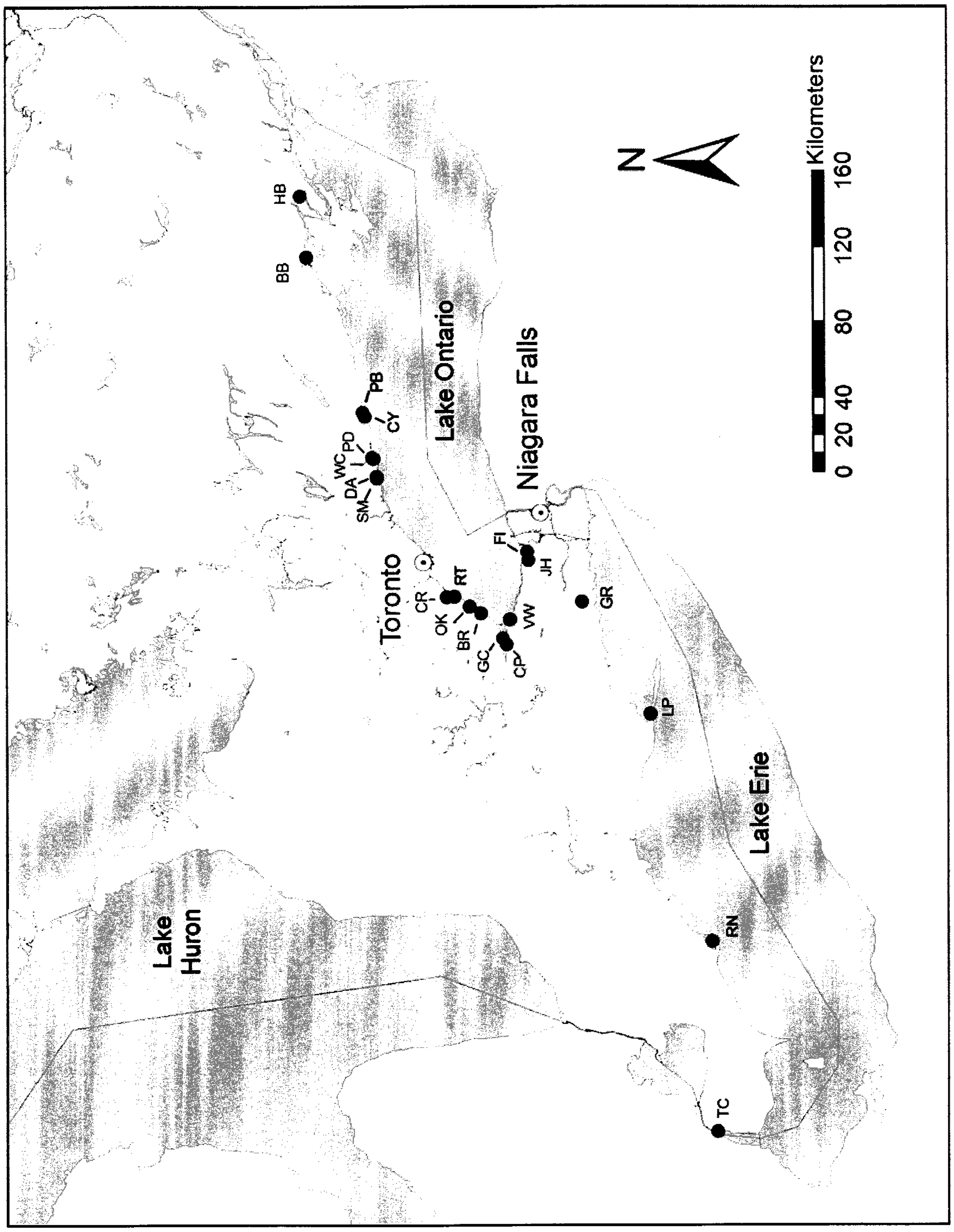

Lake Huron
Toronto
Lake Ontario
Niagara Falls
Lake Erie
N
Kilometers
0 20 40 80 120 160
HB
BB
PB
CY
PD
WC
DA
SM
CR
RT
OK
BR
GC
CP
VW
FI
JH
GR
LP
RN
TC

Figure 2-2. The relationship between wetland area and a) species richness: $\log y = 1.0565 + 0.0755*\log x$, b) abundance: $\log y = 1.1679 + 0.2402*\log x$, and c) W_{IMBCI}: $\log y = 0.5025 + 0.1318*\log x$ for 18 coastal wetlands of southern Ontario. Wetland area measurements before $\log_{10}$ transformation were in hectares.

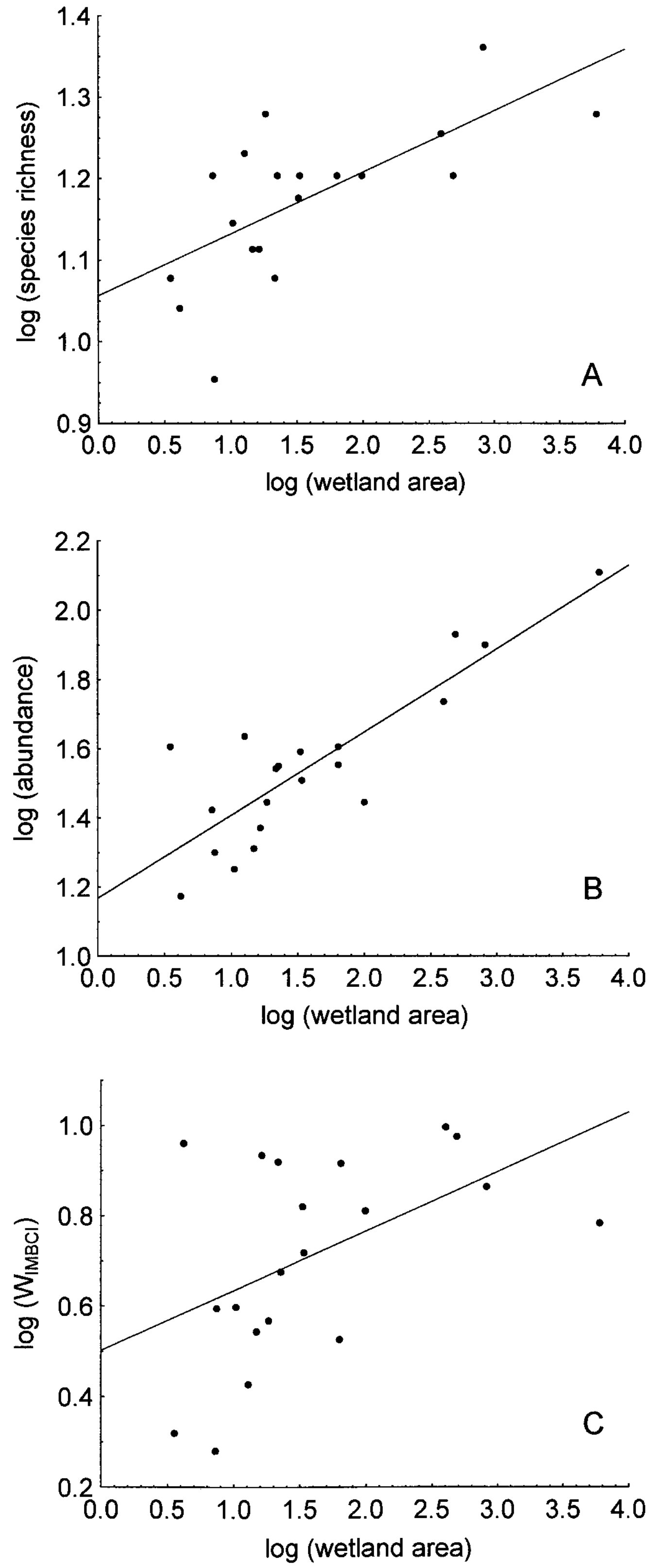

1.4
1.3
1.2
1.1
1.0
0.9
log (species richness)
A
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
log (wetland area)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
log (abundance)
B
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
log (wetland area)
1.0
0.8
0.6
0.4
0.2
log (W_IMBCI)
C
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
log (wetland area)

Figure 2-3. The effect of sample date on a) richness, b) abundance, and c) W_{IMBCI} of wetland birds taken at the same three point counts in a southern Ontario marsh, Cootes Paradise during 2008. Shown are means ± 1SE.

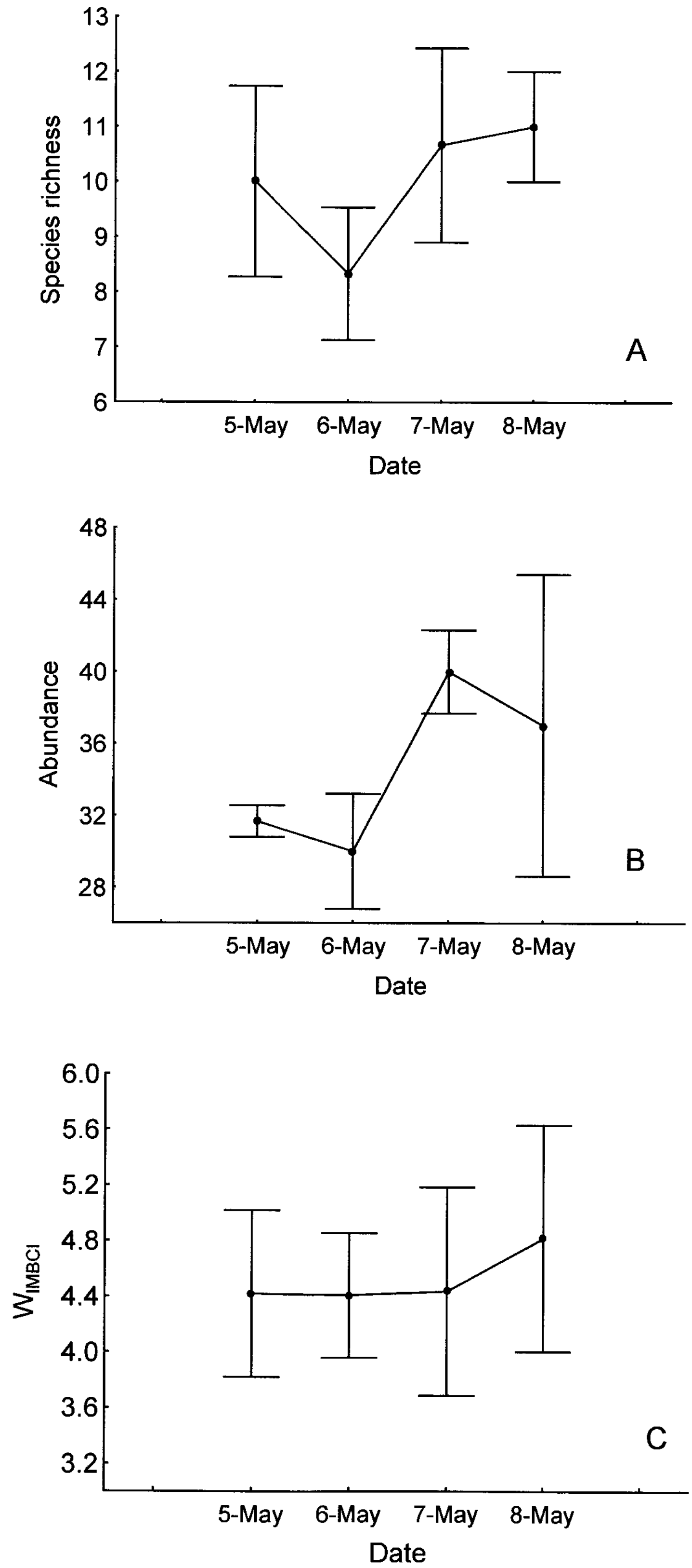

13
12
11
10
9
8
7
6
Species richness
A
5-May 6-May 7-May 8-May
Date
48
44
40
36
32
28
Abundance
B
5-May 6-May 7-May 8-May
Date
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
W_{IMBCI}
C
5-May 6-May 7-May 8-May
Date

Figure 2-4. Species accumulation curve with increasing number of point counts at Second Marsh, 2008. Vertical arrows represent the number of point counts needed to obtain 80% and 90% of the cumulative species richness calculated using the logarithmic function.

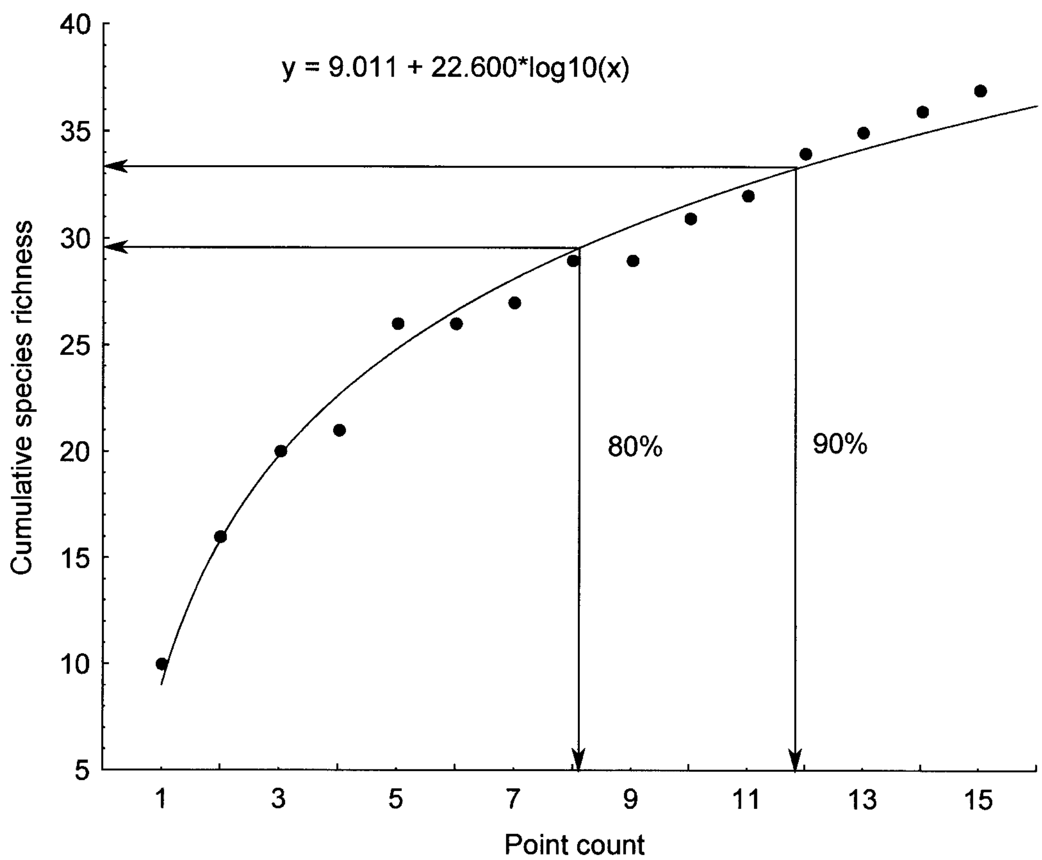
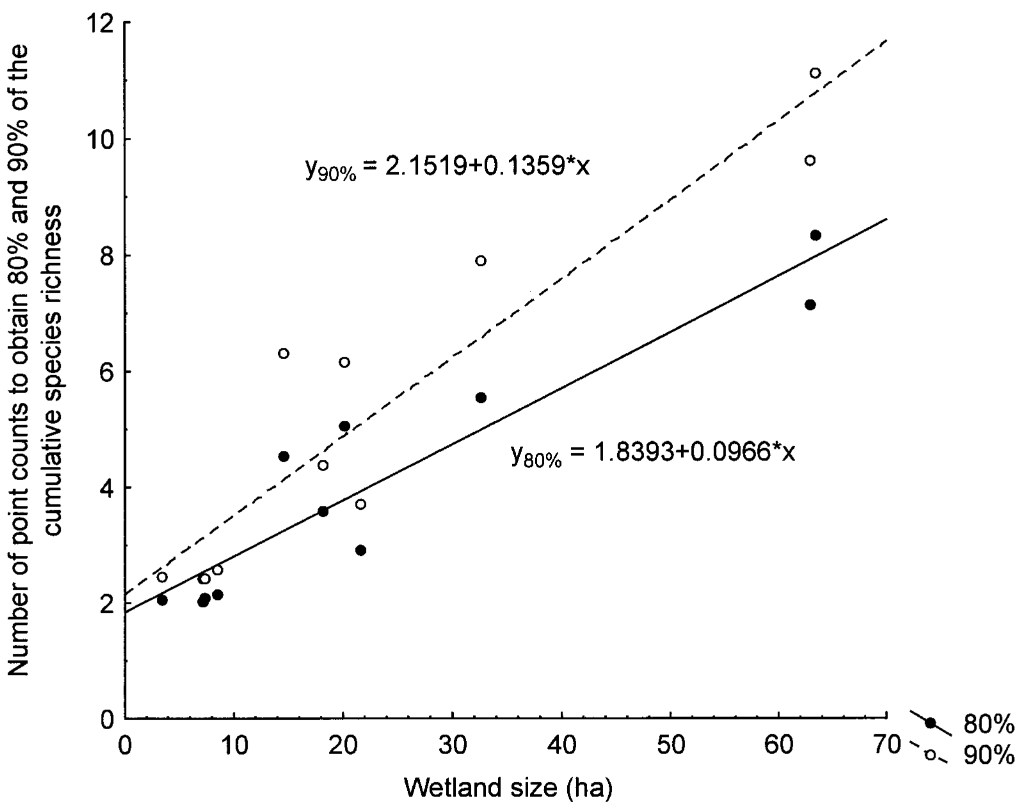

y = 9.011 + 22.600*log10(x)
Cumulative species richness
40
35
30
25
20
15
10
5
80%
90%
1
3
5
7
9
11
13
15
Point count

Figure 2-5. The relationship between wetland size and the number of point counts needed to sample 80% and 90% of the cumulative marsh bird richness. These functions may be used to determine how many point counts should be conducted at marshes of varying sizes to detect 80% and 90% of the marsh bird richness. 80%: $R^2 = 0.859$, $P < 0.0001$; 90%: $R^2 = 0.853$, $P = < 0.0001$


Number of point counts to obtain 80% and 90% of the cumulative species richness
Wetland size (ha)
y90% = 2.1519+0.1359*x
y80% = 1.8393+0.0966*x
80%
90%
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70

CHAPTER 3:

IMPACTS OF ADJACENT LAND USE AND ISOLATION ON MARSH BIRD COMMUNITIES

Lyndsay A. Smith and Patricia Chow-Fraser

ABSTRACT

Over the next half century the human population is expected to grow rapidly, resulting in the conversion of rural areas into cities. Wetlands in these regions are therefore under threat, even though they have important ecosystem services and functions. Many obligate marsh-nesting birds in North America have shown declines over the past 40 years, and it is important to determine if urbanization is responsible for these declines. We surveyed 20 coastal marshes in southern Ontario, Canada, and found that obligate marsh-nesting birds preferred rural over urban wetlands, generalist marsh-nesting birds showed no preference, while synanthropic species showed a trend towards increased richness and abundance in urban marshes. The Index of Marsh Bird Community Integrity (IMBCI) was calculated for each wetland and we found significantly higher scores in rural compared to urban wetlands. The presence of a forested buffer surrounding the marsh was not an important factor in predicting the distribution of generalists, obligates, synanthropic species, or the IMBCI. More isolated marshes had a lower species richness of obligate marsh-nesters and a lower IMBCI than less isolated marshes. Based on our results, we recommend that urban development be kept at least 1000m away from any wetland, as it negatively affects the abundance and richness of obligate marsh-nesters. We also recommend that all existing wetlands be conserved to mitigate against isolation effects and to preserve biodiversity.

INTRODUCTION

Land transformations, specifically through urbanization, are considered to be the most important factor contributing to species extinction rates during this century (Marzluff et al. 2001). Since almost 60% of the world's population lives within 100 km of the coast (Vitousek et al. 1997), land transformations in these regions may have deleterious effects on extremely sensitive systems. Coastal wetlands are unique environments at the interface between aquatic and terrestrial systems and are some of the first habitats impacted by landscape disturbance and upstream pollution (Uzarski et al. 2005, Seilheimer and Chow-Fraser 2006). Wetlands were once considered useless wastelands but are now recognized for their many important functions including local and global climate stabilization, erosion protection, flood attenuation, and sediment and water quality control (Williams 1991, Burbridge 1994). In addition to these ecosystem functions, they provide important habitat for many species including fish, invertebrates, mammals, and birds.

Concern over recent declines in many wetland-dependent bird species has led to an investigation into land use practices and the potential role they play in this decline. Secretive wetland birds, such as the American Bittern (*Botaurus lentiginosus*), American Coot (*Fulica americana*), Common Moorhen (*Gallinula chloropus*), King Rail (*Rallus elegans*), Least Bittern (*Ixobrychus exilis*), Pied-billed Grebe (*Podilymbus podiceps*), Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), and Yellow Rail (*Coturnicops noveboracensis*), are quite sensitive to wetland changes because they are marsh obligates and require this habitat for both nesting and feeding (Peterson and Niemi 2007). The King Rail, Yellow Rail, and Least Bittern have been designated species at risk and are listed federally in Canada as endangered, of special concern, and threatened, respectively (COSEWIC 2000, 2001a, 2001b). The North American Breeding Bird Survey shows continental-scale declines for wetland obligates including the King Rail, American Bittern, Black Tern (*Chlidonias niger*), American Coot, and Common Moorhen between 1966 and 2007 (Sauer et al. 2008). The Least Bittern and Sora populations appear to be stable, while the Swamp Sparrow (*Melospiza georgiana*), Marsh Wren (*Cistothorus palustris*), Virginia Rail, and Pied-billed Grebe show significant increases (Sauer et al. 2008).

Landscape alteration primarily affects birds by clearing habitat and potential nest sites, but it can also increase the abundance of predators and nest parasites (Robinson et al. 1995) including domestic cats (*Catus silvestris*) and racoons (*Procyon lotor*), along with a suite of synanthropic avian species such as the European Starling (*Sturnus vulgaris*), House Sparrow (*Passer domesticus*), and Rock Pigeon (*Columba livia*; Marzluff 2001). Urbanization has also been shown to elicit behavioural changes in birds such as human habituation (Donaldson et al. 2007) and changes in song frequency in response to noise in urban environments (Slabbekoorn and Peet 2003).

Land-use studies focussing on birds have increased greatly since the 1980's, although studies are still lacking in coastal systems (Marzluff et al. 2001).

Most studies examine the impact of an urbanization gradient on the land-bird community (Blair 1996, Reynaud and Thioulouse 2000, Mackey and Currie 2001, Schulze et al. 2004, Miller et al. 2007), and the general finding is that with increased urbanization there is an increase in the density of birds and a decrease in the avian species richness (Blair 1996, Marzluff 2001). Few studies have looked at wetlands within the urban context (but see DeLuca et al. 2004, Pearce et al. 2007), and there is a pressing need for studies examining the impacts of land use, specifically urbanization, on coastal wetland birds throughout southern Ontario (Miller et al. 2001).

DeLuca et al. (2004) developed and used the Index of Marsh Bird Community Integrity (IMBCI) to examine the influence of land use at varying spatial scales surrounding wetlands on marsh birds of Chesapeake Bay, USA. High values of this index reflect a high integrity wetland consisting of species whose attributes represent undisturbed areas and species with marsh-specialist life history traits (O'Connell et al. 2000). The IMBCI scores were reduced significantly when urbanization reached 14% at the 500 m scale and 25% at the 1000 m scale (DeLuca et al. 2004). One hypothesis to explain this pattern is that high levels of urbanization in close proximity to the wetland create habitat for generalist species (Blair 1996), and these generalists could then invade marsh habitat and subsequently lead to increased interspecific competition (DeLuca et al. 2004). We wanted to test this hypothesis by examining patterns of generalist species richness, obligate species richness, and associated IMBCI scores in wetlands bordered by varying degrees of disturbance.

In addition to urbanization, marsh isolation is an important factor influencing bird communities. Isolation could be the result of infilling or draining for either urban development or various rural land uses including agriculture. Marsh isolation limits the amount of potential nesting and feeding habitat nearby, and could influence metapopulation dynamics such as source-sink relationships (Semlitsch and Bodie 1998). Populations in more isolated wetlands have a lower probability of rescue effects because the chance of migration and recolonization is lower, and therefore are less likely to be rescued from extinction (Semlitsch and Bodie 1998). More isolated marshes tend to have a lower avian species richness than less isolated marshes, and wetland-complexes hold more species than more isolated wetlands (Brown and Dinsmore 1986). In this study, we will determine the effect of marsh isolation on wetland bird communities. Therefore, the specific objectives of this study are to determine how 1) adjacent land use, and 2) marsh isolation, influences wetland bird communities in southern Ontario coastal marshes.

METHODS

Study area

From 2006-2007, we conducted point counts in 20 coastal wetlands of Lake Erie and Lake Ontario, Ontario, Canada (Figure 3-1). This shoreline contains the remnants of a once extensive coastal wetland system that has succumbed to the pressures of a growing human population. Between 1800 and 1985, over 80% of wetlands in southern Ontario have disappeared due to agricultural or urban development (Snell 1987). These marshes are now primarily eutrophic systems with dominant emergent vegetation such as native, alien and putative hybrid species of cattails (*Typha* spp.), the exotic species of common reed (*Phragmites australis*), and several native species of bulrush (*Schoenoplectus* spp.).

Avian sampling

All point counts were sampled from a canoe between 1 May and 27 July, 2006 and 2007. Each count was conducted twice throughout the season at least 10 days apart and the results of each survey were averaged. All counts were conducted between sunrise and four hours after sunrise, and surveys were not conducted in high winds (>20 km/h) or during periods of rainfall. Point counts were 10 minutes in length and a 25 m radius full circle was used. We located our first sample point at the emergent vegetation-water interface closest to the canoe launch point but at least 25 m from the shore. Once we arrived at the point count, one minute was allowed for birds to settle. We recorded all birds seen and heard regardless of age (immature vs. adult) or sex. We counted all individuals which were landing, flushing, wading, perching, or calling within the point count area. If the bird was foraging in the wetland (e.g. swallows, swifts, terns, gulls, birds of prey) they were included in the point count if they were <25 m above the wetland. If birds were flushed upon our approach (e.g. herons or egrets), they were included in the count.

After the 10 minute passive period, we broadcasted the songs of secretive marsh birds in the following order including the American Coot, American Bittern, Least Bittern, Pied-billed Grebe, Sora, Virginia Rail, Common Moorhen, King Rail, and Yellow Rail. Calls were broadcast at a sound level of 70-85 dB at a distance of 1 m from the front of the speakers which were oriented to broadcast directly into the patch of emergent vegetation. Speakers were held at a height of 0.75 m above the water surface.

In the broadcast sequence, each species' call varied in length (35 to 110 sec), but each species' call was separated by a 30 sec pause. Call-broadcasts were played for a total of 14 min after the passive period and 2 min were left at the end of the call-broadcasts for us to listen for responses. Subsequent point counts were located by paddling further into the wetland and were located at least 200 m apart to ensure sample independence. We conducted more point counts in larger wetlands surveying as many points as possible during the morning sampling period, or until we surveyed the entire wetland.

Land use classification

Land use analysis was performed using the Southern Ontario Land Resources Information System (SOLRIS; OMNR 2008) and ArcMap 9.2 (ESRI

Inc. 2006). SOLRIS is a geographical information system platform consisting of digital polygons for 23 different land use classes for all of southern Ontario (Table 3-1). For analysis, we grouped these 23 land use classes into 5 subclasses: forest, rural/wildlands, marsh, urban, and open water. We were specifically interested in comparing rural/wildlands to urban areas. Rural/wildlands represent and combination of natural areas and areas that are sparsely settled which border natural areas (exurban) or agriculture (rural; Marzluff et al. 2001).

It is important to note that SOLRIS was created based on aerial images from 2000-2002, whereas our study will utilize information collected from 2006-2007. We updated known land use changes using 2005 Ministry of Natural Resources shapefiles and Google Earth satellite images. To determine the extent of unknown changes we randomly selected five sites and identified changes in land use since 2000-2002 using Google Earth images from 2004-2007. Since changes involved the conversion of on average 0.23% of the land at varying scales from either rural/wildlands or forest to impervious urban areas or roads, we concluded that they were negligible and did not modify information for the remaining wetlands.

For analysis, we used the proportion of each land-based sub-class (including marsh) out of the total amount of land in the sample. To determine if the wetlands were buffered by a forest or not, we visually inspected GIS images, but also looked at the proportion of forest cover within the 500 m radius. If forest composed >20% of the land at the 500 m scale, sites were considered to be buffered. To determine adjacent land use, we selected the land use (other than forest) that composed the majority of land at the 1000 m scale. Therefore, sites could be placed into four categories: urban buffered, urban no buffer, rural buffered, and rural no buffer (Table 3-2). To measure isolation we used the amount of marsh within 4000 m from the edge of the wetland of interest because birds are highly mobile and are more likely influenced by isolation at a large spatial scale (Brown and Dinsmore 1986). Turkey Creek wetland was removed from this analysis because at the 4000 m scale, part of the area entered into a region for which we did not have GIS data.

Statistical analysis

All analyses were performed using Statistica 6.0 (StatSoft Inc. 2001) except for Partial Mantel tests which were performed using Passage Version 1.1 (Rosenberg 2004). To determine the influence of forested buffers and adjacent land use on the wetland bird community, we used a two-factor analysis of variance. The first factor was the presence or absence of a forested wetland buffer, and the second factor was the land use adjacent to the buffer (rural/wildlands or urban areas). We tested the effects on both the richness and abundance of obligate and generalist marsh-nesting birds (Table 3-3). Richness was calculated as the overall site presence/absence and abundance was averaged between the two seasonal point count visits and then averaged for the total number of point counts at each wetland. We tested for species-specific trends in abundance between urban and rural, and buffered and non-buffered sites for the Red-winged Blackbird (*Agelaius phoeniceus*), Song Sparrow (*Melospiza melodia*), Yellow Warbler (*Dendroica petechia*), Common Yellowthroat (*Geothlypis trichas*), Marsh Wren, Swamp Sparrow, Virginia Rail, and Mute Swan (*Cygnus olor*).

We also tested the effect of land use and buffer presence on the IMBCI scores (DeLuca et al. 2004). This index is modelled after the Index of Biotic Integrity (IBI) proposed by Karr and Dudley (1981), where biotic integrity measures the ability of an area to support and maintain an adaptive species community and function similar to the natural habitat of the area. Wetlands with high integrity scores contain marsh bird communities with many wetland-specialized species, and few generalists. The index is calculated using a guild-based approach and specifically includes foraging, nesting, and migratory guilds, along with breeding range. Scores for individual species are shown in Table 3-3 and are produced by simply adding each life history trait. Next, a total W_{IMBCI} value can be calculated for the wetland as:

$$W_{IMBCI} = \left[\left(\frac{\sum S_{IMBCI}}{S_N} \right) + MO_N \right] - 4 \qquad \text{DeLuca et al. (2004)}$$

Where S_{IMBCI} is each species' individual score, S_N is the total number of species, MO_N is the number of marsh obligate nesters detected. Four is subtracted to keep a scoring scale that starts at zero and is constant (DeLuca et al. 2004). We also examined land use impacts on the overall site species richness, and the species richness and abundance of synanthropic species.

We used simple linear regression to determine the effect of isolation on obligate richness and abundance, generalist richness and abundance, the IMBCI, and overall site species richness. The proportion of surrounding marsh within 4000 m was used as our measure of isolation and was ArcSin(squareroot) transformed for all analyses. Graphs show non-transformed data and all R^2 values reported are adjusted R^2 values.

A confounding factor in many wetland-land use studies is the influence of wetland area, which has been well documented in the literature (Brown and Dinsmore 1986, Findlay and Houlahan 1997, DeLuca et al. 2004, Benassi et al. 2007, Smith and Chow-Fraser Chapter 2). We performed a two-factor ANOVA using the same independent treatment groups, but this time with marsh size as the dependent variable to see if our land use categories were grouping larger marshes together or smaller marshes together. We also looked for a potentially confounding relationship between isolation and marsh size using correlation. We found that more isolated marshes tended to be smaller ($r = 0.442$, $p = 0.058$), and therefore we used Partial Mantel tests to look at the effect of marsh isolation on the dependent variables that yielded significant regressions. Partial Mantel tests determine the effect of one independent variable (marsh isolation), while holding the effect of the other correlated independent variable constant (marsh size).

All dependent variables were normally distributed and were checked for heteroscedasticity for analyses of variance. We squareroot(x+1) transformed the W_{IMBCI} data, but it continued to show slight heteroscedasticity (Bartlett's test p = 0.012). We also squareroot(x+3/8) transformed obligate abundance and it also still showed heteroscedasticity (Bartlett's test p = 0.0016). Obligate species richness showed no variance for urban, buffered sites, which always contained only one obligate species. Variances between urban/non-buffered, rural/buffered, and rural/non-buffered were homogeneous for obligate species richness. We squareroot(x+1) transformed the Mute Swan abundance data to bring it closer to normal for the buffered/rural grouping. We decided to proceed with the parametric tests for these analyses due to the robustness in analysis of variance tests, and the fact that our samples sizes for each treatment group were relatively similar.

RESULTS

Adjacent land use

There was no significant relationship between land use ($F_{1,16} = 0.548$, $p = 0.470$) or buffer presence ($F_{1,16} = 0.563$, $p = 0.464$) and wetland area. We found a higher richness ($F_{1,16} = 6.85$, $p = 0.019$) and abundance ($F_{1,16} = 8.42$, $p = 0.010$) of obligate marsh-nesting birds in rural sites as compared to urban sites (Fig. 3-2A, 2B). There was no effect of a forested buffer on the richness ($F_{1,16} = 0.428$, $p = 0.522$) or abundance ($F_{1,16} = 3.09$, $p = 0.098$) of obligate marsh-nesters.

Generalist marsh-nesters showed no apparent difference in use of urban and rural sites (richness: $F_{1,16} = 0.336$, $p = 0.571$; abundance: $F_{1,16} = 2.54$, $p = 0.131$), or between buffered and non-buffered sites (richness: $F_{1,16} = 2.60$, $p = 0.126$; abundance: $F_{1,16} = 1.09$, $p = 0.312$; Fig. 3-2C, 2D). Synanthropic species showed a trend towards higher richness ($F_{1,16} = 2.59$, $p = 0.127$) and abundance ($F_{1,16} = 2.37$, $p = 0.143$) in urban areas, although the results were not significant (Fig. 3-2E, 2F). There was no effect of a forested buffer on the richness ($F_{1,16} = 1.20$, $p = 0.290$) or abundance ($F_{1,16} = 0.004$, $p = 0.949$) of synanthropic birds.

The W_{IMBCI} scores were significantly higher in rural sites than urban sites ($F_{1,16} = 7.12$, $p = 0.017$), although there was no significant effect of buffer ($F_{1,16} = 0.404$, $p = 0.534$; Fig. 3-3). There was no difference in overall wetland species richness between urban and rural sites ($F_{1,16} = 0.141$, $p = 0.712$), and buffered and non-buffered sites ($F_{1,16} = 1.56$, $p = 0.230$).

Species-specific results suggest that the Red-winged Blackbird, Song Sparrow, Marsh Wren, and Swamp Sparrow are sensitive to adjacent land use practices (Table 3-4). The Red-winged Blackbird and Song Sparrow were found in higher abundances in urban contexts regardless of the presence of a forested buffer ($F_{1,16} = 0.462$, $p = 0.507$; $F_{1,16} = 0.410$, $p = 0.531$; respectively). The Marsh Wren and Swamp Sparrow preferred rural wetlands, and also showed no significant preference for buffered or non-buffered sites ($F_{1,16} = 4.03$, $p = 0.062$; $F_{1,16} = 0.132$, $p = 0.721$; respectively).

Isolation

The amount of marsh habitat within 4000 m of the wetland significantly influenced the bird community at the study site. Sites with more surrounding marsh habitat (less isolated wetlands), had a higher W_{IMBCI} value than those more isolated wetlands, even when holding the influence of wetland area constant (Mantel r = 0.290, p = 0.001; Fig. 3-4A). Less isolated wetlands also contained significantly more obligate marsh-nesting species (Mantel r = 0.295, p = 0.004; Fig. 3-4B), even when controlling for wetland area. There was no effect of isolation on generalist richness (R^2 = 0.00, p = 0.860; Fig. 3-4C), obligate abundance (R^2 = 0.068, p = 0.147), generalist abundance (R^2 = 0.00, p = 0.706), or overall site species richness (R^2 = 0.00, p = 0.596).

DISCUSSION

This study illustrates the far-reaching effects that urbanization can have on nearby natural systems. Even though each wetland unit was relatively void of immediate human presence, the influence of the adjacent land use was still apparent as shown by changes in the bird community. Our findings contribute to the growing body of evidence that suggests obligate marsh-nesters prefer wetlands in more undisturbed landscapes, and less isolated wetlands.

Although we can not directly demonstrate that competition between generalists and obligates led to the segregation of niches between urban and rural sites, our data do support this hypothesis (DeLuca et al. 2004). This anthropogenic niche differentiation may be directly demonstrating the ability of generalists to live in, or close to, human environments. Many bird species once adapted to natural environments have taken to human-dominated habitats for either nesting or feeding. For example, many cliff-nesting species such as swallows now use human structures for nesting, while gulls and corvids exploit human environments for food (Johnston 2001). It is extremely unlikely that species such as marsh-obligate nesters would be able to use human-associated habitats, as they rely solely on aquatic habitat, which is often only completely abolished when humans move in.

The fact that birds are adapting to live with humans appears to be part of natural evolution. For example, some European synanthropes, who have been living with humans for close to 1000 years, show increased fecundity and decreased longevity compared to their North American counterparts (Martin and Clobert 1996). This shift could be due to an adaptation to increases in human and associated predators. Those individuals able to quickly reproduce more young may be at an advantage, and therefore pass on more of their genes (Martin and Clobert 1996). It is important to stress that while the evolution of synanthropism may be a natural process to coping with the increasing human presence, it is not a solution (Johnston 2001). If species are forced to evolve too quickly, as is the current situation with the exponential human population growth and required infrastructure, extinctions may result instead of evolution (Johnston 2001, Cohen 2003).

Based on the results of this study, we recommend that urban development not be permitted within 1000 m of any wetland since it negatively affects the abundance and richness of obligate marsh-nesters. Even though urban marsh habitat does not seem to be the most suitable for obligate marsh-nesting birds, it is still important for generalist marsh-nesters. Many of these generalist species are Neotropical migrants, and already face many difficulties including habitat destruction on breeding and wintering grounds (Sarmiento 2000), and danger associated with migration (Newton 2006). It is important to recognize the importance of all wetlands, including existing urban wetlands, because they provide habitat for generalist species, which are equally important for ecosystem functioning.

The presence of a forested buffer (defined in our study as forest cover of >20% within 500m from the wetland edge) does not appear to be as important as the land use that is adjacent to the buffer in predicting species richness. This finding for marsh birds is quite different than the literature for other wetland species and hydrological processes that illustrates their importance in controlling water quality and conserving habitat for other wetland-associated organisms (Carter 1996, Norman 1996, Crosbie and Chow-Fraser 1999, Robichaud et al. 2002, Houlahan and Findlay 2004, Bried and Ervin 2006, Gamble et al. 2006). More research needs to be conducted to uncover the reason why wetland birds respond differently than other species to the presence or absence of a forested buffer.

We also recommend that all existing wetlands be conserved to mitigate against isolation effects and to preserve biodiversity. Less isolated wetlands were associated with higher integrity values and obligate species richness, but it is important to point out that some of the more isolated marshes had equally high values. This indicates that small, isolated wetlands are not expendable (Semlitsch and Bodie 1998) and should be included with larger marshes in wetland protection legislation because they also provide important habitat for marsh birds.

Future research should strive to determine the reason for urban-avoidance in obligate marsh birds. Low-frequency urban noise from traffic and machinery is thought to interfere with avian communication methods, and can lead to lower densities of breeding birds near roads (Reijnen et al. 1995, Reijnen et al. 1996, Forman and Alexander 1998). Marsh-birds primarily communicate using low frequency sounds to facilitate long-distance transmission through dense marsh habitat (Cosens and Falls 1984), and human noise could be interfering with communication in urban environments (Slabbekoorn and Peet 2003). In-depth long-term studies are also needed to monitor nest survival rates, predator communities, and food abundance within the context of varying land uses surrounding wetlands to determine other potential mechanisms of urban-avoidance.

It is important to preserve the remaining wetlands in southern Ontario, and the undisturbed land surrounding them, to ensure that natural ecosystem processes and services continue to function. The continued functioning of wetlands in this region is not only important for our future benefit, but also for those species that require marsh habitat for their survival, and are integral in the proper functioning of these ecosystems. It is our hope that these remaining wetlands will stay undisturbed through the implementation and development of policy, future wetland research, and monitoring for early detection of changes and potential threats to these sensitive, yet powerful, ecosystems. This paper is another stark reminder of the tumultuous impact that humans are having on bird communities, as they are forced into environments far away from the human presence. We fear for the day when they can go no further.

MANAGEMENT IMPLICATIONS

Obligate marsh birds were sensitive to the amount of urbanization within 1 km of the wetland edge. When wetlands had more urban development than rural areas within 1 km, there was a shift in the bird community from obligates to synanthropic species. While obligate marsh birds preferred rural areas over urban areas, generalists showed no difference in use, indicating the importance of preserving urban wetlands as well. Therefore, existing urban wetlands should be conserved, in addition to rural wetlands, and development should be limited in the surrounding area.

The IMBCI can be used to indicate the degree of human disturbance surrounding wetlands, and should be used to assess the health of coastal marshes along the shores of Lake Ontario and Lake Erie. Marsh isolation should be another consideration when managing wetland habitat for birds. Less isolated marshes were selected for use by more obligate species and less isolated marshes also had higher IMBCI scores than more isolated marshes. Therefore, managers should strive to maintain wetland complexes, as they are preferred habitat for sensitive bird species.

Wetland protection in southern Ontario is limited only to Provincially Significant Wetlands (PSW) and those evaluated by the OMNR as containing endangered or threatened species. Once designated as a PSW, development is limited within 120m of the wetland edge (OMNR 1999, Provincial Policy Statement (PPS) 2005). Our study has shown that high levels of urban development within 1 km of the wetland edge can cause avoidance by obligate marsh birds, and therefore, the Provincial Policy Statement (2005) should be extended to protect areas within 1 km of the wetland edge.

REFERENCES

Benassi, G., C. Battisti, and L. Luiselli. 2007. Area effect on bird species richness of an archipelago of wetland fragments in Central Italy. Community Ecology 8:229-237.

Blair, R. B. 1996. Land use and avian species diversity along an urban gradient. Ecological Applications 6:506-519.

Bried, J. T., and G. N. Ervin. 2006. Abundance patterns of dragonflies along a wetland buffer. Wetlands 26:878-883.

Brown, M., and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. The Journal of Wildlife Management 50:392-397.

Burbridge, P. R. 1994. Integrated planning and management of freshwater habitats, including wetlands. Hydrobiologia 285:311-322.

Carter, V. 1996. Environmental gradients, boundaries, and buffers: an overview. *in* G. Mulamoottil, B. G. Warner, and E. A. McBean, editors. Wetlands: environmental gradients, boundaries, and buffers. Lewis Publishers, Boca Raton, Florida.

Cohen, J. E. 2003. Human population: the next half century. Science 302:1172-1175.

Cosens, S. E. and J. B. Falls. 1984. A comparison of sound propagation and song frequency in temperate marsh and grassland habitats. Behavioral Ecology and Sociobiology 15:161-170.

COSEWIC, 2000. COSEWIC assessment and update status report on the King Rail *Rallus elegans* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +10pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC, 2001a. COSEWIC assessment and status report on the Yellow Rail *Coturnicops noveboracensis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 62 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

COSEWIC, 2001b. COSEWIC assessment and update status report on the Least Bittern *Ixobrychus exilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 10pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Crosbie, B., and P. Chow-Fraser. 1999. Percentage land use in the watershed determines the water and sediment quality of 22 marshes in the Great Lakes basin. Canadian Journal of Fisheries and Aquatic Science 56:1781-1791.

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24:837-847.

Donaldson, M. R., K. M. Henein, and M. W. Runtz. 2007. Assessing the effect of developed habitat on waterbird behaviour in an urban riparian system in Ottawa, Canada. Urban Ecosystems 10:139-151.

ESRI Inc. 2006. ArcMap 9.2.

Findlay, C. S. and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11:1000-1009.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.

Gamble, L. R., K. McGarigal, C. L. Jenkins, and B. C. Timm. 2006. Limitations of regulated "buffer zones" for the conservation of marbled salamanders. Wetlands 26:298-306.

Houlahan, J. E., and C. S. Findlay. 2004. Estimating the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality. Landscape Ecology 19:677-690.

Johnston, R. F. 2001. Synanthropic birds of North America. *in* J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Kluwar Academic Publishers, Norwell, Massachusetts.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Mackey, R. L., and D. J. Currie. 2001. The diversity-disturbance relationship: is it generally strong and peaked? Ecology 82:3479-3492.

Martin, T. E. and J. Clobert. 1996. Nest predation and avian life-history evolution in Europe versus North America: a possible role of humans? The American Naturalist 147:1028-1046.

Marzluff, J. M. 2001. Worldwide urbanization and its effects on birds. *in* J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, Massachusetts.

Marzluff, J. M., R. Bowman, and R. Donnelly. 2001. A historical perspective on urban bird research: trends, terms, and approaches. *in* J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, Massachusetts.

Miller, J. R., J. M. Fraterrigo, N. T. Hobbs, D. M. Theobald, and J. A. Wiens. 2001. Urbanization, avian communities, and landscape ecology. *in* J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Kluwar Academic Publishers, Norwell, Massachusetts.

Miller, C., G. J. Niemi, J. M. Hanowski, and R. R. Regal. 2007. Breeding bird communities across an upland disturbance gradient in the western Lake Superior Region. Journal of Great Lakes Research 33:305-318.

Newton, I. 2006. Can conditions experienced during migration limit the population levels of birds? Journal of Ornithology 147:146-166.

Norman, A. J. 1996. The use of vegetative buffer strips to protect wetlands in southern Ontario. *in* G. Mulamoottil, B. G. Warner, and E. A. McBean, editors. Wetlands: environmental gradients, boundaries, and buffers. Lewis Publishers, Boca Raton, Florida.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. Ecological Applications 10:1706-1721.

OMNR, 2008. Southern Ontario Land Resource Information System. Ver.1.2. Land Information Ontario, Ministry of Natural Resources, Queen's Printer for Ontario, Toronto.

Pearce, C. M., M. B. Green, and M. R. Baldwin. 2007. Developing habitat models for waterbirds in urban wetlands: a log-linear approach. Urban Ecosystems 10:239-254.

Peterson, A. C., and G. J. Niemi. 2007. Evaluation of the Ohio Rapid Assessment Method for wetlands in the western Great Lakes: an analysis using bird communities. Journal of Great Lakes Research 33:280-291.

Provincial Policy Statement. 2005. Section 3 of the Planning Act. Ministry of Municipal Affairs and Housing. Queen's Printer for Toronto, Ontario.

Reijnen, R., R. Foppen, C. Ter Braak, and J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. The Journal of Applied Ecology 32:187-202.

Reijnen, R., R. Foppen, and H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in dutch agricultural grasslands. Biological Conservation 75:255-260.

Reynaud, P. A., and J. Thioulouse. 2000. Identification of birds as biological markers along a neotropical urban-rural gradient (Cayenne, French Guiana), using co-inertia analysis. Journal of Environment Management 59:121-140.

Robichaud, I., M. Villard, and C. S. Machtans. 2002. Effects of forest regeneration on songbird movements in a managed forest landscape of Alberta, Canada. Landscape Ecology 17:247-262.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Rosenberg, M. S. 2004. PASSAGE Version 1.1. Pattern analysis, spatial statistics, and Geographic Exegesis.

Sarmiento, F. O. 2000. Breaking mountain paradigms: ecological effects on human impacts in managed Tropandean landscapes. Ambio 29:423-431.

Sauer, J. R., Hines, J.E., Fallon, J., 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Schulze, C. H., M. Waltert, P. J. A. Kessler, R. Pitopang, Shahabuddin, D. Veddeler, M. Muhlenberg, S. R. Gradstein, C. Leuschner, I. Steffan-Dewenter, and T. Tscharntke. 2004. Biodiversity indicator groups of tropical land-use systems: comparing plants, birds, and insects. Ecological Applications 14:1321-1333.

Seilheimer, T. S., and P. Chow-Fraser. 2006. Development and use of the

Wetland Fish Index to assess the quality of coastal wetlands in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Science 63:354-366.

Semlitsch, R. D., and J. R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Slabbekoorn, H., and M. Peet. 2003. Birds sing at a higher pitch in urban noise. Nature 424:267.

Snell, E. A. 1987. Wetland distribution and conversion in southern Ontario, Working paper No. 48. Canada Land Use Monitoring Program, Inland Waters and Lands Directorate, Environment Canada, Burlington, ON, Canada.

StatSoft, Inc. (2001). STATISTICA (data analysis software system), version 6. www.statsoft.com.

Uzarski, D. G., T. M. Burton, M. J. Cooper, J. W. Ingram, and S. T. A. Timmermans. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five great lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31:171-187.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science 277:494-499.

Williams, M., editor. 1991. Wetlands A Threatened Landscape. Basil Blackwell Ltd., Cambridge, Massachusetts.

Table 3-1. SOLRIS designation of 23 land use classes and descriptions, grouped into sub-classes for analysis.

Land use class	Sub-class	Description
Open cliff and talus	Rural/wildlands	Vertical or near-vertical exposed bedrock > 3 m in height / slopes of rock rubble at the base of cliffs. Subject to active processes / < 25% vegetative cover
Open shoreline	Rural/wildlands	Substrate consists of unconsolidated parent or mineral material. Subject to active processes / < 25% vegetative cover
Open bluff	Rural/wildlands	Steep to near-vertical exposure of unconsolidated material > 2 m in height. Subject to active processes / < 25% vegetative cover
Open sand barren and dune	Rural/wildlands	Exposed sands formed by extant or historical shoreline or Aeolian processes. Subject to active processes / < 25% vegetative cover
Open tallgrass prairie	Rural/wildlands	Ground layer dominated by prairie gramminoids; variable cover of open-grown trees. Tree cover < 25%; shrub cover
Tallgrass savannah	Rural/wildlands	Ground layer dominated by prairie gramminoids; variable cover of open-grown trees, 25% < tree cover < 35%
Tallgrass woodland	Forest	Ground layer dominated by prairie gramminoids; variable cover of open-grown trees, 35% < tree cover < 60%
Forest	Forest	Tree cover > 60%. Upland tree species > 75% canopy cover > 2 m in height
Coniferous forest	Forest	Tree cover > 60%. Upland conifer tree species > 75% canopy cover > 2 m in height
Mixed forest	Forest	Tree cover > 60%. Upland conifer tree species > 25% and deciduous tree species > 25% of canopy cover > 2m in height
Deciduous forest	Forest	Tree cover > 60%. Upland deciduous tree species > 75% of canopy cover > 2 m in height
Plantations – tree cultivated	Forest	Tree cover > 60%, minimum 2 m in height, linear organization, uniform tree

		type
Hedge rows	Forest	Tree cover > 60%, minimum 2 m in height, linear arrangement, minimum 10 m width, maximum 30m width
Transportation	Urban	Highways, roads
Extraction	Urban	Pits, quarries
Built-up area pervious	Urban	Urban recreation areas, e.g. golf courses, playing fields
Built-up area impervious	Urban	Residential, industrial, commercial and civic areas
Swamp	Forest	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree or shrub cover > 25% - dominated by hydrophytic shrub and tree species
Fen	Marsh	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface. - tree cover (trees > 2m high) ≤ 25% - sedges, grasses and low (< 2 m) shrubs dominate, sedge and brown moss peat substrate
Bog	Marsh	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree cover (trees > 2m high) ≤ 25% sphagnum peat substrate
Marsh	Marsh	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree and shrub cover ≤ 25% - dominated by emergent hydrophytic macrophytes
Open water	Open water	No macrophyte vegetation, trees or shrub cover
Undifferentiated	Rural/wildlands	Includes all agricultural features (e.g. field and forage crops and rural properties) as well as urban brown fields, and openings within forests

Table 3-2. Sites categorized as buffered (B) or not buffered (N), and adjacent land as urban (U) or rural (R). GIS land use measurements are shown as proportions. GIS land use at Westside Creek, Port Darlington, Crysler Point, and Blessington Bay were overridden by visual data due to habitat configuration surrounding the wetland at the 1000 m scale. Proportion marsh indicates the proportion of the land within 4000 m of the wetland that is marsh habitat.

Site	Site code	Category	GIS forest cover within 500 m	Visual inspection if buffered	GIS adjacent urban 1000 m	GIS adjacent rural 1000 m	Visual inspection of adjacent land use	Proportion marsh ($\times 10^{-4}$)
Van Wagners	VW	NU	0.030 (<0.2)	No	0.726	0.254	Urban	37.51
Westside Creek	WC	NR	0.058 (<0.2)	No	0.520	0.385	Rural	68.34
Oakville Marsh	OK	NU	0.076 (<0.2)	Partial	0.939	0.004	Urban	0
Port Darlington	PD	NR	0.108 (<0.2)	No	0.464	0.392	Rural	100.28
Turkey Creek	TC	NU	0.110 (<0.2)	No	0.729	0.128	Urban	-
Bronte Creek	BR	NU	0.132 (<0.2)	Partial	0.803	0.051	Urban	3.37
Second Marsh	SM	NU	0.183 (<0.2)	Partial	0.496	0.358	Urban	53.11
Crysler Point	CY	NR	0.200 (=0.2)	Partial	0.490	0.276	Rural	87.91
Jordan Harbour	JH	BR	0.211 (>0.2)	Yes	0.210	0.616	Rural	50.46
Long Point	LP	BR	0.212 (>0.2)	Yes	0.099	0.712	Rural	64.59
Credit River	CR	BU	0.216 (>0.2)	Partial	0.833	0.027	Urban	17.81
Grand River	GR	BR	0.227 (>0.2)	Yes	0.140	0.643	Rural	23.60
Port Britain	PB	BR	0.250 (>0.2)	Yes	0.053	0.784	Rural	58.58
Fifteen Mile Creek	FI	BR	0.250 (>0.2)	Yes	0.201	0.614	Rural	87.95
Grindstone Creek	GC	BU	0.275 (>0.2)	Yes	0.388	0.349	Urban	97.26
Hay Bay	HB	BR	0.299 (>0.2)	Partial	0.021	0.704	Rural	223.55
Rattray	RT	BU	0.435 (>0.2)	Partial	0.694	0.006	Urban	37.51
Cootes Paradise	CP	BU	0.501 (>0.2)	Yes	0.488	0.138	Urban	36.90
Blessington Bay	BB	BR	0.597 (>0.2)	Yes	0.196	0.255	Rural	385.38
Rondeau	RN	BR	0.841 (>0.2)	Yes	0.075	0.118	Rural	726.23

Table 3-3. Individual species scores for calculation of the Index of Marsh Bird Community Integrity (IMBCI). S_{IMBCI} represents the score for each species. Each category ranges from one to four with one representing marsh-feeding generalists, non-marsh nesters, resident species, and those distributed throughout North America. Species with a category score of four are marsh obligates, Neotropical migrants, and have a distribution limited within North America.

Common name	Scientific name	Foraging habitat	Nesting substrate	Migratory status	Breeding range	S_{IMBCI}
American Goldfinch	*Carduelis tristis*	1	1	1	1	4
Mourning Dove	*Zenaida macroura*	1	1	1	1	4
European Starling[d]	*Sturnus vulgaris*	1	1	1	1	4
American Robin	*Turdus migratorius*	1	1	1	1	4
Northern Cardinal	*Cardinalis cardinalis*	1	1	1	1	4
Herring Gull	*Larus argentatus*	1	1	1	1	4
Ring-billed Gull	*Larus delawarensis*	1	1	1	1	4
Gull spp.	*Larus* spp.	1	1	1	1	4
Cedar Waxwing	*Bombycilla cedrorum*	1	1	1	1	4
Northern Flicker	*Colaptes auratus*	1	1	1	1	4
Turkey Vulture	*Cathartes aura*	1	1	2.5	1	5.5
Double-crested Cormorant	*Phalacrocorax auritus*	1	1	2.5	1	5.5
Mute Swan[d]	*Cygnus olor*	1	2.5	1	1	5.5
Canada Goose [c]	*Branta Canadensis*	1	2.5	1	1	5.5
Song Sparrow [c]	*Melospiza melodia*	1	2.5	1	1	5.5
Mallard	*Anas platyrhynchos*	2.5	1	1	1	5.5
Wood Duck [c]	*Aix sponsa*	2.5	1	1	1	5.5
Duck spp.	Family: Anatidae	2.5	1	1	1	5.5

Common Grackle [c]	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Chimney Swift[d]	*Chaetura pelagica*
Killdeer	*Charadrius vociferous*
Spotted Sandpiper	*Actitis macularia*
Lesser Yellowlegs	*Tringa flavipes*
Semipalmated Plover	*Charadrius semipalmatus*
Tree Swallow	*Tachycineta bicolour*
Barn Swallow	*Hirundo rustica*
Purple Martin[d]	*Progne subis*
Bank Swallow	*Riparia riparia*
Cliff Swallow	*Petrochelidon pyrrhonota*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
Swallow spp.	Family: Hirundinidae
Caspian Tern	*Sterna caspia*
Baltimore Oriole	*Icterus galbula*
Belted Kingfisher	*Ceryle alcyon*
Yellow Warbler [c]	*Dendroica petechia*
Willow Flycatcher	*Empidonax traillii*
Eastern Kingbird	*Tyrannus tyrannus*
Sedge Wren [c]	*Cistothorus platensis*
Red-winged Blackbird [c]	*Agelaius phoeniceus*
Common Loon	*Gavia immer*
Great Egret	*Ardea alba*
Common Moorhen [a,b]	*Gallinula chloropus*
Common Yellowthroat [c]	*Geothlypis trichas*
Gray Catbird	*Dumetella carolinensis*

1	2.5	1	2	6.5
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	1	4	1	7
1	2.5	2.5	1	7
1	2.5	2.5	1	7
1	2.5	2.5	1	7
2.5	1	4	1	8.5
2.5	2.5	2.5	1	8.5
1	2.5	4	1	8.5
1	2.5	4	1	8.5

Osprey	*Pandion haliaetus*	1	2.5	4	1	8.5
Common Moorhen/ American Coot [a,b]	*Gallinula chloropus/ Fulica Americana*	2.5	3.25	2.5	1	9.25
Common Tern	*Sterna hirundo*	1	2.5	4	2	9.5
Swamp Sparrow [a]	*Melospiza Georgiana*	2.5	4	1	2	9.5
Green Heron	*Butorides virescens*	2.5	2.5	4	1	10
Black-crowned Night Heron	*Nycticorax nycticorax*	2.5	2.5	4	1	10
Great-blue Heron [c]	*Ardea herodias*	2.5	2.5	4	1	10
American Coot [a,b]	*Fulica Americana*	2.5	4	2.5	1	10
American Bittern [a,b]	*Botaurus lentiginosus*	2.5	4	4	1	11.5
Marsh Wren [a]	*Cistothorus palustris*	4	4	4	1	13
Black Tern [a]	*Chlidonias niger*	4	4	4	1	13
Sora [a,b]	*Porzana Carolina*	4	4	4	1	13
Virginia Rail [a,b]	*Rallus limicola*	4	4	4	1	13
Least Bittern [a,b]	*Ixobrychus exilis*	4	4	4	1	13

[a]Marsh-nesting obligates, [b]secretive species, [c]marsh-nesting generalists, [d]synanthropic species.

Table 3-4. Species-specific changes in abundance between primarily urban or rural adjacent land uses. All interaction effects and effects of the presence/absence of a forested buffer were not significant. Abundance represents the average abundance/wetland and data shown are means ± 1SE (back-transformed values for the Mute Swan).

Species	Urban (n = 9)	Rural (n = 11)	$F_{1,16}$	P
Red-winged Blackbird	5.57 ± 0.325	4.14 ± 0.409	4.45	0.051
Song Sparrow	0.630 ± 0.102	0.417 ± 0.097	3.80	0.069
Yellow Warbler	0.324 ± 0.135	0.330 ± 0.064	0.0003	0.987
Common Yellowthroat	0.213 ± 0.109	0.504 ± 0.170	1.06	0.319
Marsh Wren	0.500 ± 0.333	1.33 ± 0.336	5.40	0.034
Swamp Sparrow	0.296 ± 0.197	0.879 ± 0.107	6.36	0.024
Virginia Rail	0.250 ± 0.132	0.296 ± 0.154	0.293	0.596
Mute Swan	0.395 ± 0.173	0.084± 0.058	2.61	0.126

Figure 3-1. A map of 20 coastal wetland study sites in southern Ontario, Canada surveyed between 2006 and 2007.

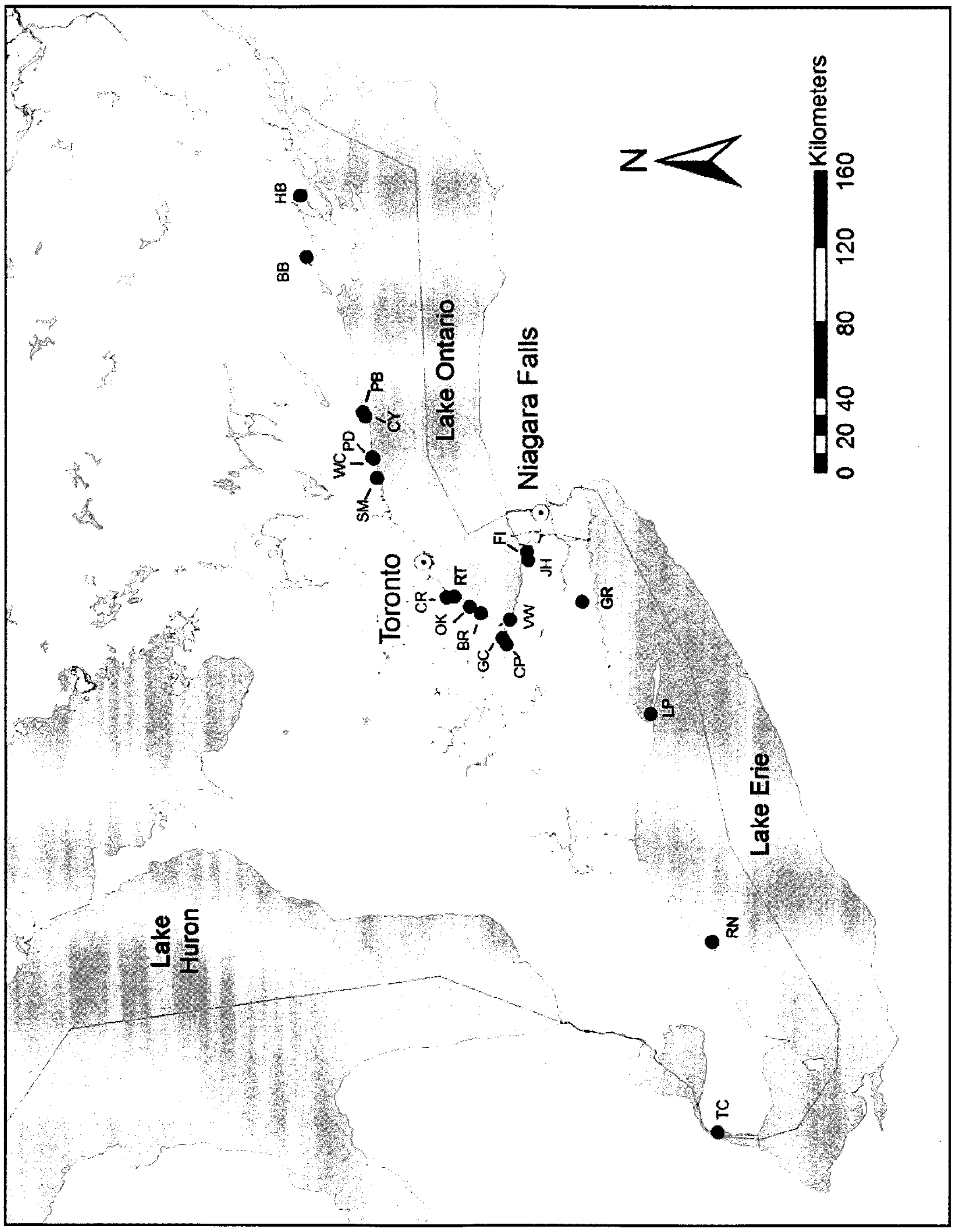

Lake Huron
Lake Erie
Lake Ontario
Toronto
Niagara Falls
HB
BB
PB
CY
PD
WC
SM
CR
RT
OK
BR
GC
CP
VW
FI
JH
GR
LP
RN
TC
N
Kilometers
0 20 40 80 120 160

Figure 3-2. Variation in obligate richness and abundance (A, B), generalist richness and abundance (C, D), and synanthropic species richness and abundance (E, F) between urban and rural, and buffered and non-buffered sites. Shown are means ± 1SE. Back-transformed data are shown for obligate abundance.

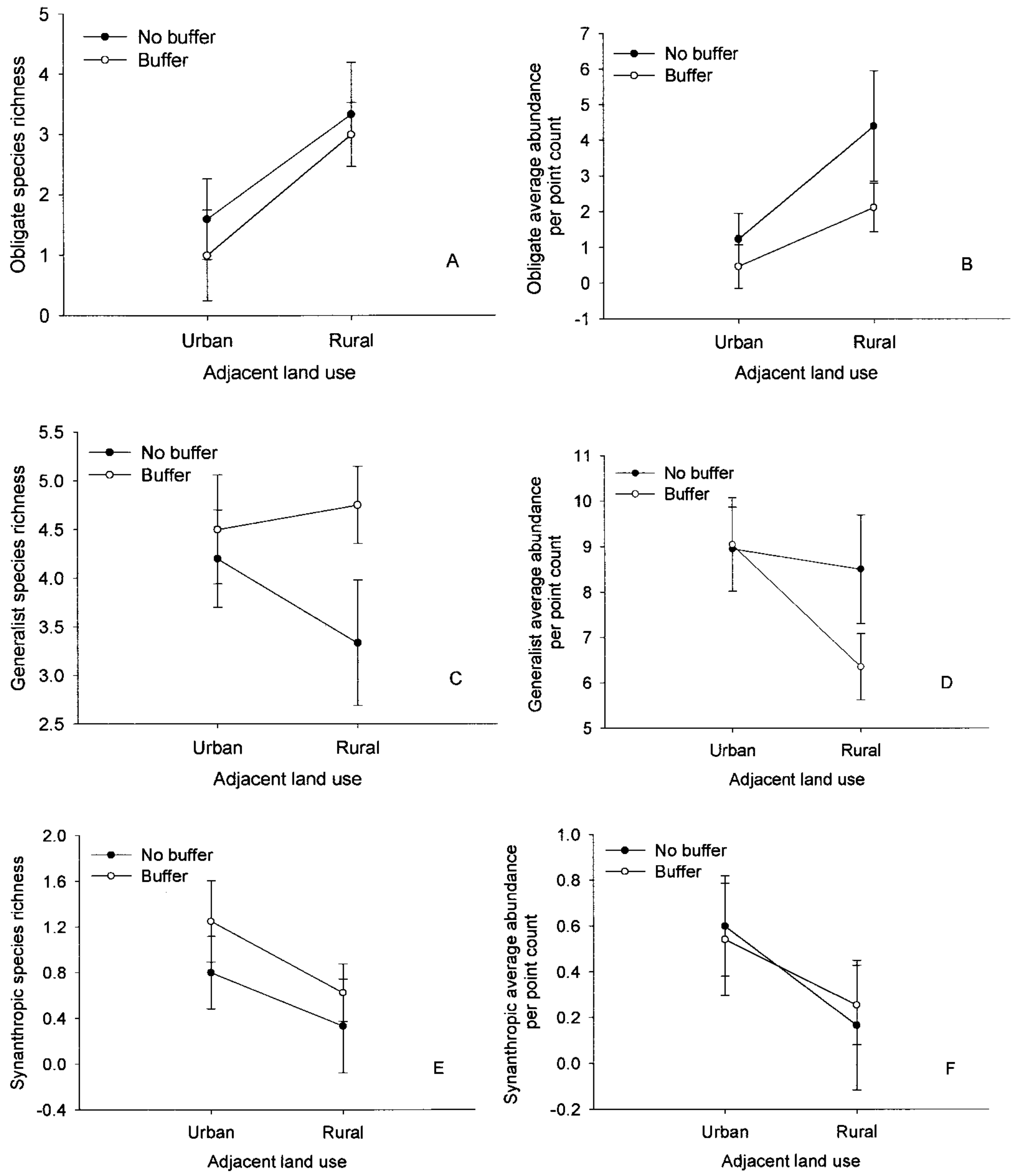

No buffer
Buffer
Obligate species richness
Adjacent land use
Urban
Rural
A
Obligate average abundance per point count
B
Generalist species richness
C
Generalist average abundance per point count
D
Synanthropic species richness
E
Synanthropic average abundance per point count
F

Figure 3-3. The effect of adjacent land use and the presence of a forested buffer on the Index of Marsh Bird Community Integrity at 20 coastal marshes in southern Ontario. Back-transformed data are shown.

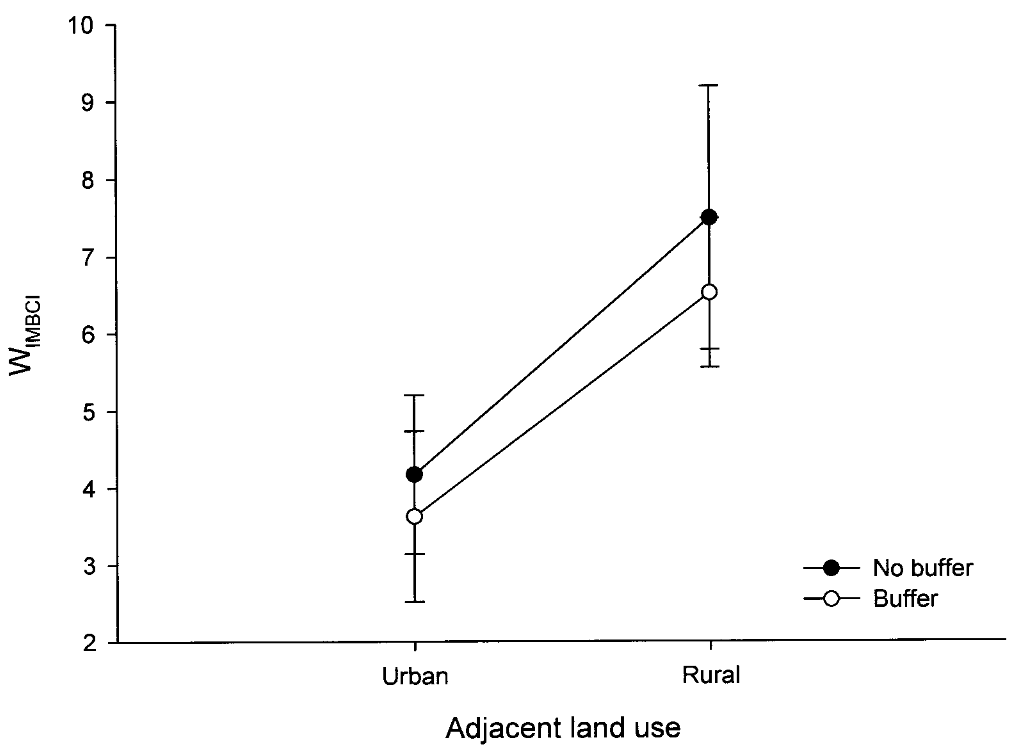
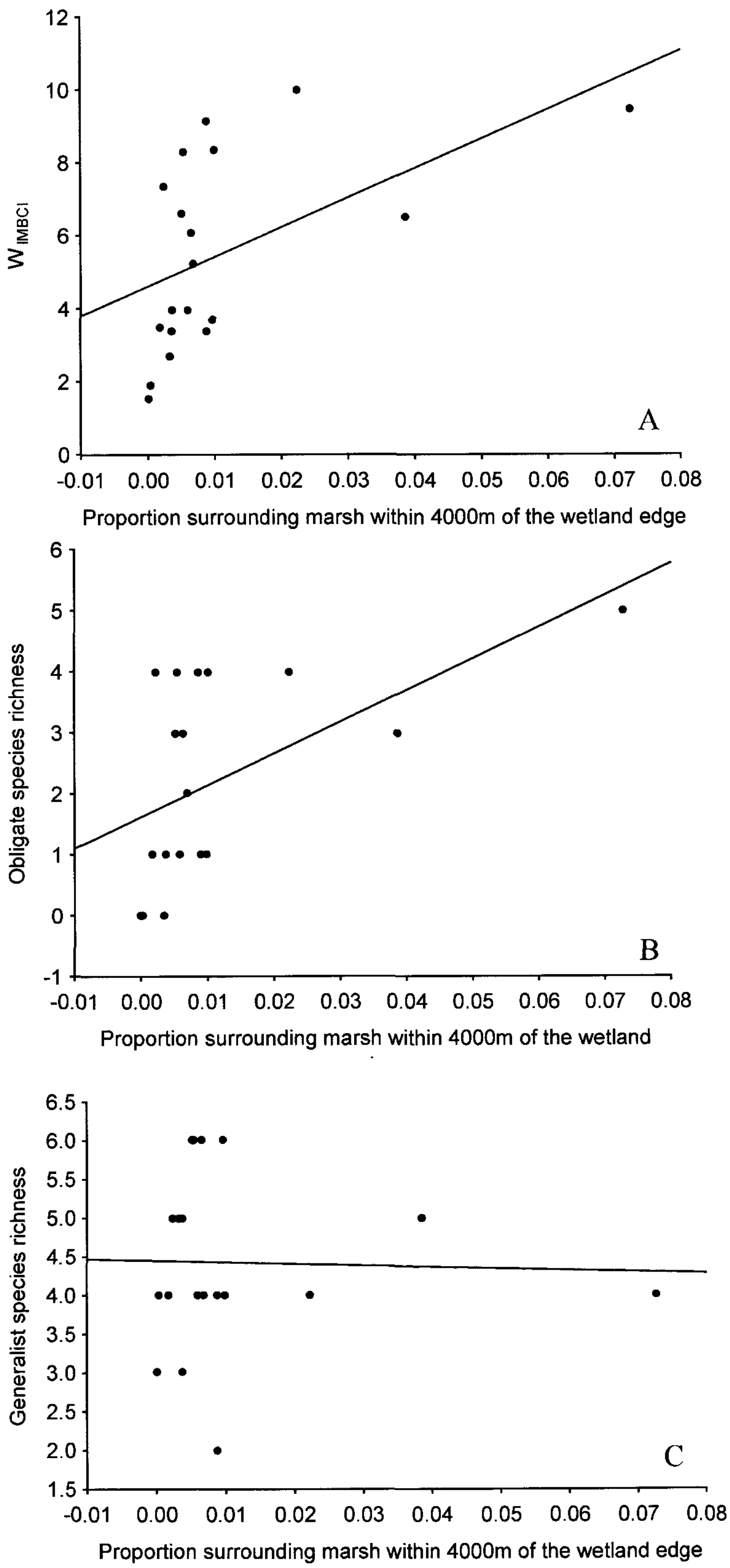

10
9
8
7
6
5
4
3
2
W_{IMBCI}
Urban
Rural
Adjacent land use
No buffer
Buffer

Figure 3-4. The effects of isolation on the W_{IMBCI}, obligate species richness, and generalist species richness for 19 coastal marshes in southern Ontario.


12
10
8
6
4
2
0
W_{IMBCI}
A
-0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08
Proportion surrounding marsh within 4000m of the wetland edge
6
5
4
3
2
1
0
-1
Obligate species richness
B
-0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08
Proportion surrounding marsh within 4000m of the wetland
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
Generalist species richness
C
-0.01 0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08
Proportion surrounding marsh within 4000m of the wetland edge

CHAPTER 4:

APPLICATION OF THE INDEX OF MARSH BIRD COMMUNITY INTEGRITY TO COASTAL WETLANDS OF GEORGIAN BAY, ONTARIO

Lyndsay A. Smith and Patricia Chow-Fraser

ABSTRACT

Ecological indicators have gained increasing attention within the scientific community over the past 40 years because of their ability to detect potential ecological threats. Several taxonomic groups have been used successfully as indicators including most prominently fish, invertebrates, plants, and birds. In the Great Lakes Region, there has been recent concern over the applicability of using indicators on a basin-wide scale due to species range restrictions and lake-based differences. The objective of this study was to determine the ability of the Index of Marsh Bird Community Integrity (IMBCI) to indicate land use disturbance surrounding coastal marshes of Georgian Bay and Lake Ontario. To meet this objective, we surveyed birds and vegetation in seven marshes in both Georgian Bay (low disturbance) and Lake Ontario (high disturbance). We found fewer bird species and significantly fewer birds in Georgian Bay marshes compared to Lake Ontario. Lake Ontario marshes were surrounded by significantly more altered land than Georgian Bay marshes, and had poorer water quality. Even with these differences in wetland quality, we found no significant difference in IMBCI scores. This inconsistency could be due to vegetation differences affecting the strength of the index, because Georgian Bay wetlands had significantly more bulrush and floating vegetation, while Lake Ontario wetland vegetation was taller and cattail-dominated. The findings of this study suggest that the IMBCI may not be useful on a basin-wide scale in the Great Lakes region in detecting human disturbance surrounding wetlands.

INTRODUCTION

By 2050, the global human population is expected to reach 9 billion, with more than half of that population living within 100 km of the coast (Vitousek et al. 1997, Cohen 2003). With this growing population comes the need for increased agriculture and infrastructure, most often at the expense of natural areas. These land use changes alter ecosystem processes and wildlife communities, and place additional stress on coastal ecosystems, such as coastal wetlands (Robinson et al. 1995, UNEP 1995, Crosbie and Chow-Fraser 1999, Houlahan and Findlay 2004).

Before European settlement (circa 1800), wetlands covered 2.38 million hectares of land in southern Ontario (Snell 1987). By 1982, it was estimated that 90% of these wetlands had been lost, primarily due to draining for agriculture (Snell 1987), and these trends have likely continued to this day. Not included in these wetland loss statistics is the quality of the remaining wetlands, and recent studies have shown that many coastal wetlands in southern Ontario are highly degraded (Chow-Fraser 2006). These degraded wetlands along the shores of Lake Erie and Lake Ontario are in sharp contrast to the relatively undisturbed wetlands along the shoreline of eastern Georgian Bay. Many of these marshes have remained essentially undisturbed due to low levels of watershed disturbance, with many watersheds in the region consisting of primarily forest, with minimal cottage development (Croft and Chow-Fraser 2009).

Ecological indicators have received considerable attention over the past 40 years because of their ability to detect changes in environmental condition (Niemi and McDonald 2004). The development and use of indicators is essential to designate important ecological areas and those in need of attention. Ecological indicators are superior to traditional abundance or richness measurements because they contain information about the role of each species in the environment and their sensitivity to disturbance. The ability of species to indicate environmental condition led to the development of the Index of Biotic Integrity (IBI) concept. Integrity represents the ability of a community to support and maintain an adaptive group of organisms and functions comparable to the natural habitat of that area (Karr and Dudley 1981). Several taxa have been used as environmental indicators including fish (Wang et al. 2001, Uzarski et al. 2005, Seilheimer and Chow-Fraser 2006), insects (Anderson and Vondracek 1999, Schulze et al. 2004), plants (Croft and Chow-Fraser 2007, Brazner et al. 2007), and birds (DeLuca et al. 2004, Crewe and Timmermans 2005, Howe et al. 2007).

Ever since canaries were used in mines to detect dangerous gas levels, birds have been viewed as good indicators of environmental condition (Van Biema and Walsh 1995). They are a highly mobile taxon, and can be easily surveyed in less time than other indicators using standard sampling methods such as point counts (Ralph 1981, Reynaud and Thioulouse 2000). Bird indices have been developed for use in forested systems (Canterbury et al. 2000), riparian zones (Bryce and Hughes 2002), along urban-rural gradients (Reynaud and Thioulouse 2000), and in wetlands (DeLuca et al. 2004).

In wetlands, several avian indices have been developed to indicate human land use disturbance either next to wetlands or in the watershed. Insectivorous birds have been shown to respond as indicators of human disturbance in Great Lakes coastal wetlands (Brazner et al. 2007). The Sedge Wren (*Cistothorus platensis*), Common Yellowthroat (*Geothlypis trichas*), and Sandhill Crane (*Grus canadensis*) are indicators of low disturbance, while the Common Grackle (*Quiscalus quiscula*) and European Starling (*Sturnus vulgaris*) indicate coastal wetlands which have been highly degraded (Howe et al. 2007).

Crewe and Timmermans (2005) used data from the Marsh Monitoring Program (a long-term Great Lakes wetland bird and amphibian survey) to calculate a marsh bird IBI for wetlands of the Great Lakes Basin. Several marsh bird species were found to be good indicators of less disturbed wetlands including the Black Tern (*Chlidonias niger*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and Least Bittern (*Ixobrychus exilis*). DeLuca et al. (2004) also developed an IBI for marsh birds in wetlands of Chesapeake Bay, USA called the Index of Marsh Bird Community Integrity (IMBCI). This index uses species-specific feeding, nesting, migratory, and breeding distribution information to assign each species a score and then a composite score for the entire wetland. IMBCI values were found to be significantly reduced when urbanization covered

25% or more of the land within 1 km of the wetland edge, demonstrating that marsh birds are affected by local land use practices.

In this study, we examine 1) the applicability of the IMBCI to coastal marshes of eastern Georgian Bay, and 2) the suitability of using birds as indicators of wetland health on a basin-wide scale.

METHODS

Study sites

Between 2006 and 2007, we visited 14 coastal marshes in southern Ontario, Canada to survey birds, vegetation, and water quality (Fig. 4-1, Table 4-1). Seven of these marshes were along the shore of Lake Ontario, bordered by primarily agricultural or urban areas. The other seven marshes were along the eastern shoreline of Georgian Bay, downstream from vastly forested watersheds. We chose wetlands of approximately equal size to account for prominent species-area relationships that exist for wetland birds in southern Ontario (Smith and Chow-Fraser Chapter 2).

Bird surveys

We visited each site once during the breeding season between 15 May and 13 July. All point counts were conducted from a canoe between sunrise and four hours after sunrise and no surveys were conducted in high winds >20 km/h or during periods of rainfall. Point counts were 10 min in length and a 25 m radius full circle was used. The first sample point was located at least 25 m from the shore at the emergent vegetation-water interface closest to where the canoe was launched. We recorded all birds seen and heard regardless of sex and counted all individuals that were landing, flushing, wading, perching, or calling within the point count area.

After the 10 min passive period, we broadcasted the songs of secretive marsh birds including the American Coot (*Fulica americana*), American Bittern (*Botarus lentiginosus*), Least Bittern, Pied-billed Grebe (*Podilymbus podiceps*), Sora, Virginia Rail, Common Moorhen (*Gallinula chloropus*), King Rail (*Rallus elegans*), and Yellow Rail (*Coturnicops noveboracensis*) in that order. Calls (70-85 dB 1 m from the source) were broadcast from speakers oriented directly into the patch of emergent vegetation at a height of 1 m above the water surface. In the broadcast sequence, each species' call varied in length (35 to 110 sec), but each species call series was separated by a 30 sec pause. Call-broadcasts were played for a total of 14 min after the passive period and 2 min were left at the end of the call-broadcasts for us to listen for responses. Subsequent point counts were located by paddling further into the wetland and were at least 200 m apart to ensure each individual was a new detection (Siegel et al. 2001).

Vegetation surveys

Vegetation surveys were conducted in conjunction with point counts. We estimated the percent cover of emergent vegetation, floating vegetation, and open water within the 25 m radius point count. Cattail species were not differentiated and therefore narrow-leaf (*Typha angustifolia*), broadleaf (*T. latifolia*), and hybrid species (*T.* X*glauca*) were grouped. Floating vegetation included primarily fragrant water lily (*Nymphaea odorata*) and common yellow pond lily (*Nuphar variegate*), but if other floating species were found, they were included. Dominant emergent plants were identified and the height of the dominant vegetation species was estimated (Paracuellos and Telleria 2004).

Water quality sampling

We sampled water quality between 28 May and 4 July 2001-2002 and 2006-2007. Water quality samples were taken in open water, no less than 10 m from the edge of the emergent vegetation. If wetlands contained dense submergent vegetation, we chose deeper areas with less submergent vegetation. Water samples were taken using a 1 L Van Dorn at half depth of the water column, and transferred into acid-washed 1 L Nalgene bottles. Water samples for chlorophyll analysis were transferred to opaque Nalgene bottles. All samples were frozen until analysis. We used a YSI 6600 multi-parameter probe to measure dissolved oxygen, temperature, and conductivity (Seilheimer and Chow-Fraser 2006).

Based on water quality samples, we then calculated the Water Quality Index (WQI) for each wetland which was created from 12 water quality variables (Chow-Fraser 2006). WQI scores range from -3 to +3 with negative scores representing highly degraded wetlands and positive scores representing more pristine wetlands. For detailed water quality sampling protocols and development of WQI scores please see Chow-Fraser (2006).

Land use

To determine land use adjacent to the wetland, we used two digital platforms. For Lake Ontario wetlands, we used the Southern Ontario Land Resources Information System (SOLRIS; OMNR 2008) and ArcMap 9.2 (ESRI Inc. 2006). SOLRIS is a Geographic Information System (GIS) database containing polygons of 23 different land use classes. For Georgian Bay wetlands, we used IKONOS satellite imagery because SOLRIS coverage was limited to ecoregions 6E and 7E which are south of our study sites.

We estimated land use at a scale of 1 km from the edge of the wetland because land use within this proximity has been shown to affect the bird community (DeLuca et al. 2004, Crewe and Timmermans 2005, Smith and Chow-Fraser Chapter 3). We used the Braun-Blanquet scale (Braun-Blanquet 1932) to determine if the amount of altered land within the 1 km buffer was <5, 5-25, 25-50, 50-75, or 75-100% of the total buffered area. Each of these ranges were then assigned a number from one to five for analysis, one representing <5% altered and five representing 75-100% altered. IKONOS images were captured between 2002 and 2003, and SOLRIS data was based on images from 2000-2002.

Statistical analysis

All analyses were performed using Statistica 6.0 (StatSoft Inc. 2001). For the analysis of species richness, we used the overall presence/absence for each species detected at the wetland. For avian abundance, we took the total number of birds counted at each wetland divided by the number of point counts conducted at each wetland (either one or two based on size). We used the IMBCI as a measure of wetland integrity as it has been shown to accurately reflect land use (DeLuca et al. 2004, Smith and Chow-Fraser Chapter 3). To calculate the IMBCI, each species seen or heard at the wetland was assigned a score based on four life history characteristics. Species with a high score would be Neotropical migrants, nest and feed only in wetlands, and have a limited breeding range in North America. Species producing a low score would be a resident species, nest outside the wetland, occasionally feed in wetlands, and be widely distributed throughout the continent. High IMBCI scores indicate marsh bird communities with many wetland-specialized species, and few generalists.

To examine differences in wetland size, avian richness, avian abundance, the IMBCI, and the WQI between Georgian Bay and Lake Ontario we used independent t-tests. For land use using the Braun-Blanquet scale, all vegetation variables, and Julian day we used the non-parametric Mann-Whitney U-test and we report z-values adjusted for ties.

RESULTS

Wetland study sites did not vary significantly in size between Lake Ontario and Georgian Bay (Table 4-2). We did not find a significant difference in species richness between lakes, although Lake Ontario wetlands had on average two more species per wetland. There was a significant difference in the number of wetland birds per site, with significantly fewer individuals in Georgian Bay wetlands. Even though IMBCI values did not show a difference between lakes, wetlands of Lake Ontario were significantly more disturbed than those in Georgian Bay according to the degree of urbanization and agricultural development. Lake Ontario sites also showed significantly poorer water quality than did Georgian Bay sites.

These differences in bird communities could be a result of differences in dominant wetland vegetation between the lakes (Fig. 4-2, Table 4-3). Wetlands in Georgian Bay had significantly more bulrushes and floating species than those in Lake Ontario wetlands which contained significantly more cattails, and taller vegetation. These vegetation differences were not related to differences in sampling dates since the periods overlapped (15 May to 3 July for Lake Ontario wetlands, and 31 May to 20 June for Georgian Bay wetlands).

There were several birds that were only detected in one or the other region. Species which were only counted in Georgian Bay include the Purple Martin (*Progne subis*), Blue-winged Teal (*Anas clypeata*), American Bittern (*Botaurus lentiginosus*), Eastern Kingbird (*Tyrannus tyrannus*), and Herring Gull

(*Larus argentatus*). Species only detected in Lake Ontario include the Mute Swan (*Cygnus olor*), Cliff Swallow (*Petrochelidon pyrrhonota*), Mallard (*Anas platyrhyndhos*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Common Tern (*Sterna hirundo*), European Starling (*Sturnus vulgaris*), American Robin (*Turdus migratorius*), Northern Cardinal (*Cardinalis cardinalis*), Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), Least Bittern (*Ixobrychus exilis*), Marsh Wren (*Cistorthorus palustris*), Belted Kingfisher (*Ceryle alcyon*), and Chimney Swift (*Chaetura pelagica*).

DISCUSSION

The overall goal of this paper was to determine the ability of the IMBCI to differentiate between levels of land use disturbance in Georgian Bay and Lake Ontario. This index has been successfully applied to both wetlands of Chesapeake Bay, USA and coastal marshes of Lake Erie and Lake Ontario (DeLuca et al. 2004, Smith and Chow-Fraser Chapter 3). It is also currently recommended for use at "marshes in any landscape context" in the Mid-Atlantic Region by the United States Environmental Protection Agency (U.S. EPA 2006). Contrary to its previous success, we found that this index did not explain land use disturbance when comparing bulrush-dominated, Georgian Bay coastal marshes to cattail-dominated wetlands of Lake Ontario.

This is not the first time that the applicability of indicators on a basin-wide scale has been called into question. Bird indicator species, such as the Common

Yellowthroat (*Geothlypis trichas*), have previously been identified as good indicators of human disturbance; however, when used at a basin-wide scale these trends were not apparent (Brazner et al. 2007, Howe et al. 2007). This is because Common Yellowthroats are found in varying abundance between lakes and therefore may not be good indicators of human disturbance. Several other indicator groups have shown significant variation between lakes including wetland obligate plants, amphibian species richness, and native fish species (Brazner et al. 2007, Seilheimer and Chow-Fraser 2007). Several insect indicator species also show greater variation based on ecoregion than landscape disturbance (Anderson and Vondracek 1999).

The results of this study and others suggest that it may be difficult to develop accurate indicators of coastal marsh health in the Great Lakes Region without taking into account lake-based differences (Brazner et al. 2007). For example, Lake Ontario, Lake Erie, and western Lake Huron have areas that are highly impacted by human disturbance, but Lake Superior and Georgian Bay remain relatively undisturbed (Brazner et al. 2007). Another concern for the broad geographic application of indicator species is that rare species, which are often the most sensitive, tend to have restricted geographic ranges and habitats (Niemi and McDonald 2004). For example, the Least Bittern (*Ixobrychus exilis*) is a threatened species in Canada and is only found in coastal marshes of Lake Michigan, Lake Huron, Lake Ontario, and Lake Erie and is absent in marshes of Lake Superior. This species contributes a very high species score in the IMBCI and therefore its absence due to range restrictions could artificially affect IMBCI scores.

Even though several bird indicator species have been shown to be poor indicators at a basin-wide scale, other avian guilds proved to be more representative indicators. The abundance of insectivorous birds in coastal wetlands has been shown to be a strong indicator of human disturbance on a basin-wide scale, showing little lake-based variation, as well as several other indicator taxa such as invasive wetland plant species, spring peepers (*Pseudacris crucifer*), and rock bass (*Ambloplites rupestris*; Brazner et al. 2007).

It was never the goal of this study to downplay the importance or applicability of biological indicators, because there are many studies that have developed and used indicators with great success (Schulze et al. 2004, Crewe and Timmermans 2005, Uzarski et al. 2005, Seilheimer and Chow-Fraser 2006, Croft and Chow-Fraser 2007). We suggest that indicators should be thoroughly tested when being considered for use across large geographic areas (see Seilheimer et al. 2009). Future research should test the ability of the IMBCI to detect land use changes among only cattail-dominated marshes of Georgian Bay and Lake Ontario to determine if wetland vegetation or geographic region was the driving factor causing the differences found in this study.

The Index of Biotic Integrity concept was originally developed so that researchers could use native species to indicate the health of a specific region. It is important that we do not forget that the definition of biological integrity is "the ability of an area to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization *comparable to that of natural habitat of the region*" (Karr and Dudley 1981). This suggests, in agreement with this study, that if variation in natural habitat is not considered in indicator development, we may be inaccurately representing the health of an area. Misinterpreting the integrity of a region could lead to severe consequences, especially when using IBI's for site assessments prior to development. It is our hope that this study will stimulate both future research into indicator variation between regions, and discussion on appropriate indicators for use in the Great Lakes Region.

MANAGEMENT IMPLICATIONS

The IMBCI may not be useful in distinguishing wetland health between marshes of Georgian Bay and Lake Ontario, especially when the marshes contain different dominant vegetation types.

REFERENCES

Anderson, D. J., and B. Vondracek. 1999. Insects as indicators of land use in three ecoregions in the Prairie Pothole Region. Wetlands 19:648-664.

Braun-Blanquet, J. 1932. Plant sociology: the study of plant communities. McGraw-Hill, New York, NY, USA.

Brazner, J. C., N. P. Danz, G. J. Niemi, R. R. Regal, A. S. Trebitz, R. W. Howe, J. M. Hanowski, L. B. Johnson, J. J. H. Ciborowski, C. A. Johnston, E. D. Reavie, V. J. Brady, and G. V. Sgro. 2007. Evaluation of geographic, geomorphic and human influences on Great Lakes wetland indicators: A multi-assemblage approach.
Ecological Indicators 7:610-635.

Bryce, S. A., R. M. Hughes, and P. R. Kaufmann. 2002. Development of a bird integrity index: using bird assemblages as indicators of riparian condition. Environmental Management 30:294-310.

Canterbury, G. E., T. E. Martin, D. R. Petit, L. J. Petit, and D. F. Bradford. 2000. Bird communities and habitat as ecological indicators of forest condition in regional monitoring. Conservation Biology 14:544-558.

Chow-Fraser, P. 2006. Development of the Water Quality Index (WQI) to assess basin-wide land-use alteration on coastal marshes of the Laurentian Great Lakes. *in* T. P. Simon and P. M. Stewart, editors. Coastal Wetlands of the Laurentian Great Lakes: Health, Habitat and Indicators.

Cohen, J. E. 2003. Human population: the next half century. Science 302:1172-

1175.

Crewe, T. L., and S. T. A. Timmermans. 2005. Assessing biological integrity of Great Lakes coastal wetlands using marsh bird and amphibian communities. Project # WETLANDS3-EPA-01 Technical Report, Bird Studies Canada, Port Rowan, Ontario.

Croft, M. V., and P. Chow-Fraser. 2007. Use and development of the wetland macrophyte index to detect water quality impairment in fish habitat of Great Lakes coastal marshes. Journal of Great Lakes Research 33:172-197.

Croft, M. V., and P. Chow-Fraser 2009. Non-random sampling and its role in habitat conservation: a comparison of three wetland macrophyte sampling protocols. Biodiversity and Conservation. Online publication date 13 March 2009.

Crosbie, B., and P. Chow-Fraser. 1999. Percentage land use in the watershed determines the water and sediment quality of 22 marshes in the Great Lakes basin. Canadian Journal of Fisheries and Aquatic Science 56:1781-1791.

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake Bay, USA. Wetlands 24:837-847.

ESRI Inc. 2006. ArcMap 9.2.

Houlahan, J. E., and C. S. Findlay. 2004. Estimating the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality. Landscape Ecology 19:677-690.

Howe, R. W., R. R. Regal, J. M. Hanowski, G. Niemi, N. P. Danz, and C. R. Smith. 2007. An index of ecological condition based on bird assemblages in Great Lakes coastal wetlands. Journal of Great Lakes Research 33:93-105.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Niemi, G. J., and M. E. McDonald. 2004. Application of ecological indicators. Annual Review of Ecology, Evolution and Systematics 35:89-111.

OMNR, 2008. Southern Ontario Land Resource Information System. Ver.1.2. Land Information Ontario, Ministry of Natural Resources, Queen's Printer for Ontario, Toronto.

Paracuellos, M., and J. L. Telleria. 2004. Factors affecting the distribution of a waterbird community: the role of habitat configuration and bird abundance. Waterbirds 27:446-453.

Ralph, J. C. 1981. Terminology used in estimating numbers of birds. Studies in Avian Biology 6: 577-578.

Reynaud, P. A., and J. Thioulouse. 2000. Identification of birds as biological markers along a Neotropical urban-rural gradient (Cayenne, French Guiana), using co-inertia analysis. Journal of Environment Management 59:121-140.

Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.

Schulze, C. H., M. Waltert, P. J. A. Kessler, R. Pitopang, Shahabuddin, D. Veddeler, M. Muhlenberg, S. R. Gradstein, C. Leuschner, I. Steffan-Dewenter, and T. Tscharntke. 2004. Biodiversity indicator groups of tropical land-use systems: comparing plants, birds, and insects. Ecological Applications 14:1321-1333.

Seilheimer, T. S., and P. Chow-Fraser. 2006. Development and use of the Wetland Fish Index to assess the quality of coastal wetlands in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Science 63:354-366.

Seilheimer, T. S., and P. Chow-Fraser. 2007. Application of the wetland fish index to northern Great Lakes marshes with an emphasis on Georgian Bay coastal wetlands. Journal of Great Lakes Research 33(SI 3):154-171.

Seilheimer, T. S., T. Mahoney and P. Chow-Fraser. 2009. Comparative study of ecological indices for assessing human-induced disturbance in coastal wetlands of the Laurentian Great Lakes. Ecological Indicators 9: 81-91.

Siegel, R. B., D. F. Desante, and M. P. Nott. 2001. Using point counts to establish conservation priorities: how many visits are optimal? Journal of Field Ornithology 72:228-235.

Snell, E. A. 1987. Wetland distribution and conversion in southern Ontario, Working Paper No. 48. Inland Waters and Lands Directorate, Environment Canada.

StatSoft, Inc. (2001). STATISTICA (data analysis software system), version 6. www.statsoft.com.

UNEP (United Nations Environmental Program). 1995. Global Biodiversity Assessment, V. H. Heywood Ed. Cambridge University Press, Cambridge.

U.S. EPA (United States Environmental Protection Agency) 2006. A Manager's Guide to Indicator Selection. U.S. EPA Office of Research and Development, Washington, DC 20460, EPA/600/S-06/002.

Uzarski, D. G., T. M. Burton, M. J. Cooper, J. W. Ingram, and S. T. A. Timmermans. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five great lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31:171-187.

Van Biema, D. and J. Walsh. 1995. Prophet of poison. Time Magazine 145:26-34.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science 277:494-499.

Wang, L., J. Lyons, P. Kanehl, and R. Bannerman. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. Environmental Management 28: 255-266.

Table 4-1. A list of coastal marshes surveyed for birds, vegetation, and water quality along the shores of Lake Ontario and eastern Georgian Bay between 2001 and 2007.

Site	Site code	Lake	Year sampled for birds and vegetation	Year of land use (1 km buffer)	Year of water quality sampling
Corbman Bay	CRB	Georgian Bay	2006	IKONOS 2003	2006
North Bay 2	NB2	Georgian Bay	2006		2006
North Bay 3	NB3	Georgian Bay	2006		-
Parry Island 1	PY1	Georgian Bay	2006	IKONOS 2002	2006
Picnic Island 2	PI2	Georgian Bay	2006		-
South Bay 1	SB1	Georgian Bay	2006		-
South Bay 2	SB2	Georgian Bay	2006		-
Bronte Creek	BR	Ontario	2006		2002
Credit River	CR	Ontario	2006		2002
Crysler	CY	Ontario	2007		-
Darlington	DA	Ontario	2006	SOLRIS 2000-2002	2001
Oakville Marsh	OK	Ontario	2007		-
Rattray Marsh	RT	Ontario	2007		-
Van Wagners	VW	Ontario	2007		2007

Table 4-2. Differences in wetland size, avian species richness, avian abundance, IMBCI, land use, and the WQI between Georgian Bay and Lake Ontario coastal wetlands. Shown are means ± 1SE and significant results are indicated with an *.

Variable	Lake			
	Georgian Bay (n = 7)	Lake Ontario (n = 7)	Test statistic	P
Wetland size (ha)	6.44 ± 2.17	8.26 ± 1.55	t = 0.680	0.509
Species richness	5.9 ± 0.88	7.9 ± 1.0	t = 1.49	0.162
Average abundance per wetland	8.2 ± 1.9	13.7 ± 1.6	t = 2.25	0.044*
IMBCI	3.04 ± 0.37	4.23 ± 0.90	t = 1.22	0.245
Land use (Braun-Blanquet and % altered, 1 km buffer)	1.29 ± 0.18 (<5%)	4.86 ± 0.14 (76-100%)	z = 3.34	<0.001*
WQI	1.22 ± 0.12	-1.39 ± 0.24	t = 8.59	<0.001*

Table 4-3. Differences in vegetation variables and Julian day between Georgian Bay and Lake Ontario coastal wetlands surveyed between 2006 and 2007. Shown are means ± 1SE and significant results are indicated with an *. Z-values represent the results of Mann-Whitney U-tests.

Variable	Lake			
	Georgian Bay	Lake Ontario	z	P
% cattails	0.14 ± 0.14	44.3 ± 5.45	3.26	<0.01*
% bulrush	20.0 ± 7.2	0 ± 0	2.25	0.025*
Average vegetation height (m)	0.54 ± 0.07	1.63 ± 0.19	3.04	<0.01*
% open water	27.9 ± 9.0	40.1 ± 5.3	1.16	0.247
% floating	33.6 ± 10.3	0 ± 0	2.61	<0.01*
Julian day	160 ± 2.5	162 ± 8.7	0.19	0.848

Figure 4-1. A map of the lower Laurentian Great Lakes showing coastal wetland study sites surveyed along the shoreline of Lake Ontario and Georgian Bay.

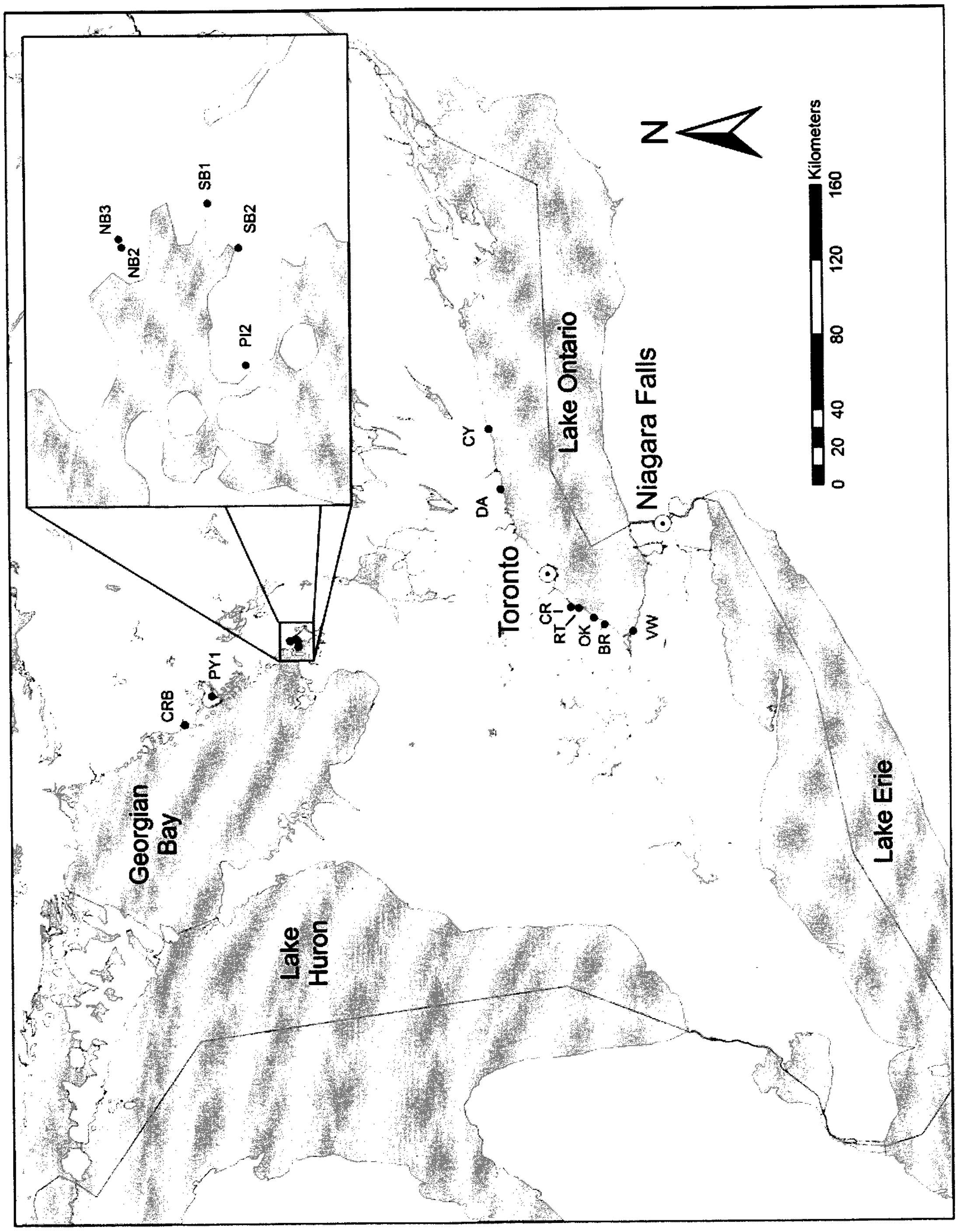
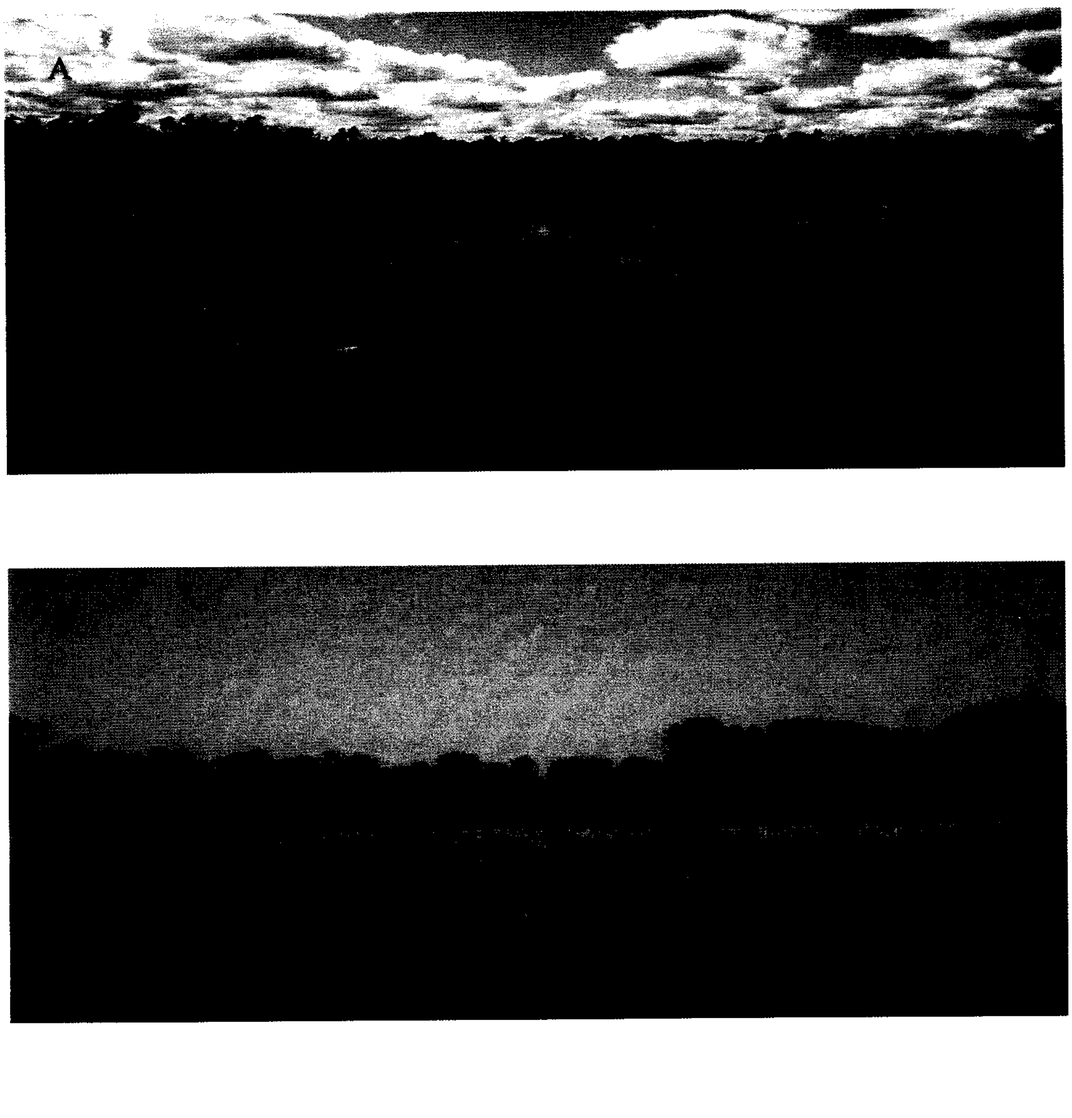

NB3
NB2
SB1
SB2
PI2
CY
DA
Toronto
CR
RT
OK
BR
VW
PY1
CRB
Georgian Bay
Lake Huron
Lake Ontario
Niagara Falls
Lake Erie
N
0 20 40 80 120 160
Kilometers

Figure 4-2. A figure showing typical wetlands A) along the eastern shore of Georgian Bay, and B) along the north shore of Lake Ontario.


A

CHAPTER 5:

THE INFLUENCE OF WATERSHED LAND USE AND WETLAND WATER QUALITY ON MARSH BIRD COMMUNITIES

Lyndsay A. Smith and Patricia Chow-Fraser

ABSTRACT

Many marsh bird species have shown declines over the past 40 years through the North American Breeding Bird Survey, and habitat loss is thought to be the driving force behind these declines. With the exponentially growing human population comes the need for additional infrastructure, and therefore the conversion of natural areas into urban areas. These land use changes indirectly affect downstream aquatic systems, such as coastal wetlands, through increased nutrient inputs and decreased water quality. We surveyed 14 coastal wetlands in southern Ontario to determine the impact of watershed land use and wetland water quality on marsh bird communities. Within the highly degraded landscape of southern Ontario, wetland area was more important than watershed land use in predicting wetland water quality, and this emphasizes the importance of large marshes in highly disturbed contexts. We also found that marsh size was more important than wetland water quality in predicting the Index of Marsh Bird Community Integrity (IMBCI), and the abundance and richness of obligate marsh-nesting birds and insectivorous birds. We did find that sites with more insects tended to have a greater abundance and richness of insectivorous birds, although these results were not statistically significant. Therefore, obligate marsh-nesting birds and insectivorous birds do not appear to be affected by wetland water quality, at least for the range of water quality values included in this study, and a more important factor controlling insectivorous bird communities may be food abundance. We hope that these results will aid in the

conservation of large wetlands in southern Ontario and stimulate future research into factors affecting the distribution of wetland birds.

INTRODUCTION

The impacts of watershed land use on downstream aquatic systems and wetland water quality has been well documented in the literature (Crosbie and Chow-Fraser 1999, Houlahan and Findlay 2004, Chow-Fraser 2006). Large-scale land alterations in watersheds through agriculture and urban development lead to water quality impairment through increased nutrient inputs. Excess nitrogen, phosphorus, and suspended solids accumulate in wetlands reducing water clarity and increasing light attenuation. These water quality changes subsequently affect sensitive aquatic organisms and plant communities, resulting in more tolerant plant and animal communities, while eliminating rare and sensitive species (Houlahan et al. 2006, Seilheimer and Chow-Fraser 2006, Croft and Chow-Fraser 2007).

Obligate wetland birds require marsh habitat for nesting and feeding and many species have shown continent-wide declines over the past 40 years based on the North American Breeding Bird Survey (Sauer et al. 2008). The Marsh Monitoring Program has shown similar trends and even more drastic declines for additional species over the past 10 years (Crewe et al. 2006). Concern over these declines has led to the listing of the King Rail (*Rallus elegans*), Least Bittern (*Ixobrychus exilis*), and Yellow Rail (*Coturnicops noveboracensis*) in Canada as endangered, threatened, and of special concern, respectively (COSEWIC 2000, 2001a, 2001b). While it is widely accepted that humans are the cause of these declines, the direct mechanisms are not completely understood, especially in coastal wetland systems.

One route through which land use may impact wetland bird communities is through changes in the aquatic environment. The amount of altered land in the watershed has been shown to be directly related to the wetland water quality (Crosbie and Chow-Fraser 1999, Houlahan and Findlay 2004, Chow-Fraser 2006), and to adversely affect plant (Houlahan et al. 2006, Croft and Chow-Fraser 2007), fish (Seilheimer and Chow-Fraser 2006), and insect communities (Anderson and Vondracek 1999, Gage et al. 2004, Chipps et al. 2006). Marsh-obligate nesters such as the Least Bittern, American Bittern (*Botaurus lentiginosus*), Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), King Rail, Yellow Rail, Pied-billed Grebe (*Podilymbus podiceps*), Black Tern (*Chlidonias niger*), Common Moorhen (*Gallinula chloropus*), and American Coot (*Fulica americana*) rely primarily on the aquatic environment for food and nesting, and it is likely that these species will be affected by water quality impairment. Another avian group that has shown responses to anthropogenic disturbance in the watershed are insectivorous birds (Brazner et al. 2007). Many insects rely on the aquatic environment for at least some part of their life cycle (Elzinga 2000), and therefore birds using wetlands for feeding may be good indicators of the health of the aquatic environment.

In this paper we examine the impacts of watershed land use on bird communities in coastal wetlands of southern Ontario. We hypothesize that disturbance in the watershed alters the bird community through the aquatic environment, and we predict that sites with lower water quality will have fewer obligate marsh-nesting species, insectivorous birds, and lower integrity values predicted using the Index of Marsh Bird Community Integrity (IMBCI; DeLuca et al. 2004).

METHODS

Study sites

We surveyed bird communities in 14 coastal wetlands throughout the Laurentian Great Lakes Region of southern Ontario, Canada between 2006 and 2007. Wetlands ranged in the degree of eutrophication, and the proportion of altered land in the watershed ranged from 62% to 95% (Fig. 5-1, Table 5-1). Wetlands also varied in size from 3.5 ha to 5963.6 ha. We selected sites to represent a range of disturbance; however, we also relied on landowner permission and wetland accessibility. These wetlands were cattail-dominated marshes (*Typha* spp.) and were either riverine or lacustrine systems.

Land use

We analyzed land use at the quaternary watershed level using the Southern Ontario Land Resources Information System (SOLRIS; OMNR 2008) and ArcMap 9.2 (ESRI Inc. 2006). SOLRIS is a geographical information system platform consisting of digital polygons of 23 different land use classes for all of southern Ontario (Table 5-2). For analysis, we grouped these 23 land use classes into two subclasses: altered land and unaltered land. For our measure of disturbance, we calculated the proportion of altered land in each watershed.

It is important to note that SOLRIS was created based on aerial images from 2000-2002, whereas our study will utilize information collected from 2006-2007. We identified changes in land use since 2000-2002 using Google Earth images from 2004-2007 for three randomly selected sites at a scale of 4000m from the edge of the wetland. We determined that the data were a good representation of current land use because differences were minimal, and involved the conversion of on average 0.6% of the land from either rural/wildlands or forest to impervious urban areas or roads.

Water quality

Wetland water quality was sampled primarily between 2001 and 2002 (Table 5-1) at 13 sites. We did use water quality data for three wetlands which were collected in 1995, 1996, and 2007. Based on water quality samples, we then calculated the Water Quality Index (WQI) which was created from 12 water quality variables. WQI scores can range from -3 to +3 with negative scores representing highly degraded wetlands and positive scores representing more pristine wetlands. For detailed water quality sampling protocols and development of WQI scores please see Chow-Fraser (2006).

Avian sampling

All point counts were sampled from a canoe between 1 May and 27 July. Each count was conducted twice throughout the season at least 10 days apart and the results of each survey were averaged. All counts were conducted between sunrise and four hours after sunrise, and surveys were not conducted in high winds >20 km/h or during periods of rainfall. Point counts were 10 minutes in length and a 25 m radius full circle was used.

We located our first sample point at the emergent vegetation-water interface closest to the canoe launch point but at least 25 m from the shore. Once we arrived at the point count, one minute was allowed for birds to settle. We recorded all birds seen and heard regardless of age (immature vs. adult) or sex. We counted all individuals which were landing, flushing, wading, perching, or calling within the point count area. If the bird was foraging in the wetland (e.g. swallows, swifts, terns, gulls, birds of prey) they were included in the point count if they were <25 m above the wetland. If birds were flushed upon our approach (e.g. herons or egrets), they were included in the count.

After the 10 minute passive period, we broadcasted the songs of secretive marsh birds in the following order including the American Coot, American Bittern, Least Bittern, Pied-billed Grebe, Sora, Virginia Rail, Common Moorhen, King Rail, and Yellow Rail. Calls were broadcast at a sound level of 70-85 dB at a distance of 1 m from the front of the speakers which were oriented to broadcast directly into the patch of emergent vegetation. The speakers were held at a height of 0.75 m above the water surface. In the broadcast sequence, each species' call varied in length (35 to 110 sec), but each species call was separated by a 30 sec pause. Call-broadcasts were played for a total of 14 min after the passive period and 2 min were left at the end of the call-broadcasts to listen for responses. Subsequent point counts were located by paddling further into the wetland, and all point counts were at least 200 m apart to ensure each individual was a new detection (Siegel et al. 2001). We conducted as many point counts at each site as was possible in the morning sampling period or until we surveyed the entire wetland.

Insect Sampling Protocol

We sampled insects at three wetlands in 2007 using Malaise traps to capture flying insects to gain a greater knowledge of the total biomass, abundance and richness of insects within the wetlands. Malaise traps were positioned at the first two point counts in the study wetlands, and were set up in emergent vegetation. Traps were set with soapy water at Oakville Marsh on 18 June 2007, Jordan Harbour on 25 June 2007, and Van Wagner's Pond on 3 July 2007. Traps were then allowed to accumulate insects for one week, and samples were frozen shortly after collection. For identification, samples were thawed overnight and then processed the following day. Insects were identified to order and subsequently stored in 70% ethanol. Prior to weighing, we strained the insects and then allowed the ethanol to evaporate for 24 hours in a fume hood.

Insectivorous birds included in the analysis were the Red-winged Blackbird (*Agelaius phoeniceus*), American Goldfinch (*Carduelis tristis*), Cliff Swallow (*Petrochelidon pyrrhonota*), Tree Swallow (*Tachycineta bicolour*), Barn Swallow (*Hirundo rustica*), Purple Martin (*Progne subis*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Common Grackle (*Quiscalus quiscula*), Yellow Warbler (*Dendroica petechia*), Song Sparrow (*Melospiza melodia*), Swamp Sparrow (*Melospiza Georgiana*), Marsh Wren (*Cistothorus palustris*), Eastern Kingbird (*Tyrannus tyrannus*), Chimney Swift (*Chaetura pelagica*), Cedar Waxwing (*Bombycilla cedrorum*), Willow Flycatcher (*Empidonax traillii*).

Statistical analysis

All analyses were performed using Statistica 6.0 (StatSoft Inc. 2001). In order to determine the relative importance of both watershed land use and wetland area on the WQI, we used Akaike's Information Criterion (AIC). Comparing model support allowed us to identify which model was most parsimonious and most closely reflected the actual data. We calculated *i* to examine the difference between the AIC*c* (AIC corrected using a bias adjustment for small sample sizes) for each candidate model and the model with the lowest AIC*c* score. Akaike weights (w_i) were calculated for each model to examine the relative likelihood of the model given the data. These resulting weights sum to one across all models and are interpreted as probabilities where a model with an Akaike weight approaching one is strongly supported by the data (Johnson and Omland 2004). Wetland area was log10-transformed for this analysis and the measure of disturbance we used was the proportion of altered land in the watershed.

We also used AIC to examine the impact of water quality on several bird communities while considering the already known impact of wetland size (Smith and Chow-Fraser Chapter 2). We looked at the effect of the WQI on obligate marsh-nesting birds, insectivorous bird species, and on the Index of Marsh Bird Community Integrity (IMBCI; DeLuca et al. 2004). This index is modelled after the Index of Biotic Integrity (IBI) concept where biotic integrity measures the ability of an area to support and maintain an adaptive species community and functional organization that is synonymous with the natural habitat of the region (Karr and Dudley 1981). High integrity scores indicate wetlands containing marsh bird communities with many wetland-specialized species, and few generalists. The index was developed with a guild-based approach and specifically examines foraging, nesting, and migratory guilds, along with breeding range. We used Pearson correlation to examine the relationship between insect communities and insectivorous bird communities.

RESULTS

We found wetland area to be a better predictor of the WQI than the amount of altered land in the watershed (Table 5-3) with larger wetlands showing improved water quality ($\beta = 0.594$, SE = 0.243). Wetland size alone ($w_i = 0.833$)

was 16 times more likely to be the best model to explain variation in the WQI than the model including disturbance alone ($w_i = 0.052$). Also, the model with wetland size alone was eight times more likely to be the best model to explain the WQI than the model including both size and disturbance ($w_i = 0.115$).

Wetland size was also more important than water quality in influencing the wetland bird community (Table 5-4). The IMBCI was better predicted by wetland size alone than by the WQI or a model incorporating the WQI and size. The IMBCI increased with increasing wetland size (ß = 0.486, SE = 0.264). The average abundance and richness of obligate marsh nesting birds was 2.64 and 2.74 times (respectively) more likely to be predicted by wetland size than the WQI. Larger wetlands had on average more obligate marsh-nesting birds (ß = 0.535, SE = 0.255) and more obligate marsh-nesting species (ß = 0.604, SE = 0.240).

We also found wetland size to be more important than the WQI for predicting the abundance of insectivorous birds per point count, larger marshes containing more individuals than smaller marshes (ß = 0.464, SE = 0.267). We found an opposite result than expected for the influence of size and water quality on the richness of insectivorous birds. The model including both wetland size and the WQI was on average 14.1 times more likely to predict the richness of insectivorous birds than models including wetland size and the WQI alone. For the model including both size and the WQI, the number of insectivorous species was negatively related to water quality (ß = -0.707, SE = 0.234) but positively related to wetland size (ß = 0.986, SE = 0.234).

Overall, we collected 4,300 insects from 7 different orders (Fig. 5-2, Table 5-5). We had water quality data for only two out of three wetlands and therefore could not empirically show that water quality affected the insect community. We therefore chose to examine if insect abundance could predict the insectivorous bird community. We found that sites with a greater insect abundance also tended to have more insectivorous birds ($r = 0.9624$, $p = 0.175$, Fig. 5-3a), although these results were not statistically significant. There was no correlation between the richness of insectivorous birds and insect abundance ($r = 0.6427$, $p = 0.556$, Fig. 5-3b).

DISCUSSION

Wetland area was an important factor for predicting water quality in coastal wetlands of southern Ontario. We found that watershed land use was not the most important predictor of water quality for the range of disturbance in our study (62-95% altered land). The finding that larger wetlands have better water quality is consistent with other studies (Kim et al. 2001, Houlahan and Findlay 2004). Larger wetlands have an increased ability to support a larger plant community, and may therefore filter nutrients and sediments more efficiently than small wetlands.

The marsh bird communities in this study were always better predicted by wetland size than by water quality in the wetland. This finding is another example of the wide-reaching effects of the species-area relationship for wetland birds in southern Ontario (Smith and Chow-Fraser Chapter 2). We found that the WQI was not a good predictor of the wetland bird community in southern Ontario marshes. This could be related to the small range of degradation and lack of reference conditions in this study (WQI scores all ranged from -2.31 to 0.613), with no wetlands scoring higher than 1.0, which indicates "very good" conditions.

Another reason for the absence of an effect of water quality on the wetland bird community could be that birds prefer wetlands with higher nutrient levels (Hoyer and Canfield 1994, Crozier and Gawlik 2002). Wetlands with higher WQI scores (less impacted sites) are not as productive as sites with lower WQI scores, and generally support primarily pollution-intolerant species of submersed aquatic vegetation, with few emergent species (Croft and Chow-Fraser 2007). Most obligate marsh-nesting birds rely on some form of emergent vegetation (primarily *Typha* spp.) for nesting in southern Ontario, and therefore some degree of eutrophication may be preferred for nesting birds.

Hoyer and Canfield (1994) showed that the abundance and biomass of birds using 46 Florida lakes was significantly positively related to nitrogen, phosphorus, and chlorophyll a concentrations. These findings were corroborated by a study in the Florida everglades that tracked bird communities in wetlands ranging from non-enriched to enriched conditions (average total phosphorus 8 ug/L and 116 ug/L, respectively). Enriched wetlands had a greater coverage of cattails, and also contained more birds than non-enriched wetlands (Crozier and Gawlik 2002).

While eutrophication is a natural process, often occurring as lakes age over hundreds of years, the forms of eutrophication encountered in settled areas of the Great Lakes represent cultural eutrophication, which is an accelerated, unnatural form. Therefore, responses of birds to increased nutrient inputs may reflect true patterns, but ones that have been magnified by humans. Future studies should be done to look at a very broad range of disturbance in order to determine the point at which wetlands either become too oligotrophic or too eutrophic to sustain suitable nesting vegetation.

Since we could not prove that sites with poorer water quality had fewer insects, we cannot make direct conclusions about the impact of water quality on insect communities. Previous studies have shown that increased disturbance near wetlands can lead to water-quality impairment and a decrease in the diversity of macroinvertebrates (Chipps et al. 2006). Poorer water quality in wetlands has also been linked to lower total insect abundances at coastal wetlands in the Great Lakes Region (Kashian and Burton 2000).

Insectivorous birds were positively related to insect abundance in our study; sites containing more insects also contained a greater number of insectivorous birds. Three main factors may be considered ultimate controlling variables for habitat selection in birds: 1) food, 2) structural and functional habitat requirements, and 3) shelter from enemies and the elements (Hilden 1965). Food abundance is ultimately important for birds in controlling nest success, nestling growth rates, and juvenile survival for many species (Quinny et al. 1986, Rodenhouse and Holmes 1992, Cox et al. 1998, Sparling et al. 2007). Birds have the ability to choose territories with more food, and can even increase clutch size in response to increased food availability (Martin 1989).

Food availability was positively related to nest success for Red-winged Blackbirds nesting in storm-water retention wetlands, indicating that higher rates of nest success for birds may be associated with higher insect abundance (Sparling et al. 2007). Mallards (*Anas platyrhynchos*) breeding in wetlands with greater food availability produced ducklings with a greater body mass, faster growth rates and increased survival rates than in wetlands with fewer insects (Cox et al. 1998). Future studies on avian habitat selection should incorporate data on food availability because it could be an important factor for predicting species occurrence patterns and reproductive success.

In addition to reproductive requirements, insects are an important food source during migration, and bird abundance has been shown to be predicted by insect abundance for migratory bird populations (Newton 2006). Also, coastal areas in particular are important stopover sites for migrating birds and have been shown to contain more insects than inland areas (Smith et al. 2007). Therefore, coastal wetlands are also important stopover sites for migrating birds, and future research should examine migratory use of wetlands in relation to food availability for birds in southern Ontario.

In this paper, we highlight another potential route through which land use may indirectly impact bird communities, and we hope that these results would stimulate future research. Future studies should strive to include a large number of wetlands across a broad range of land use and water quality conditions, and include a sampling program for insect abundance, to determine if water quality is a potential path through which land use impacts the wetland bird community and subsequent nest success.

MANAGEMENT IMPLICATIONS

These findings stress the importance of retaining large wetlands, especially in highly disturbed contexts, to filter nutrients and control water quality.

REFERENCES

Anderson, D. J., and B. Vondracek. 1999. Insects as indicators of land use in three ecoregions in the Prairie Pothole Region. Wetlands 19:648-664.

Brazner, J. C., N. P. Danz, G. J. Niemi, R. R. Regal, A. S. Trebitz, R. W. Howe, J. M. Hanowski, L. B. Johnson, J. J. H. Ciborowski, C. A. Johnston, E. D. Reavie, V. J. Brady, and G. V. Sgro. 2007. Evaluation of geographic, geomorphic and human influences on Great Lakes wetland indicators: A multi-assemblage approach. Ecological Indicators 7:610-635.

Chipps, S. R., D. E. Hubbard, K. B. Werlin, N. J. Haugerud, K. A. Powell, J. Thompson, and T. Johnson. 2006. Association between wetland disturbance and biological attributes in floodplain wetlands. Wetlands 26:497-508.

Chow-Fraser, P. 2006. Development of the Water Quality Index (WQI) to assess basin-wide land-use alteration on coastal marshes of the Laurentian Great Lakes. *in* T. P. Simon and P. M. Stewart, editors. Coastal Wetlands of the Laurentian Great Lakes: Health, Habitat and Indicators.

COSEWIC, 2000. COSEWIC assessment and update status report on the King Rail (*Rallus elegans*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii +10pp.

COSEWIC, 2001a. COSEWIC assessment and status report on the Yellow Rail (*Coturnicops noveboracensis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 62 pp.

COSEWIC, 2001b. COSEWIC assessment and update status report on the Least Bittern (*Ixobrychus exilis*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. v + 10pp.

Cox, R. R., M. A. Hanson, C. C. Roy, N. H. Euliss, D. H. Johnson, and M. G. Butler. 1998. Mallard duckling growth and survival in relation to aquatic invertebrates. The Journal of Wildlife Management 62:124-133.

Crewe, T. L., S. T. A. Timmermans, and K. E. Jones. 2006. The Marsh Monitoring Program 1995 to 2004: A Decade of Marsh Monitoring in the Great Lakes Region. Published by Bird Studies Canada in cooperation with Environment Canada. 28pp.

Croft, M. V., and P. Chow-Fraser. 2007. Use and development of the wetland macrophyte index to detect water quality impairment in fish habitat of Great Lakes coastal marshes. Journal of Great Lakes Research 33:172-197.

Crosbie, B., and P. Chow-Fraser. 1999. Percentage land use in the watershed determines the water and sediment quality of 22 marshes in the Great Lakes basin. Canadian Journal of Fisheries and Aquatic Science 56:1781-1791.

Crozier, G. E., and D. E. Gawlik. 2002. Avian response to nutrient enrichment in an oligotrophic wetland, the Florida Everglades. The Condor 104:631-642.

DeLuca, W. V., C. E. Studds, L. L. Rockwood, and P. P. Marra. 2004. Influence of land use on the integrity of marsh bird communities of Chesapeake

Bay, USA. Wetlands 24:837-847.

Elzinga, R. J. 2000. Fundamentals of Entomology, 5th edition. Prentice-Hall, Upper Saddle River, New Jersey.

ESRI Inc. 2006. ArcMap 9.2.

Gage, M. S., A. Spivak, and C. J. Paradise. 2004. Effects of land use and disturbance on benthic insects in headwater streams draining small watersheds north of Charlotte, NC. Southeastern Naturalist 3:345-358.

Hilden, O. 1965. Habitat selection in birds. Annales Zoologici Fennici 2:53-75.

Houlahan, J. E., and C. S. Findlay. 2004. Estimating the 'critical' distance at which adjacent land-use degrades wetland water and sediment quality. Landscape Ecology 19:677-690.

Houlahan, J. E., P. A. Keddy, K. Makkay, and C. S. Findlay. 2006. The effects of adjacent land use on wetland species richness and community composition. Wetlands 26:79-96.

Hoyer, M. V., and D. E. Canfield Jr. 1994. Bird abundance and species richness on Florida lakes: influence of trophic status, lake morphology, and aquatic macrophytes. Hydrobiologia 297/280:107-119.

Johnson, J. B., and K. S. Omland. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution 19:101-108.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Kashian, D. R. and T. M. Burton. 2000. A comparison of macroinvertebrates of two Great Lakes coastal wetlands: testing potential metrics for an index of ecological integrity. Journal of Great Lakes Research 26:460-481.

Kim, J. G., Rejmánková, E., and H. J. Spanglet. Implications of a sediment-chemistry study on subalpine marsh conservation in the Lake Tahoe basin, USA. Wetlands 21:379-394.

Martin, T. E. 1989. Breeding productivity considerations: what are the appropriate habitat features for management? Pages 455-472 *in* Manomet Symposium.

Newton, I. 2006. Can conditions experienced during migration limit the population levels of birds? Journal of Ornithology 147:146-166.

OMNR, 2008. Southern Ontario Land Resource Information System. Ver.1.2. Land Information Ontario, Ministry of Natural Resources, Queen's Printer for Ontario, Toronto.

Quinney, T. E., D. J. T. Hussell, and C. D. Ankney. 1986. Sources of variation in growth of Tree Swallows. Auk 103:389-400.

Rodenhouse, N. L., and R. T. Holmes. 1992. Results of experimental and natural food reductions for breeding Black-throated Blue Warblers. Ecology 73:357-372.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966-2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Seilheimer, T. S., and P. Chow-Fraser. 2006. Development and use of the

Wetland Fish Index to assess the quality of coastal wetlands in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Science 63:354-366.

Siegel, R. B., D. F. Desante, and M. P. Nott. 2001. Using point counts to establish conservation priorities: how many visits are optimal? Journal of Field Ornithology 72:228-235.

Smith, R. J., F. R. Moore, and C. A. May. 2007. Stopover habitat along the shoreline of northern Lake Huron, Michigan: emergent aquatic insects as a food resource for spring migrating landbirds. Auk 124:107-121.

Sparling, D. W., J. Eisemann, and W. Kuenzel. 2007. Nesting and foraging behaviour of Red-winged Blackbirds in stormwater wetlands. Urban Ecosystems 10:1-15.

StatSoft, Inc. (2001). STATISTICA (data analysis software system), version 6. www.statsoft.com.

Table 5-1. Fourteen coastal wetland study sites in southern Ontario, Canada.

Study site	Site code	Proportion altered land in the watershed	Wetland size (ha)	Years sampled for:		
				Birds	Water quality	Insects
Blessington Bay	BB	0.6181	98.1	2007	2002	-
Bronte Creek	BR	0.6849	7.2	2006	2002	-
Cootes Paradise	CP	0.6987	63.0	2006	2002	-
Grindstone Creek	GC	0.7396	18.1	2006	2002	-
Credit River	CR	0.7471	14.7	2006	2002	-
Oakville Marsh	OK	0.7611	3.5	2007	-	2007
Long Point	LP	0.7689	5963.6	2006	2001	-
Fifteen Mile Creek	FI	0.8151	22.3	2007	2002	-
Grand River	GR	0.8192	811.0	2006	2001	-
Second Marsh	SM	0.8454	63.5	2007	1995	-
Jordan Harbour	JH	0.8518	32.7	2007	2002	2007
Turkey Creek	TC	0.8804	16.2	2007	1996	-
Van Wagners Pond	VW	0.9347	12.6	2007	2007	2007
Rondeau	RN	0.9484	483.4	2007	2001	-

Table 5-2. SOLRIS designation of 23 land use classes and descriptions, grouped as altered or unaltered for analysis.

Land use class	Grouping	Description
Open cliff and talus	Unaltered	Vertical or near-vertical exposed bedrock > 3 m in height / slopes of rock rubble at the base of cliffs. Subject to active processes / < 25% vegetative cover
Open shoreline	Unaltered	Substrate consists of unconsolidated parent or mineral material. Subject to active processes / < 25% vegetative cover
Open bluff	Unaltered	Steep to near-vertical exposure of unconsolidated material > 2 m in height. Subject to active processes / < 25% vegetative cover
Open sand barren and dune	Unaltered	Exposed sands formed by extant or historical shoreline or Aeolian processes. Subject to active processes / < 25% vegetative cover
Open tallgrass prairie	Unaltered	Ground layer dominated by prairie gramminoids; variable cover of open-grown trees. Tree cover < 25%; shrub cover
Tallgrass savannah	Unaltered	Ground layer dominated by prairie gramminoids; variable cover of open-grown trees, 25% < tree cover < 35%
Tallgrass woodland	Unaltered	Ground layer dominated by prairie gramminoids; variable cover of open-grown trees, 35% < tree cover < 60%
Forest	Unaltered	Tree cover > 60%. Upland tree species > 75% canopy cover > 2 m in height
Coniferous forest	Unaltered	Tree cover > 60%. Upland conifer tree species > 75% canopy cover > 2 m in height
Mixed forest	Unaltered	Tree cover > 60%. Upland conifer tree species > 25% and deciduous tree species > 25% of canopy cover > 2m in height
Deciduous forest	Unaltered	Tree cover > 60%. Upland deciduous tree species > 75% of canopy cover > 2 m in height
Plantations – tree	Unaltered	Tree cover > 60%, minimum 2 m in height,

cultivated		linear organization, uniform tree type
Hedge rows	Unaltered	Tree cover > 60%, minimum 2 m in height, linear arrangement, minimum 10 m width, maximum 30m width
Swamp	Unaltered	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree or shrub cover > 25% - dominated by hydrophytic shrub and tree species
Fen	Unaltered	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface. - tree cover (trees > 2m high) ≤ 25% - sedges, grasses and low (< 2 m) shrubs dominate, sedge and brown moss peat substrate
Bog	Unaltered	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree cover (trees > 2m high) ≤ 25% sphagnum peat substrate
Marsh	Unaltered	Open, shrub and treed communities - water table seasonally or permanently at, near, or above substrate surface - tree and shrub cover ≤ 25% - dominated by emergent hydrophytic macrophytes
Transportation	Altered	Highways, roads
Extraction	Altered	Pits, quarries
Built-up area pervious	Altered	Urban recreation areas, e.g. golf courses, playing fields
Built-up area impervious	Altered	Residential, industrial, commercial and civic areas
Undifferentiated	Altered	Includes all agricultural features (e.g. field and forage crops and rural properties) as well as urban brown fields, and openings within forests

Table 5-3. Model weights selected using Akaikie's Information Criterion for the influence of wetland size and watershed disturbance on the WQI for 13 southern Ontario coastal marshes.

Model	k	RSS	AICc	Δi	w_i
Size	3	7.554	1.609	0	0.833
Disturbance + Size	4	7.344	5.576	3.967	0.115
Disturbance	3	11.562	7.143	5.535	0.052

Table 5-4. Model weights selected using Akaikie's Information Criterion for the influence of wetland size and wetland water quality (WQI) on bird communities in 13 southern Ontario coastal marshes.

Dependent variable	Model	RSS	AICc	Δi	w_i	Importance weight
IMBCI	Size	55.7	27.6	0	0.520	0.613
	WQI	58.2	28.2	0.591	0.387	0.480
	Size + WQI	51.9	31.0	3.44	0.093	
Overall obligate richness per wetland	Size	22.1	15.6	0	0.654	0.762
	WQI	25.8	17.6	2.02	0.239	0.346
	Size + WQI	20.9	19.2	3.60	0.108	
Obligate average abundance per wetland	Size	29.1	19.1	0	0.662	0.749
	WQI	33.8	21.1	1.94	0.251	0.338
	Size + WQI	28.5	23.2	4.07	0.087	
Overall insectivorous bird richness per wetland	Size	61.4	28.8	4.08	0.114	0.990
	WQI	89.0	33.7	8.91	0.010	0.886
	Size + WQI	32.1	24.8	0	0.876	
Mean insectivorous bird abundance per wetland	Size	424.3	54.0	0	0.664	0.740
	WQI	490.2	55.9	1.88	0.260	0.337
	Size + WQI	423.5	58.3	4.31	0.077	

Table 5-5. Insect biomass, abundance and richness at three coastal wetlands in southern Ontario sampled using Malaise traps in 2007.

Site	Average insect abundance per site	Average insect biomass per site (g)	Overall site insect species richness
Oakville Marsh	942.5	1.14	6
Jordan Harbour	1524	1.65	7
Van Wagners	1833.5	1.74	6

Figure 5-1. Map of coastal wetland study sites in southern Ontario, Canada.

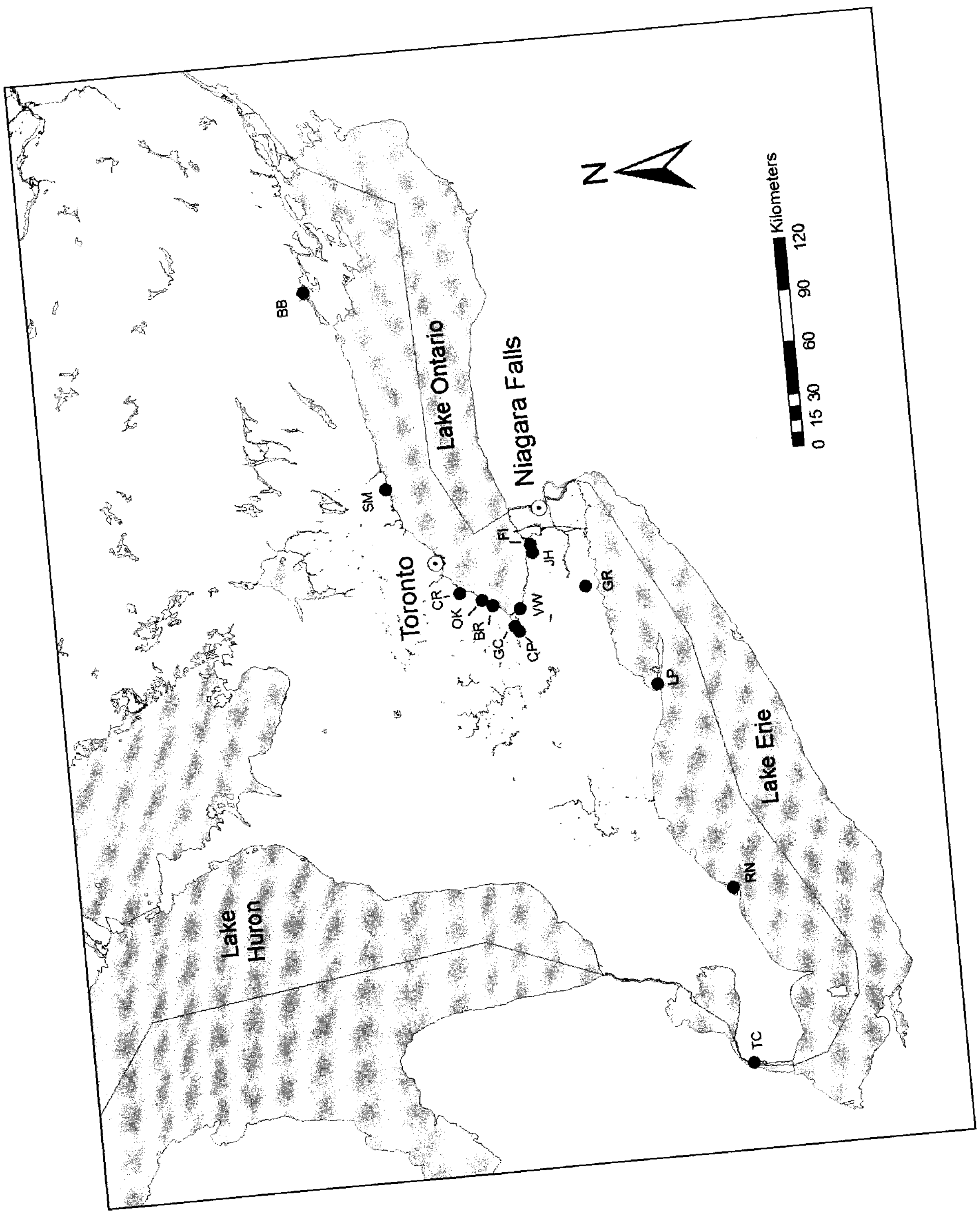

N
Kilometers
0 15 30 60 90 120
Lake Ontario
Niagara Falls
Toronto
Lake Erie
Lake Huron
BB
SM
CR
OK
BR
GC
CP
VW
FI
JH
GR
LP
RN
TC

Figure 5-2. Percent of total insect biomass for each insect order found at three coastal wetlands in southern Ontario.

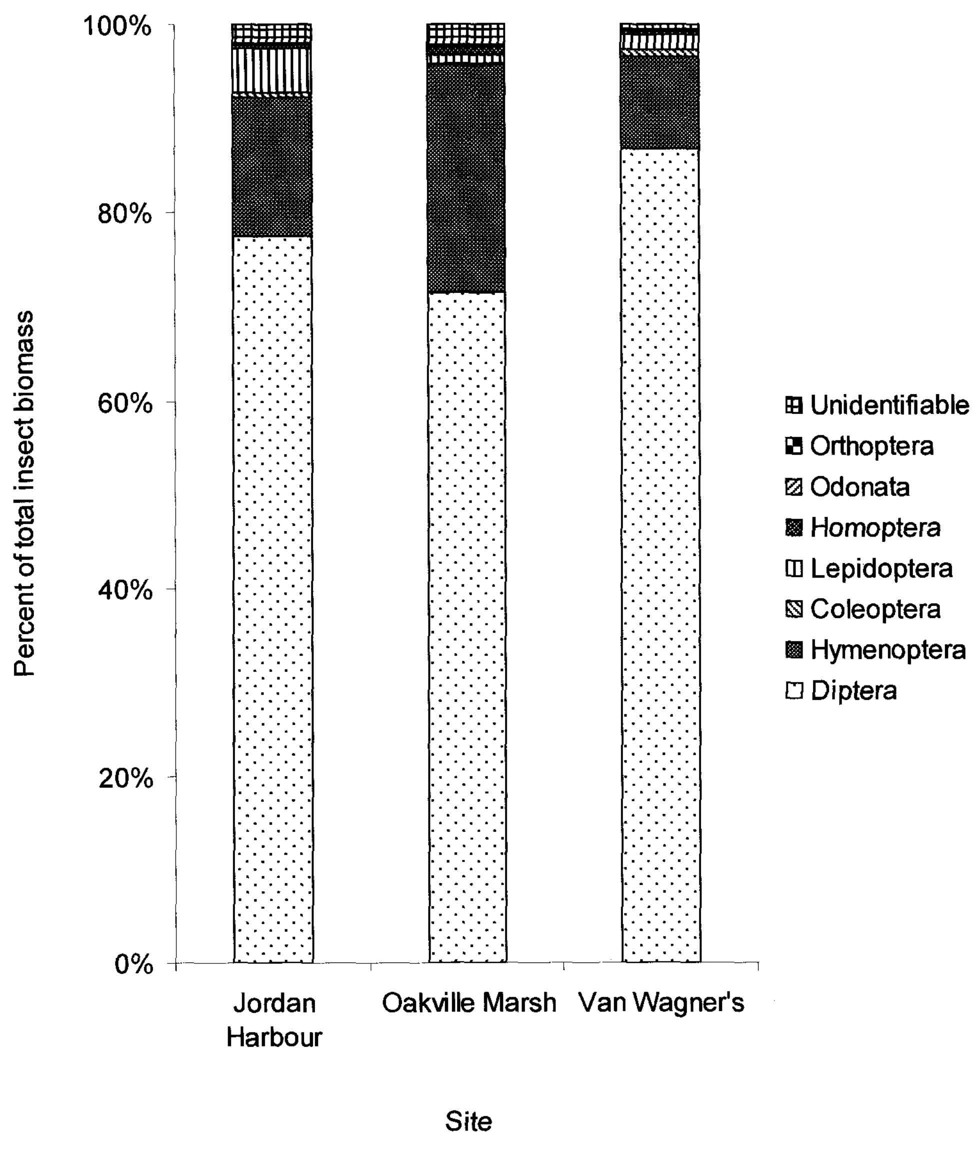
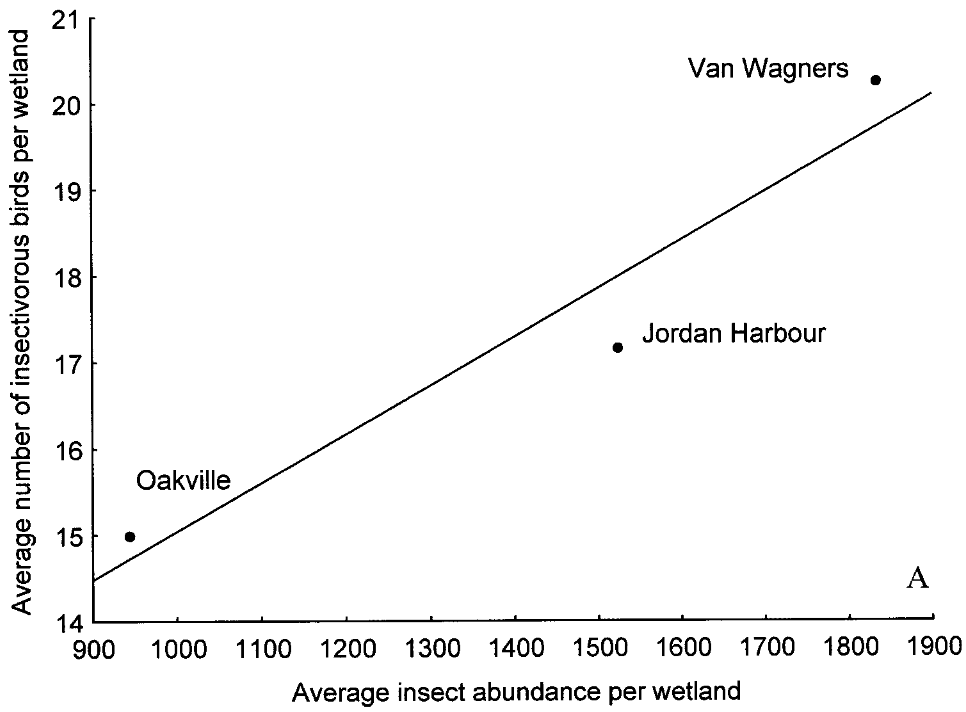
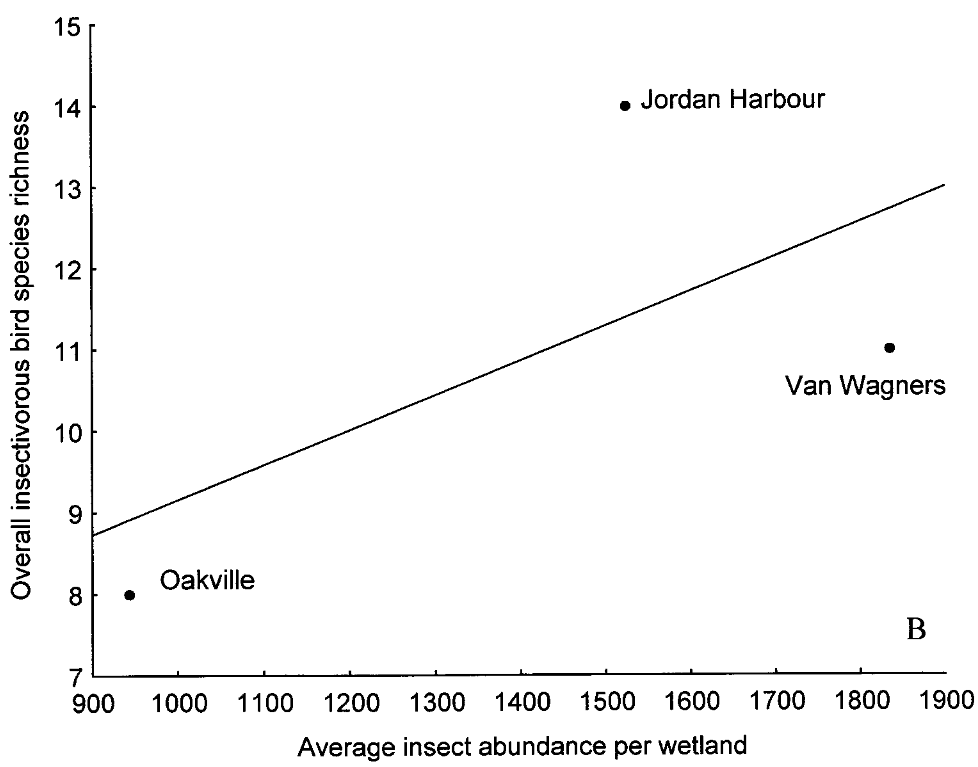

100%
80%
60%
40%
20%
0%
Percent of total insect biomass
Jordan Harbour
Oakville Marsh
Van Wagner's
Site
Unidentifiable
Orthoptera
Odonata
Homoptera
Lepidoptera
Coleoptera
Hymenoptera
Diptera

Figure 5-3. Correlation between wetland insect abundance and the abundance (A) and richness (B) of insectivorous birds at three wetlands in southern Ontario.


21
20
19
18
17
16
15
14
Average number of insectivorous birds per wetland
Van Wagners
Jordan Harbour
Oakville
A
900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900
Average insect abundance per wetland


15
14
13
12
11
10
9
8
7
Overall insectivorous bird species richness
Jordan Harbour
Van Wagners
Oakville
B
900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900
Average insect abundance per wetland

GENERAL CONCLUSIONS

Thesis summary

The primary objectives of this thesis were to examine several aspects of monitoring programs for marsh birds to recommend effective monitoring techniques and to determine the impacts of land use on marsh bird communities in southern Ontario to make recommendations to policy makers. In chapter 1, I found that call-broadcasts were an effective means to monitor secretive marsh birds, with call-broadcasts detecting more species and individuals than passive surveys. Periods of silence between species broadcasts were also important in detecting secretive species, which were detected more often during silent periods than would be expected by chance. Species sharing similar nesting and feeding niches, such as the Sora and Virginia Rail, were more likely to vocalize to each other's calls than birds occupying different nesting and feeding niches. Finally, interior point counts detected more marsh-obligate nesters and fewer generalist species than did edge point counts, and these distribution differences led to higher wetland IMBCI scores at interior point counts than edge point counts.

Chapter 2 applied the species-area relationship (SAR) concept to marsh birds in southern Ontario. There was a positive SAR and a positive integrity-area relationship, with the Marsh Wren, Swamp Sparrow, and all obligate species combined showing area-sensitive patterns. These results suggest that larger wetlands tended to contain more species and species representing higher biological integrity than small wetlands. Even though larger wetlands tended to have higher biological integrity, several small wetlands had comparable integrity

values indicating that small marshes are still important habitat. The SAR was also used to determine effective sampling efforts for wetlands of varying size. The final function revealed a positive relationship, indicating that larger wetlands need to be sampled more extensively than smaller wetlands to avoid underestimating species richness.

In chapter 3, I examined the impact of adjacent land use and marsh isolation on marsh bird communities. Marshes within primarily rural areas consisted of a bird community with many obligate marsh-nesters and few synanthropic species. Marshes surrounded by urbanized areas contained few obligate marsh-nesting species and more synanthropic species. Generalist marsh birds showed no preference for either urban or rural adjacent land uses, as there was no difference in abundance or richness between land use types. The IMBCI performed well in indicating land use within 1 km, with rural wetlands producing higher integrity scores than urban wetlands. In addition to land use, marsh isolation was an important predictor of the bird community. More isolated marshes had lower IMBCI scores and fewer obligate marsh-nesting species than less isolated marshes.

Chapter 4 compared the ability of the IMBCI to distinguish between the degree of landscape disturbance surrounding relatively undisturbed Georgian Bay coastal wetlands and highly degraded Lake Ontario coastal wetlands. In general, Georgian Bay marshes had fewer birds and fewer bird species than marshes of Lake Ontario. Lake Ontario sites had significantly lower water quality and more altered land within 1 km of the wetland edge than Georgian Bay marshes. Irrespective of these differences in land use and water quality, IMBCI values for Georgian Bay and Lake Ontario were statistically similar, and even tended to be higher in Lake Ontario. This discrepancy in performance of the index may be directly due to differences in vegetation. Georgian Bay marshes had more bulrushes and floating vegetation, while Lake Ontario wetlands had more cattails and taller vegetation.

The goal of Chapter 5 was to determine if land use at the watershed scale influenced marsh bird communities through the aquatic environment. First, I wanted to establish that increased disturbance in the watershed indeed leads to a decrease in wetland water quality. Instead, wetland area was a more important factor in predicting wetland water quality, at least for the small range of watershed disturbance in this study (62-95%). Next, I tested to see if wetland water quality could predict the abundance and richness of several avian guilds considered to rely heavily on aquatic resources. Water quality was inferior to wetland size in predicting the IMBCI, and the abundance and richness of obligate marsh-nesting birds and insectivorous birds. Insect sampling results, in conjunction with bird surveys, suggest that birds may select wetlands based on food availability, because wetlands with more insects tended to contain more insectivorous birds.

Recommendations for monitoring

Marsh bird monitoring programs are currently in use and are being expanded throughout North America to track long term changes in population sizes. Several protocols have been established including the North American Marsh Bird Monitoring Protocol (U.S. EPA) and the Marsh Monitoring Program protocol (MMP, Environment Canada). These protocols vary in several aspects including point count radius, duration, number of visits, and optional parameters to be measured such as background noise, water depth and salinity levels.

Each protocol has unique strengths which correspond to weaknesses in the other. Some strengths of the North American Protocol include the possibility of monitoring very small wetlands, the requirement that surveys are conducted three times throughout the season, the requirement of participants to pass a self-administered test every year, and the option of recording several other parameters including water depth and salinity during surveys. Strengths of the MMP include the use of a fixed-radius point count which allows for standardized comparisons, consistent use of broadcasts for all focal species regardless of what species were detected at the site in the first year, inclusion of a larger area for habitat analysis, and a mandatory rating of background noise levels. Deciding on which to use for long-term monitoring should be done based on the prevalence of use of each program in the region of interest.

The MMP has been used extensively throughout the Great Lakes Region and therefore I would recommend its use for tracking long-term population trends in southern Ontario wetlands with the following modifications. The MMP should be modified to include both shoreline and interior point counts instead of the option of performing one *or* the other. Interior point counts, especially in very large marshes, were more effective than edge point counts at detecting focal species, but edge point counts detected more generalist species. I suggest including both types of counts in order to get a good representation of the entire marsh bird community. The inclusion of both shoreline and interior point counts has obvious implications for scientific studies and site assessments prior to development, but the impact of including both shoreline and interior counts for long-term monitoring is not clear. If these programs are consistently missing these species, then the overall trend may not be affected; however, if the information from these programs is being used to describe wetland health, then using only shoreline counts is not an accurate representation of the bird community.

Other findings from this study support the use of multi-species call-broadcasts, periods of silence between species calls during the broadcast sequence, and the inclusion of a final time period after broadcasts to listen for responses. These techniques are already in use for these programs and it is important that they remain an integral part of the standard protocol in the future, and a part of future scientific studies on secretive wetland birds. Another suggestion for improving monitoring programs would be to incorporate guidelines on sampling effort for marshes of varying size. This can be done using the species-area relationship and the functions derived in Chapter 2 to determine appropriate sampling effort. Ensuring sufficient sampling effort in monitoring programs may have similar implications for the data as including interior and shoreline point counts. Prolonged use of inadequate sampling protocols may not affect the detection of long-term population trends, but they may result in data that cannot be used for assessing wetland health. The findings of this study suggest, that as a general rule of thumb, larger wetlands need to be sampled more thoroughly in order to accurately represent avian species richness.

Recommendations for management

Wetland management should be adaptive and be directed by the specific needs of each wetland because they are unique, and are often threatened by many dynamic stressors. In this study, I have identified various factors which are important for the maintenance of suitable marsh bird habitat, which should be only one component of effective wetland management plans.

1. The first and most prominent finding of this study was the importance of large marshes. Large wetlands are very important habitat for all birds, including both obligates and generalists, and this is because they contain both edge and interior habitats. IMBCI scores were higher in larger wetlands, but several small wetlands still produced high scores. Therefore, wetland management plans should strive to preserve wetlands

of all sizes because they contain obligate marsh bird species that rely solely on wetland habitat for survival.

2. Obligate marsh birds were also sensitive to the amount of urbanization within 1 km of the wetland edge. When wetlands had more urban development than rural areas within 1 km, there was a shift in the bird community from obligates to synanthropic species. While obligate marsh birds preferred rural areas over urban areas, generalists showed no preference, indicating the importance of preserving urban wetlands as well. Therefore, existing urban wetlands should be conserved, in addition to rural wetlands, and development should be limited in the surrounding area.
3. The IMBCI can be used to indicate the degree of human disturbance surrounding wetlands, and should be used to assess the health of coastal marshes along the shores of Lake Ontario and Lake Erie. When using this index in large marshes, point counts should be conducted from both the shoreline and the interior of the marsh in order to survey the entire bird community. This index may not be useful in distinguishing wetland health between marshes of Georgian Bay and Lake Ontario, especially when the marshes contain different dominant vegetation types. Marsh isolation should be another consideration when managing wetland habitat for birds. Less isolated marshes were selected for use by more obligate species and less isolated marshes also had higher IMBCI scores than more isolated

marshes. Therefore, managers should strive to maintain wetland complexes, as they are preferred habitat for sensitive bird species.

In summary, the ideal habitat for obligate marsh birds consists of large wetlands, surrounded by undisturbed land within 1 km of the wetland edge, surrounded by many other marshes, and containing sufficient vegetation to support nests. Even though obligate marsh birds show specific preferences, generalists are able to use many different habitat types, and it is also important to preserve habitat for them. Therefore, wetland management plans intending to preserve habitat for all marsh birds should conserve wetlands of all sizes in both urban and rural settings and preserve as many wetlands as possible to mitigate against isolation effects.

A call for action

Our findings suggest that the current provincial regulations for wetland conservation are inadequate for meeting the needs of obligate marsh birds. These inadequacies are as follows.

1. In order for wetlands to be even considered for protection in southern Ontario, they must be evaluated by the Ontario Ministry of Natural Resources Wetland Evaluation System (OMNR 1993) to receive the status of a Provincially Significant Wetland (PSW). Wetlands under 2 ha in size

are not even considered for evaluation unless the evaluator provides rationale for inclusion. This rationale must include the fact that the wetland provides habitat for rare or significant species. Many coastal wetlands of Georgian Bay are less than 2 ha in size, yet still contain sufficient habitat used by many wetland birds which may or may not be rare or significant species. Wetlands of all sizes should therefore be considered for evaluation, and should be protected with equal representation.

2. One criterion for designation of a wetland as a PSW is that it contains habitat for threatened or endangered species based on endangered species legislation. This protection often comes too late, usually after the population has experienced massive population declines (Gamble et al. 2006). Therefore if a wetland provides habitat for any wildlife species, it should be regarded as significant.
3. Wetland protection in southern Ontario is limited only to PSWs and those evaluated by the OMNR as containing endangered or threatened species. Once designated as a PSW, development is limited within 120m of the wetland edge (OMNR 1999, Provincial Policy Statement (PPS) 2005). Our study has shown that high levels of urban development within 1 km of the wetland edge can cause avoidance by obligate marsh birds, and therefore, the provincial guidelines should be extended to protect areas within 1 km of the wetland edge.

4. Another downfall of the PPS is that wetland protection can be waived if developers can show that wetlands will not be harmed in any way due to the planned development within the 120m guideline. Again, this buffer is far too small when considering habitat for wetland birds.
5. The PPS does not currently provide the same minimal protection to non-evaluated wetlands as it does to PSWs. The extreme effort that it would take to visit all of the wetlands in southern Ontario, and even Georgian Bay alone, is time and cost-prohibitive, and therefore all wetlands should be granted automatic protection through the PPS until all wetlands have been properly evaluated.

On a positive note

Over recent years, there has been an increase in global awareness of environmental issues, and also an increase in the number of publications on the impacts of urbanization on birds (Marzluff et al. 2001). Recognizing that our development practices may not be sustainable has led to an increase in wildlife research and monitoring efforts so that we may begin to understand the impacts we are having on wildlife communities. The development of policy and the increasing recognition wetlands are receiving, provides hope that the preventive measures we put in place today will preserve habitat and ecosystem function in the future.

REFERENCES

Gamble, L. R., K. McGarigal, C. L. Jenkins, and B. C. Timm. 2006. Limitations of regulated "buffer zones" for the conservation of marbled salamanders. Wetlands 26:298-306.

Marzluff, J. M., R. Bowman, and R. Donnelly. 2001. A historical perspective on urban bird research: trends, terms, and approaches. *in* J. M. Marzluff, R. Bowman, and R. Donnelly, editors. Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, Norwell, Massachusetts.

OMNR. 1993. Ontario Wetland Evaluation System, Southern Manual, 3rd Ed. NEST Technical Manual TM-002.

OMNR (Ontario Ministry of Natural Resources). 1999. Natural Heritage Reference Manual for Policy 2.3 of the Provincial Policy Statement.

Provincial Policy Statement. 2005. Section 3 of the Planning Act. Ministry of Municipal Affairs and Housing. Queen's Printer for Toronto, Ontario.